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Impact of manufacturing engineering efficiency to the industry advancement

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1. Introduction

The manufacturing environment during later several decades has changed very much; it became modern and competitive for mastering new design and manufacturing methods in many industrial fields. The need of new products development and processes manufacturing engineering at the same time has increased. The new manufacturing strategy when developers, manufacturers, suppliers and customers are located in various companies and countries reduced new product lead time and delivery to customer.

Manufacturing engineering objective is to develop process for production of a new product choosing all necessary operations, machine tools, tooling and other aspects of planning and control of a manufacturing. It takes place between product design and the creation of the overall manufacturing process, as a planning and developing activity. Manufacturing engineering refers very broadly to all the activities required to create and produce products in the strong limit of budget, time and high innovation requirements and quality parameters. In other words, it is placed in the intermediate position between product design and production departments and includes a factory operation. Designers, unfortunately, give too little consideration to important product life cycle issues such as product parts' fabrication, assembly, test, repair, and modification. This is true even though designers are increasingly aware to design product parts so that they can be fabricated economically and still meet high performance requirements [1].

First steps solving manufacturing engineering problem were development of computer aided process planning (CAPP) systems aiming systematization of the work variety and creation of the product manufacturing process route [2]. The enterprise resources planning (ERP) systems in parallel have been developed also [3]. Later all these developments have been introduced into computer integrated manufacturing (CIM) systems [4]. The main problem of mentioned systems development is an imperfect use of overlapping cross-disciplinary work and neglecting of borderland research questions and implementation. If no real implementation in industry is applied, then no feedback of appropriate good practice and case studies are examined and disseminated, and best results and developments are achieved. Features of the manufacturing engineering, in particular, at the early stage of new product and process development still are analyzed insufficiently. The strongest effect of the manufacturing process, resources and costs has decisions and solutions made on the early stage of product and process development. On the other hand, for low production volume and high products variety, the lack of effective algorithms and mathematical models, other techniques and software leads to a block of new advancements in manufacturing engineering. The seminal collaboration among industrial organizations and technical universities and colleges guarantees finding of new development ideas in a manufacturing engineering field and getting the higher skill bachelors and masters. This is obviously in Lithuania and the whole European Union (EU), because many previous advanced manufacturing positions in EU step by step are lost. The new investments for theoretical and experimental works achieving advancement in manufacturing engineering and innovative products development are permanently made in the framework of EU research programs. This research partially is made applying such research fund.

The aim of this research is to develop and generalize theoretical methods of creative advancement the manufacturing engineering. It is based on wide collaboration among developers of products and processes, manufacturers, customers and people from universities. The work integration of various jobs in mental and experimental activity developing of new products, and approach of concurrent engineering and close cooperation among academia and industry are leading moments of this research. Research novelty of this paper is concentrated on the origination of the manufacturing people collaborative work methodology in different activity areas.

2. Manufacturing engineering advancement in modern manufacturing environment

Manufacturing engineering includes product design and manufacturing system design as well as operation of the factory during new product lead time to customer delivery. The well known methods of concurrent engineering and design for excellent are widely applied seeking overlapping of product and process design procedures. The increase of new products variety and performance, and decrease the production volume, product lead time and manufacturing cost pursues the developers to search new efficient methods and techniques for manufacturing engineering. Very efficient approach is integrated creation of new product and process applying modeling at the early product development stage and specialized software for structures and cost optimization [5, 6]. Many of these developments have been implemented in industry and universities study modules. The crisis, recession and high competition, unfortunately, forces to search the new ways to increase advancement of manufacturing engineering, because it can help seeking higher labor productivity, and success in marketplaces.

The long manufacturing engineering research experience of paper authors' and last research publications of

other explorers [7, 8] show that there are not enough new investments in this area. It is necessary to make many changes in manufacturing engineering routine, in particular, activating collaborative approach of this procedure, which is based on the learning through experience in work, education, research and new business situations created and checked by estimation of available alternatives. These new product and process alternatives are presumption of opportunities for manufacturing engineering and production innovation. Benchmarking methodology and appropriate consideration of laser and other high technologies impact on manufacturing efficiency in two EU countries sheet metalworking industry have been made [9]. The knowledge-based cross-disciplinary learning program is proposed for developers and employees to increase the competitive capabilities and collaboration [10]. It consists of virtual and rapid prototyping, computer integrated manufacturing and is illustrated by appropriate case studies and experimental examples.

