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Content

Research on Electric Resistance Sintering of Nickel Based Powder

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Abstract. In the paper, electric resistance sintering of nickel based powder is discussed upon. For accomplishing the research, a numerical model of powder under sintering had been developed upon applying the finite element method; in addition, calculations providing an opportunity to estimate the electric and thermal phenomena that occur during the sintering process had been performed. A sintering form for electric resistance sintering had been created as well. In addition, tests of the morphology and the microstructure of sintered specimens as well as research of their porosity had been carried out and a hardness of the specimens had been established upon applying the Vickers' method.

Keywords: sintering, powder, nickel, electric resistance

1. Introduction

Powder metallurgy is a very rapidly progressing technology for mass production of high precision details of metals, their alloys, ceramics and various composite materials. It is particularly important for Lithuanian industry which has no own metallurgical base, so it saves energy & raw materials and enables to obtain unique details that cannot be produced in other ways.

Powder metallurgy is production of various details and tools of powders of metals, their alloys and non-metallic materials. The mixtures of these powders are pressed and then sintered. When details are produced in this way, melting the metal before its casting is not required. In addition, this process is easily mechanised and automated. In this way, it is possible to produce components of complex configurations which do not require further machining and the material consumption coefficient almost reaches 100 per cent (waste-free production). Another advantage of this technology is that the powder can be produced of waste (metal chips). Details produced upon applying the powder technology have a better structure, as compared to other details; they are free of certain defects, such as liquation and so on. But these details are porous. Porosity is a useful property for antifriction materials; however, it is harmful for constructional (structural, engineering) materials, because it worsens their mechanical properties. The principal technological operations of powder metallurgy include:

- production of the initial materials (powder);
- powder pressing;
- sintering the pressed products at a temperature lower than the melting point of the metals.

Pressing and sintering are the key operations. Dependently on their purpose, details after sintering can be used directly or be additionally processed (cemented, nitrogenised and so on). At present, powder metallurgy is applied for production of magnets, electrodes, contacts, slider bearings, brake blocks, and filters. In addition, this technology enables replacing the scarce metals with cheaper ones (1-7).

2. The run of the research

The principal stages of the research include:

- development of a numerical model of powder under sintering upon applying the finite element computing software ANSYS. The performed calculations provide an opportunity to estimate the electric and thermal phenomena that occur during the electric resistance sintering process;
- designing and creation of a special sintering form for electric resistance sintering. The special form was created to avoid pouring of the powder before the sintering, to ensure its pressing as well as its distribution over the whole cross-section of the electrodes and a preservation of a certain shape after the sintering;
- choosing a powder and its sintering;
- tests on morphology, microstructure and porosity of the specimen;
- establishment of microhardness of the specimens upon applying the Vickers' method.

3. Calculation of electric phenomena and heat exchange in the sintering process upon applying the finite element method

In course of the numerical modelling, a model of object of research had been developed, whereas the finite element computing software ANSYS was applied for the calculations. The model is formed of copper electrodes and a layer of nickel under sintering (Fig. 1).

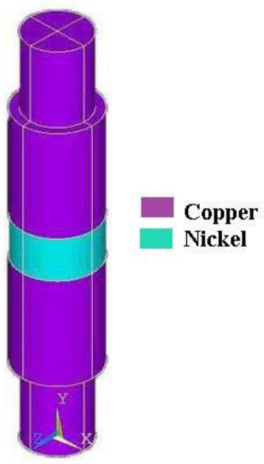


Fig. 1 - Sintering process 3D model

Mathematical modelling of the sintering process was performed by estimating the thermal properties (such as thermal capacity, thermal conductivity, the coefficient of heat transmission by natural convection) for a specific material (8-9).

In solving problems related to variation of the temperature pattern in a solid body, it should be taken into account that the said variation is highly affected by thermal exchange processes at the contact points. The coefficient of heat transmission by natural convection of the surface predetermines the distribution of the temperature in the detail.

4. Designing and creation of the sintering form

The sintering form (Fig. 2) is made of structural steel S355. It is a non-standard detail. In course of its creation, the below-described factors important for the sintering process were taken into account:

- a comfortable and easy use: assembling of the form before sintering and its disassembling after the sintering.
- choosing a shape and a size of the sintering form that enable to apply the standard electric welding equipment for electric resistance sintering process
- choosing an electric insulation material to avoid electric current shunting process and the current flowing through the wall of the form.

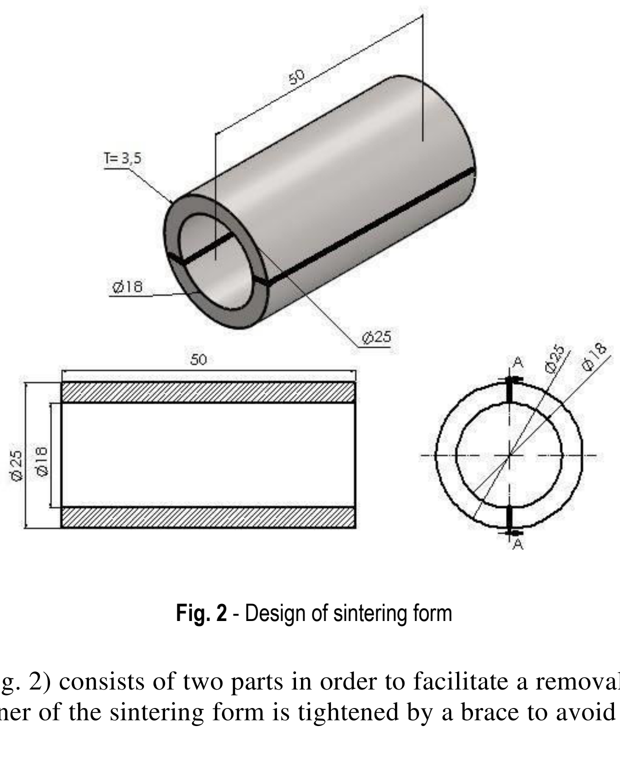
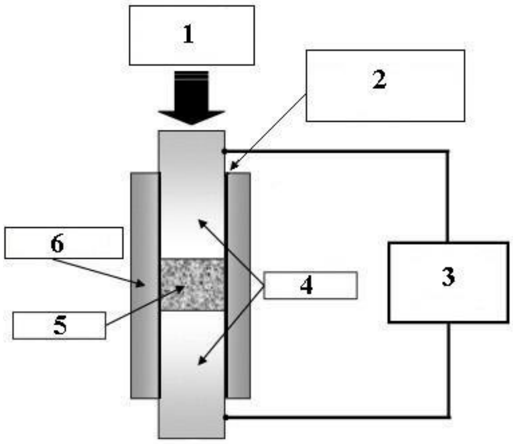


Fig. 2 - Design of sintering form

The sintering form (Fig. 2) consists of two parts in order to facilitate a removal of the detail from it after the sintering process. The container of the sintering form is tightened by a brace to avoid powder falling from the form during the sintering process. The internal walls of the container's details were covered by Teflon strip PTFE (Heliopolis).



1 - compression force; 2 - electric insulation material; 3 - current source; 4 – electrodes; 5 – powders; 6 - sintering form

Fig. 3 - Scheme of sintering process

5. Powder choosing and its experimental sintering

For the sintering process, the nickel based powder was chosen (Table 1). Because of its corrosion resistance, nickel is used for producing stainless steel and other corrosion-resistant alloys. Nickel is excellently fit for precious metals' alloying (covering). Nickel alloys foam or nickel alloys grid is used for gas diffusion in electrodes and alkaline fuel elements. In addition, nickel alloys is usable in ceramics, magnets, batteries as well as in production of robots, electronic devices, in medical equipment (for example, X-ray devices), for telephone details.

Table 1 - Chemical composition of Ni based powders, %

C	Cr	Ni	Si	Fe	B
0.3–0.6	8–14	Base	1.2–3.2	2–5	1.7–2.8

Sintering was accomplished upon using resistance spot equipment Tecna 4625N (Fig. 4). During the sintering process, the following parameters were controlled:

- the value of compression force (daN);
- the sintering time (s);
- the amperage of current (A).

Fig. 4 - Resistance spot equipment ,,Tecna 4625N“

Total eight tests were carried out during the research. The specimen sintering regimes are presented in the Table 2. Two parameters were varied during the sintering: the sintering time and the sintering current.

Table 2 - Regimes of sintering process

Nr of specimens	Compression force, daN	Sintering time, s	Sintering current, A
S1	300	7	1350
S2	300	7	2250
S3	300	7	3150
S4	300	7	4500
S5	300	3	2250
S6	300	11	2250
S7	300	14	2250

6. The results

In course of the numerical modelling research, a model of the object under research had been developed and the calculations providing an opportunity to estimate the electric and thermal phenomena that occur during the sintering process had been performed. The obtained results are presented in Fig. 5 to 6.

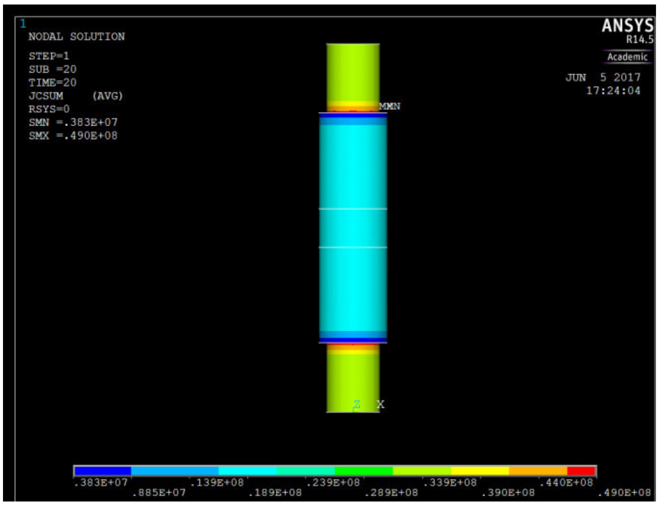


Fig. 5 - Distribution of current density during sintering, A/m^2

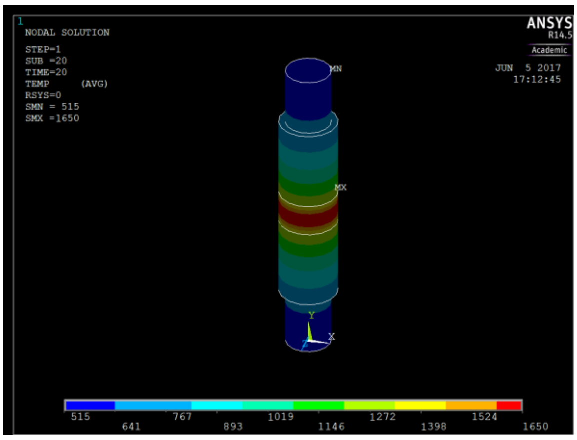


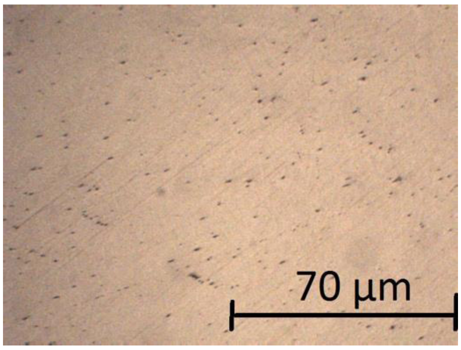
Fig. 6 - Distribution of temperatures during sintering, ^{0}C

It can be seen from the presented results (Fig. 6) that the maximum temperatures are fixed between the electrodes where the powder is sintered. The melting-point of nickel based powder is 1455 ^{0}C and the melting-point of metal between the electrodes is 1650 ^{0}C. The said temperature is sufficient for powder sintering.

