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COMPUTER AIDED DECISION SUPPORT IN PRODUCT DESIGN ENGINEERING

Marina Novak

Original scientific paper

Product design engineering is a complex discipline, which is undergoing a transformation from informal and largely experience-based domain to scientific oriented domain. Computational intelligence can contribute greatly to product design process, as it is becoming more and more evident that adding intelligence to existing computer aids, such as computer aided design systems, can lead to significant improvements in terms of effectiveness and reliability of various tasks within product design engineering. Providing computer aided decision support is one of the computational intelligence methods that proved to be effective in enabling more intelligent and less experience-dependent design performance. In this paper, some of the most crucial areas of product design engineering process that require additional computational intelligence in terms of computer aided decision support are presented together with some examples of intelligent knowledge-based modules applied to this areas.

Keywords: *product development, design engineering, design for X, computational intelligence, decision support, knowledge-based modules*

Računalno potpomognuto podupiranje odluka u konstruiranju proizvoda

Izvorni znanstveni članak

Konstruiranje proizvoda složena je disciplina, koja prolazi kroz preobrazbu iz neformalnog i na iskustvu temeljenog područja na znanstveno orijentirano područje. Računalna inteligencija može napraviti značajan doprinos u procesu konstruiranja proizvoda. Sve više je naime očito, da dodavanje inteligencije postojećim računalnim alatima, kao što su sustavi za računalom podržano konstruiranje, može dovesti do značajnih poboljšanja u pogledu učinkovitosti i pouzdanosti različitih zadataka unutar konstruiranja proizvoda. Pružanje računalno potpomognutog podupiranja odluka jedan je od postupka računalne inteligencije koji se pokazao učinkovitim u omogućavanju inteligentnijeg konstruiranja, koji manje ovisi o iskustvu. U ovom radu prikazani su neki od najvažnijih područja procesa konstruiranja koji zahtijevaju dodavanje računalne inteligencije u smislu računalno potpomognute podrške odlučivanju, skupa s primjerima inteligentnih na znanju utemeljenih modula primijenjenih na ova područja.

Ključne riječi: *razvoj proizvoda, konstrukcijski inženjering, konstruiranje za X, računalna inteligencija, potpora odlučivanju, moduli temeljeni na znanju*

1 Introduction

The use of computers is essential in modern design process. Computer Aided Design (CAD) is extensively applied in a wide range of industrial branches. However, there is a body of opinion that the benefits of applying conventional CAD software tools are below expectations. The development of CAD systems and their applications in engineering practice have been greatly influenced by rapid increases in the performance of computer hardware. Emphasis has been laid on the implementing numerical methods and computer graphics. Hence, CAD still concentrates rather too much on providing a means for representing the final form of design, whereas designers also need a continual stream of advice and information.

Design problems are known to be ill-defined. The problem statement usually sets a goal, some constraints within which the goal must be achieved, and some criteria by which a successful solution might be recognised. The solution is unknown, and there is no certain way of proceeding from the statement of the problem to a statement of the solution. Moreover, many design constraints and criteria also remain unknown and existing CAD approaches, based on conventional programming methods [1], are not able to help the designer in dealing with uncertainty and inconsistencies [2]. Thus, the quality of design solutions still depends mostly on the designer's skill and experience.

In order to make design process more intelligent and less experience-dependent, existing CAD systems should be supplemented with some intelligent modules that will provide advice when needed. In the last decade, various artificial intelligence applications to product design engineering have been reported. The book edited by D. T. Pham [3] is a good collection of early examples related to this area, while A. Kusak and F. A. Salustry made a good overview [4] of more recent developments in this research field. It is evident that computational intelligence applications to design are now the subject of intensive development and implementations.

There are various approaches to provide computer aided decision support in product design engineering. Stacey et al. [5] reported on a computational intelligence approach, called signposting, to support decision making in design. Signposting provides both inference knowledge and strategic problem-solving knowledge by focusing on the dependencies between design parameters. Another approach was reported by Danesh and Jin [6] who created an agent-based decision network to support decision making in collaborative design. Each designer is represented with a software agent in an objective-based negotiation environment. Agents were also used by Chao et al. [7] to model interactions between design systems used by multiple teams working on large-scale, complex design problems. Mussi [8] presented a method for building decision support systems based on decision theory using value of information derived by validating hypotheses crucial to task completion, which is typical of product design engineering situations.

Taking into account all these approaches and methods, several intelligent rule-based modules for providing decision support in product design are being developed in Laboratory for intelligent CAD systems at the Faculty for mechanical engineering, University of Maribor, Slovenia. In this paper, four of these modules are presented in Sections 3-6. Before that, the need for decision support in product design is discussed, and some crucial areas for this support are defined in Section 2.

