INTERNATIONAL JOURNAL FOR SCIENCE
AND INNOVATIONS FOR THE INDUSTRY

INNOVATIONS IN DISCRETE PRODUCTIONS

YEAR III, ISSUE 1/2015, SOFIA
ISSN 1314-8907

Publishers:

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING

NATIONAL SCIENTIFIC TECHNICAL SOCIETY
AUTOMATION IN DISCRETE PRODUCTIONS

INTERNATIONAL JOURNAL FOR SCIENCE AND INNOVATIONS FOR THE INDUSTRY

INNOVATIONS IN DISCRETE PRODUCTIONS

YEAR III, ISSUE 2 / 2015
ISSN 1314-8907

EDITORIAL BOARD

1. Prof. Dr. Dimitar Damianov – chairman, BG
2. Prof. Dr. Ivo Malakov, BG
3. Prof. Dr. Dimcho Chakarski, BG
4. Rrof. Dr. Todor Neshkov, BG
5. Prof. D.Sc. Vesko Panov, BG
6. Prof. Dr. Lubomir Dimitrov, BG
7. Prof. Dr. Sc. Hristo Shehtov, BG
8. Prof. Dr. Sc. Kiril Angelov, BG
9. Prof. Dr. Diana Antonova, BG
10. Prof. Dr. Vassil Kostadinov, BG
11. Prof. Dr. Stefan Kartunov, BG
12. Prof. Dr. Ivan Dimitrov, BG
13. Prof. Dr. Kakha Demetrashvili, GE
14. Prof. Dr. Silviu Makuca, RO
15. Prof. Dr. Predrag Dasic, RS
16. Prof. Dr. Ivan Lashin, RU
17. Prof. Dr. Uwe Fuessel, DE
18. Assos. Prof. Dr. Pancho Tomov, BG

Publishers:

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING

NATIONAL SCIENTIFIC TECHNICAL SOCIETY AUTOMATION IN DISCRETE PRODUCTIONS

108, Rakovski Str., 1000 Sofia, Bulgaria, **tel.** (+359 2) 987 72 90, **tel./fax** (+359 2) 986 22 40**,** journal@mech-ing.com,

CONTENTS

THE APPLIANCE OF OPEN INNOVATION CONCEPT IN SMEs IN REPUBLIC OF MACEDONIA

Asst. Prof. Janevski Z. PhD.[1], Asst. Prof. Davitkovska E. PhD.[1], Res. Asst. Petkovski V. PhD.[1],
Institute of Economics - Skopje, "Ss. Cyril and Methodius" University in Skopje, Republic of Macedonia [1]
E-mail: zoran.janevski@ek-inst.ukim.edu.mk, elena@ek-inst.ukim.edu.mk, vladimir@ek-inst.ukim.edu.mk

Abstract: *The open innovation is a concept of growing acceptance in the field of innovation management. It is based on the idea that companies can leverage the knowledge generated externally to improve their innovation performance. Open innovation as a process can promote shorter innovation cycles, increase in industrial research, and better optimization of the resources. However the process of open integration is much harder for implementations in SMEs than larger enterprises. The reasons behind the low integration of the open innovation as a process can be seen in the low capacity of the SMEs to deal with the open innovation process, low awareness of the benefits of the open innovation process, lack of knowledge for the intellectual law and rights, etc. This paper is based on the empirical research on 63 SMEs, in order to determine the factors (reasons) for low implementation of the open innovation process in the SMEs in Republic of Macedonia.*

Keywords: OPEN INNOVATION, SME, SMALL AND MEDIUM-SIZED ENTERPRISES, INNOVATION ABSORPTION, INNOVATION PROCESS

1. Introduction

The open innovation is a concept of growing acceptance in the field of innovation management. It is based on the idea that companies can leverage the knowledge generated externally to improve their innovation performance. Open innovation is based on the traditional innovation process which represents a crucial aspect of promoting the growth and development of SMEs. But the process of innovation is usually foreseen as a great financial burden for the SMEs, and inquiring finance for the relatively long and enduring process of research and innovation can present a devastating process for the SMEs [1]. Therefore, new ways of innovation must be looked for, in which open innovation represents a viable alternative for companies. Open innovation as a process can promote shorter innovation cycles, increase in industrial research, increased innovation and better optimization of the resources [2]. Open innovation is defined as "the purposive use of inflows and outflows of knowledge to, respectively, accelerate internal innovation, and expand the markets for external use of innovation process" [3]. Open innovation can be a part of any of the four different types of innovation including the innovation in process of production, innovations in business model, innovations in product and innovation in organization. All of these types of innovations can be made easer through the concept of open innovation, by creating a mutual trust between the SMEs and their innovation partners.

The SMEs sector is very important for Macedonian economy. According to the data of the State Statistical Office [4], the number of active business entities in the Republic of Macedonia in 2014 was 70,659 and SMEs represent 99.7 percent of them. They engaged about 76.7 percent of total number of employees and created 65.6 percent of the value added [5].

According to the Innovation Union Scoreboard 2014 [6] Republic of Macedonia is a modest innovator ranking 31st out of 35 countries with Summary Innovation Index of 0.2458 much below 0.5539 which is the EU average. Situation with SME's innovation are even worst. Macedonia is ranked 31st based on SMEs innovating in-house indicator (0.0155), and 19th regarding Innovative SMEs collaborating with others indicator (0.3590) which gives some perception on open innovation adoption by the SMEs in Republic of Macedonia. Regarding innovation outputs, SMEs introducing products or process innovations indicator is 0.5938 (ranked 15th) and SMEs introducing marketing/organizational innovations indicator is 0.3615 (ranked 24th). So, the open innovation is still a relatively new process in Republic of Macedonia with only small portion of enterprises actually practicing it [7]. The reasons behind the low commitment to the innovation in general can be seen in the lack of innovation network, lack of funding and venture capitalist and very small percentage of GDP devoted to research and development [7]. The low capacity of absorption and the technical problems which SMEs face considering the implementation of new research and developments techniques puts the SMEs into an utmost difficult position on the bargaining side of the process that is open innovation. Despite the larger enterprises witch can reserve a lot more assets into the research and development program SMEs rely on having their idea and innovation process increase their chances of market success. But, the lack of information and data concerning the process of open innovation is one of the possible reasons for low level of awareness for the process of open innovation amongst the Macedonian SMEs. [7]. Also, the lack of networking structure at national and regional level on tackling Open Innovation issues can be foreseen as one of the crucial problems for implementation of open innovation process especially among SMEs.

This paper concerns awareness and constraints for adoption open innovation strategies in SMEs in Republic of Macedonia. The constrains have been categorized and reviewed concerning four open innovation aspects: human constrains, general constrains, policy constrains, and constrains that have evolved due to the rise of global competition [8].

2. Theoretical Review

Open innovation is a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with each organization's business model [9]. This means knowledge inflows to the focal organization (leveraging external knowledge sources through internal processes), knowledge outflows from a focal organization (leveraging internal knowledge through external commercialization processes) or both (coupling external knowledge sources and commercialization activities) [9]. The traditional (closed) innovation system has some serious shortcomings and there is an urgent need of establishing a contemporary innovation system – an open innovation system. The contrasting principles of closed and open innovation are presented on Table 1.

Table 1: *Comparison between Closed and Open Innovation Principles.*

Closed Innovation principles	Open Innovation principles
The smart people in the field work for us.	Not all the smart people in the field work for us. We need to work with smart people inside and outside the company.
To profit from R&D and Innovation, we must discover it, develop it, and ship it ourselves.	External R&D and Innovation can create significant value: internal R&D and Innovation is needed to claim some portion of that value.
If we discover it ourselves, we will get it to the market first.	We don't have to originate the research to profit from it.
The company that gets an innovation to the market first will win.	Building a better business model is better than getting to the market first.
If we create the most and the best ideas in the industry,	If we make the best use of internal and external ideas, we will win.

We should control our IP, so that our competitors don't profit from our ideas	We should profit from others' use of our IP, and we should buy others' IP whenever it advances our business model.

There are two important kinds of open innovation: outside-in and inside-out. The outside-in part of open innovation involves opening up a company's innovation processes to many kinds of external inputs and contributions. Inside-out open innovation requires organizations to allow unused and underutilized ideas to go outside the organization for others to use in their businesses and business models [10]. In contrast to the outside-in branch, this portion of the model is less explored and hence less well understood, both in academic research and also in industry practice. In order to further improve the scientific capabilities and commercialize the research output from projects such as the LHC, new businesses and business models must be identified, explored, and undertaken [10].

In addition to being beneficial for large "firms as well as for small and medium-sized enterprises (SMEs) [3], SMEs can open their own innovation processes to implement internal ideas otherwise unexplored, to ensure access to external ideas, to enable better utilization of their partially hidden innovation potential, to share the wealth and efficiency in resource allocation (e.g. per unit cost accounting basis), to extend their potential for growth via alliances and or attraction of funding, to be offered ample opportunities by larger companies to access resources/knowledge otherwise far too expensive for them [11].

3. Empirical Research

The research aims to acquire knowledge about open innovation adoption by SMEs in Republic of Macedonia. The focus is to identify SMEs characteristics especially related to their innovation activities in general, and in open innovation process in particular. The main goal is to identify Macedonian open innovation trends and practices and identify constraints for open innovation adoption. Several specific objectives of this research are:

- To assess the level of open innovation awareness amongst Macedonian SMEs
- To assess the open innovation adoption by SMEs
- To identify the key actors involved in open innovation process in Macedonia
- To recommend measures to improve open innovation adoption rate by SMEs

The survey was conducted using a questionnaire as a research tool for data collection. The questionnaire was developed and placed online using the Google Drive, and emails with a request to fill in the questionnaire were sent to 63 SMEs. Responses were received from 36 respondents, representing 57 percent response rate which is much higher than the average response rate of 35.7 percent for studies that utilized data collected from organizations [12]. Still, the margin of error for this sample size is 16.7 percent, so the survey results are not representative, but only indicative and will use as a pilot for tuning the final design of full research that will be carried out in the next phase.

Respondent sample is consisted of 21 micro, 14 small and 1 medium enterprises. Almost one fifth of all enterprises (19.4 percent) do not have innovation budget at all, and 44.4 percent spent only 0-1 percent from their income on innovation activities (Table 2).

Table 2: *Percentage of income spent on innovation activities.*

Percentage of income spend on innovation [%]	Percentage of enterprises [%]
0	19.4
0-1	44.4
1-2	8.3
2-4	25.0
4-6	0.0
6-10	0.0
10-15	0.0
15+	2.8
Grand Total	100.0

SMEs in Macedonia do not pay much attention on innovation activities. The results also show that 72.3 percent of all enterprises do not have employees dedicated to any innovation activities (16.7%) or only 0-3 percent of the employees are part of some innovation activities in the company (55.6%) (Table 3).

Table 3: *Employees dedicated to innovation activities.*

Percentage of employees dedicated to innovation from all employees [%]	Percentage of enterprises [%]
0	16.7
0-3	55.6
3-6	11.1
6-10	2.8
10-15	0.0
15-20	8.3
20-30	0.0
30+	5.6
Grand Total	100.0

83.3 percent of all SMEs have not heard about the concept of Open Innovation, and 94.4 percent have no knowledge about Open Innovation concept at all. Despite the low awareness amongst Macedonian SMEs, 54.5 percent of all SMEs have cooperated with other companies or organizations in any of their innovation activities, so the SME are not aware of, but still they use the Open Innovation concept.

Table 4: *Main Innovation Partners of Macedonian SMEs.*

Type of Innovation Partner	Mean	n
Suppliers of equipment, materials, components or software	7.5	21
Clients or customers from the private sector		9
Government, public or private research institutes		8
Universities or other higher education institutes		7
Clients or customers from the public sector		5
Competitors or other enterprises in the sector		5
Consultants or commercial labs institutes		0

Table 4 illustrates the type of innovation partners of the SMEs. According to the results the most common partners into their innovation activities are their suppliers (38.2 percent) and clients from the private sector (16.4 percent). The most unlikely partners of the SMEs in innovation activities are the clients from the public sector, competitors and consultants or commercial labs.

Table 5: *Open Innovation Concept Applicable per Type of Innovation.*

Open Innovation Concept Used or Intended to be Used per Type of Innovation		n	Response rate [%]
Product Innovation	Yes	28	84.8
	No	5	15.2
Process Innovation	Yes	15	83.3
	No	3	16.7
Business Model Innovation	Yes	21	80.8
	No	5	19.2
Organization Innovation	Yes	20	18.7
	No	3	13.0

Table 5 shows the percentage of SMEs that intent to use or are already using the concept of Open Innovation for different type of innovation activities. According to the results, all four types of innovation activities are appropriate to be implemented with the Open Innovation concept.

80.6 percent of the SMEs have dedicated no part of their innovation budget for Open Innovation activities, have no dedicated employees for open innovation and also have no product developed in the last three years which is based on the open innovation principles. 19.4 percent of all respondents spent 0-5 percent of their innovation budget on open innovation activities, resulting in 0-10 percent of their new products developed implementing open innovation concept.

According to the answers provided by the SMEs presented on Table 6, the key constraints regarding Human Resources are the scarcity of skilled employees in their companies (93.3 percent) and the high level of the wages which is burden for their financial condition (36.7 percent).

Table 6: *Key Constraints in Implementing Open Innovation in SMEs.*

Key Constraints	n	Response rate [%]
Recruiting Constraints (Human Resources)		
Scarcity of skilled employees	28	93.3
Wages of the skilled employees are too high, it is a great burden for us	11	36.7
General Constraints		
Lack of knowledge in implementing new technology	18	54.5
Lack of quality managers in the country	18	54.5
The labor market lacks skilled workers	17	51.5
Competition Constraints		
Increase quality of product/service	24	72.7
Increase marketing activity	22	66.7
Policy Constraints		
Government policies, laws and regulations	19	73.1
Unfavorable business climate	17	65.4

The main general constraints are the lack of knowledge to implement new technology (54.5 percent) and the lack of skilled workers on the Macedonian labor market (51.5 percent). In an era of globalization and enormous influence that Internet technologies have on people's private and professional life, the competitiveness constraints to adoption of the open innovation competition constraints, or activities that should be undertaken to compensate the barriers related to competition. The first one is to increase the quality of the products/services (72.7 percent) and to increase the marketing activities (66.7 percent). The last aspects of the constraints for implementing Open innovation in SMEs are the so called policy constraints.

Table 7: *Factors Affecting Success of Implementing Open Innovation Concept in SMEs.*

Open Innovation Success Factors for SMEs	n	Response rate [%]
Support by the top management	19	57.6
Collaborators' training for Open Innovation	18	54.5
Allocate enough resources (employees, time and budget)	14	42.4
Managing an idea generation process (selection and prioritization of the ideas)	11	33.3
Managing the intellectual property (protection and valorization)	11	33.3
Ability to measure Open Innovation success in Enterprises	9	27.2
To have a corporate culture that promotes idea-sharing	7	21.2
Support by the middle management	3	9.1
Existence of systematic and organized approach for acceptance of external ideas	3	9.1
Proper selection and encouraging of partnerships	3	9.1

The last aspects of the constraints for implementing Open innovation in SMEs are the so called policy constraints. Macedonian SMEs have identified the following two key constraints: 1) problems with the government policies, laws and regulations that are not in favor of the open innovation concept, and 2) the unfavorable business climate presence in the country.

Results presented on Table 7 shows that according to the SMEs themselves three main factors important for successful implementation and practice of Open Innovation concept in SMEs are: Support by the top management, Collaborators' training on Open Innovation and Allocation of enough resources (including employees, time and budget) dedicated to Open Innovation.

4. Conclusion

SMEs on their innovation path can follow two possible approaches. The first one is to perform the innovation activities fully in-house (so called close innovation), but for small firms this is a big challenge because they typically struggle with lack of financial resources, scant opportunities to recruit specialized workers, poor understanding of advanced technology, and so on. The second approach is to adopt an innovation model to use ideas and knowledge from outside the firm's boundaries, so called open innovation concept.

The awareness of Macedonian SMEs on Open Innovation is not satisfactory. It is evident from the research results that in general they do not pay proper attention on innovation activities (both closed and open), but the fact that they do not have even idea and information on good SMEs open innovation practices and strategies should raise a 'red flag' among all innovation stakeholders in the country.

The research finds that the two main constraints for the low level of open innovation adoption rate by the SMEs are the problem related to the scarcity of skilled employees and the problem with the government policies, laws and regulations that are not supportive to the open innovation paradigm.

Despite overcoming both key constraints depend more on innovation policy makers, the SMEs themselves could make some actions to improve as well. The research suggests that the most obvious measures are to build a strong commitment and support for open innovation concept by the SME's top management (in most cases the owners of the firms), and to take joint activities with firm's collaborators and partners with focus on promotion and training on Open Innovation concept.

5. Literature

[1] Zimmermann Volker (2014), KfW SME Panel 2013: How German SMEs finance their innovations, KFW Economic Research, pg. 1-3.

[2] Gassmann Oliver & Enkel Ellen (2004), Towards a Theory of Open Innovation: Three Core Process Archetypes, Institute of Technology Management, University of St. Gallen, Switzerland, pg. 1-2.

[3] Chesbrough Henry (2006), "Open Innovation: The New Imperative for creating and Profiting from Technology", Harvard Business School Press, United States, pg. 2.

[4] State Statistical Office of Republic of Macedonia. 2015a. Number of active business entities, 2014. News Release No: 6.1.15.14. Available at: http://www.stat.gov.mk/pdf/2015/6.1.15.14.pdf [Accessed 18 May 2015].

[5] State Statistical Office of the Republic of Macedonia. 2015b. MAKStat Database. Available at http://makstat.stat.gov.mk/pxweb2007bazi/Dialog/Saveshow.asp [Accessed 18 May 2015].

[6] European Commission (2014), Innovation Union Scoreboard 2014. European Commission, Brussels.

[7] Josimovski Sasho (2011), “Thematic Report 2011 under Specific Contract for the Integration of INNO Policy Trend Chart with ERAWATCH”, Pro Inno Europe, pg. 9-15.

[8] Rahman Hakikur & Ramos Isabel (2013), “Challenges in Adopting Open Innovation Strategies in SMEs: An Exploratory Study in Portugal”, Issues in Informing Science and Information Technology, Volume 10, pg. 435.

[9] Chesbrough Henry & Bogers Marcel (2014), “Clarifying an Emerging Paradigm for Understanding Innovation, Explicating Open Innovation”, Explicating Open Innovation, ISPIM, Dublin.

[10] Chesbrough Henry (2015), “From Open Science to Open Innovation”, Institute for Innovation and Knowledge Management, ESADE, Science Business Publishing.

[11] ANNAIN, VDC & INNONET (2011), “Open Innovation: Benefits for SMEs”, EURIS, Brussels.

[12] Baruch, Yehuda & Holtom C. Brooks (2008), “Survey response rate levels and trends in organizational research”, Human Relations vol. 61 no. 8, pg. 1139-1160.

TECHNOLOGY HIGH-SPEED SHARPENING CARBIDE TOOLS

ТЕХНОЛОГИЯ ВЫСОКОСКОРОСТНОГО ЗАТАЧИВАНИЯ ТВЕРДОСПЛАВНЫХ ИНСТРУМЕНТОВ

A.P. Rechenko D., Titov Y., Balova D.
Department of cutting machines and tools, OmSTU, Omsk, Russian Federation

Abstract: *Modern machines allow to position cutting tools relative to the workpiece with an accuracy of 1 micron, but increasing of producing detail accuracy can be achieved only by an increase of sharpness of the cutting tool, which will guarantee allow to cut required metal pads of the size of 2 ... 5 microns, and will reduce the time spent on finishing operations. Existing manufacturing techniques and sharpening of cutting tools let to receive the sharpness of the blade up to 10 microns. A further increase of sharpness is only possible with the use of high-speed sharpening.*

Modern machines allow to position cutting tool relating to workpiece within the accuracy of 1 µm, but fabrication operation accuracy increase can be achieved only with increasing of sharpness of cutting tool that will guaranteed allow to cut necessary metal pad of size 2…5 µm, and also will allow to decrease time spending on finishing operations. Existing fabrication and sharpening technologies of cutting tool allow getting blade sharpness up to 10 µm. Further increasing of sharpness using existing technologies and equipment is impossible [3, 4, 5].

Existing equipment of aerospace enterprises with metal cutting tool doesn't supply stable quality and production of processing key details of aircraft engine and rockets. That's why production of engines comes to individual (selective) selection while assembling engine components. That is existing technologies, wherein cutting tool, process conditions and metal-working machinery, do not make it possible to get stable sizes and quality of work pieces surface in full. The best accuracy that enterprises can really reach in cutting edge machining is approximately 10 µm.

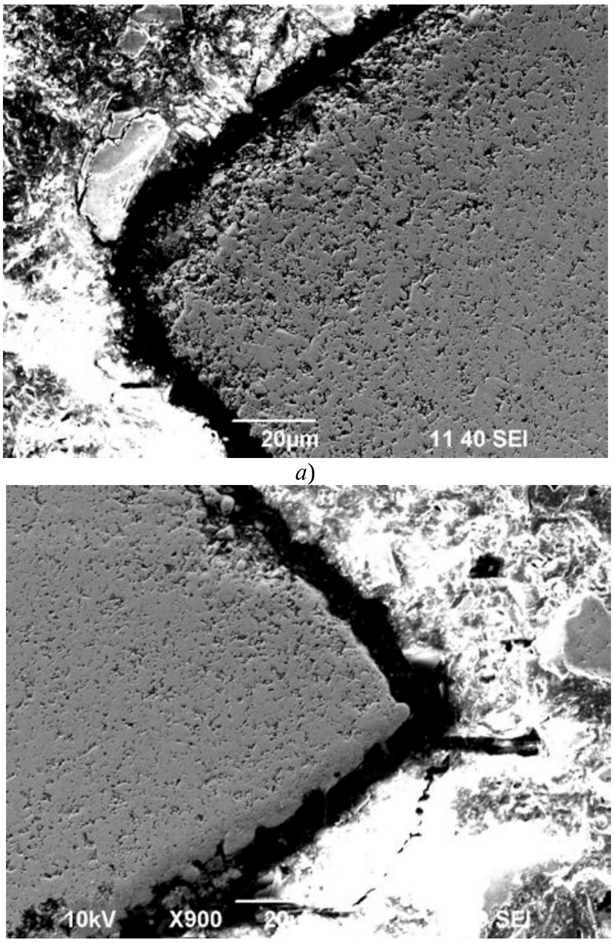
While making turbine blade disk many spark-out operations are utilized at manufacture. It is related to the fact that existing machines and software allow to position cutting tool in relation to work part with accuracy of 1 µm, however, metal cutting tool that is used for treating heat resistant alloy, has sharpness (cutting blade corner radius) of 10…15 µm. For reaching required manufacturing accuracy machine operator has to size details many times, at that, while moving cutting tool for 10 µm, it is pressed into the detail, however, there is no cutting action because of its fragility. The machine operator has to increase depth of cut and repeat the action, at that during another approach cutting edge cuts into the detail and cuts metal pad to excess that can lead to defect of the detail. Using existing metal cutting tool it's almost impossible to get required accuracy.

