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## Integrated design of material, manufacturing, product and performance

Lars-Erik Lindgren\*

*Luleå University of Technology, 971 87 Luleå, Sweden*

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### Abstract

The ever-increasing emphasis on sustainable growth affects mechanical engineering tremendously. The components and products must be efficient, durable and light. Potential cost and weight savings without compromising performance can be realized by extending the design space of engineering design to include manufacturing process as well as material chemistry. This requires more advanced computational support than what is common in today's Computer Aided Design. The paper proposes a modelling approach for evaluation the integrated effects of material and manufacturing on component performance. Material and process models are the key ingredients and are exemplified in the paper.

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### 1. Introduction

The paper is an outcome from a number of research projects at Luleå University of Technology and promotes an extended approach to design for performance. It describes a methodology for achieving optimal performance of products based on integrating material and manufacturing into the design process. However, realizing the potential cost and weight reduction with this extension requires the use of computational support. This will not only contribute to more efficient products but also companies.

Manufacturing is often only seen as the step to realize a product as efficiently as possible. However, many manufacturing processes deteriorate material properties and distort the geometry of the component. But there is also a positive side. It is possible to utilize the manufacturing to create wanted microstructure that has beneficial properties

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\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .  
*E-mail address:* [author@institute.xxx](mailto:author@institute.xxx)

as well as residual stress states. Integrating the design of the manufacturing process and the product makes it thus possible to optimize the product performance further. This integration of manufacturing and product design can be extended one step further by including design, in a limited sense, of the material itself. Typical examples of the latter are modification of bulk and/or surface chemistry of the material during the manufacturing. An extreme end is additive manufacturing based on powder bed fusion methods. Then the material producer delivers powders with wanted chemistry as well as size distributions. The company producing the final product creates the material microstructure as well as the geometry of the component in their process in order to achieve the best possible performance.

Simulations are essential when designing and optimizing products with the above described extended design space. There are additional challenges in this context compared to standard Computer Aided Design (CAD) due to the non-linearity of the models and the need of more material and process information when modeling. Thus this extension of the design space requires competence but it also builds competence. The latter occurs already when developing the models before any simulation has been executed. The company acquires a better understanding of its own processes already when determining the information needed for the models. Competence is a core trait of a company and its employees as indicated in Fig. 1. Furthermore, carrying out the simulations and evaluating their results strengthen the competitiveness of a company and further contributes to its collective competence.

The paper describes a couple of examples where advanced models are used to decrease weight, cost and maintain product performance.

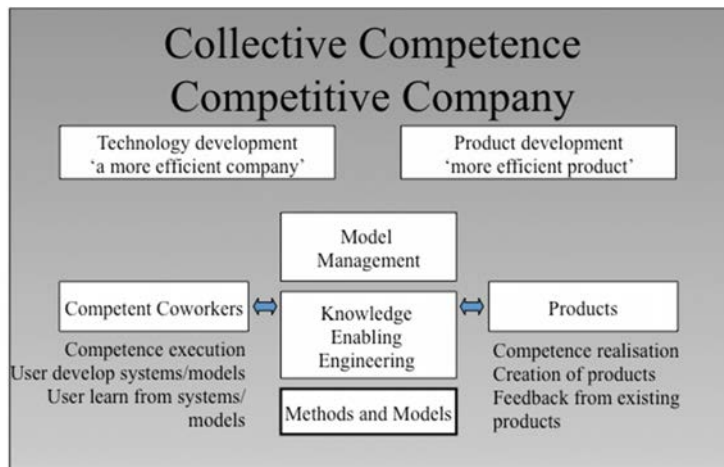


Fig. 1. The Competent Competitive Company.

## 2. Industrial examples

Hot stamping is a process where the forming process is used to give the final microstructure and properties of the component. The forming in the hot state is advantageous as the material is then easy to form, ductile. The rapid cooling when in contact with a cold tool gives a martensitic structure of the steel. The process is therefore often called press hardening. The final product has a high strength and good energy absorption. Therefore, these components are often used at locations in vehicles subjected to impacts. Then the components must be able to absorb energy, protect the passenger and have a low weight. Gestamp HardTech has developed a soft zone technique in order to control the buckling of the component during an impact. The soft zones are created by heating parts of the tool in order to reduce the cooling rate in these regions and thereby the martensite content of the hot formed steel, see Fig. 2. The company used computer simulations both to design the manufacturing process as well as evaluate the impact behavior of the formed component.

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