NEW WAYS IN EDUCATION WITH SHAPE DESIGN

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Abstract

Today's product development process is characterized by increasing complexity of products. Subsequently universities have to adapt and constantly improve the content of their courses to prepare the future graduates for the free market economy. An approach at Technische Universität Darmstadt to expand the scope of CAD education, is the introduction of a new one-week tutorial on shape design with Siemens NX. This paper will describe the teaching concept and its implementation. The concurrently submissions of the examinations with content from realistic industrial tasks play an important role during the course.

Keywords: Computer aided design (CAD), Product modelling, Evaluation, Shape Design

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1 INTRODUCTION

In the field of information and communication technology continuous change and improvement is the norm. Subsequently, universities have to adapt and constantly improve the content of their courses. An additional challenge is the preparation of future graduates for the free market economy and the requirements of their future employers.

Today the application of integrated virtual product development is an indispensable part of engineering education as well as industrial training (Anderl, 2014). The use of software solutions is well integrated in product development. 3D CAD systems are firmly established and are not only used for sketching, designing 3D solid geometries or simulating functionality but also to design freeform surfaces (Barthelmes, 2013). They support engineers in the design of products and beyond. Traditionally, virtual design is based on simple geometric primitives such as points, lines, faces and solids, which can be created, linked and manipulated by using various mathematical operations (Rieg, 2012). However, the design options with basic geometries, like volume primitives, are limited.

Freeform surfaces are utilized in many industrial sectors, including automotive, aircraft or consumer goods. For example the design of car bodies with its interior and exterior components is an important task within the automotive industry and involves the design and modification of freeform surfaces in all steps of the process chain. The complex shapes and styling surfaces employed in body design or ergonomically shaped surfaces of articles of daily use can only be designed with great effort if it is possible at all. Generative shape design helps to solve this problem (Kornprobst, 2008; Braß, 2009).

To appropriately use modern CAD tools for these tasks, the engineer must have sufficient knowledge of freeform surfaces and curves. Although freeform surfaces account for only 15 percent of an average product geometry compared to planar or regular geometric shapes, they contribute about 85 percent of the total product costs in the design and manufacturing process(Bonitz, 2009). Across the industry an upward tendency for the number of freeform surfaces has been observed (Bonitz, 2009).

Based on the requirements of cross-company cooperation in virtual product development, including product structure control, access management or workflow management, comprehensive logistics of product data is becoming more important in product development processes. The data and its structure is contained within Product Data Management Systems (PDM systems) (Rieg, 2012).

It is necessary to balance the need for scientific education and practical knowledge of industrial processes. As a result students should have reasonable expectations about the industry's requirements for engineers.

In the following chapters the teaching concept and its implementation are discussed. The strategy for the assessment of academic achievement is illustrated in the examinations chapter. The paper is concluded with a summary of the results.

2 TEACHING CONCEPT

In the future, the increased availability of complex computer aided manufacturing methods will allow more complex products but will also require university graduates to better understand modern design methods. To further this understanding is the aim of the course "CAD Shape Design" of the department of Computer Integrated Design at Technische Universität Darmstadt. Within the Mechanical and Process Engineering curriculum for engineers at Technische Universität Darmstadt the completion of one practically oriented one-week course with forty working hours of this kind is mandatory.

As shown in Fig.1 the teaching concept consists of three main parts. Firstly, lectures with theoretical content, especially elementary knowledge about freeform curves and surfaces. Secondly, exercises in which the students practically design freeform surfaces in modern CAD systems under supervision and learn to apply the acquired knowledge. Thirdly, examinations where the students have to demonstrate their mastery of the fundamentals of freeform curves and surfaces. The tutorial's goal is to teach the techniques for handling freeform surfaces. Hence all functions which are typically used for the creation or editing of freeform surfaces are discussed. The CAD system used for the exercises and examinations is Siemens NX 9.0 while the data produced by the students is stored within the Product Data Management System Siemens Teamcenter 10. The theoretical principles which are taught, are software-independent and can be implemented also with other software from different vendors.

