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UNIVERSITY TEACHING AND AUTHORITATIVE COMPETENCES OF PRODUCT DEVELOPMENT ENGINEERS

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Abstract: *University, in field of technical sciences, has the task to increase professional skills of students, by using effective and coordinated teaching, to the level of science educated engineers as very important profession in industrial world. Dynamical development of modern industrial society demand continuous improvement and adaptation of course content and methodology of education in order to provide appropriate quality of teaching. This is primarily related to education in the areas of Product Development, which is the main priority in education of product development engineers. This teaching integrated professional and methodical knowledge of theoretical and applied basic objects in design and dimensioning of systems and components based on defined requirements in a holistic engineering thinking and action. Paper discusses this problem and gives relevant competencies that are necessary to ensure in education of development engineering at the bachelor and master studies.*

Key words: *university teaching, product development*

1. INTRODUCTION

A company success in modern conditions is possible to achieve by introducing innovative products and product processes. It is necessary to consider market needs, customer wishes, concurrence etc. Innovative products in mechanical engineering are different from other products, in one hand it is assembly of mechanical, electronic and informatics components and on the other mechanical product development must consider all product life cycle phases. Application of micro mechanical, micro electronic and micro optical components in combination with software components (Fig.1), manufacturing and assembly process are completely automated. Innovative products are characterized by strong logistic backup related to product exploitation maintenance and recycling.

Therefore application of innovative products and product processes is very complex and demands new work approach, which is primarily related to resource optimization, precision defining of competence and cooperative work approach. In comparison to convectional primarily functional oriented approach, cooperative work process is based on interdisciplinary project teams, methodical work approach is connected to specific parallel process structure (simulate engineering) with use of modern information technologies. This approach has influence on shortening time period for creating and lunching new product (time to market), reduction of prices (design to cost) and to insure quality (best quality).

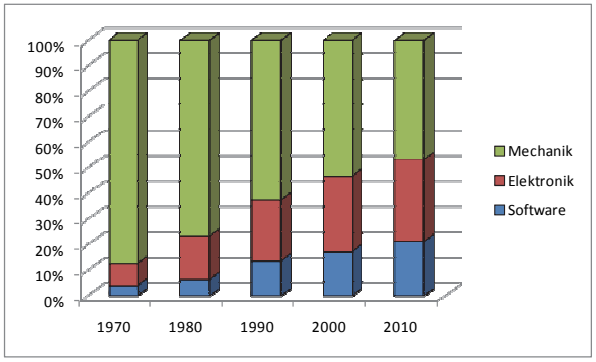

Fig.1. Perpetrators of functions by modern products

Cooperative processes foundation are methods and systems which in all phases transparently present complete product development process and manufacturing. Methodical approach implements application of different product development methods, methods for planning and process management, as well as project management and organization management. Systematic approach implements computer backup in all phases of the product development process and manufacturing. Modern prototyping can significantly accelerate the product development process. This is largely present application of simulations and virtual reality.

Future market determines the strategy of planning products and process. Starting from the strategy of the company analyzed the potential for new business, identify ideas for new products and processes, and develop and evaluate product concepts. The result of the strategic planning of products and processes are development of new innovative products, their production and market launch.

Modern companies must have access to comprehensively educated engineers so that they can solve complex problems. This raises the need for universities to undertake a proper education reform, according to the demands of contemporary techniques and technology.

The word engineer is derived from the Latin root *ingenium*, meaning "cleverness". Engineers are today researchers, designers, technologists, analysts, managers, agricultural (and bio) engineers, architects and builders of roads, bridges, railways, machinery, tools, buildings and equipment for various purposes.

The engineer tasks in the field of product development in the future are varied. They deal with the entire life cycle

of a product, from a product idea to its concretization through manufacturing, distribution and recycling. The development is about developing new products or improving existing products and to fulfil market needs through creativity, innovation and technology. For realization of this tasks of develop engineers has to possess knowledge of which technologies for successful creation of products and production are availably and to take in account available material and energetic resources as well as environmental protection.

2. PRODUCT CREATION, PRODUCT DEVELOPMENT, DESIGN

Development of successful product represents important factor for value of today's companies. Furthermore will be defined concepts of product creation, product development and design. This is necessary because the current understanding of the concept allows different forms and interpretations, which leads to misunderstandings and problems in communication between participants in research, teaching and industrial practice.

Mechanical elements are perpetrators of the elementary functions of machinery, apparatus, equipment or technical systems in general.