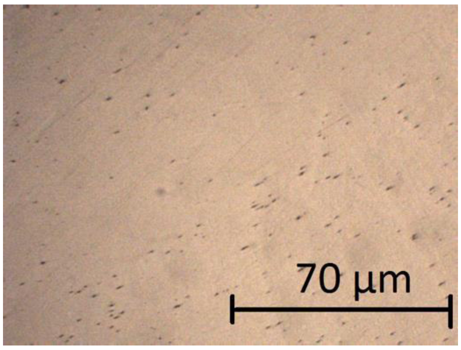
During the study, it was found that sintering of nickel based powder was not successful in all the cases (Table 2). It was predetermined by different parameters of the sintering regimes: the sintering time set for the specimen S5 was too short and the value of the sintering current chosen for the specimen S was too low.

The samples sintered by S1 and S5 regimes did not form a homogeneous structure and were therefore not investigated.

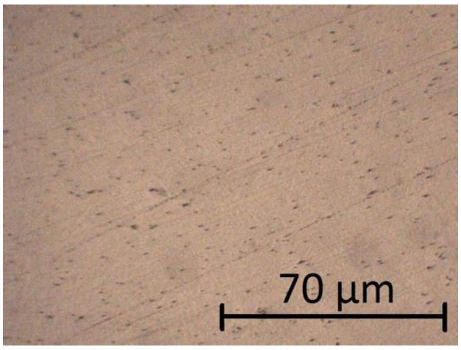
Upon striving to estimate the structure of the sintered layer, the tests on morphology and microstructure of the specimens had been carried out during the research. It was found that the sintered specimens were distinguished for a homogeneous microstructure with a low number of pores.



S2



S6



S7

Fig.7 - The microstructure of the specimens

The structure of the sintered powder was analysed upon applying optical microscopy methods. The essence of the said methods is establishing the ratio between the area of pores and the area of the microsection under analysis. „Scion Image®“ analyses a graphical image and calculates the areas of individual graphical objects.

In the presented photos of morphology and microstructure (Fig. 7), pores clearly can be seen. The powder was sintered at different parameters (Table 2), when sintering time and current were varied and the said variation affected the porosity.

The performed calculations of porosity of the specimens show that porosity of sintered specimens is not high and varies between 0.27 % and 0.89 %. It was predetermined by the parameters of the sintering regime: the sintering time and the sintering current, the compression degree and the powder heating degree. It was found during the research that when the sintering time is 7 s and the sintering current is being increased from 2250 to 4500 A, the porosity of the specimen increases from 0.41 to 0.89 %. The most influence was caused by variation of current: increase of the current caused increasing of the porosity: however, porosity is relatively low. The most optimal parameters of sintering were the current of 2250 A and sintering time of 11 s.

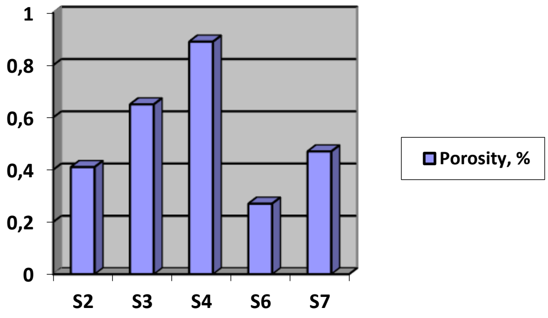


Fig.8 - The porosity of the sintered specimens

In order to estimate the mechanical properties of the sintered layer during the research of electric resistance sintering, the tests on microhardness of specimens had been carried out (Fig. 9).

Measurements of microhardness of specimens were carried out upon applying the Vickers method at the load of 200 g (HV0.2) and the holding time of 10 s. The average value of metal microhardness was calculated on the base of 5 results of measurements.

During the tests on microhardness of specimens, it was found that the specimen S2 was distinguished for the minimum value of microhardness, its average value was 411 HV. The microhardness of the sintered layer is predetermined by the chemical composition of the powder and the technological parameters of the sintering process.

The measurements of microhardness of the investigated specimens show that both the sintering current and the sintering time affect the microhardness of the sintered layer. It was found that if the sintering current is being increased from 2250 to 4500 A (at sintering time is 7 s), the microhardness of the specimens consecutively grows from 411 to 518 HV; and if the sintering time is increased from 7 to 14 s (at sintering current is 2250 A) – the microhardness of the specimens increases in the beginning from 411 to 531 HV (at the sintering time of 11 s), and then starts decreasing (Fig. 9).

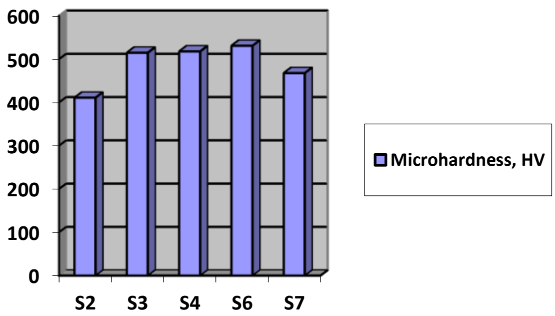


Fig.9 - The microhardness of the sintered specimens

It is known from literature sources that the microhardness of a Ni based powder layer formed by flame spraying can be equal to 330–370 HV. The tests of microhardness of the specimens sintered upon applying the electric resistance method showed that microhardness of the specimens varied between 411 HV and 531 HV and the results of some measurements achieved 600 HV. The maximum average microhardness of the sintered layer, i.e. 531 HV, was obtained at the sintering current of 2250 A and the sintering time of 11 s. In this case, the minimum porosity of the specimen (0.27 %) was obtained.

The results of calculations of porosity and microhardness of sintered specimens during the research show that the said results depend on the sintering regime and the temperatures of sintering.

7. Conclusions

1) The research showed that application of electric resistance sintering process for nickel based powder enables producing details of complex configurations and the material consumption coefficient becomes considerably lower as compared to traditional manufacturing technologies.

2) It was found that a numerical model of powder under sintering enabled to estimate the electric and thermal phenomena that occur during the sintering process. The research showed that during electric resistance sintering the maximum temperature is in the powder (between the electrodes) and it achieves 1650 ^{0}C.

3) The performed tests on the porosity of the specimens show that porosity of the sintered specimens is not high: it varies between 0.27 % and 0.89 %. It was found in the run of the research that when the sintering time is 7 s and the sintering current is being increased from 2250 to 4500 A, the porosity of the specimen increased from 0.41 to 0.89 %.

4) The performed tests on the microhardness of the sintered specimens showed that when the sintering current was being increased from 2250 to 4500A, the microhardness of the specimens consecutively grew from 411 to 518 HV; and when the sintering time was being increased from 7 to 14 s – the microhardness of the specimens was growing from 411 to 531 HV (at the sintering time of 11 s) and then began decreasing.

5) The results of the research show that the sintering time and the sintering current are the principal sintering parameters in Ni based powder sintering (upon applying the electric resistance method) which predetermine the qualitative indicators of the sintered layer. The optimum parameters of electric resistance technology include: the sintering time of 11 s and the sintering current of 2250 A. When powder is being sintered at the said parameters, the porosity is equal to 0.27 % and the average microhardness - to 531 HV.

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Possible Malfunctions and Causes of Failure of a Hydraulic Hammer for the Destruction of Rocks

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Abstract: The article analyzes the occurrence of possible malfunctions in the process of destruction of rocks when using hydraulic hammers. The most responsible and expensive rubbing pair of a hydraulic hammer is the hammer - the cylinder liner, guide bushings in which the hammer rods move. As a result of all the adverse effects on the rubbing surfaces of the striker and the mating parts, coarse scuffing can occur, which leads to the failure of the entire hammer. The authors also highlighted the issues of diagnosis and repair of hydraulic hammers. Repair of hydraulic hammers can be divided into: current repair, which can often be done at the place of operation, repair of medium complexity and major repairs. During the current repair, tightening of loose threaded joints, replacement of damaged parts, some seals or individual components (hydraulic accumulators, hydraulic valves) is carried out, if possible without complete disassembly of the hydraulic hammer.

Key words: machine, hydraulic hammer, destruction, striker, pressure, pump, power cylinder

1. Introduction

One of the directions of the development of the economy of the Republic of Kazakhstan at present time is the use of its raw material base. This requires finding energy- and resource-saving technologies of the exploitation of mineral deposits and promising methods of rocks destruction. Therefore, the creation of new and improvement of existing methods of rocks destruction, including impact, is a relevant scientific and technical objective. The use of mining machines with active operating members can be considered a promising direction here. These are mounted hammers, buckets of active action of mining and construction excavators and dynamic plows of underground combines, and the structures of impact systems of buckets and plows includes several impact devices.

2. Results and discussion

Currently, dozens of different companies around the world manufacture many models of hydraulic hammers, suitable for mounting as a replaceable working body on hydroficated construction machines, i.e., excavators (Fig. 1), loaders, manipulators, etc. Hydraulic hammers are used to destroy various durable structures and materials.

Fig. 1 – Excavator

The main element of a hammer is its striker, i.e. a certain mass m, which must be moved a certain distance from a tool and accelerated to a given speed V towards the tool. Impact energy, i.e. the kinetic energy of the striker is equal to mv2/2. In order to accelerate the striker to the desired speed, an appropriate force must be applied to it, the value of which is determined by the pressure of the hydraulic fluid and the area affected by this pressure, as well as gas pressure in the pneumonic cell and the corresponding area of the end of the striker, which is affected by gas pressure [1].

The shorter the striker travel, the greater should be the force that accelerates it. However, the same reactive force acts in the opposite direction, i.e. transmitted to the base machine. Therefore, the power that accelerates the striker is limited by the capability of the base machine to perceive it at the maximum reach of the implement.

In order to choose a hydraulic hammer for any excavator or other hydroficated base machine, first of all, it's necessary to know the weight of an excavator. The weight of the hammer should be approximately 0.1 part of the weight of the excavator, but should not exceed the weight of a bucket with soil. The smaller the weight of the hydraulic hammer, the better for the excavator in the transport position, the less loads on the implement of the excavator when pointing the hammer to the point where it should work. But on the other hand, the greater the mass of the hydraulic hammer, the less effort is required to press it against the object of work, the less vibration transmitted to the base machine during the operation of the hydraulic hammer [2].

The next indicator that determines the possibility of using the hydraulic hammer on this excavator is the hydraulic fluid consumption, which is always given in the technical characteristics of the hammer. This indicator should correspond to the capacity of the excavator's hydraulic pump, which will power the pressure line of the hydraulic hammer. If the pump's capacity of the base machine exceeds the required fluid consumption of the hydraulic hammer, then pressure peaks may occur during its operation that adversely affect the durability of both the hydraulic hammer and the hydraulic units of the base machine. If the pump's capacity is less than the minimum fluid consumption of the hydraulic hammer, then it may not work stable or will not work at all.

A very important indicator is the level of the working pressure of the hydraulic hammer. Naturally, the pressure that can provide the pump of the base machine should not be less than the working pressure of the hydraulic hammer. If the maximum pressure of the hydraulic pump is 10 ... 15% more than the working pressure of the hydraulic hammer, then a safety valve must be provided in the pressure line for powering the hydraulic hammer, which accordingly limits this level.

