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FORECASTING OF INDUSTRIAL NEEDS AS A GUIDELINE FOR ENGINEERING EDUCATION

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ABSTRACT

The demands set to the engineering designers nowadays have been discussed. After the world industrial trends and foreseen developmental industry tendencies have been presented, the forecast of demands for engineering design are formulated. The questionnaire example for identification of the industrial needs and a matrix for evaluation of correlation between the contents of design science and industrial needs have been shown. The need for taking into account future industrial needs in education of engineering designers has been emphasized.

Keywords: Engineering design, requirements, engineering education, technological forecasting

1 INTRODUCTION

Modern education of design of machines and mechanical devices should prepare the future engineers to work in a production enterprise operating in conditions of sharp competition. The principal condition of the success of the enterprise is ability to design the products which, at the outside, cover the market requirements, the products with the bottom line, manufactured within a short time. Without a properly prepared engineers the manufacturing company, sooner or later, will stop to exist as a competitive one.

The present education process at the mechanical faculties (from the Polish perspective) does not ensure the graduates the knowledge and skills which are necessary to undertake innovative tasks in engineering design. Among others, students do not familiarize (or do insignificantly) with the principles of design for all the product life cycle (‘design for life’), with multi-aspect design (‘design for X’), as well as with methods of ‘concurrent engineering’ and with the principles of team collaboration.

In particular, in the process of design of a product, an engineer ought to cover:

(i) Current and predicted market requirements, as well as obligatory to particular product class formal canons (‘product design’);

(ii) Realization possibilities of the production system, where the design will be realized (‘design for manufacturing’);

(iii) Requirements of the assembly process (‘design for assembly’);

(iv) The need to provide the product with required values of its features (‘design for quality’, ‘quality function deployment’);

(v) Necessity to minimize financial input to activate the production.

Basic problems of mechanical engineering industry are: improvement of manufacturability, reliability and ability to repair (serviceability) of machines and mechanisms. Assessment and evaluation of reliability of mechanical devices, seems to be difficult in particular. By comparison with electronic systems, mechanical devices are considerably more difficult to mathematical modeling. The number of the variables which influence on the reliability, complex relationships between them and variety of dynamic loads bring about the fact that – on the contrary to as it is in electronics - there have been so far no generally accepted and effective procedures which would enable to satisfactory predict reliability as well as failures of mechanical systems.

It is vital that the evaluation of manufacturability, reliability and ability to repair should not be carried out after the design has been finished, to the contrary: it should be an integral part of the design process. Conventionally, these features are verified when the basic structure of elements and their arrangement has been already determined. It causes the occurrence of a huge iteration loop in the design process, which is disadvantageous. Application of suitable computer software for advanced calculation procedures, simulation programs and engineering databases would enable an appropriate selection of the physical form without the need to repeat a large part of the design process.

It is commonly known that the quality of the machines depends remarkably on the design process. It has been proved that the design involves only a small part of cost of a new product development whereas it determines predominant proportion of the whole realization cost. Therefore, achievement of a progress in production of the machines, interpreted through the prism of three features as follows: manufacturability, reliability and serviceability depends on abilities to evaluate these attributes during the design. It requires not only cooperation of experts in the branches mentioned before and theoretical and experimental research followed by careful result analysis but also availability of multi-functional computer software for aiding design, simulation, bases of the engineering knowledge and other advisory systems.

That is why it is extraordinarily important to meet current and predicted industrial requirements in the academic syllabus. It is necessary to include especially the forecasting of needs, since a 'contemporary' student will be employed 'tomorrow', and he will undertake the designs 'the day after tomorrow'. All these issues require a properly directed education of the future engineers – creators of a new technology. The limitation of the hours in the academic timetables cannot be an excuse for omitting in the engineering education the issues mentioned above.

2. DEVELOPMENTAL TENDENCIES OF THE WORLD INDUSTRY

The world industry intervening trends can be introduced in the following four categories [1] :

Changes concerned with the products,

Changes in the process of realization of the products,

Changes of the market requirements,

Changes in the field of cooperation.

