DECISION SUPPORT TO POLYMER MATERIAL SELECTION

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Abstract: To succeed means to develop and produce a product with optimal properties for considerable lower price in comparison to similar products on the market. Material selection is one of crucial decisions in product development process affecting quality as well as price of future product. In technical praxis, the designer has to evaluate the information gathered from material data sheets and simulations, engineering analysis and animations of future product performance in virtual environment. Afterwards, he or she has to seek interdependences between them and finally choose the optimum from the broad list of materials. Wide spectrum of various polymers at disposal should be outlined here, as it presents a problem to the designer at polymer material selection process. The proposed decision support system model is an attempt to solve this dilemma and will focus on function, technical features and shape of developing product. Other criteria, like serviceability, technical feasibility and economic justification are going to be considered accordingly. The major benefits concern inexperienced designers along with small and medium sized enterprises (SMEs').

1 INTRODUCTION

Material selection is one of many stages in product design process. The engineer has to progress through this process in order to design a model, semi-product or a final one. Within this process the designer has to take numerous decisions at all stages of design like material selection, process selection, analyses and simulations, diverse evaluations of the developing product, tool design and industrial design where ergonomic and aesthetic attributes should be considered.

Product development process is decision making process since the engineer has to take considerable amount of decisions whilst designing. Younger inexperienced design engineers have major difficulties at solving this query. One product development phase, material selection, will be discussed here in order to overcome decision making barrier, the decision support system for plastic product design is proposed. This computer aid will offer recommendations and guidelines according to the required parameters, shape or/and function of the product and could also be helpful for experienced designers using the system as a verification tool. What is more, it is expected that small and medium sized enterprises (SMEs') will characterize proposed system as a major acquisition as they could economize at human resources and benefit on financial field.

This article presents an explanation of material selection methodology and polymer material selection in praxis, all collected in Section 2. Section 3 envisages the intelligent decision support system with graphic mode as Section 4 represents the implementation of proposed decision support system for polymer material products' design. Conclusions are tersely collected in Section 5.

2 MATERIAL SELECTION

Material selection is a significant stage of design process and a complex task, whose execution varies from enterprise to enterprise in accordance with staff and the economic aptitude of the company. In this section material selection methodology is described and divided in four general approaches to polymer material choice upgraded with presentation of this process in praxis.

2.1 Material Selection Methodology

In general, material selection methods can be, accor-

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ding to Ashby and Johnson (2005), arranged in four different selection methods called Selection by Analysis, Selection by Synthesis, Selection by Similarity and Selection by Inspiration. All methods require input data in the form of design requirements specific for each method.

Selection by Analysis is the most systematic and robust as input requirements are objectives, functions, and constraints, and furthermore, they are precisely defined and unambiguous. Its deficiency derives from this particular distinctiveness, which causes the method to fail in the case of imprecise inputs or imperfectly formulated rules. Previous experience and analogy are key factors in the Selection by Synthesis method, where design requirements appear in the form of intentions, features, and perceptions. This method is used, when knowledge of the solved cases can be exploited and transferred to other product with some features in common. Selection by Similarity is the selection method, where input is already known or potential material solution and its purpose is to find substitutive material for an existing product, often initiated by design requirement changes due to e.g. environment legislation. The less uniformed method is Selection by Inspiration, where input is pure curiosity and the designer's task is to examine and analyse other solutions for a specific feature, in a systematic way. This method is used when no scientific method is helpful. All material selection methods and their variations are implemented in numerous variations as engineering praxis.

2.2 Polymer Material Selection in Praxis

Usually the methodology of material selection involves making a list of properties that you must have for future application and the list of properties that are desired for this particular application. These *must* and *want* properties are then matched with the properties of available polymer materials on the market. In engineering praxis, four basic groups of material properties are reviewed:

- Physical (specific heat, coefficient of thermal expansion, thermal conductivity, heat distortion temperature, glass transition temperature)
- Chemical (composition, additives, fillers, crystallinity, environmental degradation, spatial configuration, molecular weight, flammability)
- Mechanical (tensile and compressive properties, heat distortion, pressure-velocity limit, toughness, stress rupture resistance, creep resistance)
- Dimensional considering manufacturing conditions (manufacturing tolerances, stability, available sizes, moldability, surface texture)

In order to illustrate the importance of polymer materials' idiosyncrasies (Budinski and Budinski, 2010), each group of followed properties should be described.

2.2.1 Physical Properties

Physical properties are material characteristics that pertain to the interaction of these materials with various forms of energy and human senses. Generally they could be measured without destroying the material. Density is a physical property determined with weighting or measuring the volume of the product. Physical properties like feel and colour are even easier to determine while they affect the customer as he or she only looks at it. Nevertheless, they are not marginal material properties and their importance rises in today's consumer oriented society. The designer has to acknowledge that plastic feels different from metal and yellow is happier colour in comparison to brown.

2.2.2 Chemical Properties

Chemical properties are related to the structure of polymer material, its formation from the elements of which the material is made, its reactivity with chemicals and environments. These properties cannot be visually inspected and are measurable in chemical laboratory.

