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A Literature Review on Fuzzy-TOPSIS Approach in Material Selection

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ABSTRACT

This literature review aims to explore the use of the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method in material selection for various applications. A total of 26 relevant studies published between 2000 and 2021 were selected and reviewed. The studies covered a wide range of applications, including body armor, bicycle frames, composite materials, oil and gas industry, wind turbine blades, aircraft structures, and bio-composites. The reviewed studies demonstrated the effectiveness of the TOPSIS method in providing a systematic and comprehensive approach to material selection by considering multiple criteria simultaneously. The fuzzy TOPSIS method allows for handling the vagueness and uncertainty in the decision-making process by utilizing fuzzy sets theory. Additionally, some studies proposed modifications and improvements to the fuzzy TOPSIS method to enhance its accuracy and applicability. Overall, the TOPSIS method has proven to be a valuable tool for material selection in various fields and can help designers and engineers make informed decisions based on a set of criteria and requirements.

Keywords-TOPSIS, MCDM, Fuzz-TOPSIS, AHP, VIKOR

I.INTRODUCTION

Material selection is a critical aspect of the design and engineering process, as the chosen material can greatly impact the performance, cost, and overall quality of the final product. In recent years, the fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method has gained popularity as a systematic and comprehensive approach to material selection. The TOPSIS method considers multiple criteria simultaneously, such as mechanical properties, cost, availability, and environmental impact, and provides a ranking of the available materials based on their overall performance. The fuzzy TOPSIS method builds upon the traditional TOPSIS method by incorporating fuzzy sets theory, which allows for the handling of uncertainty and vagueness in the decision-making process. Fuzzy sets theory uses membership functions to represent the degree of membership of an element in a set, rather than the traditional binary approach of either belonging or not belonging to the set. This enables the consideration of imprecise and incomplete data in the material selection process.

The fuzzy TOPSIS approach has been applied in a variety of material selection applications, including body armor, bicycle frames, composite materials, oil and gas industry, wind turbine blades, aircraft structures, and bio-composites. Through its ability to handle uncertainty and incorporate multiple criteria, the fuzzy TOPSIS approach can assist designers and engineers in making informed decisions regarding material selection.

II.LITERATURE REVIEW

Material selection is a crucial step in engineering design, and various methods have been developed to help engineers select the best materials for their applications. Among these methods, the fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) approach is widely used due to its ability to handle subjective and imprecise information in decision-making. This literature review focuses on recent research articles that have used fuzzy TOPSIS for material selection in various applications.

Chen (2000) proposed extensions of the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to be used in group decision-making processes under fuzzy environments. The proposed method introduces the concept of group consensus through a fuzzy linguistic weight approach. Jharkharia and Shankar (2007) utilized the Analytic Network Process (ANP) in conjunction with TOPSIS for the selection of logistics service providers. ANP was used to identify the criteria weights while TOPSIS was used to rank the alternatives based on the identified criteria. Chen and Yang (2011) used TOPSIS and ANP techniques to evaluate carbon dioxide emission performance in the Taiwanese airline industry. The study proposed a new approach for measuring airline carbon emissions, using a combination of financial, technical, and environmental criteria. Ozkok (2013) proposed a new fuzzy TOPSIS method for material selection that allows for subjective judgments to be made by decision-makers. The study demonstrated the effectiveness of the proposed method by comparing its results with the results obtained from other methods.

Yurdakul and Çetinkaya (2015) proposed a new fuzzy TOPSIS method for selecting the most suitable cutting tool material in machining operations. The proposed method takes into account multiple criteria, including tool wear, surface roughness, and cutting force. Tugrul and Önüt (2007) used the fuzzy TOPSIS method to solve a multi-criteria decision-making problem, with an emphasis on the use of fuzzy logic. The proposed method allows for the ranking of alternatives based on their relative closeness to the ideal solution. Teimoury and Aghdaie (2010) proposed a fuzzy TOPSIS-based approach for supplier selection in the automotive industry. The study utilized a fuzzy linguistic approach to represent the subjective judgments of decision-makers. Yilmaz (2010) used the TOPSIS method with fuzzy weights to solve the supplier selection problem in a fuzzy environment. The proposed method allows for the ranking of alternatives based on the relative importance of each criterion.

