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**NATIONAL SCIENTIFIC TECHNICAL SOCIETY
AUTOMATION IN DISCRETE PRODUCTIONS**

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EMERGENCY BRAKING OF FAST RUNNING LOADING / UNLOADING HOISTS

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Abstract: Cranes integrated in the logistic chain are vital elements to ensure safety and economic efficiency of transport. So safety is an essential factor for service of cranes in nuclear plants or metallurgical plants. For service of ship-to-shore-cranes the economic efficiency is an additional dominating aspect. A main assembly of every crane is the hoist. Following is shown, which internal forces occur in the components of a hoist with safety brake and are to be considered while dimensioning. In addition a concept for the design and the control of the braking system is shown in order to reduce the internal forces in hoist components of the rotational part of the drivetrain as couplings and gearing.

Keywords: CRANE, HOIST, SHIP-TO-SHORE CRANES, BRAKING SYSTEM

1. Starting point

Due to instationary service hoists are dynamically loaded structures. Especially for the case of emergency-off of safety oriented hoists with a safety brake on the rope drum disc high dynamic internal forces occur in the drivetrain [1, 2, 3]. Thus exists the risk of component failure, which can be observed in practical applications. The failure of a component, especially the hoist gearing, results in consequences relating safety and availability and is to be prevented. Thus a target oriented approach in planning of open winches is of special relevance.

2. Hoist structure

Generally hoists consist of a drive train, to the ends of which loads are applied: At one end the motor and the brake are located, at the other end the load is attached. At safety oriented hoists as in ship-to-shore-cranes (Fig. 1), in nuclear plant cranes and in cranes for transporting molten metal this looks a little bit different.



Fig. 1 Container Terminal Wilhelmshaven.

To cover a rupture of the drive train an additional safety brake is located on the board disc of the rope drum mostly. Thus a load can be applied in the middle of the drive train [1]. In comparison to the general hoist structure a modified dynamic behavior of the hoist is the consequence.

3. Braking process

It is task of brakes in hoists, if required, to stop the hoist within a certain time or without exceeding a certain further hoisting distance or lowering distance. Subsequent the hoist is to be hold in the reached position in the first instance.

During deceleration a braking torque must be delivered by the brakes. Amount and direction of the braking torque comply with the considered load case, which can be understood as the transition between two service conditions. The service conditions respectively the transitions between them can be visualized in the four-quadrant-diagram (Fig. 2).

The actions of motor and brakes during a braking procedure are not permanent. In fact a sequence of omitting and adding loads on

the drive train occurs. Especially the case of emergency-off is considered here with its special chronological scenario.

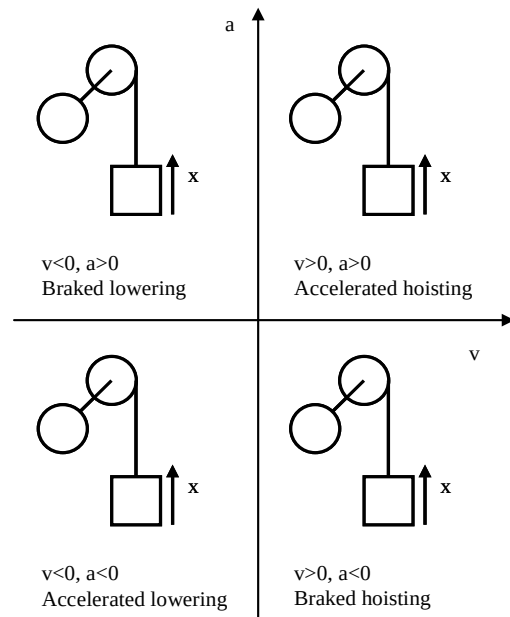


Fig. 2 Container Terminal Wilhelmshaven.

4. Reference system

For a closer look a partly redundant hoist with safety brakes is considered (Fig. 3).

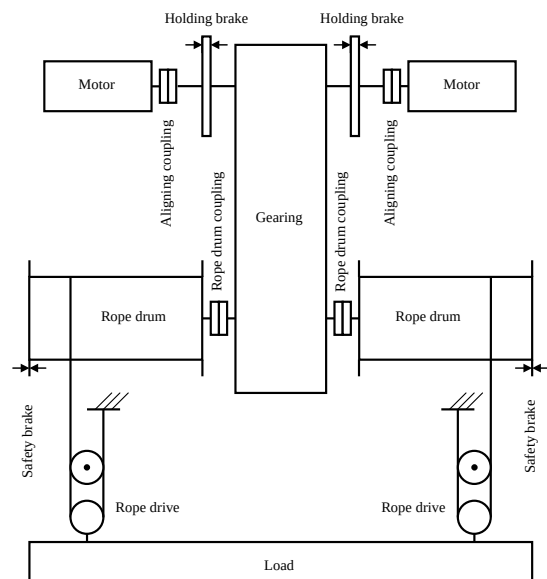


Fig. 3 Reference System.

Central element of the hoist is the gearing. The load is suspended by a load attachment device and a rope drive with 8/2 reeving. Both ropes are running onto a drum each, which are coupled with the gearing output shafts. On the board disc of each rope drum a safety brake is located. The hoist is driven by two motors which are connected to the gearing input shafts. On the motor shafts axis a service brake is located each.

The reference hoist is described by following data:

Motor speed	$n_1=1500\text{min}^{-1}$
Hoisting speed	$v_H=45\text{m/min}$
Mass motor shaft	$\theta_1=20\text{kgm}^2$
Mass rope drum shaft	$\theta_2=500\text{kgm}^2$
Mass load attachment device	$m_{LAM}=10\text{t}$
Mass SWL	$m_{SWL}=52\text{t}$
Radius rope drum	$r=0.5\text{m}$
Gearing ratio	$i_G=26.2$
Rope drive ratio	$i_S=4$
Service brake torque	$M_{BB}=5.8\text{kNm}$
Dead time service brake	$t_{totBB}=0.4\text{s}$
Safety brake torque	$M_{SB}=130\text{kNm}$
Dead time safety brake	$t_{totSB}=0.1\text{s}$
Gearing stiffness	$c=4\text{e}4\text{Nm/rad}$
Clearance drum coupling	$s=3^\circ$

5. Load cases

The hoist underlies in service different load cases, described by following parameters:

- Concerning the direction of movement holding, hoisting and lowering can be distinguished.
- Concerning the variation of speed constancy, acceleration and deceleration can be distinguished.
- Concerning the load suspended at the rope drive loads from dead load (load attachment device) to full load (load attachment device plus safe working load) may occur.

Concerning the internal forces are switching processes of interest. In doing so changes between following service conditions can occur:

- Suspended load
- Hoisting
- Lowering
- Service-stop
- Emergency-stop
- Emergency-off

Following load cases are considered, which will lead to high internal forces in the drivetrain by trend. Considered is the case of emergency-off for a hoist, which disposes of a fast acting safety brake and a slow acting service brake. Emergency-off means, that energy supply is cut off spontaneously and all components react accordingly. The motor torque is omitted and the brakes apply mechanically.

6. Kinetics

For the hoist represented as a rigid body model the behavior of load speed over time can be calculated. As a result for example the speed over time for different mechanical braking scenario out of hoisting/lowering the dead load are gained (Fig. 4).

The rigid body approach does not consider elasticity and clearance in the hoist system. Accordingly it is of interest to investigate the influence of these properties. Therefore the rigid body model is expanded by adding the elasticity of the gearing and the clearance in the rope drum coupling.

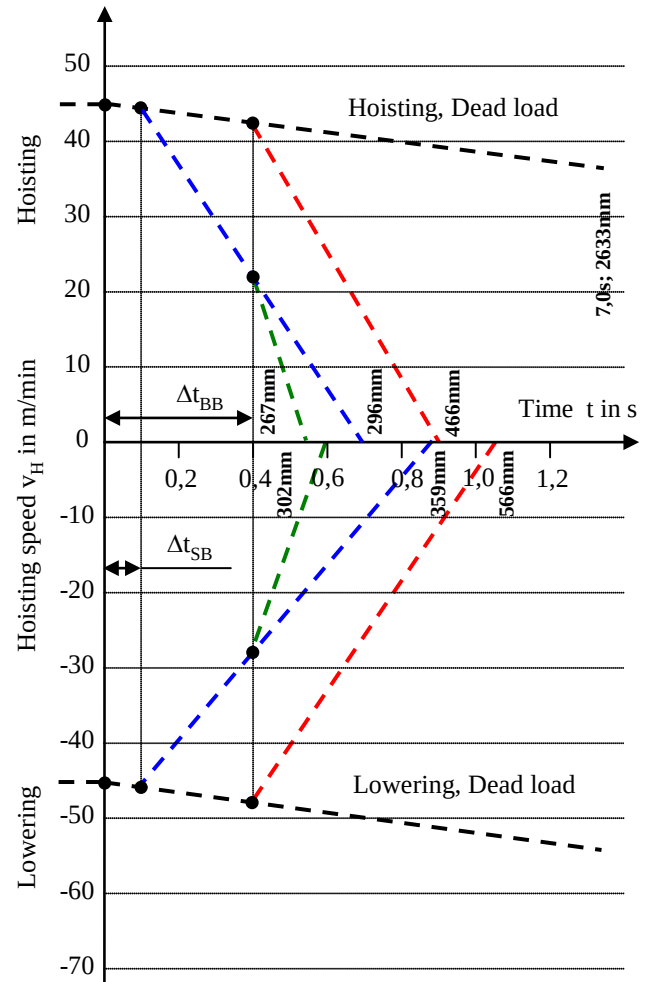


Fig. 4 Speed characteristics for braking dead load

7. Braking during hoisting

Examinations show the special relevance of the load case emergency-off out of hoisting the maximum load.

As observed the deceleration of the hoist occurs quickly. This is caused mainly due to the braking by the high load. Thus the deceleration process is finished as fast that the service brake (holding brake) with greater dead time in general is not or fairly not coming into action anymore. Firstly the torque for braking the motor mass is supplied by the load and the safety brake and transferred to the motor mass via the drive train.

With several assumptions the maximum relative gearing input torque for braking with the safety brake out of hoisting (+) or lowering (-) is calculated as

$$M_{G \text{ rel max}} = \phi_5 (MF(LF \pm BF_{SB}) - LF) + LF$$

Here the torque jump resulting out of the change of service condition according to the rigid body model is assessed with the dynamic factor for drives ϕ_5 corresponding EN 13001-2 [4].

The dynamic peak torques (Fig. 5) can occur, as far as they are supported by the static load, braking torque and inertia torque. Details regarding this are to be determined by an elasto-kinetic analysis. It is obvious for the considered load case that internal forces resulting in the drive train are a multiple of the static holding torque.

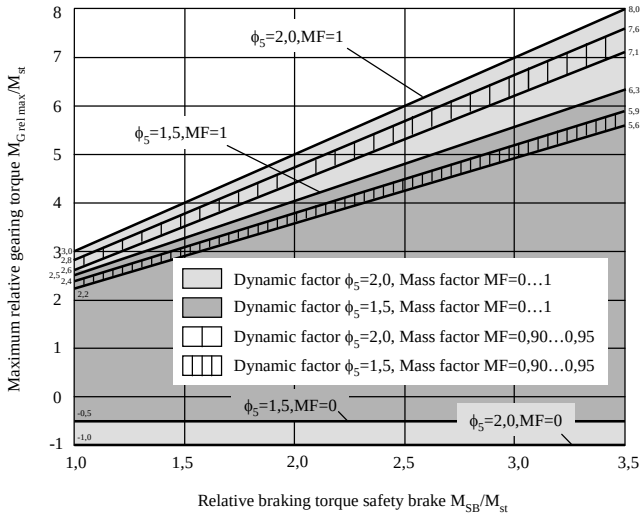


Fig. 5 Maximum relative gearing torque

8. Braking during lowering

Analyses show that especially the load case of emergency-off out of lowering the dead load is of interest.

Emergency-off immediately initiates switch-off of the motor and activation of the safety brake. For the mentioned data a maximum relative gearing input torque of $M_{G \text{ rel max}} = 8.9$ is calculated (Fig. 6). That means the gearing torque is factor 8.9 higher than the maximum static loading of the drive train.

During lowering the hoist is driven by the load, which is hold in steady state condition by the motor. When the safety brake gets into action, the stoppage is executed very fast for this case as well. On one hand this is caused by the low load level, dead load. Assuming clearances in the drive train (in gearing and/or couplings) it is expected furthermore, that a flank change will occur. During this the motor side masses and the braked load side are uncoupled. Respectively the motor side masses need not to be decelerated.

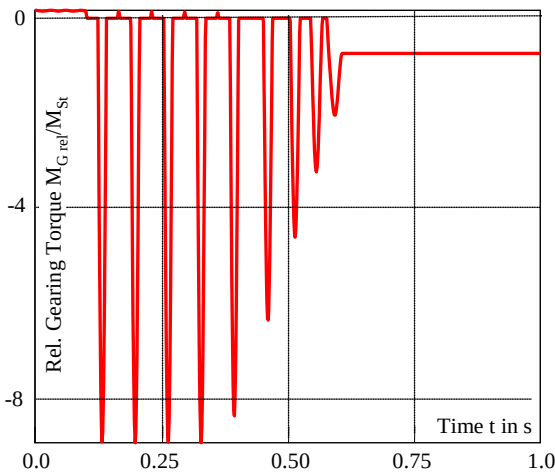


Fig. 6 Gearing torque according to elasto-kinetic hoist model

At an appropriate constellation the load side will stand still before running through the clearance is finished. In this case after running through the clearance a shock will occur. The motor side pitches on the standing load side. Toothed wheels and bearings in the gearing are loaded significantly by this shock. A special shock load may occur to the bearings of helical gears. In this case the shock is led in

axial direction of the shafts and with it on the roller bearing acting as fixed bearing.

9. Gearing loading

From the calculations maximum internal gearing torques much higher than according to static or rigid body approaches can be derived. Especially in the gearing such shock-like internal loads appear after running through clearances in relation with Hertzian contacts (toothing, roller bearings). To ensure safety such maximum internal loads must be covered statically. To ensure durability such maximum internal loads should not lead to pre-damages, which would lead to fatigue under further service loading.

10. „Intelligent“ braking

As measure to reduce peak values and amplitudes of the internal loads is considered: Synchronous and balanced action of all brakes participating in the braking process, here the service brake and the safety brake. This leads to a direct participation of the service brake in the braking process. This ideally results in a switching scenario with dead times of the service brake and the safety brake of $\Delta t_{BB} = \Delta t_{SB} = 0s$. Requirement is a holding of the motor torque until both brakes get into action.

Remains the question with which amount of torque the safety brake and the service brake should act. Favourable would be braking in a way that the quasi static internal torque before braking is still present during braking. Assuming these requirements given for the structure of the reference hoist following braking factors for the safety brake and the service brake for the braking out of hoisting (-) or lowering (+) are calculated:

$$BF_{BB} = \mp \left(LF + MF \frac{\theta_{ges}^*}{M_{st}^*} \frac{\Delta \omega}{\Delta t} \right)$$

$$BF_{SB} = \mp (1 - MF) \frac{\theta_{ges}^*}{M_{st}^*} \frac{\Delta \omega}{\Delta t}$$

For the reference hoist the brake factors and their sums are calculated as shown for braking out of hoisting (Fig. 7) and out of lowering (Fig. 8).

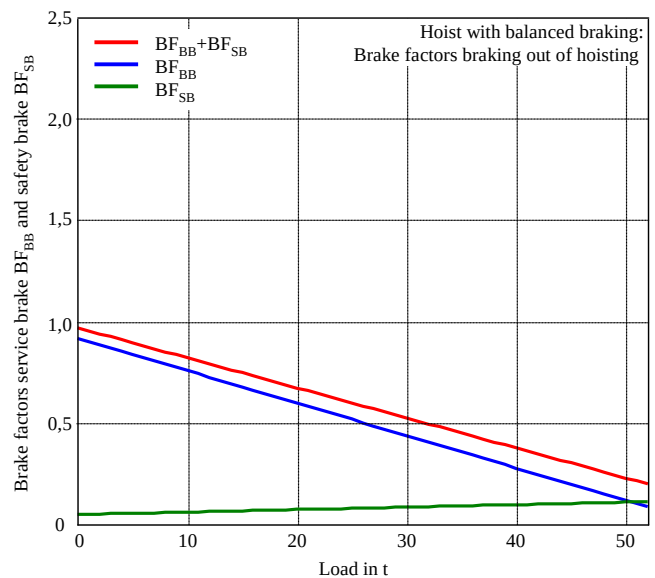


Fig. 7 Braking factors for braking out of hoisting

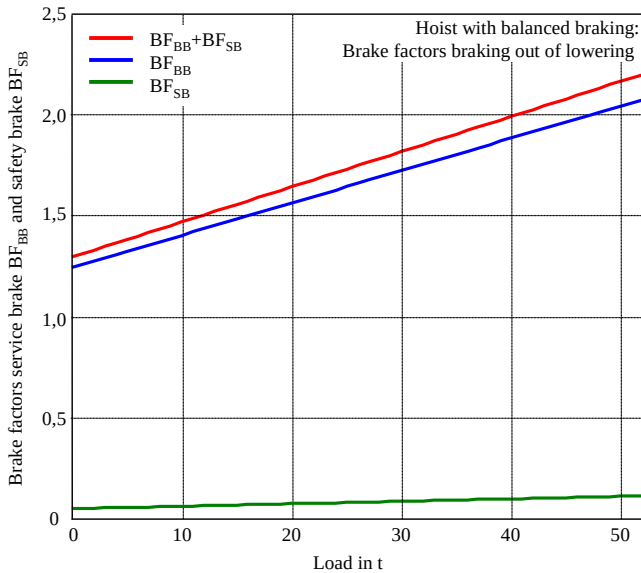


Fig. 8 Braking factors for braking out of lowering

For braking out of hoisting the safety brake has to be applied to a little account only ($BF_{SB}=5\%-12\%$). The service brake has to deliver a significant torque under partial load. With increasing loads up to full load the braking torque of the service brake is decreasing continuously ($BF_{BB}=92\%-8\%$).

For braking out of lowering the safety brake has to deliver only a small torque ($BF_{SB}=5\%-12\%$). The service brake has to deliver a significant torque under partial load. With increasing loads up to full load the braking torque of the service brake is increasing continuously ($BF_{BB}=124\%-208\%$).

11. Conclusions

For the higher internal loads occurring especially due to emergency-off [3] the hoist may be not dimensioned reasonably and efficiently. Assuming a corresponding hoist concept this also applies for emergency-stop, a load case occurring more often. Accordingly measures have to be considered in order to reduce internal loads induced to the drive train. The internal loads in the drivetrain are reduced especially by “intelligent braking”. Ideally the braking process is designed in a way, that during braking in the drivetrain between motor and safety brake the torque during static hoisting is present also. Hereby the maximum values as well as the amplitudes of the internal forces are reduced significantly. Suitable measures to be applied are:

- Reduction of clearances and increase of system elasticity. As result shocks can be reduced and absorbed, as well as internal loads are reduced in connection with system damping.
- Minimization of dynamic effects. Following EN 13001-2 [4] this may be realized by little clearance and a gradual implementation of the braking torque.
- Reduction of mass factor MF. By a small share of the motor mass in relation to the total mass of the drivetrain the torque put through the gearing is reduced.
- Minimization of brake factor BF_{SB} . A small braking torque of the safety brake generally leads to less braking action and reduced internal forces.
- Braking action synchronous to motor switch-off. Is he motor moment decreasing before braking action

takes place, the drivetrain is relieved slightly. The resulting internal forces can be prevented by synchronicity of the events.

- Synchronized application of safety brake and service brake. In order to prevent torques put through the drive train a synchronized application of both brakes is inevitable. As a result the collision of the non-braked massive drive side mass (motor) and the braked load side mass (rope drum) is prevented. Corresponding shocks in assemblies with clearances as gearing and rope drum coupling are reduced. In typical hoist structures the dead time of the safety brake is significantly lower than that of the service brake. An expansion of dead time of the safety brake in most cases cannot be accepted. Accordingly a suitable approach is to shorten the dead time of the service brake [5].
- Balanced braking torque of safety brake and service brake. For adjusting the torques in the drive train defined braking torques at safety brake and service brake are required. Advisable is the balancing of both braking torques according to the energies to be dissipated at the locations of brakes. These braking torques depend on the service condition and the suspended load. Brakes with controllable torques are applied ideally. For cranes they are not state of the art today. Instead of the step less adjustment of torques a stepped adjustment of braking torques may be considered. This is realized by a parallel arrangement of several smaller brakes at one braking location. Hereby an approximation of the ideal condition is achieved.

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PREPARATION OF MULTI-COMPONENT POWDER OF ANY HIGH SOLIDS PROCESS

ТЕХНОЛОГИЯ ПОЛУЧЕНИЯ УЛЬТРАДИСПЕРСНЫХ ПОРОШКОВ ВЫСОКОСКОРОСТНЫМ СПОСОБОМ

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Abstract: The possibility of obtaining ultra-disperse powders by high speed way with a particle size that does not exceed the declared value. The research of the mechanical method of obtaining ultra-disperse powders. Dispersion of obtained powder was defined for various materials. The dependence of the dispersion of the obtained powder was indentified from the choice of abrasive tools on Bakelite and metal bonds.

KEYWORDS: NANO- AND ULTRA-DISPERSE POWDER, HIGH SPEED WAY, MECHANICAL METHOD, ABRASIVE DISK, LIQUID NITROGEN

Currently, the key factor of economic development and national defense capability is the development of new materials, their processing and use. Current direction of development of modern science is to provide nano- and ultrafine powders of various metals and study their properties. Because ultrafine particle size powders have unique combinations of chemical, electrical, magnetic, radio-mechanical and other properties that determine new functionality, constructional and operational characteristics. The structure of the powder has a significant effect on the properties, depending on the production method [1]. There are following requirements for the methods:

- 1) The high speed of forming of particles birth centre and the low speed of their growth;
- 2) The provision of temporary stability of the particles, the surface protection from spontaneous oxidation and sintering in the manufacturing process;
- 3) Preparation of the particles or grains of a prescribed size;
- 4) Effective production and efficiency;
- 5) Control of the parameters [2,3].

Methods of preparation of nano- and ultrafine materials are divided into physical, chemical, biological and mechanical.

The main methods of mechanical grinding are crushing and grinding of solid materials, melt dispersion, processing of solid (compact) materials by cutting. Mechanical methods are based on the effects of large deforming stresses: dragging, pressure, pressing, vibration, cavitation processes and etc. [4].

Mills of various types are applied for the mechanical grinding of solids: planetary, ball, ink, swirl, vibration and others. Due to the fact that in the preparation of ultrafine and nano powders grinding work is proportional to the surface area, it is necessary to use high power mills [2].

The main advantages of using a mechanical method of grinding (mills) are:

- 1) Preparation of nano and ultrafine powders of multicomponent alloys in a single step;
- 2) The ability to grind various materials and produce alloys powders in large quantities;
- 3) The relative simplicity of the technology.

Disadvantages of the mechanical methods:

- 1) The size distribution of the particles and the variety of forms;
- 2) The difficulty of controlling the composition of the product during grinding;
- 3) The more complex components and accuracy the factor of merit, the harder it is to control the metal structure, and the higher the cost of the production;
- 4) The possibility of contamination of nano and ultrafine powders with the attrition of grinding bodies or working bodies of mills [5,6].

The mechanical method is promising for the development of nano- and ultrafine powders of multicomponent

alloys, however, for a more efficient use of it, knowledge of the physical processes occurring during mechanical stresses are very useful [7,8]. Therefore, it's necessary to determine the possibility of a high-speed method and experimental study of the processes occurring in solids in the manufacture of powders [9]. Installation, applied in the experiment, represents the mill.

Processing of the material was carried out at the circumferential speed of the grinding disk up to 300 m / s, while the synchronistic rotational and reciprocating motions of the workpiece. The grinding wheel was used as the grinding disc with abrasive elements (abrasive head with diameter of 12 mm). The workpiece carried order was about 1 mm / min while feeding nitrogen from the cryogen reservoir through the thermohose to the work zone was about 1 l / min. The particle sizes of the powder were regulated by circumferential speed of the grinding disc, choice of abrasive heads and workpiece supply [10].

The workpiece set coaxially to one of abrasive heads in the clamping device was rotated. After reaching predetermined rotational speed by the grinding disc, the workpiece was continuously cooled with liquid nitrogen during the whole abrasion process. Grinding wheel was linked up with workpiece until the contact, whereby the workpiece was grinding by abrasion. The powder was removed from the grinding chamber, using a blowing trap of the particles, connected to a device for collecting ground product. After abrasion of the workpiece, the device was disconnected, the ground material was removed from the collection device, set a new workpiece (Figure 1) [11].