Structural elements are functional technical systems and assemblies for the technical construction. They consist of a large number of building blocks (machine elements), whose combination is build appropriate units.

In Machine elements belong, beside mechanical elements, also mechatronic, pneumatic, electrical, electromagnetic, electronic, optical, biological and other elements.

The product creation is the part of the product life cycle (Fig. 2). It starts by determining needs, developing ideas for products and finishes with production.

Under the product development involves the interdisciplinary process in the company. This process is based on product planning, begins by defining the product profile, within this process continuously running further development, and ends with the product that is feasible for production and it can properly work. Therefore, the iterative procedures of the analysis and synthesis are performed, which are represented on Figure 3 through 7 activities. This process should aim at close cooperation between the various departments and divisions.

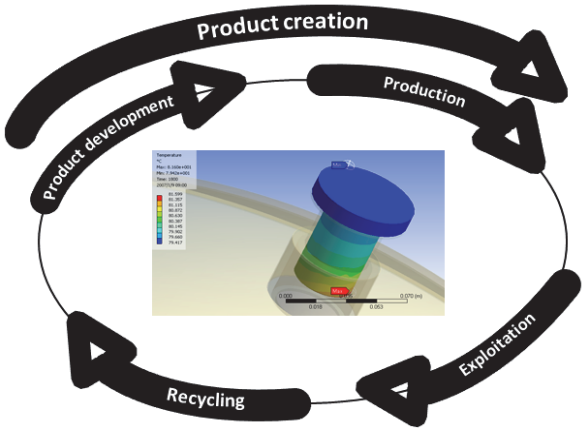

Fig.2. Product life cycle

The development process is carried out in the core of the organizational unit "product development", but also in various other departments such as design, testing, analysis, prototyping and with support of Department for Standardization and Patent Department.

So, organizational unit Design should be considered as part of product development. It is located next to other organizational units, such as Testing. On the other hand, the expression Design is in the company includes the process. This iterative process begins by clarifying the task and ends with the production documentation.

In product development there are different professions such as, for example, designers, CAD engineers, test engineers, standardization and patent engineers. Various activities oriented towards synthesis or analyses are performed depending on the profession.

University -educated engineers in the field of Product Development does not have to be specialists in all the seven fields of activity (Fig. 3), but they need to be able to take into account all of the above.

Product Development engineers, whose main task is in modelling of functions, to determine the form, choose the material, dimensioned product and its components and preparation of production documentation, referred to as designers. Designer therefore mainly takes steps of synthesis, with a focus on budgets and testing. Designers are therefore in the process of formation of new mechanical and mechatronic products involved in the development, management and shaping.

3. TASKS AND GOALS OF UNIVERSITY TEACHING IN PRODUCT DEVELOPMENT

One of the key areas related directly to product development are machine elements. Lectures of machine elements have to provide an overview of machine elements, to describe the main stresses, to give knowledge of methods of dimensioning and design and to deepen their knowledge in selected examples. A large number of products and industrial sectors in mechanical engineering make it impossible to complete mastery of specific skills. It is the task of further education in professional fields.

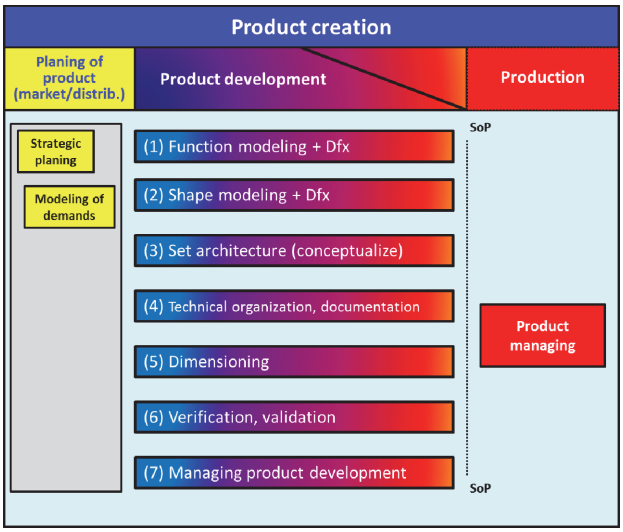

Fig.3. Position of Product Development in process of Product Creation

The demand for completeness in considering the mechanical elements can not be filled because of the diversity and continuous progressive development in technical areas and a limited number of weekly teaching hours. To include the new machine elements in teaching it is necessary to continuously adapt the contents of the current developments in the industry.

