Christian Brecher, Cathrin Wesch-Potente (Eds.)

Proceedings of CoE-Conference 2013

Integrative Production Technology for High-Wage Countries

RWTH AACHEN HOUSE UNIVERSITY OF PRODUCTION

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Simulation and Formation of Crystallization in Semi-Crystalline Polymers

Spekowius, M.

Abstract

Because of their wide range of application and complex properties, it is desirable to have a precise simulation of the global part properties. This is only possible by taking inhomogeneous material properties into account. For the prediction of these properties it is necessary to calculate a high resolution texture of the local microstructure in the part. Thus the microstructure simulation is an important tool for the investigation and development of new simulation models, e.g. for the computation of shrinkage and warpage. With the goal to predict a high resolution texture of the microstructure in injection moulded parts the simulation software "SphäroSim" is developed at the IKV and extended with new models for the prediction of flow induced crystallization.

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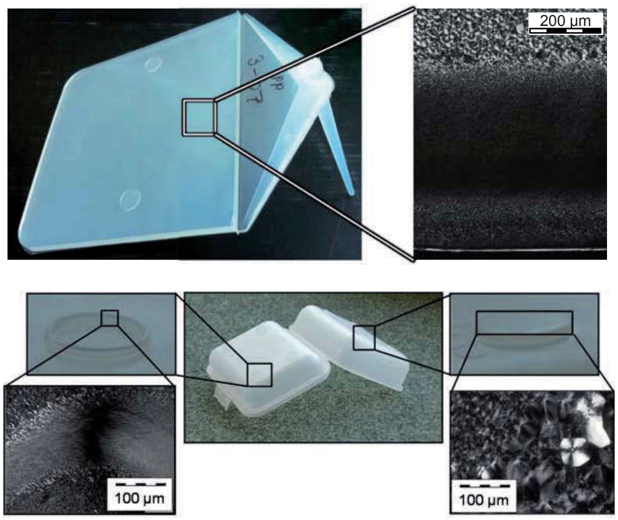
Integrative Production Technology for High-Wage Countries

Simulation and Formation of Crystallization in Semi-Crystalline Polymers

Marcel Spekowius

INSTITUTE OF PLASTICS PROCESSING (IKV) – AACHEN, GERMANY

Microstructure of Semi-Crystalline Polymers



- Microstructure varies over cross-section and flow path
- Significant influence of rheological and thermal conditions in the melt
- Dimensioning is done under the condition of homogeneous material properties
- Microstructure influences the global properties of the part

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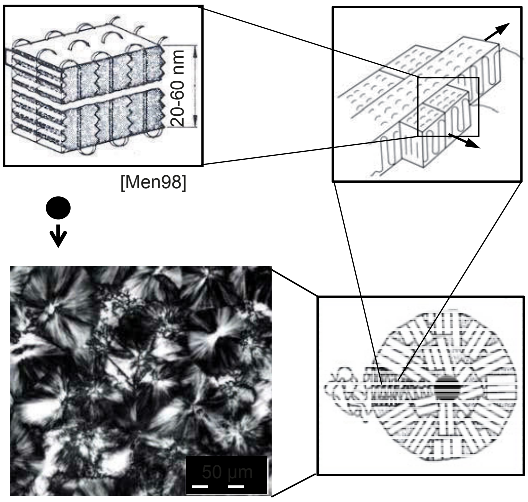
Table of Contents

- Introduction
- Formation of Crystallization
  - Microstructure Formation
  - Flow Induced Effects
- Simulation of Crystallization
- Simulation Results
- Conclusion

Microstructure Formation



- Nuclei are created in the melt
- Polymer chains attach to the nucleus (folding) => crystal lamellae
- Growth speed independent of flow field but depending on temperature
- Nucleation influenced by flow field and temperature

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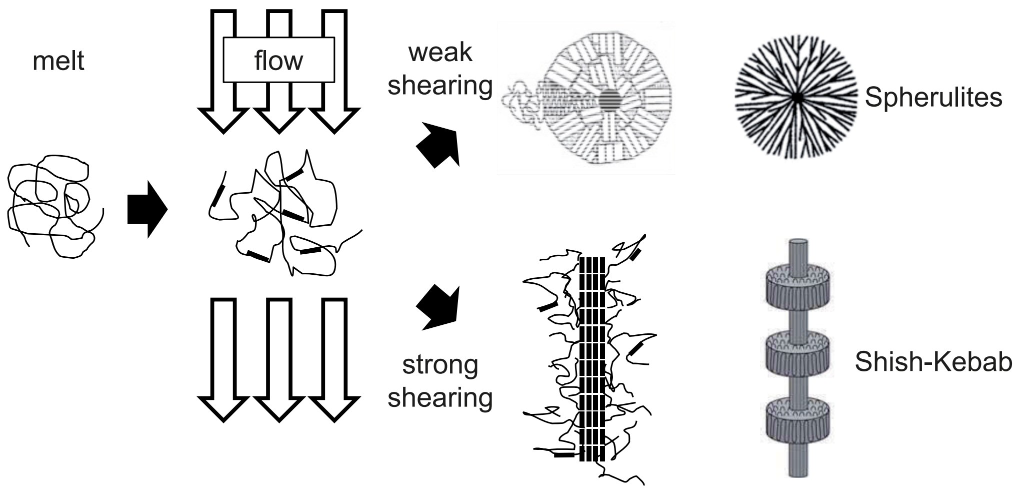
Flow Induced Effects



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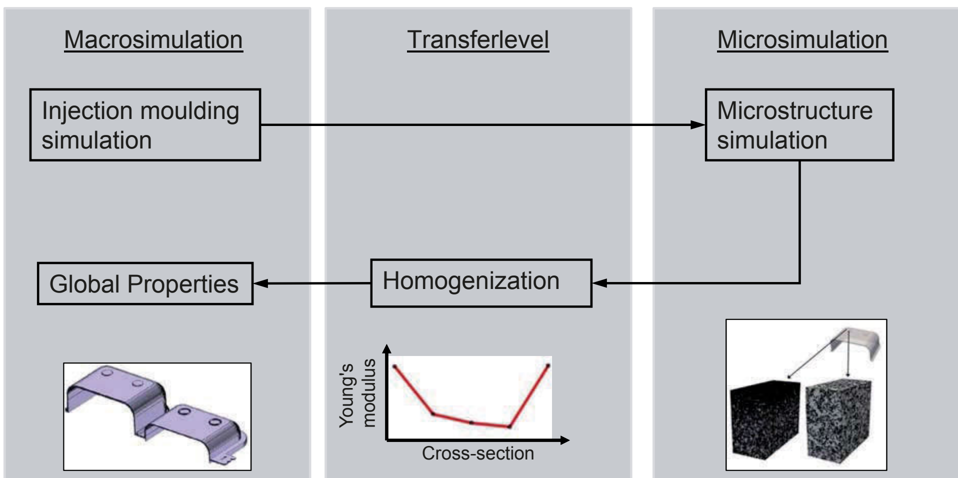
Integrative Simulation Including Microstructure Simulation



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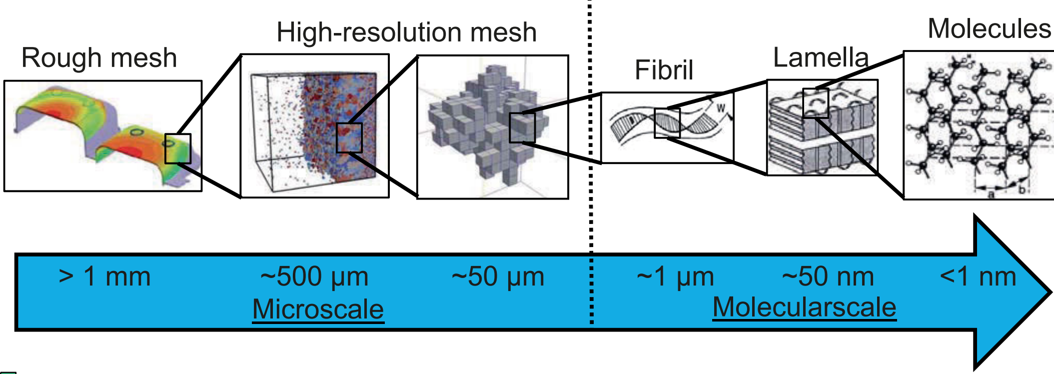
SphäroSim

Problem: Prediction of global effects, e.g. shrinkage and warpage requires knowledge about the microstructure

Simulated with SphäroSim | **Not simulated with SphäroSim**



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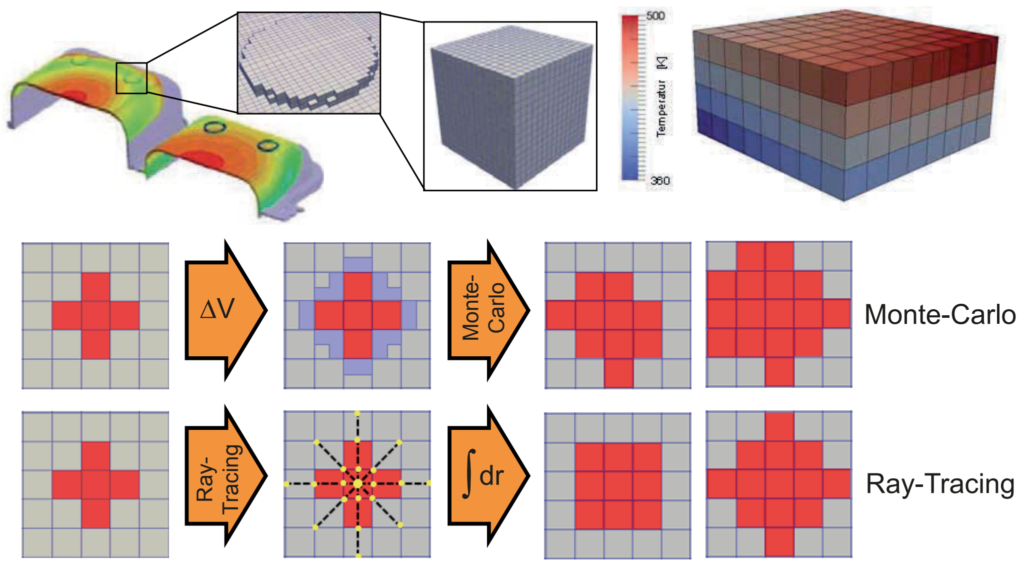
Simulation Approach



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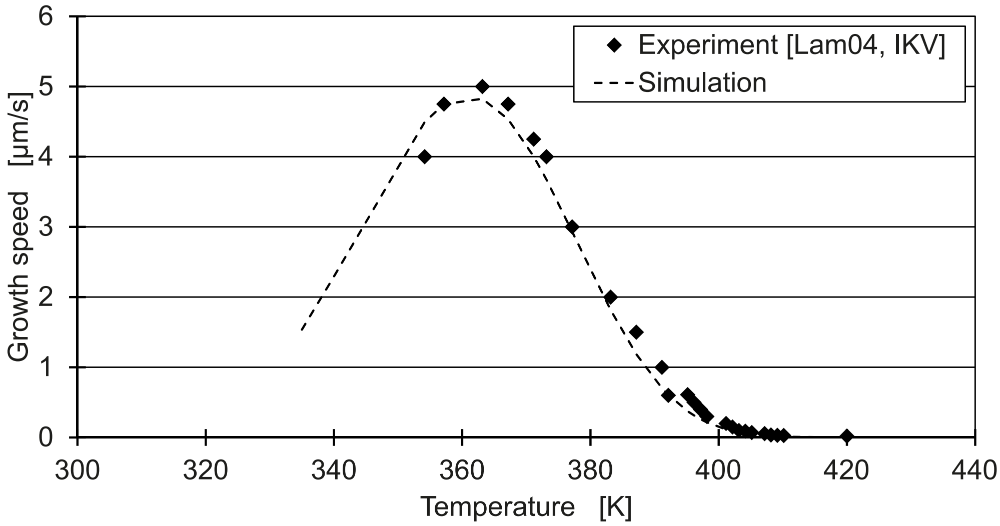
Growth Speed



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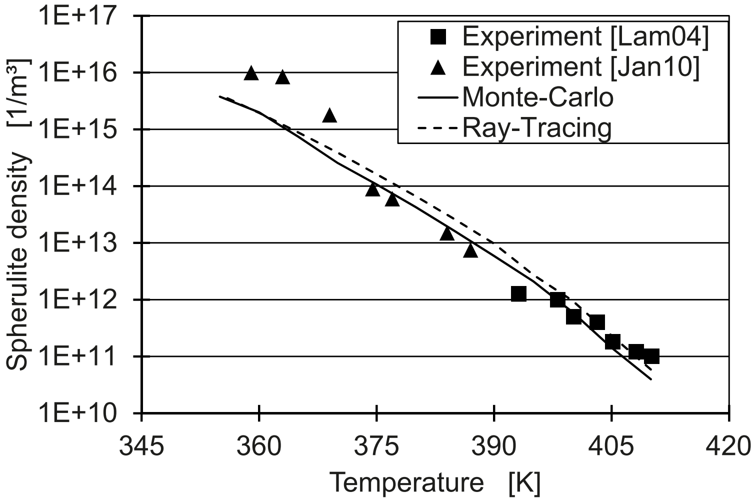
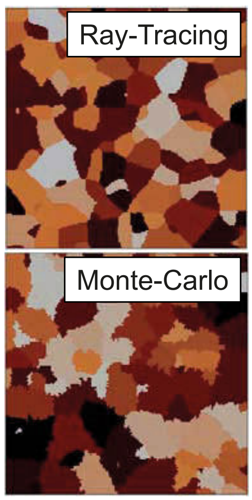
Quiescent Crystallization





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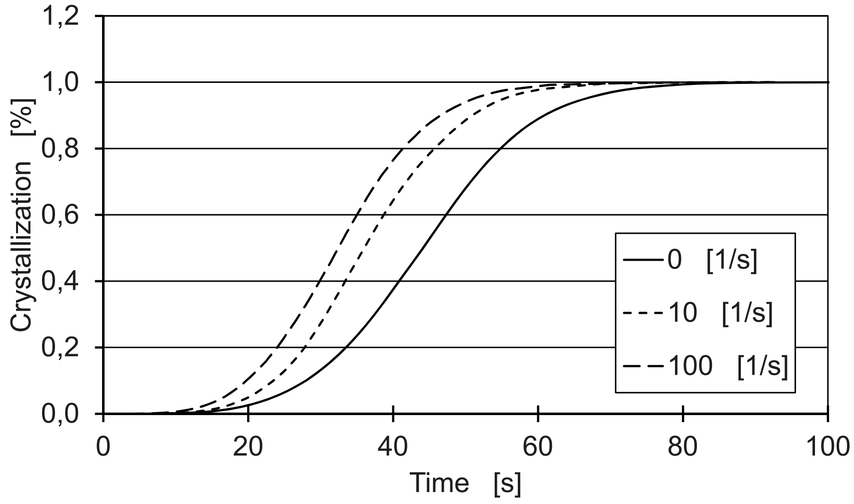
Flow Induced Crystallization



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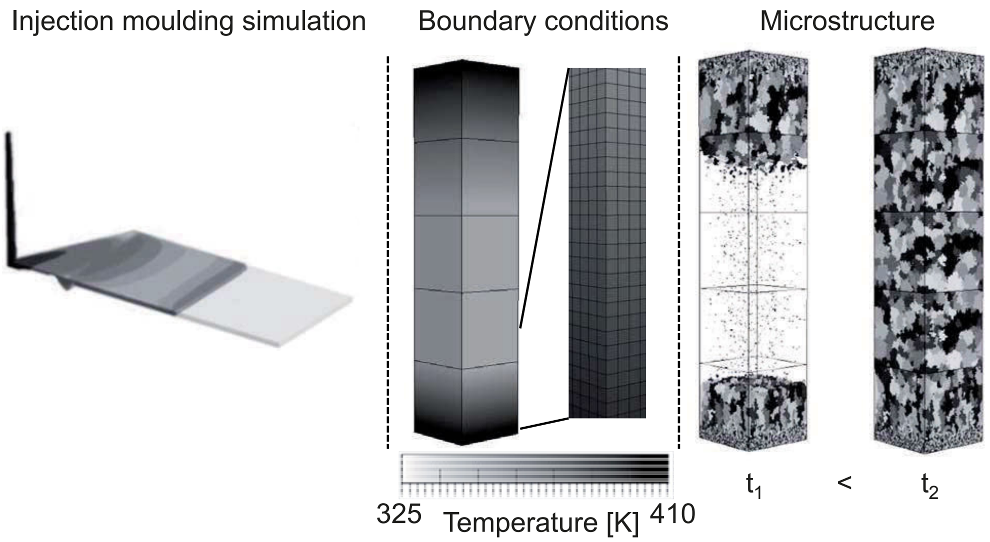
Integrative Simulation of Plastic Components



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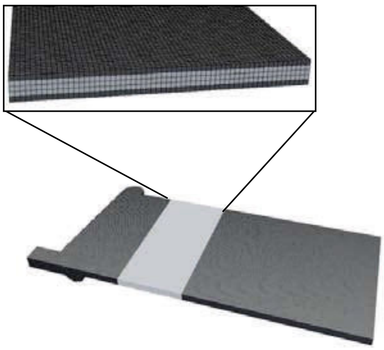
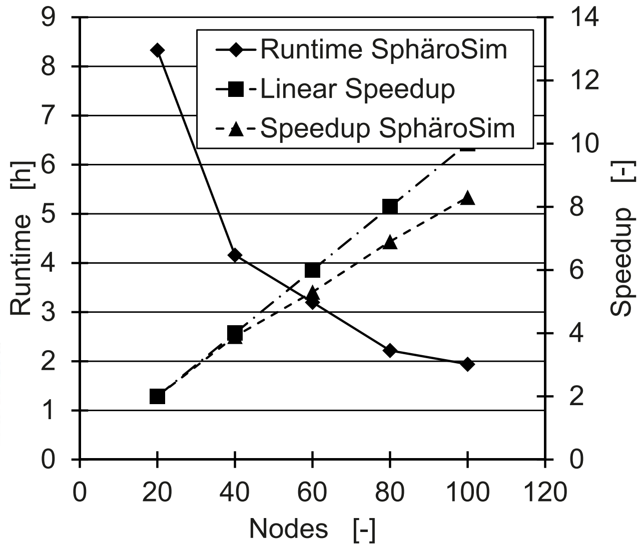
Parallelization of SphäroSim





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Conclusion

- Solidification of polymer melts is a complex problem
- Temperature and flow are the most important parameter
- The software SphäroSim is developed within the cluster of excellence for usage in multi-scale simulation chains
- Flow induced effects are calculated with the reptationmodel
- Parallelization of SphäroSim shows good results

- Next research goals for simulation of crystallization:
  - Validation of flow induced crystallization models with experimental data
  - Further optimization of the performance
  - Prediction of Shish-Kebab

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Thanks for your attention!

Bild 15

Viable inspection system within the context of the ICD-D

Frank, D.

Abstract

The Viable-Systems-Model (VSM), which was first introduced by Stafford Beer has proven to be a convenient framework for the design of self-optimizing production systems. With the design of the management model, Beer introduced the principles of viability and recursion as the central structural characteristics of his model: He defines five main management systems in order to guarantee the viability of a system. Being a recursive system, the VSM allows setting the focus on different levels of depth for system design and development. The VSM has been used in several cases to design enterprises, organizations or even governmental structures. However, the application of the model to technical systems, i.e.to develop the architecture of technical systems has not been done so far. After a short introduction to the main principles of the VSM it will be shown how the structure and design rules of the VSM can be transferred to a robot inspection system. Furthermore, it will be presented how to connect viable processes and technologies cited to the research of the cluster of excellence on a higher recursion level.

Viable inspection system within the context of the ICD-D

A framework based on the viable systems model

The Inspection System - Components

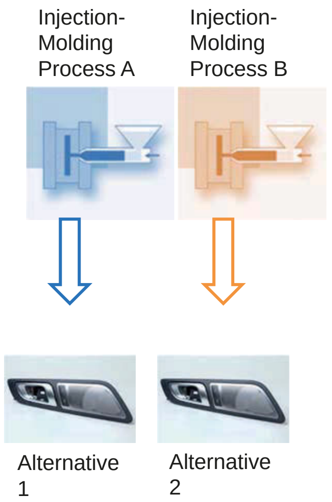
- Industrial Six-axis-robot:
  - 0.01 mm repositioning accuracy
  - 3kg handling capacity (for sensors, cameras, grippers, etc.)

Additional components (to be procured):

- Six-axis force/torque sensor for force-path and torque-angle trends
- Force control system – to enable quick and easy learning of paths and movements
- Optical sensor equipment (white light microscope for surface measurements, cameras for automatic positioning)
- Endeffectors to interact with objects

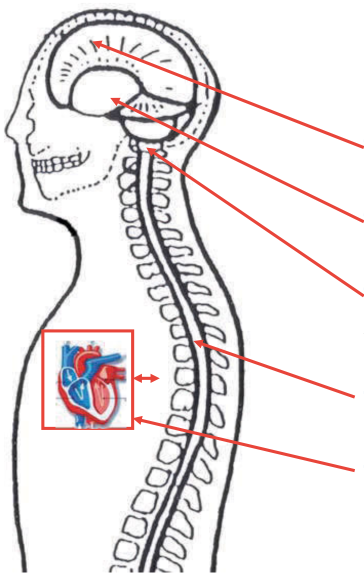
Flexibility and automation are main reasons to use the robot for an inspection system.

The Inspection System – Functionalities (Planned



- Supporting product realization by e. g.:
  - Supplying measurements for process selection
  - Verifying supply components against specifications
  - Evaluating tolerances
- End of line inspection
  - Helps to objectively inspect certain parameters (average clearance between parts, correct position of components)
  - Offers the possibility of inspecting multiple parameters within one inspection step
- Describing customer requirements through measurements
  - Competing products → benchmarking
  - Validation of design concepts using reference data

The Viable Systems Model (VSM)



- The three main characteristics of a viable system according to Beer are: Viability, autonomy and recursion.
- The human organism is a model example of viable system. It can be used to explain the necessary functions of a viable system:

The cortex represents the identity of a person and contains values and visions of the future

The interbrain perceives, filters and transmits information from the environment to other parts of the system

The brain stem controls and supervises muscles and organs. Although it receives control information from the interbrain and the cortex, **it can act autonomic**.

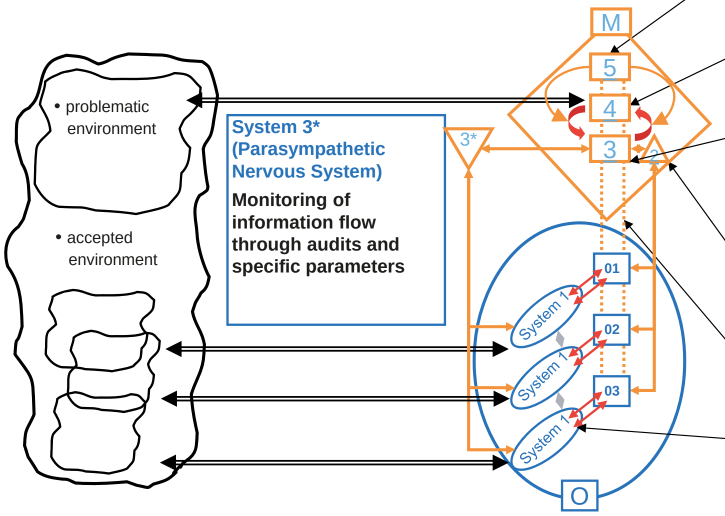
The spinal cord allows real-time transmission of information between muscles and organs → acts as a bypass to save time

The heart is a single operation unit. It also contains another viable system with all the necessary functions **(recursivity)**.

Source: BEER 1972; BEER 1973

Systems within the VSM

Abstract visualization of the VSM, in order to be viable, a system must contain all these functions



System 5: (Cortex)
Balances current situation and future perspective, represents identity and values.

System 4: (Interbrain)
Derives future goals and plans incorporating the outside perspective

System 3: (Interbrain)
Steering of operative system, synchronization of operating units

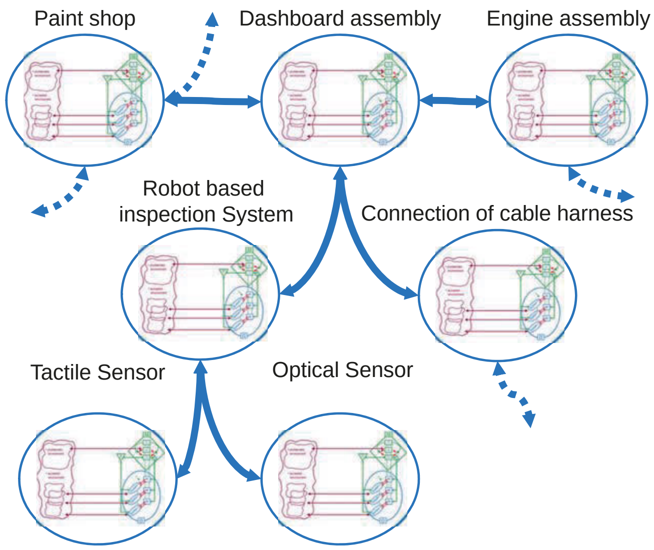
System 2: (Nervous system)
Coordinates activities of System 1 units by communicating and damping or diminishing specific information

Command Channel (Spinal chord)
Information bypass from System 1 to System 3, 4 and 5

System 1: (Organs & Muscles)
Control system of the operating units. Acts mostly autonomic, within given task.

Recursion of the VSM Transferred to the ICD-D

Control units of operative systems (System 1s) represent metasystems (Systems 3, 4 and 5) for lower levels of the recursion:



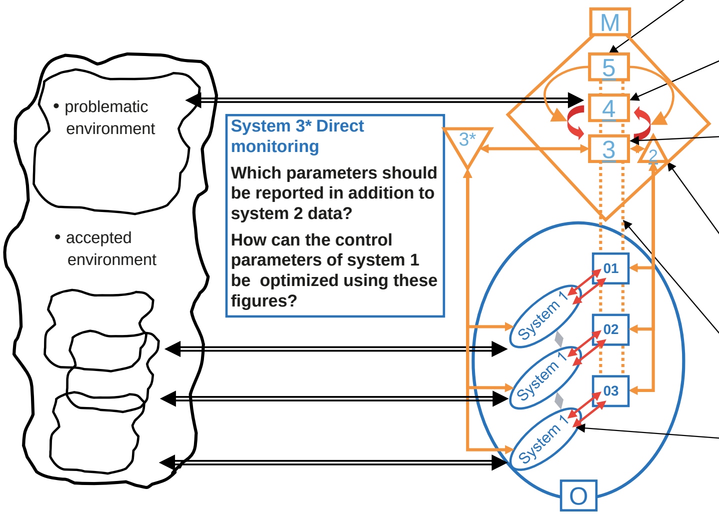
Recursion level: Shop floor (D1)
System 3 of the dashboard assembly defines timeframe for inspection, goals for the accuracy and so on. It synchronizes the EOL inspection in respect to the necessary connections

Recursion level: Manufacturing Cell (D2/D3)
The inspection system controls and synchronizes the use of the sensors for different dashboard alternatives autonomously.

Recursion level: Technology (D2/D3)
The inspection systems represent operative units from the perspective of the manufacturing cell. A sensor or the arm of the robot has a distinguished function and works in combination with other technologies.

VSM Model of the Shop Floor Level

The VSM helps to establish the link between organizational (Shop floor) and technological (Manuf. systems) research



System 5: Policies/ Identity
Which specific policies are needed to utilize the inspection system? (e.g. quality premises)

System 4: ERP-System
How can the data support the inspection and order policies? → adapting networks

System 3: Process control
What are the specific tasks of the inspection system, how does the shop floor have to control the inspection system?

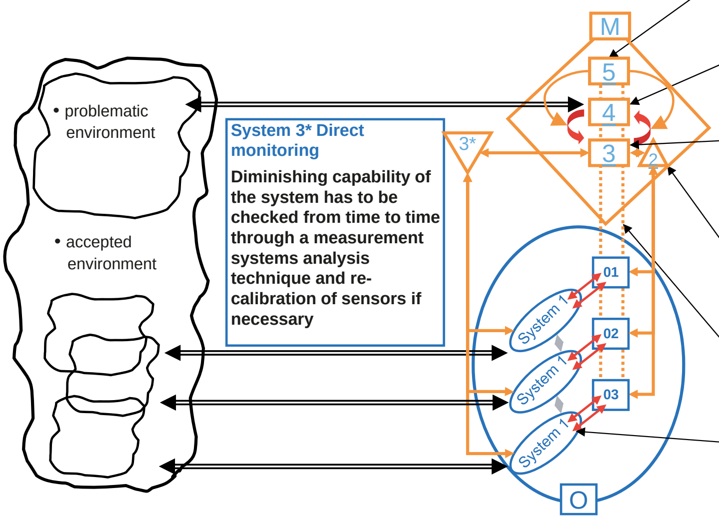
System 2: PLS/MES-System
What kind of data flows through?
What kind of interfaces are necessary?
What kind of system is necessary?

Command Channel: Escalation routines
Are quality emergency procedures necessary, what data triggers such an emergency?

System 1: Inspection System
How does the system communicate to other level 1 systems?

VSM Model of the Manufacturing Cell Level

The application to the manufacturing cell shows the applicability of the VSM to technological systems



System 5: Identity – System knows its purpose
Are special policies needed from the perspective of the inspection system?

System 4: PLS/MES-System
What data is needed to adjust the system externally? How can the inspection system be integrated in an existing MES?

System 3: Process control
What kind of movement control mechanism is useful for the purpose of the system (force controlled, camera controlled)?

System 2: Data bus & amplifier
Do data thresholds have to be defined?

Command Channel: Escalation routines
Excessive sensor load or unknown situations trigger a stop command

System 1: Sensors, Robot arm, etc.
Which inspection tasks are necessary and which technologies (sensors) can fulfill these tasks?

Summary & Outlook

- Technological systems such as the inspection system presented, can be described using a VSM-framework
- Future research focus and remaining challenges within the system itself and its context can be displayed within the VSM
- With the help of the VSM the inspection system can be positioned within the ICD-D and connections are directly visible

Analytical modeling and simulation of process forces in milling

Cabral, G. F.
gustavo.francisco.cabral@ipt.fraunhofer.de

Keywords:
milling, simulation, forces, design, planning

Abstract

Applying software tools helps producing enterprises with highly qualified employees to plan and optimize production processes more efficiently. Modern tools for planning and designing milling processes usually consider only the macro contact conditions between the workpiece and milling tool and are very limited for designing processes with specific cutting edge geometries.

In this work, an innovative analytical approach for determining the geometrical conditions and deriving the process forces in five-axis milling is presented. The simulation of the engagement conditions is based on parameters which are obtained through numerical extraction models. The geometrical cutting conditions are analytically calculated. The proposed analytical model considers the cutting edge geometry and evaluates the uncut chip dimensions including chip thickness, width, length and cross-sectional area. The cutting forces are predicted by using oblique cutting theory, considering the ploughing and shear forces acting on the tool edge.

The developed models are currently being implemented in a software tool using coupled simulations which allows a simulation-based planning of milling processes.

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Altintas Y. Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design. New York: 1. ed. Cambridge University Press, 2000

Analytical Modeling and Simulation of process forces in milling

Cluster-Conferences 2013

Gustavo Cabral

Aachen, den 23./ 24. September 2013

Agenda

1 **Introduction**

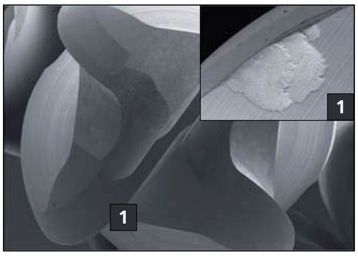
2 **Design of milling processes**

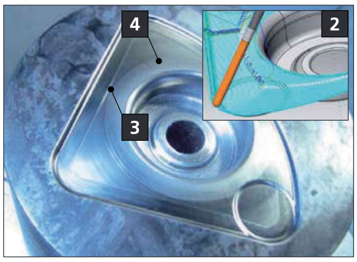
3 **Process modelling and simulation**

4 **Case study**

5 **Summary and outlook**

Problem description
Challenging limitations of machining processes





Unfavorable cutting conditions

- Low material removal rates
- Unfavorable chipping formation mechanisms
- High affinity to adhesion and diffusion due to strong reactivity of certain materials
- High pressure on upper area of rake face due to high chip curvature and hence low contact length

  → Process disturbance, re-work and workpiece rejection

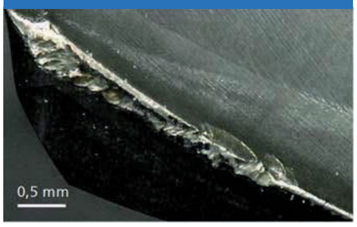
Progressive tool wear leads to unwanted effects in process:

- Increase of process forces and temperatures
- Recalibration of tools parameters and demanded new-calculation of the NC-Path in CAM
- Undesired surface marks due to tool change
- Increasing roughness of the generated surface
- Undefined residual material

High tool wear, bad surfaces, long processing times

Problem description
Challenging limitations of machining processes

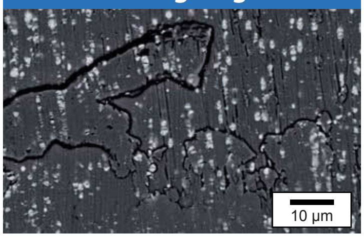
Tool wear



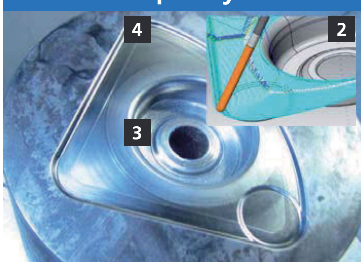
Unfavorable chip formation

Burr formation

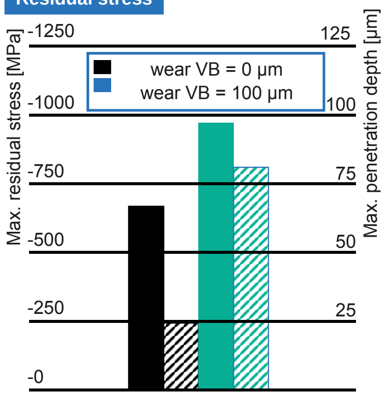
Ploughing



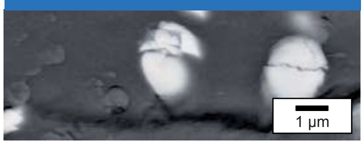
Surface quality issues



Residual stress



Micro-structure defects



Project overview
Current solutions for improving the process performance

- Optimization of the cutting tools
  - Cutting tool macro and micro geometry optimization
  - Preparation of the cutting edges, rake and clearance angles, tool diameter, tool form, cutting edges distribution etc.
  - Cutting tool material
  - Development of coatings (PVD, CVD / CBN, Diamond etc.)
  - Development and utilization of lubricants
- Improvement in the machine tool
  - Improved process kinematics (Multi-axis milling, ultra-sound technology etc.)
  - Higher and adaptable cutting speed
- Improvement in the clamping systems
- Process monitoring
- Improved process design and planning
  - Selection of optimized cutting conditions
  - Process simulation

There is plenty room for improvement of process design and planning

Agenda

1 Introduction

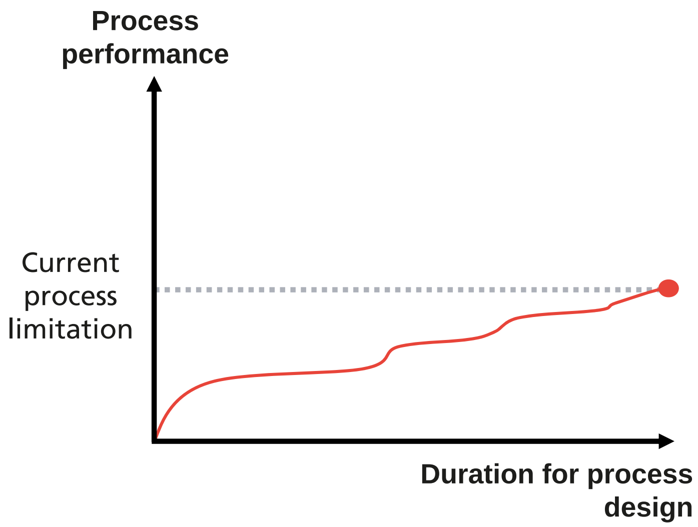
2 **Design of milling processes**

3 Process modelling and simulation

4 Case study

5 Summary and outlook

Milling process design
Common practice for designing advanced milling processes



Common methodology

- Testing methods mostly experimental
- Strongly based on experience
- No standardized methodologies and technology databases

Drawbacks

- Low parameters and material removal rates
- Long ramp-up times for setting-up new milling processes

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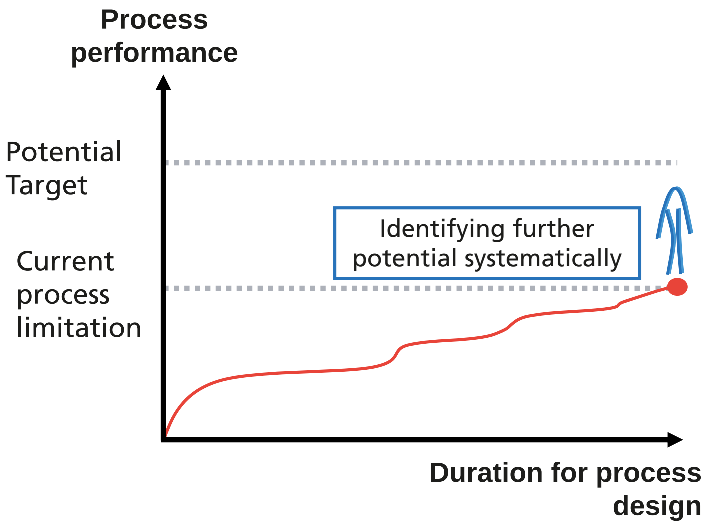
Milling process design
First objective: increase of process performance



Common methodology

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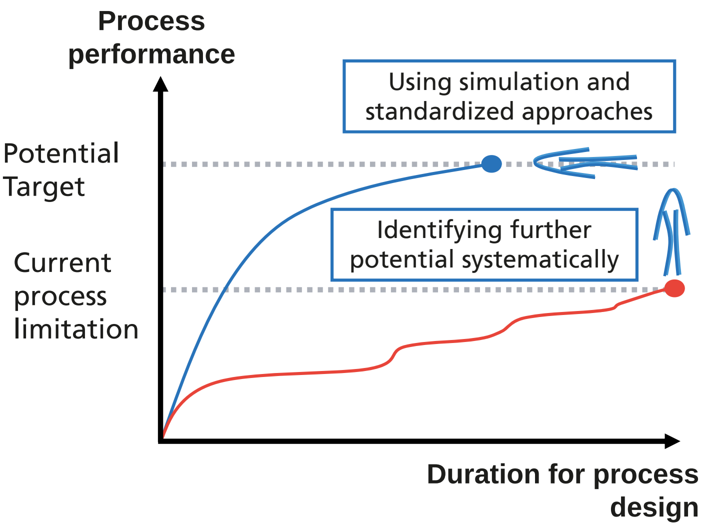
Milling process design
Second objective: reduction of duration for process design



Common methodology
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- No standardized methodologies and technology databases

Drawbacks
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- Long ramp-up times for setting-up new milling processes

Agenda

1 **Introduction**

2 **Design of milling processes**

3 **Process modelling and simulation**

4 **Case study**

5 **Summary and outlook**

Methodology for a Simulation and Analysis of Milling Processes
Which Questions Should be Answered…?

Question I

Which variables are significant for the process performance

Question II

How can the mechanical loads sufficiently be determined during the process planing?

Question III

How can the developed simulation models be used for designing and planing machining processes?

System definition and limitation
Relevant parameters for the proposed simulation

Machine
- Design
- Kinematics
- Properties/ Stiffness
- Tool holder

Process
- Force
- Torque
- Temperature
- Power
- Energy

Settings
- Macro contact conditions (from correspondents a_e, a_p, tool orientation etc.)
- Feed rate f_z
- Cutting speed v_c
- Cantilever length
- Cutting fluid

Workpiece
- Material
- Mechanical, chemical and thermal properties
- Geometry
- Rim zone
- Microstructure
- Inhomogeneities

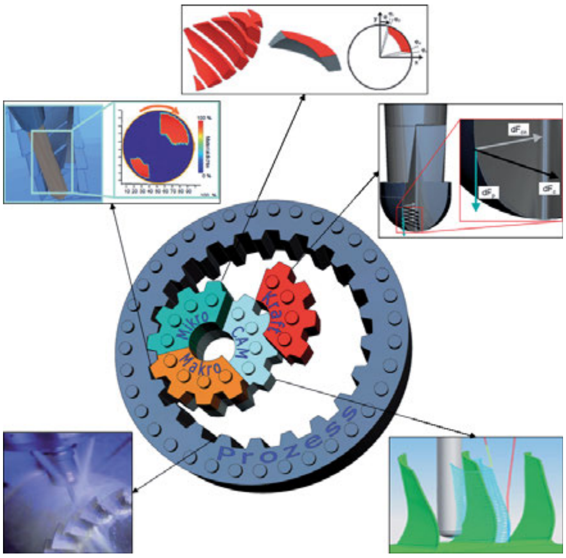
Chip geometry
- Thickness, length, width, cross-sectional area
- Other parameters : impact factor, compactness ratio etc.

Disturbances
- Vibrations
- Environmental influences
- Operator
- Control errors

Milling tool
- Cutting edge rounding
- Macro and microgeometry
- Material
- Hardness
- Stiffness

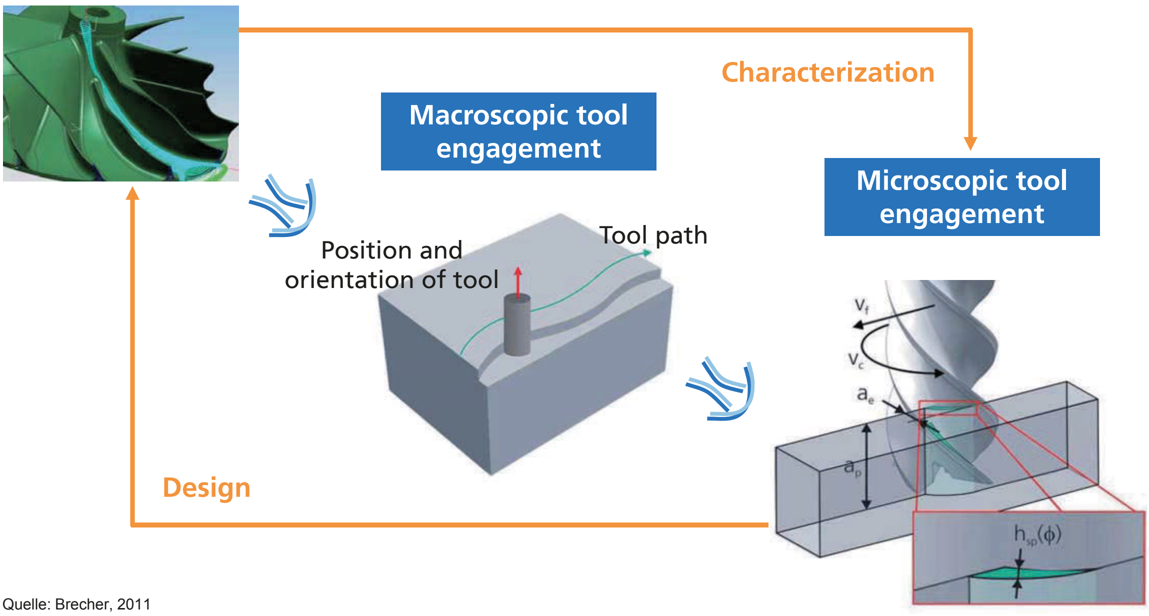
Output
- Wear
- Breakage
- Surface roughness
- Rim zone influence
- Form error

Methodology for simulation of milling processes
Development of a modular simulation tool



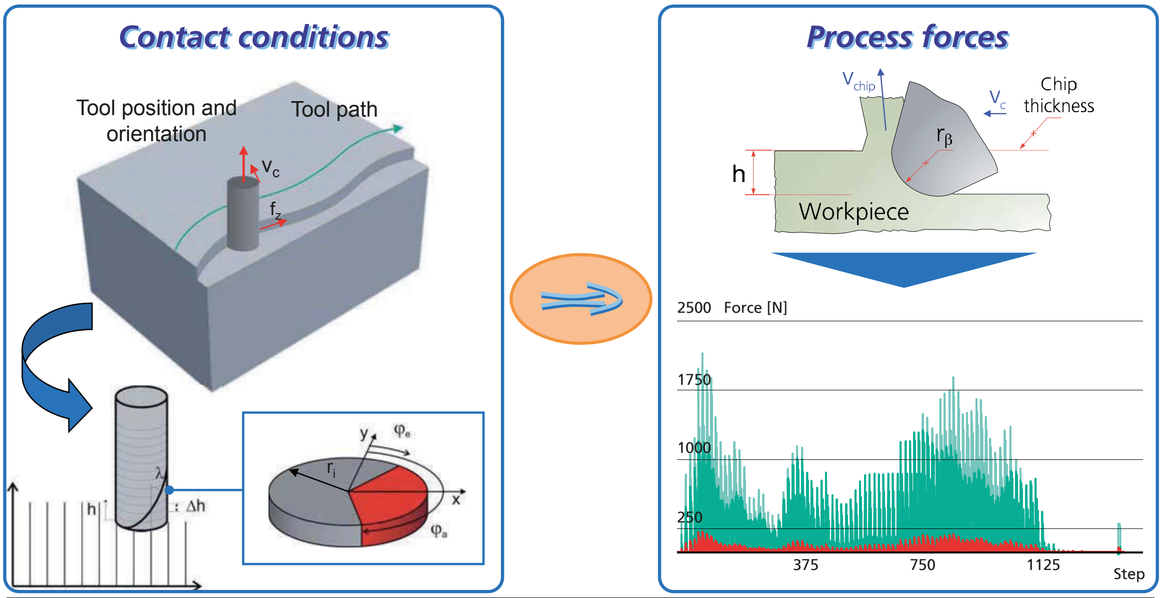
- The simulation is modular built:
  - Macro simulation: considers just the tool macro geometry (tool form, diameter and length etc.) and uses dexel-based algorithms for calculating the macro contact conditions
  - Micro simulation: considers the tool micro geometry (cutting edges, rake angle, helix angle, etc.) for calculating the micro contact conditions
- Macro- and microsimulation are integrated in a CAM-based environment
- The data from both simulations is available for the implementation of different models: forces, temperatures, residual stresses etc. (the red block can be replaced)
- The models are dependent on the process, i.e. the boundary conditions and needs from different processes are considered)
- Data transfer between the simulation and process in both direction

Methodology for simulation of milling processes
Analysis of engagement conditions as prerequisite



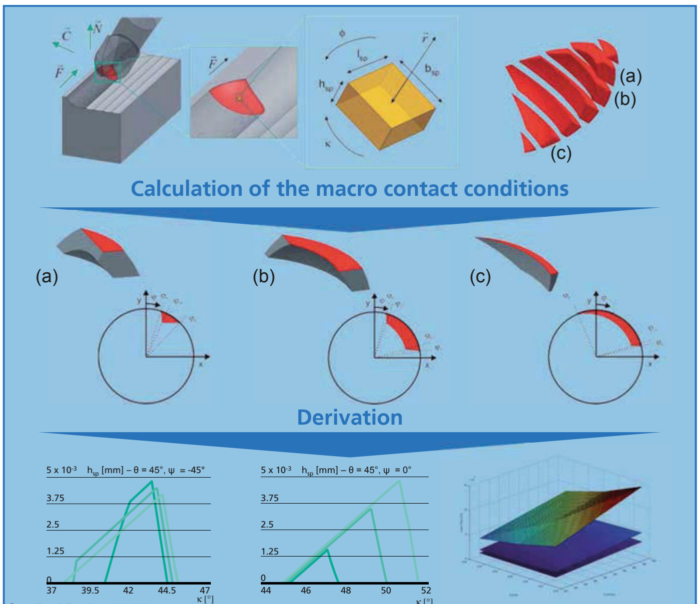
Quelle: Brecher, 2011

Simulation aproach
From „macro“ to „micro“ contact conditions



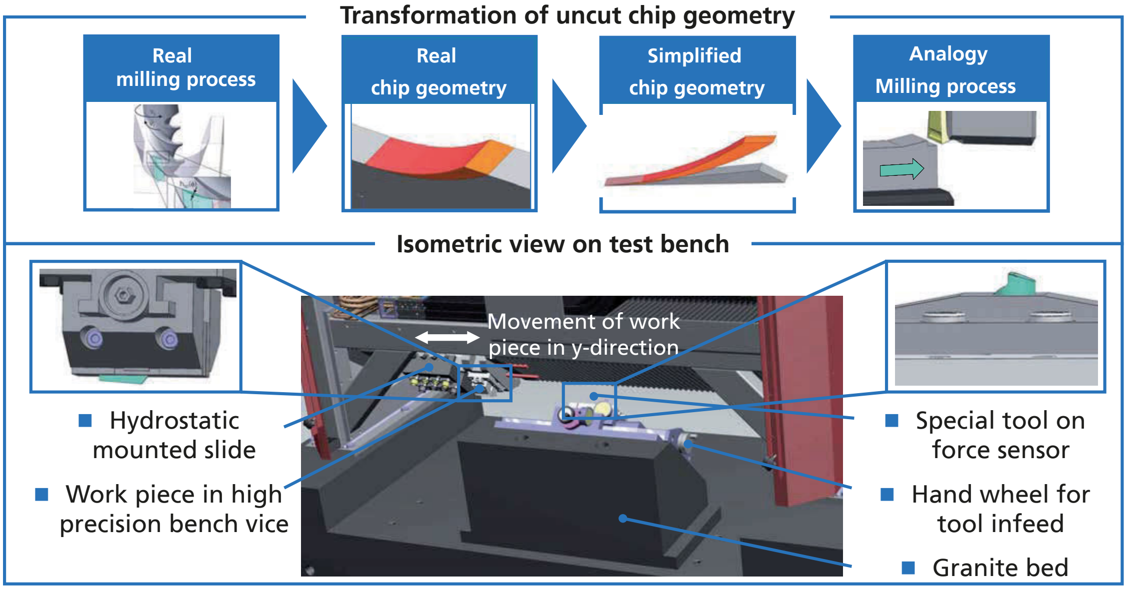
Geometrical modeling

- Modeling of the kinematics of the milling process
- Tool geometry
  - Discretization of the tool along the tool axis and radial direction
  - The single tool „slices“ are considered as thin end mills
  - Consideration of any tool geometry (circumferential milling)
- Chip geometry
  - Cross-sectional area, thickness, width, length
- Further derivated parameters
  - Impact factor, compactness ratio, chipping time, engagement diagram, surface generating area, local cutting speed



Quelle: Klocke, 2011

Methodology for a Machinability Analysis
Analogy Milling Test Bench



Force modeling
Approach

Orthogonal Cut

Orthogonal cut is a process in which the cutting tool have no helix angle and the surface generated by the cut is parallel to the previous surface (constant chip thickness).

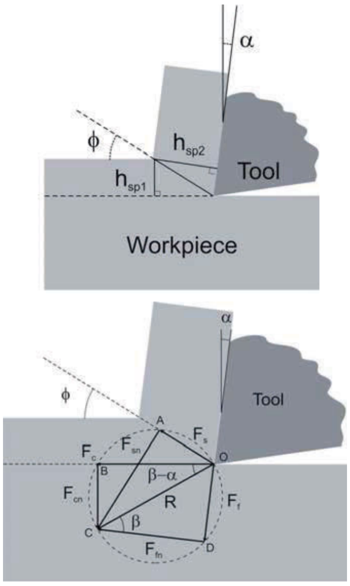
Shear Stress Calculation

The cutting area is divided into infinitesimal areas and the shear zone is assumed to be a thin shear plane. Through the experiments, an equation for the shear stress is calculated in function of the **cutting speed**, **rake angle** and **uncut chip thickness**

Coefficients Calculation

The force coefficients are calculated in function of the shear stress and the tool geometric parameters – radius, helix and rake angle.

Force modeling
Based on the Altintas-Merchant model



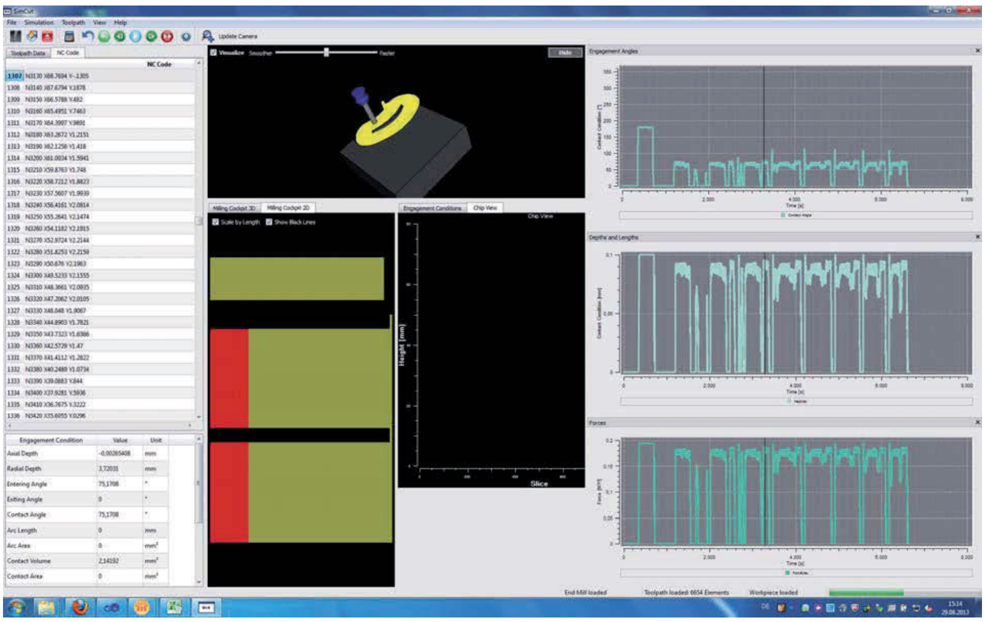
- The force in x and y direction are called cutting (Fc) and normal cutting (Fcn) force, respectively.
- In both of then the cut and edge effects are considered, according to Altintas formulation:

$$dF = F_e + F_c$$
$$dF = \left(k_e + k_c h_{sp}\right) b$$

- The edge forces are obtained by curve fitting extrapolating the values measured to a case that the chip thickness is zero.
- It is also considered the influence of the cutting edge rounding and the ploughing effect

Quelle: Altintas, 2000

SimCut
Simulation tool under development



Agenda

1 Introduction

2 Design of milling processes

3 Process modelling and simulation

4 Case study

5 Summary and outlook

Methodology for a Machinability Analysis

Uncut Chip Thickness is Significant for Occurring Forces

Parameterization

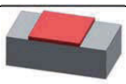
- Orthogonal cutting
- Straight uncut chip geometry
- v_c = 70 m/min
- h_{cu} = 10; 30; 50 µm
- b_{cu} = 1 mm
- l_{cu} = 20 mm

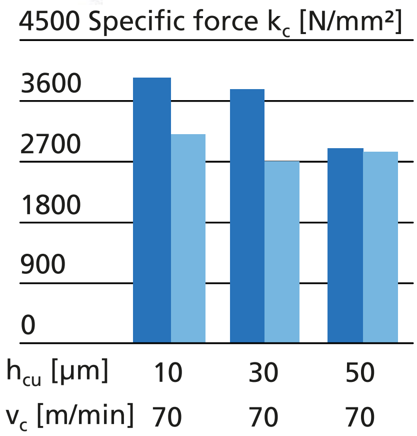
Nomenclature

- NiCr19NbMo
- X6NiCrTi26-15

Specific force evaluation

$k_c = F_c / (b_{cu} * h_{cu})$





- Small h_{cu} lead to higher specific forces
- Possible causes are scale and size effects, e.g.
  - Lower propability for occurence of material specific failures
  - Ratio of cutting edge rounding to h_{cu} increases

Cutting velocity v_c and uncut chip thickness h_{cu} are relevant for process design

Ploughing effect

The cutting edge rounding and the ploughing effect

15
r_β [µm]: 10
h_{sp} [µm]: 5
vc [m/min]: 70
h_{sp}/r_β: 0.5

17
r_β [µm]: 10
h_{sp} [µm]: 10
vc [m/min]: 70
h_{sp}/r_β: 1

19
r_β [µm]: 10
h_{sp} [µm]: 20
vc [m/min]: 70
h_{sp}/r_β: 2

21
r_β [µm]: 10
h_{sp} [µm]: 5
vc [m/min]: 140
h_{sp}/r_β: 0.5

23
r_β [µm]: 10
h_{sp} [µm]: 10
vc [m/min]: 140
h_{sp}/r_β: 1

25
r_β [µm]: 10
h_{sp} [µm]: 20
vc [m/min]: 140
h_{sp}/r_β: 2

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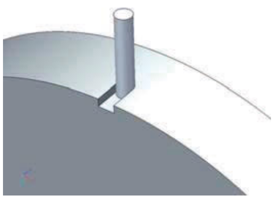
End milling

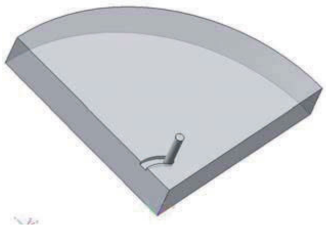
Comparison of three different milling strategies

Linear path



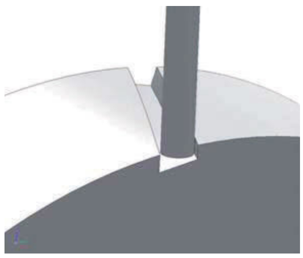
	Full engagement	Groove opening
φ_e	-0,1659°	90°
φ_a	180,1659°	180,1659°
φ_c	180,3318°	90,1659°
a_p	6 mm	6 mm
a_e	12 mm	6 mm
f_z	0,035 mm	0,035 mm
D_s	450 mm	450 mm

Circular path



	Full engagement	Groove opening
φ_e	-0,1471°	90°
φ_a	180,1872°	180,1872°
φ_c	180,3343°	90,1872°
a_p	6 mm	6 mm
a_e	12 mm	6 mm
f_z	0,035 mm	0,035 mm
r_{Bahn}	50 mm	56 mm

Tool orientation



	Full engagement	Groove opening
β_f	3°	3°
β_{fn}	-7,5° – +5,8°	-7,8° – 5,8°
$\varphi_{c,oben}$	variable	variable
$\varphi_{c,unten}$	variable	variable
a_p	7,4 – 8,1mm	6,7 – 7,8mm
f_z	0,035 mm	0,035 mm
D_s	450 mm	450 mm

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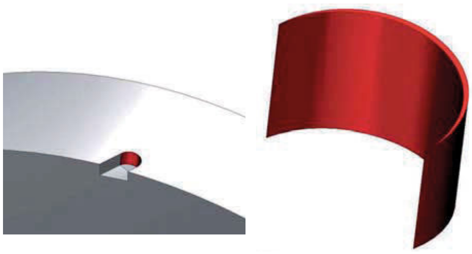
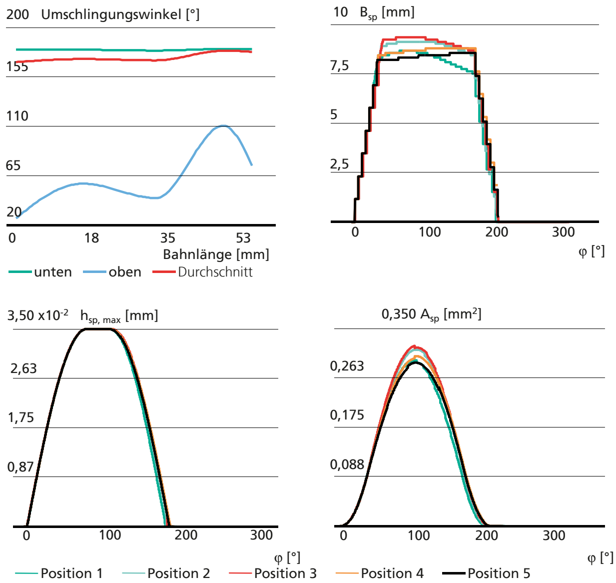
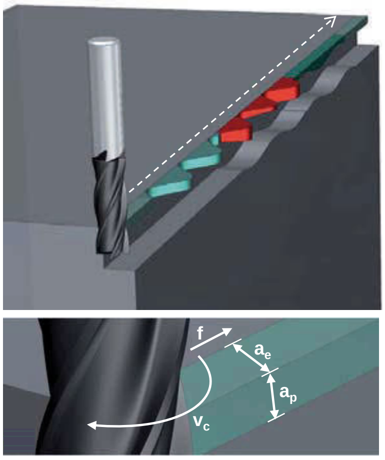
End milling
Changing the tool orientation to distribute the load along the flute

Position	β_{fn}	Length [mm]
1	−7,8271°	2,5116
2	−4,3736°	20,0931
3	−2,1880°	38,9307
4	+4,3484°	56,5127
5	+5,7814°	64,0478



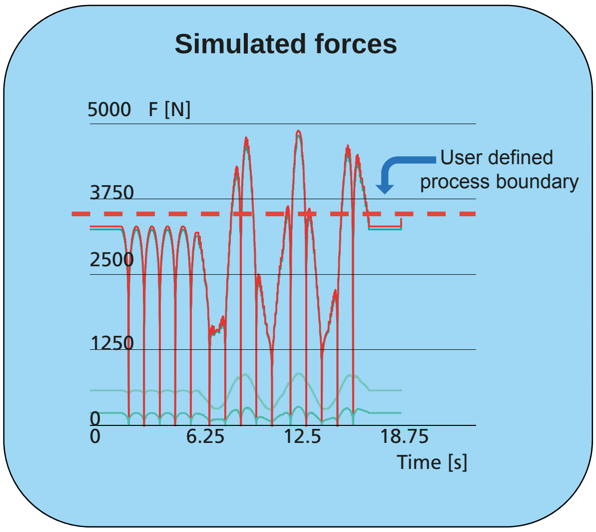


Expansion to more complex chip geometries and tools
Example: sinus wave milling



Milling tool
End mill
D = 6mm
λ = 30°
Z = 4

Process parameters
Orientation: Orthogonal
fz = variabel [0,04 – 0,1 mm]
ae = variabel [0 – 6 mm]
ap = variabel [1 – 4mm]
vc = 140 m/min



Agenda

1 Introduction

2 Design of milling processes

3 Process modelling and simulation

4 Case study

5 **Summary and outlook**

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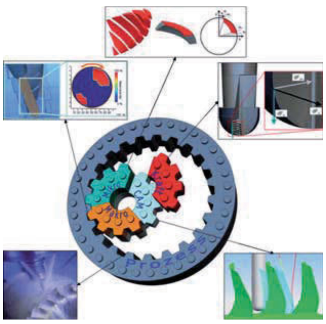
Summary and Outlook



Summary

- Systematic and standardized determination of thermo-mechanical loads in the chipping zone is of major importance
- Simulation is a valid technique for achieving this aim
- Important factors to be considered in the simulation are the uncut chip geometry, the workpiece geometry/material, the tool geometry and the cutting strategy
- On this base a fast and precise milling process design can be supported

Outlook

- Further development and qualification of models for simulation of milling process is one of the objectives of this work
- The future work will focus on the simulation of the workpiece properties in a process chain

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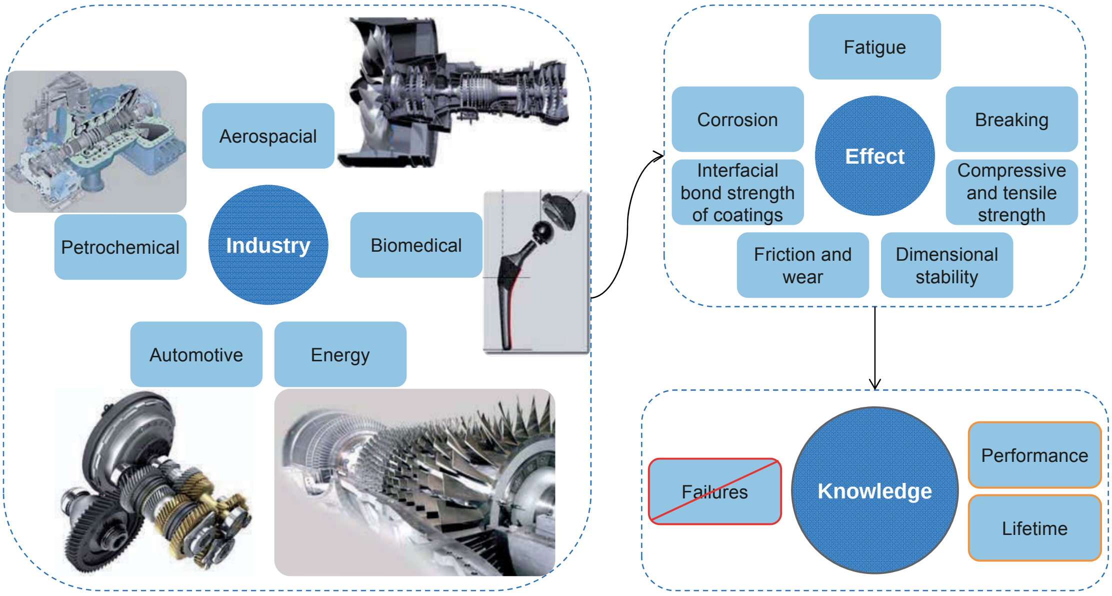
Outlook
Next step: simulation of the surface properties in a process chain



Thank you for your attention

Autonomous generation of process knowledge in milling

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Keywords:
Self-optimization, modeling, milling

Abstract

Process knowledge is a key factor of production and is decisive for the success of a company. It is also an integral part of the self-optimization approach which is currently researched within the Cluster of Excellence. In this context, process knowledge in machine readable form is required to provide the self-optimizing manufacturing system a basis for decision making and optimization processes.

In this presentation, an innovative approach for milling processes is introduced. It illustrates how a manufacturing system can be enabled to generate process knowledge in machine readable form autonomously. The presentation is structured in three sections. In the first section, the general self-optimization approach for manufacturing processes as well as the process independent modeling methodology are briefly presented to describe the initial situation. The second section includes the new concept for the autonomous generation of process knowledge in milling and shows some of the first results to implement this concept. The results are a configuration assistant to define a modeling task, an intelligent method to organize experiments, a genetic algorithm to determine model coefficients and a communication interface. The last section closes the presentation with a brief summary.

Autonomous generation of process knowledge in milling

Cluster-Conferences 2013

Thomas Auerbach

Aachen, den 23./ 24. September 2013

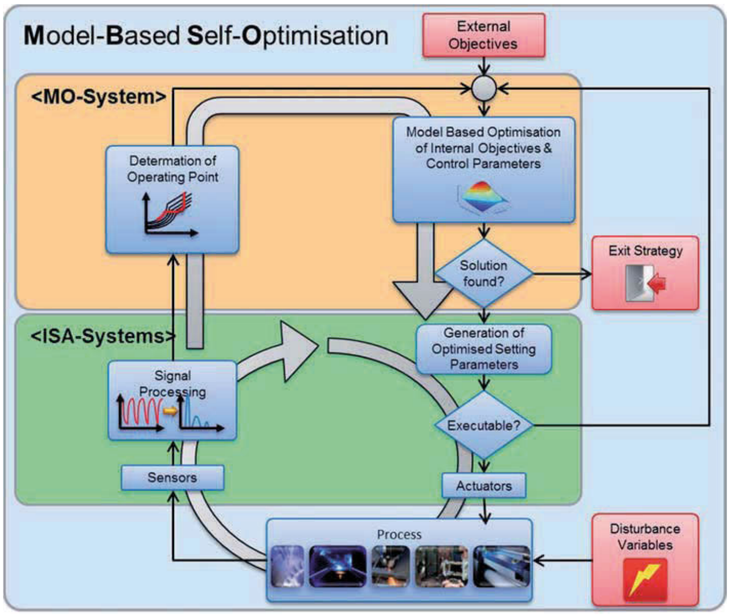
Agenda

1 **Initial situation / Motivation**

2 **General idea and first results**

3 **Summary**

How to realize self-optimisation in manufacturing processes?



1 Analysis of the actual situation

2 Determination of system goals

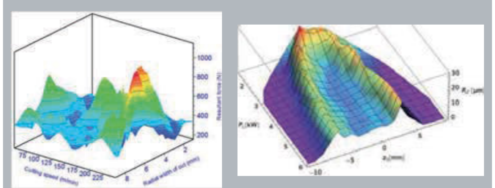
3 Adaptation of the system behaviour

Self-optimisation requires machine readable knowledge

Basic prerequisite for the model-based self-optimisation

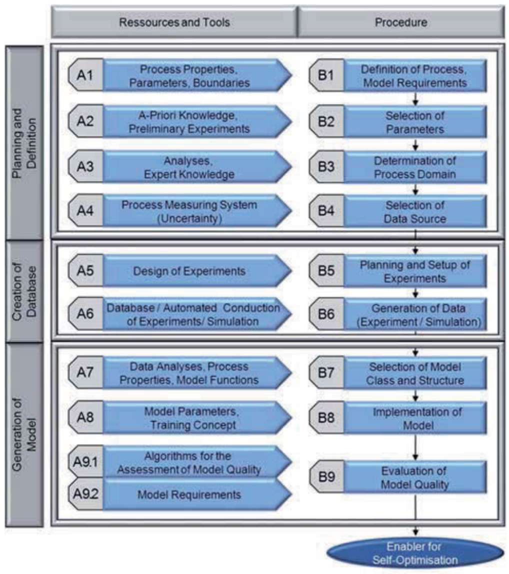
Physical relationships in manufacturing process

Surrogate models of the manufacturing process



Process knowledge in machine readable form

Modeling methodology



Agenda

1 Initial situation / Motivation

2 General idea and first results

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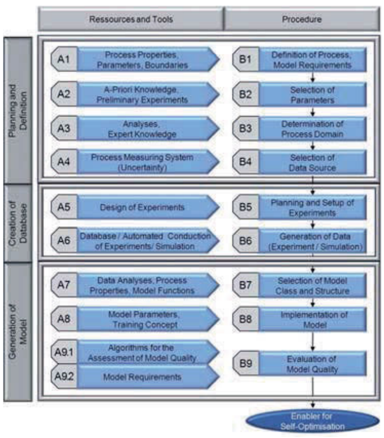
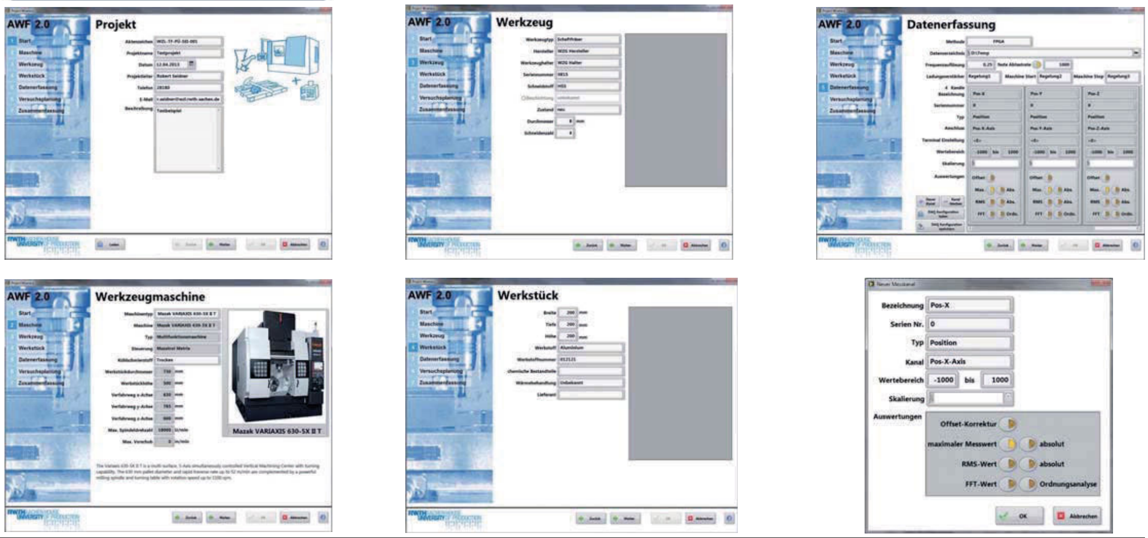
Research hypothesis

A manufacturing system is able like the human being to develop machine readable process knowledge autonomously.



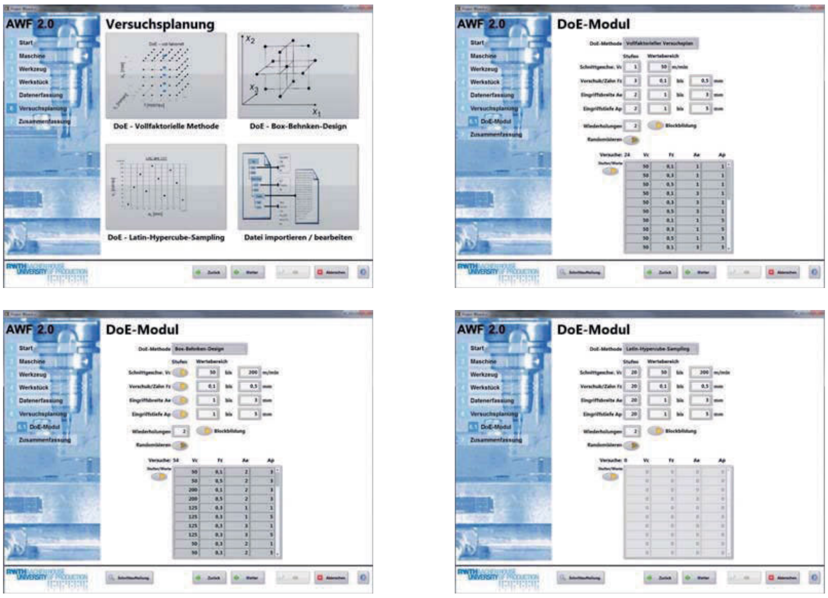
First results: Configuration assistant I/II

Configuration of the test environment

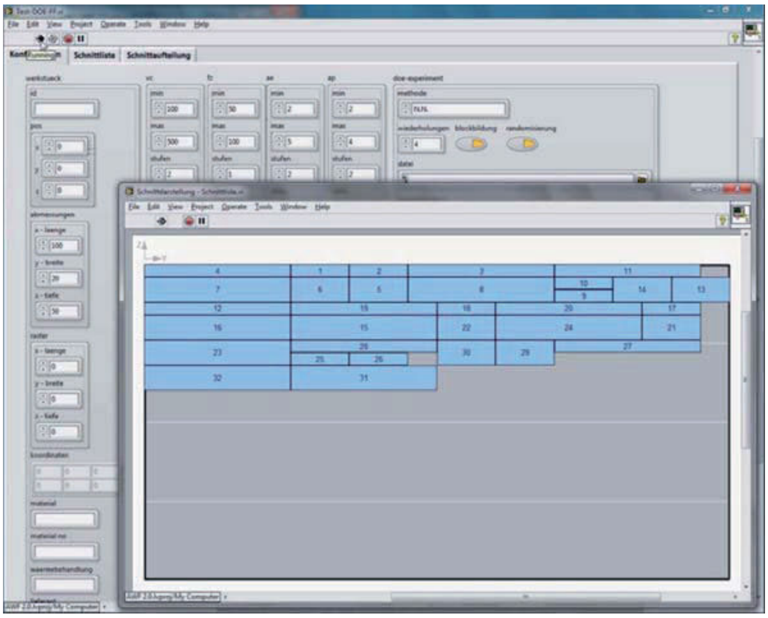


First results: Configuration assistant I/II

Configuration of the experiments



First results: Intelligent organization of experiments



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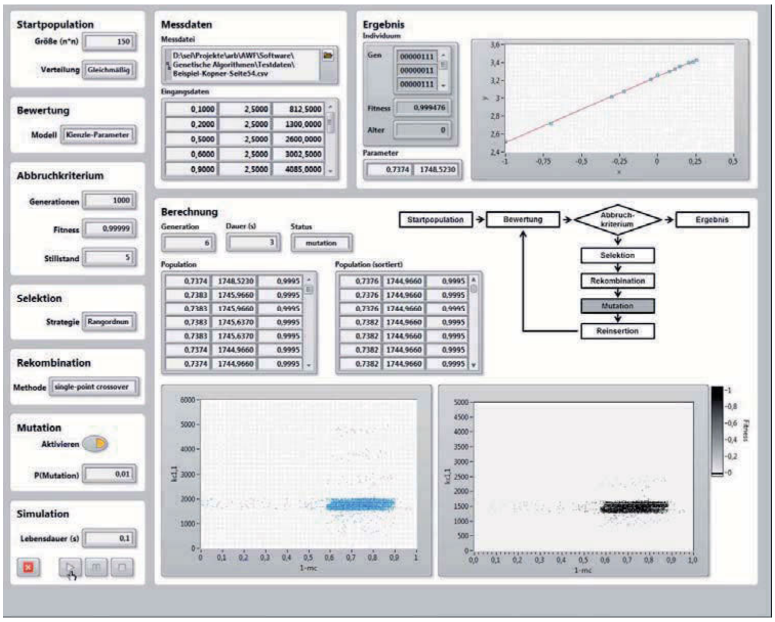
First results: Development of a genetic algorithm to determine model coefficients



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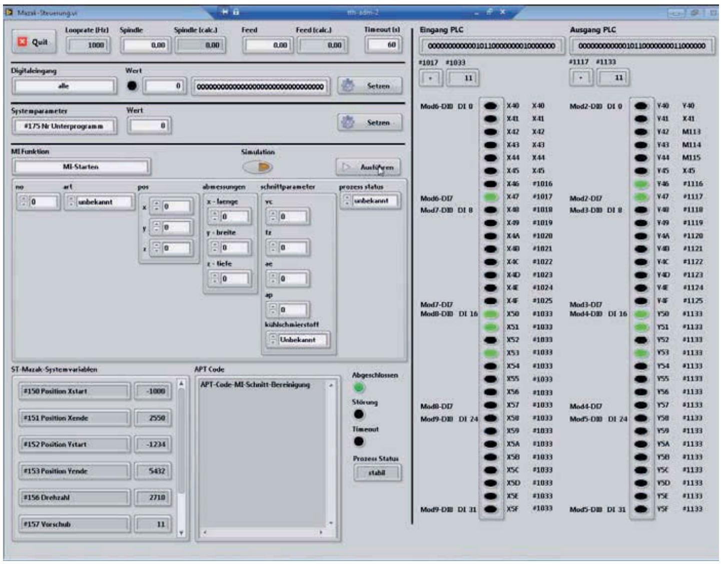
First results: Communication with the machine

Information processing unit	Machine
	

Agenda

1 **Initial situation / Motivation**

2 **General idea and first results**

3 **Summary**

Summary

- Current research activities within sub-project D2 focuses on the development of a testing platform, that is able to generate process knowledge in milling autonomously.
- The general concept and some first results were presented.
- First results are:
  - A configuration assistant to define the testing conditions and the experiments,
  - A genetic algorithm to determine optimal model coefficients,
  - An algorithm to organize the required milling experiments as well as
  - A communication interface to enable the information flow between the information processing system and the machine.