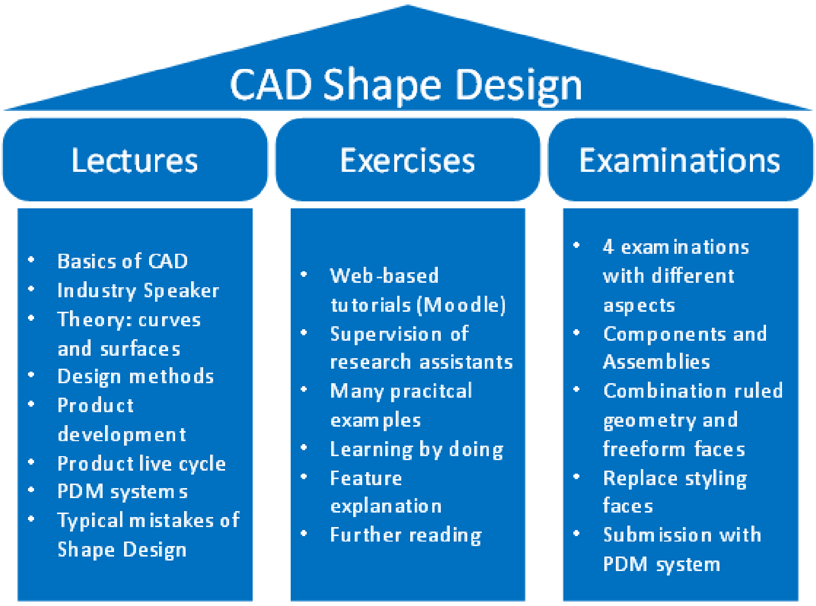

Figure 1. Layer model of the course

In the lectures, students are introduced to the basics of Computer Aided Design (CAD). Prior knowledge of CAD is not required. The main subjects are product development within the product life cycle and the associated process chains. The differences between generative, accumulative, and hybrid solids are explained as well as the different parametric descriptions of curves and faces. This includes Beziér surfaces and B-Spline surfaces. Selected industry speakers contribute the perspective on practical use. Typical mistakes are discussed and modern design strategies are shown in live demonstrations.

During the exercises, the students use web-based tutorials (Chen, 2010). These are provided through the Moodle-based e-learning platform of Technische Universität Darmstadt. With this platform, every student is able to access the contents of the tutorial wherever he or she is and is able to work on their assignments with any computing device available to them. The exercises typically take place in computer laboratories under the supervision of a research assistant but can also be completed at home or elsewhere at any time. The examinations are concurrently submissions with content from the exercises and are described in detail in Chapter 4.

Special about this course is that besides the theoretical fundamentals of approximatively and interpolatively curve and surface descriptions a direct reference is made to the existing features of the CAD system. Thus, the knowledge from basic courses such as math and Basics of Computer Aided Design is consolidated and placed in a meaningful context. In additionto that, an industrial company established in economy in the field of engineering services is integrated. They illustrate the relevance of freeform surfaces in a lecture and a demonstration of real parts from the automotive industry.

The concept of one-week block course has the advantage that students can concentrate on its content and do not have to work on topics from other courses of the course of studies. Existing events have shown that untrained users in the use of CAD systems usually need some time if they want to enter the system again after a break of about a week. To use this time more effectively the teaching concept of a block course was chosen.

3 IMPLEMENTATION

The following implementation will show the way the tutorial with freeform surfaces is structured. The subject matter of shape design is divided in six main chapters. Table 1 shows the six chapters with the associated content, which is taught during the tutorial.

Table 1. The six main chapters of the tutorial

Chapter 1	Organization
Chapter 2	Basic elements of Shape Design
Chapter 3	Shape Design
Chapter 4	Edit Functions for Shape Design
Chapter 5	Analysis Functions for Shape Design
Chapter 6	Repair of Faces

In general, there are many lessons learned by completing exercises in the different chapters, which are representative of realistic tasks in the industry. Special attention is paid to the so-called Features, which consist of predefined shapes whose size is controlled by parameters (Krieg et al., 2013).

Since there are students enrolled within the Mechanical and Process Engineering Master's course at Technische Universität Darmstadt who have no prior experience with CAD systems in general the basics of CAD systems are discussed in the beginning. In addition to that, the students can work on the exercises and examinations for five additional hours each day outside of the supervised exercises.