Ad 1. *Changes concerned with the products*. Request on increasing effectiveness, reliability, integrity, economy etc., contribute the necessity of a maximum utilization of existing technologies and give rise to formulation the new ones. In many devices there is a tendency to decrease a number of mechanical elements, which leads to multi-functional elements of a complex structure. Mechanical devices are equipped in electronic and computer control systems, transforming them from purely mechanical systems into electromechanical ones with features of an artificial intelligence ('smart systems'). Increasing number of programmable processors are introduced even in plain traditional mechanical devices.

Ad 2. *Changes in the process of realization of the products*. Competition enforces shortening the production time. For instance, according to American sources [2] the time of realization of the aircraft engines is going to be contracted 60%, and the industrial semiconductors industry has reduced the time up to tenfold (relatively to the 80's). It has been achieved by introducing concurrent engineering techniques for product design and manufacturing. Since devices and technologies become increasingly complex and the designers must operate with increasing number of information, interdisciplinary teams are the must. Computer information systems have become the industry drivers and exert a powerful influence on the design, research and manufacturing processes. Advances of the computer engineering as well as prevalence of internet result in the rapid increase of rate of transmitting information and data management for use in the products and manufacturing processes.

Ad. 3. *Changes of the market requirements.* Globalization of competition and the decreased demand for standard products are the issues recently observed. On the other hand, the demand for their variety and for agile response to users' needs increase. The requests for the quality still increase.

Ad. 4. *Changes in the field of cooperation*. The importance of distribution and retailers networks is on the increase. The number of distributed design teams as well as companies set up opportunistically for co-operative realization of particular projects grow. Owing to an increasing complexity of engineering systems, improving their functioning becomes more and more difficult. It is perceived that the increasing amount of specialists is accompanied by the decreasing number of generalists who can integrate the complex systems. There is considerable need for including in the design such experts who could overcome the complexity of the demands, and not only some of the specific problems. Nowadays, designers frequently do not understand what the problem of system integration consists in [3]. There are accounts that in Europe and the USA changes in the design fall frequently in time of production planning, whereas in Japan this occurrence does not take place. It is considered that the present way of organization of the product development process needs to be revised.

3. FORECAST OF THE WORLD INDUSTRIAL DEVELOPMENT FOR THE NEAR FUTURE

In the short term the following tendencies are foreseen:

- The complexity of devices, production processes and their maintenance will be increasing,
- An increasing complexity of engineering systems will cause incapability of one engineer to solve the whole issue necessary to be covered in the project. Engineers will be forced to use ready modules (subsystems) prepared beforehand, which will be recorded in data bases. Thus, in the work of designers, the importance of synthesis and integrative activities will increase.
- Intensification of global competition will be the reason for surviving only the best products on the market,
- The significance of a short time-to-the-market for the product will grow,
- Owing to advances in monitoring systems of the work conditions, it will be possible to provide designers with current information about the behavior of the machines during their field operation. Accordingly, performing of the design process as a principal operation in the continuous improvement of a machine features will become possible,

- Thanks to progression in the field of computer systems most designs will be made by the distributed teams.
- In view of significant complexity of design problems, there will be growth of importance of various models used for early verification of the design solutions as well as for evaluation of the production cost.
- Competition will force the designers to extreme utilization of construction materials and manufacturing resources. This will enhance the importance of optimization methods and decision making in conditions of uncertainty and risk,
- Society will strengthen emphasis on environment protection demands and conditions of human work as well as on regarding complex issues of the whole cycle of the product's life.

