Expert Systems with Applications 41 (2014) 2964–2980

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Comparative analysis of MCDM methods for pipe material selection in sugar industry

L. Anojkumar [a,*], M. Ilangkumaran [a], V. Sasirekha [b]

[a] Department of Mechatronics Engineering, K.S. Rangasamy College of Technology, Tiruchengode, 637215 Namakkal, Tamil Nadu, India
[b] Department of Computer Applications, K.S. Rangasamy College of Engineering, Tiruchengode, 637215 Namakkal, Tamil Nadu, India

ARTICLE INFO

Keywords:
FAHP
TOPSIS
VIKOR
ELECTRE
PROMETHEE
Material selection
Corrosion
Wear

ABSTRACT

The material plays an important role in an engineering design process. The suitable material selection for a particular product is one of the vital tasks for the designers. In order to fulfil the product's end requirements, designers need to analyze the performance of various materials and spot suitable materials with precise functionalities. Due to the presence of large number of materials with diverse properties, the material selection process is complicated and time consuming task. There is a necessity of systematic and efficient approach towards material selection to choose best alternative material for a product. The aim of this paper is to describe the application of four Multi Criteria Decision Making methods for solving pipes material selection problem in sugar industry. FAHP-TOPSIS, FAHP-VIKOR, FAHP-ELECTRE, FAHP-PROMTHEE are the four methods used to choose the best alternative among the various materials. The ranking performance of various MCDM methods is also compared with each other and exploring the effectiveness and flexibility of VIKOR method. Five stainless steel grades such as J4, JSLAUS, J204Cu, 409 M, 304 and seven evaluation criteria such as yield strength, ultimate tensile strength, percentage of elongation, hardness, cost, corrosion rate and wear rate are focussed in this study to choose the suitable material.

1. Introduction

In the design and development of any structural elements, material selection is one of the most challenging issues and it is also critical for the success and to meet the demands of cost reduction and better performance. Generally, experts are choosing a material by adopting the trial and error methods with investment of huge cost or build on collection of past data leading to lass of time (Shanian & Savadogo, 2006). While selecting alternative materials, a clear understanding of functional needs for each individual component is required and various important criteria need to be considered. An improper selection can negatively affect productivity, profitability and reputation of an organization (Karande & Chakraborty, 2012). The complex inter-relationships between variety of materials and its selection criteria frequently make the material selection process a difficult and time consuming task. Hence, a systematic and efficient approach to material selection is necessary in order to select the best alternative for a product. Thus the great efforts need to be extended to determine criteria that influence material selection for a product to eliminate unsuitable alternatives and select the apt material alternative using simple and logical methods (Rao & Patel, 2010). The non commensurable and conflicting nature of the evaluation criteria of material selection can be solved using MCDM method. The aim of this paper deals with the selection of opt material for the pipes from the set of five material alternatives and seven evaluation criteria for sugar industry application.

2. Literature review

This section aims to review the various perceptions of methodologies in material selection problem, application of MCDM in material selection, literature review on sugar industry and identification of research gap.

2.1. Literature review based on material selection methodologies

In this section, the material selection methodologies are reviewed for replacing the existing material to select a right candidate material. The selection of material methodologies presented in this article contains important selection attributes and its applications. Sapuan, Jacob, Mustapha, and Ismail (2002) proposed a prototype knowledge based system (KBS) for material selection in the engine components. Manshadi, Mahmudi, Abedian, and Mahmudi (2007) have proposed Weighting Factor Method

* Corresponding author. Tel.: +91 9943570353.
E-mail address: anoj83@gmail.com (L. Anojkumar).

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http://dx.doi.org/10.1016/j.eswa.2013.10.028

(WFM) through combination of non-linear normalization with a Modified Digital Logic (MDL) method and demonstrated the ability of the methods with comparison of Digital Logic (DL) method. The MDL method applied to select a best material for cryogenic storage tank and spar for the wing structure. Sapuan (2001) has proposed KBS in the domain of polymeric based composite material selection process. Ljungberg (2007) has proposed model for selecting suitable material for development sustainable products. Ramalhete, Senos, and Aguiar (2010) have develop the digital tool for material selection problem. Findik and Turan (2012) attempted the weighted property index (WPIM) method to select the best material for lighter wagon design. Finally the results shows aluminum alloy is the opt material for lighter wagons. Fayazbakhsh, Abedian, Manshadi, and Khabbaz (2009) proposed the Z-transformation method for selecting the suitable material for cryogenic storage tank. Bovea and Gallardo (2006) have applied the life cycle impact assessment method for evaluating and selecting the suitable material for eco-design. Enab and Bondok (2013) have used the finite element method for choosing the suitable material for designing the tibia component of cemented artificial knee. Florez and Castro-Lacouture (2013) proposed a mixed integer linear programming model with combination of objective and subjective factors and to select the appropriate building material. Ipek, Selvi, Findik, Torkul, and Cedimoğlu (2013) attempted to solve the materials selection problem in the manufacturing field using expert system model.