2 The need for decision support in product design

Product design engineering has a significant decision making element. Intelligent decision support systems are especially needed in product design engineering because of high complexity associated with the decisions and of the risks associated with making wrong decisions.

In modern product design various strategies are used to develop a successful product. Computer-aided techniques included in CAD tools in the broader sense, such as geometric modelling, virtual representations, simulations, analyses, etc. represent a red line of this process. The related software is nowadays very sophisticated and offers great functionalities to designers at their work. Yet, the efficient use of these tools, which have been changing constantly and rapidly over the time, can be quite challenging. The advice on how to use these computer programmes to make the best of them is needed very often. In the last few years, most of the CAD packages actually provide some basic decision support in this context. However, the aim of this paper is to concentrate on decision support related to more professional engineering problems rather than just to the use of CAD tools.

Product design engineering is a very complex iterative process, searching for optimal design solutions. In many cases, the basic parameters for the optimising process are the results of structural or some other type of engineering analysis. Finite Element Analysis (FEA) [9] is the most frequently used numerical method for simulation and verification of the conditions in the structure being analysed. If the structure does not satisfy given criteria, certain optimisation steps, such as redesign, use of other materials, etc., have to be taken. The range of structures that need to be analysed is very wide, from the obvious ones that are meant to carry any kind of mechanical load and/or the analysis is even prescribed by special engineering standards [10], to more special, on the first sight not so obvious cases [11-14]. In any case, the initial design is made in a geometric modeller, analysed by FEA or some other method for engineering analysis and then re-designed in the modeller. This optimisation loop is repeated until the final design that satisfies the given criteria is developed.

Since existing CAD tools fail to provide functional advice, the quality of the initial design, analyses and re-design actions, and also the number of iterative steps needed to reach the final solution depend mainly on the designer's experience. Design experts can efficiently perform structural design optimisation. They have built up their experience over time by working on design and analysis of problems for various products. Their strategy when dealing with a design problem is based mainly on heuristics or rules of thumb. But what about less experienced designers? Is it possible to avoid trial-error behaviour and help them to perform computer-aided design optimisation more efficiently? Evidently, traditional design optimisation systems that concentrate on numerical aspects of design process are not successful in integrating numerical parts with human expertise [15].

In order to overcome this bottleneck in product design process, decision support is needed in both pre- and post-processing phase of the analysis [16]. Computer systems that provide such an advice are called intelligent analytical aids. Two representatives of these kinds of decision support systems are presented in more detail in Sections 3 and 4.

Another part of product design engineering process that needs to be mentioned when discussing the need for decision support is certainly the one where some specific design criteria need to be satisfied. Development teams often have difficulty to link customer's specifications and needs to specific design issues they face. For this reason, many design engineers address specific design aspects by using so called Design for X (DfX) methodologies, where X may correspond to one of many quality criteria, from more general, such as reliability, appropriateness for assembly, robustness, and maintainability, to more specific, like environmental impact, ergonomic and aesthetic value, etc. [17]. Mainly analytically oriented CAD tools again hardly provide some useful professional advice and information regarding these aspects of product design. The examples of intelligent consultative decision support systems discussed in Sections 5 and 6 show that computational intelligence can offer some very useful design guidelines in this respect [18].

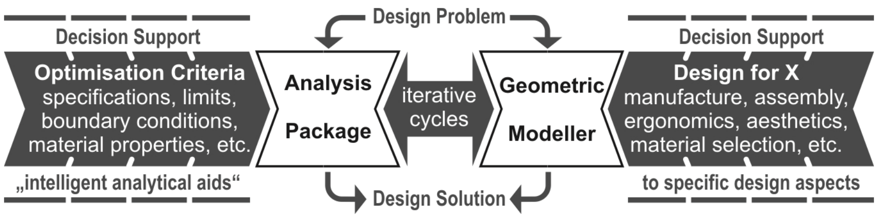


Figure 1 Key area in product design process requiring decision support

Fig. 1 shows basic framework of the product design process where two key areas that require decision support are exposed. Computer-aided geometric modeller and analysis package are basic CAD tools within the product design engineering process. On the analysis side of the process intelligent analytical aids help the designer to perform analysis-based design optimisation, while on the other side of the process decision support is provided to some specific design aspects. In both cases, the main research goal is to encode the knowledge and the experience required in dealing with engineering design problems into a Knowledge Base (KB) that can be used by a computer system. The proposed intelligent KB modules should provide help in terms of advice and design recommendations that would in available circumstances lead to the best possible match between design problem and design solution.

