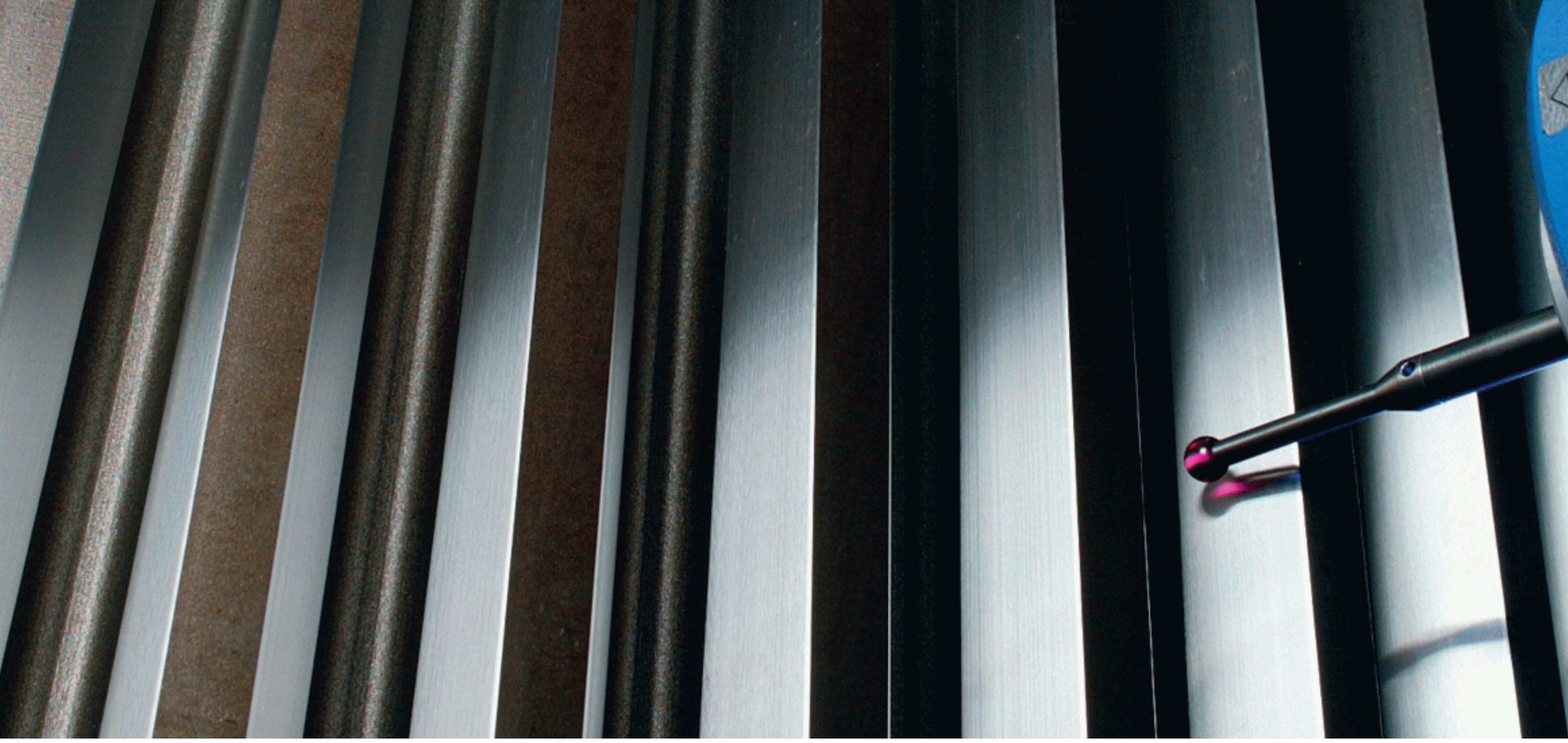

Aachen Forum on Gear Production

Gear Finishing Technology and Quality Inspection

9th - 10th November 2021

Thomas Bergs, Christian Brecher (Eds.)

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über https://portal.dnb.de abrufbar.

Thomas Bergs, Christian Brecher (Hrsg.):

Aachen Forum on Gear Production
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1. Auflage, 2022

Apprimus Verlag, Aachen, 2022
Wissenschaftsverlag des Instituts für Industriekommunikation und Fachmedien an der RWTH Aachen
Steinbachstr. 25, 52074 Aachen
Internet: www.apprimus-verlag.de, E-Mail: info@apprimus-verlag.de

ISBN 978-3-98555-012-8

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9th – 10th November 2021, Aachen

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Functional and Ecological Traceability of Process Chains – A Data and Model-Based Approach

Presenter:

Prof. Dr.-Ing. Thomas Bergs MBA

Laboratory for Machine Tools and Production Engineering
WZL of RWTH Aachen University

Summary

Ensuring component functionality is a decisive quality criterion. The data recorded in the individual manufacturing processes must be available at all times and contain up-to-date information about the component, the preceding processes and the production equipment used. In case of a quality problem, the manufacturing company must be able to immediately identify the origin of the problem within the component's manufacturing chain and take effective measures to rectify it. Data- and model-based approaches can be used to design manufacturing processes in such a way that they operate more efficiently and conserve resources, while at the same time generating information content for traceability. A coupling between data and process models allows the sustainable mapping of functional cause-effect relationships and thus a technological coordination of the individual manufacturing processes with regard to the resulting component properties and the ecological footprint.

In complex manufacturing chains (e.g. gear manufacturing), the individual manufacturing steps must be optimally coordinated to meet component requirements. In general, high demands are placed on the control of the manufacturing process chain with regard to availability, quality and economic efficiency (productivity). Furthermore, there is a need for energy-saving measures to meet the continuously increasing environmental requirements. In detail, the resulting challenges differ between the use cases. Based on this background, various aspects of a data- and model-based process design will be considered. It will be shown that data collection must be target-oriented and should only be carried out to the extent that is actually useful. In a next step, this data must be evaluated in a knowledge-based manner. Only by networking the information from manufacturing, in particular by involving the employees, the basis is created for optimizing process chains with regard to the resulting component functionality.

However, the analysis of a single manufacturing process is not sufficient to realize complete traceability of the entire manufacturing chain. The concept of the digital twin at manufacturing chain level represents a significant further development. As a basis, the individual process steps are described with data and models. The structured storage and evaluation of the generated data makes it possible for new use cases to shorten the process setup through self-learning strategies. For the implementation of the manufacturing chain digital twin, the creation of uniform interfaces for all processes within the chain is mandatory. An efficient and automated data exchange is necessary between the individual manufacturing steps as well as the measuring devices. This is particularly important for heterogeneous production lines with machines of different specifications. This requires the implementation of generally accepted exchange formats.