Otherwise, in case of any emergency situations, some details of the hydraulic hammer may fail, for example, the studs tightening the body parts of the hammer, or the bolts securing the directional control valve, the hydraulic accumulator may be damaged, or the seals may be damaged. The technical capacity of the hydraulic hammer is determined by its effective power, i.e. the product of impact energy and frequency of impacts. The greater the strength of the material that needs to be destroyed with the hydraulic hammer, the greater influence on the capacity is exerted by the value of the impact energy [3].

The hydraulic hammer with greater impact energy enables to chip larger pieces from the solid to break through thicker layers of pavement and destroy larger concrete structures. If it is required to destroy any relatively thin coatings or structures or to destroy solid rocks into relatively small pieces, hydraulic hammers with a less impact energy but with a higher frequency of impacts will be more preferable. The impact energy of the hydraulic hammer must be such that the destruction of the processed material under the tip of its working tool lasts in no more than 15 ... 30 seconds. In the destruction of viscous materials such as, for example, frozen soil, various limestones and similar materials, impact energy has a decisive influence on the capacity of the hydraulic hammer, since for the formation of cracks in the processed material it is necessary to hammer the working tool to a sufficiently large depth [4].

The same amount of energy can be obtained due to the speed of the striker or due to its mass. With equal impact energy, the hydraulic hammer with the greater mass of the striker will be more effective, because it has more the product of mv, numerically equal to the power impulse.

Apart from the capacity of the hydraulic hammer, consumers are also interested in reliability and service life. These properties of the hydraulic hammer are greatly influenced by the materials used, production technology and design features.

Ceteris paribus, the reliability of the hammer will be the higher, the fewer the number of parts, the fewer the number of seals, the fewer threaded joints, the fewer outriggers on the external surface of the hammer, the more smoothly the shape and cross section of the parts subjected to impact loads change.

Another important criterion when choosing the hydraulic hammer is ease of serviceability and maintainability. Serviceability is ensured by good accessibility to lubrication points, to tools for attaching hoses to connecting pipes for refueling hydropneumatic accumulators and the pneumonic cell, as well as simple replacement of working tools. Among its important operational indicators are its ergonomic indicators, i.e., emitted external noise and vibration impact on the base machine. During operation, the hydraulic hammer emits impulse noise, the source of which is the impact of the striker on the tool. Ceteris paribus, the emitted noise will be less if the hydraulic hammer's impact block is not placed between two cheeks pulled together by studs, but inside a closed box-shaped casing, especially if noise-absorbing pads, breaking sound "bridges", are installed between the impact block and the casing.

As for the vibration effect on the base machine, then at equal impact energy and hammer's mass, the greater this effect, the greater the frequency of the hammer blows. When choosing the hydraulic hammer, it is necessary to take into account not only the indicators given in its technical characteristics, but also the conditions of its future operation, the intensity of its use, the durability of the processed material [5].

During the use of hydraulic hammers, various types of failures occur, which leads to the need to perform repair or some kind of adjustment work. The likelihood of failures increases if the requirements and recommendations of the instruction manual are not complied with. Failures can also occur depending on the structure features, materials used and production technology. In the simplest cases, repairs can be performed at the construction site, but in some cases, repairs must be performed in workshops that have the necessary technological equipment and qualified personnel.

There are cases when it is not possible to start the hydraulic hammer at the first switching on after mounting it on the excavator. First of all, it is necessary to check the correctness of the power lines connection to the hydraulic hammer - “pressure”, “drain”, make sure that the hydraulic hammer is pressed against the object of work, and that its tool is pushed fully in the axle box, check the pressure value in the pressure supply line, measure, using a hydrotester, the value of hydraulic pump flow of the base machine. If the parameters of the pumping station of the base machine correspond to the technical characteristics of the hydraulic hammer and its connection to the hydraulic system is correct, then the new hydraulic hammer should work, since each item of the hydraulic hammer is tested at the manufacturer's stand.

During the operation of the hydraulic hammer, all its friction pairs are subject to wear: the tool’s shank – the tool’s bushes, sleeve-striker of the power cylinder (or the cylinder’s body itself), the piston valve – distributor’s sleeve. The volume of parts’ wear is greatly affected by the cleanliness of hydraulic fluid (oil). When using pure oil, the parts of the directional control valve usually work the entire service life of the hydraulic hammer.

The most responsible and expensive rubbing pair of the hydraulic hammer is sleeve-striker of the power cylinder, guide bushes in which the striker’s rods move. When manufacturing these parts, there are high requirements on the accuracy and cleanliness of the processing of mating surfaces. When the striker moves, its sliding speed relative to the surfaces of the power cylinder reaches 8 ... 9 m/s. In addition, these parts are affected by impact loads, which also have a radial component, the value of which is strongly influenced by the wear of the tool – tool’s sleeve pair [6].

As a result all adverse effects on rubbing surfaces of the striker and mating parts, coarse scuffings can appear, which leads to the failure of the entire hammer. If not very deep scuffings are formed only on the piston part of the striker (there are no contact seals) and on the mirror of the cylinder’s sleeve, then such parts can be preserved during repairs. Coarse risks can be cleaned up by grinding, without eliminating them to the full depth, after which these parts can serve for quite some time. If surfaces of the striker’s rods are damaged (scuffing or corrosion), then in this case when repairing the hydraulic hammer, the striker must be replaced with a new one, since damaged surfaces that are sealed by contact seals will fail these seals.

When making a new striker, it is important to observe the necessary gaps between rubbing surfaces of mating parts. When manufacturing repair sleeves of the power cylinder, apart from ensuring high surface cleanliness, measures should be taken to reduce the coefficient of friction. A reduction in the coefficient of friction can be achieved by nitriding the surfaces, saturating the surface with molybdenum disulfite, and other physical and chemical treatments. As already mentioned, the load of the hydraulic hammer’s striker, interchangeable tools and tool’s bushes are greatly affected by the wear of the latter.

With a large gap between the tool and its bushes, which appears due to natural wear, when the hammer operates, longitudinal axes of the striker and tool intersect and the striker interacts with the end of the tool with its edge rather than the centre. At the same time, additional radial forces and bending moments act on the striker and tool. These forces are proportional to the sine of the angle between the respective axes. The value of maximum allowable wear in a pair of sleeve-tool of the tool is usually regulated in the operating manual of the hydraulic hammer. Often, operators do not comply with these recommendations, which, eventually, leads to breakdowns of the tool itself, its bushes and even damage to the striker. The tool or striker can burst across the cross section or get chipped in the work of colliding ends. To reduce the harmful effect of the skewness of axes of the striker and tool, in my opinion, it is advisable to make a sphere by a radius at the end of the tool, the centre of which lies approximately in the middle or slightly lower than the middle of the supporting surface of the tool’s bushes. In this case, the contact of the striker and tool, even when axes are skewed, lies near the centre of the end of the striker and, therefore, the probability of chipping of colliding ends decreases. Another type of breakdown encountered in the operation of hydraulic hammers is the separation of studs that tighten body parts of the hydraulic hammer, and the studs that tighten cheeks of the hydraulic hammer, between which impact block of the hydraulic hammer is located. The studs themselves are designed correctly: the diameter of the body of the stud is made smaller than the internal diameter of the thread. In this case, the tensile stresses that appear in the stud when it is tightened and under working loads take the greatest value in the body of the stud, and not where the thread is located. However, the breakage of studs often occurs along threads in the area of the nut end. Such destruction indicates that additional stress arises in the destruction zone due to local bending moment. This bending moment, in turn, is due to the fact that surfaces to which the ends of nuts are adjacent are not parallel. The non-parallelism of the tightened surfaces is due to the fact that tolerances for deviation from the parallelism of the mating surfaces of all parts can be added up. Therefore, when manufacturing all joined parts, it is necessary to tighten tolerances and ensure their observance, or introduce some compensators into the structure, for example, use nuts with a spherical surface of the end and conical washers.

Repair of hydraulic hammers can be divided into: current repair, which can often be done at the place of operation, repair of medium complexity and major repairs. During the current repair, loosened threaded joints are tightened, damaged parts, some seals or individual nodes (hydraulic accumulators, directional control valves) are replaced, if possible without a complete disassembly of the hydraulic hammer [7].

Before performing more complex repairs, preliminary diagnostics must be done. The hydraulic hammer is installed on the stand, the symptoms of malfunctions are determined, the places of external oil leaks are determined, it is established whether the striker is moving, if such a phenomenon is observed. If necessary, the value of oil pressure in the pressure power line is measured. After that, assumptions are made about the reasons of the failure or unsatisfactory operation of the hydraulic hammer. Next, the hydraulic hammer is disassembled and the parts are diagnosed.

Repair of medium complexity is carried out in workshop conditions. The hydraulic hammer is completely disassembled and all hydraulic seals, the tool's bushes and the interchangeable tool are replaced, light tears on the piston part of the striker is cleaned, damaged parts of threaded joints are replace. Before assembly, all parts are thoroughly washed, purged with compressed air and lubricated. Tightening of threaded joints must be performed with a torque wrench in accordance with the recommendations of the operating manual for this hammer model.

The major repair of the hydraulic hammer is carried out in cases where the repair of medium complexity is insufficient to restore the hydraulic hammer. During the major repair of the hydraulic hammer, as a rule, there is a need to replace the striker, the power cylinder's sleeve (if it is provided for by the design of the hydraulic hammer), guide bushes, in which the striker's rods move. Less common are cases where boring of holes in the axle box is required in which the tool's bushes are mounted. In these cases, the outer bore diameter of bushes is performed according to the actual diameter of the axle box after its boring [8].

Sometimes, during the major repair, it is necessary to replace cheeks in which the impact block is placed. If the hydraulic hammer is used for crushing oversized rocks or the destruction of reinforced concrete structures, then its cheeks often hit the destroyed material. The lower ends of cheeks are worn out severely, and if there are any holes or windows in cheeks that are stress concentrators, then cracks can appear in cheeks after prolonged use. In some cases, it is possible to repair cheeks by deep cutting the crack and its welding. After performing a medium repair or major repair, the hammer must be tested on a stand.

3. Conclusions

Thus, making conclusions on the second chapter when choosing the hydraulic hammer, it is necessary to take into account not only the indicators given in its technical characteristics, but also the conditions of its future operation, the intensity of its use, the strength of the processed material.

1. In order to choose the hydraulic hammer for any excavator or other hydroficated base machine, first of all, you need to know the weight of an excavator.

The weight of the hydraulic hammer should be approximately 0.1 part of the weight of the excavator, but should not exceed the weight of the bucket with soil.

The smaller the weight of the hydraulic hammer, the better for the excavator in the transport position, the less load on the implement of the excavator when pointing the hammer to the point where it should work. But on the other hand, the greater the mass of the hydraulic hammer, the greater the impact energy and, accordingly, the capacity and less effort is required to press it against the object of work, the less vibration transmitted to the base machine during the operation of the hydraulic hammer.

2. The next indicator, which determines the possibility of using the hydraulic hammer on this excavator, is hydraulic fluid consumption, which is always given in the technical characteristics of the hammer.

This indicator should correspond to the capacity of the excavator's hydraulic pump, which will power the pressure line of the hydraulic hammer. If the pump capacity of the base machine exceeds the required fluid flow of the hydraulic hammer, then pressure peaks may occur during its operation that adversely affect the durability of both the hydraulic hammer and the hydraulic units of the base machine. If the pump capacity is significantly less than the minimum fluid flow of the hydraulic hammer, then the hydraulic hammer may work unstably or will not work at all.

