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DEVELOPMENT OF MATERIAL SELECTION SOFTWARE FOR NON-FERROUS METALS

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Abstract: A huge number of materials are available to the modern engineer, but selecting the appropriate material for engineering application is a complex task. This work tries to solve the material selection problem by developing the material selection software. The software adopts the Multi Attribute Decision Making technique for the selection. An optimization criterion (goal programming) was introduced, and the software uses this to prioritize materials suitable for an application. The software contains a graphical user interface as front end and a database management system as back end. Database was created, and by writing structured query language statements, commands were executed by the database management system. Nonferrous materials with their properties were stored in the database. Management system uses the algorithm to search the database and select optimum material based on desired criteria input in the graphical user interface. The material selection software developed in this research work was tested for selection of material. A criterion for selecting material for connecting rod for motor bikes application was given. The software scanned through the database and searched for materials with range of these properties and optimizes each and ranked them. Results displayed two aluminum materials and found out that Aluminum 7075-T73 was the optimum material for the application. Software was validated using Granta Cambridge Engineering Selector software which showed that the material selection software developed in this work is valid for selection of materials.

Keywords: Material Selection, Optimization, Software

1. Introduction

The selection of proper materials and product replacement is critical in engineering design. There are about 40,000-80,000 materials available with at least 1,000 ways to process them

(Ashby, 2005). Also, there are many new materials are being developed by the activities of material engineers in search of materials with better quality and low cost. Choosing a traditional material for application may be safely conservative but it rejects the opportunity for innovation of new materials. An example of products in which a new material has captured market is the airframe used in aviation industry; from low density woods to aluminum and currently composite, in order to meet the demand of low weight and low fuel consumption.

Proper selection of materials is a crucial part of engineering design process as it controls cost, manufacturing process and performance of a product (Pramanic & Islam, 2004). New concurrent engineering has provided engineers a systematic methodology to reduce product development time and also incorporate early design measures to prevent manufacturing problems. A potentially important decision-making activity that precedes this is the material selection (Ronald, 1998). Improper decisions lead to huge prices and failure of components after manufacturing.

For each product, the design engineer must consider the fundamental properties of the material (i.e., physical, mechanical, tribological, chemical properties, respectively) in accordance with its light weight and raw material price in order to propose the best candidate material (Poddar et al, 2009). Thus the combination of material and process will have a significant bearing on the quality of part and thus the process selected must be appropriate for the material (Scallan, 2003).

The primary source of data for material and process selection has traditionally been hard copy, requiring the employment of literature searches to identify data in printed handbooks and data sheets. This method is usually time consuming, tedious and may not be effective considering the vast number of materials and process from which to choose and the multifaceted nature of the selection task (Djassemi, 2012).

The use of computers can assist engineers to make material property information easily accessible with optimum selection. This research focuses specifically on material selection at early stage of design. In an attempt to solve the problem of material selection, a software was developed with a database containing nonferrous metals, a management system which access the suitability of the materials and eliminates unsuitable materials and a graphic user interface to input the design criteria and select the optimum material.

2. Materials and Methodology

2.1 Materials for the Software Development

The materials for the software development includes the following requirements:

- Windows 7 operating system
- Minimum memory (RAM): 2 GB
- Hard disk space: 200GB
- Visual Basic 2010 programming language
- Visual Basic.net Development Environment

2.2 Methodology

2.2.1 Procedure of the Material Selection

The stage of design considered in this work was at the concept design to access suitability of all the materials in the database. The general model of approach was used in this work while **Figure 1** shows the process of selection in this work.