From a technical point of view, many elements that are necessary to achieve functional and ecological traceability as well as a data- and model-based design of the manufacturing chain already exist. However, the use of these elements can still be further optimized. Various technical as well as legal, corporate and sociocultural factors are the reasons why traceability is not yet fully utilized. Before added value can be generated through digitalization, the hurdles must be overcome at least in part. The result will be a modern production environment in which complete traceability and predictability of processes and process chains are given. Through a common exchange system, customers and supplying companies will have access to the product properties and relevant information at any time and anywhere. Employees will be empowered by visualization systems to make faster and more knowledge-based decisions. In addition, by knowing the ecological footprint of the manufacturing chain, companies can make energy-saving measures and thus realize resource-saving production.

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Functional and ecological traceability of process chains -
A data and model-based approach

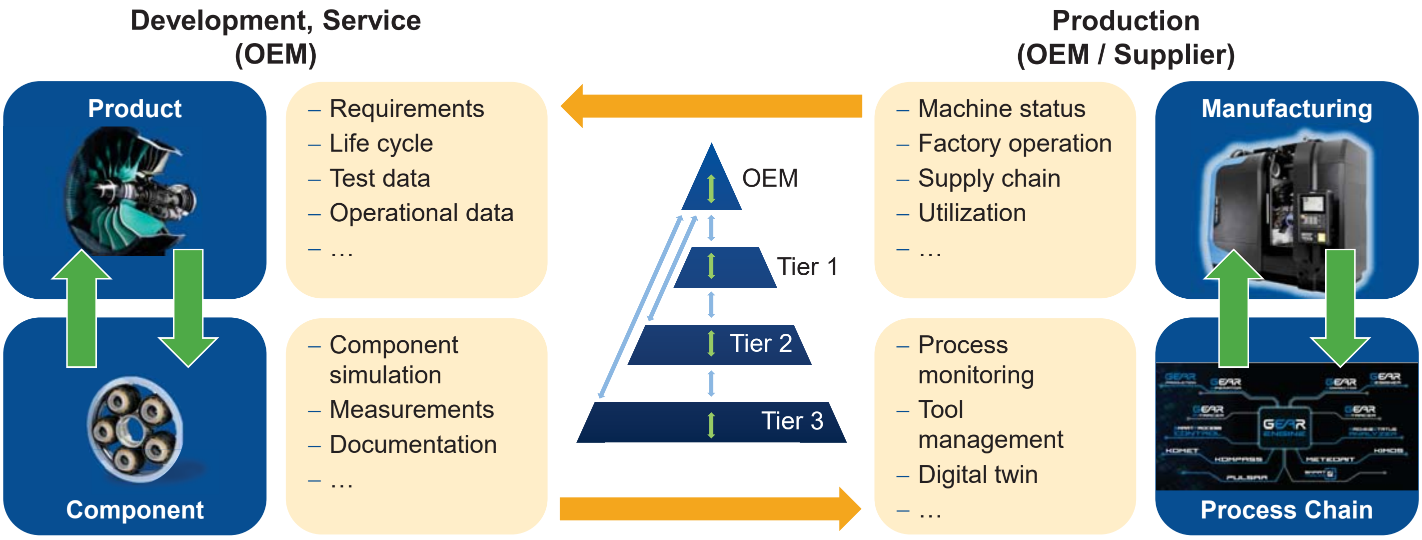
Prof. Dr.-Ing. Thomas Bergs MBA
WZL of RWTH Aachen University - Chair of Manufacturing Technology

Traceability

Traceability of products along the supply chain

Image Sources: Apple tree: © xalanx | stock.dobe.com; Apple: © Delphimages | Fotolia.com; Apple cake: © Maria Panzer | einfachbacken.de

Traceability
Data categories at different levels



Traceability creates trust and increases competitiveness

Source: Rolls-Royce Deutschland, www.schwegler.de; klingelnberg.de

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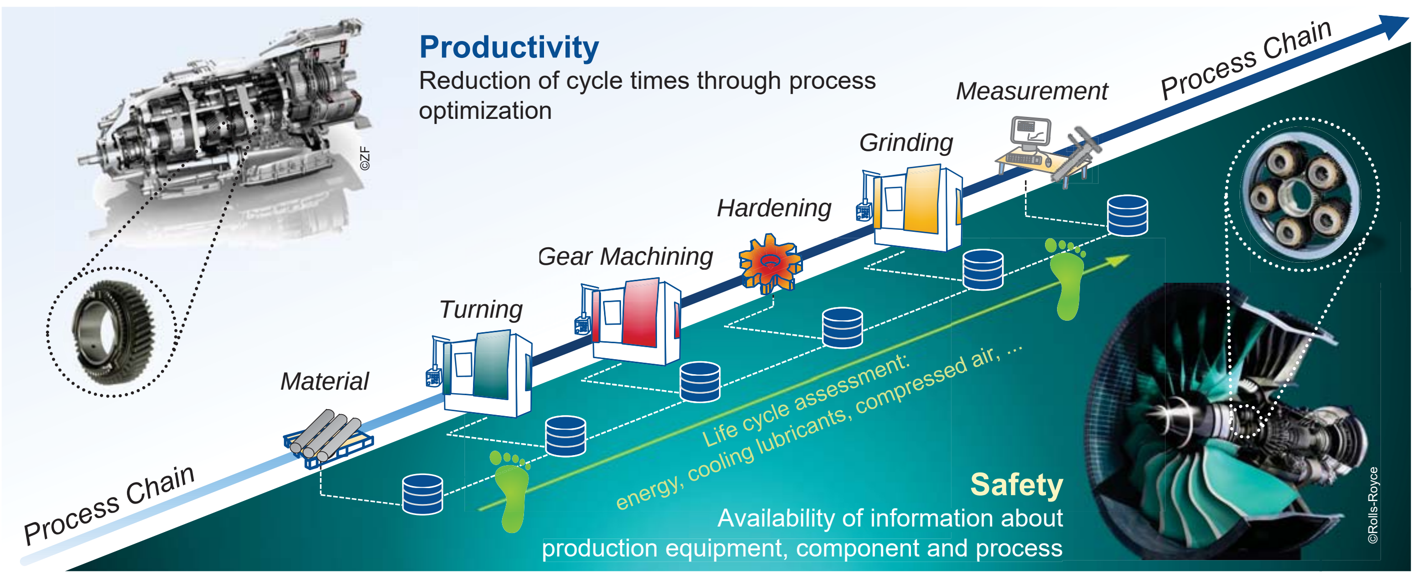
Traceability
Internal traceability of product and process chain