Using the .vtk-Standard for Stress Visualization of Special Gears

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Keywords:
Gear, Beveloid, VTK, Tooth Contact Analysis

Abstract

Through the development of new processes and products a need for special transmissions and gears arises constantly. They are mostly characterized by complex kinematics and geometries. These transmissions and gears can usually not be analyzed using standard software. Either the contact characteristics are modeled in a commercial FE-software, which costs a lot of effort. Or software for this special case has to be developed. Sometimes this results in strong simplifications to enable standard gear software to analyze the parts. In order to overcome this barrier for special transmissions and gears (e.g. beveloids), the general tooth contact analysis software ZaKo3D can be used [HEMM07, ROET12].

The software ZaKo3D calculates the loads on the tooth flanks and the stresses in the tooth root. Until now no possibility exists to visualize the loads and tooth root stresses in each calculated rolling position. Therefore this presentation describes, how the vtk-format [PRAH12] can be used to visualize the calculated results. In two test cases is shown, how a stress-analysis can be performed, by connecting ZaKo3D and the visualization tool kit ParaView. As test-cases beveloid gearings are used. The axes of the first gearing are parallel, the axes of the other gearing are crossing. It is shown for both test-cases, how the position of the contact line and the overlap influence the maximum tooth root stresses.

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Using the .vtk-Standard for Stress Visualization of Special Gears

Cluster-Conferences 2013

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Dr.-Ing. Markus Brumm
Prof. Dr.-Ing Christian Brecher

Aachen, den 23./ 24. September 2013

Structure

1 **Introduction**

2 **State of the Art**

3 **Integration of vtk-Standard into ZaKo3D**

4 **Stress-Analysis of a Beveloid Gear with Parallel Axes**

5 **Stress-Analysis of a Beveloid Gear with Crossed Axes**

6 **Summary and Outlook**

Types of Gears

Parallel Axes

Cylindrical Gears

- Involute Gear
- Cycloid Gear
- Circular Arc Gear
- Wildhaber-Novikov-Gears
- Driving Pin Gears

Others

- Internal Gears
- Rack

Intersecting Axes

Bevel Gears

- Straight Bevel Gears
- Skew Bevel Gears
- Spiral Bevel Gears

Others

- Face Gears
- Beveloids with Intersecting Axes

Crossing Axes

- Hypoid Gears
- Worm Gears
- Crossed Helical Gears Transmission
- Beveloids with Crossing Axes

Software Overview – Tooth Contact Analysis

Software	Producer	Functionality
STplus	FZG / FVA	Analytical, different standards, load collective
STIRAK	WZL / FVA	FEM-calculation, line contact, geometry from generating simulation with tool
RIKOR	FZG / FVA	Analytical, slice model
DZP	FZG / FVA	Dynamic contact analysis by use of mass-spring-system
PlanKorr	LMGK / FVA	Analytical acc. to DIN, stiffness from FEM
Romax	Romax Tech.	Analytical acc. to DIN
KISSsoft	KISSsoft AG	Different analytical methods, load collectives
Mdesign LVR	TEDATA	Analytical acc. to DIN
KIMoS / Becal	Klingelnberg	Analytical, geometry from manufacturing simulation
SNESYS	FZG/FVA	Worm Gears, acc DIN
…		

Coverage of Gear Types by the Presented Sofware

Parallel Axes

Cylindrical Gears

Involute Gear	✓
Cycloid Gear	✗
Circular Arc Gear	✗
Wildhaber-Novikov-Gears	✗
Driving Pin Gears	✗

Others

Internal Gears	✓
Rack	✗

Intersecting Axes

Bevel Gears

Straight Bevel Gears	✓
Skew Bevel Gears	✓
Spiral Bevel Gears	✓

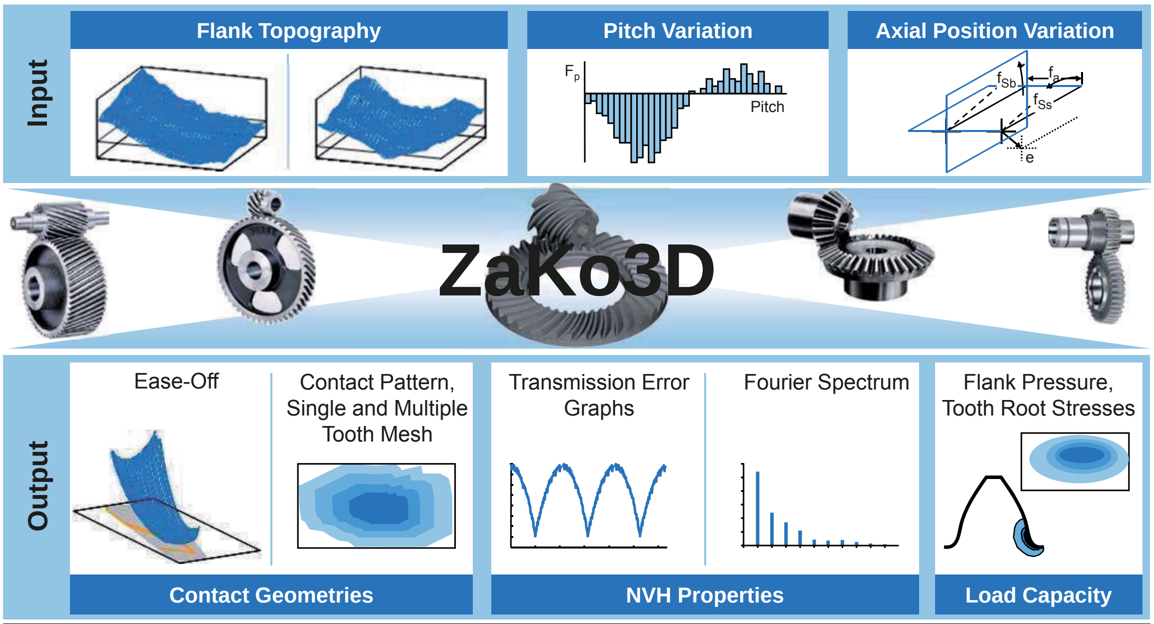
Others

Face Gears	✗
Beveloids with Intersecting Axes	✗

Crossing Axes

Hypoid Gears	✓
Worm Gears	✓
Crossed Helical Gears Transmission	✗
Beveloids with Crossing Axes	✗

Features of the Tooth Contact Analysis Software ZaKo3D



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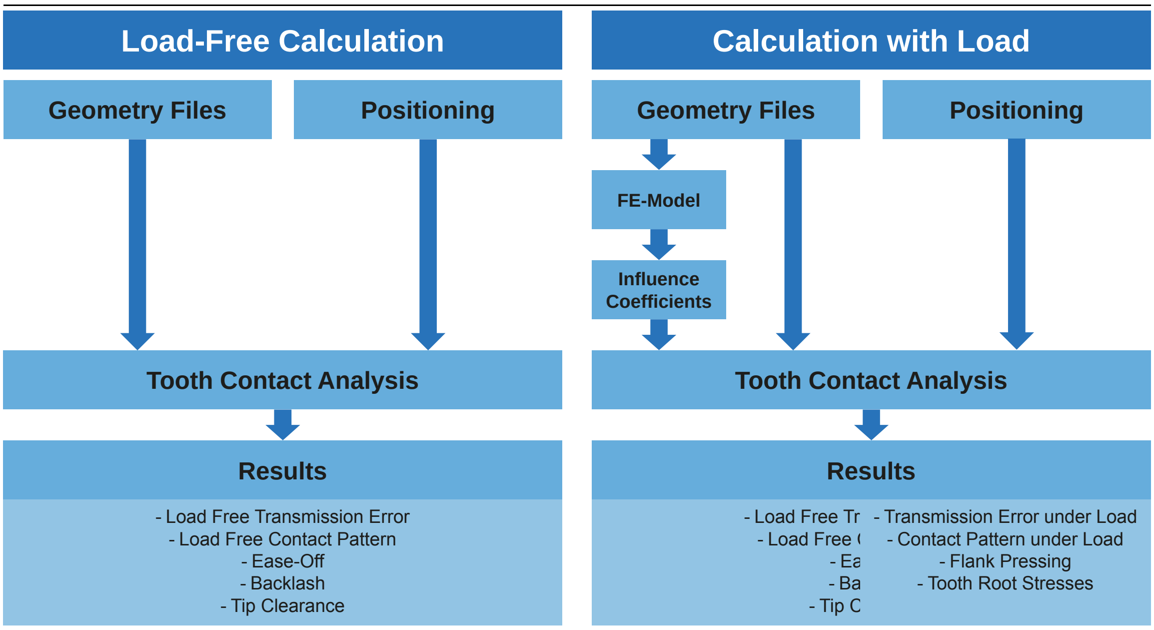
5 Stress-Analysis of a Beveloid Gear with Crossed Axes

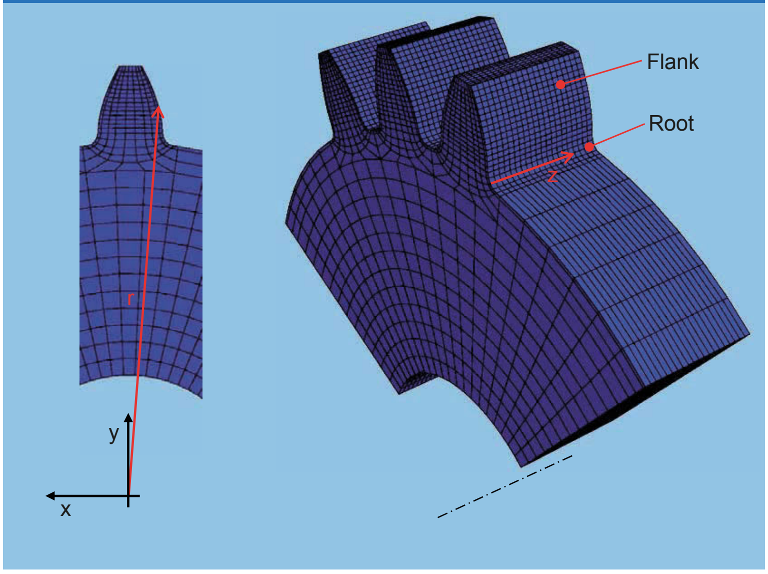
6 Summary and Outlook

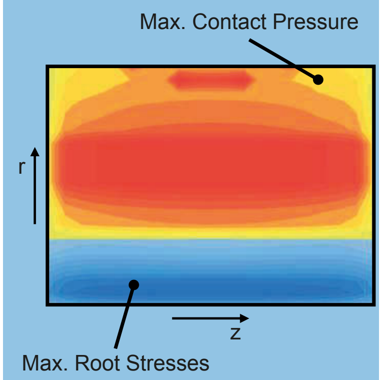
Calculation Procedure of ZaKo3D



Actual Visualisation of Contact Pressure and Root Stresses

FE-Model	Actual Visualisation





- 2D-Visualisation
- r-z-Coordinates
- Maxima over all Mesh Positions

Structure

1 Introduction

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5 Stress-Analysis of a Beveloid Gear with Crossed Axes

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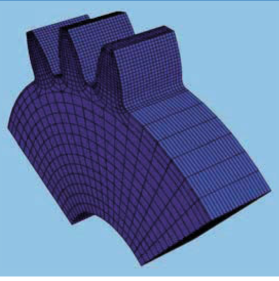
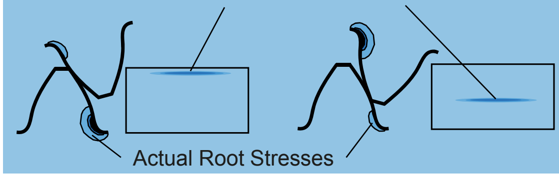
Integration of vtk-Standard into ZaKo3D

FE-Model



ZaKo3D Results



Mesh_Position_n.vtk

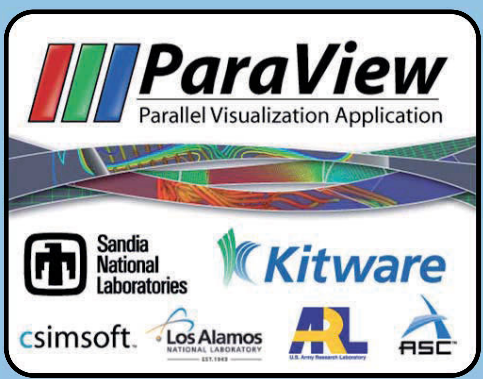
Mesh_Position_ ... .vtk

Mesh_Position_1.vtk

- POINTS
- CELLS
- CELL_TYPES
- POINT_DATA

Visualization of .vtk-Data with ParaView

Paraview



- Scientific Result Visualization
- Supports .vtk-Standard
- 3D-Visualization:
  - Anaglyph (red-blue)
  - Interlaced (e.g. shutter)

Mesh_Position_n.vtk

Mesh_Position_ ... .vtk

Mesh_Position_1.vtk

- POINTS
- CELLS
- CELL_TYPES
- POINT_DATA

Structure

1 Introduction

2 State of the Art

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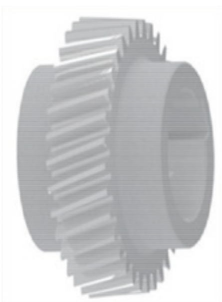
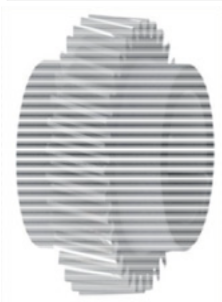
4 Stress-Analysis of a Beveloid Gear with Parallel Axes

5 Stress-Analysis of a Beveloid Gear with Crossed Axes

6 Summary and Outlook

Test Case - Beveloid Gear with Parallel Axes





Gear 1

b_1 = 16 mm
α_n = 20°
θ_{f1} = -3.6°
θ_{a1} = -3.6°
β_1 = 19.463°
z_1 = 33
m_n = 2.0 mm
d_{a1} = 74.000 mm
x_{e1} = -0.0721

Gear 2

b_2 = 16 mm
α_n = 20°
θ_{f2} = 3.6°
θ_{a2} = 3.6°
β_2 = -19.463°
z_2 = 33
m_n = 2.0 mm
d_{a2} = 74.000 mm
x_{e2} = -0.0721

Tool Data

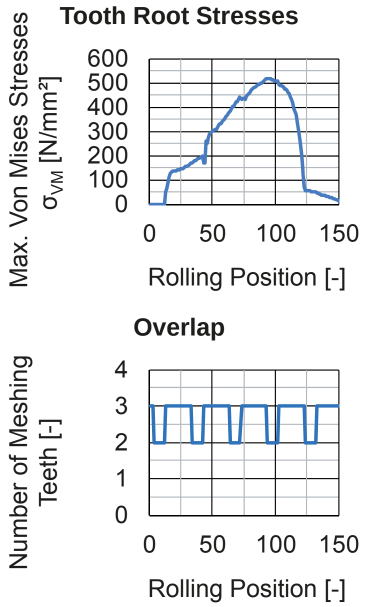
h_{aP0} = 2.500 mm
h_{fP0} = 2.600 mm
ρ_{fP0} = 0.500 mm
α_{P0} = 20°
d_0 = 200 mm
z_0 = 3
Lead: Right Hand

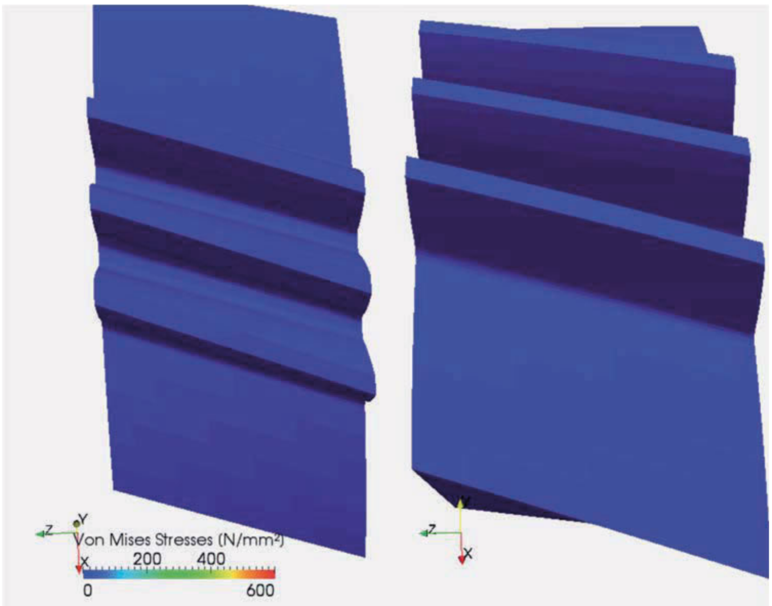
Positioning

a = 70 mm
Σ = 0°

T_1 = 372.0 Nm
T_2 = 372.0 Nm

Test Case 1, Parallel Axes: Tooth Root Stress Analysis – Complete Meshing





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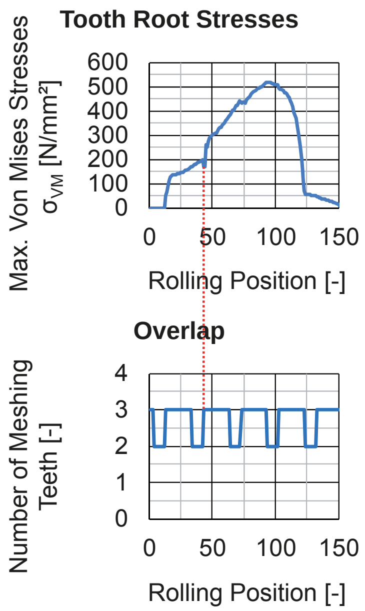
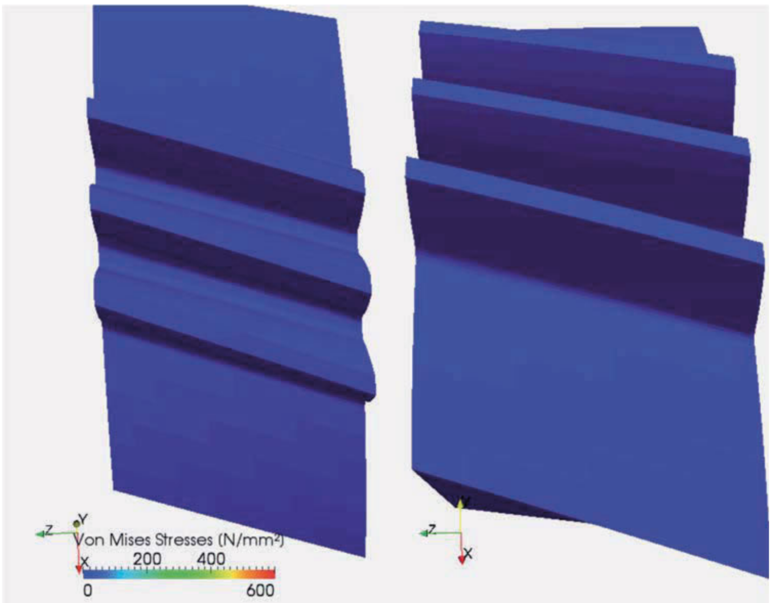
Test Case 1, Parallel Axes: Tooth Root Stress Analysis – Rolling Position 0-43





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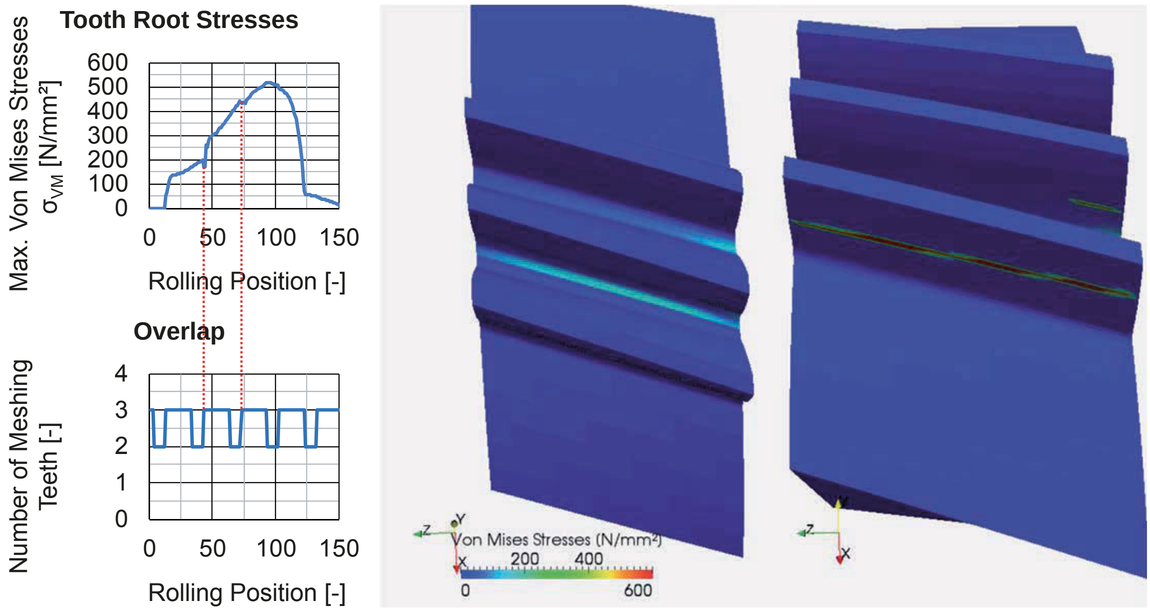
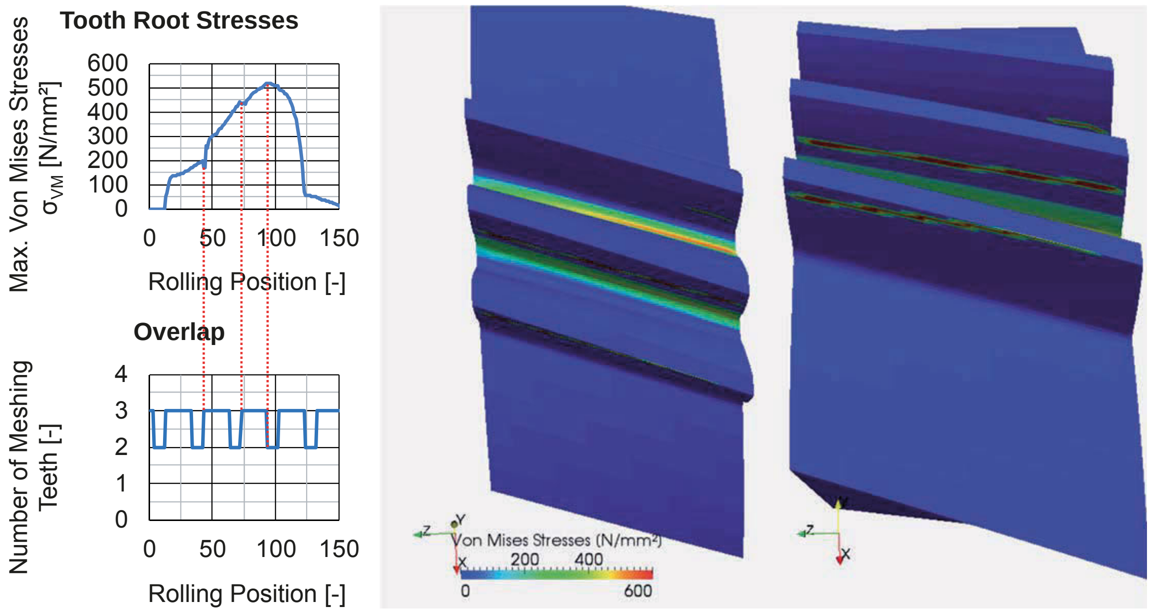
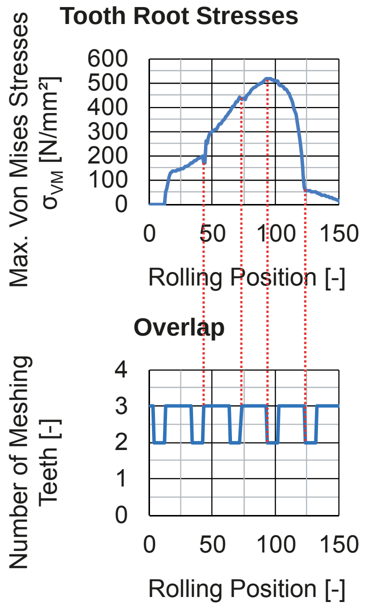
Test Case 1, Parallel Axes:
Tooth Root Stress Analysis – Rolling Position 43-73

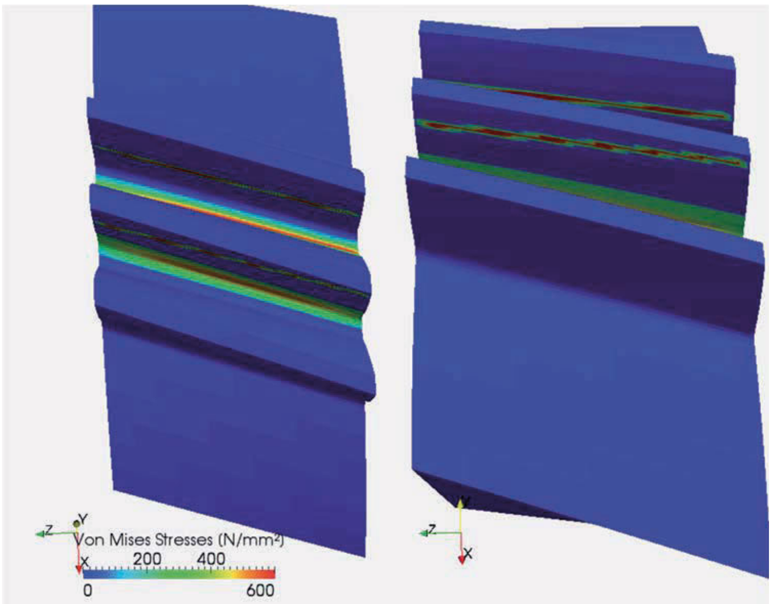


Test Case 1, Parallel Axes:
Tooth Root Stress Analysis – Rolling Position 73-94

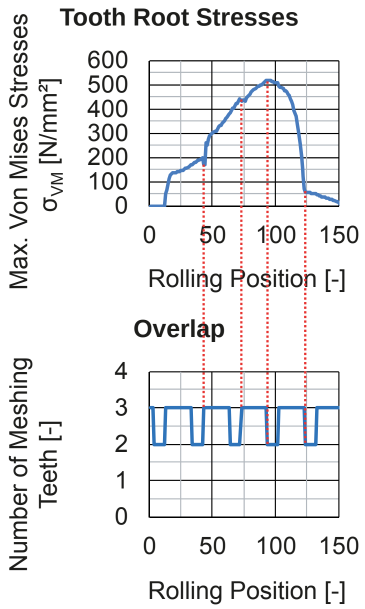


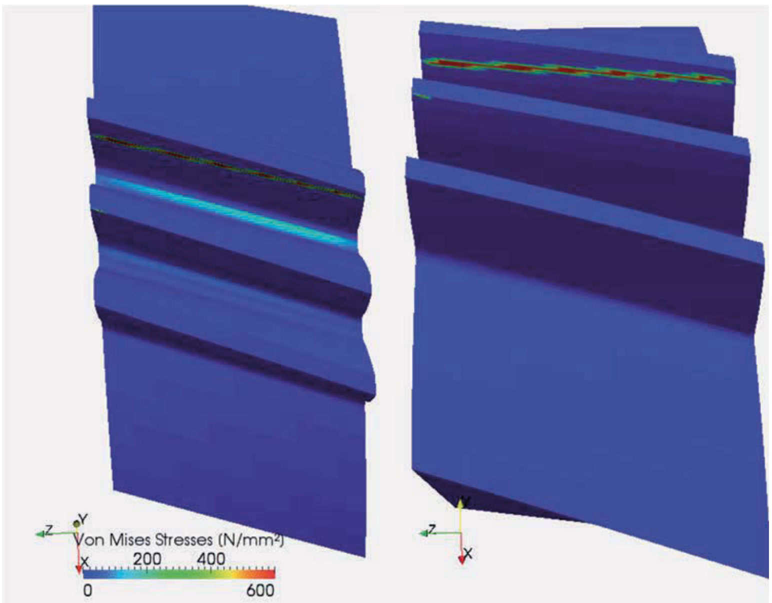
Test Case 1, Parallel Axes: Tooth Root Stress Analysis – Rolling Position 94-123





Test Case 1, Parallel Axes: Tooth Root Stress Analysis – Rolling Position 123-150





Structure

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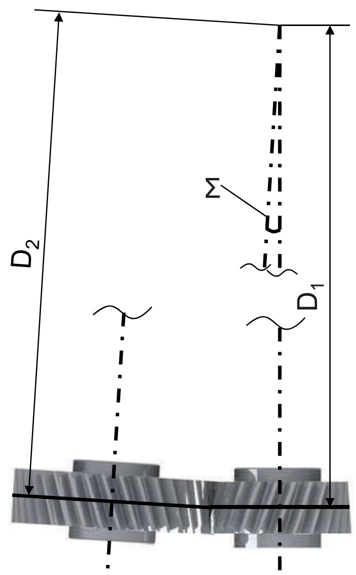
Test Case - Beveloid Gear with Crossed Axes



Gear 1	
b_1	= 36.1 mm
α_n	= 20°
θ_{f1}	= -3.65°
θ_{a1}	= -3.65°
β_1	= 19.3°
z_1	= 25
m_n	= 3.5 mm
d_{a1}	= 99.590 mm
x_{e1}	= -0.03

Gear 2	
b_2	= 37.0 mm
α_n	= 20°
θ_{f2}	= 0°
θ_{a2}	= 0°
β_2	= -19.3°
z_2	= 36
m_n	= 3.5 mm
d_{a2}	= 140.380 mm
x_{e2}	= -0.2362

Tool Data	
h_{aP0}	= 5.425 mm
h_{fP0}	= 5.376mm
ρ_{fP0}	= 1.085 mm
α_{P0}	= 20°
d_0	= 200 mm
z_0*	= 3
Lead*:	Right Hand

*Only Grinding Worm

Positioning and Load	
a	= 0 mm
Σ	= 3.6°
D_1	= 1799.87 mm
D_2	= 1799.23 mm
T_1	= 1500.0 Nm
T_2	= 1041.7Nm

Source: Brecher, Brumm, Hübner, Henser: Influence of the Manufacturing Method on the Running Behaviour of Beveloid Gears, Prod. Eng. Res. Devel., Bd. 7, Nr. 2-3, S. 265–274, 2013

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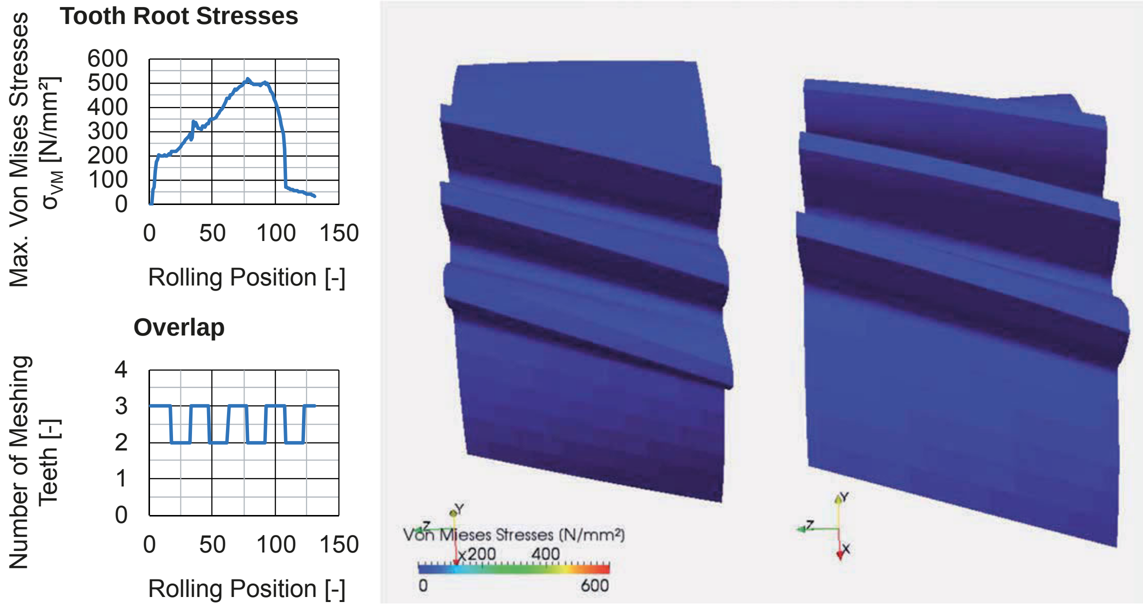
Test Case 2, Intersecting Axes, Pinion: Tooth Root Stress Analysis – Complete Meshing



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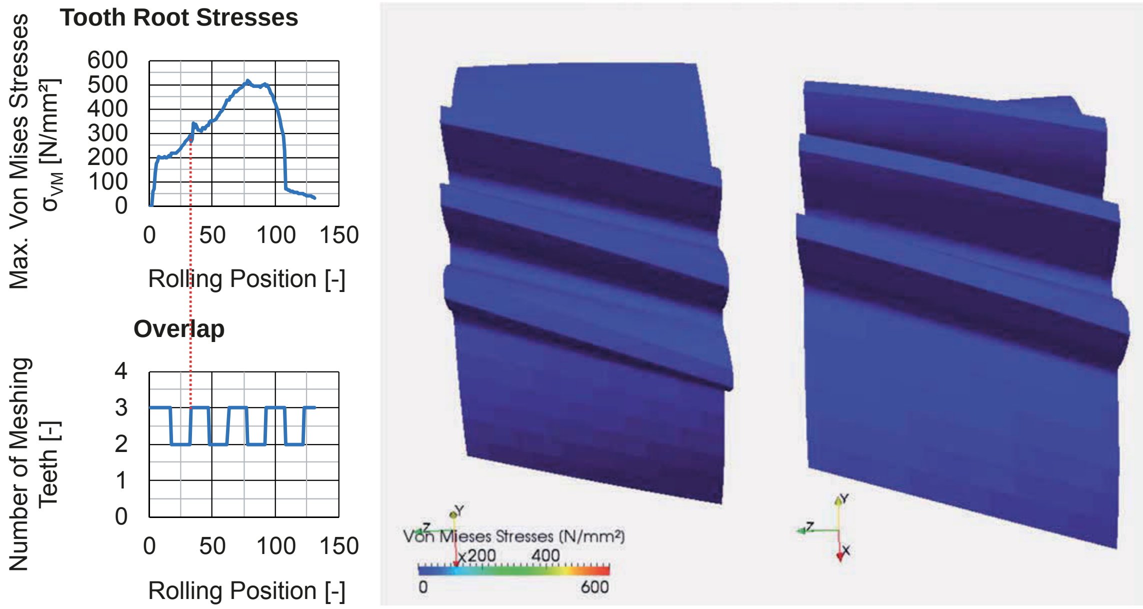
Test Case 2, Intersecting Axes, Pinion : Tooth Root Stress Analysis – Rolling Position 0-32



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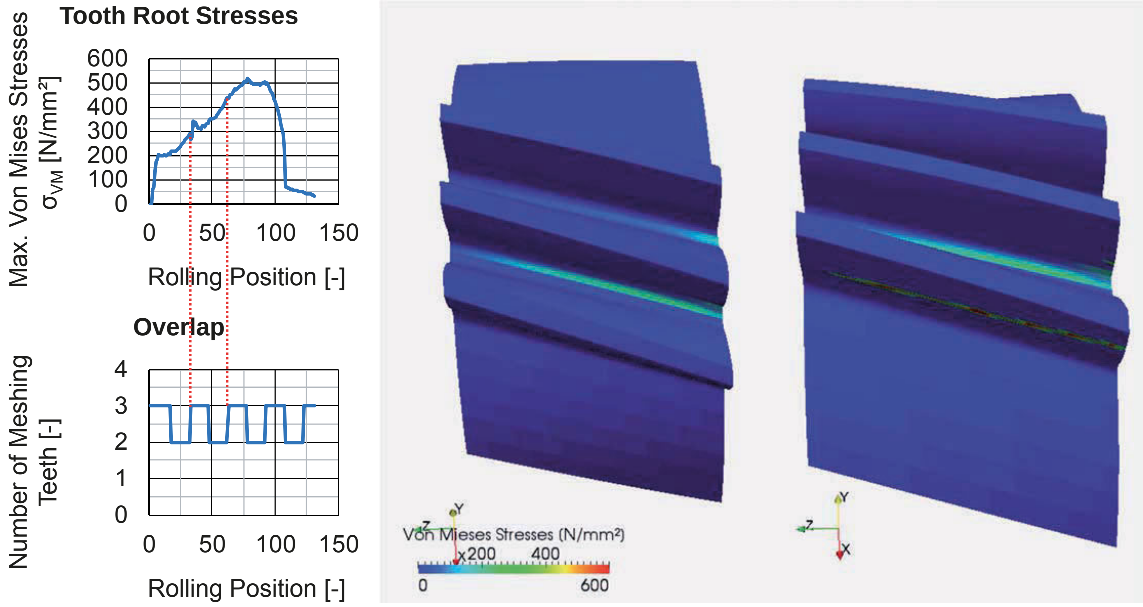
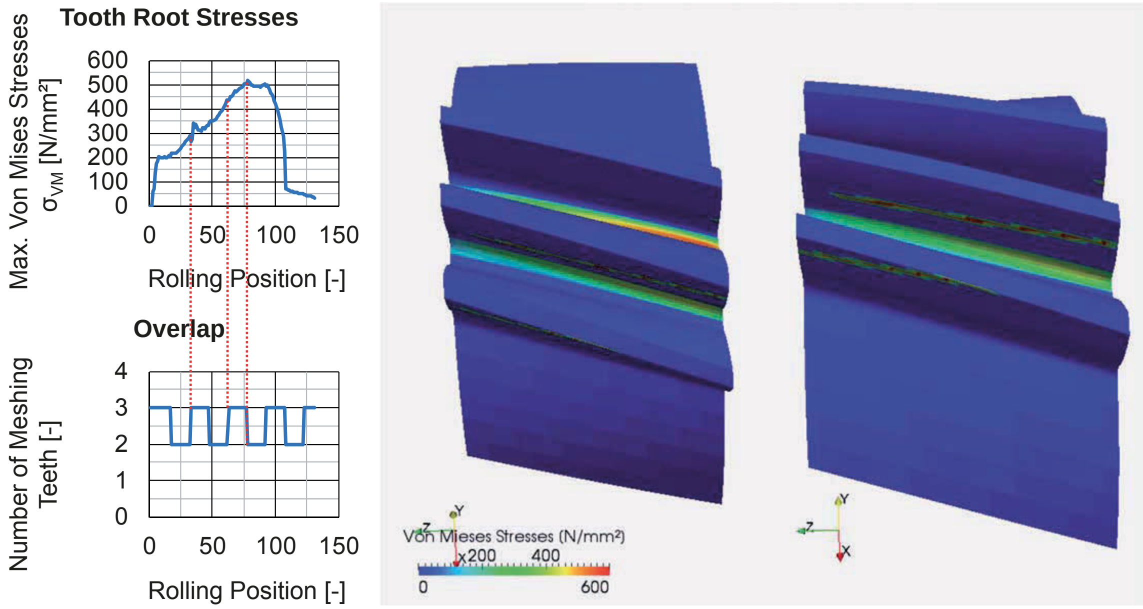
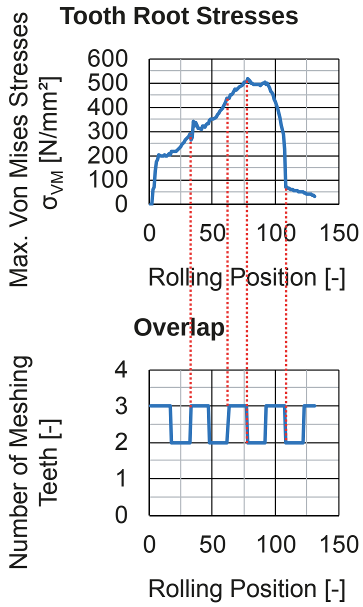
Test Case 2, Intersecting Axes, Pinion : Tooth Root Stress Analysis – Rolling Position 32-63

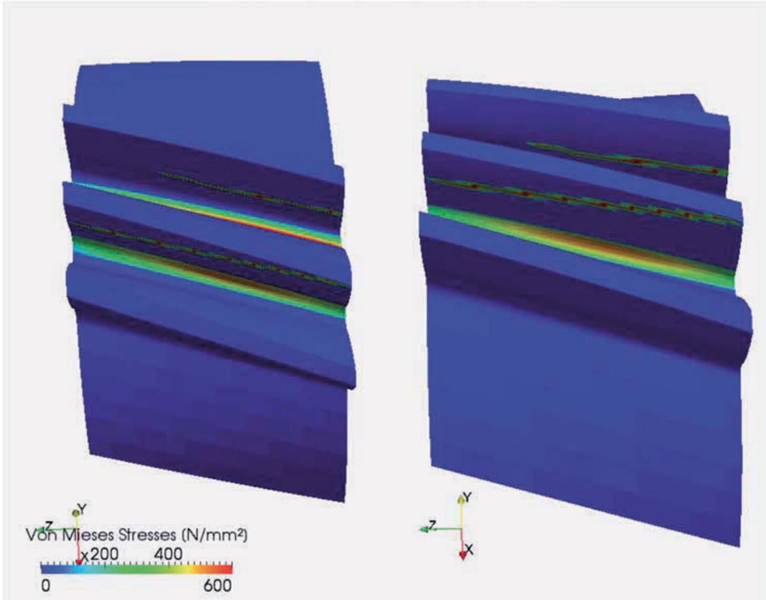


Test Case 2, Intersecting Axes, Pinion : Tooth Root Stress Analysis – Rolling Position 63-78

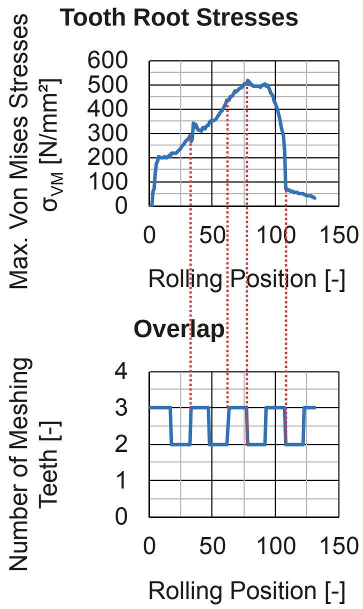


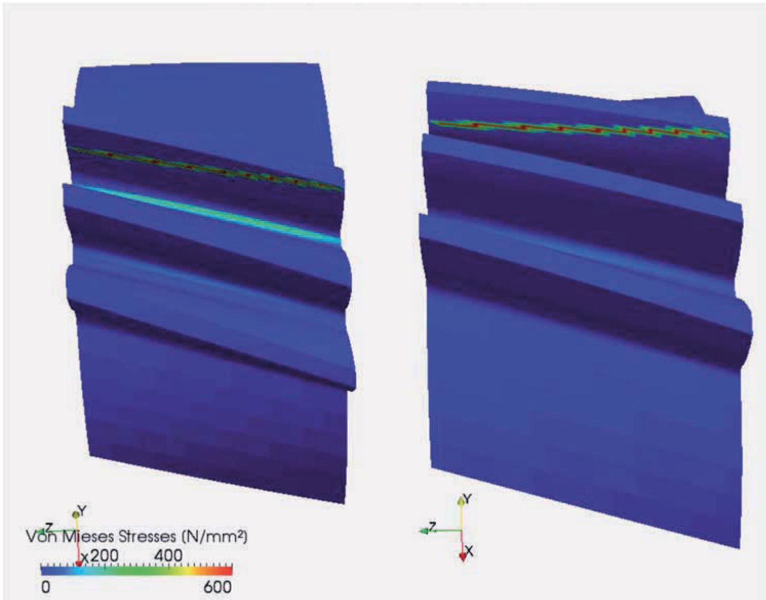
Test Case 2, Intersecting Axes, Pinion :
Tooth Root Stress Analysis – Rolling Position 78-108





Test Case 2, Intersecting Axes, Pinion :
Tooth Root Stress Analysis – Rolling Position 108-132





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6 **Summary and Outlook**

Summary and Outlook

Summary

- ZaKo3D was equipped with the .vtk-interface
- By using the .vtk-standard the visualization toolkit ParaView can be used to visualize the calculation results of ZaKo3D
- In a test case was shown, how contact loads and overlap influence the tooth root stresses

Outlook

- Connecting ZaKo3D to the AixVipMap platform using the .vtk-interface
- Enable users from industry to use the 3D-visualization of loads and stresses (e.g. in the software platform “WZL Gear Toolbox”)

MPC of an Injection Moulding Process - From physical Modelling to Model-based Control

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Abel, D.

Hopmann, C.

Reßmann, A.

Keywords:
Model Predictive Control, Process Modeling and Identification, Cavity Pressure Control, Injection Moulding

Abstract

Today's manufacturing systems are getting more and more complex. High-level control algorithms, such as Model Predictive Control, potentially allow for making use of rising computational power. Through the use of mathematical process models, a controller can be tailored to fit a specific process more closely than it would be possible with classical PID controllers, allowing for better and more precise control.

Many production systems – such as the injection moulding machine considered here - can be equipped with interchangeable tools (in this case moulds) that have significant influence on process behaviour. As the machines built-in control systems are typically developed independently of the tools, challenges arise in adjusting the process model to the combination of machine and mould. Although the process behaviour is qualitatively similar for different combinations, significant quantitative differences are to be expected.

In order to automatically adjust the process model and to allow for the use of the model in a Model Predictive Controller, a procedure for identifying the behaviour of an injection moulding process has been developed in cooperation between the Institute for Automatic Control (IRT) and the Institute of Plastics Processing (IKV) [HO2013]. The identification procedure can be carried out in an operational state that is close to regular operation and therefore is potentially embeddable into a real-life workflow. It is based on a physically motivated grey-box model. In a previous contribution, a process model of an injection moulding process was identified. Based on the identified model, now a Model Predictive Controller is implemented and first control results are shown.

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[HO2013] Hopmann, Ch.; Reßmann, A.; Reiter, M.; Zöller, D.; Abel, D (2013): Strategy for Robust System Identification for Model Predictive Control of Cavity Pressure in an Injection Moulding Process, The 11th International Symposium of Measurement Technology and Intelligent Instruments.

MPC of an Injection Moulding Process - From physical Modelling to Model-based Control

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Prof. Dr.-Ing. Ch. Hopmann, Dipl.-Ing. Axel Reßmann

Institute of Plastics Processing (IKV) at RWTH Aachen University

23.09.2013

Outline

- Introduction, Motivation
- Physically Motivated Model
- Identification Procedure
- Model Predictive Control
- First Control Results
- Summary and Outlook

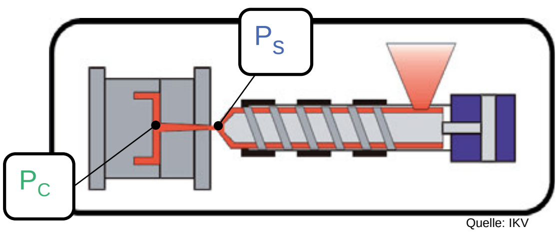
Introduction: Motivation

- Today‘s manufacturing systems get more and more complex
- High available computational power theoretically allows application of complex control algorithms
- Complexity often limits acceptance for high-level control

- Use computational power to let the machine help the user set up the process
- MPC as potential Method to make the use of control algorithms more intuitive

Introduction: Injection Moulding Process

Quelle: Arburg

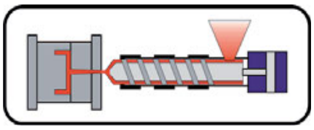


Quelle: IKV

- Important Process Values
  - Screw Pressure P_S
  - Cavity Pressure P_C

Introduction: Motivation

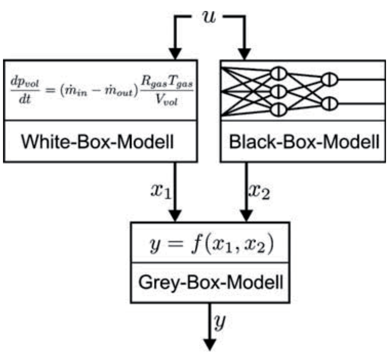
Quelle: Arburg



Quelle: IKV

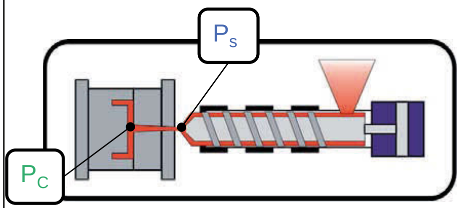
- Different manufacturor for machine and mould
- Controller needs to be able to cope with different moulds and materials
- Cavity pressure sensor is part of the mould, not the machine
- Still: basic qualitative behaviour should stay the same
- Machine needs to „get to know“ the mould
  - > Process identification nescessary

Physically Motivated Model

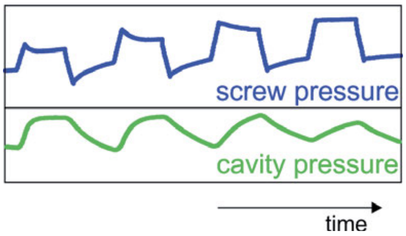


- Formulations for dynamical process models are manifold
- White-Box Model vs. Black-box Model
  - Physically-based (white-box) models completely interpretable but show limits
  - Black-Box (e.g. Neural Network) model are flexible, but not generaliseable
- For our purpose: Grey-box model
  - Use an interpretable, physical-based model for basic structure, parametrize it using black-box methods (e.g. characteristic map)

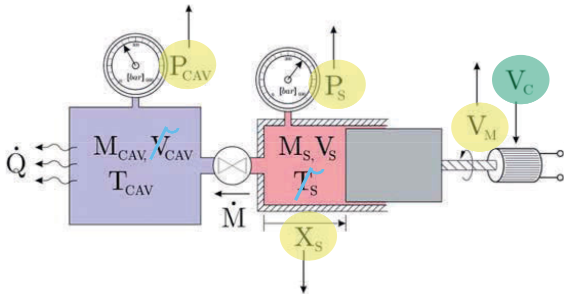
Physically Motivated Model



Quelle: IKV

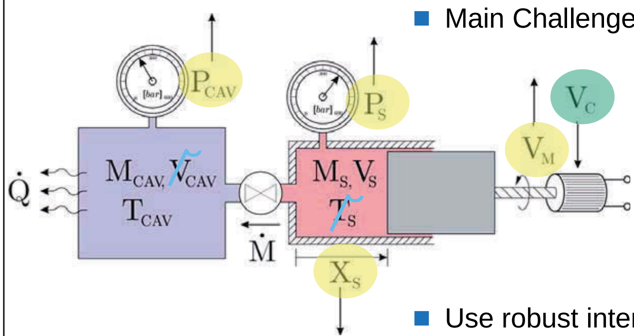


- Screw volume and cavity volume are modelled as pressure vessels
- Screw feed decreases available volume V_S, leading to higher pressure
- Pressure difference results in mass flow between pressure vessels
- Heat flow out of the cavity volume decreases pressure, allowing for more material to follow



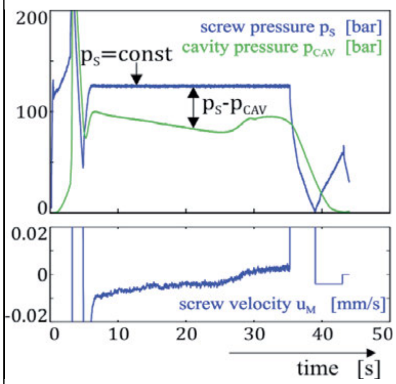
Process Identification

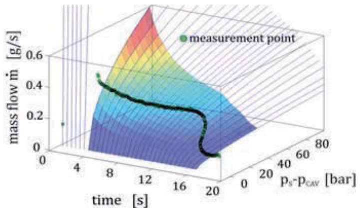
- Need to find characteristic values/maps to parametrize the process model
- Main Challenge: Identification of flow channel behaviour



- Use robust intermediate controller to set up the process and create identification data

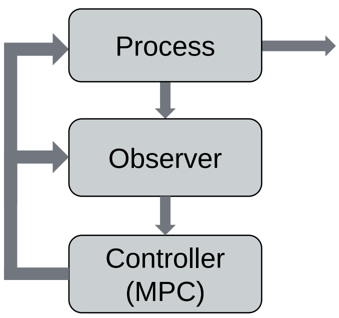
Process Identification: Flow Channel behaviour

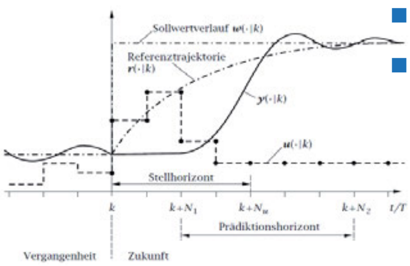




- Implemented simple PI controller
- run the process with constant screw pressure
- use the aquired data for creating a characteristic map
- Advantages:
  - process run with constant screw pressure is feasible and can be incoporated into real-life workflow
  - process is still based on the machine-internal sensors
  - data aquired hereby cannot be calculated beforehand

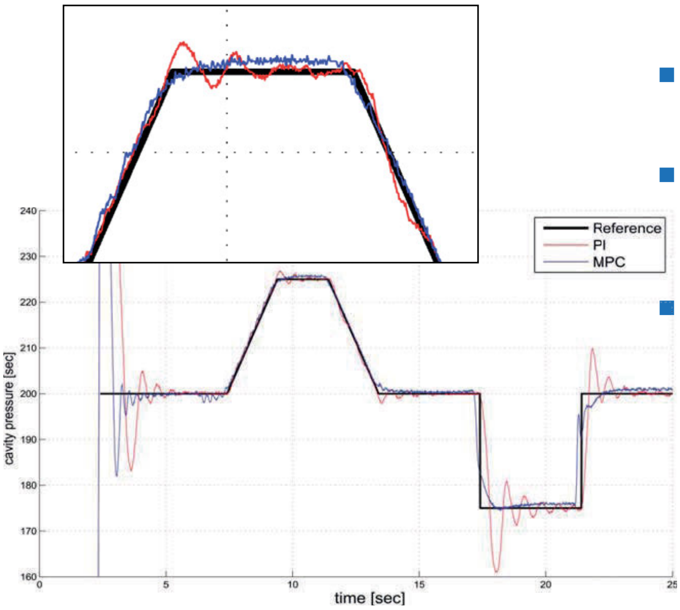
Model Predictive Control





- Use an optimization based on the model to select best control inputs
- Optimization for prediction horizon, penalty function incorporates:
  - Deviation from reference trajectory
  - Change in control inputs
- Constraints incorporated for min/max speed
- Observer is used to obtain model states
- Optimization is repeated every time step (8ms for the following results)

First Control Results



- Comparison of PI used for and MPC
- Stable and reassonable performance with very ow amount of tuning
- Characteristic advantages:
  - Significanly reduced overshoot for step-like inputs
  - Better tracking of trajectory due to prediction

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Seite 10

Summary and Outlook

- Implemented Model Predictive Control using a physical-based, easily interpretable model
- Model is parametrized using data that is aquired on-line (and is not available beforehand)
- Achieved good first control results with very low amount of tuning
- Procedure needs to be validated with different moulds
- Influence of characteristic model errors needs to be investigated

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Seite 11

ICMEg – the Integrated Computational Materials Engineering expert group - a new European coordination action

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Keywords:
Integrated Computational Materials Engineering, ICME, network of stakeholders, standardization, platform concepts, processing/microstructure/property relationships

Abstract

Based on the results of the first funding period of the CoE, the ICMEg proposal has been submitted to the European commission towards establishing a global standard for information exchange in Integrated Computational Materials Engineering- ICME. Communication standards and protocols shall be established at the scale of the process/resp. the component, at the scale of the microstructure as also for the basic underlying thermodynamic models and for models at the electronic, atomistic and mesoscopic scales. After shortly identifying the benefits of Integrated Computational Materials Engineering ICME in general, the presentation will briefly describe the ICMEg consortium, outline the vision and mission of this project and detail its practical implementation.

Acknowledgement

The ICMEg proposal is based on results of the first funding period of the Cluster of Excellence "Integrative Production Technologies for High Wage Countries", which was funded by the Deutsche Forschungs-gemeinschaft. The proposal eventually has been formulated and submitted during the ongoing second period of this Cluster of Excellence. The ICMEg project itself now is funded by the European Commission under grant NMP3-CA-2013-606711 and will formally be launched in October 2013.

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ICMEg – the Integrated Computational Materials Engineering expert group
a new European coordination action

Cluster-Conferences 2013

Georg J. Schmitz, Ulrich Prahl

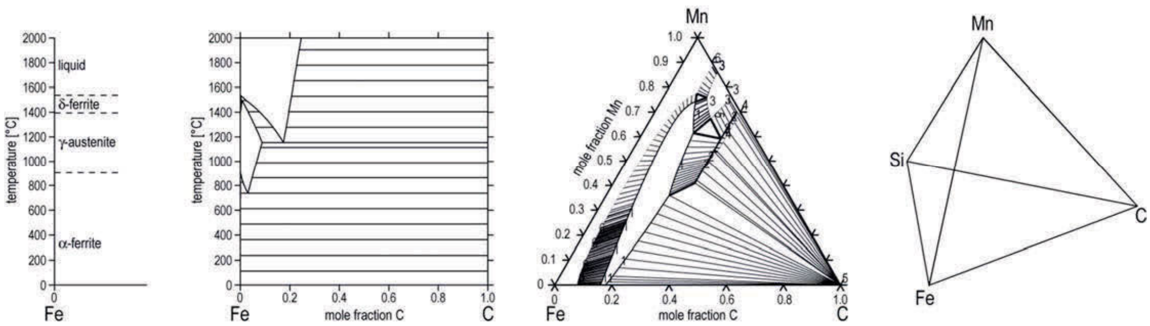
ACCESS e. V., RWTH Aachen University

Institute of Ferrous Metallurgy, RWTH Aachen University

Aachen, den 23./ 24. September 2013

What is ICME?

I-C-M-E…..looks like a quaternary system ☺….



The unaries

***"I"** like integrative, integrated, integration, integr*:* appears in different contexts ranging from social life, mathematics, natural sciences, engineering and others. Key issue for social integration is e.g. communication using a **standard** for information exchange - the common language. With respect to integration in "time" the word **history** seems adequate, while integration of knowledge over time leads to **experience.**

***"C"** like computational, computers, computation, comput** : in short: anything which can be performed on a computer like **simulations**, handling of large **datasets**, description of **iterative processes**, computer control and steering**, storage of data and knowledge**, mimicking of real processes in **virtual reality**, computer games, **e-learning** etc.

***"M"** like materials:* classification of **materials** may be on the basis of different **types** like e.g. plastics, rubbers, metallic alloys, ceramics, concrete, biomaterials, composites. Other schemes hold for their individual **shape** like bulk materials, thick films, thin films, coatings or for specific **functionalities** and **properties** like e.g. conductors, isolators, structural materials and many, many others.

***"E"** like engineering*: all activities related to **design, construction, manufacture, production, assembly, operation** and **repair/recycling** of **materials, components** and **systems** e.g. for consumables, investment goods, public infrastructure or exploitation of raw materials and resources.

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The binaries ME, IM, IE, IC, CE and CM

binary	keywords
ME	grain size, grain boundaries, local and global crystallographic orientations i.e. "texture", phase-fractions, precipitates, dislocations and defects, "microsegregation", solution hardening,….. composition, heating/cooling rates, heat treatments, pressure/atmospheric conditions, specific deformation and recrystallisation procedures, external electric or magnetic fields, ultrasonic agitation, seeding particles, epitaxy…
IM	metal-matrix composites, reinforced ceramics like cermets, textile- or steel-reinforced concrete, reinforced polymers
IE	….
IC	…
CE	Components, properties of components, distortions,…, fatigue, failure
CM	Calphad, MD-simulations, Phase-Field, Cellular Automata

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The quaternary system: ICME

There is an ambiguity w.r.t. the term “engineering”, which is applied to a product/component in CE/ICE in and to a specific material in CM/CME.
Focus of ICME thus is on

engineering the properties of a component as a function of the local properties of the material inside the component
and
along its entire production and service life cycle

CE: Finite Element Methods – a success story

History [edit]

The finite element method originated from the need for solving complex elasticity and structural analysis problems in civil and aeronautical engineering. Its development can be traced back to the work by Alexander Hrennikoff (1941) and Richard Courant[1] (1942). While the approaches used by these pioneers are different, they share one essential characteristic: mesh discretization of a continuous domain into a set of discrete sub-domains, usually called elements. Starting in 1947, Olgierd Zienkiewicz from Imperial College gathered those methods together into what would be called the Finite Element Method, building the pioneering mathematical formalism of the method.[2]

Hrennikoff's work discretizes the domain by using a lattice analogy, while Courant's approach divides the domain into finite triangular subregions to solve drawing on a large body of earlier results for PDEs developed by Rayleigh, Ritz, and Galerkin.

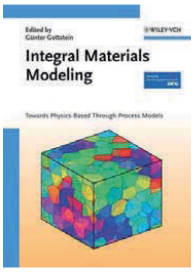
Development of the finite element method began in earnest in the middle to late 1950s for airframe and structural analysis[3] and gathered momentum in the 1960‘s

very successful !!

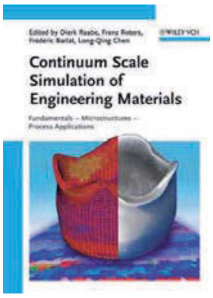
present developments: „multiphysics“

But : What‘s about materials data entering such simulations?

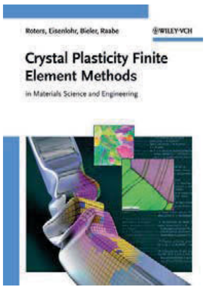
CME: Computational Materials Engineering



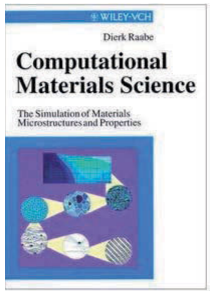
2007



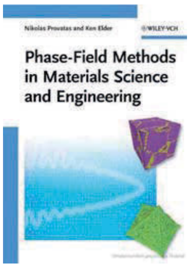
2004



2010

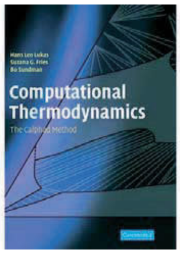


1998



2010

2012



2007

Why ICME?

a) because it can be done right now (…and was not possible earlier)!

Currently all these approaches have reached a level allowing for valuable contributions to modern engineering tasks within knowledge driven production models. The capabilities of the respective software tools and the present availability of computational power make efforts towards the integration of all these approaches possible, meaningful and timely.

History of ICME

In view of the

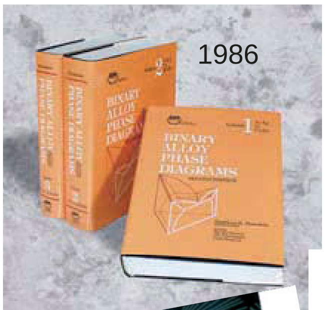
„C“

in ICME:

ICME history
starts about the 1960s

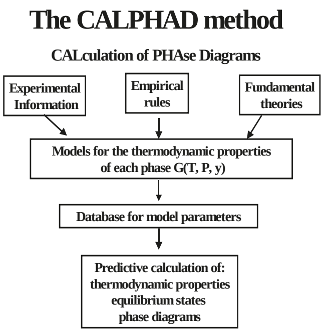
i.e. about 50 years ago

Computational Thermodynamics (phase equilibria)



„I disliked computers. Thus I started studying metallurgy, because I thought this subject would be too complicated to be ever put on a computer……“

Bo Sundman, one of the creators of Thermo-Calc



www.calphad.org

1969 Formation of CALPHAD.

1971 Sub-lattice model for 2 comp. (Hillert and Steffansson, KTH).

1977 Development of Thermo-Calc starts

Theories of phase transitions/ Phase-field models

van der Waals (1893)

Korteweg (1901)

Landau-Ginz

Cahn

Halpern)

Langer (phase field

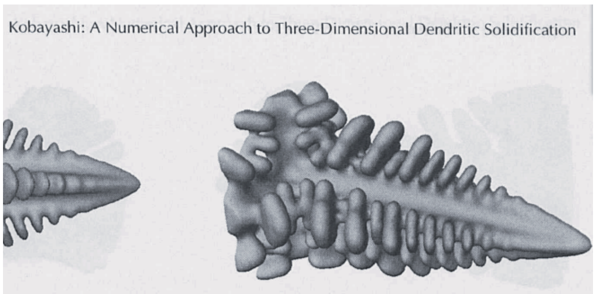
Kobayashi se field

Steinbach (1 del

Elder (2002) p

2010

Kobayashi: A Numerical Approach to Three-Dimensional Dendritic Solidification



PHYSICA D

Physica D 94 (1996) 135-147

A phase field concept for multiphase systems

I. Steinbach [a,*], F. Pezzolla [a], B. Nestler [a], M. Seeßelberg [a], R. Prieler [a], G.J. Schmitz [a], J.L.L. Rezende [b]

[a] ACCESS e.V., Intzestraße 5, D-52072 Aachen, Germany

[b] Foundry Institute RWTH Aachen, D-52056 Aachen, Germany

Received 20 November 1995; accepted 30 November 1995

Communicated by H. Müller-Krumbhaar

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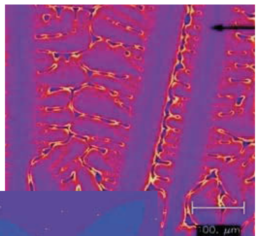
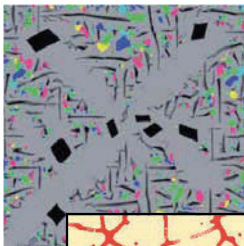
multi-phase-field simulations of technical alloy grades

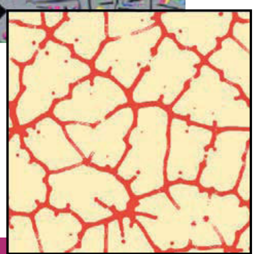


Steel
(e.g. stainless steel)

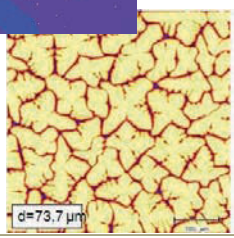


Al-alloys
(e.g. KS 1295)

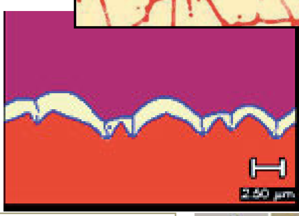
cast iron
(e.g. GJS)



Mg-alloys
(e.g. AZ 91)



Superalloys
(e.g. IN 718)



Solders
(e.g. SAC)

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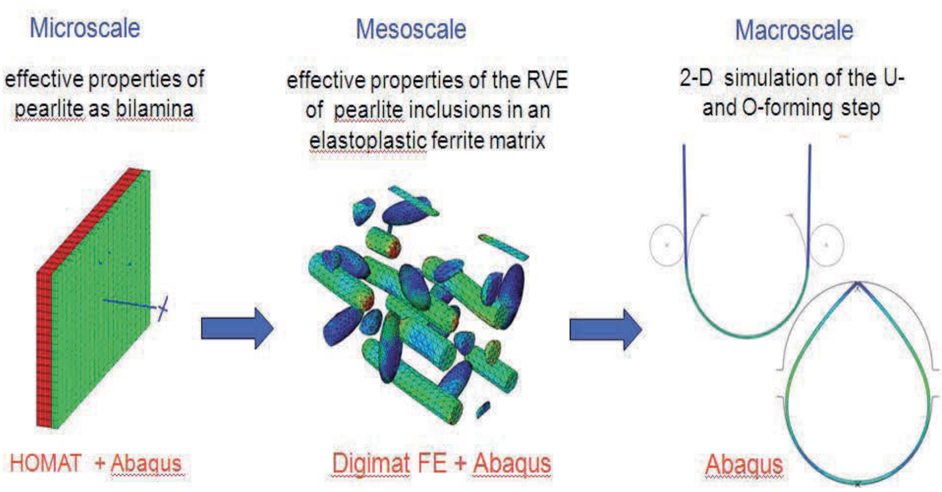
access

eventually: derive properties from –simulated- microstructures



Why ICME?

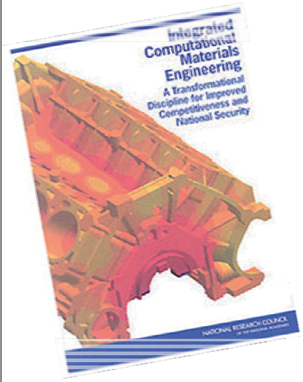
a) because it can be done right now (…and was not possible earlier) !

Currently all these approaches have reached a level allowing for valuable contributions to modern engineering tasks within knowledge driven production models. The capabilities of the respective software tools and the present availability of computational power make efforts towards the integration of all these approaches possible, meaningful and timely.

b) because benefits are to be expected

"Integrated computational materials engineering (ICME) as an emerging discipline aiming to integrate computational materials science tools into a holistic system will accelerate materials development, transform the engineering design optimization process, and unify design and manufacturing." [NRC_2008]

Benefits of ICME…



- …
- reductions in materials development *time*
- *improved materials properties*
- shorter material certification *times*
- reductions in product development *time*
- substantial reduction in experimental *efforts*
- weight *savings* for specific components
- *improved capabilities* of the components
- …

several of these claims hold for CME alone (without drawing on „I“)

Global Optimum—the Nash equilibrium

The optimum of a process chain might

- and will (!!) –

differ from a chain of individually optimised process steps

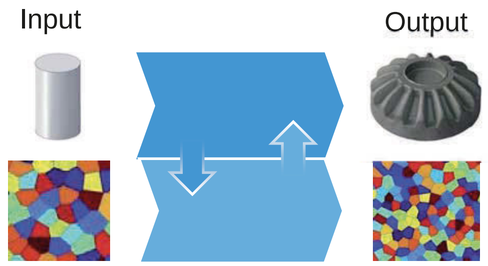
Ignore the blonde!
scene taken from „A beautiful mind“

ICME Models are complex Meta-Models

Individual model	ICME Meta-Model

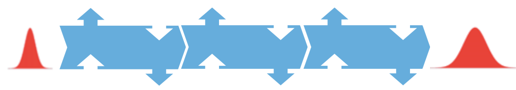
Individual model

- Parameters influencing accuracy either known or reasonable estimates
- essentially stable behaviour

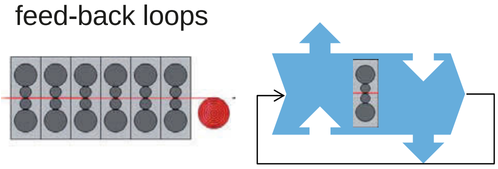


ICME Meta-Model

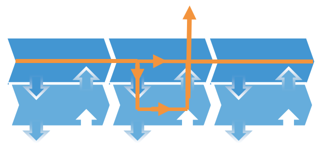
- non-linear interactions between models
- propagation of uncertainities



- feed-back loops



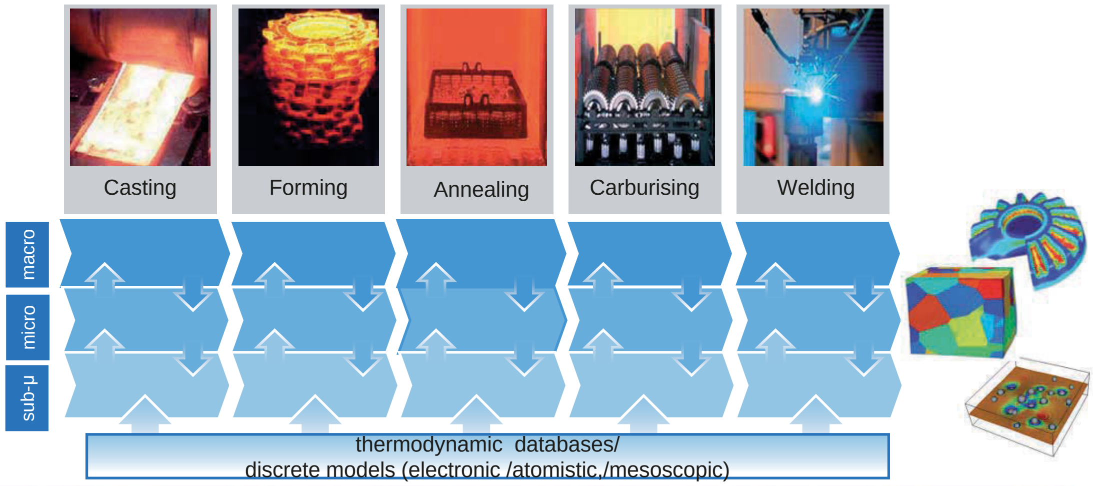
- bifurcations



production platform .vs. simulation platform

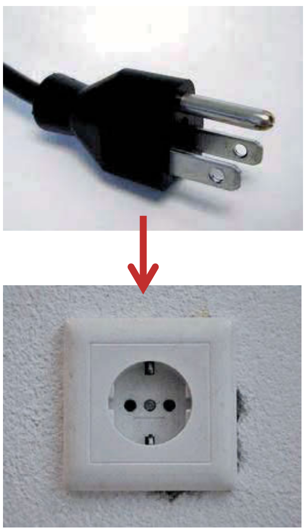
Individually taylored simulation chain	Parameter variations for a pre-configured chain	modular customized simulation chains

Vision: plug & play for ICME



Comprehensive, standardized, modular and extendable modeling platform being efficiently adaptable to a specific material, process-chain and product

benefits of standardization

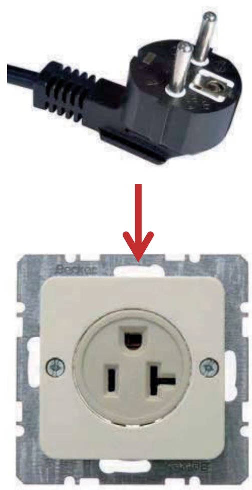


Have you ever tried
to get

that one

into

that one?



Who ????

Who will/can create standards for ICME?

Industrial users ?

Soft

all of us !!!

Academic institutions?

nobody?

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ICMEg

ICMEg

the Integrated Computational Materials Engineering expert group

a new coordination and support activity of the European Commission

co-ordinator: Dr. Georg J. Schmitz,

Access e.V. at the RWTH Aachen

Salt Lake City, July 2013

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Proposal ICMEg at a glance

…combine the emerging field of
Integrative **C**omputational **M**aterials **E**ngineering **(ICME)** with succesful standardization schemes:

2008 2011 2012

HTML

JPEG
Joint **P**hotographers **E**xpert **G**roup

MPEG
Movie **P**ictures **E**xpert **G**roup

..towards most beneficial standardization in ICME and an
Integrative **C**omputational **M**aterials **E**ngineering expert **g**roup:

ICMEg

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Mission of ICMEg

The **Mission of ICMEg** is

to establish and to maintain a network of contacts to

- simulation software providers around the world
- governmental and international standardization authorities
- ICME type users of simulation software
- different associations in the area of materials and processing
- academic developers of simulation software

to define and communicate an ICME language in form of an open and standardized communication protocol

to establish a legal body for a sustainable further development of the initial standard

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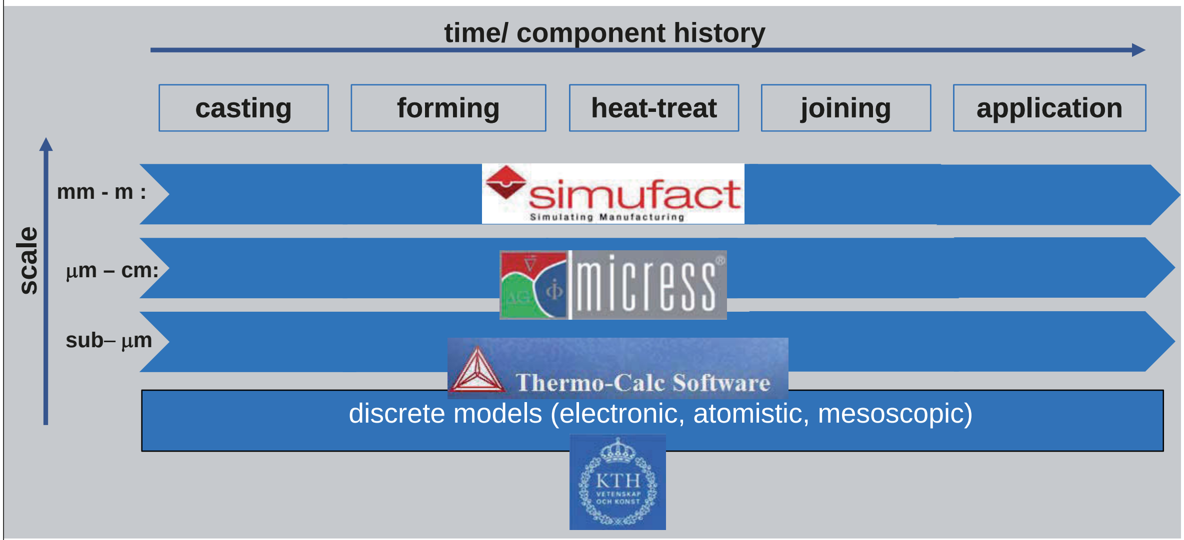
Coupling along the life cycle



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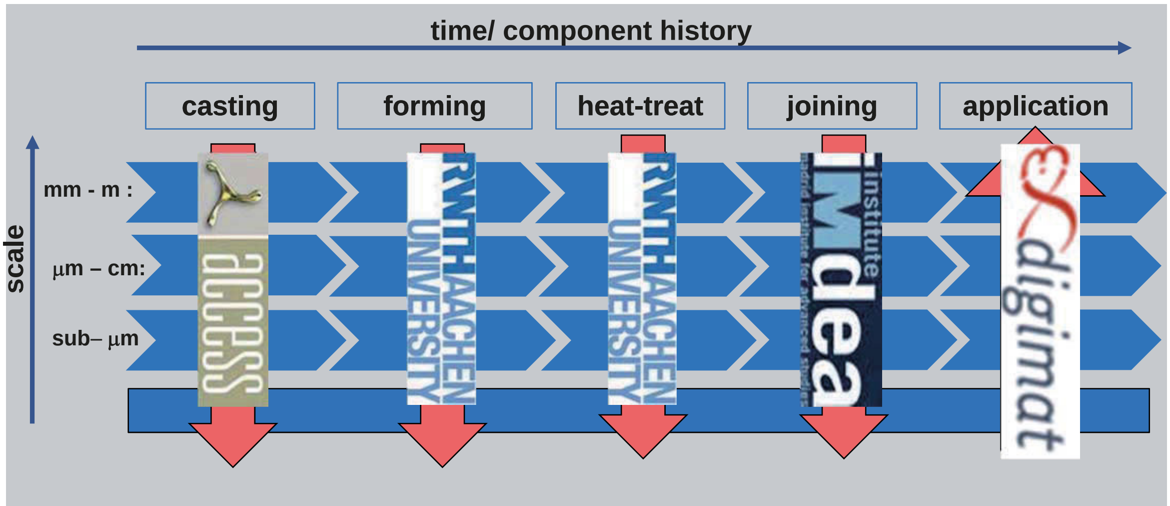
Coupling across the scales



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cross sectional activities

administrative

scientific/
technological

project management

numerical methods

dissemination

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associated members/ international steering committee

partner	country	type	contact
National Institute of Standards and Technology (NIST)	US	Government	Dr. James A .Warren
Thermo-Calc Inc	US	SME	Dr. Paul Mason
Bundesamt für Materialforschung (BAM)	Germany	Government	Prof. Pedro D. Portella
Tata Consultancy Services (TCS)	India	Industry	Dr. A.K. Singh
CTC Solutions	Japan	Industry	Dr. S. Nomoto.