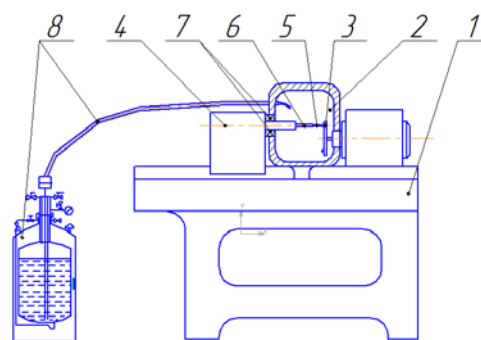
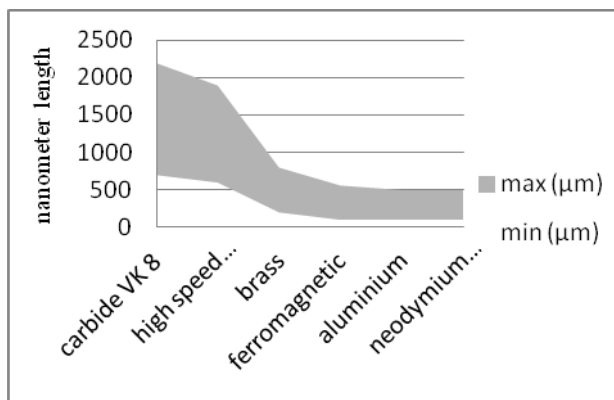
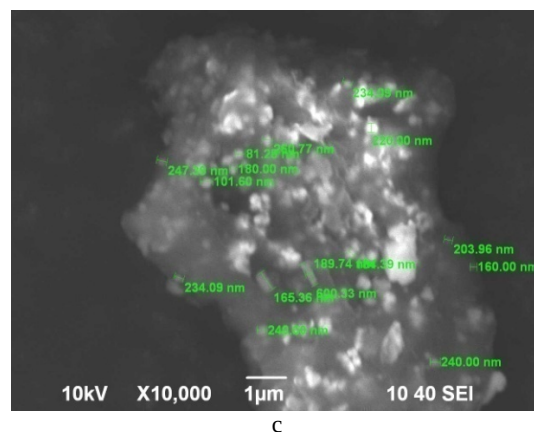


Fig. 1. Installation scheme: 1 – frame; 2 - airtight enclosure; 3-abrasive wheel; 4-work feeder; 5-workpiece; 6- work holder; 7- airproof cell; 8- feeder of liquid nitrogen to the work zone.

Experiments were carried out with materials having different hardness, friability, toughness (Fig. 2) [12,13].



The collected powders had a particle size in the range from 100 nm to 1.5 microns (Fig. 3). The average particle size of the steel powder VK8 was 1100 nm, HSS P18 - 950 nm, of brass - of 400 nm from a ferromagnet - 280 nm. The best results were obtained with powders of aluminum and neodymium magnet (Fig. 3c).



During the experiments were used abrasive elements on the bakelite and metal bonds.

From the obtained data follows that the variation in the dispersion decreases with decreasing of grain of abrasive elements range (Fig. 4).

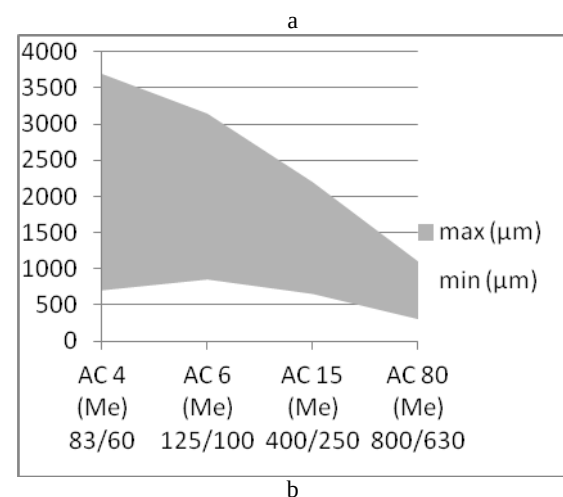
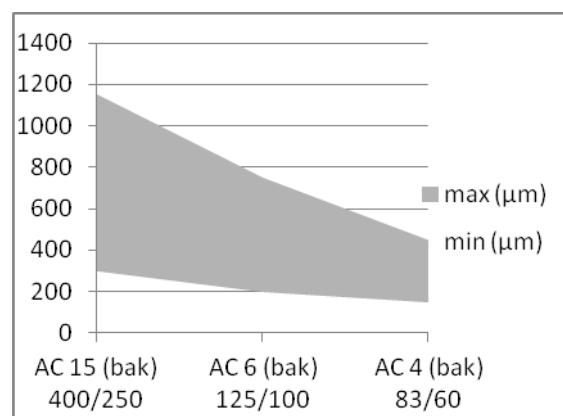
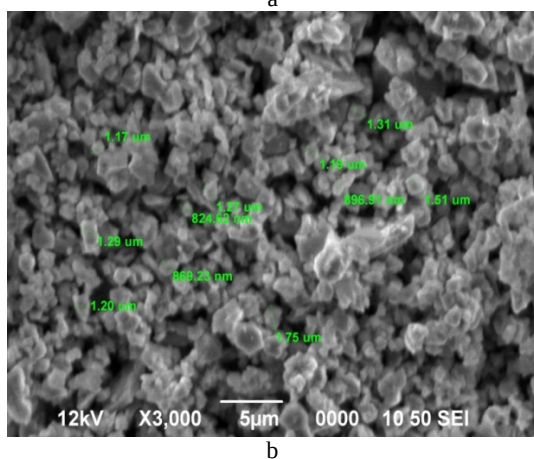
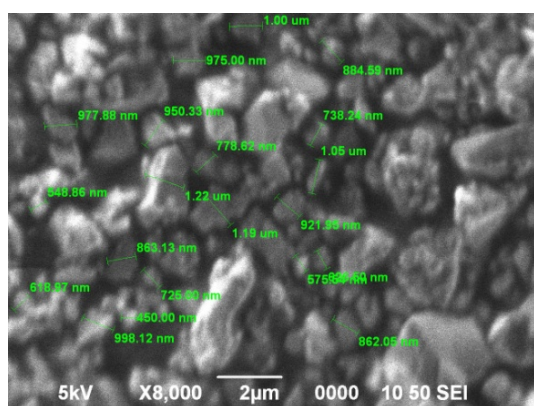


Fig 4. The dependence of the dispersion of the obtained powder by the choice of grinding tool on bakelite bond (a) and metal bond (b).

The mechanical processing method with using of a grinding wheel provides wasteless processing of the workpiece, reducing the spread of sizes and the possibility of obtaining particles less than 0.1 mm. Adding liquid nitrogen reduces the

occurrence of high temperatures generated by abrasion at high speeds, thus decreasing the fire hazard in the work [14,15,16].

The detection of the dispersion dependence of obtained powder from the material, from which it was derived, as well as the choice of abrasive tools - undoubtedly important. More important will be to identify the dependence of different properties of the material on dispersion of the obtained powder for understanding the fundamentals and principles of high-speed

particles chipping from different material from abrasive elements. It is also necessary to investigate the properties of the obtained powder of a magnetic material on X-ray apparatus for determining the magnetic properties, compared with the starting material.

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METHODOLOGICAL ASPECTS OF A SUSTAINABLE DEVELOPMENT TRAINING IN THE HIGHER EDUCATION IN BULGARIA

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Abstract: Learning different aspects of the international quality standards turned into an urgent necessity in the students' training, which gives them a possibility quickly to adapt to the practice during their professional realization as specialists. Generally, the preparation of the students of quality management in our country is well accepted in the different educational institutions and is conformable to their specific features. As a disadvantage it may be shown the fact, that the students' training is limited only to the knowledge for quality management receiving. It may achieve a wider range, including a preparation for environment standards (ISO 14000), for safety (ISO 18000) and for quality, which basic principles further the management of this combination and, in the long run, for one sustainable development.

The purpose of the present article is to be worked-out and presented the basic methodological aspects for sustainable development training in the higher education, which will give an opportunity to the students to receive wider knowledge in this field.

With the help of the basic methodological aspects, has been worked-out a concrete model syllabus for sustainable development training of the students from the higher technical schools in our country.

Keywords: ASPECTS, TRAINING, SUSTAINABLE DEVELOPMENT, HIGHER EDUCATION,

1. Introduction

Learning different aspects of the international quality standards turned into an urgent necessity in the students' training, which gives them a possibility quickly to adopt to the practice during their professional realization as specialists. Generally, the preparation of the students of quality management in our country, is well accepted in the different educational institutions and is conformable to their specific features. This training has been still restricted only in receiving knowledge for quality management [1, 2, and 3].

In recent years, in a number of European universities is being quickly introduced sustainable development training of students. Here the question is about training according to the environment standards (ISO 14000), for safety (ISO 18000) and for quality, the combination of which corresponds to the needs of production enterprises their articles to answer to the complex conditions for high quality and environment protection. All these demands, staked from the very stage of the development of the relevant article (product) and executed in the process of its production, form prerequisites for one sustainable development.

The purpose of the present article is to be worked-out and presented the basic methodological aspects for steady development training in the higher education, which will give an opportunity to the students to receive wider knowledge in this field. In order to achieve this aim, a correspondent syllabus is necessary.

2. Character of the sustainable development training

Sustainable development training's introducing in the higher education aims at both making the student acquainted with the basic normative documents and developing habits needed for working-out high quality products, minimum production expenses and maximum corresponding to the demands for environment protection.

In the present article are worked-out the basic methodological aspects of such students' training in specialties, connected with the machine-building production [4].

Basic methodological aspects

1. Training for production technologies' choice, constituent elements and appropriate materials, which to allow the recycling of the products after the term expiration of working.
2. Training on determination of the effect of the already produced article on the environment during its whole term of working.
3. Learning all laws and standards, connected with the environment protection, which have connection with the article being produced, and their correspondent application from its development stage to its going out of production.
4. Receiving the knowledge, necessary in connection with suppliers, trades and customers, who to be informed and made literate enough, in order to the trade and exploitation of the article to be relevant to the staked on it demands for environment protection.
5. Learning and determining the expenses, connected with the environment protection during the term of article's exploitation.
6. Training on determining the influence of the energy and fluids used on the environment during the time of the whole exploitation cycle.
7. Creating habits for presenting a new product and emphasis on innovations, used in its working-out, in order to protect the environment.

The presented basic methodological aspects of the sustainable development training for students from machine-building specialties, suppose working-out a syllabus with a concrete matter [5].

3. Sustainable development training syllabus

The offered syllabus for training students from machine-building specialties consists of the next modules (Fig. 1):

1. Industrial production and eco-development. Instruments and methods for sustainable development of the industrial production.
3. "Clean" technologies and innovations.
4. Science and communications.
5. Project of an article (product).
6. Production experience in an industrial enterprise.

Each of the modules shown, has its own aim, and the first four modules have a number of disciplines, being learnt, too. After taking an examination in them, the students receive the needed knowledge and a level of competency and they can go on to a next module.

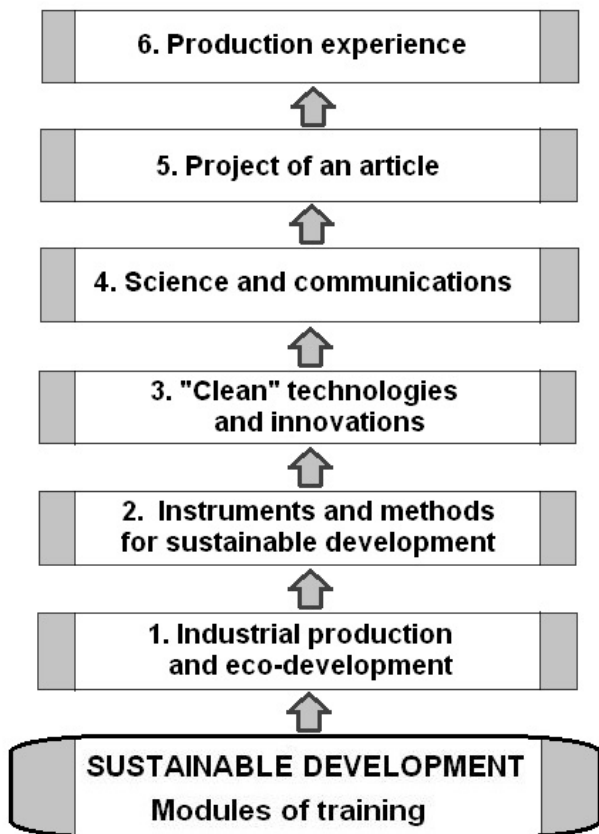


Fig.1. Sustainable development training syllabus

Module 1. Industrial production and eco-developments

Aim:

- Achieving the necessary scientific and organizational competency for realization industrial production, corresponding to the sustainable development requirements;
- Knowledge according to legislation requirements for ecological production;
- Made acknowledged with new technologies and their connection with the innovations;
- Enlargement of the culture on environment protection;
- Determining the place of the industrial enterprise in the conditions of a global competition.

Disciplines being learnt:

1. Eco-management
 - Law and environment;
 - Industrial production and ecology;
 - Sociology of the industrial production;
 - Products and systems for sustainable industrial production and indicators for its sustainable development;
 - Management, oriented to production, corresponding to the ecological requirements.
2. Eco marketing
 - Competition and environment;
 - Trade communication;
 - Industrial ownership;
 - Laws, standards, normals, etc.;
 - Forthcoming introducing of new regulations;
 - Eco-labels.
3. Production treatment after the term of exploitation
 - Eco-toxicology;
 - Recycling of the production and materials;
 - Throwing-out the recycled products;
 - Economic effect of the recycling;
 - Treatment and valuation of the waste matter.

In this module of training are included meetings and discussions with specialists from the industrial production, experts on standardization and visits of industrial enterprises, too.

Module 2. Instruments and methods for sustainable development of the industrial production

This module could provisionally be divided into two parts. Each of them has an aim and correspondingly forming it disciplines.

The first part's of the module aim:

- Giving the parameters for environment protection and the safety in the stage of the task for working-out the article;
- Ways of determining the exploitation term of the article;
- Clearing-up and concrete formulation of the criteria for ecology in the working-out stage;
- Presenting of an eco-plan for choosing materials, way of transportation and treatment of the waste matter;
- Research the effect of the ready product on the environment and the consumption of energy during its whole exploitation cycle;
- Using different methodological means of working-out of ecological products: computer software;
- Presenting the optimal way of recycling.

Disciplines being learnt in this part of the module:

1. Exploitation term of the articles
 - Analysis of the possible term for exploitation of the article;
 - Quality assessment of the article in the exploitation term;
 - Indicators for determining the achieving the staked ecological parameters from the article in the exploitation term.
2. Quality assessment
 - Functional analysis;
 - Evaluation of the article in a connection with the achieving of the parameters staked;
 - Experiment plan.
3. Means for working-out of eco-articles
 - Using of appropriate computer software;
 - Safety and ergonomy of the article being worked-out.
4. Used energy and fluids
 - Sources of renewed energy;
 - Managing energy consumption;
 - Energetic calculations.

The second part's of the module aim:

- Practical acknowledgment with CAD software products for working-out of the articles, choosing materials, determining the exploitation term: CATIA, FUSIMAT, PLM-Catia, etc.;
- Training on using different inter discipline connections at working-out the articles;
- Acknowledging with the methodological approaches at working-out different variants eco-articles: with "a continuing exploitation term and weak spreading-out" and "a short exploitation term and great spreading-out";
- Acknowledging with the methods and approaches at working-out of already produced similar eco-articles.

In the second part of the module have been learnt the computer software and have been worked-out projects in different fields of the machine-building: auto building, electrical equipment, electronic articles, aeronautics, shipbuilding, etc.

In the task of each of the projects are staked requirements the article to be relevant to certain ecological demands at using innovation technologies.

Module 3. "Clean" technologies and innovations

Aim:

- Deepening the students' knowledge and widening their competences in the sphere of technologies;
- Discovery of new and innovative technologies;

- Analysis of advantages and disadvantages of the technologies, used until now.

Disciplines being learnt:

1. Technology of production
 - In the machine-building;
 - In the electro technical production;
 - In the automation;
 - Production processes: founding, welding, etc.;
 - Surfaces treatment;
 - Metrological control.
2. Technical servicing
 - During the exploitation cycle;
 - Current and planned technical servicing;
 - Integration of the technical servicing from the very stage of working-out the article.

Module 4. Science and communications

Aim:

- Deepening the knowledge in using the scientific methods and approaches at working-out the articles;
- Argumentation of the choice of the production technology and the choice of the most
- appropriate materials;
- Using of existing and working-out new documentation for the article;
- Training in a team at working-out articles with ecological requirements.

For execution of the aims shown, the students study:

- Applies science: physics-chemical and mechanical qualities of the materials, technologies for treatment of different kinds of materials, etc.
- Communications: the ways of integration in teams on working-out similar projects.

Module 5. Project of an article (product)

The teaching staff, with the participation of production enterprises, offers to the students to work-out a project for an article, with included requirements for environment protection. It is necessary to be ensured adequateness of the project with the aims of the sustainable development training.

Module 6. Production experience in an industrial enterprise

The training of the students has to finish with a practical experience in an industrial enterprise not less than one semester. During the practice, the students work-out their personal project, or take part in a team on working-out another concrete project for an article. The requirement is to be ensured to the students a correspondence between the aims of the sustainable training and the content of the production practice in the enterprise. At the end of the practice, the students present a written report and go in for an oral defense.

4. Conclusions

1. There are worked-out the basic methodological aspects of students' training on sustainable development in the universities in Bulgaria. These aspects are for the students from the machine-building specialties of the universities.
2. On their foundation, a syllabus for sustainable development training has been worked-out, which consists of six independent modules. For each module has been shown the aim, which has to be reached and have been shown the disciplines, or the ways, in which it to be realized.
3. The worked-out basic methodological aspects could be used successfully at training students from another specialties of the higher education, too, as for them to be offered the existing, corresponding to them, syllabus.

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INFLUENCE OF PARAMETERS BY ELECTRONIC RAY ON PROPERTIES OF SUPERFICIAL LAYERS OF OPTICAL ELEMENTS OF EXACT INSTRUMENT-MAKING

ВЛИЯНИЯ ПАРАМЕТРОВ ЭЛЕКТРОННОГО ЛУЧА НА СВОЙСТВА ПОВЕРХНОСТНЫХ СЛОЕВ ОПТИЧЕСКИХ ЭЛЕМЕНТОВ ТОЧНОГО ПРИБОРОСТРОЕНИЯ

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Abstract: In the article are presented the results of researches of action of electronic ray on optical elements. The analysis of surfaces of elements before and after a beam-processing the method of atomic-force microscopy shows that in first case the height of microburries makes 50...60 nm, and in second case goes down to the level of 0,5...1 nm. Influence of parameters of electronic ray is set on the height of microburries: the increase of closeness of thermal influence of ray in 6 times results in diminishing of height of microburries in 3...4 time, diminishing of rate of movement of ray in 5 times results in diminishing of height of microburries in 5...6 times. It is shown that by optimization of the modes of beam-processing of elements it is possible substantially to improve (to 50...60%) properties of its superficial layers and basic operating descriptions of devices. Thus probability of destruction of elements and death devices in the conditions of intensive external thermal influences, devices can undergo that at their storage, portage and application, diminishes in 1,5...2 time.

KEYWORDS: OPTICAL GLASS, ELECTRONIC RAY, SURFACE LAYERS, ELEMENTS OF PRECISION INSTRUMENTS

1. Introduction

Application expanding conditions (higher heating temperature, external pressure, thermal shock effects, etc.) devices with optical elements for measurement and control of thermal objects of different physical nature (laser modules for fiber optics, sights to observe in the visible and the infrared of the spectrum, IR-devices targeting and tracking of different objects, etc.) make high demands on their technical and operational characteristics (resistance to external heat and mechanical stress, sensitivity, reliability, etc.) [1-3]. This is because in these conditions there is a deterioration of the surface layers of the optical elements up to their destruction (cracking, chipping and other defects), leading to failure of the devices based on them.

That is the anticipation of these adverse events at the stage of design and manufacture of devices considered to optical elements is urgent. In a number of studies conducted by different authors in this direction [4-6] was found that one of the most promising directions in the elimination of undesirable changes in the properties of the surface layers of the optical elements is their finishing moving electron beam. In particular, the possibilities of an electron beam method in the formation of surface layers on the elements of optical glass with altered physic and chemical properties were shown [7].

2. Results and discussion

Systematic studies on the effects of the electron beam on the surface layers of the elements are very limited nowadays. Therefore, in this paper the results of studies on the influence of the main parameters of thermal effects (heat flux density, its speed), low-energy electron beam ($E \leq 10$ keV) in the surface layers of the elements of optical glass (K8, K108, K208, BK10, TF110) are presented.

In order to find the regularities of thermal influence of the electron beam on the elements of optical glass and mode control processing it is necessary to know changes in the structure of the modified layers of materials, the height of the residual microscopic irregularities on the treated surfaces of the glass and the depth of their melting depending on implemented in practice processing modes: heat flux density from electron beam $F_n = 7 \cdot 10^6 \dots 5 \cdot 10^8$ Wt/m², the speed of its movement according to the optical elements $V = 8 \cdot 10^{-3} \dots 5 \cdot 10^{-2}$ m/s. Characteristics of the studied glasses, methods of preparation of their surfaces, as well as modern methods of studies of the properties of the surface layers of glass are standard and well-known [2].

The research results of the surface elements of optical glass by scanning electron microscopy method showed that on the surface of the machined glass (K108, K208, etc.), the presence of various micro roughnesses are the most characteristic: tiny cracks of 0,1...1,5 mm depth, as well as "hillocks", bubbles, dots etc., those sizes are $3 \cdot 10^{-3} \dots 2 \cdot 10^{-2}$ microns. After the electron beam treatment on the surface of the glass bubbles and points sizes (diameters) decrease in 3...5 times, the "bumps" and other unevenness smaller than 1...3 microns are not detectable, i.e. by treating the surface with an electron beam glasses they "cleared" and minor defects disappear. Surface analysis of optical glasses before and after electron beam treatment by AFM shows that in the first case, the height of asperities is 50...60 nm, and in the second case it reduces to 0,5...1 nm level. That is why the following effect parameters of the electron beam at the height of the residual microscopic irregularities (fig.1, 2) were established: the increase of the density of heat exposure to the beam up to 6 times reduces the height of the residual microscopic irregularities in 3...4 times. Reducing the speed of the beam is 5 times reduces the residual height of asperities in 5...6 times.

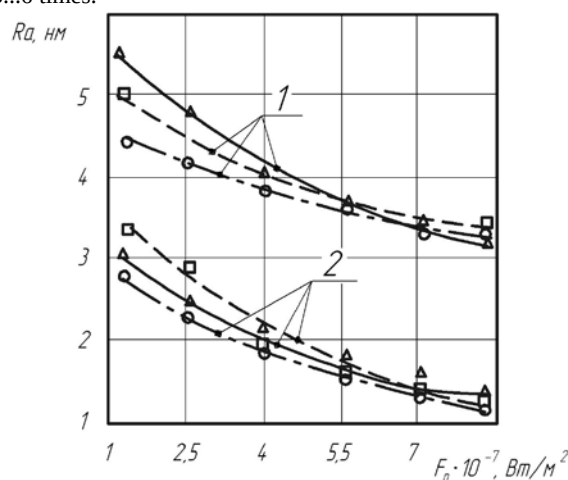


Fig.1. The dependence of the height of the residual surface roughness of the optical elements of glass on the density of the electron beam exposure to heat: 1 – $V = 5 \cdot 10^{-2}$ m/s; 2 – $V = 8 \cdot 10^{-3}$ m/s; — — — — K8 glass element; - - - - TF110 glass element; - · - · - BK10 glass element; Δ , $\circ$, $\square$ – experimental points.

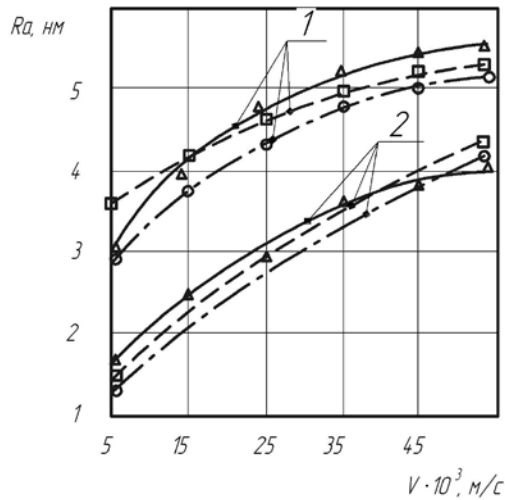


Fig.2. The dependence of the height of the residual surface roughness of the optical elements of glass on the velocity of the electron beam: 1 – $F_n = 7 \cdot 10^6$ Wt/m²; 2 – $F_n = 5 \cdot 10^8$ Wt/m²; ———— – K8 glass element; - - - - - TF110 glass element; - · - · - BK10 glass element; Δ , $\circ$, $\square$ – experimental points.