Priority in education of product development engineers makes the teaching of machine elements and design methods. In the basic (bachelor) studies in education is used a structured methodological approach. This includes the methodological development of products at a basic level, a systematic approach for designing and shaping including CAD as well as arrangement of elements and transfers to other machine elements. Scientific specialization methodological approach in solving structural problems and switching of used methods as the focus of teaching methodological product development in subsequent semesters.

Focus of teaching in the area of machine elements/science of the design should be a synthesis of technical systems as a structural problem. It allows the acquisition of technical and methodological competencies, which provide a fascinating process of innovation and increase creativity.

The synthesis of technical systems has special importance in education. Shaping of parts and components to the design of machinery confronts students with the structural complexity of the work and conveys the necessity of continuous finding suitable compromise.

Tasks should be adapted to acquire skills, which promote creativity and motivation creased through success. For a holistic approach – from the market and the product idea, including design and prototyping to the planning process and considerations of costs including and project planning - required intensive exercise and teamwork on the project. It is very good to connect with colleagues in the field of production engineering and economics.

It should be noted that the theoretical basis of mechanical engineering indispensable foundations of teaching in the field of machine elements and complete professional competences acquired during their studies. When comprehensive teaching of machine elements is performed, it is essential important is connection transferred the contents to the basics of mechanical engineering. Main subjects here are Mathematics, Engineering Mechanics, Materials, Production Technology and Electro and Information Technology. Measuring and control technology as well as thermodynamics complement the basic knowledge needed to acquire professional (technical) skills. It is important also education in the knowledge of the rules of the technical drawing in terms of technical language. Generally with machine elements must be taken into account the importance of the current guidelines and standards.

Basic knowledge of production with the corresponding parameters of the production process, shaping and material processing is a prerequisite for understanding the machine elements as well as production-oriented and cost effective design. Students must at an early stage identify and detect opportunities and constraints of modern production processes. Industrial practice has the same importance for learning the theoretical basis from the beginning of the actual education of machine elements.

Future-oriented, successful teaching in the field of machine elements/basics of design on basic or bachelor studies of dimensioning and shaping of parts and components for the given conditions integrates technical and methodological knowledge of basic subjects in complete engineering approach. An important goal of learning in the teaching of machine elements/basics of design is the integration of technical and methodological knowledge of individual disciplines.

Because of the importance of Product Development in terms of professional competence and innovation readiness mechanical engineers need to ensure adequate distribution of classes and distribution points of study for teaching and especially in exercises. Requirements for the shortening of studies must lead to a reduction in the volume of training in the field of Product Development.

Content of teaching in the field of machine elements must constantly be updated and aligned with trends in industrial practice. In addition to conventional mechanical machine elements should be taken into account and a number of pneumatic, electric, electromagnetic, electronic, optical, biological, and other elements.

The study of mechanical machine elements such as, for example, joints, springs, bearings, guides and gears are a central part of the class of Machine elements. The goal of learning machine elements is that in variable terms of the spectrum of application of machine elements (many classic elements become obsolete) tends to their correct application in industrial practice.

The diversity of modern machine elements demand coordinated teaching and learning concept. Non-mechanical machine elements due to time and the teaching constraints may not have the same amount of teaching as a mechanical machine elements. There is a possibility that some of the teaching contents transferred to other subjects at the bachelor and master studies.

Design of technical systems in terms of price (Design to Cost) is a priority in the product development process. Economic selection criterion must be constantly present in the consideration of machine elements. Design to cost as the basis for a successful construction must be methodically examined. It is important from the very beginning to future mechanical engineers to demonstrate the importance of product prices, they have to adopt as a significant factor in his work. Exclusive transfer ideal technical solution does not correspond to the professional reality. Discussion of possible alternative solutions in terms of costs, having in mind the possible disadvantages and risks must be constantly present in practical training.

The engineer is required to always act in accordance with the state of art in technique. Central importance in the description of the state of art has guidelines and standards. Accordingly, students must be trained to use these documents. In the area of product development, there are a number of guidelines and standards. Guidelines and standards for the design and dimensioning of machine elements should be learn on the basis of physical principles, as a result of scientific research. Of course, it can not and should not any standard in teaching Product Development discussed in detail. Implementation of standards should always work through appropriate

examples. Thereby should always emphasize the importance of legal guidelines and standards.