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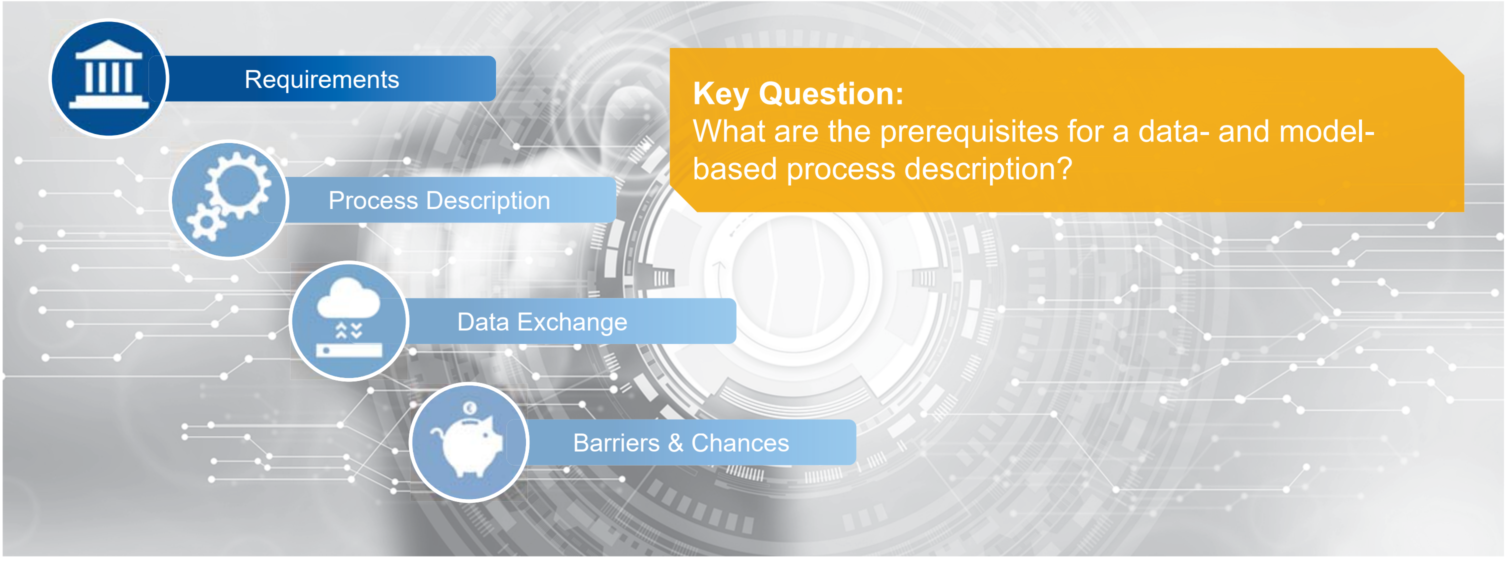
Outline



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Linking technology and process knowledge
A data and model-based approach

Comprehension
Cause-effect principles

Knowledge
Databases on causal relationships

Models
Process and simulation models

Planning | Learning

Managing | Deciding

Data
Availability of all relevant data

Information
Visualization of real-time data

Analysis
Description of the correlation of process variables

Data and model-based process design favors process capability

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Linking technology and process knowledge
Measurability and effort of data collection

What to measure?

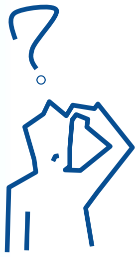
Target variables must...

...be functionally describable

...be assignable to sub-processes and their KPIs

How to measure?

– Component (geometry, roughness, surface integrity)
– Tool (power consumption, process boundary conditions)
– Operational (OEE, equipment maintenance, auxiliary material consumption)

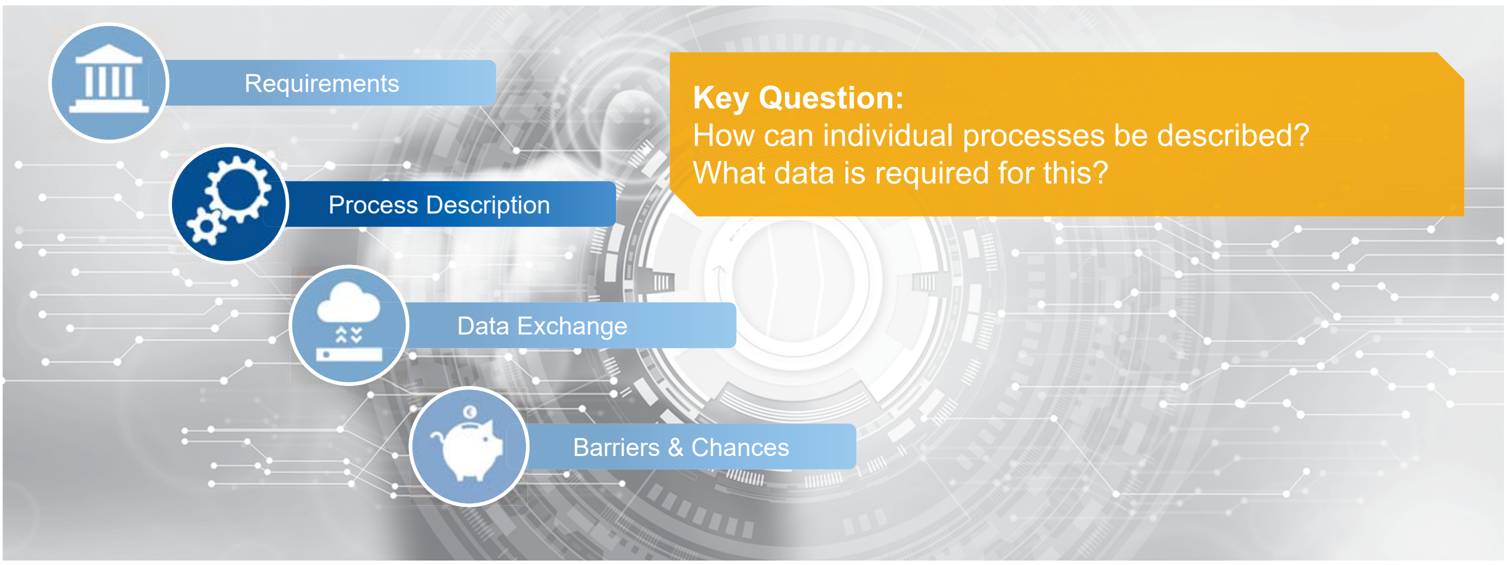


How to evaluate?