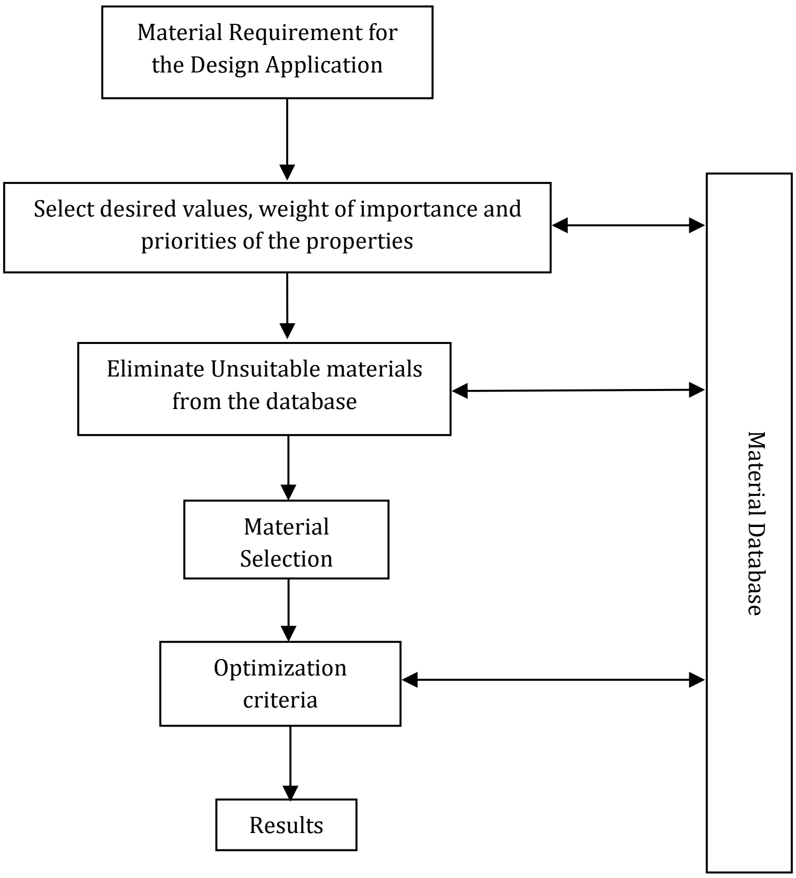

Figure 1. Flow Chart for the Selection of Material

2.2.2 The Optimization Algorithm

A search through the database with large number of materials and none restrictive criteria could lead to a selection of a variety of materials. Recently, Multi Criteria Decision Methods are used to find optimal materials. In this work, the method of selection is the simple additive weighting of method of the Multi Attribute Decision Making and the optimization method is the goal programming of the Multi Objective Decision Making. Optimization simply means combining the attractive properties of materials while avoiding their drawbacks. This is an effective method to handle a decision concerning multiple and conflicting goals. The stages of optimization in this work are given below.

1. The starting point is the analysis of material requirements by the user
2. User chooses the right properties and enters boundary values. Up to 5 criteria can be entered at the same time, software shortlists viable materials and eliminate unsuitable materials.

P_1= Property 1, example: fracture toughness

P_2= Property 2, example: density

Boundary values = minimum, maximum value of properties. Materials that meet the criteria of P_1 are collected in a sub database as M_1, same is done for P_1, P_2, P_3 …P_n to have M_2, M_3, $M_{n.}$ Materials that are common to M_1, M_2, M_3, M_n are those that meet all the criteria of P_1, P_2, P_3 …P_n are the satisfactory materials.

3. Each material property is assigned a weight value depending on the importance for the application. A weighted property is obtained by multiplying the numerical value of the property by the weighing value.

If P_1 = Fracture toughness and weight value w_1, then weight property is P_1w_1

4. For each of these weighted properties, the values are scaled such that the best numerical value does not exceed 100. Others are scaled proportionally. The scaled value V_{sa} for a given candidate material is defined in Equation 1.

$$V_{sa} = \frac{num\ val}{\max val} \times 100 \qquad (1)$$

Where num value = numerical property value of the material, max value = maximum property value in the list

Although for some applications, certain material properties are more desirable when they have low numerical values as in the case of density, electrical resistivity. For these properties, the lowest value other than the highest is rated 100 and scaled. The scaled value V_{sb} for a given candidate material is defined in Equation 2.

$$V_{sb} = \frac{\min val}{Num\ value} \times 100 \quad (2)$$

Where min value = minimum value of property in the list, Num val= numerical property value of the material

Space is provided on the interface to declare whether a low or high value is desired for the software to know which scaled formula to use.

