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Procedia CIRP 50 (2016) 2 – 7

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26th CIRP Design Conference

Material Selection Based on a Product and Production Engineering Integration Framework

Jerome Kaspar[a], Dirk Baehre[b], Michael Vielhaber[a]*

[a]*Institute of Engineering Design, Saarland University, Campus E2 9, 66123 Saarbruecken, Germany*
[b]*Institute of Production Engineering, Saarland University, Campus A4 2, 66123 Saarbruecken, Germany*

* Corresponding author. Tel.: +49 (0) 681-302-71304; fax: +49 (0) 681-302-71317. *E-mail address:* vielhaber@lkt.uni-saarland.de

Abstract

Material selection is an essential aspect of engineering processes of both products and production systems, and often crucial for the success of the resulting products. In practical engineering, however, material selection is often executed in a hands-on manner and not based on an integrated optimization process taking all relevant product and production engineering aspects into account. This contribution presents a formalized approach to better support material selection decisions. The approach is part of an overall material-oriented development methodology and features a material selection method which takes product, production process and material information into account in an integrated way.

Peer-review under responsibility of the organizing committee of the 26th CIRP Design Conference

Keywords: Integrated Product and Production Engineering; Material Selection; Material-Oriented Development

1. Introduction

Material selection is an essential aspect of engineering processes of both products and production systems, and often crucial for the success of the resulting products. Material decisions are heavily interlinked with the products' as well as the production systems' properties and characteristics. In practical engineering, however, material selection is often executed in a hands-on manner and not based on an integrated optimization process taking all relevant product and production engineering (PPE) aspects into account. This contribution will present a formalized approach to better support material selection decisions.

PPE describes the phases in the product lifecycle, in which all aspects of an envisioned product are conceptualized, laid out and detailed along with the respective production equipment. In parallel and closely interrelated, the product's material is determined and defined. Thus, product, production and material definition build the three dimensions of product and production engineering. Holistic approaches in this area have therefore to consider all three dimensions and their interrelationships in an integrated way. In previous work, the authors introduced a generic PPE integration framework, which links inputs and outputs (i.e. impacts and requirements) of engineering with the process phases of both domains. Thereby, it provides a generic basis for the development of analysis and synthesis methods for a wide range of integrated PPE aspects.

In this contribution, the integration framework is applied on the specific aspect of material selection. After summarizing its main ideas in section 2, section 3 will give a short overview on material selection. On this basis, section 4 will introduce a general material-oriented development methodology which will then be brought together with the integration framework to form an integrated material selection method in section 5. Finally, section 6 will discuss the findings and conclude.

2. Product and Production Engineering Integration Framework

In order to allow holistic and integrated decisions in product engineering and production engineering taking both domains equally into account as well as considering domain-spanning material aspects, the authors developed a product

Peer-review under responsibility of the organizing committee of the 26th CIRP Design Conference
doi:10.1016/j.procir.2016.04.181

and production engineering (PPE) integration framework which can serve as a basis for a variety of domain-spanning engineering applications [1].

Thus, product definition, production definition and material definition build the three dimension of the framework. For each dimension, the framework defines three maturation phases from a concept via a layout to a detail level, and it evaluates interrelationships between all these nine phases. These interrelationships build the horizontal axis as well as the roof of the House of Quality-like representation of the framework, see figure 1.

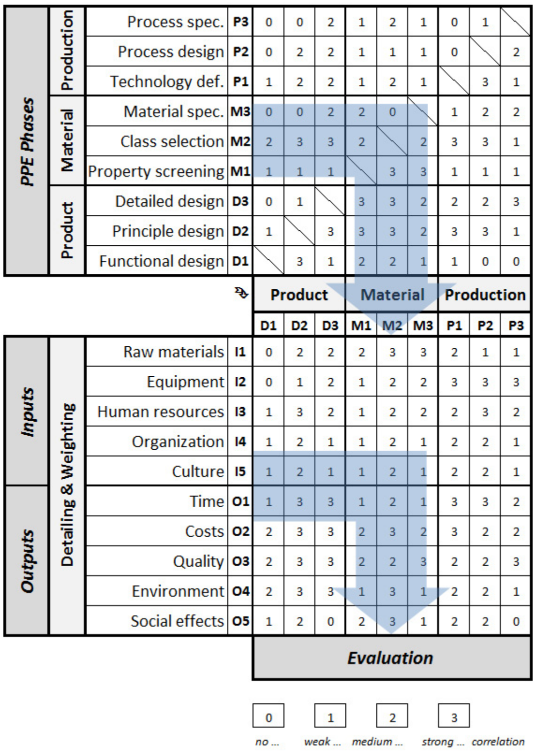

Fig. 1. Product and production engineering integration framework as presented in [1]

Decisions in this environment are on the one hand influenced and constrained by external impacts and boundary conditions. In the integration framework, these inputs have been categorized in raw material, equipment, human resources, organization and culture-related impacts. On the other hand, requirements define the desired outputs of product and production engineering. These outputs have been categorized into time, cost and quality requirements as well as environmental and social effects. Both inputs and outputs build the vertical axis of the framework representation in figure 1. In the main matrix area of the framework, then, inputs and outputs are correlated with the maturation phases from the horizontal axis; strength of the correlations are evaluated on a generic basis, initially.

Applying the integration framework on engineering questions such as material selection would now require to detail and weight both the boundary conditions (inputs) and the requirements (outputs). Then, the correlations have to be re-evaluated, the interrelationships of the PPE phases have to be re-considered, and the material evaluation has to be executed on this information basis. Section 5 will elaborate on this application in further detail.

3. Material Selection Today

Engineering design represents the process of translating a new idea or a market need through a more detailed concept, or rather a technical draft, into an ultimate construction a product can be manufactured from. Therefore, each of these stages require decisions about feasible materials depending on the product itself, commonly dictated by the design, as well as the manufacturing process (form, join and finish).

Nowadays, the variety of available engineering materials placed at the constructor's disposal is large; according to Moeller [2] approximately 40,000 of metallic and non-metallic each. Thus, without guidance, the selection of the few best suited materials with regard to the respective system or product requirements is difficult and time-consuming, but still insufficiently precise only and furthermore no longer up-to-date. Due to this fact, there is an urgent need for a systematic approach of a material-oriented product development process.

The scientific literature, however, contains numerous approaches, methods and procedures for a systematic material selection. Indeed, these closely resemble the common problem-solving cycle, but are still different in terms of their priorities. Thus, Grosch [3], Ehrlenspiel et al. [4] and Fischer [5] first provided the link between the traditional product development process and an overall systematic approach to material selection, highlighting material-relevant decisive fields.

An internationally accepted and well-known standard for material selection is represented by Ashby [6], see figure 2.

Fig. 2. Four main steps of the material selection guideline by Ashby: translation, screening, ranking, supporting information [6]