3 Support to finite element mesh design

Within FEA, a number of different idealised mesh models of the structure usually need to be created until the right one that ensures low approximation errors and avoids unnecessary computational overheads is found. The trouble is that each mesh has to be analysed, since the next mesh is generated with respect to the results derived from the previous mesh. Considering that one FEA can take from a few minutes to several hours and even days of computer time, there is obviously a strong motivation to design optimal finite element mesh models more efficiently – in the first step or at least with minimum trials. As an alternative to the conventional trial-and-error approach to this problem the Finite Element Mesh Design Expert System named FEMDES was developed in our laboratory [19]. The system was designed to help the user to define the appropriate finite element mesh model easily, faster, and less experience-dependent.

There is no clear and satisfactory formalisation of the mesh design know-how. Finite element design is still a mixture of art and experience, which is hard to describe explicitly. At the same time, the finite element type selection is considered as relatively easy task. However, today's FEA software tools offer to the user a wide range of different, but often also very similar elements. Even the elements that are meant to be used for the same generic type of analysis may have different geometric shape and polynomial function [20]. Thus, selection of the most appropriate type of the elements to be used for certain analysis became a complex task that requires a lot of knowledge and experience. Most of novice finite element users need advice which type of finite elements should be used for the analysis to get satisfactory results at reasonable consumption of computing resources.

On the other hand, many reports have been published in terms of problem definition, an adequate finite element mesh (chosen after several trials), and results of the analysis. These reports were used as a source of training examples for machine learning algorithms to construct more than 1700 rules for finite element mesh design by generalising given examples [21, 22]. The way in which inductive logic programming techniques [23] were applied to develop the KB in this particular case is presented in detail in [24].

Fig. 2 shows how FEMDES is to be applied within the FEA pre-processing phase. The user has to define the problem (geometry, loads, and supports). The data about the problem needs to be converted from the FEA pre-processor format into the symbolic qualitative description to be used by the KB module [25]. The task of the system is to propose the appropriate types of finite elements and to determine the mesh resolution values. A command file for the mesh generator can be constructed according to the results obtained by the intelligent system.

For FEMDES, we have built our own program to gain the most efficient correlation between the knowledge and the program part of the system. Like the KB, the shell is also written in Prolog. This enables the proper use of the KB for mesh design (inference engine), and also communication between the user and the system (user interface). A very important and useful feature of the user interface is its capability to explain the inference process, by answering the questions "Why?" and "How?"

The user has to prepare the input data file before running the system. The structure that is to be analysed needs to be described in exactly the same way as the training examples were presented to the learning algorithm in the knowledge acquisition phase. This can be done automatically by using the geometric model of the structure. Currently FEMDES is not integrated within any commercial FEA pre-processor. Thus, the problem description needs to be made manually. This takes some time, especially for structures that are more complex. However, following a few simple algorithms the task does not require special knowledge and experience.

To simplify the learning problem, the training set used for developing of the knowledge base was designed with the aim of being representative of a particular type of structures. The following limitations were taken into account:

- all structures were cylindrical,
- only forces and pressure were considered as loads,
- highly local mesh refinement was not required.

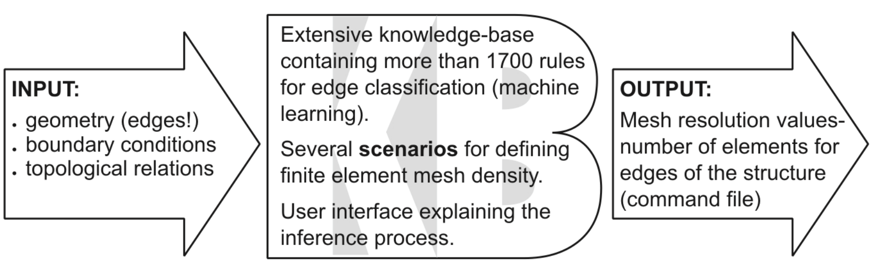


Figure 2 FEMDES application within the pre-processing phase of the analysis

Despite these limitations FEMDES can also be applied as a general tool for determining the mesh resolution values for real-life three-dimensional structures. The results of the system have to be adjusted subsequently, according to the specific requirements of the particular analysis. Furthermore, they can always serve as a basis for an initial finite element mesh, which is subject to further adaptations considering the results of the numerical analyses. It is very important to choose a good initial mesh and to minimise the number of iterative steps leading to an appropriate mesh model. Thus, FEMDES can be very helpful to inexperienced users, especially through its ability to explain the inference process, as presented in Fig. 3.

```
2 finite elements are proposed for edge "a22".
[ how | change | next | complete | exit | help ] (next)  -->  help
      how - explain the inference process
   change - user amendment to the result of inference process
     next - proceed the inference process (default)
 complete - complete the inference process without further user input
     exit - terminate the inference process
     help - this explanation
[ how | change | next | complete | exit | help ] (next)  -->  how
  ============ Begin of the inference explanation ===========
According to rule no. 60 (Acc=1) the edge "a22", which is:
   short and
      has opposite edge "a32", which is
         not important
should have 2 finite elements.
  ============ End of the inference explanation ============
[ change | next | complete | exit | help ] (next)  -->
```

