Knowledge Based System and Optimization of Ashby's Methodology in Materials Selection for Aircraft Cabin Metallic Structures

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Abstract

Materials selection processes have been the most important aspects in product design and development. A knowledge-based model and methodology in the materials selection for the design of metallic structures inside the aircraft cabin is discussed. Overall aircraft weight reduction means substantially less fuel consumption. Part of the solution to this problem is to find a way to reduce weight of metallic structures inside the cabin. Two previously proposed decision making methodologies in materials selection, Improved Compromise Ranking Method and Graph Theory and Matrix Approach Method, are reviewed and tested. Pre-defined constraint values, mainly mechanical properties, physical properties, and various manufacturing techniques, are employed as relevant attributes in the process. Aluminum alloys and steels with high strength-to-weight ratio that are currently being used in the structures and high strength magnesium alloys as alternatives to the structures are tested using the methodologies and ranked results are compared for any disparity. Finding the shortfalls, if any, between these two methodologies and identifying the solution to these shortfalls by optimization of Ashby's approach is the focus in this research.

Introduction

In simple engineering designs, a design engineer can select materials simply from materials handbook. However, selecting materials for complex designs using this approach with respect to the materials' properties is almost impossible. There has been significant work done in developing a systematic procedure in materials selection and is referred to as knowledge-based systems (KBS). A knowledge base consists of rules and techniques for representing knowledge in the structure. KBS are developed by collectively employing data and knowledge, where data is the results of measurements and knowledge is the connection between items of data [1]. KBS is vital in the process of materials selection. Employing

KBS and various optimization methodologies such as Ashby's charts, appropriate materials for aircraft cabin metallic cabin can be selected. A general structure of KBS is illustrated in Figure 1.

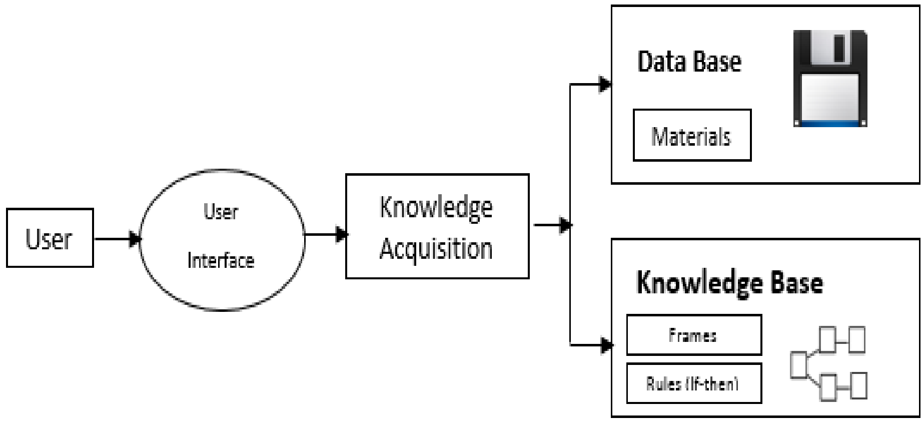

Figure 1. Structure of the knowledge-based system [2]

Methodology

V. Rao [3, 4] has proposed two distinct methodologies for materials selection in engineering design: Matrix Approach Method and Improved Compromise Ranking Method. The Matrix Approach Method includes finding material suitability index values of all the short-listed materials using a MxM matrix and ranking them in the order of highest to the lowest. The material with the highest material suitability index value is the best material for the design. On the other hand, Improved Compromise Ranking Method includes finding the performance matrices (P_i) values of each short-listed material. P_i values determine the best and the worst material among the short-listed materials. The material with the lowest P_i value is the best material. Desired attributes among short listed materials for aircraft cabin metallic structures include low cost and low density referred to as non-beneficial attributes, while high modulus of elasticity, high yield strength, high tensile strength, and high fracture toughness collectively referred to as beneficial attributes. A set of materials are short listed for certain metallic part in the aircraft cabin. These materials are given in Table 1 with their respective attribute values. These values were obtained from ASM Alloy Center Database available through the UNT library. In the table, the first two materials are high strength aluminum alloys. The next two materials are considered to be alternatives to the ones currently in use and also belong to the same family of alloys. The last two materials are high strength magnesium alloys and have lighter weight with competitive strength.

Secondly, Ashby's charts are used and optimized to short list another set of materials satisfying the similar attributes. These materials may or may not be similar to the ones previously short listed. Matrix Approach Method and Improved Compromise Ranking Method are once again used to find the ranking of this set of materials. The objective is to compare and recognize the difference between rankings of two sets of materials produced by two distinct methodologies and address the outcome.

Properties	Shortlisted Materials					
	AL 7075-T651	AL 2024-T4	AL 2024-T6	AL 2024-T81	Mg AZ31B	Mg AZ61A
Density (gm/c^3)	2.78	2.74	2.75	2.75	1.77	1.8
Yield Strength (MPa)	345	248	345	372	150	165
Tensile Strength (MPa)	421	359	427	421	235	285
Young's Modulus (MPa)	71	72	72	72	44	44
Fracture Toughness (MPa√m)	26.9	38	37	37	16	16
Price (USD/Kg)	2.25	2.43	2.43	2.43	3.7	3.65

Table-1. Shortlisted materials for aircraft cabin metallic structures with their attribute values [5]

Conclusion

Two previously proposed methodologies are tested for materials selection of aircraft cabin metallic structures. Short-listed materials that are individually ranked based on the methodologies have produced results with significant inconsistency. Materials selected for a particular engineering design are desired to have the best materials regardless of the methodologies used. This problem is addressed by short listing a different set of materials using Ashby's charts and its optimization. This set of short-listed materials will be tested once again using the same methodologies. The new ranking of materials will be compared with the ones previously generated and observe the difference. It is desired to eliminate or reduce the level of inconsistency in ranking of short-listed materials and hence select the best materials for aircraft cabin metallic structure.

References

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