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Intelligent systems for the prognosis of energy consumption in manufacturing and assembly

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Abstract

This paper is based on a current research project and describes methods which aim to contribute to the estimation of the energy consumption in the production of goods. Today, the energy a product requires during its operation is the object of many activities in research and development. However, the energy necessary for the production of goods is very often not analyzed in comparable depth. The energy consumption in production and disposal is determined very early in the product development process by designers and engineers, for example, through selection of raw materials, explicit and implicit requirements concerning the manufacturing and assembly processes or through decisions concerning the product architecture. Today, developers and engineers have at their disposal manifold design and simulation tools, which can help to predict the energy consumption during operation relatively accurately. In contrast, tools with the objective to predict the energy consumption in production and disposal are not available apart from the first material databases, such as Eco Materials Adviser in Autodesk.
Calculations of the energy consumption in the production can be based on certain volumes and/or the weights of the components or of certain sections of the components. For example, the milling volume for milling operations can be used to determine the energy necessary for this milling operation. Research in production technology can these days provide the necessary tables and equations to determine this energy, if only the milling volume and the milling operations are defined accurately enough. The geometry is developed today almost exclusively in three-dimensional CAD systems. In such systems, the volumes and weights of all components are available today; therefore, the extension is very promising to couple future systems with CAD systems.

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1. Introduction

The energy necessary for the production of goods, e. g. the energy for raw material generation, for casting or for milling, can very often not be analyzed in depth in early stages of product development processes, because the common tools of product development existing today, such as geometry generating tools called CAD-systems (computer aided design), do not support designers and engineers in this endeavor. The importance of the energy for production becomes apparent, for instance, in the field of passenger cars. In this field, even conservative studies [1], [2] come to the conclusion that about 20% of the total energy used by a product is needed for its production and about 10% for its disposal. For other products, such as mobile phones, the proportion of total energy used in production and disposal can rise up to 80%. The energy consumption in production and disposal is determined very early in the product development process by designers and engineers, for example, through selection of raw materials, explicit and implicit requirements concerning the manufacturing and assembly processes or through decisions concerning the product architecture. Today, developers and engineers have at their disposal ~~of~~ manifold design and simulation tools, which can help to predict the energy consumption during operation relatively accurately. For instance, the energy consumption of a car under development, expressed in

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litres per 100 km, can be predicted with an accuracy of 0.1 litres years before this specific car will be built. Frequently, large amounts are invested only to achieve relatively small improvements of the energy consumption during operation. In the area of the motor vehicles, for example, methods such as the start-stop-systems or hybrid systems are applied, which can achieve improvements of the energy efficiency in the one-digit percent area.

In contrast, tools with the objective to predict the energy consumption in production and disposal are not available, apart from the first material databases such as Eco Materials Adviser in Autodesk. Moreover, initial investigations in the research project showed that the available databases deviate quite substantially for identical materials and weights from one another. Very probably, a conscious view of the energy consumption in the production can lead to obvious energy savings. This statement cannot be quantified at the moment for this area; however, an analogy concerning systems for costs prognosis can underline the potential. In this area, the conscious consideration of costs during design led, in the past, to cost savings of up to 70% without restricting the functionality of the components and products (for example, see Ehrlenspiel et al. [3]). Energy saving potential in the production in a similar order of magnitude could lead to improvements in the two-digit percent area of the entire energy balance of a product; improvements of this magnitude can hardly today be reached in the energy consumption in the operation. Today, designers and developers must more or less "blindly" decide, because it is in today's industrial reality impossible to predict the energy consumption in the production. It is hypothesized that intelligent tools and procedures can shift the knowledge concerning production energy consumption into earlier phases and massively can increase the potential for improvement (Figure 1).

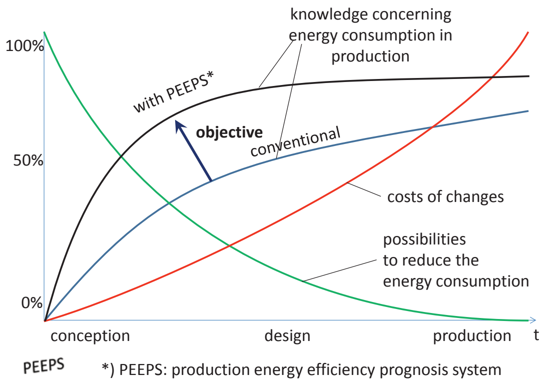

Fig. 1. Early evaluation of production energy consumption

In this representation, which is based on similar representations in the area of early determination of product properties (compare Bernard&Stetter [4]), it is clearly recognizable that in the early phases of the product development, the energy consumption can be influenced significantly more by product changes, and this in connection with considerably smaller change costs.

2. State of the Art

Numerous research activities belong to the state of the research in the area of eco design. Tischner et al. [5] offer a good overview. In these activities, energy consumption plays usually a central role, and in the frame of the Life Cycle Assessment (LCA), the production is also considered as a part of the life cycle (for example, see Finnveden et al. [6]). Especially in this scientific area, the international standard ISO 14031 is to be cited, which supports a comprehensive judgment of the sustainability. Notable are the works of Herrmann et al. [7] which connect the methodologies of the life cycle assessment, multi-criterion analysis and environment achievement indicators. In recent years, the so-called "exergie" has moved into the center of interest as a central measurement means for sustainability. Current works, such as Thompson et al. [9], show first integrations of sustainability considerations and tools also into CAD systems, however, an integration is solely achieved by means of integrating check lists. A current project at the TU Chemnitz focuses on the IT support of energy sensitive product development. However, the main focus here is on the aspects of product data management (PDM) and Enterprise Resource Planning (ERP) (Reichel et al. [10]). Prior works, which also need to be considered, concern the integration of information about the energy consumption in the first production steps of the raw materials. The CAD systems Autodesk Inventor and Solidworks offer expansions which should allow the estimation of the resource consumption already in the design phase. The current version of Autodesk Inventor 2012 offers the expansion Eco Material Adviser, which, by means of an Internet-based database, can, amongst other possibilities, provide information concerning the materials, the raw material fabrication procedure, the energy consumption, the CO2-emission and the water consumption. The database is operated in collaboration with Granta design and includes information about 3,000 materials and selected fabrication procedures. Besides Inventor 2012, the current version of Solidworks also offers an expansion "Sustainability", which provides information concerning the CO2 emission and the energy consumption. The expansion "Sustainability" additionally offers the possibility to automatically find