Study of fractogram surface layers of the optical elements of glass before and after electron beam treatment showed that the depth of the main-heat zone or the thickness of the fused layer can reach 250..300 microns and substantially depend on of the density of the heat exposure to the beam and its speed (fig.3-6): an increase in the heat exposure to the beam from $7 \cdot 10^6$ Wt/m² to $5 \cdot 10^8$ Wt/m² leads to an increase in the depth of melting of the optical element from 50 microns to 300 microns; an increasing the velocity of the beam from $8 \cdot 10^{-3}$ m/s to $5 \cdot 10^{-2}$ m/s, on the contrary, leads to the reduction in the depth of melting from 150 microns to 30 microns.

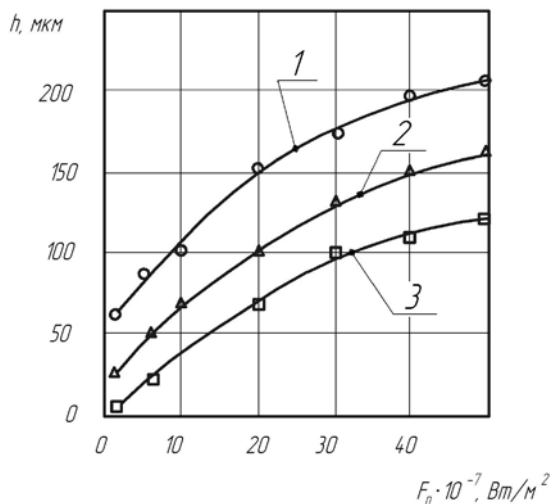


Fig.3. The dependence of the thickness of the melted layer of the optical elements of glass on the density of the electron beam exposure to heat ($V = 5 \cdot 10^{-3}$ m/s): 1 – the element of the optical glass K8; 2 – the element of the optical glass K108; 3 – the element of the optical glass K208; Δ , $\circ$, $\square$ – experimental points.

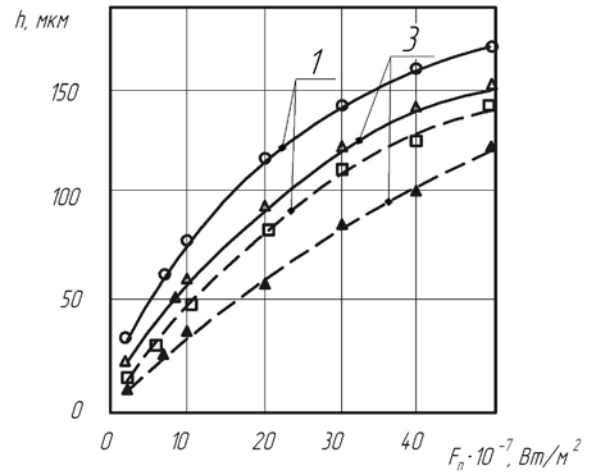


Fig.4. The dependence of the thickness of the melted layer in the elements of the optical glasses BK10 (1) and TF110 (2) on the density of the thermal effect of the electron beam: ———— – $V = 5 \cdot 10^{-3}$ m/s; - - - - - $V = 4 \cdot 10^{-2}$ m/s; Δ , $\circ$, $\square$ – experimental points.

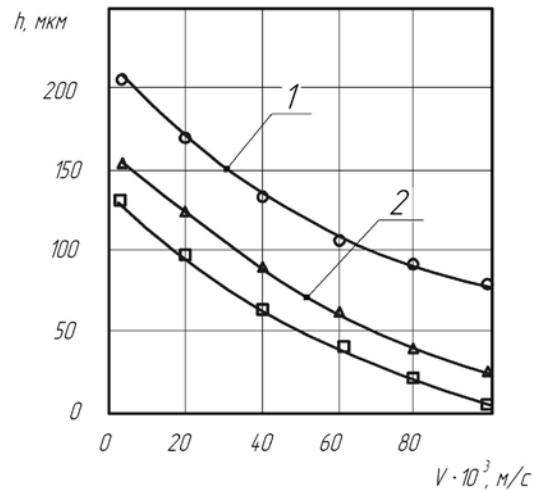


Fig.5. The dependence of the thickness of the melted layer of the optical elements of glass on the speed of the electron beam ($F_n = 6 \cdot 10^8$ Wt/m²): 1 – the element of the optical glass K8; 2 – the element of the optical glass K108; 3 – the element of the optical glass K208; Δ , $\circ$, $\square$ – experimental points.

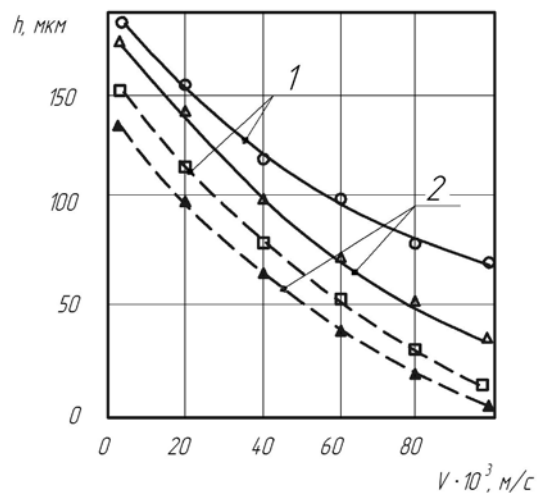


Fig.6. The dependence of the thickness of the melted layer in the elements of the optical glasses BK10 (1) and TF110 (2) on the speed of the electron beam: ———— – $F_n = 6 \cdot 10^8$ Wt/m²; - - - - - $F_n = 3 \cdot 10^8$ Wt/m²; Δ , $\circ$, $\square$ – experimental points.

A detailed study of sections of scans surfaces of the optical elements of glass after the electron beam treatment points to the local smoothing irregularities, significant dependence on the surface shape of the processing modes. So that, with a deep melting (250...300 mm) there is a clear undulating surface of the section. That is why this modified layer has a clearly melted oriented structure depth reflow.

Thus, the electron beam, melting surface of the optical glass elements, changes the properties of the material in depth. Due to this formed with electron beam the surface layers of the elements are changed in different degree of chemical composition. Thus, the analysis of changes in the elemental composition of the glass surface K108, held with spectrometer wave dispersion showed decrease in Na and O concentration, and an increase of Si concentration and constant of K concentration. At the same time, by X-ray analysis on an example of the untreated and treated by electron beam heating BK10 it was showed that significant quantitative changes in the chemical composition of its surface was not observed, however, it is possible to conclude that the improvement of the uniformity of element distribution in micro glass surface layer after the electron beam treatment.

Spectra analysis of the concentration dependence of element distribution in the treated and untreated surfaces of the electron beam optical glass (e.g., glass K8, K108 and BK10) also indicate on the instability of K_2O and Na_2O on the depth of the electron beam exposure.

In the study of the elements of optical glass by ultra-soft X-ray reflexometer method was found that the electron beam in the treated cell the surface structure corresponds to the crystalline state, in which a violation of coordination of silicon atoms is virtually nonexistent.

It is also established that the electron beam treatment of the optical elements of glass reflow leads not only to homogenization of the surface but also to the surface oriented rearrangement in silicon-oxygen network of the glass, close to that of quartz glass, which has a high heat resistance to external-heat.

3. Conclusion

It was found that the electron beam, melting surface of the optical glass elements, changes the properties of the material in depth. Due to this formed with electron beam the surface layers of the elements are changed in different degree of chemical composition. Thus, the analysis of changes in the elemental composition of the glass surface K108, held with spectrometer wave dispersion showed decrease in Na and O concentration, and an increase of Si concentration and constant of K concentration. At the same time, by X-ray analysis on an example of the untreated and treated by electron beam heating BK10 it was showed that significant quantitative changes in the chemical composition of its surface was not observed, however, it is possible to conclude that

the improvement of the uniformity of element distribution in micro glass surface layer after the electron beam treatment.

It is also established that the electron beam treatment of the optical elements of glass reflow leads not only to homogenization of the surface but also to the surface oriented rearrangement in silicon-oxygen network of the glass, close to that of quartz glass, which has a high heat resistance to external-heat.

Thus, by optimization of electron-beam processing of elements of optical glass (up to 50...60%) the properties of their surface layers and the basic technical and operational characteristics of the devices can be significantly improved. The probability of failure of elements and the failure of the devices under intense external-heat, which the units during storage, transport and use may be exposed, decreases in 1,5...2 times.

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A NEW APPROACH TO AUTOMATED DESIGN OF A MINIMUM MASS CARDAN COUPLING

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Abstract: While designing a Cardan coupling it is necessary to assess the assembly-ability of its components as well as to ensure that they do not interfere with each other during normal operation. In practice, this is done by use of prebuilt sample models, where everything is checked by experimenting. The authors share herewith their idea for developing a new approach to designing Cardan couplings, where all operations are performed in an automated way as early as the design stage,

Keywords: CARDAN COUPLING, AUTOMATED DESIGN, ASSEMBLY

1. Introduction

One of the most substantial applications of Cardan couplings is to connect rotating shafts arranged at an angle to each other, and to transfer torque from one shaft to the other. Various designs are used in practice, the most common joint to connect the shafts is the Hooke's joint, where two forks are connected by a crosspiece with perpendicular axes, through needle roller bearings.

While designing a Cardan joint, it is necessary to assess the assembly-ability of its components, as well as the manufacturability of such a connection. In effect, this comes down to ensuring non-interference of the components in any possible positional relationship within the chosen range of intersection angles of the shafts, as well as during the components' assembly. So far such checks have been commonly carried out by pre-building several sample models of the design, and using them for simulated checks, since 2D mapping only cannot provide sufficiently reliable compatibility.

In this publication the authors propose a new method and algorithm for automated checking of the assembly-ability of individual components of a Hooke's joint in the course of designing a minimum mass coupling.

2. Current state

The rotation of the two forks with different angular velocities not only complicates the interference check but also affects in a complex manner the forks' instantaneous velocity values. This makes it difficult to carry out a correct strength estimate of the forks. The estimate is realized with some reserve, basing on the forces and the corresponding torque and bending moment values in two limit positions [1, 2 and 6]. This makes the strength estimate to a great extent conditional. At higher speeds of rotation, the dynamic load on the components of the Cardan coupling substantially increases, and the design is required to take this factor into account too [4, 7].

The foregoing necessitates an optimization of the Cardan coupling design, and calls for a new design approach which requires the solving a sequence of problems:

1. A parametric description of the mathematical model representing the base design for modelling a minimum size Cardan transmission;
2. Development of a method for accurate determination of the tangential and axial forces acting on the joints for an arbitrary rotation angle of the drive fork;
3. Development of an algorithm for determining the conditions allowing assemblability of the fork and crosspiece for a specified size as early as the design stage;
4. Development of an algorithm for determining the size of the forks under the condition of non-interference in motion, with an accurate 3D spatial model of the joint, at various shaft

intersection angle values, and in arbitrary relative positions of the fork legs;

5. Checking the state of tension of the components of the Hooke's joint for each specific position.

The present article is focused mainly on solving task №3.

3. Problem solution

The mathematical model adopted in [3, 5] was adopted here as the mathematical model for describing the fork shape.

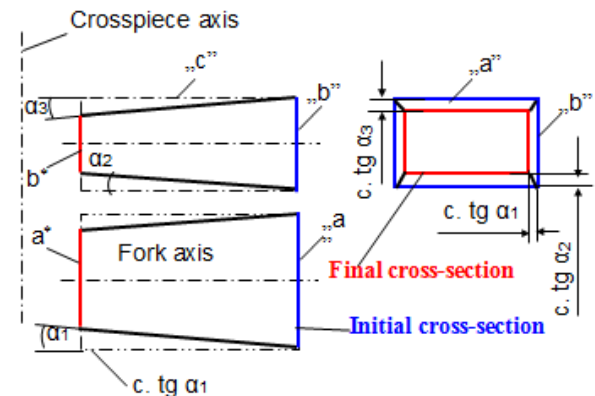


Fig. 1 Parametric model of the fork legs $a \times b$, $a^* \times b^*$ – initial and final cross-section values; c – leg length; α_1 , α_2 , α_3 – angles defining the final cross-section

For convenience in compiling the mathematical model of the design, the values ($a^* \times b^*$) of the final cross-section – the one nearer the fork's eye – are to be represented via the α_1 , α_2 , and α_3 angles (Fig. 1). Different angle values result in rectangular or trapezoidal shape of the final and intermediate cross-sections, with different size.

3.1 Determining the conditions for assemblability of the fork and the crosspiece

The assemblability conditions are examined for two cases: for non-chamfered and for chamfered (chamfer angle β) fork eyes.

To determine the assemblability conditions for non-chamfered fork eyes, the limit position of the crosspiece is examined (Fig. 2), determined by the following:

Point A of the upper journal lies on the border line of the upper eye bore; point G of the lower journal lies in the internal plane of the lower eye; point D lies on the right border line (or the extension thereof) of the upper eye bore; the geometric axes of the crosspiece and the bore are at an angle of 45° with respect to each other.

Thus the horizontal straight line FD determines the limit position of the upper eye relative to the lower eye. In this position, the crosspiece touches the three points A, D, and G. On displacement of point A upward, the touching point of the

crosspiece will move away from point D. Then the distance between FD and the lower eye will correspond to the minimum distance between the eyes at which assembly is possible.

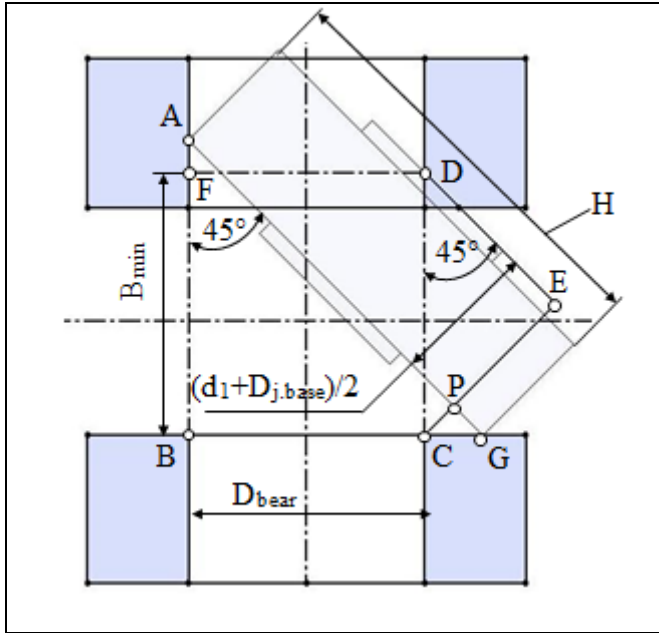


Fig. 2 Diagram for determining the assemblability conditions for the fork and crosspiece for non-chamfered fork eyes.

- (1) From the isosceles right-angled $\triangle ABG$, the side $BG = H/2^{1/2}$ is determined.
- (2) Segment CG is determined along $\Rightarrow$
 $CG = BG - D_{bear}$
- (3) From the isosceles right-angled $\triangle CPG$, the side $CP=PG=CG/2^{1/2}=(BG - D_{bear})/2^{1/2}=(H/2^{1/2} - D_{bear})/2^{1/2}$ is determined;
where: H – crosspiece height, mm.
- Segments PE and CE are determined through (4).
- (4) $PE = (d_1 + D_{i.base})/2$;
 $CE = PE + CP = (d_1 + D_{j.base} + H - D_{bear} 2^{1/2})/2$;
- where: $D_{j.base}$ – diameter of the base of the crosspiece journal, mm.

From the isosceles right-angled $\triangle DCE$, the following is determined:

$$(5) \quad B_{min} = CD = 2^{1/2} \cdot (d_1 + D_{j.base} + H - D_{bear} 2^{1/2})$$

The condition which guarantees assemblability is: $B \geq B_{min}$.

If the eyes are chamfered at an angle β (Fig. 3), the distance B_{min} determined for non-chamfered eyes must be increased by the difference between the enlargement of the upper eye (segments KM and NP) and the lower eye. Then for B_{min}^β , (6) can be written.

$$(6) \quad B_{min}^\beta = B_{min} + (KM - NP)$$

Since $KM = D_{bear} \cdot \tan \beta$, and $NP = \tan \beta \cdot (D_{bear} + D_{eye})/2$ for B_{min}^β obtains the value $\Rightarrow$

$$(7) \quad B_{min}^\beta = B_{min} + \tan \beta (D_{bear} - D_{eye})/2;$$

where: D_{eye} – outer diameter of the eye, mm.

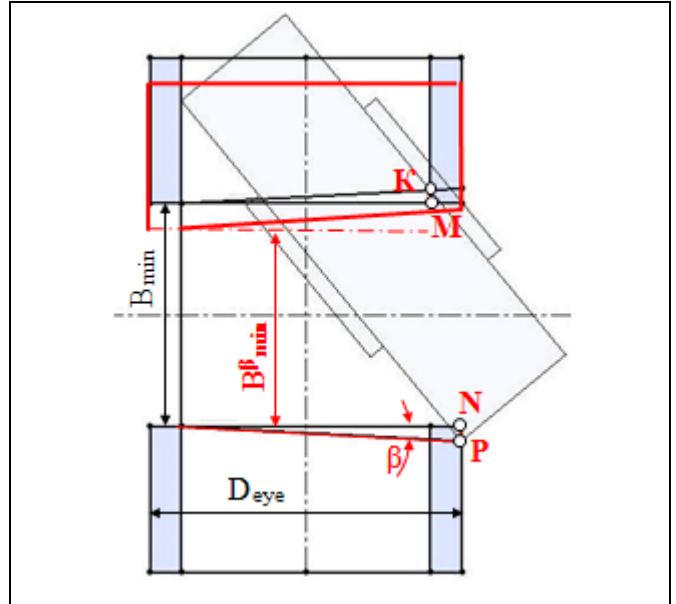


Fig. 3 Diagram for determining the assemblability conditions for the fork and crosspiece for fork eyes chamfered at angle β .

Due to strength considerations, in order not to reduce too much the eye height L_{eye} and affect the integrity of the bore, the value of angle β may have to be restricted: the chamfered part should not exceed 1/3 of the eye height.

3.2 Determining the minimum fork dimensions

The components comprising the fork design are: a hub, connected with two identical legs, each ending with an eye. The main geometric parameters characterizing the design are (Fig.4):

hub – a cylinder with an outer diameter D_{hub} , inner diameter d_{hub} , and length L_{hub} ;

eye – a cylinder with an outer diameter D_{eye} , inner diameter d_{eye} , and length L_{eye} ;

leg – a prismatic geometric base shape with dimensions $a \times b \times c$, with an initial cross-section representing a rectangle with dimensions $a \times b$ touching the hub face and displaced relative to the geometrical axis of the fork by a distance of R_0 .

Through varying the α_1 , α_2 , and α_3 angles, the geometric base shape can morph into a right or skewed pyramid with a square or rectangular base.

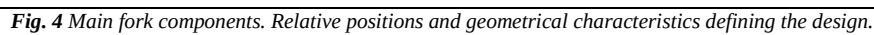
The following parameters for relative position of the individual components have been defined in relation to the geometrical axis of the fork:

- Parameter B – the distance between the eyes positioned symmetrically with respect to the fork's geometrical axis.
- Parameter R_0 – determines the position of the leg in relation to the hub and eye.
- The distance between the eye and the hub is determined through the c dimension of the leg.

Geometrical and design characteristics of the bearing:

Four versions of design implementation have been assumed, namely I, II, III, and IV. Outer and inner bearing diameter D_{bear} , d_{bear} ;

- diameter and length of the needle d_n , l_n
- thickness of the bearing housing base b_{bear} ;
- inner bearing shoulder: $m=0$ mm for versions I and III; $m=3$ mm for versions II and IV;
- clearance between the journal face and the bearing base when assembled: $c=0.5$ mm.



- c) If $\alpha_2 = 0$, the maximum displacement of the conditional final cross-section of the leg coincides with the eye's geometric axis, and the distance between the conditional and actual final cross-sections is equal to δ_{eye} .
- d) If $\alpha_2 > 0$, then the minimum limit value for the location of the initial base cross-section $r_{base.sect}^{min}$ is determined by the condition that the leg must not protrude inside the hub bore: $r_{base.sect}^{min} = d_{hub}/2$.
- e) If $\alpha_2 = 0$, then the inner surface of the leg cannot be positioned under the inner face surface of the eye. Then the initial base cross-section must be located outside of the hub thickness, which necessitates supplementing the leg with a new geometric shape similar to the assumed one, to serve as a material bridge between the initial cross-section and the hub. These conditions determine also the location of the starting point of the base cross-section $r_{base.sect}^{min} \geq B/2$.
- f) The highest part of the base cross-section may be located at the level of the outer face surface of the eye. Then $r_{base.sect,max} \leq B/2 + L_{eye} - b$.
- g) Dimension b of the initial cross-section of the leg must be located within $d_{hub}/2$ (lower limit) and $B/2 + L_{eye}$ (upper limit), which means that its maximum overall dimension in this direction must be $b_{max} \leq B/2 + L_{eye} - d_{hub}/2$. Its minimum value can be assumed to be $b_{min} \geq L_{eye}/2$.
- h) The final cross-section should be located within the thickness of the eye.
- i) The maximum value (a_{max}) of parameter a of the base cross-section may not exceed the eye diameter $a_{max} = D_{eye}$, while the minimum value can be assumed to be $a_{min} = d_1$ (journal) = $d_{in.dia}$ (bearing inner diameter).
- j) Angle α_3 is only related to the strength characteristics of the final cross-section. No specific limitations need to be introduced for it, as it is dependent on the two limitations described above.

4. Conclusion

- The applied approach for designing a Cardan coupling can serve as the initial stage of software development. 3D imaging combined with automated computation of certain parameters would reduce the duration of the design phase and provide greater certainty in the final result via suitable visualization.

- Characteristic for the examined approach is the intent of the authors not to focus on any specific case, but rather to develop the algorithm to cover all possible design variations resulting from the variety of input data, in a way such that the mass of the designed Cardan coupling is minimal.

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STUDIES AND RESEARCH ON THE DESIGN AND CONSTRUCTION OF A MACHINE FOR TENDERIZE MEAT WITH THE PNEUMATIC ACTION AND AUTOMATION MODULES.

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Abstract: The mechanical tenderization , during meat processing, can be the advantageous solution for rapid maturation of the product. This method represents the possibility to modulate the working process on optimal variants of applying the impact force, the pressing time and the relaxation time of the product.

In this paper there is presented an experimental model of machine of our own conception for the optimization of the tenderization process of the meat.

The paper, presents the adequate system of pneumatic action and the automation elements of the working parameters which were made as our own conception for construction of a machine for meat tenderization. Within the elaborated pneumatic scheme of driving there are identified the elements that can be electrically driven and the basis established scheme includes the programmable controller of the process.

Keywords: TENDERIZATION, PRESSING FORCE, PNEUMATIC, AUTOMATION, OPTIMIZATION PROCESS, MICROCONTROLLER.

1. Introduction

The mechanical tenderization methods, most used have been the ones that involve pins or blades that do not have possibilities of changing the working parameters. The method proposed by us for meat tenderization is made by beating and it allows adjusting the working parameters of the machine to different types of processed meat.

In this paper the authors present a machine for meat tenderization by mechanical method. The authors present a pneumatic machine for meat tenderization with elements of automation of the entire working process of tenderization.[9],[10].

By own conception of the pneumatic action scheme and automatic system which endow the machine, the authors create the possibility to modulate the working process (of tenderization) in diverse variants of applying the impact force, the pressing time and the release time of the product after each working cycle [1][3]. The entire process is controlled by a microcontroller which has programing possibilities after a cyclograme which was established by the operator.