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Expected outputs from ICMEg:

A) 2 International Workshops with a minimum of 100 participants each

B) 2 books on:
- „Directory of software providers for ICME“
- „Software standards for successful ICME“

C) Specifications of standards for information exchange in ICME settings

D) Foundation of an Association of Software providers for ICME

Kick-off :

October 9th - 11th 2013

Aachen, Germany

ALL OF YOU ARE CORDIALLY INVITED TO CONTRIBUTE !!!

www.icmeg.eu

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CSP-2: How to move forward in production theory development?

Potente, T.

Hauptvogel, A.

Keller, M.

Rosenberg, M.

Prote, J.

Wolff, B.

Keywords:
production theory, production function, viable system model, value chain

Abstract

Developing a production theory is no easy feat. Starting from the 50s, researchers started to develop production theories (e.g., Gutenberg, Heinen, Kloock, Matthes, etc.) that explain the complex relationship between input factors and output. Since 2006, the Cluster of Excellence "Integrative Production Technology for High-Wage Countries" of RWTH Aachen University researches organizational methods and technology to be able to (1) offer customized products at competitive prices and (2) quickly adapt to the market while assuring constant product properties [1]. To leverage the existing results of the first research period, a holistic production theory is needed that takes the complexity of today's production in high-wage countries into account. To address this challenge and develop a new theoretical framework, we build upon existing concepts that are able to cope with today's complexity in production [2], [3], [4]. Furthermore, we focus on the integration and combination of existing theories to ensure usability and credibility across many research and practical fields.

Bibliography

[1] C. Brecher, Integrative Produktionstechnik für Hochlohnländer. Heidelberg: Springer-Verlag, 2011.

[2] H. Dyckhoff, Produktionstheorie: Grundzüge industrieller Produktionswirtschaft. Springer-Verlag, 2006.

[3] E. Gutenberg, Produktion - Grundlagen der Betriebswirtschaftslehre. Springer-Verlag, 1983.

[4] S. Beer, Diagnosing the System for Organisations. Wiley, 1985.

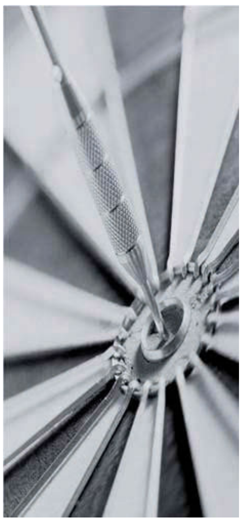
CSP-2: How to move forward in production theory development?

Cluster-Conferences 2013

Dipl.-Wi.-Ing. Michael Keller

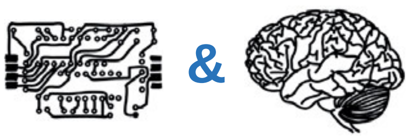
Aachen, den 23./ 24. September 2013

The overriding objective it to develop a production theory

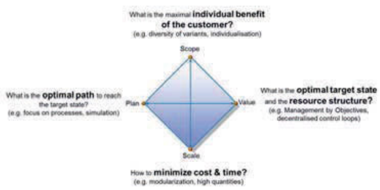


Our approach incorporates both theory and cluster practice top-down and bottom-up:

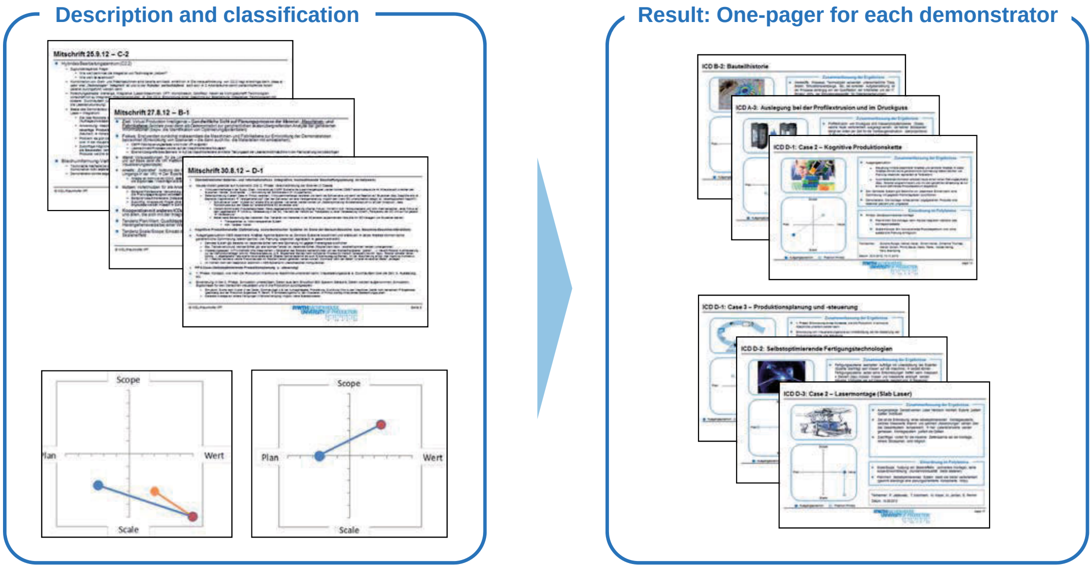
- **Top-down (theoretical lens)**
  - Deterministic model
  - Cybernetic model



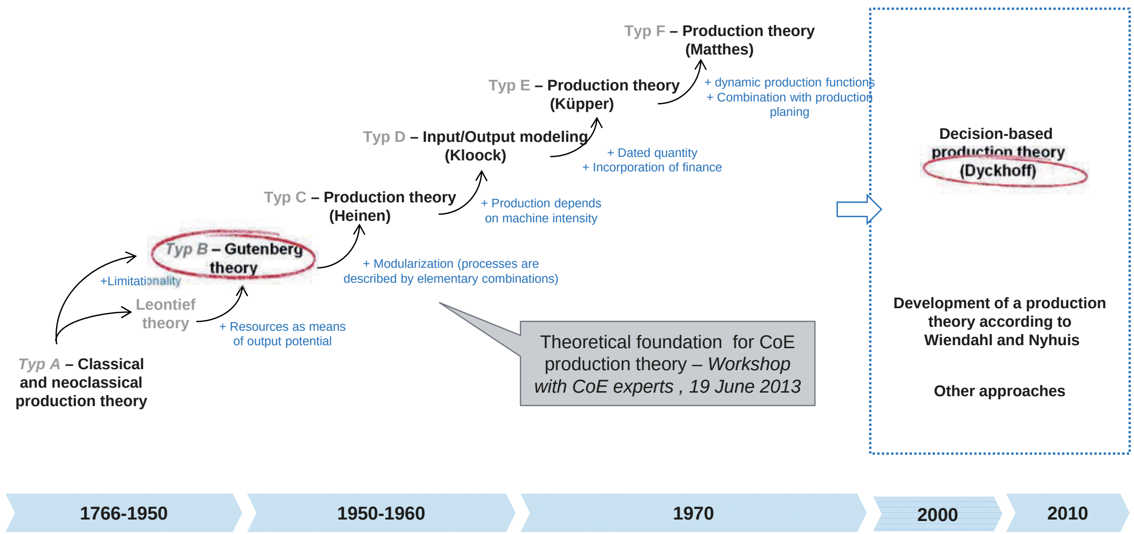
- **Bottom-up (practical lens)**
  - Scale vs. Scope
  - Plan vs. Value



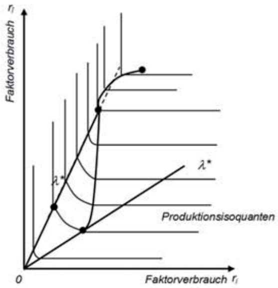
Objective of the first workshops with ICDs: Consolidation of the results and demonstrator’s positioning and development



Future CoE production theory should incorporate the advantages of existing and established approaches



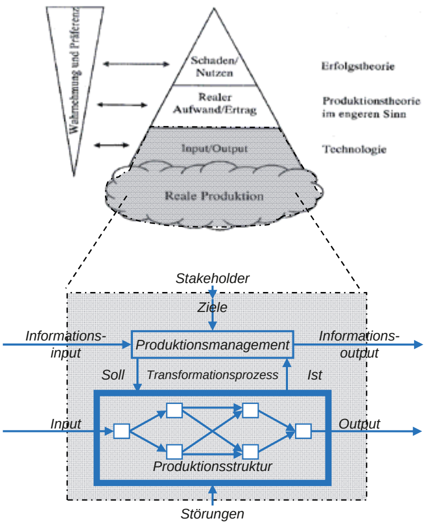
Production function (Gutenberg)



- **Description:**
  - Considers microeconomic perspective: input (dispositive factors, potential factors, consumption factors) and output (final product, intermediary product, waste)
  - Builds on simple notion that an increase in output requires an increase of inputs
  - Transformation process described in technical units and labor
- **Advantages:**
  - Relationship of input and output widely accepted concept to describe efficiency of production
  - Indirect relationship of input and output allows simulation of technical properties such as pressure, temperature or force
  - Takes into account potential (machinery) and consumption factors (i.e. wearing) thus allowing optimization calculations
- **Disadvantages:**
  - Does not take into account status factors such as tools and inventories
  - High number of machines and consumption factors causes high complexity (non-linear optimization problem)
  - Production functions designed for a specific case of production (limited generalizability)

Source: Fandel, 2005, Produktion I, Springer-Verlag, page 101-118; Gutenberg, E., 1983, Grundlagen der Betriebswirtschaftslehre, Bd. 1, Die Produktion

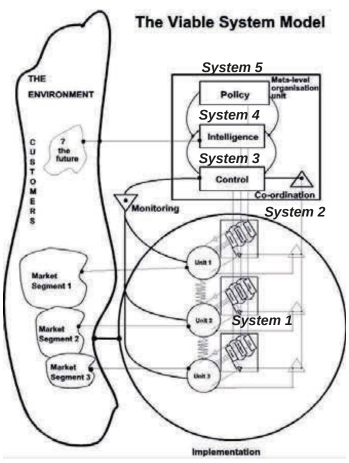
Decision-based production theory (Dyckhoff)



- **Description:**
  - Integrates a decision-based perspective to the field of production theory
  - Assumes that current production theories are special cases of a general production theory that is still to be developed
  - Argues that the result/success of a production can be measured with a single, one-dimensional, real-valued figure
- **Advantages:**
  - Considers economic, social and ecologic assessment criteria
  - Supports the investigation of real and highly complex production systems via a system-based view
  - Predicts outcomes and allows simulation
  - One success function allows preferences across the system
- **Disadvantages:**
  - Very general approach; generalizes the approaches of existing production theories even further

Source: Dyckhoff, H. (1994) Betriebliche Produktion. 2. Aufl., Berlin et al.; Dyckhoff, H. (2003b) Neukonzeption der Produktionstheorie. In: Zeitschrift für Betriebswirtschaft 73, S. 705–732.; Dyckhoff, H./Spengler, T.S. (2007) Produktionswirtschaft. 2. Aufl., Berlin et al.; Dyckhoff, H. (2006) Produktionstheorie. 5. Aufl., Berlin et al.

Viable System Model (Stafford Beer)



Core elements

- Describes, diagnoses and models management functions and information flows at all organizational levels
- **System 1:**
  - Performs a value-adding process (production)
- **System 2:**
  - Coordinates the activities of system 1 (e.g., scheduling of shared resources)
- **System 3:**
  - Controls rules, rights, resources and responsibilities of system 1 - represents the big picture view of the processes in system 1
  - Interface to system 4/5
- **System 4:**
  - Responsible for looking outwards to the environment to monitor how the organization needs to adapt to remain viable
- **System 5:**
  - Steers the organization as a whole
  - Balance demands from different parts of the organization

Value-add

- Extends organizational theory by introducing a cybernetic, system theory approach

Benefit for CoE

- Offers a modeling approach to integrate the various research areas into an holistic framework
- Provides rules, mechanisms and structures to understand and shape complex, non-deterministic behavior pattern of production systems

Source: Beer, Stafford (1985) S. 128: Diagnosing the System for Organisations. 1990, John Wiley & Sons / Malik, F. (2002) S.84 ff; Management komplexer Systeme, Haupt

Workshop with CoE experts kicked off several work streams to approximate CoE production theory development

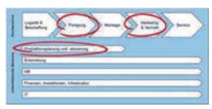
Workshop with CoE experts: 19 June, 2013

Key results

- Identification and assignment of 35 theories (or part of theories) to the core topics „product", „resource", planning process", and „production process"
- Identification of seven approaches to integrate and combine theories (or part of theories) such as scale hopping, model and data integration, tolerance management etc.

Next steps

- **Workshop-stream 1 (ICD-level, practical lens)**
  - Discuss the origin of the demonstrator based on corporate functions
  - Elaborate theories and models that are applied in the demonstrator



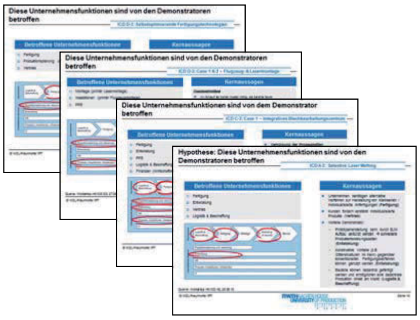
- **Workshop-stream 2 (CoE experts, theoretical lens)**
  - Deep-dive into applied theories
  - Discuss combination and connection of theories

- **Integrating framework**
  - Build framework and assign applied theories
  - Ensure integration of theoretical foundations (Gutenberg & Dyckhoff) and approaches (deterministic & cybernetic modeling)

Workshop stream 1: Corporate functions and theoretical foundations

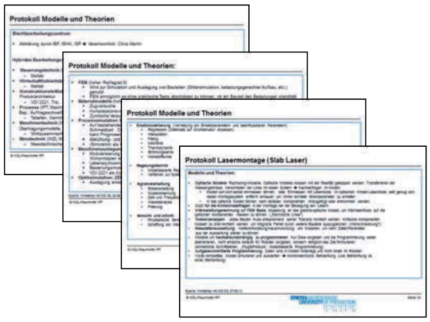
Corporate functions

- Porter’s value chain model identifies the most important corporate functions such as logistics, production, finance, etc.
- First results reveal that the demonstrator addresses challenges of different corporate functions



Theoretical foundations

- Theoretical foundations of demonstrators extremely diverse from purely technical models to economic theories
- First results reveal at least a limited number of theoretical clusters such as process, machine and measurement models



Workshop stream 2: Theory development and combination of theories

Theory development

- Classical theories describe closed systems with clearly defined boundaries
- Modern theories describe systems with high uncertainty, system dynamics or turbulences
- Production theories are either too narrow (not generalizable) or rely on black boxes to describe complex transformation processes

We will use a twofold approach, comparable to classical mechanics and quantum mechanics in the natural sciences:

- Interdependencies between sub-systems should be described with simple relationships (i.e. Guttenberg functions)
- Influence factors and disturbances should be described with cybernetic means

Combination of theories

- In the cluster of excellence, researchers of different disciplines rely on different grounding theories for their work
- Units of measure and scales are very different and we ware faced with the challenge of how to combine the different theories into one common approach

We need to integrate different theories horizontally and vertically by overcoming boundaries:

- Identify representative components that can be transferred to another theory or scale
- Homogenization of structures to identify common elements of complex structures that can be simplified

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Thank you for your attention !

Analysis of friction stir welded blanks made from DC04 mild steel and aluminum AA6016

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Keywords:
dissimilar joint, joining, friction stir welding

Abstract

Due to increasing demands for lightweight structures in automotive applications the use of sheet metal components made from aluminum and steel is a promising approach for weight reduction [HEN11]. However, in conventional fusion welding processes the formation of intermetallic phases due to the metallurgical affinity of aluminum and iron is a serious problem [SPR11]. Friction stir welding (FSW) is a solid-state welding technology [THO95], whereby the formation of intermetallic phases is reduced to a minimum [JIA04]. Within the work butt joints were produced using sheet metals of the aluminum alloy AA6016-T4 and DC04 mild steel with a thickness of 1 mm. The produced dissimilar joints showed approximately 85 % of the tensile strength of the base material AA6016. In metallographic investigation it was found that during welding the microstructure of the aluminum base material changes due to plastic deformation and increasing temperature [MIS05]. In order to find a proper explanation of the reduction in tensile strength, short time heat treatment experiments in the temperature range between 250 °C and 450 °C were carried out using aluminum base material both, with and without preliminary prestrain. With additional hardness measurements the change of mechanical properties in the contact zone of both base materials and in the heat affected zone was examined.

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Analysis of friction stir welded blanks made from DC04 mild steel and aluminum AA6016

Cluster-Conferences 2013

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Aachen, den 23./ 24. September 2013

Outline

1. Motivation and topics
2. State of the art
3. Characterization of friction stir welded blanks
4. Hardness measurement
5. Short-time heat treatment of aluminum alloy
6. Conclusion and outlook

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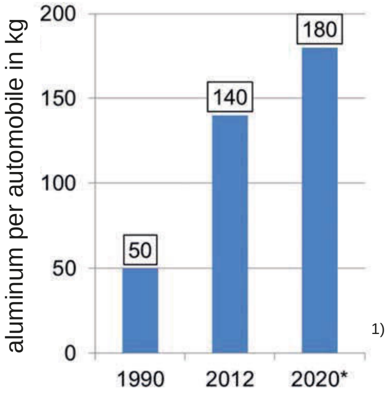
Motivation and topics

Motivation

- increasing demands for lightweight structures in automotive applications
  → increasing aluminum components in cars
- hybrid blanks for a new lightweight design with respect to optimized loading



What is necessary?

- joining technology for aluminum and steel
- basic knowledge about local characteristics of hybrid blanks
- basic knowledge about forming limits and forming characteristics of hybrid blanks

[1] Seidensticker M., Reiß C.: "Megatrend automobiler Leichtbau – Abspecken dank Aluminium", In: Presse-Information, ALUMINIUM Messe 2012, 9. Weltmesse und Kongress, Düsseldorf, 2012.

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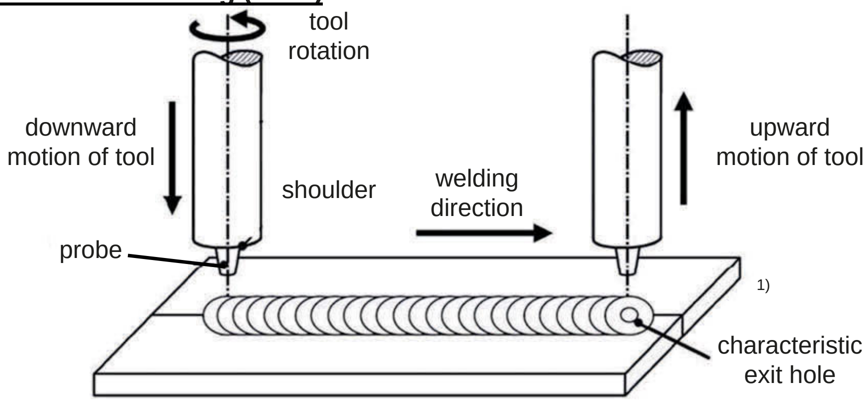
State of the art

- differences in physical properties of aluminum and steel

  → necessity of welding technology with low process temperature

- **Friction Stir Welding (FSW)**



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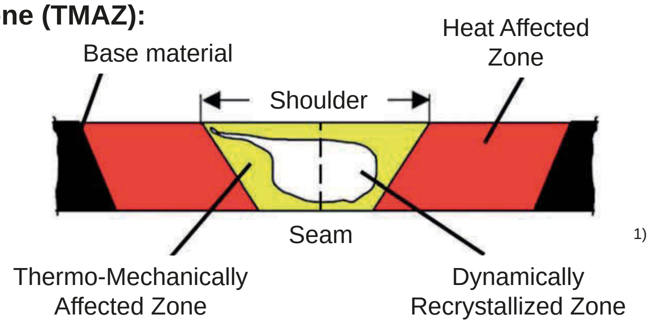
State of the art

Microstructure development

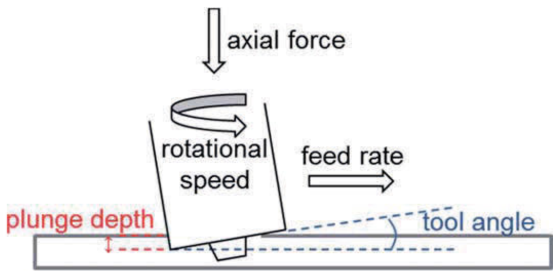
- **Base material:** no structural changes
- **Heat Affected Zone (HAZ):** influence of temperature → changes of microstructure and alloy-based changes of precipitations
- **Thermo-Mechanically Affected Zone (TMAZ):** influence of temperature and deformation
- **Dynamically Recrystallized Zone (DRZ):** high material flow speed and process temperature → completely new microstructure



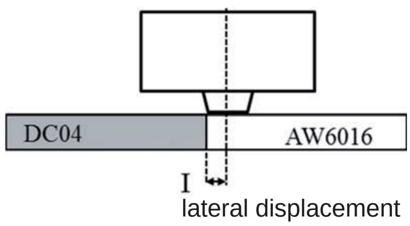
[1] Khaled T.: „An Outsider Looks at Friction Stir Welding", Report at the Federal Aviation Administration, No: ANM-112N-05-06, USA, 2005.

Parameters of FSW process

- **machine tool:**
  - force-controlled vs. <u>position-controlled</u>
  - stiffness
  - deflection of welding table



- **tool:**
  - geometry (shoulder, pin)
  - material (tungsten carbide)
- **welding parameters:**
  - rotational speed + feed rate
  - axial force or <u>plunge depth</u>
  - lateral displacement
  - tool angle
  - positioning of blanks with respect to welding direction



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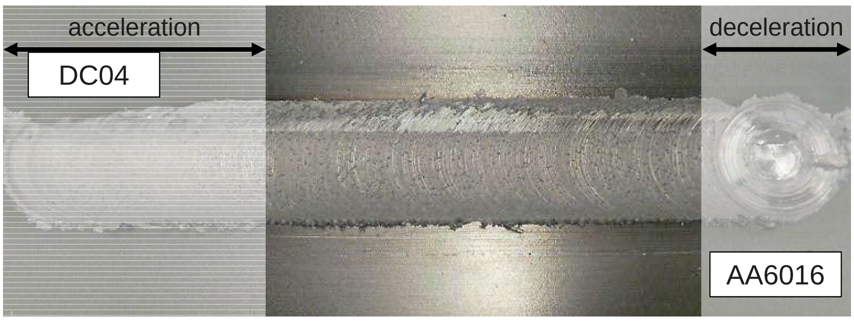
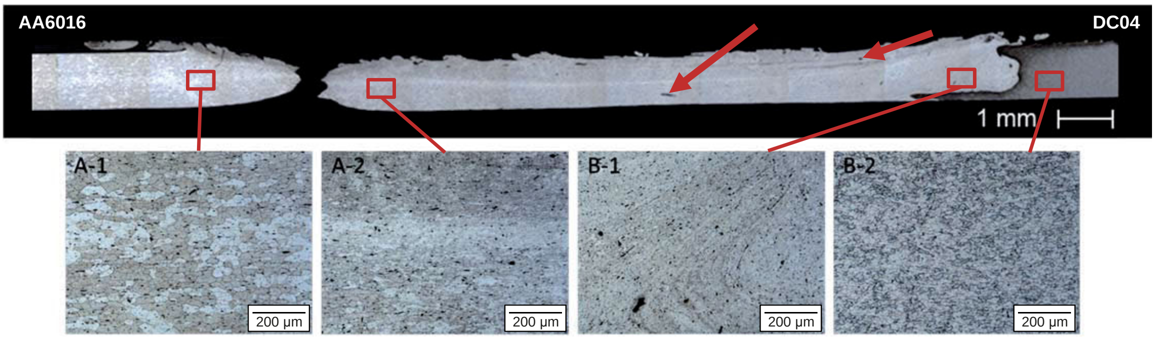
Characterization of friction stir welded blanks (I)

Characteristics

- low temperature → no intermetallic phases
- joining of materials that cannot be welded conventionally (steel + aluminum)
- characteristic surface structure
- different regions of microstructure



Characterization of friction stir welded blanks (II)



Tensile tests and microstructure analysis

- FSW blanks show ~ 85 % tensile strength compared to aluminum base material
- crack appears in transition between TMAZ and HAZ
- FSW blanks show different zones of microstructure
- small steel particle in aluminum // no failures

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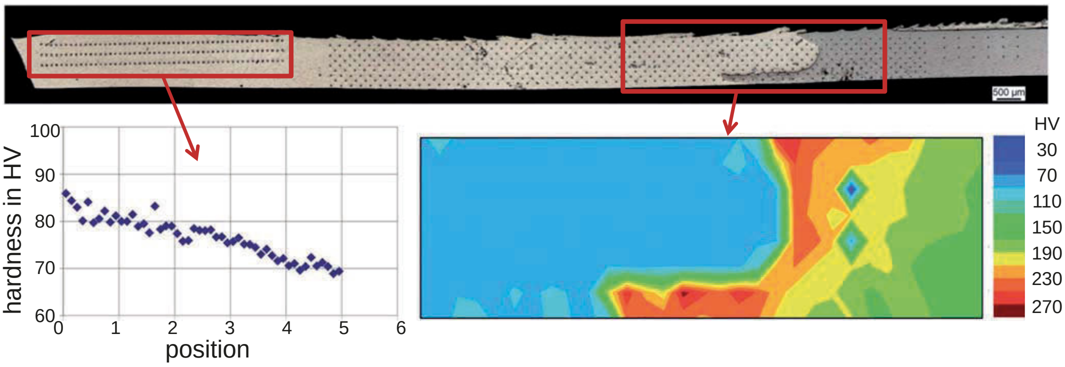
Hardness measurement

- Measurement of micro hardness (Vickers)



- Right: increase in hardness of steel (from 150 to 250 HV)
  hardness of aluminum about 70 HV
- Left: increasing hardness of aluminum from TMAZ to HAZ

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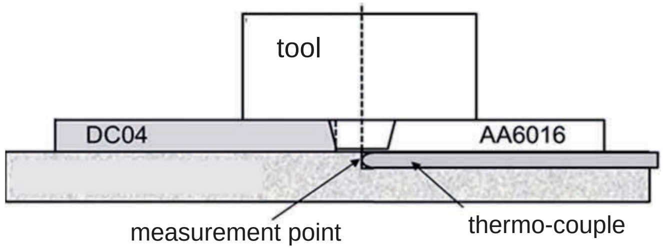
Measurement of FSW-process temperature

- same parameter-set
- integration of thermo-couple into the welding table
- measurement at the center of welding process
  → highest process temperature

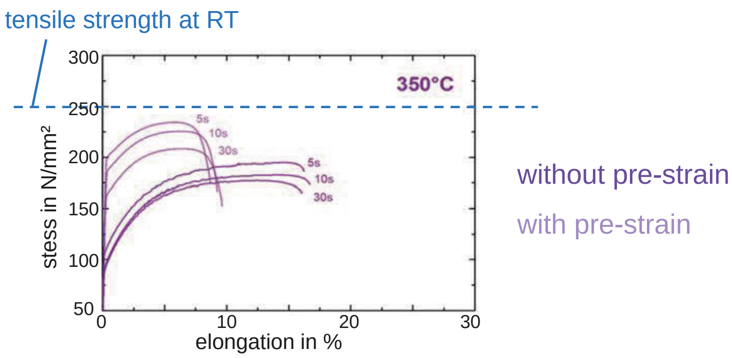


- **Results:**
- T_{max} ~ 425 °C
- T > 250 °C ~ 10 sec

Short-time heat treatment of aluminum alloy

Short-time heat treatment:

- at T > 250°C: reduction of tensile strength due to dissolution of (Mg_2Si)-precipitations [1)]
- nearly same results for different duration of heat treatment
- influence of deformation (pre-strain) still unclear



1) Kerausch M. et al.: „Finite Element Analysis for Deep Drawing of Tailored Heat Treated Blanks", Advanced Materials Research, Vol. 6-8, 343-352, 2005.

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Conclusion and outlook

Summary

- FSW of DC04 and AA6016 successful
- characteristic microstructure development due to process temperature and deformation
- characteristic hardness profile of welding zone due to process temperature and deformation
- dissolution of (Mg_2Si)-precipitations due to heat treatment leads to a change of mechanical properties

Further investigations

- further investigations of the effects of heat and deformation
- start conductive-assisted FSW
  – find parameter-set
  – different tools (material, geometry)

Thank you for your attention!

Benefits and Barriers of Interdisciplinary Work. Supporting and investigating interdisciplinarity.

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Keywords:
Interdisciplinarity, Interdisciplinary Innovation Management, Clusters of Excellence, Publication Network Analysis

Abstract

In two qualitative interview studies benefits and barriers of interdisciplinary work in a research cluster has been investigated, as well as using a visualization of the publication behavior.

First findings indicate that the primary motivator for interdisciplinary collaboration is intrinsic motivation and curiosity for the other disciplines. Interdisciplinary work uniquely allows unite knowledge and comprehend complexity beyond the scope of disciplinary research. Problems were seen in the missing language that allows interdisciplinary communication. Missing depth of research as well as defined interfaces between subjects poses another problem, as well as a tight schedule.

Furthermore in an interview study regarding the usefulness and interpretability of publication visualization motives and barriers to use such a visualization were investigated. In particular the most often mentioned motive for using such visualization was the motivation that could be drawn from it. Furthermore it would allow to plan publications ahead of time and give retrospective insights into one's and other's publication behavior. As barriers the amount of missing information in this particular information was mentioned. This included the quality of publications and the range of possible interpretation of such graphs. Some participants were sure, that such visualization would not change the behavior of established scientists. Measures to improve both visualization and accompanying services were derived from these findings.

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Benefits and Barriers of Interdisciplinary Work. Supporting & Investigating Interdisciplinarity

CSP1: Scientific Cooperation Engineering
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Prof. Martina Ziefle

Aachen, 23th September 2013

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Agenda

1 **Overview "Interdisciplinary Innovation Management"**

2 **Supporting and investigating interdisciplinarity in research clusters**

3 **Lessons learned and outlook on future work**

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Overview „Interdisciplinary Innovation Management"

- Part of the CSP 1 Team: Scientific cooperation Engineering
  - – Main target: Sustainable Management of Human Resources and Integrative Research

- **Research questions:**
  - – How can one **measure scientific success** in interdisciplinary teams?
  - – Which means can **support interdisciplinary cooperation**?
  - – How does the **cybernetic approach** apply for management of interdisciplinary success?

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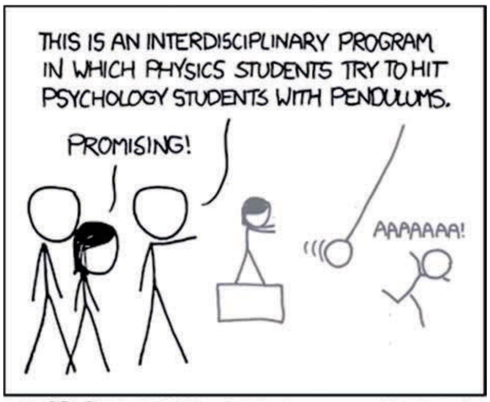
How we started our work



MY PROFESSORS HAD AN ONGOING COMPETITION TO GET THE WEIRDEST THING TAKEN SERIOUSLY UNDER THE LABEL "INTERDISCIPLINARY PROGRAM."

Key issues

- What is interdisciplinarity?
- What is interdisciplinary success?
- What are benefits and barriers of interdisciplinary work?
- How can one support interdisciplinary work in research cluster

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What is interdisciplinarity?

- **No unique definition**
- **Broad definition:** „communication and collaboration across academic disciplines" (Jacobs/Frickel 2009)
- **Narrow definition:** „Interdisciplinary studies is a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline and draws on disciplinary perspectives and integrates their insights to produce a more comprehensive understanding or cognitive advancement" (Repko 2008)
- **Four forms of interdisciplinary work (Julie Thompson-Klein 1990):**
  - Borrowing (of analytic tools from other disciplines)
  - Solving Problems (with no intention of achieving a conceptual unification of knowledge)
  - Increase consistency of subjects or methods (partial overlapping of disciplines in the same field)
  - Emergence of an *interdiscipline*

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What is interdisciplinary success?

- **OECD** 1998: "highly competent proficiency in a single discipline is the only acceptable basis for interdisciplinary success"
- **Lamont (2009):** Interdisciplinarity = separate criterion for excellence: Combining traditional standards of disciplinary excellence with interdisciplinary presents a greater challenge, …, because 'expert generalist criteria … have to be met at the same time' (Lamont 2009 p. 210)

Problem for interdisciplinary work:

- Sticking to the disciplines punishes the boundary-crossing activities because they are often not perceived as cutting edge research in the home discipline
- "Reception problem" (Salter and Hearn 1996)
- Daily work is burdened by the different perception of quality/success

Framework conditions for the Aachen House of Production:

- **Criteria**: publications, third-party funding, patents, completed dissertations

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Interdisciplinary success – What is relevant for us?

- Criteria must be fulfilled
- Interdisciplinary Innovation Management: Focus on **publications** (first), because they are publically available
- **To be considered:**
  - Concept of successful can differ between the disciplines and cause difficulties in the daily work
  - Different concepts of success might cause different goals
  - It is to be expected that results are not easy to be placed in public (“Reception Problem”)
  - Conflict between interdisciplinary idea and individual goals

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Investigating interdisciplinary work in research cluster

- **Our approach:** Combination of:
  - User-centered design of a publication visualization tool for steering, self-measurement and scientific analysis of interdisciplinary teams
  - accompanying research in form of surveys, interviews, user tests

- **Recent research:**

  Study 1: User-centered design of publication visualization tool: “Evaluation of the publication network visualization approach for interdisciplinary teams“

  Study 2: Accompanying research: “Perceived Benefits and Barriers of interdisciplinary work“

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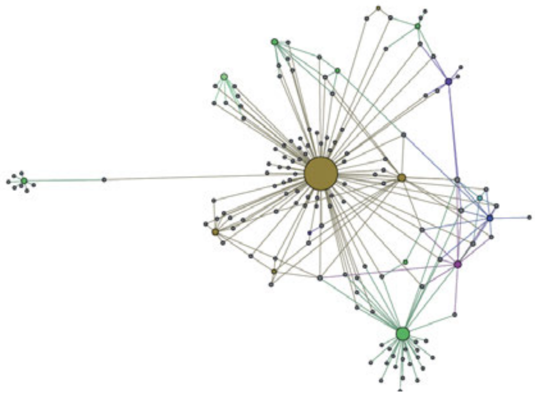
Study 1: Evaluation of publication network visulaization approach



- **Background:**
  - Publication Visualization approach developed to support interdisciplinary work in the Aachen House of Production
  - Tool is developed to support: self measurement of researcher, scientific analysis of interdisciplinary teams, steering interdisciplinary teams
- **Focus:** Analysis of future users of publication network visualization approach:
- **Method:** Interview with prototype presentation; N=6
- **Research questions:** What are the pros and cons of the presented approach?

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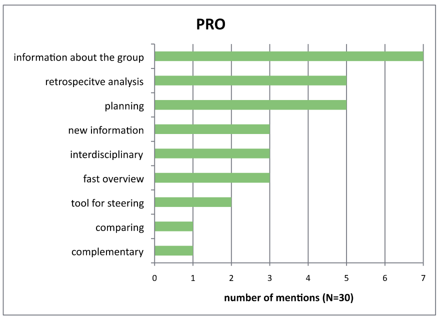
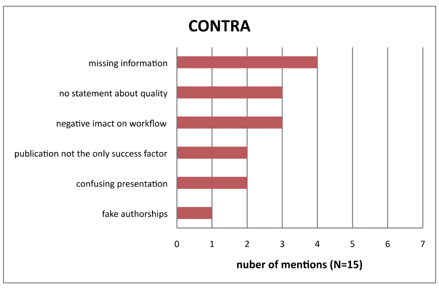
Pros and cons of visualization tool





- ‚[…] when I relate myself with the others, that mirrors the level of cooperation quite good..”
- “Retrospectively you can say, he has done his job”
- “[…] here you can see whether the people have worked interdisciplinary or not”
- “There is no information about first author or impact factor available”
- “I did a lot of conferences, but this is not available in this visualization”
- “Of course you can see a lot of things but the focus is on quantity not quality”

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Pros and cons of visualization tool

- **Summary:**
  - Positive basic attitude
  - Potential is especially seen in general information about the group, retrospective analysis and planning
  - The main cons are missing information, especially about the quality about the publications

- **Wishes & suggestions for improvement**
  - Ease of use
  - Continuous analysis via time factor
  - Integration of more information (outlet, impact factor)
  - Filter-function
  - Integration of more sociometric data (project, offices etc.)

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Study 2: Evaluation of benefits and barriers of interdisciplinary work

- **Background:** In literature there are named several benefits and barriers within the context of interdisciplinary teams. It is necessary to find out whether they are also true for large scale research clusters
- **Focus:** Identification of benefits and barriers revealed within the Aachen House of Production
- **Method:** Interview; N=6
- **Research questions:**
  - What are the pros and cons of interdisciplinary work?
  - Is the innovative potential of interdisciplinary teams higher than of others?

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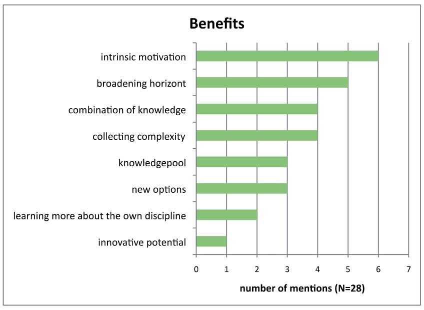
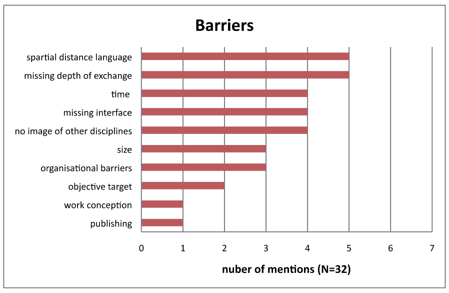
Benefits and Barriers of interdisciplinary work





- **Knowledge pool:**"[…] it is good to know that there are others you can ask"
- **Broadening horizon:** "[…] it's like a transition from low mountain to high mountains. I recognize that there is more than I previously knew"
- **Innovative potential:** "The benefit of leaving the own discipline […] is basically the innovative potential"
- **Image of other disciplines:** "Mechanical engineers are thinking that it is enough to look it up in a lexicon […]"
- **Size:** "There are really a lot of people, it is impossible to know everyone […]"

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Benefits and Barriers of interdisciplinary work

- **Summary:**

Benefits:

- Main benefits are **personal development** (broadening own horizon) and **curiosity hunger for knowledge** (intrinsic motivation)
- Interdisciplinary character of work offers the chance to capture the complexity of production technology
- The work within the X-Cluster was perceived to be innovative

Barriers:

- Main barrier is the heterogeneous language and Definition of terms
- A lot of discussions/things remain superficial, because there is not the space/time to slip into other disciplines topics
- Changing workforce enhances the knowledge exchange and cooperation

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Lessons learned and outlook on future work

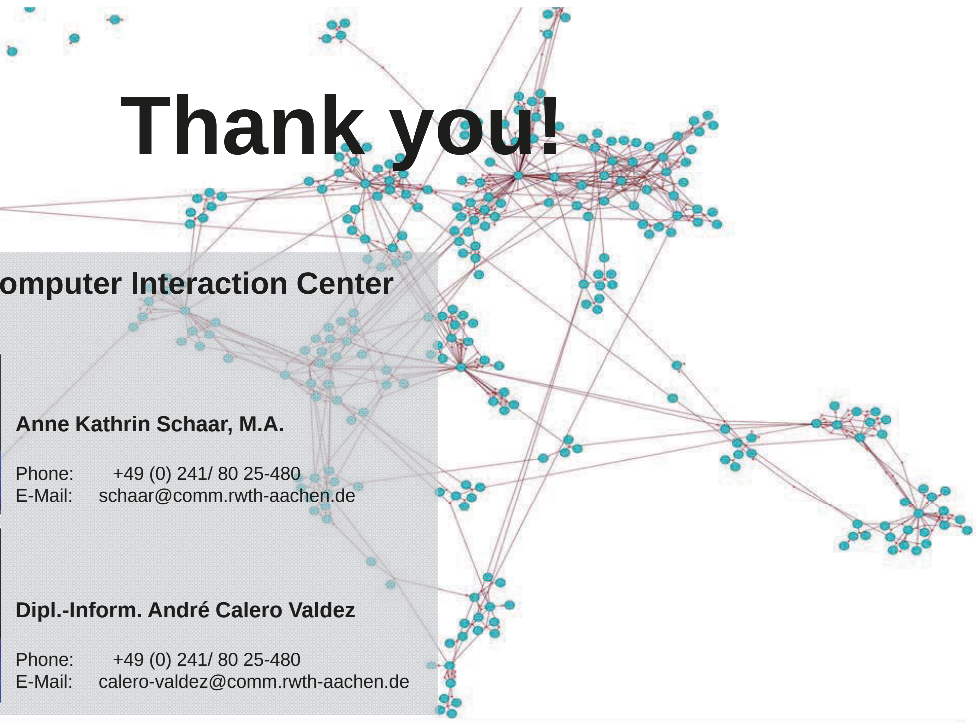
- Publication visualization = promising approach
- It is necessary to follow a user-centered design approach to design a useful tool
- Knowledge exchange is wanted and welcome
- The mutual understanding and lack of time charges the interdisciplinary workflow

Overall result:

- It is important to learn more about the differences between the disciplines (language, methods, success criteria) to find an adequate way to deal with them

Future work:

- Study “scientific success criteria within the cluster”
- Workshop “publishing interdisciplinary”
- Further development of publication visualization on the “Scientific Cooperation Portal”



Thank you!

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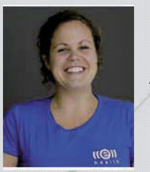

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Investigating and supporting interdisciplinarity in research clusters

- **What is interdisciplinarity?**
- **What is interdisciplinary succes?**
- What are benefits of interdisciplinary work?
- Howare barriers of interdisciplinary work?
- How can we support interdisciplinary work?

➔ External factors

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Investigating and supporting interdisciplinarity in research clusters

- What is interdisciplinarity?
- What is interdisciplinary succes?
- **What are benefits of interdisciplinary work in the cluster?**
- **What are barriers of interdisciplinary work cluster?**
- **How can we support interdisciplinary work within the cluster?**

➔ External factors

➔ Internal factors

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Interdisciplinarity vs. Mulit- and Transdisciplinarity

- **Multidisciplinarity:** *Disciplinary juxtaposition within a topic without structural cooperation or synthesis across disciplines*
- **Transdisciplinarity:** *Disciplinary boarders as well as boarders between science and the outside world are crossed by integrating additional stakeholder*

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Adaptive Function Templates for Improved Function Structure Applicability

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Keywords:
Function Structures, Koller Methodology, Adaptive Function Templates

Abstract

In early phases of product development processes, the concept of function structures is well-established. It is used to clarify product functions and in addition forms the basis for the generation of solution principles by systematically combining them with morphological boxes.

However, their application is not only beneficial and three main disadvantages can be elaborated. First, function structures characteristically depend on the background of their operator. Second, they are non-reversible. It is facile to hypothesize function structures with existing products in mind and moreover to turn already given structures into products. Nevertheless, with unidentified context and main functions there is no unambiguous method to set up function structures in hindsight. Third, function structures are difficult to apply with mixed levels of product embodiment.

An improved approach is presented to overcome those limitations. It is based on function templates that are related to existing function carriers. This is realized by setting up function blocks consisting of the conventional function description and in addition to that of function carriers and corresponding sub-functions. Algorithmically, the level of detail of the templates is adapted to match that of the traditionally conceived functions. Mixed levels get controllable through the adaptive nature of the templates. By providing information on the context due to function carrier inclusion, solutions get traceable and pre-created templates help generating unambiguous structures.

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Adaptive Function Templates for Improved Function Structure Applicability

Cluster-Conferences 2013

Jan Erik Heller and Jörg Feldhusen

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Aachen, den 23./ 24. September 2013

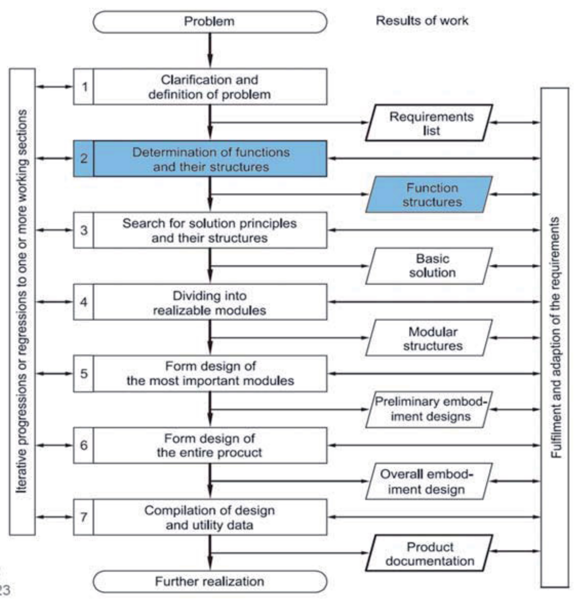
Motivation

We want to make the concept of function structures applicable for concept generation of machine tools.

Agenda

1. Functions in Systematic Engineering Design
2. Koller's Methodology
3. Challenges for its application
4. Adaptive Function Templates
5. Conclusion and Outlook

Design Process



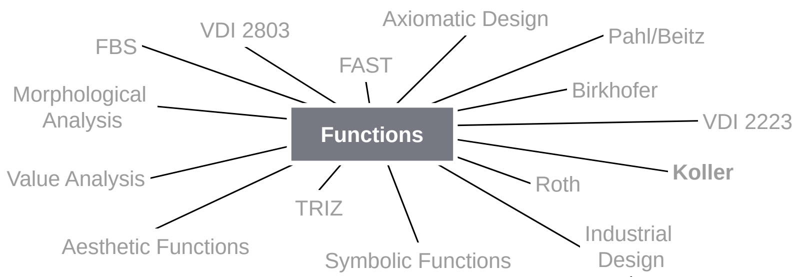
Source:
VDI 2223

- essential part of design process
- applied in early phases
- used to generate basic or principle solutions

- **needed to make the problem manageable**

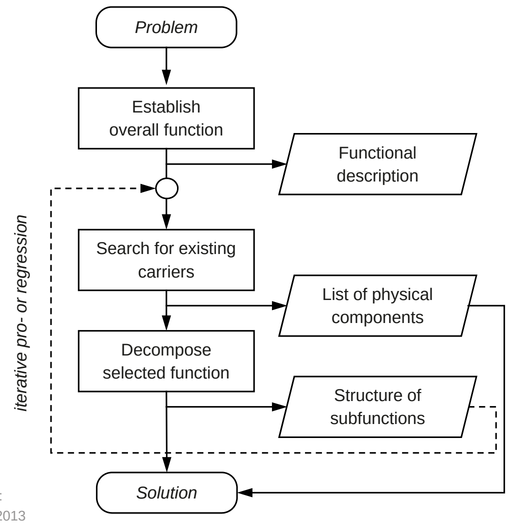
Functions in Engineering Design

- defined transformation
  between input and output
- usually represented by **verb+noun**
  „***brew coffee***“



General Procedure for Function Structures

conventional approach



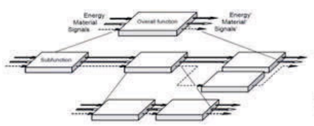
Source:
Heller 2013

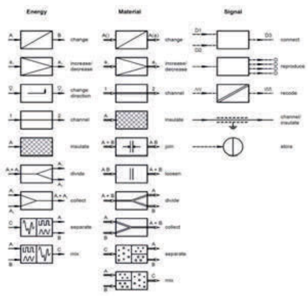
Koller Methodology

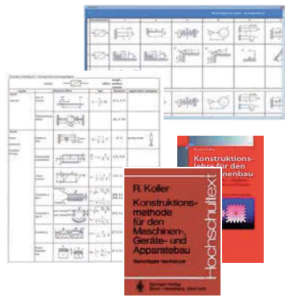
- decomposition
- down to lowest level

- use of elementary functions

- catalogues of physical effects

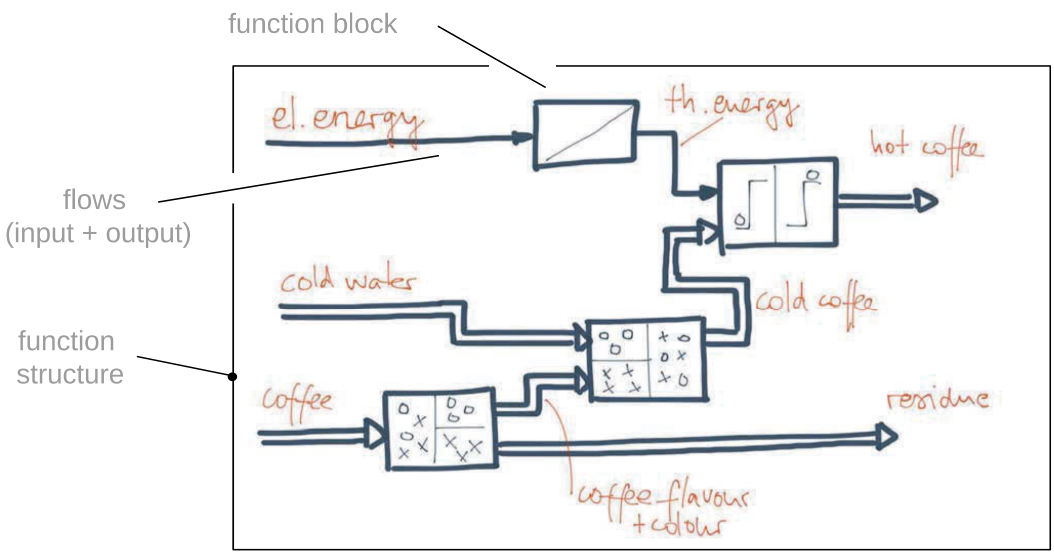




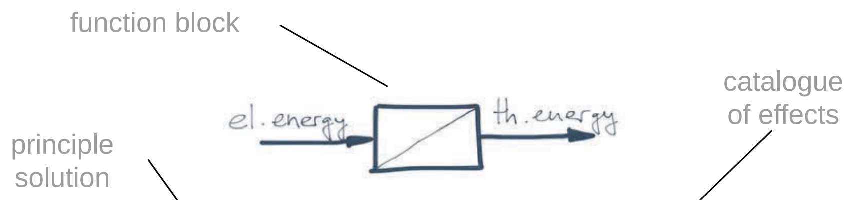


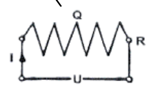
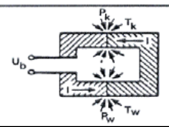
Sources:
Koller 1998, Pahl/Beitz 2007

Examples – Graphical Representation



Examples – Principle Solutions

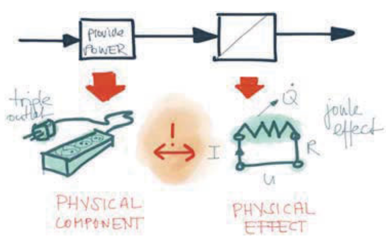


10.08 voltage, el. current,	Joule effect		$\dot{Q} = U \cdot I$	[30], S.301	electric heating
el. field	Peltier effect		$Q = \Pi \cdot I$ Π=Peltier coefficient	[14.2], S.313 Valvo-Heft Peltier-Batterien	cooling unit

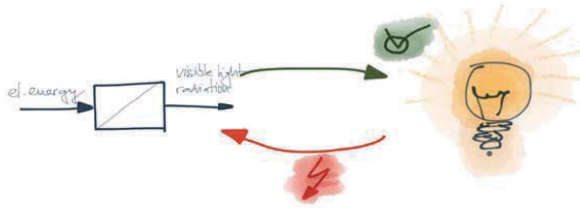
Three Challenges

background of the operator

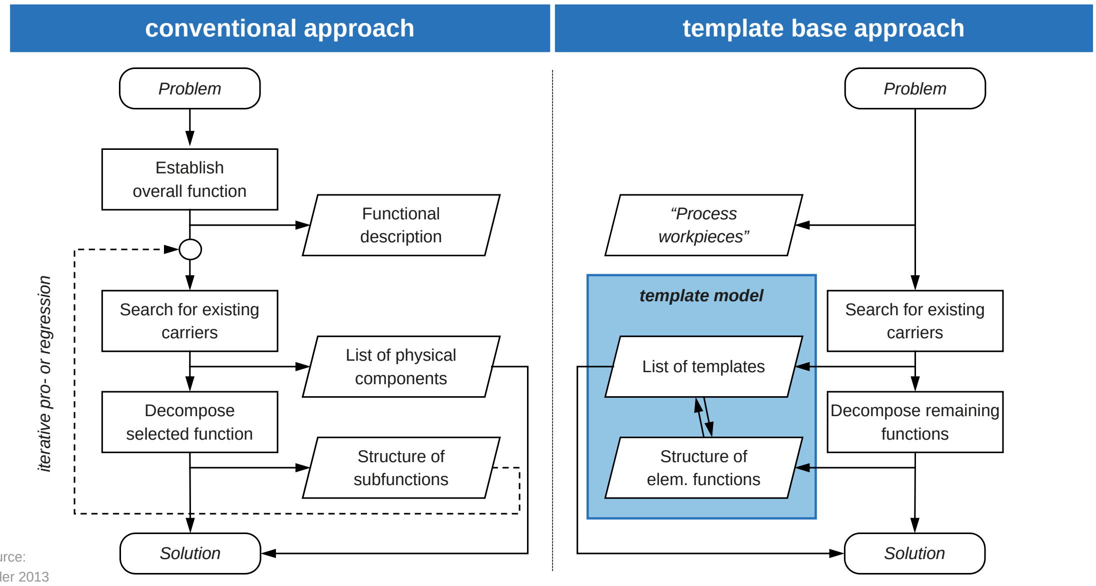
mixed levels of embodiment



non-reversibility



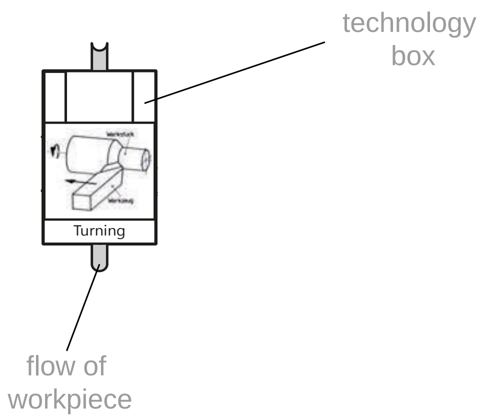
Templates for Function Structures



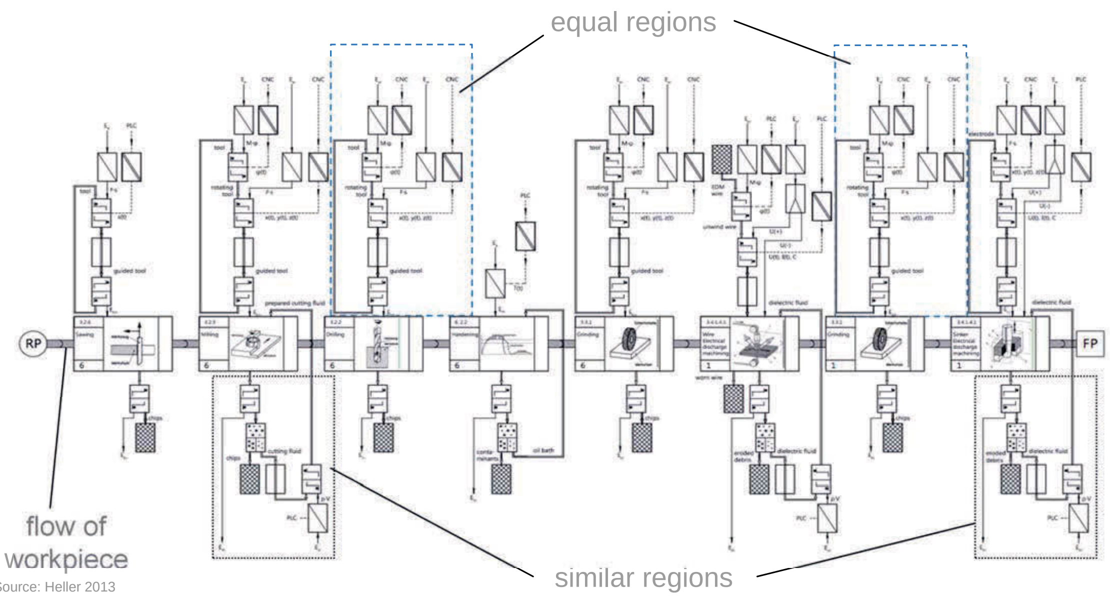
Source:
Heller 2013

Function Structures for Manufacturing

- starting points for function structures
- modelling along technology chain

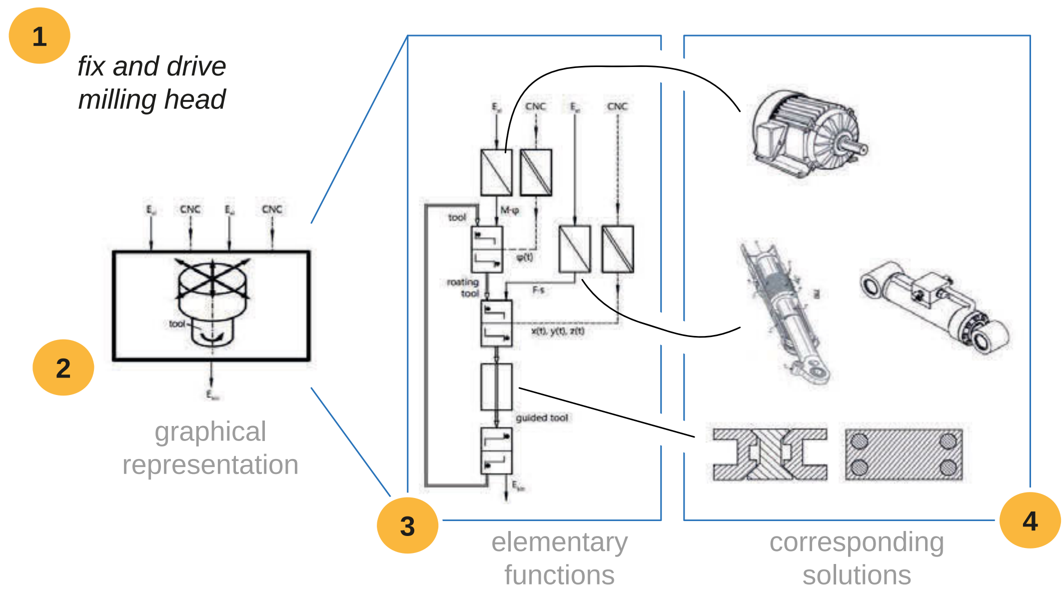


Technology Chain with Function Structure

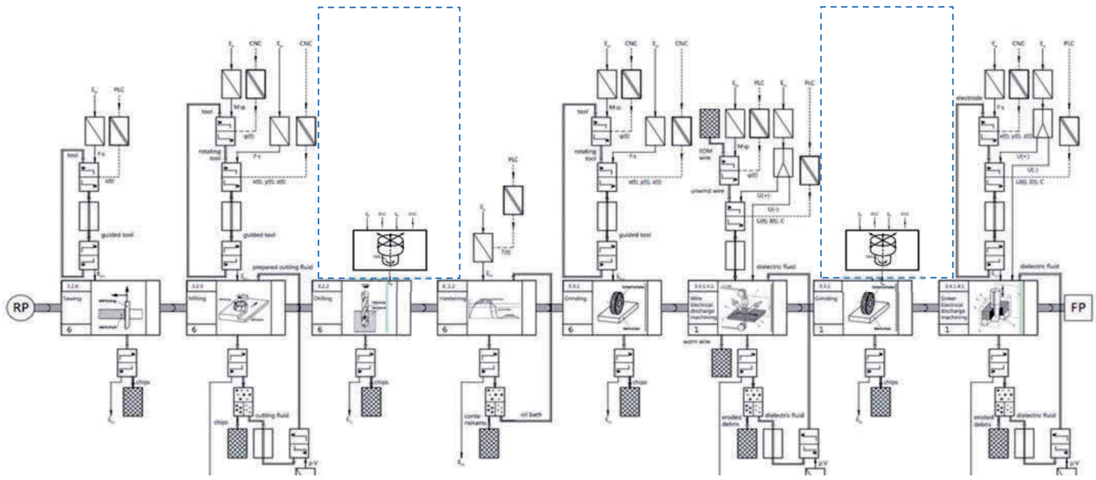


Source: Heller 2013

Template



Adaptive Function Templates



modelling with templates | decompose templates | recompose templates

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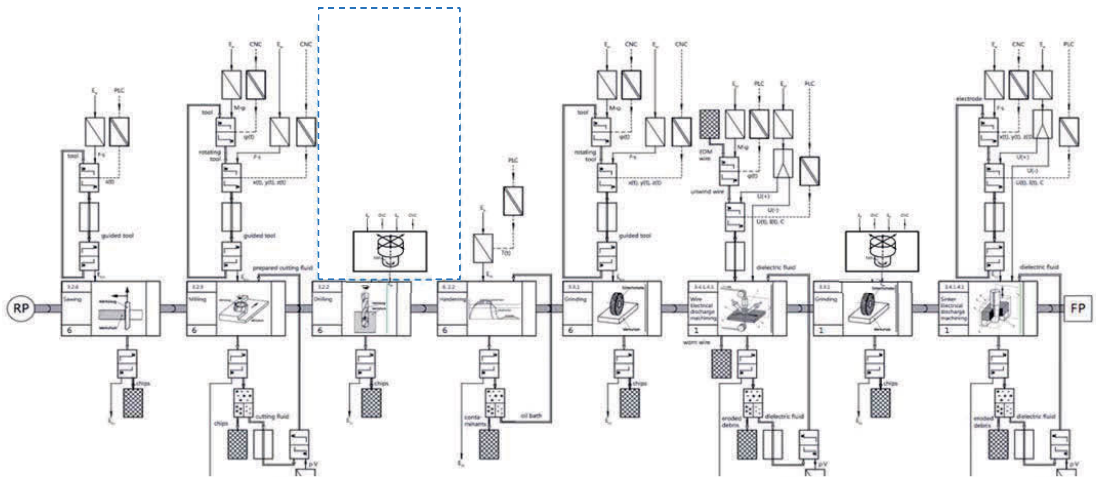
Adaptive Function Templates



modelling with templates | **decompose templates** | recompose templates

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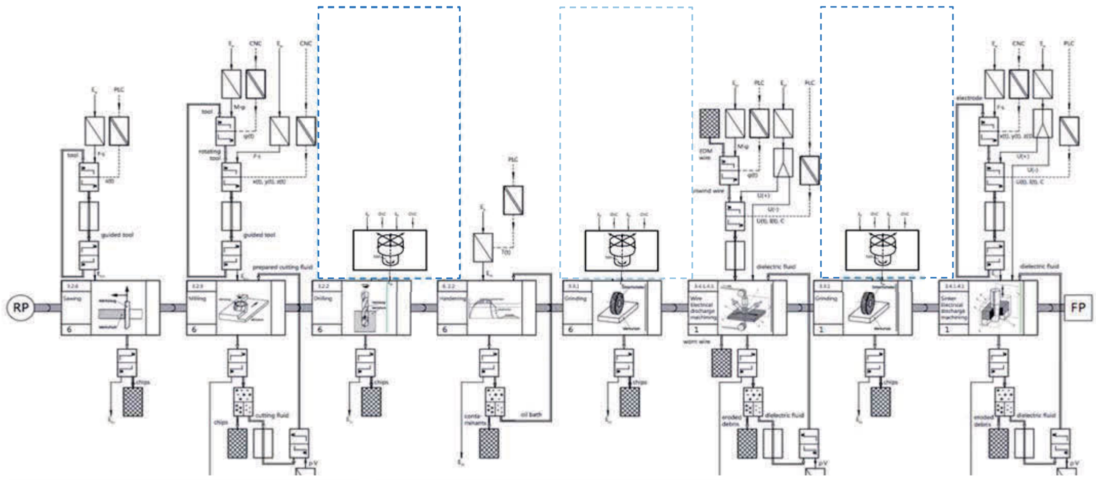
Adaptive Function Templates



modelling with templates | decompose templates | recompose templates

Conclusion and Outlook

What I talked about

- Functions in SED + one possible approach (Koller)
- Challenges for its application (3 aspects)
- Need for systematic approach for machine tools conceptualisation
- Adaptive Function Templates

What is still left to do

- Validation of AFTs in industrial application
- Implementation in software tool
- Automated de- and recomposition
- Future: expand the concept to other areas

Performance Measurement within Interdisciplinary Clusters of Excellence

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Keywords:
Performance Measurement, Clusters of Excellence, Key Performance Indicators, Balanced Scorecard

Abstract

Adequate concepts of performance measurement depict a continuous challenge for promoters and science managers of interdisciplinary clusters of excellence. This can be explained by an augmenting degree of complexity with regard to scientific structures and scientific behavior in interdisciplinary forms of collaborative research, demanding tailor-made solutions to reflect and improve interdisciplinary scientific performance. Performance measurement aims at initiating learning processes through the reflection of performance on different organizational levels, such as the individual scientist, scientific teams or the entire cluster. In this context, the definition and collection of scientific key performance indicators (KPIs) is important as a base for steering decisions in interdisciplinary scientific collaborations. This includes indicators to measure e. g. the quality of scientific exchange, output and sharing of information in contrast to e. g. classical monetary indicators of profit-organizations.

During the presentation, the focus is set on the implemented cluster-specific Balanced Scorecard of the Cluster of Excellence Integrative Production Technology for High-Wage Countries. Here insights about central research results and future challenges of interdisciplinary scientific performance measurement are presented.

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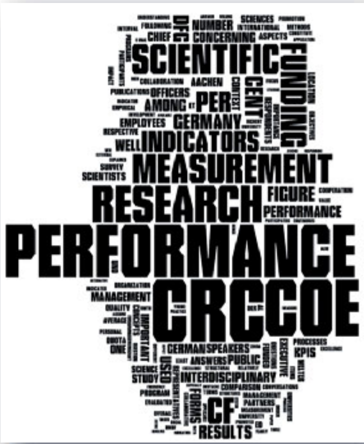


Source: developed with wordle.net 2013

Performance Measurement within Interdisciplinary Clusters of Excellence

Cluster-Conferences 2013

Florian Welter M.A.

Claudia Jooß M.A.

Dr. rer. nat. René Vossen

Prof. Dr. rer. nat. Sabina Jeschke

Aachen, 23th September 2013

Agenda

Interdisciplinary scientific co-operation in clusters of excellence (CoE)

Performance measurement

Central aspects of CoE performance measurement

Outlook – contemporary funding phase (11/2012-10/2017)

Cross Sectional Processes 1 – fields of action and research

Knowledge & Cooperation Engineering

Which means and tools are suitable to retrieve and manage interdisciplinary knowledge?

Interdisciplinary Innovation Management

How can a visualization instrument for cooperation contribute to ensuring success in interdisciplinary research teams?

Diversity Management

How can people from different cultures become a successful scientific team?

Performance Measurement

How can cluster performance be operationalized and measured in order to support the cybernetic management of highly complex scientific cooperation?

Source: freedigitalphotos.com 2013

Different forms of scientific co-operation (a)

Unidisciplinarity in science

– **Scientists from a single discipline** work together to address a common research issue (cf. Pohl et al. 2010)

Crossdisciplinarity in science

– **Methods and approaches** from a discipline are **used in another discipline**

– E. g. econophysics → physical methods are used to solve issues in economics (cf. Hillerbrand/Schneider 2012)

Multidisciplinarity in science

– **Different disciplines** work **independently** on a common issue

– **No integration** of methods → independent application of methods

– **Disciplinary results** (cf. Pohl et al. 2010)

Source: freedigitalphotos.com – dream designs 2010

Source: freedigitalphotos.com – sheelamohan 2012

Source: freedigitalphotos.com – renjith krishnan 2011

Different forms of scientific co-operation (b)

Interdisciplinarity in science

- **Different disciplines co-operate** on a common issue
- **Integration and combination** of scientific methods, paradigms, issues, etc.
- **Results** of interdisciplinary co-operation **surpass the sum of disciplinary results** (cf. Defila/Di Giulio 1998)

Source: freedigitalphotos.com – ddpavumba 2012

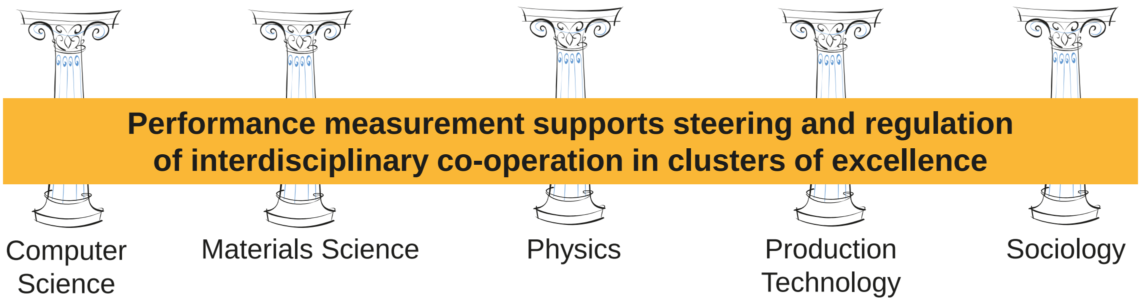
Transdisciplinarity in science

- **Necessity for transdisciplinarity** in science **due to an increasing complexity and uncertainty** of scientific issues
- Integration and combination of different **scientific methods and practical knowledge/practitioners** (cf. Bergmann 2010; Mittelstraß 2003)

Source: freedigitalphotos.com – Idea go 2009

Internal challenges for an interdisciplinary cluster of excellence

- **Overcoming the pillarization** of single disciplines
- **Interactive process of interdisciplinary co-operation**, learning and knowledge generation
- Coping with **heterogeneity of actors** (e. g. structural, cognitive and cultural)



Source: Microsoft ClipArt 2013

Agenda

Interdisciplinary scientific co-operation in clusters of excellence (CoE)

Performance measurement

Central aspects of CoE performance measurement

Outlook – contemporary funding phase (11/2012-10/2017)

Performance measurement at a glance

Performance

- Capability of an organization to **reach objectives**
- **Multidimensional** form (e. g. finances, quality or processes)
- Characterized by **interdependencies**, integrating **strategic and operational aspects** (cf. Grüning 2002)

Performance measurement

- **Roots** in **business administration**
- Improves achievement of objectives and **promotes cross-hierarchical communication and cooperation** (cf. Horváth et al. 2001)

Key performance indicators

- Represent quantitative **data compressing a complex reality** (cf. Lachnit 1979; Gladen 2002)
- **Different methods** can be used for collection, e. g. **reporting, evaluations, interviews** (cf. Weber/Schäffer 2006)

Source: freedigitalphotos.com – SundayMorning 2013

Central approaches of Performance measurement

Finance- and value-oriented approaches

- Point of culmination in one superior indicator (mathematical operation)
- Focus on a financial perspective and respective indicators

Quality management-oriented approaches

- Logical operation of indicators
- Holistic perspective (e. g. on enterprises)
- Focus on standardized rating scales

Performance measurement

Process-oriented approaches

- Logical operation of indicators
- Focus on (cross-)organizational processes

Scorecard-based approaches

- Logical operation of indicators
- Holistic perspective (e. g. non-profit-organizations)
- Tailor-made operationalization of strategic targets into indicators

Sources: cf. Hilgers 2008; Horváth/Seiter 2009; Kozielski 2010

Agenda

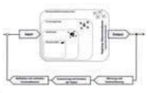
Interdisciplinary scientific co-operation in clusters of excellence (CoE)

Performance measurement

Central aspects of CoE performance measurement

Outlook – contemporary funding phase (11/2012-10/2017)

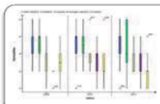
Performance measurement with a cluster-specific Balanced Scorecard



Development of a cluster-specific Balanced Scorecard to measure performance on **different levels** to initiate cluster-internal **learning processes**

Modeling of **performance indicators and their relationships** (e.g. number of publications, quality of research co-operation or contacts to industrial partners)

Data collection via web-based partly standardized questionnaire **once a year** among the staff of the CoE



Statistical analyses of collected data, identification of **key performance indicators**

Discussion of results and recommendations of action with the **cluster management board** and further CoE **staff** to increase interdisciplinary performance

Sources: Welter 2013; freedigitalphotos.com 2013

Exemplary results – key performance indicators (KPI) (a)

KPIs were identified by the following steps:

- Determination after **completion of three surveys in the years 2009, 2010 and 2011** (Ø = 111 participants)
- **Spearman's rank correlation coefficient** calculated with all ordinal scaled variables
- Comparison of the amount of **correlation pairs per indicator**
- **Identification** of indicators whose **size effects** were > 0,3 (c. f. Bortz/Schuster 2010; Cohen 1988)
- Applying a **significance test** (α=0,01)

Source: openitmag.com – seo design 2013

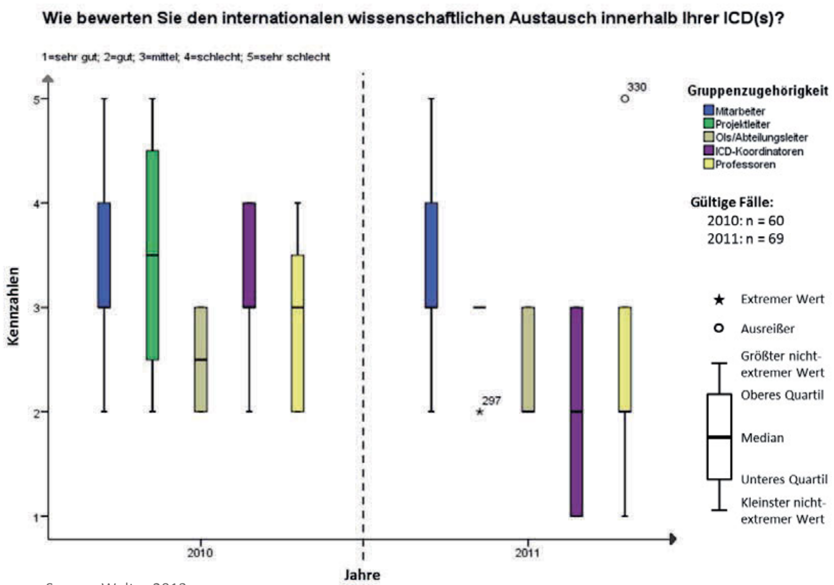
Exemplary results – key performance indicators (KPI) (b)

Top 5 identified KPIs (ranked by the amount of correlation pairs per indicator)

Average correlation coefficient (significant at 1% level, two-sided) per indicator	Amount of correlation pairs per indicator	Indicator
0,412	76	International scientific exchange
0,396	69	Scientific cooperation
0,571	58	Contentment with cluster-internal hierarchies
0,428	56	Influence of staff turnover
0,397	54	Publicity

Source: Welter 2013

Exemplary results – box-plot-diagram (international scientific exchange)



Source: Welter 2013

Strengths and weaknesses/criticism → potential for improvements

Strengths

- **Involvement of CoE staff** in performance measurement by means of surveys
- **Two types of reference points** for performance indicators:
  - Comparison of **different groups/hierarchies** (professors, cluster management board/ICD-deputies, group leaders/chief engineers, research assistants)
  - Comparison of **time-lines** (2009, 2010, 2011)
- **Feedback and regulation** in terms of a **cybernetic control loop**
- Initiation of **a continuous improvement and organizational learning process**

Weaknesses/criticism

- Only measurement of **cluster-internal performance**
  → Possibilities of **external benchmarking?**
- Too much **emphasis on means of surveys**
  → Implementation of **different methods for measurement**
- Too many **'soft' performance indicators**
  → **Adaption of existing set of indicators** and integration of **new indicators**

Agenda

- **Interdisciplinary scientific co-operation in clusters of excellence (CoE)**
- **Performance measurement**
- **Central aspects of CoE performance measurement**
- **Outlook – contemporary funding phase (11/2012-10/2017)**

Updated DFG performance criteria for clusters of excellence

Research
- Quality of research program **(international comparison)**
- Originality **and willingness to take risks**
- Influence on the research area
- Value added through interdisciplinarity
- **Application orientation, knowledge transfer and cooperation with (inter-)national partners**

Involved researchers
- Quality of the involved researchers
- Concepts promoting young researchers with regard to scientific training and career
- Concepts for equal opportunities among male and female researchers

Structures
- Influence on the structural development of the university
- **Value added of cooperations with further institutions**
- Organization, management **and infrastructure**
- **Implementation and sustainability of the cluster of excellence**


Source: freedigitalphotos.com – jscreationzs 2013

Sources: DFG/WR 2010

Next steps and research questions

Core tasks in CSP1 performance measurement (2012-2017)

Re-design of the **cluster-specific Balanced Scorecard** for **cluster-internal performance measurement** (inter alia concerning key performance indicators and target system)
→ Which virtual means support a faster data collection and graphical performance analysis?

Benchmarking to measure **cluster-external performance** (inter alia functional and competition-oriented benchmarking)
→ In how far is it possible to benchmark the cluster with other interdisciplinary systems?

Methods and concepts to analyze the intellectual capital and to identify desiderates of the cluster of excellence
→ Which methods of intellectual capital reporting support a sustainable cluster development?

Sources: freedigitalphotos.com – digitalart 2011; Jeroen van Oostrom 2013; Salvatore Vuono 2013

Thank you for your attention!

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Source: Microsoft ClipArt 2013

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Simulation-Based Path-Planning for Robot-Machine-Cooperation

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Keywords:
Simulation, Machining, Robot, Path-Planning

Abstract

Integrating technologies within a machine tool can help increasing productivity by shortening through-put times. Along with the integration of multiple technology modules such as a laser and a milling spindle, there is often the integration of multiple end-effectors which allow simultaneous use of the often expensive technology modules. Besides the possibility of parallel manufacturing on different workpieces, for example with two separate workspaces, it is also desirable to use both end-effectors within one workspace on the same workpiece. However, due to the high level of integration such cooperation scenarios require a high degree of automated path-planning mechanisms that have to be developed specifically for the given machine tool.

This presentation highlights certain aspects that have to be taken into account for developing a control architecture that allows simultaneous machining of a milling spindle and a robot. It proposes a simulation-based path-planning concept and demonstrates the abilities of the developed simulation framework regarding the validation of a cooperation process. While the machine spindle mills a five-axis workpiece the robot tries to debur another section of the moving workpiece.