5. The scaled individual weighted properties of each material are then summed to give a comparative performance index. The material with the highest p.i is considered to be the best. The algorithm for the selection is seen in the **Figure 2**.

2.2.3 Software Development Model

The software was developed using incremental model. Incremental development is based on the idea of developing an initial implementation, exposing this to user comment and evolving it through several versions until an adequate system has been developed (Somerville, 2006). This will enable development of the system with each version (module) adding functionality to the previous version (module).

2.2.4 Procedure for Database and Management System Development

The incremental model was used for the development of the database of this work. The database development was separated, i.e. specification and creation of schema to define data in the database-from user processes that makes use of the database. The database developed in this work is a single database that contains different tables that satisfy multiple requirements. The database of the material selection was populated using existing Matweb database of materials (MatWeb - The Online Materials Information Resource, 2015).

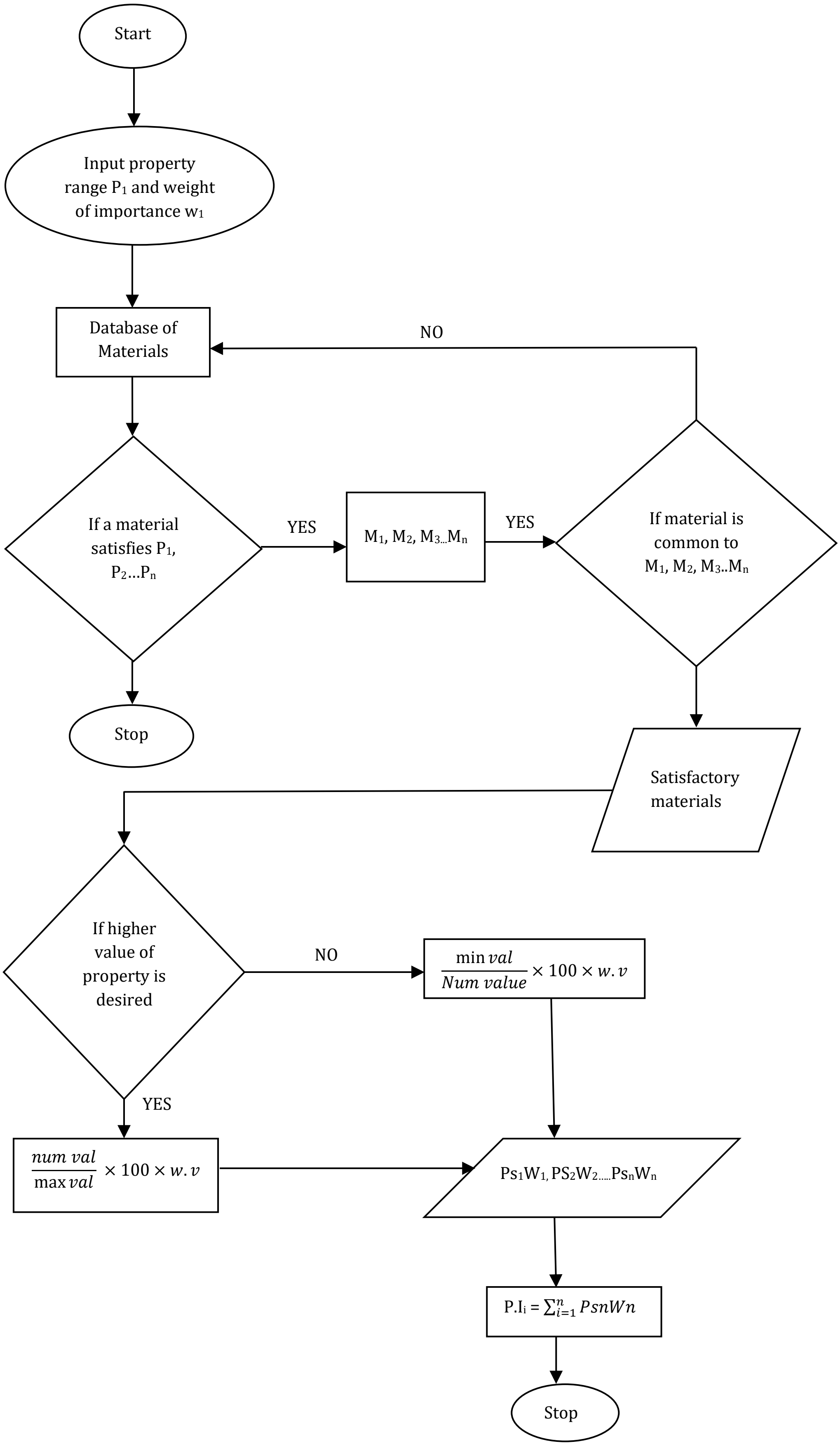

Figure 2. Algorithm for the material selection

2.2.5 Software Implementation

This project was implemented using Visual Basic 2010 programming language because of enormous advantages; the structure of the Visual Basic programming language is very simple, particularly as to the executable code. Visual Basic is not only a language but primarily an integrated, interactive development environment ("IDE"). The Visual Basic-IDE has been highly optimized to support rapid application development ("RAD"). It is particularly easy to develop graphical user interfaces and to connect them to handle functions provided by the application. The IDE used in this project is Visual Studio 2010; Visual Studio supports different programming languages and allows the code editor and debugger to support (to varying degrees) nearly any programming language, provided a language-specific service exists.

2.2.6 Description of Coding