2. The mechanical structure of the machine. Design and description of scheme kinematical

In figure 1 there is presented the design of this machine, with the following components [9] :

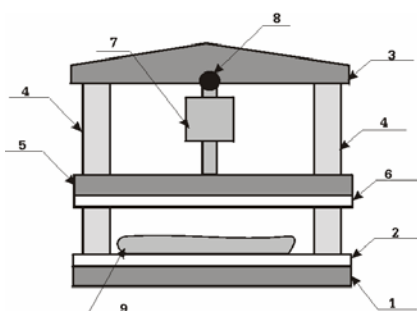


Fig. 1. The machine for meat tenderization with mechanical operation

1. Frame
2. Meat placement place – (PTFE)
3. Upper securing cross part
4. Guiding colons
5. Pressing mobile plate
6. Pressing element (PTFE)
7. Pneumatic driving cylinder
8. Coupling ball
9. Product for processing (meat)

The construction and the role of elements are given by their features needed for function. This way, the two guiding colons (4) are jointed with the machine frame (1) and with the upper securing cross part (3). On the two colons (4) slides the pressing plate (5). The movement of the pressing plate (5) is ensured by the driving pneumatic cylinder (7). In turn, the driving pneumatic cylinder (7) is fixed on the upper securing cross part (3) by coupling ball (8) that has the role of taking possible coaxial deviations. The rod of the driving pneumatic piston (7) is jointed with the pressing plate (5) determining its movement.

The functioning of the machine consists of pressing the product (9) between the placement element (2) that is fixed on the machine frame (1) and the pressing element (6) that is jointed with the pressing plate (5). The elements (2) and (6) are made of PTFE (Polytetrafluoroethylene, teflon) in order to meet the requirements of the machine that processes food.

During the function the machine has the following states:

1. Repose – the pressing plate is located in the upper part, the space between the placement element and pressing element is maximal. In this position the product can be put into the machine.
2. The movement of the pressing plate until the product is caught between the two elements. This movement is produced by the pneumatic cylinder.
3. The effective pressing, when the product is caught between the two elements, it is pressed with a force that is proportional with the air pressure from the pneumatic cylinder.
4. Upward movement of the pressing plate done by the pneumatic cylinder until repose position. This state shows the finishing of the processing.[8],[9],[10].

The operator places the product on the surface of the placement element when the machine is at repose state. Then there is given a command of descending of the pressing plate until the effective pressing is made. In this state the product stays a time established by the technology of processing a certain type of meat. When this time ends there is given the command for lifting the pressing plate until the repose state. During the pressing state of the machine the operator can either modify the time of pressing or the pressing force in function of the technology of a specific meat (see below).

The function of the machine is determined by a series of constructive and technological factors. They have been determined in function of the necessities of product processing.

The result of processing is mainly determined by the following factors:

- The processing degree – this refers to the ratio between the initial and final states of the product.
- The quality of processing – it refers to the range of maintaining the product features at the end of processing.

It is obvious that the higher the processing degree, the lower its quality. By determining and choosing the best technological parameters we try to reduce this tendency.

The mechanical construction of machine assumes the knowing of the kinematical scheme so that the operation condition to be fulfilled. On the basis of its design and working principle that have been already presented the kinematical scheme is presented in the figure 2.

1. Placement plate
2. Mobile pressing plate.
3. Guiding colons – jointed with the placement plate.
4. Sliding bearings; they are jointed with the mobile plate for pressing and they glide on the guiding colons.
5. Upper securing cross part – it is jointed with the guiding colons.
6. Coupling ball – for correcting eventual coaxial deviations.
7. Driving pneumatic cylinder.

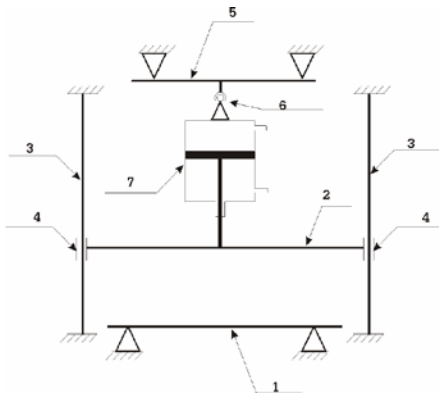


Fig. 2. The kinematical scheme of the machine

3. The pneumatic installation for action.

The machine is driven by mean of a pneumatic cylinder. In order to adjust the working parameters in a wide range and to achieve the automation goal of machine there was adopted a pneumatic scheme of operating which is presented in the figure 3.

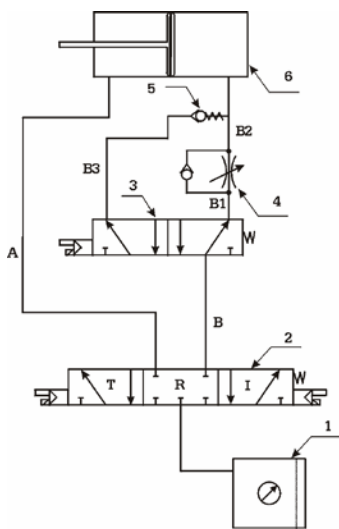


Fig. 3. Pneumatic operating scheme.

In figure 3 is presented pneumatic scheme with the following components :

1. Air pressuring unit – compressor.
2. Distributor with electrical command 5 HP/3 positions – it determines the working status (direction).
3. Distributor with electrical command 5 HP/2 positions – it determines the working way.
4. One-way switch of flow – drosel.
5. Anti – back flap.
6. Pneumatic cylinder.

The functioning of the pneumatic installation is characterized by three states:

- Release state – distributor (1) position R.
- Operating – piston pushing – distributor (1), position I
- Operating withdrawal of piston – distributor (1), position T.

In function of the distributor state (2) there are possible two working ways:

- With operation – controlled piston pushing (adjusting the speed at pressing) – distributor (2) not operating.
- No control at piston pushing (maximal speed) – distributor (2) operating.

With the first working way the impact force will equal the pressing force. With the second one the impact force will be given by the following formula (.1.):

$$Fi = \frac{Ep}{d} = \frac{\frac{m_p \times v_p^2}{2}}{Gi - Gp} = \frac{m_p \times v_p^2}{2 \times (Gi - Gp)} \quad (1)$$

where:

Fi – the impact force

Ep – the energy of pressing plate

d – the distance of pressing action

mp – the mass of the pressing plate plus the mass of the pressing element

vp – the speed of the pressing plate at the impact moment

Gi – the initial thickness of the product

Gp – the thickness of the pressed product

With the controlled speed working way the functioning is as follows:

- Distributor (3) not in action
- Distributor (1) is brought in position I
- The air from the preparing unit follows the way branch B – branch B1 – flow flap – branch B2 – pneumatic cylinder. The air from cylinder will be evacuated on A way into the atmosphere. Due to flow flap (4), the speed of the piston will be determined by the flap adjustment. It is important that on the B3 way air will not circulate due to anti back flap (5).
- In order to withdraw the piston, the distributor (2) is brought to T position where the air circulation will be: preparing unit – A branch – head of the piston. The evacuation of the air will be made as follows: piston – B2 branch – flow flap – B1 branch – B branch – atmosphere. In this case, the flow flap will have no effect because of the direction sense of the air circulation. As for the previous case, on the B3 branch there will not be any air circulation due to the anti back flap.[6].

For the working way with maximal speed, the functioning will be as follows:

- Distributor (3) in action
- Distributor (2) brought in I position
- The air from the preparing unit follows the following path: branch B3 – flap (5) – branch B2 – pneumatic cylinder. The air from the cylinder will be evacuated on the A path into the atmosphere.
- For piston withdrawal, the distributor (2) is brought in position T, where the air circulation will be: preparing unit – A branch – head of the piston. The evacuation of the air will be made through the following path: piston – branch B2 – flow flap – branch B1 – branch B – atmosphere. In this case the flow flap will have no effect due to the direction sense of the air circulation. On the B3 branch will be no air circulation due to the anti back flap.

4. The electrical installation for operation and the automation modules.

For the achievement of the operating and automation electrical scheme are needed the operation conditions for each state of machine as described above. In parallel, the operating must comply with the technological conditions of the process. Besides that the operating should follow the requirements imposed by the functioning parameters.[8],[10].

4.1 Operating principles and conditions

The operating principles result from the technological requirements as well as from the researching methods that are desired to be applied. The establishing of the working pressure that influence both moving speed of the mobile plate will be made exclusively by hand through adjusting the pressure at the air preparation unit as well as by adjusting the one way flow flap.

Firstly, there will be adopted two operation ways:

- Manual operation – where the operator controls manually the movement of the mobile plate;
- Automation operation – where the operator establishes the functioning parameters and the cycle if automation driven by automation component.

On the contrary with the manual operation, the automatic operation makes an entire functioning cycle. This cycle can be described as having the following states:

1. Descending the mobile plate until the pressing of the product is done.
2. Keeping the product under pressure for a certain time called **pressing time**.
3. The release of the pressing by removing the pressure and lifting the mobile plate on a reduced distance enough for removing pressure on the product.
4. Keeping the release state for a certain time called **release time**.
5. Return to the pressure state (# 2).
6. Repeating points 2 and 3 by a number of times called **number of subcycles**.
7. Withdrawal of the mobile plate in the upper part, finishing a cycle.

The operating conditions are determined by a series of factors as follows:

- Machine architecture
- Technological parameters
- Flexibility in changing the value of the functioning parameters
- Ensuring operation protection
- Ensuring the functioning within the limits of the working parameters.

4.2 The block operating scheme

From the pneumatic operation scheme result the elements that can be electrically driven; they are:

- Distributor of machine states (sense of direction) – this has two driving coils by which the distributor is brought to one of the three states: R, I and T (see above).
- Distributor of the working way – by which there will be established the way the piston will be driven, the controlled speed or the maximal speed.

The block scheme is presented in figure 4.:

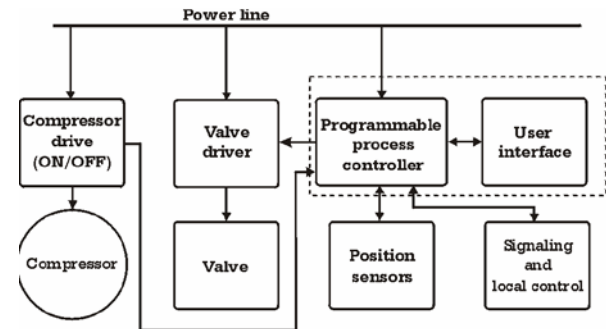


Fig. 4 The operating block scheme

The block scheme with the following components :

- Power line – electricity supply line
- Compressor drive – on/off switch of the compressor
- Valve drive – air valve operating block
- Position sensors – position sensors and state; they are:
 - Superior course cut-off
 - UP position of mobile plate transmitter
 - DOWN position of mobile plate transmitter
 - Cut – off protection flap – the machine is endowed with a flap that limits the working space of the machine in order to ensure operator protection [5].
 - Sensor of compressor state – it signals the state of the compressor ON/OFF
- Programmable process controller, User interface.
- Signaling and local control – through these features the operator can make functioning commands; they are:
 - Signaling of UP movement of the mobile plate
 - Signaling of DOWN movement of the mobile plate
 - Signaling the working way – manual/automatic
 - Signaling the driving mode – normal speed/maximal speed
 - Command of DOWN movement of the mobile plate
 - Command of UP movement of the mobile plate
 - Command START automatic cycle
 - Command STOP automatic cycle

4.2.1. Scheme electric drive

Pneumatic scheme resulting from items that can be electrically operated. These are:

- Distributor machine states (sense) - it has two coils is operated by the retailer brought in one of three states, R, I, T (see above)
- Distributive approach - that will determine how to drive the piston, controlled speed or full speed.

Compressor drive circuitry is shown in the figure below. Also in this scheme it is and transformer that provides the necessary voltage supply 24V DC-dispensers shareholders. In figure.5 is presented electric drive compressor scheme.

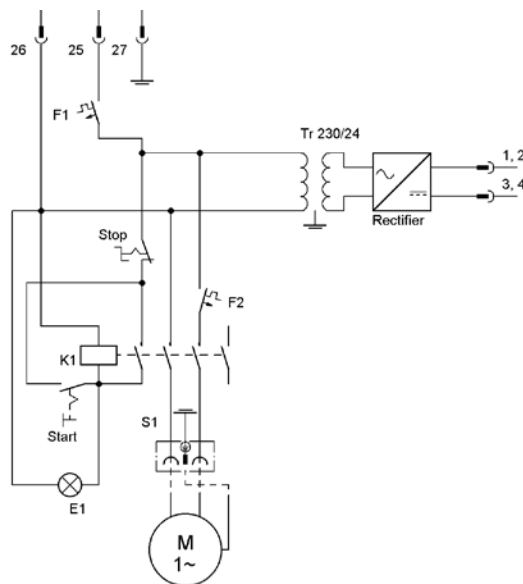


Fig.5 Electric drive compressor scheme

Notations in the figure represent:

- 1, 2, 3, 4, 25, 26, 27 - is generally placed in positions of connector switchboard
- F1 - Breaker - general
- F2 - breaker / thermal - compressor motor protection
- K1 - power contactor compressor
- S1 - connecting compressor outlet
- Start - start button compressor
- Stop - stop button compressor
- E1 - compressor status signaling lamp
- Tr 230/24 - the processed 230V / 24V
- Rectifier - 24V DC voltage rectifier + filtering shareholder distribution

Scheme of electric drive pneumatic distributor is shown in Figure 6. Also in this scheme are summarized these elements:

- Adapters level position sensors
- Local signaling Power
- Power Position Sensor

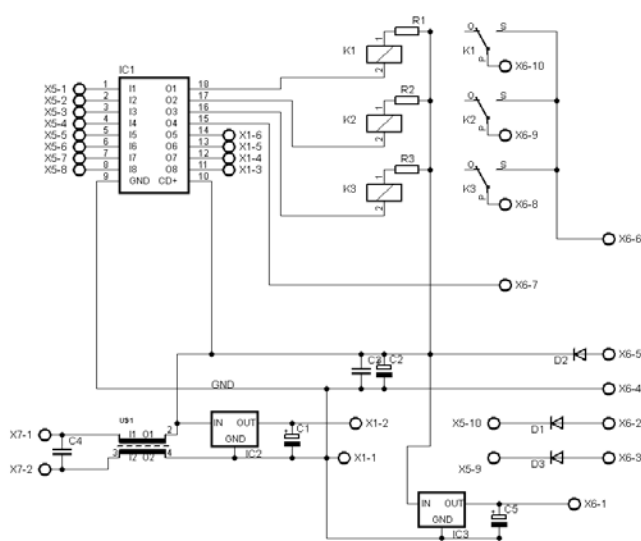


Fig. 6 Scheme of electric drive pneumatic distributor.

4.3 Elements of automation and possibilities to use

The block scheme of electrical operation is endowed with the programmable controller of the process that is the main element of machine commands [8],[9].

Programmable process controller is a real time programmable module with 8 digital entries and 8 digital exits. The implemented program into the controller has to comply with the functioning requirements of the machine. The controller is presented in the figure below.

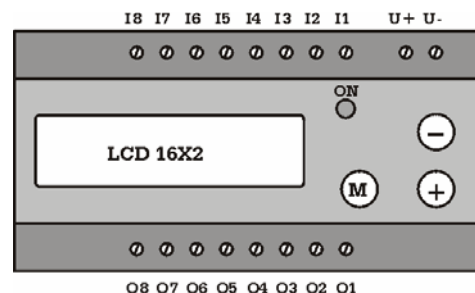


Fig. 7 The programmable controller

In the upper part there are 8 entries, from I1-I8. Also, here is mounted the power switch U+, U-. The exits O1-O8 are located in the bottom part. The connections to the controller are made by coupling the signal cables with the screw connectors according with the signal. The interface with the user is made of an alphanumeric screen of LCD type which has 2 rows and 16 characters on each row. Also, there is a small bulb signaling that the processor is ON. The user can change the parameters by operating one of three buttons:

M- menu

+ - plus – increase a value

- minus – decrease a value

The implemented program in the controller implies the approaching of some aspects related to the state of the machine, the working way and the working parameters. The controller having as signals of entry the position sensors, the state of the compressor starting connector, the state of the protection flap and the state of the switchers of working way and driving mode can operate separately each state of the machine. The states of the machine are given by the working way and the position of the mobile plate.

With manual mode, the state of the machine is not limited by the program but for the lifting of the mobile plate so that the pneumatic cylinder of driving should not reach at the end of the course (at the limit).

With automatic mode the machine states have been described below and they are:

- Repose
- Descending the plate
- Pressing
- Release
- Lifting the plate

Also, the programmer should allow the user to set values for the working parameters. The working parameters are:

- Pressing time
- Release time
- Number of subcycles
- Time of error for movement

The last one, the time of error for movement is a parameter that limits any movement in time. If this time is exceeded, it is assumed that a defect has occurred and a system error is started. The error is removed by stopping and starting the air compressor. The program is structured in several sections:

- Initialization
- Detecting the state of the machine
- Manual working way – if selected
- Automatic working way – if selected
- Parameters setting mode
- Error into the machine

The two active machine working ways, automatic and manual, can be graphically represented.[5],[10]. With the same aspect there can be represented each of the working states of the machine: the working graph of the repose state, of the pressing state, of the release state, etc. For instance, for the automatic working way, the graph of the function is presented below:

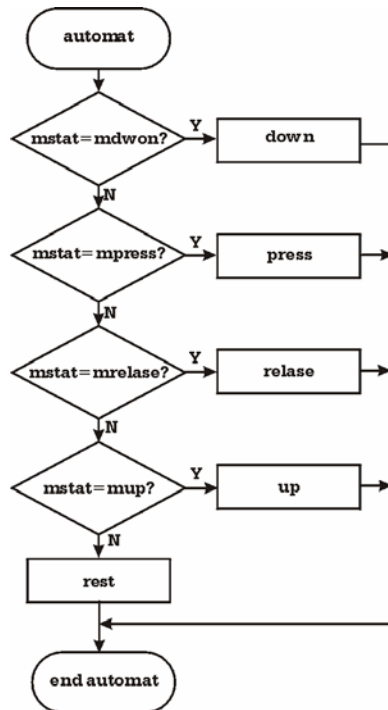


Fig. 8 The working graph of the automatic working way

In this working mode the states are tested and for every one it is executed the specific function. The states noted in the figure with their correspondents are:

- mrest – repose
- mdown – Down movement
- mpress – Pressing
- mrelase – Release
- mup – Up movement

If the system variable is not something that implies movement (mdown, mpress, mrelase or mup) it results that it is in mrest – repose.

5. Conclusions

- The mechanical tenderization is a modern technological component of the process of meat manufacture. It allows the worker to modulate the working state of the machine on different optimal variants of applying the impact force, the pressing time and release of the product. It permits the worker to adjust the working parameters to the type of the meat; this issue makes this paper original;

- The experimental model of the machine presented in the paper is of our own conception and it can solve the problem of meat tenderization within the meat processing technology;

- The authors have designed and constructed a pneumatic installation of operating the machine for mechanical tenderization where all working states of the process are automatic;

- The programmable controller of the process has his own software program that ensures a programming variant after a cyclograme that was established by the operator;

- The working graphs that are presented in the paper determine the recording of the functioning cyclograme that is needed for the performance of functioning.

- The present paper opens directions for researching in automation of different steps of technologies for meat processing.

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THE DEPENDENCE OF THE PHYSICAL AND MECHANICAL PROPERTIES OF TOOL STEEL ALLOYS FROM THE TYPE OF MACHINING

ЗАВИСИМОСТЬ ФИЗИКО-МЕХАНИЧЕСКОГО СОСТОЯНИЯ ИНСТРУМЕНТАЛЬНЫХ ЛЕГИРОВАННЫХ СТАЛЕЙ ОТ ВИДА МЕХАНИЧЕСКОЙ ОБРАБОТКИ

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The results of studies of the influence of the type of machining and tool material to the structural state of the surface layer and the fatigue strength of XBC steel during machining are shown. Processing with the composite-10 tool in a surface layer for α - and γ - phases is accompanied only by compressing residual pressure while abrasive processing promotes occurrence of stretching pressure of an I-type. Increasing of cutting speed of the composite-10 tool from 50 to 200 m/min does not lead to significant changes in fatigue strength.

KEYWORDS: CUTTING, TOOL STEEL, GRINDING, TURNING, AUSTENITE, MARTENSITE, MICROHARDNESS, RESIDUAL STRESSES, FATIGUE STRENGTH

Introduction. The impact of high temperatures and pressures in the cutting zone has a decisive influence on the formation of surface layers in the machining tool alloy steel. Structural changes occurring during this process depend on the value of the factors above, as well as the chemical composition and structure of the original material. Unlike conventional heat treatment, this changes happens in the course of plastic deformation caused by high contact pressure, speed of heating and cooling the surface layers of metal [1].

In the case of the machining of high-strength structural steels two zones of the structural state are formed in the surface layers: directly at the surface - area of secondary hardening and the surrounding area, corresponding to the structure of the quick high-temperature release. Depth of zones of structural changes in the surface layers of the steel at various machining types is determined by various combinations of temperature and pressure contact pairs [2, 3]. Machining of tool alloy steel with cutter has little effect on the strength and ductility of both soft and hardened steels, but has a significant influence on their resistance to cyclic stresses [4]. This is explained by the development of fatigue failure, usually from the surface and in a small volume; while every local weakening of the material causes a shift with tears and thus fatigue cracks later [5].

The grinding of tool steel alloys usually leads to a decrease in fatigue resistance, which is conditioned by the occurrence of tensile residual stress during processing [6]. The rough turning also reduces the fatigue resistance of structural and tool steels because of worst microgeometry of the surface. However, different types of turning have different effects on endurance, and more rougher the machining, the lower endurance will be in the details made of structural steel [7]. Therefore, fine turning with small feeds provides a surface with good microgeometry, a smaller number of defects (gaps, cracks, tears) and reinforcing effect. The most significant effect of turning on endurance of alloy steels have the rate of feed, the radius of the rounding of the cutting edge, the rake angle and the cutting speed [8]. The changing the depth of cut has little influence on the fatigue resistance of steels, since the microgeometry of the machined surface has no significant dependence of this parameter; and some increase in work hardening by increasing the depth of cut is offset by the growth of residual tensile stresses [9].

Usage of superhard cutting materials based on wurtzite boron nitride –composite-10, which has a high thermal conductivity, contributes to shift of the level of residual stresses and, consequently, improves the strength properties of the material [10, 11]. However, the question of using nitride ceramics in the processing of tool alloy steel by turning and grinding isn't studied enough.

Objective. Study the effect of the type of tool material and machining conditions on the strength characteristics and structural condition of the surface layers of tool steel alloy 107WCR5.

Study methodology. To study the effect of the type of tool material on the structural state of the surface layers of the studied steel 107WCR5 obtained by grinding abrasive wheels and turning cutters of composite-10. Technological process of manufacturing the samples consists of cutting round bars for workpiece, pre-turning, semifinished and finish machining. To study the effect of the grinding process of steel 107WCR5, hardness HRC 54 ... 56 samples were prepared in the form of cylinders of 10 mm height and 50 mm in diameter, and effects of turning - 250 mm long, which were hardened at a temperature of 850 °C (with cooling in oil) and tempered at a temperature of 200 °C in air.

Grinding was carried out on cylindrical grinding machines 3Б12 with abrasive wheel: 1А1 250х16х76 63С 6 CM1K and wheel 1А1 250х16х5х76 ГА 125/100 100% БСТ from composite-10.

Turning was performed on a turning machine 16К20 with cutters of composite-10 and different processing rates - the cutting speed $V = 20, 40, 80, 160$ and 250 m/min, feed $s = 0,07$ mm/rev and depth of cut $t = 0,25$ mm. X-ray studies were conducted by stratified analysis on a diffractometer ДРОН-3 in Fe K α -radiation. The amount of residual austenite (f_γ) in the samples was determined from measurements of the integrated intensity of X-ray lines (110) and (111) α and γ -phases in view of repeatability factor:

$$f_\gamma = \frac{S_\gamma}{0,66 \cdot S_\alpha + S_\gamma} \cdot 100\% \quad (1)$$

where S_α ; S_γ – the integrated intensity of X-ray lines α and γ -phases, respectively. The numerical values of S_α and S_γ are determined by computation of respective lines. I-type stresses in the surface layers were evaluated by X-ray diffraction as the sum of the principal stresses ($\sigma_1 + \sigma_2$) by the formula:

$$\sigma_1 + \sigma_2 = \frac{E}{\mu} \cdot \text{ctg} \Theta \cdot \Delta \Theta \quad (2)$$

where E - modulus of elasticity; μ - Poisson's ratio; $\Delta \Theta = \Theta - \Theta_0$ - angle difference, K_α - components of α and γ phases after machining (Θ) and the original (Θ_0). Research of microhardness of the surface layers of samples was performed on microhardness tester ПМТ-3 with a load of 0.2 N and 0.5 N.

