Development of A Materials Selection Process in Engineering Design and Manufacturing

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Abstract : - The selection of proper materials is fundamental to engineering design. Engineering materials are many hence a formalized selection process is required to select a reliable material for a product. The objective of this project was to develop an online material selection process based on principles of decision theory and implement it as an information processing routine on a computer system. A case study was undertaken that involved selection of a material in the design of a reverted two stage compound gear train. Selection was done in two stages: screening followed by ranking. The first stage reduces the large material database to a small candidate list which are locally available and meets the critical property limits such as strength. The second stage involves ranking the candidate materials using indices formulated from availability, cost and machinability. Supporting information is then sought and used to narrow down the ranked materials to a final choice allowing a definite match to be made between design requirements and material attributes. This material selection system helps the designer perform the rigorous process of material selection for the gear train at fast speeds thus saving time and money during design.

1.OBJECTIVES

To develop an online materials selection process that will be based on the principles of decision theory. To develop a knowledge intensive methodology for screening and ranking engineering materials. To implement the materials selection process so developed as an information processing routine on a computer system. To document and evaluate the materials selection process so developed by means of a case study (A Reverted two stage compound gear train)

2. STANDARDS AND CODES

A standard is set of specifications for parts, materials, or processes intended to achieve uniformity, efficiency, and a specified quality. One of the most important purposes of a standard is to place a limit on the number of items in the specifications so as to provide a reasonable inventory of tooling, sizes, shapes, and varieties. A code is set of specifications for the analysis, design, manufacture and construction of something. The purpose of a code is to achieve a specified degree of safety, efficiency, and performance or quality. However, it's important to observe that safety codes do not imply absolute safety. This project and the case study identify materials to Unified Numbering System (UNS) standards. An ideal case of choice of standards should be based on such factors as the location where the product is applicable and acceptability of the standard under the applicable design/construction code. In this case therefore, Kenyan Standards (KS) would have been preferred.In order to provide a consistent basis for basic specifications of the materials, only UNS standards for the materials have been used. In some cases where the material's common name is available, then the material's common name is given. In order to provide a consistent basis for basic specifications of the materials, only UNS standards for the materials have been used. In some cases where the material's common name is available, then the material's common name is given.

3. MATERIAL SELECTION

Selecting materials usually begins in the preliminary design stage. The problem of material selection usually involves the selection of materials for a new product or new design, and re-evaluation of an existing product or design to reduce cost, increase reliability and improve performance.

3.1 SELECTION OF A MATERIAL FOR A REVERTED TWO STAGE COMPOUND GEAR TRAIN

Gears are machine elements that transmit motion by means of successively engaging teeth. This form of transmission is possible because of the rigidity of the material from which the gear wheels are made. From kinematical point of view, gear wheels may be assumed to be completely rigid, such that there is no deformation whatsoever when the gear wheel is subjected to force. Thus the kind of transmission of motion that occurs in gear drives is known as a positive drive in which there should be no loss of motion at all. This is as opposed to belt drives, for instance, in which loss of motion may occur due to creep, slip or both creep and slip of the belt relative to the pulleys.

4. MODES OF GEAR FAILURE

Bending failure:

Every gear tooth acts as a cantilever. If the total dynamic load acting on the gear tooth is greater than its beam strength, failure due to bending will occur i.e. the tooth will break. To avoid such failure, the module and face width is adjusted such that the beam strength is greater than the dynamic load.

Pitting:

It's surface fatigue failure which occurs due to much repetition of Hertz 6contact stresses. The failure occurs when the surface contact stresses are higher than the endurance of the material. It starts with formation of pits which continue to grow resulting in the rupture of the tooth. To avoid pitting, the dynamic load must be less than the wear strength of the gear tooth.

Scoring:

Excessive heat is generated when there is an excessive surface pressure, high speed, or failure of lubrication system. This causes a stick- slip phenomenon in which shearing and welding takes place rapidly. To avoid scoring, proper design of parameters such as speed, pressure and proper flow of the lubricant should be carried out.

Abrasive wear:

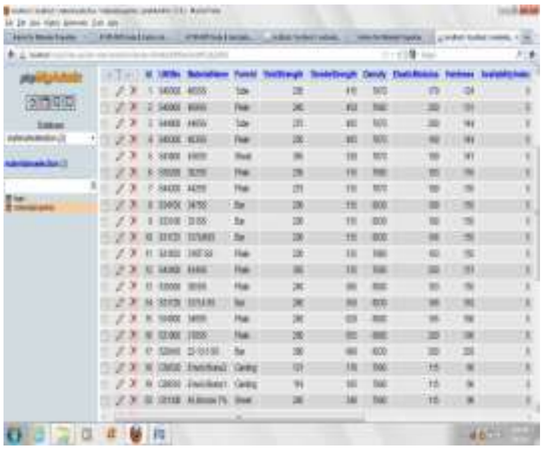
Foreign particles in the lubricant such as dirt, dust or burr can cause loss of material from contacting surfaces of teeth. This type of failure can be avoided by providing filters for lubricating oil or by using high viscosity oil which forms a thicker film and permits easy passage of such particles without damaging the gear surface.

Corrosive wear:

Corrosion of teeth surface is mainly caused due to the presence of corrosive elements such as additives present in lubricating oils. In order to avoid this type of wear, proper anti-corrosive additives should be used.