The material selection software is designed to select materials based on their performance index, composition and application. User can also view properties of materials. Its methods that perform adding category, material and property, selection of material based on performance index, composition, application and display materials are saved in a separate class where they are declared public and called inside other modules.

2.2.7 Testing

Testing is the process of executing a program with the intent of finding errors. Software testing is the process of evaluating a software item to detect differences between given input and expected output. The program's responses shall be tested to every possible input. These will include, unit testing, integration testing and system testing:

- Unit Testing is a level of software testing where individual units/ components of software are tested.
- Integration Testing tests integration or interfaces between components, interactions to different parts of the system such as an operating system, file system and hardware or interfaces between systems.
- System Testing was also carried out. In the system testing, different parts of the whole system were tested. Also, all interfaces between the integrated units were checked for any discrepancies that might arise due to merging them into one system.

2.2.8 Validation of the Software

This is the process of checking that a software system meets specification and that it fulfills its intended purpose. Software validation is the process of evaluating software to determine whether it satisfies specified requirements (IEEE-STD-610). This is done to ascertain the degree to which the software reflects the underlying construct, i.e whether it outputs what it purports to output.

Granta CES EduPack 2011 will be used for the validation of this software because it is the most standard widely used software for material selection in mechanical design.

3. Results and Discussion

3.1 Results from the Validation of the Material Selection Software

The results of the Proposed Software and the Classic Software are shown in **Figure 3** and **Figure 4**. The design engineer specified choice of material properties and weights through the GUI. The main objective of the software is to generate output displaying the selected materials with ranks. At this point, same input will be entered, and the outputs were observed from the two different software. The output from the proposed software is shown in **Figure 5.**