In the first chapter, organization, the required preferences of the CAD-System and the mathematical fundamentals, such as continuity, tangency or curvature continuity are discussed. The modeling tolerance, which plays a crucial role in the sewing of faces, is explained in detail. The submission process of the examinations will be described specifically for the PDM system. Among other things, there is a detailed explanation of the basic workflow. The chapter closes with tips from industrial experiences, for instance the idea of clean surface design which avoids problems in downstream processes, such as chatter marks in milling processes.

The basic elements of shape design comprise the content of the second chapter. The features for creating points and curves are discussed. Curves with given form, curves with freeform, curves from curves and curves from bodies are considered in more detail. These elements are the base for the following chapters on shape design. A solid understanding of these is important since mistakes in the preparation of a shape design will propagate through the whole design process.

The chapter on shape design covers a large part of the available features for part design. In detail, mesh surfaces and sweep surfaces are covered, such as the often used features "Through Curve Mesh" or "Sweep". In addition to that, the design of surfaces from imported point clouds is discussed. Among the detailed explanations of many features, practical examples and demonstrative figures are shown. General information on shape design with features completes the chapter.

The bulk of new products are adaptive designs. An adaptive design changes a portion of an existing solution to create a new product (VDI 2209). The fourth chapter deals with the issue of editing existing surfaces. The students are required to trim, divide and extend defective surfaces. The topics surface scaling, modification of boundaries, change of degrees and stiffness of a surface, change of the surface normal and the manipulation of the base points of surfaces are also addressed. The focus is on the functional change of surfaces, but also aesthetic changes are discussed.

The penultimate chapter deals with the analysis functions, which can contribute to a better understanding of shape designs on the one hand, but on the other hand might also be necessary to conduct specific changes of the design. In addition to the standard measurement functions the specialized analysis functions for curves and surfaces are explained. In the domain of curves, transitions can be checked for continuity. That means, testing whether continuity, tangency or curvature continuity conditions are satisfied. Additionally, a curve's curvature profile can be analyzed for the detection of local and absolute maxima or minima. Surfaces can be analyzed similarly. In addition, functions for grid and base analysis, radius analysis, reflection and draft analysis are available.

Finally, a typical procedure for the repairing of a damaged shape designs is shown in Chapter 6. Defective surface models which cannot be sewed because of gaps in the surface composite serve as an example. The replacement of triangular faces and clean-up of tolerance errors, complete the last chapter. Each exercise subject concludes with an examination. The contents of the examinations are considered in the following chapter.

4 EXAMINATIONS

The examination includes four parts and will take place during the week after every respective topic. In the following paragraphs the parts are explained and their educational intention are explained in detail. Detailed images will provide a better understanding. Figure 2 shows an overview of the complete examination process and the distribution of the marks to be attained with each individual exam.

