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Development of an expert system to select materials for the main structure of a transfer crane designed for disabled people

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ABSTRACT

This paper shows the development of an expert system for the selection of materials to be used in the construction of the main structure of a crane-like device for transporting persons with physical disabilities. The proposed method includes a stage in which the theory of the characteristics of the materials was used and another one that involves solely computational development with the application of fuzzy logic. For this, the fuzzy logic toolbox of Matlab® was used and both the data input and output of the solution were worked out on Simulink®. The data used were 32 alloys with features such as ultimate stress, yield stress, elongation, availability in the country (Chile), cost, ease of welding, hardness, fracture type, and corrosion (fresh water, water vapor or air). The end result gave a material that met 100% of the requirements, three met 90% and two only 75%. The most important conclusions are two: (1) the selection characteristics were based on the particular needs, but a great advantage of this system is that it can be used countless times in similar tasks or it can be modified only in those parts that need to be changed, also serving as a reference for creating other expert systems, and (2) it combines the use of an expert system with fuzzy logic, so that the overall system is enhanced.

1. Introduction

Selection of materials is a critical element in a design process, and it is usually an empirical and complex procedure (Lan, Guan, Jiao, & Xu, 2010; Rahman, Odeyinka, Perera, & Bi, 2012). Different types of materials and technologies are available for building design and construction, while new materials and advanced technologies are continuously being introduced into the market (Rahman et al., 2012). To build a device or machine the selection of materials has to be optimal, because the final product needs to be of good quality at a reasonable cost (Dobrzański & Madejski, 2006). In design, the material selection is greater than before and the vast activity in materials science has formed new materials, but all materials are concentrated in six groups (metals, polymers, elastomers, ceramics, glasses, and composites) and the range of materials available to the engineer is larger than in the past (Findik & Turan, 2012).

The problem is what materials are appropriate and how to make the selection. Shortage of information is the main difficulty for the decision, and the complex interrelationships among various selection criteria make the selection process more challenging to the designers, but the use of rules to make decisions and selection strategy may facilitate the choice of the best material (Ashby, Bréchet, Cebon, & Salvo, 2004; Prasad & Chakraborty, 2013; İpek, Selvi, Findik, Torkul, & Cedimoğlu, 2013). A selection strategy has the following components: (a) the formulation of constraints that must be satisfied if the material fulfills the desired function, (b) the formulation of a function that measures how well the material matches the requirements, and (c) a search procedure to explore the solution and identify and classify materials according to their ability to meet the requirements (Ashby et al., 2004).

There are several methods to solve the materials selection problem, some of they are:

- The cost per unit property method: this is suitable for initial screening in applications where one property stands out as the most critical service requirement (Findik & Turan, 2012).
- The limits on properties method: the performance requirements are separated into three groups (lower limit, upper limit, and target value properties), and, after screening, the selected materials are those whose properties are above the lower limits, below the upper limits, and within the target values of the particular requirements (Findik & Turan, 2012).

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- The weighted property index method: each property is weighted and the weighted property values are calculated to give a proportional weighted property index (Findik & Turan, 2012).

Materials must meet certain mechanical and physical requirements. Some characteristics that often consider the different methods to select materials are: cost, corrosion, temperature effects, thermo-mechanical treatments, hardness, tensile, thermal coefficient, strength (tensile and yield), elongation, Young's module, Poison's ratio, weldability, availability, density, wear resistance and durability, geometry, manufacturing process, external loading, operating environment, etc. There are other more specific characteristics according to each particular case. (Edwards, 2005; Findik & Turan, 2012; Ozsarac, Findik, & Yildirim, 2006).

Depending on the nature of the data the attributes can be numeric or non-numeric. Numeric attributes are values of precisely measurable properties, such as density, modulus, strength, electrical and thermal conductivity, etc. Non-numeric attributes can be Boolean (yes/no) or can be described by a ranking (good, average, poor, or simply A to E), for example, resistance to corrosion or to wear. The supporting information can be specific or general. The first includes design guidelines, case studies, failure analyses, known applications, experience with the material, etc., and the second can include supplier information, standards and codes, sector-specific approval, and others (Ashby et al., 2004).