Figure 3 An example of inference process explanation within FEMDES program

4 Support to analysis-based design improvements

The post-processing phase of the engineering analysis represents a synthesis of the whole analysis and is therefore of special importance. It concludes with the final report of the analysis, where the results are quantified and evaluated with respect to the next design steps, which have to follow, the analysis in order to find an optimal design solution. The sources for post-processing are numerical results of the computation performed in the previous phase of the analysis. The data is stored in a computer file. In spite of the fact that the records are quite well ordered, the numerical figures are hard to follow in the case of a complex real-life problem, when the data file is usually complex and extensive. Nowadays FEA software is very helpful at this point, as it offers adequate computer graphics support in terms of reasonably clear pictures showing the distribution of the unknown parameters inside the body of the structure.

However, the user still has to answer many questions and solve many dilemmas in order to conclude the analysis and compose the report. The designer has to be able to judge whether the results of the analysis are correct and reliable, and also to decide what kind of design changes are needed, if any. Most users need advice to interpret the analysis of the results adequately. Unfortunately, this kind of help cannot be expected from the present software. Traditional systems tend concentrate on numerical aspects of the analysis and are not successful in integrating the numerical parts with human expertise.

In order to overcome this bottleneck, we decided to collect and encode the knowledge and experience needed to propose appropriate design actions that may lead to design improvement. In this way the prototype of the intelligent consultative system PROPOSE for supporting design decisions considering the results of a prior stress/strain or thermal analysis was developed [26]. PROPOSE provides a list of redesign recommendations that should be considered in order to optimise a certain critical area within the structure.

Fig. 4 shows that, as a result of applying PROPOSE the user may expect a list of redesign recommendations, based on the expert interpretation of the results of the prior numerical analysis. As a rule, several redesign steps are possible for design improvement. The selection of one or more redesign steps to be performed in a certain case depends on requirements, possibilities and wishes.

The system was developed in several steps. The most important step was to develop the knowledge base, where knowledge acquisition was the most crucial task. Theoretical and practical knowledge about design and redesign actions were investigated and collected. A wide range of different knowledge is needed to explore possible design actions that should follow the engineering analysis. Knowledge acquisition was carried out in three different ways:

- from a literature survey,
- from examinations of old engineering analyses, and
- from interviews with human experts.

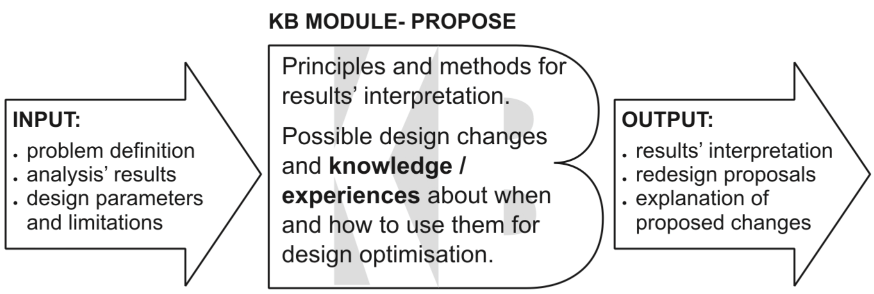
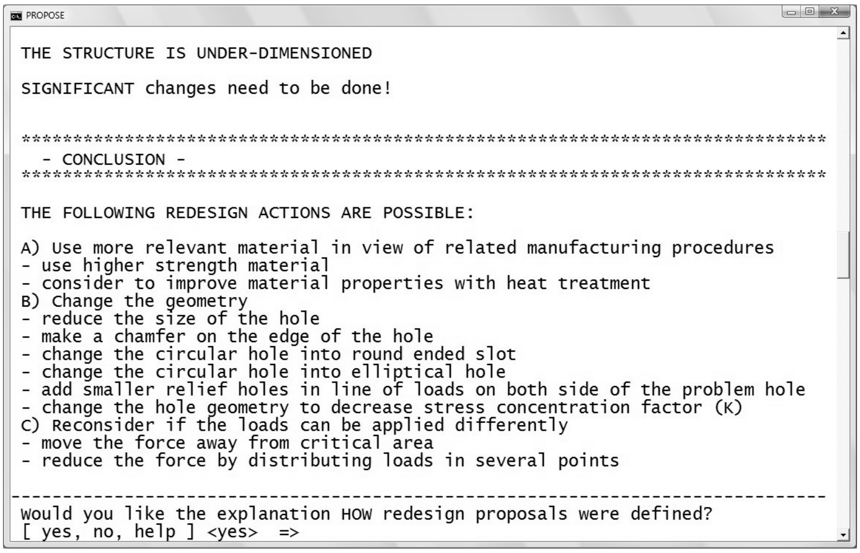


Figure 4 PROPOSE application within the post-processing phase of the analysis



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PROPOSE

THE STRUCTURE IS UNDER-DIMENSIONED

SIGNIFICANT changes need to be done!