4. SKILLS, ABILITIES AND TEACHING METHODS

4.1. Skills and abilities

Through teaching and exercises in the field of machine elements students must acquire basic knowledge for understanding the process and content of work in the design and product development. The work system must overcome through the exercises and thus gain their own experience. They must govern the application of the theoretical basis for dimensioning and design the concrete machine. Knowledge of machine elements and criteria for their selection in the design process are the basic competences for further education in Product Development.

Special significance for the individual activities of design and interdisciplinary communication between engineers and others involved in the process of industrial product development and production is the ability to sketch. 2D and 3D drawings can be quickly in any situation to convey important information. Despite the implementation of CAD, the practice of sketching layouts, sections and spatial representation is very important. Drawings are an important element of communication to discuss alternative solutions to the team and the starting point for further CAD modelling.

CAD technology is now further advanced and offers powerful features to create 2D drawings and 3D models for products. Thus it provides information about the product that are essential in the chain of product development process (eg. ⇔ FEM CAD, CAD ⇔ simulation, CAD ⇔ Rapid- Prototyping, CAD ⇔ PPS, CAD ⇔ CAM). CAD technology applied today as a standard tool in product development. Therefore, CAD technologies have to be involved in the teaching of Product Development. It must also be taken into account through the use of new technology of virtual product development which leads to changes in procedures regarding the product development process. For mastering the field of CAD technology must be provided additional teaching in education in the field of product development. The scope and content, and applied systems must be coordinated with the capacity and capabilities of a particular university.

During the study, students must acquire a higher level of skills and abilities. These include social and communication skills (eg. teamwork, responsibility, self-esteem, decision-making ability, capability presentations), problem solving skills, the use and application of computational tools and the provision of information. Acquiring these skills can not be achieved in isolation of the individual courses, but must be a fundamental element of the entire concept of teaching faculty.

Teaching in machine elements should be organized as a separate structure - a combination of lectures with intensive exercises in groups - with appropriate forms of training such as team work, project work and tests.

4.2. Didactic (teaching methodology)

In structuring the content of subject teaching of machine elements and their didactic presentation of methodology of design should be used as a "red thread", to enable the classification of teaching materials in the overall context of the science of the design. Considering the available time and capacity, good knowledge of mechanical and non-mechanical elements can contribute to a better understanding of the similarities in the structure, dimensioning and shaping elements. Consequently design methodological aspects rely on connections of function, operation and construction as the basic features must be represented by general principles for the concrete embodiment of machine elements. This contributes to a design methodical structuring of machine elements makes an important contribution to thinking about variants and systems.

In education in the field of Product Development should be integrated work with real objects. Presentation of real objects in the classroom encourages knowledge and concepts about the construction and properties machine elements and technical systems. "Active Analysis" of technical systems - through the disassembly and display functions on real examples and finally generalization of abstract functions - should be integrated in the teaching. Therefore it is necessary to have available an adequate technical systems.

In the process of synthesis should provide the ability to produce simple components or semi-finished products and the process of developing the model of rapid prototyping.

The significance of this didactic element increases with decreasing practical knowledge and skills of today's students.

Student learning should be enhancing through the active work (exercise). In order to continue the product development increased space and capacity to discuss practical teaching materials that are lighter teaching volume based on the simple fact switched to independent learning

Technical and methodological knowledge and associated skills to strengthen and deepen through independent development of design tasks and projects. Exercises preferably in small groups, they are very important part of education in the product development. Active student participation must be ensured through proper exercises. In this way, the project work in small groups increases student motivation and thus success in the teaching.

Independent studies in university education have great significance. By moving the acquisition of factual knowledge - which can easily be found in the relevant textbooks - in self-learning frees space for enhancing teaching and to gain additional experience through discussion with teachers to students. This kind of education corresponds to the original principle of university education according to Humboldt, where the professional competence of students significantly increases through practical experience.

5. AUTHORITATIVE COMPETENCES

5.1. Profiles of engineering competences

Task of teams in Product Development is to achieve multiple compliance, exchange of information, to debate, dispute resolution and formal policies. It is important to establish the personal competencies, which are very important for the successful operation of the team. It is also important real competence, which team members have in relation to the upcoming task, only to be successfully solved. After extensive research in this direction, clearly defined following relevant competencies: professional competence, methodological competence, social competence, creative potential and ability elaboration. Furthermore will be defined the above mentioned competences.

