DESIGN IN MECHANICAL ENGINEERING - MULTIDISCIPLINARY APPROACH

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Engineering design and Industrial design contain the same field of action with different objectives and different approaches to objective realization. Mechanical engineering is specific in product development. Functions, structures, behaviors etc. in exploitations, production and in development are different (more complex) comparing to other technical systems. It needs multidisciplinary approach which includes all aspects of engineering design, aesthetic design, ergonomic design, bionics in design, ecology in design, etc. Interaction of approaches and contents of engineering and industrial Design is presented. Expansion of approaches and methods in field of Engineering Design gives possibility to present directions of this development. Systems for interactive communication are of great support for these activities. At the end of the article these systems are presented.

Key words: Design, Mechanical Engineering.

DIZAJN U MAŠINSTVU - MULTIDISCIPLINARNI PRISTUP

Inženjerski dizajn (konstruisanje) i industrijski dizajn odnose se na isto područje tj. na razvoj tehničkih sistema ali su im pristupi i cinjevi u realizaciji različiti. Osim toga mašinski sistemi su specifični u pogledu razvoja. Funkcije, strukture, ponašanje i dr. u ekspoloataciji, izradi i u razvoju se značajno razlikuju u poređenju sa drugim tehničkim rešenjima. Sve to nameće potrebu za multidisciplinarnim pristupom koji uključuje sve aspekte inženjerskog dizajna, estetskog dizajna, ergonomskog dizajna, bionike, ekologije i dr. Dat je prikaz međusobnog preklapanja sadržaja i pristupa u razvoju proizvoda kod inženjerskog i industrijskog dizajna. Ekspanzija razvoja metoda i pristupa u oblasti inženjerskog dizajna dala je povod za prikaz pravaca ovog razvoja. Prikazana je i procedura multidisciplinarnog pristupa u razvoju mašinskih sistema. Na kraju su prikazani sistemi za interaktivnu komunikaciju razvijeni poslednjih godina, a čiji je značaj izuzetan za povećanje efikasnosti odvijanja ovog procesa.

Ključne reči: inženjerski dizajn, mašinstvo, konstruisanje

INTRODUCTION

In general, the design is activity which is significantly represented. The world is covered by institutions which perform different kinds of design activities and processes. The objectives of all of them are to obtain the new products i.e. technical solutions and ideas for these solutions in a short way and time and with a high quality level. Transformation of knowledge to technical solutions is extremely important for economic prosperity of enterprises, states and for entire global society. It is possible to divide design institutions into three groups: institutions for Engineering Design, institutions for Industrial Design and institutions which try to combine those two approaches. Some of them have impressive results and have become famous. These results can be evaluated as new design

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methods and approaches, a new way of design education, a new design philosophy, etc.

Numerous conferences in the area of Engineering Design give opportunity to present results, new methods and approaches, their applications and results, industrial results etc. The principal among them is International Conference on Engineering Design – ICED, which was last held in Paris in August 2007 – ICED-07. Also, numerous journals present the top results in Engineering Design area. Journalof Engineering Design, Research in Engineering Design, Design Studies are the leading journals in this area. The Design Society is trying to coordinate the activities of the conferences, journals and special interest groups SIG in the global sense.

In the area of Industrial Design, activities are predominantly separated from Engineering Design and are performed in different way. Exhibitions, competitions, jury indicators and evaluations etc. stimulate and direct designers' activities. Popular journals which present designers' results for public evaluation also act in the sense of Industrial Design popularity.

In Mechanical Engineering technical (mechanical) systems are complex and have to be more and more aesthetic, and ecologically designed. Bionics, ergonomics, surroundings, etc. increasingly effectuate new ideas, knowledge and solutions in the area of Design in Mechanical Engineering. All of the mentioned have to be included in innovation and sustainability of Design in Mechanical Engineering.

Product development comprises design process, development of technology, development of user needs etc. Extremely important area of product development is the development of ideas for the new product. Relation between the reached level of knowledge, technology, user and market needs, society surroundings, environment etc. create the platform for product idea generation. Methods and philosophy of product idea generation are a complex area of research. From this point of view, the design process is an executive stage of product development.