2.2. Literature review on MCDM in material selection

One of the most important stages in material selection process is ranking and choosing the right material for a particular application. MCDM methodologies are rapidly growing in the material selection problem. Mainly a large number of factors influencing the selection process into a critical issue (Chatterjee, Athawale, & Chakraborty, 2011). Holloway (1998) explained the importance of material selection in engineering applications and also enlightened the impact of environment due to improper selection of material. Jahan, Ismail, Sapuan, and Mustapha (2010) and Jahan, Ismail, Mustapha, and Sapuan (2010) reported that, the material selection using MCDM techniques are increasing gradually in engineering applications. Shanian and Savadogo (2006) have proposed Elimination and Choice Expressing the Reality (ELECTRE) model for selecting suitable material for loaded thermal conductor. Karande and Chakraborty (2012) applied the multi objective optimization on the basis of ratio (MOORA) method for select the opt material for flywheel, cryogenic storage tank, product used in high temperature oxygen rich environment and sailing boat mast. Bahraminasab and Jahan (2011) are used comprehensive VIKOR method to material selection for femoral component of knee replacement in medical field. Rao (2008) applied the improved compromise ranking method to select the apt material for engineering applications, from which two examples are illustrated to explain the proposed model. The first one is to select the apt material for metallic bipolar plate and another one is to select optimum material for high temperature environment with four alternatives and four criteria. Jahan, Mustapha, Ismail, Sapuan, and Bahraminasab (2011) applied VIKOR method for selecting the suitable material for rigid pin of shaft. Chatterjee, Athawale, and Chakraborty (2009) proposed a compromised ranking and outranking method for material selection problem. Here, ELECTRE I is used to obtain partial ranking and ELECTRE II is used for computing the final ranking of alternatives. Maniya and Bhatt (2010) have proposed the preference selection index method to select the best material to avoid the relative importance among criteria. Hambali, Sapuan, Ismail, and Nukman (2009) discussed the importance of Analytical Hierarchy Process (AHP) in material selection problem. Sapuan, Hambali, Ismail, and Nukman (2010) proposed AHP for selecting the suitable composite material for bumper beam. Mayyas and group (2011) proposed an AHP method for the material selection of automobile body panels. Cicek and Celik (2010) have proposed modified Fuzzy Axiomatic Design Model Selection Interface Algorithm (FAD-MSI) model and successfully applied to the various material selection problems. Wang and Chang (1995) proposed a fuzzy multiple criteria decision making approach for selecting the best suited tool steel material for a specific manufacturing application, such as die design, jig and fixture design. Shanian and Savadogo (2009) have proposed TOPSIS, block TOPSIS and VIKOR for material selection problem in high safety requirements in structural elements of aerospace and nuclear industries. Rao and Patel (2010) have proposed a novel multiple attribute decision making (MADM) method to helps the decision maker to deal with the problem of material selection for an engineering design considering both qualitative and quantitative attributes. Jahan, Ismail, Sapuan, et al. (2010) and Jahan, Ismail, Mustapha, et al. (2010) applied the linear assignment method for material selection and reported that, it is relatively simple comparing to other MCDM methods. Chatterjee and Chakraborty (2012) have proposed the extended PROMETHEE II (EXPROM2), a complex proportional assessment of alternatives with gray relations (COPRAS-G), ORESTE (Organization, Rangement Et Synthese De DonnesRelationnelles) and operational competitiveness rating analysis (OCRA) methods for gear material selection problem. Chatterjee et al. (2011) proposed complex proportional assessment (COPRAS) and evaluation of mixed data (EVAMIX) methods to evaluate a suitable material for cryogenic storage tank. Ilangkumaran, Avenash, Balakrishnan, Barath Kumar, and Boopathi Raja (2013) have proposed FAHP integrated with preference ranking organization method for enrichment evaluation (PROMETHEE) to evaluate the optimum material for automobile bumper. The impeller material selection problem is solved by using FAHP-TOPSIS method (Jajimoggala & Karri, 2013). Liu, Liu, and Wu (2013) have presented an interval 2-tuble linguistic VIKOR (ITL-VIKOR) method for solving the material selection problem under uncertain and incomplete environment. Chakraborty and Chatterjeeb (2013) have applied VIKOR, TOPSIS and PROMETHEE methods for material selection problem and also found that among the three methods, the VIKOR model produced ideal results. Maitya and Chakraborty (2013) have proposed Fuzzy TOPSIS method to select the suitable abrasive material for grinding wheel. Jahan and Edwards (2013) used VIKOR method for material selection problem with interval numbers and target based criteria. Mansor, Sapuan, Zainudin, Nuraini, and Hambali (2013) have describe the application of Analytical Hierarchy Process (AHP) for evaluating the suitable natural fiber polymer composite for the design of passenger vehicle center lever brake component.

2.3. Literature review on sugar industry

Handful researchers have made an attempt to reduce the failure rate in the sugar industrial equipment. The many failures were interrupted the production process and create financial impact. Due to this reason for increased machine ideal time, maintenance time and reduce production quality in the sugar industry. The following literature are detailed the problems in the sugar industry. Pravin, Rajesh, Singhal, and Goyal (2007) reported that, U$250 million is lost due to corrosion failures in Indian sugar industries. Wesley, Goyal, and Mishra (2012) has absorbed, AISI 444 has the better corrosion performance compared to AISI 1010 and similar to AISI 304 grade steel. Rajesh Kumar (2011) has suggested sulphanilamide, sulphapyridine and sulphathiazole as the anticorrosive medium to reduce the corrosion of the process equipment in sugar industries. Prado, Uquilla, Aguilar, Aguilar, and Casanova (2010) evaluated the effect of sugar cane juice on carbon steel roll and