3. A very important indicator is the level of the working pressure of the hydraulic hammer.

Naturally, the pressure that can provide the pump of the base machine should not be less than the working pressure of the hydraulic hammer. If the maximum pressure of the hydraulic pump is 10 ... 15% more than the working pressure of the hydraulic hammer, then a safety valve is provided in the pressure power line of the hydraulic hammer, which limits this level accordingly.

Otherwise, in case of any emergency situations, some details of the hydraulic hammer may fail, for example, the studs tightening body parts of the hammer, or the bolts securing the directional control valve, the hydraulic accumulator may be damaged, or seals may be damaged. If an adjustable pump with a power regulator is installed on the base machine, than it is desirable that the pressure value at which the power regulator starts to operate does not exceed the level of the working pressure of the hydraulic hammer. Otherwise, the power regulator of the hydraulic pump can operate in each cycle of the hammer's work, which reduces the service life of the hydraulic pump.

4. The technical capacity of the hydraulic hammer is determined by its effective power, i.e. product of impact energy and frequency of impacts. The greater the strength of the material that needs to be destroyed with the hydraulic hammer, the greater the influence on the capacity is exerted by the magnitude of the impact energy.

The hydraulic hammer with a higher impact energy allows chipping larger pieces from the solid, to break through thicker layers of pavement and destroying larger concrete structures. If it is required to destroy any relatively thin coatings or structures or to destroy solid rocks into relatively small pieces, hydraulic hammers with a lower impact energy but with a higher frequency of impacts will be more preferable. The impact energy of the hydraulic hammer must be such that the destruction of the processed material under the tip of its working tool occurs in no more than 15 ... 30 seconds. In the destruction of viscous materials such as, for example, frozen soil, various limestones and similar materials, impact energy has a decisive influence on the capacity of the hydraulic hammer, since for the formation of cracks in the processed material, it is necessary to hammer the working tool to a sufficiently large depth. The hammer's impact energy is the kinetic energy of the striker E = mv2 / 2, where m is the mass is of the striker and v is the velocity of the striker at the moment of collision with the tool. The same value of energy can be obtained due to the speed of the striker or due to its mass. At equal impact energy, the hydraulic hammer with the greater mass of the striker will be more effective, because it has more the product of mv, numerically equal to the momentum of the force.

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Operational Multi-purpose Control of the Composition of Mechanical Units at a Power Plant

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Abstract: In this article, the authors examined the issues of operational multi-purpose control of the composition of mechanical units at a power plant. criteria that are a prerequisite for the implementation of control actions by the composition of units at power plants. An algorithm has been developed for the operational control of the composition of mechanical units at a power plant, which is a multi-purpose control process. The analysis showed that the scope of this method of convolution of criteria in the operational management of the composition of units at hydroelectric power plants is very limited. It should be noted that the above methods of convolution of the criteria do not make it possible to form a set of alternative solutions, since they are oriented towards the implementation of a given control criterion. Based on the application of operational multi-purpose control over the composition of mechanical units, an analysis is made of the actual operating conditions of the power plant.

Keywords: management, units, power plant, reliability, criterion.

1. Introduction

Operative management of the composition of aggregates at the station is a process of multipurpose control. In the general case, the multipurpose control problem can be represented in the form (U, f, R), where U is the set of controls; f is mapping of U in the income space Em; R is a binary relation on Em, by which the income is compared. Instead of income, fines can be considered. Then in the first case, the optimal control will correspond to the majorants, and in the second - to the minorants. By virtue of duality of the relation R both cases are essentially equivalent.

Then the task of multipurpose control is to select the space of solutions $G\ (U, f, R)$ for given U, f and R. This space has the property of λ-separability, which can be written as

$$R1 < R2 \Rightarrow G(U, f, R1) \subseteq G(U, f, R2).$$

Thus, if the problem (U, f, R) has a solution for the λ- separable relation R, then it has a solution for any relation $R1$embedded in $R2$. Here λ - convolution problem (U, f, R) is called a single-criterion problem $(U, g, >)$ where $\lambda \in \mathrm{E}m$, $g(\lambda, f)$ is the map solution of g in the space of income to Em, but also specifies a particular kind of relationship (in this case "more"). In this case the function $g\ (\lambda, f)$ and relationship type (>) or (<) represents the maximization or the minimization of income or fines, respectively, i.e., is a management criterion. The transition to λ - convolutions is the main method of solving the multipurpose control problem, which is most often interpreted as a choice problem with a given optimality criterion and more rarely as a choice with an identifiable decision-making operator (DMO) optimality criterion. In the latter case, it is assumed that the decision-making process of DMO is based on individual criteria.

As selection principles, various selection functions from a limited set can be used, such as Pareto, aggregate extreme, tournament, scalar, majority, lexicographic and hierarchical. In the context of operational management of the composition of aggregates at stations, the convolution of the DMO criteria is an obligatory condition for the implementation of the control actions arriving at the executive mechanisms, which was already noted in the first chapter.

In this case, control is defined by expression $V(X) = \dfrac{\sigma_{\Delta x}}{m_x}$,where $\delta_{\Delta x}$, m_x is the standard deviation of the forecast number of aggregates from the actual per day and the mathematical expectation of the actual number of mechanicalunits at the station per day, based on the conditions for covering the active (reactive) load of the station.

Verification DE_2 in this expression describes the dual-purpose control of the composition of aggregates at the station level, when the decision of the DMO depends on the economy and reliability of the regime at the current time, it can be represented by the expression:

$$R * \text{э} \subseteq S * \text{э} \ and\ R * \text{н} \subseteq S * \text{н}.$$

We have already talked about various approaches to the determination of $R * e$ and $R * n$.They are functions of value, which represent a degenerate case of the utility function in accordance with the classification proposed in [1]. In this article, we discuss various ways of convolution of criteria of the form DE_2. For the case when a criterion is given, the use of methods of scalarization, severe priority and lexicographic ordering is suggested. In the latter case, it becomes possible to divide the domain of finding the solution into certain zones, in each of which a certain optimality principle is realized. It should be noted that the above methods of convolution of the criteria do not provide an opportunity to form a set of alternative solutions, since they are oriented toward the implementation of a given management criterion. Nevertheless, such methods of controlling the composition of aggregates can be used at hydroelectric stations that operate in a fully automated control mode (so-called HPPs at a "lock") or at small power stations that, as a rule, do not perform systemic regulatory functions.

2. Research method

The most interesting case of convolution of the dual-purpose task of controlling the composition of aggregates at a station is the use of the procedure for identification of DMO objectives on the basis of the apparatus of the theory of possibilities. In this case, it becomes possible to expand the scale of the criteria used to manage the composition of the aggregates and to single out the individual convolution of the criteria that DMO uses. On the basis of this, it is possible to create a "fan" of solutions, the dimension of which will be determined by the set of bundles used by DMO in the implementation of multipurpose control of the composition of mechanicalunits at hydroelectric stations. The use of such a method of solving a multi-purpose task in the operational management of the PS as a whole and in managing the composition of the mechanicalunits at the station in particular is a new and original [1,2].

Accounting for the multipurpose nature of operational dispatch management of energy facilities on the basis of identification of ODA optimality criterion is most preferred, as it organically fits into the basic principles of the situational approach to management.

Using the method of scalarization for the operational management of the composition of aggregates at the hydroelectric power station. Suppose, when making decisions, there is i-quality of different goals, each of which can be characterized by its criterion f_i. If there is a way to weigh each criterion according to its degree of importance (or usefulness) in general multicriterion space, there is a possibility of comparing the algebraic preference of one over the other objectives, i.e. by replacing all f_i by one common function:

$$f = \sum_{i=1}^{n} v_i f_i \rightarrow extr,$$

where v_i means weight coefficients of the criteria and

$$\sum_{i=1}^{n} v_i = 1,$$

i.e. weight coefficients appear in the expression. It can be calculated in the following way:

$$P_{pn} = 1 - \frac{\sum_{i=1}^{n} \Delta Z_i}{\sum_{i=1}^{n} Z_f} \tag{1}$$

where $i = 1, n$is the number of time intervals in the daily section; $Z_{fi}, Z\, pn.i$- the actual and forecasted number of aggregates in the i-th time interval.

Obviously, expression (1) is a one-form form of recording a multicriteria problem, which is represented as some synthesized goal. Very often this method of solving multicriteria problems is called the weighting method or the method of scalarization, implying that the target vector is measured by its projections using the weighting procedure.

In the case of dispatching the modes of the HPP aggregates and their composition, as already noted, several management objectives are realized: the fulfillment of the specified requirements for the operating mode of the station (the current and reactive power of the station is given in a given amount), maintaining the normal operational reliability of the hydroelectric mechanicalunits by controlling it current state and by choosing the optimal value of the rotating power reserve, and also observing the economical conditions of the HPP operation modes (minimization of water flow, passing it through the turbines of the hydroelectric station) [1-2]. A formalized description of this management process is defined by an expression if a task that does not meet the requirements listed is called incorrectly delivered and can be written in the form:

$$Az = u;\ u \in U,$$

where A is the operator, which together with u are the initial data for obtaining the solution z.

After obtaining estimates of the operational reliability of HPPs, the question arises as to their form of introduction into the target function of controlling the number and composition of hydroelectric mechanicalunits.

The statement of the problem in this case will have the following form:

$$Q(X, U) + k \cdot E(X, U') \Rightarrow min.$$

The following restrictions are represented:

$W(X, U) = 0$ – balance

$R(X, U) > 0$ - regime

$S'(X, U) > 0$ – reliable

where $Q (X, U)$ is the vector of the flow of water passing through the HPP turbines;

X, U are the vectors of the dependent and independent variables, respectively; $E (X, U')$ is a vector for taking into account the parameters of the operational reliability of the hydraulic mechanicalunit, extracted from constraints of the form $S'(X, U) > 0$. In this case, U 'is understood as preventive controllers; k is the conversion factor of the dimensionality of the vector E into the dimension of the objective function Q.

In this case, the term entering the objective function can be written as

$$kE(X, U') = \sum_{i=1}^{m} v_i a_i,$$

where m is the number of control parameters whose values, at the time of making a decision to change the station regime, go beyond the regulatory levels;

vi - "weight or importance" of the i-th control parameter;

ai is the scale factor.

In this setting, the list of parameters (factors) varies both in dimension and in composition. The values of vi can be determined only on the basis of a limited sample compiled during a special analysis. This task is set out in the second chapter.

The greatest difficulty is the calculation of the coefficients ai. Strictly speaking, a_i is an economic estimate of the severity of the symptom of a possible disruption of operational reliability, determined by the fact of monitoring the i-th parameter. Since each of the monitored parameters is "tied" to a certain element of the aggregate block (to the thrust bearing of the generator, its cooling system, etc.), then knowing the repair costs of these nodes IA_i, one can roughly calculate the value of the mathematical expectation of damage associated with deviations in the value i-th controlled parameter from the standard $M(U_{S.Z.})$[1-2]:

$$M(U_{S.Z.}) = \overline{\omega_i} I_{ai},$$

where $\overline{\omega_i}$ is the failure flow parameter of the $_i$-th equipment element [3-6].

If as a source of information characterizing a violation of the operational reliability of the mechanical unit could be taken, it is obvious that when forecasting the number of aggregates necessary to cover the reactive power of the plant, the use of the expression $\delta ZQ < \delta Q$ as a management model will be associated with the performance following conditions and assumptions [1, 2].

There is the possibility of assigning this or that precautionary protection to a specific element of the aggregate mechanical unit. There is a static estimate of the cost of repairing the i-th item of equipment. The assumption is used, which is connected with the fact that if on the aggregate block all the preventive protection included in the list are triggered, then

$$kE(X, U') = \sum_{i=1}^{m} v_i I_{ai},$$

is when the weighting parameters are normalized.