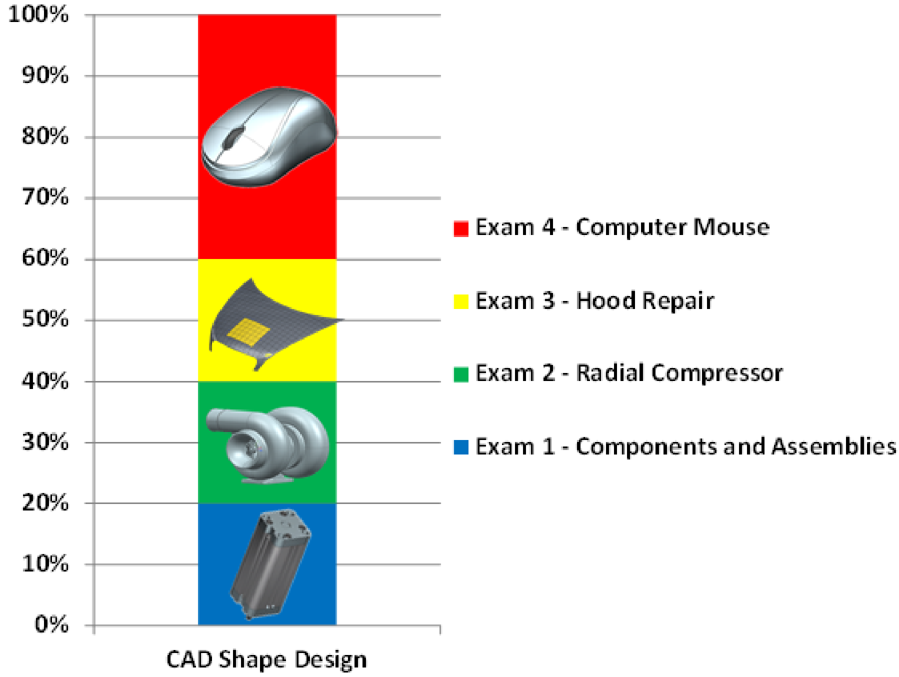

Figure 2. Overview and Distribution of Marks

4.1 Components and Assemblies

In the first examination the students have to design parts from existing drawings. These must be assembled together with the other components of a pneumatic cylinder, which are provided by the faculty. The objective is the submission of the pneumatic cylinder as a complete assembly. The single components are representative examples of most of the available features in the modeling application which were previously introduced. The pneumatic cylinder bottom can be designed exclusively with one volume primitive and features. This requires the "top-down" design method. However, the cylinder body is ideally designed with sketches. The newly designed and previously provided individual components must be assembled by assembly constraints. This examination is the basis for the following three examinations. The student shall demonstrate his understanding of the relationship between individual components and assemblies and the meaningful usage of design features. Figure 3 shows the content of the first examination, which is the process leading from drawings to individual components and finally to assemblies. The evaluation criteria for this examination are correct choice of features and meaningful order of them. The top-down method is specified. Furthermore, the assembly constraints and the correct geometric dimensions are graded.

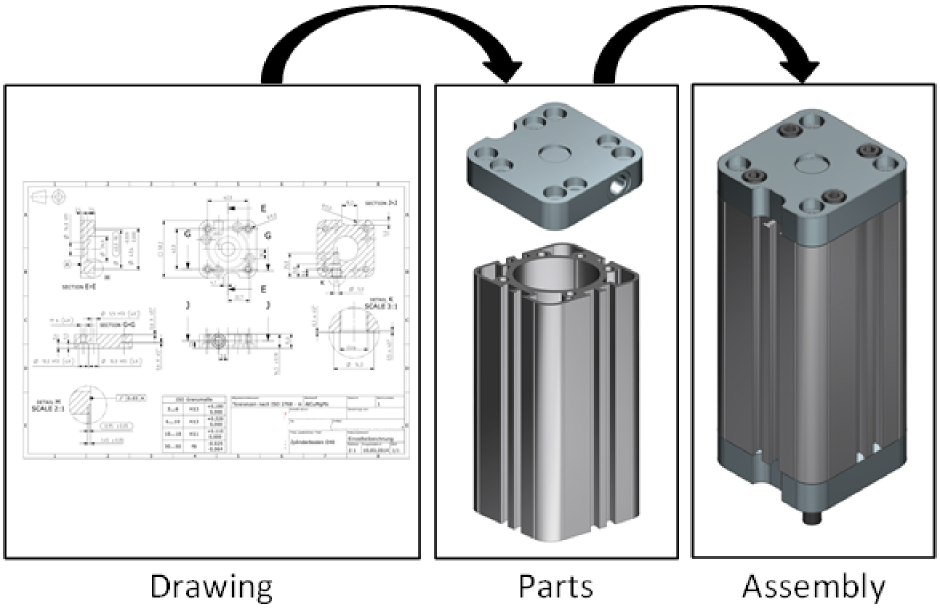

Figure 3. Examination #1 - Cylinder bottom, Cylinder body and Cylinder

4.2 Radial Compressor

The second examination is a combination of shape design with freeform surfaces and solid modeling with volume primitives. To demonstrate a realistic industrial problem, the task is to design a radial compressor impeller. The initial situation is an existing compressor housing with predefined space for the impeller and formal requirements such as the number of blades or gap distances for the housing. The radial compressor impeller consists of a basic body which should be designed with solid elements and the blades which should be designed with freeform curves and surfaces. In addition to the design of the radial compressor impeller a cross-section analysis must be conducted beforehand. Finally, the impeller must be mounted in the housing assembly.
The aim of the examination is the systematic investigation of existing components to combine formal conditions with the feature-based design and freeform surfaces. Figure 4 shows the different steps of the second examination: input information, cross-section analysis, feature-based and shape design and assembly. The evaluation criteria in this examination are the same as the criteria from the first one, but there is also marked the surface quality of the blades, like minimum radius and surface transitions.