Of all the details of aircraft engines, building from heat-resistant alloys, 20% satisfy requirements of manufacturing accuracy, defect list is compiled for 50% of the details (at that their value decrease for 1/3) and 30% are completely discarded. Taking into account this fact, engine builds by selective method with the fittest sizes. In the most cases during engine repairing it's impossible to change worn part for a new one, because while producing the standardization is not providing. For standardization it's necessary to increase accuracy of manufacturing that will lead to increasing of details number that fit to size requirements.

For cost savings and increasing in performance of aircraft details manufacture from heat resistant alloys, it's necessary to solve scientific and technical problem of cutting tool development with the blade corner radius less than 1 µm (super blade). This tool will let to decrease number of details with damages, decrease defective goods on account of accuracy increase and production efficiency.

Classical methods and mode of sharpening with using of finishing operations allow to get the blade with sharpness not less than 5…6 µm (illustration 1,a). Machining was at the sharpening mode of *V*=30…40 m/s, *S*=1…1,5 m/min and *t*=0,01 mm/ double stroke.

High speed machining was at the sharpening mode of *V*=260…280 m/s, *S*=1…1,5 m/min and *t*=0,01 mm/double stroke it allows to get the blade with sharpness of 1…2 µm (illustration 1,*b*).



a)

b)

Fig.1. *Blade carbide cutting tool, from:*
a) the classical sharpening with finishing operation;
b) high speed sharpness

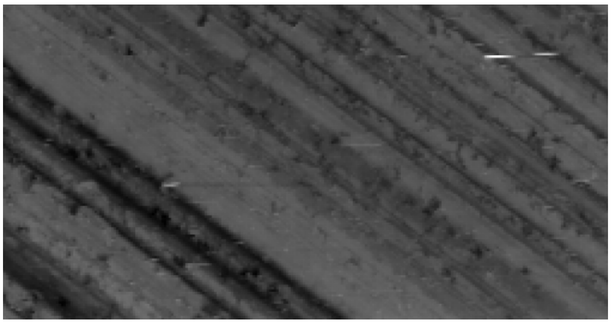
Researches were conducted on a scanning electron microscope Jeol JCM-5700. X-ray analysis is shown in Table 1. Error measurement is from 0.32 to 0.47%.

Table 1

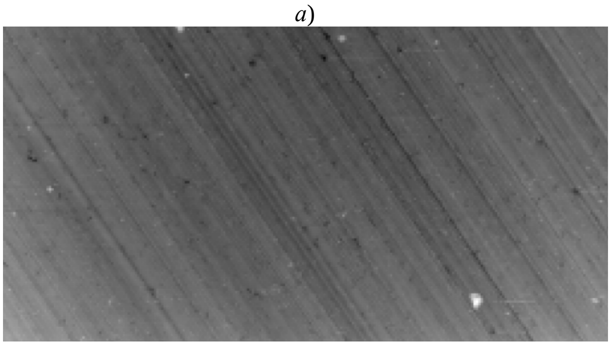
Element	Classical sharpness	High speed sharpness
	Mass %	**Mass %**
C	18.77	14.84
O	2.25	-
Co	5.49	6.06
W	73.49	79.09
Total	100.00	100.0

Table 1 shows that for a classical sharpening WC content (tungsten carbide) is about 92%, and Co (cobalt) is about 5.5% and O (oxygen) is about 2.25% that confirms the formation of oxides on the surface of the cemented carbide. Changes in the chemical composition say about high temperatures and may be cutting forces while sharpening. Thus at high speed sharpening WC content (tungsten carbide) is about 94%, and Co (cobalt) is about 6%, which corresponds to the initial composition and to the GC1105 alloy condition (Sandvik Coromant). At the same time on the tested surface oxides are not observed.

Parameters of surface and quality of sharpening are shown in figure 2 and table 2.



a)



b)

Fig. 2. *The machined surface obtained:*
a) the classical sharpening with finishing operations;
b) high speed sharpening

Table 2

Parameter	**Classical sharpening**	**High speed sharpening**
The average value of the microrelief	3,496 µm	0,350 µm
The maximum value of the microrelief	5,105 µm	0,393 µm
The minimum value of the microrelief	1,910 µm	0,323 µm
Blade corner radius	8…10 µm	0,8…2 µm

Main researches in this work are related to obtaining high-quality blade carbide cutting tool that provides an opportunity of sharpening different steels used in the aviation and aerospace industries with the potential accuracy of the technological system. We considered steel 12X18H10T and alloy VT3-1.

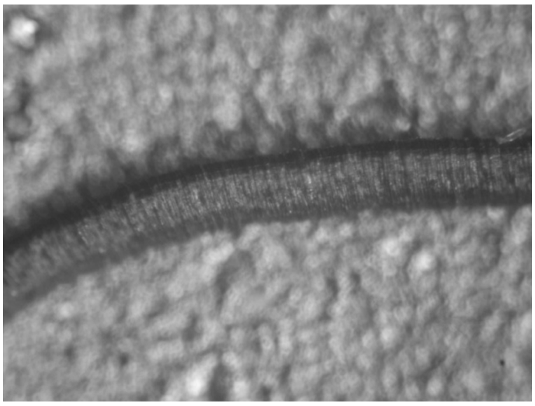
Using of carbide with a corner radius of less than 1 µm, on turning operations it is possible with cutting depth not less than 2-3 µm. To confirm this assertion, researches were conducted at the outer turning of parts: from steel 12X18H10T, HRC 41 ... 42; titanium alloy VT3-1, HRC 39 ... 40 (initial diameter D = 42,8 mm and the length L = 20 mm) on the lathe with CNC EMCO 450 Concept Turn. Turning was carried out with sharpened carbide blade CNMG 120408 alloy 1105 Sandvik Coromant (the sharpness of the blade is 0.8 ... 1 µm) at cutting speeds V = 60 and 120 m / min, feeding S = 0,05 and 0.08 mm / rev and the depth t = 3 µm.

The results of the researches:

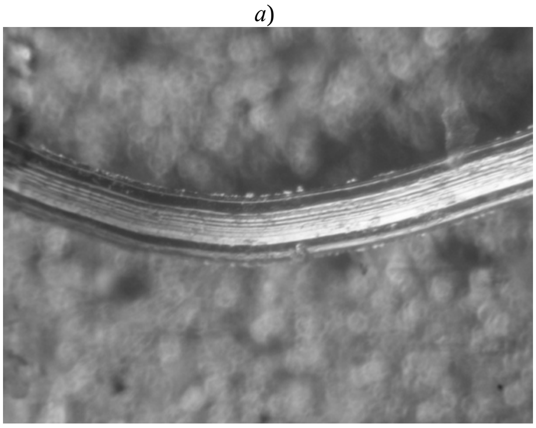
1. Turning was provided at the cutting depth of 3 µm and control of the size of the parts was made every 10 passes, and the obtained size was monitored and compared with the required nominal. According to the obtained measurements was developed characteristic curve of resistance of carbide. The magnitude of technological wear of the plate is assumed equal to 10 µm in all cases.

2. Dependencies of resistance of cutting tools for turning steel 12X18H10T has the form: T = 0,000 • V2 - 0,338 • V + 50,6; when turning VT3-1: T = 0,000 • V2 - 0,25 • V + 37.

3. Figure 3 shows a cutting formed as a result of processing. The type and shape corresponds to the normal type of chips. The length of microcuttings is 5 ... 10 mm. Cauterizes and annealing colors are not observed one the cuttings, that indicates small value of the contact temperatures.



a)



b)

Fig. 3. *Cuttings, obtained by treating:*
a) top surface, x500; б) cutting chip surface, x500

4. The quality of the detail treated surface that is determined with the height of the irregularities is sufficiently high. The magnitude of irregularities (surface roughness) is in the range of Ra = 0,08 ... 0,12 µm. The accuracy in size is $\Delta = \pm$ 0,25 µm (deviation of the actual size from the nominal size).

Working accuracy and machined surface quality is a logical and appropriate because working accuracy and surface quality is 5-8% of the depth of cut.

References

1. Yanyushkin A.S., Lobanov D.V., Kuznetsov A.M., Stlidzan M.V. Analysis of methods for determining the radius of rounding cutting // Proceedings of the Bratsk state University: Series of the Natural Sciences and engineering. V. 2. Bratsk: BrSU, 2006. P. 256-260.
2. Yanyushkin, A.S. Technology instrumental supply of products from composite non-metallic materials. / A.S. Yanyushkin, D.V. Lobanov ; Bratsk. - 2012. - 296 p.

FORCES AND DEFORMATIONS IN THE LINEAR ROLLER BEARING

СИЛИ И ДЕФОРМАЦИИ В ЛИНЕЕН РОЛКОВ ЛАГЕР

Assoc. Prof. Pandev G., PhD., Eng.,
Faculty of Applied Mechanics – University of Chemical Technology and Metallurgy, Sofia, Bulgaria
gpep@uctm.edu

Abstract: *To the modern machines, especially those for the workflow automating, have been made more greater demands regarding the accuracy of their work under different conditions. In relation to this, in most constructions have been used linear bearings, which are especially suitable because of a number of their advantages.*

The present article aims to show the determination of the forces and deformations of a linear roller bearing of specifically selected series, depending on the speed and acceleration at work, as forces and friction coefficients in different parts of the bearing have been previously specified and taken into account in the calculation.

As a result of the dimensioning it becomes possible to determine the duration of operation of the linear roller bearing of the so-set conditions, and the deformations in the various parts under load.

Keywords: LINEAR ROLLER BEARING, DIMENSIONING,

1. Introduction

Comparing the characteristics of different systems allows bearings to identify their advantages and disadvantages when operating in specific conditions and in certain construction of machinery.

The linear bearings are widely used in the precise mechanics, automation, and devices to measure and control because of their following advantages over the other types of bearings: sliding, hydrostatic and others :

- Absence of any kind of windage;
- A guaranteed interchangeability, based on the rapid development of their standardizing, resulting in minimizing the operating costs;
- Very low friction, depending on the speed of displacement.

In the present publication it will be considered a specific type of linear bearings [3,4], which are characterized by a very high precision of manufacturing and load capacity. This allows them to be put in constructions, requiring absence of windage, specified stiffness, low coefficient of friction. As a result, the construction of the machine is characterized by a long duration of operation. The load capacity, rigidity and duration of operation are highly dependent on the number and shape of the rolling elements constituting the construction of the linear bearing.

The friction coefficient μ while sliding, depends to a large extent on the nature of the material of the contacting elements, the state of their surfaces, load and speed. Its values are in the range 0.05 to 0.2 [1]. It increases very quickly when the sliding speed tends to 0 - then the value of μ can reach a maximum value of 0.3. Depending on the construction embodiment, the coefficient of friction μ in the linear bearings in question has a value from 0.0005 to 0.005, which is approximately 10 to 400 times smaller than that of a sliding bearing of the same dimensions.

The dynamic load (load capacity) C of a linear bearing corresponds to the duration of operation, equivalent to 100,000 m displacement, wherein the load of the elements remains constant – it does not change in value and in direction. At the same time, the static load must not be in any case greater than the dynamic one.

The duration of the exploitation (resource of work) of the linear bearing is defined as the distance in meters traveled by one of its guiding to the first signs of fatigue from one of the constituent elements.

The constructional varieties of linear bearings are the following:

- With a separator for pellets, rolls, or needles;
- With an insert for recirculation of the pellets or rolls;
- With a monorail (Fig. 1). This type of a linear bearing is characterized by a high rigidity, great dynamic and static load capacity, stable functioning, and a very good sealing of the support.

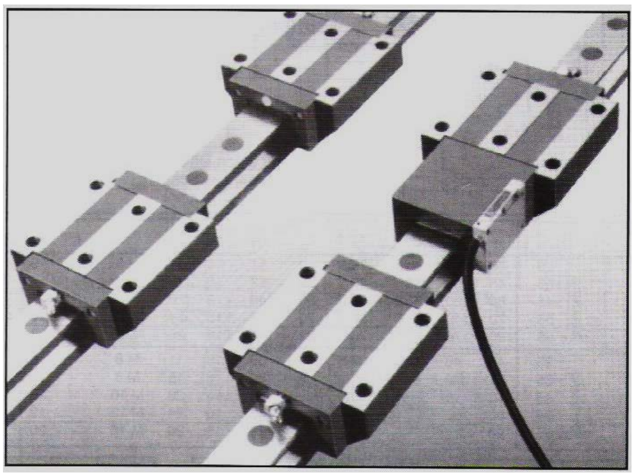


Fig. 1. *Linear roller bearing type monorail*

The objective of this article is to show the determination of the forces and deformations of linear roller bearing and choosing a particular series, depending on the load, speed and acceleration at work, as the frictional forces in different parts of the bearing and the coefficient of friction have been specified in advance and taken into account when calculating.

2. Characteristics of linear roller bearing

They are the following (Fig. 2) [3]:

- Four classes of tolerances : from G0 to G3;
- Three classes of preloading: V1, V2 and V3, defined as a percentage of the load capacity C;
- Five type sizes (series) : 25, 35, 45, 55 and 65;

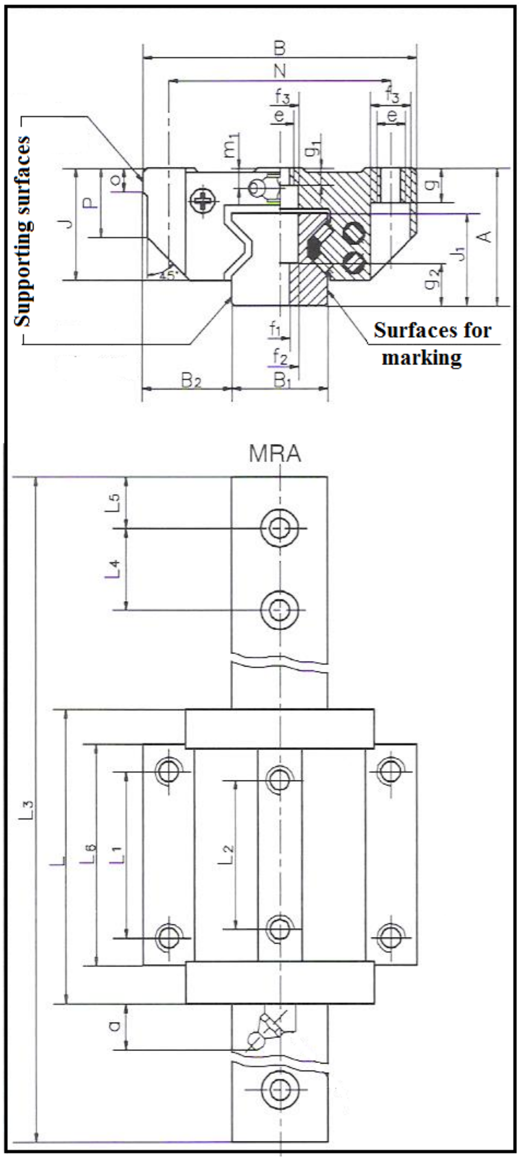


Fig. 2. *Construction of the linear roller bearing series MRA*

- Four series : Table 1.

Table 1. Series of linear roller bearing

Indication	MRA	MRB	MRC	MRD
Type of the support	standard	standard long	compact	Compact long

●The linear roller bearing operates in a temperature range from **-40°C** to **+80°C**, as for a short period can last up to +120°C.

- The standard length of the rail is calculated by the formula

(1) $\mathbf{L_3 = (n + k.p).L_4 + 2.L_5\ (\pm\ 2\ mm)}$, (Fig. 2) [3]

as the values of n, p and k are given in Table 2.

*Table 2. The value of the coefficients **n**, **p** and **k***

Series	n	p	k
MR 25	9	6	1 to 16
MR 35	14	5	1 to 13
MR 45	10	4	1 to 11
MR 55	12	4	1 to 9
MR 65	7	4	1 to 7

- The loading and the types of variations of the support of the bearing are shown on Figure 3.

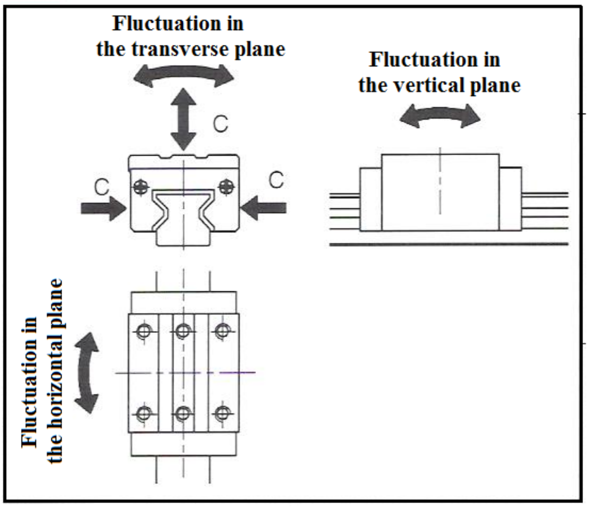


Fig. 3. *Loading C and fluctuations of the support*

The functioning of a linear roller bearing in normal conditions is performed at a speed up to 3 m/s (180 m/min) and acceleration up to 50 m/s^2 [2,3].

In cases where the lubrication of the bearing is carried out with oil, the power for moving F_R can be determined under dependency (2) for speeds lower than 30 m / min, as the coefficients of friction are shown in Table 3.

(2) $$\mathbf{F_R = F_{A,G} + v\ .\ f_{A,v} + F_{w,G} + v\ .\ f_{w,v} + F_j\ .\ \mu,}$$

where :

$\mathbf{F_R}$ – force for moving, N
v – speed, m/min
$\mathbf{F_{A,G}}$ – friction force of cleaner of lubricant at low speed, N
$\mathbf{f_{A,v}}$ – friction coefficient of cleaner of lubricant in a function of the speed, (N)/(m/min)
$\mathbf{F_{w,G}}$ – friction force of the the support at low speed, N
$\mathbf{f_{w,v}}$ – coefficient of friction of the support in a function of the speed, (N)/(m/min)
$\mathbf{F_j}$ – the sum of all external forces applied to the the support, N
μ – friction coefficient of the bearing.

When lubricating of the bearing with grease the friction force in the support $\mathbf{F_{w,G}}$ is initially the same as with the lubrication with an oil, but decreases after a few operation cycles outward - return.

Table 3. Values of the coefficients and the forces of friction lubrication with oil for linear bearing with a class of pretension V2

			MRA/MRC	MRB/MRD		
Series	$\mathbf{F_{A,G}}$ **(N)**	$\mathbf{f_{A,v}}$	$\mathbf{F_{w,G}}$ **(N)**	$\mathbf{F_{w,G}}$ **(N)**	$\mathbf{f_{w,v}}$	**μ**
25	7	0,15	5	6	0,25	0,001
35	9	0,20	8	10	0,35	0,001
45	11	0.25	12	15	0,50	0,001
55	13	0,30	16	20	0,70	0,001

3. An example for dimensioning a linear roller bearing

The presented example shows how to determine the limit of resistance against fatigue. It has not yet been developed a method for determining the limit of wear resistance.

The forces acting on the linear roller bearing, can be determined by approximation of the linearized characteristic curve of the deformations in all cases of its application.

As a result has always been obtained an approximate value, as the characteristic curve of the support can be linearized, while the elastic deformations of the rest of the structure of the bearing are overlooked.

__3.1. Determination of the impacts on the support (Fig. 4)__

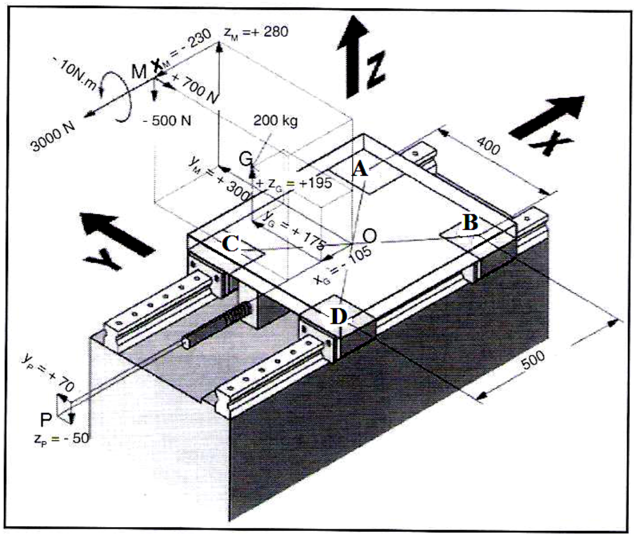


Fig. 4. *Coordinates and load applied on the the support*

The matrix of external influence on the bearing, seen in point **M** (-230, +300, +280), has the following form:

$$\tau_1 = \tau_{(ext \to syst)} = {}_{M}\left\{ \begin{matrix} -3000, & -700, & -500 \\ -10, & 0, & 0 \end{matrix} \right\}$$

This matrix is calculated for point O (0,0,0) by:

$$\tau_1 = {}_{O}\left| \begin{matrix} -3000, & -700, & -500 \\ -10 + (0{,}3x\text{-}500) - (0{,}28x\text{-}700), & 0 + (0{,}28x\text{-}3000) - (\text{-}0{,}23x\text{-}500), & 0 + (\text{-}0{,}23x\text{-}700) - (0{,}3x\text{-}3000) \end{matrix} \right\}$$

The moment to point O is determined by the relationship

$\overrightarrow{M_O} = \overrightarrow{M_M} + \overrightarrow{OM} \wedge \overrightarrow{\mathbf{R}}$ and then for τ_1, reduced in point O is obtained

$$\tau_1 = {}_{O}\left\{ \begin{matrix} -3000, & -700, & -500 \\ 36, & -955, & 1061 \end{matrix} \right\}.$$

The impact of the transmission mechanism on the system of the linear bearing is applied in point **P** (0, +70, -50) and then the matrix has the form:

$$\tau_2 = \tau_{(transm \to syst)} = {}_{P}\left\{ \begin{matrix} F, & 0, & 0 \\ 0, & 0, & 0 \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} F, & 0, & 0 \\ 0, & -0{,}05.F, & -0{,}07.F \end{matrix} \right\}$$

The interaction between of the bearing and the rail of the support is seen in the following four points – A, B, C и D (Fig. 4).

In point **A** (+K/2, +Q/2, 0) the rail of the bearing has an impact on the support A and the matrix τ_3 is:

$$\tau_3 = \tau_{(rail \to supp.A)} = {}_{A}\left\{ \begin{matrix} X_A, & Y_A, & Z_A \\ L_A, & M_A, & N_A \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} 0, & Y_A, & Z_A \\ 0{,}5\,Q.Z_A, & -0{,}5\,K.Z_A, & 0{,}5\,K.Y_A \end{matrix} \right\}$$

as $X_A = 0$, the friction forces are negligible, $L_A = 0$, $M_A = 0$ и $N_A = 0$ provided that the rigidity of the system is high enough and the geometry is sufficiently accurate to disregard the moments of the fluctuations of the support in the three planes as shown in Figure 3.

In an analogous manner is defined the impact of the rail and the support in the remaining three points – B, C and D.