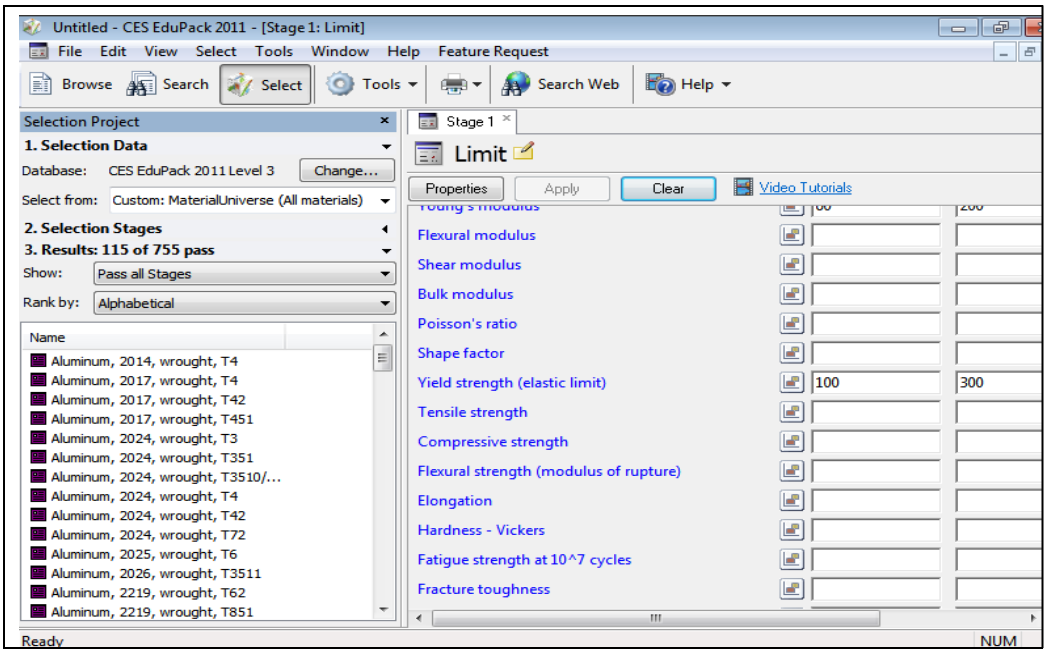

Figure 3. Limit values of The Classic Software

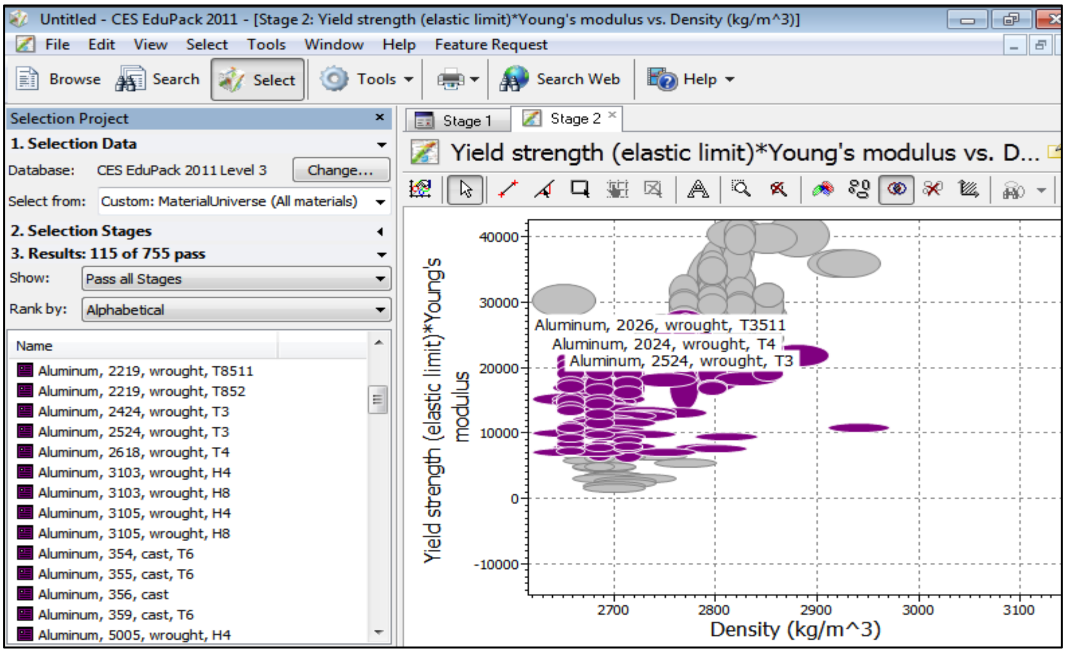

Figure 4. Selected Materials in form of Graph from The Classic Software

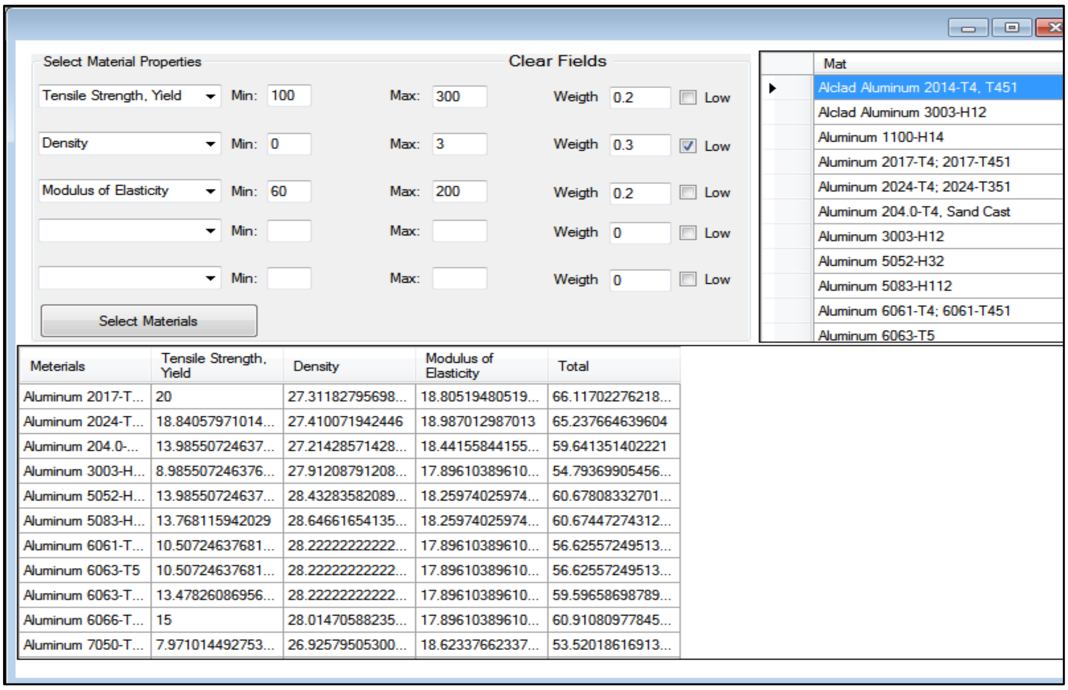

Figure 5. Selected Materials from The Proposed Software

3.2 Discussion

This study was intended as a means of selecting a suitable material for an application. In order to achieve this target, software was developed for the material selection. The different steps involved in the development were discussed in Section 2.

Testing was done with the intent of finding errors. This was done by testing different units and modules in the system as seen in **Table 1** and **Table 2**. The test results revealed that categories were added and deleted easily, newly developed materials were added and deleted easily, and properties of different materials were added and deleted successfully. Also, the results revealed that properties of materials were viewed, and more importantly optimum materials were also selected using the performance index selection module. Materials were also selected based on application and composition. Different units and interfaces between the integrated units were checked for any discrepancies that might arise due to merging. Results of the testing showed that the system is working just fine.