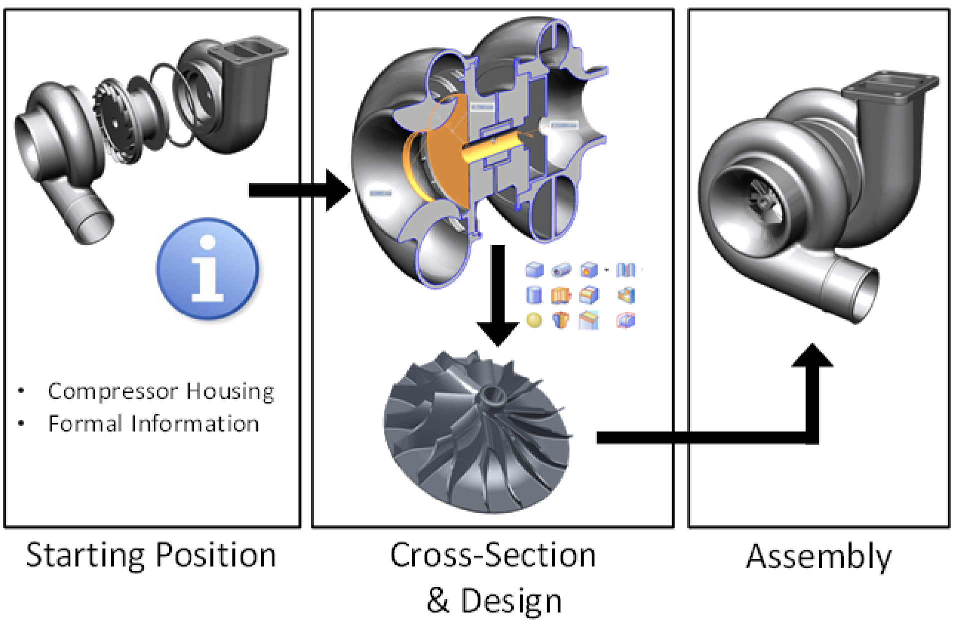

Figure 4. Examination #2 - Radial Compressor

4.3 Hood Repair

The third examination is a typical task in the field of interior and exterior design in the automotive industry. Vehicle development depends on styling surfaces in the visible areas of the car, which are designed based on aesthetic considerations. Manufacturing specific design rules are not respected in the first drafts. A vehicle development project usually takes about two to three years. The main cost drivers are changes during the vehicle's product development process (Gusig, 2010). Changes are usually caused by styling modifications, but these often affect only a specific area of the component. The challenge is to confine changes to the modified regions with the tools and design methods of CAD-systems. Thus, a modification of other regions can be avoided.
The intention of the examination is the analysis of a composite of new styling surfaces and subsequent selective editing. Here, the relevant faces have to be identified and integrated into the existing design by using the learned features and methods. If the styling requires it, all transitions have to be smoothed. Figure 5 shows the different steps of the third examination: hood, new styling faces, cut out of affected areas, adaptive design. The evaluation criteria in this examination are the correct order of the features, the structur of the assembly and if there exists Class A Surface quality.