In point **B** (+K/2, -Q/2, 0) the rail impacts on the support B :

$$\tau_4 = \tau_{(rail \to supp.B)} = {}_{B}\left\{ \begin{matrix} 0, & Y_B, & Z_B \\ 0, & 0, & 0 \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} 0, & Y_B, & Z_B \\ -0{,}5Q.Z_B, & -0{,}5K.Z_B, & 0{,}5K.Y_B \end{matrix} \right\}$$

In point **C** (-K/2, +Q/2, 0) the rail impacts on support C :

$$\tau_5 = \tau_{(rail \to supp.C)} = {}_{C}\left\{ \begin{matrix} 0, & Y_C, & Z_C \\ 0, & 0, & 0 \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} 0, & Y_C, & Z_C \\ 0{,}5Q.Z_C, & 0{,}5K.Z_C, & -0{,}5K.Y_C \end{matrix} \right\}$$

In point **D** (-K/2, -Q/2, 0) the rail impacts on support D :

$$\tau_6 = \tau_{(rail \to supp.D)} = {}_{D}\left\{ \begin{matrix} 0, & Y_D, & Z_D \\ 0, & 0, & 0 \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} 0, & Y_D, & Z_D \\ -0{,}5Q.Z_D, & 0{,}5K.Z_D, & -0{,}5K.Y_D \end{matrix} \right\}$$

In point **G** (-105, +175, +195) the weight force acts on the system and then

$$\tau_7 = \tau_{(weight \to syst)} = {}_{G}\left\{ \begin{matrix} 0, & 0, & -P \\ 0, & 0, & 0 \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} 0, & 0, & -P \\ -0{,}175.P, & -0{,}105.P, & 0 \end{matrix} \right\}$$

After bringing all matrices to point O, it can be applied the principle of the dynamics :

(3) $$\tau_1 + \tau_2 + \tau_3 + \tau_4 + \tau_5 + \tau_6 + \tau_7 = \delta$$

as

(4) $$\delta = {}_{G}\left\{ \begin{matrix} -m.\gamma, & 0, & 0 \\ 0, & 0, & 0 \end{matrix} \right\} = {}_{O}\left\{ \begin{matrix} -m.\gamma, & 0, & 0 \\ 0, & 0{,}195.\,m.\gamma, & -0{,}175.m.\gamma \end{matrix} \right\}$$

m = 200 kg, the mass of the system

$\gamma = 6$ m/s^2, the maximum acceleration.

As a result is obtained the following system of six equations

(5.1) $-3000 + F = -m.\gamma$
(5.2) $-700 + Y_A + Y_B + Y_C + Y_D = 0$
(5.3) $-500 + Z_A + Z_B + Z_C + Z_D - P = 0$
(5.4) $36 + 0{,}5Q(Z_A - Z_B + Z_C - Z_D) - 0{,}175P = 0$
(5.5) $-955 - 0{,}05F + 0{,}5K(-Z_A - Z_B + Z_C + Z_D) - 0{,}105P = 0{,}195m.\gamma$
(5.6) $1061 - 0{,}07F + 0{,}5K(Y_A + Y_B - Y_C - Y_D) = -0{,}175m.\gamma$

From equation (5.1) can be determined the force F :

(6) $\mathbf{F} = 3000 - m.\gamma = 3000 - (200 \,.\, 6) = 3000 - 1200 = \mathbf{1800}$ **N.**

Equations (5.2) and (5.6) contain 4 unknowns. From the hypothesis that the geometry is perfect and rigidity of the system is infinite, it can be assumed that under the influence of moments around an axis z, we have $Y_A = Y_B$ и $Y_C = Y_D$.

These two equations can be presented as

$$700 + 2Y_A + 2Y_C = 0$$

$$1061 - 0{,}07.1800 + 0{,}5K.\,2(Y_A - Y_C) = -0{,}175 \,.\, 200 \,.\, 6$$

from where is obtained: $\mathbf{Y_A = Y_B = -550}$ **N**, $\mathbf{Y_C = Y_D = +900}$ **N.**

Equations (5.3), (5.4) and (5.5) contain four unknowns. The acceptance of the same hypothesis as above allows to make the following assumptions:

- $Z_{A/F} = Z_{B/F} = Z_{C/F} = Z_{D/F} = \mathbf{Z_F}$, where $Z_{A/F}$ is the vertical force, exerted by the rail on support A, and it represents the sum of the vertical forces (the same goes for $Z_{B/F}$, $Z_{C/F}$ and $Z_{D/F}$);
- $Z_{A/Mx} = -Z_{B/Mx} = Z_{C/Mx} = -Z_{D/Mx} = \mathbf{Z_{Mx}}$, where $Z_{A/Mx}$ is the vertical force, acting through the rail on the support A, and occurring a sum of the moments, relative to an axis x (the same goes for $Z_{B/Mx}$, $Z_{C/Mx}$ and $Z_{D/Mx}$);
- $Z_{A/My} = Z_{B/My} = -Z_{C/My} = -Z_{D/My} = \mathbf{Z_{My}}$, where $Z_{A/My}$ is a vertical force, acting through the rail on support A, and occurring a sum of the moments, relative to an axis y (the same definition goes for $Z_{B/My}$, $Z_{C/My}$ and $Z_{D/My}$).

Then from equation (5.3) is obtained

$Z_A + Z_B + Z_C + Z_D = 4.Z_F = (m.g) + 500 =$
$= (200.9{,}81) + 500 = 1962+500 = 2462$ N.

Or $\mathbf{Z_F} = 2462/4 = Z_{A/F} = Z_{B/F} = Z_{C/F} = Z_{D/F} = 615{,}5$ N.

From equation (5.4) follows

$Q/2 \,.\, (Z_A - Z_B + Z_C - Z_D) = Q/2 \,.\, (4 \,.\, \mathbf{Z_{Mx}}) = 0{,}175\ P - 36$
$= (0{,}175 \,.\, 200 \,.\, 9{,}81) - 36 =$
$= 343{,}36 - 36 = 307{,}35$ N.m

Then $\mathbf{Z_{Mx}} = 307{,}35/2.Q = 307{,}35\ /2.0{,}4 = 384$ N =
$= Z_{A/Mx} = - Z_{B/Mx} = Z_{C/Mx} = - Z_{D/Mx}$

From equation (5.5) is obtained

$K/2 \,.\, (- Z_A - Z_B + Z_C + Z_D) = K/2 \,.\, (4.Z_{My}) = - 2.K.Z_{My} =$
$= - 0{,}195 \,.\, m \,.\gamma + 0{,}105 \,.\, P + 0{,}05 \,.\, F + 955 =$
$= - 0{,}195.200.6 + 0{,}105.200.9{,}81 + 0{,}05.1800 + 955 = 1017$ N.m

Then $\mathbf{Z_{My}} = 1017/2.K = 1017/2.0{,}5 = 1017$ N =
$= Z_{A/My} = Z_{B/My} = - Z_{C/My} = - Z_{D/My}$

Then we receive

$Z_A = Z_{A/F} + Z_{A/Mx} + Z_{A/My} = 615{,}5 + 384 - 1017 = -\ 17$ N
$Z_B = Z_{B/F} + Z_{B/Mx} + Z_{B/My} = 615{,}5 - 384 - 1017 = -\ 786$ N
$Z_C = Z_{C/F} + Z_{C/Mx} + Z_{C/My} = 615{,}5 + 384 + 1017 = +2017$ N
$Z_D = Z_{D/F} + Z_{D/Mx} + Z_{D/My} = 615{,}5 - 384 + 1017 = +1248$ N.

From the obtained results it can be concluded that the vertical force impacting by the rail on the supports A and B shall be designed in a negative direction of z-axis and thus subjecting them to strength.

The vertical force acting through the rail respectively on the supports C and D, is designed in a positive direction of z-axis and subjecting them to pressure.

From the calculations made was established, that the linear roller bearings of the series **MRC 25 V1** may incur without a problem values obtained for the forces [4].

3.2. Resource of working of the bearing L

It is determined by the equivalent force P and a dynamic load C by the relationship:

(7) $L = a\,(C/P)^{10/3} \,.\, 10^5$ m,

where a – safety coefficient.

The equivalent force P_i, which is used in formula (7) depends on the one hand on the calculated above forces in the four points of the the support, and on the other hand on the applied preloading :

(8) $P_i = F_P + 2/3 \,.\, F_i \rightarrow$ when $F_i \leq 3.\, F_P$

(9) $P_i = F_i \rightarrow$ when $F_i > 3 \,.\, F_P$

where F_P – force of preloading,

and $F_i = |Y_i| + |Z_i|$.

For the selected in the above section linear roller bearing, the dynamic load C = 27 700 N [4], and the preloading is 3% for it. Then

$F_P = 27\ 700 \,.\, 0{,}03 = 831$ N,

which allows to determine the following equivalent workloads :

$F_A = |-550| + |-17| = 567$ N or $P_A = 831 + 2/3.567 = 1209$ N.

$F_B = |-550| + |-786| = 1336$ N or $P_B = 831 + 2/3.1336 = 1722$ N.

$F_C = |+900| + |-2017| = 2917$ N or $P_C = 2917$ N.

$F_D = |+900| + |-1248| = 2148$ N or $P_D = 2263$ N.

From the above results it is established that the support is the busiest in p. C. Its resource of working L at a safety coefficient a = 1.0.

(10) $L = 1{,}0 \,.\, (27\ 700/1980)^{10/3} \,.\, 10^5 = 660 \,.\, 10^6$ m.

3.3. Determination of deformations

To determine the values of deformations under load the bearing is used Formula 11. It linearizes the elastic deformations of the support at a load.

(11) $\delta = (D \,.\, F)/C$,

where :

D – Elastic deformations of the the support under load equal to dynamic load C;

F – load on the the support (compression, tension, torsion).

For linear roller bearing of the series **MRC 25** the values of D are the following :

MRA/MRC 25	Compression	Tension	Torsion
V1	36	62	52
V2	34	56	46
V3	30	53	44

The values of the estimated deformations are given in Table 4.

Table 4. *Values of the deformations in the support*

Supp.	Condition	Calcul	Value exact
A	Tension	$\delta_1 = 62.17/27\ 700 = 0\ \mu$	$\approx 0\ \mu$
A	Torsion	$\delta'_1 = 52.550/27\ 700 = 1\ \mu$	$\approx 1\ \mu$
B	Tension	$\delta_2 = 62.786/27\ 700 = 1{,}76\ \mu$	$\approx 1{,}5\ \mu$
B	Torsion	$\delta'_2 = 52.550/27\ 700 = 1\ \mu$	$\approx 1\ \mu$
C	Compr.	$\delta_3 = 36.2017/27\ 700 = 2{,}62\ \mu$	$\approx 4\ \mu$
C	Torsion	$\delta'_3 = 52.900/27\ 700 = 1{,}7\ \mu$	$\approx 1{,}5\ \mu$
D	Compr.	$\delta_4 = 36.1248/27\ 700 = 1{,}62\ \mu$	$\approx 2{,}5\ \mu$
D	Torsion	$\delta'_4 = 52.900/27\ 700 = 1{,}7\ \mu$	$\approx 1{,}5\ \mu$

4. Conclusions

There have been analyzed the advantages of linear roller bearings relative to other constructions of bearings. It was found that the coefficient of friction in the linear roller bearing is for example 10 to 400 times smaller than that of the sliding bearing of the same size, which is beneficial to the bearing capacity and its operation.

There have been considered in detail the characteristics of the linear roller bearing – the classes of the tolerances, of the preloading, the series, the temperature range, and the conditions under which it can work - speed, acceleration, load. There have been determined the friction forces between different parts of the bearing at oil lubrication.

It has been solved an example with predefined specific output values, and has been chosen a corresponding series of a linear roller bearing, taking into account all impacts on the support, based on which has been solved a system of six equations. It allows to be identified the forces, acting in the four points of the support, as well as the type of tensions - tension and compression. It has been specified the resource of working on the linear roller bearing, according to the specified busiest point of the the support, as well as the deformations in those points.

References

1. АРНАУДОВ К., И.Димитров, П.Йорданов, Л.Лефтеров. Машинни елементи. Техника, София, 1980.
2. CHEVALIER A. Guide du dessinateur industriel. Edition HACHETTE *Technique*, 2004.
3. Corbet J.-Cl., A. Ducruet, L. Huchet. Le CODOTEC, 1996.
4. Prospect SCHNEEBERGER, 2012.

VIRTUAL FULL FACTORIAL EXPERIMENT IN THE SIMULATION OF A CONTINUOUS PROCESS SPD COMMERCIALLY PURE TITANIUM WITH THE INFLUENCE OF FRICTION FACTOR

ВИРТУАЛЬНЫЙ ПОЛНЫЙ ФАКТОРНЫЙ ЭКСПЕРИМЕНТ ПРИ МОДЕЛИРОВАНИИ НЕПРЕРЫВНОГО ПРОЦЕССА ИПД ТЕХНИЧЕСКИ ЧИСТОГО ТИТАНА С УЧЕТОМ ВЛИЯНИЯ ФАКТОРА ТРЕНИЯ

Leading Researcher, Dr. Semenov V.I.[1, 2], Prof., Dr. Huang S.-J.[3], Prof., Dr. Shuster L.Sh.[2], Assoc. Prof., Dr. Chertovskikh S.V.[2]

[1]Institute of Oil and Gas Technologies and Novel Materials, Ufa, Russia,
semenov vi@rambler.ru

[2]Ufa State Aviation Technical University, Ufa, Russia
okmim@ugatu.ac.ru, agraab@mail.ru

[3]National Taiwan University of Science and Technology, Taiwan, R.O.C.
sgjghuang@mail.ntust.edu.tw

Abstract: *With the use of computer modeling in the environment of the DEFORM-3D software, a virtual full factorial experiment has been conducted for the processing of commercially pure titanium by equal-channel angular pressing (ECAP) via the Conform scheme. In the course of the modeling, the effect of independent parameters (the rotation velocity of the working wheel, the friction factor on the lateral surfaces of the working wheel and the friction factor between the billet and the die) has been evaluated. As a result of the experiment, a regression equation has been obtained and the most important individual factors and their mutual combinations that influence the response parameter (strain intensity) have been identified.*

KEYWORDS: *COMPUTER MODELING, COMMERCIALLY PURE TITANIUM, VIRTUAL FULL FACTORIAL EXPERIMENT, FRICTION FACTOR, STRAIN INTENSITY.*

1. Introduction

Currently, there is interest in research aimed at enhancement of the strength of metals by microstructure refinement to a submicrocrystalline (SMC) size using severe plastic deformation (SPD) processing [1]. One of the SPD processing techniques is equal-channel angular pressing (ECAP) [2, 3] and its advanced modification - ECAP-Conform [4], which was developed to produce long-length billets with a bulk SMC structure and enables creating preconditions for practical implementation of SPD processing. Fig. 1 illustrates the principle of the ECAP-Conform process.

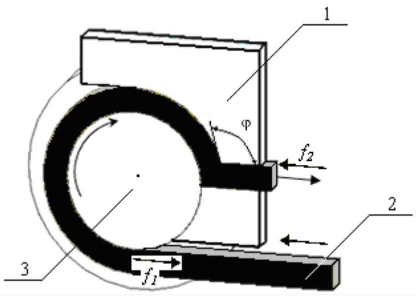


Fig. 1. *Principle of an SPD technique - equal-channel angular pressing - Conform (ECAP-Conform): 1 – stationary die; 2 - billet; 3 – working wheel - punch*

This process, based on structure refinement by SPD processing and implemented on an ECAP-Conform setup, is an effective way to increase the strength of metals and alloys. However, to produce long-length semi-products using this process, it is necessary to solve the problem caused by a revealed contradiction. This contradiction lies in the fact that to feed the billet in the deformation zone, it is necessary to use active friction force on the lateral surfaces of the working wheel, i.e. to have the maximum friction coefficient (f_1). At the same time, to implement directly the deformation process and produce high-quality semi-products with a defect-free surface, it is required to ensure the lowest value of the friction coefficient (f_2) in the deformation zone.

The use of fragmentary application of a lubricant only on those surfaces where it is necessary to have a low friction coefficient leads to lower productivity and mechanization of SPD processing. The processing, which is already not cheap, becomes even more expensive. Thus, to improve the efficiency of SPD processing by the ECAP-Conform technique is necessary to find a compromise solution, which would enable the use of one option of preparation of the billet surface prior to deformation processing, able to ensure the feeding of the billet in the deformation zone and fabrication of semi-products of the required quality in the deformation process.

In scientific and practical activities, in particular, in the analysis of tribological systems, of significant importance are numerical methods for the study of complex processes, including computer modeling using the latest software products [5, 6]. The efficiency of the methods applied for modeling and solving of engineering problems grows significantly, if at the stage preceding the design of the actual manufacturing process, conditions are created to assess the influence of the most important independent parameters.

The application of mathematical methods is one of the most rational approaches to solving problems related to assessing the effectiveness of non-standard metal forming processes. In this regard, it seems reasonable to conduct numerical simulation using the planning of a virtual full factorial experiment (FFE) [7].

The advantage of FFE is the ability to describe the process in full compliance with the algorithm of physical experiment, taking into account the established assumptions. FFE is the most easily implementable method among the numerous methods of physical experiment. The aim of conducting the FFE is to obtain a linear mathematical model of the process, which will allow defining the future strategy for conducting a real experiment.

Thus, the purpose of modeling is to perform a virtual SPD processing by ECAP-Conform with the use of FFE, and to identify the rational processing velocity in combination with a universal preparation of the billet surface in the conditions of fabrication of long-length SMC semi-products.

2. Research procedure

In order to obtain more complete information about the studied dependencies, the authors used FFE when performing modeling. Experiment planning is a procedure of selecting the number and conditions of the experiments, which are necessary and sufficient to obtain a mathematical model of the process [8]. It is important to consider the following: a tendency to minimize the number of experiments; simultaneous variation of all variables that determine the process; the choice of a clear strategy that allows making grounded decisions after each series of experiments. Prior to planning a full-scale experiment, it is necessary to gather additional information about the object under study, employing the skills and knowledge obtained in previous studies, or described in literature [9].

The planning of the experiment was conducted on the basis of the modeling of the processing of long-length semi-products from commercially pure titanium, using the ECAP-Conform technique. The principle of the device for ECAP-Conform is presented in Fig. 1.

The object of study is commercially pure titanium VT1-0, the rheological properties of which were entered when developing the numerical model [10].

For the purposes of numerical simulation, the standard application software package (ASP) *DEFORM-3D* was applied.

To perform the simulation and factorial experiment with the *DEFORM-3D* software, three-dimensional models were preliminarily created with the *Kompas-3D* software.

Assumptions

1) The material of the billet in the initial state is isotropic and has no initial stresses and strains;

2) The temperature of deformation is assumed to be 200^{o}C;

3) The angle of the channels intersection is 120°;

4) The tool is absolutely rigid, and the geometry of the tool is taken into account automatically;

5) The initial billet material is assumed ductile;

6) The selected number of modeling steps is 100, taking into account a full passage of the billet through the die and obtaining a stable result;

7) The billet is divided into 43553 trapezoidal elements.

We believe that at the stage of preparation of the modeling task, the most significant factors influencing the fabrication of defect-free semi-products in the conditions of severe deformation at a temperature of 200° C are factors of friction (contact parameters) of the billet with different parts of the tool and the deformation velocity, conditioned by the rotation velocity of the working wheel. In this connection, it was decided to perform a virtual FFE using a two-level model with three unknown variable factors, followed by the formalization of the results in the form of a regression equation and the optimization of the selected factors.

Thus, as independent variables in the process of drawing with shear, characterizing the running of the process and its effectiveness from the point of view of the deformation force, we chose the friction factor from the upper and lower surfaces of the working wheel, which determines the efficiency of feeding of the billet in the deformation zone, f_1 (X_1), the friction factor from the forming tool parts, f_2 (X_2), the deformation velocity (the rotation velocity of the working wheel) V (X_3). The deformation force P (Y) was determined as the response parameter (dependent parameter).

The factors were varied at two levels. The variation intervals of the variable factors and their real-scale values are shown in table 1.

Table 1. Factor levels

Factors	X_1	X_2	X_3 (*V, m/min.*)
Basic level (X_i)	0.50	0.50	20
Variability interval (ΔX_i)	0.25	0.25	10
Upper level (x_i = 1)	1	1	30
Lower level (x_i = – 1)	0	0	10

The number of experiments N was determined from the number of factors k in accordance with the formula:

$$N = 2^k = 2^3 = 8 \quad (1)$$

It is required to determine such values of f_1, f_2, V, at which the lowest deformation force P is ensured.

3. Experimental results and discussion

The mathematical model after the implementation of the full factorial experiments takes the following form:

$$y=b_0+b_1x_1+b_2x_2+\ldots+b_{12}x_1x_2+b_{13}x_1x_3+ +b_{23}x_2x_3\ldots+b_{123}x_1x_2x_3, \quad (2)$$

where b_i is the regression coefficient.

For calculating the coefficients of this model, the extended matrix of experiment planning and results has been used (table 2).

Table 2. *Extended matrix of plan 2^3 and results of experiments*

Experiment No.	x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	*y (kN)*
1	+	+	+	+	+	+	+	+	13.3
2	+	-	+	+	-	-	+	-	16.5
3	+	+	-	+	-	+	-	-	10.7
4	+	-	-	+	+	-	-	+	12.7
5	+	+	+	-	+	-	-	-	23.2
6	+	-	+	-	-	+	-	+	19.8
7	+	+	-	-	-	-	+	+	13.5
8	+	-	-	-	+	+	+	-	12.9

Fig. 2 *illustrates the solution of the problem of numerical simulation of the ECAP-Conform process, as a result of which the minimum deformation force has been obtained.*

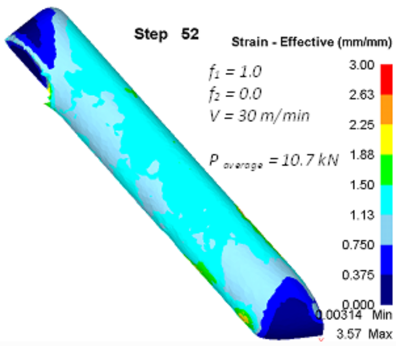


Fig. 2. *The result of the simulation of the ECAP-Conform process: distribution fields of accumulated strain. Deformation force $P_{average}$ = 10.7 kN*

The regression coefficients were calculated using the formula:

$$\mathrm{b_i} = \frac{\sum_{i=1}^{N} x_i y_i}{N}, \quad (3)$$

where i = 0, 1, 2, …, 8.

On the basis of the calculations, the following general form of a linear regression equation has been obtained:

$$y=15.33X_0 - 0.15X_1+2.88X_2-2.03X_3+0.20X_1X_2-1.15X_1X_3 - 1.28X_2X_3 - 0.50X_1X_2X_3 \quad (4)$$

Equation (4) shows that the most significant influence on the deformation force is exerted by the friction factor in the sliding contact between the billet and the tool f_2 (X_2) and the deformation velocity V (X_3). Moreover, it can be seen from the coefficients of the regression equation that the deformation force will decrease with an increase of both factors. A much smaller influence on the deformation force is exerted by the active friction factor f_1 (X_1) from the upper and lower surfaces of the working wheel which feeds the billet in the deformation zone. While the greatest and unidirectional influence is extered by the factors X_2 and X_3, it becomes possible to select the option of universal preparation of the billet surface. It should be noted that double and triple mutual interactions have ambiguous interpretations, and therefore complex interactions should be analyzed separately and with reference to the specific operating conditions of a multicomponent system.