Simulation-Based Path-Planning for Robot-Machine-Cooperation

C-2 – Multi-Technology-Platforms

Cluster Conference, 23. Sept. 2013

Johannes Nittinger, WZL

Agenda

1 **Introduction**

2 **Current Work**

3 **Demonstration**

Agenda

1 **Introduction**

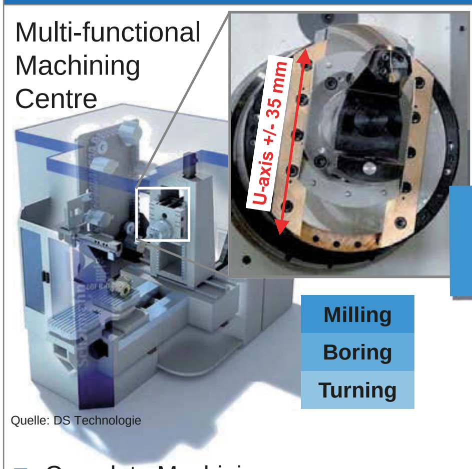
2 **Current Work**

3 **Demonstration**

Technology Integration - Multi-Technology-Platforms

State of the art

Multi-functional Machining Centre

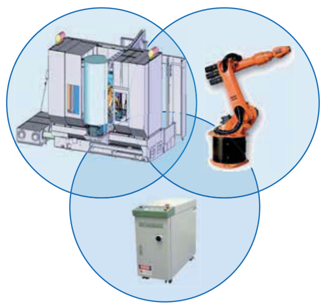


Quelle: DS Technologie

- Complete Machining
- High Accuracy
- High Flexibility

Multi-Technology-Platform (C-2)

Machining Centre
Chiron "Mill"



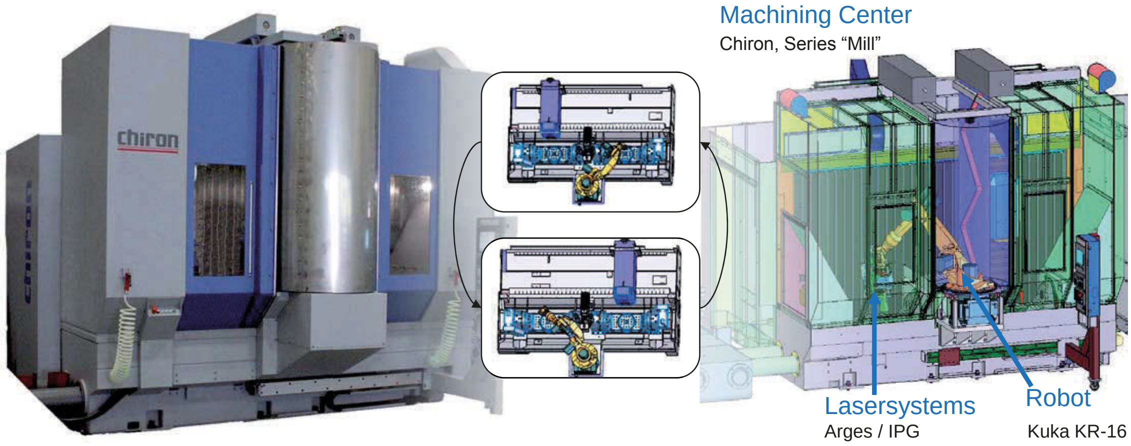
Robot
Kuka KR-16

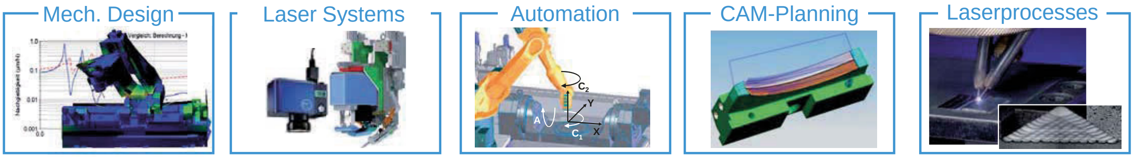
Laser Processes
Handling
Milling
Boring
Turning

Laser System
Arges

- Enlargement of the type of Workpieces
- Reduction of Processing Time
- Increase of Productivity for small Lot Sizes
- Reduction of Planning Cost

Multi-Technology-Platform: Hybrid Machining Centre

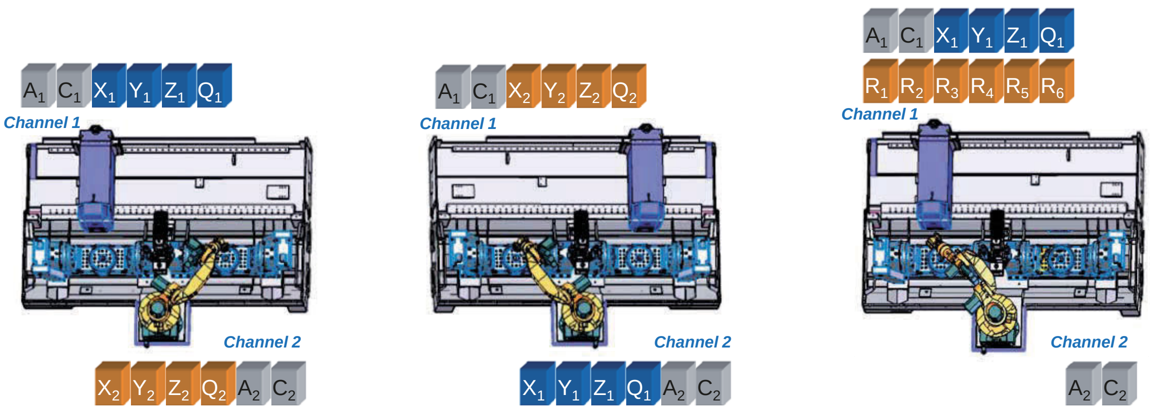




Possible Machining Configurations of the Hybrid Machining Centre

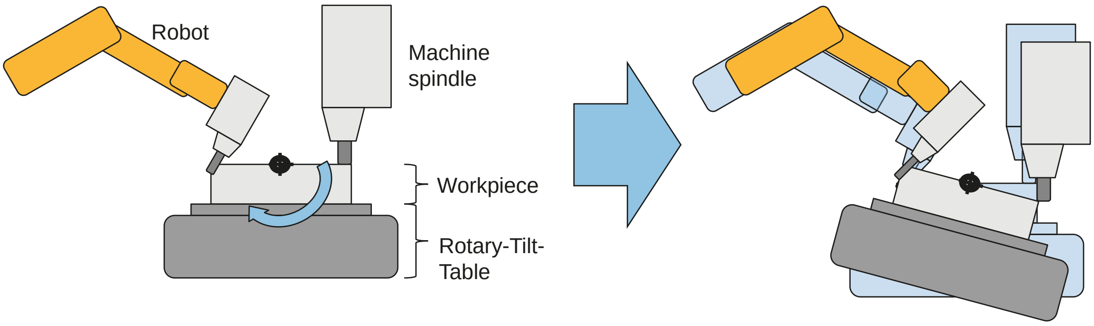
Today: machining of robot or machine within one workspace

Goal: Simultaneous manufacturing on the same part



Challenges

- How can multiple end-effectors using different kinematic setups cooperate effectively within an MTP?
  - How can multiple simultaneous paths be defined within a single NC-program?
  - How and where is the computation of axis-transformations?
  - How can collisions be ruled out?
  - For what manufacturing processes or operations does it make sense?



Seite 8

Agenda

1 Introduction

2 Current Work

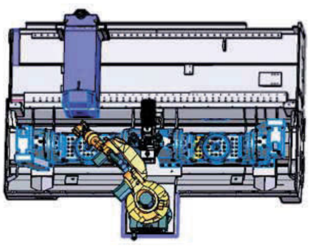
3 Demonstration

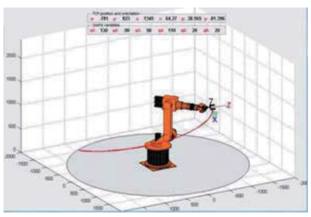
Seite 9

Robot-based deburring

- Deburring of workpieces while they are still being milled
- Pilot-process for simultaneous machining
- Installation of a deburring spindle for the robot
- Deburring process is planned within the CAM-System

Simulation



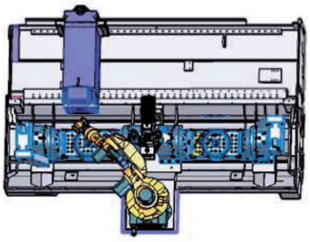


- The damage potential for cooperating processes is high
  - Very limited space for robot and spindle
  - Highly dynamic movements
  - Complex machine kinematics
  - Different robot orientation in each workspace

Extensive simulation and collision detection is essential!

- The necessary degree of detail for the simulation has to be determined
  - Physical simulation of machine and controller?
  - Kinematic model with a simple NC-interpreter?
  - Can the simulation be performed within the NC-controller?
- Integration of the simulation into the CAM-system

Path-Planning Strategies for simultaneous machining



- Development of generic concepts for planning different processes with two TCPs
  - Example one: spindle path is planned independently, robot path is planned around the spindle movement (master- and slave-path)
  - Example two: spindle path and robot path are planned simultaneously and each path can be altered if the other path benefits from that
- Including simulation for decision-making during path generation
- Development of a methodology for including any given process or operation in common CAM-systems

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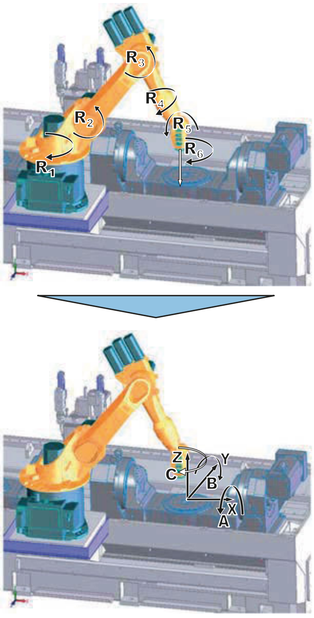
Axis-Transformation



- Current concept at the Hybrid-Machining-Centre:
  - Robot and spindle are programmed in G-code
  - Robot and spindle are programmed in workpiece-coordinates
  - Each NC-program can be used in both workspaces equally
- These advantages need to be preserved!
- Resulting objectives for the development of the extended concept:
  - Implement a deterministic inverse-kinematic-transformation for both robot and spindle
  - Transformation must be calculated within the machine controller
  - The same NC-program must work in both workspaces, so each workspace needs a (slightly) different transformation

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Agenda

1 Introduction

2 Current Work

3 Demonstration

Demonstration

Demonstration

Thank you for your attention!

Manufacturing of lattice structures in solid shells by Selective Laser Melting

Hinke, C.

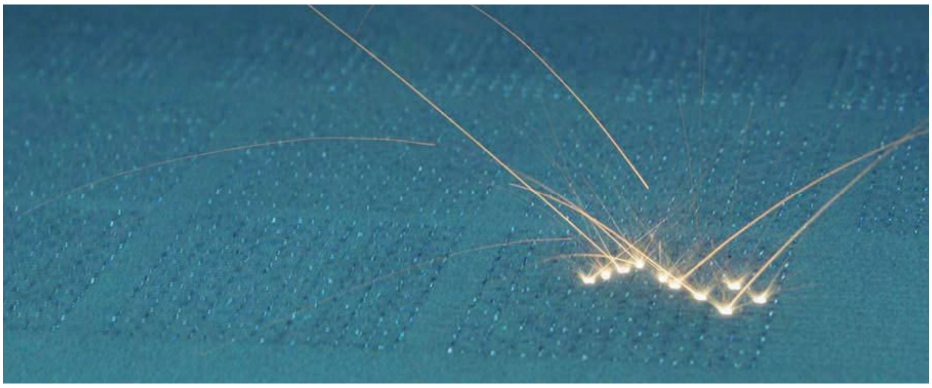
Abstract

Lattice structures belong to the group of complex structures that can be manufactured in almost any arbitrary shape by Selective Laser Melting (SLM). Particularly for light-weight applications the outstanding mechanical properties of lattice structures such as the high ratio of stiffness / weight are from great interest. Current investigations are undertaken to comprehensively understand the behavior of lattice structures under various loading to explore the design freedom given by SLM. This presentation presents first results about the compressive behavior of f2ccz-type lattice structures in solid shells made of 316L-powder. To determine the influence of side shells and top shells compressive tests are performed on specimens with and without top shells according to DIN 50134. Transition layers are needed to overcome process restrictions to manufacture shells on lattice structures without build errors. A comparison of different types of transition layers situated between lattice structures and top shells is given. Derived from this, design rules to manufacture solid shells on lattice structures with varying cell widths are presented to improve stability and surface quality of top shells.

Compressive behavior of lattice structures in solid shells manufactured by (SLM)

Dipl.-Wirtsch.-Ing. Simon Jens Merkt

CoE Conference

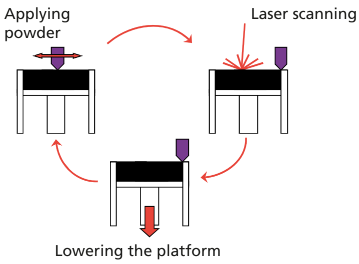


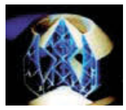
Agenda

- **Introduction and Motivation**
- Transition layer design
- Simulation results
- Manufacturing of specimens
- Examination of specimens
- Compression test results
- Future work

Selective Laser Melting (SLM) principle

Sliced 3D-CAD model



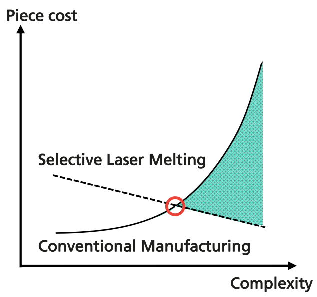


Functional metallic part from serial material

Data preparation → **Manufacturing** → **Post processing**

Technology potential of SLM

Lattice structures



Weight reduction for free

- Lattice structures in functional parts:
  - Improved functionalities (stiffness, damping, etc.)
  - Weight reduction (up to 50 %)
  - Reduction of scanning time

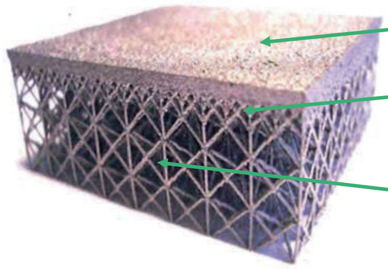
Various applications of cellular material

Application Group	Examples
Lightweight	Aircraft wing panels, robotic arm, automobile hood
Energy absorption	Automobile bumpers, blast shock wave protection
Heat exchangers	Heat sinks for electronic components, transpiration coolers
Sound control	Sound dampers, silencers for jet engine intakes
Vibration control	Gas-tight seals between engine stages in turbines, machine housings
Medical implants	Bone implants
Buoyancy	Floater for measuring fill levels in hot or corrosive media

Working scope and challenges

- **Objective**: Integration of lattice structures in solid shells
- Manufacturing restraints:
  - Residual stress
  - Stair step
  - Warping
  - Balling effect
  - Dross formation

State-of-the-art transition layer design



Source: Olaf Rehme Cellular design for laser freeform fabrication

Agenda

- Introduction and Motivation
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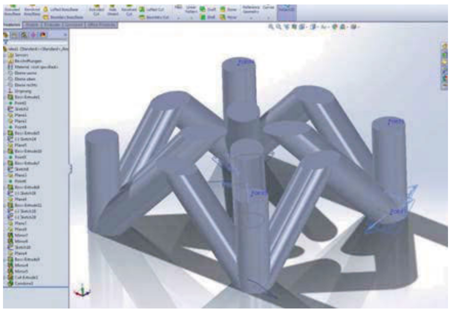
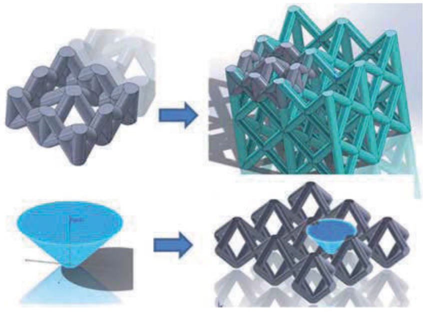
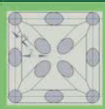
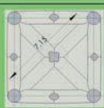
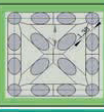
Development of different transition layer designs



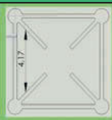
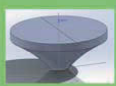
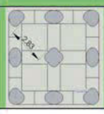


- Evaluation criteria:
  - Added volume
  - Supporting area
  - Manufacturability
  - Transferability
  - Mechanical properties

Evaluation of different transition layer designs (1)

Transition layer	CAD model	Added Volume [mm³]	Supported area [mm²]	Max-gap distance between supported areas [mm]		Manufacturability [α°]	Mechanical stability	Transferability
1		40.41	12.03		2	45°	+	$f_2$ccz + fcc - D-bcc -
2		37.72	4.26		7.15	25°	+	$f_2$ccz + fcc 0 D-bcc -
3		47.44	14.37		4.76	35°	+	$f_2$ccz + fcc 0 D-bcc -
4		57.70	17.51		1.38	35°	+	$f_2$ccz + fcc 0 D-bcc -

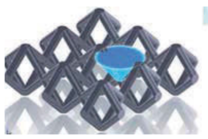
Comparison of different transition layer designs (2)

Transition layer	CAD model	Added Volume [mm³]	Supported area [mm²]	Max-gap distance between supported areas [mm]		Manufactur ability [α°]	Mechanical stability	Transferability
5		19.65	11.21		4.17	33°	-	$f_2$ccz + fcc 0 D-bcc -
6		44.77	38.48		2.40	45°	+	$f_2$ccz + fcc + D-bcc +
7		32.66	10.15		2.83	45°	+	$f_2$ccz + fcc - D-bcc -

Evaluation results of transition layer designs

Transition layer	Added Volume	Supported area	Max-gap distance between supporting areas	Manufactur-ability	Transferability	Score
1	3	1	6	7	2	19
2	4	0	1	0	3	8
3	2	1	3	6	3	15
4	0	2	6	6	3	17
5	7	1	4	6	3	21
6	**2**	**6**	**5**	**7**	**6**	**26**
7	5	1	5	7	2	20

Evaluation range: 0 – 7 points



Agenda

- Introduction and Motivation
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- **Simulation results**
- Manufacturing of specimens
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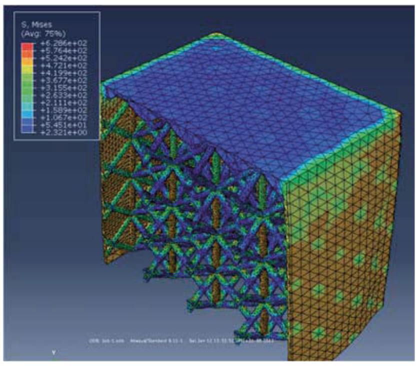
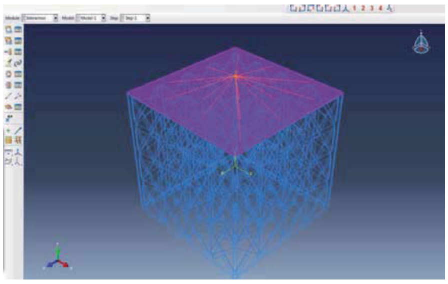
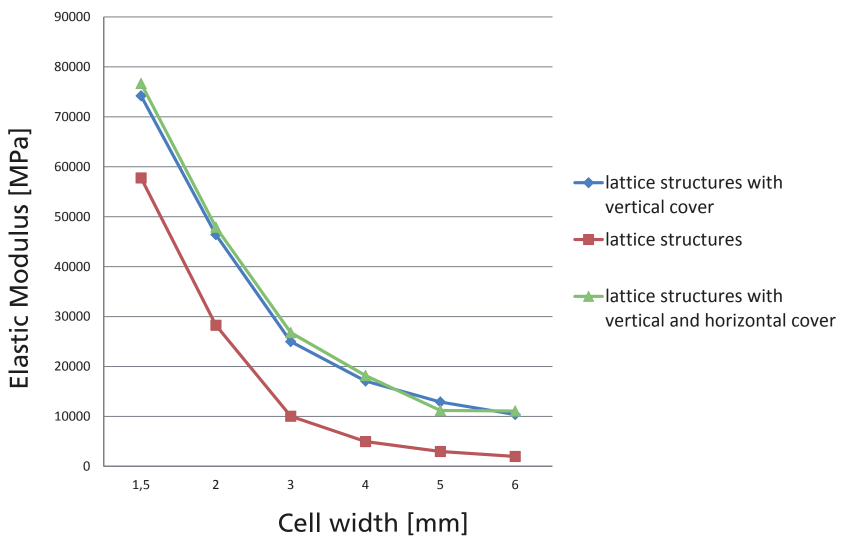
Simulation framework for compression tests





Material	Elastic Modulus [MPa]	Poisson's ratio	Maximum yield strength [MPa]	Shell thickness [mm]	Strut diameter [mm]	Cell type	Cell width [mm]
1.4404	210000	0,33	500	0,25	0,5	f2ccz	1.5 – 6

Comparison of Elastic Modulus



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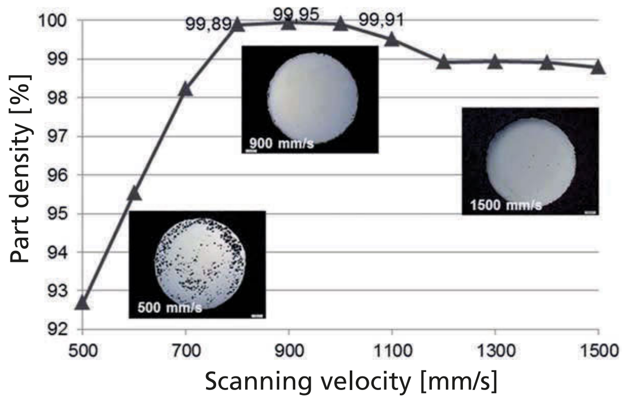
Specifications of SLM machine

Technical Data

Effective building volume (including building platform)	250 mm x 250 mm x 215 mm (9.85 x 9.85 x 8.5 in.)
Building speed (material-dependent)	2 - 20 mm³/s (0.0001 - 0.001 in³/sec.)
Layer thickness (material-dependent)	20 - 100 µm (0.001 - 0.004 in.)
Laser type	Yb-fibre laser, 200 W
Precision optics	F-theta-lens, high-speed scanner
Scan speed	up to 7.0 m/s (23 ft./sec.)
Variable focus diameter	100 - 500 µm (0.004 - 0.02 in.)
Power supply	32 A
Power consumption	maximum 5.5 kW
Nitrogen generator	standard
Compressed air supply	7,000 hPa; 20 m³/h (102 psi; 26.2 yd³/h.)
Dimensions (B x D x H)	
System	2,000 mm x 1,050 mm x 1,940 mm (78.8 x 41.4 x 76.4 in.)
Recommended installation space	approx. 3.5 m x 3.6 m x 2.5 m (137.9 x 141.8 x 100 in.)
Weight	approx. 1,130 kg (2,491 lb.)
Data preparation	
PC	current Windows operating system
Software	EOS RP Tools; Magics RP (Materialise)
CAD interface	STL. Optional: converter for all standard formats
Network	Ethernet
Certification	CE, NFPA

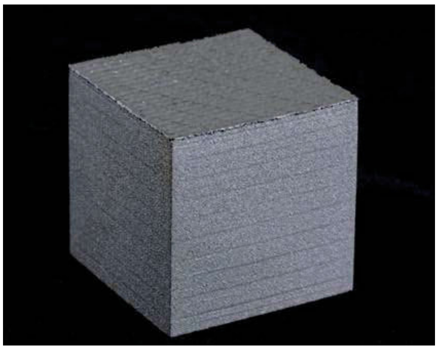
Source: http://www.rmsiberia.com/Producto/eosint_m270_en.pdf

Parameters for manufacturing of specimens

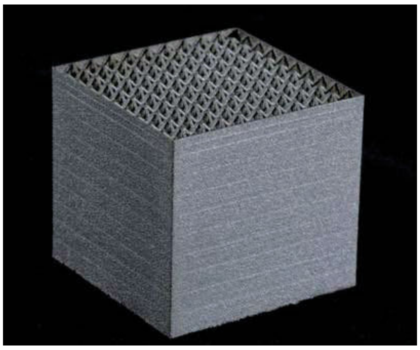


- Laser power = 195W
- Layer thickness = 30µm
- Contour-Hatch scan strategy

Manufactured specimens



Lattice structure with H & V shell



Lattice structure with V shell

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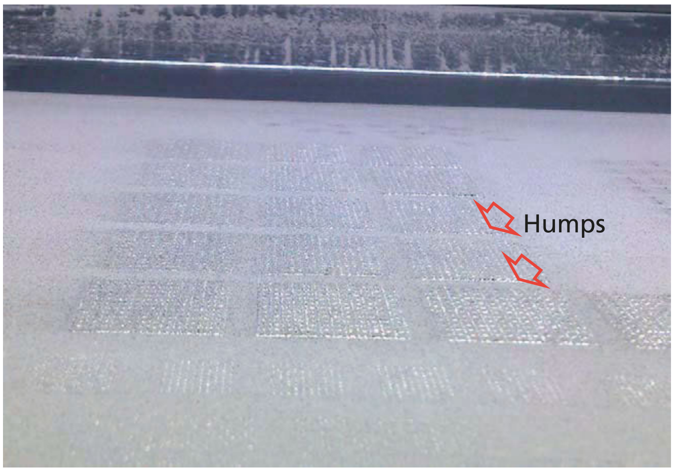
Errors during manufacturing (1)



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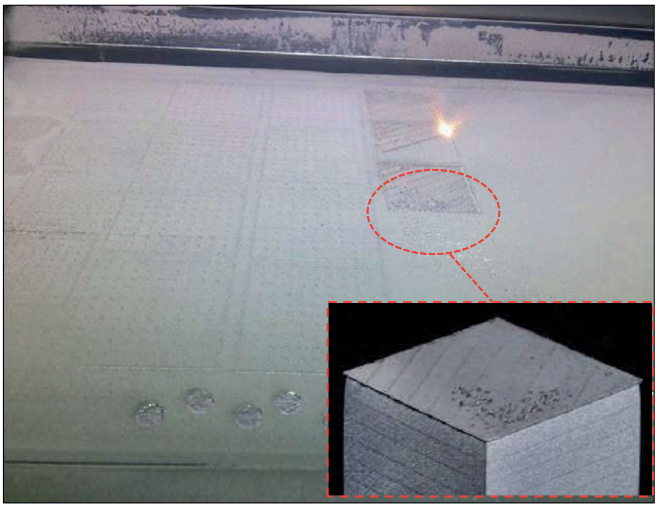
Errors during manufacturing (2)



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Agenda

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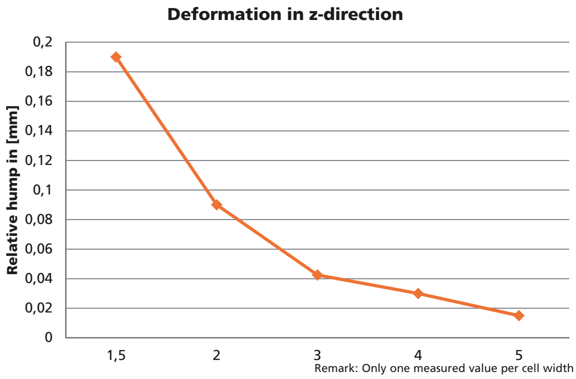
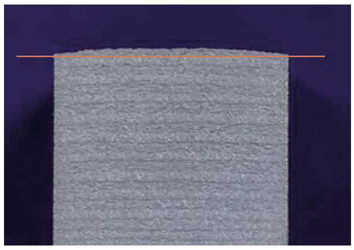
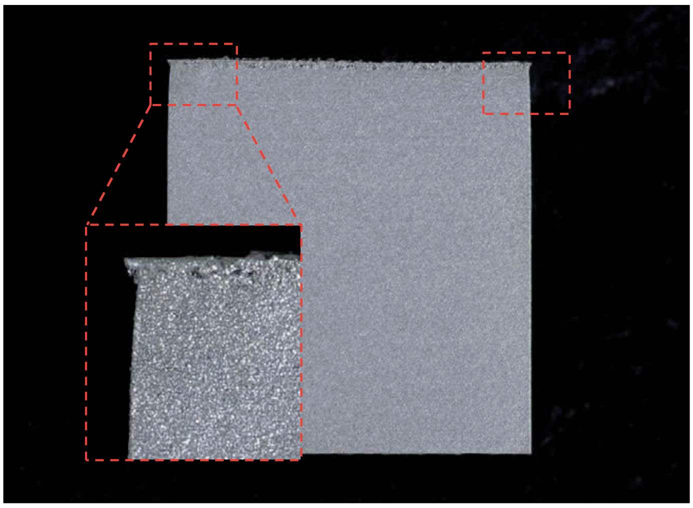
Geometric accuracy of manufactured specimens (1)



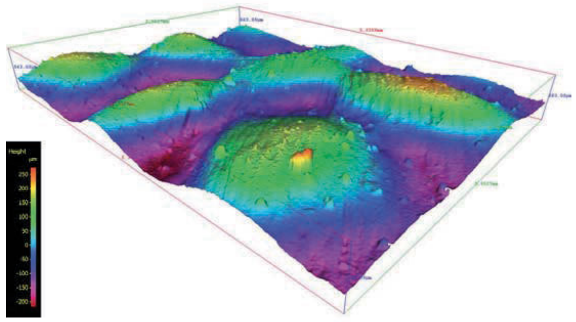


Geometric accuracy of manufactured specimens (2)



Surface quality of top shell (2)

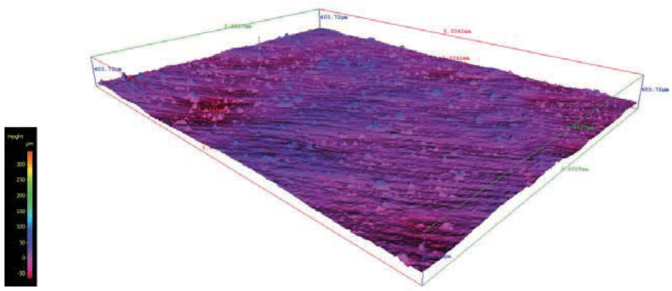
State-of-the-art transition layer design



Surface roughness: Ra=15 μm

Surface quality of top shell (1)

New transition layer design



Surface roughness: Ra=3.7 μm

Reduction of 80 %

Agenda

- Introduction and Motivation
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- **Compression test results**
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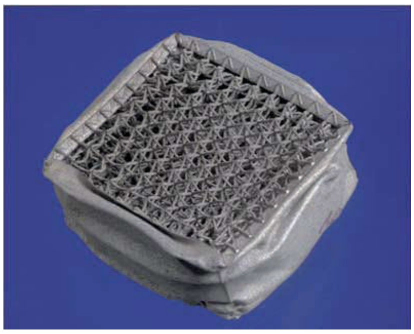
Compressed specimens

Vertical and horizontal shell

Vertical shell



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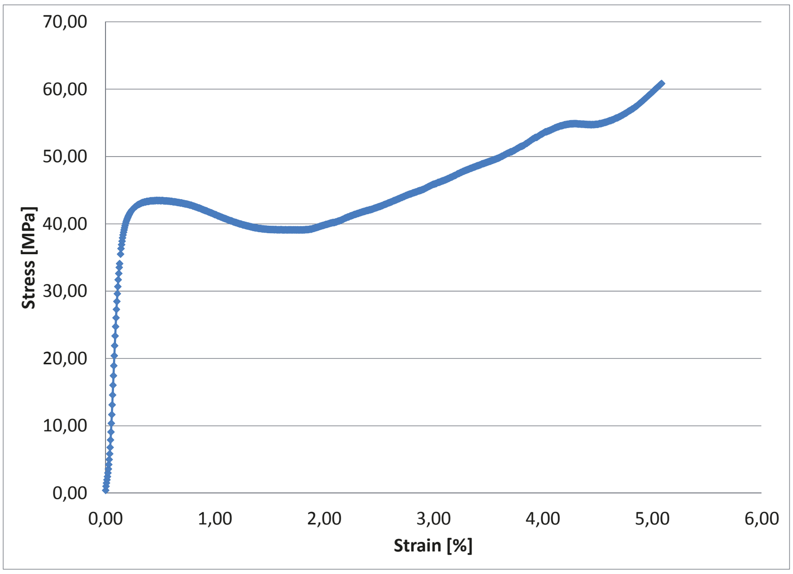
Stress-strain-curve (cell width=3mm)



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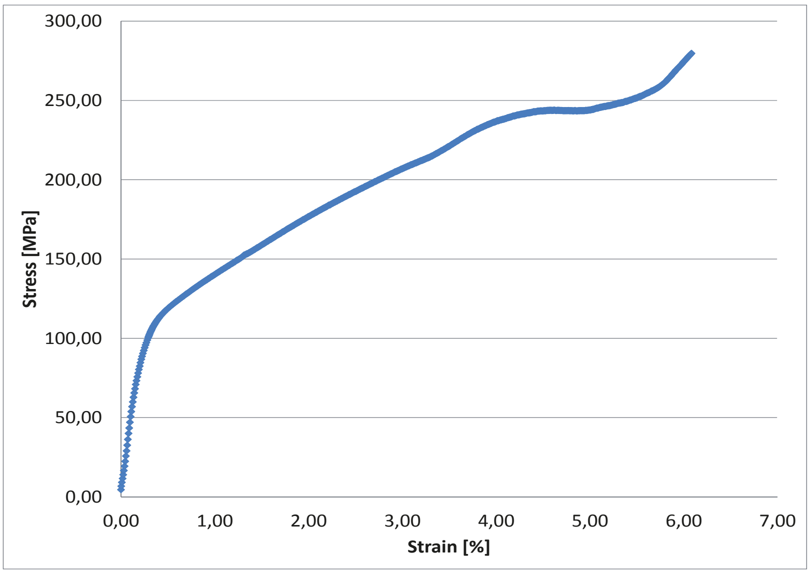
Stress-strain-curve (cell width=2mm)



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Agenda

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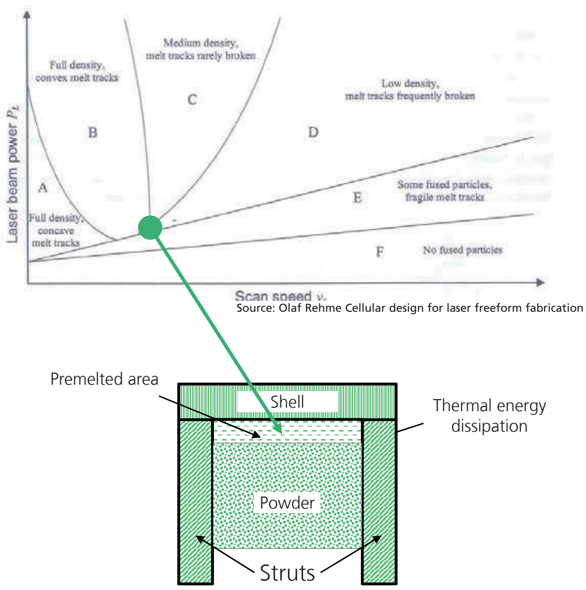
Future work “Zero-transition layer”



Source: Olaf Rehme Cellular design for laser freeform fabrication

Thank you for your kind attention.
Any questions?

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Human Factors and Quality Management: "I" and "Q" in complex supply chain systems

Stiller, S.

Abstract

Supply chains are not only technical but socio-technical systems: Besides the availability and quality of information all decisions in supply chains are influenced by the character and personality profiles of the decision makers. Examinations of business processes are only successful by considering these human factors. However, quality management models which take human information process capabilities and character into account do not exist. Hence, a new business game – the << Intelligence and Quality Game (IQ-Game)>> is developed by WZL and HCIC of RWTH Aachen which supports the understanding of complex cross-company processes and effects. Its concept is based on Goldratt's Game which simulates fluctuations in multi-stage production lines. Because of the restricted playing possibilities, the Goldratt Game is not adequate to achieve the research objectives. In IQ-Game player's options are enlarged when he has to manage supply chains including decisions on purchase order quantity, inspection planning and production quality. Moreover, the business game takes credit to both – technical cause and effect relations considering the quality in supply chains and human factors of the deciders. Before the simulation game starts, all participants have to fill out questionnaires from which their personality profile (such as social skills and risk aversion) can be deducted. The overall target of the business game is to identify a convenient information quality level for human decision making. By simulating possible events in supply chains, the available information and KPIs for the deciders can varied in between each game round, while the overall success is measured on financial success in terms of profit. The study gives proof to the fact that both disciplines human an life sciences and quality management are essential for the successful management of supply chains.

Human Factors and Quality Management: "I" and "Q" in complex supply chain systems

Cluster Conference

RWTH Aachen University

Dipl.-Wirt.-Ing. Sebastian Stiller

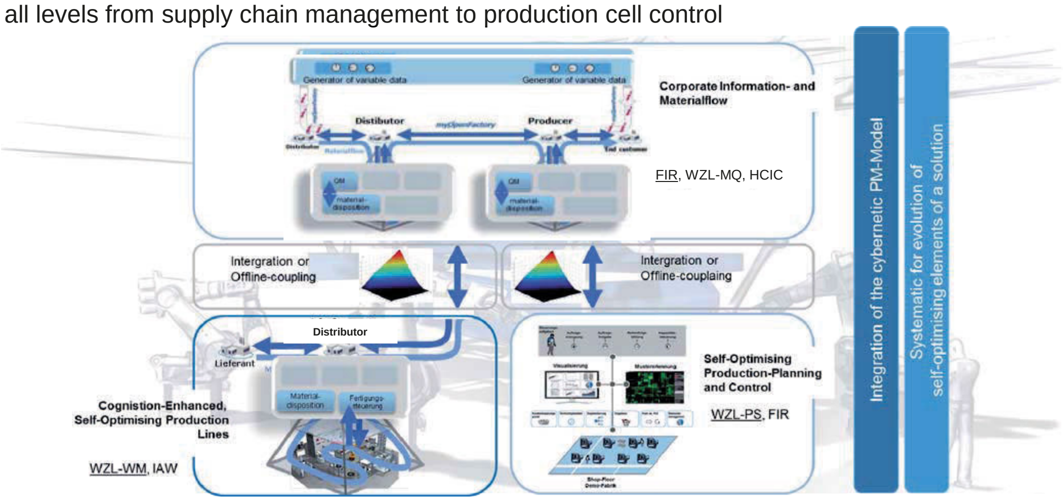
WZL of RWTH Aachen, Department for Quality Management

Aachen – 23rd September 2013

Research areas and goals for the 2nd funding period
ICD D1 – Cognition enhanced, Self-Optimising Production Networks

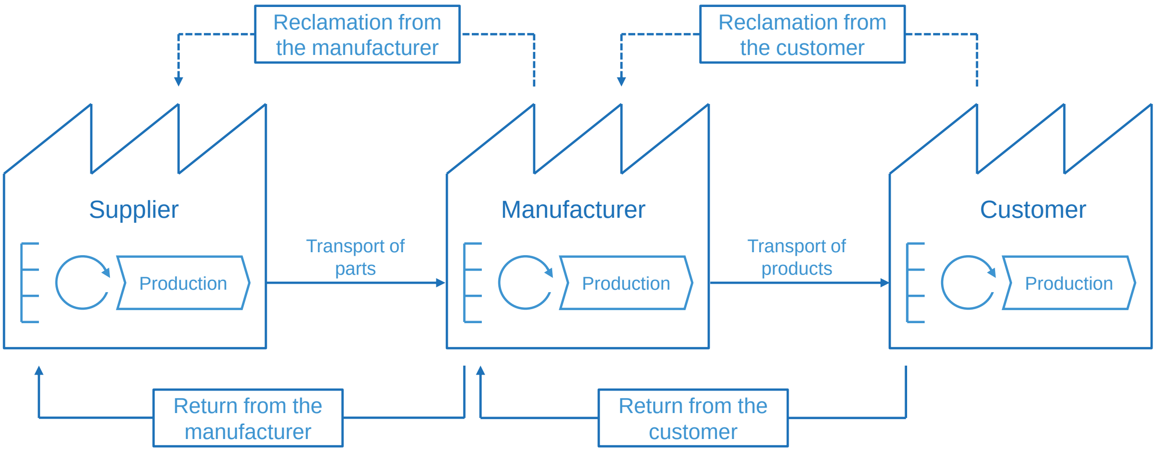
Cognition-enhanced, Self-Optimising Production Networks

- **Further elaboration, verification and validation of the cybernetic reference model** addressing all levels from supply chain management to production cell control

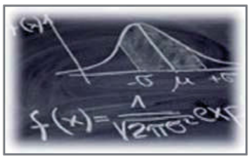


Quality and logistic policies in supply chains

What happens in supply networks from quality management perspective?



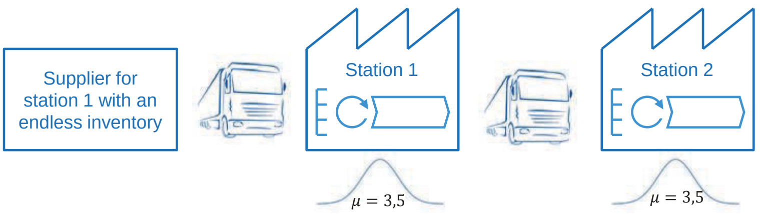
Goldratt‘s Game – the challenge of variance in process chains



A quality simulation game – how Goldratt Game works?

Rules of the Game

1. A supply chain consists of two stations are regarded.
2. At the beginning of the game each station starts with an inventory of 4 products.
3. In each round the number on the rolled die represents the required amount of products.
4. The forwarded amount of products to the next station is the minimum of the number on the die and the current product amount in the inventory. (Reason for the supply fluctuation)



Result:

- If you play 40 rounds you won’t reach about 110 products in station 2 (3,5 ·40 = 110)
- Because of the supply fluctuation you will reach less than 110 products

The Goldratt Game needs to be extended in order to fit to the research objectives

Could Goldratt's Game serve as a reference for the analysis of human behavior in supply chains?

Aspects:

1. *The player isn't able to make **decisions** about the required amount of products.*
2. *Quality is not linked to overall entrepreneurial supply chain performance.*
3. *The **quality** of the required products is not considered.*
4. *The player can't make **decisions** about the quality level.*
5. ***Human characteristics** such as* confidence *between the participants in a supply chain is not covered.*
6. *…*

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Analyzing human behavior in supply chains

*A **business game** should help to analyze the influence of human personality on supply chain success.*

Approach of the business game development:

1. Generation of ideas and intentions for the business game
2. Formulation of the mathematical functions
3. Modifiable factors in the developed business game

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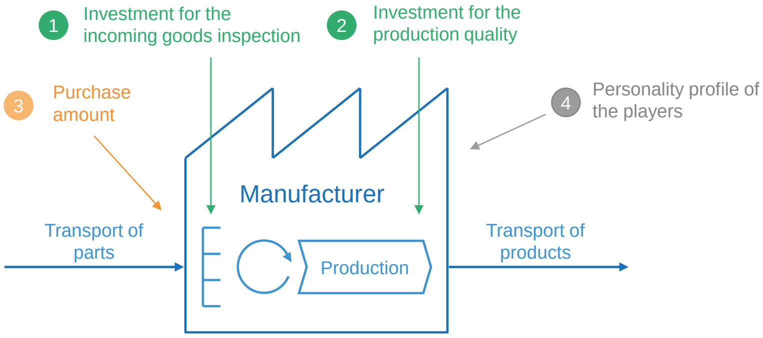
The general setup of the IQ-Game

What should the player of the business game learn?

The player takes the role of the manufacturer.
The player has to find the right quality management policies.



- Three policies can be influenced by the player in order to optimize the manufacturers success.
- The player has to reflect his strategy according to different business events.
- The player has to identify the cause-and effect chains and find the right levers to respond to business events.

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The IQ decision cockpit

Gewinn und Verlustrechnung:

Kosten aus Wareneingangsprüfung: | Kosten aus Lager und Logistik: | Kosten aus Produktion und Vertrieb:

Qualität des Zulieferers:

Prüfkosten der letzten Runde:
Erstattung aus Reklamation:
Σ=

Lagerhaltungskosten:
Bestellkosten:
Opportunitätskosten:
Σ=

Produktionskosten:
Kosten für Reklamationen:
Σ=

Qualität der Produktion:

Preis / Teil

Teile

Wareneingangs-Prüfung
Gelieferte Teile:
Reklamierte Teile:
Lieferqualität:

Lager und Logistik
Lagerbestand:
Bedarf:

Produktion und Vertrieb
Verkaufte Produkte:
Reklamierte Produkte:
Produktionsqualität:

Preis / Produkt

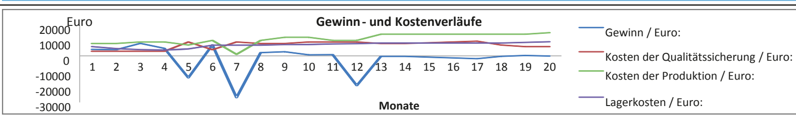
Produkte

HCIC Human-Computer Interaction Center

WZL RWTHAACHEN

Produktionsplanung und -steuerung:
Kosten für die Wareneingangsprüfung:
Materialbestellung beim Lieferanten:
Kosten für die Produktionsqualität:

Runde abschließen



Formulation of the mathematical functions

Which mathematical functions are required?

The mathematical functions form the foundation of the business game.

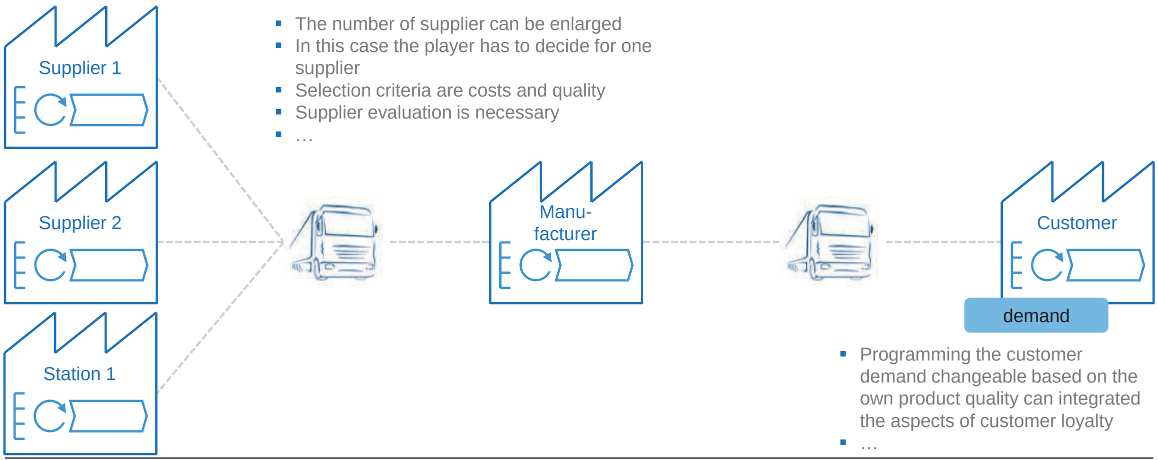
Examples:

- Profit
- Revenue
- Production quality
- Range of the incoming goods inspection
- Quality of the parts from the supplier
- …

These functions are implemented in a first prototype of the business game and validated.

Modifiable factors in the developed business game

Many more variation parameters are possible for the further implementation…



- The number of supplier can be enlarged
- In this case the player has to decide for one supplier
- Selection criteria are costs and quality
- Supplier evaluation is necessary
- …

- Programming the customer demand changeable based on the own product quality can integrated the aspects of customer loyalty
- …

Summary and outlook

Which are the next steps?

- The Goldratt Game simulates the supply fluctuations but neglects many other aspects like product quality, incoming goods inspection, …
- The developed IQ-Game extends the Goldratt Game adding decision possibilities about quality politics and human profiling
- Next the developed business game should implemented in a user-optimized operator interface and validated

- In the future variations in the business game should be analyze to discover possibilities for improvements and to reach the research objectives

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Integrated Product and Tool Development

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Keywords:
Integrated Product Development, Simultaneous Engineering, Tool Development Method

Abstract

In the course of cost pressure and rising product customization, the effective coordination between different areas of the process chain has become a substantial strategic success factor. Since tool making often is the critical path between product development and serial production, the design and arrangement of the interface between product and tooling has significant influence on time, cost and quality. Recent studies, however, show a deficit in the compliance with costs, schedules and quality, which is particularly based on errors and insufficient coordination within the interface between product and tooling.

The purpose of this project is the extension of existing methods within the product development processes regarding the aspect of producibility, especially concerning tooling. Thereby product developers should get additional methodological elements to the prevailing product development process methods that help to achieve the goal of an integrated product and tool development. This method includes the formalization of interactions between product and tool, the identification of the solution space as well as an approach for reducing the identified solution space systematically. The developed method will be validated in selected companies.

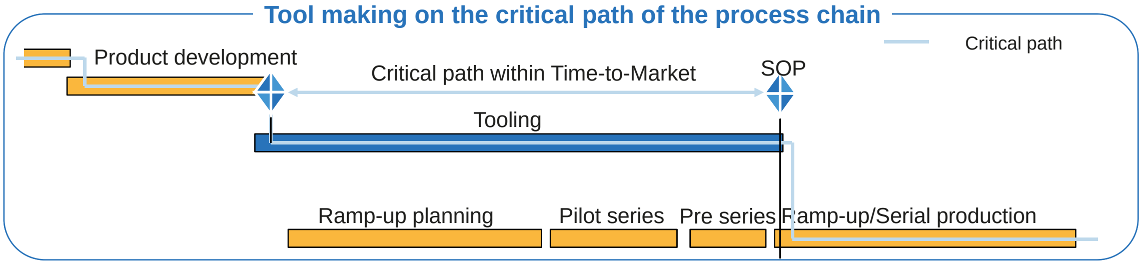
Integrated Product and Tool Development

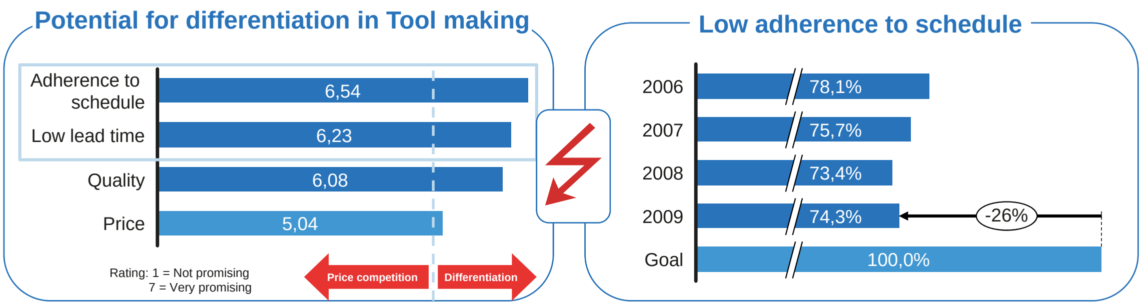
Cluster-Conference September 2013

Abassin Aryobsei

Aachen, 23./ 24. September 2013

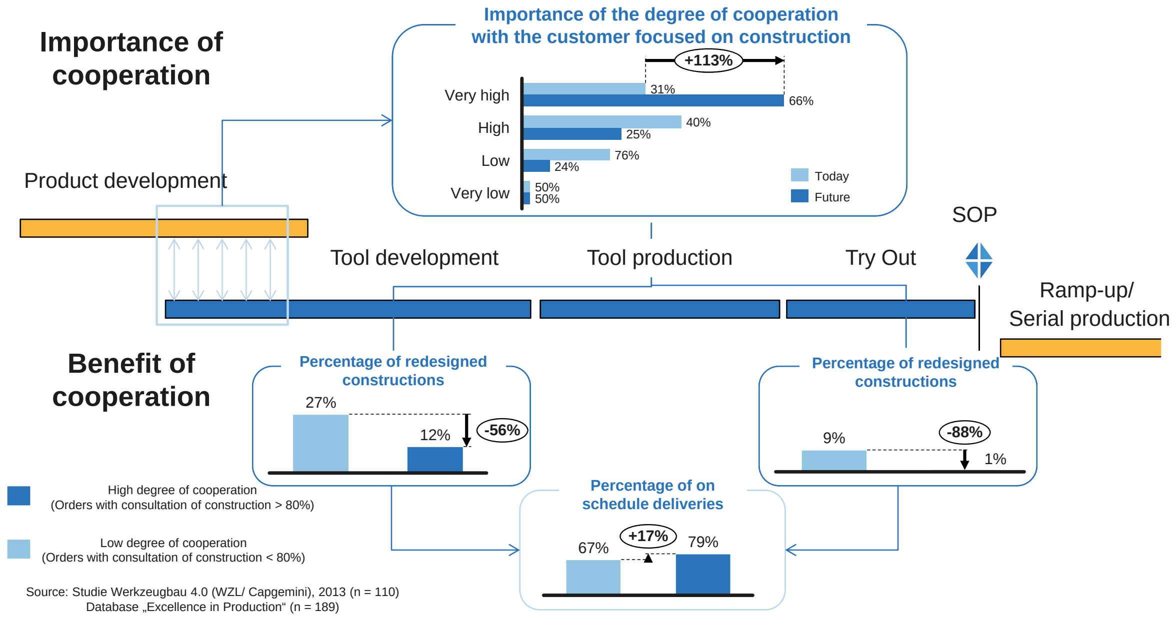
Motivation: Time is the most important factor of differentiation





Source: Survey "Operative Exzellenz im Werkzeug- und Formenbau", 2010. (n = 64)

Motivation: An early cooperation between tool making and product development increases the adherence to schedule



Research question: Main and secondary research questions

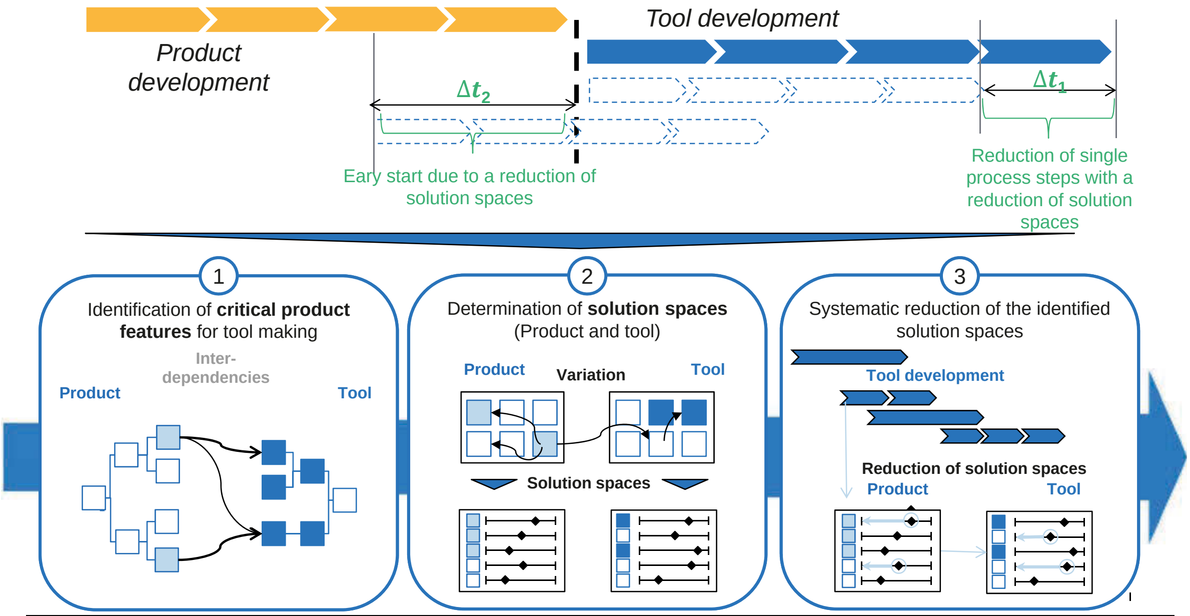
Main research question

- How can the Time-to-Market be reduced with an integrated product and tool development based on the systematic identification and reduction of the degrees of freedom?

Secondary research questions

- How can the interdependencies between product features and tool components be formally visualized so that the critical product features can be easily identified?
- How can the variation of features within the product and the associated tooling help to identify the solution spaces?
- How can an earlier start of the tool development process be achieved through a systematic reduction of degrees of freedom within the product itself?

Approach: Method for integrated product and tool development



The identification of critical product features is the basis for further research

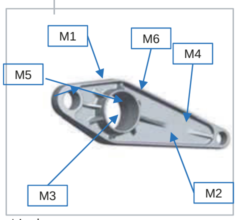
Product features | **Interdependencies** | **Components**

		Feature	Specification	Risk (1-5)
Shape	M1	Local component thickness 1	2 mm	1
	M2	Local component thickness 2	4 mm	5
	M3	Position Cable passage 1	40/30 mm	3
Material	M4	Material	AlCuMg	1
	M6	Surface quality outside	3 µm	2
	...	...	...	.

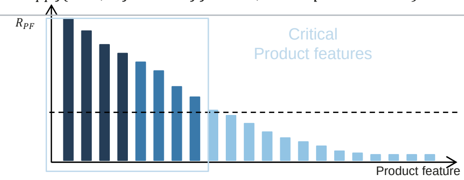
Influence: 0,1 / 0,2 / 0,4

	Component	Time to develop*	Functional group
t_{thp} C_{mat} C_{cpx} ...	Mold insert	4	Machine adaptors
t_{thp} C_{mat} C_{cpx} ...	Mold core	30	Molding
t_{thp} C_{mat} C_{cpx} ...	Ejector pins	15	Temperature control system
t_{thp} C_{mat} C_{cpx} ...	...	2	Ejector system

t_{thp} Throughput time
C_{mat} Material costs
C_{cpx} Complexity costs



Relevance of product feature regarding tool development time:
R_{PF} *f(Risk, influence of feature, development time...)*



* In days

Summary & Outlook

Main results

- Concept of the methodology for the Integrated Product an Tool Development
- Database analysis

Future results

- Further detailing of the methodology
- Validation of the methodology in various tooling firms

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Thank you for your attention!

WZL RWTHAACHEN

Laboratory for Machine Tools and Production Engineering
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Simulative study of the interrelationships of a multi-stage supply chain, taking into account the product quality

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Keywords:
supply chain, simulation, procurement, product quality

Abstract

Production systems are exposed to increasing uncertainty and susceptibility. Nowadays inter-company relationships regarding different demand situations combined with changing product quality issues between different companies have not been investigated intensively yet. With the simulation of a multi-stage supply chain it will be possible to understand the interrelationships between varying quality issues in a supply chain, combined with different demand scenarios. To reach this, the method of design of experiments will be applied. In a first step the target of the simulated system is to reach minimum stock values while having a minimum amount of stock out situations. In a second step price functions will be added to the model, so that it will be possible to simulate conditions in different industry sectors. The results which will be obtained in these experiments will be used for the experimental design in the demonstration factory on RWTH Campus Cluster Logistics. A real multi-stage supply chain will be built up using different ERP-Systems at RWTH Campus Cluster Logistics. Due to the obtained results from the previous simulations a more effective way of experimental design will be guaranteed.

Simulative study of the interrelationships of a multi-stage supply chain, taking into account the product quality

Cluster-Conferences 2013

Marcel Groten

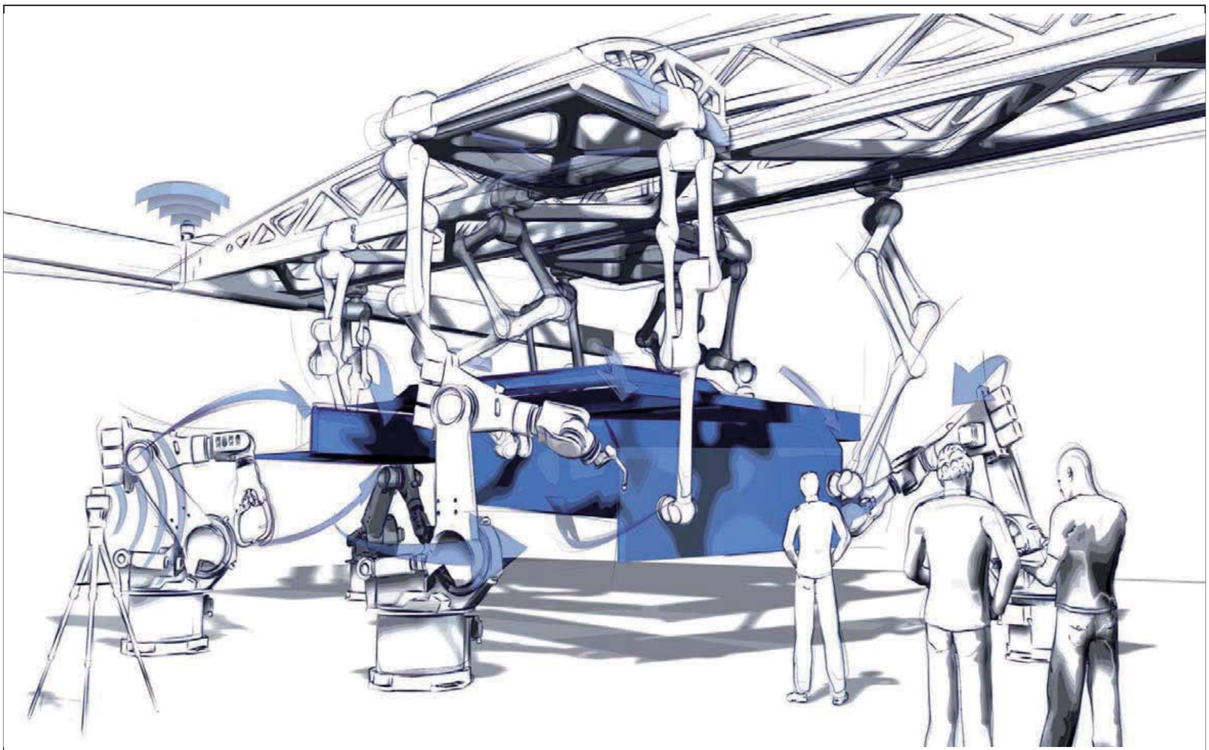
Aachen, den 23./ 24. September 2013

Agenda

1 **Introduction**

2 **Project Status**

3 **Outlook**



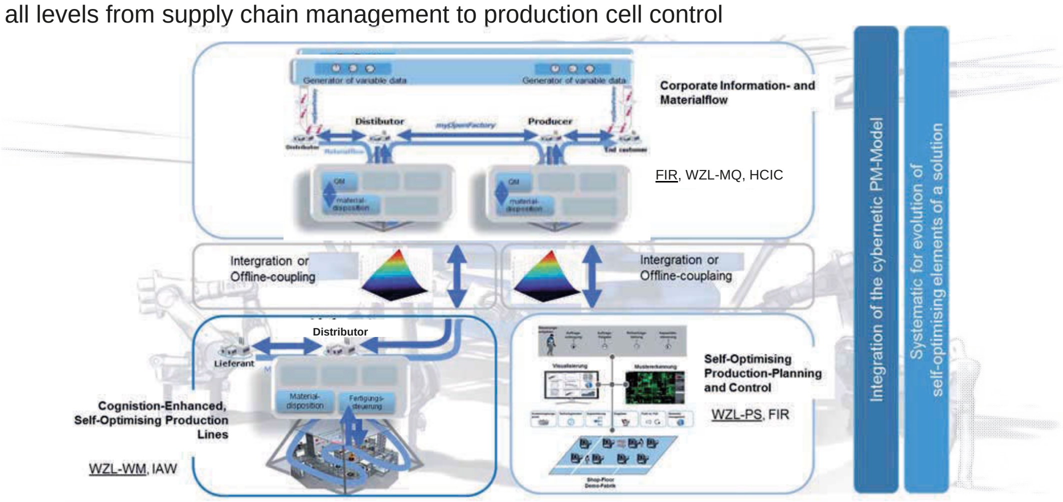
SELF-OPTIMISING PRODUCTION SYSTEMS

Design production systems that adapt to volatile and changing boundary conditions

Research areas and goals for the 2nd funding period
ICD D1 – Cognition enhanced, Self-Optimising Production Networks

Cognition-enhanced, Self-Optimising Production Networks

- **Further elaboration, verification and validation of the cybernetic reference model** addressing all levels from supply chain management to production cell control



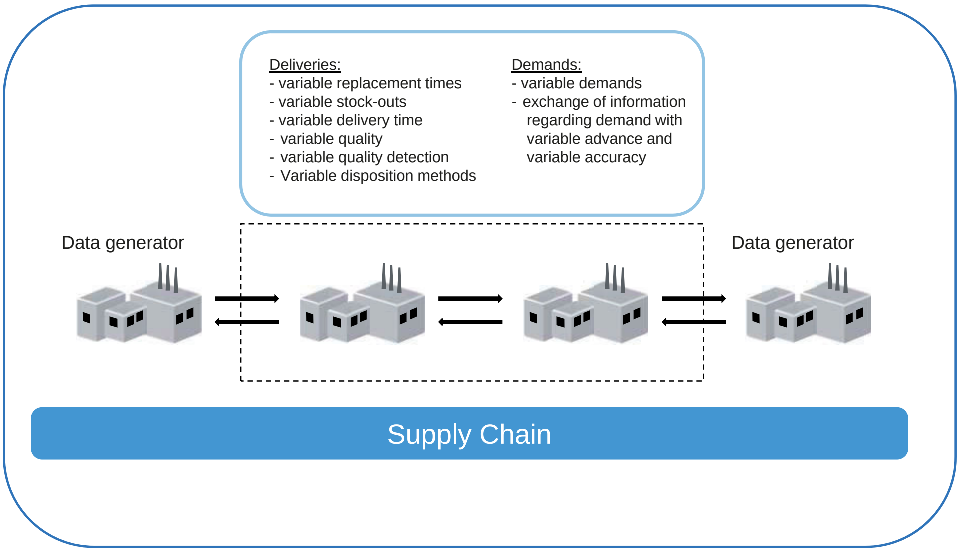
Agenda

1 Introduction

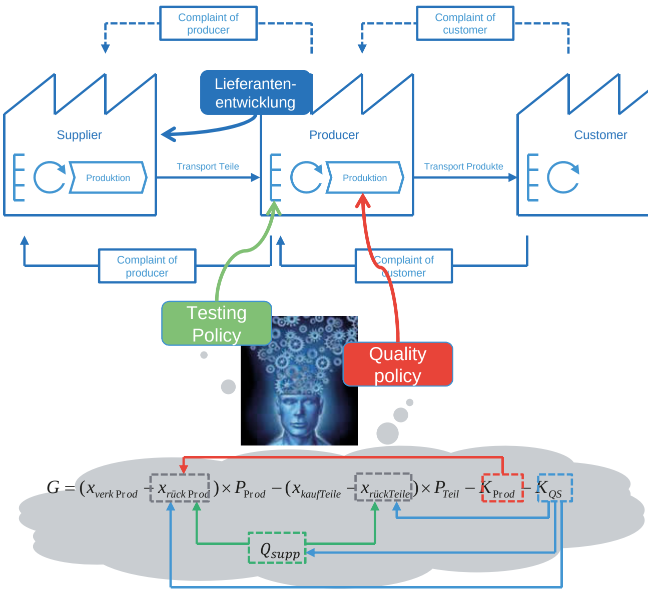
2 Project Status

3 Outlook

Variable parameters in the virtual supply chain scenario



Quality management of Production networks



Research question:

Quality policy of the company

- Investment decisions in the quality level of the manufacturing processes

Testing policy of the company

- Decisions about the "confidence" in the supplier's products

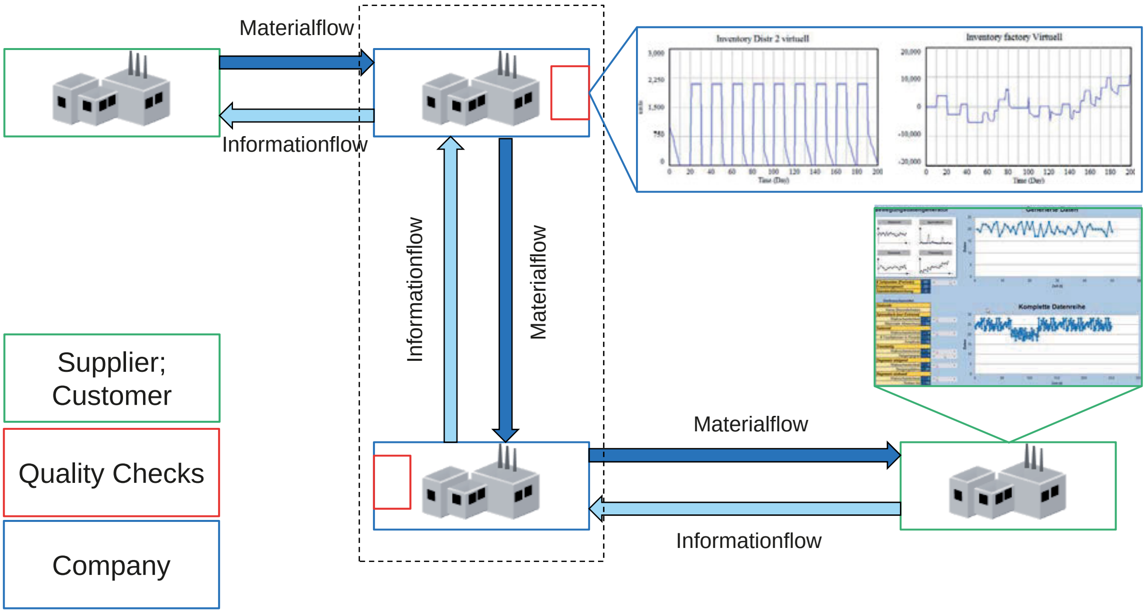
Supplier development

- Decisions on the investment / disinvestment in the development and control of suppliers processes

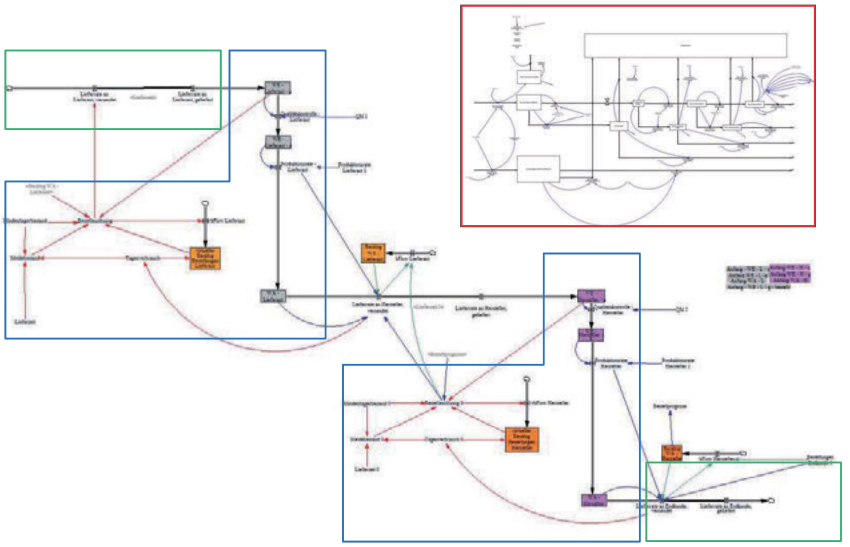
Quality management in supply chains

→ The quality management decisions play a important role in the selection of the disposition process and the suppliers

Structure of the simulation model



Structure of the simulation model



Supplier; Customer

Quality Checks

Company

RWTH AACHEN UNIVERSITY HOUSE OF PRODUCTION

Agenda

1 **Introduction**

2 **Project Status**

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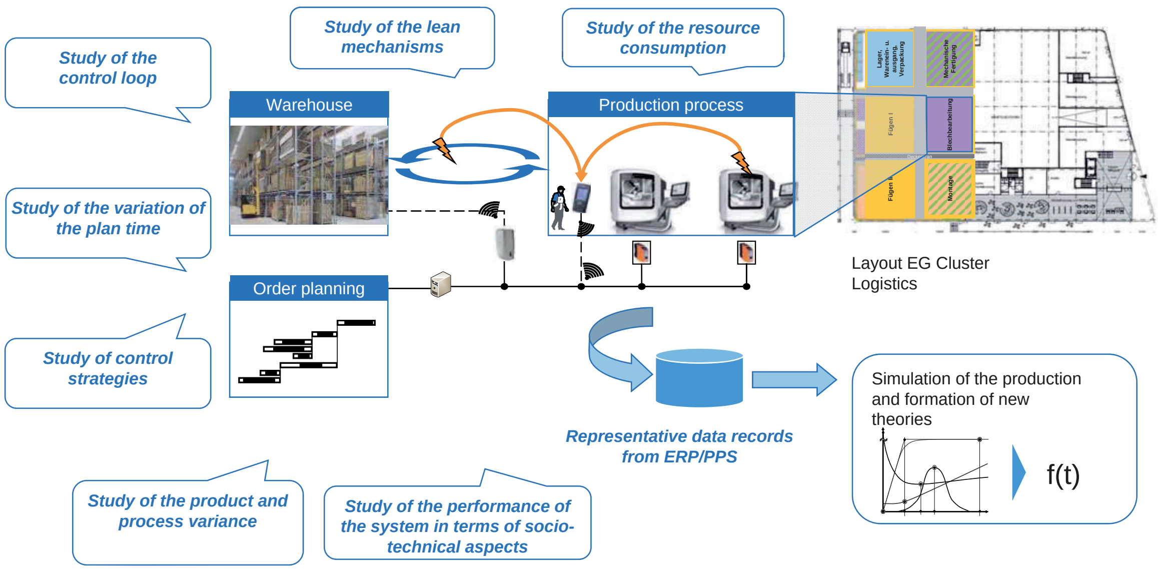
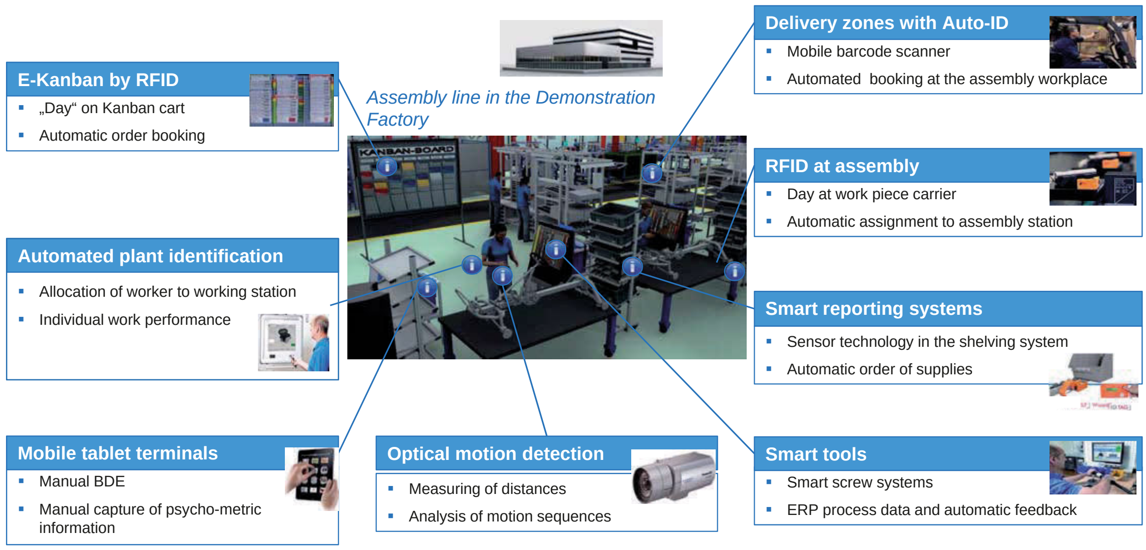
The Demonstration Factory enables an experiment based research as well as education and further education in a real production environment

Generation of product data



Modern information and communication technologies form the basis of a cyber physical production system (CPS)



Additive manufacturing of automatically optimized profile extrusion dies

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Keywords:
Additive Manufacturing, Profile extrusion die, Selective Laser Melting, Surface Finishing

Abstract

The design and manufacture of profile extrusion dies is characterised by costly running-in-trials before the start of production. Significant cost and time savings can be achieved by shifting these running-in-trials on the computer. For this reason, the Chair for Computational Analysis of Technical Systems (CATS) and the Institute of Plastics Processing (IKV) developed in the first phase of the Cluster of Excellence an optimisation framework for the automated optimisation of the flow channel geometry in profile extrusion dies. The simulation-based, virtual optimisation, however, often leads to complex flow channel geometries with free-form surfaces. Therefore, conventional manufacturing techniques are fast approaching their limits and are often not applicable.

Against this background, the manufacturing of profile extrusion dies by Selective Laser Melting (SLM) is studied. The SLM process has the potential to economically manufacture dies with any complexity in short times. A major challenge here is to ensure a sufficient surface quality in the flow channel. The process-related roughness of SLM surfaces does not meet the high demands that are placed on the surface quality of extrusion dies. In a first step, therefore, appropriate strategies for the reworking of flow channel surfaces in SLM tools, that are economically applicable to complex free-form surfaces, will be investigated.