RELATION BETWEEN ENGINEERING AND INDUSTRIAL DESIGN

The term "design" is very complex and includes various activities directed to obtain technical solution. This term means preparation (planning), transformation process of knowledge to technical solution and outcome of this process i.e. technical solution itself. Also, design implies drawing, sketch or full presentation of technical solution. Out of English, other languages have a set of words to denote this area. Translation sometimes can be imprecise and wrong. Also, the word "design" in other languages causes trouble in view of the meaning. The main examples are as follows. In English language there are two design areas, Engineering Design and Industrial Design. Both of them have the same objective, to create the technical solution. Engineers possess methods and rules of how to transform knowledge into technical solution. In the German language the term for this area is "Konstruktionstechnik" and in Serbian "Konstruisanje". Translation of Engineering Design in the Serbian language as "Projektovanje" is not fully correct, apart for some exceptions. This word has the meaning "Projekt= zamisao" and "Projektovanje= osmišljavanje= komponovanje gotovih celina". It means that the word „projektovanje" can be used for complex systems which can be combined of beforehand developed components or subsystems. This is the reason why in the Serbian language it is suitable to use „Inženjerski dizajn" in the same way as in English. "Konstruisanje" and "Projektovanje" are not Serbian words either, but „Inženjerski dizajn" is more precise.