A priori, it can be stated that in the considered conditions the minimum value of the deformation force can be obtained at the optimal combination of the independent parameters adopted in this study.

It is of practical interest to solve the optimization problem dealing with defining the actual values of the independent parameters considered in the virtual experiment of numerical simulation and providing the minimum value of the deformation force when implementing ECAP-Conform. This task is solved by the "steepest ascent" method [6].

Steps in the variation of the factors were calculated in the real scale. For this purpose, we first identified the product of the coefficients with the corresponding intervals of factor variation, i.e. $b_i \Delta X_i$, then in proportion to these products steps were assigned. Using the values of $b_i \Delta X_i$, the steps in the variation of the factors were determined as follows. From the technological considerations, the step in the variation of the factor of friction from the upper and lower surfaces of the working wheel was selected (Δ_1 = 0.05). The steps for the other factors were derived from the following proportions:

$$\frac{b_1 \Delta X_1}{b_2 \Delta X_2} = \frac{\Delta_1}{\Delta_2}; \frac{b_1 \Delta X_1}{b_3 \Delta X_3} = \frac{\Delta_1}{\Delta_3}, \qquad (5)$$

The sequence of the stages of the steepest ascent is presented in table 3.

Table 3. Steepest ascent

Factors	X_1 (the factor of friction from the upper and lower surfaces of the working wheel, f_1)	X_2 (the factor of friction from the forming tool parts, f_2)	X_3 (the deformation velocity V, *m/min*)	Y (the deformation force P, *kN*)
b_i	0,25	-0,8	-0,2	
$b_i \Delta X_i$	0,125	-0,4	- 4,0	
Step	0,05	-0,16	- 1,6	
Step after rounding	0,05	-0,2	- 5,0	
Basic level (X_i)	0,5	0,5	20	
Mental experiment	0,45	0,3	15	
Practical experiment	0,45	0,3	20	13,20
Mental experiment	0,55	0,7	15	
Mental experiment	0,55	0,3	25	
Practical experiment	0,55	0,7	15	17,90
Mental experiment	0,45	0,7	20	
Mental experiment	0,55	0,3	20	
Practical experiment	0,55	0,3	30	12,20
Practical experiment	0,55	0,3	10	14,50

Some of the mental experiments were implemented in a computer model (Table 3). Experiment planning using the steepest ascent showed that under these conditions the deformation force will be minimum at high friction from the upper and lower surfaces of the working wheel ($f_1 \approx 1.00$), at the friction, tending to the minimum values, from the forming tool parts ($f_2 \approx 0.00$), as well as at a high deformation velocity ($V \approx 25$ *m/min*). If the indicated values of independent parameters are observed, it is possible to ensure the deformation force $P \approx 10.7$ *kN* (Fig. 2). However, the objective of the study was to provide SPD processing by ECAP-Conform with the minimum possible deformation force under the condition of a universal preparation of the billet surface.

By solving the inverse problem we were able to choose such an option of universal surface preparation and deformation force, at which the value of the deformation force $P \approx 12.5$ *kN*, which is quite acceptable, is achieved.

Here, it is necessary to ensure $f_1 = f_2 = 0.3$ and the deformation velocity $V \approx 30$ *m/min*.

Fig. 3 shows the simulation results for the above values of variable factors in the context of the stated task of the study.

Thus, a universal preparation of the billet surface is possible, ensuring the minimum value of the deformation force. On this basis, for a practical implementation of processing of commercially pure titanium by ECAP-Conform, an option of preparing the billet surface can be proposed, combining a sub-lubricant layer and a technological lubricant.

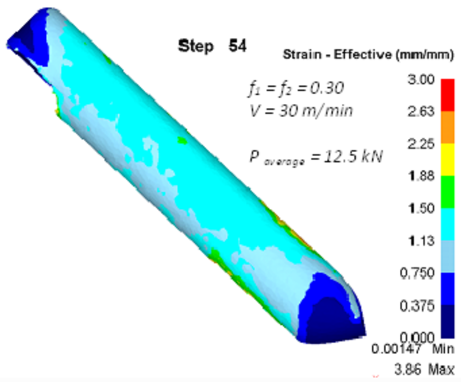


Fig. 3. *The result of the simulation of the ECAP-Conform process after solving the inverse problem: the distribution field of accumulated strain. Deformation force $P_{average}$ = 12.5 kN.*

The rheological properties of such a combination would correspond to a material with a high shear stress in the area of the sliding contact. This assumption requires further research.

4. Practical implementation of the obtained dates

To assess the correctness of the obtained simulation results and their possible use in a real process were made long length semi-finished products of commercially pure titanium. Installation for the implementation of SPD by scheme ECAP-Conform represented in Fig. 4.

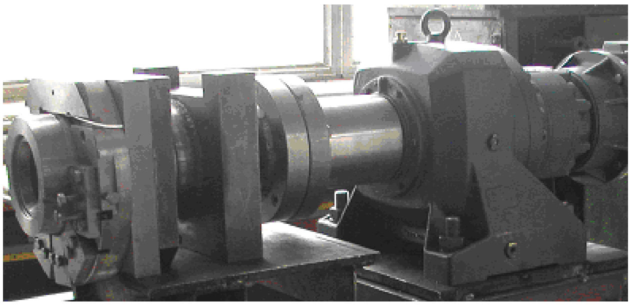


Fig. 4. *The machine for continuous sever plastic deformation.*

For practical implementations use sub-lubricant coating trinitraftorborate in combination with a graphite lubricant on the basis of the polymer and isopropyl spirit for practical implementations use sub-lubricant coating trinitrotoluene in combination with a graphite lubricant on the basis of the polymer and isopropyl spirit. This combined preparation of the billet surface allows providing a coefficient of friction in the region of 0.25 - 0.3 and high shear stress in the lubricating layer in the process according to the scheme of ECAP-Conform. The deformation velocity was 30 m/min.

In Fig. 5 show the semi-finished products of commercially pure titanium after ECAP-Conform. Analysis of semi-finished products showed that the proposed preparation of the workpiece surface ensures the production of defect-free products with the desired surface quality.

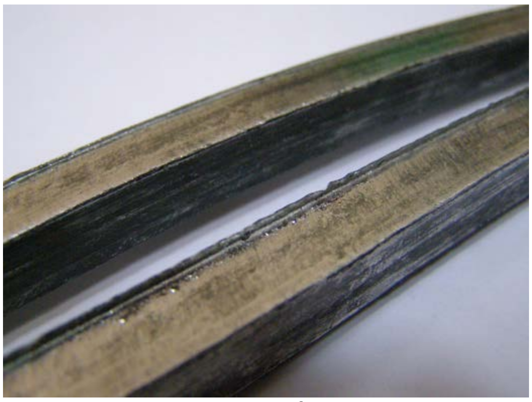


Fig. 5. *Produced semi-finished products*

Conclusions

1. As a result of a virtual full factorial experiment, it has been established that the most significant influence on the deformation force is exerted by the friction factor in the sliding contact between the billet and the tool f_2 (X_2) and the deformation velocity V (X_3). It has also been found that the active friction factor f_1 (X_1) from the upper and lower surfaces of the working wheel, which feeds the billet in the deformation zone, has a much smaller influence.

2. The virtual full factorial experiment, conducted using the steepest ascent method in the process of numerical simulation, has allowed us to determine the numerical values of friction factors from the upper and lower surfaces of the working wheel, f_1 and from the forming parts of the tool, f_2, which are universal for the SPD processing of commercially pure titanium by the ECAP-Conform technique.

3. For a practical implementation of processing of commercially pure titanium by ECAP-Conform, an option of preparing the billet surface can be proposed, combining the application of a sub-lubricant layer and a technological lubricant.

Acknowledgements

The authors acknowledge gratefully the financial support allocated for research in the framework of the joint Russian-Taiwanese research project RFBR-MOST No. 15-58-52015 NNS_a and MOST- 104-2923-E-011-003-MY3.

References

[1] R.Z. Valiev, *Bulk Nanostructured Metallic Materials: Production, Structure and Properties.* Moscow: Akademkniga Pub, 2007. – 398 p. (in Russian).

[2] V.M Segal, V.I. Reznikov, V.I. Kopylov, et al. *Processes of Plastic Structure Formation in Metals/*Minsk: Nauka i Tekhnika, 1994. 232 p. (in Russian).

[3] Segal V.M. *Engineering and commercialization of equal channel angular extrusion*//Mater. Sci. Eng. A. – 2004; V. 386.P. 269 – 276.

[4] G.I. Raab, R.Z. Valiev, *Equal-channel angular pressing//*Izvestya Vuzov. Tsvetnaya Metallurgiya -2000 – Vol. 5, p.50-53 (in Russian).

[5] S. Petrović Savić, D. Adamović, G. Devedžić, B. Ristić, A. Matić *Contact Stress Generation on the UHMWPE Tibial Insert*//Tribology in Industry, Vol. 36, No. 4 (2014) 354-360.

[6] A. Belhocine, A.R. Abu bakar, M. Bouchetara *Numerical Modeling of Disc Brake System in Frictional Contact*//Tribology in Industry, Vol. 36, No. 1 (2014) 49-66.464

[7] F.S. Novik, Ya.B. Arsov, *Optimization of Processes in Technology of Metals by Experiment Planning Methods.* Moscow: Mashinostroenie; Sofia: Tekhnika. 1980. 304 p. (in Russian).

[8] Yu.P. Adler, *Pre-planning of Experiments*. Moscow: Znanie. 1978. 72 p. (in Russian).

[9] Yu.P. Adler, *Introducton to Experiment Planning*. Moscow: Metallurgiya. 1969. 158 p. (in Russian).

[10] P.I. Polukhin, G.Ya. Gun, A.M Galkin, *Resistance to Plastic Deformation of Metals and alloys.* Moscow: Metallurgiya. 1976. 486 p. (in Russian).

MECHANICS OF TECHNOLOGICAL INHERITANCE

Blumenstein V., prof., Doctor of Sciences

T.F. Gorbachev Kuzbass State Technical University, Kemerovo, Russia

blumenstein@rambler.ru

Abstract: *Increasing demands for the quality and longer service life of machine parts require methods of strengthening treatment with plastic deformation of the surface (PDS). The PDS processes become significantly more efficient when technological inheritance is taken into consideration. The mechanics of technological inheritance was developed by the author and exemplified by the life cycle of a part, including processes of cutting and PDS as well as fatiguing, which occurs during the operation stage. Theoretical and experimental findings include key patterns of technological inheritance and can be applied to engineering of efficient strengthening processes.*

Keywords: TECHNOLOGICAL INHERITANCE, DEFORMATION SITE, DEGREE OF SHEAR DEFORMATION, PLASTICITY RESERVE

1. Introduction

One of the crucial challenges of contemporary machine engineering is to make sure using processing methods that machine parts have a longer service life. The service life of machine parts is, in many ways, determined by the behavior of the surface layer. Its parameters are formed throughout the entire design process. Among the processing methods which improve the service life of a part at final stages of the processing route are the methods of plastic deformation of the surface (PDS) that are widely applied to manufacture. Practical application has proven that with the correctly assigned modes of PDS the service life of a part can increase 5 times or more. At the same time, the incorrectly assigned PDS modes and disregard of properties accumulation occurring prior to PDS can cause the rupture of the surface during the manufacture or premature failure of the part during operation.

When designing a route for strengthening machining and when evaluating the service life of a machine part technological inheritance (TI) has to be taken into account. This means exposing and applying the functional dependencies between the parameters of the surface behavior and performance parameters. That, in its turn, requires an analysis of that behavior initiation at all stages of the life cycle of a part. In most cases, the dependency between the surface layer and technology, on the one hand, and the surface layer and the part service life, on the other hand, is established empirically. That, in its turn, contradicts to the practical application needs because new materials, new articles and new operation conditions require a whole new set of time-consuming and labor-intensive experiments.

The author underlines four crucial aspects.

1. Manufacturing engineering is developed to the point when the accumulation of scientific facts and findings do not generate new knowledge any more.
2. High rates of machine engineering development, occurrence of new materials and more complicated machine operation environment require a shorter period for design-to-manufacture facility by reducing experiments and increasing design work. That, in its turn, generates the necessity in more complex but also more accurate models of metal behavior under loading. It is especially critical for strengthening treatment.
3. A plethora of specific data, unfortunately, can not always make the basis for contemporary automated process engineering techniques. That requires the exposure and description of physical dependencies between the phenomena and processes under study. It also requires making the information obtained systematic and structured to be further used in contemporary information technologies.
4. The patterns of technological inheritance are too complex to be exposed as various stages of surface stressing (e.g., cutting, plastic deformation of the surface, operation fatiguing) are currently studied by means of various methodologies and definitions.

Despite the complexity of the phenomena that develop in the surface layer, the author has described them from a phenomenological perspective using the fundamentals of the mechanics of deformable environments. The core of this approach is that the physical behavior of the surface layer is interpreted as a result of the plastic flow of metal within the deformation site, with the plastic flow developing under the conditions of complex stress-strain behavior. This approach includes not only the conventional parameters of surface layer behavior such as roughness, waviness, hardness, residual stresses but also the degree of shear deformation, degree of plasticity reserve depletion, which are well-known in strain theory.

The life cycle of a part is seen as a continuous process of depletion by the metal surface layer of plasticity reserve. The stages and steps of such process are controlled by stressing programs.

The models of formation and transformation of the surface layer during cutting, plastic deformation of the surface (PDS) and operation fatiguing were developed and patterns of such phenomenon were studied. The end-to-end analysis and computations of hereditable deformation parameters of the surface layer during machining and operation of parts were carried out.

In addition to the above, the processes occurring in the surface layer were described in a way adapted to the use by engineers.

1. Problem solution: prerequisites and aids

Technological inheritance is one of the key areas of research study in machine engineering, which has been done in the Soviet Union and Russia since 1930s.

When analyzing how accurate metalcutters can process machine parts, Sokolovsky A.P. found that inaccuracies copy themselves throughout the entire design process [1]. Kovan V.M. suggested a dimensional analysis from the final (assembly) to the initial (workpiece) manufacturing stages [2]. At that time the part to be manufactured carried hereditary information and its accuracy characteristics were getting “copied” (inherited) throughout the entire design process.

By early 1960s demands for reliability of machine parts increased and that, in its turn, required a new approach to evaluating engineering procedure. After performing a set of studies researching the accuracy and quality of the surface of parts of bearings Yatsheritzyn P.I. established that the properties of treated surfaces had to be studied in relation to the whole set of performed operations [3]. Together with Ryzhov E.V. and Averchenkov V.I. he showed that a design process includes certain “barriers” that disrupt some parameters describing the surface layer of a product [4]. There are positive and negative factors of technological inheritance. During process engineering the structure of a process should involve operations, which would generate more obstacles for negative factors to reach the final operation.

A.M. Dal’skiy proved that inheritance played a role in making sure that high-precision parts of machines are reliable [5]. Together with A.S. Vasilyev and A.I. Kondakov, he gained new knowledge about process environments [6]. Primary forms of inheritance were established such as parametric and structural and, also, the inheritance of interaction characteristics between a workpiece and its external environment, which are found in process environments at various levels. The prevalent opinion is that hereditary information is carried by the thin surface layer, which is getting formed throughout the entire design process.

A.G. Suslov believes that technological inheritance is represented by various structural models [7].

The author of this article developed the scientific foundation for the mechanics of technological inheritance. Its fundamentals are shown below [8].

1. The conceptual foundation of technological inheritance is formed by the fundamentals of the strain and fracture mechanics.

2. The TI mechanics is based on the categories of life cycle (LC) and continuous processes of deformation accumulation and depletion of plasticity reserve in the metal surface layer of a part during machining and operation that follows.

3. The fundamentals of TI mechanics are exemplified by the life cycle of a part, including cutting, plastic deformation of the surface and operation fatiguing affected by cyclic loading.

4. Each machining or operation step is seen as a stressing stage. Stressing stages are interpreted through stressing programs and how complete they are. They are described in terms of the phenomenology of deformation accumulation and plasticity reserve depletion.

5. Stressing stages are divided into a set of steps of quasimonotonous deformation, which determine the patterns of deformation accumulation in the surface layer of a part.

6. Operation fatiguing, in its turn, involves two stages. The first one begins with cyclic loading and ends with the point of the complete depletion of plasticity reserve and the occurrence of visible faults (cyclic life stage). The second stage begins with the point of surface material discontinuity and ends with the complete failure of a part (separation into fragments) and is described with the cyclic crack growth diagram (cyclic crack growth stage).

7. Interrelated deformation processes occur in the surface at each stressing stage and step. According to the ideas of mechanics, during stressing at each stage there occurs a deformation site (DS), plastic deformations accumulate, plasticity reserve of metal is gradually depleted, residual stresses occur and transform. Thus, the surface layer is getting formed with specific hereditable properties.

8. Ontological models of processes are based on the patterns of formation and transformation of the deformation site at the stages of life cycle.

9. At each stage the deformation site forms under the exposure to stressing. The behavior of the DS reflects the surface behavior. The DS is the carrier of hereditary information; its form, dimensions and behavior are fully and adequately determined by the properties accumulated (inherited) prior to that.

10. TI is seen as a common pattern when deformation accumulation at a certain quasimonotonous stage is determined by stressing program and its history. The evaluation of stressing programs is made on the basis of the computation of DS stress and strain state (SSS).

11. Stressing history is described in terms of stressing programs within the prior time periods. Stressing history affects the stressing programs at a certain stage by altering the intensity of deformation accumulation and plasticity reserve depletion.

12. TI is exemplified by the terms of non-hereditable (reversible) and hereditable (irreversible) damage or by the terms of depleted and residual plasticity reserve.

13. The TI mechanics governs engineering techniques of new design of strengthening treatment by means of PDS, of plasticity control and of efficient control for the surface behavior at each stage of stressing by means of physical methods.

3. Solution to the problem under discussion

We are discussing the life cycle of a machine part undergoing the stages of cutting, plastic deformation of the surface and stressing with the exposure to operation cyclic loading. A more characteristic type of fatiguing is multicycle stressing of a machine part, which, in its turn, includes two stages such as cyclic life and fatigue crack growth.

Parameters known as terms of mechanics of deformable solids are used for TI mechanics problem solving:

- Stress state index:

$$\Pi = \frac{\sigma}{\mathrm{T}} = \frac{1/3(\sigma_1 + \sigma_2 + \sigma_3)}{1/\sqrt{6}\sqrt{(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2}}; \quad (1)$$

- Degree of shear deformation:

$$\Lambda = \\ = \langle \frac{2}{\sqrt{3}} \int_0^t \sqrt{\frac{1}{2}\left[\left(\xi_x-\xi_y\right)^2 + \left(\xi_y-\xi_z\right)^2 + (\xi_z-\xi_x)^2\right] + + \frac{3}{4}\left(\eta_{xy}^2 + \eta_{yz}^2 + \eta_{zx}^2\right)} \rangle\, dt; \quad (2)$$

- Residual stress tensor:

$$[\mathrm{T}\sigma_{\text{ост}}]_{ij} = \left[\mathrm{T}\sigma_{\text{деф}}\right]_{ij} + \left[\mathrm{T}\sigma_{\text{раз}}\right]_{ij} + [\mathrm{T}\sigma_t]_{ij}; \quad (3)$$

- Degree of plasticity reserve depletion [9]:

$$\Psi = \Psi_1 + \Psi_2 = \Psi_1 + (\Psi_{21} + \Psi_{22}) = \\ = n\varphi_0 \int_0^{\Lambda_k} \Lambda_i^{n-1} d\Lambda + \left(\int_0^{\Lambda_k} \frac{d\Lambda}{\Lambda_p} - \varphi_0 \int_0^{\Lambda_k} \Lambda_p^{n-1} d\Lambda \right), \quad (4)$$

where σ – average normal stress; T – shear stress intensity; $\sigma_1, \sigma_2, \sigma_3$ – principal components of a stress tensor; $\xi_x, \xi_y, \xi_z, \eta_{xy}, \eta_{yz}, \eta_{zx}$ – components of a deformation rate tensor; $\left[\mathrm{T}\sigma_{\text{деф}}\right]_{ij}$ – load stress tensor; $\left[\mathrm{T}\sigma_{\text{раз}}\right]_{ij}$ – unloading stress tensor; $[\mathrm{T}\sigma_t]_{ij}$ – thermal stress tensor; Ψ_1– component dependent on flow stress or on accumulated deformation; Ψ_2 – component dependent on metal plasticity with $\Pi = const$; Λ and Λ_p – accumulated and maximum permissible degree of shear deformation with a certain stress state index Π; n – strain-hardening coefficient; φ_0 – coefficient determined by plasticity tests. In unstrengthened metal $\Psi = 0$, when plasticity reserve is completely depleted, $\Psi = 1$.

The TI mechanics is based on continuous deformation accumulation and plasticity reserve depletion in the surface of a part affected by stressing programs.

Strengthening curve $\sigma_s = \sigma_s(\Lambda)$, ultimate plasticity curve $\Lambda_p = \Lambda_p(\Pi)$ and fatigue crack growth diagram $V = V(K)$ in the coordinates «stress intensity coefficient K– fatigue crack growth rate V» are used as initial metal characteristics.

It is assumed that the surface behavior is known and is described in terms of deformation mechanics for the case of annealed work material as

$$\begin{cases} \Lambda_{ij|i=0,j=0} = 0; \\ \Psi_{ij|i=0,j=0} = 0; \\ \Lambda_p = \Lambda_p(\Pi); \\ [\mathrm{T}\sigma_{\text{ост}}]_{ij|i=0,j=0} = 0, \end{cases} \quad (5)$$

where i stands for the number of a stressing stage and j – for the number of a quasimonotonous step at this stage.

It is established that machining by cutting and by plastic deformation of the surface comprises three steps of quasimonotonous deformation. Deformation alternates where these steps approach each other and plasticity reserve partially recovers.

The first stage – cutting – starts with initial (zero) values of deformation and of degree of plasticity reserve depletion (fig. 1).

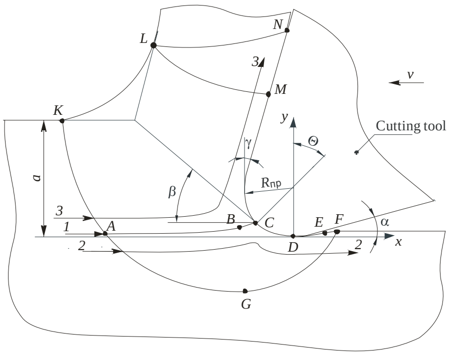


Fig. 1. *Orthogonal cutting model:*
α – rear angle; γ – front angle; ρ – tool edge radius; Θ – indentation angle; a – cutting depth; S – feed

According to the flow pattern, deformation site *KLMCDEFGAK* is seen to comprise two areas: higher and lower than some current line 1, which overlaps with line *ABC*.