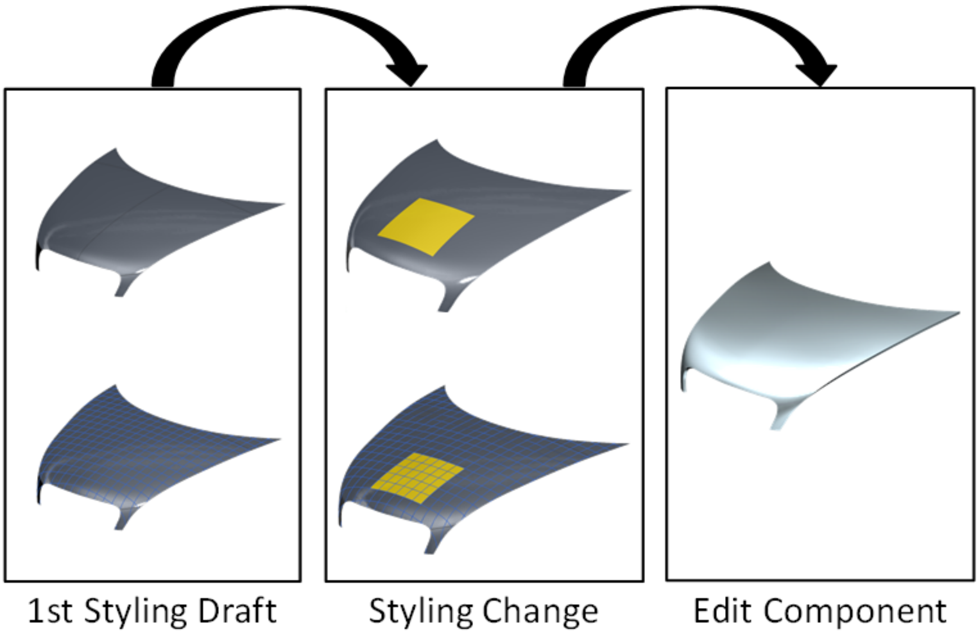

Figure 5. Examination #3 - Hood Repair

4.4 Computer Mouse

The fourth and last examination is the design of a computer mouse. In contrast to the previous examinations, the input variables are limited to the given electronic components, which must be installed on the inside, and the environment in which the mouse shall be used. More precisely, the typical hand position of the user of a computer mouse. With a predesigned hand, the students can derive section curves which can be used as basic curves for the design of freeform surfaces. These should present an ergonomic shape to the mouse user. Afterwards, a solid model must be generated by sewing the individual patches together. The conclusion of the examination is the submission of the complete mouse assembly, including the electronic components, in the PDM system. During grading, the focus lies on the logical structure and the meaningful selection of features, aesthetic aspects are not considered.
The aim of this examination is to create self-made section curves in order to use them as a base for the generation of freeform surfaces. By sewing the surfaces together to form solid models and the final submission of the entire assembly, a complete product development process is passed, starting with requirements defined by the environment. Figure 6 shows the content of the fourth examination: environmental conditions, create section curves, shape design and sewing, assembly. The evaluation criteria in this examination are the same criteria from the first one. In addition to that there is also marked if the mouse is complete with its top and bottom part.