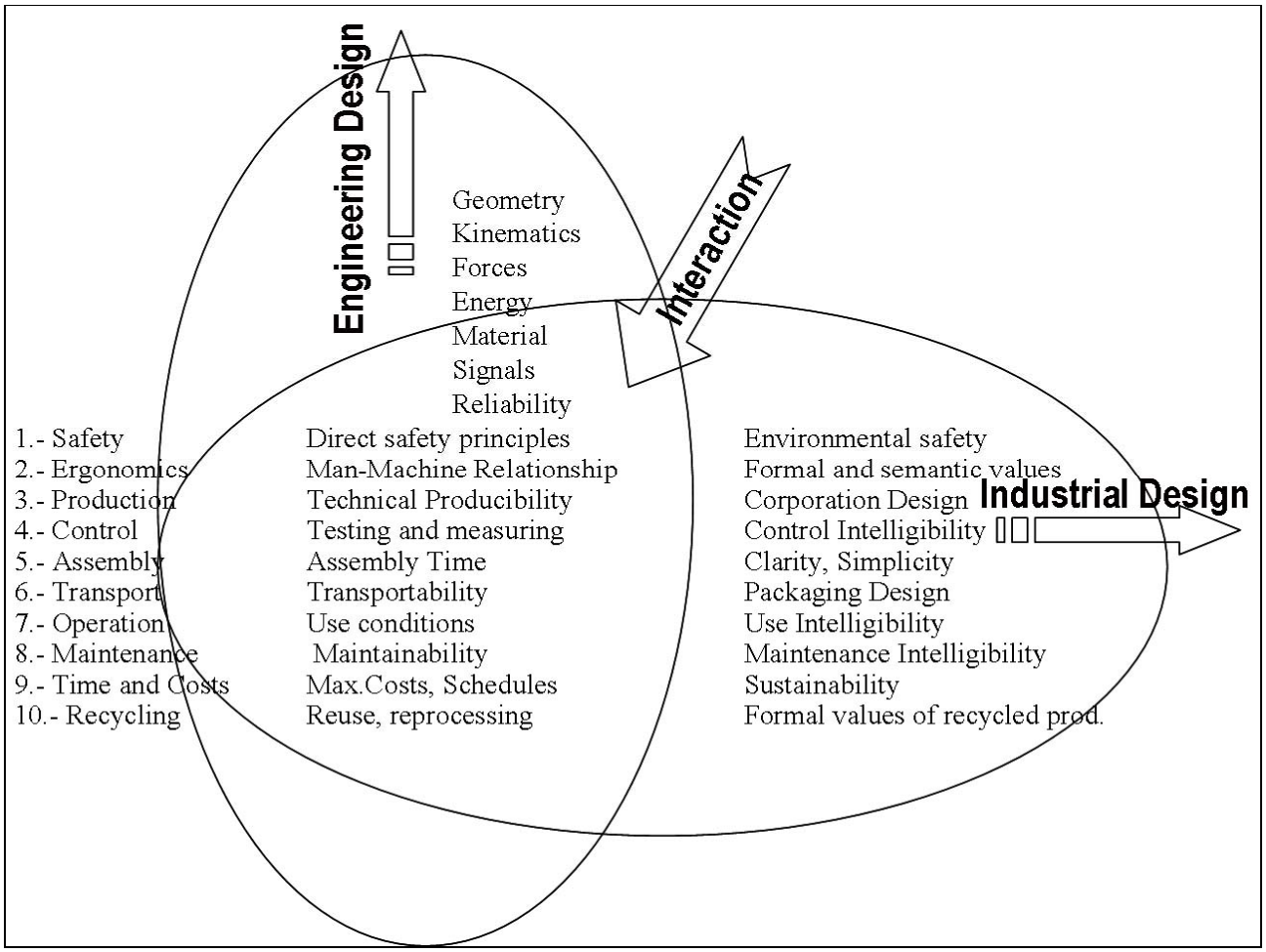

Figure 1. Relation between Engineering Design and Industrial Design [Freddi A.,-Univ. of Bologna]

Industrial Design is the area where the artists create industrial products. It is the art for industry. The artists use artistic approach, such as observation, imagination, composition, etc. meet user needs on the market. They are especially oriented to product aesthetics but have to solve all other technical tasks with the poor technical knowledge. In these cases they have to work in cooperation with engineers. The next important detail is that in the World of artists the term Industrial Design, is colloquially transformed into “Design” only. Without translation this word is transmitted in other languages like in Serbian and then words Design and Aesthetic sound pleonastic. Considering Engineering Design and Industrial Design, the term Aesthetic Design has a certain role in both areas.

Considering orientation and objectives of Engineering Design and Industrial Design these two branches have a great part of action which is the same. Professor Alesandro Freddi from the University of Bologna, has presented this interaction in the graphic sense (Fig.1). The ten (10) features of the technical solutions are considered. Safety in Engineering Design considers Direct safety principles and Industrial Design considers predominantly Environmental safety. Control in Engineering Design treats using testing and measuring and in Industrial Design using control intelligibility of designer and user. The transport feature Engineering Design treats like transportability but Industrial Design in view of packaging design. Operation of developed system, Engineering Design harmonizes with the use conditions, Industrial Design harmonized with user intelligibility. According to the presentation in Fig.1, Industrial Design continues development of the mentioned and other features starting from the features developed in Engineering design. In the cases of products of a simple structure, the whole design process can be performed by industrial designers. In this case, and maybe in the case of more complex systems, industrial

designers perform engineering activities in an artistic way, which can be very wrong. The aim of the Fig. 1 is to show a great interaction of Engineering and Industrial Design, and that Engineering Design needs additional activities which are special in Industrial Design. Also, Industrial Design in the cases of complex systems, such as systems in Mechanical Engineering, needs a strong base (knowledge and skills) which is available in engineering designers. Products with high level of performances and quality, and suitable for market competition, have to be developed in harmonized activities of engineers and artists. For this purpose, they both have to be educated in the way which stimulates this cooperation. Figure 3 shows relation between science, art and design.

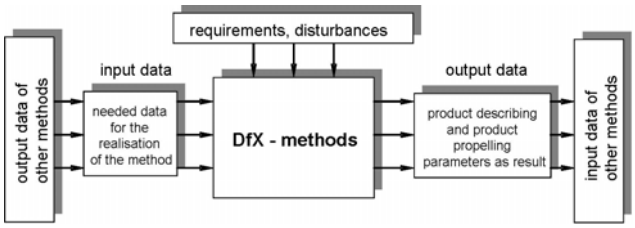

Figure 2. Description of DfX procedure method in Engineering Design
[Meerkamm H.- TU Erlangen]

Engineering Design is based on defined procedures, methodologies and theory. Research and application try to establish certain methods which can lead from simple idea to the project in the form of complex information structure for production, use, maintenance, recycling, etc. Procedures include knowledge organization, process organization, information flow, stages, operations and activities which lead step by step to the result of design process. Procedures can be defined in general, in the sense of design synthesis, in the sense of design analysis etc. In Figure 2 general procedure in design analysis using DfX (Design for X) methods is presented.

Industrial Design, contrary to Engineering Design, is based on designers' abilities and skills. Using studies, impressions, intuition, etc. a designer generates ideas how to create composition, improvements or corrections. Science is also the base for artistic design process. Knowledge, theoretic, empiric, hypothesis, etc. can be directed to decision-making in artistic design process.