The EU research project IRMA [11] displayed many problems in manufacturing engineering. Such situation demands to activate this procedure in both corporative and educational ways. Project IRMA research is based on the analysis of current situation of manufacturing engineering area in the all 27 EU countries by created appropriate questionnaire. It was three groups of analyzed problems: 1) co-operation level between universities and enterprises, 2) study programs related to the manufacturing engineering in universities, and 3) skills and competences management in universities and enterprises related to the manufacturing engineering. One university of technology and one technological faculty of other university, and twelve enterprises from Lithuania have been involved in the mentioned analysis. The results after poll have been systematized and proposals for improvement the collaboration among the enterprises and educational organizations seeking better advancement of manufacturing engineering have been made. The mentioned collaboration was oriented on the better partnership of universities and enterprises in sharing jobs among university lecturers and companies' engineers and managers, students practice and work after graduation. Special attitude was divided to industry input improving facilities, software and hardware, other technique in universities laboratories for manufacturing engineering studies. Very important are real industrial topics of Master Science (MSc) thesis and implementation of PhD students' research results. This approach has been developed on the analysis performed by comparing theoretical and practical issues of concurrent development products and processes.

3. Results and discussions

3.1. Estimation of manufacturing engineering level in Lithuanian industry

Estimation of manufacturing engineering level in Lithuanian industry by developed questionnaire of IRMA project promoter has been performed. Twelve private small and medium enterprises (SMEs) and one large company participated in the analysis. Analysis results showed that the majority (about 78%) considered enterprises have from 5 to 15 years of activity while rest enterprises have activity from 20 to 50 and more than 50 years. The number of employees fluctuated in the limits from 11 to 50 in 25% of enterprises, from 51 to 100 on 17%, from 101 to 500 on 42% and from 501 to 1000 on 17% of enterprises. Percentage of employees with academic backgrounds (university graduates) from 11 to 50 has been on 58% of enterprises while in the rest enterprises (42%) graduated people are les than 10%. In general, graduated specialists number in enterprises is sufficient, but the most part of graduates has been educated 10-20 years ago. This is a reason that enterprises have applied computers and appropriate software not sufficiently in manufacturing engineering area. On the other hand there is no necessary for intensive software application because small number of new products and engineering tasks.

The application of innovative manufacturing engineering methods using specialised software is presented in Table 1. Despite of 100% usage of modern software (SW) technologies, the other results are not very optimistic: even 42% of enterprises are not optimizing product design according to price and manufacturing cost. Only in 25% of enterprises CAPP systems usage is intensive, but 33% – rare and even 42% are not using CAPP system at all, maybe Lithuanian enterprises do not believe in their activity effectiveness applying CAPP systems.

Usage of ERP, MRP (Material Resources Planning) systems, logistics, innovation of manufacturing tools is very low too. Normally these systems use only 42% of Lithuanian enterprises and 17% use rarely or do not used implicitly.

Table 1

Innovative manufacturing engineering methods used at enterprises

Innovative method	Usage, %			
	Intensive	Normal	Rare	No used
Modern software (SW) technologies	25	42	33	0
Optimization of product design focused on price and manufacturing costs (CAD etc.)	25	33	0	42
Modern CAPP systems and their implementation	25	0	33	42
Approaches during the production phases	0	58	33	8
ERP, MRP systems, logistics, innovation of manufacturing tools	25	42	17	17
Environmental impacts of cutting edge manufacturing technologies	25	33	25	17

3.2. Cooperation level between industrial and educational sectors

The two Lithuanian universities (one technological) have participated in analysis. The general information of considered universities is presented in Table 2. For improvement of manufacturing engineering education in University of Technology *A* the innovative teaching methods and modern software have been implemented in the study process, as distance education environments (Moodle, WebCT, CDK, and so on), web-based interdiscipline learning platform "IIDSP" [10], Integrated Computer Aided Manufacturing Engineering system "SAT" [2], intelligent models for integrated product and process development, analysis and creation models of manufacturing process and cost forecasting at the early stage of a new product, or new business development stage [3, 5].

Table 2

General information of considered universities

General information	University of Technology A	University B (technological faculty)
Years of activity	More than 70	50
Number of students	15000-20000	10000-15000
Percentage of students doing their studies in the manufacturing engineering sector	6-10	6-10
Total number of teaching staff	1001-2000	1001-2000

The main manufacturing engineering advancement features as cooperation level between academia and industry, the match of universities study programs, the skills of university personnel and possibility to improve study programs and facilities have been analyzed and considered in this research. It was interesting to know enterprises opinion related with study programs further perfection seeking of manufacturing advancement. The technical staff as heads or leading specialists of product and process development departments in enterprises and computer-aided manufacturing engineering professors and lecturers in universities has been involved in this analysis. The level of cooperation features between universities and enterprises is illustrated in Fig. 1.

