MANUAL AND COMPUTER-AIDED MATERIALS SELECTION FOR INDUSTRIAL PRODUCTION: AN EXERCISE IN DECISION MAKING

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Summary

Students are introduced to methods and concepts for systematic selection and evaluation of materials which are to be used to manufacture specific products in industry. For this laboratory exercise, students are asked to work in groups to identify and describe a product, then to proceed through the process to select a list of three candidates to make the item from. The exercise draws on knowledge of mechanical, physical, and chemical properties, common materials test techniques, and resource management skills in finding and assessing property data. A very important part of the exercise is the students' introduction to decision making algorithms, and learning how to apply them to a complex decision making process.

Significance

Materials selection is the process of choosing materials from which to make products in industrial production. A familarity with materials selection is critical to product designers, to product and manufacturing engineers, and to industrial technologists who will have close review over production lines and problems. In addition, a study of the decision making involved is sound basic education for today's college students.

The Problem

Ten years ago, when this researcher first started a study of the materials selection process, very little in the way of computer tools was available to aid the designer or engineer in the process. At that time, an article in Metals Progress[1] described an early but well-designed system for polymer selection used at John Deere's corporate headquarters in Moline, Illinois. Other true systems for selection were manual in basis, including several card-based methods. The most notable of these was developed by H. Laurie Miller of Northern Telecom, in Canada[2]. Mr. Miller explored several manual methods, including transparent overlays to identify matches to requirements and slotted cards for appropriate materials. None of these methods were adequate to deal with the large quantities of data involved: They are even less adequate today.

Manual Methods

In spite of the problems, most industries continued, as they do today, to select materials for production of products without the use of computing tools. There are essentially only four 'practical' approaches to materials selection in use throughout industry:

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1. Use the material that was used last time
2. Use something that is in stock or heavily used for other products
3. Call in a materials supplier to evaluate the problem and recommend a suitable material.
4. Use an in-house expert or hire a consultant who has training in materials selection (the materials 'expert').

The consequences of the first three approaches will be clear upon a moments introspection. Formal university training in materials selection (option 4) is strangely rare. The program in Industrial Materials at the Division of Technology in San Jose State University attempts to give each graduating student an introduction to the rudiments of manual methods for materials selection. Because this field can so easily be expanded to encompass stress analysis, mechanical design, and other disciplines, it is important to distinguish the method of selection from the methods for product design. Our students are given the handout that follows this report to help them learn and execute the selection process.

Computer Solutions

In 1978, the first Apple II microcomputers were beginning to be marketed. No one even dreamed that IBM Corporation would ever show any interest in the ''toy box'' computer market. In that context, the only computer systems powerful enough to handle the computation, and especially the data storage and manipulation required for materials selection, were large minicomputers and main-frames. Such large systems were controlled by the data processing staff. For this reason, early studies showed very limited user access to such systems even where they existed, and the cost of system development was exorbitant for most engineering and design groups.

In 1981, the researcher established that it was indeed possible for a computer program, given appropriate input, to select materials from a database which will perform competitively to materials selected manually by professional materials engineers. In other words, given the parameters of the study[3], the computer could successfully select materials very similarly to expert materials applications engineers. The algorithm developed for use in the program for this research was refined from several studied from all over the country and even in England. It also incorporated studies of the decision-making methods used by a number of expert materials selection engineers from John Deere, Amana, and Rockwell Collins Avionics Division.

An algorithm is a mathematical model of a process, which in this case can be applied as a rule by the program as it evaluates data from a database. It constitutes a decisionmaking rule, and as such it represents an effort to establish some artificial, expert system capabilities for materials selection. In the research program, the computer will attempt to minimize 'Z' in the equation

$$Z = \sum_{i=1}^{n} |(Xi - Yi) / Yi|$$

as 'i' varies from 1 to 'n' properties. This equation is the main algorithm used by the program to evaluate materials. X_i is a material property found in the databank, and Y_i is provided by the selector as a target specification for each property during program startup. Minimizing the value of Z gives us the materials with properties that offer the smallest total percent deviation from specifications.