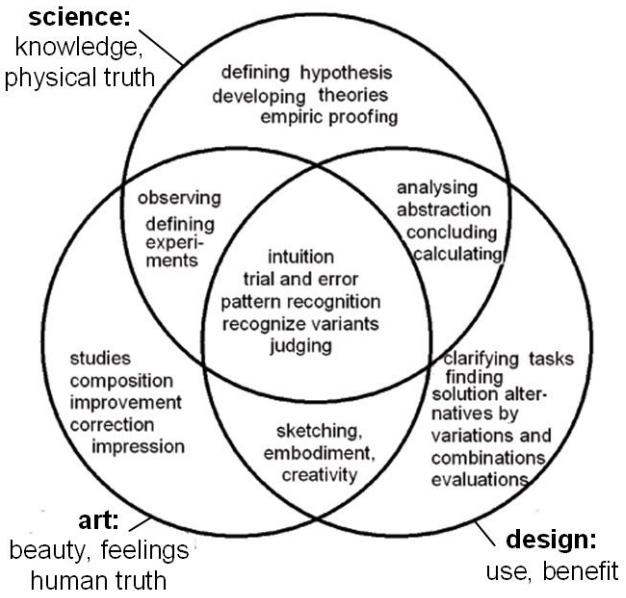

Figure 3. Main aims and methods of art, design and science [Franke H.J. – TU Braunschweig]

ENGINEERING DESIGN SCIENCE

The last International Conference on Engineering Design ICED-07 held in Paris, August 2007 gives very simple structure of science of Engineering Design. All conference presentations were divided into the following groups: Assessment, Computation, Design for X, Education, Innovation, Knowledge, Organization, Theories & Methodologies, and User. Theoretical thinking about product development or about design process, philosophy and visions based on experiences and intuition can be a challenge and support for the new methods or products creation. General objective of design science is to create a procedure combined of certain methods which can provide transformation of reached level of knowledge to the technical solutions. At the moment, this transformation is predominantly performed by the mental approach with support of developed methods which can be used for realization of certain parts of the general transformation in design process.

Computations are an important area of Engineering Design. Numerical and analytical methods and analysis in combination with experimental results provide data for progress of design process. The data transformation performed by different kinds of calculations presents the main part of transformation processes in design. The knowledge (what?, how?, when?, where?,...) is propulsive and the subject of transformation with the aim to product defining. The knowledge identification,

collection, processing, storage, organization and use are the subject of Knowledge Engineering which is also a special area of Design science.

Design for X is a set of methods directed to many kinds of product features, limitations, and conditions connected to the technologies, market, user needs etc. These methods provide information, analysis, synthesis etc in certain of the mentioned areas. By combination of DfX methods, procedure for certain product development can be satisfied. Also, by using DfX methods it is possible to develop more complex design methods which can lead to the products of high performances, for example Robust methods. In Engineering Design DfX methods are with the top concretization and application. The results verify innovations in Engineering Design and Industry which can be a special separate area. The innovation contains new applications of design approaches to the new industrial applications and design solutions. These results are verification of developed methods, verification of design quality or improvement of applied approach. Organization of design process and product development is also a special separate area of design science. Design team arrangement, team collaboration, responsibilities, etc. have to be performed in the way which can guarantee maximal effects with the minimum of time. Management of the process in small or big enterprises etc. has to be defined at the scientific base. The role of product development management is higher and more complex compared to design process. That is the reason for special field of activities in Design science.

Theories and methodologies of design process and product development have to be the major results of Design science. Some of the developed methods give good results and can be improved or transformed to the new ones which can be more effective. Also, the user needs and market needs directed product development policy and they present themselves an important area of design science. It is not enough to develop product and very often it is necessary to develop user needs and market for a certain new product. The questions connected to the user are fully justifiable to be a separate and specific area of Design science. Also, education in Engineering Design needs systematic approach. It is necessary to develop a specific way of thinking and multi-objective approach. That is the reason why Design science is developing as a special field of design education which contains specific approaches, philosophy and methods for this purpose.