– Challenge: Data processing
– Algorithms: Correlation vs. causality

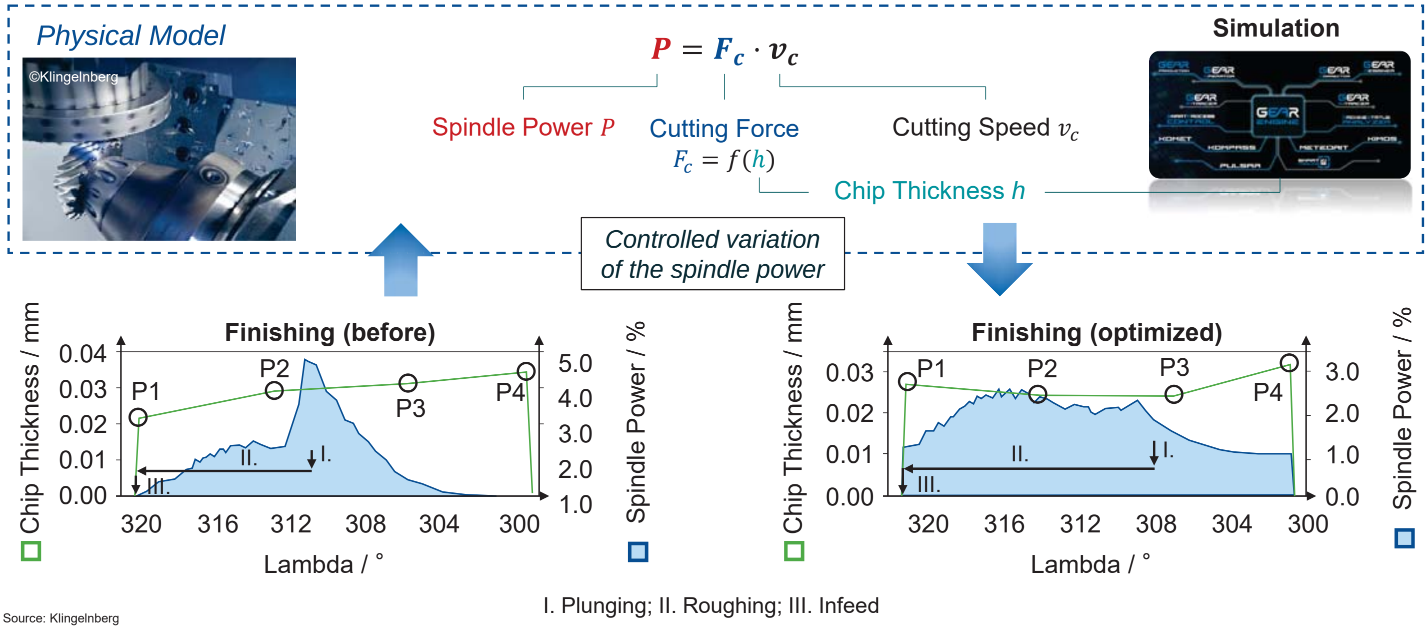
Effort of data collection depends on the type and scope of the data required

Outline



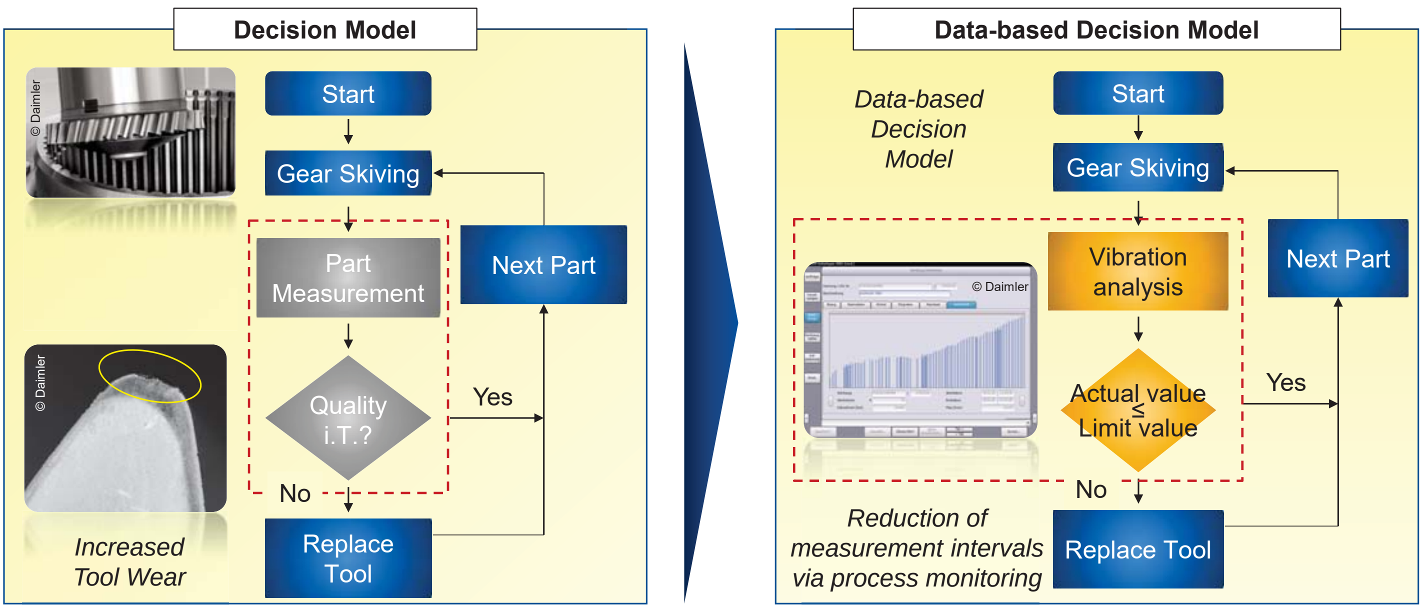
Key Question:
How can individual processes be described?
What data is required for this?

Intelligent use of data for optimized process design
Data and model-based design in bevel gear milling



