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An expert system based material selection approach to manufacturing

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ABSTRACT

Selection of proper materials for a diverse mechanism is one of the hardest tasks in the design and product improvements in various industrial applications. Materials play a vital and important function during the entire design and manufacturing process. The wrong selection of materials often leads to huge prices and ultimately results in product breakdown. Hence, the designers need to identify and select suitable materials with specific functionalities in order to attain the preferred output with the minimum cost concern and specific applicability. This paper tries to solve the materials selection problem by means of an expert system approach to manufacturing. According to this method either four or five different properties are inspected for each automotive part such as impact resistance, lightness, formability, corrosion resistance and low prices for bumpers; strength, formability, vibration absorption and low cost for flywheels; and strength, formability, corrosion resistance, biocompatibility and a small price for implants. Then, these were made more efficient using the expert system approach. Due to performing most of the above mentioned properties, polymeric materials {such as PP (polypropylene), HDPE (high density polyethylene) and PMMA (polymethyl methacrylate)} are selected for the bumpers; GFRPs (glass fiber reinforced plastics) and CFRPs (carbon fiber reinforced plastics) composites for high speed running, and cast iron and steel for low speeds for the flywheels; and finally stainless steel and polymeric materials {such as PVC (polyvinyl chloride) and PE (polyethylene)} were found to be the best materials for automotive parts. The selected materials were almost identical to those obtained by previous authors.

1. Introduction

Design of goods is no longer considered a problem solving procedure. With the initiation of technology and competent software tools for computation, it has become more of a decision making process that involves precise assessment of design alternatives. A decision is a pledge to employ resources. Problem solving is creating and cleansing information interrupted by decision making.

Shortage of information is the main problem met by the decision making group. This shortage of information can be defeated by the use of appropriate materials and focusing toward a precise action using the notions of probability and statistics. The use of decision making rules may facilitate the choice of the best material, arranging diverse options and ranking the alternatives from best to worst. Thus, it places the base for choosing, categorizing and arranging our alternatives and assists in the general evaluation of the alternatives.

Material selection and replacement are significant parts of the design course. Without appropriate material selection through the design course, money and time can be exhausted in the redesigning or fabrication of the designed part. While there is no true or false response to a design dilemma, it is vital that the paramount material is selected. A diversity of selection actions have been expanded to resolve this duty, and a regular assessment was also made in [1,2]. In [2] there is a broad overview of materials screening and choosing methods. The chart method, computer-aided materials selection and knowledge-based systems are the common techniques in material screening. ELECTRE (ELimination and Choice Expressing REality), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), and AHP (analytic hierarchy process) are utilized for material selection. Fuzzy techniques have been employed either independently or with other techniques such as genetic algorithm, neural networks, KBS (Knowledge-based system), and MCDM (multicriteria decision making) techniques. From these techniques, AHP is an influential and flexible decision making process. While there are hundreds of alternatives to be

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evaluated, the couple-wise assessment way presented by the conventional AHP is not suitable. Even though ELECTRE techniques have excellent output, as the amount of options raises, the sum of calculations raises quickly. ELECTRE simply decide the level of every substance and do not provide arithmetic assessment for recognizing dissimilarities amid choices. TOPSIS is a superior option for material selection since it is helpful for qualitative and quantitative information, and comparatively simple and rapid. This is particularly helpful in relating with a big amount of choices and criteria; the techniques are totally appropriate for working with computer databases relating to material assortment [3–8].

The above multicriteria decision making (MCDM) techniques mentioned order the determined materials from the best to the worst choice. However, in order to decide the alternative materials which will be used in an application, knowledge and experience is needed. For this reason, a system is needed to select suitable materials from the database that contains more than 100 thousand materials and to help in their application.

Computer aided design methods have proved to be too complicated for the signifying aspirant fabricating procedure and objects grouping [7]. Knowledge-based systems (KBSs) are systems found in the techniques of artificial intelligence (known as expert systems). KBS is described as a computer method that is intended to reproduce human problem-solving via artificial intelligence and suggestion to a database of knowledge on a meticulous topic. Materials can be described from the data from experiments and by knowledge from known information. Data are identified as the consequence of measurements that can be given in numbers, but information signifies the relation between objects of data and is frequently articulated in basic words. There as well as computer simulation based resolutions are easy weighting techniques [3] for material evaluating and selecting. The instruments of artificial intelligence have also been raised in numerous periods to resolve the material transmission dilemma [6,8].