All this makes it very difficult to obtain an accurate estimate of the control vector $k \cdot E(X, U')$, which can manifest as an overestimation or underestimation of operational reliability relative to the economic parameters of the operating mode of the HPP. This, in turn, can lead to incorrectness of the decision taken in terms of changing the operating mode of the HPP. Constant scanning of the current mode of the station requires constant correction of the weight coefficients, which, as shown, is a rather cumbersome process. All of the above seriously limits the scope of using this method of convolution of criteria for the operational management of the aggregate composition at HPP [1].

Use of the principle of strict priority to accounting of operational reliability. Let us consider the general formulation of this method for reconciling the criteria. All considered criteria are ranked. Then one is allocated - the most important one, and the rest are translated into restrictions. Let us suppose that the goal criteria are prioritized, with the most important criterion in the first place: $f_i = f_1, f_2, f_3, \dots f_n$.

With the help of the chosen most important criterion f_1 one-criterion function is formed, which allows obtaining a set of admissible solutions:

$$f_i \Rightarrow extr,$$

$When\ \forall i = 2, \dots n;\ f_i > \min f_i.$

If f_1 has a deterministic value, then the solution is unique; for a probability character f_1, a certain subset of probabilistic plans [1] appears.

The application of this principle allows us to normalize the estimates of operational reliability in relation to the economic criterion for the operational management of the aggregate composition. This allows us to move from quantitative assessments to the scale of relations [1,2]. The formulation of the problem can be formulated as follows. The target function $Q\ (X, U) \Rightarrow min$ associated with the minimization of the energy carrier at the hydro station will be realized when the following constraints are fulfilled: $W\ (X, U)\ =\ 0, R\ (X, U) >\ 0, S\,'(X, U)\ >\ 0.$

Moreover, a restriction of the form $E\ (X, U\,') \in S\ (X, U)$ can be distinguished from $S\ (X, U)$ and written as follows:

or $\sum_{i=1}^{m} v_i \geq NOR$, where $\sum_{i=1}^{m} v_i$.

$$\sum_{i=1}^{m} v_i < NOR,$$

is the total "weight" of the control parameters ($i\ =\ 1,2, \dots, m$), the values of which at the considered moment of time t exceed the established norm NOR.

In [1,2] the possibility of implementing the above control method is shown, when the monitoring of the fact of the alarm activation is used as a source of information on the violation of the operational reliability of the hydraulic mechanical unit. At the same time under NOR in can be roughly calculated the value of the mathematical expectation of damage associated with deviations of the value of the i-th monitored parameter from the standard $\mathrm{M}(U_{S.Z.})$[1-2]:

$$M(U_{S.Z.}) = \overline{\omega_\iota} I_{ai},$$

where $\overline{\omega_\iota}$ is the failure flow parameter of the i −th equipment element (1) is understood as some "normative setting", which is defined as the mathematical expectation of the sum of the weight indicators of the preventive protections in the list under consideration.

The NOR definition can be based on an imitative statistical model, which, given the equiprobable law of the distribution of protection operation in the considered time interval, allows us to present a certain tuning card. Fig. 1 shows its appearance in relation to the Novosibirsk HPP.

3 Results and discussion

Knowing the average number (or giving them) of the protection actions in the considered time interval, which can be adopted in the limit of 0.5 ... 1 h in the operational dispatching control, we can find the value NOR, as in the neighborhood of the point $t\ =\ t_{k+1}$ every continuously differentiable function $f\ (t)$ can be approximated by the straight line $f(t) \approx f(t_{k+1}) + (t - t_{k+1}) f'(t_{k+1})$, for example, if the average number of alarms is approximately one, set point "will be approximately equal or the weight of the priority protection (whose weight for Novosibirsk HPP is 0.075), or weight of a medium-two protections, or weight the three - four non-priority protections.

An analysis of the actual operating modes of the Novosibirsk HPP shows the reality of this situation. Therefore, the calculated tuning card can be directly used in the control of the station, especially since it allows its rapid correction.

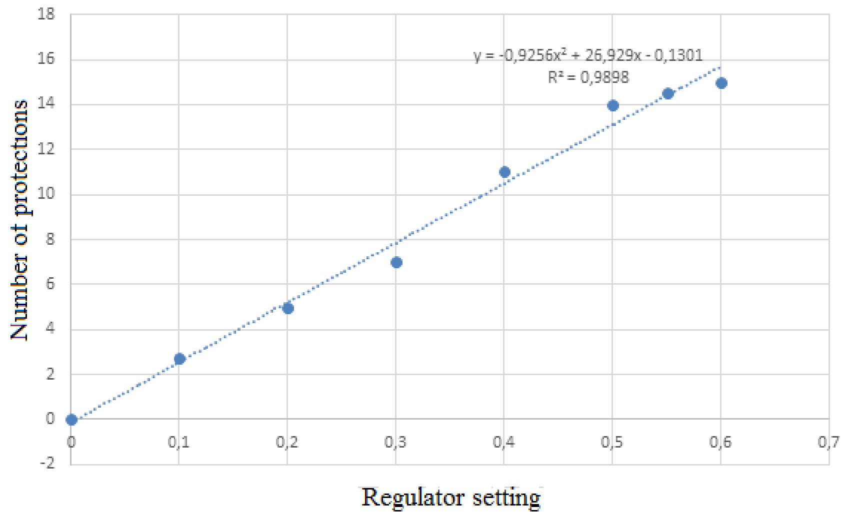

Fig.1. - Configuration map for the Novosibirsk HPP

4. Conclusions

The action of a_1 is more preferable than the action of a_2 if and only if:

a) $G_1(a_1) > G_2(a_2)$ or

b) $G_1(a_1) = G_2(a_2), i = 1, \ldots, k, \quad G_k + 1(a_1) > G_k + 1(a_2), \exists k = 1, \ldots \ldots$ n-1.

In other words, it is believed that the criteria $G_1, \ldots, G_n$ are ordered in order of importance. In this case, the action of a1 is preferred to the action of a_2 if it has a larger value for G_1, regardless of how good or bad it is by other criteria.

Only if the values of G_1 for them coincide, the criterion G_2 is introduced, etc. Such a method of ordering makes it possible to artificially partition the entire domain of decision-making G into zones. The principle of decomposition is based on the experience gained in the practice of exploitation. The management criteria are internally consistent and logically justified, which gives serious advantages for the formalization of management in the process control system. On the other hand, it must be clearly understood that such an approach is based on certain assumptions within which the proposed method for controlling the composition of aggregates at the station is implemented.

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Adaptive Control Systems Effect on the Process of Cutting Parts on Numerically Controlled Machines

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Abstract: Reliability and quality of machining parts are the main issues of automated production. Vibration resistance of machines has a direct relationship with the quality parameters of products, and also affects the reliability of components and parts of CNC machines. This article discusses the most popular ways to solve the problem of vibration resistance of CNC machines, and the importance of introducing adaptive control systems in automated production. Recent researches of methods for studying the occurrence of vibration in the metalworking process, methods for solving the vibration problem are considered. An option for solving vibration suppression during processing due to adaptive control of cutting conditions is proposed.

Keywords: ACS-adaptive control systems, vibration dampers, damping, cutting modes, self-oscillations, relaxation vibrations, dynamic vibration dampers.

1. Introduction

Present day production is becoming more energy-saturated and automated with the forcing of parameters with respect to speed, power and load.

The technological environment is largely an essential component of the country's industry and in a great extent determines its economic potential.

Industrial automation of production primarily includes automation of the manufacturing process and production at all the stages, and comprehensively covers the areas of production activity including monitoring, planning, the financial and economic field of activity, accounting, logistics and personnel management.

The most important component of the technological environment is its equipment that implements the technological process.

The present day engineering industry pays great attention to the issues of vibration resistance of machines. Vibration resistance of machines is closely related to their rigidity and both factors often determine achievable productivity. Vibrations limit the acceptable cutting conditions during machining (especially the speed and depth of cutting), lead to a corrugated or crushed surface of the part, increased hardening of its surface layers, reduced machining accuracy, resistance of the cutting tool, disruption of machine connections and its accelerated wear. When significant vibrations occur, the work usually has to be stopped.

When considering any vibration process, one has to operate with the following concepts:

a) the vibration frequency in hertz is the number of oscillations of the investigated value per second;

b) the period of vibration is the time of one vibration of this value expressed in seconds;

c) the amplitude of the vibration is the maximum deviation of the oscillating value from the average position;

d) the peak-to-peak amplitude of the vibration is the distance between the extreme positions of the oscillating value and is equal to the double amplitude.

The main types of vibrations encountered in the machine-tool-component system, as well as their causes, are as follows.

The vibrations transmitted from outside (from nearby forging equipment of gear-cutting or gear-shaping machines, powerful engines, etc.). In these cases the frequency of vibrations arising during cutting is the same or an integer number of times higher than the frequency of exciting vibrations. This phenomenon is especially often encountered when machines are mounted on weak floors, galleries, etc.

2. Results and discussion

The methods of fighting in these cases are elimination of the source of vibrations or transferring the machine, strengthening the foundation, the use of vibration damping pads and other methods.

Vibrations caused by the imbalance of rapidly rotating parts of the machine or workpiece. In these cases the centrifugal force changes its direction, which causes vibrations in the units of the machine. The vibration frequency is equal to the number of revolutions of the unbalanced part or assembly per second. The method of fighting consists in balancing the structural element that excites vibrations.

Vibrations associated with machine transmission gear defects. Incorrectly cut, worn, or poorly mounted gears cause periodic forces to be transmitted to the bearings, and therefore to the spindle and machine bed, which under certain conditions can cause vibrations. Sometimes coarse stitching of belts, fluid pulsation in the pipelines of the machine and other transmission gear defects contribute to the same effect. The method of fighting is to eliminate the exciting cause of vibration.

Vibrations caused by a variable cross-section of the cut or the intermittent nature of the cutting process. Turning the shafts with eccentric necks, turning the square rods into round, planing discontinuous surfaces are typical examples of these exciting causes.

For many machining processes, the more or less intermittent nature of cutting is their characteristic feature. This includes milling, drawing, chiseling, the work of the grinding wheel, which is unevenly dull around the circumference, etc. The vibration frequency in this case is equal to or multiple of the frequency of the disturbing force. Usually, the phenomenon is more complicated due to the interaction of these forced vibrations with the so-called self-vibrations.

The occurrence of vibrations is easily explained in all the cases considered; this is the presence of a periodic disturbing force. For the same reason, vibrations of this type are collectively called forced vibrations.

Forced vibrations of small amplitudes always occur when working on machines. They pose a serious danger only for finishing machines. For other machines under normal operating conditions, they disrupt operation only in the case of resonance.

Very rarely in machines there are observed parametric vibrations that arise due to the variable rigidity of individual elements of the main movement drive. For example, the cause of such vibrations can be bending shafts, significantly weakened by keyways.

More often you can find relaxation (discontinuous) vibrations that mainly occur in the feed chains of supports, carriages, tables of the turning, boring, milling and other machines. Such vibrations are often known as "uneven feed". Relaxation vibrations are manifested in the form of rhythmic abrupt movements of the unit instead of uniform translational motion. The indicated phenomenon is observed when the kinematic feed chain has low torsional rigidity, and the friction forces in the guides of the assembly are large.

As a result, the kinematic chain is twisted like a spring, then jerkily moves the unit, which, after passing a certain path, brakes again, and the phenomenon repeats. An additional condition for the occurrence and keeping such vibrations is the condition that the coefficient of friction of motion is lower than the coefficient of rest friction (which takes place in the vast majority of cases).