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Additive manufacturing of automatically optimized profile extrusion dies

Cluster-Conferences 2013

Nafi Yesildag, M.Sc.
Insitut für Kunststoffverarbeitung

Aachen, den 23./ 24. September 2013

Outline

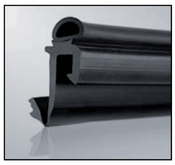
- Introduction and motivation
- Die manufacturing by Selective Laser Melting
- Surface finish and reworking strategies
- Summary and outlook

Derived demands for profile extrusion for individualized production

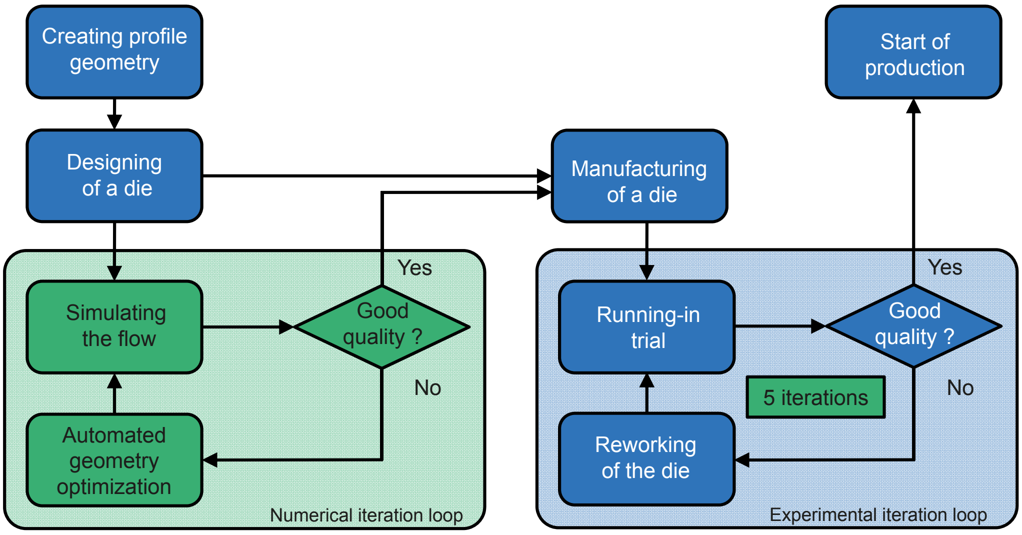
- Extrusion process profitable for mass production
- Growing customer's demand for individual lot sizes
- Fixed costs for die and design become a factor (running-in trials)

➔ Cooperation with the Chair for Computational Analysis of Technical Systems

➔ Partial replacement of running-in-trials with virtual die optimization on the computer

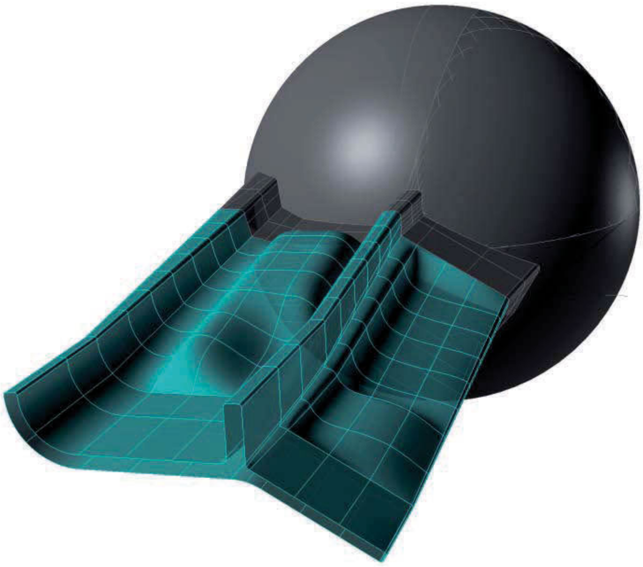


Approach for profile extrusion die design



Conventional approach for profile extrusion die design
Die design using automated shape optimization

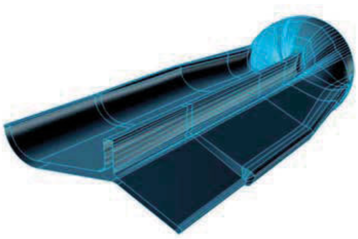
Optimization leads to complex flow channel geometries



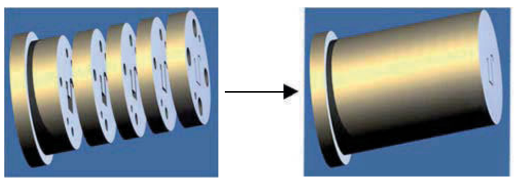
- Numerical optimization often leads to free-form surfaces
- Conventional manufacturing processes often not applicable
- Special manufacturing technologies needed

➢ High potential of additive manufacturing

Advantages of the additive manufacturing of profile extrusion dies

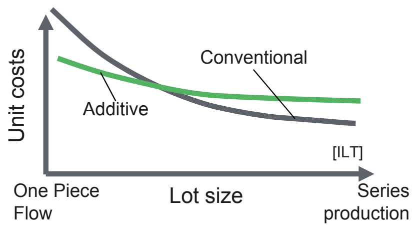


Arbitrarily shaped flow channel geometries possible



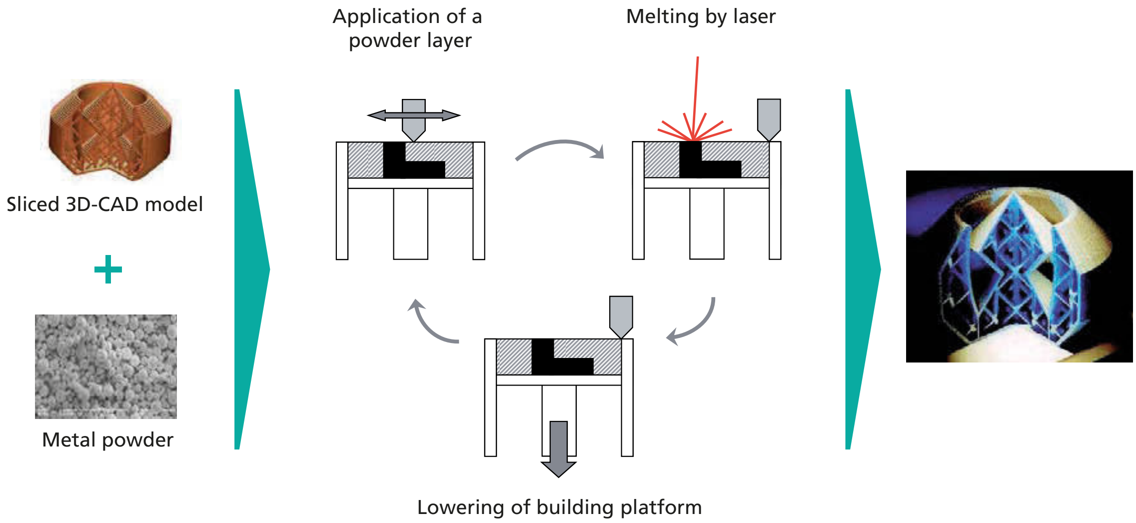
Reduction of the amount of parts

Integration of functions in one process step



Individualised manufacturing with lower costs than conventional processes

Selective Laser Melting (SLM)



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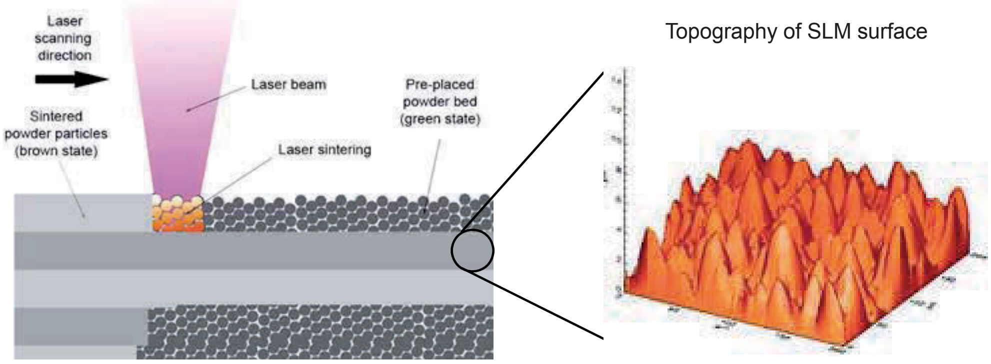
Surface roughness of SLM-dies



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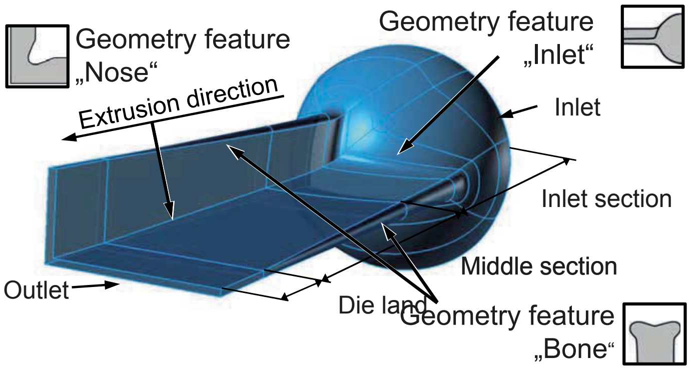
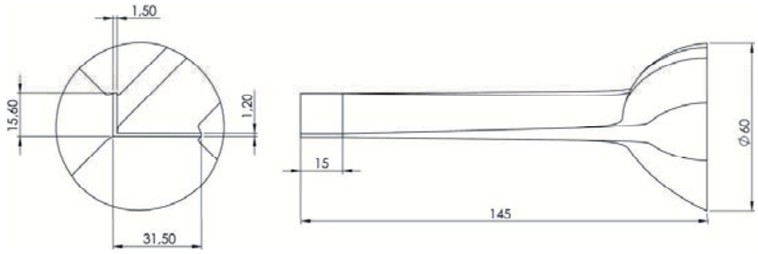
- Roughness of SLM surfaces: Rz ≈ 30 µm
- Required roughness of the flow channel surface: Rz ≤ 1 µm
- Complex flow channel → Conventional methods for surface finishing not applicable

Aim: Surface finishing strategies tailored for flow channels with free-form surfaces

Test Case: Die for the production of a L-profile





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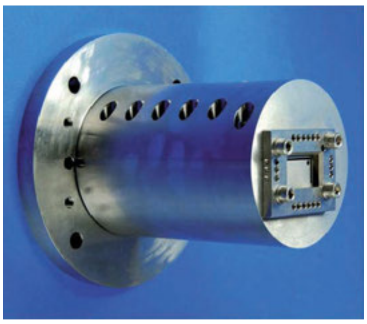
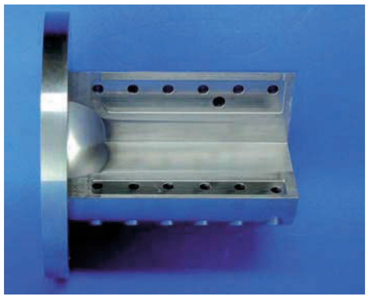
Additive manufacturing of three-quarters of the die

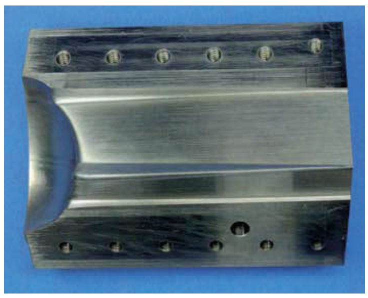


2 samples
4 different cases

SLM

Conventional





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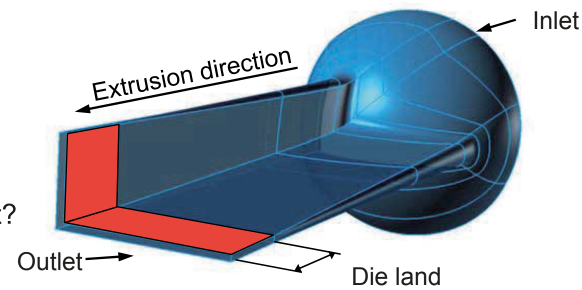
Sample 1: Reworking by milling

Case 1: Untreated die

- Characterization of SLM surfaces
- Reference for the investigated finishing strategies

Case 2: Reworking of the die land by milling

- Die land is critical for shape and surface quality of the extruded profile.
- Is reworking of only the die land sufficient?



Sample 2: Reworking by Micro-Machining Processing (MMP)

Case 3: Reworking of the whole flow channel by MMP

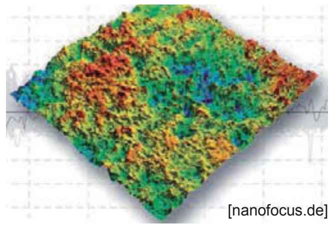
- MMP: mechanical-physical-chemical surface treatment in a closed process chamber
  - → Mechanical: Flow of high-energy particles along the surface
  - → Physical-chemical: Combination of the particles with a catalyst
- Reworking of free-form surfaces possible
- Achievable surface roughness: Rz ≈ 3 - 4 µm

Case 4: Reworking of the whole flow channel by MMP + milling of the die land

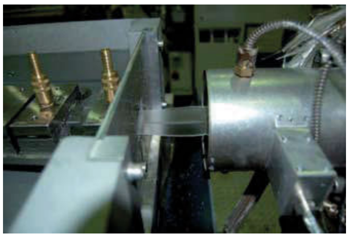
- Combination of the cases 2 and 3

Benchmarking of the surface finish in the different cases

Roughness of the profile surface



Microscopic characterisation of the die and profile surface



Influence on the plant performance and process parameters

Investigation of plate-out in the extrusion die

Summary & Outlook

- Die manufacturing by SLM is investigated.
- Roughness of SLM surfaces is not sufficient for the extrusion process.
- The surface finishing strategy must deliver a sufficient surface finish of the profile and be applicable to free-form surfaces.
- Different surface finishing strategies are tested on a die for the production of a L-profile.

- Topology optimization
- Adaptation of the system peripherals (die tempering)

Thank you for your attention!

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Improvement of Global Footprint Design decisions by the use of an evolutionary algorithm

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Keywords:
Global footprint, globalization, complexity, genetic algorithm

Abstract

Globalization has opened global markets to production industries. Following the markets producing companies started to set up sites all around the globe. The historically emerged production networks have become more and more complex due to the increasing amount of sites, products and customer markets. Nowadays the global footprint design of producing companies is a complex decision situation for managers in charge. The multitude of influencing factors and possible choices combined with the low amount of time available to managers create a major challenge. With the developed IT tool called "OptiWo" the decision maker gets the broad input of needed information in a compact manner. The influencing factors are used as input data to generate a virtual global production footprint. By the use of an evolutionary algorithm the virtual footprint is optimized regarding its total landed costs. With the use of interactive and intuitive visualization, the decision basis supports the decision making process effectively. On this way the decision maker is able to overview the complex decision background in a short amount of time and make better decisions in global footprint design.

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Improvement of Global Footprint Design decisions by the use of an evolutionary algorithm

Cluster-Conferences 2013

OptiWo

Dipl.-Wirt. Ing. Carsten Witthohn

Aachen, den 23./ 24. September 2013

Agenda

1 **Motivation**

2 **Project approach with "OptiWo"**

3 **Conclusion**

Page 1

Agenda

1 **Motivation**

2 **Project approach with "OptiWo"**

3 **Conclusion**

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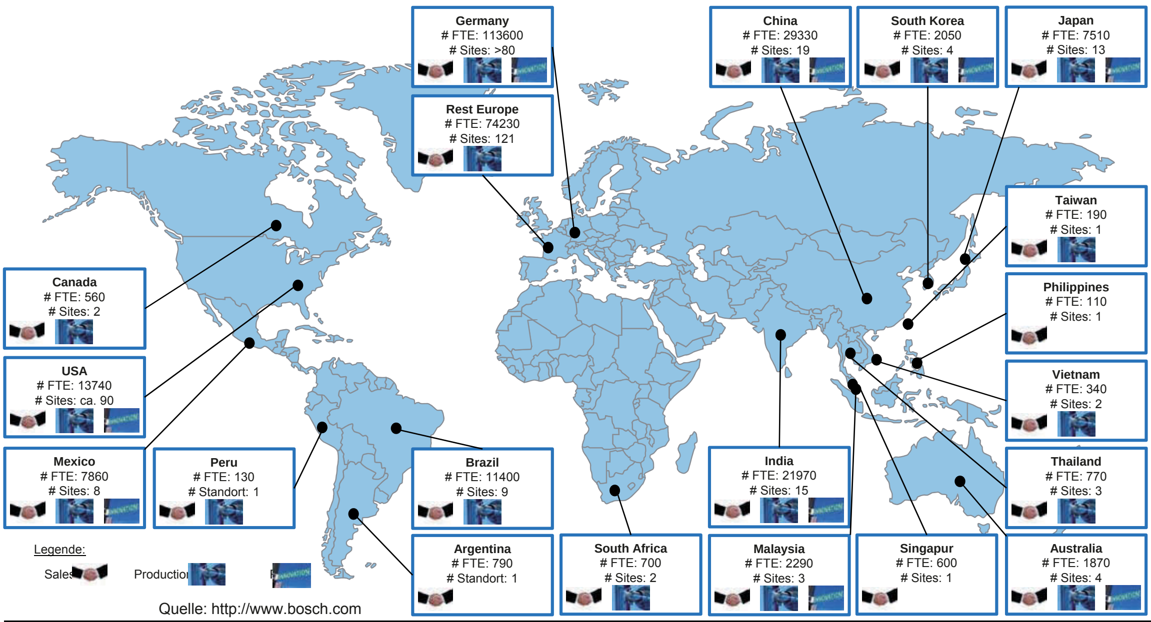
Example global footprint of Bosch: Over 400 sites all over the world

BOSCH



Quelle: http://www.bosch.com

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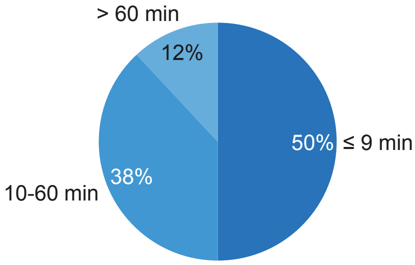
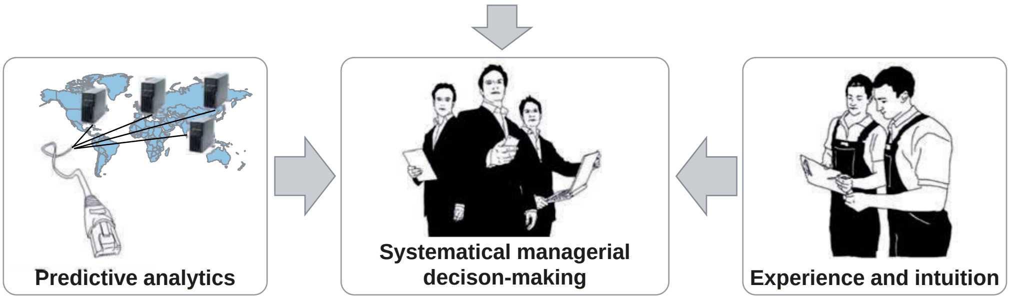
Key challenge in the management of global production networks today

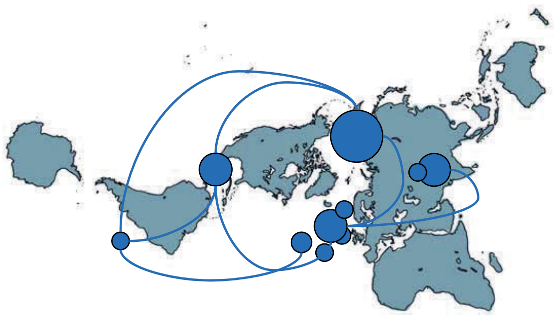
A CEO needs to take about **250 decisions** (Ø140 tasks) per week – more than 50% of these decisions are taken in less than **9 minutes**





Quelle: Iyengar, S., 2012. How to make choosing easier, TED

The complexity of global production networks today can only be handled by using data and creating transparency



$\sim 10^{4700}$

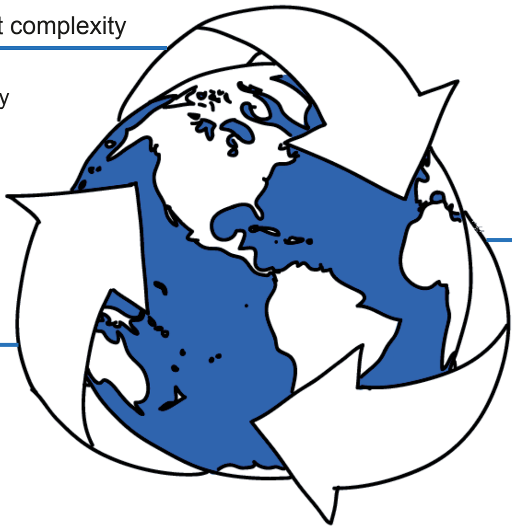
Solution space for this network*
(Comparison: Atoms in our universe ~10^{78})

* Reference: 10 production sites, 188 product groups, 995 available production resource (one business unit of a global manufacturer)

Three criteria should be applied when planning your global footprint design using the green field approach

Assessment of management complexity

- Maximum site size
- Network complexity and variety in sites
- Economies of scale based on the product program



Minimization of costs

- Optimization of the global footprint with an evolutionary algorithm (OptiWo)

Risk assessment

- Redundancies of the global footprint for risk minimization

Quelle:

Agenda

1 Motivation

2 Project approach with "OptiWo"

3 Conclusion

Project approach with “OptiWo“

Build-up of data basis

- Target volumes per product
- Possible production sites
- Resources, processes
- Scenarios (dynamic in volume change)

Modeling of current situation as reference

- Develop trust in the model
- „Calibration“ of the model

Green field planning of global footprint

- Minimal restrictions
- Minimization of costs
- Risk assessment
- Assessment of management complexity

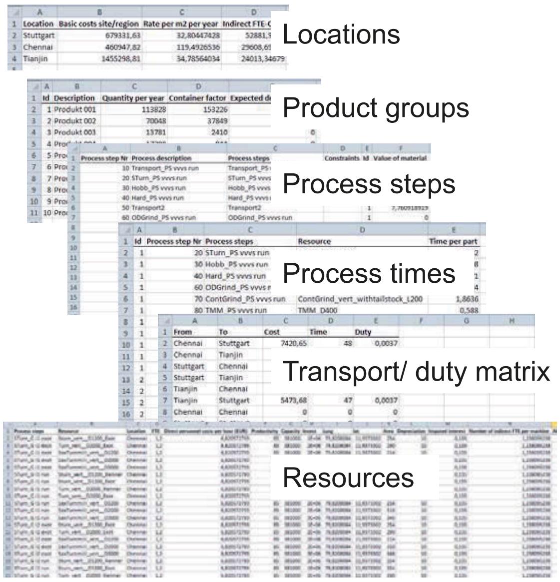
Vision – ideal global footprint

- Assessment of alternative scenarios
- Sensitivity analysis
- Development of a future vision for global footprint

Decision round

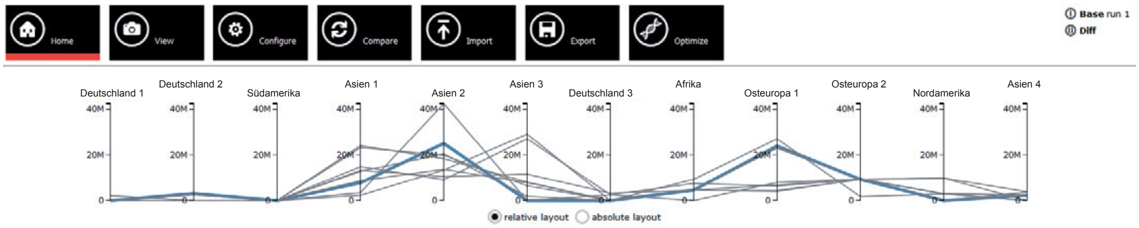
- Derivation of real global footprint to be implemented
- Principles and rules for global footprint design
- Roadmap
- Migration plan

The data integrated into the tool is based on six simple standardized tables



- All possible locations with overhead costs
- Product groups with volumes and transport information
- Alternative process chains and technologies per product
- Transport and customs information between all sites
- Cost information, e.g. labor costs, for all sites
- Material costs per product for each region

Interactive visualization of results
Overview/ Home View



Description	Total cost	Baseline/Diff/Action
run 1	81.421.052,93	Base Diff
run2	83.954.971,42	Base Diff
run3	84.049.557,18	Base Diff
run4	80.038.904,52	Base Diff
run5	82.665.335,73	Base Diff
run6	83.283.053,19	Base Diff
run7	83.607.446,18	Base Diff
run8	81.948.110,64	Base Diff
run9	83.602.672,01	Base Diff
run10	81.421.052,93	Base Diff

Interactive visualization of results
Tree map - visualization of the resource utilization in the network

Tree map - Overview

1. The size of each rectangular area represents the resource capacity (e.g. number of machines) or site area
2. Depending on the resource utilization the color changes from red (low) to green (high)
3. Search for machines or sites is possible and will be highlighted

Tree map -Site View

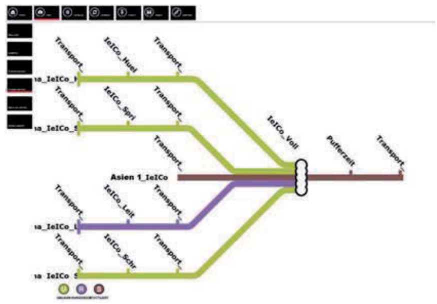
- Large site with high resource utilization
- High number of machines

- Small site with relatively low resource utilization
- Low number of machines

Interactive visualization of results

Detailed Views – Process overview/ Product View

Process overview – Tube map



- The process overview allows to identify the production process of a product
  - The colors reflect locations
  - “stations” suggest process steps
  - “change - stations” show assemblies

Product view

- Product overview shows the products and their distribution to the sites on process step basis to identify
- A resource view to identify the distribution of resources on sites is also available

Quelle:

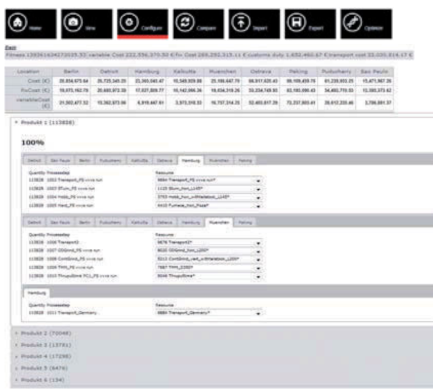
Interactive visualization of results and reconfiguration

Configurator/ Sensitivity Analysis

Sensitivity Analysis

- Allows to determine, how robust the solution is against the variation of specific cost parts
- For example: The influence of a rise of transportation costs on the whole footprint can be calculated

Configurator



- The configurator allows to change the footprint manually
- Optimization can be started again with the new data model

Agenda

1 **Motivation**

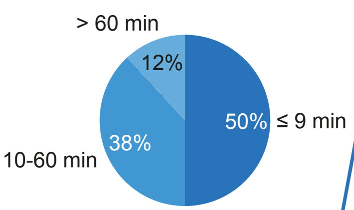
2 **Project approach with "OptiWo"**

3 **Conclusion**

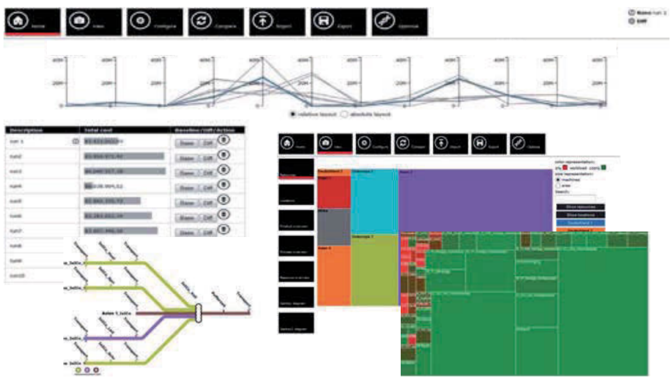
Interactive visualizations help managers in charge to determine complex information efficiently

A CEO needs to take about **250 decisions** (Ø140 tasks) per week

– more than 50% of these decisions are taken in less than **9 minutes**



Interactive Webtools instead of PowerPoint and Excel to support global footprint decisions



Source: * Iyengar, S., 2012. How to make choosing easier, TED

Thank You!

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Machine development for direct, mould-less production systems

Schrage, J.
Biermann, T.

Keywords:
Selective Laser Melting, SLM, Machine

Abstract

In this presentation the approach for the development of a reference architecture for direct, mould-less production systems is described. Typical SLM machines can be divided in three major modules: optical system, the process chamber and the build platform. In this framework a new high productivity machine will be developed that fulfills the following requirements:

- Increase of the laser-on time up to 100%
- Reduction of the auxiliary times
- Scalability of the build volume
- Scalability of the build up rate
- Machine flexibility

The presentation comprises first concepts of a process chamber of a SLM machine with its technical. The process chamber consists of a gas-tight cabinet, a build platform for mounting the substrate plate, linear drives for the powder recoater movement, interfaces for powder feeding and condition sensors. By integrating two scanning systems in this process chamber an extended scan field size of 200 mm x 400 mm can be realized that allows for new process strategies. Due to parallelization of two scan processes an enormous increase of the build up speed is possible. Or else by overlapping both scan fields new scan strategies like double beam processing is possible. To conclude the presentation the results of the technical evaluation of the process chamber concepts and the design of the winning concept are shown.

Machine development for direct, mould-less production systems

Cluster-Conferences 2013

Fraunhofer Institute for Laser Technology ILT
Chair for Laser Technology LLT
Dipl.-Ing. Johannes Schrage
Dipl.-Ing. Tim Biermann

ICD A2

Aachen, 24th September 2013

AGENDA

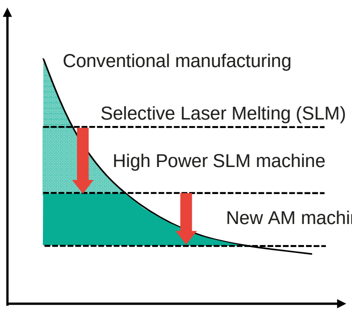
1 Motivation and introduction

2 Methodology for technical and economical evaluation

3 SLM machine concepts

4 Summary and outlook

Motivation and introduction
Increase in productivity by new AM machines



Concept Laser X line 1000R

SLM Solutions SLM 500 HL

- Increase of laser power
  - Laser power up to 1 kW
  - Increase of laser beam diameter
  - Skin-Core principle
- Increase of build chamber
  - V = 630 x 400 x 500 mm^3
  - Parallelization of machine set-up by a changeable chamber
- Parallelization of SLM processes
  - Usage of multiple laser sources
  - Two scan fields

No consistend tendency of development of SLM machine technology

Source: Concept Laser GmbH, SLM Solutions GmbH

AGENDA

1 Motivation and introduction

2 Methodology for technical and economical evaluation

3 SLM machine concepts

4 Summary and outlook

Methodology for technical and economical evaluation
Functional machine structure

- Modularisation of SLM Machinery
  - Powder management
  - Energy management
  - Process management
  - …
- Development of concepts for each module
- Evaluation of the concepts
  - Technical Evaluation
  - Economical Evaluation
- Design and Construction
- Process Development

1. Functional machine structure model
2. Definition of reference process
3. Modelling of performance contributions on component level
4. Identification of performance drivers on component level
5. Identification of optimization measures of SLM machines

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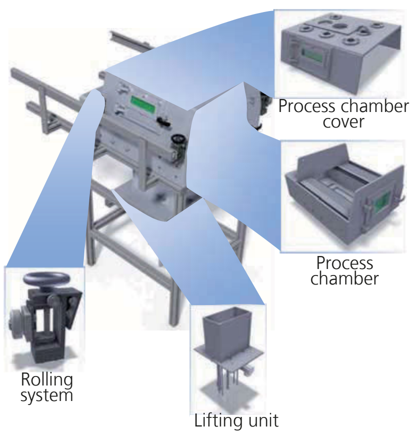
Methodology for technical and economical evaluation
Functional machine structure



- SLM machine
  - Process chamber
    - Build platform
    - Lifting unit
    - …
  - Optical system
    - Laser
    - Scanner
    - …
  - Gas management
    - Circulation pump
    - Filter system
    - …

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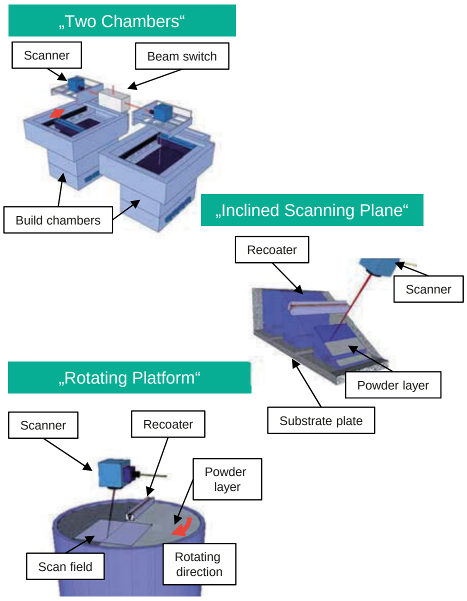
Methodology for technical and economical evaluation
Functional machine structure



SLM machine

- Process chamber
  - Build platform
  - Lifting unit
  - …
- Optical system
  - Laser
  - Scanner
  - …
- Gas management
  - Circulation pump
  - Filter system
  - …

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Methodology for technical and economical evaluation
Definition of a reference process

Machine preparation
- Cleaning of process chamber (e. g. after material change)
- Change of gas filters

Pre-processing
- Preparation of CAD data
- Mounting of substrate plate
- Starting gas flow
- Heating of the build platform
- Set-up of „Layer 0“

SLM process
- Powder delivery into the recoating unit
- Deposition of powder layer n
- Processing of powder layer n
- Lowering the build platform
- Return of recoating unit

Post-processing
- Cool-down of build platform
- Deflating the shielding gas atmosphere
- Removal of powder material
- Removal of build part

- The SLM machine occupancy time is represented by a reference process
- Subdivision of the temporal sections in value-adding and non-value-adding time shares

Following VDI 3423: Verfügbarkeit von Maschinen und Anlagen

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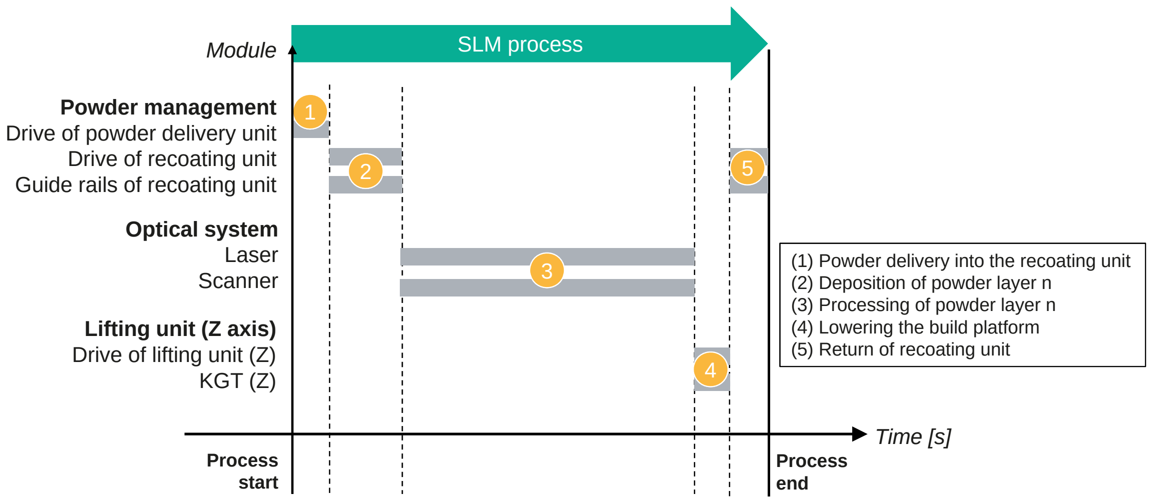
Methodology for technical and economical evaluation
Definition of a reference process



Methodology for technical and economical evaluation
Identification of performance drivers

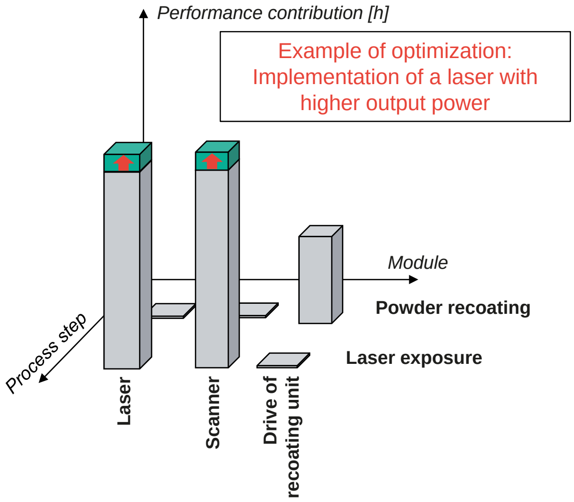
Technische Parameter	Maschinenkonfiguration a	
Bauraumvolumen	250x250x300	mm³
Anzahl der Bauraummodule	1	
Bauraummodul mobil (ja/nein)	nein	
Laserstrahlquelle	IPG SM Faserlaser	
Laserleistung (max.)	1000	W
Laserstrahldurchmesser	100	µm
Scanfeldabmessung	250 x 250	mm²
Anzahl Laserstrahlquellen	1	
Anzahl Scanfelder	1	
Anzahl der Hubantriebssysteme	1	
Heizleistung der Bauplattformheizung	5	kW
Schleifwelle (ja/nein)	nein	
Positionssensorik für Schicht-0-Erkennung (ja/nein)	nein	

Technische Parameter		Bearbeitungsaufgabe a	
Anzahl der Schichten		5000	Schichten/Bauprozess
Belichtungszeit		180	s/Schicht
Beschichtungszeit		35	s/Schicht
Anteil der Komponenten an Beschichtungszeit	Achse Pulverförderung	4	s
	Achse PAE	30	s
	Achse Hubeinheit	1	s
	Pulverabstreifelement	30	s
	Schutzgaspumpe	35	s
Anteil der Komponenten an Belichtungszeit	Laser	180	s
	Scanner	180	s
	Schutzgaspumpe	180	s
Standzeit Pulverabstreiferelement		10000	Schichten
Dauer Rüstprozess (manuell)		2	h
Dauer Rüstprozess (automatisiert)		0,5	h
Losgröße		15	Einheiten
Einheiten pro Bauprozess		3	Einheiten / Bauprozess
Pulverwerkstoff		AlSi10Mg	
Kornfraktion des Pulverwerkstoffs		25 – 56	µm
Bauteilvolumen pro Einheit		1000	cm³
Bauteilgewicht pro Einheit		2,7	kg
Supportvolumen pro EInheit		120	cm³

Following VDI 2885:
Einheitliche Daten für die Instandhaltungsplanung und Ermittlung von Instandhaltungskosten

Methodology for technical and economical evaluation
Identification of performance drivers

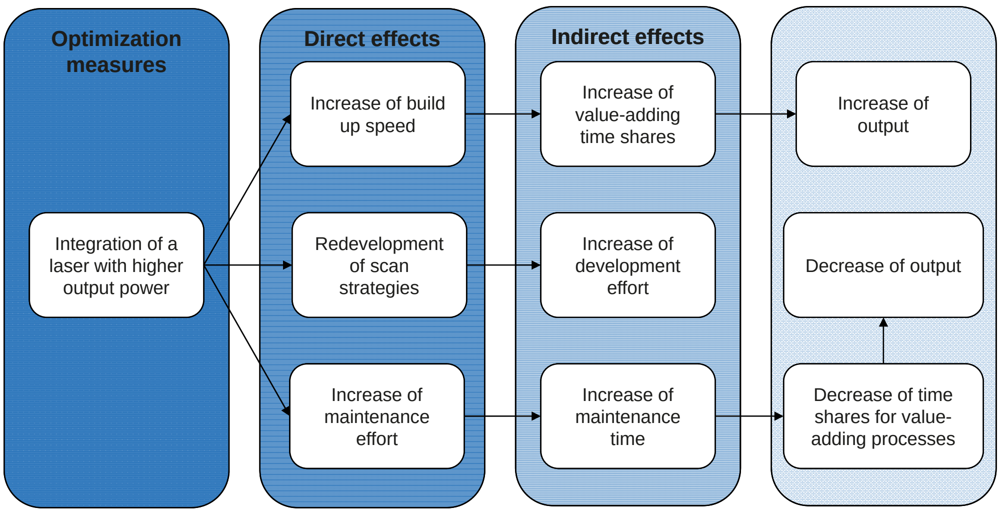
Performance contribution



- Assignment of each SLM machine component to the performance contribution
- Visualization of value-adding and non-value-adding process steps
- Sensitivity analysis for identification of optimization measures

Following DIN EN 60300-3-3: Anwendungsleitfaden - Lebenszykluskosten

Methodology for technical and economical evaluation
Identification of optimization measures of SLM machines



AGENDA

1	Motivation and introduction
2	Methodology for technical and economical evaluation
3	SLM machine concepts
4	Summary and outlook

SLM machine concepts
Objectives of new machine concept

List of requirements

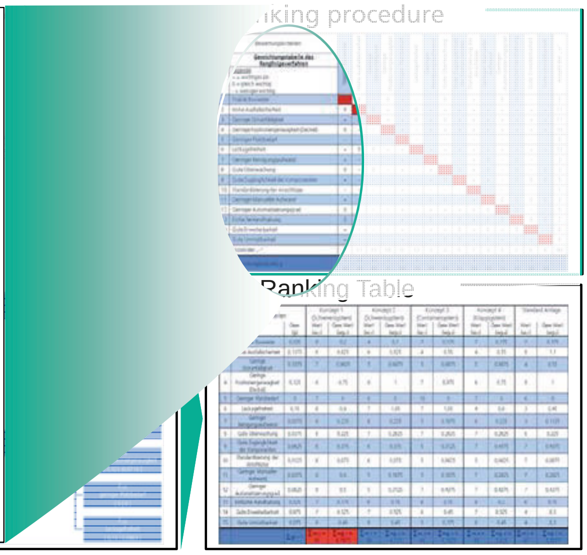
Fraunhofer Institut für Lasertechnik	Anforderungsliste für eine SLM-Anlage		Prozess-kammer
Änder.	**F/W**	**Anforderung**	**Verantw.**
		Stoff	
	F	1. Temperaturbeständige Ausführung der Komponenten bis max. 150°C	
	W	2. Automatische Übergabe des Restpulver an Pulvermanagement	
	F	3. Prozesskammer vollständig inertisierbar bis 100 ppm	
	F	4. Kontakt von Pulver mit bewegten Bauteilen vermeiden	
	W	5. Einkoppelfenster aus Vollquarz	
		Energie	
	F	1. Einkopplung der Laserstrahlung ermöglichen	
	F	2. Einstellung des Arbeitsdrucks ermöglichen (max. 140 mbar)	
		Signal	
	F	1. Sauerstoffgehalt der Atmosphäre (in der Gassammelleitung) ($O_{2,ist}$ und $O_{2,soll}$)	
	F	1. Temperatur der Substratplatte, der Prozesskammer und des Schutzgas (T_{SUBP}, T_{SG} und T_{PK})	
	F	2. Absolutposition der Substratplatte ($z_{B,ist}$ und $z_{B,soll}$)	
	F	1. Strömungsgeschwindigkeit des Schutzgases/Volumenstrom (v_{SG})	
	F	2. Geschwindigkeit der Pulverauftragseinheit (v_{PAE})	
	F	1. Position der Pulverauftragseinheit ($\bar{x}_{P,ist}$ und $\bar{x}_{P,soll}$) …	

- 100% laser-on time
  - Optimum utilization of laser beam sources
- Minimum auxiliary times
  - In process: powder deposition, powder delivery
  - Before process: mounting of substrate plate, preheating, set-up of process gas atmosphere
  - After process: dismounting of substrate plate, cool down, removal of powder
- Flexibility of the machine structure
  - Scalability of build up rate
  - Scalability of build volume

SLM machine concepts
Evaluation of SLM machine concepts

- Utility analysis
  - Comparisor criterions →
  - Scoring of t criterions
  - Identificatio concept witl multiplicatio factor with t

- High robustness
- High reliability
- High positioning accuracy
- Low space requirement
- Low gas leakage
- Low cleaning effort
- High monitoring possibilities
- High accessibility of components
- High degree of standardization of interfaces
- Low manual effort
- High degree of automation

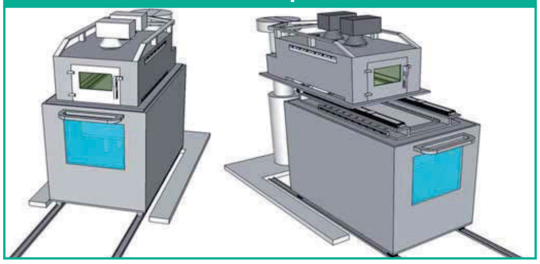


SLM machine concepts
Concepts of the SLM process chamber

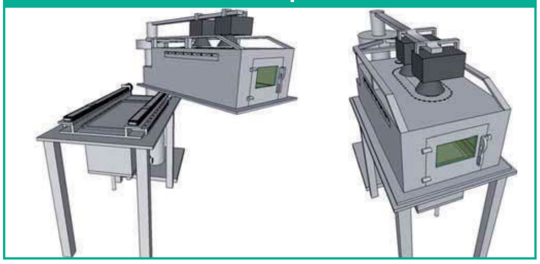
Concept 1

Concept 2

Concept 3

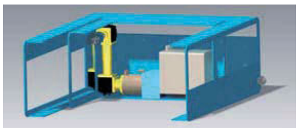


Concept 4

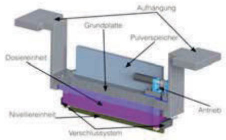


SLM machine concepts
Concept of the SLM machine

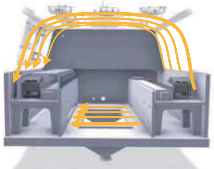
Optical system



Recoating unit



Process gas flow



SLM machine

Main facts

- Build volume
  - 400 mm x 200 mm x 300 mm
- Optical system
  - 2 lasers and 2 scan systems for parallel processing
- Recoating unit
  - powder delivery in both directions
- Process gas flow
  - Flow optimized design of process chamber and recoating unit

AGENDA

1	Motivation and introduction
2	Methodology for technical and economical evaluation
3	SLM machine concepts
4	Summary and outlook

Summary and outlook

Modularisation of SLM Machinery

Powder management | Energy management

Process management | …

Development of concepts for each module

Evaluation of the concepts

Technical Evaluation | Economical Evaluation

Design and Construction

Process Development

- Development of SLM process chamber completed
- Development of further machine modules like powder delivery unit, shielding gas management and optical system are in progress

Summary and outlook

Modularisation of SLM Machinery

Powder management | Energy management

Process management | …

Development of concepts for each module

Evaluation of the concepts

Technical Evaluation | Economical Evaluation

Design and Construction

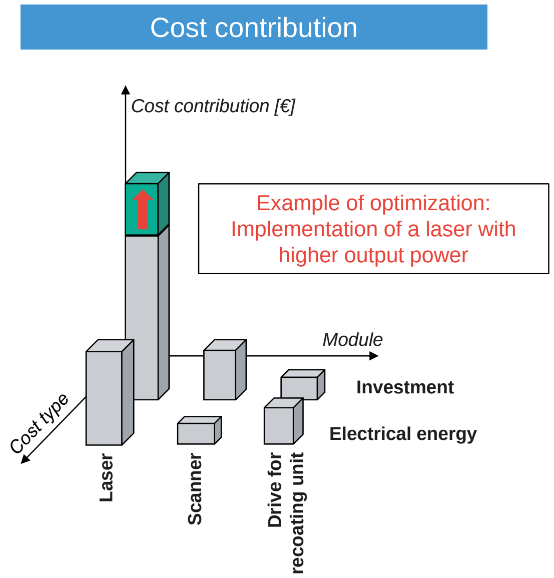
Process Development

Product life cycle (PLC)

Product planning | Design and developme nt | Productio n | Distributio n | Utilization | Disposal

- Economical evaluation of machine concepts by means of life cycle costing
- Development of life cycle cost models
- Investment costs
  - Production costs, development costs, procurement costs, …
- Costs in utilization phase
  - Maintencance costs, energy costs, tooling costs, …

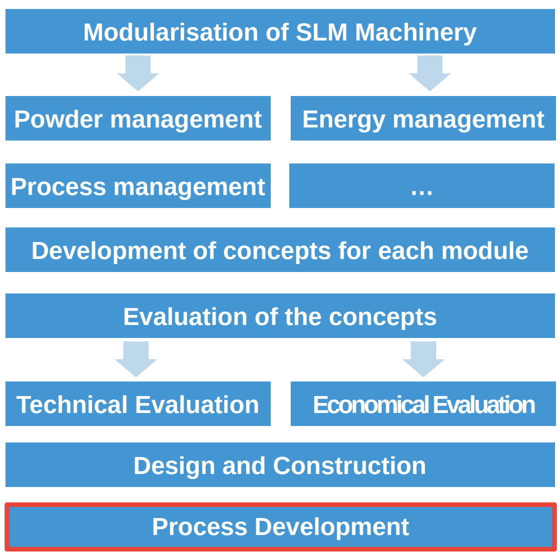
Summary and outlook



- Assignment of each SLM machine component to the performance contribution
- Visualization of value-adding and non-value-adding process steps
- Sensitivity analysis for identification of optimization measures

Following DIN EN 60300-3-3: Anwendungsleitfaden - Lebenszykluskosten

Summary and outlook



- Process development
  - Multi-scanner system
  - Multi-beam process
- Reduction of auxiliary times
  - New process strategies
- Automated process start
- Investigation of process gas flow

Thank you for your attention!

Any questions

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Adaptive Sequence Planning for Production Networks

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Keywords:
adaptive manufacturing planning, production networks

Abstract

The manufacturing industry faces a pressure to innovate. The increasing competition from low-wage and emerging economies as well as changing market requirements towards shorter product life cycles and individualized products necessitate more flexible and adaptive production processes [BRE2007,KAG2012].

One possible approach is to automate process planning. As a result, production facilities could autonomously adapt to new products or changes within the facility. Additionally, production processes could be continuously optimized towards changing goal systems. In this talk we therefore present an approach for an autonomous planning and control system for future manufacturing facilities.

To allow for flexible processes, such future manufacturing facilities are organized as *production networks*: Here, modular *manufacturing units (MU)* provide self-contained *manufacturing services*. To facilitate flexible flow of materials, the facility must provide complete interconnectivity as well as interoperability between the MUs.

In such a setup, a user does provide a declarative description of the desired product. By using this formalized description the system autonomously derives all feasible manufacturing sequences. During the actual production the planning system calculates the optimal manufacturing sequence given the available manufacturing services and the current state. In case of unplanned changes or new orders, the system triggers an update of the plan and adapts the production plan to these changes.

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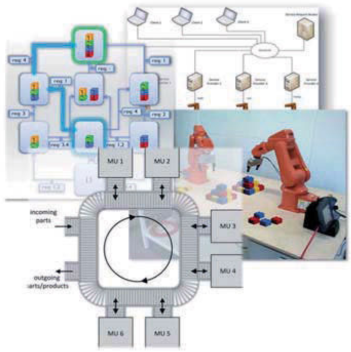

Adaptive Manufacturing Planning for Production Networks

Daniel Ewert

Institute of Information Management in Mechanical Engineering

Aachen, 23rd/ 24th september 2013

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Outline

- Motivation: trends in production
- Adaptive manufacturing planning
  - Automatic generation of manufacturing instructions
  - Adaptive optimal manufacturing by continuous replanning
- Applicability and limitations
- Summary & Outlook

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Motivation – trends in production

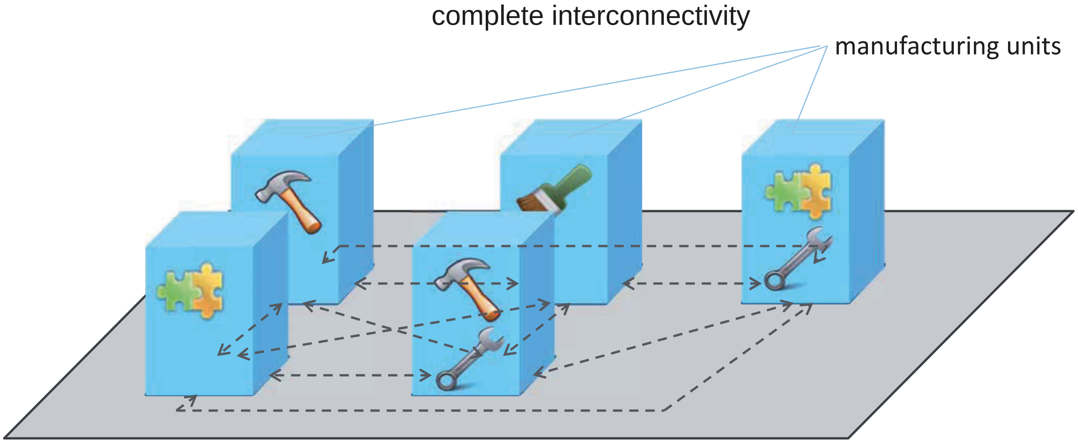
- Industrial production, state of the art:
  - economies of scale
  - expensive ramp-up
  - production lines build for single products
- Problem:
  - increasing competition from low-wage and emerging economies
  - Trend towards shorter product life cycles
  - Demand for individualized, variant-rich products

→ Demand for adaptive and flexible manufacturing systems

Approach: automate process planning
- Provide generic production facilities
- Only define what to do, not how
- Production system plans and executes manufacturing autonomously

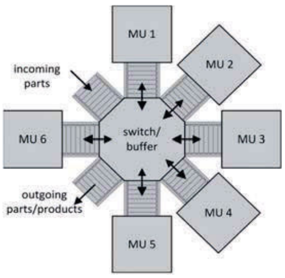
Prerequisite: Production Networks - Flexible Manufacturing Systems

- Production facility of modular *manufacturing units (MU)*
- MU provide one or more generic *manufacturing service*
- Prerequisite for flexible processes: complete interconnectivity

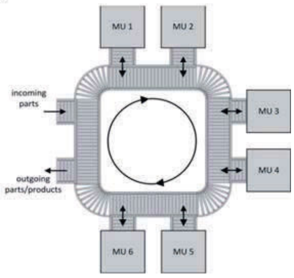


Production Networks – possible implementations

Conveyor belt based



hub based transportation



Circular transportation

Autonomous transport vehicle based

KARIS- Kleinskaliges Autonomes Redundantes Intralogistik System (KIT)

MultiShuttle Move® - Cellular Transport Systems (Frauenhofer IML)

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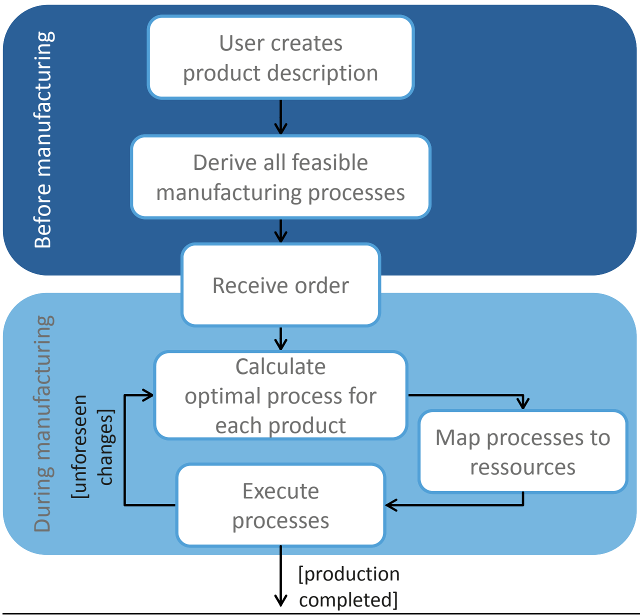
Adaptive Manufacturing Planning – general process



- Hybrid strategy
  - Precalculate computationally expensive tasks
  - Allows fast decision making during manufacturing
- Assignment to executing hardware only during manufacturing
  - →machine indepency
  - →improved reusability and scalability

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Adaptive Manufacturing Planning – comprehensive model

Manufacturing Domain
- concepts & terminology
- parts specification

Product
- list of parts
- features: obtained properties & relations for each part
- dependencies between features
  - restricts sequence
  - optional time slot

Service
- capability: producible features
- applicability: requirements for handled parts
- usage:
- com. protocol
- parametrization

- Manufacturing Domain
  - Ontology based
  - Examples: MASON, AVILUS, ADACOR
- Product: declarative description of desired product
- Service: description of realizable manufacturing step
- Goal: Separation of task and execution
  → Define goal instead of process

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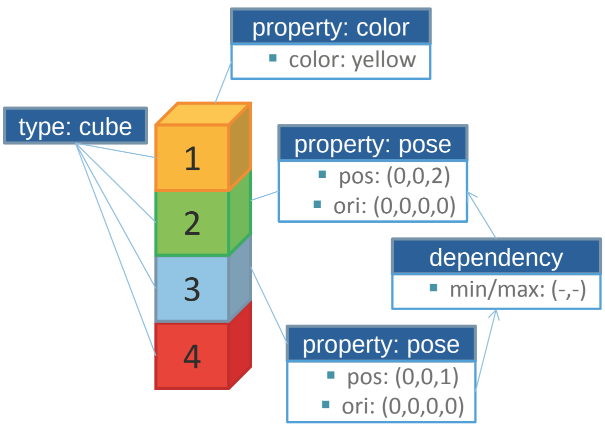
Adaptive Manufacturing Planning – examples

- Toy model product



- assembly service (simplyfied)
- Capability:
  pose
- Applicability:
  - object size < 15cm
  - object weight < 1 Kg
- Usage:
  - IP: 137.226.188.123
  - Protocol: plain text
  - Command: move
    - param1: “$object”
    - param2: “$x,$y,$z”

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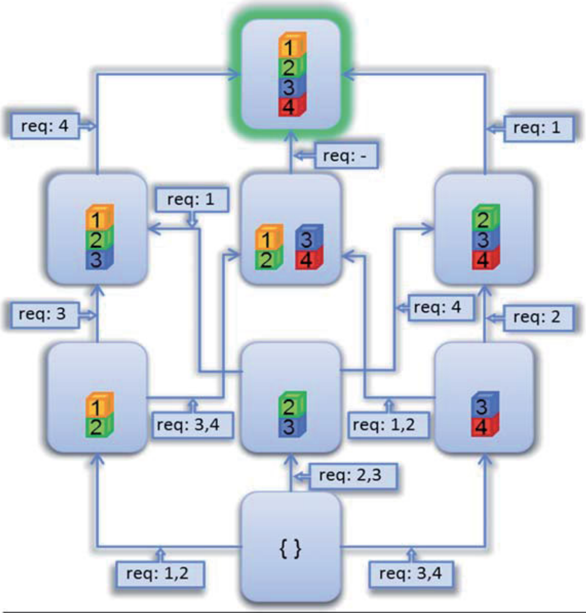
Adaptive Manufacturing Planning – process derivation



- Recursively construct state graph from product description
  - "Deconstruct" product description by removing one unrestricted feature
  - Remove parts with no features left
  - Continue until completely removed.
- Result: State graph
  - **Holds all feasible manufacturing sequences for given product**
  - Nodes: State of the product
  - Edge:
    - Transforming manufacturing step
    - Required additional parts/materiel
    - costs of execution

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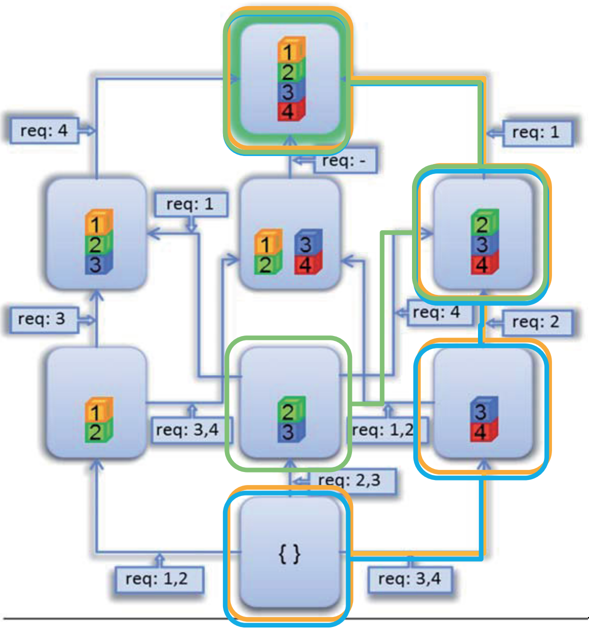
Adaptive Manufacturing Planning – online planning & control



- Task:
  Find manufacturing process for each product, so that resource utilization and throughput is maximized
  - avoid resource conflicts
  - optimize for given goal system
- Subtasks:
  - Identify suitable manufacturing resource for given manufacturing step
  - Calculate individual manufacturing process for each product

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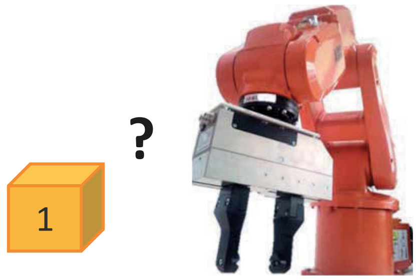
Adaptive Manufacturing Planning – resource identification



- Prolog-based knowledgebase
  - parts specification as fact base
  - service applicability as logical rule
- Returns suitable service for given part and feature

Manufacturing Domain

```
%%% Type data %%%%%%%%%%%%%%%%%%
cube('b1').
...

%%% object data %%%%%%%%%%%%%%%%
cube('b1', 1.0, 1.0).
...

%%% data accessors %%%%%%%%%%%%%
has_size(X, Y) :- block(X, Y, _).
has_weight(X, Y) :- block(X, _, Y).
```

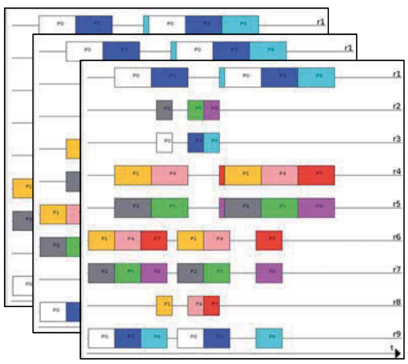
Service desc.

```
%%% service desc. rules %%%%%%%

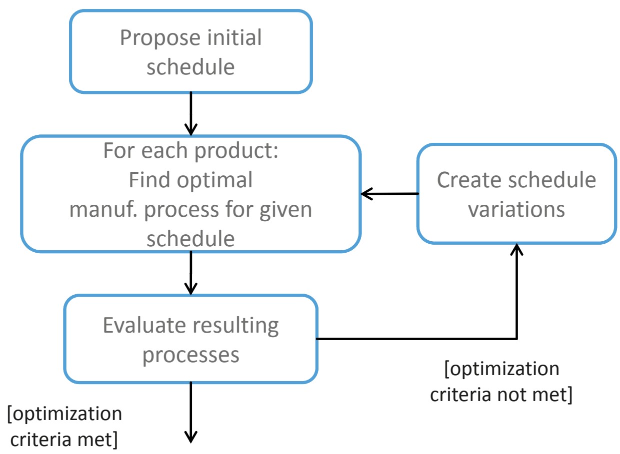
realizes_pose(assemblyservice_1, X)
    :- has_weight(X,Y), Y < 4.0,
   has_size(X,Z), Z < 1.5.

...
```

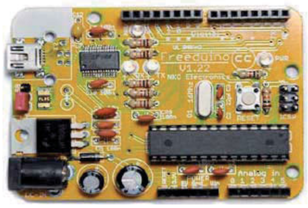

Adaptive Manufacturing Planning – calculation of optimal processes



- Evolutionary Approach
  - Assign products to service time slots → schedule
  - Optimize schedule using evolutionary algorithm

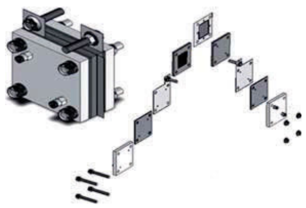


Applicability & Limitations



Freeduino microcontroller board

Parts: 42
Graph
- Nodes: $4.3*10^{13}$
- Edges: $9.2*10^{17}$



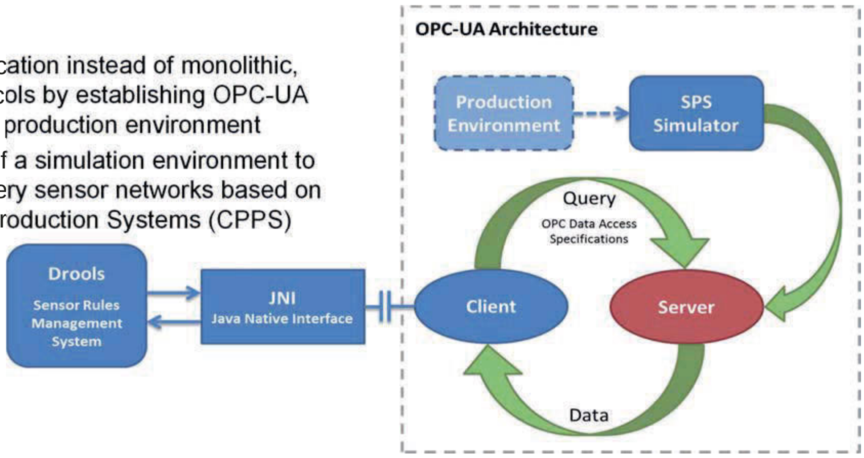
fuell cell (simplified)

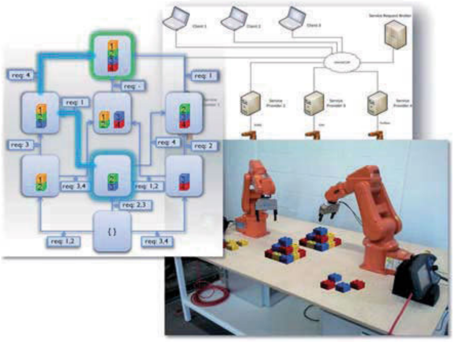
Parts: 17
Graph
- Nodes: 31
- Edges: 49

- Products
  - Computational complexity depending on number of parts and dependencies
  - Products must allow variation but not complete arbitrary manufacture
- Production techniques
  - must be discrete
  - must be reliably reproducible
  - manufacturing steps should not influence each other

Summary & Outlook

- Summary
  - Adaptive and optimal production due to continuous process replanning
  - In depth planning prior to assembly and fast decision derivation during assembly
  - Machine independent task description
- Outlook
  - Unified communication instead of monolithic, proprietary protocols by establishing OPC-UA standards for the production environment
  - Implementation of a simulation environment to integrate machinery sensor networks based on Cyber Physical Production Systems (CPPS)





Thank you!

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Scalability of the mechanical properties of SLM produced micro struts

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Merkt, S.

Hammer, C.

Hinke, C.

Prahl, U.

Bleck, W.

Abstract

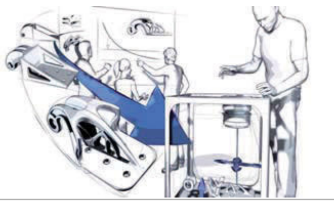
Selective Laser Melting (SLM) is a manufacturing process that builds up metallic parts layer by layer directly from 3D-CAD data with almost no restrictions to geometric complexity.

One of the main challenges of the SLM process is to improve its efficiency by increasing the build rate and thereby decreasing time and cost.

One way is to increase laser power and beam diameter to melt more volume in a shorter time. The other way is to reduce the volume that has to be melted.

The volume can be reduced due to the limitless geometric freedom offered by the SLM process. With the SLM process it is possible to generate hollow parts for better exploitation and adaption of the volume to specific load cases. Large volumes can be replaced by lattice structures with a certain volume fraction, saving weight and production time by maintaining the stiffness of the structure. To ensure, that the mechanical properties of the new light weight structures are comparable to the properties of solid base material, several different lattice structures have already been investigated, all consisting of numberless little struts.

Little struts are built in various formats to investigate the scalability of the mechanical properties. The results are shown in this presentation and can be used for better prediction of the mechanical properties of lattice structures manufactured by SLM.



Scalability of the mechanical properties of SLM produced micro struts

Cluster-Conferences 2013

Jan Bültmann

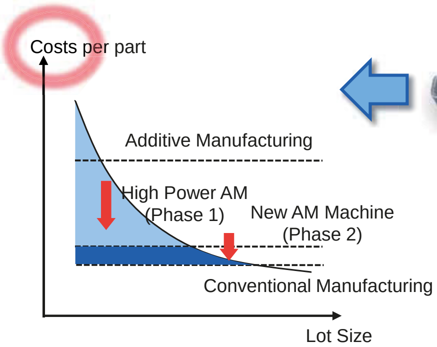
Simon Merkt, Christine Hammer, Christian Hinke,
Ulrich Prahl, Wolfgang Bleck

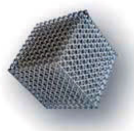
Aachen, den 23./ 24. September 2013

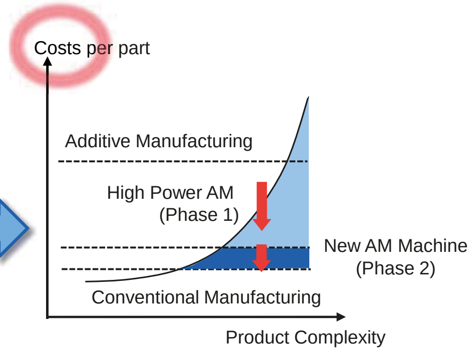
Agenda

- Introduction
- Motivation
- Lattice Structures
- Surface Quality
- Experimental Setup
- Scalabilty of the mechanical Properties
  - Diameter
  - Surface
  - Number
  - Angle
- Summary
- Conclusion
- Next Steps

Introduction







Individualization for free

Complexity for free

Motivation

Costs depend on processing time

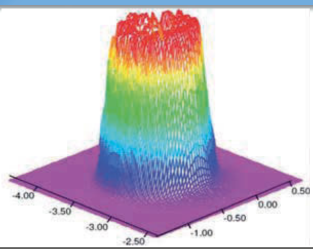
Processing time depends on the generated volume

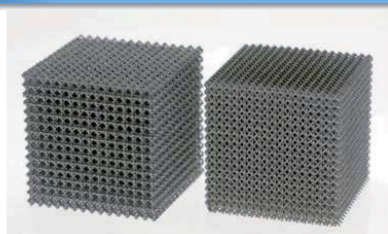
Way 1: Increasing the laser power

Way 2: Reducing the volume

High Power Selective Laser Melting

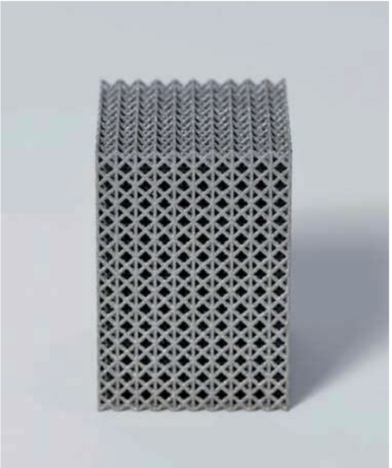
Lattice Structures



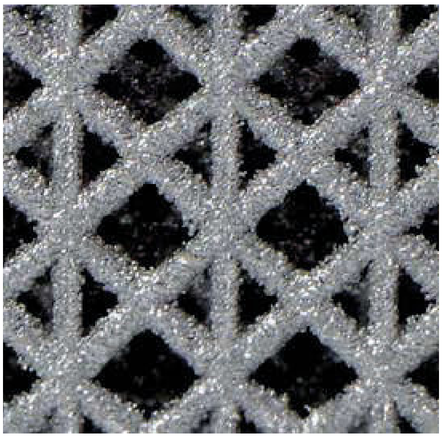


Lattice structures

Lattice Structure

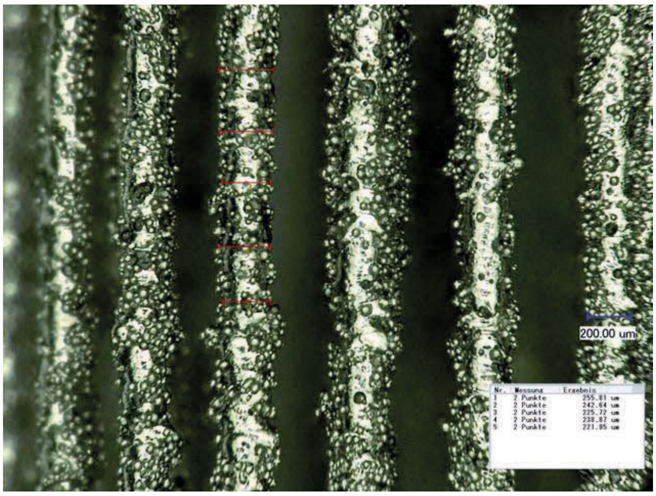


Thousands of little Struts



Surface Quality

Thousands of little powder particles



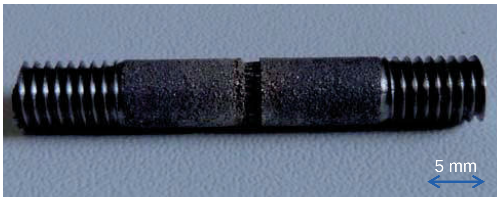
Roughness

- Ra = 10 µm
- Rz = 60 µm
- Strut Diameter 200 to 700 µm

- Hypothesis:
  Small struts have a lower Ultimate Tensile Strength and Uniform Elongation due to the increasing impact of surface roughness and defects.

Experimental Setup

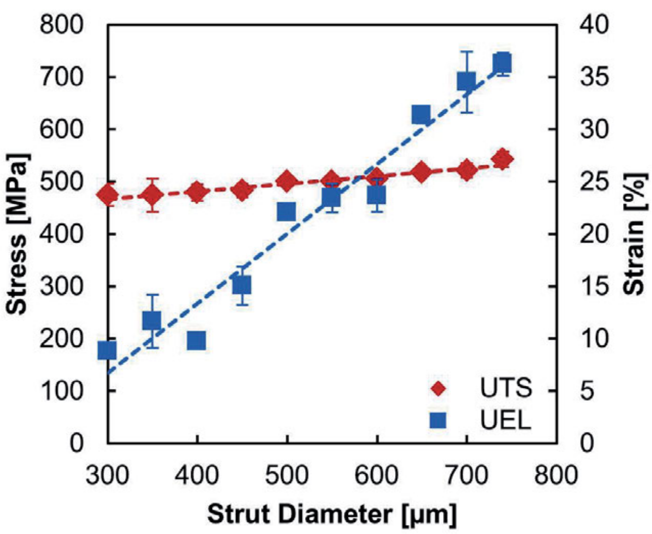
Geometry

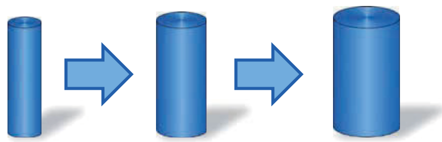


Parameters

- Material: 1.4404 / 316 L / X2CrNiMo17-12-2
- Laser power: 195 W
- Scanning velocity: 900 mm/s
- Layer thickness: 30 µm
- Focus diameter: 80 µm
- Scan line spacing: 50 µm
- Scan line rotation: 90°

Different Diameter

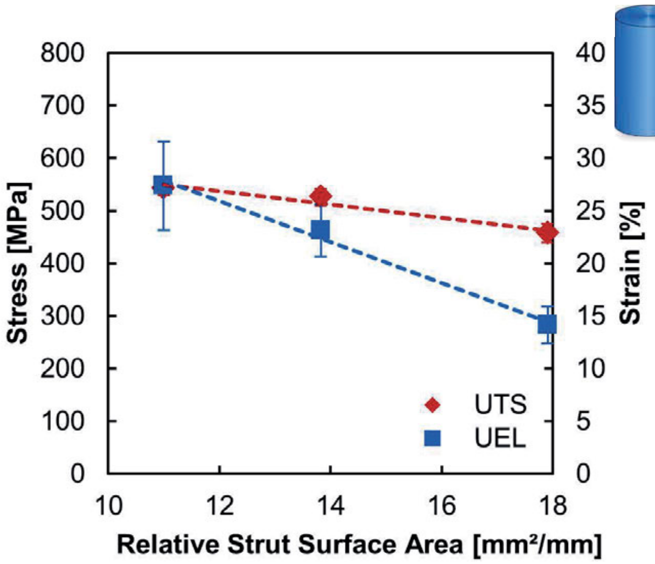


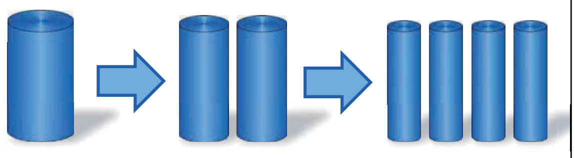


Strut diameter has almost no influence on the Ultimate Tensile Strength.

The Uniform Elongation is decreasing with the decreasing strut diameter, because the ratio of surface area to volume is increasing and the chance for an inhomogeneity that will lead to an early necking is increasing, too.

Constant Volume, Different Surface Area

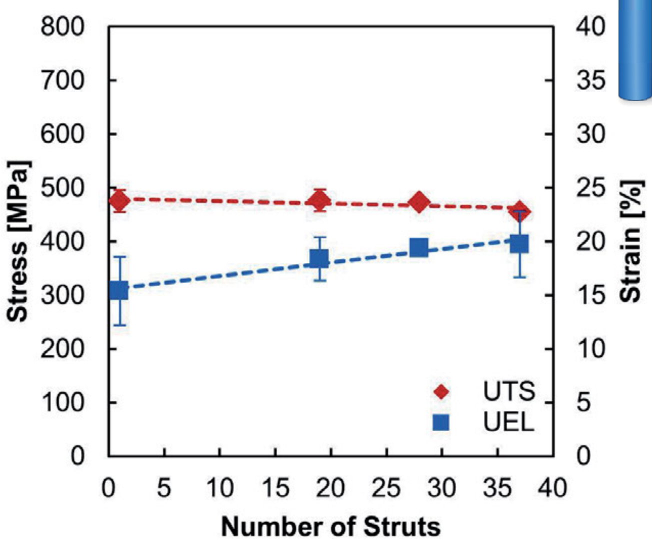


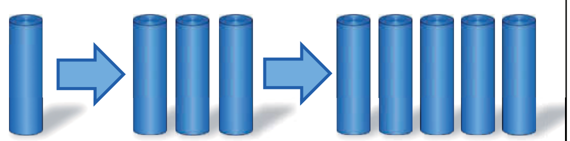


The surface area has almost no influence on the Ultimate Tensile Strength.

The Uniform Elongation is decreasing with increasing surface area, because of the higher chance for an inhomogeneity that will lead to a early necking is increasing, too.

Number of Struts

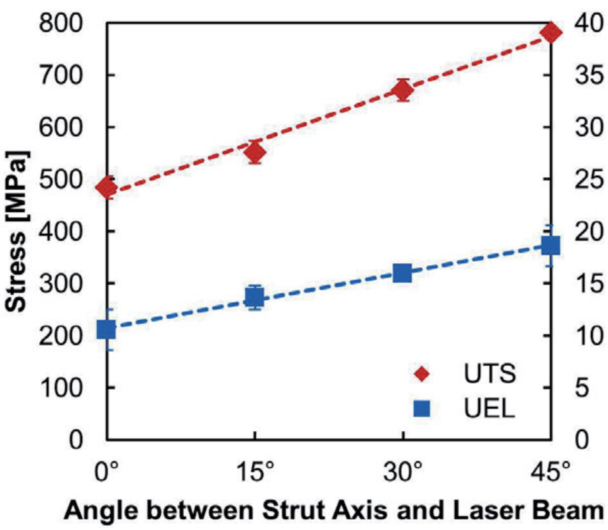


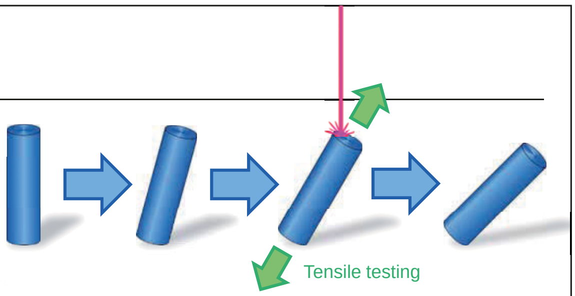


The surface area has almost no influence on the Ultimate Tensile Strength.

The Uniform Elongation is increasing slightly with the number of struts, because an early failure of single struts with an inhomogeneity is less severe.