FEATURES OF DESIGN IN MECHANICAL ENGINEERING

The main attributes of machine systems are a high level of complexity, complex shape of components, relatively high dimensions, a great effect on the environment, and on humans themselves. Also, the strong design constraints line as high level of load capacity, high level of reliability, low level of vibration, noise and other kinds of pollution. That is the reason why it is necessary to combine the design process and process of product development of a set of sub-areas which lead to the product of high quality.

Education, knowledge and skills of designers in mechanical engineering have to be combined of general knowledge of mechanical engineering, knowledge about engineering design and product development, knowledge about ergonomics, bionics, aesthetics, ecology, etc. Special knowledge about certain machine systems is also welcome. Knowledge about engineering design contains design process (Conceptual design, Embodiment design, Design for X), development of machine systems, decision making, special methods (axiomatic methods, optimization methods, etc.). These areas of knowledge have to provide designer skills for product definition for conceptual and embodiment design of machine systems. Figure 4 shows conceptual design and embodiment design of chosen machine system. Conceptual design is defined by a sketch which contains machine parts structure and principle of action (function). Conceptual stage of design process includes the following set of design operations: functional structure definition, choice of function carriers, creation of design solution, and choice of optimal conceptual solution. Transformation of conceptual design to embodiment design is performed by a set of design operations and activities. A group of operations is decision operations, such as decision about selection of machine parts material, machine parts shape and selection of production method. The next group of operations is calculation of machine parts dimensions combined with design parameters of machine parts optimization and decision making about these parameters. Embodiment design is the top complex stage in design process of machine systems. A set of special design methods has been developed to

improve and accelerate this design stage. Those are methods for machine parts shape modeling, shape optimization, axiomatic design, design parameters optimization, robust design etc.

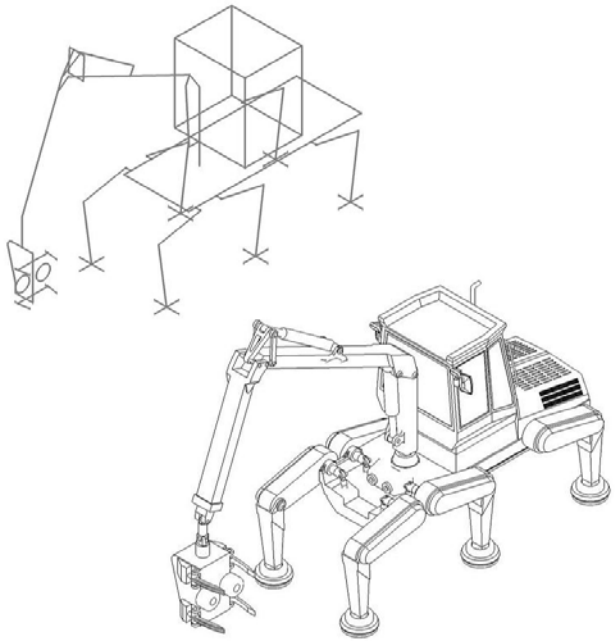

Fig. 4. Conceptual and embodiment design of machine system

Bionics presents in itself transformation of biologic systems into technical systems. Numerous machine systems were created by transforming the principles, shapes etc. of biologic systems. In the case of forest machine (Fig. 4 and 5), the principle of motion using six legs has been transformed from animals, for example from a river crab (Fig.5b). The principle of cutting the tree can be also transformed from the cancer hand principle. The principles of control, flying, swimming etc. can be transformed from animals or of the other biological systems. That is why Bionics is an important aspect of designer education in mechanical engineering.

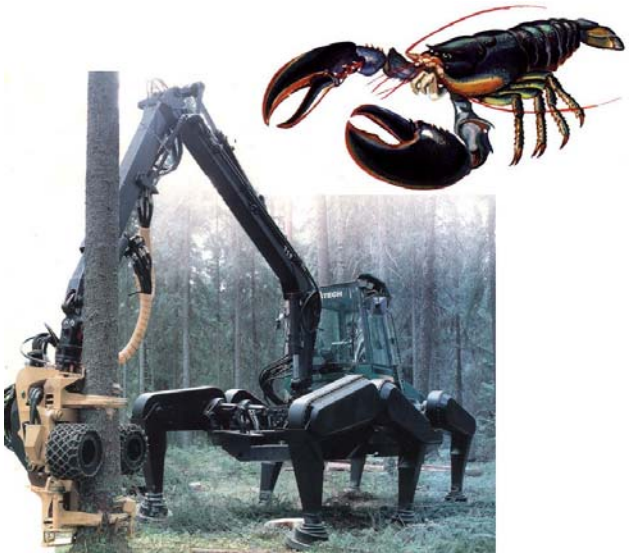

Fig. 5.Relation between principles of forest machine and biological principle of the river cancer