Under **social competences** are following parameters or social behaviour and personal characteristics:

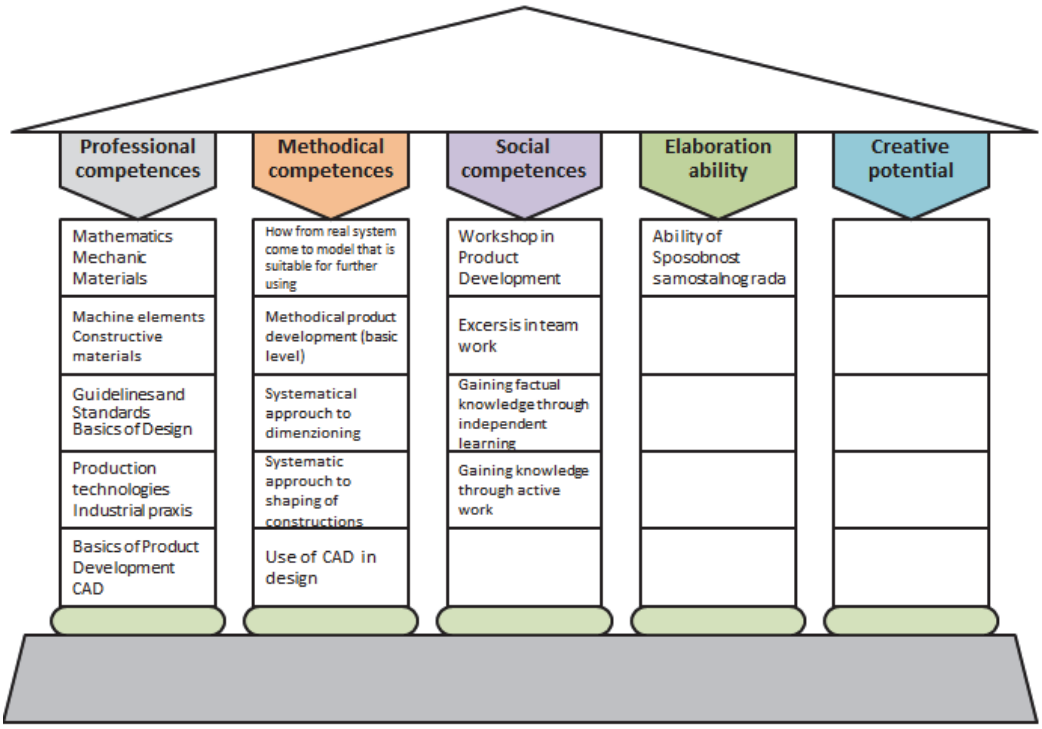

Fig.4. Authoritative competences in field Product Development on basic (bachelor) studies