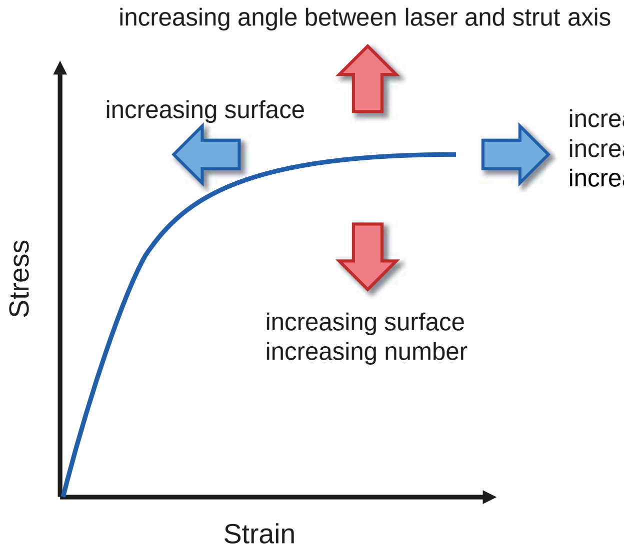
Different Angles

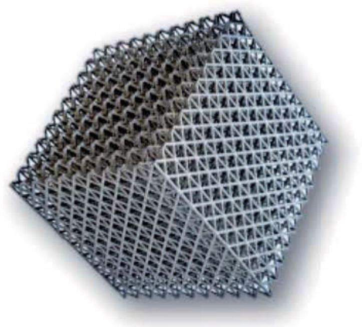




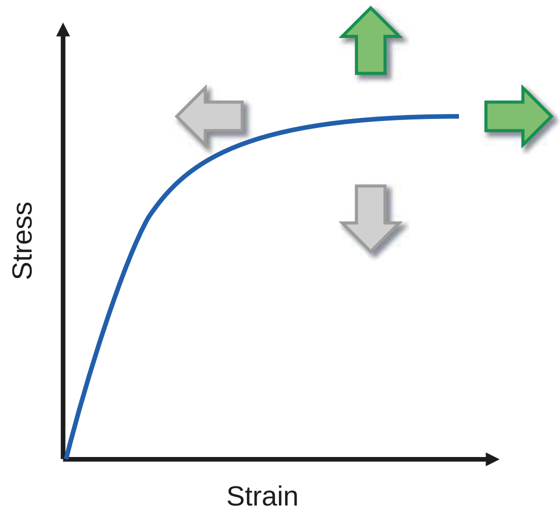
A higher angle between laser beam and strut axis leads to both a higher Ultimate Tensile Strength and Uniform Elongation, because the crack formation is along the layers of the SLM process and with an increasing angle the cross section area for the crack formation is increasing, too.

Summary



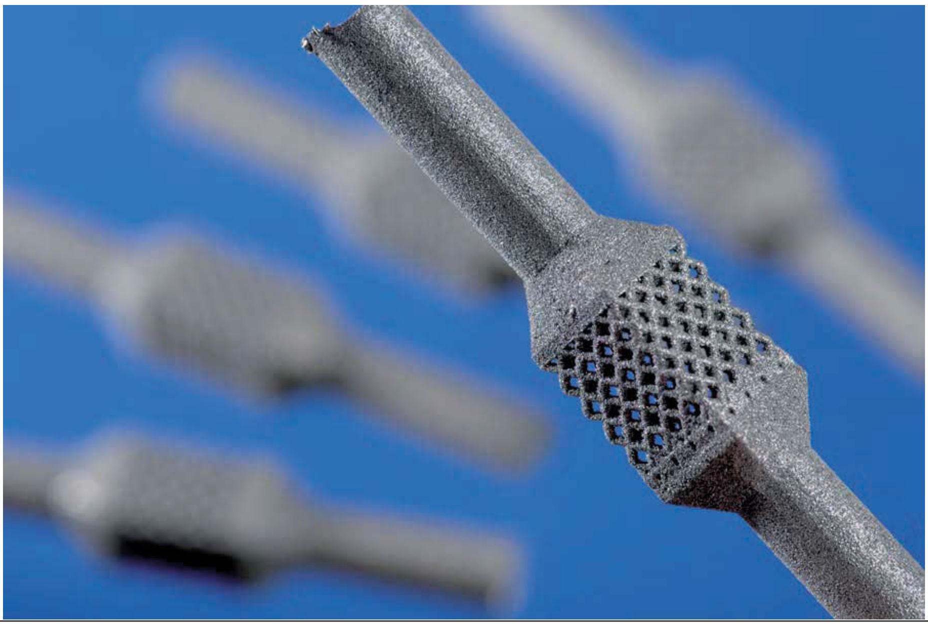


Conclusion



- Hypothesis:
  Small struts have a lower Ultimate Tensile Strength and Uniform Elongation due to the increasing impact of surface roughness and defects.
- Answer:
  Small struts have almost the same Ultimate Tensile Strength, but a lower Uniform Strain.
  The mechanical properties of SLM produced micro struts are not scalable. Few big struts are better than many small ones with the same area, and they should be generated with a high angle between laser and strut axis.

Next Steps



Thank you for your interest!

Any questions

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Assembly of Large Components in a Smart Factory

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Keywords:
integrative production, self-optimizing assembly, Industry 4.0

Abstract

Complying with tolerance requirements during the industrial production of large components is a major challenge. Environmental influences, which appear to be controllable for the production of small components, have a significant effect on the production of large components. Whilst manufacturing processes are heavily influenced by temperature fluctuations affecting the resulting part geometry, assembly processes of large components, such as aircraft shell elements, are especially influenced by gravitation which results in the deformation of assembly parts and requires compensation. The compensation of environmental influences during automated process control requires large amounts of measurement data regarding e.g. process parameters, temperature and part geometry. The accumulated data is used for the development of models which describe the interdependency of components, processes and the production system. Based on these models, compensation strategies can be developed and evaluated. A single control system can not handle and process the required data volume in an appropriate amount of time. Ongoing interconnection of production resources to a 'Smart Factory' distributes the data to specialized computer systems and the processed data is made available for the individual control systems on demand.

Within this contribution, the benefit of a networked production systems in a 'Smart Factory' is discussed and strategies to avoid or how to react on component deformation in downstream processes will be presented.

Bibliography

Kagermann, H. et al.: Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group, 2013.

Brecher, C. et al.: Integrative Production for High-Wage Countries. Springer, ISBN 978-3-642-21066-2, 2012.

Assembly of Large Components in a Smart Factory

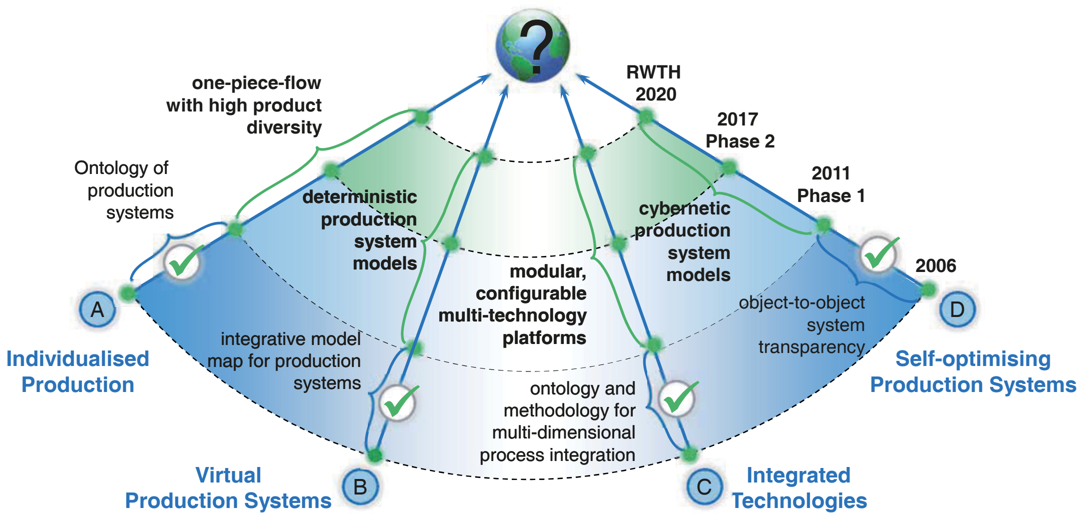
Cluster-Conferences 2013

Markus Janßen
ICD D3 Project Coordinator

Aachen, den 23./ 24. September 2013

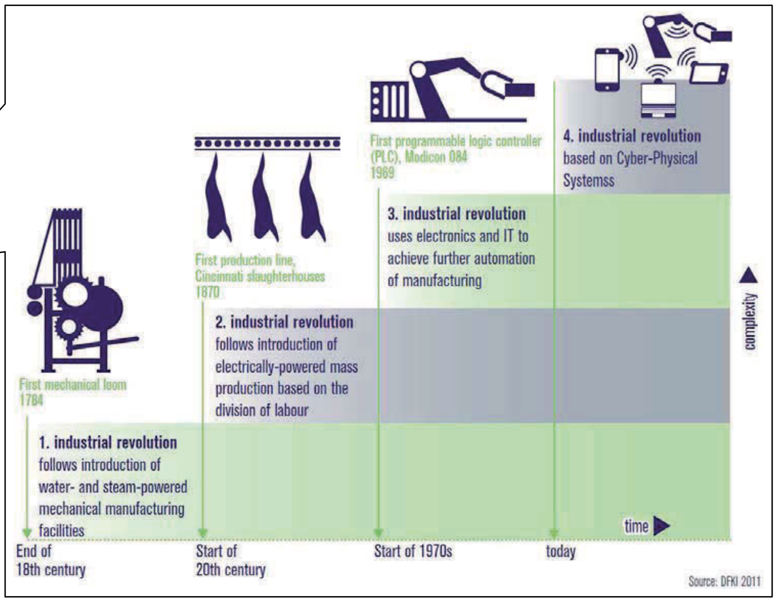
Roadmap for the 2nd funding period of the CoE

Vision of Integrative Production Technology



Source: Renewal Proposal for a Cluster of Excellence: "Integrative Production Technology for High-Wage Countries“, p. 13

"Securing the future of German manufacturing industry"



Source: Recommendations for implementing the strategic initiative INDUSTRIE 4.0, final report, p. 13

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Page 2

"Securing the future of German manufacturing industry"

- Priority areas for action
  - Standardisation and open standards for a reference architecture
  - Managing complex systems
  - Delivering a comprehensive broadband infrastructure for industry
  - Safety and security as critical factors for the success of Industrie 4.0
  - Work organisation and work design in the digital industrial age
  - Training and continuing professional development for Industrie 4.0
  - Regulatory framework
  - Resource efficiency

Source: Recommendations for implementing the strategic initiative INDUSTRIE 4.0, final report, p. 2

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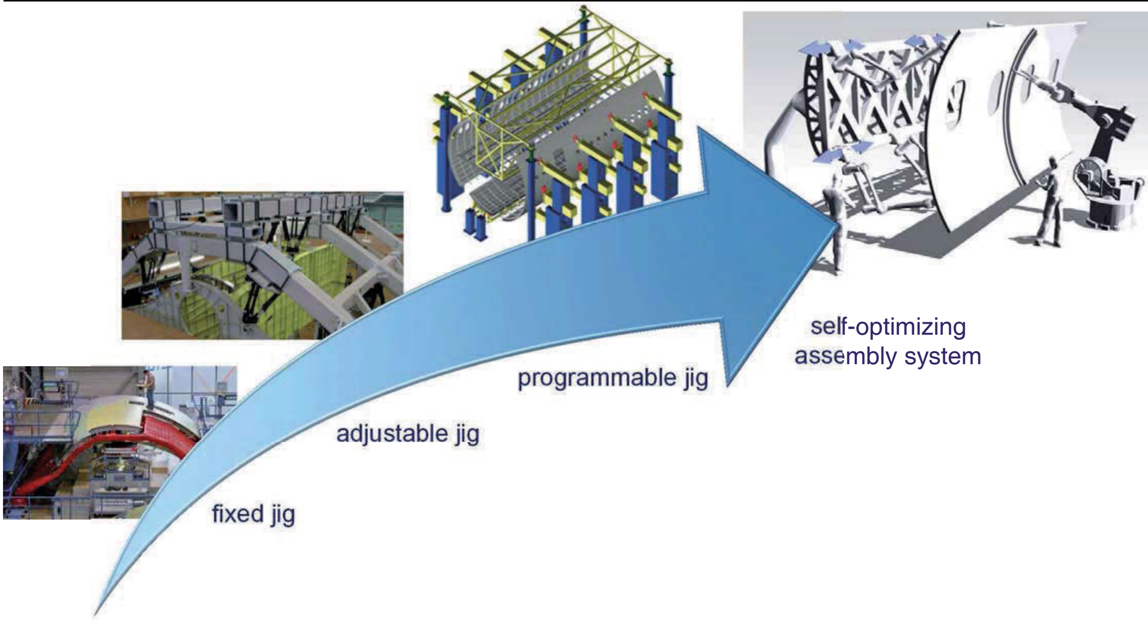
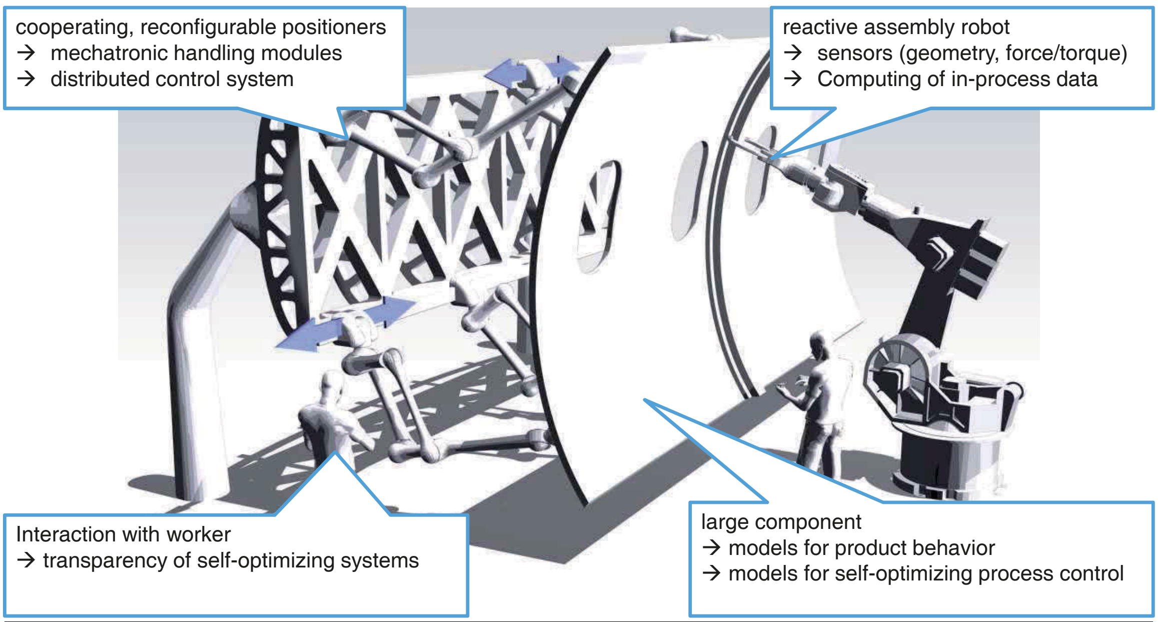
Page 3

Trend in assembly systems for large components: Decreasing amount of steel and increasing flexibility & complexity



Vision of self-optimizing assembly of large components



Managing complex assembly scenarios

- Product and process complexity
  - Product specific deformation and compensation
  - Models and real-time data for self-optimizing process control
  - Distributed control system for efficient computing and data processing

- Assembly system complexity
  - Resource efficiency requires reconfigurability
  - reconfigurability requires (mechatronic) modularity
  - Orchestration of modular systems requires a networked production

"Smart Factory"

e.g. Campus Cluster „Integrative Production Technology"

Preparing future research topics for Industry 4.0

VDI

- VDI working group „Industrie 4.0 – Begriffe, Referenzmodelle, Architekturkonzepte" (FA 7.21)
  - CoE members:
    - Dr.-Ing. Marcel Mayer (IAW): ICD D Deputy Coordinator
    - Markus Janßen (WZL): ICD D3 Coordinator
    - Dr.-Ing. Walter Kimmelmann (WZL)
  - Objective: guidelines and standards

- Contribution at AWK 2014
  - Focus: **Industry 4.0 - The Aachen Approach**
  - Session 4 „Cyber Physical Production Systems (CPPS)"
  - Presentation 2 „Precision Manufacturing and Assembly of Large Components"
  - Experts from
    - Alstom
    - FFT EDAG
    - PremiumAerotec
    - MAN
    - …

Thank you for your attention!

- Contact:

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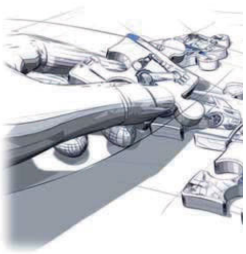
Page 8

Supporting technology transfer via web-based platforms

Aghassi, S.

Abstract

In order to stay globally competitive enterprises face an increasing pressure to be innovative. Furthermore, the rising complexity of new technologies forces enterprises into RnD-cooperations with third parties as technology development can often not be handled by one organization on its own. In spite of this need for technological innovations, lots of excellent research results from academia remain unexploited. The reason for this often lies in a lacking industrial partner for commercialization of developed technologies, which again is often caused by lacking visibility. Although several measures are taken to bridge the gap between research and industry, their success is not broadly achieved. In the past years, with the rising technical capabilities of modern Web 2.0 and social software technologies, several web-based portals were set up in order to support technology transfer, and increase the visibility of the developed technologies at various research establishments. Within CSP3 a technology transfer portal will be set up within the Cluster of Excellence, in order to create transparency about the technologies developed within the Cluster and the people behind them. In a first step portal usage is considered for internal use by cluster members only, prospectively the portal could be opened up to potential industrial partners. The technology transfer portal is part of the »Scientific Cooperation Portal«, developed together with CSP1.



Supporting technology transfer via web-based portals

CSP3
Susanne Aghassi
Fraunhofer Institute for Production Technology IPT

Cluster Conference
Aachen, 24.09.2013

Agenda

1 **Overview and objective of CSP3**

2 **Technology transfer portals**

3 **Conceptual and practical approach**

4 **Current state of work and outlook**

Agenda

1 **Overview and objective of CSP3**

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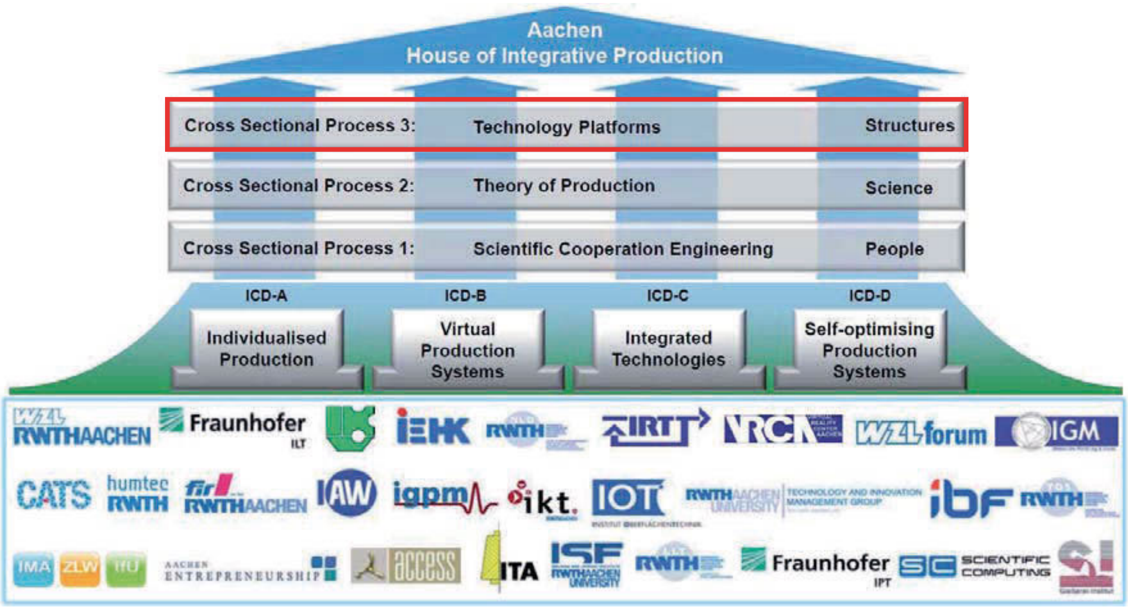
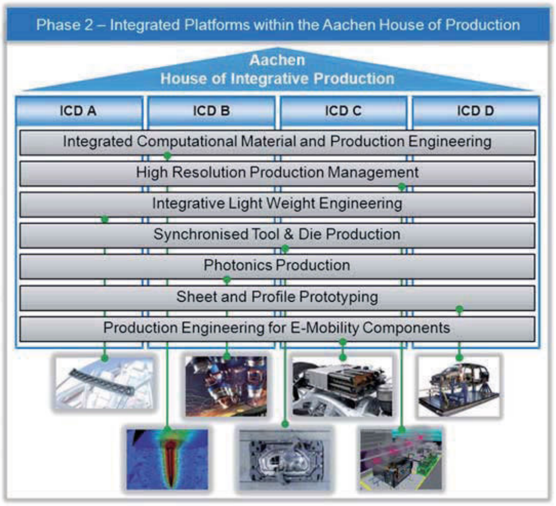
Overview of the Cluster of Excellence
Overall structure

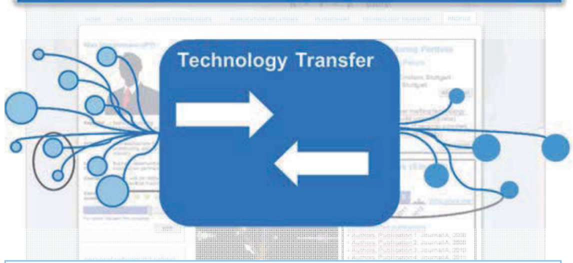


CSP3 Technology Platforms
Physical and virtual approach

Extension of former B&T-cases (phase 1) to technology platforms (phase 2)



Knowledge and technology transfer within and beyond the cluster of excellence



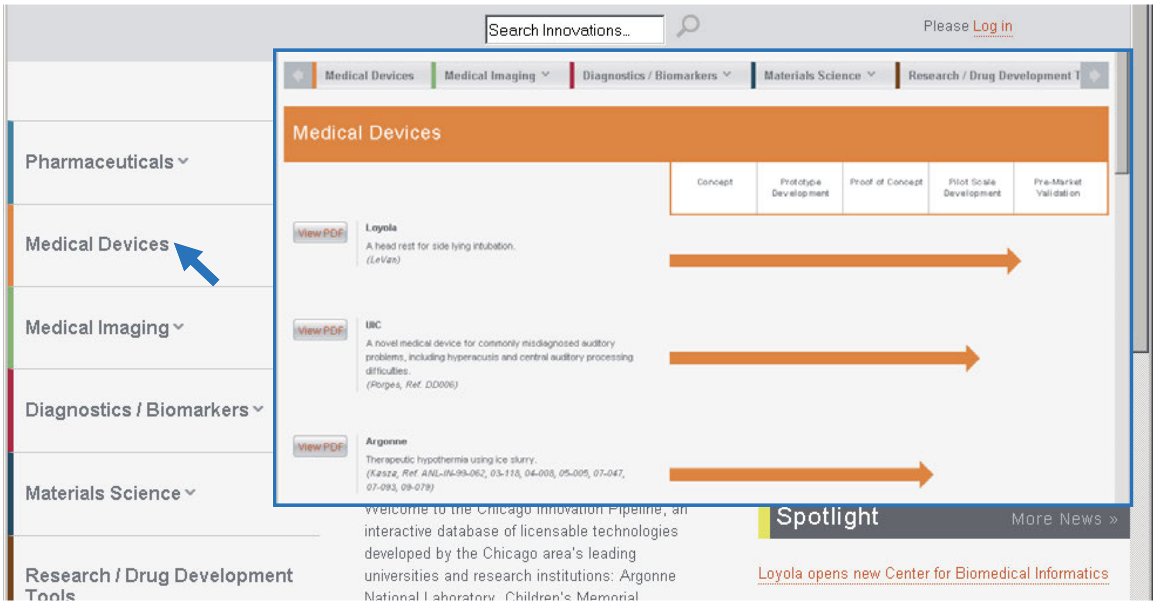
Goal and objective

- **Development of a virtual platform** supporting technology transfer between science and industry
- **Enabling** the implementation of research results into **innovation**
- **Bundling** of and **simplifying access** to information
- Discussion forum and **meeting point** of expert communities in a virtual platform

Agenda

1. Overview and objective of CSP3
2. **Technology transfer portals**
3. Conceptual and practical approach
4. Current state of work and outlook

Technology transfer portals
Example portals from other research clusters



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Source: http://chicagoinnovationpipeline.org

Technology transfer portals
Example portals from other research clusters

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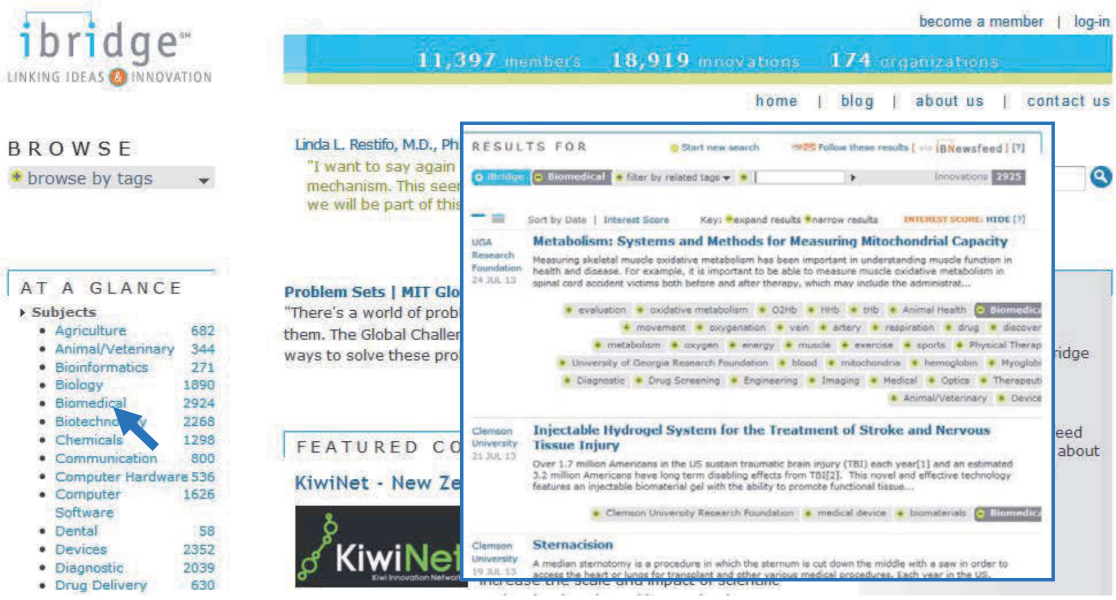
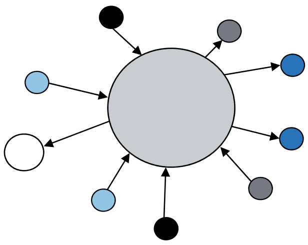
Source: http://techtransfer.ima.kit.edu/

Technology transfer portals
Example portals from other research clusters

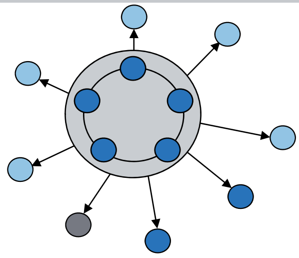


Source: http://www.ibridgenetwork.org/

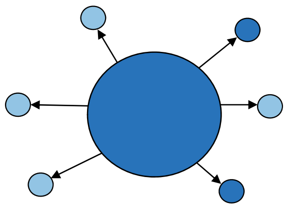
Technology transfer portals
Different types



Portal Type I
e.g.: iBridge Network



Portal Type II
e.g.: Chicago Innovation Pipeline



Portal Type III
e.g.: KIT Technology Market

Legend

- Individuals
- Industry
- Universities/ Institutes
- Other technology transfer portals
- DBs connection

Source: „Supporting Technology Transfer via Web-based Platforms", Schuh, Aghassi, Calero-Valdez, PICMET 2013

Agenda

1 Overview and objective of CSP 3

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Seite 10

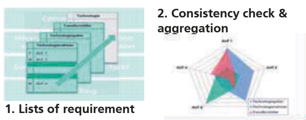
Conceptual approach
Design model for technology transfer portals

Transfer partners and goals 1

- Description of characteristic attributes of the transfer situation and goals of the transfer
  - Technology supplier based
  - Technology consumer based
  - Portal manager based
- ➢ Characterized transfer situation
- ➢ Prioritized goals

Requirements 3

- Deduction of specific requirements for the technology transfer portal
- ➢ Generic requirement framework
- ➢ Consistent requirement clusters

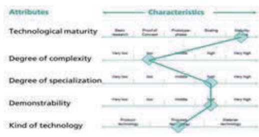


1. Lists of requirement

2. Consistency check & aggregation

Transfer object 2

- Description of technologies according to characteristics relevant to technology transfer
- ➢ Generic technology description for technology transfer portals

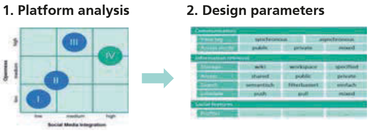


Portal elements 4

- Identification and analysis of existing technology transfer portals
- Identification, structuring and if necessary expansion of the existing functions
- ➢ Characterized portal elements
- ➢ Structured portal elements

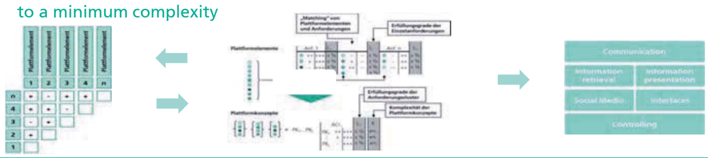
1. Platform analysis

2. Design parameters



Configuration logic for technology transfer portals 5

- Key factors and their interdependencies concerning the portal elements (compatibility of platform elements)
- Model for situation-specific design of a transfer portal
- Evaluation of portal elements and their interaction with regard to their degree of meeting the requirements
- ➢ Method to configure a transfer situation-specific technology transfer portal with regard to a minimum complexity



Source: „Design Model for Technology Transfer Portals“, Schuh, Aghassi IEEM 2013

Practial approach
Prototype of the »Scientific Cooperation Portal«

- Development of a web-based collaboration portal with CSP1
- Access to the »Scientific Cooperation Portal« via the cluster platform (nor further login necessary)
- Diverse collaboration functions as well as access to the latest results of cluster meetings such as MAKs or CSP-Workshops
- Main CSP3-functionality: »Technologies«
  - Technology information sheet for each technology developed within the cluster
  - User / expert profiles that can be linked to technologies
  - In the future: possibility to open parts of the information for public access

➢ Gain transparency about the developed technologies within the cluster, the people behind them and their interconnections

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Agenda

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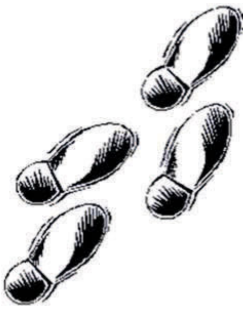
Technology Transfer Portal
Current state and outlook



- Research and analysis of state-of-the-art concepts for technology transfer portals
- Requirements analysis
- Deduction of required elements, functions and services (rough concept of technology transfer portal)
- Successive prototypal implementation within the »Scientific Cooperation Portal« together with CSP1
- Generation of first content within the next MAK
  - Technology information sheets
  - Cluster terminologies
  - Methodologies used within the CoE
- Test and evaluation within the CoE starting from end of 2013

Thank you for your attention!

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Self-optimizing assembly of aircraft shells in global referencing systems

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Keywords:
assembly, automation, metrology

Abstract

Volatile markets impose a significant pressure on assembly systems to handle unknown situations efficiently. Replacing fixed jigs and fixtures by programmable robots can increase the flexibility and reactivity of a production system. Changing boundary conditions and process deviations need to be compensated during assembly as well as short-comings of the robots, e.g. low stiffness and higher systematic deviations. In order to master these challenges, self-optimization is a key technology to control robots in jig- and fixtureless assembly. In order to self-optimize the robots' short-comings perceptive capabilities by using metrology are required to determine the current assembly states. Global referencing systems represent a communication standard to enable the information exchange between the robots and metrology systems inside an assembly cell. Robots can then use the enhanced assembly state information to align the process to a virtual planning state during the real assembly. Grasping forces and geometric deformations of an aircraft shell are to be measured to allow the identification of parameters for a prediction model of the aircraft shell deformation during assembly. This model will be used by the robots for the self-optimizing assembly of clips and frames with compensation of deformations and for assuring their correct position in the aircraft.

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Schmitt, R, Witte, A, Janßen, M, Bertelsmeier, F (2013) Modeling of Component Deformation in Self-optimizing Assembly Processes, 222, ISMTII 2013: The 11th International Symposium on Measurement Technology and Intelligent Instruments - Metrology - Master Global Challenges

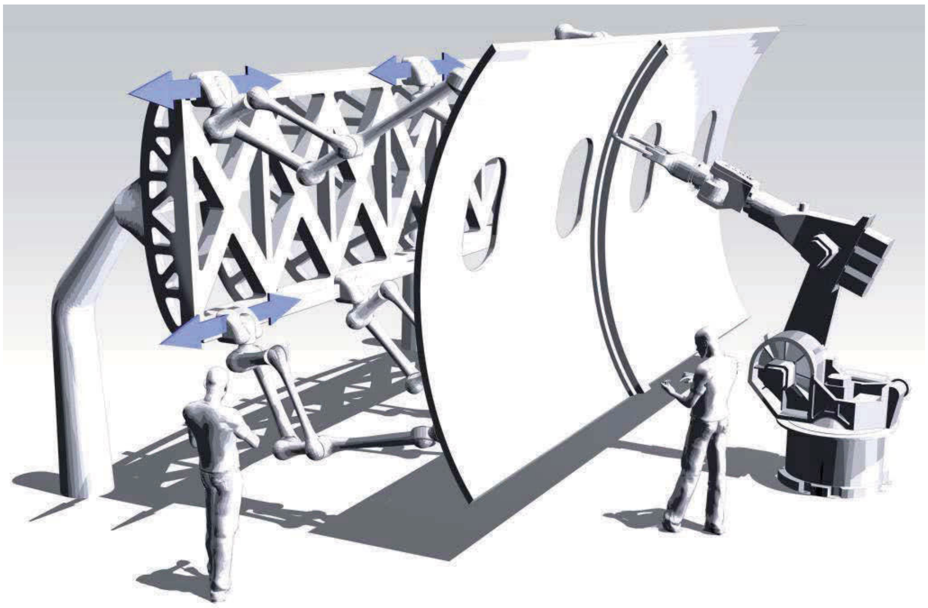
Self-optimizing assembly of aircraft shells in global referencing systems

Cluster-Conferences 2013

Alexander Schönberg

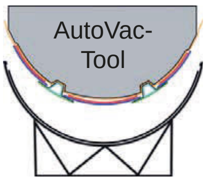
Aachen, 24. September 2013

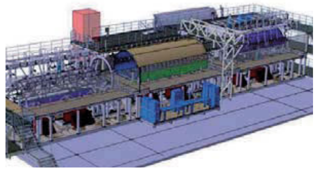
Self-optimizing assembly of aircraft shells



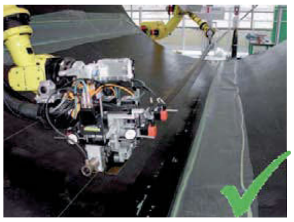
Increasing the flexibility through robot based assembly systems

fixed jigs

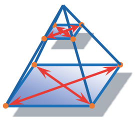


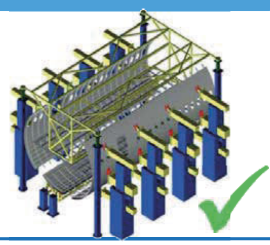


… → stringer integration → shell assembly → barrel assembly → …



→ **Research**





Robots are not able to position large-structures precisely using only mechanics

Pictures: PremiumAerotec, FFT EDAG, Dürr

Agenda

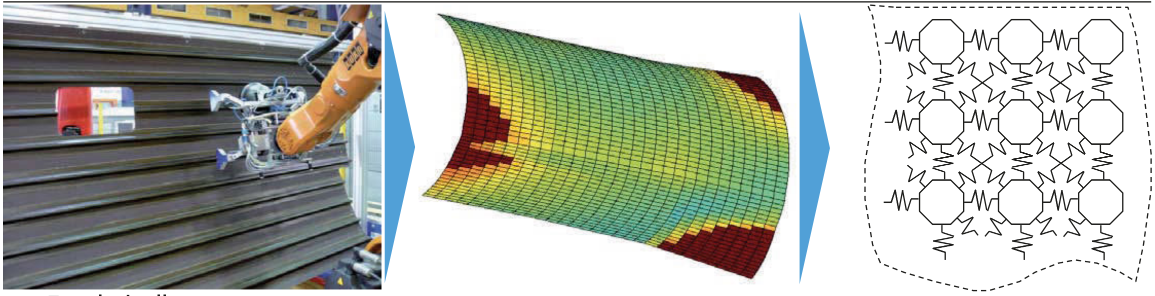
1 **Self-optimizing assembly of aircraft shells**

2 **Global referencing systems**

3 **Perception of shell structure deformation**

4 **Research Roadmap**

CFRP-shell modeling

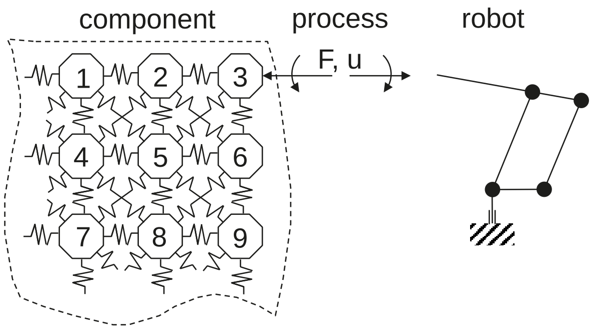


- Real shell
  - CFRP (anisotropy)
  - Integrated stringer
  - Window section
  - …
- Model of metrology data
  - Twisted at 16 measurement points
  - linear interpolation at >2000 points
  - stiffness not implemented
- Mathematical model
  - local stiffness uses rigid shell elements
  - global stiffness using springs
  - adapted spring constants for stringers, frames and windows

Objective: identification of model parameters for self-optimizing process control

Deformation model of the panel

- mathematical approximation of the panel by a matrix of stiff shell elements which are connected by springs
  - global compliance
  - locally rigid stiffness
- Compromise between accuracy and efficiency
  - Calculating the force values to untwist a **local area** of the panel
  - Approximation of the radial deformation



$$\begin{pmatrix} F_1 \\ F_2 \\ \vdots \\ F_n \end{pmatrix} = \begin{pmatrix} k_{1,1} & k_{1,2} & \dots & k_{1,n} \\ k_{2,1} & \ddots & \dots & k_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ k_{n,1} & k_{n,1} & \dots & k_{n,n} \end{pmatrix} \cdot \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{pmatrix}$$

F: force k: stiffness u: radial deformation

Agenda

1 Self-optimizing assembly of aircraft shells

2 Global referencing systems

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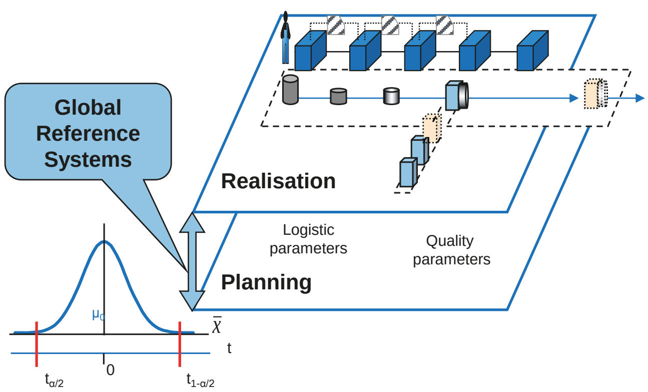
4 Research Roadmap

Versatile Assembly takes place in the real production world and requires a close match to the virtual planning

Quick and controlled transfer of virtual planning the real world



Approach

- Versatile (self-optimizing) Planning with ideal models is possible today
  - Self-optimization takes place mainly in the virtual world
  1. Planning with deviations of real world gets complex quickly
  2. It is easier for the real units to **navigate** on the planning path

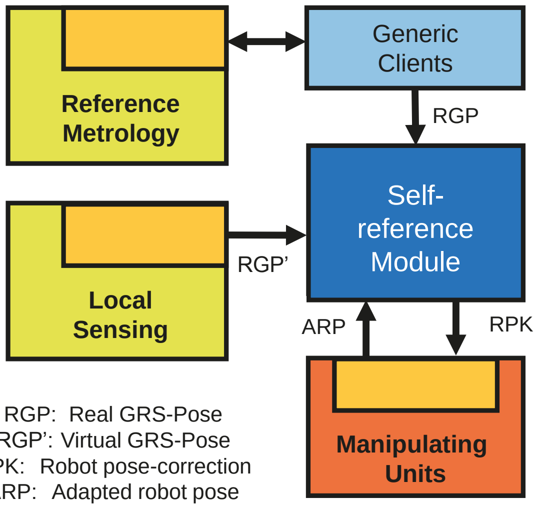
→ **Perception is needed for both approaches**

→ **Navigation on the path, not towards a target**

Global Reference Systems (GRS) gather deviations between virtually planned paths and their realisation in the real world assembly

Global Referencing Systems represent a modular Communication Network based on Planning Data

Components und Data Flow



RGP: Real GRS-Pose
RGP': Virtual GRS-Pose
RPK: Robot pose-correction
ARP: Adapted robot pose

GRS Reference Metrology

Metrology is a part of the infrastructure → there is no direct link to the machines

Common coordinate system in Production aligned to Simulation

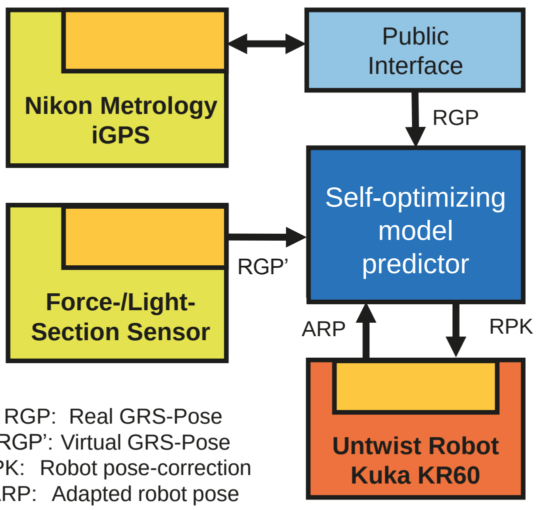
Detection of spatio-temporal relationships

Metrology for local sensing

Local sensing detects workpiece deviations in the process-reference system

Global Referencing Systems represent a modular Communication Network based on Planning Data

Components und Data Flow



RGP: Real GRS-Pose
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RPK: Robot pose-correction
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GRS Reference Metrology

iGPS surveys the robots and references signals of other metrology systems

Assembly is required to be done in aircraft coordinate system

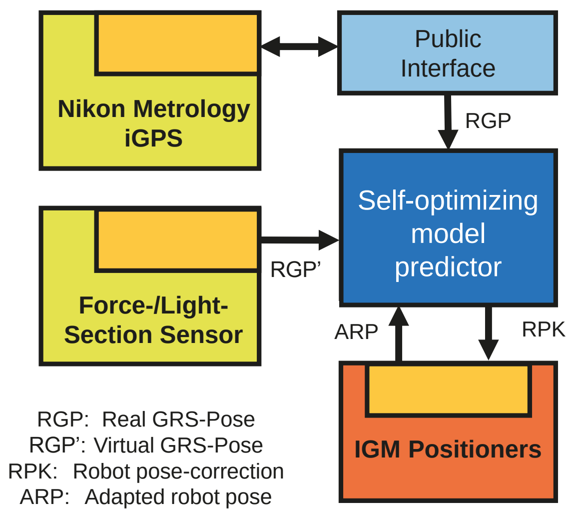
Processes are mostly static → no need for temporal reference

Metrology for local sensing

Force and light section sensing detects assembly state

Global Referencing Systems represent a modular Communication Network based on Planning Data

Components und Data Flow



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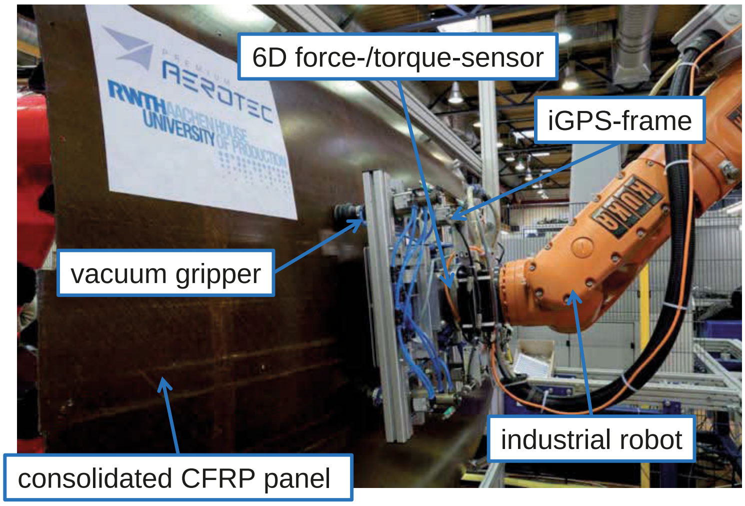
2. **Global referencing systems**
3. **Perception of shell structure deformation**
4. **Research Roadmap**

6D-force sensor



- Force control
  - robot movements are controlled bye the applied loads on the panel
  - the necessary loads for a local untwisting are calculated by the model of the component deformation behavior

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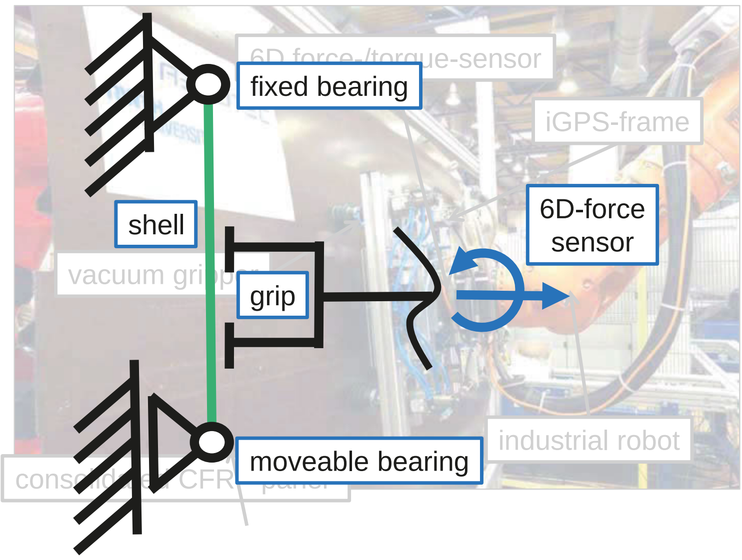
6D-force sensor



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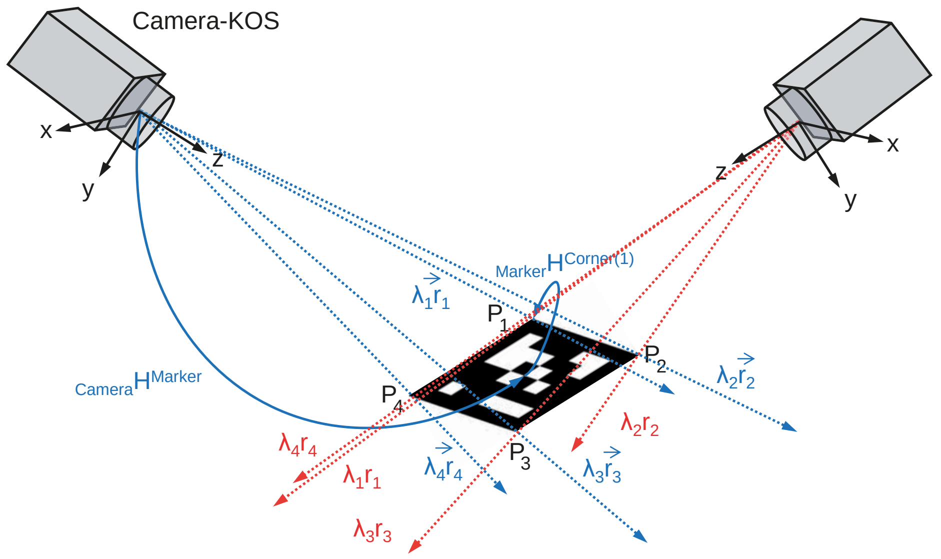
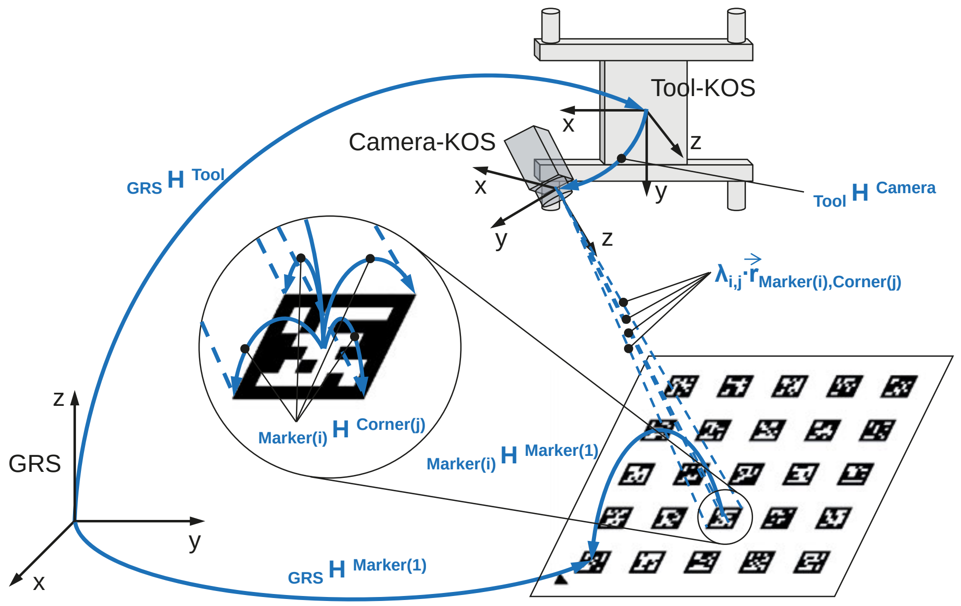
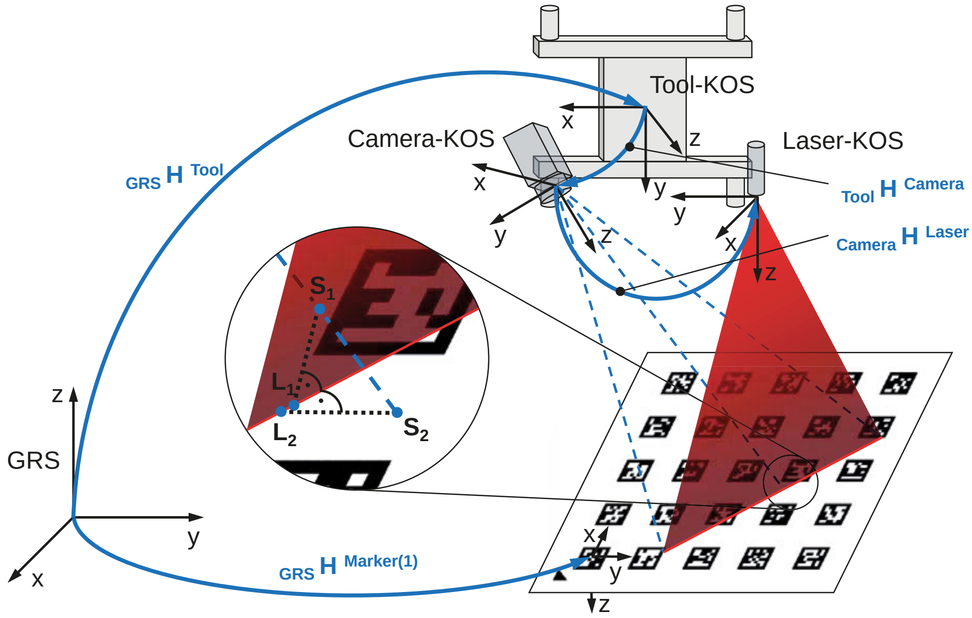
Optical sensor 1/4



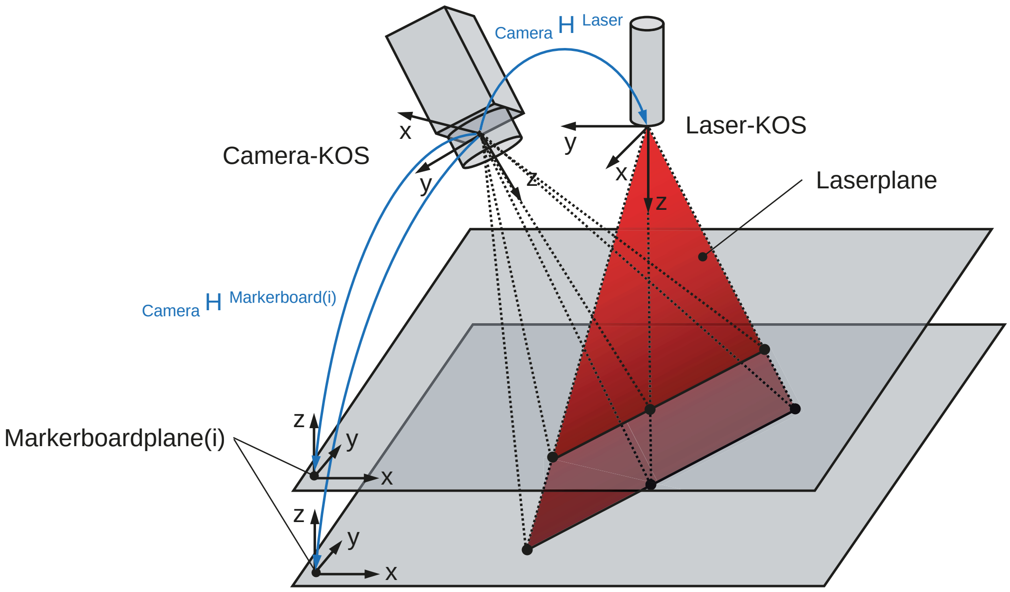
Optical sensor 2/4



Optical sensor 3/4



Optical sensor 4/4



Agenda

1 **Self-optimizing assembly of aircraft shells**

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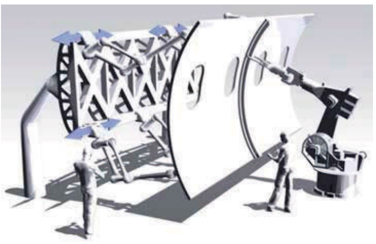
Research Roadmap

2013 | 2016 | ?

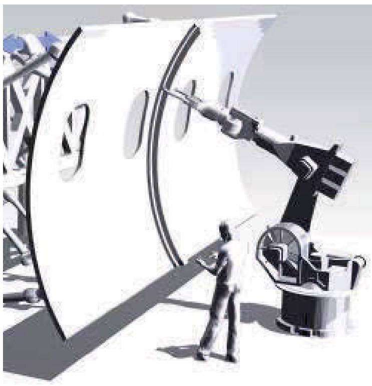


- Shell positioning with aluminium structure and fixed/moveable bearing
- Screw-joining without drilling

- Shell positioning with industrial robot and positioners
- Screw-joining without drilling

- Shell positioning with positioners
- Drill-/Riveting joining

Self-optimizing assembly of aircraft shells in global referencing systems



Thank you

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Fabrication of Hierarchical Structures by Direct Laser Writing and Multi-Beam-Interference

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Keywords:
Direct laser writing, Multi-beam-interference, hierarchical structures, laser structuring, functional surfaces

Abstract

Micro- and nano-structuring and thus functionalization of surfaces is a key feature for many applications ranging from light guidance devices for consumer electronics to bio-compatibility of implants. To create the desired functionalization hierarchical structures are often required. These structures can be considered as a micro-structure with a superposed nano-structure.

The approach presented in this talk therefor also divides the structuring process into two parts. The micro-structure is accomplished by direct laser writing which reaches structure sizes down to of few μm while the nanostructure is subsequently added by a multi-beam-interference (MBI) approach. The influence of the two subsequent processing steps on the final structure geometry and the process limits for the generating of hierarchical structures by this approach are investigated.

Fabrication of Hierarchical Structures by Direct Laser Writing and Multi-Beam-Interference

Cluster-Conferences 2013

Michael Steger

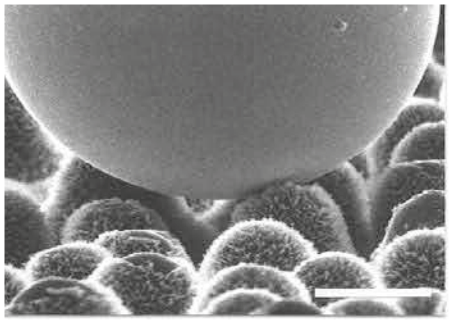
Aachen, den 23./ 24. September 2013

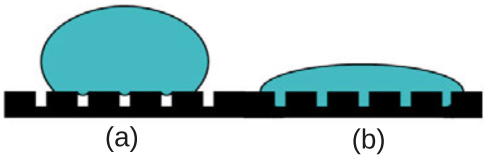
CONTENT

- Motivation
- Approach and basics of multi-beam-interference
- Micro structuring by direct laser writing
- Nano structuring by Multi-Beam-Interference
- Hierarchical structures by subsequent structuring
- Summary

Motivation

- Importance of functional surfaces
  - ➢ Mimicking nature: Lotus effect
- Structure consists of a µm-scale structure superposed with a nanostructure
- Hierarchical structures
  - Lower contact angle
  - Higher stability
- Creation of hierarchical structures
  - Structure size, density of the structures
  - Application on 3D surfaces





(a) Cassie-Baxter wetting
(b) Wenzel wetting

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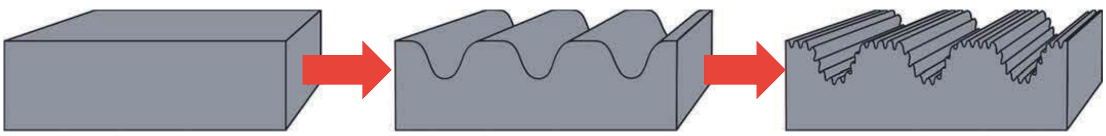
Fabrication of hierarchichal structures

- Approach with subsequent structuring by laser ablation
  1) Micro structuring by direct writing
  2) Nano structuring by Multi-beam-interference
- Sample material: polyimid foil (Upilex)



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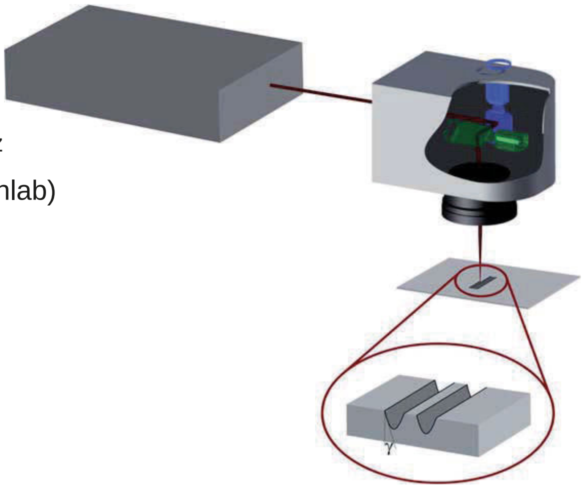
Micro structuring: Setup

Setup

- 3ω - Nd:YVO_4 – laser (Hyperrapid, Lumera Laser)
  P = 20 W, τ < 15 ps, λ = 355 nm, 400 kHz
- Galvo scanner (intelliSCANde14, Scanlab)
- f-Θ lens f = 32 mm



Goal

- Small structures < 10 µm,
- Line structures with large angle γ

Changed parameters

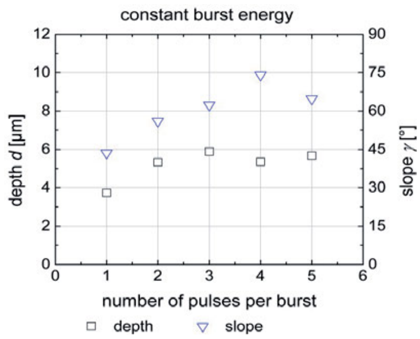
- Pulse energy, scanspeed, bursts, repeats

Micro structuring: Results

- Small structures → small energy
- Maximal angle without bursts γ = 57°

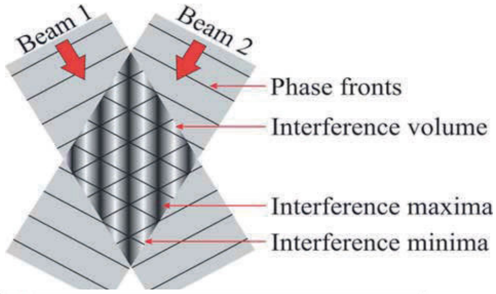
→ distribution of energy on several pulses in a burst

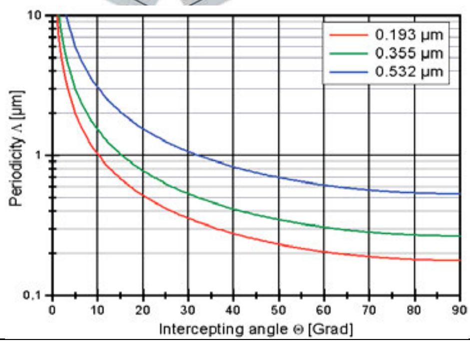
- Energy per pulse can be reduced to still get ablation
- Ablated lines get smaller and deeper with increasing number of pulses
- Ablated volume is for burst ablation smaller than for single pulses at pulse same energy
- Maximal angle γ = 65°



Basics of Multi-beam-interference

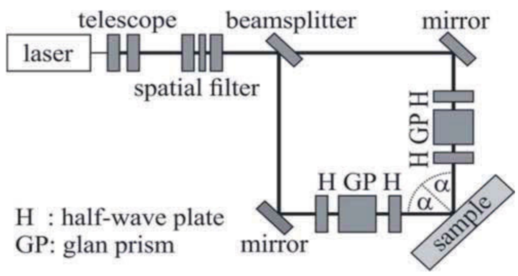
- Multi-Beam-Interference
  - Intensity modulation created by 2 or more intercepting, coherent laser beams
  - Intensity modulation occurs in whole intercepting volume
  - Periodicity depends on beam setup and laser wavelength
  - For symmetrical setups the pattern is stable in the z-plane
  - Promising approach for direct nano structuring of 3D surfaces

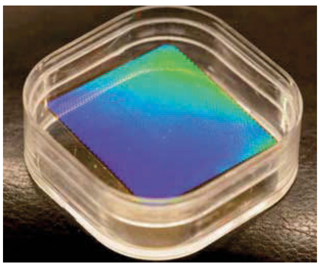




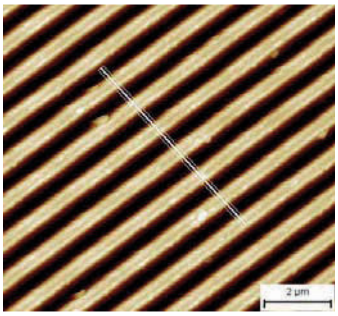
Nano structuring: Experimental setup

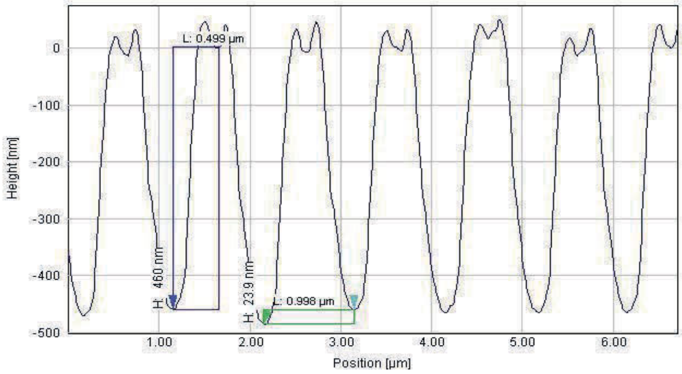
- Two beam interference setup
  - Nd:YAG Laser: 355 nm, 38 ns
  - Spot diameter: 500 – 1000 µm
  - results in 1D line wise structure
  - applied on unstructured and micro structured samples
  - variation of structure periodicity by adjusting of the intercepting angle α
  - beam incidence parallel and perpendicular to the micro-structure
- Sample material: polyimid foil (Upilex)
  - Unstructured/native surface
  - Pre-strucutured surface





Nano structuring: Plane Surfaces





- Periodicity: 1 µm; Fluence 1,81 J/cm²
- Groove: width 600 nm, depth 430nm
- Bulges at the edges of the grooves

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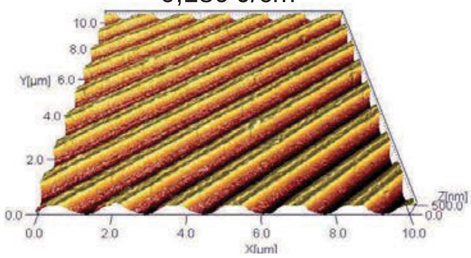
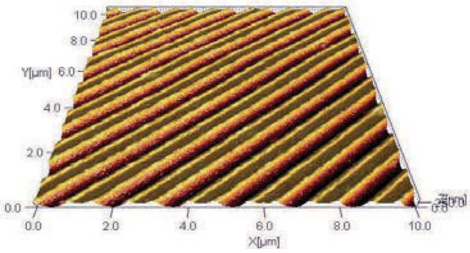
Nano structuring: Fluence variation

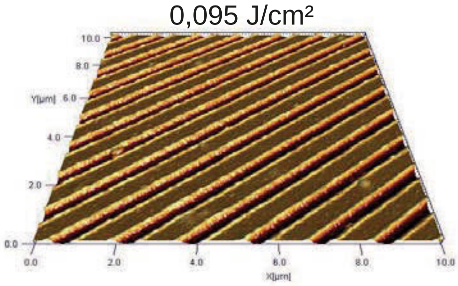
0,180 J/cm²



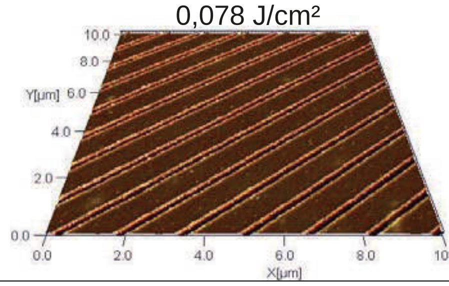
0,131 J/cm²



0,095 J/cm²



0,078 J/cm²



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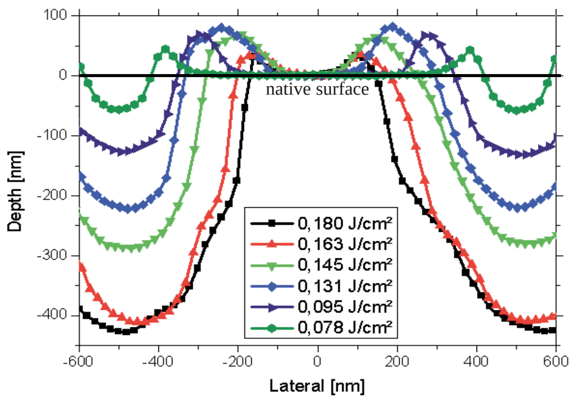
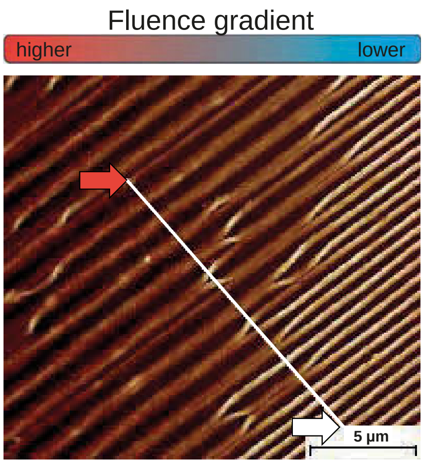
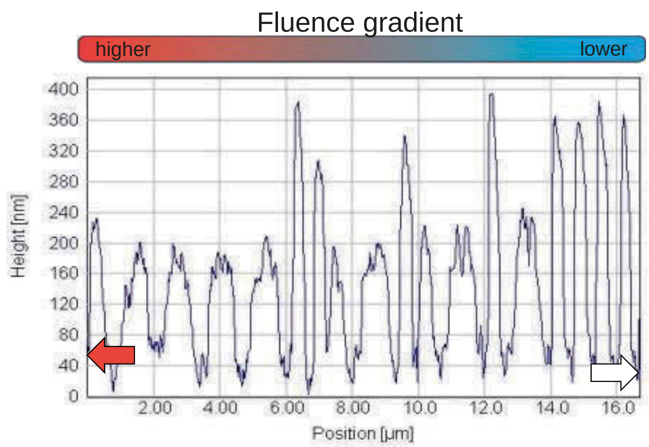
Nano structuring: Fluence variation



- Depth increases with higher fluence
- Maximal ablation depth per pulse close to 180 J/cm²
- Groove: width 600 nm, depth 430nm
- Native surface between the bulges
- Bulges height shows a maximum at 0.131 J/cm²

Nano structuring: Fluence limit



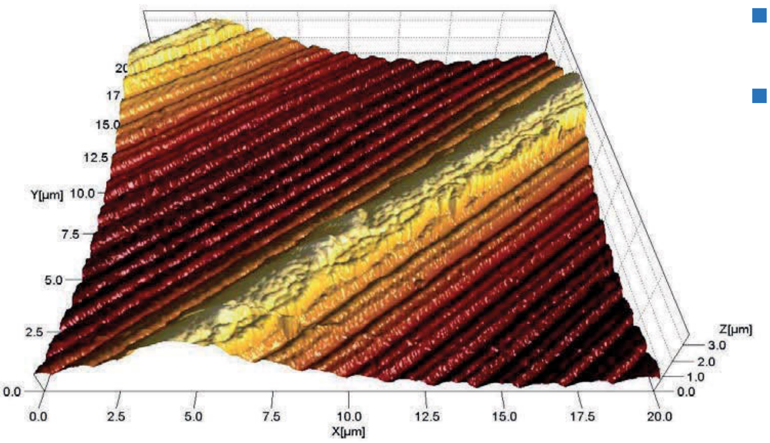


- With a reduction of structure periodicity, the process window decreases

Nano structuring

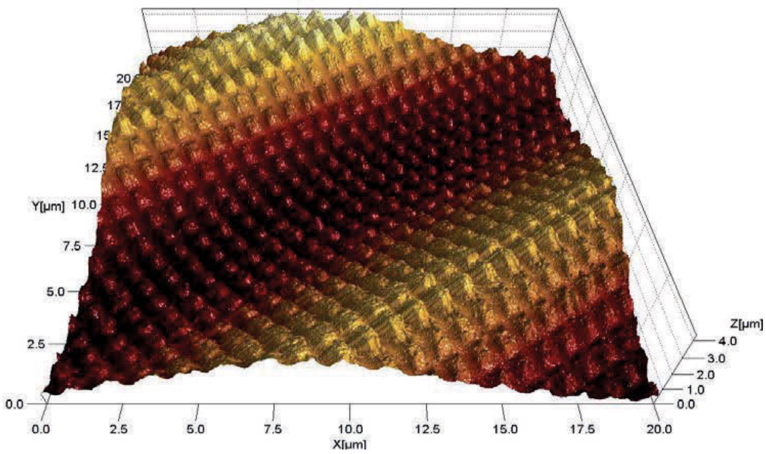
angle α [°]	periodicity [µm]	fluence [J/cm²]	max. depth [µm]
10,2	1000	0,180	440
13,7	750	0,095	350
19,8	525	0,068	275
24.4	430	0,061	125

Hierarchical structures: Perpendicular incidence



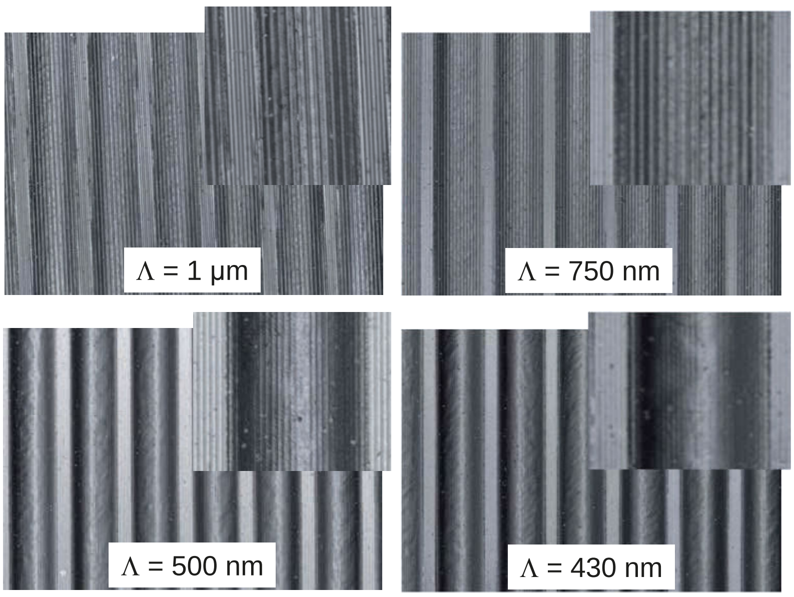
- Interference pattern can be transferred in 3D surfaces
- Bulges at the edges still occur

Hierarchical structures: Second nano structuring



- Interference pattern can be transferred in 3D surfaces
- Bulges at the edges still occur
- 2D Intensity modulation leads to a distorted pattern on a 3D surface
- Depth varies depending on angle due to the change
- Higher stability against folding of the structure

Hierarchical structures: Different periodicities



- Microstructure

  Depth: 5.1 µm

  Slope 42°
- Nanostructure covers the microstructure completly for 1 µm – 500 nm
- At 430 nm maybe incomplete coverage of the flanks

Summary

- Micro structuring with ps-bursts allows to create smaller structures compared to single pulse ablation
- Multi-beam-inference allows the simultaneously nano structuring of an area which size depends on the available pulse energy
- Creation of hierarchical structures is feasible with the following limitations:
  - the nano structures are perpendicular to each other, not necessarily to the surface
  - the variation of structure depth depending on the angle between surface and interference pattern

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Self-optimizing assembly of individualized laser systems

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Keywords:
self-optimizing, assembly system, optical system

Abstract

The self-optimized optical system assembler requires an actuating setup to interact with physical elements that compose the optical system itself. Such system aims to achieve a final modular software with easy access and simple user comprehension. The development was separated in three major processes, which also depicts layers of abstractions. The lowest layer (less abstracted) is the interfacing process, which consists in creating middleware responsible to provide full access from the system running the software to the peripherals. The second layer is the integration process that summarizes in transforming the access to hardware as separated entities to a single input/output unified system. The highest layer is the modularization process that is required to supply flexibility and portability by wrapping the software. An active-safety system is designed to prevent accidents that may occur in actuating system due to the diversity of errors that such systems are susceptible. In addition, it presents error handling in all abstraction layers to assist troubleshooting. These layers are developed concurrently, and currently the Integration layer is virtually finished, while the interfacing layer still needs to be implemented the safety system device, and the modularization layer can only parse a simplified STEP file into the software.

In-Mould Metal Spraying: New production technology for metallised plastic components

Hoppmann, C.

Wunderle, J.

Keywords:
thermal spraying, coating transfer, injection moulding

Abstract

The material combination of metal and plastics is of particular interest to engineering because of their wide range of properties and in terms of weight saving compared to a pure metal construction. In the field of electronics metal and plastics are used because of their conductive/non-conductive behavior. In the housing for enclosed electronics the properties of the metal component can also be used to improve the electromagnetic compatibility. To coat metal on plastic components a new process the "In-Mould Metal Spraying" is developed. The technology combines the thermal spraying of metals with the injection moulding process of plastics. In a first step a metal layer is thermally sprayed onto the surface of the injection mould. In the second step this metal coating is overmoulded with thermoplastic material. During injection moulding and demoulding the metal coating is released from the mould surface and thereby transferred to the plastic part. By this process a conductor track can be produced or a thin metal coating can be integrated on plastic components to improve the EMC properties of the manufactured components. A first preliminary test shows the feasibility of the new technology.

In-Mould Metal SprayingIn-Mould Metal Spraying: New production technology for metallised plastic components

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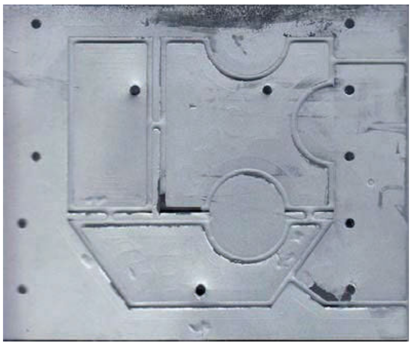
INSTITUT FÜR KUNSTSTOFFVERARBEITUNG
IN INDUSTRIE UND HANDWERK AN DER RWTH AACHEN

Dipl.-Ing. J. Wunderle

Prof. Dr.-Ing. Ch. Hopmann

Aachen, den 23./ 24. September 2013

Agenda



- State of the art of metallising plastic components
- Thermal spray process
- In-Mould Metal Spraying
- Conclusion and outlook

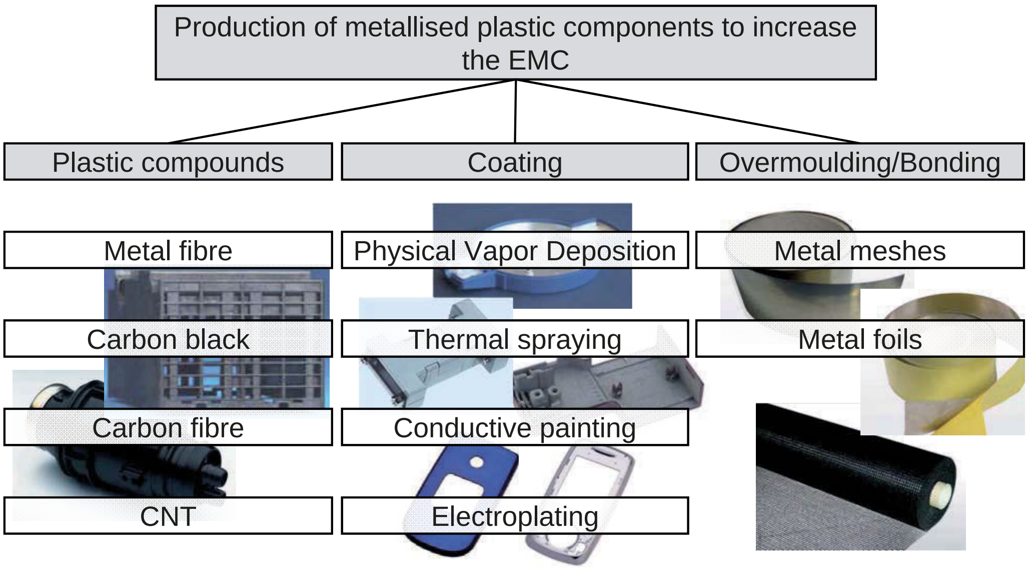
Definition of Electromagnetic Compatibility (EMC)

EMC aims to ensure that equipment, items or systems will not interfere with or prevent each other's correct operation through unintentional emission and absorption of electromagnetic interference.