No intensive cooperation with universities; scale of cooperation with universities at the different levels is as follows:

- at the regional level: 50% of enterprises – "normal", and 42% – "rare";
- at the national level: only 25% of enterprises – "normal", and 75% – "rare" or "no cooperation";
- at the international level: only 8% of enterprises – "normal", and even 75% – "no cooperation".

The various cooperation activities and intensity among enterprises and universities have been applied (Table 3). The principal actions are cross participation in students' education and employees training, and creation of Master Science (MSc) students' thesis and PhD students' dissertations topics related to the manufacturing engineering problems. No intensive, unfortunately, cooperation and mostly "no cooperation" have been stated; usually rare enterprises' personnel participate in the trainings organised by universities. The rest features of cooperation activity are expressed as follows:

- enterprise's personnel participating in the trainings organised by universities: mostly "rare" (67% of enterprises);
- enterprise provides equipment or access to equipment for use, for a defined set of studies: mostly "no cooperation" (67% of enterprises);
- student / PhD mobility, traineeships within enterprise structures: mostly "rare" and "no cooperation" (33 and 33% of enterprises);
- exchange of personnel between enterprise and universities – participation in trainings / researches: only 33% of enterprises – "rare", and even 58% "no cooperation";
- cooperation with intermediaries / companies exits: mostly "rare" and "no cooperation" (42 and 25% of enterprises).

The research analysis results of the universities study programmes quality related to the manufacturing engineering are presented in Table 4. The majority of enterprises agree with quality of current programs or agree to some extent. Fig. 2 shows the common view of universities current study programs.

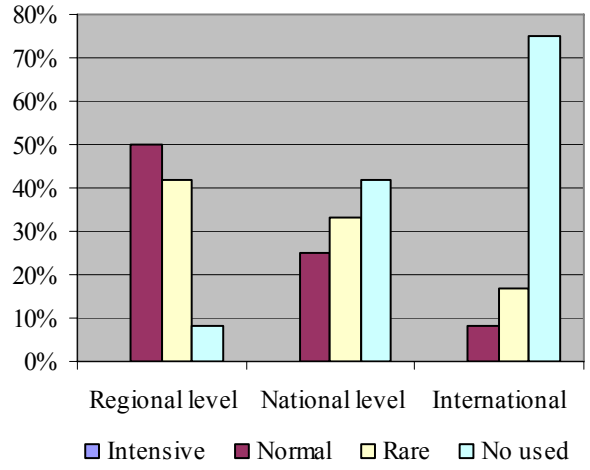

Fig. 1 Level of cooperation between universities and enterprises

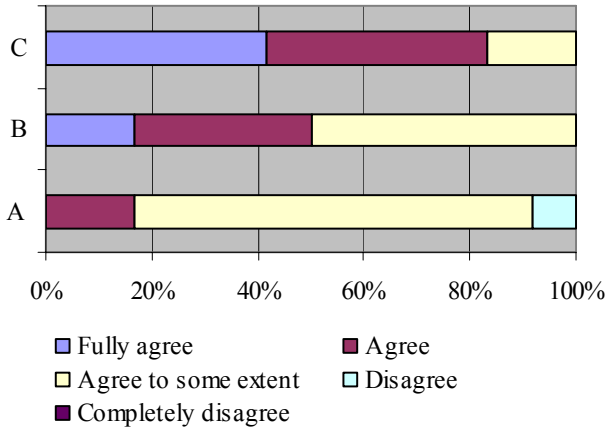

Fig. 2 The quality of universities study programs in education of manufacturing engineering

Table3

Activities covered by the cooperation between enterprises and universities

Activities	Opinion, %			
	Intensive	Normal	Rare	No cooperation
Enterprise's personnel participating in the trainings organised by Universities	0	17	67	17
Enterprise provides equipment or access to equipment for use, for a defined set of studies	0	0	33	67
Student / PhD mobility, traineeships within enterprise structures	0	33	33	33
Exchange of personnel between Enterprise and Universities – participation in trainings / researches	0	8	33	58
Cooperation with Intermediaries / Companies exits	8	25	42	25