The deformation site contour during cutting is described with a set of points and lines: KL – non-contact swarf edge; LM – end line of metal plastic flow; point M stands for the end of plastic contact of swarf with the cutting tool and point N – point of separation of swarf from the cutting tool front surface, it stands for the end of elastic contact of swarf with the cutting tool; KAG – starting line of metal plastic flow (front boundary of deformation site); point G stands for inmost depth of plastic deformation growth; GF – end line of metal flow (back boundary of deformation site); ABC – critical current line, which separates metal flows into those turning into swarf and those going under the tool; $MCDE$ – cutting tool contour line; EF – back non-contact edge; point E – point of separation of the cutting tool from the treated surface.

The metal plastic flow occurs along current lines with some of them (e.g. current line 3-3) being displaced into swarf and the others (e.g. current line 2-2) being displaced under the tool. Some critical current line 1 (ABC) is the boundary between them.

Deformation accumulates and plasticity reserve is depleted along current lines under the conditions of a certain state of stress with the swarf creating additional hydrostatic stress and altering the nature of SSS in the area of *ABCDEFG*.

Depending on the stressing diagram and degree of plasticity reserve depletion metal flows may split at point *A*, along current line *ABC* (1-1) or at point *C*, which will generate miscellaneous kinds of swarf.

Within the three stages of quasimonotonous deformation: deformation $\Lambda_{\text{рез}}$ accumulates, plasticity reserve is partially depleted by the value of $\Psi_{\text{рез}}$, residual stresses described by tensor $[T\sigma_{\text{ост}}]_{\text{рез}}$occur in the surface:

$$(6)\quad \begin{cases} \Lambda_{\text{рез}} = \Lambda_{ij|i=1,j=3} = \sum_{j=1}^{j=3} \Lambda_j\,; \\ \Lambda_p = \Lambda_p(\Pi); \\ \Psi_{\text{рез}} = \Psi_{ij|i=1,j=3}; \\ \Psi_{\text{рез}} = \int_0^{\Lambda_{\text{рез}}} \left[n\varphi_0 \Lambda_j^{n-1} + \left(1 - \varphi_0 \Lambda_p^n\right) \frac{1}{\Lambda_p} \right] d\Lambda; \\ [T\sigma_{\text{ост}}]_{\text{рез}} = [T\sigma_{\text{ост}}]_{ij|i=1,j=3}. \end{cases}$$

The surface behavior after the treatment by cutting is initial for the stage of PDS (fig. 2).

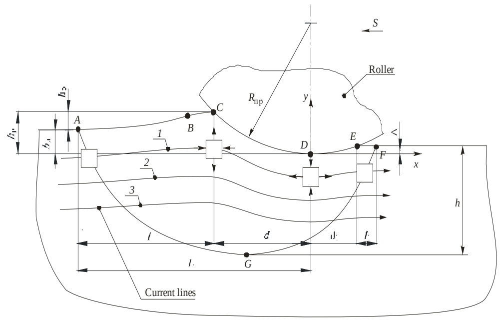


Fig. 2. *PDS model: S – feed; $R_{\text{пр}}$ – contour radius of deforming tool (roller)*

The PDS process is viewed in the axial section of the shaft where the plane of principal deformations is located. The following points, lines and areas were specified in the DS cross-section: $h_{\text{д}}$ – active preload, equal to the depth of the tool indentation; $h_{\text{в}}$ – height of elastic and plastic wave prior to the deforming tool; $h_{\text{р}} = h_{\text{д}} + h_{\text{в}}$– estimated preload, equal to the elevation view of the contact front arch; Δ – height of elastic and plastic metal recovery following the deforming tool; Δd– length of the bottom view of the contact front arch (length of the DS contact front zone); d_1 – length of the bottom view of the contact rear arch DE (length of the DS contact rear zone); l – wave length preceding the deforming tool (length of the DS front non-contact area); $L = l + d$ – length of the DS front area; l_1– length of the DS secondary area. Along the DS cross-section plastic deformation occurs at point A and ends at point F. The DS cross-section includes front non-contact area ABC, contact area CDE and rear non-contact area EF. The front non-contact area, in its turn, comprises concave line AB and convex line BC.

When the surface layer is exposed to stressing, material particles move into the DS along current lines 1, 2 and 3, plastic deformation reaches depth h. It results into the surface layer characterized with a various depth for shear deformation, plasticity reserve utilization and residual stress tensor.

Close enough interrelation exists between the DS geometric parameters. Moreover, close interrelation is found between the DS parameters, on the one hand, and segments of treatment modes and surface quality parameters, on the other [8].

The interrelation specified above is used to describe boundary and initial conditions for TI mechanics problem solution.

Residual stresses as a result of cutting are removed during the PDS stage, involving stressing and creation of plastic deformation site. Within the three steps of quasimonotonous deformation: plastic deformation keeps accumulating and plasticity reserve keeps getting depleted. It results in a new behavior of the surface characterized by a specific degree of shear deformation, of plasticity reserve depletion and residual stress tensor:

$$(7)\quad \begin{cases} \Lambda_{ij|i=2,j=0} = \Lambda_{\text{рез}}; \\ \Psi_{ij|i=2,j=0} = \Psi_{\text{рез}}; \\ \Lambda_{ij|i=2,j=3} = \sum_{j=1}^{j=3} \Lambda_j = \Lambda_{\text{ППД}}; \\ \Lambda_p = \Lambda_p(\Pi); \\ \Psi_{\text{ППД}} = \Psi_{ij|i=2,j=3} = \\ = \int_{\Lambda_{\text{рез}}}^{\Lambda_{\text{ППД}}} \left[n\varphi_0 \Lambda_j^{n-1} + \left(1 - \varphi_0 \Lambda_p^n\right) \frac{1}{\Lambda_p} \right] d\Lambda; \\ \Lambda_{\text{мех}} = \Lambda_{\text{рез}} + \Lambda_{\text{ППД}}; \\ \Psi_{\text{мех}} = \Psi_{\text{рез}} + \Psi_{\text{ППД}}; \\ [T\sigma_{\text{ост}}]_{ij|i=2,j=0} = [T\sigma_{\text{ост}}]_{\text{рез}}; \\ [T\sigma_{\text{ост}}]_{ij|i=2,j=1} = 0; \\ [T\sigma_{\text{ост}}]_{ij|i=2,j=3} = [T\sigma_{\text{ост}}]_{\text{ППД}}. \end{cases}$$

Value $\Psi_{\text{ППД}}$ stands for a degree of plasticity reserve depletion during PDS, involving the stressing history. Within two machining stages such as cutting and PDS degree of shear deformation $\Lambda_{\text{мех}}$

has been accumulated and plasticity reserve $\Psi_{мех}$ has been depleted. In addition, the residual stress tensor depends on the total accumulated deformation.

The mechanics models for multicycle fatiguing such as cyclic life and fatigue crack growth during operation were introduced.

The initial state for cyclic life is described with values $\Lambda_{мех}$, $\Psi_{мех}$ and $[T\sigma_{ост}]_{ППД}$. This stage is characterized by further accumulation of deformation occurring when tensors of operation (fatigue) $[T\sigma_{уст}]$ and residual $[T\sigma_{ост}]_{ППД}$ stresses go in with each other. Compressive residual stresses after the exposure to PDS result in more favorable fatiguing diagrams.

In each fatiguing cycle the degree of shear deformation continues to accumulate and plasticity reserve continues to deplete itself where there is quasimonotonous deformation. Residual stresses partially get partial relaxation. At the completion moment of cyclic life the residual stress tensor equals to 0.

During cyclic life, deformation $\Lambda_{ЦД}$ has accumulated and plasticity reserve $\Psi_{ЦД}$ has been depleted. As a result, within the three stages of cutting, of PDS and of cyclic stressing ultimate deformation has accumulated and plasticity reserve has completely been depleted at a point of probable surface metal failure. That behavior is denoted by value $\Psi = 1$; there appears a visible crack in the surface.

Further fatiguing (stage of fatigue crack growth) is described in terms of fatigue crack growth diagrams $V = V(K)$ in the coordinates «stress intensity coefficient K– fatigue crack growth rate V». The crack development begins with threshold coefficient of stress intensity K_{th} and ends with the ductile failure of a part specimen corresponding to critical coefficient of stress intensity K_{fc}.

Fatiguing ends with a complete fragmentation of a part, which is described by the parameters of failure damping.

At various stages and steps of the life cycle of a strengthened part any exposure can be applied to an extent that will increase their duration. First of all, we are speaking of thermal exposure that will enable complete or partial recovery of initial properties (metal plasticity reserve). This can be a mechanical action altering the character of load application and generating a new mechanical state of a product and so on. The structure of process model and kinetic equations incorporates other thermal and mechanical stressing stages.

4. Findings and discussion

Theoretical and experimental study of the mechanics of technological inheritance was performed. It is found that the surface properties formation is affected by stressing programs $\Lambda = \Lambda(\Pi)$, which are shown in the coordinates «stress state index Π – degree of shear deformation Λ».

The stressing program-based TI patterns, which have been specified, are shown below.

1. Technological inheritance exposes itself in the formation of hereditary stressing programs in relation to hereditary deformation sites, which act as a set of initial and boundary conditions for problem solution occurring in the strain mechanics.
2. Stressing history is described in terms of the programs occurring at the prior stressing stages.
3. At each following stage technological inheritance manifests itself through the transformation of stressing programs compared to the stressing programs of the material lacking such strain history.
4. Inherited stressing program «fades out» and deformation accumulation rate reduces at each following stage subject to the exponential hereditary law.
5. Residual stress state in terms of inheritance depends on total (accumulated) values of deformation degree and degree of plasticity reserve depletion.
6. Residual stress state together with the stresses caused by external loading forms an index and, thus, forms a stressing program at the stage of cyclic life.
7. Technological inheritance is a pattern. It is a characteristic feature of prior stressing programs to affect the formation of stressing programs at the following stages, which are also the results of specific stressing history of the metal surface of a product.

5. Conclusion

The description of technological inheritance is, first of all, the description of the impact of the complex alternate character of plastic deformation flow within the prior time periods on the formation of properties during the stressing stage under study.

Solving problems by means of terms and concepts of the mechanics of strain does not mean denying conventional beliefs about the surface quality of machine parts. At the same time, it means that in order to study technological inheritance more completely and profoundly, primary (ontological) patterns of surface formation, which have been accumulated throughout science advancement, can be applied as boundary and initial conditions to the solution of problems arising in mechanics.

6. References:

1. A.P. Sokolovskiy, Science behind manufacturing engineering, Mashgiz, Moscow, 1955, 515pp.
2. V.M. Kovan, Calculating machining allowance in machine engineering, Mashgiz, Moscow, 1953, 208pp.
3. P. I. Yashcheritsyn, Technological inheritance and performance properties of parts, Science and technology, Minsk, 1971, 210 pp.
4. P. I. Yashcheritsyn, E.V. Ryzhov, V.I. Averchenkov, Technological inheritance in machine engineering, Science and technology, Minsk, 1977, 256pp.
5. A.M. Dal’skiy, Engineering support of the reliability of high-precision machine parts, Mashinostroyeniye, Moscow, 1975, 223 pp.
6. Technological inheritance in machinery manufacturing, A.M. Dal'skiy, B.M. Bazrov, A.S. Vasilyev and others; in: A.M. Dal'skiy (Ed.), Moscow Aviation Institute Publishers, Moscow, 2000, 364 pp.
7. A.G. Suslov, Quality of the surface layer of machine parts, Mashinostroenie Publishers, Moscow, 2000, 320 pp.
8. V.Yu. Blumenstein, Mechanics of technological inheritance during treatment and operation of machine parts / V.Yu. Blumenstein, V.M. Smelyanskiy, Mashinostroyeniye-1, Moscow, 2007, 400 pp.
9. Yu.K. Filippov, Evaluation criterion for the quality of parts produced by cold forging//Forging and stamping production, 1999, № 2, P. 3-9.

DEVELOPMENT AND IMPLEMENTATION OF MANAGEMENT SYSTEM OF QUALITY - MAIN FACTOR FOR SUSTAINABLE DEVELOPMENT OF PRODUCTION SYSTEMS

M.Sc. Dimitrov B. [1], Eng. Math. Bruseva M.PhD[2]
"EMU JSCo" Targovishte, p. code 7707, Razboina - Republic of Bulgaria[1], Faculty of International Economics and Administration - Varna Free University „Chernorizets Hrabar" - Republic of Bulgaria[2]

Borislav.Penev.Dimitrov@gmail.com

mariya.bruseva@gmail.com

Abstract: *Quality management systems based on the International Standards ISO (International Organization for Standardization) is a revolutionary way to increase the competitiveness of Bulgarian companies in the energy sector on the European and international energy market. The implementation of international standards and management systems is becoming a major tool to reduce production costs, increase productivity, reduce the cost of manufactured products and services through the creation of optimal models of governance and organization of the key processes in the energetic sector companies. Development and implementation of management systems, good manufacturing practices and achieving product compliance with European and international standards is a promising trend. In proposed authors post after presentation of the International Organization for Standardization ISO is studying and analyzing systems applied quality management in projects in the field of energy development.*

Keywords: ISO (International Organization for Standardization), INTEGRATED OPERATIONAL MANAGEMENT SYSTEM, STRATEGIC MANAGEMENT, QUALITY.

1. Introduction

In the rapidly changing business environment as a result of expressed in the global financial and economic crisis, many Bulgarian companies reorient medium- and long-term development strategies, looking for new ways and mechanisms to safeguard the market position by changing the product portfolio, reduce costs and eliminate inefficient business processes.

In these conditions, the implementation of international standards and management systems is becoming a major tool to reduce production costs, increase productivity, reduce the cost of manufactured products and services through the creation of optimal models of governance and organization of the key processes in the business of enterprises. Development and implementation of management systems, good manufacturing practices and achieving product compliance with European and international standards is a promising trend. Businesses in Bulgaria, following this trend, continuously strive to improve management activities by applying models of planning and use of resources that enable effective and efficient organization of business, improving products and services and expand market presence in the long-term satisfaction the needs and expectations of end users.

In today's world, economic development and competitiveness of a country depends on many indicators - implemented innovations, energy efficiency, consumed resources, production facilities and human resources, the national transport system and others. The possibility of free movement of people, goods and services within the European Union (EU) contributes to acquire economic benefits at each Member State. Solving economic national plan requires long-term investment, clearly aware of the low level of return on the funds for the initial period. Methodologies of national and international organizations indicate guidelines and general principles governing project management. The application of standards in each case requires compliance with national legislation and customer requirements. Every successful project is one if not only met the criteria in the charter, but if through him achieve customer satisfaction, improve public scheme and gaining economic advantage.

Implementation of strategic management in organizations is becoming more popular and significance, evaluated through the prism of intense globalization processes and dynamic environment. In times of economic instability make business decisions often have strategic character, even if not so designed. The reasons for this are different, but most often the reaction of business organization in her attempt to adapt or to anticipate certain and expected of her events. Management is a complex and dynamic process, the results of which depend on the action of objective and subjective factors [1]. In this dissertation the focus is on identifying the scope of the international management standard ISO (International Organization for Standardization) and different methods of decision-making in strategic management and planning. In the exhibition offers an interpretation on the review of scientific literature by offering the author's view on the peculiarities of management decision and the types of problems in the organization. Submit the appropriate management methods and said their degree of applicability of the various stages in the process of strategic management.

In proposed authors post after presentation of the International Organization for Standardization ISO is studying and analyzing systems applied quality management in projects in the field of energy development. Based on thorough analysis concludes that the implementation of ISO standards is the main tools of sustainable production systems.

2. International Organization for Standardization

International Organization for Standardization (English International Organization for Standardization) or ISO (from the Greek ίσος - equal) is the largest international body for developing and publishing standards, composed of representatives of 148 national standards organizations (data from the end of 2004.). Founded in London on February 23, 1947 delegates from 26 countries. Central Secretariat of the organization is located in Geneva, Switzerland. Published by the (far more than 13,700 in number) industrial and commercial standards are used by all countries. It is a worldwide federation of national standards bodies (bodies - members of ISO) from different countries. ISO develops voluntary standards

ISO standards.

The ISO organization develope only required by the market standards. This is done by experts from industry sectors that have requested standards and which will subsequently apply them.

Etymology: The organization is usually referred to simply as ISO ("ISO"). This name is often wrongly deciphered by an international standardization organization or something. It should know that in fact the word ISO is not an acronym, but came from the Greek word ίσος (Issos), meaning the same. The English name is International Organization for Standardization (IOS), while French is the Organisation internationale de normalisation (OIN). It was difficult to establish a common acronym, so the founders chose ISO as the universal short name of the organization. However, it should be noted that ISO in its documents identify themselves precisely as International Organization for Standardization.

Hystory, structures and activity

The organization known as ISO, was established in 1926 as the International Federation of National Associations of standardization (ISA). Activities and halted in 1942 and during World War II. After the war, ISA (Industry Standard Architecture) is approached by a coordination committee of the newly created United Nations Organization (United Nations) and the standards functioning her UNSCC (United Nations Standards Coordinating Committee), a proposal for the formation of new global standards together one NGO. In October 1946, delegates from 25 countries of ISA and UNSCC met in London and decided to join forces to create a new international organization for standardization. The new organization officially became operational on February 23, 1947 under the name International Organization for Standardization official languages English, French and Russian. The organization is based in Geneva, Switzerland, and from 2013 worked in 164 countries.

ISO standards contribute to the development, manufacture and supply of safer and environmentally friendly products and services that facilitate international trade and make economic actors impartial[2]. Standards help to transfer technology to developing countries. They protect users and consumers and make their lives more secure.

Fig. 1 *Global distribution if ISO standards*

ISO standards management system should not be confused with product standards.

The creation of standards done by specialists of member countries organized in almost 200 number of technical committees (Technical Committee, TC), formed in various areas of industry and services. Examples:

• TC 1 - Screw threads (thread);
• TC 68 - Financial services (Services in the field of Finance);
• TC 193 - Natural gas (natural gas);
• TC 228 - Tourism and related services (tourism and services in the field);

A specific case is the formation of the **Common Technical Committee** of ISO and IEC standardization activities in the enormous volume of information technology. The Committee is the first and only of its kind at the time and is called **ISO/IEC JTC1** (Joint Technical Committee 1). His work is distributed between **18 subcommittees** (Sub-Committees, SC).

Each ISO standard has name and the format is „ISO HHHH: yyyy Name" where „HHHH" is the number of standard „yyyy" is the year of issue, „Name" describes the object of standardization. For example: **ISO 9000: 2000 Quality management systems - Fundamentals and vocabulary** (Systems of quality management. Basic principles and vocabulary) [3].

ISO documents are protected by copyright, ie their free copying and distribution is prohibited. Both paper and electronic copies are sold at uniform prices throughout the world.

Bulgaria became a full member of the International Organization for Standardization on January 1, 1955 On May 1, 1958 our country took part in the International Electrotechnical Commission (IEC) as well as full member.

3. Analysis of applied systems for quality management in projects in the field of energy development.

After the accession of Bulgarian economy to the European Union is particularly relevant question to increase its competitiveness. In the Bulgarian management theory problem for the certification of enterprises in the field of energy under international ISO standard is not enough depth studies and world practice shows fairly good results. The study of this problem and its application in business practice are especially relevant, given this and that today in a global economy and a strong turbulent environment of the competitiveness of individual companies depends on the successful development of the national economy as a whole.

In the present publication have been studied and analyzed 14 sites in the field of energy development, which are distributed as follows: 3 with international participation, three are of strategic importance for the Republic of Bulgaria, 8 were from the distribution network. In all embedded objects function integrated IMS. The survey was conducted in accordance with the sampling method for conducting audits inner. From the analysis it is found that the total number of tested sites only 8 (57%) are very well integrated operational management system. Of these 6 (43%) sites were found slight discrepancies in mandatory procedures of ISO 9001: 2008 and BS OHSAS 18001: 2007.

The research and analyzed data relied on reports of past and internal control audits for the 2009-2013 year. Conducting audits made by teams of external auditors (consultants) and representatives of the relevant systems in facilities with adequate competence. Only 3 of the 27 sites is unappreciated and unproven competence of the auditors in the energy sphere.

Continuous improvement is provided by the management of 27 sites and the sites of the teams who have realized the need to continually improve efficiency the integrated system of quality management and health and safety at work. The managements of the 27 sites take actions aimed at improving the quality policy and objectives quality and safety, audit results, analysis of the data, corrective and preventive actions and improving processes in their management, but experienced some difficulty in updating quality policies and actually set achievable targets and the quality control and safety at work[4].

Although all sites developed systems in internal checks made at the expert level, most of them were identified significant gaps. For the purpose of the study was developed with the program plan and a questionnaire that preliminary were agreed with the management of companies. In the process of study and conducting internal audits it was estimated up to date an embedded system.

The scope of the study includes information and evidence of compliance with all requirements of ISO specifications included in IMS:

• Monitoring, measuring, reporting and reviewing progress against the objectives and related key tasks performance indicators;

- Operational control of key processes;
- Management responsibilities for policy at all sites;
- The links between the basic requirements, policies, goals and objectives for achieving compliance;
- Legal requirements, responsibilities and competence of staff, according actions and procedures;

The analysis is the study of existing models Management System (QMS) ISO 9001: 2008 27 energy facility, which was built system and there is realized voluntary certification.

We will separate the energetic sites in two groups:

- Energy projects with perceived need for quality management, which are implemented, maintained and certified integrated systems;
- Energy projects that meet the statutory requirements in energy regulations;

Analyze the risks have been assessed risks identified in critical control points and monitor the critical limits. Only 8 of the 27 sites is created procedure and monitor the ongoing processes to their subsequent analysis. Based on the conclusions from the observations recommended the management of objects continuation of embedded IMS meeting the requirements of ISO 9001: 2008 and BS OHSAS 18001: 2007.

General requirements for the documents in the 27 sites developed and implemented IMS according to the requirements of ISO 9001: 2008 and BS OHSAS 18001: 2007 are covered with some exceptions in 7 projects.

Management of documents and records is governed by the order determined in mandatory procedures of ISO 9001: 2008 for management of documents and records. For these clauses is not acceptable to have major discrepancies in identification documents and records[5].

Based on the extensive research we can conclude that this is a prerequisite for the low quality of the product to maintain IMS and inability of understanding and that there will be systemic problems with product quality controlled by IMS.

Hazards identified in the risk assessment and the measures envisaged to limit, control and prevention are complied with only 19 of the auditees.

After identifying opportunities to improve corporate governance and increase technological readiness and competitiveness of Bulgarian energy companies, by way of their certification standards ISO (International Organization for Standardization) is needed in each building, implementation and certification of IMS / integrated system / control, to reach a higher level of competitiveness. Integrated system management of the business to be based on the requirements of international standards BS EN ISO 9001: 2008, BS EN ISO 1401: 2004 and BS OHSAS 18001: 2007[6].

As a summary of the research we can say that the requirements of ISO 9001 can be interpreted elastic. This allows each project to IMS according to ISO 9001: 2008 and BS OHSAS 18001: 2007 to migrate in the direction and at the EMS System (environmental management) ISO 14001: 2004.

This means that the integrated management systems IMS purposefully can bring in as much as possible a large number of sites and the requirements of ISO 14001: 2004 can analyze and develop a new model of integrated system.