2.2.3 Mechanical Properties

Mechanical properties are the features of material, which are put on view when it is exposed to a force. They are related to the elastic or plastic behaviour of the polymer and they often require destruction for measurement. Term mechanical is used because they are usually used to indicate the suitability of the material for use in mechanical applications – parts that carry a load, absorb shock, resist wear, etc.

2.2.4 Dimensional Properties

Dimensional properties include as well manufacturing considerations like manufacturing tolerances and moldability. This category concerns also the surface texture and its roughness, which is measurable and essential for many applications. Available size, shape, finish and tolerances of the product are also important polymer material selection factors.

3 DECISION SUPPORT IN GRAPHIC MODE FOR POLYMER MATERIAL SELECTION

In recent years, many decision support systems where developed and some successfully launched in real applications (Turban et al., 2004). The significance of material selection dilemma is obvious as several models were developed to support the designers at this stage of design (Đurić and Devedžić, 2002).

Building the decision support system in graphic mode presented in this paper aiming at a successful and efficient performance is a complex assignment. The development methods included in research are a combination of special domain knowledge expertise in the field of polymer materials and human cognition in the field of design knowledge. Human knowledge useful for problem solving is of special importance and is in the form of rules relating to modern plastic materials' selection and correlated manufacturing processes, assisted by the field of Design for Manufacturing (DfM) (Molcho et al., 2008).

A graphic mode of proposed system will be related to three major groups of polymer materials: thermoplasts, thermosets and elastomers, which will all be arranged and presented in individual circles. Within the framework of each circle several technical features carefully selected to cover all essential material properties described in Section 2, will be assigned:

- Mechanical properties (strength, bending strength and working temperature),
- Production process (injection moulding, compression moulding, spin casting and extrusion),
- Chemical properties (resistance to base, acid, gas/oil, hot water),
- Working environment (internal/external use, fire resistance).
- Optical properties (colouring possibilities).

All three circles will have the same framework so the parameters, introduced to the system by the user will reflects trough all of them.

The system model will provide polymer material suggestions in discussed case, e.g. the designer receives two polymer material results, epoxy and diallyl phthalate (DAP), whose properties are introduced in the outer ring of the circle.

The significant feature of the system is two level solutions. The primary result will be the possible plastic material choice, many of them or none. The database of the polymer materials will play the key role here. Afterwards, the system's knowledge base containing human cognition of plastic material selection and DfM will be of special importance as the system will be able to evaluate the candidates for potential material choices, which were just over the boundaries created by introduced parameters. Thus, some polymers are going to become a secondary solutions presented to the designer in form of notices containing recommendations about the advantages of each suggested solution. Considering the described decision support system with graphic mode, the enterprises will be able to compete at the global market by selecting the optimal material for their product.

4 IMPLEMENTATION OF DECISION SUPPORT SYSTEM MODEL

The decision-making process is a constant for every designer aiming at a successful and efficient performance. Alternatively to experts' acquired domain knowledge, we decided to develop an intelligent decision support system (Edwards and Deng, 2007) in order to overcome the bottle neck - plastics material selection.

The knowledge base will contain human cognition useful for problem solving in the form of rules relating to modern plastic materials' selection and correlated manufacturing processes, assisted by the field of Design for Manufacturing (DFM). Different approaches to knowledge acquisition (McMahon et al., 2004) and the appropriate formalisms for the presentation of acquired knowledge within the computer program will be of special importance.

The potential for transparent and modular IT rules, whose advantage is neutral knowledge representation, uniform structure, separation of knowledge from its processing and possibility of dealing with incomplete and uncertain knowledge, is planned to be compared with more flexible knowledge presentation systems, such as fuzzy logic, where fuzzy sets and fuzzy rules will be defined as a part of an iterative process upgraded by evaluating and tuning the system to meet specified requirements. Tuning will be the most delicate job whilst building a fuzzy system as fuzzy sets and rules should frequently be adjusted during the system's construction. The main goal for the system is to apply domain knowledge, including human cognition, relations and experiences in the knowledge base of the system, which will, together with the data base, serviceable for a complex reasoning procedure behind the inference engine leading to qualified design recommendations and guidelines for designing plastic products.

The user interface will be developed with a special attention, in order to enable transparent and efficient system application. Two different application modes have been anticipated, in regard to the type of input and output data. Question and answer guided mode will be used mostly at the beginning, when the first set of parameters has to be presented to the system. During the data processing phase, the system may present additional questions or ask for more parameters. In this case, guided and graphic modes will be used to present the problem to the user. The solution in the final phase will also be presented in graphic mode.

5 CONCLUSIONS

Human cognition along with experiences is engineer's main advantage. Consequentially, inexperienced designers and SMEs' are kept in the background here as their decision making process is aggravated. Decision support system model proposed here could be of great importance for the engineering praxis as designers have difficulties at acquiring expert knowledge and experiences. Proposed system model will be able to offer some recommendation and design guidelines on the field of design and knowledge expertise in the field of polymer materials. The designer will benefit much due to faster, less experience dependent design process, consecutively higher efficiency and friendlier working environment.

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