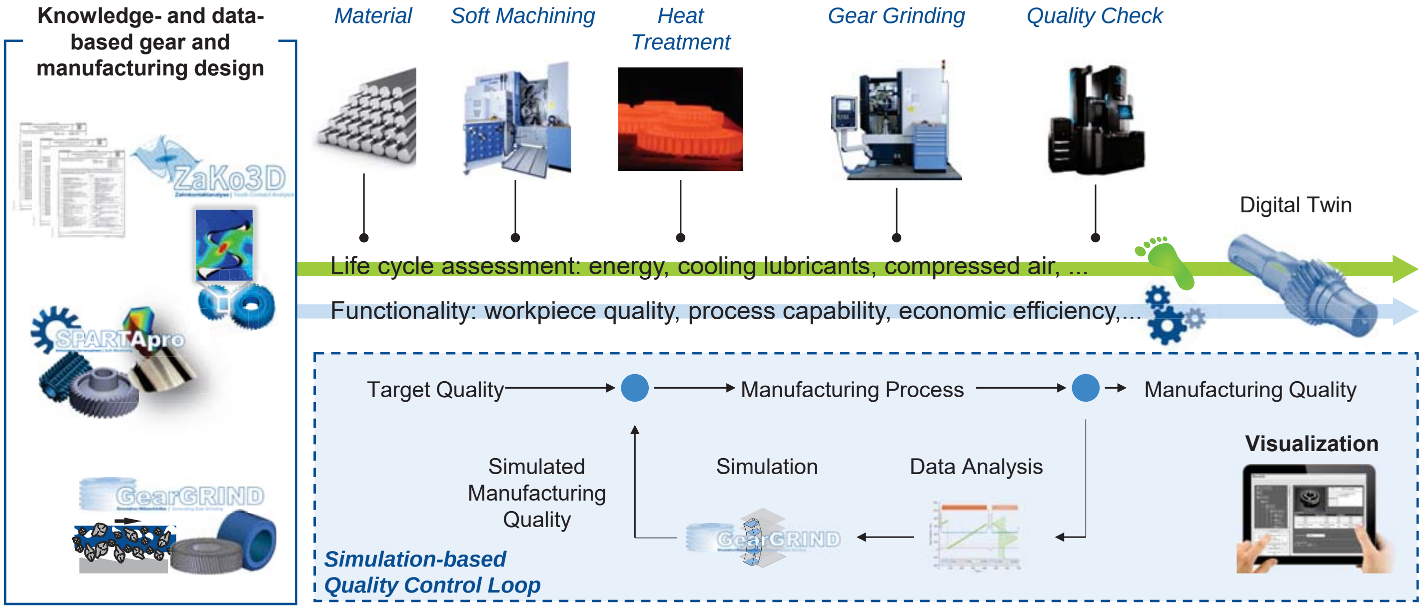
Source: Klingelnberg

Intelligent use of data for optimized process design
Quality assurance through process monitoring during gear skiving



Source: Daimler

Intelligent use of data for optimized process design
Linking production and simulation data



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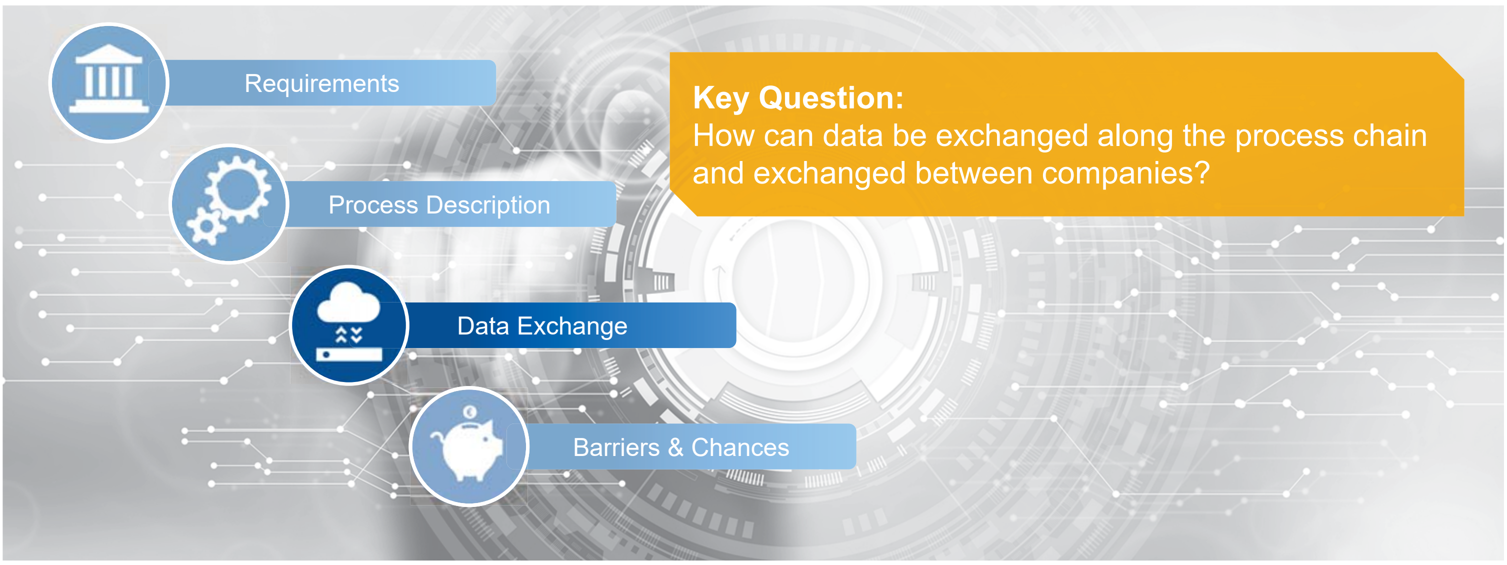
Outline



