Title:
Multi Criteria Material Selection for Eco-design

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Keywords:
Material selection, eco-design, multi criteria decision making, structural optimization

DOI: 10.14733/cadconfP.2014.129-130

Introduction:

In recent years, structural optimization has changed the way we think of product development. Optimizers allow to explore every possible product shape with the aim of maximizing performance, minimizing cost and accounting for environmental factors from the early phases of the design process. Material selection plays a big role, as one of the first and most binding choices of the product development. Current material selection schemes are too generic and bound to a less shape-driven design, which doesn't take full advantage of the optimization potential. They were developed for constant or self-similar shape products and allow for a substantial degree of subjectivity when defining weight values for non-constant shape models. This paper proposes a computer-aided material selection scheme for structurally optimized products. It aims at integrating a multi-criteria decision-making approach with the product awareness of a structural optimization, in order to systematically define the ranking weight values. The procedure comprises four main steps: a) initial material screening, to obtain a list of product and process compatible materials, b) statistical analysis of the design space through a factorial DoE (Design of Experiment), to rank the effect of each material property on the environmental impact, c) Multi Criteria Decision Making, to rank materials according to each material property importance, d) structural optimization, to identify the best possible shape for the chosen material.

Main idea:

From the analysis of the state of the art, it is clear that to improve current material selection schemes, the main goal should be a deeper analysis of the design space (the collection of all possible material-shape combinations). However, even with discrete geometry dimensions, the design space is made of countless combinations and it would be impossible to study each one in detail. Thus, this paper proposes a methodology based on a statistical approach, which helps the designer in determining the importance of each material property on the overall environmental impact of the product. These values can then be easily used as weights in a multi criteria decision-making process, in order to obtain a ranked list of compatible materials.

The methodology comprises four main steps (Fig. 1).

- Initial material screening to obtain a list of product and process compatible materials.
- Statistical analysis of the design space through a factorial DoE (Design of Experiment) to rank the effect of each material property on the environmental impact.
- Multi criteria decision-making to rank materials according to each material property importance.
- Structural optimization to identify the best possible shape for the chosen material.

The first three steps are devoted to the identification of the best material, while the last one is a classical optimization aimed at finding the best product shape for the chosen material. To support each step, the methodology integrates CAE tools and a DOE system. Figure 1 shows by means of an IDEF0 diagram, the aforementioned activities and flows of information and data.

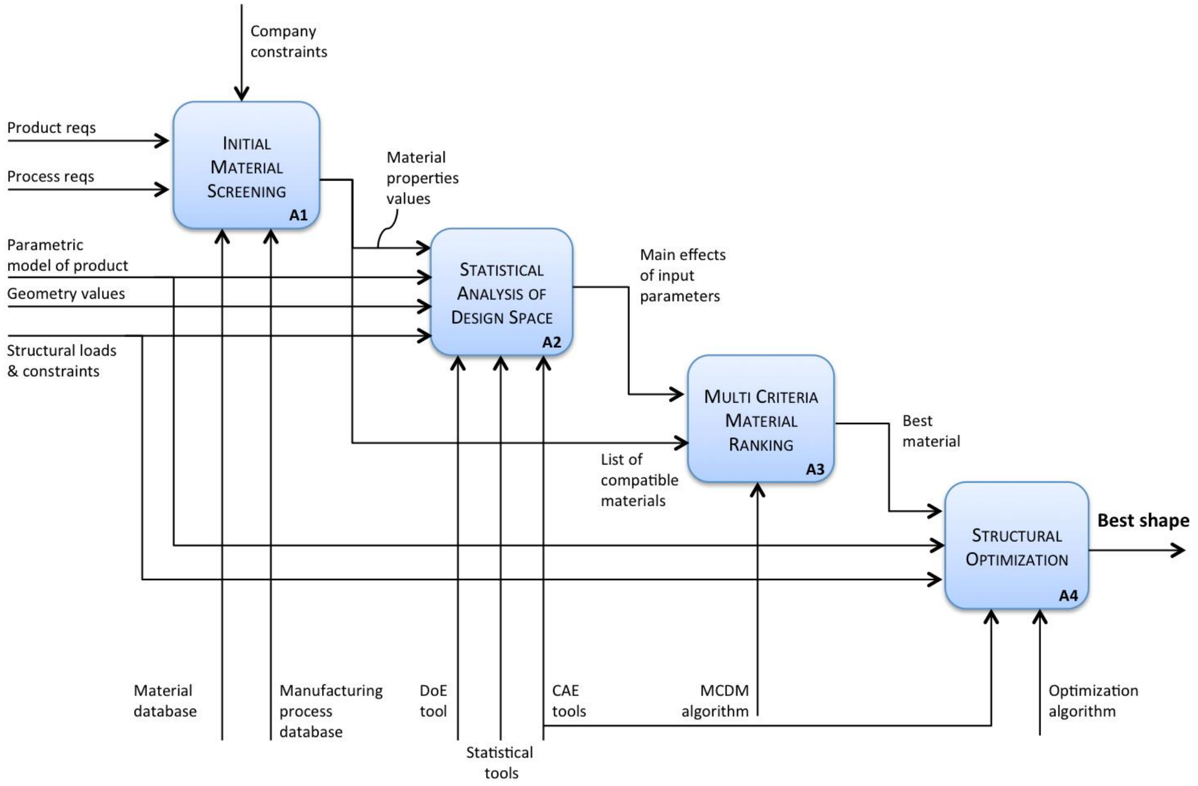

Fig. 1: Methodology workflow.

Conclusions:

The traditional approach to material selection is that of assigning weight factors to each relevant material property, in order to rank materials by giving the correct emphasis to each decision criteria. The upside: experienced engineers can be good at assessing relative weights. The downside: the method relies on judgment. In assessing weights, judgments can differ.

The absence of an effective way to systematically define weight factors is mainly caused by lack of product awareness. While it is often impossible to establish a direct relationship between decision criteria and product characteristics, this is not the case with material selection for mechanical applications. Thanks to CAE tools, the designer can identify how input variables affect the final product, thus giving the correct emphasis to each material property.

This paper has proposed a computer-aided material selection methodology based on the integration of a multi-criteria decision-making approach with structural optimization, in order to systematically define the ranking weight values. This has been achieved by describing the design space through a statistical DoE (Design of Experiment), in order to identify the relative environmental importance of each material property.

The methodology has been tested on a simple case study concerning the design of an environmentally friendly I-beam. The results confirm the feasibility of the proposed approach in improving material selection when a relevant number of decision criteria is involved.