4. Conclusion

International standards have strategic tools and guidance that help companies respond to some of the complex challenges of modern business. They ensure that business operations are possible - effective, increase productivity and help companies reach new markets. ISO International Standards ensure that products and services are safe, reliable and of good quality. For businesses, they are strategic tools that reduce costs by minimizing waste and errors and increasing productivity. They help companies to access new markets and create a level playing field for developing countries and facilitate free and fair world trade.

Advantage of international standards is that they are carriers of technological, economic and social benefits. They help to harmonize the technical specifications of products and services of the industry to more effectively remove barriers to international trade.

Business international standards are strategically tools and guidance that help companies to deal with some of the most complex challenges of modern reality. They ensure that business operations are as efficient as possible, to increase productivity and help companies gain access to new markets.

Following the successful model implemented an integrated management system for quality is achieved improvement of quality management in the company, meeting the requirements of customers, suppliers, partners and regulatory requirements. To be competitive in the European, Bulgarian companies have to meet a number of requirements related to the quality and safety of products, introduction of new technologies, environmental protection, safety, quality control and others.

Apart from raising serious competitiveness, implementation and effective use of quality standards leads to lower production costs, increase productivity at a reduced cost, increase profits and eliminate inefficient business processes.

Using of Management systems, are a tool for increasing the efficiency of operations in Bulgarian enterprises and their sustainable development.

References

1. В. А. Качалов, „Аудит систем менеджмента на соответствие требованиям ISO 9001, ISO 14001, OHSAS 18001", Москва- ИздАТ, Година на издаване: 2012 г.;

2. А. М. Шаммазов, Р. Н. Бахтизин, Р. Г. Шарафиев, К. Э. Писаренко, В. Ж. Квитко, „От контроля количества к управлению качеством. История развития системы менеджмента качества ГОУ ВПО УГНТУ", Уфа, Година на издаване: 2009 г.;

3. JNN Консулт ЕООД & Saga Technology Ltd, "Бяла книга на съвременните интелигентни системи за управление на бизнеса в България", Saga Technology, Година на издаване: 2006 г.;

4. Георги Тасев, "ISO 9001: Практическо ръководство на отговорника по качество", Раабе България, Година на издаване: 2009 г.;

5. Творчески колектив, "ISO 9001 за малките и средните предприятия", БДС Компас, Година на издаване: 2007 г.;

6. http://www.bds-bg.org

Authors:

M.Sc. Borislav Penev Dimitrov –
Expert public health and safety
"EMU JSCo" Targovishte, p. code 7707, Razboina
Tel: +359 601 6 69 11, Mob. +359 886 26 27 23

Assoc. Prof. Eng.Math. Mariya Nikolova Bruseva, PhD
Varna Free University, Chayka resort, Varna, 9007
Tel: +359 52 359 572, Mob. +359 897 80 55 02

FINANCIAL - ECONOMIC ASSESSMENT OF INNOVATIVE PROJECTS

Eng. Math. Bruseva M.PhD.[1]

Department of International Ecnomics and Politics – Varna Free University, Bulgaria [1]

mariya.bruseva@mail.com

Abstract: *The national economy restructuring ,the European Union membership and globalization clearly outline the necessity of implementation of various activities, including innovation by which companies to form long-term competitive advantages. This creates the need for implementation of systematic and reliable research of the effectiveness of the implemented innovation as a component of overall efficiency. This requires improvement and grounded updating of traditional approaches to financial and economic evaluation of the planned innovation and related activities. In the proposed work are presented the opportunities for planned innovations economic assessment with the help of financial and economic instruments through the use of information technology.*

Keywords: INNOVATION, INNOVATION PROJECT, ECONOMIC EVALUATION, FINANCIAL-ECONOMIC INDICATORS, INFORMATION TECHNOLOGY

1. Introduction

The national economy restructuring, the European Union membership and globalization clearly outline the need for the implementation of various activities, including innovation by which companies to form long-term competitive advantages. This creates the necessity of implementation of systematic and reliable research of the implemented innovation effectiveness as a component of overall efficiency. This requires improvement and grounded updating of traditional approaches to financial and economic evaluation of the planned innovation and related activities. The reason is that this tool is not used in an adequate level by industrial enterprises managers, plans developing for implementing innovation is rather random in nature, and appropriateness analysis of the planned rarely does.

Determination of appropriateness of the implemented resources in any innovation and related activities at the planning stage allows the decision maker to assess whether this innovation is justified in respect of implementation funds.

The successful innovation implementation is a prerequisite for a competitive market presence in the industrial enterprises economy. In the existing conditions, the use of appropriate tools for determining financial and economic feasibility of implementing an innovation and related activities is necessary.

Important role for the economy prosperity plays the ability of creation and implementation of innovation. Innovations implementation is a determining factor for enterprises competitiveness increasind. An important step to overcome the existing lagging behind the developed European economies is to promote innovation process in the country. The European and global experience points that skillful use of research, advanced technologies and innovation, makes it possible to take active steps to increase the competitiveness of the economy and raise living standarts. The transition to the knowledge economy and joining global information society appears to be the main challenge.

Industrial Enterprise is a multifaceted entity having social, technical, legal, economic, product-market and organizational and managerial aspects, and builds specific policies for implementation of various activities. Effectiveness evaluation of the activities in industrial enterprises does not contribute for improving the decision quality. The used criteria to evaluate the businesses performance needs systematization and respective inclusion in the summary approach to the assessment of their activities.

The planed innovation financial-economic analysis performance for the development of any industrial establishment and development of a common approach to financial and economic evaluation of innovation is a necessary task in modern society[4].

The planned innovations assessment opportunity is presented in the proposed work understandably with the help of financial and economic instruments through the use of information technology.

2. Theoretical assumptions about the innovation nature and related activities

The innovation process is a sequence of actions, from generating ideas for innovation to develop the final product and its commercialization, which are described and justified in the innovation project. This is a creative, cyclical, complex and expensive process, a result of a number of interrelated activities, which type and specificity depend of the scale of the innovation project and are not always innovative. For the realization and implementation in their entirety and complexity specific interdisciplinary knowledge and skills are required [1].

Whatever field of application is innovation is associated with novelty, which should be a value above all because the enterprise is on the way to realize it. The essence of innovation due to the specifics of its manifestation, enables multifaceted interpretation which leading to the formulation of new questions that need to be addressed. Innovation is a knowledge-based and involves product creation, creation of process or technology and innovation is measured by the degree of novelty for the firm and / or market. Innovation leads to increased competitiveness of the enterprise, industry, economy, or to increased user satisfaction. It is a process and result of the process in the core of which is innovation.

The effective use and implementation of innovations should be well planned, adequate to market realities and financial capabilities of industrial enterprises. This requires further development of existing tools for assessing the appropriateness of the expenses for innovation and development of a common approach for evaluation.

Innovation is most often defined as a change aimed at renewal or introduce something new and useful in practice, it is possible to happen in different areas: business, society, politics, science, art and more. There are different concepts of innovation, in 1934. Joseph Schumpeter first defines innovation as a useful change - an engine for economic development. He specifies 5 main cases of innovation in the economy:

- New product introduction;
- New method of production;
- New market opening;
- New source of raw materials / resources for production use;
- Creation of new organization of work or relationships between companies in the same industry.

Depending of the adopted principle of classification different types of innovation are known. Depending on the degree of novelty distinguish radical (revolutionary) and incremental (compilations, improvements, imitations, etc.). Innovate. The most common innovations are compilations (such as mergers characteristics of multiple devices in one as a printer / scanner / copier), improvements and modifications. According to the outcome distinguish product, process, market, financial, organizational, logistics and others. innovation. The creation of new products and services, and the change in the ways of selling, advertising, delivery are among the most - popular innovation today. Usually innovations are seeking a solution to a problem such as:

- Customers unmet needs;
- Unused opportunities for production and sales of product sought;
- Basic model unsatisfactory performance characteristics;
- Basic product unsatisfactory reliability, quality;
- Basic product production, delivery, sale higher cost;
- Technical and structural difficulties in the production process.

Key factors determining the success of an innovation is its relevance and utility, the company's ability to mobilize quickly knowledge and skills for implementation and the possibility of organizing production and sales faster than competitors, flexibility in modifying innovation for different markets and customers.

Innovation process stages.[3]

1. Market analysis, including analysis of customer needs, and analysis of the existing and future competition.
2. Evaluation of the technical and organizational resources of the company and their own potential sources of innovation.
3. Defining the subject of innovation activities and terms of reference.
4. Establishing and structuring team for the realization of design.
5. Development of a concept for the realization of innovation with a linear schedule and an estimate of the project cost and the expected results. Comparative analysis.
6. Decision on the implementation or rejection of the project.
7. Development of technical project in detail remit.
8. Feasibility study of innovation. Adoption of the final budget for its realization.
9. Making innovation.
10. Testing.
11. Innovation implementation.
12. Promotion.
13. Results evaluation. Conclusion.

Basic steps in the innovation implementation.

(1). Generating ideas for innovation.
(2). Selection and evaluation of idea for innovation.
(3). Protection of the idea.
(4). Investigation of the idea usefulness and market opportunities.
(5). Check of the idea feasibility.
(6). Planning and organizing of the implementation.
(7). Development of a test sample (prototype).
(8). Testing.
(9). Manufacturing of the new product / service.
(10). Monitoring, control and adjustment of the new product / service.

It is possible unification of some of these steps or another sequence, depending on the specific situation and capabilities of the enterprise.

3.Financial economic evaluation of innovative projects[2]

Project evaluation is aimed to determine whether and to what extent new or advanced technologies and products will improve the competitive position of the company. The assessment of innovative projects can be viewed in different ways: economic evaluation; social; evaluation from a strategic perspective; environmental assessment; independent risk assessment; net present value, calculated on the basis of equivalent risk-free flows; net present value calculated based on risk-adjusted discount rate. That ultimate goal of any innovation requires investment and projects to be evaluated by the financial economic perspective. Evaluation of the innovation project should reflect the full potential of new or advanced technologies and products to bring benefit to the company not only for one year but for a certain period. This allows to reflect the time factor, appearing in the different starting point of production commencement[5].

In the present publication the author is considering the step " Selecting and evaluating of idea for innovation."in the stage "Feasibility study of innovation", and the author of the publication offers for - optimal assessment of innovative projects to apply the following assessment methods:

- Net present value (NPV - Net Present Value)
- Internal rate of return (IRR - Internal Rate of Return)
- Payback period (PVP - Payback Period)
- Profitability Index (IP - Index Probability)

Method of net present value

Present days investment and innovation analysis assumes that the net present value is the most practical application. [4] It is the leading indicator for evaluating the effectiveness of investment projects, as best indicator to what extend has improved the welfare of the owners (shareholders) of the company. This method determines whether the sum of the discounted net cash income over the duration of the economic life of the project exceeds the amount of discounted investment costs. The formula for calculation of the "net present value for the investment that has more than one cash flow has the form:

$$NPV = -C_0 + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \dots\dots\dots\dots + \frac{C_n}{(1+r)^n}$$

The criterion for evaluating and ranking the projects under consideration is the method: the maximum positive net present value. On this basis, displays the following rule of decision:

NPV> 0 - the project is considered

NPV <0 - the project is rejected

NPV = 0 - the project is on the verge profitable / unprofitable and further analysis is needed.

Method of internal rate of return

IRR represents that discount rate that equalizes the amount of positive cash flows discounted by the amount of negative (cost) cash flows generated by the project. In other words, IRR is the discount rate at which the net present value becomes zero. If we use the formula for finding the net present value, internal rate of return will be the rate of discounting in the following equation:

$$-C_0 + \frac{C_1}{(1+IRR)} + \frac{C_2}{(1+IRR)^2} + \dots\dots\dots + \frac{C_n}{(1+IRR)^n} = 0$$

To assess the project effectiveness by using the IRR indicator is necessary to know what is the market rate.As market interest rate can be used interest rate at which the bank would grant a loan. In this case, if:

IRR> r - project is considered

IRR <r - the project is rejected

IRR = r - project on the border profitable / unprofitable

Payback period method

This method is one of the most popular and widely used methods of evaluation and selection of investment options. The method payback period determining the length of time needed to recover the initial investment at the expense of financial results of the investment. If the cash incomes in the years are the same, the formula for determining the payback period is as follows:

$$PBP = \frac{IC}{NI}$$

PBP - payback period

IC - initial investment

NI - average net cash flow

Index Profitability Method

The index of profitability shows the value (income) obtained from every lev initial investment while respecting the time value of money. The formula for calculation of the profitability index is as follows:

$$PI = \frac{\frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + ... + \frac{C_n}{(1+r)^n}}{C_0}$$

The criterion of selection the project is as follow:

If PI> 1 project is considered

If PI <1 project is not accepted

If PI = 1 project on the border profitable / unprofitable

Information technology use for financial - economic evaluation of innovative projects[1]

To provide investment evaluation, especially for the calculation of economic indicators, and especially for IRR it is mandatory to apply software - an essential element of information technology. The author has developed a method by which, after analysis and preparation of input data for the calculation of economic fundamentals and relevant calculations assessing the economic efficiency. As a result of calculation of financial indicators, net present value, internal rate of return, payback period and profitability index the method valued the planned innovation activities. It is a tool to assist management practice in planning innovation activities and various associated with them to.

4 Conclusion

Innovations are one of the main factors for the successful development of business in a competitive market environment. There are a variety of methods for the assessment of innovative projects. The main methods used by international financial institutions are described in the development of net present value method and the internal rate of return. Other specified methods serve to introduce additional criteria for assessing innovation, but also complement the information on the return of investments for realization of innovative projects. We must seize the opportunities of modern information technologies. Each innovative project itself is unique depends of the company and particular area of application which fact gives flexibility to not necessarily apply unified approach to financial - economic evaluation. It is recommendable analysts to reconsider which methods are best suited for use in different versions for innovation. Nevertheless of the manner of conducting assessment of each project this is a tool for increasing the efficiency of operations in Bulgarian enterprises and their sustainable development .

References

1. Славов Здр., Брусева М, Николаева В., Ненков Ст., Стоилов Т., Стоилова Кр., Владимиров М. Методи и одели за взимане на бизнес решения, ВСУ, Варна, 2013
2. Брусева М., „Съвременни подходи за оценка на инвестиционните проекти и ролята им за повишаване на конкурентноспособността на фирмите в процеса на инвестиране, МЕЖДУНАРОДНА НАУЧНО–ПРАКТИЧЕСКА КОНФЕРЕНЦИЯ „УСТОЙЧИВО РАЗВИТИЕ- 2013” 14 – 19.06.2013, х-л „Ханът” – КК „Св.Константин и Елена”, Варна
3. ВИСОКОТЕХНОЛОГИЧЕН БИЗНЕС ИНКУБАТОР, Ръководство за иновации за малки и средни предпиятия ,Регионална Агенция предприемачество и Иновации - Варна, по проект№ 014664 „Регионална иновационна стратегия на Североизточен район за планиране” , 2012
4. Костова В.,Оценка на иновационната дейност на малки и средни предприятия, Автореферат, ВСУ, Варна, 2011
5. http://www.e-dnrs.org/?page_id=3388

Author:

Assoc. Prof. Eng.Math. Mariya Nikolova Bruseva, PhD

Varna Free University, Chayka resort, Varna, 9007

Tel: +359 52 359 572, Mob. +359 897 80 55 02

A STUDY ON THE IMPLEMENTATION OF THE DISCIPLINED CONVEX OPTIMIZATION METHOD FOR THE IDENTIFICATION OF THE DYNAMIC SYSTEMS' MODELS

Lect. Danila A. PhD.[1]
" Transilvania " University – Brașov, Romania [1]
adrian.danila@unitbv.ro

Abstract: *In this paper the author investigated the implementation of the convex optimization method in the area of the estimation of model parameters from experimental data. The investigation focused on the identification of processes within the technical environment such as: the liquid flow process, the mechanical vibrating process and the electric arc discharge. The theoretical support related to the convex optimization algorithm is emphasized in the first section of the paper. The preconditions for the implementation of the algorithm within the system identification context are also presented. In the third and the fourth sections, the main analysis is made. The mathematical models of the processes under investigation and the software implementations are depicted. The results showed that for an input signal, equivalent with the Dirac impulse, the disciplined convex optimization algorithm provide consisted estimate of the process under investigation which is similar to the results from the classical least-squares identification algorithm. These results are the basis for further investigations on the implementation of the convex optimization algorithm for system identification.*

Keywords: SYSTEM IDENTIFICATION, CONVEX OPTIMIZATION, DYNAMIC MODEL

1. Introduction

The convex optimization method has been introduced since decades to solve a special class of mathematical optimization problems which includes least-squares and linear programming problems.

The method has been implemented in areas such as, [1] automatic control systems, estimation and signal processing, communications and networks, electronic circuit design, data analysis and modeling, statistics, and finance. Recently, the convex optimization method was successfully used in real-time optimization within computers embedded in products. The main advantage of the convex optimization method is that this method is reliable and can solve the convex optimization problems in a predictable amount of time.

The convex optimization has been studied for about a century. The first systematic study of convex sets was made by Minkowski. The mathematics of convex sets was then developed by Bonnesen, Fenchel, Eggleston and others. During the 1960's, Luenberger introduced the generalized inequalities in nonlinear optimization. In the 1980's, the convex optimization method has developed due to Nesterov and Nemirovski, [1] who were the first to point out that the interior-point methods - developed to solve linear programming problems - may be used to solve convex optimization problems as well. Nowadays, important contributions in convex optimization algorithms and related topics, including software developments are due to Boyd and Vandenberghe.

In this paper, the author investigated the implementation of the convex optimization algorithm for the identification of the dynamic systems' models parameters from experimental data. This approach is less quoted in the technical literature, [1], [5].

In systems identification and in its related adaptive control, the predictable demand of hardware, software, and computational time resources are crucial. In this direction, the convex optimization proves more efficient than the classical system identification methods.

2. Prerequisites and means for solving the problem

An optimization problem has the following form:

$$\begin{aligned} &\text{minimize} \quad f_0(\mathbf{x}) \\ &\text{subject to} \quad f_i(\mathbf{x}) \le b_i \quad i=\overline{1;m} \end{aligned} \tag{1}$$

Where the vector $\mathbf{x} = \begin{pmatrix} x_1 & \ldots & x_n \end{pmatrix}^T$ is the optimization variable of the problem, the function $f_0 : \mathbf{R}^n \to \mathbf{R}$ is the objective function, the functions $f_i : \mathbf{R}^n \to \mathbf{R}$, $i=\overline{1;m}$ are the constraint functions, and the constants $b_1 \ldots b_m$ are the bounds for the constraints.

In the linear program, the objective and constraint functions are linear and satisfy the equality:

$$\begin{aligned} &f_i(\alpha\cdot\mathbf{x}+\beta\cdot\mathbf{y}) = \alpha\cdot f_i(\mathbf{x}) + \beta\cdot f_i(\mathbf{y}) \\ &(\forall)\mathbf{x},\mathbf{y}\in\mathbf{R}^n;\ \alpha,\beta\in\mathbf{R} \end{aligned}. \tag{2}$$

If the objective and constraint functions are not linear, then the optimization problem is called a nonlinear program.

If the objective and constraint functions satisfy the inequality:

$$\begin{aligned} &f_i(\alpha\cdot\mathbf{x}+\beta\cdot\mathbf{y}) \le \alpha\cdot f_i(\mathbf{x}) + \beta\cdot f_i(\mathbf{y}) \\ &(\forall)\mathbf{x},\mathbf{y}\in\mathbf{R}^n;\ \alpha,\beta\in\mathbf{R} \text{ with } \alpha+\beta=1 \text{ and } \alpha\ge 0\ \beta\ge 0 \end{aligned}, \tag{3}$$

then, the optimization problem is called a convex optimization problem.

The solution of the optimization problem is a vector ξ^* which has the smallest objective value among all vectors that satisfy the constraints: $f_0(\xi) \ge f_0(\xi^*)$ for any ξ with $f_i(\xi) \le b_i$; $i=\overline{1,m}$.

In the least-squares optimization problem with no constraints, the objective function is of the following form:

$$f_0(\mathbf{x}) = \|\mathbf{A}\cdot\mathbf{x}-\mathbf{b}\|_2^2 = \sum_{i=1}^{k}\left(\mathbf{a}_i^T\cdot\mathbf{x}-\mathbf{b}_i\right)^2 . \tag{4}$$

Where: $\mathbf{A}\in\mathbf{R}^{k\times n}$ with $k\ge n$, $\mathbf{a}_i^T$ are the rows of $\mathbf{A}$, and the vector $\mathbf{x}\in\mathbf{R}^n$ is the optimization variable.

The analytical solution of the least-squares problem is given by the following expression.

$$\mathbf{x} = \left(\mathbf{A}^T\cdot\mathbf{A}\right)^{-1}\cdot\mathbf{A}^T\cdot\mathbf{b} \tag{5}$$

The least-squares problem has known high accuracy and high reliability algorithms such as the linear least-squares algorithm. The computer time needed to solve a least-squares optimization problem is approximately proportional to $n^2\cdot k$. The convex optimization problem also benefits of dedicated algorithms such as the interior-point algorithm. The amount of steps needed to solve some optimization problems by means of the interior-point algorithm is in the range between 10 and 100. Each step requires on the order of

$\max\{n^3; n^2 \cdot m; F\}$, where F is the cost of evaluating the first and the second derivatives of the objective and constraint functions, [1].

Given a dynamic process, the aim in system identification is to determine an estimate of the system's model from input / output sequences of data acquired from the given process.

In the followings we will consider the problem of system identification as a convex optimization problem.

3. Solution of the examined problem

Consider two sequences of data $\{u[k]\}_{k=1}^{N}$ and $\{y[k]\}_{k=1}^{N}$, related to the signals at the input / output ports of a given linear, time-invariant system.

As known, a single-input, single-output, dynamic process may be represented in the discrete time domain by means a difference equation given in the general form as follows:

$$M : y[k] = -\sum_{i=1}^{na} a_i \cdot y[k-i] + \sum_{j=1}^{nb} b_j \cdot u[k-j] \tag{6}$$

Where a_i ; $i = \overline{1;na}$ and b_j; $j = \overline{1;nb}$ are the model's parameters.

Based on the general form of the dynamic process above and on N sequence of data acquired from the process, a set of N equations with $na + nb + 1$ unknowns is obtained. The matrix - vector form of the given set of equations is the following.

$$S : \mathbf{\Phi} \cdot \mathbf{\Theta} = \mathbf{Y}. \tag{7}$$

Where: $\mathbf{\Theta} = [a_1, \ldots, a_{na}; b_0, \ldots, b_{nb}]^T$ is the vector of the true parameters, $\mathbf{Y} = [y_1, \ldots, y_N]^T$ is the vector of the noise free output data, and $\mathbf{\Phi}$ is the noise free input / output data, [6] In reality, the measured sequences of data are corrupted by noise. Therefore, the least-squares identification problem reduces to the computation of the pseudo-solution of the above set of equations. This is equivalent to the problem of the Euclidean norm minimization:

$$V_N(\hat{\mathbf{\Theta}}) = \|\mathbf{\Phi} \cdot \hat{\mathbf{\Theta}} - \mathbf{Y}\|. \tag{8}$$

Where $\hat{\mathbf{\Theta}}$ is the vector of the estimated parameters and $V_N(\hat{\mathbf{\Theta}})$ is the objective / the cost function. Follows that the least-squares identification of the parameters may be interpreted as a convex optimization too.