********************************************************************************
  - CONCLUSION -
********************************************************************************

THE FOLLOWING REDESIGN ACTIONS ARE POSSIBLE:

A) Use more relevant material in view of related manufacturing procedures
- use higher strength material
- consider to improve material properties with heat treatment
B) Change the geometry
- reduce the size of the hole
- make a chamfer on the edge of the hole
- change the circular hole into round ended slot
- change the circular hole into elliptical hole
- add smaller relief holes in line of loads on both side of the problem hole
- change the hole geometry to decrease stress concentration factor (K)
C) Reconsider if the loads can be applied differently
- move the force away from critical area
- reduce the force by distributing loads in several points

--------------------------------------------------------------------------------
Would you like the explanation HOW redesign proposals were defined?
[ yes, no, help ] <yes>  =>
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Figure 5 An example of the conclusions and consequent redesign recommendations obtained by the PROPOSE system

Knowledge acquisition was not an easy task. Recommendations on redesign are scarce, and are dispersed in many different design publications. Many reports on analyses contain confidential data and cannot be used. On the other hand, interviews and examination of existing redesign elaborations depend on cooperation with experts, and can be time-consuming. Therefore, the scope of the results is greatly limited by the experts.

Production rules were selected as an appropriate formalism for encoding knowledge, because they are quite similar to the actual rules used in the design process. Each rule proposes a list of recommended redesign actions that should be taken into consideration, while dealing with a certain problem, taking into account some specific design limits. The rules are generalised, and do not refer only to the examples that were used during the knowledge acquisition process. They can be used whenever the problem and the limits match with those in the head of the rule. In such a case, applying of the appropriate rule will result in a list of recommended redesign actions for dealing with the given problem.

When using the PROPOSE system, the user has to answer some questions stated by the system in order to describe the results of the engineering analysis. In addition, critical areas within the structure need to be qualitatively described to the system. This input data is then compared with the rules in the knowledge base, and the most appropriate redesign changes to be taken into account in a given case are determined and recommended to the user (Fig. 5). The system provides constant support to the user's decisions in terms of explanations and advice. Finally, the user receives an explanation of how the proposed redesign changes were selected and also some more precise information on how to implement a certain redesign proposal, including some pictorial explanations. Fig. 6 shows an example of such an explanation for the proposed design action: "*add smaller relief holes in the line of loads on both sides of the problem hole*".

The qualitative description of the problem area should be as general as possible, in order to cover most of the problem areas, instead of addressing only very specific products, which is characteristic of most of the other research projects in this field [27, 28]. For this reason, the number of predefined attributes is relatively small. However, by answering some additional questions, the problem can be defined in a more refined manner. In cases when the problem area can be described to the system in different ways, it is advisable to run the system several times, each time with a different description. Thus, the system is able to propose more design actions, at the expense of only a few more minutes at the console. The larger number of proposals may confuse the user, who thus needs help in the form of explanations of the proposals. On the other hand, more proposals provide more options for design improvements.

The PROPOSE system was evaluated in two ways. First, experts who had already been involved in the knowledge acquisition process evaluated the system. Then some real-life examples were used to test the performance of the system. The experts that participated in the evaluation process are practising designers and some academics. They individually evaluated the system from two points of view.

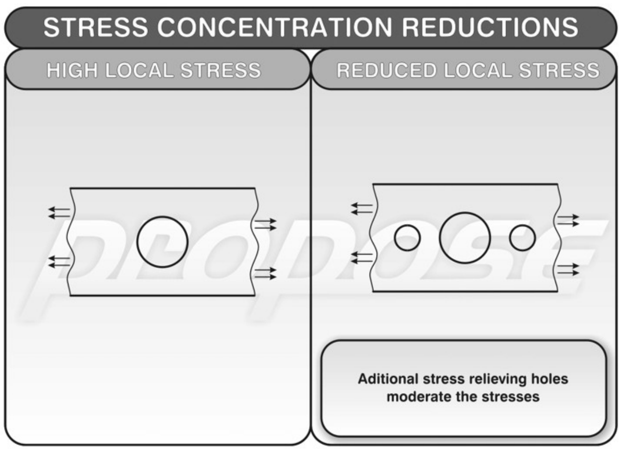

Figure 6 Pictorial explanation of the proposed redesign action

First, the experts analysed the performance of the system using some real-life examples. They also evaluated the user interface by inspecting how well the system helps and guides the user, or even enables him or her to acquire some new knowledge. The suitability, clearness and sufficiency of the redesign proposals were also evaluated. All comments, critiques and suggestions presented by the experts were taken into consideration and led to numerous corrections and adjustments of the system.