The most common type of vibration when working on metal cutting machines is self-vibration.

A self-vibration or "self-excited" process is a process in which undamped vibrations can be excited due to an energy source that does not have vibrational properties. Such a connection of a vibrating element with an energy source is called feedback.

The external side of the phenomenon in these cases is that when machining a perfectly balanced part on a perfectly working machine with a massive foundation, strong vibrations can occur. They occur immediately after the start of cutting and disappear when it stops. Consequently, the cause of vibration lies precisely in the cutting process itself. Self-vibrations occur more often and easier with flow chips. It is characteristic that their frequency remains unchanged when the cutting speed varies over a wide range.

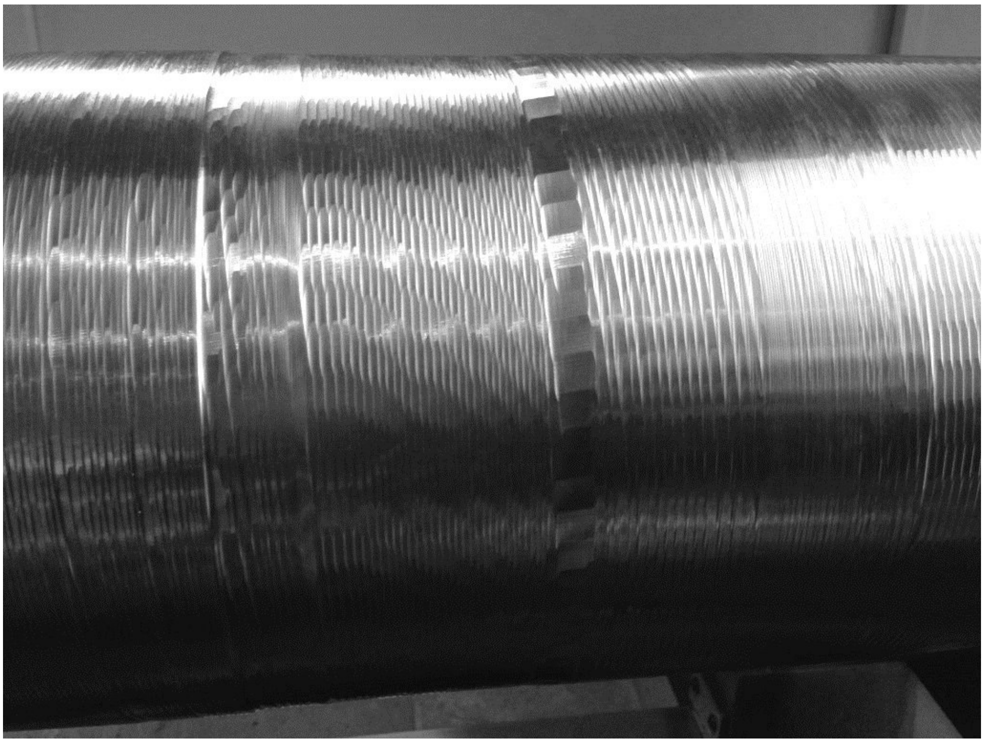
The onset of self-vibrations can be "hard" or "soft". In the first case, vibrations begin due to changing the cutting force as a result of any reason: not quite uniform allowance, the presence of a solid inclusion in the metal, uneven movement of the feed mechanism, etc. Changing the cutting force causes an additional tool pulling. Vibrations arise immediately in full force and are further supported by the energy of the machine drive. With a "soft" start, self-vibrations begin to increase gradually from zero, and the cause of their excitation is a consequence of the behavior of the metal in front of the blade at the moment of cutting, a plastic "stagnant" zone is formed in front of the fore face, the size and shape of which depend on many factors and which directly affects the value cutting forces.

When machining on metal-cutting machines, forced vibrations arise under the action of external periodic disturbing forces due to the discontinuity of the cutting process, the unbalance of the rotating masses, manufacturing and assembly errors of gears, and the rhythm of operation of closely located machines. Forced vibrations are eliminated by reducing the amount of disturbing forces and increasing the machine rigidity.

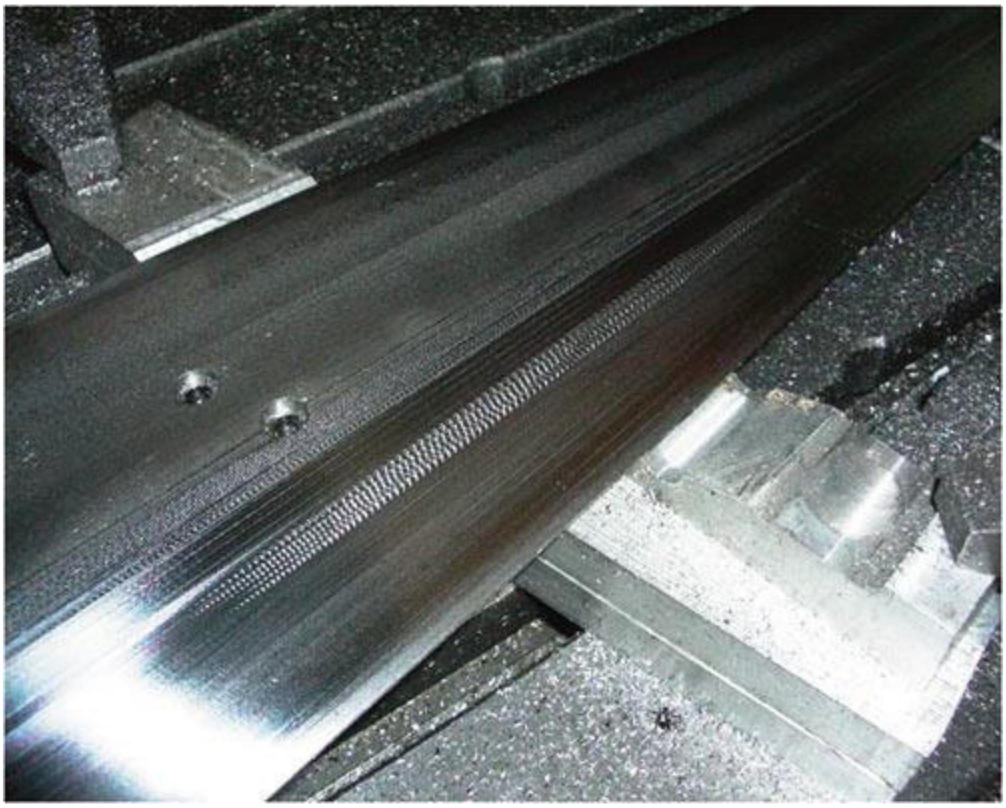
Tool vibrations reduce the quality of the treated surface (roughness increases; waviness appears); the dynamic nature of the cutting force is enhanced, and the loads on the moving parts of the machine increase by tens of times, especially under resonance conditions, when the frequency of the natural vibrations of the system coincides with the vibration frequency during cutting.

Vibrations due to physical nature are, respectively, mechanical and acoustic vibrations of material particles of the elastic medium of a solid, liquid, or gas. They accompany any technological process and are characteristic of such an important stage in the life cycle of the technological environment as the operation phase.

These factors reduce the technical level of the equipment, worsen the quality indicators of technological processes and production, in particular, such important indicators as environmental and safety indicators. Ultimately, all this greatly reduces the competitiveness of mechanical engineering production.



a)



b)

Fig. 1 – Surface quality with forced vibrations (a - turning, b - cutting)

The main thing that follows from the consideration of various types of vibrations is that different types of vibrations are caused by different causes and require different counteractions.

Let's consider the basic measures to fight self-vibrations. All the measures taken can be conditionally divided into technological and structural. The technological measures include changes in certain aspects of cutting modes and tool geometry, the structural ones consist in the use of special tools and devices or in increasing rigidity of machine components. The first group of measures is easier to implement, but they are sometimes associated with reduced productivity, deterioration in the surface quality, or are not effective enough. The second group of measures is more time-consuming but they give better and more stable results.

The technological measures include:

1. Changing the cutting speed. A significant increase in the cutting speed often eliminates self-excited vibrations. So at high-speed milling the specified result is already obtained when working in the speed range 80 – 100 m/min; less often there are reached the speeds of 150-180 m/min. However, at very high cutting speeds vibrations from transmission gear defects or imbalance of rapidly rotating parts can begin to affect, which is especially important with thin boring, turning and other finishing methods. Sometimes the limited capabilities of the tool and the machine do not allow increasing speed; then the cutting speed has to be reduced.

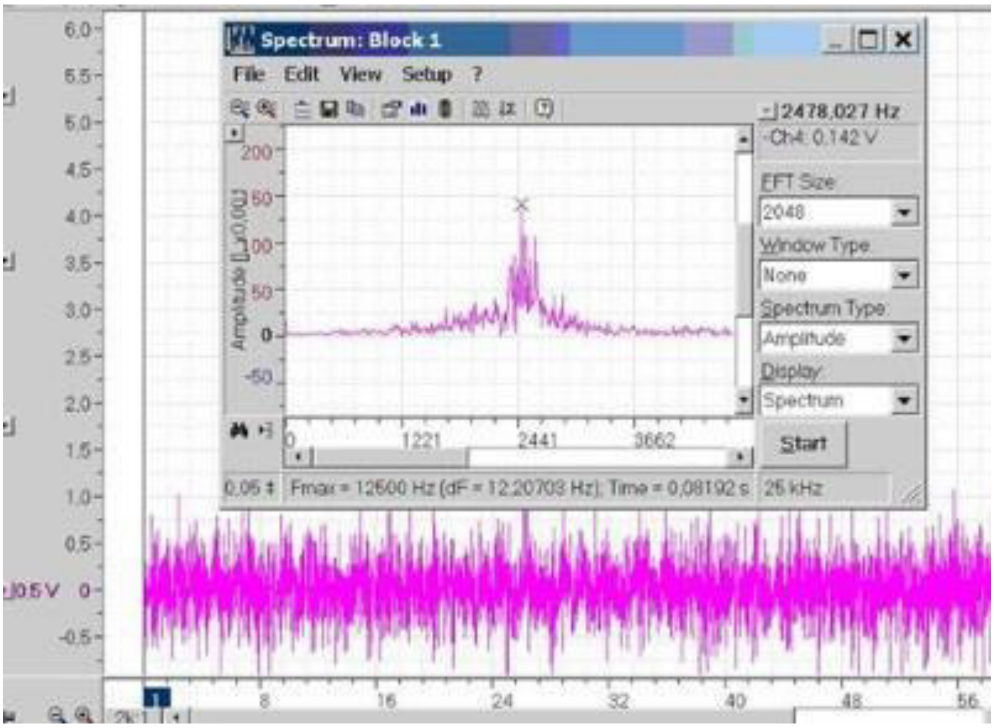


Fig. 2. – Vibration amplitude depending on the cutting speed

2. Changing the feed and depth of cutting. When turning and milling, increasing the feed while reducing the depth of cutting leads to decreasing vibrations. This logically follows from the well-known position that vibrations occur the easier, the wider and finer the cut chips. For the same reason, increasing the main angle in terms of φ and decreasing the radius of curvature of the tip of the cutter r also reduce vibrations.

3. Changing the cutting angles. Increasing the fore angle γ with reducing the cutting force contributes to more smooth operation. Reducing the rear angle α greatly reduces low-frequency radial vibrations (i.e., vibrations of the part), but contributes to the intensifying high-frequency tangential vibrations (i.e., cutter vibrations).