The least-squares algorithms used in system identification require the input sequence is a white - noise process with zero mean and known variance, [2]. In contrast, the convex optimization algorithm will not work properly with random processes sequences. In this case the convex optimization should reduce to finding a maximum likelihood estimate of the parameter vector, [1].

However, the simple least-squares algorithm in system identification will also work if the input is a discrete Dirac impulse. In this case, the system's response is a sequence of the discrete weighting function. In this case the convex optimization algorithm will work too. In the followings, we will use this approach to determine the model estimates of parameters from experimental input / output data with known pulse inputs. The proposed processes were: a liquid flow process, a mechanical vibrating process and an electric discharge.

4. Results and discussion

In purpose to investigate the ideas presented above, the following tools were used: (a) a liquid flow test band and a mechanical vibratory test band from the Electrical Machines Laboratory at the "Transilvania" University from Brașov; the liquid flow test had two flow meters with 5% accuracy in the range of $0.01 - 1.0$ [dm^3]. The flow was computed by means of a microcontroller application and an RS232 communication - which is part of the test-band. (b) For the experiment, the mechanical vibratory test - band was equipped with a 12-bit/8-bit digital accelerometer, MMA8452Q from FreescaleSemiconductor and a MSP430 microcontroller. (c) The algorithm implementation used the cvx, SeDuMi library, [3] and the MatLab software environment. The serial communication between the microcontrollers and the PC was made by means of the RS232 port and a software application written in the VisualBasic. The main interface of the communication application is depicted in Figure 1. The interface consists in several objects that allow the user to control de data stream from the microcontroller.

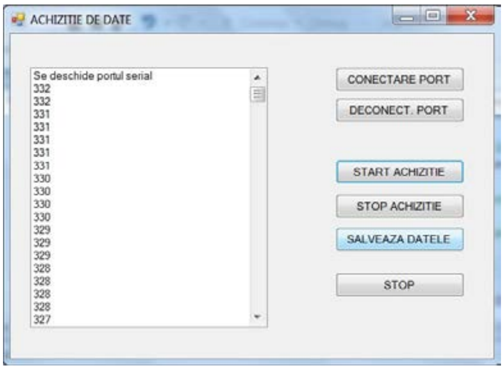


Fig. 1 *The communication application - graphical interface.*

The implementation of the convex optimization algorithm and the associated computations were made within the MatLab environment by means of a dedicated application.

4.1. The identification of a liquid flow process

Consider the flow of the liquid from a tank, (C - the surface of the tank) within pipes and a valve (R_h - the equivalent hydraulic resistance); the input / output signals are the input and the output flow.

The reduced - order linear model of the liquid flow process is given by equivalent transfer function is represented in the following expression [4].

$$G(s) = \frac{1}{R_h \cdot C \cdot s + 1}; \quad s = \sigma + j \cdot \omega; s \in \mathbf{C}. \tag{9}$$

Given the sampling period of the discrete dynamic processes, **Грешка! Показалецът не е дефиниран.**T_e , the given transfer function may be translated into the discrete space.

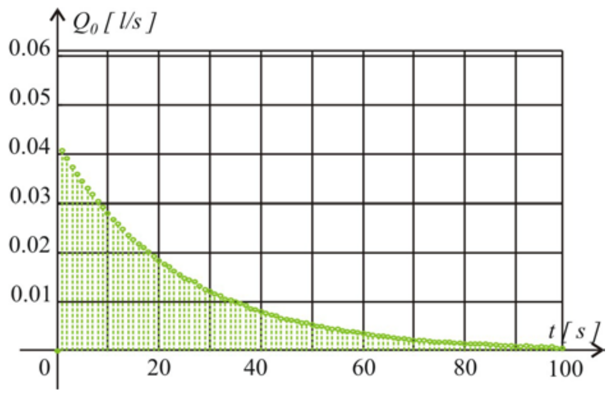


Fig. 2 *The experimental measurements of the weighting function of the liquid flow system.*

The expression of the equivalent operational transfer function is of the following form:

$$G\left(q^{-1}\right)=\frac{b\cdot q^{-1}}{1+a\cdot q^{-1}}. \qquad (10)$$

Where q^{-1} is the shift operator. The difference equation that depicts the flow process will result from the expression above as follows.

$$M_1 : y[k]=-a\cdot y[k-1]+b\cdot u[k-1] \qquad (11)$$

The expression above is of the form given in (6).

In this experiment the liquid flow test band was used. A measured sequence of the outlet flow is depicted in Figure 2.

The implementation of the disciplined convex optimization algorithm produced the results summarized in Table 1.

Table 1: *The true values and the estimations of the liquid flow model parameters in the expression (10).*

	a	b
True values [-]	-0.9591895	0.04081054
Average of estimations [-]	-0.9557563	0.03401063
Residuals [%]	75.0894818	79.16553542

4.2. The identification of a mechanical vibratory process

We consider a two-sided pendulum implemented as shown in Figure 3.

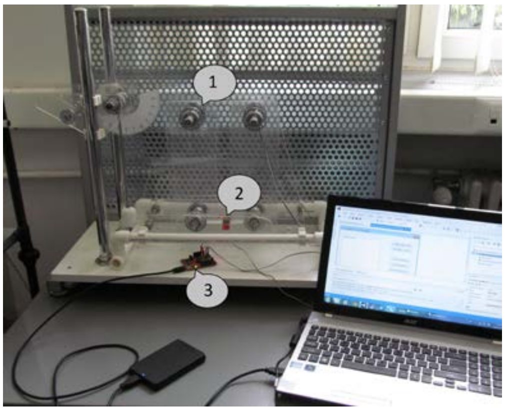


Fig. 3 *Two-sided pendulum test-band.*
1 - the mechanical part of the test band; 2 - the digital accelerometer; 3 - the microcontroller.

The test-band's hammer shuts the pendulum ensemble with a known impulse; the mobile part oscillates. The oscillations of the mobile part are measured by means of the accelerometer and the displacement of the mobile part is estimated and recorded within the computer.

The mechanical vibratory process may be represented by a second-order element with the transfer function given by the following expression.

$$G(s)=\frac{k_a\cdot\omega_n^2}{s^2+2\cdot\zeta\cdot\omega_n\cdot s+\omega_n^2};\quad s=\sigma+j\cdot\omega;\, s\in\mathbf{C} \qquad (12)$$

Where k_a is the gain / the proportional coefficient, ζ is the damping ratio and ω_n is the natural frequency of the given system.

The expression above may be transformed into the discrete domain as previous and a second - order operational transfer function is obtained:

$$G\left(q^{-1}\right)=\frac{b_0+b_1\cdot q^{-1}}{1+a_1\cdot q^{-1}+a_2\cdot q^{-2}}; \quad y[k-1]=q^{-1}y[k];\, k\in\mathbf{Z} \qquad (13)$$

The expression above lead to a second - order difference equation as follows.

$$M_2 : y[k]=-a_1\cdot y[k-1]-a_2\cdot y[k-2] +b_0\cdot u[k]+b_1\cdot u[k-1], \qquad (14)$$

which also is of the general form (6).

The experimental results are depicted in Figure 4. The measurements were affected by noise and nonlinearities due to the frictions within the mechanical system.

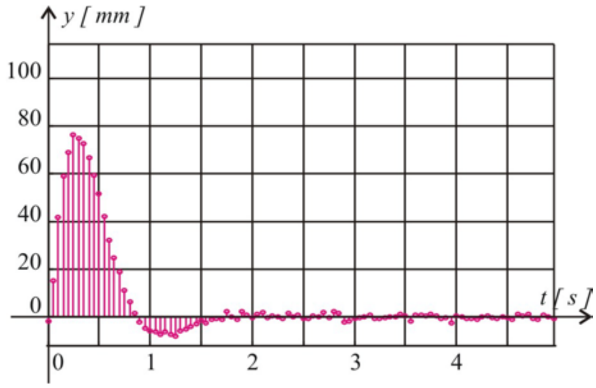


Fig. 4 *The experimental measurements of the weighting function of the mechanical vibratory system.*

In Table 2 were presented the results of the implementation of the disciplined convex optimization algorithm.

Table 2: *The true values and the estimations of the mechanical vibratory model parameters in the expression (14). *Note: the parameter b_0 is equal to zero both in the true model and in the resulting estimations and it was omitted.*

	a_1	a_2	b_1
True values [-]	-1.7144	0.75999	0.79665
Estimations Test no 1 [-]	-0.93306	0.5489	0.56422
Estimations Test no 2 [-]	-1.1189	0.22025	0.41354
Estimations Test no 3 [-]	-0.90722	0.54706	0.53752
Estimations Test no 4 [-]	-1.0369	0.37758	0.49148
Residuals [%]	41.7277	44.2820	37.0250

The residuals is not as good as in the previous experiment due to the higher level of the measurements noise.

4.3. The identification of an electric arc discharge

In the followings, the convex optimization was used to estimate the mathematical model of a time series from a practical experiment described in [7] referring to the study of the electric discharge in inert gas (argon). The experimental setup, presented in Figure 5 consisted of one closed combustion chamber provided with a plasma nozzle, a DC voltage supply (0 ... 220 V / 5A) and a DC boost converter. The converter was commutated at 12.5 Hz. The arc occurred at each commutation for a short period of time. The voltage drop and the arc current intensity were measured by means of a voltage transducer of type UxTT2 (0-400V / -10V ...+10V) and a current transducer of type LEM HP05(0-5A / 0 - 10V). The data were recorded by means of a two channel oscilloscope, Metrix OX6202. The plasma gas was argon. During the discharge, at the nozzle outlet, an indirect water vapor was injected. The arc current and the arc voltage drop were measured and recorded.

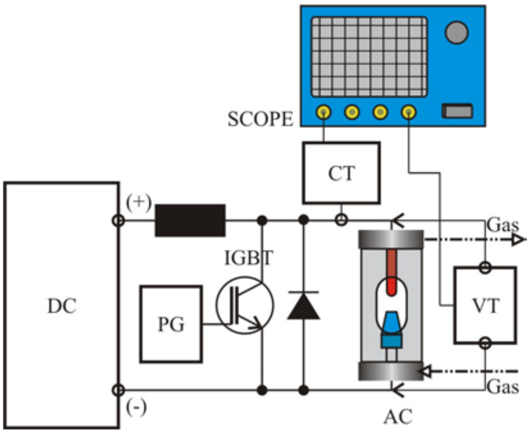


Fig. 5 *The schematic of the experimental setup*
DC - voltage supply, PG - pulse generator, AC-plasma chamber, CT - current transducer, VT - voltage transducer

The analytical model proposed for experimental identification of the time-series is given in the following expression.

$$i(t) = A \cdot e^{-\alpha \cdot t} + B \cdot e^{-\beta \cdot t} \cdot \cos(\omega_1 \cdot t) + C \cdot e^{-\beta \cdot t} \cdot \sin(\omega_1 \cdot t) \tag{15}$$

Where: the proportional factors $A; B; C \in \mathbf{R}$ are constants, the attenuations $\alpha; \beta \in \mathbf{R}_+$ and the angular frequency $\omega_1 = 2 \cdot \pi \cdot f_1$.

After the implementation of the *z*-transform, in the previous expression, the following complex representation results.

$$\begin{aligned} I(z) = {} & A \cdot \frac{1}{1 - e^{-\alpha \cdot T_e} \cdot z^{-1}} \\ & + B \cdot \frac{1 - \left(z \cdot e^{\beta}\right)^{-1} \cdot \cos(\omega_1 \cdot T_e)}{1 - 2 \cdot \left(z \cdot e^{\beta}\right)^{-1} \cdot \cos(\omega_1 \cdot T_e) + \left(z \cdot e^{\beta}\right)^{-2}} \\ & + C \cdot \frac{1 - \left(z \cdot e^{\beta}\right)^{-1} \cdot \sin(\omega_1 \cdot T_e)}{1 - 2 \cdot \left(z \cdot e^{\beta}\right)^{-1} \cdot \cos(\omega_1 \cdot T_e) + \left(z \cdot e^{\beta}\right)^{-2}}; z \in \mathbf{C} \end{aligned} \tag{16}$$

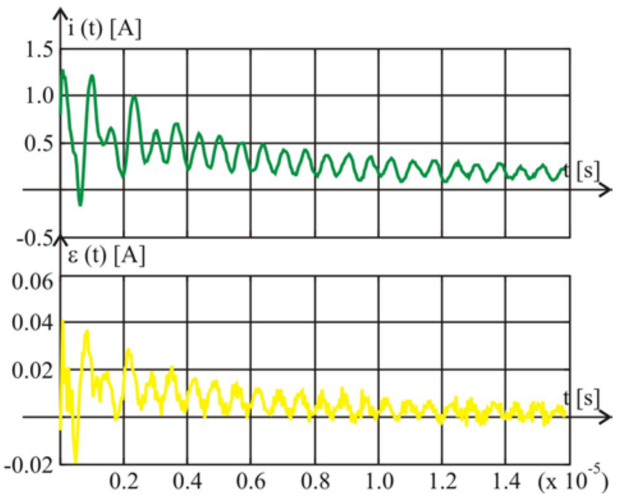


Fig. 6 *Sample sequences.*
The upper: plot the discharge current. The lower plot: the estimation error.

Taking into account the properties of the shift operator, q^{-1}, the discrete-time equivalent model of the time series results from the expression above as follows:

$$\begin{aligned} i[k] = {} & -a_1 \cdot i[k-1] - a_2 \cdot i[k-2] - a_3 \cdot i[k-3] \\ & + b_0 \cdot \delta[k] + b_1 \cdot \delta[k-1] + b_2 \cdot \delta[k-2]; k \in \mathbf{Z} \end{aligned} \tag{17}$$

Where were $\delta[k]$ is the value of the discrete Dirac pulse at step k . The expressions of the coefficients $a_i; b_j; i = \overline{1;3}; j = \overline{0;2}$ are complicated and are not given here.

In Figure 6 an example of the samples sequence plot is given.

The implementation of the disciplined convex optimization algorithm produced the results presented in Table 3.

Table 3: *Estimated parameters of the model in expression of the electric arc discharge. *Note: The parameters b_1 and b_2 resulted much smaller than b_0 and were omitted..*

	a_1	a_2	a_3	b_0
Estimated parameters [-]	-0.16823	0.22173	0.91494	0.019069

The residuals of the identification are depicted graphical in Figure 6.

5. Conclusion

The paper presented a study on the implementation of the disciplined convex optimization method in the field of system identification. The classical least-squares algorithms used to estimate the parameters lead to the minimization of the residuals cost function. The best accuracy of the estimate is obtained if the input signal is a white-noise process. The analysis in this paper proved that an equivalent minimization problem may be solved by means of the disciplined convex optimization algorithm in the case the input signal is a digital Dirac impulse (in practical experiments a short pulse). Further studies are to be made to examine the implementation of the disciplined convex optimization algorithm in the case the input signal is a random sequence.

6.References

[1] Boyd, S. , L. Vandenberghe . Convex Optimization, Cambridge, UK, Cambridge University Press, 2004.

[2] Söderström, T. , P. Stoica . System Identification, Cambridge, UK, Prentice Hall International, 1989.

[3] Grant, M. , S. Boyd, CVX: Matlab Software for Disciplined Convex Programming (web page and software. http://stanford.edu/boyd/cvx, 2015.

[4] Ogata, K., Modern Control Engineering, Upper Saddle River, New Jersey, USA, Prentice Hall, 1997.

[5] Manchester I. R., in: Joint 48th IEEE Conf. on Decision and Control and 28th Chinese Control Conf. Shanghai, P.R. China, December, 16-18, 2009., page 1551-1556.

[6] Danila, A. , Dynamic Systems Modeling and Identification, Brașov, Editura Universității ,,Transilvania", 2013, (in Romanian).

[7] Danila A., in: Electrical and Power Engineering (EPE), 2014 Int. Conf. and Exposition, Iași, România, October 16 - 17, 2014, file no. 547 on CD.

CALCULATION OF FREQUENCY CHARACTERISTICS OF SPLIT PHASE OF POWER TRANSMISSIONS LINES

Bekbayev A., Dzhamanbayev M., Khidolda Y., Karbozova A.
Kazakh National Technical Research University named after K.I Satpayev, the Republic of Kazakhstan

bekbaev_a@mail.ru

Annotation: *The article discusses the free-running sweep split phase (SP) power lines. We derive a nonlinear differential equation of torsional movement split phase by using Lagrange's equation of the 1st kind. In order to obtain an approximate solution of the nonlinear problem applied the method of Van der Pol. Analyzed degree of influence of parameters of power lines on the frequency of torsional vibrations of SP.*

Keywords: POWER TRANSMISSIONS LINES, SPLIT PHASE (SP), KINETIC ENERGY OF SP, AMPLITUDE OF THE TORSION, LAGRANGE EQUATION, METHOD OF VAN DER POL

Equation of twisting movement of split phase (SP) is determined from Lagrange equation [1]

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\varphi}(t)}\right)-\frac{\partial L}{\partial \varphi(t)}=0 \qquad (1)$$

where $L=E_k-E_d$ – Lagrange function (E_k - kinetic energy , E_d - deformation energy).

Kinetic energy of SP from rotational motion [2].

$$E_k=\int_0^{\ell}\frac{J_\phi}{2}\left(\frac{\partial \Phi(z,t)}{\partial t}\right)^2 dz \qquad (2)$$

where $F(z,t)$ - function, which determines phase twisting in random point and in random moment of time, ℓ – length of span, J_ϕ - inertia moment of split phase

$$J_\phi=\frac{nP_0}{g}R^2 \qquad (3)$$

where R - radius of splitting, n - number of splitting (number of wires in phase), P_0 – weight of 1 meter wire, g – acceleration of gravity.

For approximation of SP by the single degree of freedom system we assume, that its twisting along the span occurs only by single space form $\psi(z)$. In this case we imagine the function $F(z,t)$ as follows.

$$F(z,t)=\varphi(t)\psi(z)=\varphi(t)Sin\frac{\pi z}{\ell} \qquad (4)$$

where $\varphi(t)$ - generalized coordinate, $\psi(z)$ - coordination function, which satisfies the boundary conditions.

Kinetic energy of SP considering formula (4) converts to

$$E_k=\frac{nP_0R^2\dot{\varphi}^2(t)}{2g}\int_0^{\ell}Sin^2\frac{\pi z}{\ell}dz=\frac{nP_0\ell R^2}{4g}\dot{\varphi}^2(t) \qquad (5)$$

Considering the condition, that relation between extending and tension of wire has linear character, then deformation energy of *i* split phase wire is determined by formula [3]

$$E_{d\,i}=T_0\left(L_\varphi-L_0\right)+\frac{EF}{2\ell}\left(L_\varphi-L_0\right)^2 \qquad (6)$$

where E - Young's modulus, F - cross sectional area of the wire.

Wire length in static equilibrium L_0 and length L_φ, corresponding to twisted state of *i* wire of SP, are determined by approximate formula, known from higher mathematics course.

$$L_0=\int_0^{\ell}\left[1+\frac{1}{2}\left(\frac{\partial y(z)}{\partial z}\right)^2\right]dz \qquad (7)$$

$$L_\varphi=\int_0^{\ell}\left[1+\frac{1}{2}\left(\frac{\partial q_\varphi(z,t)}{\partial z}\right)^2\right]dz \qquad (8)$$

where $q_\varphi(z,t)$ – function, describing the configuration of SP wire considering its twisting.

After geometrical calculations of SP twisting along the span the expression for function $q_\varphi(z,t)$ is determined

$$q_\varphi(z,t)=y(z)-RF(z,t)\cos\mu_i \qquad (9)$$

where $y(z)$ - coordinate function, describing the position of static equilibrium of wire in span, is determined by known formula

$$y(z)=\frac{P_0}{2T_0}z(\ell-z) \qquad (10)$$

In the expression (9) the angle μ_i determines mutual location of separate wires in a bundle. If we denote initial angle coordinate one of the wires, which is conditionally taken as a first, by μ_1, then next angles μ_i will be determined by formula

$$\mu_i=\mu_1+\frac{2\pi(i-1)}{n}\ ; \qquad (i=\overline{1-n}) \qquad (11)$$

Difference of wire lengths with (9) and (10) (prime is a derivative by z)

$$L_\varphi-L_0=0{,}5RCos\mu_i\left\{RCos\mu_t\int_0^{\ell}\left(F'(z,t)\right)^2dz-2\int_0^{\ell}y'(z)F'(z,t)dz\right\} \qquad (12)$$

Omitting the intermediate transformations and calculations, we can represent the final result for the deformation energy of the SP, taking into account the difference in the lengths of wires (12)

$$E_d=\sum_1^n E_{di}=\frac{\pi^4EFR^4\sum_1^n Cos^4\mu_i}{32\ell^3}\varphi^4(t)+$$

$$\frac{\pi^2 R^2 T_0 \sum_1^n Cos^2\mu_i}{4\ell}\left(1-\frac{4EFP_0^{\ 2}\ell^2}{\pi^4 T_0^{\ 3}}\right)\varphi^2(t) \qquad (13)$$

It should be noted that for transformation into account following relationships

$$\sum_1^n Cos\mu_i = 0 \quad \text{and} \quad \sum_1^n Cos^3\mu_t = 0$$

Forming Lagrange function and substituting in equation (1), we obtain the nonlinear differential equation,

$$\ddot{\varphi}(t) + \omega_k^{\ 2}\varphi(t) = -\nu\varphi^3(t) \qquad (14)$$

Where V – a small parameter, which depends on the characteristics of the SP.

$$\nu = \frac{\pi^4 gEF}{4P_0\ell^4}\frac{1}{n}\sum_1^n Cos^4\mu_i \qquad (15)$$

ω_k - Is the frequency of the twisting motion of the linearized system

$$\omega_k^{\ 2} = \frac{\pi^2 gT_0}{P_0\ell^2}\left(1+\frac{8EFP_0^{\ 2}\ell^2}{\pi^4 T_0^{\ 3}}\right)\frac{1}{n}\sum_1^n Cos^2\mu_i \qquad (16)$$

The solution of the nonlinear differential equation (14) is performed by method of Van der Pol [4]. According to the method of Van der Pol, we shall seek solutions (14) and its first derivative with respect to time in that form

$$\varphi(t) = f(t)Sin[\omega_k t + \alpha(t)] \qquad (17)$$

$$\dot{\varphi}(t) = \omega_k f(t)Cos[\omega_k t + \alpha(t)] \qquad (18)$$

Where $f(t)$ - variable amplitude, $\alpha(t)$ - variable initial phase, ω_k -proper frequency of the linearized system, determined by the formula (16).

Omitting the intermediate calculations, we represent the final result

$$\varphi(t) = f_0 Cos\left[\left(\omega_k + \frac{3\nu}{8\omega_k}f_0^2\right)t\right] \qquad (19)$$

From (19) we can see, that the wave circular frequency SP ϖ_k which depends from the amplitude of the torsion f_0 is equal to

$$\varpi_k = \omega_k + \frac{3\nu}{8\omega_k}f_0^2 \qquad (20)$$

Equation (20) represents the amplitude frequency response of SP and sets dependence of the frequency of free torsion motion from the amplitude of the torsion and SP characteristics.