5 Support to ergonomic and aesthetic product design

In order to deliver suitable design solutions, designers have to consider a wide range of influential factors. Ergonomics and aesthetics are certainly among the most complex considerations. Less experienced designers could meet several problems in the design stage. Some computer tools are available to be used for evaluating of the ergonomic condition of the product [29]. However, a lot of experience and knowledge in the field of ergonomics is required in order to choose and carry out the appropriate redesign actions to improve the ergonomic value of the product within a reasonable time [30]. On the other hand, the aesthetic design phase still depends mainly on the skill and experience of the designer and is not supported by any computer tool of any practical value.

In this context, we have developed an intelligent consultative system named OSCAR that is able to support the designer through the decision making process when defining the ergonomic and aesthetic parameters of the product [31 ÷ 34].

Since the aesthetic and ergonomic properties of the product are established in the early phases of product development, the intelligent advisory system should be able to support this process with minimum data requirements. The ergonomic analysis and aesthetic evaluation should be performed on the CAD model. After that, the intelligent system can be used again to advise the user which design changes are possible or even necessary in order to improve the ergonomic and/or aesthetic value of the product.

In order to improve the ergonomic and aesthetic value of the product, the design recommendations are proposed to the user by using the expert knowledge collected in the KB of the system and the case-specific data given by the user (Fig. 7).

For proper control over each design aspect being covered by the system, we decided to build two separate knowledge bases, containing the theoretical and practical knowledge about the design and redesign actions, one for the ergonomic part and the other for the aesthetic part of the system. If the user applies only one part of the system, the inference engine is able to use the separate KB that belongs to that part. On the other hand, if the complete system is used, both knowledge bases are used. In this case, some special rules are applied to harmonise the ergonomic and aesthetic design recommendations, when necessary.

Fig. 8 shows an example of the system's output in terms of results of the inference process, recommending a type of hand tool grip, considering some important ergonomic goals that are weighted according to their computed confidence.

OSCAR is a research prototype. In order to narrow the area of research, we have limited the KB to cover ergonomic and aesthetic aspects of hand tool design.

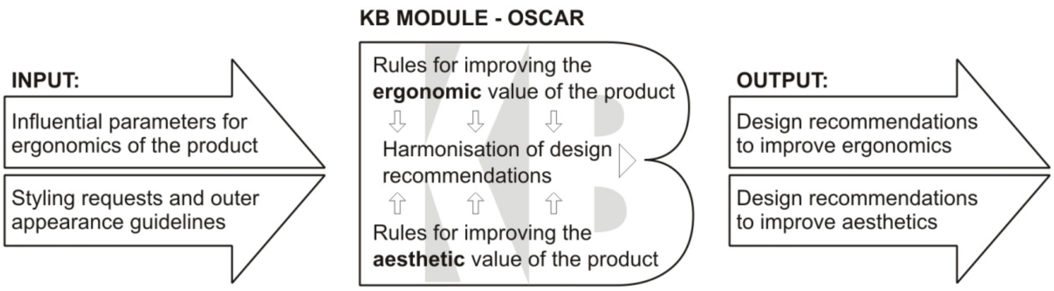

Figure 7 Intelligent support to ergonomic and aesthetic design

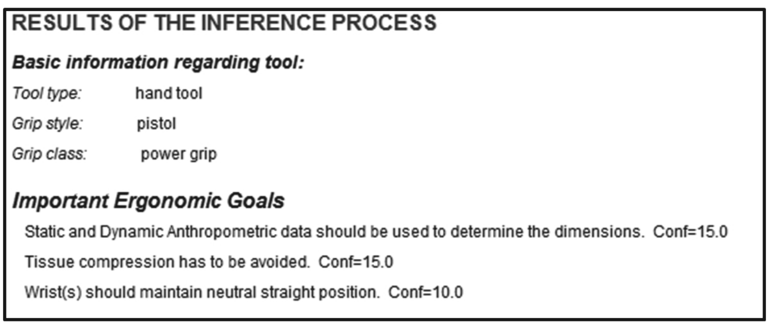

Figure 8 An example of the inference process explanation within OSCAR program

In context of this limitation, the global hand tool ergonomic design goals [35] that need to be followed by the designer of the hand tool in order to meet health, safety and efficiency requirements have been specified. The following are some of the ergonomic design goals recognised as the most important:

- consider the anthropometrical data to define the dimensions and configurations;
- maintain the wrist in the neutral straight position;

- avoid tissue compression;
- reduce the excessive forces;
- protect against vibration, heat, cold and noise;
- ensure that the task can be performed at the appropriate height;
- reduce the static load;
- consider cognitive ergonomics.