Technological progress nececciates an increasing EMC

- The number of electronic products is steadily increasing.
  - Rise of the electromagnetic noise level
- The working frequencies rise and new digital techniques are introduced.
  - Interference levels with higher frequencies
  - Interference level get broadbanded
- The packing density is increased by progressive miniaturisation.
  - Noise receivers move closer to sources of interference
  - Low power consumption increases sensitivity to disturbance

Methods to improve the EMC of plastic parts

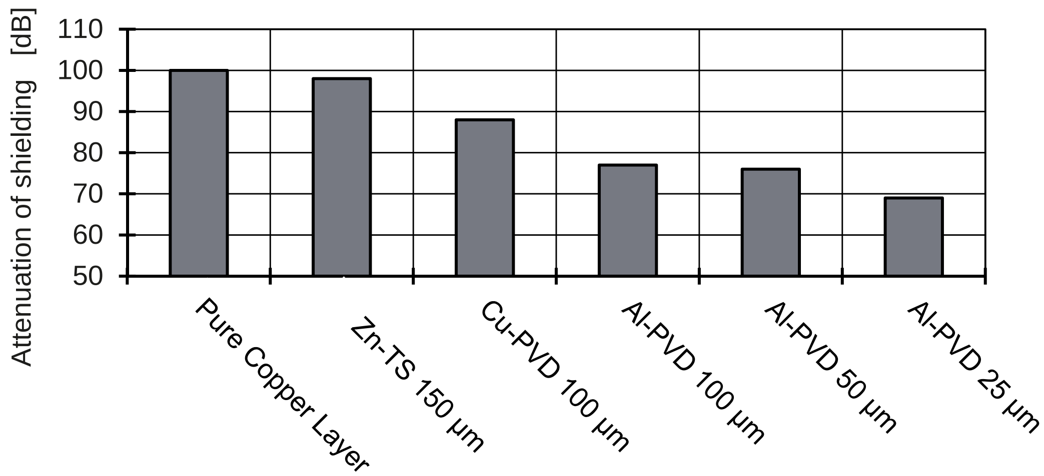


[Ticona GmbH, AARONIA, HARTING KGaA]

Advantages and disadvantages of the presented methods

Compounds	Coating	Overmoulding/Bonding
+ Components have EMC properties directly after the production + Processing in conventional injection moulding	+ Layers can be subsequently applied in any thickness + Coating can be applied locally	+ Integrated process with short cycle times + Metal layer can be used to improve the mechanical properties
– Low Shielding compared to pure metal layers – High filler content leads to reduced flowability	– Additional pre-and post-treatment steps necessary – Layer application leads to dimensional inaccuracy	– Limited freedom of design – Inflexible – Finishing and automation necessary

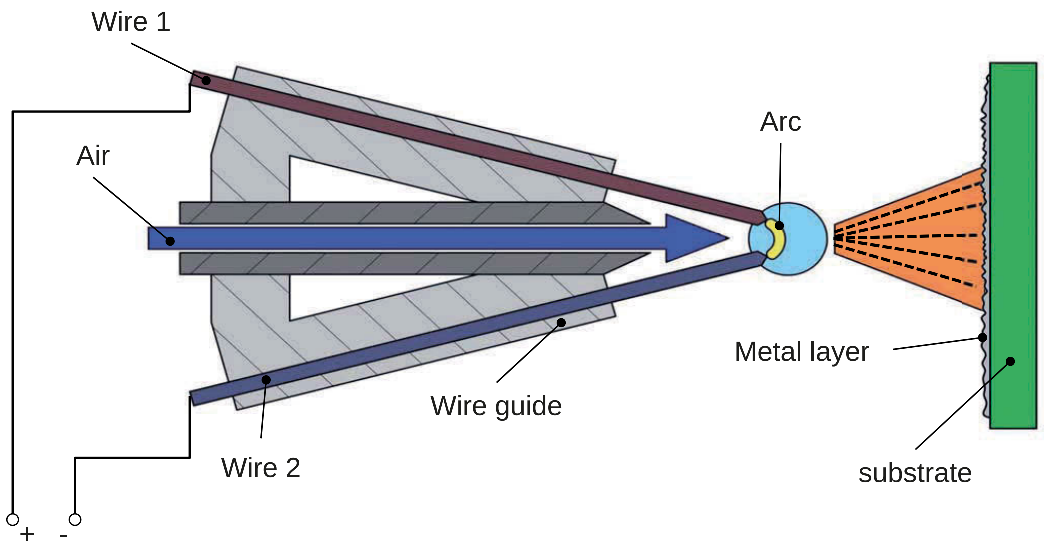
Beam attenuation through different metal layers at 30 Mhz



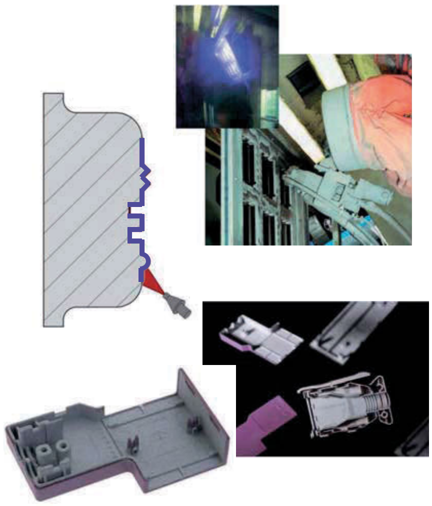
TS: Thermal Spraying
PVD: Physical Vapor Deposition

[Harting]

Principle of metal coating by arc spraying



Interim conclusion and motivation



[Harting KGaA]

Context

- There are several methods to improve the EMC of plastic components which have different restrictions.

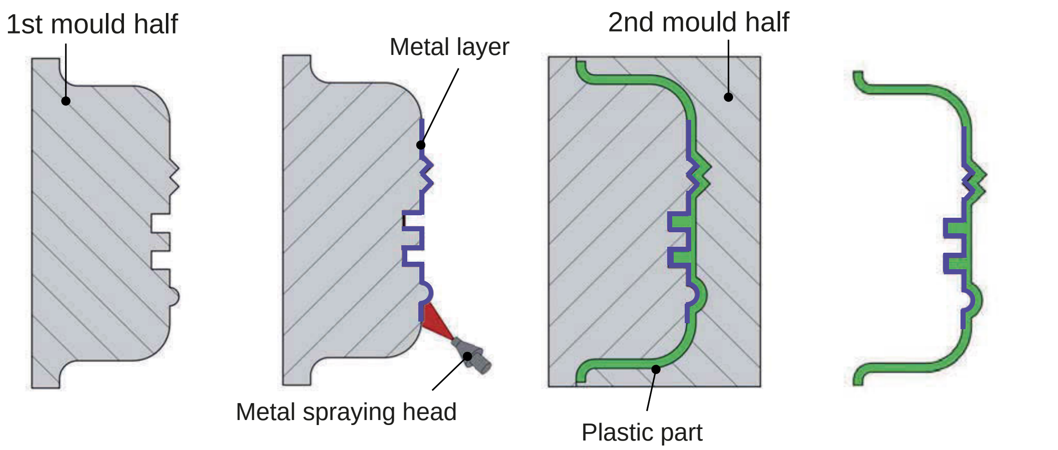
Objectives

- A method is developed that enables injection moulding components to be metallised economically and in the shortest possible cycle time in large-scale production.

Approach

- A method based on the thermal spray process and the injection moulding process is to be developed.

Procedure: In-Mould-Metal-Spraying (IMMS)



1. Open mould

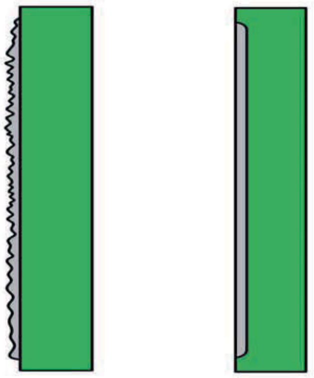
2. Spraying metal layer

3. Closing mould and overmoulding plastic

4. Demoulding with transferred coating

Advantages of the in-mold metal spraying

Different layer structures



layer structure thermal spraying

layer structure IMMS

Possibilities of IMMS

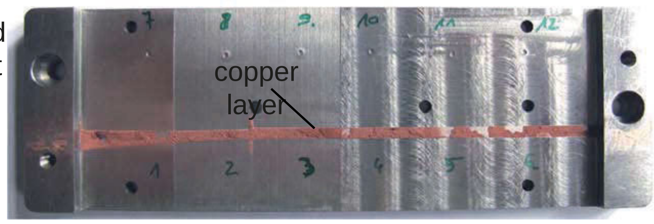
- The surface corresponds to the defined shape of the cavity of the mould.
- A variation of the layer thickness between 0.1 mm and 20 mm is possible.
- Over a range of 10 MHz to 1 GHz a attenuation between 70 and 110 dB is possible.
- The coating is resistant to corrosion.

Research topics

- Which mould surface is able to release the coated metal layer?
- Which thermal spray process enables the production of such a layer?
- Is it possible to predict transferability?

Preliminary experiments

Mould insert

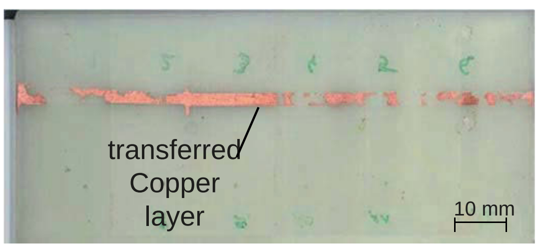


ground surface (manual)

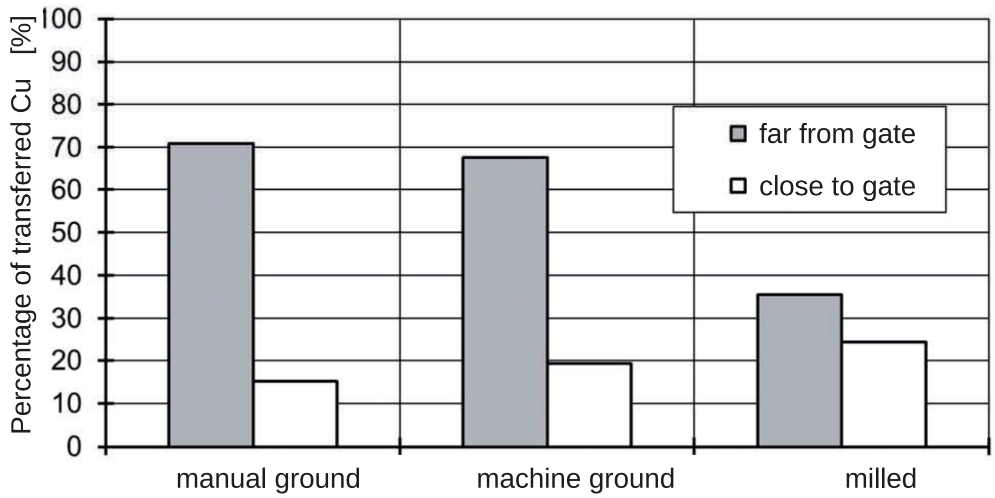
ground surface (machine)

milled surface

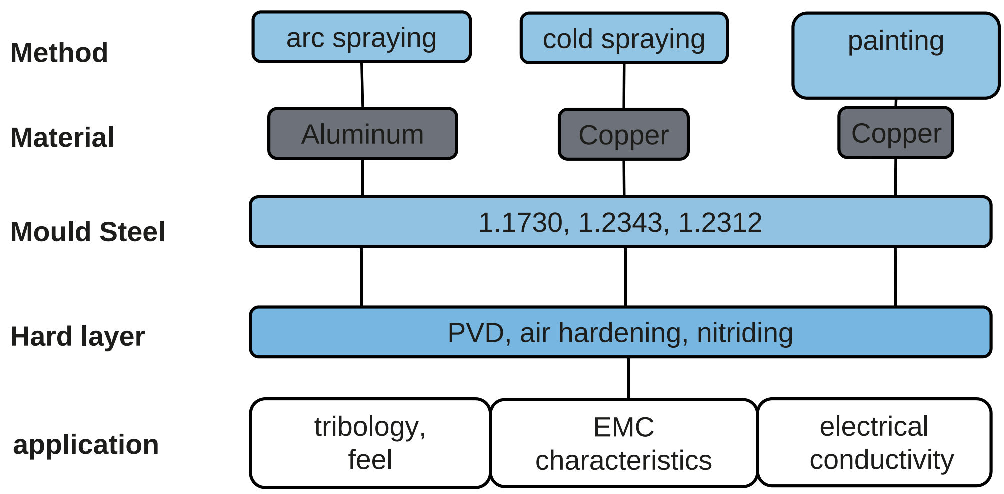
Plastic carrier



Transferred portion of the copper layer on the plastic carrier



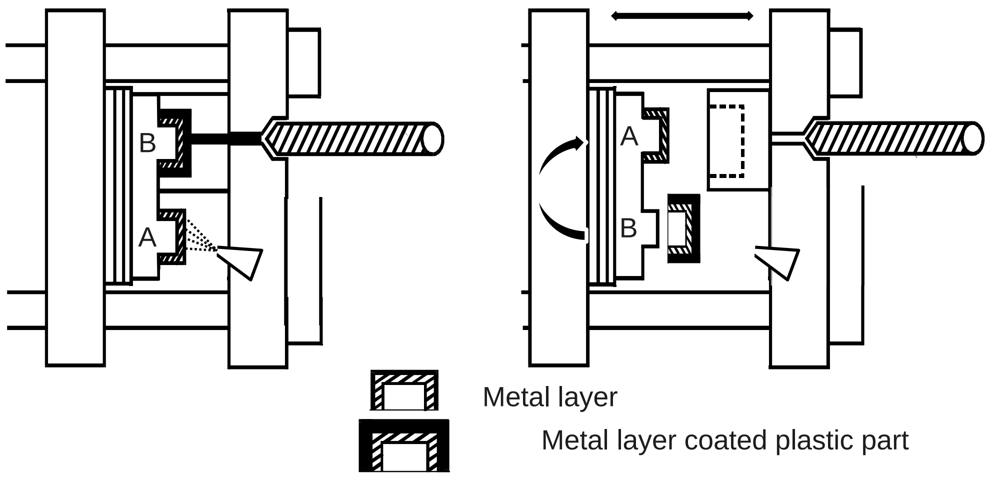
Next steps



Integrated moulding technology for the automated production of metallised plastic parts

A) Thermal spraying
B) Injection moulding

A) Rotation
B) Demoulding



Conclusion and outlook

- There are several methods to improve the EMC of plastic components.
- In thermal spraying coatings have a very good attenuation, but the surface properties of the components are changed.
- Based on a newly developed process the thermal spray shielding layers can be produced with exactly definded surfaces.
- The transfer of the copper layer depends on the surface and the distance from to the gate.
- An integrated moulding technology is to be developed.
- The transferrability is going to be predictable using mould filling simulation software.

Model-Based Assembly Control Concept

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Keywords:
model-based, engineering, control, automation

Abstract

Production cells are typically built up of many heterogeneous components which are controlled by a central unit such as a standard programmable logic controller. Engineering of such cell controllers is usually based on an imperative programming paradigm. All possible decision situations are defined manually and coded offline, which is an acceptable method for simple or fixed recurring automation tasks. Implementing complex control and adaptation strategies however leads to disproportionately high engineering efforts, which incur whenever process changes are required. The topic of the presentation is a model-based assembly control concept. The concept enables the use of degrees of freedom during the assembly process concerning the requests of the hardware and its reconfiguration, e.g. gripper changes. The advantage of the proposed concept is the flexible online combination of elementary actions instead of imperative coding of fixed control sequences. The model-based control operates on models, which are executed online in contrast to state-of-the-art model-to-code generation.

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Model-Based Assembly Control Concept

Cluster-Conferences 2013

Adam Malik

Aachen, 23./ 24. September 2013

Content

1 Assembly Example and Motivation

2 Control Concept and Validation

3 Conclusion and Outlook

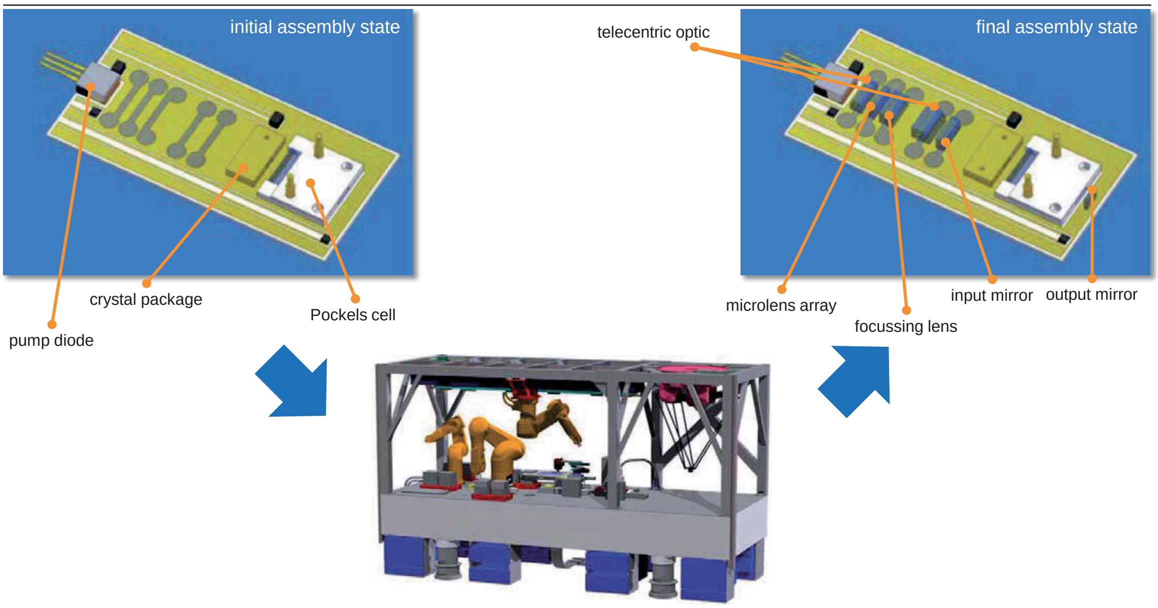
Content

1 Assembly Example and Motivation

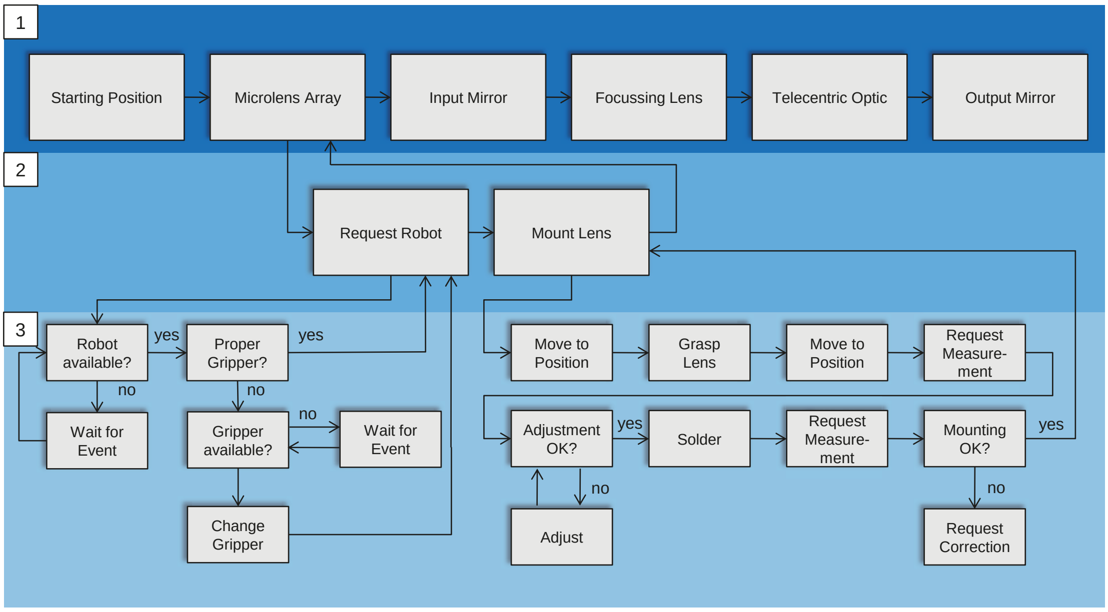
2 Control Concept and Validation

3 Conclusion and Outlook

Assembly Example and Motivation
Micro-Slab Laser Assembly



Assembly Example and Motivation
Micro-Slab Laser Assembly – Decision Situations



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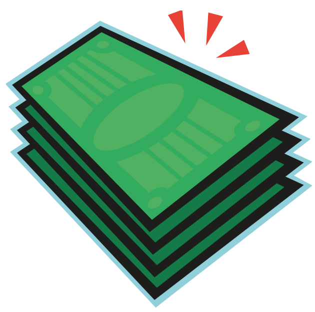
Assembly Example and Motivation
Disadvantages of Today‘s Automation

- Usually based on programmable logic controllers
- Imperative programming paradigm
- All decision situations manually defined and coded offline
- Acceptable for simple or fixed recurring automation tasks
- Disproportionately high engineering efforts in case of implementing complex control and adaptation strategies
- Engineering efforts incur whenever process changes are required



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Content

1 **Assembly Example and Motivation**

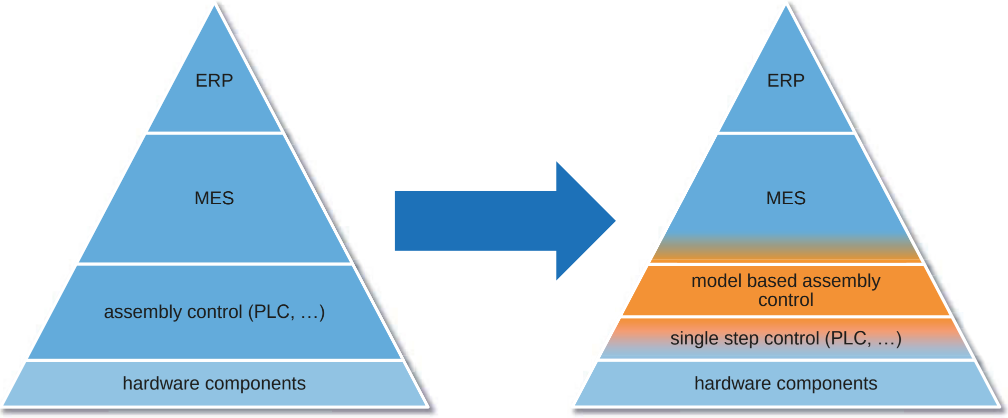
2 **Control Concept and Validation**

3 **Conclusion and Outlook**

Control Concept and Validation
Code Generation vs. Interpretation

- Model Driven Development
  - Paradigm which focuses on using abstract knowledge representation in the form of domain models
  - Domain models allow the separation of the problem specification from the implementation details
  - The best known realization is OMG MDA (Model Driven Architecture)
- Code generation
  - Model-based techniques are already used in control technology
  - The common way is the transformation of models into fixed control code
  - Code can be executed using e.g. programmable logic controllers or industrial PCs
- Interpretation and direct execution of models
  - Enabling dynamic re-planning of actions to be executed
  - Changes affect only the model and hence can be implemented more quickly
  - No recompilation and less testing of the software are needed
  - The model is interpreted at run time and can be modified at run time

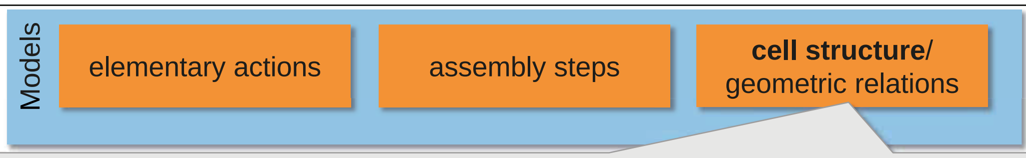
Control Concept and Validation
Model-Based Control as Superordinate Control



- Fixed control code
- Predefined control strategies
- Anticipated decision situations
- Whole control on PLC-level

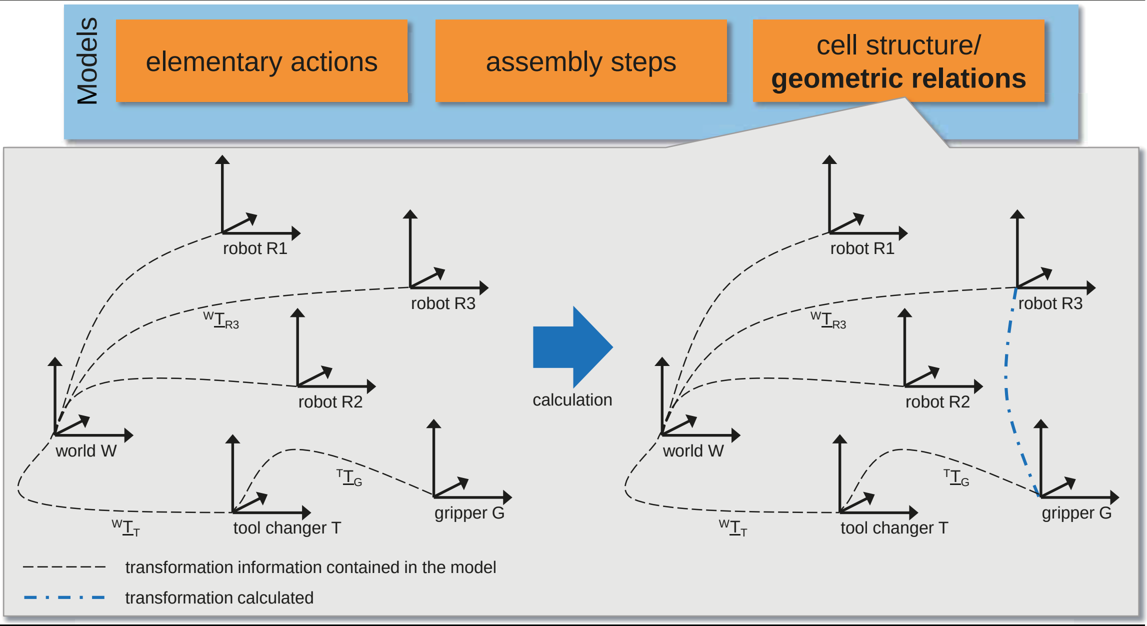
- Online-planning
- Flexible control strategies
- Online-decisions
- Only single steps on PLC-level

Control Concept and Validation
Cell Structure

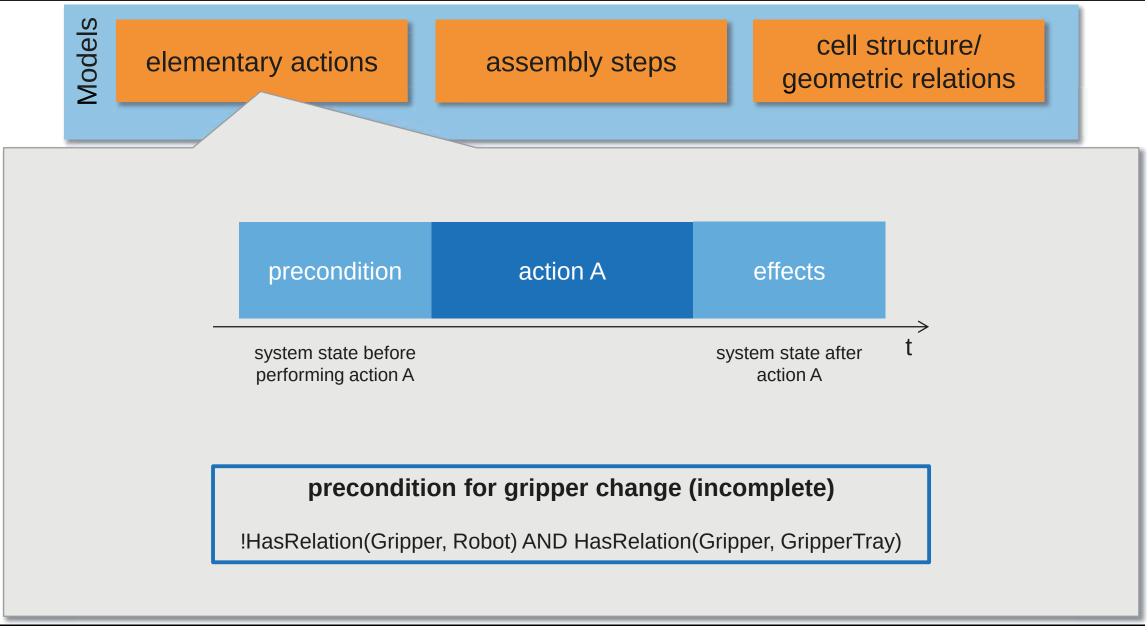


- Domain specific language
- Model elements
  - Component types
  - States of component type
  - Component type inheritance
  - Binary relations between components
  - Binary relation inheritance
  - Component instances
- Multiple inheritance allowed

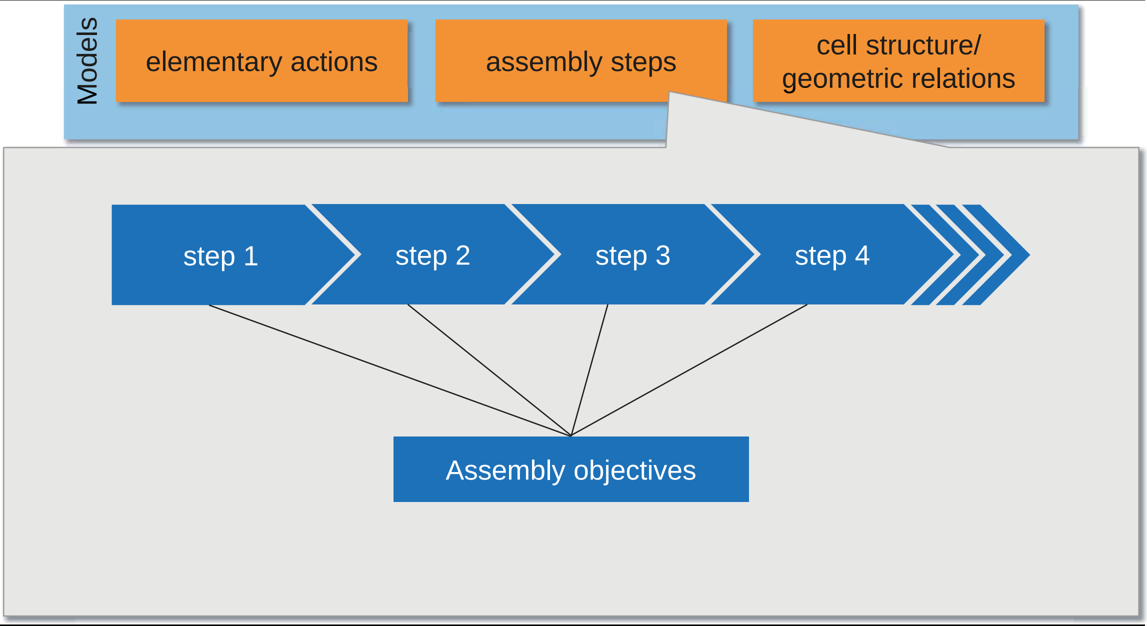
Control Concept and Validation
Geometrical Relations



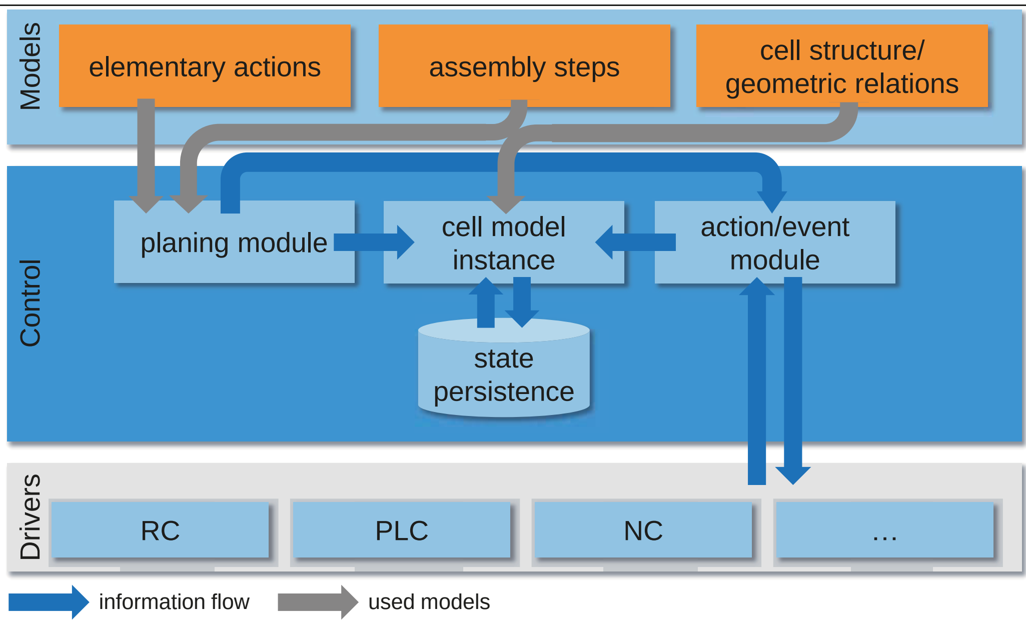
Control Concept and Validation
Elementary Actions



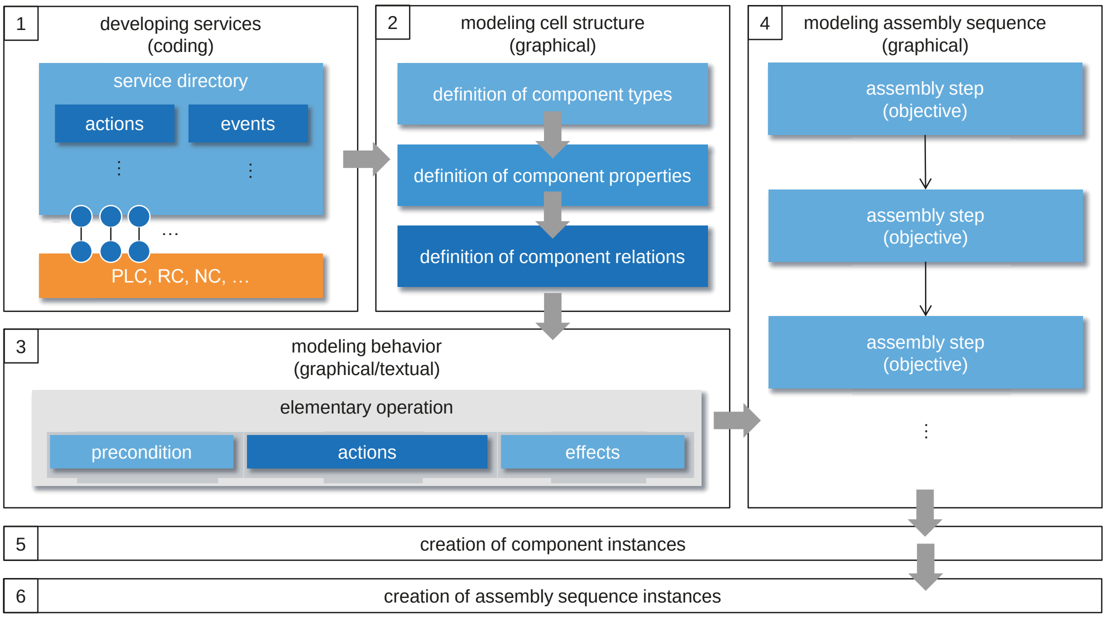
Control Concept and Validation
Assembly Steps



Control Concept and Validation
Logical Structure

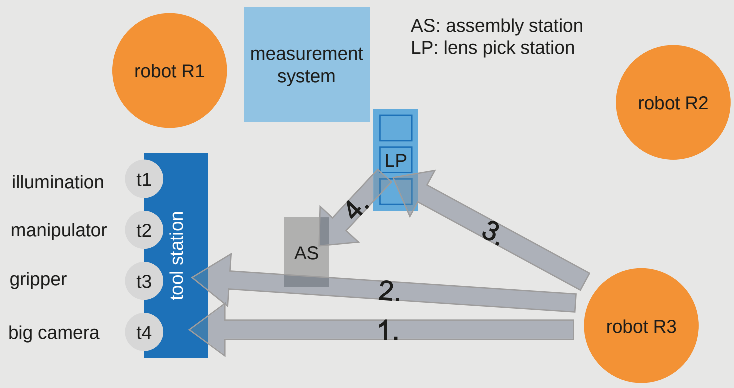


Control Concept and Validation
Engineering Methodology



Control Concept and Validation
Use Case

- Initial state: Robot R3 is holding the wrong tool
- Assembly task: Positioning of a lens on the slab using the gripper
- Required steps:
  1. put camera down
  2. take gripper
  3. pick lens
  4. position lens on slab



Content

1 **Assembly Example and Motivation**

2 **Control Concept and Validation**

3 **Conclusion and Outlook**

Conclusion and Outlook
Model-Based Assembly Control

- Advantages
  - Online action planning
  - Declarative description
  - Less manual coding
- Disadvantages
  - Subordinated controllers e.g. the PLC still have to be programed manually to offer services
  - Use of elementary robot moving commands (linear movement)
  - Modelling efforts
- Outlook
  - Validation by more complex assembly use cases in order to test the computation times during the action sequence planning
  - Further planning approach for the assembly of products with a variable assembly sequence depending on e.g. measuring results
  - An automatic PLC code skeletons generation based on a service definition
  - Automated model building based on hardware self-description

Influence of surface pre-treatment on the transferability of Zn-EMC-coatings

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Keywords:
EMC coatings, wire arc spraying, injection moulding

Abstract

Plastic injection molded parts offer various advantages regarding the weight reduction, production costs and design diversity. However, they are not capable of offering electromagnetic compatibility (EMC) as the non-conductive plastic part cannot work as a shield against electrical radiation disturbance. To functionalize injection molded plastic parts for EMC purposes, these can be coated with electrical conductive metals like zinc. To apply a zinc coating onto plastic parts, injection mould inserts were coated by means of wire arc spraying and subsequently the coatings were transferred onto the injected polymer. The mould inserts were roughened by grinding and by grit blasting using different types of grit material. The obtained surface topography was analyzed by means of confocal laser microscopy. The achieved topography influences the bond strength of the applied zinc coating and consequently the transferability of the coating onto the injected plastic significantly. A high roughness of the injection mould insert lead to an adherent coating which cannot be transferred, whereas the coating deposited on a surface with a low roughness did not adhere to the surface preventing a processability using injection moulding. The surface topography had to be well adjusted depending on the hardness of the mould insert to allow good transferability of the EMC coating.

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DE000001948639 A: Verfahren zum Herstellen von Kunststoffteilen mit einem Metallüberzug (Method to Produce Plastic Parts with Metal Coatings) (1969), Leslie, E., Edwin, M. R, in German

Ehrenstein, G. W.: Handbuch Kunststoff-Verbindungstechnik. Carl Hanser Verlag, München 2004

Influence of Surface Pre-Treatment on the Transferability of Zn-EMC-Coatings (ICD C-3)

Cluster-Conferences 2013

Dipl.-Ing. Christiane Schulz

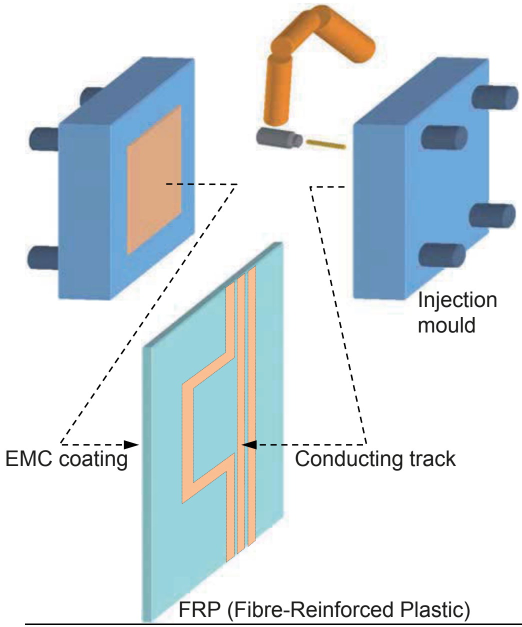
Aachen, den 23./ 24. September 2013

Agenda

[greenasathistle.com]

- EMC Coatings
- Wire Arc Spraying
- Surface Topography Parameters
- Surface Pre-Treatment
- Bond Strength
- Results
- Summary
- Outlook

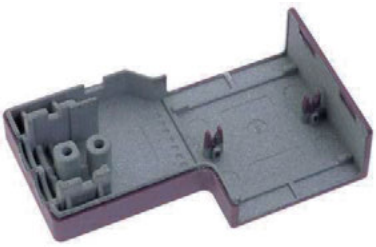
Objective



In-Mould Metal Spraying Process (IMMS)

- Thermal spraying of metals directly onto the injection mould insert surface (carrier body)
- Transfer of metal layer onto injection moulded FRP (Fibre-Reinforced Plastic) parts
- Integration of electrical functionality
  - Conducting tracks
  - EMC coatings (electromagnetic compatibility)

EMC-Coatings



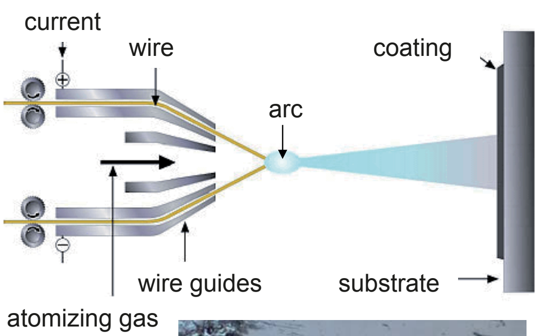
[Harting GmbH & Co. KG]

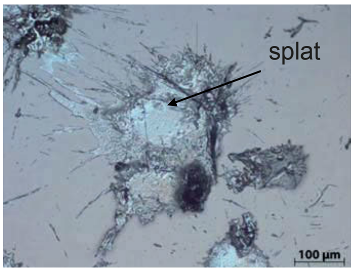
- ElectroMagnetic Compatibility (EMC)
- Prevention of emission and absorption of electromagnetic waves
- Plastic parts not capable of offering EMC protection
  ➔ Electrically conductive coating
- Materials used: Cu, Al, Ag, Ni, Zn
- Todays coating processes
  – Electroplating (only applicable for ABS plastics)
  – PVD (restrictions for plastic material)
  – Wire arc spraying directly onto plastic part (rough surface)

➔ New approach:

Coating of mould insert, transferring coating onto plastic part

Wire Arc Spraying





- Thermal Spray process
- Applicable for electrical conductive materials
- Feedstock material: two massive or cored wires (∅1.6 – 5 mm)
- Arc is ignited between wire tips
- Molten droplets are propelled towards substrate by atomizing gas (e.g. compressed air or N_2)
- Coating is formed by overlaying splats
- Process characteristics:
  – Particle velocity ~150 m/s
  – Arc temperature: 4000-5000 °C
  – Most economical thermal spray process

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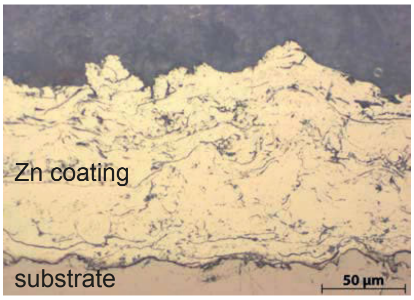
Wire arc sprayed Zn-coating



- Coating characteristics
  – Porous structure (5-15 %)
  – Bond strength (5-8 MPa)
    Grit blasting corundum (EKF 16)
- Applications for arc sprayed Zn:
  – Cathodic corrosion protection
    ▪ Bridges
    ▪ Offshore Wind Energy Towers
    ▪ Reinforcements in concrete contacted with Zn as sacrificial anode
  – Contact area of capacitors
  – EMC

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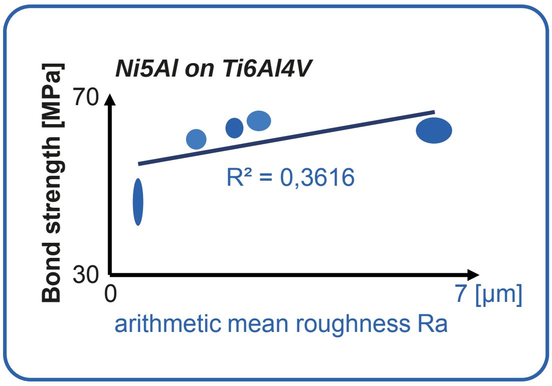
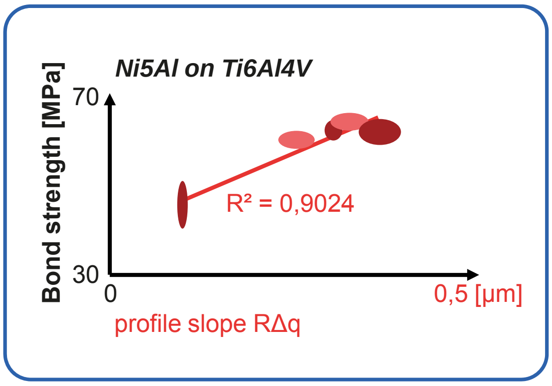
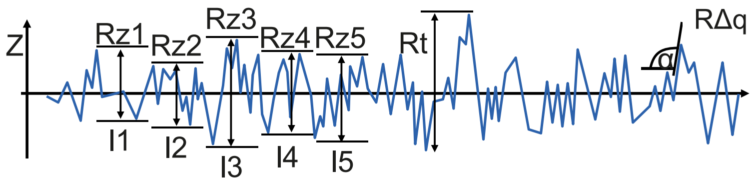
Relationship Between Roughness Parameters and Bond Strength







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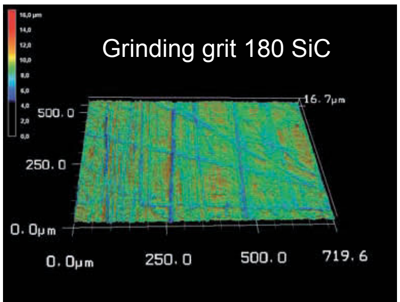
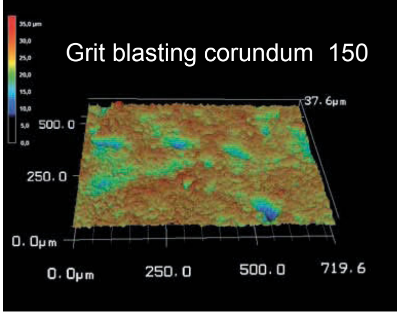
Surface Pre-Treatment





- Manual grinding
  - Variation of grit size
    - 400 (fine)
    - 80 (rough)
- Grit blasting
  - Variation of material
    - Corundum (spattered, 63-90 µm (F150))
    - Glass beads (spherical, 90-150 µm)
- Milling

Surface Preparation – Manual grinding

- Sandpaper grit 400 SiC
  - Coating delaminates during spraying, no coherent coating

- Sandpaper grit 180 SiC
  - Coating almost delaminates, but coherent coating

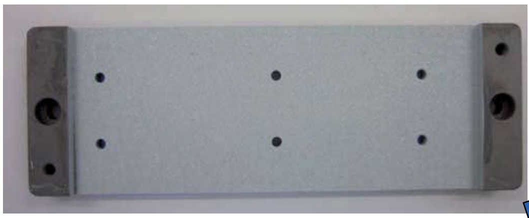
- Sandpaper grit 80 SiC
  - Adherent coating, little delamination

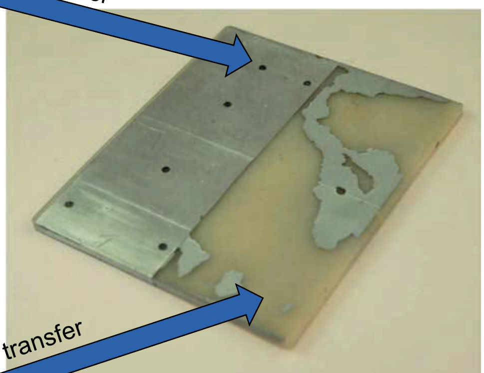
Bond strength has to be high enough to allow coating to adhere to mould insert!

Influence of Surface Pre-Treatment on Transferabiliy

Manual ground grit 180 SiC

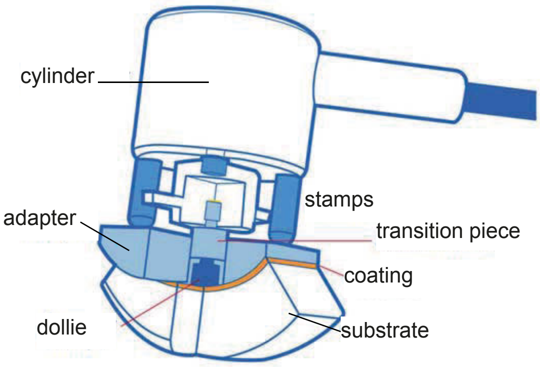
Grit blasted with corundum 150 (63 - 90 µm)





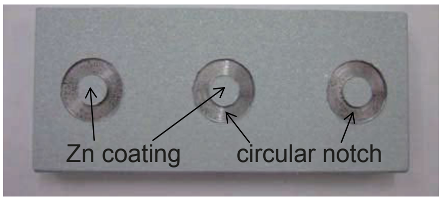
Bond strength has to be low enough to allow tranfer of coating onto polymer!

Bond Strength Test (PAThandy)



- Milling of circular notch into coating
- Dollies glued onto coating (3 per coating)
- Coating pull off
- Record of bond strength and failure mode (adhesive, cohesive, glue failure)

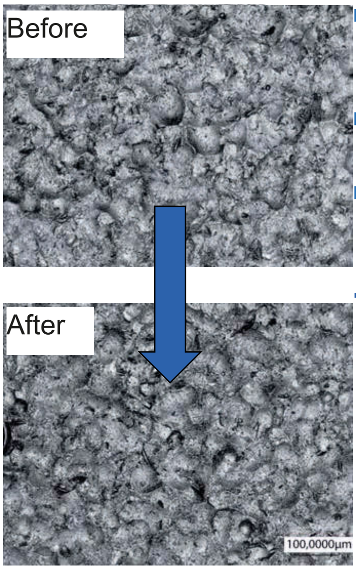
Bond Strength Test on carrier body 1.1730



- Corundum blasting (63 - 90 µm)
  - Mean bond strength 6 MPa
- Glass bead blasting (90 - 150 µm)
  - Coating delamination due to preparation for bond strength test
  - Bond strength not quantifiable (< 6 MPa)
- Sandpaper ground (grit 80 SiC)
  - Coating delamination due to preparation for bond strength test
  - Bond strength not quantifiable (< 6 MPa)
  - breakouts

Surface Condition Before and After Pull off

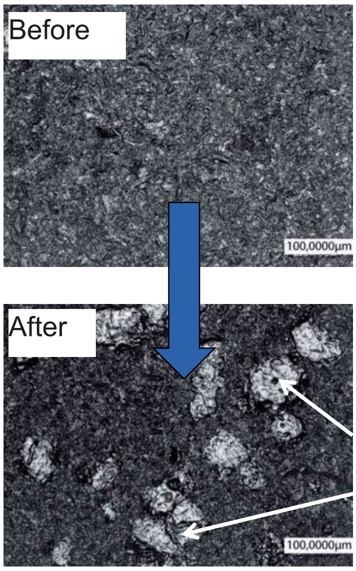
1.1730 glass bead blasted



- Complete coating delamination
- No adherent zinc splats
- Topography seems unchanged

→ Mould insert might be used without further treatment

1.1730 corundum blasted



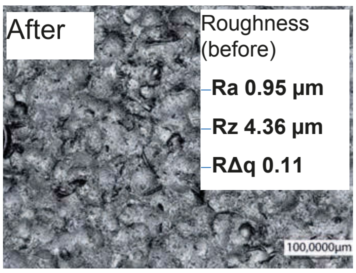
- Some zinc splats did not delaminate

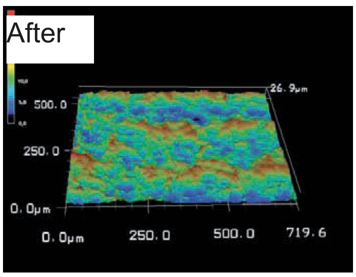
→ Mould must be grit blasted prior to further use

Zinc splats

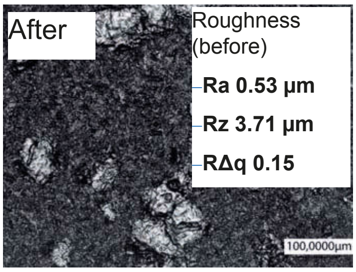
Surface Condition After Pull off

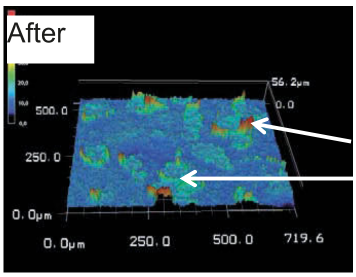
1.1730 glass bead blasted





1.1730 corundum blasted



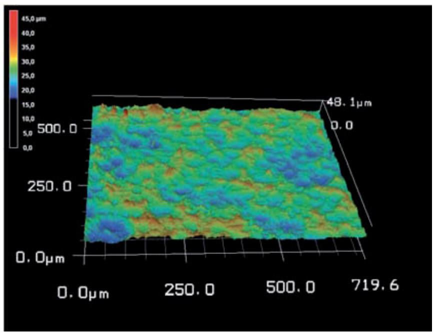


- Surface topography influences bond strength significantly
- Lower Ra and Rz do not lead to lower bond strength
- Ra and Rz are not sufficient for describing surface topography

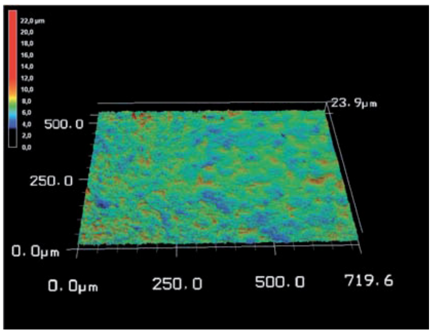
→ RΔq might show better correlation

Zinc splats

Surface Pre-Treatment – Influence of Material Hardness

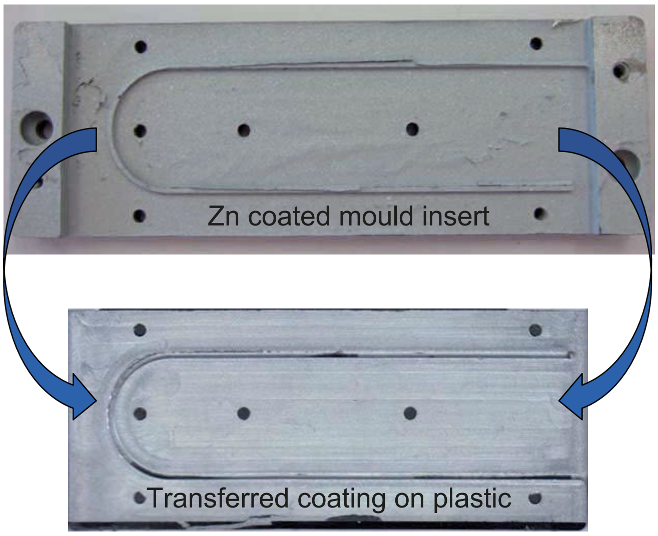


- Material 1.1730, 273 HV0.1
- Glass bead blasting
- Roughness parameters
  - Ra 0.95 µm
  - Rz 4.36 µm → Zn adheres to mould insert
  - RΔq 0.11



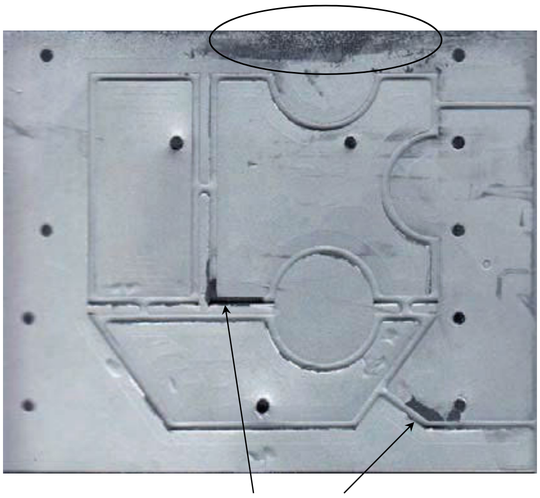
- hardened steel (unknown), ~650 HV0.1
- Glass bead blasting
- Roughness parameters
  - Ra 0.21 µm
  - Rz 1.51 µm → No adhesion
  - RΔq 0.09

Results – Coating Transfer of Complex Shaped Forms



- No surface pre-treatment!
- > 95 % of Zn coating tranferred
- Milling tracks provide sufficient adhesion

Results –Transferred IKV Logo



First approach: no surface pre-treatment (milling tracks)

➔ No coating adhesion on mould insert

Second approach:

➔ Surface pre-treatment: glass beads (milling grooves still visible)

➔ sufficient coating adhesion

- > 95 % of Zn coating is transferred onto injected polymer
- Holidays in sharp edges and corners
- Prevention
  - Rounded corners
  - Parameters adjusted to geometry

Summary

- Grit blasting using glass beads (90-150 µm) leads to topography which shows good results in first tests regarding transferability
- Surface pre-treatment has to be adjusted depending on hardness of mould insert
- Achieved topography influences bond strength and consequently transferability
- Carrier body topographies (amount of asperities, slope of asperities and undercuts) need to be described with further suitable parameters (RΔq might be promising)
- Required bond strength for coating transfer x < 6 MPa

Outlook

- Investigation of EMC properties
- Variation of coating thickness
- Variation of coating material (Al, Cu)
- Reducing oxidation of coating by means of nitrogen as atomizing gas
- Investigation of further surface topographies
- Investigation of relationship between surface pre-treatment, roughness parameters and bond strength
- Identification of more suitable roughness parameter; ISO 25178 takes 3D surface texture into account
- Haptic properties for “cool touch effect” (analysis of transferred coating)
- Specification for successful transferability (max/min bond strength)

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Slide 18

Determination of process variables in CO2 lasercutting and GMA welding

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Keywords:
process emission, laser cutting, gas metal arc welding, product quality, surrogate modeling

Abstract

Measurement of process variables is key for self-optimization of manufacturing processes. Within the Cluster of Excellence at RWTH Aachen University, several achievements were made in setting up sensor systems that provide novel information on the operating points of melt based manufacturing processes. These achievements contribute to a gradual increase in system transparency which is seen as an enabler for self-optimization.

In laser cutting of sheet metal, the process of melting metal and ejecting it from the kerf influences product quality. A sensor system for process observation has been implemented which is coupled coaxially to the processing laser beam. This system delivers an image from the zone of laser material interaction allowing the detection of thermal emission. The acquired image of the thermal emission is used to extract surrogate criteria which can be correlated to process variables [1][2][3]. By this, information is gained which helps determining process variables of the current process.

In GMA welding, product quality settles in the process of melting a fillet wire with electrical power resulting in a specific weld seam geometry. This process can be observed by measuring current, voltage and properties of the meltpool. This information is used to extract surrogate criteria which are correlated to product quality.

Both works show how process measurands are used to determine process variables which cannot be measured directly. The work on deriving surrogate criteria shows to add transparency to the manufacturing processes and therefore to the transparency of the overall manufacturing systems

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Determination of process variables in CO_2 lasercutting and GMA welding

Ulrich Thombansen

Thombansen, Ulrich [1]; Purrio, Marion [4]; Buchholz, Guido [4]; Hermanns, Torsten [3]; Molitor, Thomas [2]; Willms, Konrad [4]; Schulz, Wolfgang [3]; Reisgen, Uwe [4]

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Content

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Measurement of process variables in melt based manufacturing processes

- Requirements from the approach of model based self optimisation for manufacturing processes
- Pulsed gas metal arc welding
- Lasercutting
- Resumee

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Content

Measurement of process variables in melt based manufacturing processes

- Requirements from the approach of model based self optimisation for manufacturing processes
- Pulsed gas metal arc welding
- Lasercutting
- Resumee

Self-Optimising Manufacturing Systems – Scope

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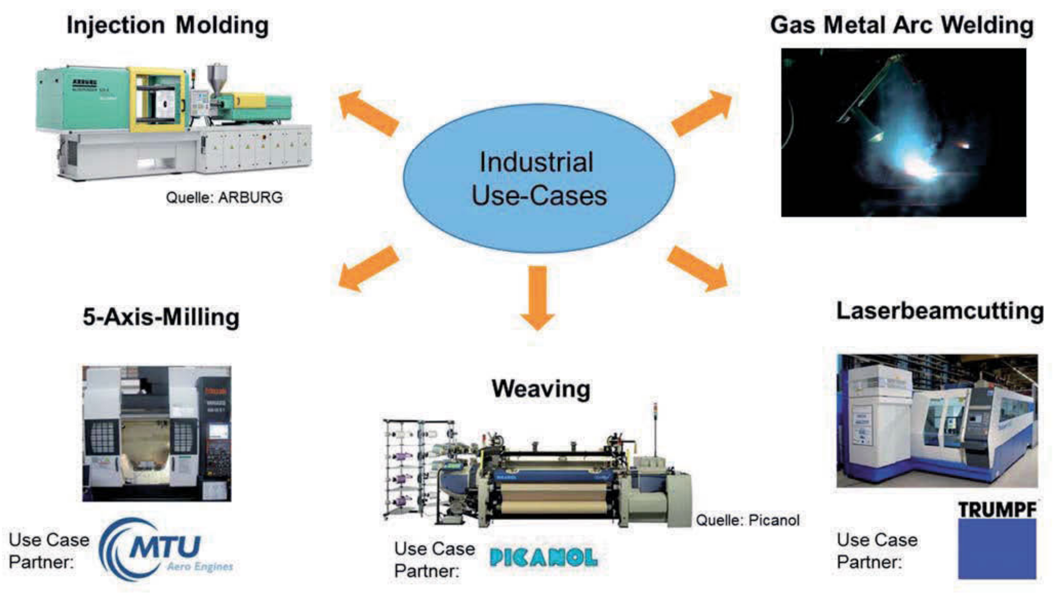

Self-Optimising Manufacturing Systems – Objectives

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Transformation

Base Material

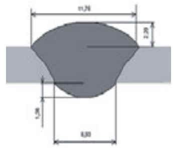
Manufacturing System
-Machine
-Process
-Control

Manufactured Product

Objective: Product Quality (PQ)

- Primary Technical Quality
  - Laserbeamcutting: roughness of cut-face
  - GMA Welding: joint geometry
- Primary Economic Quality
  - Rigging and Set-Up Resources
  - Processing Resources
  - Handling Resources
  - Manufacturing Duration
  - Scrap-Rate

PQ in Lasercutting
Roughness of
Cut-Face



PQ in GMA-Welding
Geometry of
Welding-Joint

Self-Optimising Manufacturing Systems – Approach

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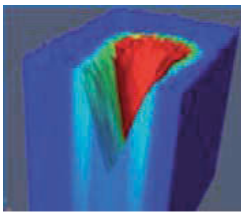
Generation of Process Knowledge

Generation of Meta-Model

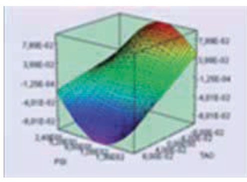
Implementation of Self-Optimisation

Simulation



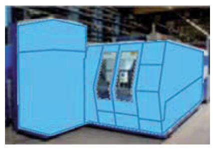
Experiment

Interpolation



Evaluation

Cognition & Optimisation



Self-Optimising Manufacturing Systems – Hypothesis

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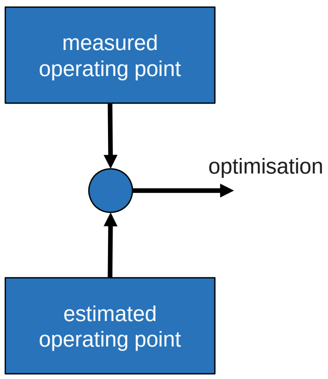

- Executing control on a system where the manufaturing result/quality cannot be observed directly
  - Criterion which determines quality cannot be measured during processing
  - Manufacturing result settles after a time delay
  - Transfer function from setting parameter to product quality cannot be determined a priori
- Approach
  - Provide a surrogate criterion to correlate a measurand to process variables
  - Enable the manufacturing system to determine the operating point
  - Optimise setting parameters

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Seite 6

Content

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Measurement of process variables in melt based manufacturing processes

- Requirements from the approach of model based self optimisation for manufacturing processes
- Pulsed gas metal arc welding
- Lasercutting
- Resumee

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Seite 7

Pulsed Gas Metal Arc Welding – Application

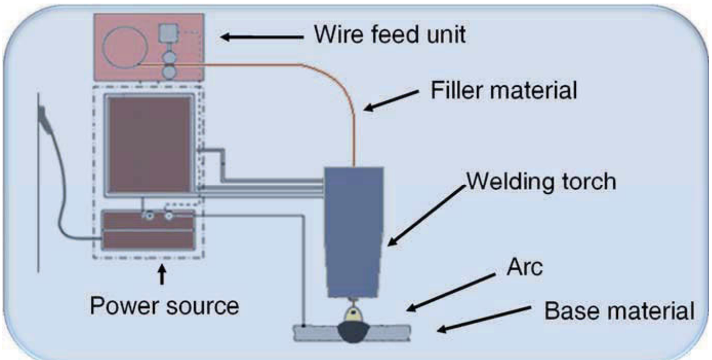
Pulsed gas metal arc welding process

Highly flexible process

Potential for individual products with high-quality weld geometry joints

Setting Parameters (SP)
pulse parameters, nozzle distance, wire feed rate, material feed-rate, gas flow volume

Process Variables (PV)
feed rate, weld pool geometry, energy deposition per unit length, material transfer



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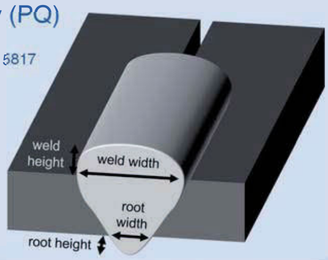
Pulsed Gas Metal Arc Welding – Process Characteristic

Product quality (PQ)

according to DIN EN ISO 5817



Process variables (PV):
gap width due to positioning faults or thermal distortion, material feed rate, current, voltage

Weld geometries over gap width

Gap 1.0mm Gap 1.7mm Gap 2.9mm

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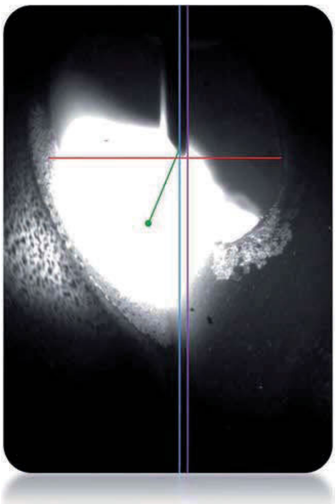
Pulsed Gas Metal Arc Welding – Experimental Setup

Initial situation

- In situ sensor information for direct process monitoring are not available
  - Pre – no control regarding the influences of the process
  - Post – only information about postprocessing gainable

Challenges

- Realisation of a machine vision system for an online weld pool observation for pulsed gas metal arc welding
- Implementation of optical system
- Development of image processing algorithms



Application example

- Spray-arc on fillet weld
- Analysed characteristics:
  - Gap position
  - Wire position
  - Weld pool boundary

Deduced information

- Properties of the weld pool like weld pool width (quality criterion)
- Position of the torch relative to the gap

Content

Measurement of process variables in melt based manufacturing processes

- Requirements from the approach of model based self optimisation for manufacturing processes
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- Resumee

Lasercutting – Application

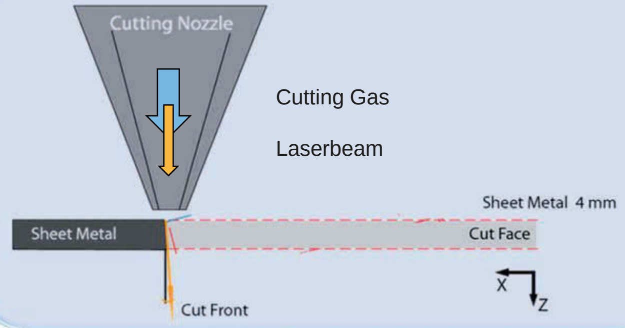
Lasercutting

Industry's primary process for metal sheet cutting

Potential for high quality individualised manufacturing of plane freeform parts

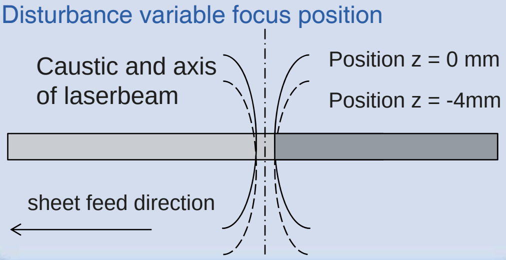
Setting Parameters (SP)
laser power, feed rate, gas pressure, nozzle diameter

Process Variables (PV)
focus positon, energy absorption, gas flow, melt film forces, kerf width



Lasercutting – Process Characteristcs

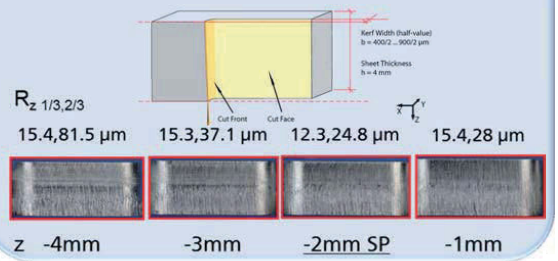
Disturbance variable focus position



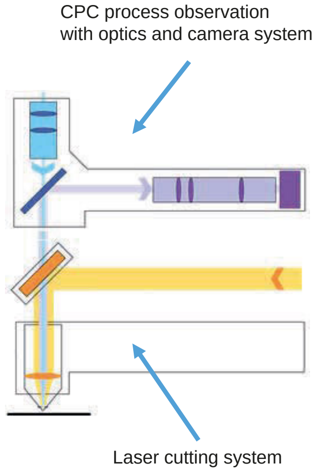
Product quality
- Roughness
- Dross
- Striation

Process Variables (PV) :
focus positon, energy absorption, gas flow, melt film forces, kerf width

Roughness of the cut-face over focus position



Lasercutting – Experimental Setup



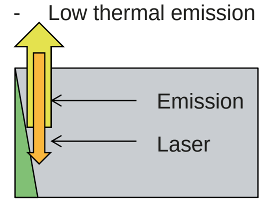
Sketch of the process observation system or laser cutting with coaxial process control parts (CPC)

Process observation in CO_2 Lasercutting

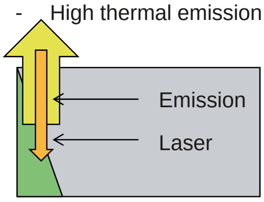
- Process observation
  - Optical system for coaxial process monitoring
  - 4kHz imaging system
- Coupling of processing beam and observation
  - Beamsplitter for CO_2 radiation and thermal radiation
  - Observation of the interaction zone
- Detection of properties
  - Thermal emission radiated through the surface plane as a surrogate for current state of the process

Lasercutting – Measuring Process Variables

Low feed rate
- Low absorption
- Low thermal emission



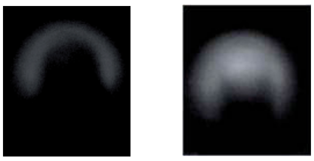
High feed rate
- High absorption
- High thermal emission



Detecting and analysing process emission as a surrogate for process variables (PV)

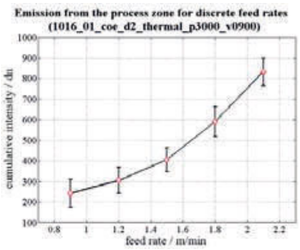
- Emission establishes in interaction with
  - Laserbeam properties like caustic and power
  - Transport properties inside the kerf (gas jet, melt)
  - Machine properties like feed rate
- Influenced through setting parameters (SP)
  - Feed rate
  - Laser power
  - Focus position
- Results in product quality (PQ)
  - Roughness of the cut face
  - Operating point

Lasercutting – Data from process observation



Vf = 0.9 m/min Vf = 2.1 m/min

Images showing the thermal emission from the Interaction zone for different feed rates



Normalised realtionship between emitted radiation and feed rate

Analysing acquired signals

- Images from the experiment with feed rate variation
  - Increased amount of radiation for higher feed rates
- Detected emission from the cut front
  - Integrated intensity on the sensor
  - Error bars cover 2000 consecutive measurements

→Relationship intensity ./. feed rate shown by imaging system
→Variation in feed rate can be correlated to intensity

Content

Measurement of process variables in melt based manufacturing processes

- Requirements from the approach of model based self optimisation for manufacturing processes
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- Resumee

Resumee

- Measuring process variables in melt based manufacturing processes
  - Use surrogate criterion
  - Bridge between process variables and measurands
  - Reduce process models to allow fast numerical computation

- Self-Optimisation of manufacturing systems
  - Measure surrogate criteria to gain information about the operating point
  - Use process knowledge to take the actions required to optimise the operating point

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at RWTH Aachen

DFG Deutsche Forschungsgemeinschaft

Hyperslice Visualization of Metamodels for Manufacturing Processes

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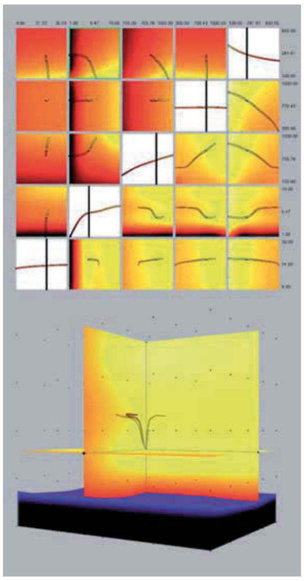
Keywords:
visualization, multi-dimensional data, simulation output analysis, hyperslices

Abstract

In modeling and simulation of manufacturing processes, complex models are used to examine and understand the behavior and properties of the product or process. Computer simulations allow for fast investigation of a large number of alternative designs. This helps to identify optimal designs for improving the process. However, every single simulation can take up to several hours or even days. Thus, in order to reduce the computation time, global approximation models are constructed to serve as surrogates for the original complex models and are often referred to as metamodels. These are multi-dimensional in input and output and often have complex parameter interdependencies and are, thus, hard to understand. Specialized visualizations can greatly help in exploring and understanding them. Therefore, we created an application that provides different possibilities of exploring such multi-dimensional metamodels. We combined hyperslices with direct volume rendering and added further aids for better understanding. This includes navigation along trajectories which are traced along the gradient of the data field to easily navigate between minima and maxima. Additionally training points of metamodels can be displayed what helps metamodel-creators in understanding their creation process.