Analysis of the equation allows making the following conclusions:

- at small amplitudes f_0 of frequency autonomous oscillation of SP ϖ_k is close to the frequency of the linearized system ω_k. The increase in frequency with increasing amplitude of torsion occurs theoretically up to infinity.

- In practical calculations, the influence of the amplitude of the torsional movement of the split phase on the frequency autonomous oscillation can be neglected as the calculation formulas with sufficient accuracy can take a simplified expression (16). For example, when the amplitude φ_0 = 600 (slightly higher than the actual amplitude of the torsion SP at the dance), the maximum difference between the ϖ_k and ω_k is not more than 1.5%.

References

1 Guliaev V.I., Bazhenov V.A., Popov S.L. Applications of the theory of nonlinear oscillations of mechanical systems.-Moscow «High school» ,1989.

2 Bekmetev R.M., Zhakaev A.S., Shirinskih N.V. Swinging of conductors of power lines. – Alma-Ata, «Science» KazSSR, 1979. Page 152.

3 Bekmetev R.M., Dzhamanbayev M.A. Methods of calculating the dynamic loads at swinging of conductors/ collection of reports of Soviet experts at an international meeting on swinging of conductors of ETL/.-Sochi, October, 1985.

4 Bat’ M.I., Dzhanelidze G.U., Kelzon A.S. Theoretical Mechanics in examples and problems III. –Moscow.: «Science»,1973, page 487.

ASPECTS OF RISK MANAGEMENT IN LOGISTICS ACTIVITIES OF ENTERPRISES. APPLICATION OF FAULT TREE ANALYSIS (FTA)

НЕКОТОРЫЕ АСПЕКТЫ УПРАВЛЕНИЕ РИСКАМИ В ЛОГИСТИЧЕСКОЙ ДЕЯТЕЛЬНОСТИ ПРЕДПРИЯТИЙ. ПРИМЕНЕНИЕ АНАЛИЗ ДЕРЕВА ОТКАЗОВ (FTA)

Assoc. Prof. Ph.D. Eng. Nikolov B.[1], Eng. Tcholakova V.[2]
Faculty of Management – Technical university of Sofia, Bulgaria[1]

Abstract: *Risk management in logistics enterprises is one of the important topics in the management of supply. In today's global reality characterized by constant and rapid changes that make high degree of uncertainty and risk, make the logistics activity critical.*
The purpose of this article is to present the main aspects of risk management including the construction of the risk profile in logistics activity in enterprises and demonstrate the applicability of the FTA, which was developed conditional example. This will considerably facilitate efforts directed at risk management in logistics activity in enterprises.
***KEYWORDS**: RISK MANAGEMENT, LOGISTICS, LOGISTIC ACTIVITY, FTA*

1. Introduction

For many enterprises, the traditional operational strategies directed to “stock” setting up and investments in buffer capacities, that will take the high initial demand, cannot match the business environment and to be competitive. That motivates the enterprises to direct their efforts to search and apply strategies that will create an opportunity for quick and adequate reaction of the changes in the business environment and at the same time the expenses are reduced to a minimum [1].

The risk assessment in any activity as well as in the logistic management is a key element and has a determinant role for the way of functioning and the competitive power in particular and for the enterprise as a whole.

2. Presentation

2.1. Key role of logistics in business management in the dynamics of the modern business environment

The modern dynamics of the business environment, considerably exalted in result of the world crisis, places new outlines in the global world. New economic sectors are formed as a result of new demands and preferences as well as different consumer values. The adaptation of the enterprises to all these changes is turning to be a critical stage in their management. The growing variability of the business environment is getting so big that it is impossible to predict. In addition to that the new risks coming into existence create huge risk for the enterprises as well as high insecurity in their operations.

Keeping the dynamic balance between the way of functioning of the enterprises and the requirements and characteristics of the business environment as well as creating of competitive privileges is getting more and more difficult goal [2].

Along with the already mentioned above, another two factors for the modern business cannot be skipped, and they are time and space where the connection between them is the logistics.

The logistic itself is defined as one of the main competitive privileges. For instance – Martin Christopher, [5] defines the effective management of logistics and chain of supply as a main resource of competitive privilege – which means the position of having a long upper hand of the consumer’s preference among the competitors can be achieved by better logistic management and chain of supply.

On figure1 is presented a simplified model of the enterprise, consumers and competitors or the so called the 3 C’s – the three ways of interdependence between them [5].

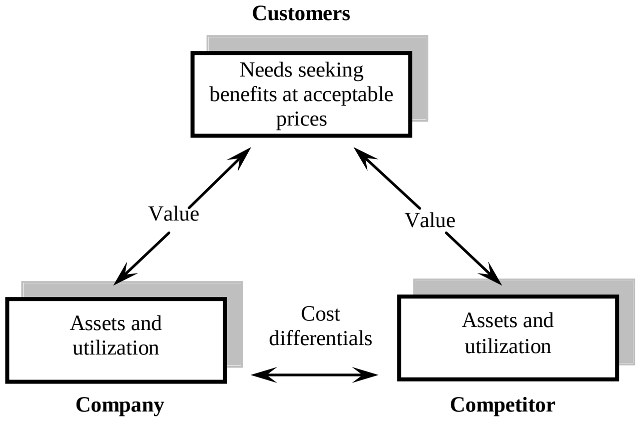


***Fig.1** Competitive advantage and the “Three Cs” (Source: Ohmae, K., The Mind of the Strategist, Penguin Books, 1983)*

According to Martin Christopher [5] the resource of competitive privilege is detected in first place in the ability of the enterprises to determine themselves from the consumers and the competitors and in second place – operating by less expenses to generate higher profit.

Gleissner and Femerling [6] define the logistics as a competitive instrument and means for rationalization.

In that way the logistic services can generate different opportunities for strategical competitive privilege. On the other hand, the good organization of the logistic systems can develop the potential of rationalization that can give a stable competitive privilege of the enterprise.

According to Harrison and van Hoek, [7], you need to clearly set the goals and their essentiality and measurability so you can clearly define the logistic privileges. Basically three “firm goals” are dissociated - quality, time and price. Later on they determine two main ways of logistic privilege formation and the variability in the logistic process and managing the vagueness - they are called “supportive capabilities”.

The goal and achieving of competitive priorities are in the basis of the enterprises competitive power that is assessed as inner value for any of them and it is connected with certain characteristics. The competitive priorities and all factors of the same character are very dynamical and the way of getting them stable in the modern dynamics of the business environment must be directed to searching a broad complex of different processes and activities connected to quality, reliability, price, speed including manufacturing and distribution.

Logistic management as a management of the whole flow of products, information, people, financial resources etc… must keep close connection with the whole complex of activities and processes. The high coordination and harmonization in management of the logistic process together with the rest of the activities and processes in the enterprises is in the basis of high loyalty creation to the customers and in the basis of achieving stable competitive privileges.

2.2. Risk profile and risk profiling in management of the logistic activity.

The large and quick changes in the business environment put in central stage the topic of risk and risk management. The risk management is an essential key element exerting extreme influence on the activity of the enterprises. They cause different risk situations because of their complicated nature.

The possibility of identifying and evaluating the risk situations is in the basis of adequate reaction and respectively adequate management that can minimize the risk results e.g. decreasing the loss amount, opening new opportunities etc. This means it decreases the potential negative risks and increases the potential of the positive risks and the buffer effect when you can’t avoid the risk situation. In that way “taking the risk” creates an environment for the enterprise to cope with the negative influence (fig.2).

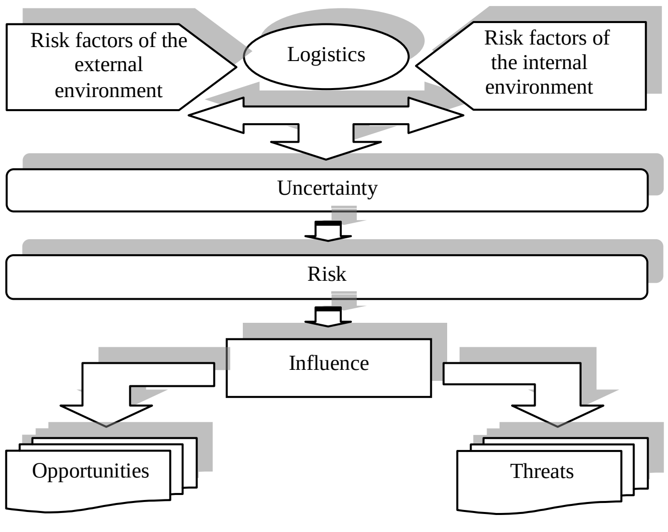


Fig.2 *Risk resource and influence*

The global factor and the permanent development of the information technologies constantly change and create a completely different way of functioning of the logistics and the logistic systems. They create new structures of competition, communication, manufacturing locations etc…

Risk management in the logistic activity in the enterprises has a huge impact on the way of functioning and the competitive power. In 2011 Aon Global Risk Management Survey [4] records „supply chain failure” as one of the top three risks shown by the respondents in the industries – biotechnologies, pharmaceuticals, consumer’s goods, machinery and equipment and non-aviation transport.

The large risk variety in different types of business are typical in the logistic activity as well , like financial risks, transport risks, outsourcing risk, political risks etc...

Determining of the risk profile that has an effect on the “risk exposition” in certain period of time is of a great significance for reaching an effective risk management. Defining the separate risk groups, specific risks as well as their potential effect – their probability and consequences connected with the logistic activity, afford an opportunity for defining the target risk profile or the so called “desired” risk profile. This determining will be connected with the risk appetite, the set goals, the method of management etc… For instance, if we look at logistic macro-model that consists of three main components – supply, manufacturing and distribution, we can define the four main group risks – business environment, consumers, products and services , raw material suppliers(fig.3).

Based on the risk analysis we can create a risk profile where the accent will be directed to all key risks and risk areas of this activity, strengths and weaknesses, opportunities, risk tolerance guideline, priority set up etc… It is important to be highlighted that forming of a significant risk profile is a major step to forming of an integrated risk management.

In that way the risk management in the logistic activity will be connected with “constant” correction in the current risk profile, i.e. risk defining (risk groups, specific risks etc…) that has high influence and effects and will be directed to different ways of decreasing. This will form the so called “desired“ risk profile.

In result of development and defining of the risk profile the threats will be identified as well as the logistic activity possibilities and guidelines for building of effective risk management strategies.

2.3. Application of Fault Tree Analysis (FTA) for risk rating in the logistic activity

Fault tree is a graphic method that can make a quantitative risk analysis in different stages of the activity e.g. in the process planning stage, in the operation stage etc… Here this method will be applied in a different way and it is risk analysis in the logistic activity.

On the basis of presenting the separate reasonable factors and logic connection along with the identified event (“top” event) a quantification can be done for the possibility that it will be realized (fig.4). This allows thorough understanding of the logistic activities and revealing of the events that lead to risk realization.

FTA application consists of consecutive stages and is exemplified by model example. The example illustrates some possible situations related to the raw material supply.

First stage. Determination of the main event

In the example the main event related to the raw material supply is “Delay of delivery”. On this basis a graphic model of the lowest level events is built up and it is showing the link between the separated elements related to the main event.

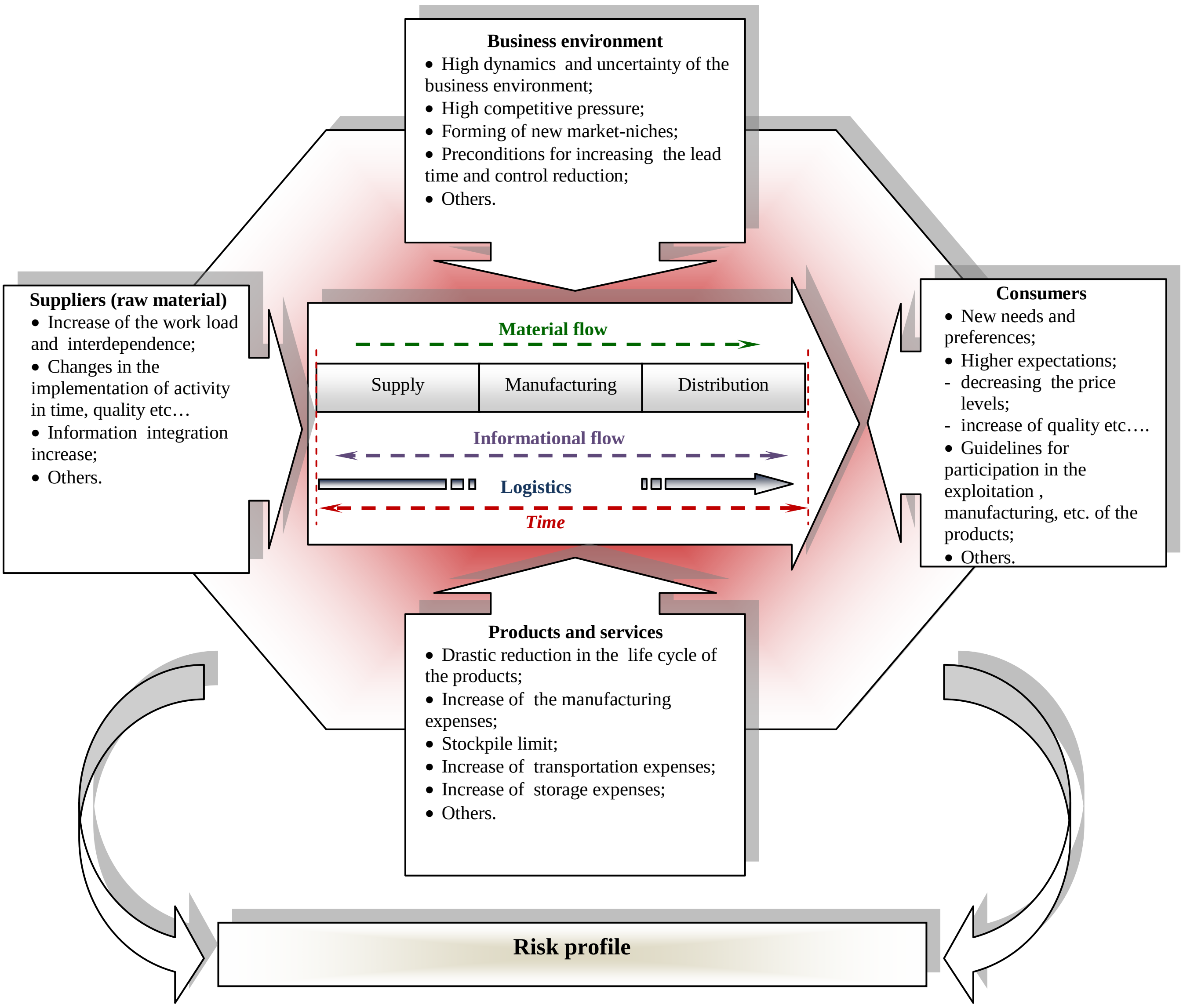


Fig.3. *Risk profile set up in the logistic activity*

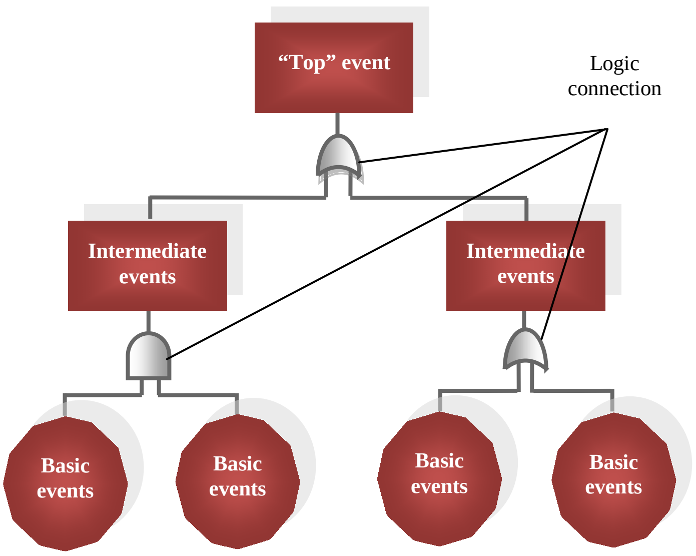


Fig.4. *Fault tree*

Second stage. Identifying the reasons leading to the main event

A few possible reasons are shown (possible situations) that are related to the main event realization, like:

- *Incorrect specification of the raw materials – inaccuracy in the raw material description, inaccuracy in the date of order;*
- *Incorrect determination of the time between initiation and realization of the order or the so called “lead time” – determination of unreal time of delivery, omission in lead-time delivery overview;*
- *“Problem” with invoicing - incorrect invoicing, invoicing delay.*

On the basis of these two stages we can set up a graphic model showing the links between the separate “elements” with the main event (fig.5).

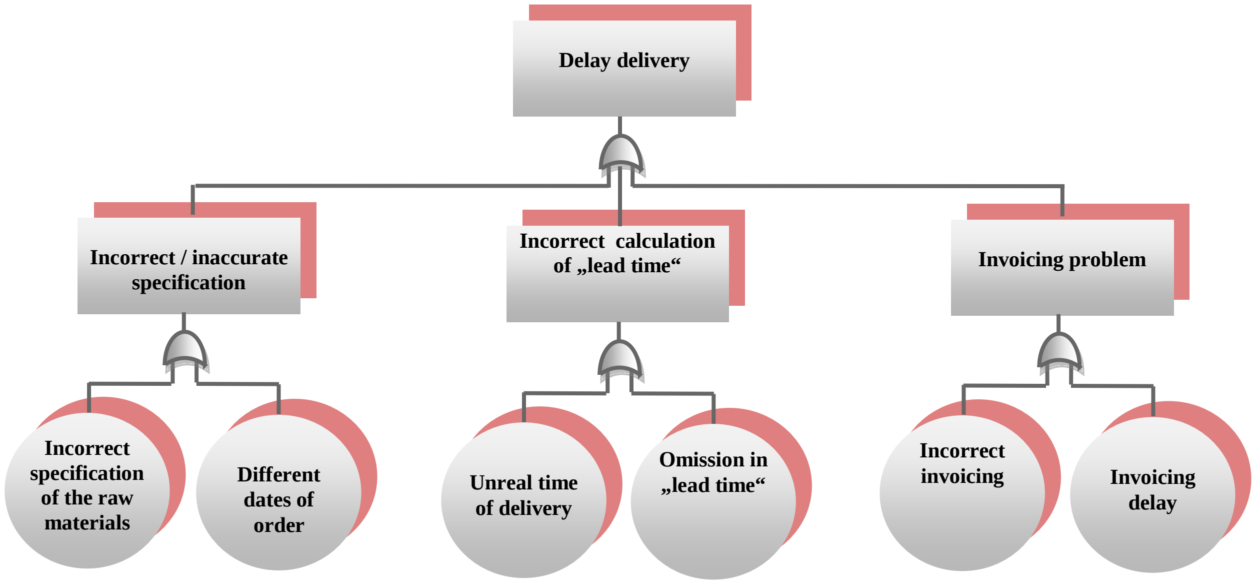


Fig.5 *Fault tree of delay delivery*

In this case the logistic operation between the separate "elements" will be "or" because every separate activity will lead to risk realization at higher level.

Third stage. Determination of the possibility of every separate event

The possibility determination begins with the main event and in the example given it can be determined on the basis of statistic data for certain period of time.

For example, if we have "inaccuracy" in the raw material inventory in a month for 10 out of 50 orders, the possibility for accuracy is 0.8, respectively the possibility for inaccuracy is 0.2. For the rest of the parameters::

Different dates of order – 0.55 (0.45);

Unreal time of delivery – 0.45 (0.55);

Non-inspection of lead time – 0.35 (0.65);

Wrong invoicing – 0.90 (0.10);

Delay invoicing – 0.70 (0.30).

Forth stage. Determination of the possibility for delivery delay

To determine the possibility of delivery delay we need to determine the possibilities for any of the intermediate events on the basis of the main events. Having in mind the logistic operation "or" and determination of the separate event's possibility, the possibility of delay delivery event can be determined by calculation of "negative event" from one:

$$P = 1 - \prod_{i=1}^{n} (1 - P_i) \qquad (1.1)$$

Where:

P – in this case – possibility that the delivery will not be delayed;

P_i – in this case – possibility of accuracy of the examined situations, $i=1,\ldots,n$,

In the first case we will begin with calculation of the possibility that there is no "incorrect" specification of the raw materials where the intermediate event eventuates from two main events: inaccuracy in the raw material specifications and inaccuracy of the date of order. Using formula 1.1 we have:

$$P = 0{,}91$$

Respectively for the possibility that there is no "incorrect" calculation of lead time where the intermediate event eventuates from two main events: unreal time of delivery and omission in lead time we have:

$$P = 0{,}64$$

For the possibility that "there is no" problem with the invoice, where the intermediate event eventuates from two main events: wrong invoicing and delay invoicing, we have:

$$P = 0{,}97$$

Therefore, in this example, on the basis of the calculations made, the possibility that *there will be no delivery delay is*: 0,99, i.e. the risk is 0,01.

The demonstrated method of risk evaluation in the logistic activity has many priorities like high flexibility and this gives opportunities for analysis of many factors and possible situations. The realization of top-down method allows us to focus our attention to all negative events connected to the main event.

3. Conclusion

Risk management is of main importance and a key stage of the activity of any enterprise. The few aspects that are examined are connected with the risk and its evaluation. They affect the risk profile and the risk profiling and are in the basis of effective risk management in the logistic activity of the enterprises. This gives opportunities for the enterprises in the logistic departments and this leads to construction of effective strategies and their management. The demonstrated method of risk evaluation by adapting the FTA technique in the logistic activity gives an opportunity for considerably deeper analysis and evaluation of the risks in the examined sphere.

Bibliography:

1. Димитракиева С., ”Управление на финансовите ресурси”, Варна, България, 2013г., ISBN 978-954-2912-41-5.
2. Димитракиева С., Ралчева Д., “Възможности на системата за управление на взаимоотношенията с клиентите за ефективно управление на бизнес стратегията на организацията”, Девета международна научна конференция ”Мениджмънт и инженеринг”, гр.Созопол, 2011г., стр. 678-684,ISSN 1313-7123.
3. Николов Б., Управление на риска в производствените системи (Класически и алтернативни решения), Кинг, 2012, ISBN 978-954-9518-70-4
4. Aon, Global Logistics Practice: World-Class Global Logistics Risk Management, 2012.
5. Christopher M., 2013. Logistics and Supply Chain Management ePub eBook, Pearson UK, 2013, http://www.aon.com/attachments/risk-services/Marine-World-Class-Global-Logistics-Risk-Management.pdf
6. Gleissner H., J. Christian Femerling, 2013.Logistics: Basics – Exercises – Case Studies, Springer International Publishing Switzerland 2013, ISBN 978-3-319-01768-6.
7. Harrison A., van Hoek R.,2008., Logistics Management and Strategy Competing through the supply chain, Third edition, Prentice Hall, 2008, ISBN: 978-0-273-71276-3
8. Langevin A., Riopel D.,2005. Logistics Systems: Design and Optimization, Springer Science+Business Media, Inc.,2005, ISBN 0-387-24971-0, e-ISBN 0-387-24977-X