Table 4

Universities study programmes quality related to the manufacturing engineering

Universities study programmes quality	Opinion, %				
	Fully agree	Agree	Agree to some extent	Disagree	Completely disagree
A: Study experience of graduates at university help prepare the graduates for the "enterprise world"	0	17	75	8	0
B: Universities graduates are well prepared from the theoretical point of view but they miss the practical skills	17	33	50	0	0
C: Lifelong learning activities are important at every level of studies and workplaces	42	42	16	0	0

Table 5

Organization features of cooperation among universities and enterprises

Organization of cooperation	Opinion, %				
	Fully agree	Agree	Agree to some extent	Disagree	Completely disagree
A: The current universities structure should be changed in order to be designed more for technology transfer / enterprise-universities cooperation	8	25	58	8	0
B: Establishment of a department / office as an interface between the institute and business groups should be created by universities.	8	33	25	33	0
C: Innovative / advanced study programmes at universities that allow the students to develop their enterprise skills.	8	58	33	0	0
D: Involvement of universities in the programmes for supporting the start-up business or enhancement of competitiveness of existing enterprises.	8	67	25	0	0
E: Work experience for undergraduates	17	50	33	0	0
F: Cooperation among universities at national / international level, exchange of best practise, experiences and knowledge within the university-enterprise cooperation	17	33	33	17	0
G: Student and personnel mobility – at regional, national and international level	8	33	50	8	0
H: Research projects at regional, national and international level in cooperation with enterprises and intermediaries	8	50	33	8	0
I: Facilitate access of enterprises to the research results	25	42	25	8	0
J: Market opportunities – analysis of needs and requirements of the local industry – in terms of education and training	25	58	17	0	0

Table 6

Cooperation among universities and enterprises – human resources development level

Human resources development level	Opinion, %				
	Fully agree	Agree	Agree to some extent	Disagree	Completely disagree
A: Personnel who deal with the technology transfer should be qualified in special training programmes – in order to be able to carry out their multiple roles efficiently.	42	58	0	0	0
B: Universities should appoint managers / researchers who have experiences in both areas – university and industry.	17	50	25	8	0
C: The current human resources are sufficient.	0	33	67	0	0

Table 7

The improvement of study programs at the universities

Improvement of study programs		Opinion, %				
		Fully agree	Agree	Agree to some extent	Disagree	Completely disagree
A: Universities should modernise and update their study programmes according the rapid evolution		50	50	0	0	0
B: The students should be involved in "young enterprise activities"		8	58	33	0	0
C: Lifelong learning initiatives should be a part of every university studies		42	42	17	0	0
Universities should cooperate with enterprises in the following areas	D1: Skills requirements analysis	17	67	17	0	0
	D2: Training needs analysis	17	33	50	0	0
	D3: Curriculum design	25	33	42	0	0
	D4: Job placements for gradual students	25	33	33	8	0
E: Developing projects of education and trainings together with enterprises		25	50	25	0	0

The results of a current cooperation state among universities and enterprises are given in Table 5. No responses that completely disagree with current cooperation status and minority that disagree. The majority of research analysis participants agrees with existing situation or agrees to some extent.

Table 6 illustrates the human resources development level of the cooperation among universities and enterprises. The participants in general agree (58-50%) that humans may have high skill and should be qualified in special training programs in order to be able to carry out their multiple roles efficiently. Fig. 3 shows a total participants view of humans' development.

Table 7 shows the industrialists' responses of the necessity to improve the study programs related to manufacturing engineering education in universities. In general, the majority of participants agree that universities should modernise and update their study programmes according to the rapid evolution of innovative technologies and new peculiarities in manufacturing environment. Moreover, universities should cooperate with enterprises in the graduates' skills and training needs analysis, curriculum design and job placements for gradual students. Fig. 4 and Fig. 5 demonstrate overall view of participants' opinion in accordance with human resources seeking efficient cooperation among industry and universities.