Validation was done to check the authenticity of the software. The validation was done using Granta CES Edupack 2011. During the validation, same input for an application was entered into both the proposed and the classic software and the outputs were observed. In the case of selecting high strength, low-density non-ferrous materials, same input was entered into the classic software as seen in **Figure 3** and **Figure 4** showed result displayed by the classic software. The materials displayed are aluminum 2026 wrought T3511, aluminum 2024 wrought T4 and aluminum 2524 wrought T3. These materials are displayed as the best materials for the application owing to their low weight and high strength properties.

Results from the proposed software for the case above displayed different materials from which the best are 2017-T4, 2024 T4, Al 5052, Aluminum 6066 as seen in **Figure 5**. Although most of the materials displayed by both software are the 2000 series aluminum, which possesses similar properties, a precise material displayed by both software is the aluminum 2024-T4. From the above results for validation, it can be seen that the output by the two software are mostly very similar and hence it can be concluded that the proposed software is valid and can be used for materials selection at early design stage.

The developed software will help the user in selection using the above methodology by preliminary filtering, displaying alternatives, and ranking them. Users can also view information about non-ferrous metals. Furthermore, unlike the classic software, the proposed software makes it possible for user to add newly developed materials and their properties directly into the database. More so, materials can be optimized for different purposes using the above methodology.