4. FORECASTING OF NEEDS IN THE FIELD OF DESIGN

Anticipation of needs in the field of design can be based on the analysis of current trends in industry since in the period of some ten years probably there will be no revolutionary changes. One may expect that:

- designers will have to do with a great amount of information concerned with a designed object and the process of its manufacturing. Moreover, this information are to be updated continuously,
- global competition much more will focus on a short time of realization of new products,
- designers will reach for methods of structuring, decomposition and planning of complex design processes in order to decrease the amount of iterations and the risk of failures,
- there is the need for improvement of designing methods ensuring high quality and small sensitivity of the product to changing work conditions,
- better procedures of undertaking decisions by interdisciplinary teams are needed, including the risk and uncertainty assessment,
- one of the most important industrial needs is the development of communication systems because both engineering teams and companies are frequently situated in distant places,
- the design must take place in the environment assuring fast flow of the design information, with immediate covering of changes in the project,
- total integration of analytical methods with the process of the design is demanded,
- companies need better understanding of their products design process and still better design organization which should at the maximum level utilize capabilities of concurrent work,
- designers' experience and the process of the design origination ought to be recorded, in order to use in next designs. To this aim one needs methods and tools of knowledge engineering,
- fast changes of methods of manufacturing and demands of the market form the need for continuous training system of workforce,

Table 1. *Examparу list of industrial needs*

No.	Objectives	Weight (1-10)
1.	To improve the quality of design	
2.	To rationalize team decision making	
3.	To improve the designers' co-operation	
4.	To integrate analysis with the design	
5.	To explore the industrial processes of realization	
6.	To store and utilize the project experiences	
7.	To predict the effects of early project decisions	
8.	To implement continuous training of engineers	
9.	To integrate various analysis tools	
10.	To stimulate the designers' creativity and the design innovation	
11.	To reduce realization time through parallelization of activities	
12.	To make information infrastructure more efficient	
13.	To carry out optimal multicriterial designs	
14.	To master dealing with the complexity	
15.	To improve methods of evaluation of design alternatives and detecting of the design errors	
16.	To integrate the designed product data	
17.	To streamline communication between the distant experts	
18.	To integrate the design process with the process of the product manufacturing	
19.	To solve issues of integration of large companies	

- computer aided design systems will release designers from routine tasks, whereas application of modeling, simulation and multicriterial optimization will contribute to significant reducing of the product development time,
- engineers will work in a distributed environment using methods and means adjusted to such conditions. This will trigger the need for means of large scale integration of information and management systems,
- the necessity of correction in the final phases of design must be eliminated owing to advances in modelling and simulation as well as effective co-operation between the teams,
- there will be a significant progress in the field of computer methods of modelling, multicriterial optimization and adjusting of systems CAD/CAM/CAE to the needs of engineering practice.

In Table 1 a list of problems have been presented, of which solutions have been considered important by some production companies. Sources: my own survey and literature studies. The column of weights have deliberately not been completed, since the companies have had different preferences.

4.1 DETERMINATION OF PREFERRED EDUCATION CONTENTS

Table 2. *Matrix of correlation between selected issues of design and industrial needs*

Design–research issues / Industrial needs	The need weights	Information systems	Requiremewnt analysis	Methods and means of teaching	Formal models of the design process	Sociological investigations into design problems	Means of presenting of the design information	Methods of analysis, simulation, optimization, etc.	Automation systems of design	Methods of evaluation, estimation, benchmarking...	Infrastructure, means of integration of the systems	Prescriptive methods and models of design process	Methods of concurrent design
To improve the design quality													
Improve the decision making													
Improve the designers' co-operetion													
Integrate analysis with design													
To perfect industrial processes of realization													
To store and utilize the design experience													
To forecast the decision effects													
Continuous education													
To integrate analysis tools													
Creativity and innovation													
Shorten the time of realization													
Rationalization of the information infrastructure													
Optimization procedures													
Managing the complexity													
To improve evaluation and correcting the design													
To integrate the design information													
To improve comunication systems													
To improve the design for manufacturing and assembly													
To solve issues of integration of large companies													

