Designing as a Problem Solving with the Use of Knowledge and Methods DFX - Teaching Design in Context

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Abstract. The article presents a new subject in the bachelor's study of the Faculty of Mechanical Engineering at university UWB, bringing to students with basic knowledge of construction a comprehensive view of the design task.

Software support is mentioned here, enabling students to more easily solve steps with routine work and thus free up their thought capacity for creative work. Students gain directly applicable knowledge in design practice and also good preparation for further study of creative design in the master's program.

Keywords: DFX · Creative design · Properties

1 Introduction

Decades ago, it was common for every major engineering company in our country to produce standardized parts. Today's trend is completely opposite. Most designers are supported by management in the use of parts manufactured by the supplier. Production in a modern engineering-oriented company is now mostly narrowly profiled, and thanks to globalization, the market is one big company that cooperates. The use of technical products from the supplier in its own designed technical system has several pitfalls. One of them is the correct definition of the required properties. The designer must know what he needs, and at the same time, he must be able to define, sort, display these conditions, and it is also appropriate to archive them due to knowledge management. According to experience from practice and teaching, the designer often thinks of the basic specifications from only one stage of the life cycle, and that is operating. This is clearly the most important stage. However, thanks to the other stages of the life cycle, product requirements can be defined more precisely, and there are often considerable financial savings [1–3].

Today is also important to know the target group and correctly define the ideal product for it. The technical system with almost the same functions for a different target group will also have different specification requirements, which means a different ideal product. For example, what about the world of mobile phones? Years ago, it was a

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product for a small group of people. The mobile phone was limited by technological possibilities, and it offered only basic functions. Today, every mobile company offers many models per year for many target groups. This state places increased demands on the creative abilities of designers.

2 Materials and Methods

We thought about the mentioned state at our department, and thanks to the research of professor Hosnedl and others in the field of systems science about design, we managed to introduce the subject DFX into the third year of bachelor's study. This course is beneficial to high school graduates and even to the best graduates of industrial schools, as well as students of combined studies who already work professionally as designers. In addition, this DFX course does not conflict with CAD design and the application of theoretical knowledge to the design process, so it does not interfere with the traditional teaching of these courses. Its benefit, as already indicated, is the concept of the design task as a complex problem, solvable systemically from many points of view and with respect to all requirements for the proposed product. A very positive feature is that design according to DFX principles does not require additional special education from students in an artificially created subject but "only" teaches students, thanks to a systematic approach, to fully use the knowledge and skills they have already acquired in design and other technical and non-technical subjects in the previous process of vocational and general education.

At the beginning of the study, our students have so far gained basic knowledge and skills about construction, modeling and documentation of machines and related supporting theoretical and technical subjects. Only in the second followed a phase of engineering studies our students have traditionally gained comprehensive knowledge of Engineering Design Science and Methodology (EDSM), which they apply in their semester works and diploma projects at the end of their studies. There was an urgent need to complete the first stage of the study. Bachelor's degree graduates need to gain the necessary knowledge of their own design, especially in a comprehensive understanding of the design task, including awareness of the target needs of the practice. The complementary goal was to provide a high level of design tasks of bachelor's theses and, last but not least, prepare bachelor's degree graduates for easier mastering of complex concepts and applications of EDSM, including interdisciplinary projects in cooperation with industrial partners in the follow-up master's study. For bachelor's study was the extensive topic of design of technical products reworked with pragmatic use EDSM like a Problem solving with a focus on the required key properties od designed technical products for whole life cycle including their early prediction - Design for X (DFX).

3 Results and Discussion

During the semester, students create semester works, where they practically test their new knowledge and use the tools that are explained to them during the lessons. In the first step, the student has to choose an assignment from the school archive of products, or he has the opportunity to use the product which he has to design in his bachelor's thesis. The second option is recommended and is very popular with students because the student solves his semestral work, gains interesting, innovative results that he then uses in his bachelor's thesis.

We do not recommend creating very detailed design solutions in semestral work because the innovation is a matter of conceptual and preliminary design mainly. After creating the assignment, students search the current level of solutions (the State of Art). Searching for already produced products is very important from more points of view. At this stage, we also teach students that they must always think of the competitiveness of their designed product. An example is the interdisciplinary project DESIGN + on the topic of a small electric car for the city. The researchers of this project initially sought competition only in the field of small electric cars, but then found out that today's competitors are electric bicycles and electric scooters too, which perform their primary function at a significantly lower price.

The specification of requirements for the solved technical product follows. Experience has shown that more than 90% of students at the beginning of solving a design task intuitively specify the requirements only for the functionality (operation) of the future product. They completely ignore the requirements for other stages of the product life cycle. The use of EDSM leads students to consider all stages of the life cycle of the product. Students begin to respect the all product life cycle. For example, safety is not only important during the operation phase, but the product must be safe during production, transport and disposal. Scales are assigned to individual product properties classes. Here, students realize that there is a different ideal for each customer, and it is always necessary to find the target group for which the product will serve.