Hyperslice Visualization of Metamodels for Manufacturing Processes

Sascha Gebhardt

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Machine Configuration

- Complex configuration of machines for manufacturing processes
- Laser cutting: critical criteria like quality or speed affected by various configuration parameters
- Planning of whole factories also affected by criteria like speed

[www.de.trumpf.com]

Metamodels for Manufacturing Processes

- Complex models used in modeling and simulation of manufactoring processes
- Computer simulations used for fast investigation of alternative designs
- Problem: simulations can take up to hours or days
- Solution: construction of approximation models → metamodels
  - $f(\vec{x}): \mathbb{R}^n \rightarrow \mathbb{R}^m$
  - discrete sampling of the dataspace
  - interpolation via radial basis function networks

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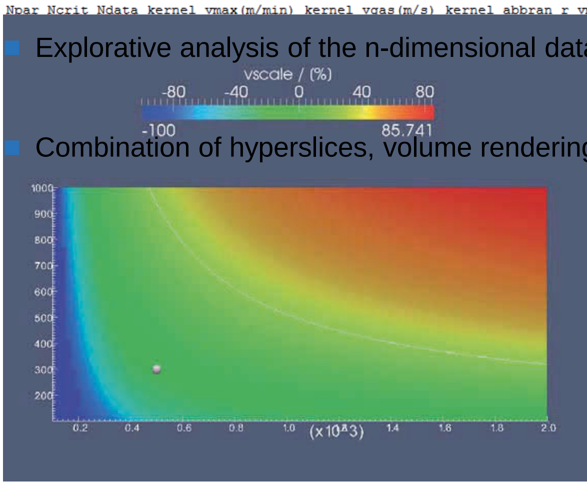
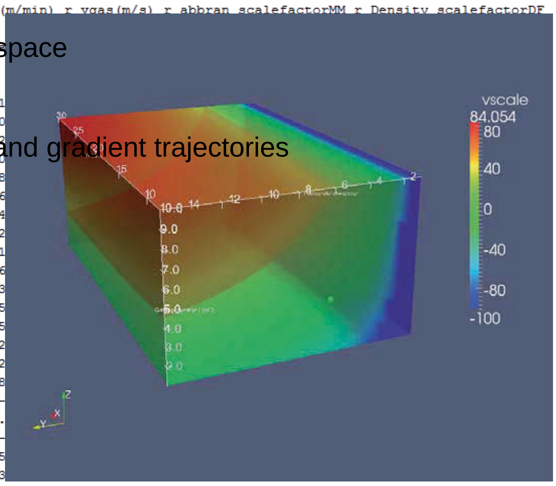
How to Analyze Metamodels

- Functions of the form $f(\vec{x}): \mathbb{R}^n \rightarrow \mathbb{R}^m$ as radial basis function networks

```
p_gas(bar) d_noz(mm) T_gas(K) T_mat(°C) d_mat(mm) v_cut(m/min) v_gas(m/s) burnup Density
Npar Ncrit Ndata kernel vmax(m/min) kernel vgas(m/s) kernel abbran r vmax(m/min) r vgas(m/s) r abbran scalefactorMM r Density scalefactorDF
```

- Explorative analysis of the n-dimensional data space
- Combination of hyperslices, volume rendering and gradient trajectories





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24.5 15 100 300 100 0.013199570562831244164 0.02010347494186799297 0.011546594231013175905 0.39349363571154860608
30 15 100 300 100 0.01921258259690960743 0.056386748114438452195 0.00059050875264410687421 0.49038063812819743248
8 1 325 300 100 0.1184757150070866738 0.093401500436106649206 0.1454468990680906626 0.39349363571155954178
13.5 1 325 300 100 0.073009315965445464869 0.066413411000950425822 0.10695656172171523479 0.31573204704357310524
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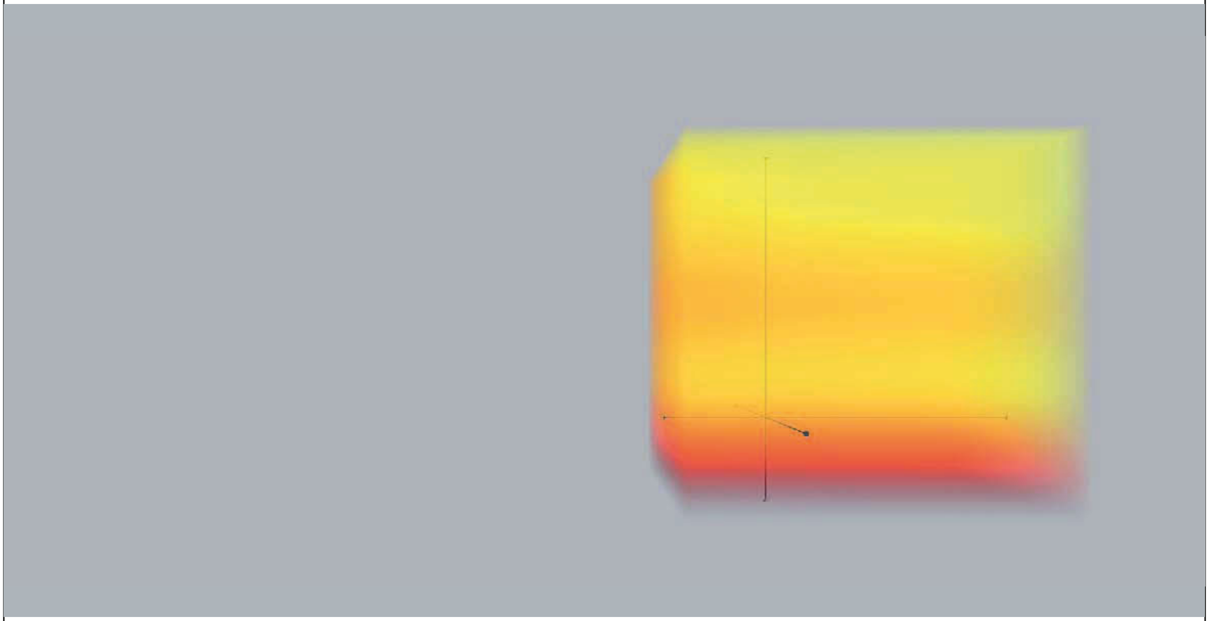
24.5 1 325 300 100 0.070270929699595599538 0.063816096068159952615 0.099133859729011369888 0.31573204704357088479
30 1 325 300 100 0.13572856465336055609 0.12389568157534956716 0.14091505781362625993 0.39349363571155387964
```

Hyperslices and Other Features



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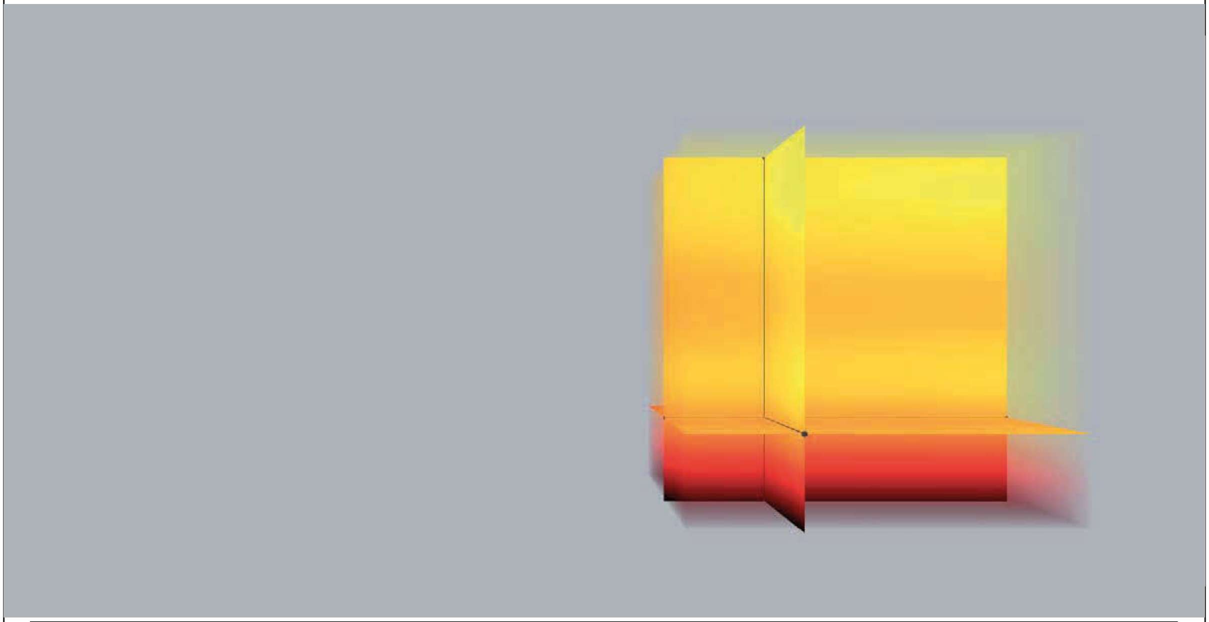
Hyperslices and Other Features



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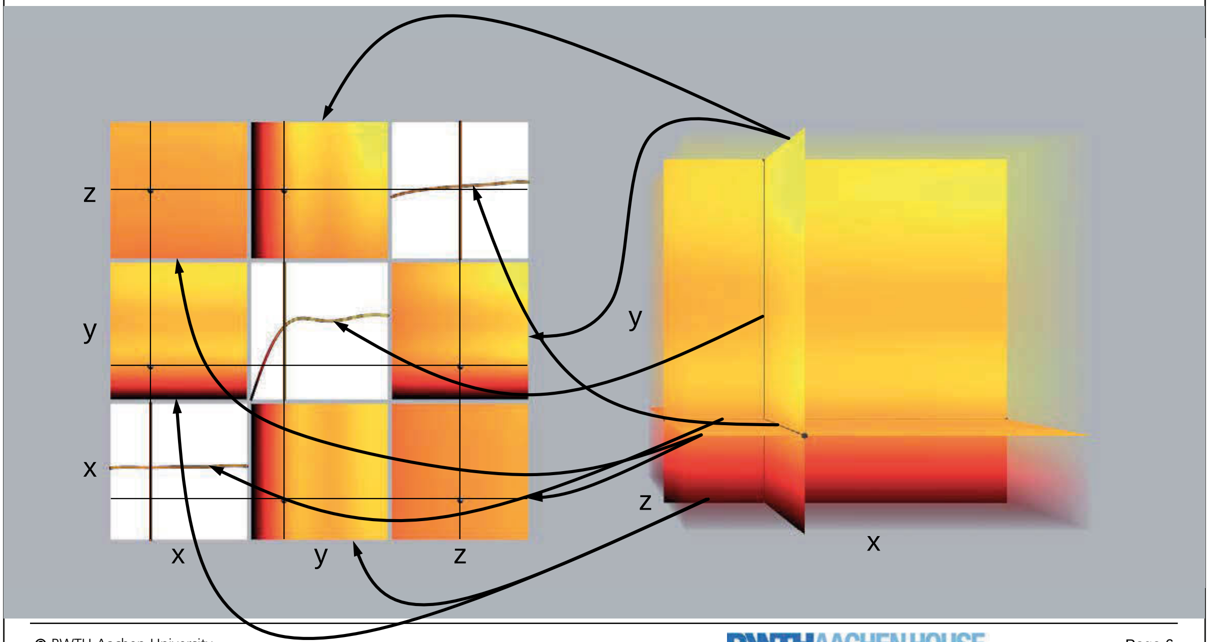
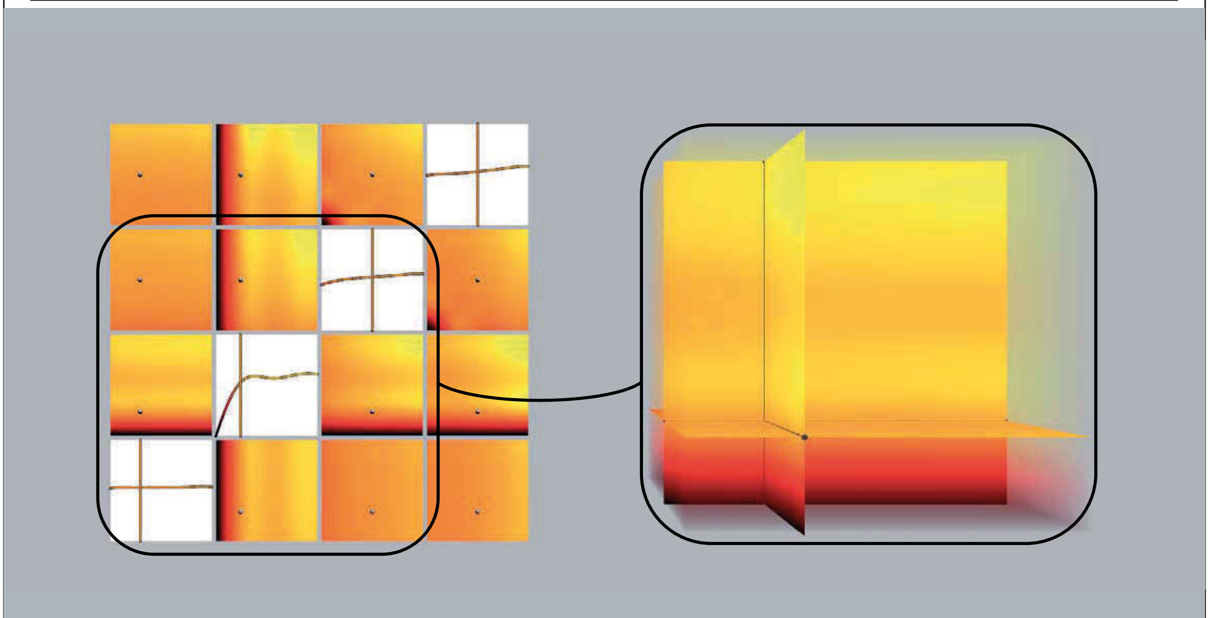
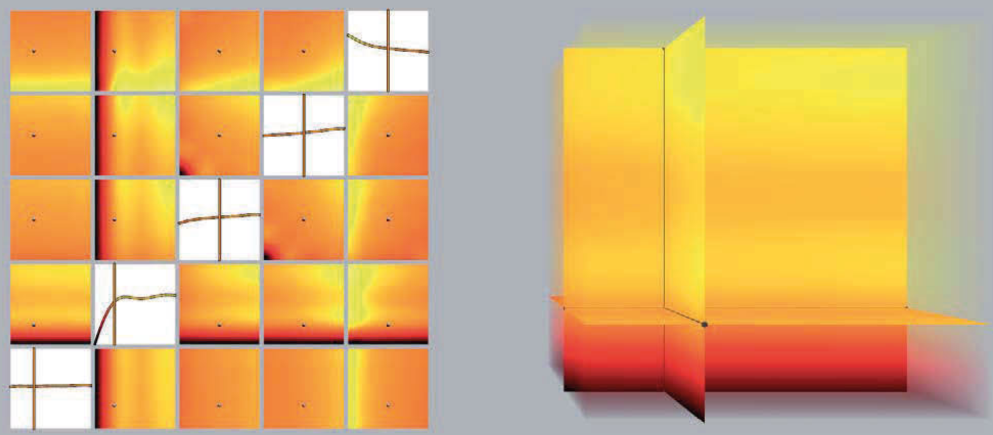
Hyperslices and Other Features



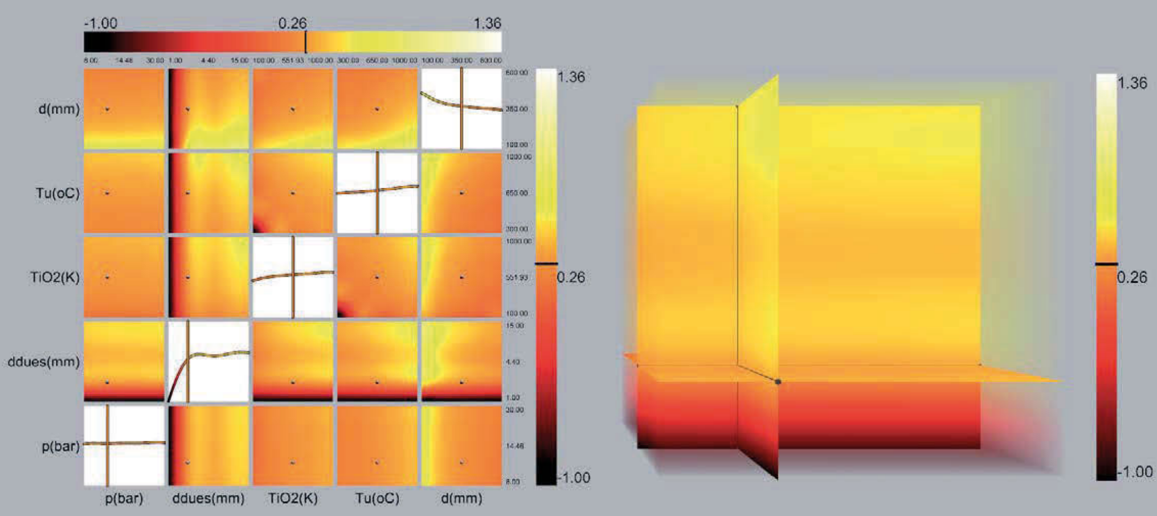
Hyperslices and Other Features



Hyperslices and Other Features



Hyperslices and Other Features



Navigation Between Extrema

- Common questions: which machine configuration allows for
  - fastest cuts?
  - best quality?
  - least energy consumtion?

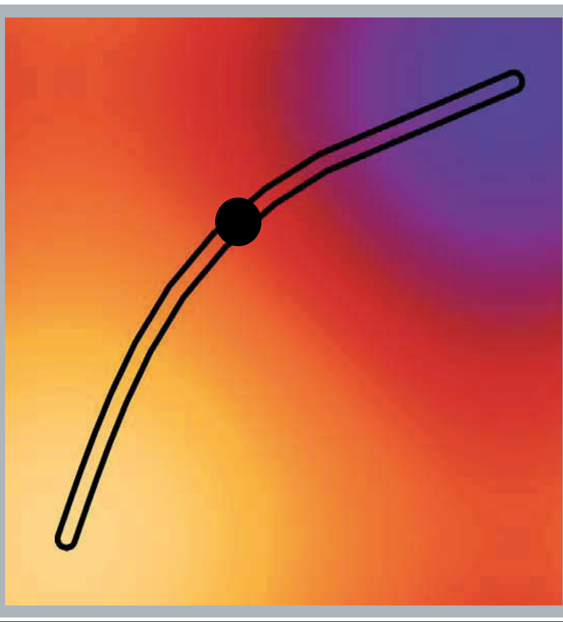
→Where are the extrema of the data space?

- Other important question: how do parameters influence another?

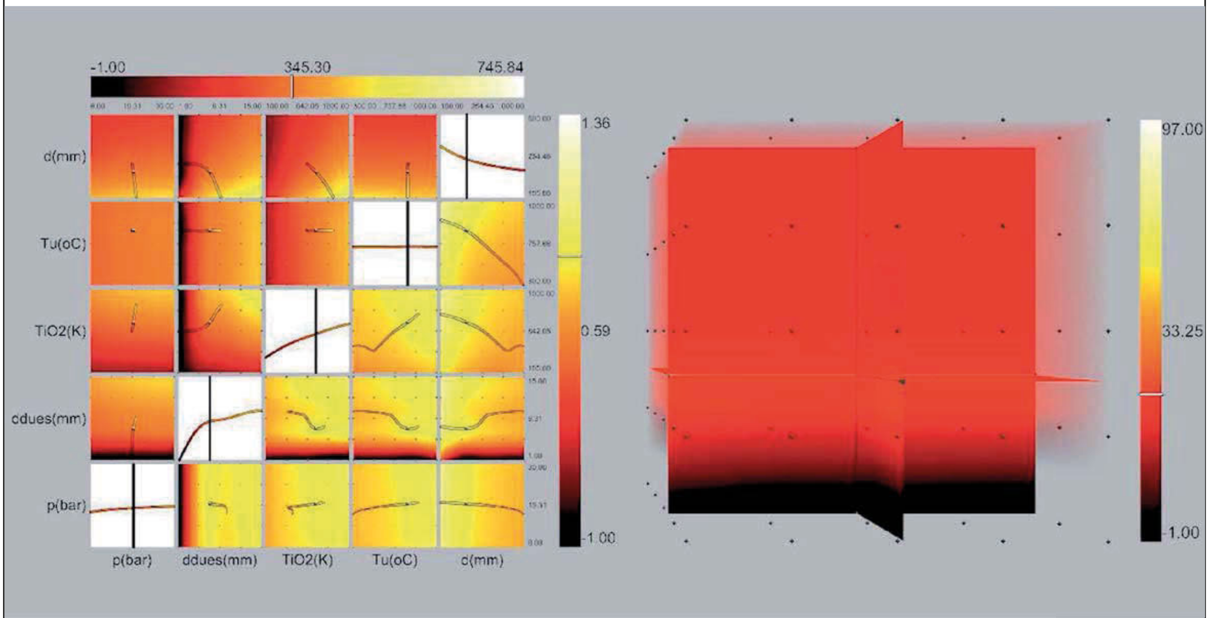
→What are the interdependencies between parameters?

- Solution: gradient trajectories

Gradient Trajectories



Look and Feel of the Application



Summary

- Visualization concept for metamodels for manufacturing processes
- Key features:
  - Hyperslices linked to volume rendering
  - Gradient trajectory naviation
  - Training point visualization
  - Direct rendering of radial basis function networks
- Areas of usage:
  - Fast configuration of machines for manufacturing processes
  - Understanding general interdependencies between different machining parameters
  - Understanding the process of creating metamodels

Future Work

- Replace configuration via sliders, etc. by direct manipulation
  - →More intuituve and faster navigation through the data space
- Perform calculations on high-end backend
  - →Faster calculations
  - →Larger metamodels
  - →Higher display quality
- Link to VPI platform
  - →Persistence of observations
  - →Consideration of previous observations
  - →Collaboration

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Guidelines for traceable Measurements on MTPs

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Keywords:
MTP, traceability, measurement technology, temperature

Abstract

Flexible manufacturing processes for high quality products at low costs are one of the main research objectives in the field of production technology. The quality inspection of large or complex workpieces manufactured on machine tools often takes place beside the production line. The manufacturing process is interrupted and transportation, handling and the loss of the original manufacturing setup influence the workpiece quality. The integration of different manufacturing processes into one machining center (MTP) ensures to be efficient in terms of time and cost and effective in terms of minimum resource consumption. The loss of semi finished products can be faced by an in-process geometric measurement of the workpiece on the MTP with regard to the desired "first-time-right-production".

Due to disturbances like machine defects or temperature fluctuations, the measurement process is not traceable. The measurement data are not comparable and cannot be used for a process improvement or process control.

New Approaches at WZL are aiming to assure the traceability of the inspection processes on the production system. The fusion of appropriate methods for the traceability of CMM's and innovative calibration methods for machine tools will allow the determination of a measurement uncertainty for the measurement system "touch probe and machine tool".

Cluster Conference 2013

Guidelines for traceable Measurements on
Multi-Technology-Platforms (MTP)

Martin Peterek, ICD-C2

Multi Technology Platforms (MTP)
Motivation for Machine Integrated Quality Inspection

Integration of different technologies in one production system: new challenges for production metrology!

- Loss of semi finished products
- Loss of original clamping for a quality inspection „off the line“
- Loss of process data for a process optimization

Need for development and integration of measuring devices and development of strategies for a holistic quality inspection management!

Objective: Traceable measuring processes on Multi Technology Platforms

Ensuring Traceability
Test Set Up: Traceability of Measurements using MTPs

Transfer of CMM methods for MT
- DIN EN ISO 15530-4
  - Cooperation with PTB
  - Adaption of the vCMM for machine tool kinematic and challenges
- DIN EN ISO 15530-3
  - Design and calibration of standard for a range of special tasks
  - Selected tasks measured and evaluated (Software) as described in DIN
- VDI 2617-11
  - Current research
  - Mid of 2013

Kinematic
- 5-Axis Machine Tool Hermle C800U
- Calibrated with Laser Tracer

Un-certainty
- M&H IR HDR
- BLUM TC 76
- Heidenhain TS220
- Renishaw RMP 600

Moni-toring

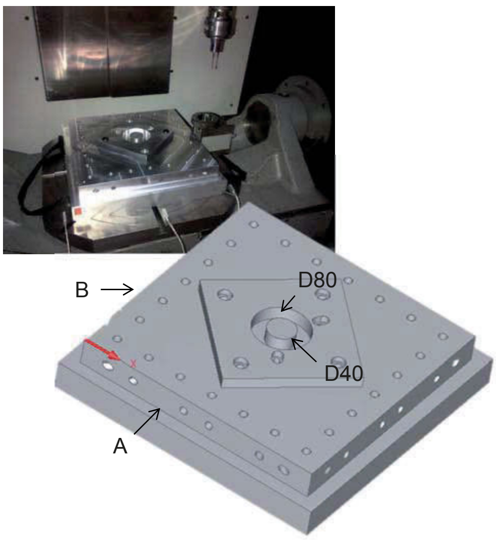
Touch-probe
- Task Specific Analysis (own Approach)
- Integration of Commercial Products

Work-piece

Software
- Specially designed standard for various tasks
- DKD calibration certificate

[1] Henzold, G.: Anwendung der Normen über Form- und Lagetoleranzen in der Praxis, DIN-Normenheft 7, Beuth Verlag

Ensuring Traceability
Uncertainty Determination with vCMM



	Simulated Uncertainty vCMM (PTB)	
	Measured	Uncertainty
D80* Diameter	79,9909	0,0096
D40* Diameter	40,0048	0,0042
D80 Form	0,0133	0,003
D40 Form	0,0124	0,0047
Angle	90,0014	0,0045
Straightness A	0,0024	0,0032
Straightness B	0,0016	0,0032

Input for vCMM:
- Calibration Data of Hermle C800U (LaserTracer)
- Touchprobe: M&H, deviation of repeated calibration measurements
- Workpiece: Al, α=23,5 * 10^-6 K^-1 (u_α= 1,0*10^-6 K^-1)
- Temperature data during Workpiece Calibration: 20°C
- Temperature data during Measurement: 22 °C (10 sensors)

Ensuring Traceability
Uncertainty Determination with Calibrated Workpieces

Calculation of Measurement Uncertainty

$$U = k * \sqrt{u_{cal}^2 + u_p^2 + u_w^2 + b^2}$$

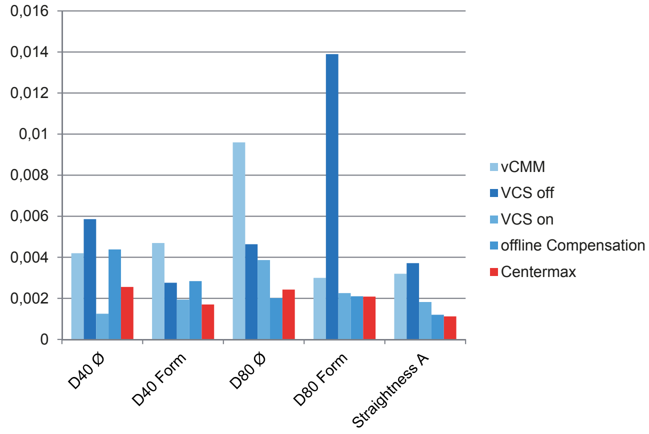
- u_{cal}: standard uncertainty calculated from the uncertainty of calibration of the calibrated workpiece (stated in the calibration certificate)
- u_p: standard uncertainty of the measurement process that is determined with

$$u_p = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})}$$

and

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

- u_w: standard uncertainty influenced by the material of the work piece*
- b: systematic deviation between y_i and the calibrated value x_{cal}
- k: coverage factor



* for length measurements (inkl. position, diameter): $u(L) = L * \sqrt{\Delta T_W{}^2 * u(\propto_W)^2 + \propto_W{}^2 * u(\Delta T_W)^2}$

[2] Hernla, M.: Uncertainty of coordinate measurements, QZ, 2010
[3] DIN ISO 15530 Geometrical product specifications (GPS) Coordinate Measuring Machines (CMM), Beuth
[4] DIN: *Guide to the Expression of Uncertainty in Measurement*, Beuth Verlag GmbH, 1995

Machine Integrated Traceable Metrology
Guidelines for traceable Measurements using Machine Tools

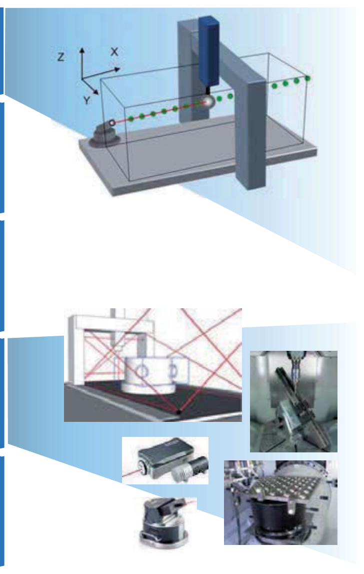
Configuration of measurement system

Minimization of disturbing factors

Traceability of measurement results

Monitoring of measurement system

Examination of product characteristics



Configuration and Calibration

- Detection of geometry errors of the machine tool (global detection of position deviation)*
- Detection of position deviation for specific measurement task (measurement points)*
- Detection of geometric contact deviation of the touch probe

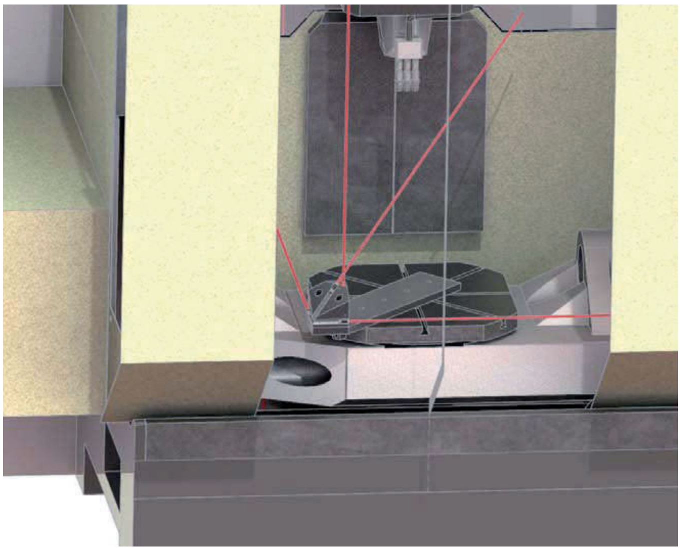
* at a specific temperature point

Monitoring of the measurement system

- Need for *Interims-Test* for measurement system's capability
- Different approaches known from machine tool testing seem to be capable (DIN ISO 230)
- Test has to be quick and user-friendly
- Standards or laser based methods in large volumes

[2] Sartori, Zhang, *Geometric error measurement ad compensation of machines*, CIRP Annals, 1995
[3] Schwenke, Knapp, Haitjema, Weckenmann, Schmitt ,Delbressine, *Geometric error measurement ad compensation of machines- An update*, CIRP Annals, 2008

Futher Steps and Absolute MultiLine System
Traceability for machine integrated Measurements



Quick Check of Machine Tools Performance

- Capability of the measurements system „machine tool“
- Traceability for the measurement process as a permanent reference system

Further Developments:

- Reference System for machine integrated measurement processes
- Geometric deviations of large scale devices (gravitation, temperature)
- Deviations of large structures (CMMs, machine tools, fixtures)
- Multilateration CMM: Trackable MultiLine
- …

Fraunhofer IPT

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How Virtual Production Intelligence Can Improve Laser-Cutting Planning Processes

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Schulz, W.

Jeschke, S.

Keywords:
Virtual Production, Laser Cutting, Data Integration, Data Analysis

Abstract

The complexity of modern production conditions demands integrative approaches in the fields of simulation and analysis to improve product quality and production efficiency. Existing concepts of virtual production meet this need to some extent. However, problems of application interoperability and data compatibility remain. One approach is the definition of a standardized file format, which is costly to create and to maintain. Other approaches avoid the need for a uniform standard by mapping data structures onto a canonical data model. Although these methods allow for simulation and examination of individual elements, the analysis of the integrated process remains a challenge. Here, the data analysis solutions from the field of the so-called intelligence-solutions can prove useful. Within this paper, a use case scenario taken from the field of laser cutting is presented. Herein, the planning for laser cutting is conducted in a modular format. A new concept is presented that addresses the requirements aforementioned and that conforms to the principles of the integration and examination of data. The new concept, called Virtual Production Intelligence, is formed by combining the concept of virtual production with "intelligence solutions" or the goal of gaining knowledge through the analysis of already completed processes.

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[2] B. Ilschner und R. Singer, Werkstoffwissenschaften und Fertigungstechnik: Eigenschaften, Vorgänge, Technologien, Springer, 2010.

[3] G. J. Schmitz und U. Prahl, Integrative computational materials engineering, Weinheim, Chichester: Wiley-VCH;John Wiley [distributor], 2012, p. 1 online resource.

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How Virtual Production Intelligence Can Improve Laser-Cutting Planning Processes

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Cluster of Excellence „Integrative Production Technology for High-Wage Countries“

RWTH Aachen University, Germany

Cluster Of Excellence Conference

October 24th-25th, 2013

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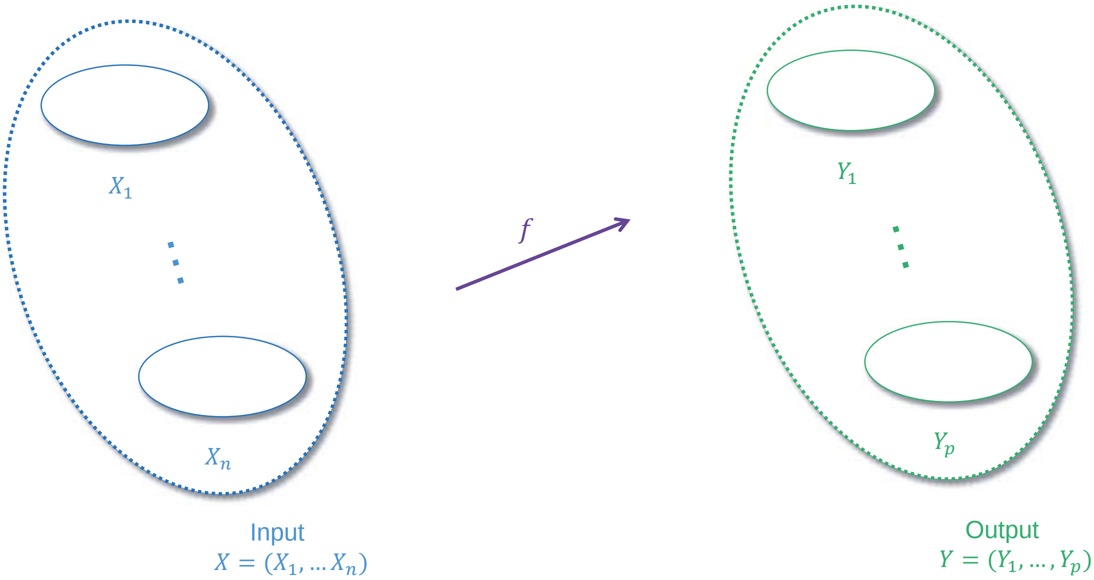
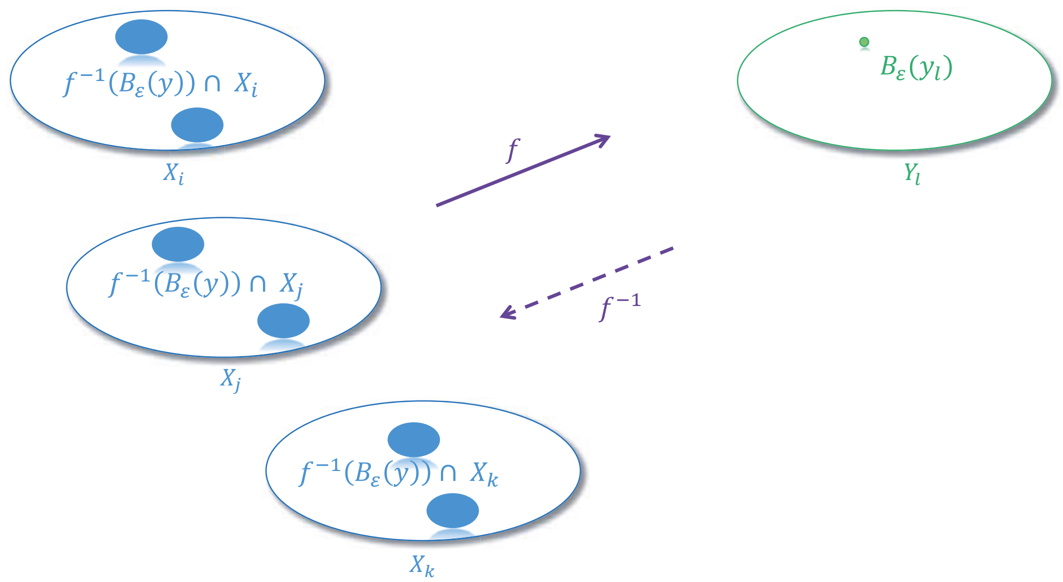
Obtain Specific Process Results: Geometric Interpretation



Obtain Specific Process Results: Geometric Interpretation



Agenda

1 **Laser Cutting: Planning and Examination**

2 **Approach: “Inversion of Simulation”**

3 **Virtual Production Intelligence**

4 **Summary and Outlook**

Laser Cutting: Planning and Examination

The Process Itself

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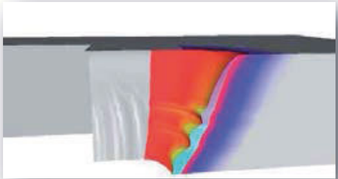
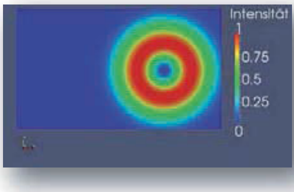
- Laser cutting is a thermal separation process widely used in shaping and contour cutting applications
- Advantage over conventional cutting techniques
  - very fast
  - very accurate
  - optical tool → no wear
- Ablation process in fusion metal cutting
  - based on thermodynamics and hydrodynamics
  - absorbed laser energy is converted to heat which melts the material
  - in the end, this melt is driven out of the cut kerf by a gas jet
  - coming out of a cutting nozzle coaxially aligned with the laser beam

Modeling & Simulation



ablation simulation for laser cutting



simulated beam propagation into cut kerf

- The modeling of a laser cutting process requires the modeling of at least three entities at the same time:
  - the gas jet
  - the laser beam
  - the material to be cut
- Therefore, it is evident that the modeling of the following quantities has to be accomplished as well as their numerical implementation:
  - the cutting gas flow
  - the radiation propagation
  - the ablation of the material

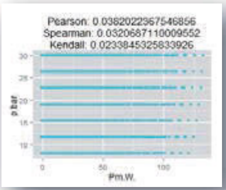
Quality Issues

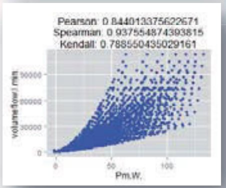
Top: The laser cutting process
Bottom: Its result

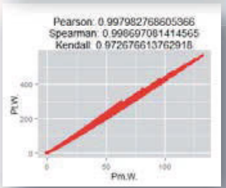
- There are, however, gaps in understanding the dynamics of the process, especially issues related to cut quality:
  - surface roughness on cut edge
  - dross formation on cut bottom
  - inclination of cut edge
- Especially it is important to understand the influence of laser parameters on those quality criteria like
  - wavelength (gas vs. solid-state lasers)
  - beam shape (gaussian vs. tophat shape)
  - polarization (circular vs. radial)

Approach: “Inversion of Simulation”

Goal, Method and Tools







Goal

- Reduction of number of parameters
- Determination of correlation between chosen output (criterion) and parameters (inputs)

Method

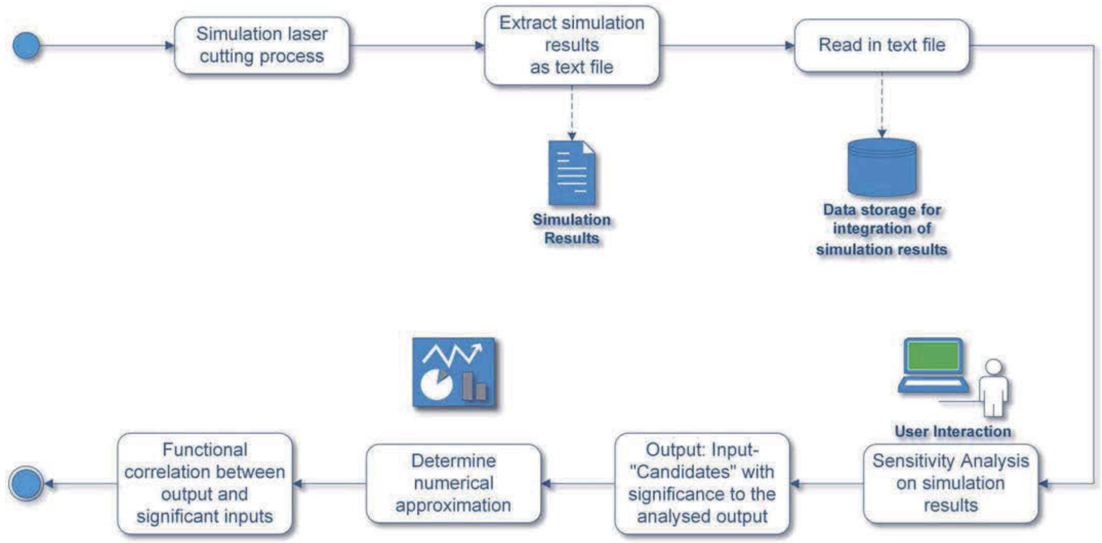
- Sensitivity Analysis

  The study of how uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input. (Saltelli *et al.*, 2004)

Tools

- Qualitative: Visualisation by scatterplots
- Quantitative: Computation of rank correlation coefficients (~~Pearson~~, Spearman, Kendall) between various criteria and parameters

Current Workflow



Virtual Production Intelligence

Related Work: The Digital Factory

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VDI-Guideline 4499 “Digital Factory”

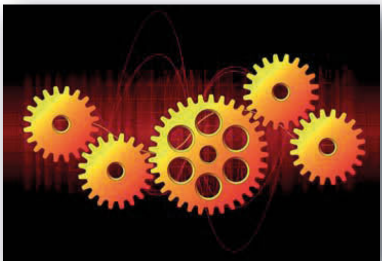
- **Definition**

  Digital factory is the generic term for a comprehensive network of digital models, methods and tools – including simulation and 3D-visualisation – integrated by a continuous data management system. (VDI Guideline 4499, 2008)

- **Aim**

  Its aim is the holistic planning, evaluation and on-going improvement of all the main structures, processes and resources of the real factory in conjunction with the product. (VDI Guideline 4499, 2008)

Role Models: Virtual Production, Business Intelligence



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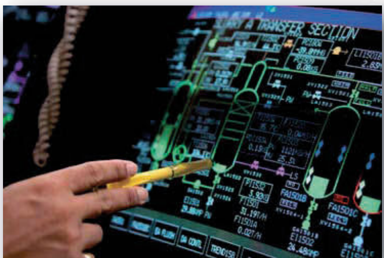

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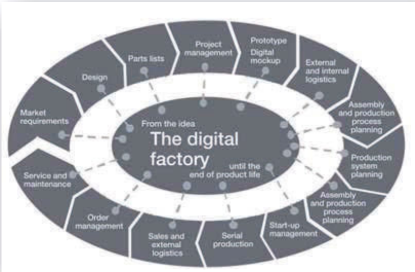
- **Virtual Production**

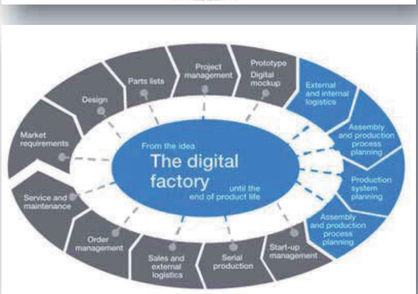
  Virtual production is the simulated networked planning and control of production processes with the aid of digital models. It serves to optimise production systems and allows a flexible adaptation of the process design prior to prototype realisation. (VDI Guideline 4499, 2008)

- **Business Intelligence**

  Umbrella term that includes the applications, infrastructure and tools, and best practices to enable access to and analysis of information to improve and optimize decisions and performance. (Gartner IT Glossary, 2012)

Virtual Production Intelligence: What? What for?





Virtual Production Intelligence (VPI)

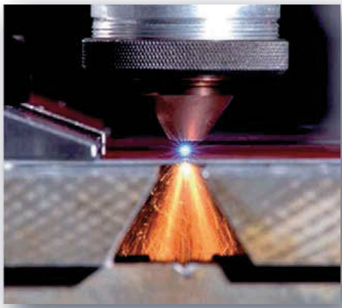
- **Definition**

  The Virtual Production Intelligence (VPI) concept brings a **holistic**, **integrated** approach to the **collaborative** planning of core processes in the fields of technology (material/machines), product, factory and production planning.

- **Aim**
  - Contribution to the realization of the Digital Factory
  - Facilitation of insight into processes
  - Identification of optimisation potentials either in virtual or in real processes

Summary and Outlook

Summary



- Laser Cutting
  - Well examined process
  - However: Gaps in understanding its dynamics, especially issues related to cut quality
- Approach: “Inversion of Simulation”
  - Determine correlations between input and output quantities
- Virtual Production Intelligence
  - Definition
  - Aim

Outlook

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1. Web-Application
   - Move from level “prototype” to next level
2. Data Integration
   - Improve data model
3. Analysing Methods
   - Global multi-dimensional, multi-objective optimisation
   - Domain decomposition
4. Numerical approximation
   - Interpolation methods using neural networks
   - Validation methods (cross validation techniques)

Thank you for your attention.

Any questions?

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Funded by DFG

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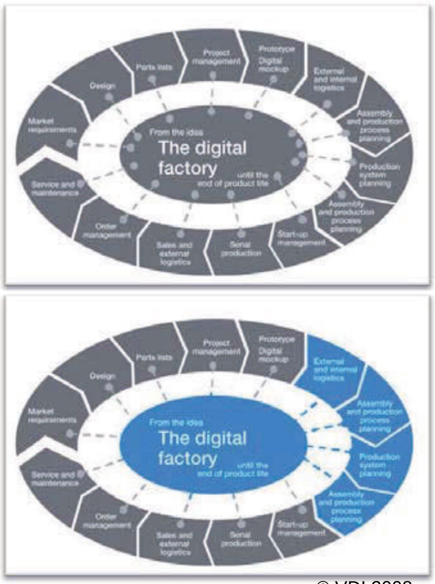
Virtual Production Intelligence: the term



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Virtual Production Intelligence (VPI)

- **Definition**

  The Virtual Production Intelligence (VPI) concept brings a **holistic**, **integrated** approach to the **collaborative** planning of core processes in the fields of technology (material/machines), product, factory and production planning as well as monitoring and control of production and product development.

- **Aim**

  Contribution to the realization of the Digital Factory.

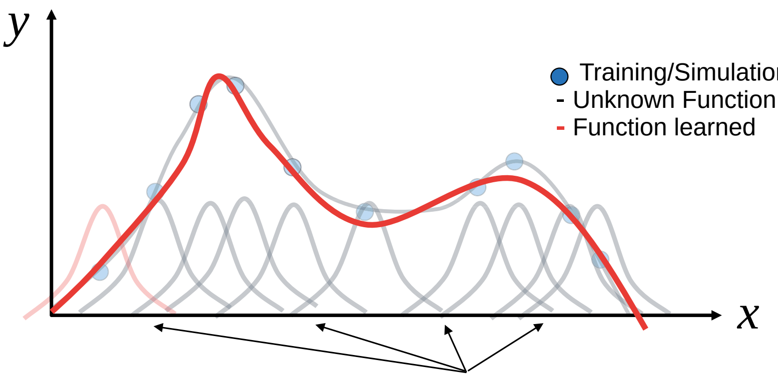
- **Terms**

  Holistic: Addressing all of the product development's sub processes.

  Integrated: Supporting the usage and the combination of already existent approaches instead of creating new and further standards.

  Collaborative: Considering roles, which are parts of the planning process, as well as their communication and delivery processes.

Numerical Approximation Method:

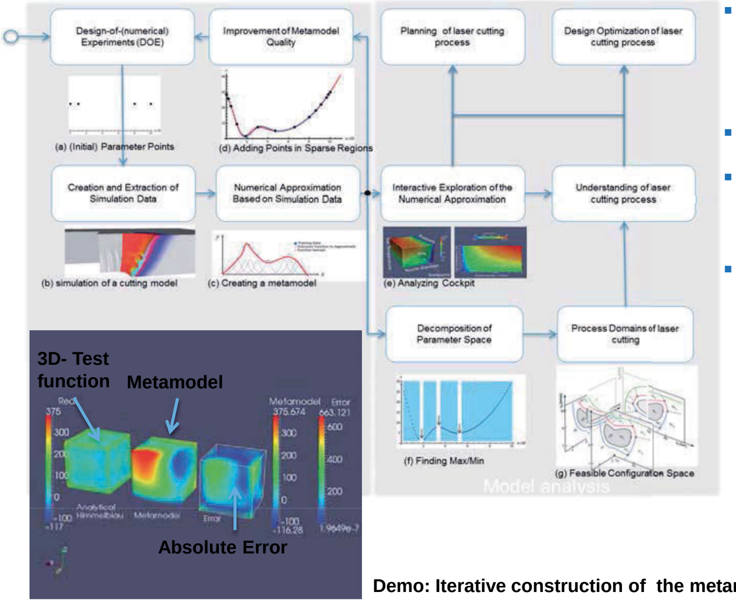


Radial Basis Functions (Kernels h_i)

Interpolating function = Sum of Kernels with weigts w_i??

$$f(x) = \sum_{i=1}^{m} w_i h_i(x)$$

Solution Ansatz (Part 2): Meta-Modeling



- **Sampling of simulation data (from Part 1)**
  - e.g. Latin hypercube
- **Interpolation Methods (RBF)**
- **Validation Methods**
  - Cross validation techniques
- **Analyzing Methods**
  - Multi-dimensional visualization
  - Global Multi-dimensional, multi-objective Optimization
  - Sensitivity analysis
  - Domain decomposition

Demo: Iterative construction of the metamodel applied to 3-D Test function

Formula Editor: Make use of it

f

f^{-1}

$B_\varepsilon(y)$ $\quad$ $f^{-1}(B_\varepsilon(y)) \cap X_i$

$f^{-1}(B_\varepsilon(y)) \cap X_k$

Enhancement in wire-based laser deposition welding

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Keywords:
wear, laser deposition welding, flexibility, productivity

Abstract

Laser deposition welding is an efficient method for applying high quality coatings to improve wear and corrosion resistance. However, a deficit is the limited flexibility in terms of varying the deposited run's geometry which is required when the filler material must be connected optimally to the actual geometry of the base material or when maximum productivity is requested. The research should explore whether the flexibility of the laser deposition welding and productivity can be increased through a specific variation of the surface power density. Up to now, modeling of this process is not possible because the material flow is highly unsteady in time and place. Reasons therefore are the unknown properties of the molten pool through the unsteady temperature field and thus varying viscosities, the influence of the gas pressure of the shielding gas and sublimation and chemical reactions. A major goal of this research proposal is to explore this process in an explanation model and to examine correlations to the process parameters.

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Enhancement in wire-based laser deposition welding

Cluster-Conferences 2013

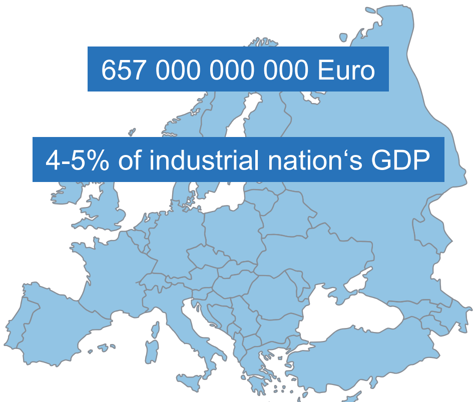
Dipl.-Ing. Maximilian Wegener

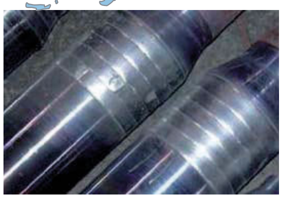
Fraunhofer IPT

Aachen, den 24. September 2013

Motivation

Costs due to wear





Source: Deutsche Edelstahlwerke (2008), Fotolia, Wöltjen Gruppe

Motivation
Wear protection and repair

Thermal spraying

Deposition welding

Reduction of wear due to coatings

- Increase of life time
- Reduction of costs an resources

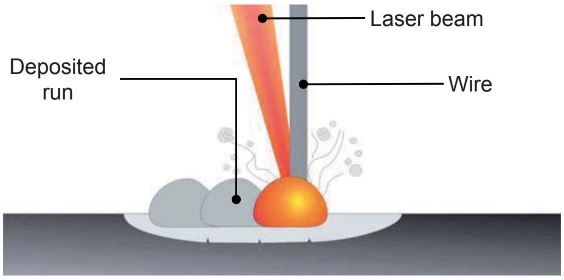
Breakdown due to damage of the part

- Exchange of the “spare parts“
- Repair due to targeted material‘s deposition

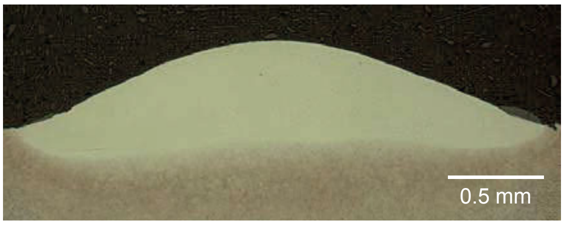
For high quality and expensive parts a good wear protection and in case of part‘s damage a repair is usually appropriated.

Source: Linde, MTP Metalltechnik

Technical Approach for coating and repairing
Laser deposition welding



Process principle of laser deposition welding



Cross-section of a deposited run

Advantages compared to conventional deposition welding

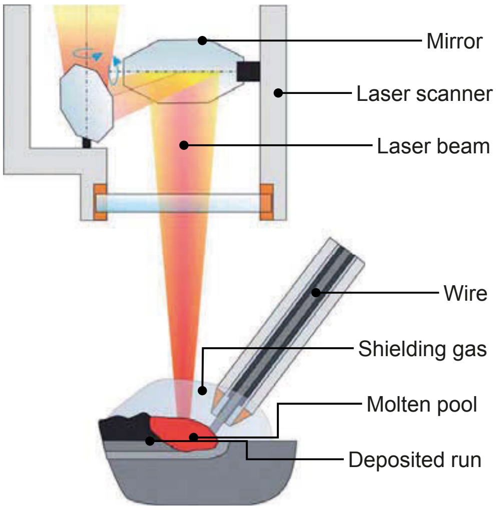
- High precision due to little and local energy input
- High coating quality due to low dilution of filler and base material

Needs – Increase in efficiency for laser deposition welding

- Increasing of the processing speed
- Improving of the process stability
- Variation of the deposited run‘s geometry

Scanner-based laser deposition welding

An innovative process for large-scale deposition welding



Process characteristics

- Use of a laser scanner with mirrors for moving the laser beam
- The width of the molten pool can be adjusted by the beam deflection

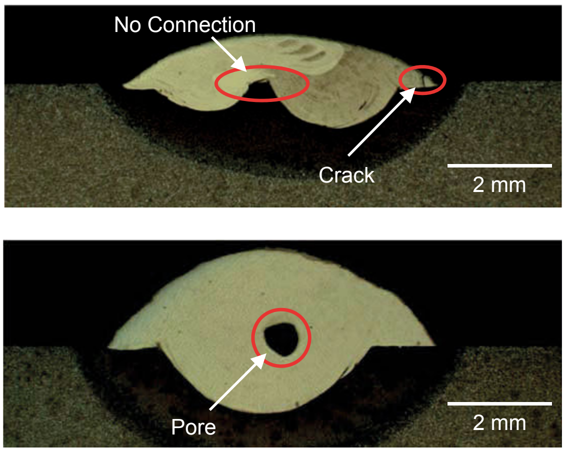
Capability

- Increase in productivity
- Flexibility concerning varying deposited runs' geometry

The process is supposed to combine the known advantages of laser deposition welding and an increase in productivity and flexibility.

Process analysis of scanner based laser deposition welding

The extension by a laser scanner causes deficits



Cross-section of deposited runs

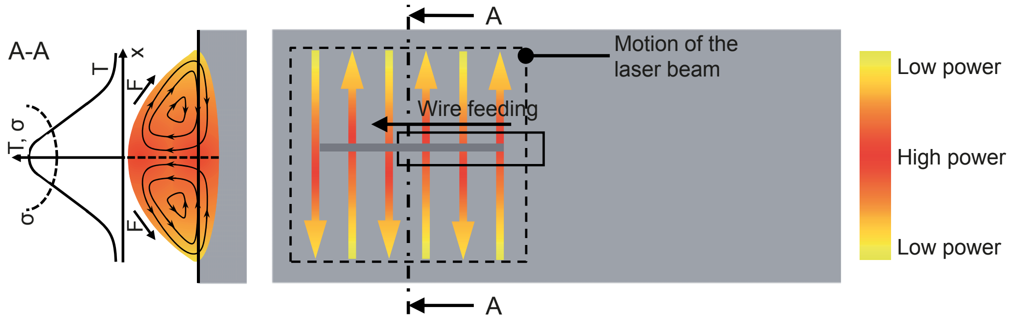
Deficits

- An empirical process layout does not afford a homogenous connection and affects the quality of the deposited runs
- Small stochastic fluctuations of process parameters lead to changes in deposition results and process interruptions
  - Connection
  - Cracks
  - Pores

Up to now, a stable process control for laser deposition welding with an adjustment of the deposited run's geometry is not possible.

Adjustments of the process control for minimizing the deficits

Specially aimed modification of the surface power density



Process determining parameters

- Surface power density
  - Laser power
  - Focal spot's shape/size
  - Laser beam's position/deflection
- Work piece feed rate
- Geometrical parameters (e.g. wire's position)

Resulting quantities

- Deposited run's geometry
- Quality of the deposited runs
  - Connection
  - Heat affected zone

Agenda

1 **Introduction**

2 **Target and research hypothesis**

3 **Scientific approach**

Enhancement of the of the process borders of laser deposition welding

Problem and target

Technical problem

- A stable process control for laser deposition welding with an adjustment of the deposited run's geometry is not possible up to now

Scientific problem

- The effects and interactions for deposited run's origin in response to the modification of the surface power density have not been clarified
- There is no model to explain the deposited run's origin with unsteady surface power density

Scientific target

- Development of a inductive, analytical-empirical explanatory model for deposited run's origin
  - Explanation of causes and effects in submodels
  - Synthesis to an explanatory model

Enhancement of the of the process borders of laser deposition welding

Research hypothesis and research questions

The deposited run‘s geometry can be adjusted by specially aimed modification of the local and temporal surface power density. This enables the increase of the procedure‘s flexibility and to produce a homogenous and little dilution.

Research question 1

Which physical mechanisms cause and determine the flow of the material?

Research question 2

How can the surface power density be controlled to achieve a specific geometry of the deposited run?

Research question 3

How can the surface power density be controlled to achieve a homogenous and little dilution?

Agenda

1 **Introduction**

2 **Target and research hypothesis**

3 **Scientific approach**

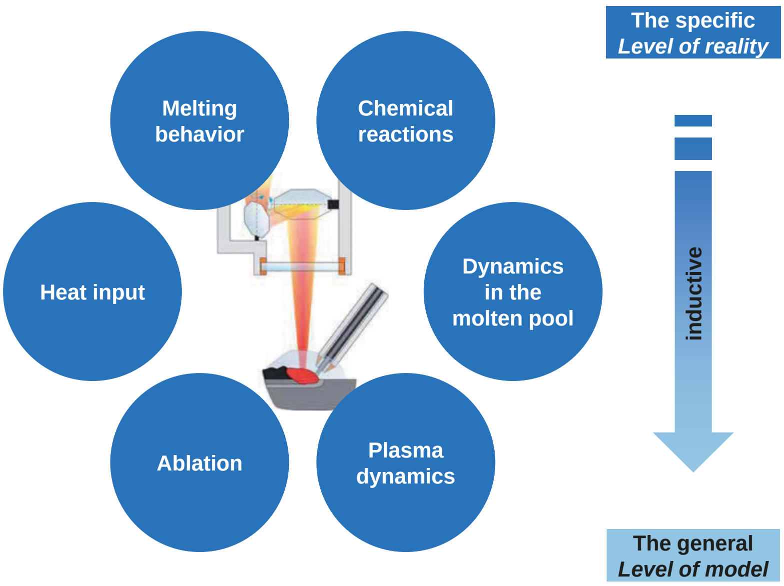
Inductive, analytical-empirical modeling
Explanation of causes and effects in submodels

Description in submodels

- Melting behavior
- Heat input
- Dynamics in the molten pool

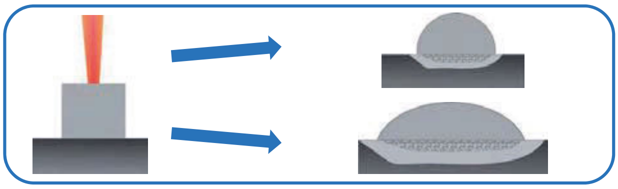
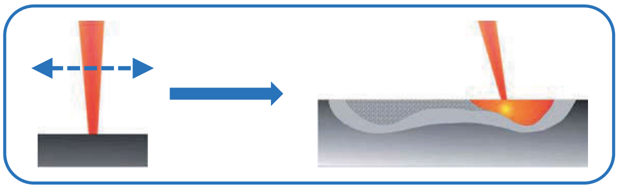
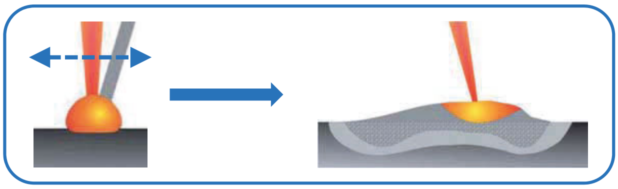
Synthesis to an explanatory model

- Knowledge-based and robust process layout
- Variable adjustment of the deposited run's geometry



Development of the submodels

Experimental investigations of the process determining parameters

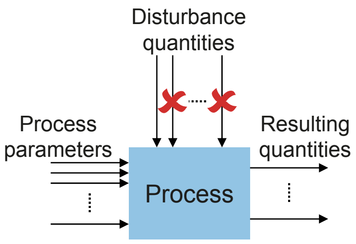
Submodel	Experiment	Process parameters
Melting behavior		■ Laser power ■ Focal spot's shape and size
Heat input		■ Laser power ■ Focal spot's shape and size ■ Laser beam's position/deflection ■ Work piece feed rate
Dynamics in the molten pool		■ Laser power ■ Focal spot's shape and size ■ Laser beam's position/deflection ■ Work piece feed rate ■ Wire's position and -feeding speed

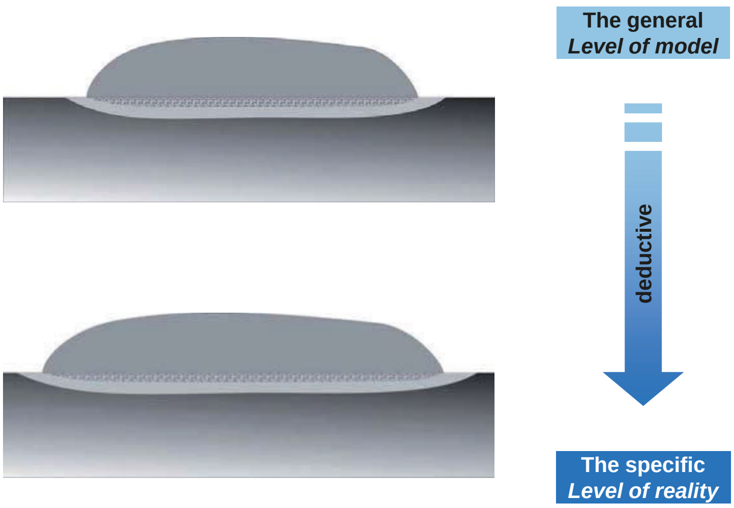
Deductive enhancement of the process borders

Draw of conclusions basing on the explanatory model

Model based enhancement of the process borders

- Process robustness
- Quality of the deposited runs
- Productivity





The use of the model is supposed to increase the productivity and flexibility without reducing the advantages of laser deposition welding.

Enhancement in wire-based laser deposition welding

Summary

Laser deposition welding

- Advantages compared to conventional deposition welding
  - High precision due to little and local energy input
  - High coating quality due to low dilution of filler and base material
- The use of a laser scanner is supposed to combine the known advantages of laser deposition welding and an increase in productivity and flexibility
- Up to now, a stable process control for laser deposition welding with an adjustment of the deposited run's geometry is not possible

Scientific approach

- Inductive, analytical-empirical modeling by the explanation of causes and effects in submodels
  - Melting behavior
  - Heat input
  - Dynamics in the molten pool
- Deductive enhancement of the process borders by drawing of conclusions basing on the explanatory model

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Value-oriented layout planning using the Virtual Production Intelligence (VPI)

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Keywords:
Factory Planning, Layout Planning, Virtual Production Intelligence

Abstract

In the context of a continuous globalization of economic activities, producing companies are facing growing market dynamics. This leads to shorter technology and product life cycles and a growing diversity of variants, caused by the production of customer individual products with smaller quantities. Due to this competitive environment, factory planning has to focus on value-adding activities. To realize a "value-oriented factory planning", the impact of decisions has to be known prior to and during the planning. If these mechanisms are well known, the specific planning project can be adjusted to the ideal ratio of costs and benefits.

Layout planning plays a significant role in factory planning, as it must integrate previous planning results and defines the later production structure on a very detailed level with a long-term impact on the building. In order to integrate the concept of value-oriented factory planning in the planning of production layouts, a layout assessment approach using the "Virtual Production Intelligence" (VPI) platform is presented. Key aim of this layout assessment approach is to measure an existing layout, which can arise from an existing factory or a layout planning project, and provide information about its "fit" in regard to production targets and boundary conditions of the specific production.

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DFG Deutsche Forschungsgemeinschaft

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WZL RWTH AACHEN

Value-oriented layout planning using the Virtual Production Intelligence (VPI)

Cluster-Conferences 2013

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Aachen, 24th September 2013

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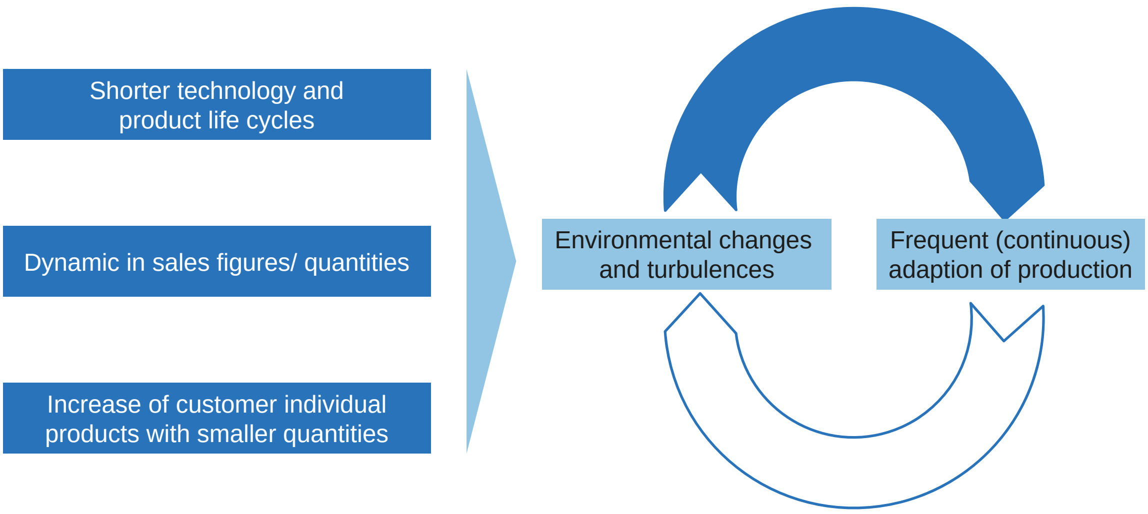
Producing companies need to adapt their production strategy frequently to remain competitive



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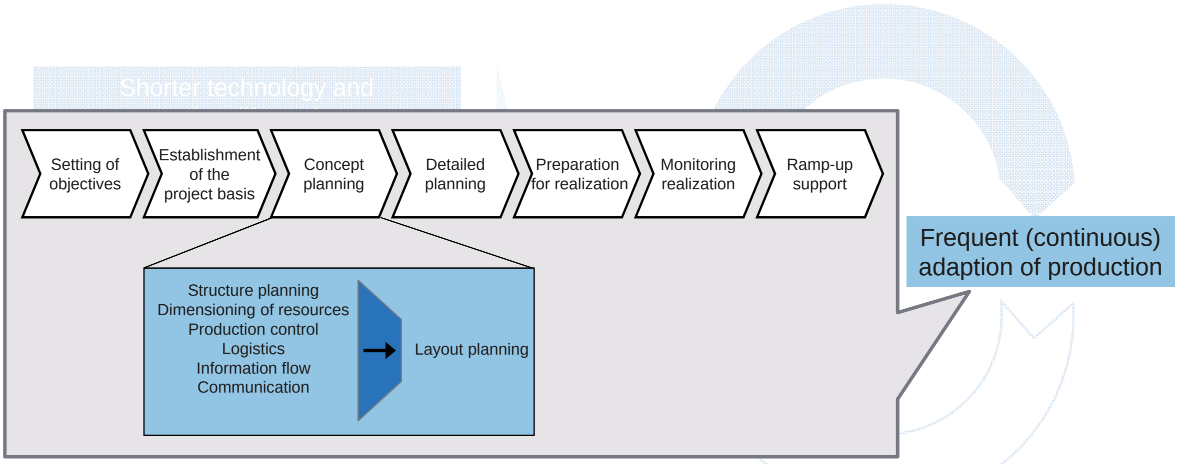
The adaption of production is realized in factory planning projects



Layout planning is a **key task** in factory planning as it integrates and combines results which partially have been developed independently before

Source: Factory planning process according to VDI 5200 (German industry standard)

Layout planning?

In scientific theory…

$$\text{MinTF} = \tfrac{1}{2} * \sum_{\substack{i=1\\ i\neq k}}^{n} \sum_{\substack{j=1\\ j\neq l}}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} F_{ik} * D_{jl} * X_{ij} * X_{kl} \quad (1)$$

$$\sum_{j=1}^{n} X_{ij} = 1 \quad \text{for all } i = 1 \ldots n \quad (2)$$

$$\sum_{i=1}^{n} X_{ij} = 1 \quad \text{for all } j = 1 \ldots n \quad (3)$$

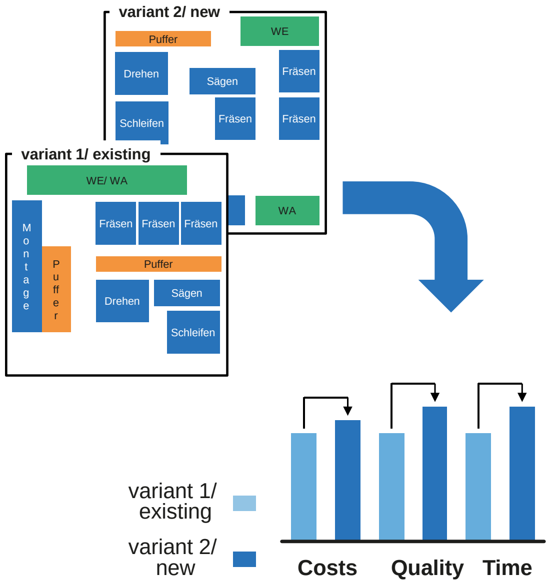
X_{ij}=1 if facility "i" is located/assigned to location "j".
X_{ij}=0 if facility "i" is not located/assigned to location "j".
F_{ik} is the flow between two facilities i and k

In industrial practice…

Key question: What is the value added by a (changing) production layout?

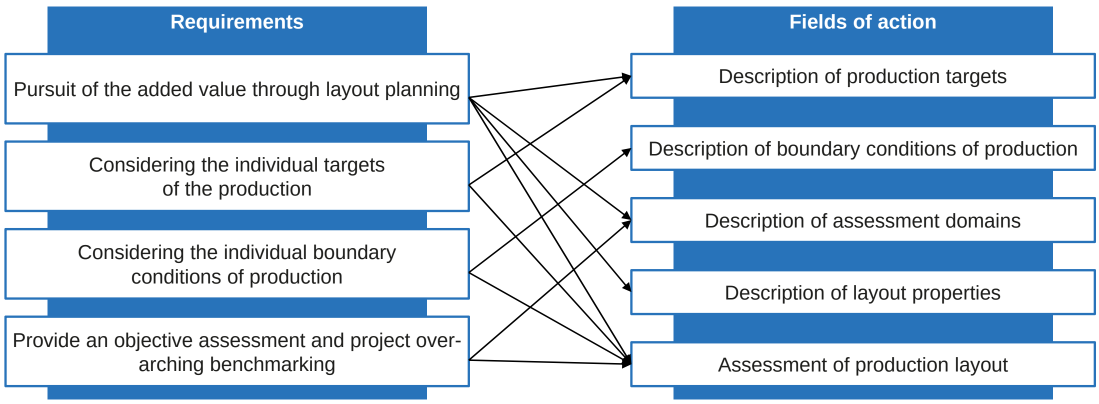
Source: Koopmans TC, Beckman M (1957) Assignment problems and the location of economic activities. Econometrica 25:53–76;

An in-planning integrated layout assessment helps the planner to pursuit a value oriented planning

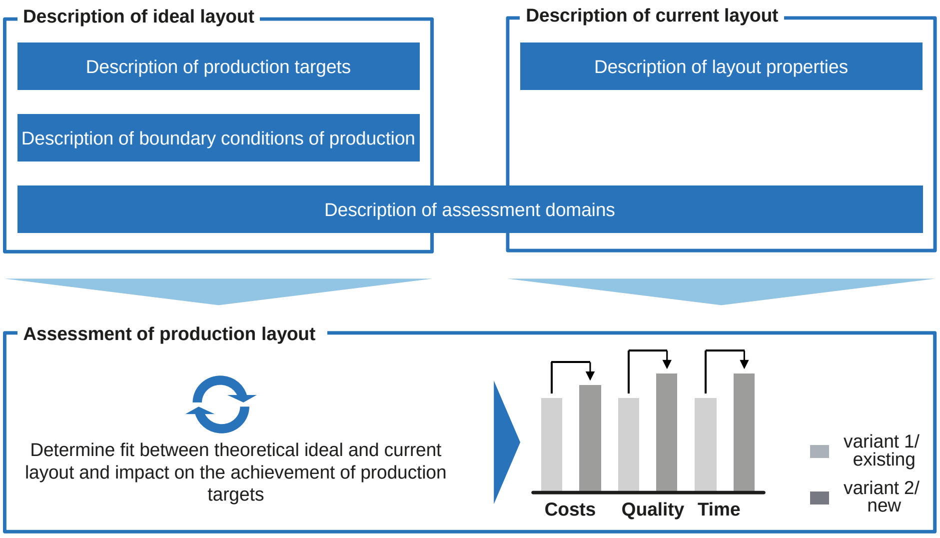


- Assessment of layout variants regarding their impact on the achievement of the production targets (cost, quality, time)
- Taking into account
  - Companies (strategic) production targets
  - Boundary conditions (Lot sizes, quantities, processes, technologies etc.)
- Holistic approach assessing different domains
  - Logistics
  - Transparency
  - Changeability
  - Communication
  - etc.

Five fields of action have been derived from the identified requirements for a value-oriented layout planning



The layout assessment is realized by comparing the layout with an abstract ideal layout using “assessment domains”



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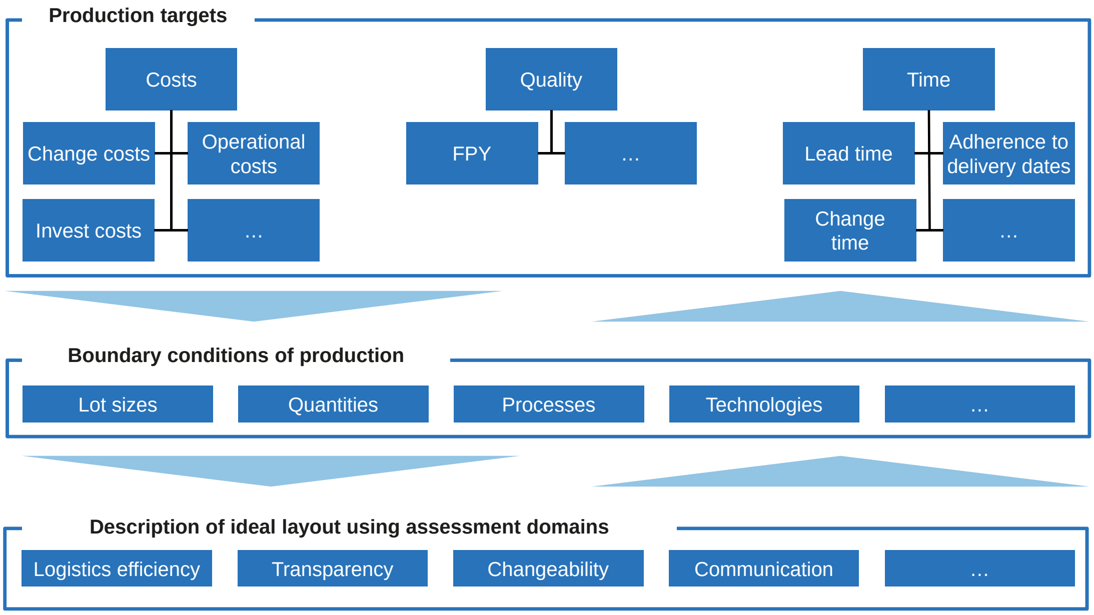
The specific ideal layout is described abstractly using assessment domains based on production targets and boundary conditions



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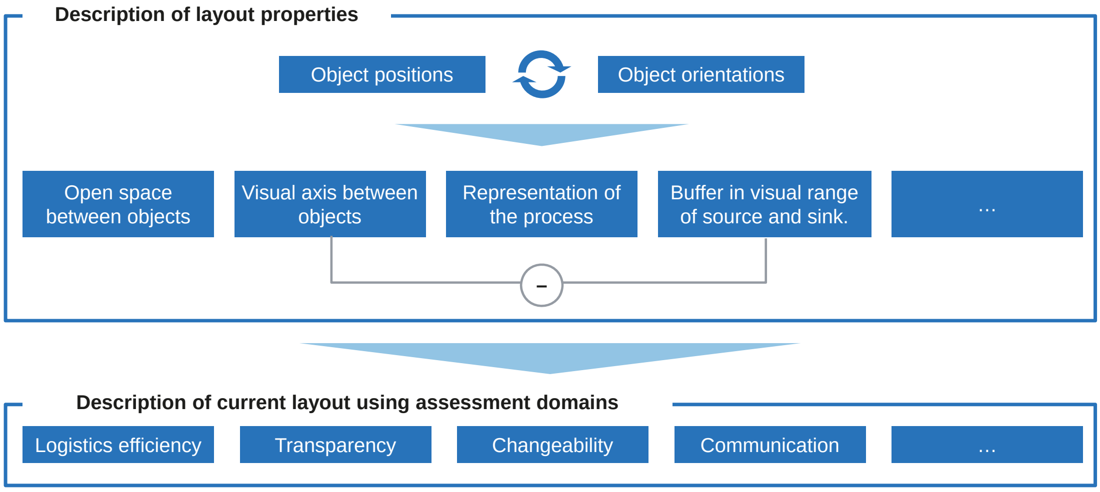
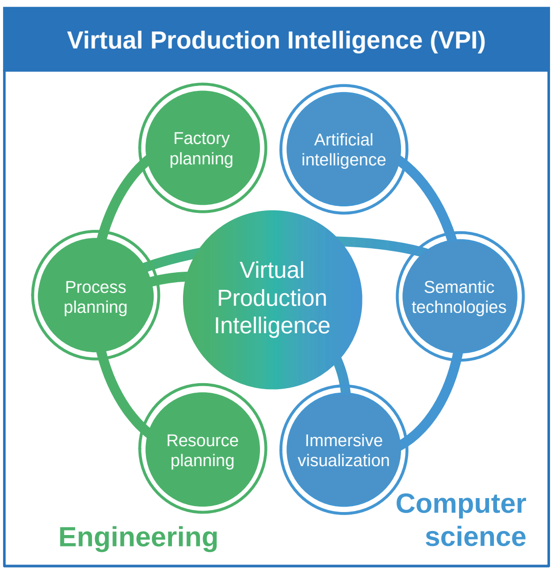
The „current“ layout is described using assessment domains based on object positions and orientations



The assessment approach is integrated into the Virtual Production Intelligence (VPI) platform at RWTH University



Demonstration case: Layout assessment will be integrated into immersive layout planning tools

aixCAVE

- 3D model
- Re-integration of changes in 3D model (e.g. positions)

- Object properties
- Material flows
- Layout assessment
- …

Factory planning desk

VPI platform

- Immersive, intuitive factory planning by integration of
  - Factory planning desk
  - aixCAVE
  - VPI platform
- Visualization of the factory scenario in the aixCAVE by real-time-connection with the factory planning desk
- **Enrichment of the factory model** with additional information distributed by the VPI platform, e.g.:
  - Object properties
  - Material flows
  - **Layout assessment**
- Manipulation of factory scenario (e.g. position or properties of machines) in the immersive environment of the aixCAVE.
- Re-integration of changes into the data models of the factory planning desk and VPI platform
- Models that were created with factory planning desk can be displayed in the aixCAVE (360° Virtual Reality 3D)
- Realistic review of proportions and visibility

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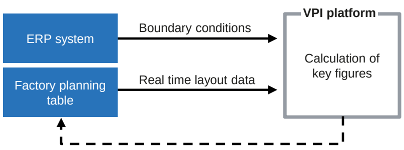
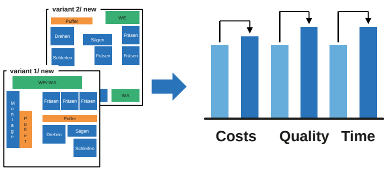
Outlook
Work packages for the next months

WP I: Tool integration



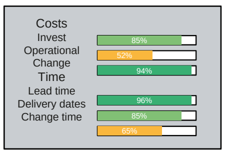
WP II: Layout assessment



WP III: Development of holistic software solution

- Visualization of planning data in 3D layout (enrichment)
- Assessment of different layout variants
- Real time transfer of changes in visTABLE model to changes in aixCAVE
- Readout of data from VPI platform for the application in the VR model (virtual planning cockpit)

2D layout on touchscreen



Assessment dashboard

3D projection

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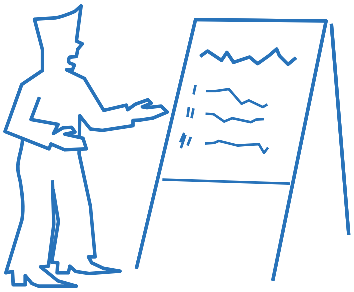
Value-oriented layout planning using the VPI
Summary



- Producing companies need to adapt their production more frequently. Thereby, they have to focus on value adding activities to ensure economic efficiency.
- To pursue a value orientation in layout planning, planners need comprehensive and significant feedback regarding the impact of their decisions
- Feedback instruments (e.g. key figures) need to take into account individual (strategic) targets of the production as well as individual boundary conditions.
- The approach will be demonstrated using the VPI platform for data integration and exploration.

Thank you for your attention

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