The KB for ergonomic part of the system contains rules on how to realise these goals within the hand tool design.

6 Support to Polymer Products' Design

The last decision support system discussed in this paper is related to design of products made of polymer materials. It is well known that polymers can offer optimal characteristics for noticeable lower costs in comparison to other more traditional materials. However, there are two groups of major decision making problems while developing products made of polymers:

(1) Due to insufficient understanding of polymer materials (knowledge spectrum about specific characteristics is far too extensive to be mastered by a single person/designer), tradition at using other favourable tested materials, and quantity of polymers on the market, these materials are not applied adequately in engineering practice.

(2) Information about polymers, their properties, related machining processes and matching design recommendations are not properly collected and organised for engineering use.

The world without products made of polymers is today almost too inconvincible to imagine. Yet, the majority of product designers are still better trained in the use of metals, and non-plastics, for product design. Their selection of the material best suited to the purpose of the product is based on their experience, creativity and product performance requirements.

On the other hand, designing parts for today's polymers requires a more involved and upfront engineering approach than ever before. This is particularly true for components that are combined into more complex parts, especially when the challenge is to reduce or eliminate the use of fasteners required to assemble them. In this context, DfX principles play a special important role in design of products made of polymers. It is evident that expert support in decision making process is essential for almost every designer to perform design successfully and efficiently. Thus, we decided to develop an intelligent advisory system to support this important design issue [36].

Today product designers have a vast menu of something over 120 thousand materials at their disposal to select from. Most of these materials belong to one of various polymers' generic families. Each generic family is unique and fulfils specific product and user applications. Polymers can replace existing materials such as metals, wood and ceramics, to create new products. Moreover, basic properties can be enhanced when polymers are mixed or alloyed with other polymers, fillers, reinforcements and other modifiers including colour to develop more unique and distinctive materials for special products [37].

There are quite many computational intelligence applications reported in this particular field of design. Fifteen years ago, Rapra Technology Ltd. [38] has claimed to launch the first ever knowledge based system for the plastic industry. Later applications were addressing separate parts of design process, i.e. the selection of specific materials, or the use of special manufacturing and corresponding tooling processes [39]. In this respect, the environmental issues are also important, as well as various practical experiments [40]. However, there has not been any reported attempt aimed to develop such intelligent system that would be applied to support the whole process of designing products made of polymers with some vital advices and practical design recommendations. Thus, our research represents a novel approach in this field.

The system discussed here is still in development phase. Fig. 9 shows the expected data flow, the content of the KB and the most important input/output data. The main objective of the system is consultancy with the designer in order to find the most appropriate material for the product application, and in continuation, related manufacturing parameters, product design guidelines and tooling recommendations, that will ensure high quality standards at low production costs.

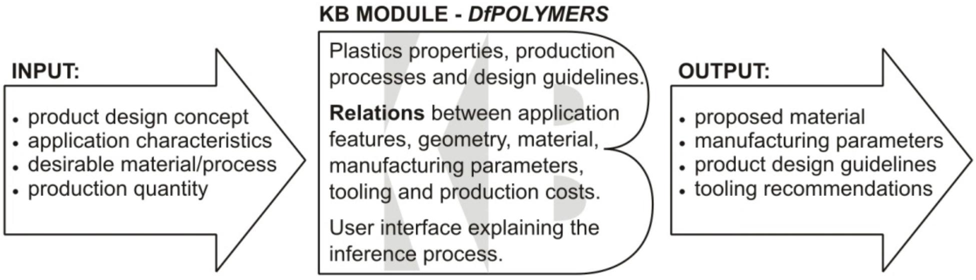

Figure 9 Intelligent support to polymer products' design

The development methods included in this research are a combination of human cognition in the field of design knowledge [41] and special domain knowledge expertise in the field of polymers. The knowledge base is going to contain human cognition useful for problem solving in the form of rules relating to modern polymer materials' selection and correlated manufacturing processes, assisted by DfX methodologies [42].