5. MATERIALS SELECTION SYSTEM

The selection system consists of a server application (WAMP) and database (Material Selection). The database stores information on a sample of materials and their properties. Pertinent database server software is MySQL. The server application comprises of Apache (server), MySQL and PHP applications on a windows platform (operating system). Server applications' purpose include: data retrieval, updating the database, enabling multiple client support and performing administrative tasks.



The homepage has three menu items: select material, material database, and administration. On the select material menu item, the "spur" link enables the user to start the process of material selection for the gear train. The material database has links for viewing and searching the material database. The third item, administration, allows the user to add to and edit material in the database. Clicking on the "spur" link, a list of locally available materials is displayed. This is done by screening the material database using availability as the non-discriminating parameter (if the material is not available it cannot be used and therefore it's dropped in the first stage of selection i.e. it's not displayed).

On selecting the "calculate stresses" option, a page for capturing properties specified by the user is displayed. This page allows one to input the design specifications for the gear.

On selecting the "calculate" button after successfully filling in all the text fields, a new page loads showing the parameters used in calculating the design stresses and a list of the qualified materials. The qualified materials are ranked using composite index in a descending order (starting with the one having the highest composite index to the one with the least composite index).

This is the second stage in material selection where screening is done using go/no-go parameters (These are minimum/maximum properties values which candidate materials must meet). In selecting a candidate material for the gear train, the bending stress was compared with the materials yield strength (go/no-go parameter) while the contact stress was compared with the materials contact stress factor (go/no-go parameter).

From the list of qualified materials above, UNS K11576 HSLA Steel was ranked the highest with a composite index of 3.1387 while UNS S20910 22-13-5 Stainless Steel was the lowest ranked with an index of 2.8678.

To search for a particular material in the database, click on the "search database" link in the "material database" menu item and a form for entering the material specifications to aid in the search is displayed. For example, using density as the search field and entering a value of 7850Kg/m3, materials in the database matching this value are retrieved and displayed.

The selection of a material for machine part or structural member is one of the most important decisions the engineering designer has to make. Poor material choice can lead to failure of a part or system or to unnecessary cost. The process of materials selection is difficult one and typically involves multiple conflicting material characteristics as well as large number of constraints.

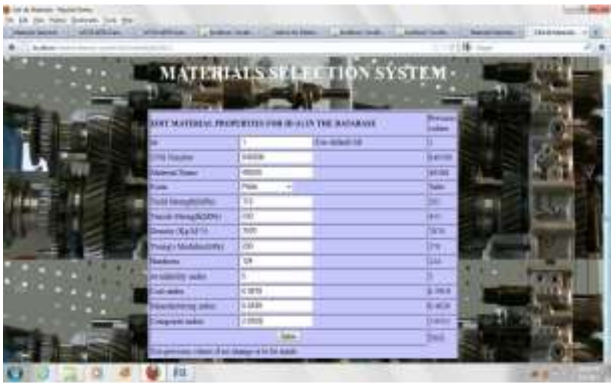
A good material selection process considers the limiting factors for a particular design exercise which include material properties, material processing, material cost and material availability. The selection of candidate materials for the gear train was done in two stages; screening of the large material database and ranking of qualified materials.

Screening was done in two steps. In the first step, using availability as the non- discriminating parameter all locally unavailable materials were eliminated from further consideration in the selection. The second step used go/no-go parameters as the basis for screening. In this case, the materials' yield strength and the contact stress factor were considered as the go/no-go parameters. Therefore, for any material to qualify it had to meet these two conditions: material yield strength had to be greater than the calculated bending stress and the material contact stress factor had to be greater than the calculated contact stress.

After screening, the second stage involved ranking the qualified materials using composite index. The composite index for a given material, by using the Analytic hierarchy process (AHP), was obtained by multiplying the availability index by a weight of 0.55, the cost index by a weight of 0.35, and the manufacturing index by a weight of and thereafter summing the weighted indices12. The material with the highest composite index was ranked the best by the material selection system.

Different materials scored differently in the different indices (i.e. availability, cost and manufacturing). No particular material was exclusively favored by all factors. Some scored high on some indices and poorly on others while others were just fair. For example, Low Carbon Steels and Low alloy Steels scored highly in the availability index as well as cost index. On the other hand, Aluminium alloys scored well in the availability index but poorly in the cost index.

From the list of the five qualified materials, UNS K11576 HSLA Steel was ranked the highest with a composite index of 3.1387. Considering the first three materials and eliminating UNS S43600 436 Stainless Steel on the basis that it’s in sheet form and hence it cannot be used in gear manufacture, the decision on which material to use relied on supporting information.



6. CONCLUSION

Optimal selection of engineering materials is done in two stages: screening followed by ranking. The first stage reduces the large material database to a small candidate list which meets the critical property limits as defined by the design equations. The second stage involves ranking the candidate materials using composite index. Supporting information is then sought and used to narrow down the ranked materials to a final choice allowing a definite match to be made between design requirements and material attributes.

The selection of a suitable material for the gear train was successfully implemented as an information processing routine on a computer system. Only data input was required, the application developed did the data manipulation and output a list of suitable materials ranked in order of preference. The selection of UNS K11576 HSLA Steel was therefore not based on past experience but on stepwise selection from first principles, considering the design problem was new.

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