Fatigue test of samples were performed as a cantilever bend with rotation. The frequency of load changes was – 15.0 Hz, the test base – 10 million cycles. For curve fatigue plotting at least 15 samples were tested, machined according to the regimen. The resulting calculation of averages $\bar{\sigma}$, $\lg \bar{N}_p$, mean-squared

departure of σ_i and $\lg N_p$, the correlation coefficient and others are the initial data to correlation equation - fatigue curve equation:

$$\lg N_p = A + M \sigma \quad (3)$$

where N_p - the average number of cycles to failure of the sample with stress σ ; A , M - factors.

Evaluation. Studies of microhardness depending on the depth of the layer during grinding with abrasive wheel and turning with cutters of composite-10 showed that the depth of the zone of the secondary quenching decreases with increasing thermal conductivity of the tool material processing. In this case area of high-temperature tempering have a depth of 30-650 microns for grinding wheel, and 8-12 mm in the case of turning cutters of composite-10. Thus, when the temperature drop in the processing zone, the depth of the damaged layer is reduced and becomes a minimum for the surface processed with turning by cutter of composite-10.

The results of measurements of residual austenite after grinding by abrasive wheels and after turning by cutter of composite-10 shown in Table 1. As seen from Tables depth of austenite impaired concentration is by several times less than the depth of impaired microhardness and when processing with abrasive wheel is equal to 120 microns by cutter of composite-10–80 microns. Noticeable changes in the concentration of retained austenite during the turning by cutters of composite-10 occur in the range of $V = 20$ -80 m/min. It can be associated with the process of adhesion of the processed material on the cutter as described in [5, 7].

The structural state of the surface layer of the studied steel during turning with cutter composite-10 (Fig. 1, a-d) is characterized by compressive stress area during α - and γ -phases, maximal at the sample's surface. The subsequent behavior of the stresses in depth for the α - and γ -phase varies and depends on the cutting speed. To investigate the rate of the minimum in γ -phase is reduced to zero at a depth of 60 micron. A characteristic feature of the process of grinding with abrasive wheel is the occurrence of tensile stresses of I-type during α -phase of structure of the high-speed release (Fig. 1, h). Their maximum value according to $(\sigma_1 + \sigma_2)$ is achieved at a depth of 30-50 micron below the surface. During γ -phase small compressive stress takes place, extending to a depth of 40 micron.

Table 1 The amount of residual austenite, f_γ , % in 107WCR5 steel after grinding by abrasive wheels and after turning by cutters of composite-10

№	Type of processing	Depth, (mm)						
		10	20	30	40	80	120	160
		f_γ , %						
1	Grinding by abrasive wheel	23	27	28	28	29	30	30
2	Turning by cutters of composite-10, 20 m/min	25	28	30	31	31	31	31
3	Turning by cutters of composite-10, 40 m/min	25	27	29	30	35	36	38
4	Turning by cutters of composite-10, 80 m/min	31	32	33	33	36	37	37
5	Turning by cutters of composite-10, 160 m/min	36	37	38	39	41	41	41
6	Turning by cutters of composite-10, 250 m/min	31	31	31	32	32	33	34

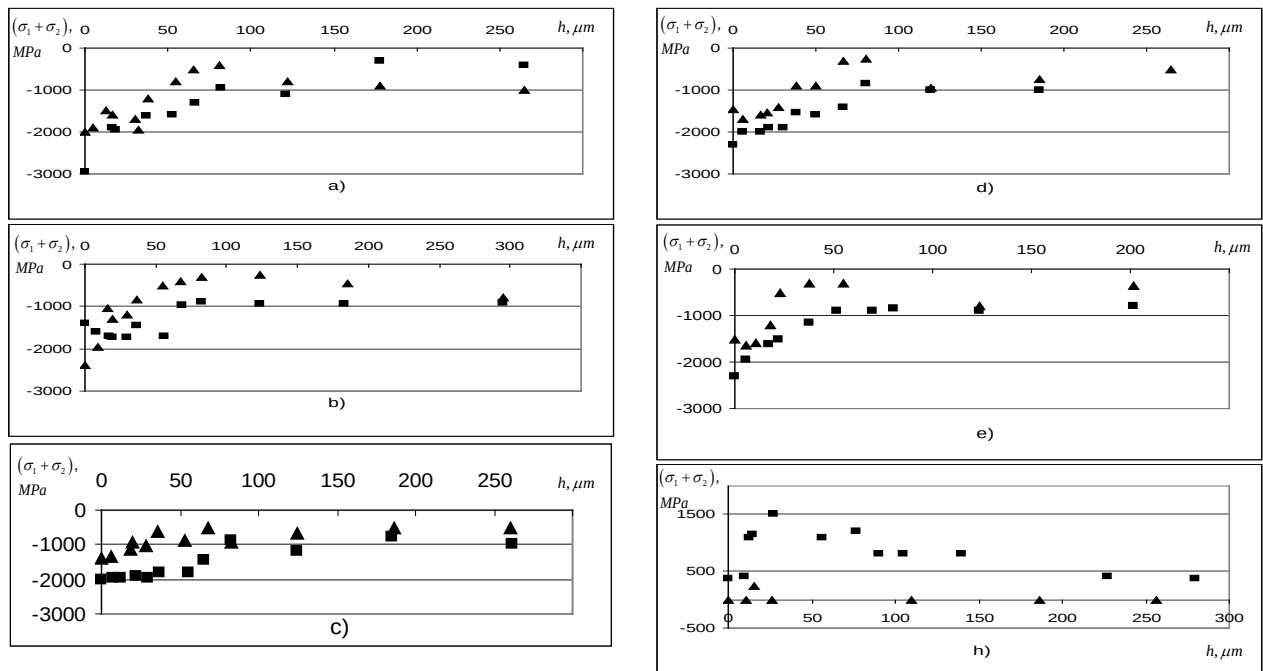


Fig. 1 - Distribution of residual stresses of the first kind in depth of the surface layer at $V = 20$ (a); 80 (b); 160 (c); and 250 m/min (d), grinding with abrasive wheel (h), (■ – γ -phase, ▲ – α -phase)

For the fatigue test four batches of samples were made. First – machined by grinding wheel according to the following routine: RPM range - 2800 rotations/min, number of revolutions of the sample - 400 rev/min; second, third and fourth - composite-10 at a cutting speed $V = 50, 100$ and 200 m/min. respectively; depth of cut and delivery rate for the last three parties remained constant and equal to $t = 0,25$ mm $S = 0,07$ mm/rev. The results of fatigue testing of the above 107WCR5 steel batches of samples are presented in Fig. 2.

Data for stress-cycle diagram, correlation coefficients and limited fatigue strength are shown in Table 2. The analysis of the test results shows that, on the basis of approved testing, fatigue resistance of the material is characterized by a sloped fragment of a diagram – beginning of stress-cycle diagram is shifted towards longevity. The stress-cycle diagram of the fourth installment sample (200 m/min.) is located below the 2nd and 3rd parties curves and the limited endurance limit is 10% lower than for the 2nd batch.

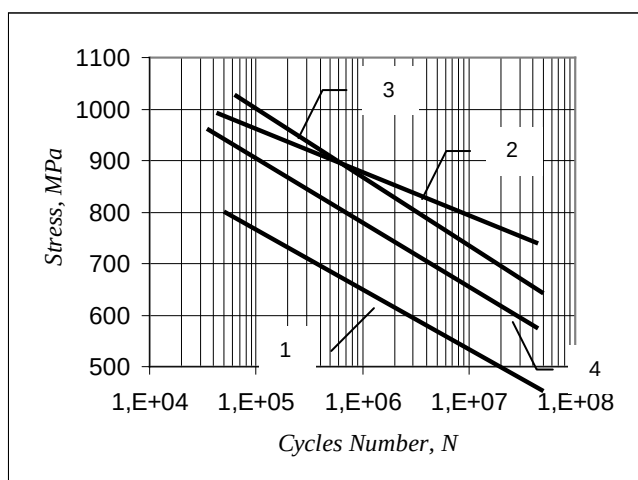


Fig. 2. - Stress-cycle diagram of 107WCR5 steel samples: grinding with abrasive wheel - (1); turning with cutter of composite-10 at a speed $V = 50$ (2), 100 (3) and 200 (4), m/min.

Table 2. The results of fatigue tests of 107WCR5 steel samples in a cantilever bending

№	Type of processing	Correlation coefficients		Limited fatigue strength σ_{-1} , MPa
		A	M	
1	Grinding by abrasive wheel	12,09	-0,0089	660
2	Turning by cutters of composite-10 R, 50 m/min	16,07	-0,01126	827
3	Turning by cutters of composite-10, 1000 m/min	12,76	-0,00776	770
4	Turning by cutters of composite-10, 200 m/min	12,27	-0,00775	735

Endurance of grinded test samples is significantly lower than endurance of samples turned with cutter of composite-10.

Narrow endurance limit for the first batch (560 MPa) is by 32% lower than for the 2nd batch. This is due to the fact that in the process of cutting with composite-10 fast tempering in the surface layers of steel goes under stress, this causes compressive residual stress of the 1st type in α - and γ -phase, slowing the decay of residual austenite. The combination of evenly spaced brittle and ductile structural components in the surface layer enhances endurance of 107WCR5 steel. While grinding with abrasive wheel is causing tensile stresses of the 1st kind in the γ -phase, partially decomposes retained austenite and increases the degree of its hardening.

Conclusion. Thus, studies of the process of grinding with abrasive wheels and turning with cutters of composite-10 a tool steel alloy 107WCR5 showed the following:

- the increase of thermal conductivity of the tool material is narrowing the area of the structural changes occurred in the surface layer of the processed material, it is minimal for turning with cutters of composite-10;
- the amount of residual austenite in the process of turning with cutter of composite-10 is lowest within the limits of cutting speed 40-80 m/min;
- the joint effect of pressure and temperature in high-speed cutting reduces the degree of strain hardening γ - phase in the surface layer;
- machining by composite-10 tool for α - and γ -phases in the surface layer is only accompanied by compressive residual stresses, while grinding with abrasive wheels contributes to the tensile I-type stress in α -phase structure of tempering speed;
- turning by cutters of composite-10 increases on 30% the endurance limit, compared with the grinding by abrasive wheels, wherein the increasing of cutting speed from 50 to 200 m/min does not cause the substantial change of resistance to fatigue.

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INTRODUCTION OF AN INNOVATIVE TECHNOLOGICAL PROCESS IN THE GEAR GRINDING WORKSHOP AT ZMM NOVA ZAGORA

ВНЕДРЕНИЯ ИННОВАЦИОННОГО ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА НА ЗУБОШЛИФОВАЛЬНОМ УЧАСТКЕ ЗММ НОВА ЗАГОРА

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Abstract: The article studies the prerequisites for the introduction of process innovations at ZMM Nova Zagora JSC. The main principles of an original approach for decreasing the degree of discrete manufacturing by introducing an innovative technological process for mechanical machining of tooth gears are expounded. The results of its introduction in the gear grinding workshop are presented.

Keywords: TECHNOLOGICAL INNOVATIONS, UNIFICATION OF TECHNOLOGICAL PROCESSES, GROUP TECHNOLOGY, GEAR GRINDING

1. Introduction

The dominant factors on the world markets in the field of machine building are price, quality and flexibility. Nowadays the modern market situation also concerns the production of metal cutting machines, which more and more frequently makes manufacturers offer new variants or modifications of existing machines. A change in the character of production is observed when the product range expands and the series decreases.

The companies, manufacturing components and units, apply different approaches in order to adapt their organisational and production structure to fast adjustment when changing from one product to another. Process innovations are a good basis for optimisation of technological expenses, for the quality of the manufactured products and for the flexibility of the production process.

2. Prerequisites for the introduction of an innovative technological process

The production of tooth gear occupies a major share in the product structure of ZMM Nova Zagora JSC and it has the following technological profile:

- Wide product range – over 560 types;
- Primarily single and small series production – from 4 to 200 items;
- Wide scope of parameters – outside diameter from 30 to 500 mm, module from 1 to 15 mm;
- Average gear accuracy grade – 6.

Conventional methods and typical technological processes are applied in the gear manufacturing process. Gear grinding, which is carried out according to the generating method, is the finishing operation for the majority of them (over 60%).

The gear grinding workshop is organised according to the object-locked areas principle, preserving its operational specialisation. The average coefficient of the ratio of operations performed per workstation is $K_{op} = 11$ and the production flexibility coefficient is $K_{pf} = 0.91$. There are six gear grinding machines in the workshop dating from 1972 to 1987, which are outdated and have exhausted service life. The cutting conditions are low: feed rate – 1000 mm/min (for rough machining) and 300 mm/min (for finish machining). The time losses for changing the machine settings, for dressing and changing the tools, and the expenses for labour and maintenance of the technological equipment are considerable.

According to company data for 2014 gear grinding machining time amounts to 13% of the total gear manufacturing time and gear grinding cost constitutes 7% of the total cost.

The analysis of the company production programme for 2012-2014 (Fig. 1) shows:

- 61 types of tooth gears drop out of production and 154 new types are introduced;

- tooth gears with external diameter of up to 400 mm (over 98.7%) and with module of up to 4 mm (about 99%) predominate;
- over 80% of tooth gears are manufactured in series of up to 200 items, which amount to between 28.6% and 40.6% of all gears in terms of quantity;
- the range of different gears manufactured in series of up to 10 items has increased 1.5 times and the range of those manufactured in series of up to 100 items has decreased insignificantly while preserving the same quantities;
- the range of different gears manufactured in series of up to 500 items has decreased more than by half whereas the quantities have decreased over 1.5 times;
- the range of different gears and quantities of the remaining types of gear are relatively stable.

As seen from the production programme data and the manufacturing conditions the production of tooth gears in ZMM Nova Zagora JSC is characterised by dynamics as to range of different gears and series production, and a high degree of production flexibility. Economically justified adaptation of this type of production can be achieved by introducing new innovative highly effective technological solutions and up-to-date highly productive technological equipment.

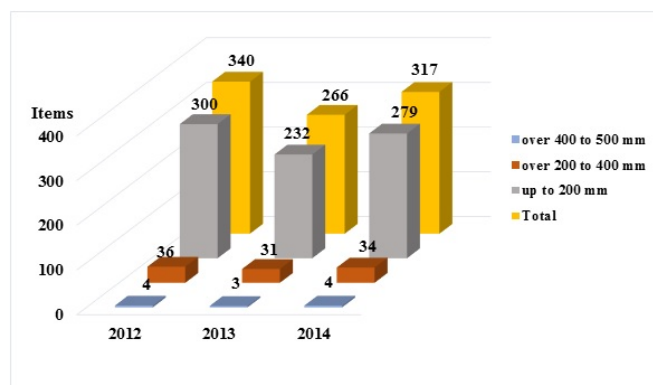


Fig. 1 Range and serial production of ground tooth gears

3. Innovative technological process

The main purpose of introducing an innovative technological process in the gear grinding workshop at ZMM Nova Zagora JSC is achieving optimal usage of the technological equipment and reducing technological expenses while guaranteeing stability of the gear grinding process, by target regulating the degree of production flexibility. A new approach to designing and implementing technological processes for machining tooth gears has been adopted in order to achieve this goal. The innovative approach is based on the principles of technology unification and group technologies [1, 2, 3, 4] and contains two main components:

- Introducing unified group technological processes taking into consideration the technological equipment in the gear grinding workshop.

- Development of engineering and technical tools for the implementation of a flexible gear grinding process guaranteeing optimal technological expenses.

The main differences between the existing conception and the innovative one amount to the organizational and technological structure of the preparation and implementation of production processes.

The innovation encompasses the current for 2014 317 types of tooth gears, whose individual technological processes (ITP) are systematized according to the type and sequence of the implemented technological operations. The tooth gears are grouped according to technological characteristics in 6 complex technological groups, for each one of which a complex tooth gear is created. Intelligent parametric 3D models are developed for complex tooth gears within the SolidWorks engineering design system. The group technological operations for machining tooth gears from each complex technological group (76 group technological operations for 317 tooth gears in total) are specified. The complex operational groups are formed by classifying the tooth gears from the complex technological groups by module. Twelve unified technological operations (UTO) are intended for them, each one of them with a defined unified setting for gear grinding machines.

The content of route and operational groups for each complex technological group is specified. Route groups comprise tooth gears, machined at different settings of the machines of one and the same group route technological process. Operational groups include tooth gears, whose technological operations are performed at the same unified settings of the machines.

The aggregate of group route technological processes of a complex technological group forms a unified group route technological process (UG RTP) for machining the tooth gears from this group. The developed structural variants of UGRTP for machining the 317 tooth gears are illustrated through the structure of UGRTP of one of the complex technological groups (Fig. 2). The abbreviations below the graphical images of this figure constitute accepted alphabetical codes for formal description of types of technological operations. This UGRTP comprises ITP of 9 types of tooth gears, divided in 4 route groups – Group D, Group E, Group J and Group I. The tooth gears from each group can be manufactured in one batch.

The sequence of UTO for machining the tooth gears from one operational group determines the group operational technological process for this group. The aggregate of the group operational technological processes for tooth gears from the same complex operational group form the unified group operational technological process (UGOTP) for this group. The approach of forming UGOTP is illustrated through the structure of technological processes for machining the tooth gears from Group D (Fig. 3).

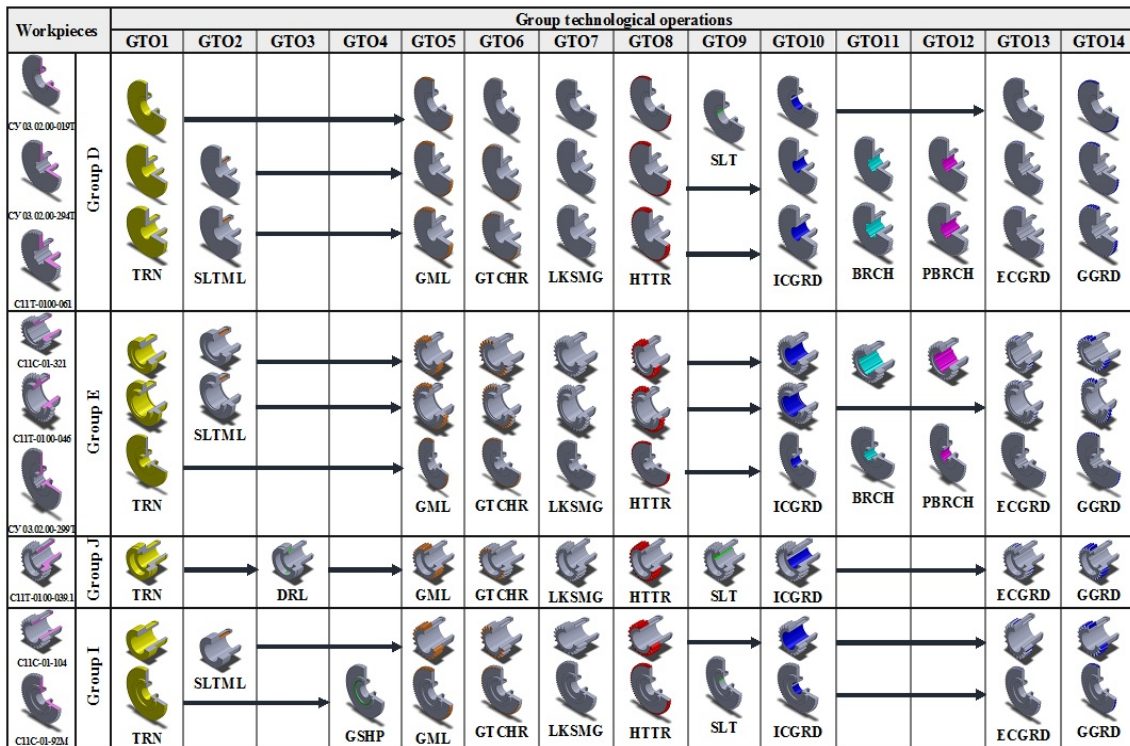


Fig. 2 Structure of a unified group route technological process

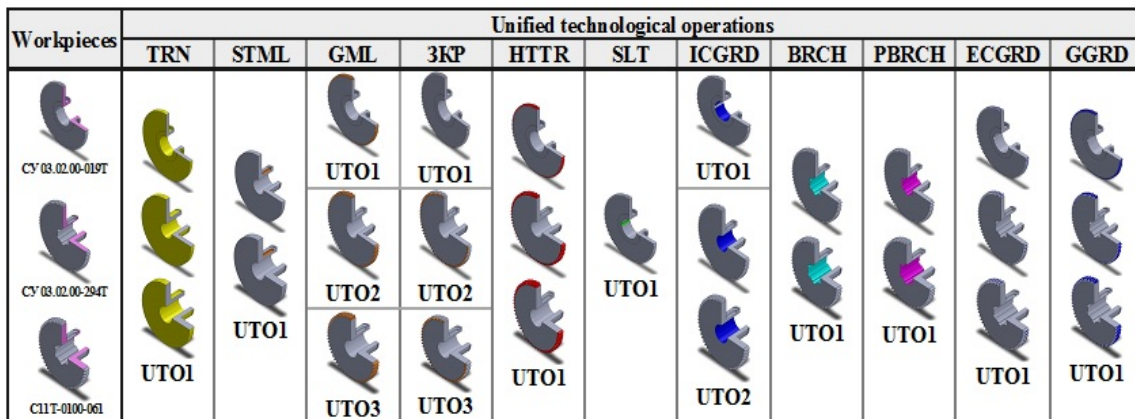


Fig. 3 Structure of a unified group operational technological process

The effective realization of innovative solutions necessitated the restructuring of the gear grinding workshop which includes updating the machines with a new CNC gear grinding machine Niles ZE400/500.

4. Results of introducing an innovative technological process

The company policy envisages the process innovation should encompass the whole production range of tooth gears step by step. The results of introducing an innovative technological process for 30 types of pilot tooth gears, divided in 5 complex technological groups, are commented on in this report (Fig. 4). Eight unified settings of the Niles ZE400/500 gear grinding machine are specified for their machining.

Complex technological groups									
Group names	Complex tooth gear	Typical tooth gears							
Group I									
Group II									
Group III									
Group IV									
Group V									

Fig. 4 Distribution of pilot tooth gears in complex technological groups

After comparing the data for machining pilot tooth gears before and after introducing the innovative technological process and the highly technological CNC gear grinding machine Niles ZE400/500 (Fig. 5), the following summary can be made:

- Automatic execution of the machining cycle, of monitoring and measuring operations, and intensified cutting modes with Niles ZE400/500 contribute to decreasing the total gear grinding time over two times (see Fig. 5a).
- The introduction of group technological processes and unified settings decreases the annual time for resetting Niles ZE400/500 over 2.8 times (see Fig. 5b), which amounts to 0.7% of the effective annual working time.
- After introducing the innovative approach, gear grinding cost price fell by 20% (see Fig 5c).

5. Conclusion

After introducing the innovative technological process and the gear grinding machine Niles ZE400/500 in the gear grinding workshop ZMM Nova Zagora JSC is expected to achieve the following positive results:

- Increasing the serial production and the production capacity through introducing unified group technological processes and decreasing the gear grinding resetting time.
- Decreasing the finished products cost price as a result of reducing the expenses for the technological preparation of the production and optimizing the production costs for gear grinding.
- Improving and guaranteeing stability of the finished products quality by also ensuring conditions for manufacturing tooth gears with up to 4 gear accuracy grade.
- Preserving and expanding the product range by ensuring a high degree of flexibility of the gear grinding process under the

conditions of a complex technological process – a wide product range and small series production.