This rule is simple and easily executed by the computer, but it is not adequate by itself, as it assumes that each property is equally important in each selection application. Since this is not the case, we must add a weighting factor to the formula so that deviations become more or less significant depending on the importance the selector assigns to each property for a given application.

The resulting algorithm is effective, but to perform this numeric calculation on each property for each material in the database can consume huge amounts of computer time, delaying user reponse time unacceptably. The algorithm is thus augmented by a simple screening tool which eliminates from consideration for any given problem all materials which do not meet specific absolute property requirements stated by the selector (user). This allows us to quickly reduce the number of materials that need to be screened. The computer will not take as long to screen the remaining candidates. As a matter of practical concern, A Hewlett Packard model 2000 time sharing minicomputer, very primitive by today's standards, using the BASIC language, never required more than three minutes to evaluate up to ten property specifications for over 300 candidates (even when time sharing).

In today's microcomputer environment, however, any high-end desktop computer can be configured as a basis for cost-effective materials selection. Minimum system requirements will depend mainly on the size of the database used, but could easily be met by a Macintosh SE/30 or better, or by a PC AT running at 8 MHz or more, and with a rapid-access hard disk drive of 20 or more Megabytes capacity. Such computer systems can also support programs that have recently been released by the American Society for Metals (ASM)[4], by Corth Publishing Group (the D.A.T.A. series)[5], and by others who have attempted to develop commercial solutions.

Future Problems

Although the researcher is attempting to develop a PC-based system that will evaluate materials from all groups (metals, plastics, and others), this has not been accomplished in the commercial market. Many factors contribute to the difficulty, but the principal one is that for each group of materials, different test standards, test methods, and data presentation are used. It is easy to develop some conversion or translation tables, but others are nearly impossible. New test standards and procedures will be necessary before such a system can really work well, and this may never be workable given the significant differences that exist between the material families.

Nonetheless, workable PC-based models for materials selection from a limited database can be developed in any classroom and engineering group by a single programmer with a little development time. This will remain an exciting field for further study for several decades to come, due to the enormous benefits that methodical materials selection offers for enhancement of productivity and product liability stature.

Conclusions

Students can undertake real selection problems based on these laboratory techniques, and those with some programming proficiency can develop prototypical computer-based selection systems. The study of these methods is of use to product engineers, manufacturing methods engineers, product designers (including industrial designers), and manufacturing managers and can result in great cost savings and in a more secure liability position through improved documentation.

References

1. Unterweiser, P. M. (April, 1977), Computer aided engineering at John Deere: A materials selection data system. Metal Progress, pp. 38-43.
2. Miller, H. Laurie (February, 1975), Systematic selection of plastic resins. Canadian Plastics, pp. 20+.
3. Bates, S. P. (December, 1981), A feasibility study of a system for computer-aided selection of materials. Dissertation, University Microfilms, Ann Arbor, MI.
4. A. S. M. (1988), MetSel, A computer program for metals selection. ASM, Metals Park, OH.
5. Corth Publishing Group. D. A. T. A. , Tools for plastics selection.

Student Handout for
Materials Selection Problems
Dr. Seth Bates

I. Abstract

This paper is a guideline for the solution of materials selection problems. Materials selection, in this context, means choosing a material from which to make a part or product in industrial production. The material chosen, clearly, must be able to withstand reasonable stresses during the life of the product, and not fail catastrophically where life or health of users is endangered.

In order to conduct the selection, you will need to think through every aspect of the part. From this you will come up with a list of properties which the material should exhibit. Your technical report should explain what the criteria are, how you arrived at them, and how you went through the process of choosing the one best material for the application.

Materials Selection Problems

II. Introduction

The selection of a material for a specific application involves methodical, thorough, and imaginative thinking. It should be approached as a big challenge to your knowledge and abilities. There are many models (procedures) available for selecting materials. This document provides you with two tools to use:

a. a model, or set of procedures, which you will use to arrive at good solutions
b. guidelines for writing up your selection report.