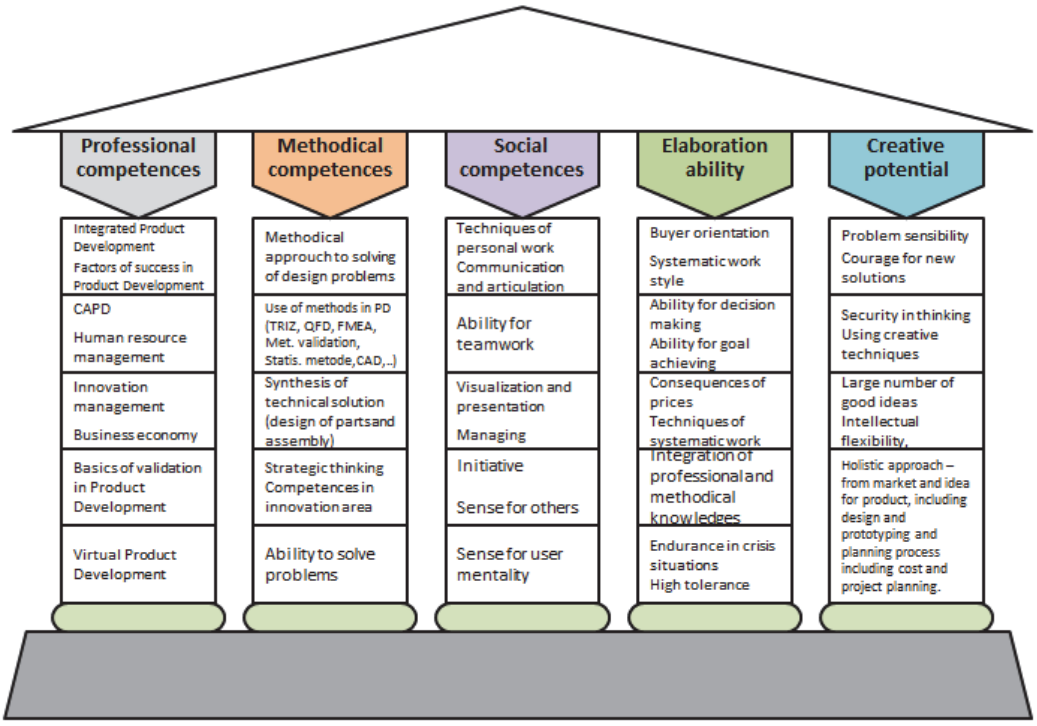

Fig.5. Authoritative competences in field Product Development on master studies

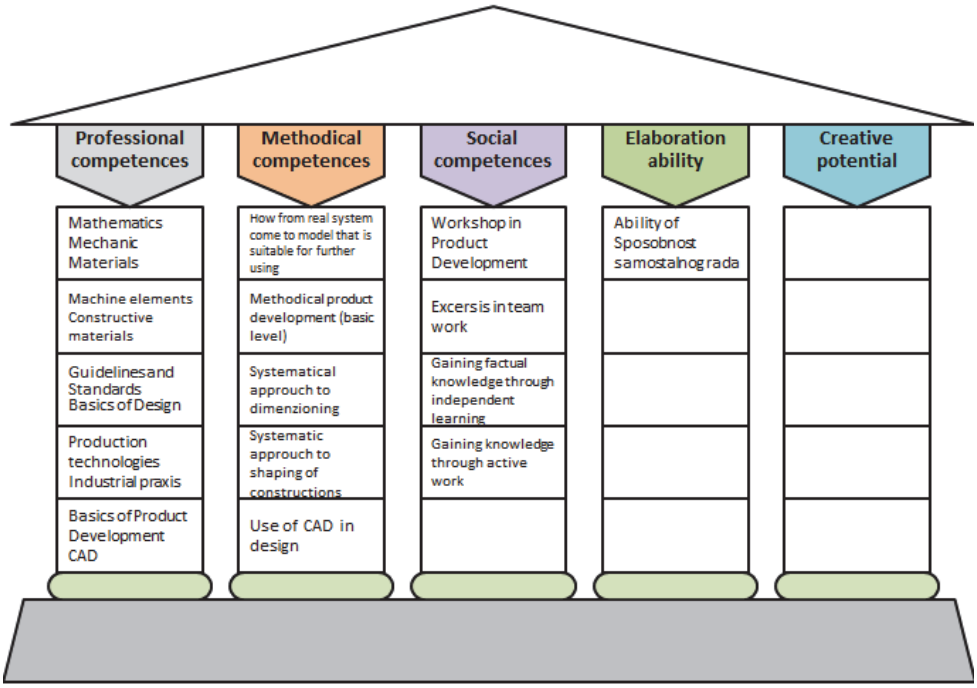

Fig.6. Authoritative competences in field Product Development on doctoral studies

- Endurance
- Motivational parameters
  - initiatives
  - work motivation
- Work styles
  - Analytical way of thinking and working
  - Orientation towards target
- Penetrability (the possibility of implementation)
- Problem solving
  - Organizational skills
- Determination
  - Determination of behaviour
- Creativity
- Team behaviour
  - Cooperation
  - Coordination
  - Willingness to discuss
  - Competence for discussion
- The behaviour in social situations

The term **professional competencies** include the practical knowledge and professional experience, as well as theoretical knowledge that an engineer in his own work use. It can be defined as "the willingness and ability to take on the basis of professional knowledge and skills of tasks and problems oriented towards a goal, if done correctly, methodically and independently solved and the results obtained adequate evaluation."

Methodical competence includes methods and proper procedures used by experienced specialists in resolving known and partially unknown problems.

Due to the accurate determination and a clear definition of professional and methodological competence, both competences are determined through answers to direct questions.

Social competence is more or less subjective but it is a very important factor, so it can not be easy determined. It can be determined through answers to indirect questions. There is difference between direct and indirect questions. In direct questions it is possible to estimate its own performance and skills of tested person. In indirect questions, tested persons are required to on the question choose between several possible answers. The rating is then performed through a personality test based on the long experience of psychologists. The team members are different personality types according to their personal and social characteristics.