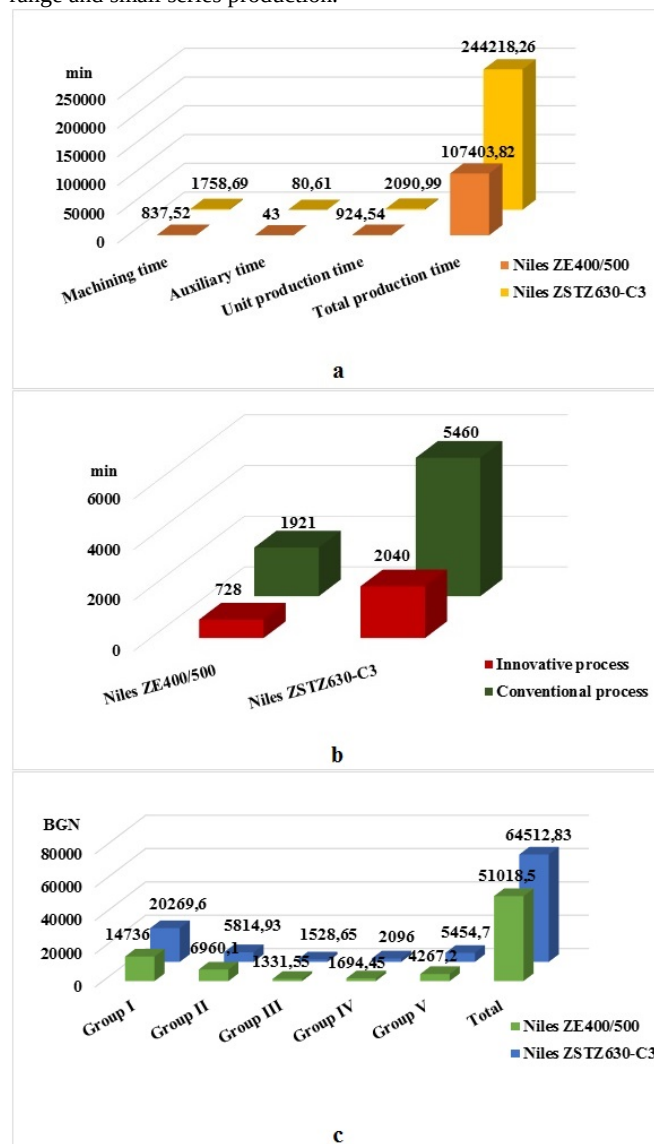


Fig. 5 Comparative analysis of production results before and after introducing the innovative technological process
a, b – production time; c – cost price;

- Increasing the degree of automation of the technological preparation and the production in the gear grinding workshop by introducing information technologies and computer technologies in design and production.
- Achieving maximum productivity in the gear grinding workshop under the conditions of a wide product range and small series production by optimizing the frequency of resetting the machines and the size of the batches.
- Improving the competitiveness and the market positions of the company.

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DEVELOPMENT OF A CANTILEVER PLATE'S MODEL AS A COMPONENT OF THE METHOD OF LOCAL APPROXIMATIONS

РАЗВИТИЕ МОДЕЛИ КОНСОЛЬНОЙ ПЛАСТИНЫ КАК КОМПОНЕНТА МЕТОДА ЛОКАЛЬНЫХ АППРОКСИМАЦИЙ

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Abstract: The paper contains a numerical-analytical solution for deflections and force factors in a cantilever plate of infinite length due to a concentrated load, which is obtained using modern data about optimal quadrature integration. The aspect of optimality is the main feature that distinguished the present solution. The formulas provide high accuracy, which is examined through comparison of the results with the finite elements method and another numerical-analytical solution. The paper also contains formulas for deflections for different laws of load distribution and ideas for their application.

KEYWORDS: THEORY OF ELASTICITY, STRESSED STATE, THE METHOD OF LOCAL APPROXIMATIONS, KIRCHHOFF PLATE, DEFLECTIONS, GEAR MODELING

1. Introduction

Due to rapid development of technologies and materials usable in mechanical engineering, the need of strength calculations' clarification rises for innovative purposes. In this context, theoretical studies of stress concentration in complex-shaped bodies with loaded ledges (such as gearings, for example), which are based on separate analysis of force factors due to an applied load, are extremely valuable. As it is noticed in [1], the standardized methods for calculating numerous sets of details of different mechanisms and machines with loaded ledges (e.g., the Russian GOST - State Standard №21354-87 "Cylindrical Involute Gear Transmissions: Strength Calculations", 1987) for bending strength of the ledges are guided by simplified conceptions. They provide neither information about force factors' distribution laws nor ways for modeling different materials with complex properties. On the other hand, there is a very effective tool – the finite elements method, which has high prevalence among engineers and researchers. However, it demands much of constructing the model properly, and has some specific disadvantages such as the locking effect, for example, which can give troubles if you desire to compute the result with high accuracy. Other reasons for building analytical solutions in parallel with improvement of the FEM modeling are, of course, urge towards having comparative results and general regularities, which could be made more precise with the FEM.

The present paper contains some basic ideas about the method of local approximations (the MLA) – a method of investigation of the stressed state of complex-shaped bodies with loaded ledges. G. A. Zhuravlev proposed it in [2, 3] in the context of modernization of a gearing's geometry accordingly to the actual stress concentration, which takes into account origin of every stress component. The method is based on two plane problems, to which the three-dimensional one is being reduced. Thus, we calculate the force factors on a cantilever plate (using classic or improved theories of plate bending) in order to use them in calculation of the respective stress components in the model of a rod with two deep symmetric hyperbolic recesses. In this connection we consider, that the contour of the hyperbolic recess approximates the contour of the ledge, and take into account the depth of the plate's sealing. It is shown in the paper [4], how the first requirement can be satisfied for a tooth of a spur pinion. The question about the depth of the sealing is observed, for example, in [3].

The problem of stress concentration in a rod with two deep symmetric hyperbolic recesses is solved in [5]. As for the problem of a cantilever plate calculation, the number of papers, which contain analytical or numerical-analytical solutions, is not big. The present paper describes a comparatively simple solution, which corresponds to a model of an infinitely long plate, clamped along one of its long sides. T. J. Jaramillo described this problem in [6]

and gave an exact solution in terms of improper integrals for the deflections and moments due to a transverse concentrated load acting at an arbitrary point of the plate. It was proposed in [6] to calculate the respective integrals using residue theory, but as it was shown in the papers [7, 8] and in the Proceedings of 2015 International Conference on "Physics and Mechanics of New Materials and Their Applications" (PHENMA 2015), the residue solution of [6] gives a big error for some calculation points. The present paper continues the course of [7] and presents a numerical-analytical solution for deflections (which is basic for calculating force factors and stresses), built with applying modern ideas about optimal quadrature integration.

We also introduce formulas for deflections, suitable for different laws of load distribution, such as uniformly distributed over a segment and over a rectangle loads, a distributed over a segment accordingly to the parabolic law load and a load, distributed over an ellipse.

2. Deflections

2.1. A numerical-analytical solution for deflections

On the analogy of [6], the plate is considered in the form of an infinitely long strip of width A and thickness h , fixed along one of its long edges. The transverse load F is applied at an arbitrary point $P(c, 0)$ of the plate, where the Cartesian coordinate system

Oxyz is located such that xy is the middle plane of the plate, Oy belongs to the fixed side and the line of F belongs to the xz plane. Let the plane $x=c$ divide the plate and the functions, which are determined in the areas $0 \leq x \leq c$ and $c \leq x \leq A$, have the indexes 1 and 2 respectively. Then, if the weight of the plate isn't considered the deflections $W_j(x, y)$, $j=1, 2$, satisfy the biharmonic equation

$$\nabla^4 W_j(x, y) = 0, \quad j=1, 2,$$

which is valid everywhere except the point P .

It is proposed in [7] to define the functions $W_j(x, y)$, $j=1, 2$, as

$$W_j(x, y) = \int_0^\infty f_j(x, \alpha) \cos(\alpha y) d\alpha,$$

where

$$f_j(x, \alpha) = (A_j + B_j \alpha x) \cosh(\alpha x) + (C_j + D_j \alpha x) \sinh(\alpha x),$$

A_j, B_j, C_j, D_j are assumed functions of the α variable.

Then the boundary conditions can be written as

$$\left. \begin{aligned} f_1(0, \alpha) &= f_{1,x}(0, \alpha) = 0; \\ f_{2,xx}(A, \alpha) - \alpha^2 \mu f_2(A, \alpha) &= 0; \\ f_{2,xxx}(A, \alpha) - \alpha^2 (2 - \mu) f_{2,x}(A, \alpha) &= 0; \\ f_1(c, \alpha) - f_2(c, \alpha) &= 0; \\ f_{1,x}(c, \alpha) - f_{2,x}(c, \alpha) &= 0; \\ f_{1,xx}(c, \alpha) - f_{2,xx}(c, \alpha) &= 0; \\ f_{2,xxx}(c, \alpha) - f_{1,xxx}(c, \alpha) &= \frac{F}{\pi D}, \end{aligned} \right\}$$

where $D = \frac{E h^3}{12(1 - \mu^2)}$ is the flexural rigidity of the plate (E is

Young's modulus, μ is Poisson's ratio).

Being solved for $A_j, B_j, C_j, D_j, j = 1, 2$, the system provides the following functions:

$$\begin{aligned} f_1(x, c, \alpha) &= \frac{F}{2\pi A D \gamma} \left[-x\alpha \cosh(x\alpha) \sum_{i=1}^4 a_i k_i + \sinh(x\alpha) \sum_{i=4}^8 a_i k_i \right], \\ f_2(x, c, \alpha) &= f_1(c, x, \alpha), \\ \gamma &= \alpha^3 \left[5 + 2(A\alpha)^2 (\mu - 1)^2 + (2 + \mu)\mu - (\mu^2 + 2\mu - 3) \cosh(2A\alpha) \right] \end{aligned}$$

i	k_i	a_i
1	$5 + 2A(A - c)\alpha^2 (\mu - 1)^2 + (2 + \mu)\mu$	$\cosh(c\alpha)$
2	$-(\mu^2 + 2\mu - 3)$	$\cosh[(c - 2A)\alpha]$
3	$\alpha(\mu - 1)(2A - c)(\mu - 1)$	$\sinh(c\alpha)$
4	$\alpha c(\mu - 1)(\mu + 3)$	$\sinh[(c - 2A)\alpha]$
5	$5 + (2A^2 - 2Ac + cx)\alpha^2 (\mu - 1)^2 + (2 + \mu)\mu$	$\cosh(c\alpha)$
6	$-(1 + cx\alpha^2)(\mu^2 + 2\mu - 3)$	$\cos[(c - 2A)\alpha]$
7	$\alpha \left[-c(\mu - 1)^2 + 2A^2 x \alpha^2 (\mu - 1)^2 - 2A(cx\alpha^2 - 1)(\mu - 1)^2 + 4x(\mu + 1) \right]$	$\sinh(c\alpha)$
8	$c\alpha(\mu^2 + 2\mu - 3)$	$\sinh[(c - 2A)\alpha]$

Thus,

$$W_j(x, y, c) = \int_0^\infty f_j(x, c, \alpha) \cos(y\alpha) d\alpha, \quad j = 1, 2,$$

and for numerical calculation of the deflections we have proposed in [10] the following formula:

$$W_j(x, y, c) = \frac{\pi}{2n} \sum_{k=1}^n F_j \left[x, y, c, \tan \frac{(2k-1)\pi}{4n} \right], \quad j = 1, 2 \quad (1)$$

where

$$F_j(x, y, c, \alpha) := (1 - \alpha^2) f_j(x, c, \alpha) \cos(\alpha y), \quad j = 1, 2,$$

and the error of (1) is $\frac{\pi}{4n}$.

Due to the behavior of the respective functions it is proposed to use different values of n for $j = 1$ and for $j = 2$. The main feature of the formula (1) is that it can be called an almost optimal one, because we use the respective result from theory of optimal quadrature integration in order to build it. However, some additional assumptions, which take into account the behavior of the integrands and substantiate selection of n values, have to be made. It is convenient to use dimensionless coordinates

$$\xi = \frac{x}{A}, \quad \eta = \frac{y}{A}, \quad \zeta = \frac{c}{A}.$$

Computational experiments show that the values of deviation between the results of the FEM modeling and the formula (1)

become more than 1% if η approach 1,00. Here we consider the following parameters of the model in ANSYS:

Length of the plate L, m	h, m	A, m	F, N	Finite elements type	Multiplicity of splitting: the side of L , the side of h , the side of A
0,2	0,002	0,01	2000	SHELL63	400
					4
					40

It is obvious that the results directly depend on the ratios of $\frac{L}{A}$ and

$\frac{y}{L}$ in the FEM model; thus, we have to consider a sufficiently long plate and calculation points, which are sufficiently removed from the side edges of the plate.

2.2. Different laws of load distribution

The following formulas in terms of improper integrals correspond to different cases of a distributed load, such as uniformly distributed over a segment and over a rectangle loads, a distributed over a segment accordingly to the parabolic law load and a load, distributed over an ellipse. Hereinafter we suppose, that r is a ratio of a distance between the sealing line of the plate and the center of a loaded area to the size A , F_x is a distributed load, q_0 is intensity of loading in the center point of a loaded area and

$$\varphi_j(\xi, \zeta, \mu) = \frac{f_j(\xi, \zeta, \mu)}{F} \mu^3 \kappa(\mu), \quad j = 1, 2, \quad \text{where } \mu = \alpha A,$$

$$\kappa(\mu) = \mu^2 + \theta^2 + (2\theta + 1) \cosh^2(\mu), \quad \theta = \frac{1 + \nu}{1 - \nu}.$$

The following formulas are proposed on the base of [8].

If the load is uniformly distributed over an interval of length 2ρ , which is parallel to the sealing line, then

$$W_j(\xi, \eta, \zeta) = \frac{F_x}{q_0} \int_0^\infty \frac{\varphi_j(\xi, r, \mu)}{\mu^4 \kappa(\mu)} \cos(\mu\eta) \sin(\mu\eta) d\mu.$$

If the load is distributed over the same segment, divided into k elementary segments of equal lengths ΔS , accordingly to the parabolic law

$$q = \frac{3F_x(\rho^2 - \varepsilon^2)}{4\rho^3},$$

where ε is the distance between the center of the segment and the calculation point, then

$$W_j(\xi, \eta, \zeta) = \frac{3F_x}{q_0^3} \int_0^\infty \frac{\varphi_j(\xi, r, \mu)}{\mu^6 \kappa(\mu)} \cos(\mu\eta) [\sin(\mu\rho) - \mu\rho \cos(\mu\rho)] d\mu.$$

If a load of intensity q is uniformly distributed over a rectangle $\zeta_1 \leq \xi \leq \zeta_2, \eta_1 \leq \eta \leq \eta_2$, then

$$W_j(\xi, \eta, \zeta) = 4q \int_0^\infty \frac{\cos[(\eta - \bar{\eta})\mu] \sin(\mu\nu)}{\mu^5 \kappa(\mu)} \bar{\varphi}(\xi, \mu) d\mu,$$

where

$$\bar{\varphi}(\xi, \mu) = \sum_{j=1}^2 \left\{ \sinh(\mu u_j) \varphi_j(\xi, \bar{\xi}_j, \mu) + [\mu u_j \cosh(\mu u_j) - \sinh(\mu u_j)] \bar{\varphi}_j(\xi, \bar{\xi}, \mu) \right\},$$

$$\bar{\varphi}_j(\xi, \zeta, \mu) = (1 + 2\theta)(2\mu\zeta C_2 + S_2 - S_1) - 2\mu(1 - \xi)C_4 - S_4 + 2\mu C_5 + t_j S_5,$$

$$t_1 = 1 + 4\mu^2 \xi, \quad t_2 = (1 + 2\theta)^2 + 4\mu^2 (1 - \xi),$$

$$S_1 = \sinh[(2 - \zeta + \xi)\mu],$$

$$S_2 = \sinh[(2 - \zeta - \xi)\mu],$$

$$S_4 = \sinh[(\zeta + \xi)\mu],$$

$$S_5 = \sinh[(\zeta - \xi)\mu],$$

$$\begin{aligned}
C_2 &= \cosh[(2 - \zeta - \xi)\mu], & C_4 &= \cosh[(\xi + \zeta)\mu], \\
C_5 &= \cosh[(\zeta - \xi)\mu], & v &= \frac{\eta_2 - \eta_1}{2}, \quad \bar{\eta} = \frac{\eta_1 + \eta_2}{2}, \\
u_1 &= \begin{cases} \frac{1}{2}[\zeta_2 - \max(\xi, \zeta_1)], & \xi \leq \zeta_2; \\ 0, & \xi > \zeta_2, \end{cases} \\
u_1 &= \begin{cases} \frac{1}{2}[\min(\xi, \zeta_2) - \zeta_1], & \xi \geq \zeta_1; \\ 0, & \xi < \zeta_1, \end{cases} \\
\bar{\xi}_1 &= \frac{1}{2}[\zeta_2 + \max(\xi, \zeta_1)], & \bar{\xi}_2 &= \frac{1}{2}[\min(\xi, \zeta_2) + \zeta_1].
\end{aligned}$$

At last, if the load is applied accordingly to the law of semi-ellipsoid over an ellipse with dimensionless semi-axes a and b , which is inclined by an angle Λ , it is proposed in [8] to use a method, based on reduction of the problem to the case of the parabolic law of load distribution. Thus, we divide the ellipse into elements with a system of equidistant chords, parallel to the free edge. The intensity of the load inside every element is

$$q(\varepsilon, \zeta) = q_0 \left\{ 1 - \frac{[\varepsilon \cos(\Lambda) + (\zeta - r) \sin(\alpha)]^2}{a^2} - \frac{[\varepsilon \sin(\Lambda) - (\zeta - r) \cos(\alpha)]^2}{b^2} \right\}^{\frac{1}{2}},$$

where $q_0 = \frac{3 F_y}{2 \pi a b}$, and we replace it with an equivalent one, which

is distributed accordingly to the parabolic law over the chord, which contains the application point of the resultant force of the element. We introduce the following notation:

NN' is the diameter of the ellipse, connected with the chosen system of dividing chords; $S_0 = \frac{NN'}{2}$; S is a linear coordinate, which is counted off the center of the ellipse along the diameter NN' ; n_e is a number of parts, into which the ellipse is divided; λ_i , $i = 1, 2, \dots, n+1$, are the coordinates of points of dividing chords' intersection with NN' ; F_k , $k = 1, \dots, n$, is the value of the resultant force on the element between λ_k and λ_{k+1} ; l_k is the coordinate of the point of the resultant force acting; ρ_k is one-half of the chord, along which the equivalent load is distributed; β is the angle between NN' and $O\xi$.

The following relations link all of the introduced parameters:

$$\begin{aligned}
\lambda_0 &= \sqrt{\frac{a^4 \sin^4(\Lambda) + b^4 \cos^2(\Lambda)}{a^2 \sin^2(\Lambda) + b^2 \cos^2(\Lambda)}}; \\
\lambda_i &= -\lambda_0 + (i-1) \frac{2\lambda_0}{n_e}, \quad i = 1, 2, \dots, n_e + 1; \\
F_k &= \frac{\pi a b q_0}{3 n_e \lambda_0^2} [3\lambda_0^2 - (\lambda_{k+1}^2 + \lambda_k \lambda_{k+1} + \lambda_k^2)], \quad k = 1, 2, \dots, n_e; \\
l_k &= -\frac{A a b q_0}{4 \pi n F_k \lambda_0^2} (\lambda_{k+1} + \lambda_k) (\lambda_{k+1}^2 + \lambda_k^2 - 2\lambda_0^2), \\
\rho_k &= \frac{a b}{\lambda_0} \sqrt{\frac{\lambda_0^2 - l_k^2}{a^2 \sin^2(\Lambda) + b^2 \cos^2(\Lambda)}}, \\
\cos(\beta) &= \frac{a^2 \sin^2(\Lambda) + b^2 \cos^2(\Lambda)}{\sqrt{a^4 \sin^2(\Lambda) + b^4 \cos^2(\Lambda)}}.
\end{aligned}$$

Thus, the method provides the following:

$$W_j = 3 \sum_{k=1}^n \frac{F_k}{\rho_k^3} \int_0^{\varphi_j(\xi, r - l_k \cos(\beta), \mu)} \frac{\mu^6 \kappa(\mu)}{\mu^6 \kappa(\mu)} \cos[(\eta + l_k \sin(\beta))\mu] \cdot [\sin(\mu \rho_k) - \mu \rho_k \cos(\mu \rho_k)] d\mu.$$

2.3. Practical recommendations for calculation

The problem of the deflections' calculation for the observed cases of load distribution consists in calculation of the respective improper integrals, which contain complex integrands. We suppose that the most effective way is building highly accurate approximate formulas, which take into account not only behavior of the integrands, but also correctly reflect the influence of the respective derivatives. The latter is very important for creation calculation algorithms for force factors and stresses.

Some approximate formulas can be found in [8]. Though they include strict limitations for calculation points and are not universal concerning material properties, they provide satisfying accuracy for steel plates within the limits of their application.

It is also useful to notice, that for deflections at the points located in the area of loading it is not hard to reduce the problem to consecutive repeated application of the formula (1). This is shown in the paper [1], where an algorithm for the case of the parabolic law of load distribution is represented.

3. Force factors due to a concentrated load

In the proceedings of PHENMA 2015 we have proposed the following formulas for the force factors due to a concentrated load – respectively, shearing force, bending and twisting moments:

$$\begin{aligned}
Q_{jx}(x, y, c) &= -\frac{\pi D}{2n} \sum_{k=1}^n F_j^{Q_x} \left[x, y, c, \tan \frac{(2k-1)\pi}{4n} \right], \\
M_{jx}(x, y, c) &= -\frac{\pi D}{2n} \sum_{k=1}^n F_j^{M_x} \left[x, y, c, \tan \frac{(2k-1)\pi}{4n} \right], \\
M_{jxy}(x, y, c) &= -\frac{\pi D(1-\mu)}{2n} \sum_{k=1}^n F_j^{M_{xy}} \left[x, y, c, \tan \frac{(2k-1)\pi}{4n} \right],
\end{aligned}$$

where

$$\begin{aligned}
F_j^{Q_x}(x, y, c, \alpha) &= \left\{ \begin{aligned} &[f_j(x, c, \alpha) \cos(\alpha y)]_{xxx} + \\ &+ [f_j(x, c, \alpha) \cos(\alpha y)]_{xyy} \end{aligned} \right\} (1 - \alpha^2), \\
F_j^{M_x}(x, y, c, \alpha) &= \left\{ \begin{aligned} &[f_j(x, c, \alpha) \cos(\alpha y)]_{xx} + \\ &+ \mu [f_j(x, c, \alpha) \cos(\alpha y)]_{yy} \end{aligned} \right\} (1 - \alpha^2), \\
F_j^{Q_{xy}}(x, y, c, \alpha) &= [f_j(x, c, \alpha) \cos(\alpha y)]_{xy} (1 - \alpha^2).
\end{aligned}$$

This solution was compared with one, which could be found in [9] for a steel plate. It is shown, that the results of [9] are qualitatively improved.

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BASIC FINANCIAL CALCULATIONS USING INFORMATION SYSTEMS FOR SOLVING BUSINESS TASKS

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An Introduction

A detailed study of the financial concepts fundamentals certainly is to give some idea on the concepts of finance. The investment world can be confusing for the investors. The investors need to go through some finance theories which will help them to understand the market behavior in a better way. There are a number of factors that influence the functioning of the investment market. The individual investor's choice of investment may vary from one person to another. While some investors go for investing in the risky securities, some investors tend to play safe in the market by investing in the less risky environment.

The finance theory concept including studying the various ways by which businesses and individuals raise money, as well as how money are allocated to projects while considering the associated with them risk factors.

1. The concept of finance theory

The concept of finance also includes the study of money and other assets, managing and profiling project risks, control and management of assets, and the science of money managing. Simply, 'financing' also means provision and allocation of funds for a particular business module or project. There are a number of finance theories that offer separate approaches to the finance hypotheses. Some of the major popular finance theories of the world are: Arbitrage Pricing Theory, Rational Choice Theory, Prospect Theory, Cumulative Prospect Theory, Monte Carlo Option Model, Binomial Options Pricing Model, Gordon Model, International Fisher Effect, Black Model, and Legal Origins Theory

2. Financial Services Company

The finance industry provides to the clients a number of services. There are different types of financial services which company can provide to different commercial sectors as well as to the individuals. Some of that types of financial services are lending money for different purposes, insurances, depository services, mortgage services, investment services, credit rating services and many more. The different types of financial services jointly create one of the largest industries of the world. Every individual as well as institution has a definite income source and a particular way of expenditure. These particular sources of income, habit of investment and expenditure habit, all come under the domain of finance. Several important finance concepts have been developed through close study of all these things [2].

3. Financial Goal - Profit versus Wealth

Every firm has a predefined goal or an objective. Therefore the most important goal of a financial manager is to increase the owner's economic welfare. Here economics welfare may refer to profit maximization or maximization of shareholders wealth. Therefore Shareholders wealth maximization (SWM) plays a very crucial role as far as financial goals of a firm are concerned. Profit is the remuneration paid to the entrepreneur after deduction of all expenses. Maximization of profit can be defined as maximizing the income of the firm and minimizing the expenditure. The main responsibility of a firm is to carry out business by manufacturing goods and services and selling them in the open market. The mechanism of demand and supply in an open market determine the price of a commodity or a service. A firm can only make profit if it produces a good or delivers a service at a lower cost than what is prevailing in the market. The margin between these two prices would only increase if the firm strives to produce

these goods more efficiently and at a lower price without quality compromising. The demand and supply mechanism plays a very important role in determining the price of a commodity. A commodity which has a greater demand commands a higher price and hence may result in greater profits. Competition among other suppliers also effect profits. Tendency is manufacturers to move towards production of those goods which guarantee higher profits. As result comes a time when equilibrium is reached and profits are saturated.