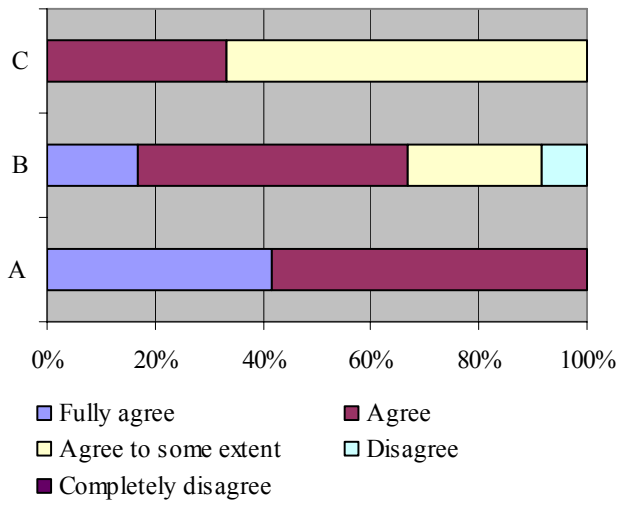

Fig. 3 Human resources development level of efficient cooperation

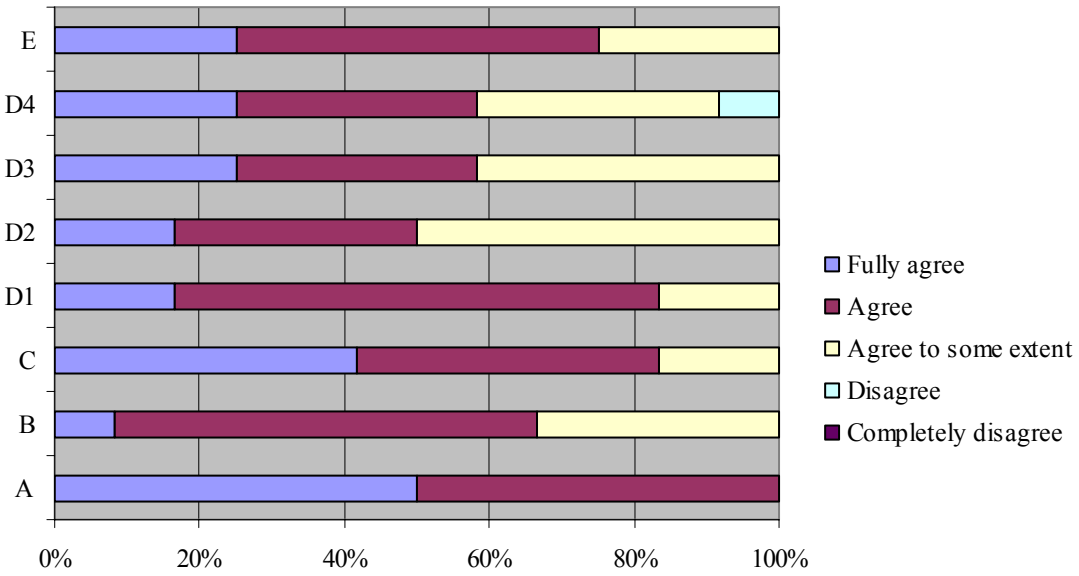

Fig. 4 Industrialists proposals for the study programs improvement

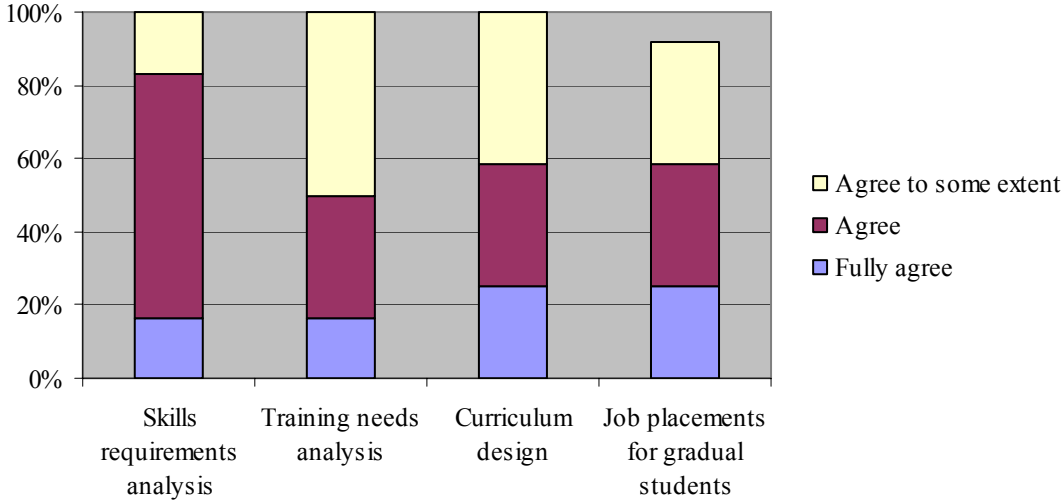

Fig. 5 Industrialists' proposals for the closer cooperation with universities

4. Conclusions

The research of this paper raised and considered actual cooperation efficiency problems among academia and industry in modern and new manufacturing environment. The cooperation is divided to improve manufacturing engineering education in universities and implementation in industry. It is stated many differences in understanding benefit of successful cooperation for both sides improving manufacturing engineering. On the other hand there are some common points of view how to improve the efficiency of such cooperation. The research is based on the responses of questionnaire; therefore, some subjectivity is available. Briefly it is concluded.