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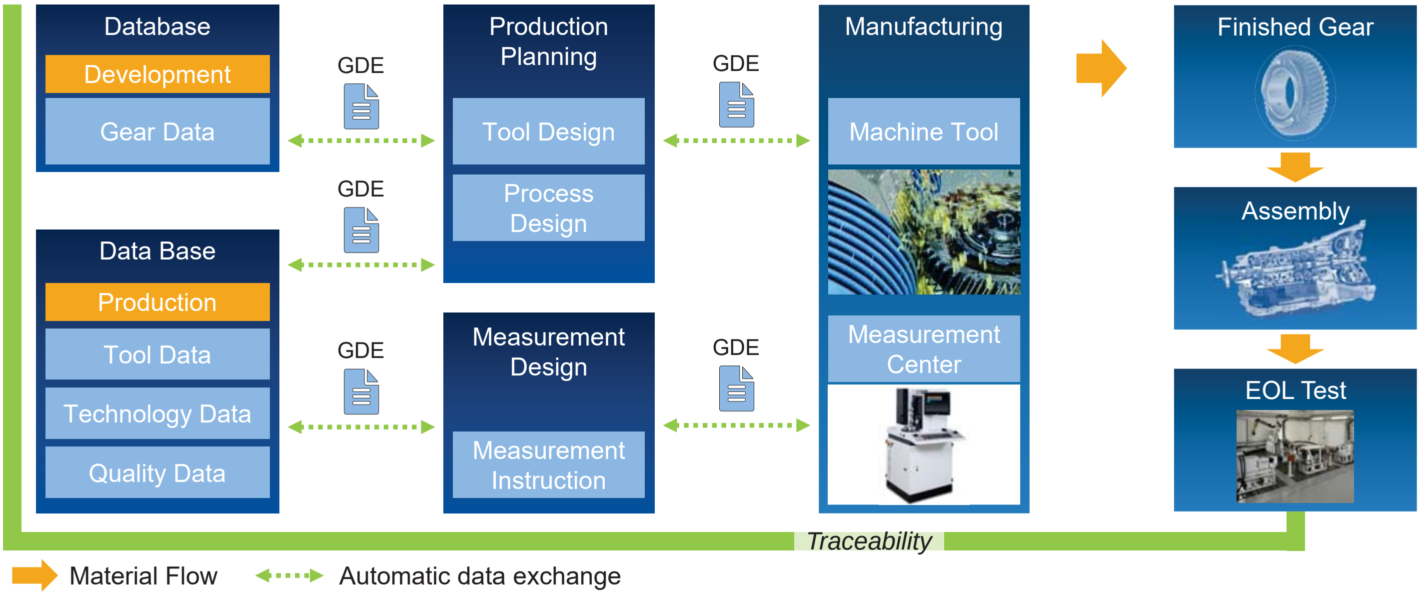
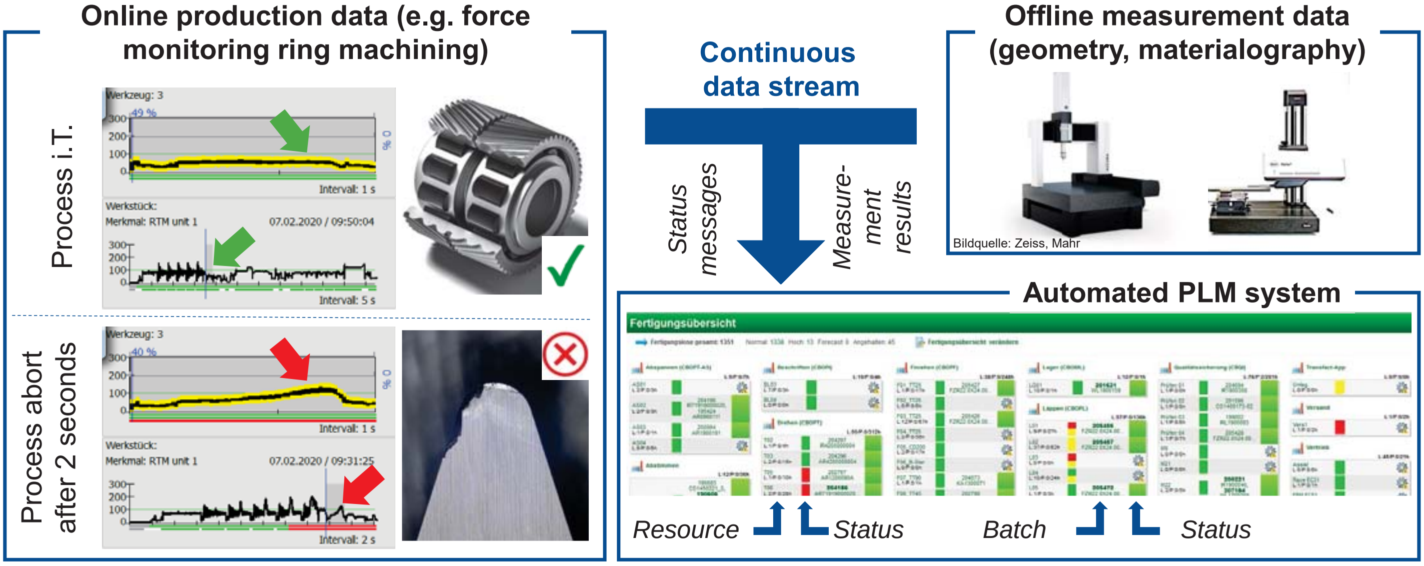
Data interface in manufacturing
GDE as interface for networked gear manufacturing



Source: ZF Friedrichshafen, VDI/VDE 2610

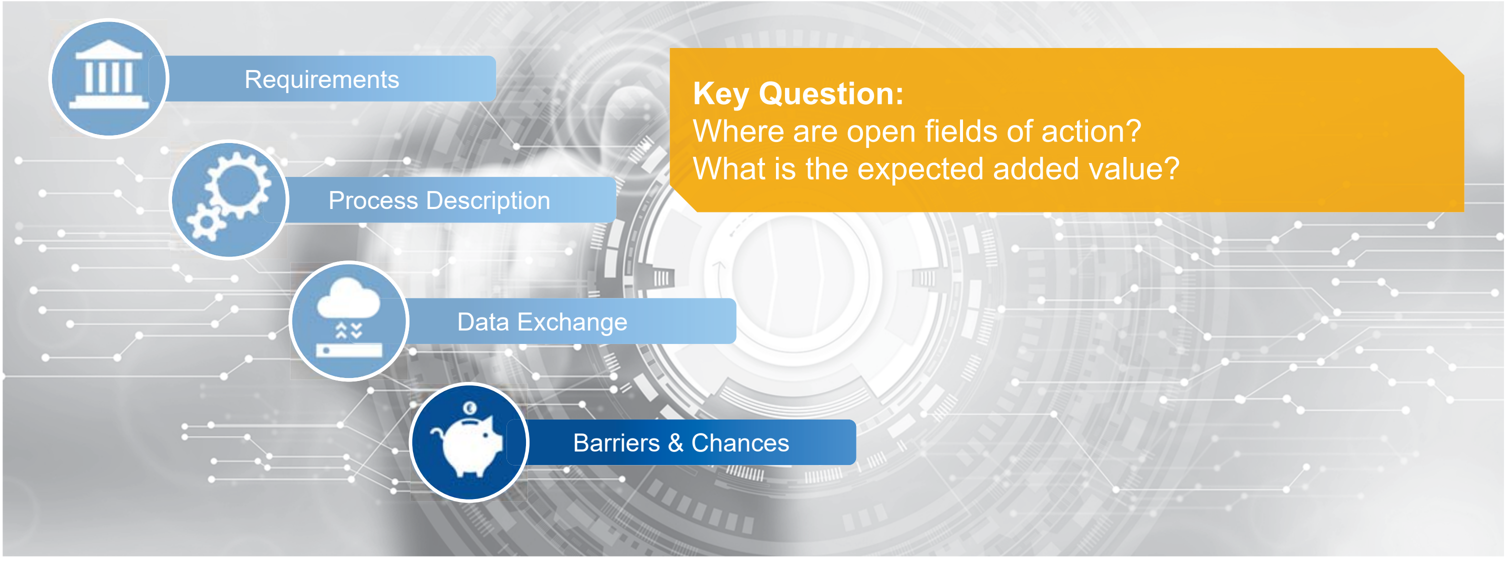
Data interface in manufacturing
Cockpit for fully networked production-accompanying condition recording