According to Adam Smith – business man while are fulfilling the own goals for profit in turn benefits the whole society. Obviously when a firm tends to increase profit it eventually makes use of its resources in a more effective manner. Profit is regarded as a parameter to measure firm's productivity and efficiency. Firms which tend to earn continuous profit eventually improvise their products according to the consumers demand. Bulk production due to massive demand leads to economies of scale which eventually reduces production cost. Lower production cost directly impacts the profit margins. Profit maximization objective is a little vague in terms of returns achieved by a firm in different time period. When measuring profit the time value of money is often ignored. It leads to returns uncertainty. Two firms which use same technology and same factors of production may eventually earn different returns. It is due to the profit margin. It may not be legitimate if seen from a different stand point [5], [6].

4. Importance of Cash Flow

In case of both personal and business finance, cash flow is an important concept. It is more important with regard to solvency. Cash flow is used as a documentation of past investments and earnings. It is also used by the business entities in order to represent the direction where they want to take their company. In the present competitive world the business cash flow becomes an important phenomenon. It is assumed that people like creditors and brokers that the person or business entity that has a decent cash flow record is in a better position to make his payments at the right time. Thus it becomes easier for such parties to obtain finance for various purposes.

Equational Representation of DCF

The Discounted Cash Flow could be represented through the following equation:

$$DCF = CF_1/(1+r)^1 + CF_2/(1+r)^2 + \dots + CF_n/(1+r)^n$$

In this formula CF stands for cash flow and r represents the rate of discount.

Discounted Cash Flow in Mathematics

The method of Discounted Cash Flow is used in Mathematics as well. The formula for discounted Cash Flow has been deduced from the future value formula. The future value formula is used to calculate the following:

* **Compounding Returns**

* **Time Value of Money**

5. Basic principles of finance

It is a basic principle of finance that separate amounts of money cannot be equated, added or subtracted if they are at different times. Interest is present in all of the problems we consider. This means that, looking backward a dollar today is worth less yesterday, or, looking forward, it is worth more tomorrow. The principle of bringing all amounts to a common point, usually called a pivot point, is absolutely fundamental when solving finance problems. Complete freedom of choice is available for the pivot point, as the correct answer to a finance problem does not depend on the chosen pivot point. Therefore, the pivot point is usually chosen for convenience of calculation.[4],[10]

The basic principles and equations are developed for elementary finance, based on the concept of compound interest. The five quantities of interest in such problems are present value, future value, also amount of periodic payment, number of periods and the rate of interest per period.

The fundamental mathematical topics on which elementary finance is based are the arithmetic and geometric sequences. Other terms in use are AP and GP, where the "P" stands for progression,

an older term for sequence. Arithmetic sequences correspond to problems where simple interest is used, and geometric sequences to those involving compound interest. We do not consider arithmetic sequences and simple interest here.

A sound understanding of basic finance is a very important and useful skill for life, even if a career in finance is not the ultimate goal. At least in western societies, everyone needs at least a basic understanding of the implications of borrowing or investing money in a compound interest environment. With the advent of the modern electronic spreadsheet, as exemplified by Microsoft Excel, it is now not only possible, but rather easy to improve drastically on this approach to the teaching of basic finance.

In the spreadsheet environment, we advocate a three-pronged approach, and it is tacit that all three approaches must yield the same result for any given problem. The approaches are:

- Traditional algebraic formulas, sometimes supplemented with the powerful Goal Seek
- Linear recursive schedule, also sometimes with Goal Seek
- Excel intrinsic financial functions

6. The basic equation

$$FV = PV(1+I)^N$$

FV = future value

PV = present value

I = interest

N = number of periods

7. Excel Spreadsheets. Financial Functions [1], [3], [7], [8], [9], [11]

Below is the list of the 5 most useful ones:

Functions	What it Does
FV	Returns the future value of an investment
NPER	Returns the number of periods for an investment
PMT	Returns the periodic payment for an annuity
RATE	Returns the interest rate per period of an annuity
IRR	Return the Internal Rate of Return for a supplied series of periodic cash flows

7.1. The RATE Function

The question to which RATE brings an answer to is:

- What is the real interest rate if they ask me for a certain amount each period to pay a loan?

	A	Descriptions
1	48	Number of periods (years, months, weeks..etc)
2	\$550	Periodic payment
3	\$24,000	Total amount of loan
4	0	The balance left to pay at the end of the period. If you omit this argument Excel uses "0".
5	0	Payment made at the beginning of the period (1) or at the end of the period (0). If you omit this argument Excel uses "0" saying that the payment is made at the end of each period which is usually the reality when you borrow money.
6	5.00%	The result with the formula using the RATE function. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2

Here is the formula in cell A6:

=RATE(A1,-A2,A3,A4,A5)*12

Notes on the formula: The payment argument is negative (-A2); If you use months as periods and you want an annual rate you multiply by 12, if you use a years as periods and you want an

annual rate you don't multiply.....; If you don't use the "Percentage" format in cell A6 the result of this example will be 0.05; The formula could also be **=RATE(A1,-A2,A3)*12** the arguments in A4 and A5 being optional

7.2. The PMT Function

The question to which PMT brings an answer to is:

- If I borrow a certain amount of money and I want it repaid

at the end of a certain period of time what will be the periodic payment?

	A	Descriptions
1	5.00%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	48	Number of periodic payments (years, months, weeks)
3	\$24,000	Total amount of loan
4	0	The balance left to pay at the end of the period. If you omit this argument Excel uses "0".
5	0	Payment made at the beginning of the period (1) or at the end of the period (0). If you omit this argument Excel uses "0" saying that the payment is made at the end of each period which is usually the reality when you borrow money.
6	-\$550.41	The result with the formula using the PMT function.

Here is the formula in cell A6:

=PMT(A1/12,A2,A3,A4,A5)

Notes on the formula: If you don't use the "Percentage" format in cell A1 enter 0.05; If you use months as periods the rate must be divided by 12 (A1/12), if you use weeks then you divide by 52 (A1/52), if there are 4 payments per year you will divide the rate by 4 (A1/4) and if the payment is annual you don't divide the rate argument (A1); The formula could also be **=PMT(A1/12,A2,A3)** the arguments in A4 and A5 being optional; If you want the

payment to show as a positive value add a minus sign before the equal sign (**=-PMT(A1/12,A2,A3,A4,A5)**)

7.3. The FV Function (Future value)

The question to which **FV** brings an answer to is:

- If I put a certain amount of money in the bank each month, how much money I will have saved at the end of a certain period of time?

	A	Descriptions
1	5.00%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	48	Number of periodic deposits (years, months, weeks)
3	\$550	Amount of periodic deposits
4	\$0	Beginning balance. If you omit this argument Excel uses "0".
5	1	Deposits made at the beginning of the period (1) or at the end (0). If you omit this argument Excel uses "0". In the case of the FV function make sure that you enter "1".
6	-\$29,279.68	The result with the formula using the FV function.
	A	Descriptions
1	5.00%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	48	Number of periodic deposits (years, months, weeks)
3	\$550	Amount of periodic deposits
4	\$0	Beginning balance. If you omit this argument Excel uses "0".
5	1	Deposits made at the beginning of the period (1) or at the end (0). If you omit this argument Excel uses "0". In the case of the FV function make sure that you enter "1".
6	-\$29,279.68	The result with the formula using the FV function.

Here is the formula in cell A6:

=FV(A1/12,A2,A3,A4,A5)

Notes on the formula: If you don't use the "Percentage" format in cell A1 enter 0.05; If you use months as periods the rate must be divided by 12 (A1/12), if you use weeks then you divide by 52 (A1/52), if there are 4 payments per year you will divide the rate by 4 (A1/4) and if the payment is annual you don't divide the rate argument (A1); The formula could also be **=FV(A1/12,A2,A3)** the arguments in A4 and A5 being optional; If you want the

RESULT to show as a positive value add a minus sign before the equal sign (**=-FV(A1/12,A2,A3,A4,A5)**)

7.4. The NPER Function

The question to which **NPER** brings an answer to is:

- How many months would it take me to repay a certain loan at a certain interest rate if I pay a certain amount each month?

	A	Descriptions
1	5.0%	The annual interest rate. Note: the format of this cell must be "Percentage" with any number of decimals. In this example the number of decimals is 2
2	\$550	Periodic payment

3	\$24,000	Total amount of loan
4	0	The balance left to pay at the end of the period. If you omit this argument Excel uses "0".
5	0	Payment made at the beginning of the period (1) or at the end (0). If you omit this argument Excel uses "0".
6	48.26	The result with the formula using the NPER function.

Here is the formula in cell A6:

=NPER(D1/12,-D2,D3,D4,D5)

Notes on the formula: If you don't use the "Percentage" format in cell A1 enter 0.05; The second argument MUST BE NEGATIVE; If you use months as periods the rate must be divided by 12 (A1/12), if you use weeks then you divide by 52 (A1/52), if there are 4 payments per year you will divide the rate by 4 (A1/4) and if the payment is annual you don't divide the rate argument (A1) ; The formula could also be

=NPER(A1/12,A2,A3) the arguments in A4 and A5 being optional;

7.5. The IRR Function (Internal Rate of Return)

The Internal Rate of Return (IRR) indicates the profitability of an investment and therefore is commonly used in business, when choosing between investments.

This measurement uses a series of cash flows (including an initial investment, along with the net income) over a number of periods, to calculate the compounded return, assuming the Net Present Value of the investment is zero.

The value of the IRR is calculated as the value of r that satisfies the following equation:

$$\sum_{n=0}^N \frac{C_n}{(1+r)^n} = 0$$

where the series of cash flows provide the values for C_n and N is the number of periods over which the returns have been made.

The Excel IRR function returns the Internal Rate of Return for a supplied series of periodic cash flows (ie. a set of values, which includes an initial investment value and a series of net income values).

The syntax of the function is :

IRR(values, [guess]),

where the arguments are as follows:

values - A reference to a range of cells containing the series of cash flows (investment and net income values) - must contain at least one negative and at least one positive value

[guess] - An initial guess at what you think the IRR might be. This is an optional argument, which, if omitted, takes on the default value of 10% (=0.1) - This is only a value for Excel to start off working with - Excel then uses an iterative procedure to converge to the IRR.

Conclusion

Each company main goal is to achieve profit, which goal requires additional operations and solving many financial problems. By optimal valuation of the cash flows, applying mathematical financial models and using the capabilities of free software - spreadsheets, management experts of the companies will be able to successfully optimize the company's activities and maximize profits.

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METHOD OF INTENSITY ASSESSMENT OF POWER LINES SWINGING

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Abstract: On the basis of long-term statistics data of wires swinging accumulated by energy systems of Kazakhstan the swinging intensity linear regression dependence has been elucidated as a function of wind speed and its direction to the power line, as well as the length of a span and the number of half-waves in the span. Lower and upper limits of regression equations parameters has been estimated.

Keywords: WIRE SWINGING, REGRESSIONAL DEPENDENCE, SWINGING INTENSITY

In the development of countermeasures for wires swinging and in the design of power lines it is necessary to take into account information about the possible intensity (range) of wires oscillations, depending on the wind speed and the characteristics of power lines. This information can be obtained from the accumulated by energy systems long-term statistical observations of wire swinging during the operation of power lines.

As shows the analysis of statistical data on the wires swinging, which took place in energy systems of West - Kazakhstan region, wires are exposed to swinging regardless of voltage classes, type of lines, effective span and the magnitude of mechanical stresses in wire. Moreover, wires oscillations appear with different number of half-waves in the span [1].

The article is devoted to the establishment of the empirical wind speed, angle of wind flow attack to the lines, span and number of half-wave dependences of swinging intensity. Selected materials cover one half-wave (18 cases), two half-wave (15 cases) and three half-wave (5 cases) swinging. The total number of observations is $n = 38$. According to the sample material, the minimum span length is 90 m. and the maximum is 367 m..

To establish an empirical dependence, the following variables were introduced:

$$A_p = \begin{pmatrix} A_{p1} \\ \vdots \\ A_{p38} \end{pmatrix} \quad X = \begin{pmatrix} 1 & x_1 \\ \vdots & \vdots \\ 1 & x_{38} \end{pmatrix}$$

where A_p - observation vector, dimension (38×1) , $X = \tilde{\lambda} V_{\perp}$ - matrix of independent variables, dimension (38×2) , $\tilde{\lambda} = \frac{\ell}{m}$; (ℓ - span length), x_i - constituting the independent variables X .

Notably, A_p - determines the intensity of swinging, $V_{\perp}$ - vertical component of the wind speed, $\tilde{\lambda}$ - the length of the half-waves, m - number of half-waves in the span.

b - vector of parameters which are to be evaluated, dimension (2×1) :

$$b = \begin{pmatrix} b_0 \\ b_1 \end{pmatrix}$$

E - vector of errors (residuals), dimension (38×1) :

$$E = \begin{pmatrix} e_1 \\ \vdots \\ e_{38} \end{pmatrix}$$

Model equations represented in matrix form

$$A_p = Xb + E \quad (1)$$

By the least squares method (LSM - method) for evaluation b [2].

$$b = \begin{bmatrix} b_0 \\ b_1 \end{bmatrix} = (X^T X)^{-1} X^T A_p \quad (2)$$

where "T" - symbol of transposition.

As a result of calculations based on accumulated statistical data we obtain a linear regression model of the first order.

$$A_p = b_0 + b_1 \tilde{\lambda} V_{\perp} = b_0 + b_1 \frac{\ell}{m} V \sin \alpha \quad (3)$$

where $b_0 = 1,785$; $b_1 = 0,0011$ - parameters of equation.

Adequacy assessing of regression model is made by F - Fisher criterion. Estimated (actual) value of F according to [3].

$$F_{act} = \frac{\sum_{i=1}^n (A_{pi}^T - \bar{A}_p)^2}{s^2} \quad (4)$$

$$s = \sqrt{\frac{\sum_{i=1}^n (A_{pi}^T - \bar{A}_p)^2}{n-2}};$$

$$\bar{A}_p = \frac{1}{n} \sum_{i=1}^n A_{pi};$$

where A_p - observed value, A_p^T - theoretical (predicted) value,

S - assessment of dispersion adequacy.

Comparison results of actual value $F_{act} = 46.78$ and table $F_{table} = 4.12$ ($F_{act} > F_{table}$) shows the reliability of regression equations. Tabulated values are defined for significance level 0.05 and degree of freedom $n - r = 36$, where r - number of coefficients of the regression equation.

Valuation of b_i coefficients is made by Student's t-test [3].

$$t_{b_0} = \frac{b_0 \sqrt{n}}{s} \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{\sum_{i=1}^n x_i^2}};$$

$$t_{b_1} = \frac{b_1 \sqrt{\sum_{i=1}^n (x_i - \bar{x})^2}}{s}; \quad (5)$$

where $\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$ (x_i - independent variables).

Calculated values of t-statistics:

Tabular value of t_α - criteria, which was calculated for the significance level $\alpha = 0.05$ and the number of degrees of freedom 36, equals to $t_\alpha = 2.03$. Seeing that $t_{b_0} > t_\alpha$ and $t_{b_1} > t_\alpha$, corresponding coefficients of the regression equation is considered significant.

For confidence interval calculation the marginal error for each indicator is to be defined [3].

$$\Delta b_0 = \frac{t_\alpha s}{\sqrt{n}} \sqrt{\frac{\sum_{i=1}^n x_i^2}{\sum_{i=1}^n (x_i - \bar{x})^2}};$$

$$\Delta b_1 = t_\alpha \frac{s}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2}}; \quad (6)$$

The lower and upper limits of regression equations parameters

$$b_0 - \Delta b_0 \leq b_0 \leq b_0 + \Delta b_0;$$

$$b_1 - \Delta b_1 \leq b_1 \leq b_1 + \Delta b_1;$$

In view of numerical values $\Delta b_0 = 0.5$ and $\Delta b_1 = 0.00033$

$$1.285 \leq b_0 \leq 2.285;$$

$$0.00077 \leq b_1 \leq 0.00143; \quad (7)$$

Analysis of these predictable swinging intensity boundaries shows that the intensity of swinging increases with the length of span, wind flow speed and the number of half-waves in the span.

The regression model (3) will be used in research of power lines swinging phenomena and in the development of methods and means of protection against swinging.

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APPLICATION OF CAD / CAM SYSTEM FOR FINDING INTERSECTION OF GEOMETRIC OBJECTS IN THE LEARNING PROCESS

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Abstract: This work is predstaveno decision of task of finding the intersection of geometric objects with the use of CAD / CAM systems in particular graphical programming environment Autocad .. The problem is solved by the method of auxiliary secant planes. Based on the studies and analyzes on resolving this type of geometric tasks is summarized methodology for finding the intersection between the two geometric objects. The process of the graphic finding the intersection by using the CAD / CAM system is illustrated step by step on the basis of the methodology.

Keywords: GEOMETRIC OBJECT, METHODS, CAD / CAM, LINE OF INTERSECTION

1. Introduction

The actual units are usually built of parts of geometric bodies. When viewing them receive limited lines crossing each other and contours. Most - great interest in the depiction of faces and bodies are lines like sections and surfaces. These lines are essential for certain technical applications, when searching the shape and dimensions of the surfaces, for example the construction of flat patterns. It is allowed in some cases complicated to build lines of intersection can be displayed approximately. The way to solve these tasks depends on the location of geometrical objects relative to the projection planes and their form. The process of finding a graphic projections of the common elements of intersecting geometric objects through various stages, including reading assignment and build a mental image of the spatial geometric objects and auxiliary geometric elements (lines, secant planes, etc.) Needed for solving mission. This often difficult to beginners in engineering graphics. Using CAD / CAM system for finding the points and the intersection of geometric lens significantly facilitates this task [1]. Formulated above problem is solved by using the graphical programming system AutoCAD, which allows for viewing of objects from different angles, off parts of objects, displaying objects in different views, creating three-dimensional images. The tasks of the graphical construction of the projections of the common elements (dots or lines of intersection) are solved by known literature methods.

Developed dozens of examples of finding the points or the intersection of various geometric objects - lines, planes, rotary and angular surfaces. With AutoCAD graphics system is presented the process of finding the intersection between the two geometric objects using the method of auxiliary secant planes. The process is illustrated step by step on the basis of the presented methodology.

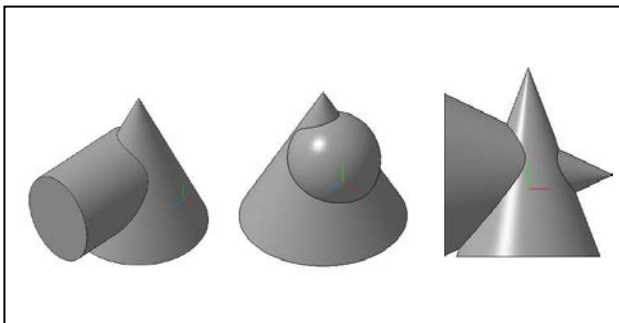


Fig. 1 Three-dimensional images of intersecting solid of revolution:
a) cone and cylinder; b) cone and sphere b) cone and the cone

2. Methods for the construction of the line of intersection of the geometrical objects

2.1. Methodology for the construction of the intersection of geometric objects by the method of auxiliary secant planes in graphical programming environment Autocad. The projections of the intersection is built in points (1, 2, 3, 4, 5) belonging

simultaneously to both surfaces. To find such points in the series at - generally used auxiliary secant planes i.e. intermediary. Can distinguish the following stages:

2.1.1. Analysis of the body - the body is examined from what surfaces is made, what is their relationship and their position relative to the projection plane.

2.1.2. Enter series auxiliary secant planes.

2.1.3. Designate points of the intersection, obtained without any additional constructions.

2.1.4. Located intersection of the secant with surfaces default.

2.1.5. The intersections of the lines are found points connected line of intersection.

2.1.6. Merging intersections and analyzes visibility.

2.2. Condition of the task: to build the intersection of geometric objects - hemisphere and cone with the software Autocad based on formulated - above methodology.

To find the intersection (each line of intersection) of the two bodies had been used method auxiliary secant planes whose planes are parallel to the horizontal plane π_2

The method of auxiliary secant planes comprises the following:

2.2.1. Construction of the two projections π_1 and π_2 task in the sizes Fig.2.

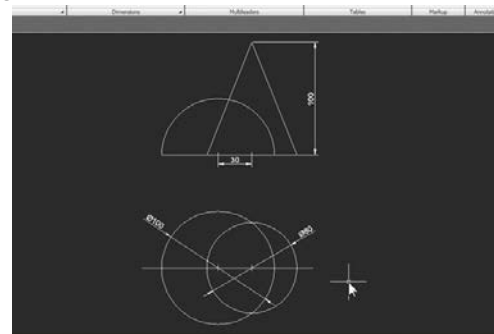


Fig. 2

2.2.2. Selects a random number secant planes planes parallel to the horizontal plane of projection, shown in Figure 3

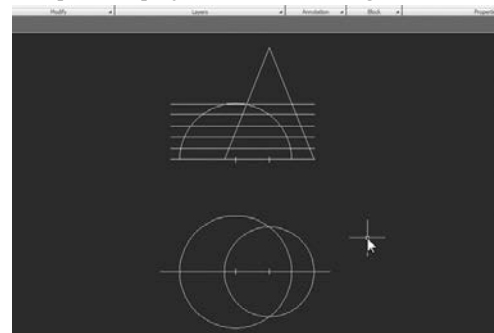


Fig. 3

2.2.3. Secant planes intersect the cone in circles with radii corresponding starting t.O top view (Figure 4).

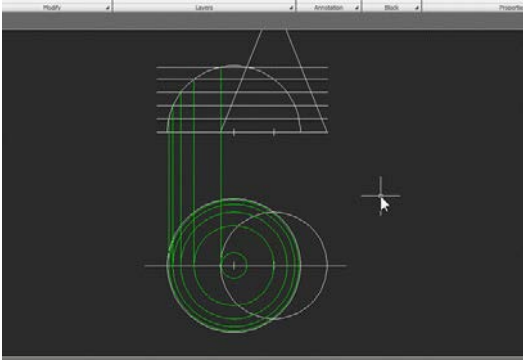


Fig. 4

2.2.4. Located projections of the basic points in the horizontal projection plane in ordinala and mean index 2. Located projections and other points in π_2 .

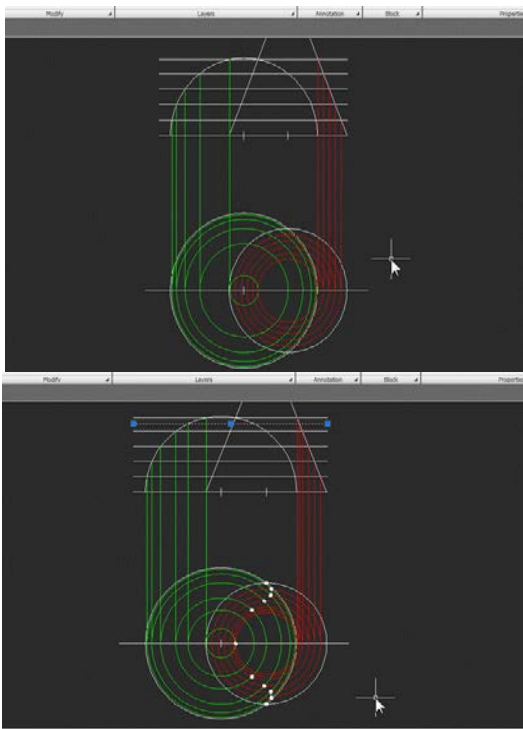


Fig. 5

2.2.5. Connecting the points obtained by using the command Spline, obtain approximate line of intersection of two surfaces in top view Figure 6.

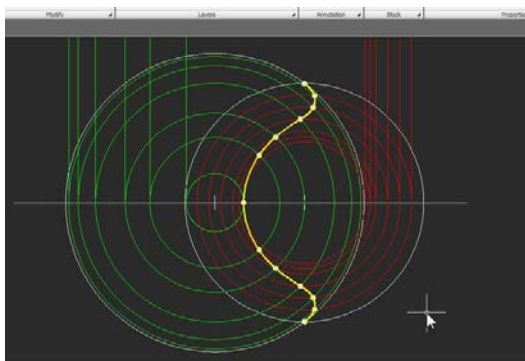


Fig. 6

2.2.6. To get the intersection in the frontal projection plane raise the points ordinala respective planes and receive the projections of points in π_1 . Construction of the points shown in yellow in Fig. 7.

