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PRODUCTION MANAGEMENT

Introduction to integrative production technology

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Abstract Production technology is a highly interdisciplinary field of research. It comprises different production domains (cutting, welding, forming, assembly, etc.), industry-sectors, materials and scales. Moreover, production has strong interdependencies with other scientific disciplines such as product development, materials engineering, business economics, information and communication technology, social science and natural science. Integrative Production Technology aims to develop a deep technology spanning perception to offer products matching customer and societal demands at competitive prices and to quickly adapt to market and societal changes while assuring constant and predictable product properties. The Cluster of Excellence (CoE) "Integrative Production Technology for High-Wage Countries" has initiated this special issue to present some of the newest results in the field. For a wider summary of results, the reader may refer to the recently published book of the CoE (Brecher and Özdemir, Integrative production technology: theory and applications. Springer, Cham, 1).

Keywords Self-optimizing production systems · Model-based control · Virtual production systems · Virtual materials engineering · Industrie 4.0 · Advanced manufacturing

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1 Introduction

Manufacturing is an essential factor for economic success, welfare and social stability in industrial high-wage countries. In the European Union almost every sixth person is directly employed in manufacturing [2] and many more jobs in other sectors are dependent on it. Moreover, the manufacturing sector is the core of a successful export economy. In Germany, for example, from 5 Euros of merchandise exports, more than 4 Euros are contributed by manufacturing [3].

Production is challenged by volatile economic, ecologic and social constraints. At the same time, production needs to handle increasing complexity due to the interdependencies between different technologies, disciplines, industry sectors, material technologies and scales. In this context, current research fields such as hybrid manufacturing processes [4], Integrated Computational Materials Engineering [5], Cybermanufacturing [6] and "Industrie 4.0" [7] address specific areas of interdependencies. The Cluster of Excellence (CoE) "integrative production technology for High-Wage Countries" builds on these results and searches for new ways towards an enhanced understanding of complex, socio-technical production systems.

2 Scientific objectives and research program[1]

Production in high-wage countries is characterized by two fundamental dichotomies that form the polylemma of production (cf. Fig. 1):

[1] For an extended version of this section, please refer to [1].

- *Market-oriented dichotomy* Manufacturing products at mass production costs (scale), which perfectly match individual customer demands (scope).
- *Resource-oriented dichotomy* Optimizing synchronization of production resources (planning orientation) while simultaneously achieving highest system dynamics (value orientation).

The vision of the CoE is to resolve the polylemma of production by theoretical, methodological and technological advances and thus contribute solutions to economically, ecologically and socially sustainable production in high-wage countries.

On the one hand, integrative production technology aims at a holistic understanding of materials, resources and processes. Therefore, complexity is reduced by the division into essential sub-systems and physical interaction laws. On the other hand, the integrative approach accepts that some parts of socio-technical production systems cannot be completely understood, modeled or explained yet, and searches for methods that "make production work" under unknown dynamic boundary conditions. The fundamental part of these methods are robust feedback-loops that enhance adaptability and increase viability.

The scientific roadmap of the CoE is based on the objective to describe and control complex production systems at an optimal operating point, focusing on individualization and technology integration.

The research area Virtual Production Systems aims to describe complex production systems by deterministic model chains with high prediction accuracy. This includes comprehensive and unified environments for the engineering of production systems and materials as well as methods for analysis and evaluation, e.g. based on inverse modelling and sensitivity analysis.

There are always some parts of socio-technical production systems whose behavior cannot be predicted with high accuracy by deterministic models. Therefore, the research area Self-Optimizing Production Systems has the objective to develop cybernetic models that are able to autonomously define, reach and maintain optimal operating points. Self-optimization has been considered at different levels of production—from the entire plant down to single processes of various domains [8]. While many cases are quite different in terms of their application, all fall back to a similar multi-level model-based control architecture.

The research area Technology Integration applies deterministic and cybernetic models for the systematic exploitation of technology integration opportunities in production systems. On the one hand, the research aims at combinations of materials and production processes for product features whose manufacture is impossible today. On the other hand, integration can be the key for optimized production chains for different applications.

Within the research area Individualized Production, the enhanced understanding of production systems is used to realize one-piece-flow of individualized products at competitive production costs. Individualized Production has many different facets—including managerial methods, engineering, ramp-up, automation and advanced processes. The CoE focuses on Selective Laser Melting as a method for direct, mold-less production [9] as well as on mold-based production systems with an emphasis on plastics extrusion and die casting, e.g. [10].

To ensure scientific, personnel and structural sustainability the Cross Sectional Processes aim for new ways of theory development, collaboration and transfer. Considering theories of production there has been a missing link between business economics and technology research. For an indication of how this missing link may be closed, the interested reader may refer to [11].

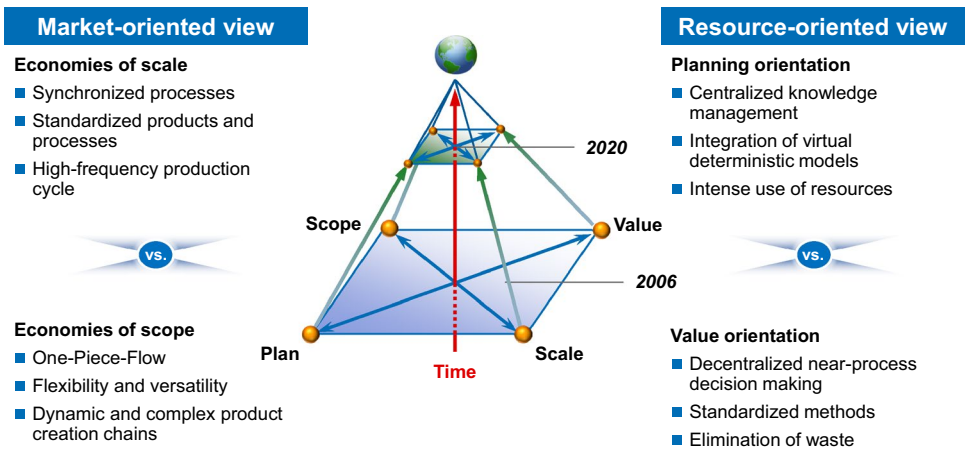

Fig. 1 The polylemma of production

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