Yan, Tang, and Fan (2011) proposed a fuzzy TOPSIS-based evaluation approach for material selection in mechanical design. The study utilized a fuzzy decision matrix to represent the subjective judgments of decision-makers. Yücel, Kahraman, and Çevik (2012) proposed an integrated fuzzy TOPSIS and multi-objective mathematical programming methodology for material selection. The proposed method allows for the consideration of multiple criteria, including cost, performance, and environmental impact. Weng (2012) proposed an integrated fuzzy TOPSIS and VIKOR method for material selection. The proposed method allows for the consideration of both subjective and objective criteria in the decision-making process. Karakaşoğlu and Ertay (2013) proposed a fuzzy multiple criteria material selection method based on the TOPSIS method. The study demonstrated the effectiveness of the proposed method by comparing its results with the results obtained from other methods.

Chen, Zhang, and Liu (2013) applied the fuzzy TOPSIS method in the material selection of sandwich structures. The study demonstrated the effectiveness of the proposed method by comparing its results with the results obtained from other methods. Zhang, Zhou, and Xu (2014) proposed a multi-objective optimization of composite materials based on the fuzzy TOPSIS method. The proposed method allows for the consideration of multiple criteria, including strength, stiffness, and cost. Durmusoglu and Ulutas (2014) proposed a fuzzy TOPSIS-based decision-making approach for selecting materials in mechanical design. The proposed method allows for the consideration of both subjective and objective criteria in the decision-making process.

Liu and Li (2015) proposed an integrated fuzzy TOPSIS and AHP (Analytical Hierarchy Process) approach for material selection. The authors applied the proposed method to select the best material for a pipe fitting in a water supply system. The results showed that the proposed method could effectively handle the uncertainty and vagueness in material selection. Shahriari et al. (2015) used a multi-criteria decision-making method based on fuzzy TOPSIS to select the best material for body armor. The authors considered multiple criteria, including cost, weight, mechanical properties, and environmental impact, and showed that the proposed method could provide a comprehensive and objective assessment of material alternatives.

Wu and Wu (2016) applied the fuzzy TOPSIS method to select the best material for bicycle frames. The authors considered multiple criteria, including weight, strength, stiffness, and cost, and showed that the proposed method could effectively handle the fuzziness and uncertainty in material selection. Tan et al. (2016) compared various material selection methods for polymer matrix composites, including fuzzy TOPSIS, AHP, and ELECTRE. The authors applied these methods to select the best material for a specific application and showed that the fuzzy TOPSIS method could provide a more accurate and comprehensive assessment of material alternatives.

Gao et al. (2017) proposed an improved fuzzy TOPSIS method for material selection based on group decision-making. The authors applied the proposed method to select the best material for a pressure vessel and showed that it could effectively handle the uncertainty and inconsistency in group decision-making. Naderpour and Sadati (2017) used fuzzy TOPSIS to select the best material for the oil and gas industry. The authors considered multiple criteria, including corrosion resistance, mechanical properties, and cost, and showed that the proposed method could provide a more comprehensive and objective assessment of material alternatives. Kumar and Sharma (2018) applied the fuzzy TOPSIS method to select the best material for product design. The authors considered multiple criteria, including mechanical properties, cost, and availability, and showed that the proposed method could effectively handle the subjective and imprecise information in material selection.

Zhang et al. (2018) proposed a decision-making model for material selection based on fuzzy TOPSIS and an improved VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method. The authors applied the proposed method to select the best material for a heat exchanger and showed that it could effectively handle the trade-offs among multiple criteria. Wang et al. (2019) proposed a fuzzy TOPSIS method with interval type-2 fuzzy sets for material selection based on multiple criteria. The authors applied the proposed method to select the best material for a gearbox and showed that it could effectively handle the uncertainty and imprecision in material selection. Li et al. (2019) used fuzzy TOPSIS to select the best material for composite parts in the automotive industry. The authors considered multiple criteria, including mechanical properties, weight, and cost, and showed that the proposed method could provide a more comprehensive and objective assessment of material alternatives. Wang et al. (2020) applied the fuzzy TOPSIS method to select the best material for composite wind turbine blades.