Ergonomic defines relation between operation of technical systems and operation of a human being. Especially, relation between control tools (batons, bars, displays,...) and position of a person who performs control has to be suitable, effective, without making a person tired and work unpleasant. The seats of operators are the main components which have to be designed in ergonomic way. The seat has to be with a kind of motion, with control tools, with the systems which can protect operator, etc. Also, operator cabin has to be adapted to human operation and to be comfortable for a long work. This is a very important part of design in mechanical engineering. Figure 6 shows some of the examples.

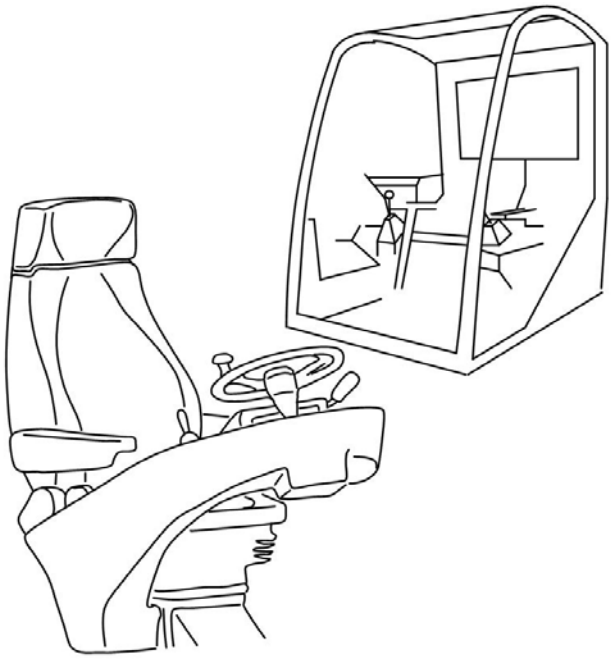

Fig. 6. Ergonomic components of machine systems

Product aesthetics means that machine system has to provide working with a pleasure, reduce tiredness, does not disturb harmony between the already existing biological and technical systems etc. The shape, dimensions and colours are the principle aesthetic features of machine systems. Human evolution has been performed over a very long period of time in natural surroundings. Shapes and colours of the flora, animals etc. have created human feelings which have to be supported by technical (machine) systems. Relation between dimensions is also defined in biological systems and if we want to design aesthetic products it is necessary to respect these relations.

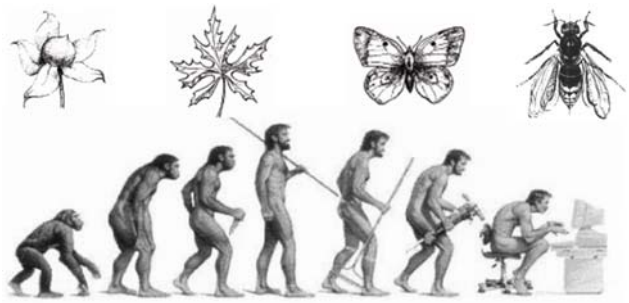

Fig.7. Aesthetic relations developed along human evolution

Ecology is an area closely related to aesthetic, bionic and ergonomic features of developed machine systems. These systems have to be harmonised with surroundings, but do not destroy ecological system additionally. Harmonised relation between soil, water, air, animals, birds, insects, flora, heat, etc. mustn't be destructed by technical (mechanical) systems in a short time or during a long time of the system operation.

Mechanical engineers educated to perform design of machine systems have also to be involved in introducing different kinds of certain machine systems, for example tool machines, energetic machines (motors, turbines,...), vehicles, rail, electric machines, etc. Elective courses have to provide opportunity for a student to choose and learn about a set of different kinds of machines or a set of one kind of machines. Some of the new directions in technical system development, like mechatronic systems, have to be included in designer education process too.