Actually, we have already developed a prototype of intelligent decision support module for polymer material selection considering environmental issues, where corresponding "Design for Environment" methodologies have been encoded into the knowledge base of the system. Product's environmental impact is defined with various ecological parameters, which could be controlled in material selection process. Recyclability is one of problematic ecological parameters for polymer materials as their recycle fracture in current supply is quite low in comparison to other materials. An example of the recommendation for polymer material selection provided by this intelligent module is presented in Fig. 10. It can be seen that confidence variable is used again in order to define the best candidates.

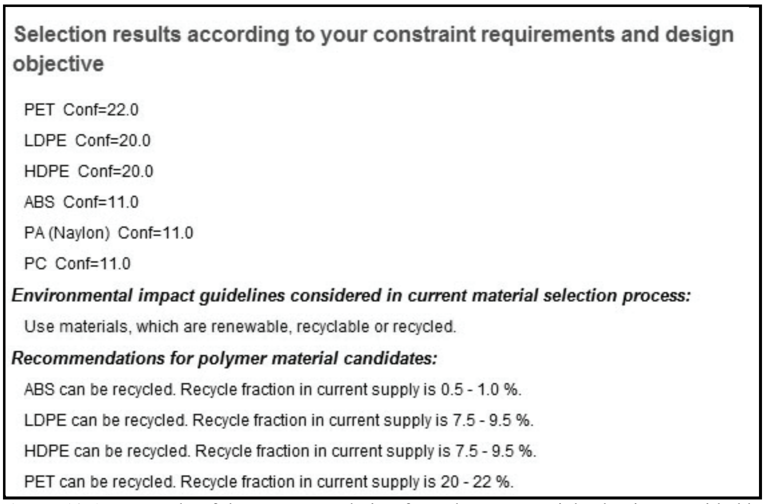

Figure 10 An example of the recommendation for polymer material selection provided by the intelligent module considering environmental issues

In this research, different approaches to knowledge acquisition [43] and the appropriate formalisms for the presentation of acquired knowledge [44] within the computer program are of special importance. The potential for transparent and modular IF-THEN 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 being compared with more flexible knowledge presentation systems, such as fuzzy logic [45], where fuzzy sets and fuzzy rules are defined as a part of an iterative process upgraded by evaluating and tuning the system to meet specified requirements.

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 be, together with the data base, serviceable for a complex reasoning procedure [46] behind the inference engine leading to qualified design recommendations and guidelines for designing polymer products.

7 Conclusion

Design optimisation is a part of the development process for almost every new product. It plays a very important role in the modern high-tech world, where only optimal solutions can win the game on the market. However, developing optimal design solutions is a very complex domain that cannot be treated adequately by using conventional CAD tools, unless the user possesses special skills and experience. Thus, many research activities are aimed at making the design optimisation process more intelligent and less experience-dependent. Many experts share the opinion that this can be achieved by supplementing existing CAD systems with some intelligent modules that will provide advice when needed. The intelligent modules discussed in this paper are important parts of the overall intelligent design optimisation cycle and are still under intensive research and development.

Design data is not always well formulated, and almost never complete. Humans can deal with such data reasonably easily, while even the most "intelligent" programs have great difficulties. Designers are also reluctant to assign responsibility for decisions to computer programs, no matter how competent they may appear. It can also be argued that an encoded design KB does not allow designers to express their creative ideas. All these and many other factors constrain the application of intelligent systems in design. Therefore, it is likely that no single technology will be adequate by itself. The designer will have available a toolkit of techniques, including intelligent modules, for information and well–defined advice for making decisions and judgements.

Engineering design is obviously much more than just modelling and analysing, and existing CAD systems need to be further explored to be able to assist in the other aspects of design as well. Future research and development of CAD systems will require radical re–thinking, considering some new approaches that have not been taken properly into account in the past. The application of computational intelligence techniques combined with DfX methodologies in design is certainly an approach that is becoming more and more important.

Experiences are an engineer's main advantage. Yet, at the beginning of one's career the experiences are limited. The possibility of acquiring experts' opinions is desirable, since they possess knowledge of specific design aspects and could contribute to the evaluation of possible design solutions. In addition, designers are often under pressure, as they have to justify management's trust in new product also supported with diverse tools for selecting and evaluating projects [47]. In bigger companies where R&D department is well established, this human knowledge and experience transfer is taking part on daily basis. However, SMEs' often face an absence of human experts due to the lack of economic sources required for hiring them. This observation leads to the conclusion that adequate computer-aided decision support offering some advice and guidelines to designers during product development process is often essential. Such decision support in product design engineering can be provided by the KB modules presented in this paper.

8
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Author's Address

Dr. Marina Novak
University of Maribor
Faculty of Mechanical Engineering
Laboratory for Intelligent CAD Systems
Smetanova 17
SI-2000 Maribor, Slovenia
E-mail: marina.novak@uni-mb.si