1. Low current cooperation level among universities and enterprises on national and international standard (25%) and no any cooperation (75%).
2. Rare enterprises' personnel trainings organized by universities and equipments providing to universities (67% of enterprises).
3. Small number of enterprises people participate in universities students education process (58% of enterprises not cooperate and 33% rare).
4. Only 17% of enterprises agree that universities prepare graduates for "enterprise world".
5. 67% of enterprises agree to involve in university curricula study modules for supporting the graduates to start-up business or enhancement of competitiveness of existing enterprises.
6. Universities should modernize and update their study modules in accordance of rapid manufacturing evolution (50% enterprises fully agree and 50% agree).

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GAMYBOS INŽINERIJOS EFEKTYVUMO ĮTAKA PRAMONĖS PLĖTRAI

R e z i u m ė

Straipsnyje nagrinėjama gamybos inžinerijos efektyvumo įtaka pramonės pažangai. Gamybos inžinerijos tikslas – sukurti naujo gaminio gamybos procesą parenkant visas reikalingas operacijas, įrenginius, įrangą ir nurodant kitus gamybos planavimo bei valdymo aspektus. Šie darbai atliekami baigus kurti gaminio konstrukciją prieš planuojant visą gamybos procesą. Pateikiamas naujas kūrybiškas požiūris į gamybos inžinerijos metodus, pagrįstas plačiu bendradarbiavimu tarp gaminių ir procesų kūrėjų, gamintojų, pirkėjų ir universitetų. Svarbiausia šio tyrimo kryptis – įvairių intelektualių ir eksperimentinių darbų integravimas kuriant naujus gaminius, vienalaikės inžinerijos metodų taikymas bei glaudus akademinio ir pramonės sektorių bendradarbiavimas. Nagrinėjami pagrindiniai pramonės ir inžinerinių studijų sektoriaus darbuotojų bendradarbiavimo aspektai. Straipsnyje pateikiami pasiūlymai studijų programoms, metodams ir kitoms techninėms priemonėms gerinti.

A. Bargelis, R. Mankute

IMPACT OF MANUFACTURING ENGINEERING EFFICIENCY TO THE INDUSTRY ADVANCEMENT

S u m m a r y

This paper deals with manufacturing engineering efficiency to the industry advancement. Manufacturing engineering objective is to develop process for production of a new product choosing all necessary operations, machine tools, tooling and other aspects of planning and control of manufacturing. It takes place between product design and the creation of the overall manufacturing process, as a planning and developing activity. The new approach of creative advancement in manufacturing engineering methods has been proposed. It is based on wide collaboration among developers of products and processes, manufacturers, customers and people from universities. The work integration of various jobs in mental and experimental activity developing of new products, and approach of concurrent engineering and close cooperation among academia and industry are leading moments of this research. The main aspects of collaboration industrialists and people in educational area are showed and discussed. The proposals for improving study programs, methods and other techniques are presented in this research.

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ВЛИЯНИЕ ЭФФЕКТИВНОСТИ ПРОИЗВОДСТВЕННОЙ ИНЖЕНЕРИИ НА МОДЕРНИЗАЦИЮ ПРОИЗВОДСТВА

Р е з ю м е

В публикации исследуется влияние эффективности производственной инженерии на модернизацию производства. Цель производственной инженерии – создание производственного процесса нового изделия, указывая все необходимые операции, оборудование, оснастку и другие аспекты планирования и организации производства. Эти работы производятся после создания конструкцию изделия перед планированием всего производственного процесса. Представляемы новый творческий подход к методам производственной инженерии основан на широком сотрудничестве между создателями изделий и процессов, производителей, покупателей и университета. Главное направление исследования – интегрирование разных интеллектуальных и экспериментальных работ создавая новые изделия, использование методов одновременной инженерии и близкое сотрудничество академического и производственного секторов. Исследуются основные аспекты сотрудничества работников производства и сферы образования. В статье представлены рекомендации для улучшения образовательных программ, методов и других технических мероприятий.

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