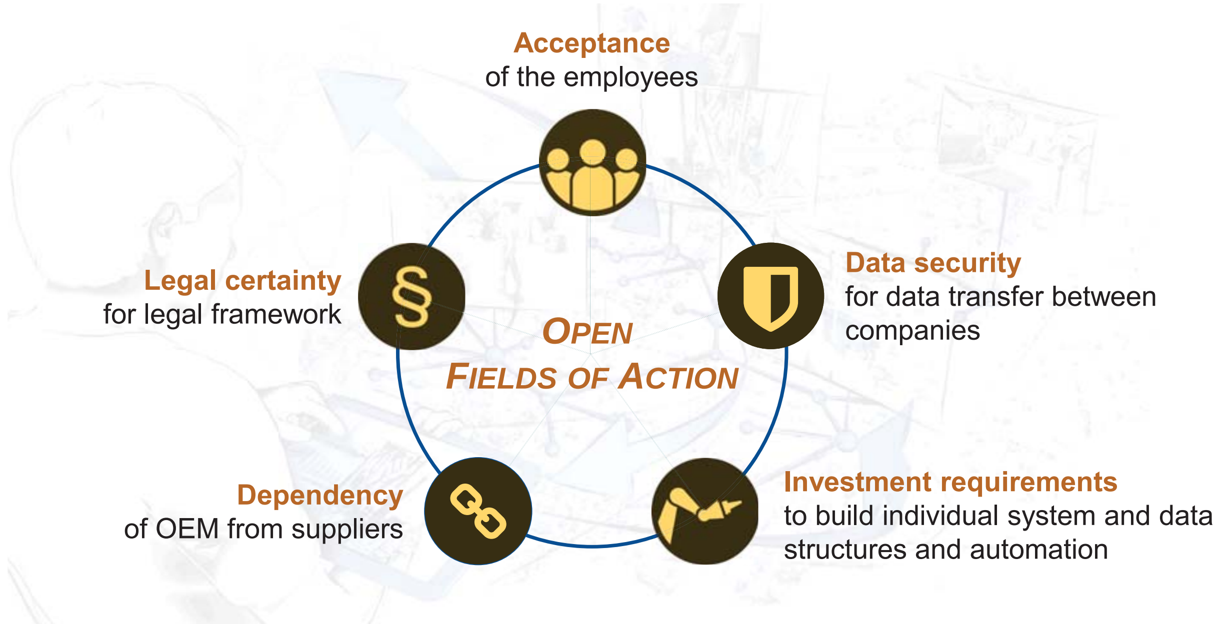
Real-time status of all components and resources as well as permanent access to component properties (back traceability)

Source: Cerobear

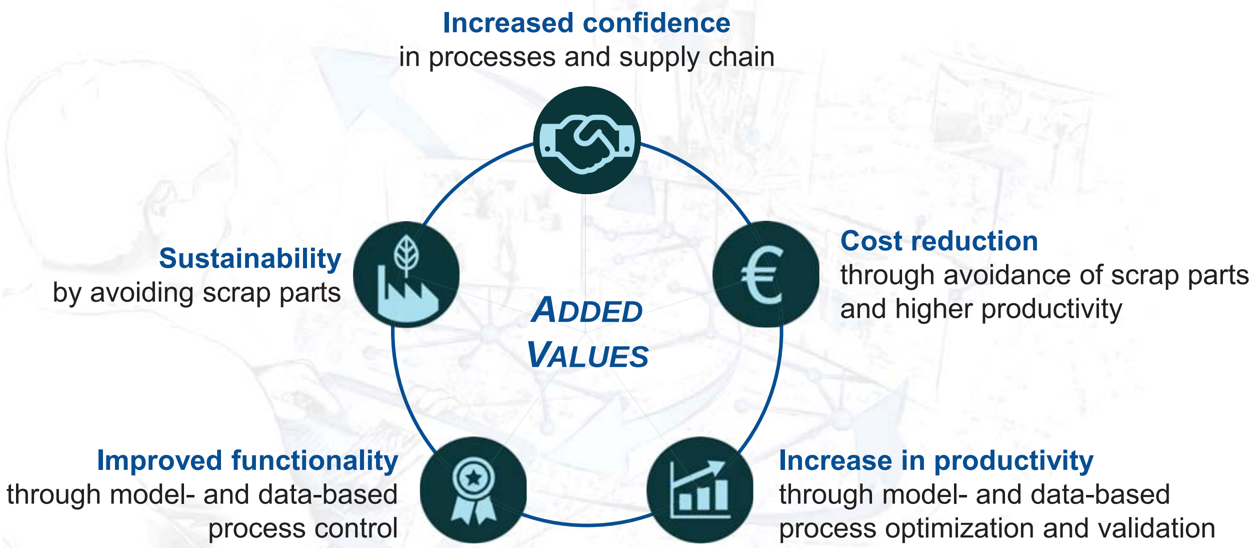
Outline



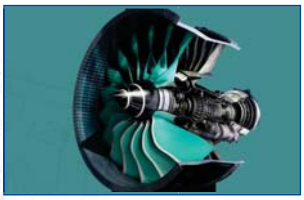
Barriers & Chances
Open fields of action