The opinion of the industry about preparation of graduates to solving the design tasks in practice is in general sceptic [4]. Their preparation is considered as too ‘theoretical’, specialized too narrowly, not including the whole cycle of the product’s life, too general or too detailed, and so on. In the corporation representatives’ opinion, graduates of engineering faculties are not prepared to efficiently design and they have not any preparation to team work. An idea for improvement of the situation may be carrying out of evaluation of usefulness for industry of the issues conveyed to students at the universities.
In table 2. the sample needs of industry have been juxtaposed (lines) to the topics in the field of engineer design (columns). Completing of the cells where there is correlation between the industrial needs and subjects of the curricula provides one with information on particularly useful contents of the studies as well as on neglected areas. Obviously, both slogans set in the table and weights of the particular needs of the industrial practice can be and should be the subject of a thorough analysis. The table has not been completed on purpose. It has been located only in the aim of indication the way of determining suggested contents of teaching the design.
If there is relation between the topic of the research and the industrial need, one must put a proper symbol in the cells, for example: **!** (strong dependency), **X** (medium dependency) or **O** (weak dependency). In the column of the *weights* one should write numbers from 1 to 10 (the bigger the digit, the higher the value).
The table is a part of the questionnaire which was sent to 49 Polish SMEs [5]. The interviewees were persons from top or medium management with over ten years working experience in industry. The supplement of the questionnaire was an earlier interview with the participants of the regional annual meeting of PSME (Polish Society of Mechanical Engineers). The participants were shown the list of 32 domain-independent methods, which should be familiar to engineers. The responders were expected to indicate methods they knew, which were in use or should be used but they were not, etc. 22 engineers responded, they were mainly on the intermediate level of management.
About the half of the respondents stressed dissatisfactory work of the designers. First of all, they pointed at exceeding design time limits, not early detection of design errors and not improving projects due to the lack of time. The suggested reasons were little motivation of employees, too small number of designing staff, and also the lack of co-operation of designers with other divisions.
As a result of asking about domain-independent methods of design and manufacturing, only seven companies confirmed applying the adapted QFD, FTA, DFA and SPC methods. The rest of the companies introduced their own, based on experience and intuition, methods for overcoming current difficulties and a spontaneous group work forms. Majority of those companies experienced troubles with keeping time limits, improving product quality and too high production costs. The difficulties caused by insufficient application of CAD/CAM systems were also stressed in a few questionnaires.
From the repertoire of known but so far little used methods many of the participants of the survey mentioned CAD and computer simulation, customer needs analysis, various production cost methods analyses, design for manufacture, specification lists, planning and scheduling methods.
Only a few of the respondents knew portfolio analysis, morphological method, FMEA or DFA. Many had not heard about rapid prototyping, ABC analysis, objective/decision tree, decision matrices, QFD, DOE, FTA, robust engineering/Taguchi methods, brainstorming, benchmarking and the like.

4. SUMMARY

Owing to engineering achievements, the development of production and organization techniques as well as strong competition, demands for the industrial products change rapidly. In order to meet the competition as well as users’ demands, producers raise the quality of the products, improve the production processes and tighten the cooperative links. The questionaire surveys as well as common sense observations suggest the existence of the evident gap between young engineers’ skills and the demands they encounter in industry. The content and the style of the education process of the engineer designers at the universities do not keep pace with the changes in industry; the changes are too slow. The awareness that engineers must be educated for the future results indicates the importance of including in the education process forecasting techniques and the market needs. Identification of current and predicted industrial needs and their comparison with the contents of education will contribute to shorten adaptation time of young engineers in the new industrial environment as well as facilitate them to undertake the creation of new technology. Monitoring of industrial needs ought to be carried out systematically. The result of the operation should be periodical updating of education syllabuses. The tables in the paper show the way how the necessary information can be gained.
Perhaps the most deficient features of engineering courses are that they still focus on the transmission of a body of knowledge neglecting the preparation for a professional career [6]. As K. Ehrlenspiel emphasizes, universities are too much 'fact transmitters' and too little 'behavior transmitters' [7].
Subject-areas related to engineering design and design for production and manufacturing should take a stronger position in the engineering faculties curricula. Those who teach engineering design methods should verify their curricular contents in co-operation with industry. They should tend to modify methods in such a way that they could be attractive for professional designers. Apart from methods based on algorithmic procedures there is a

need to create 'soft methods' [8], easily adapted to human, organizational and market factors. Since it is evident that modern technology calls for computer systems, then design methods should also be offered in the form of ready-to-use software products. Demonstration of such kind of software should also be included in engineering design education.

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