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An aggregation technique for optimal decision-making in materials selection

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ABSTRACT

Materials selection is an onerous but very important activity in the design process. An inappropriate choice of material(s) can adversely affect the productivity and profitability and hence reputation of a manufacturing organization. The complexity of materials selection makes multi-criteria analysis an invaluable tool in the engineering design process. However, the application of various multi-criteria decision making (MCDM) methods can yield different results, especially when alternatives lead to similar performance. Therefore, an aggregation technique is proposed in this paper for optimal decision-making. In this approach, ranking orders obtained by various MCDM methods are used as the input of the suggested procedure and the outputs are aggregation rankings, which help designers and engineers to reach a consensus on materials selection for a specific application. An illustrative example is given to demonstrate the application of this procedure and its effectiveness in obtaining optimal materials selection.

1. Introduction

Successful engineering product design depends greatly on the decisions being made by designers throughout the whole design process; with materials selection being a challenging activity within that process [1,2]. Although materials selection can be carried out at any stage of the product life cycle, it is usually done as part of the original design process, and again when modifying or adapting current products due to failure occurrence or satisfying different market demands. When developing new materials, optimal materials selection is of high importance in the design and/or redesign of products. Furthermore, the choice of the best material among a host of alternative materials might greatly impact the eventual success or failure of a product in the market place. An improper choice can adversely affect productivity and profitability, and even undermine the name of an enterprise because of the growing demands for through-life and extended producer responsibility [3]. Due to the importance of reliability in product design [4], for contemporary materials selection systems, the suitability of candidate materials is evaluated against multiple criteria rather than considering a single factor [5,6]. Among the many different fields, where multi-criteria decision making (MCDM) is applied, selecting the most appropriate materials for high technology components used in biomedical, aerospace and nuclear industries is particularly demanding and important to get right first time.

Materials selection using MCDM has attracted the attention of decision makers for a long time [7–12]. Choosing the most appropriate MCDM method is very significant in materials selection [13]. Some researchers have suggested applying different MCDM methods together as a more efficient design tool in order to enhance the accuracy of the final decision and for the sake of making safer engineering decisions when the difference between the alternative solutions are inherently close together [14–16]. The aggregation of individual rankings by various MCDM methods is usually done by an averaging function [14] as a basic aggregation strategy. However, when using this process, there is no guarantee of obtaining optimum results for circumstances in which there are large differences between the rankings of alternatives. As a consequence, Borda and Copeland rules [15], the most common voting aggregation techniques in group decision-making [16], are used for aggregation of MCDM results [14]. The Borda rule assigns more points to higher rankings and then adds up those points over all individual voters for every alternative. The option that has the highest points in the voters' rankings is then chosen. Copeland's method is a single-winner strategy in which the winner is identified by finding the candidate with the most pair-wise victories. Favardin et al. [17] showed that the Borda rule is significantly more vulnerable than the Copeland rule, although the probability of a tied situation is the main weakness of both techniques [16]. Therefore, there is a need for a systematic and logical scientific procedure to help decision-makers such as designers and engineers to achieve the optimum ranking of materials.

This article describes the basis of an integrated framework for assisting complex decision-making in materials selection. The next

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