III. A Model Procedure for Materials Selection

This model is presented in a number of steps which are identified as

- Part or product identification
- Properties specifications development
- Coarse screening of families
- Fine screening
- Final identification
- Reiterations

IV. Part or product identification. Identify the part or product to be manufactured. Try to use parts or products which involve only one material, for simplicity. Prepare a simple but clear sketch or drawing. Describe in detail:

a. The functions of the part - what it is and what it does
b. The operating environment - in terms of the mechanical, physical, and chemical forces that will act on the part
c. Any accidental forces that might reasonably be expected, and any accidental forces that might not be expected, but could have serious consequences
d. The potential users of the product. Indicated age range, education or training level, or any other significant factor

V. Materials specifications development. Using information from the last section (b. and c.), list in detail the types of properties and characteristics that the material must exhibit, and the values or ranges of values where possible. The following list will help:

Properties	Characteristics
a. mechanical	d. fabrication qualities
b. physical	e. economics and aesthetics
c. chemical	f. any other relevant data

For examples of relevant properties, consider those listed in the references found in the reference list. Clauser's book, other Materials Science texts, and the Materials Reference Issue are not adequate sources of information for these data.

VI. Coarse screening. Identify those properties which must be met (called 'go/no-go' properties). Using the go/no-go's, evaluate the major families of materials to determine which actually offer candidate materials from which to make your part. The families include:

a. metals - ferrous
b. metals - nonferrous
c. ceramics and glasses
d. elastomers
e. thermoset polymers
f. thermoplastic polymers
g. polymer composites
h. woods and wood composites

Then, using the go/no-go's and the databanks (references) listed above, identify specific materials from the families which passed the coarse screening. Use correct names, not tradenames (e.g. acrylic or acrylonitrile, rather than Plexiglass). You may have as many as 15 to 30 candidates (materials) at this point. Try to be selective enough to keep the number small.

VII. Fine screening. Rate all the properties that are still significant (some may not be) in terms of relative importance. Using these relative ratings, evaluate the candidates. Use Clauser's system (1975, p. 19). Identify the best 3 to 5 candidates and rank them.

VIII. Final identification. Compare the three to five final candidates on the most important points. If they all seem equally good choices, consider more subtle aspects such as aesthetics and economics. Rank them according to their relative value in this application, and explore the pro's and con's of using each one.

IX. Reiterations. Every materials selection involves compromises. At any point in the coarse or fine screening process you may see that some specification has unnecessarily limited the choice of materials, material types, or families. If this has occurred in your case, reconsider the original part description:

~Could the part be designed differently, to allow looser (or different) specifications?
~Perhaps aesthetics could be satisfied by a different method of finishing.
~Has your selection in fact identified a suitable material?

If these or other considerations apply, consider a redesign or reevaluation (reiteration). You should be flexible, and willing to change your part design. The selection of materials is a dynamic process.

X. Reference List for Selection Handout

ASM, (annual) Metals Handbook, vol. 1, Properties and Selection. Metals Park, Ohio

Clauser, H. R. (1975) Industrial and Engineering Materials. New York: McGraw-Hill.

The following are also useful:

The Materials Selector Issue of Materials Engineering (annual), Penton, Cleveland, OH.
The Modern Plastics Encyclopedia (annual), McGraw-Hill, New York, NY.
The International Plastics Selector (annual), Cordura Publications, San Diego, CA.

End of Handout

SCANNING X MICROSCOPY

Slide and Video Presentation by F. Alan McDonald
IBM Research Center

Dr. McDonald presented a slide/tape presentation on the variety of scanning microscopy techniques and the research being conducted at the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, and other research developments throughout the world in scanning X microscopes.

Please refer to Scanned-Probe Microscopes, Scientific American; October 1989, pages 98 through 105, for the formal presentation of the topic.

This article, by H. Kumar Wickramasinghe, Manager of Physical Measurements at the Yorktown Heights Center, explains how scanned-probe microscopes examine a surface at a very close range with a probe which may be just a single atom across. These microscopes can resolve features and properties on a scale beyond other microscopes.