The requirements are arranged in an Excel spreadsheet. This table of requirements specifications for TS is combined with a comprehensive SWOT evaluation and analysis, which students then use to evaluate compliance with the specified requirements. For the first time, students encounter the classification of product property requirements into property classes. They are also taught that the designer must consider properties at all stages of the product life cycle. We consider this part of DFX's teaching to be very important. Students learn a new, comprehensive view of the essence of product design.

The figure (see Fig. 1) shows an example of an Excel table header for requirements specifications, with specifications in the first property class, ie. Properties for product functionality. The table continues in the indicated sense for all property classes (see "Theory of technical systems" within EDSM).

The first step of the design is clarifying the assignment; the next stage is the search for a solution. This is a bit simplified here compared to complex science EDSM, but the principle has been retained. The student solves the problem starting from an abstract model of the transformation process (see Fig. 2), over the conceptual design (see Fig. 3) to the design of the preliminary body structure of the product (see Fig. 4) and to the final structure (see Fig. 5).

This process of solving allows students to be always on top of things and solve the thing with a greater perspective. The individual conceptual alternatives are compared with the support of Excel's software Evaluation of Alternatives of TS conceptual Structure software, which is again developed by us to support DFX. The solver in the

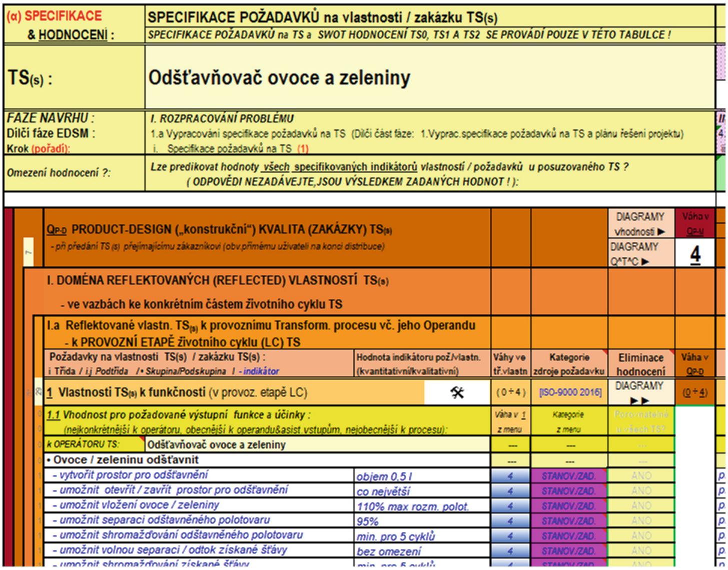

Fig. 1. Illustration of an Excel table for the specification of requirements for properties of the proposed product.

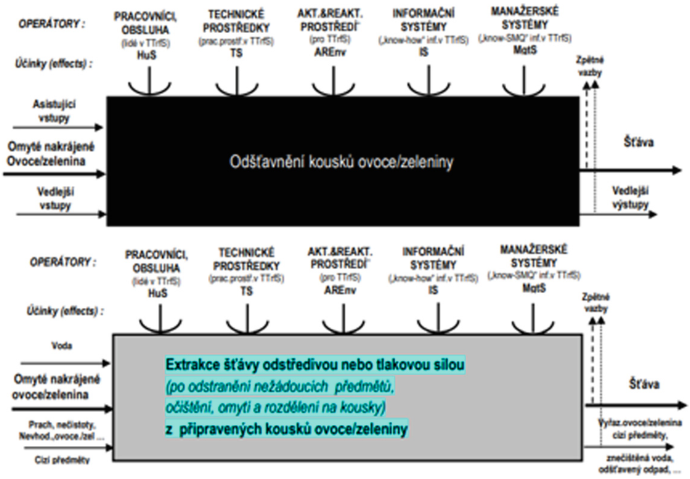

Fig. 2. Model of the transformation process expressed by a black box and the same process with an expressed technology.

software has the opportunity to evaluate the alternative with regard to the predicted quality of the solution, delivery time and delivery costs. The aim of the evaluation is to find a sub-optimal alternative that will be close to the ideal. Here, the authors often solve the problem that there are two alternatives, one is very high quality at a higher price, and the other offers a very attractive price with poorer quality. It is a question of current priority

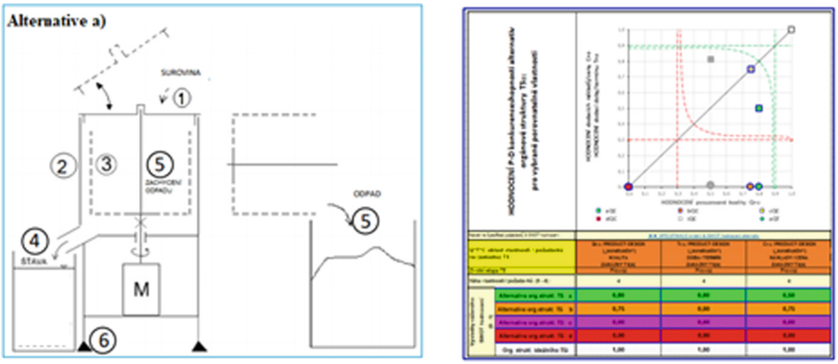

Fig. 3. Two conceptual variants of the designed product and their evaluation.