INTERACTIVE VISUALISATION

Systems for interactive visualisation have had a great expansion in development in recent times. This gives great support and challenge for establishing design processes and methods which can provide machine systems of high quality level, harmonised with all mentioned limitations and constraints. There are a few groups systems and approaches which designers can use for visualisation of designed objects and for interactive corrections. The tools which provide this opportunity are specific CAD software, virtual reality, 3D printing (fast prototyping), 3D scanting, etc. The shape modelling provides wire-models, boundary-models and solid-models. By using Non-uniform Basier Splines – NURBS modelling technique has got a very good interactive attribute, especially in the cases of free form surfaces (Fig.8). Also, parametric modelling, which can be performed by high level CAD software, gives great possibility for interactive variation, optimisation, and aesthetic harmonisation of machine part shapes. Possibility to animate developed system (assembly) makes interactivity of the system significantly broader.

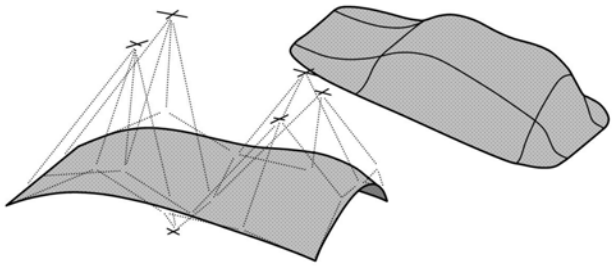

Fig. 8. Free-form parametised surfaces

Virtual reality is possibility to present a model of machine part or machine system in real space. Using screens made of the mirrors and projectors, the picture of the model is presented in real space. The system can be with a single screen, double screens, etc. to six screens. Pictures of single- and multi-screen systems have to be synchronised by corresponding software, and the picture can be clearly visible using stereo (shutter) glasses. Interaction and corrections of presented models can be performed by using corresponding sensors and interactive tools which a user keeps at the shutter glasses and gloves. In Figure 9 only the principle of this action is presented. It is necessary to mention that single-screen system needs two mirrors and two projectors. Multi-screen system needs one mirror and projector per screen.

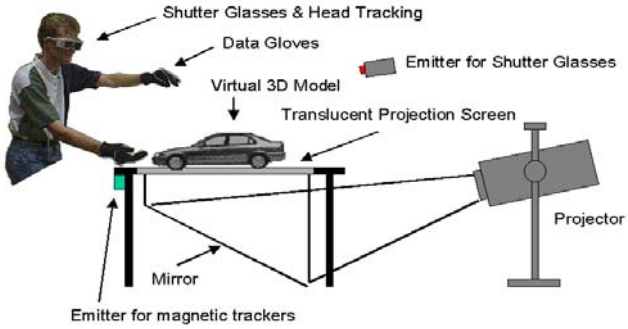

Figure 9. Principle of interaction in virtual reality presentations

Printing in 3D space needs material which has to be used for object materialisation. It can be some kind of plastics or some kind of non-metallic or metallic powder. Using this technology, machine parts or assemblies are made of this material very similar to sintering method. Some kind of materials have enough strength, thermo-resistance, etc. that can be used in real exploitation. Also, this technology is very suitable for interactive shape development. In Figure 10, one of 3D printers and printing results are presented.

Figure 10. 3D printer with printed machine part and assembly

Scanner of 3D objects gives possibility to create a set of points which covers surface of scanned object. Scanner is the system which works precisely by holding in hand. Relative relation between already scanned and the next points. Using special software, a set of scanned points can be transformed in 3D model of object. The model can be inserted into the program for 3D printing and print the scanned object. It gives possibility to multiply the existing object. Also, it gives possibility to replay objects (machine parts) with damages. This is possibility for realisation of reverse engineering, i.e. transfo-rmation the existing designs into 3D models or into drawings, which is the base for production.

Figure 11. 3D scanner device

CONCLUSIONS

Design in mechanical engineering introduces all aspects of machine systems development. Compared to other technical systems, these systems are of complex structure and need multidisciplinary approach for development. Development of machine systems contains all methods and approaches in Engineering Design (Conceptual design, Embodiment design, Design for X, Axiomatic design, Decision making,...), including Ergonomic rules, Bionic rules, and especially Aesthetic design. The systems for interactive visualisation give strong support to development of machine parts and systems with high aesthetic attributes.

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