Although a lot of scientists [1–8] have studied material selection problems for various engineering components, there is still a need to search for other techniques such as expert system methods to obtain comparative solutions for the materials selection issue. The expert system methods (EMSs) are very beneficial in material selection. In this paper, an expert system approach is presented for materials selection in manufacturing. Expert systems are computer programs representing knowledge about a thin domain for solving problems connected to that domain [9]. The utility of the expert system is two-sided: it searches the appropriate material properties for the product desired, then searches for appropriate materials having these properties in the materials knowledge base. Three examples are illustrated to demonstrate their applicability and compare their ranking performance while solving those materials selection problems under the environments given. It is observed that in these three cases, the top-ranked alternative materials exactly match with those obtained by the past researchers.

2. Literature review

Quite a lot of investigators have studied the selection of materials topic for the purpose of artifact design. For example, one specific technique of material selection was reported by a scientist in mechanical design: material choice diagrams by Ashby, and it demonstrated how this attitude can be widening to propose for environmental factors. A selection system was suggested by several investigators [10] detailing data on the environmental properties of materials for the decline of goods poisonous contact. In addition, environmental materials choice diagrams were developed by numerous researchers for the selection of materials to decrease ecological impact. These diagrams concurrently show one of the mechanical and environmental characteristic of materials. Previous investigators [11] employed life cycle assessment (LCA) for materials selection for sustainable artifact design. A matrix was projected [12] in the life cycle point of view for selecting sustainable materials for buildings. An organized approach was also proposed for material selection with ecological reflection. In addition, the idea of eco-balances was projected as input to improve ecological material options in vehicle design. A technique was anticipated [13–15] for characterization of individual health contact of poisonous chemicals for sustainable substance choice in design and fabrication. Adding to theoretical approaches, various feasible decisions maintain systems have been extended for supporting sustainable substance choice. IDEmat is software by TU of Delft, for choosing impact materials. It includes a database on the physical, mechanical, and ecological features of diverse materials [16]. Numerous investigators improved intelligent and knowledge based systems (KBS) or expert systems for material choice. A hybrid intelligent systems approach was anticipated [17] for die design for sheet metal production that includes rules for material selection. In addition, a fuzzy knowledge-based decision support system was improved [18] for manufacturing and material choice in simultaneous product design.

For the moment, an intelligent system was presented [19] for the choice of materials for the continuous die mechanism. The significance of the knowledge-based system was explained [20] in the perspective of synchronized engineering and applied it in material choice of plastic-based composite. Afterward, employment of knowledge-based system was established [21] in material choice of ceramic matrix composites for engine mechanism. A case-based reasoning (CBR) was employed [22] as a tool for material choice. CBR is the process of explaining novel problems founded on the explanation of comparable precedent problems. A knowledge-based price modeling system was developed [23] for structure design period by optimizing the choice of materials and technology. The expert system designed has been validated in tire manufacturing industry and improved the possibility of manufacturing of more sustainable products [24]. One of the superlative approaches of material choice for sustainable goods is LCE (life cycle engineering). LCE relies on "Engineering actions which contain: the application of technological and scientific values to the design and fabricate of goods although encouraging economic development, considering the need for sustainability, and simultaneously optimizing the artifact life series and minimizing contamination and waste" [25]. Hence, LCE can be described as a decision making method that allows performance, ecological, and price scope during the period of an artifact, directing design engineers supporting knowledgeable choices [26,27]. LCE contains not only conservative tools, as practical performance analysis based on mechanical, electrical, and chemical properties, but also life cycle tools to examine financial performance. Numerous investigators have applied LCE to special case studies in vehicle [28,29], building [30], and computer production [31,32], to report only a few.

3. Expert systems

An expert system is an interactive computer-based decision tool that employs both facts and heuristics to answer hard decision problems founded on the knowledge obtained from an expert. The expert system method has been applied to numerous problems of arrangement, design, and diagnostics. Nevertheless, the problems of engineering design have not been sufficiently tackled, because these problems have to be tackled in an incorporated way with knowledge from dissimilar domains and sources. Sustained study in the last two decades has recently caused the form of novel methods which will allow structure of automated incorporated de-