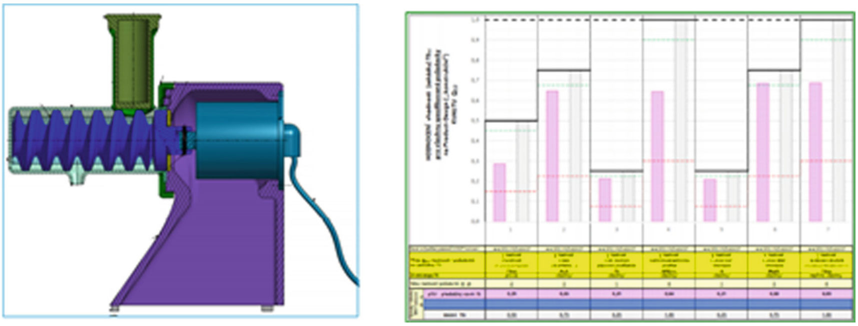

Fig. 4. Preliminary structure of the proposed product with the evaluation of its properties.

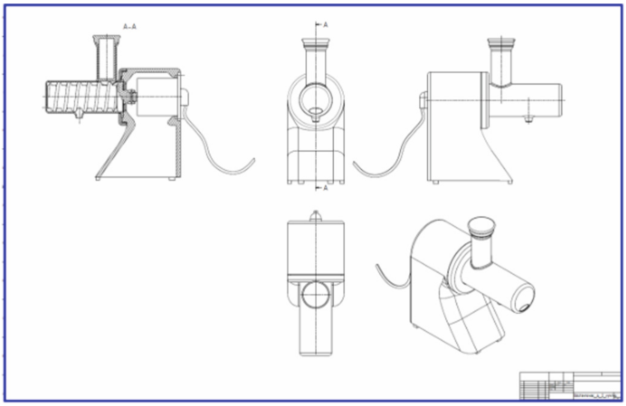

Fig. 5. The final structure of the proposed product.

which alternative the students choose. More important for work is the possibility to compare and display alternatives for further processing towards a preliminary structure of the product. The final decision on conceptual variants in practice is often very complex and depends on the target group of the project and product requirements.

Students then complete the selected conceptual structure in the form of a rough (preliminary) body structure, which takes the form of a sketch or 3D model, more detailed than the conceptual structure. The following is a software specification of TS requirements with a comprehensive SWOT evaluation and analysis, in which the author evaluates the fulfillment of the requirements of the proposed variant in comparison with the previously ideal variant of the solution. Students receive feedback on the degree of fulfillment of the set requirements for product properties.

The software shows the property classes for the product in which the requirements were met or, conversely, shows the reserves in the solution. The author should find these reserves and try to eliminate them. The student creates a design iteration of the rough building structure and again evaluates his second designed structure with the ideal. This design iteration step seems to be crucial for success in these semester projects. This phase often brings new ideas, as the author is alerted to shortcomings by evaluating his original design solution. The bachelor's theses that were connected with these semester projects are at a very high level, as their author has a clear vision and specifications of the requirements for the solution. They can also evaluate and compare individual conceptual variants. Last but not least, he can compare the proposed solution with the ideal solution and perform an iterative design step to improve the originally proposed solution.

Three Examples from Student Works

Mr. Tomas innovated his design of a manipulator with forgings in his bachelor's thesis with the help of the DFX course. After evaluating the requirements of the product, he found that the operator of the equipment was not sufficiently protected. He integrated an additional heat shield into the manipulator. At the same time, the diameter of the handling wheel was increased for better operator comfort.

Mr. Vaclav proved that the organization of the workplace could also be solved with the help of this strategy. For his bachelor's thesis, he proposed three options for organization, the stand for autonomous sorting of objects by color.

Mr. Martin took advantage of the life cycle of the technical product and decided to recycle the old Jawa motorcycle and rework it to electric power. He found a very attractively priced option, which is at the same time ecological and retains today's popular retro style.

4 Conclusions

After several years of experience in teaching the science EDSM, we know that its simplified form, used in the course DFX, is suitable for solving any problem where the author is looking for the best possible technical product design in terms of the whole life cycle and respecting all product properties. At the same time, it turns out that students accept this creative method spontaneously, which improves their semester and qualification works and is a good starting point for them to solve design problems in practice.

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