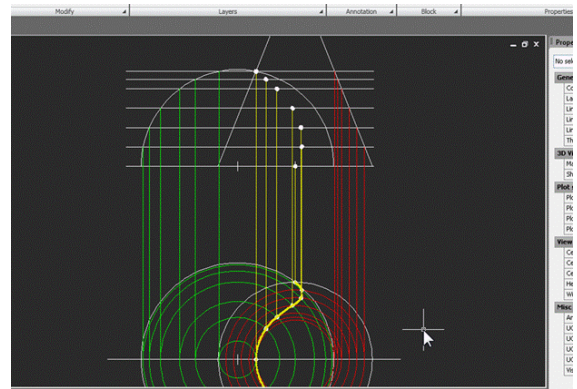


Fig. 7

2.2.7. Connecting the Dots and receiving line in π_1 (figure 8).

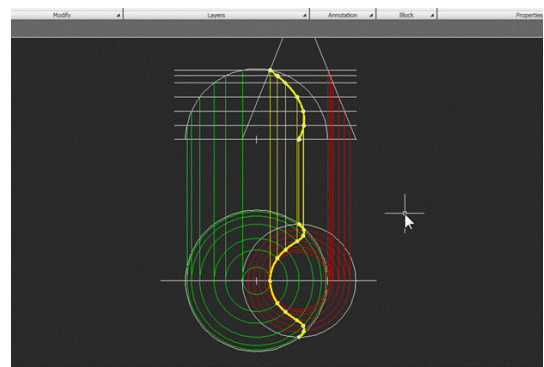


Fig. 8

2.2.8. Option in the software 3D Modeling allows to check the correctness in the construction of the intersection of the geometries shown in Figure 9 in front view and top.

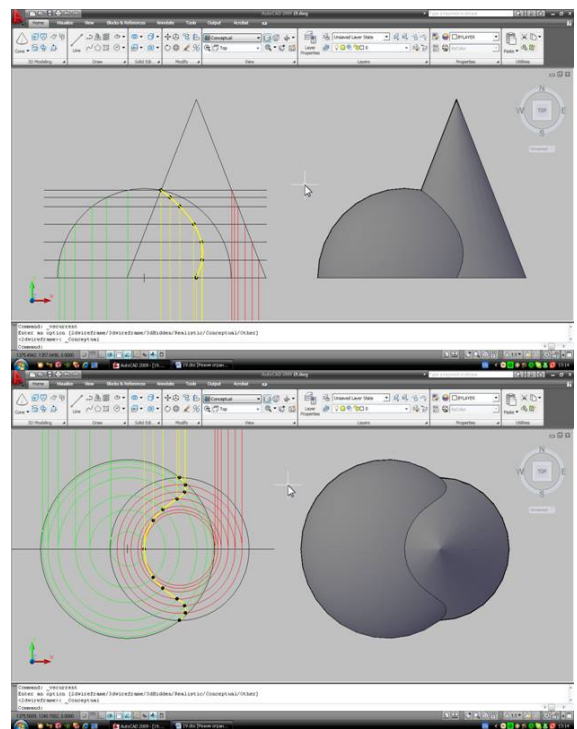


Fig. 9

3. Conclusion

Based on the application of CAD / CAM system for finding the points and the intersection of two geometric objects in the learning process can draw the following conclusions:

1. The tasks of mutual crossing of geometric objects belong to the position tasks. In their search for an item is a line belonging to both of the two geometric objects.
2. By AutoCAD graphics system creates three-dimensional geometric models, which contributes to a better absorption of the tasks of this kind through their visualization.
3. 3D modeling of geometric objects helps to accurate and clear visualization of search sections.

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THE PROCESSING OF ELECTROCHEMICAL COATINGS THROUGH SURFACE PLASTIC DEFORMATION (SPD)

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Abstract: *Because of the surface oxide film's presence, a negative electric potential and formation of the disadvantageous residual strains under the galvanic film's putting on soft metals and alloys, there are the coming of considerable technological complications. This is obstructive to the good interaction between the films and main metal. In this case it is expedient the technological combination the galvanic film of the surface with surface plastic deformation. In this case, the surface plastic deformation is realized by the tools with radial feed of the deforming elements.*

Key words: *surface plastic deformation, electrochemical covers, quality, roughness, precision.*

1. INTRODUCTION

The operating characteristics of the details and their work's time limit in considerable stage are defined by their roughness.

The applying of the surface plastic deformation (SPD) as a method for finished processing provides the improvement of the relief of the roughness and its parameters [5]. From its side it proofs the operating characteristics of the surface. It can be applied in combination with other technological methods for finished processing. The realized combination proofs physic and mechanicals characteristics of the surface layer metal [1].

The galvanic cover of the metal surfaces is one of the most applied methods for its finished processing. With this their corrosion stability and stability of the wear are rising [2].

With the making of the galvanic covers on soft metals and alloys, there are considerable technological complications which appear, because of the presence the surface oxidized layer, negative electrical potential and forming of the unfavorable remaining voltages. These complications disturb the good interactions between the surface and the main metal [2]. In this case its expedient the technological combination of the galvanic cover of the surface and SPD [1].

On a mass scale in the practice the instruments for SPD with axis feeding found their application. However they are non- applicable with the processing of thin galvanic covers. The reason is the presence of the edge defect and getting of wave in front of the deformation rollers [4].

In this case it's expedient to be used instruments with radial feeding of the deformation elements which has respective priorities [3].

2. PURPOSE AND OBJECT OF THE RESEARCH

Purpose of the present work is to be examined the technological opportunities for combining of the finished processing with galvanic soft cover and surface plastic deformation in case of recovery of the aluminum pistons for internal-combustion engines.

The objects of the research are the surfaces of the apertures for the piston pins of the diesel engines ЯМЗ-238 НБ и СМД-62.

The pins of this kind of engines are made of aluminum alloy Al25 with high contents of Si. Their hardness after heat-treating is HB 90-130.

There are presented some requirements according to the apertures for the piston pin:

- The precision of the piston's aperture ЯМЗ-238 НБ is $\varnothing 50^{+0,006}_{-0,015}$ mm; the precision of the piston's aperture СМД-62 is $\varnothing 45^{+0,005}_{-0,010}$ mm;
- Aperture's roughness is $Rz = 0,4\mu\text{m}$;
- The mutually beating of the apertures is maximum to 0,015mm.

3. EXPOSE

With work the piston is put under considerable mechanical and heat loadings from gases and inertia forces. The high maximum pressures of the gases and high frequency of the working cycles determine the accelerated character of the piston's loading.

With rendering the technological characteristics of the processing surfaces (presence of grooves and apertures) and the contact interaction of the deform elements with the surfaces, a tool with radial feeding is chosen for the surface plastic deformation [3] – Fig.1.

The tool for surface plastic deformation has two line deformation rollers. It has possibility for simultaneously machining of two apertures in the piston's tabs.

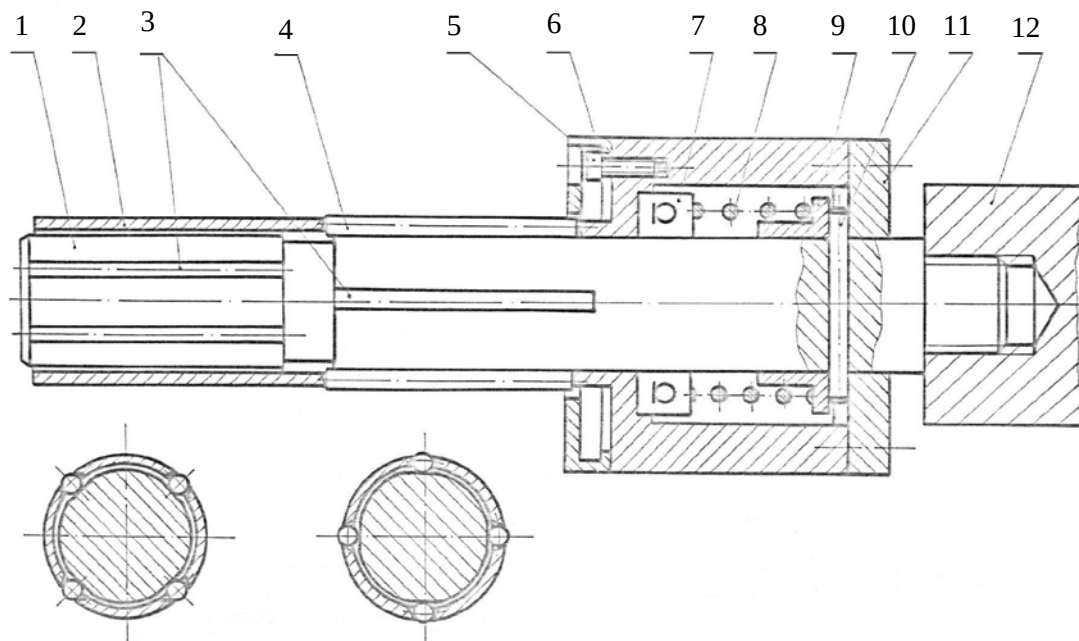


Figure 1: A tool for surface plastic deformation has two line deformation rollers

The tool has tubular bearing shaft 1 with chords 3, which made over it; a separator 2 (it carries two line cylindrical rollers 4), which is bearing through the thrust bearing 7 on the bearing shaft 1; a screw 5, a guide insertion 9, a finger 10 (which serve as a fixer), a cap 11 and a tail-end 12.

When the tools is not work situation the fixer 10 ensure establishment of the rollers 4 over the chords 3 and it go into the grooves of the cap 11. In this case the separator 2 and the bearing shaft 1 are immovable together. The tool has diametric size smaller than the diameter of the machining aperture. This allows free tool's movement – in and out of the aperture което позволява свободното му въвеждане и извеждане. The working of the tool is the following: through the tail-end 12, the tool is moved in axis direction till to contact the fulcrum 6 with the front of the detail. The continuing of the movement causes a flexion of the spring 8 from the guide insertion 9 and release the finger 10 from the grooves of the cap 11. In this way the separator 2 gives the possibility for a relatively turning with the rollers 4 round about the bearing shaft 1.

The machining scheme with such tools ensures the galvanic cover from outflow in the two apertures' ends [4].

As deformation elements are used cylindrical rollers from a steel SchCh15 (BDS 12731). They turn over a bearing shaft with chords. The rollers are polished to $Ra = 0,06 - 0,07 \mu m$.

The machining by the surface plastic deformation is going on the vertically - boring machine PK-32 with turning frequency 63 min^{-1} . The pistons are fixed in an appliance. This prevents their rotating toward to the machine. In this case the fixture is provided from the tool's jam.

Before the process of the piston's recovery it is made measuring, which is necessary for the conclusive valuation of the done. It is measured 16 pistons of the diesel

engines **AM3 238 HE** and 18 pistons of the diesel engines **СМД-62**. The measuring is made to the following parameters:

- The precision of the apertures' shapes for the piston pin, which is measured with an apparatus „TALYROND 200”;
- The apertures' diameters for the piston pin, which is measured with an universal apparatus for a length with a precision $0,0002 \text{ mm}$;
- The apertures' roughness, which is measured with an apparatus „TALYSURF-6”.
- The dimension's wear of the apertures' diameters for the piston pin is dispersing in a field $0,0636 \text{ mm}$ for $\varnothing 45 \text{ mm}$ and $0,0534 \text{ mm}$ for $\varnothing 50 \text{ mm}$. This is over that the apertures' limit.

The measured roughness is $Rz = 4,27 - 14,58 \mu m$ for $\varnothing 45 \text{ mm}$ and $Rz = 3,98 - 7,99 \mu m$ for $\varnothing 50 \text{ mm}$. This is over repeatedly the requirements for roughness $Rz = 0,4 \mu m$ which is necessary in the documentation.

The recovery cover for the piston pin's aperture is Fe-Zn alloy. The technological process is the following:

- become lighter in a nitrogen and fluorine-hydrogen acids;
- contact zinc-coating with a room temperature;
- become lighter and contact zinc-coating for the second time;
- stratification with temperature 42° and electricity force from 3 to 5 A/gm^2 .

A planned experiment is carried out on a plan B₄ (table 1) and statistic analysis. As an object of the examination before and after surface plastic deformation are the roughness and the precision of the dimensions and the shape of the machined surfaces.

Table 1: A plan of the experiment

Factors and levels of a variance					
$F_l = N / mm;$ m – number; n – min ⁻¹ ; Rz – μm	Naturals Coding	$x_1 \equiv F_l$	$x_2 \equiv m$	$x_3 \equiv n$	$x_4 \equiv l_z$
	-1	100	1	11,2	6
	0	150	3	31,5	29
	+1	200	5	63	52

Steerable factors, which are acceptable: the deform force in a unit of length F_l , the turning frequency of the bearing shaft n , the starting roughness Rz and the rate frequency of the deformation influence m (which is performed by number the separator's turning).

The following parameters are measured:

Ra is the average absolute deviation of the roughness of the section, μm ;

Rz is the height of the roughness of the section, μm ;

tp is the relatively bearing length of the section, %

Δ is the maximum diversion of a circle, μm ;

E is the dislocation of the real aperture's axis toward the geometric axis of the aperture, μm ;

Δ_r is the radial beating toward the geometric axis of the aperture, μm .

The controlled parameter's data for each model are received from two mutually perpendicular plains.

The precision of the dimensions and the shape before and after surface plastic deformation is presented by their dispersing field and the respective theoretical and experimental distribution. The last is illustrated with the following numeral characteristics:

R is the range;

$\bar{x}$ is the chosen measure of central tendency of the data set;

$\sigma[x]$ is the standard deviation;

$\sigma^2[x]$ is the variance;

γ_1 is the asymmetry;

γ_2 is the excess.

The theoretical frequency of the distribution is determinate thought characteristics of the appropriate law, which is confirmed by the Pirson criterion. In the case the hypotheses for normal, logarithmic-normal and exponential distribution are examined. The curves of the distribution are built (Fig.2).

The statistical characteristics of the distribution for the apertures' diameters show preservation of its normal character before and after surface plastic deformation. It is observed decrease of the average value of the diameter's dimension $\bar{x}$, remarkable narrowing of the probable field ω (20 – 60%), sharpened of the theoretical curve of a distribution, which is conditioned by the excess value γ_2 and displacement of $\bar{x}$ toward medium of the distribution's field. It is evident from the asymmetry value γ_1 .

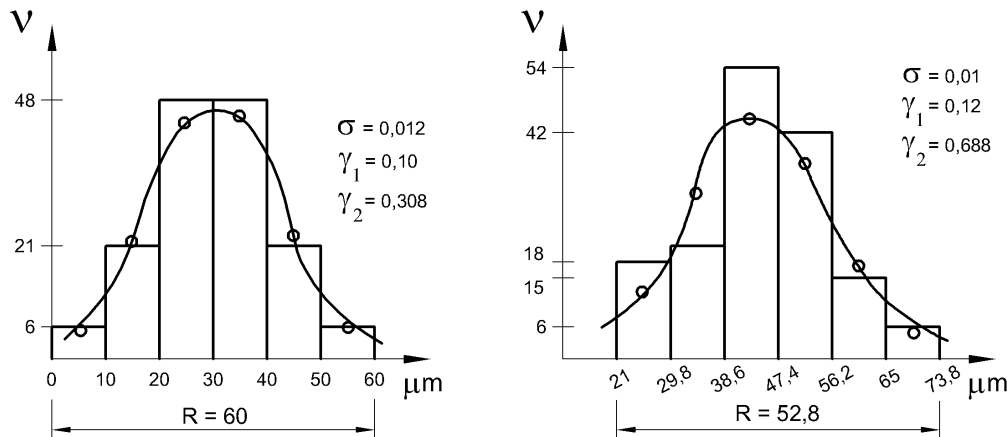


Figure 2: Curves of the distribution

The values of the three parameters for the shape's precision are determinate as a result of double measuring in exactly definitely section of the models. The graphs (Fig.3) are using for evaluation of the diversions of the right geometrical shape. The comparison of the statistical distribution characteristics of the parameters and the reading of the distribution laws, which are confirmed by the Pirson criterion (Fig.3), enable to establish the following changing in the shape's precision:

- the value of the probable distribution's field after surface plastic deformation decrease with all three controlled parameters;

- the mathematical expectance of the parameters, which characterized the shape's precision after c surface plastic deformation is less than that before surface plastic deformation;

- the percentage notability of the decrease is graded accordingly the rising line: a radial beating toward the geometric axis and the diversion of a circle;

- the grouping of the diversions' values round about the mathematical expectance evidence for presence of a calibration effect once more.

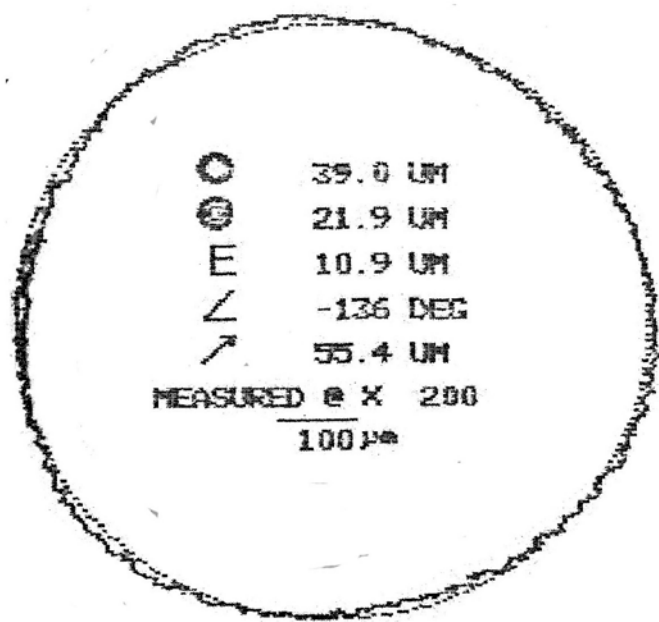


Figure 3: A graph for control the shape's precision

The received data of the planned experiment for the roughness parameters (R_a , R_z и tp) and the analyzing of the coefficients of the members in the equations of the regression show, that the greatest influence over the roughness have F_1 and outgoing R_z .

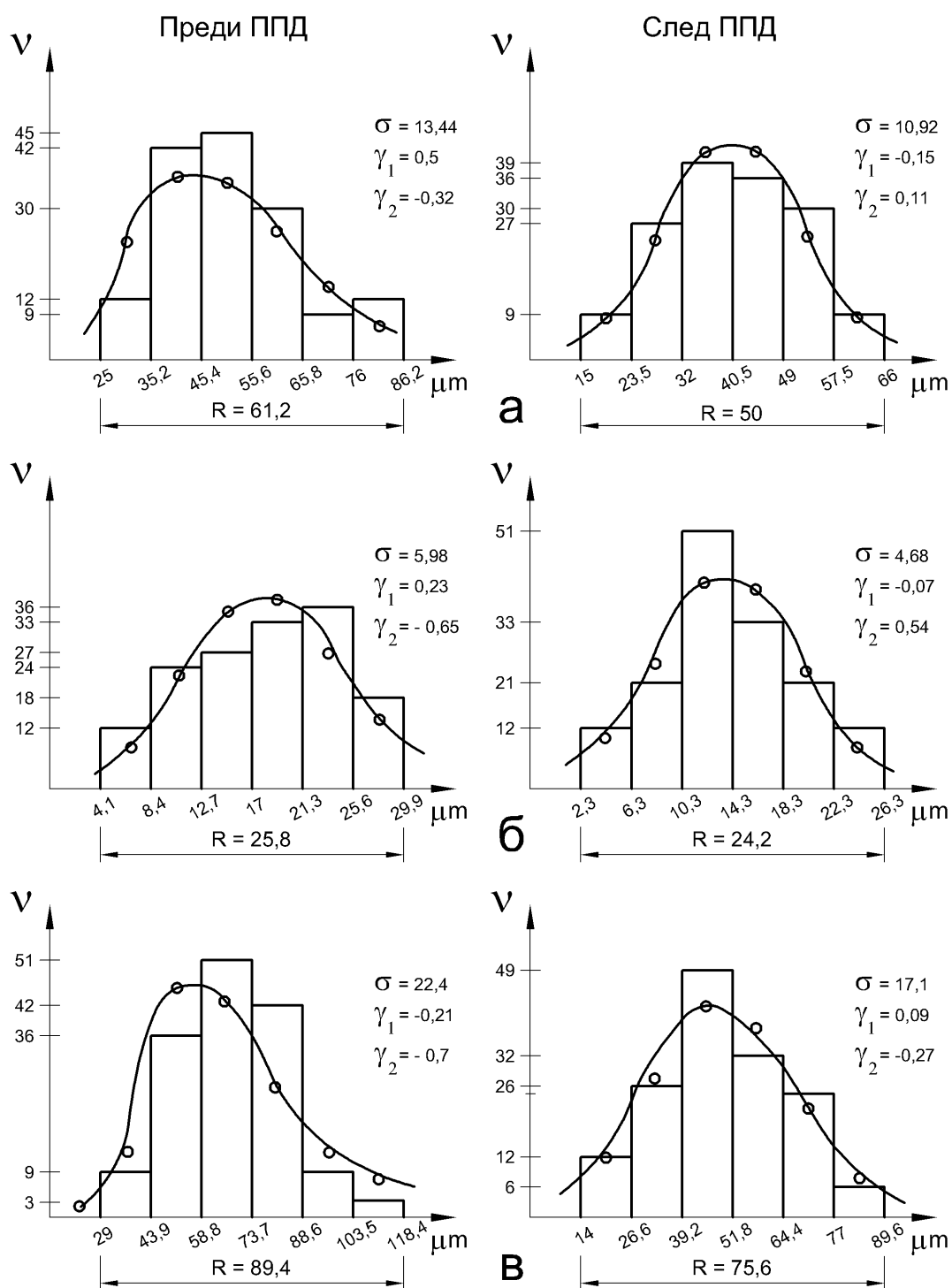


Figure 4: A distribution of the shape's diversions:
a – diversion from a circle (Δ); b – off-centered; (E) ; c – radial beating (Δ_r)

It is received adequate equations of the regression. Their comparing shows that the plasticity of the processing metal determines their structural diversity. The equations' analyse with the two levels of the outgoing roughness shows that the decrease outgoing roughness increase the influence

of other steerable factors. Fig.4 shows the out-rigger curve of the roughness profile. The favorable shapes of the curves after surface plastic deformation are obvious – the parameter tp increase vastly, respectively the carrying ability of the processing surfaces.

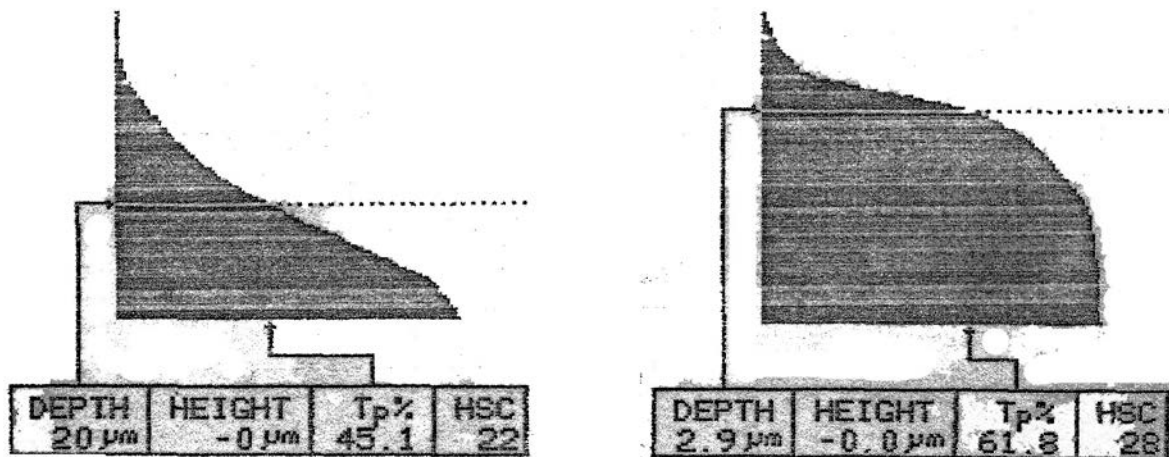


Figure 5: Out-rigger curve of the profile

4. CONCLUSION

As a result of the made research it can do the following conclusions:

- the finishing machining through surface plastic deformation of the apertures for the piston pin of the diesel engine's pistons in combination with the discussing technology for the recovery through galvanic cover ensures the necessary precision parameters;
- it is satisfied the technical requirements to the processing surfaces according the constructive documentation in reference to the received qualitative indices of the surface (**R_a** , **R_z** , diversion from a circle, diversion from a cylinder);
- the application of the surface plastic deformation over galvanic recovery surfaces allows to increase the resource for using of the internal-combustion engine's pistons and to expand the technologic possibilities of the method.

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