4. Improving the cleanliness of the working surfaces of the tools and the use of lubricating fluids. At this, vibration attenuation is achieved due to certain decreasing the cutting forces.

The structural measures include:

1. Increasing rigidity of all the elements of the machine-tool-component system. Increasing rigidity complicates the occurrence of not only self-vibrations but of any kind of vibrations in general, since this increases the frequency of the system own vibrations and, consequently, reduces the intensity (amplitude) of vibrations.

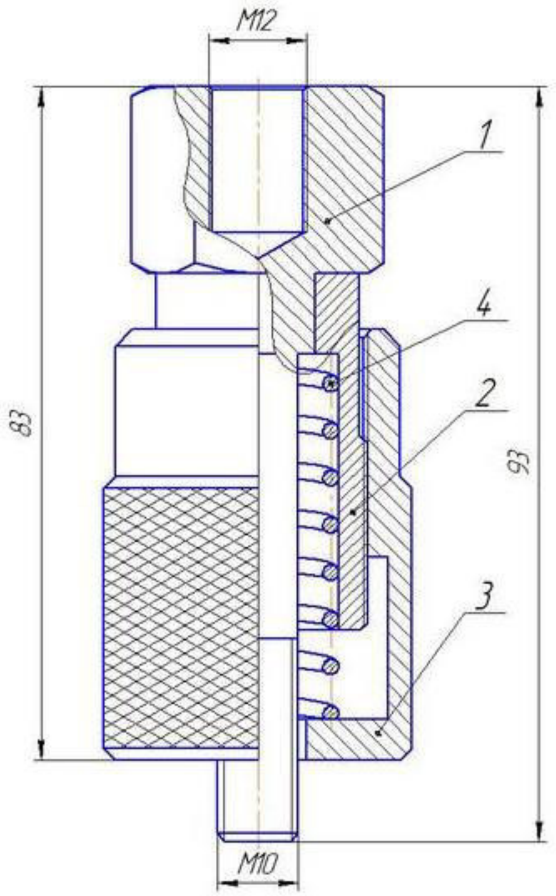
Measures to increase the rigidity of machine units were indicated in the previous section. In addition, it is necessary to pay attention to the importance of eliminating excessive clearances in bearings and guides, reliability of fastening the part in the chuck, the cutter in the tool holder, ensuring a small outreach, the uniform fit of the leash to the collar, the lance cams to the part, as well as selecting such working conditions (directions of working movements), in which the direction of the cutting force components action is the most favorable.

2. Dissipation of the energy of vibrations of the system (damping). Vibrations will decrease or stop if, with the stable amplitude of undamped vibrations, the total attenuation (absorption) energy due to the additional dampers is greater than the excitation energy.

In practice, this is achieved by using various designs of vibration dampers: of dry or viscous friction, pulse or dynamic. A vibration damper is a device which inclusion in the vibration system dramatically increases its attenuation.

Friction vibration dampers. Most of the known structures are designed to damp low-frequency vibrations of parts during their turning. These include dry friction dampers, friction dampers, etc.

When pulse absorbers are used, the impact on the dispersion of vibration energy is due to the impact of a small mass of the vibration damper with the main vibrating mass. These devices include a vibration damper designed by L.B. Erlich for boring mandrels, as well as a vibration absorber designed by D.I. Ryzhkov for dampening high-frequency vibrations of cutters (Fig. 3).



1 - screw; 2 - head; 3 - lid; 4 - spring

Fig. 3. – Pulse vibration absorber by D.I. Ryzhkov

Dynamic vibration dampers. Fundamentally, any such vibration damper is a small vibration system having an adjustable elastic vibrating element and a damping element. By adjusting the elastic element, the vibration damper is adjusted to resonance with the vibrating body on which it is mounted. Since the vibration damper vibrations are 180° out of phase, the vibrations of the body are attenuated out and eliminated.

Anti-vibration assembly of machines.

The structural measures include anti-vibration assembly of machines.

Even normally functioning equipment can always have some amount of vibrations. Let's indicate the approximate allowable vibration amplitudes for the main machines:

- turning, drilling, planing machines - 5-10 microns;
- milling, boring machines - 3–7 microns;
- grinding, precision boring machines - 1-3 microns;
- finishing machines - up to 1 micron.

Machines having the vibration amplitude above 20 microns should be considered malfunctioning or operating with vibrations of the unacceptable value.

Instruments for measuring vibrations. The main instruments by arrangement and purpose are divided into frequency meters, vibrometers (vibrographs) and accelerometers.

It is well known that to ensure the accuracy of the product dimensions in automated production, as well as for the efficiency of the manufacturing process of products there is needed the compliance with cutting conditions previously established; control and measurements of the tool itself and the workpiece; wear status of the cutting tool or grinding stone. Failure to comply with one of these components leads to breakage, wear, as well as to decreasing the accuracy of the product, i.e. leads to deterioration in the product quality.

The numerical value of vibration in the production environment is a variable since in the production environment vibrations are not constant, therefore, to reduce the characteristics of noise and vibration there should be used combined control, i.e. the regulation consists in correcting deviations of the state of the system output from each value of the vibration characteristics that go beyond the standard values.

The essence of this control is to provide end-to-end systems development processes using feedback in the electric drive when evaluating decisions. The degree of complexity of controlling the technological system of engineering support is determined by the number of input control actions, the number of technological facilities and controlled parameters of the technological process.

There are several ways to achieve this goal, one of which is controlling the cutting mode by means of increasing or decreasing the cutting parameters depending on the data obtained.

The cutting mode is characterized by three parameters:

- the cutting depth t (mm);
- the feed S (mm/rev);
- the cutting speed v (mm/min).

In this regard, the main feedback in the electric drive is built according to the position, and the position sensor acquires the decisive importance. The position sensor performs positioning, tracking the characteristics of noise and vibration, followed by the information processing.

The regulation of the vibration characteristics after the information processing can be performed using sensors of movement speed and rotation frequency speed.

3. Conclusion

The current situation testifies to the relevance of the problem of improving the efficiency of technological processes in machine-building production by means of developing automated control, minimizing noise and vibration in metal-cutting equipment.

Adaptive control systems are used to address the issues raised. An important role is played by selecting the parameter by which stabilization of the cutting conditions will be carried out, since the efficiency of the adaptive control system for the machining of parts depends on this parameter.

Machining on metal cutting machines takes place with continuous changing the conditions and parameters of the machine dynamic system. A large number of different factors that affect the machining process cannot be constant, since each of the parameters depends on all the others. The use of the results obtained and even the presence of a large database of statistical experiments cannot guarantee increasing the productivity, therefore it is important to introduce control systems and to stabilize the machining process that oversee the machining parameters in real time.

For automated control of the machining process on a CNC machine, signals of changing the cutting force and vibrations are transmitted, which are converted into the surface roughness parameter of the part that is being machined. These signals are received by a logic device that, according to certain algorithms, determines the optimal cutting speed and feed rate in real time.

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Research and Improvement of the Transmission Design Based on the Robotic Gearbox

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Abstract: This paper discusses the need to use a 3-speed transmission system to improve the energy efficiency of purely electric vehicles (EV). The energy efficiency of the electric motor varies at various operating points to meet the demand for power output. Three gear ratios of the transmission system can maintain engine speed within a stable area with relatively high energy efficiency, while different vehicle speeds are needed. The transmission required a similar compromise between efficiency and cruelty. This work is based on the lightweight EV prototype.

Keywords: electric, gearbox, inverter, motor, gearbox drive (CAT), RGB (robotic gearbox).

1. Introduction

In the last decade in the world gaining popularity of electric vehicles. This is due to the fact that these machines cause less harm to the environment, as well as the fact that the natural fuel resources, which are used in internal combustion engines, are exhausted. Electric cars are driven by an electric motor, the power of which is due to the batteries.

One of the positive technical aspects of electric vehicles is the simplified transmission. Compared to a traditional transmission, the drive motor of the electric vehicle is able to generate a constant torque at low speed and constant power at high speed [1]. Cruising ranges of EVS being expanded by increasing the capacity of accumulation of energy or improving the efficiency of the transmission system. However, most electric cars are equipped with a gearbox with fixed gear ratio. To obtain high speed and acceleration, power and torque of the drive motor must be high enough.

The transmission system of the vehicle (including vehicle fuel and electric vehicles) essentially consists of gear box, differential, drive shaft and at least two wheel axles. The transmission system can also be supplied without the drive shaft in accordance with various drive modes. The transmission system used to transmit power from the engine (motor fuel vehicle or electric drive motor vehicle) to driving wheels, and thus to bring the vehicle in motion [1].

2. Analysis of electric vehicle

Many other criteria determine the current trends of development and influence the choice of the right concept. For example, the number of transmission speeds has a large effect on the function, the complexity and therefore the cost of the vehicle. As single-speed transmission is sufficient for many vehicles in many applications, a multi-speed transmission can increase both the range and maximum speed, while maintaining good characteristics when driving. However, for two - or multi-speed transmissions in electric cars with rechargeable battery requires the ability to shift to implement smooth acceleration without interruption of traction, typical of electric vehicles [2].

Internal combustion engines typically reach maximum torque in the range from 3000 to 5000 rpm, so to keep the engine in this operating range with increase of the vehicle speed requires gear box. On the other hand, electric motors have full torque at 0 rpm and a much wider operating range. That's why most EVS have a single speed or, in some cases, two-speed transmission. Despite this, the efficiency of electric motors still varies at different speeds - they operate at maximum efficiency for about 90 percent but this can fall to 60-70 percent, particularly at low speed.

The main objective of this study is to improve the transmission system, namely, design of gear boxes for electric vehicles, which can reduce energy consumption and improve overall efficiency. The gear change to be implemented on a robotic basis.

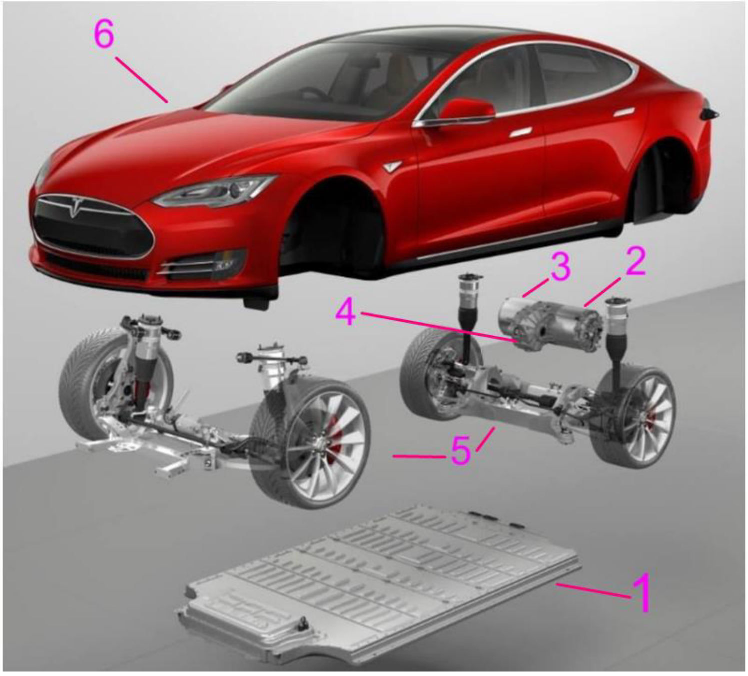
Robotic transmission (RGB) refers to a variety of semi-automatic gearboxes, which combines the features of manual transmission and automatic. As in the mechanical box of switching of speeds in robotic transmission occurs at the request of the driver. However, instead of a third pedal, which is decisive for switching speeds in a car with a manual transmission in a car with robotized transmission only two pedals. And the role of the third pedal is a system of sensors, transmitters and actuators, the onboard computer switch box speeds. Actuators are electric or hydraulic actuators, which are designed for mechanical movement of the synchronizers of the gearbox and switching on / off of the couplings [3]. Electric actuator is a gear motor, and hydraulic is a simple hydraulic cylinder whose rod is connected with the correct synchronizer.

