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A comprehensive VIKOR method for material selection

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ABSTRACT

In engineering design, material alternatives evaluate according to different criteria depending on the objectives of the problem. Performance ratings for different criteria are measured by different units, but in the decision matrix in order to have a valid comparison all the elements must be dimensionless. However, a lot of normalization methods have been developed for cost and benefit criteria, not only there has not been enough attention for engineering design situations in which approaching the target values are desirable but also the available methods have shortcomings. A new version of VIKOR method, which covers all types of criteria with emphasize on compromise solution, is proposed in this paper. The proposed comprehensive version of VIKOR also overcomes the main error of traditional VIKOR by a simpler approach. Suggested method can enhance exactness of material selection results in different applications, especially in biomedical application where the implant materials should possess similar properties to those of human tissues. Five examples are included to illustrate and justify the suggested method.

1. Introduction

Material selection is one of the most prominent activities in the design process, and it has attracted attention of researchers for more than 20 years [1–10]. An inappropriate selection of materials may result in damage or failure of an assembly and significantly decreases the performance. Since it has been found that the lowest-price might not be the promising approach to achieve the optimum material, multi-criteria decision making (MCDM) methods became popular in this field. MCDM consists of generating alternatives, establishing criteria (attributes), evaluation of alternatives, assessment of criteria weights, and application of a ranking system [11]. Each of the criteria is related with an objective in the given decision context, and normalization is used for transforming different criteria into a compatible measurement. The properties whose higher values are desirable, called positive criteria or beneficial attributes (e.g. strength, and toughness) and those properties whose smaller values are always preferable, named negative criteria, cost criteria or non-beneficial attributes (e.g. density, cost, and corrosion rate). A lot of normalization methods has been developed for cost and benefit criteria; Jee and Kang used [12] linear normalization-sum method instead of vector normalization procedure in TOPSIS and Milani et al. [13] compared vector normalization approach with four linear normalization methods in material selection. Dehghan-Manshadi et al. [14] developed a nonlinear normalization model, which normalizes data between −100 and 100 and needs to define the critical values by the designer, for positive and negative criteria. Moreover, Fayazbakhsh et al. [15] proposed Z transformation for dimensionless of the decision matrix in weighted properties method (WPM), but the output of this normalization method is around zero and does not have any provision for target value objectives. Only in the limits on properties method (LOP), that proposed by Farag [9,16], all types of criteria, including positive, negative, and target values can be considered. In LOP method, not only, the normalization approaches for the beneficial/non-beneficial attributes and target values are different, but also the applied normalization technique for target values has shortcomings. However, method of multi-criteria decision making based on ordinal data (MCDM-BOD) [17], which does not need to normalize the criteria, can be used here, but it is more appropriate during the preliminary design stages in which designers face to imprecise data (discrete or incomplete information) or intangible properties. Moreover, the other methods in material selection [18–25] do not have any provision for engineering design states in which satisfying the target value is desirable. This issue is particularly crucial in biomedical application [26–28] where the implant materials should possess similar properties to those of human tissues.

Furthermore, different MCDM methods often create different outcomes to select or rank a set of decision alternatives [29]. Voogd

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