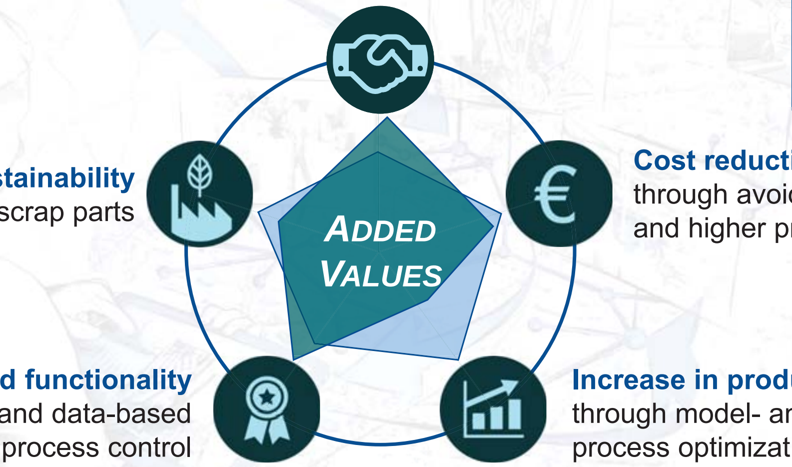


Barriers & Chances
Added value through traceability

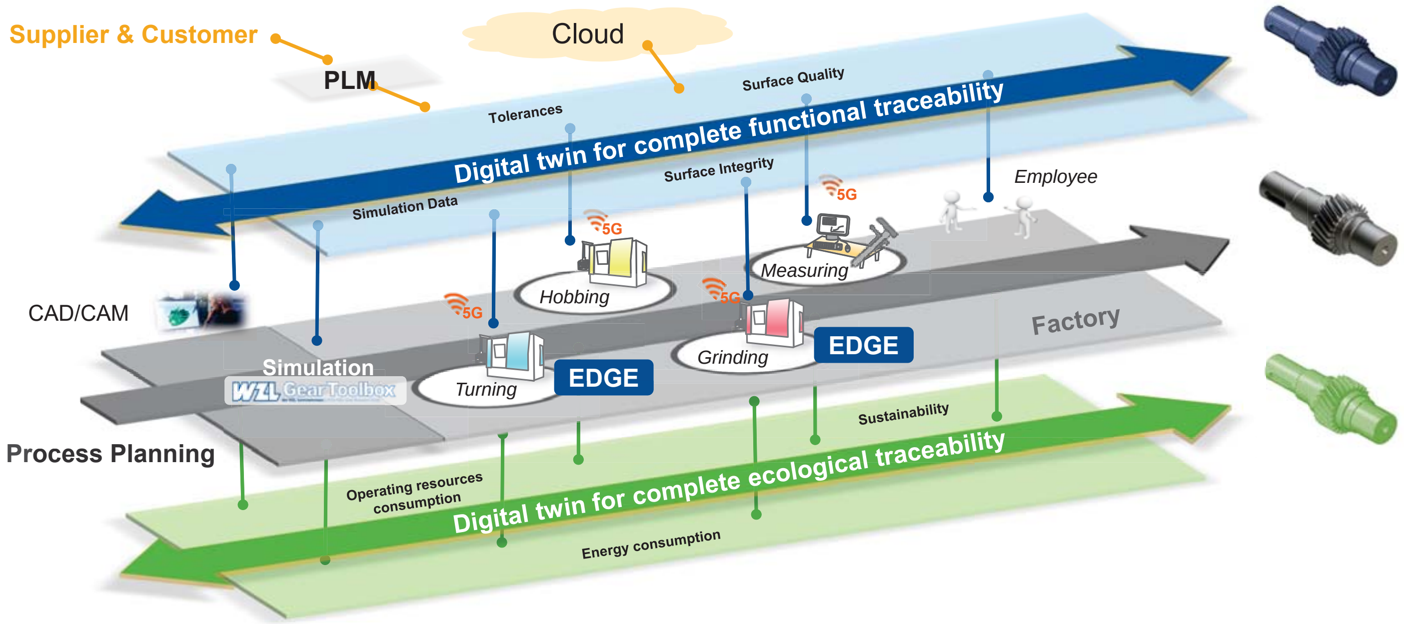


Barriers & Chances
Added value through traceability





Outlook
Factory of the future



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Thank you
for your attention

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Implementing Superfinishing of Heavy Vehicle Transmission Gears in Serial Production

Presenter:

PhD Harald Skiöld Nyberg
Scania CV AB

Additional Authors:
Mr Lars Johansson
Scania CV AB

Introduction

This conference presentation describes parts of the pre-study work done at Scania Transmission Manufacturing in preparation for the implementation of superfinishing of the gear flanks in a new generation of heavy vehicle gearbox, which was recently introduced.

Superfinishing of gears has been used in specialized high performance applications (aerospace, motorsport, etc.) for some time, but has only recently become a viable option for high volume products, such as automotive transmissions. There are in principle two driving forces for implementation of superfinishing, (1) reduction of friction losses in the transmission and (2) increased surface fatigue strength of the gear flanks. These two properties are also to some extent interconnected. A higher surface fatigue strength (pitting resistance) can enable downsizing of the gears, thus reducing frictional losses. Higher surface fatigue strength may also allow the use of a lower viscosity lubricant in the transmission, thus reducing losses through churning of the lubricant. It is however, also possible to use superfinishing as a method for direct friction reduction, and thus improve the efficiency of the transmission.

Methods for superfinishing of gears

Isotropic superfinishing (ISF)

For low volume manufacturing of gears, isotropic superfinishing (ISF) in a vibratory finishing equipment is a cost efficient alternative. It can deliver a very good surface finish with a relatively low cost equipment, that is very flexible for different part geometries. In general, no setup is needed for processing a new part design. The combination of low investment cost and high flexibility makes the method very suitable for low volume production of high performance components, such as for motorsport or aerospace applications. The downside of the method is the very long cycle time (typically in the range of hours) and thus low capacity. The process is also generally unsuited for automation. It is thus typically not a viable option for high volume serial production.

The method is based on an active chemistry, which acts to convert the outermost surface layer of the processed part to an iron phosphate compound. The reaction ceases once a very thin layer has been formed. To achieve further stock removal, the phosphate must be mechanically removed, to expose the metallic surface once more. This is done through vibratory finishing with a non-abrasive ceramic media. This media is able to remove the soft iron phosphate, but does not affect the metallic steel surface underneath it. This combination of chemical and mechanical material removal gives several benefits. Firstly, the material removal is mainly chemical, meaning that there is no machining direction as such, i.e. the resulting surface is isotropic. Secondly, the stock removal rate is largely determined by the chemical reaction rate. This enables a very uniform stock removal, compared to a purely abrasive process, where the stock removal would be determined by the local exposure to abrasive media. For complex geometries, it is very difficult to achieve a uniform exposure, leading to preferential removal of more easy to reach areas of the component and thereby a change of shape. When the stock removal is instead to a large part determined by the chemical reaction rate, this becomes much less of a problem.

Rapid isotropic superfinishing (Rapid ISF)

To meet some of the drawbacks with conventional ISF, the method Rapid ISF was developed. This method involves fixturing of each treated part in a drag finishing equipment, such that the workpiece is dragged through the vibratory vessel of non-abrasive ceramic media. This increases the removal rate of the formed phosphate layer, and thereby shortens the total processing time dramatically. Typically, the process time shortens from the around an hour to a few minutes. The fact that each workpiece is individually fixtured also makes the process much more suitable for automation, compared to the situation in conventional ISF, where the workpieces are moving freely in the ceramic media.

Polishing generating grinding

In recent years, superfinishing by polishing generating gear grinding has found its way into application. The process is basically identical to normal generating gear grinding with a grinding worm, but uses a tool with a smaller grain size and typically a soft binder phase (rubber or resin, rather than the ceramic binder used for conventional grinding tools). The process is often used in combination with grinding, using a tool consisting of a grinding and a polishing section. This enables grinding and superfinishing in the same workpiece setup, removing the problem of aligning the workpiece between operations. It also reduces the time wasted on auxiliary processes (workpiece loading, alignment and unloading). Adding a superfinishing operation will increase the cycle time of the process, both due to the time spent on the polishing grinding operation, but also due to a reduced interval between dressing cycles, since the combined tool will have a narrower grinding section than a tool intended only for grinding.

Gear honing with a polishing tool

Performing gear honing with a tool intended for superfinishing is another option for achieving a superfinished surface. Due to limitations in tool size, it will normally not be possible to perform a combined process (as is common for generating grinding). The polishing gear honing process will need to be made as a separate process. This is probably a big reason why this process option has not reached the popularity of polishing generating grinding. There may however be situations where it could be a competitive alternative.