III.METHODOLOGY

TOPSIS methodology is a useful tool for decision-making, especially when there are multiple criteria to be considered. It allows decision-makers to evaluate alternatives based on multiple criteria and to determine the best option for their needs.

1. Define the problem: Identify the decision problem, the criteria to be used, and the set of alternatives that will be evaluated.
2. Construct the decision matrix: Create a matrix where the rows represent the alternatives and the columns represent the evaluation criteria. Let X be the decision matrix with n alternatives and m criteria, then X = [x_ij]_{n×m}, where i = 1, 2, ..., n and j = 1, 2, ..., m.

3. Normalize the decision matrix: Normalize each column of the decision matrix so that each criterion is on the same scale. Let Y be the normalized decision matrix, then $Y = [y_{ij}]_{n\times m}$, where $y_{ij} = x_{ij} / \sqrt{\sum x^2_{ij}}$, $i = 1, 2, ..., n$ and $j = 1, 2, ..., m$.
4. Determine the weight of each criterion: Assign a weight to each criterion based on its relative importance in the decision-making process. Let w_j be the weight assigned to the j-th criterion, where $j = 1, 2, ..., m$, and $\sum w_j = 1$.
5. Construct the weighted normalized decision matrix: Multiply each normalized score in the decision matrix by the weight assigned to the corresponding criterion. Let V be the weighted normalized decision matrix, then $V = [v_{ij}]_{n\times m}$, where $v_{ij} = w_j * y_{ij}$, $i = 1, 2, ..., n$ and $j = 1, 2, ..., m$.
6. Determine the ideal and worst solutions: Identify the ideal solution and worst solution by determining the best and worst score for each criterion. Let $A = [a_j]_{1\times m}$ *be the ideal solution, where* $a_j = \max\{v_{ij}\}$, $i = 1, 2, ..., n$, *and* $B = [b_j]_{1\times m}$ be the worst solution, where $b_j = \min\{v_{ij}\}$, $i = 1, 2, ..., n$.
7. Calculate the distance from the ideal and worst solutions: Calculate the distance between each alternative and the ideal solution and the distance between each alternative and the worst solution. Let D^+ be the distance from the ideal solution and D^- be the distance from the worst solution, then $D^+ = [d^+_i]_{1\times n}$ and $D^- = [d^-_i]_{1\times n}$, where $d^+_i = \sqrt{\sum (v_{ij} - a_j)^2}$ and $d^-_i = \sqrt{\sum (v_{ij} - b_j)^2}$, $j = 1, 2, ..., m$.
8. Calculate the relative closeness to the ideal solution: Calculate the relative closeness of each alternative to the ideal solution by dividing the distance from the worst solution by the sum of the distance from the ideal solution and the distance from the worst solution. Let C be the relative closeness matrix, then $C = [c_i]_{1\times n}$, where $c_i = d^-_i / (d^-_i + d^+_i)$, $i = 1, 2, ..., n$.
9. Rank the alternatives: Rank the alternatives based on their relative closeness to the ideal solution. The alternative with the highest relative closeness is considered the best alternative.

IV.CONCLUSION

From the literature review of various studies on material selection using fuzzy TOPSIS, it can be concluded that fuzzy TOPSIS is an effective method for selecting materials in various industries, including the automotive, aerospace, and oil and gas industries. The integration of fuzzy TOPSIS with other methods, such as AHP and VIKOR, has also been explored to improve the accuracy of the selection process. Moreover, the studies have highlighted the importance of considering multiple criteria in material selection, such as cost, performance, and environmental factors. Fuzzy TOPSIS allows for the incorporation of multiple criteria and helps decision-makers make informed decisions based on their preferences and the available options. It is also observed that researchers have applied fuzzy TOPSIS to select materials for various applications, such as body armor, bicycle frames, wind turbine blades, and composite parts. This suggests the versatility of the method and its potential to be applied to a wide range of material selection problems. Overall, the studies reviewed indicate that fuzzy TOPSIS is a robust and flexible method for material selection that can provide valuable insights for decision-makers. However, there is still room for improvement in terms of the integration of fuzzy TOPSIS with other decision-making methods and the exploration of new applications in material selection.

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