Table 1. Unit Testing of Material Selection System

Test Cases	Explanation	Results
frmcategory_load()	load a form for add category on clicking on the add category button and check if it returns true	Successful
frmmaterial_load()	Load a form for add material on clicking the add material button and check if it returns true	successful
frmaddingproperty_load()	Load a form for adding material property on clicking the add property button and check if it returns true	Successful
Frmselc_load()	Load a form for viewing material property on clicking the material selection property button and check if it returns true	Successful
Frmpindex_load()	Load a form for selection based on performance index on clicking the performance index selection button and check if it returns true	Successful
Frmpindex2_load()	Load a form for selection based on application on clicking the select by application button and check if it returns true	Successful
Frmcons_load()	Load a form for selection of materials based on composition by clicking on the constituent element selection button and check if it returns true	Successful

Table 2. Integration Testing of the Material Selection System

Test Case ID	Test Case Objective	Test Case Description	Input	Expected Output	Results
1	Check the interface link between the main interface and the add category module	Click on the add category button	Button clicked	To be directed to the add category window	Success
2			Button not clicked		Success
3	Check the interface link between the main interface and the add material module	Click on the add material button	Button clicked	To be directed to the add material window that contains carbon, ceramic, metals and fluids	Success
4			Button not clicked		Success
5	Check the interface link between the main interface and the add property module	Click on the add property button	Button clicked	To be directed to the add property window that contains carbon, ceramic, metals and fluids	Success
6			Button not clicked		Success
7	Check the interface link between the main interface and the material property selection module	Click on material property selection module	Button clicked	To be directed to the view material property window	Success
8			Button not clicked		Success
9	Check the interface link between the main interface and the select materials based on performance index	Click on the performance index selection button	Button clicked	To be directed to the performance index interface that contains combo box for specifying property and text box for weight of importance to be input	Success
10			Button not clicked		Success

4. Conclusion

A database for the material selection software was developed and implemented using the Visual Basic.NET 2010. Property values of different non-ferrous metals were stored in the database. Graphical User Interface was implemented with the Visual Basic.NET 2010. Different functions were attached to different button, which enables the user to navigate easily through the software and specify property requirement and importance of weight for material selection. Database management system for the material selection tool was developed. MySQL query language was used in developing the database management system. This manages the data in the database. The system receives instructions through the GUI based, sends the instruction in form of queries to the database, where the management system acts accordingly and display results. System was tested for typical case study for a material selection for a connecting rod, whereby the user specifies property requirement, importance of weight and priority. Criteria for the application were entered and the software displayed aluminum 7075 as the optimum material. Validation was carried out successfully using the Granta CES Edupack 2011.

References

Ashby, M.F. (2005). *Materials Selection in Mechanical Design (4th ed.)*. Retrieved from https://doi.org/10.1016/C2009-0-25539-5

Matweb.com (2015) *MatWeb - The Online Materials Information Resource*. Retrieved from: http://www.matweb.com/search/DataSheet.aspx?MatGUID=c5e76ddf336e46d8b17ec41d5690f7e5&ckck=1

Poddar, P., Mukherjee, S. & Sahoo, K. (2009). The Microstructure and Mechanical Properties of SiC Reinforced Magnesium Based Composites by Rheocasting Process. *Journal of Materials Engineering and Performance, 18,* 849-855. Retrieved from https://doi.org/10.1007/s11665-008-9334-1

Pramanic, A., & Islam, M.N. (2014). Introduction of a new software package Teaching Design Methodology for Material Selection. *International Journal of Information and Education Technology, 4*(4), 360-363. Retrieved from https://doi.org/10.7763/IJIET.2014.V4.430

Ronald, E.G. (1998). A Decision Support System for Material and Manufacturing Process Selection. *Journal of Intelligent Manufacturing, 9,* 265–276. Retrieved from https://doi.org/10.1023/A:1008866732609

Scallan, P. (2003). 4 - Material evaluation and process selection. In P. Scallan (Ed.). *Process Planning* (pp. 109-170). Retrieved from https://doi.org/10.1016/B978-075065129-5/50005-2

Sommerville, I. (1985). *Software engineering* (2nd ed.). Wokingham, Eng: Addison-Wesley