Creative potential includes the following abilities:

- Sensitivity to problems,
- The appropriate use of creative techniques
- Availability of a large number of good ideas,
- Intellectual flexibility,
- Ability to abstract thinking.

Elaboration ability includes:

- Ability to achieve goals
- Orientation towards the customer,
- Keep in mind the requirements of the user,
- Knowledge of the consequences of costs and prices,
- Knowledge of the techniques of systematic work,
- Durability in crisis situations,
- Enthusiasm in decision-making,
- A high level of tolerance.

5.2 Authoritative competences of product development engineers

Based on the above given, in Figures 4, 5 and 6 are presented the authoritative competencies that need to gain as the primary product developers (bachelor), master's and doctoral studies.

At the basic studies, priority is acquisition of technical and methodological competencies, which are the basis for further upgrading and acquiring other competences at master studies. At this stage of education are acquired a certain extent and social competence primarily through

teamwork in the exercise, through the organization of workshops and learning active work.
The main part of the education of product development engineers and acquire the necessary competencies are achieved during the master studies. Competencies listed in Figure 5 are possible to obtain on the two-year master studies. Professional competence leaning on the knowledge acquired at the bachelor level are primarily oriented to obtain knowledge and skills in the areas of product development and the processes which are carried out at the same time. To acquire methodological competencies presented is the practical application of a number of methods to solve problems in Product Development, the ability to synthesize technical solutions, as well as the successful implementation of innovations. Social competences are focused on communication and articulation skills, teamwork and leadership as well as the ability to solve problems through their own initiatives. Very important are the competences related to the ability of elaboration. These competencies are expressed through the skills of systematic work style, integration of technical and methodological knowledge and managing in crisis situations. Competencies related to the creative potential include acquiring skills for applying creative techniques, safety at work and the implementation of new solutions as well as a holistic approach to product development.
In education of product developers engineers in doctoral studies (Fig. 6) is planned acquisition of expert scientific competencies related to the methods of scientific research, but primarily for application and development research that can be successfully applied in the development of new, sophisticated and commercially successful products. Methodical competence primarily are aimed at developing methods and procedures for the rapid implementation of the results of basic and applied research in the development of new products. Social competence are aimed at acquiring the ability to create and manage multi-disciplinary project teams, skills for conflict resolution and stability in critical situations. Competencies related to the ability of elaborating are referring to the successfully hypothesis, identification of scientific research of interest to engineering practice and formulation of research results in writing form. Creative potential involves acquiring the ability to create models for testing, prototyping and pilot plant, creating innovations and new technical solutions.

6. CONCLUSIONS

The survival and success of modern companies can be provided through innovative products and manufacturing processes. However, the use of innovative products and manufacturing process is quite complex and requires a new approach to the work, which is primarily related to the optimization of available resources, the precise definition of competence and cooperative approach to work.
Modern companies must have access to comprehensively educated engineers for work in interdisciplinary project teams so that they can solve complex problems. This raises the need for universities to undertake a proper education reform, according to the demands of contemporary techniques and technology.
Synthesis of technical systems is particularly important in education while it confront students with the structural complexity of the work and conveys the necessity of continuous finding suitable compromise. Tasks should be adapted to acquire skills, which promote creativity and it increases motivation through success. For a holistic approach – from the market and the idea of the product, including design and prototyping to the planning process and considerations of costs including and project planning - required intensive exercise and teamwork on the project. It is very good to connect with colleagues in the field of production engineering and economics.
Due to the acquisition of professional competence and innovation readiness, mechanical engineers need to ensure adequate distribution of points of studies for classes especially for exercise. Outdoor education must constantly be updated and aligned with trends in industrial practice.
CAD technology today allows creating the necessary chain of product development process (eg. FEM ⇔ CAD, CAD ⇔ simulation, CAD ⇔ Rapid-Prototyping, CAD ⇔ PPS, CAD ⇔ CAM). CAD technology and virtual technology of product development must be involved in the teaching of Product Development.
In education in the field of product development should be integrated the work with real objects because it encourages the acquisition of knowledge and concepts about the construction and properties of technical systems. This is best achieved through the active work of the students.
After extensive research in this direction, clearly are defined the following relevant competence of product development engineers: professional competence, methodological competence, social competence, creative potential and ability elaboration. Based on a detailed analysis of the work presents authoritative competencies that product development engineers need to gain at the basic (bachelor), master and doctoral studies.

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