In this paper a proposal is made for the development of an expert system to select the materials needed to implement the main structure of a drive device to help people with severe physical disabilities, which must withstand the weight of an adult and the other functional elements, and that is similar to a crane that transports the patient between the bed and the wheelchair, for example. An expert system includes a knowledge base (that contains the specific knowledge encoded in the form of rules), an inference engine (that makes inferences by deciding which rules are satisfied by known facts or objects, prioritizes the satisfied rules, and then executes the rules with the highest priorities), and a user interface (Xu, Gao, Khoshgoftaar, & Seliya, 2014).

The design of this expert system involves five principal steps:

- To determine which group of materials can be used in the structure.
- To preselect those have been used in structures or similar machines.
- To identify the most important features of each of them.
- To make a second preselection using those features.
- To select the material sought.

To develop the expert system the materials chosen were metals, because they are used most often in engineering, and their use is connected with their properties (such as environmental factors and others) (Dobrzański & Madejski, 2006). Information on the materials was obtained from books and catalogues. The computer system was made using fuzzy logic, with the corresponding Matlab® toolbox and Simulink®, where the user can send an Excel® template with all the information, and the response is delivered to the Workspace of Matlab®. A fuzzy expert system deals with the uncertainty and nonlinearity (Xu et al., 2014) and, in this case, it used Sugeno form that allows to give a proportional weighted to each property.

The need to create this expert system is to have a procedure that satisfies the specific material requirements for construct the crane structure. To propose this system allows that other people can use it in their own investigation, because the advantage is that the characteristics of the materials and the data can be changed if it needs.

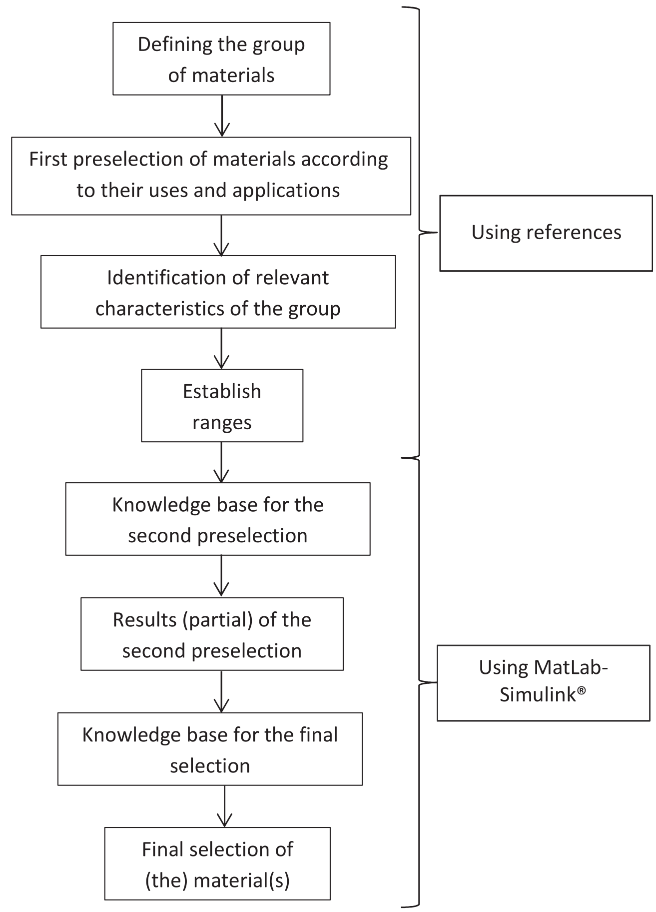

Fig. 1. Diagram of the expert system for materials selection.

Table 1
Selected characteristics to apply in the expert system.

No.	Characteristic	Situation		Observations
		Best	Worst	
1	Ultimate stress	High	Low	The higher the resistance, the less likely it is to break when loaded with weight
2	Yield stress	High	Low	The higher the yield stress, the less is the chance of being deformed by the weight that it must withstand
3	Elongation	Low	High	The smaller the elongation of the structure, the less probable it is to exceed the physical space available to it
4	Availability	Yes	No	Availability in the Chilean market increases the possibility of getting it
5	General cost	Low	High	Only reference prices provided from the literature
6	Welding	Easy	Difficult	It relates with the ease to give different shapes to the structure
7	Hardness	High	Low	According to the Brinell scale
8	Fracture type	Ductile	Fragile	Ductile fracture can show that the material is fatigued, and accidents can be prevented if it is detected early. In fragile materials it cannot be noticed
9	Corrosion	Negative	Positive	The main references were corrosion with water (fresh), water vapor, and air