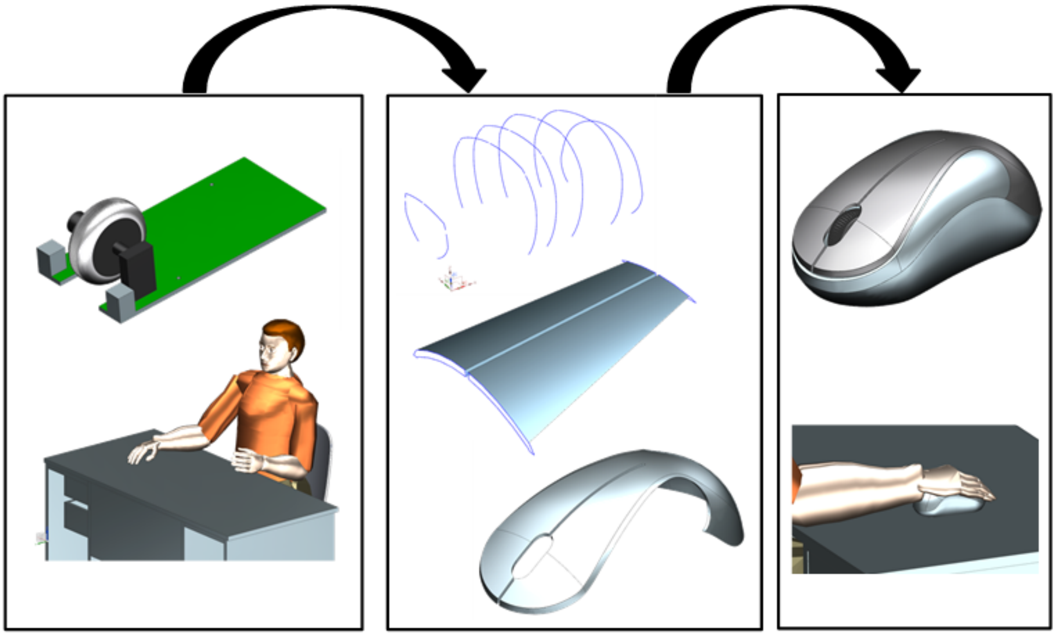

Figure 6. Examination #4 - Computer Mouse

5 CONCLUSION

A very important part of the Mechanical and Process Engineering curriculum at Technische Universität Darmstadt is the use of CAD systems and their functionalities. However, the teaching material currently includes only the fundamentals of geometric modeling. Additional courses are limited to Computer Aided Manufacturing (CAM). An approach to expand the scope of CAD education, is the introduction of a new one-week tutorial on shape design. This serves to fulfill the requirement of the industry, which demand more practical experience in the use of modern CAD systems from university graduates.

The repetition of basics should refresh and consolidate the knowledge of the students and create a basis for further exercises with basic freeform elements and prepare for the introduction of shape design. Continuous examinations with different contents ensure steady learning progress. An industrial character is given to the tutorial by submission processes within a PDM system. Students who have successfully completed the course have demonstrated mastery of not only solid modeling but also shape design and the combination of the two. They are able to edit and change components dependent on styling faces. The knowledge about the mathematical foundations of shape design is taught as well as the awareness of the consequences of freeform surface designs is promoted.

In the future, the functionality of today´s CAD systems will increase continuously. Courses which deal with special software modules are becoming more important to prepare students for the industrial environment. Future challenges are on the one hand the improvement of the content of lectures and courses to be up to date with the state of the art and on the other hand to adapt these courses to future software updates. In addition, other applications in CAD system which have been recently developed should be integrated into courses, for example synchronous technology.

REFERENCES

Anderl, R. and Binde, P. (2014) Simulationen mit NX - Kinematik, FEM, CFD, EM und Datenmanagement, 3. Auflage. München: Carl Hanser Verlag.

Barthelmes, H. (2013) Handbuch Industrial Engineering - Vom Markt zum Produkt. München, Wien: Carl Hanser Verlag.

Bonitz, P. (2009) Freiformflächen in der rechnerunterstützten Karosseriekonstruktion und im Industriedesign - Grundlagen und Anwendungen. Berlin, Heidelberg: Springer-Verlag.

Braß, E. (2009) Konstruieren mit CATIA V5 - Methodik der parametrisch-assoziativen Flächenmodellierung, 4.aktualisiserte und erweiterte Auflage. München: Carl Hanser Verlag.
Chen, J. and Roys, T. (2010) Motivations behind the Use of Web-Based Tutorials. http://www.jasonchen.org/files/2011/05/tutorials_final-paper.pdf, Urbana, USA.
Gusig, L.-O. and Kruse, A. (2010) Fahrzeugentwicklung im Automobilbau - Aktuelle Werkzeuge für den Praxiseinsatz. München: Carl Hanser Verlag.
Kornprobst, P. (2008) CATIA V5 Flächenmodellierung - Grundlagen und Methodik in über 100 Konstruktionsbeispielen. München: Carl Hanser Verlag.
Krieg, U., Deubner, J., Hanel, M., Wiegand, M. (2013) Konstruieren mit NX 8.5 - Volumenkörper, Baugruppen und Zeichnungen. München: Carl Hanser Verlag.
Rieg, F., Steinhilper, R. (2012) Handbuch Konstruktion. München, Wien: Carl Hanser Verlag.
VDI 2209 (2009) 3-D-Produktmodellierung - Technische und organisatorische Voraussetzungen; Verfahren, Werkzeuge und Anwendungen; Wirtschaftlicher Einsatz in der Praxis. Düsseldorf: Verein Deutscher Ingenieure e.V.

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