It is the computer that synchronizes the operation of the box parts, and some electronic systems are able to learn to recognize the driver's driving style and anticipate his actions. The robotic transmission was developed by European car companies to improve driving performance, especially in driving conditions in congested cities with frequent stops and starts. To achieve the above goal it is necessary to consider the design of electric vehicle.

All electric cars have a similar design. The main components are:
- Li - ion battery;
- inverter;

- the electric motor;
- transmission.

Outside most electric vehicles are like cars, running on fossil fuels. The electric car has no tailpipe and gas tank, but the overall structure is basically the same. Under the hood, instead of a huge engine, you will see only the electric motor and its controller (Fig. 1). The electric motor does not require oil, does not require adjustment, and since the exhaust pipes do not stand out, it does not require smog verification. The electric vehicle's power source is a battery that acts as a "gas tank" and supplies the electric motor with the energy needed to move the vehicle. This gives the car acceleration. When the car is idle, electric current is not processed, so energy is not consumed. The controller acts as a regulator and controls the amount of energy received from the batteries so that the engine does not burn out. This battery powers all electronic devices in the car, just like the battery in a car with a gasoline engine. Everything else in the electric car basically matches its gasoline equivalent: transmission, brakes, air conditioning and airbags. Because electric motors use an electric motor, the driver can use the engine's momentum when applying pressure to the brakes. Instead of converting all the potential energy in the engine to heat, as a fossil fuel powered car does, the electric car uses the front impulse of the engine to charge the battery. This process is called regenerative inhibition [4].



1 - lithium-ion battery; 2 - electric motor; 3 - inverter; 4 - transmission; 5 - running gear; 6 - body

Fig. 1 - Design of an electric vehicle

3. Consider each component

An electric motor is a device that converts electricity into mechanical energy. It works using the principle of electromagnetic induction.

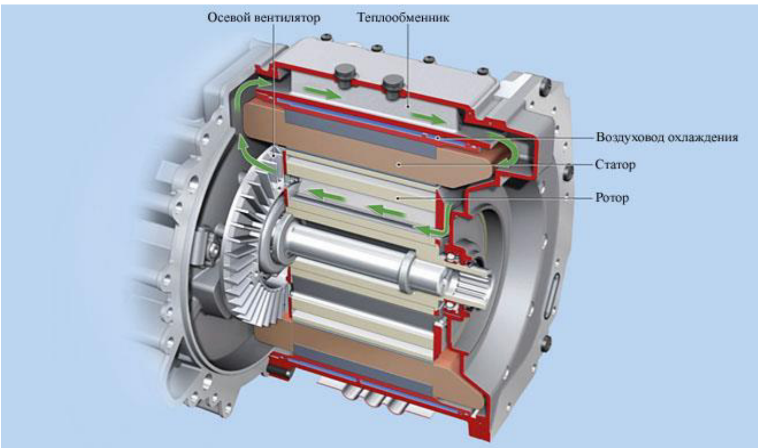


Fig. 2 - Asynchronous electric motor

The motor includes a stator and a rotor. A rotating magnetic field in the stator acts on the rotor winding and induces in it a current of induction, there is a torque that drives the rotor. The power supplied to the coils of the motor is converted into mechanical energy of rotation.

Electric motors have several types. In the electric vehicle mainly uses the asynchronous (induction) motor. Unlike other species, the induction rotor has no magnets - it's just folded steel bundles with the recessed peripheral conductors, which form a "shorted structure."

"The currents flowing in the stator windings create a rotating magnetic field, which is included in the rotor. In turn, the frequency of the magnetic field seen by the rotor is equal to the difference between the applied electrical frequency and the rotation frequency of the rotor. Accordingly, closed loop design, there is an induced voltage that is proportional to this difference of velocities between the rotor and the electrical frequency. In response to this tension within the conductors of the rotor there are currents that are approximately proportional to the voltage, hence the speed difference. And finally, these currents interact with the original magnetic field, creating a force that is torque of the rotor.

The motor power supply is supplied from the battery. The output of the battery is removed the DC voltage of the order of 300V. Battery capacity should match the power rating of the motor. The battery is located in the bottom, so has a low centre of gravity and excellent handling. It is attached to the body by means of brackets.

To convert the DC high voltage provided by the battery into three - phase AC, manufacturers use a specialized inverter. In the electric drivetrain, the inverter controls the motor. It is a key component in the car, because, like the engine control system of internal combustion vehicles, it determines driving behaviour. Regardless of whether the motor is synchronous, asynchronous or brushless DC, the inverter always works in the same way and is controlled by integrated circuit Board, which should be designed to minimize switching loss and maximize thermal efficiency. The inverter not only drives the motor, it also captures the energy released in regenerative breaking and feeds it back into the battery. As a result, the range of the car is directly related to the efficiency of the main inverter. In addition, such a converter is also designed to charge an additional 12 W battery. It is needed to power other nodes and devices. These include air conditioning, electric power steering, audio system, etc. [5].

The battery of an electric car consists of several electrochemical cells. The main objective of the battery is the conversion of chemical energy into electrical energy when it is unloaded and, accordingly, electrical energy into chemical energy (when charging). The type of battery depends on the cells it contains.

Fig. 3 - Lithium-ion batteries

Electric vehicles use lithium-ion batteries. Lithium-ion batteries have a higher energy density than lead-acid batteries or nickel-metal hydride batteries, so you can make the battery size smaller than others, while maintaining the same battery capacity (Fig. 3). Most lithium-ion batteries use a negative electrode, mainly made of carbon (eg, graphite) or lithium titanate ($Li_4Ti_5O_{12}$), with some new materials [6].

A lithium-ion battery requires recharging after a certain working time, which is carried out both from various sources from the outside, and from a generator that is installed on board the car. Each electric car has its own charging port, which allows vehicles to connect to an external power source to charge the traction battery.

The movement of transport is carried out by transmitting torque from the electric motor to the chassis using a transmission. It consists of a simple single-speed transmission (Fig. 4).

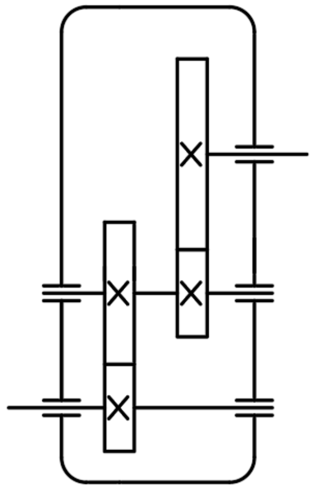


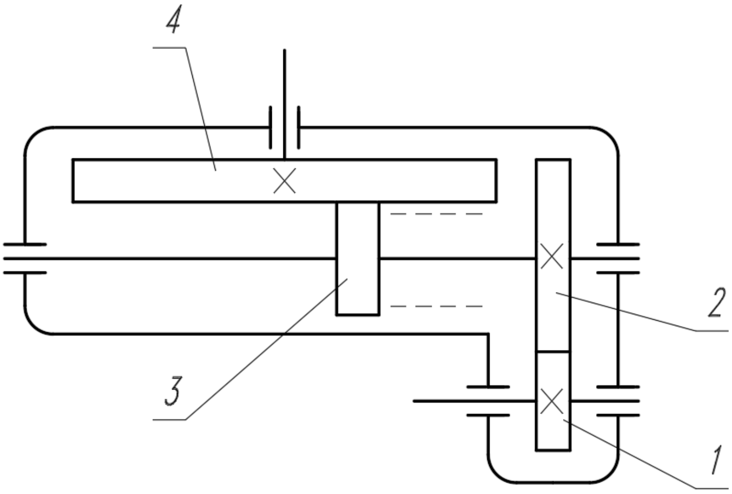
Fig. 4 - Transmission box diagram

3. Proposed transmission design

Most of the electric cars produced today are equipped with single-speed gears. The lightness of the gearboxes is due to the fact that the electric motor produces a torque much greater than the internal combustion engine.

Killed roads, sometimes even off-road, complicate the work of a single-stage gearbox, which often does not cope with its goals. In mixed driving mode, it is preferable to choose a gearbox with three or four speeds. It not only optimizes torque, but also reduces battery consumption. An electric car with a multi-speed transmission offers better performance than single-speed transmission systems in terms of faster acceleration, maximum speed, balance with mileage, etc. Based on this, in this study, it is proposed to improve a single-speed gearbox.

Figure 5 shows the proposed scheme of a 3-speed gearbox.



1 - shaft gear; 2 - wheel fixed; 3 - wheel mobile; 4 - wheel gear with socket teeth

Fig. 5 - Scheme of gearbox

This transmission is similar in principle to operate a manual transmission.

In accordance with this invention the box has three shafts, senior, intermediate and driven. The drive shaft 1 is attached to the motor shaft. The rotation shaft is transmitted to the intermediate. To the intermediate shaft has two wheels 2, 3. Wheel 2 is fixed is static. The wheel 3 can move along the axis of the shaft. On the slave shaft is attached to the static wheel 4 with end locations of the teeth of the gear having a different distance from the center of the wheel.

Gear shifting is carried out by moving the traveling wheels 3 at the rows of teeth of the wheel 4 from one row of teeth on the other (Fig.5).

Grip switching is a way to synchronize the wheel speed and rotation speed of the motor shaft. Synchronization will be carried out with sensors installed in special areas and transmitted to the computer for data processing.

After signal processing by the computer they are sent to the inverter to increase or decrease engine rpm (each gear has its own pre-programmed range) so that it was possible to change gear. The gear ratio will be used to convert values from the motor to the value required at the wheels. Strategy switching is optimized for RGB so that all switching meets robotic system. With the help of sensors it chooses the necessary speed on the road, provides the optimal combination of efficiency, performance car and the number of shifts.

The implementation of the reverse stroke is similar, but only with the change of polarity at the motor.

New designs is the wheel with end teeth. That this part is the transition from one speed to another. This wheel has a complex shape relative to the location and size of the teeth. The teeth are located in rows and each row has a certain number of teeth.

The advantage of this constructive approach is the universality, the mass of the final product, and efficiency.

The versatility of this product ensured by the fact that it can be used not only in electric cars, but also on trucks of small and medium tonnage and passenger electric transport urban and suburban consumption.

Another advantage of this design is the low weight. Weight reduction is the fact that there is no mechanism for reverse running, as well as the small number of parts, whereby the mass of this RGB weighs much less than existing analogues.

The main drawback of this type RGB is the inability to install this product on vehicles with internal combustion engine and hybrid systems, as well as the complexity of manufacture of the end teeth of the wheel.

When the motor is directly coupled to the wheels or through the special reducer, the power is determined by the needs of private modes. That is, most of the motor exposed to partial loads, and the power is not consumed. And it affects the weight of motor, cables, power supplies. With the introduction of transmission is saved the specified characteristics of the cars, but also increases the power reserve.

4. Conclusion

So when you install the gearbox to the electric vehicle improves the dynamics of transport, optimized torque. At the same time addressed one of the main disadvantages of electric vehicles, increasing the cruising range of the electric vehicle.

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