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Automated control of process conditions during drilling with imposition of vibrations

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Abstract
New construction of vibro-drilling drive gear, which is different by high processibillity and generality, is considered in the article. The range of admissible forces of vibration is determined. Formula for determination the distance between magnets depending on the vibration force is obtained. It allows to computerize calculation of setting of suggested installation.
Key words: VIBRATIONAL DRILLING, HOLE OF SMALL DIAMETER MAKING

A lot of details applied in the machines and mechanisms of different applications have holes. They are applied in all branches of industry. To achieve the required accuracy and obtain the set quality of surface layer, the treatment is fulfilled within several passes, which reduces the productivity. The improvements may be achieved by increase of supply, rate and depth of cut.

But the purpose of increased rates of the depth and supply of cutting leads to the premature failure of the tool by virtue of its inadequate strength. It is unlikely to create soon new tool materials having increased wear resistance and strength, so other methods for increase in efficiency should be applied. Among these is the choice of new or application of already known cutting schemes for process operations, where they had not been applied yet.

In such a way realization of theoretical and experimental researches in the field of drilling cut process with imposition of vibrations is currently important [1].

To provide cutting process interrupt it is necessary that the frequency exceed drilling feed. Oscillation frequency influences the amount of cutting process interrupts during drilling. Process interrupt also reduces the temperature in the area of contact of cut down layer and tool tip and provides more qualitative supply of metal-cutting oil into the area of cutting.

From the other side cyclic loading of an instrument causes fatigue failure of the areas of material tool, which is in contact with a piece and coming off facing [2].

In such a way imposition of axial vibrations may considerably increase the drilling rate in the billets made of titanium alloys, however cyclic loads, which influence the tool durability, should be considered. In connection with this, new methods for stress calculation should be developed.

At the Engineering technologies and equipment department of South-West State University there was developed a device for vibrational drilling.
Working principle of designed device is explained in the figure 3, where the profile of device for vibrational drilling is shown.

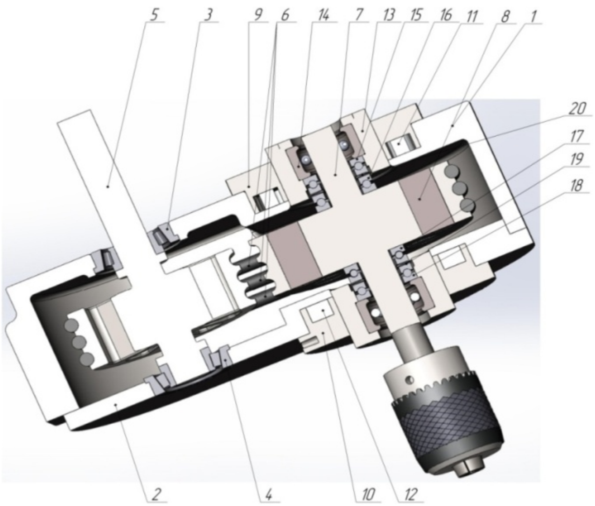

Figure 1. Device for vibrational drilling 1 – body 2 - housing cover; 3,4 – bearings; 5 - input shaft; 6 - flexible coupling; 7 - output shaft; 8 – magnets; 9, 10 – magnetic bodies; 11,12 – magnets; 13 – screw; 14 – bearing; 15,16,17,18 - axial bearings; 19,20 - springs

The tool is made of body 1 and housing cover2, where by means of bearings 3,4 there fixed an input shaft 5. Rotation of the input shaft by means of flexible coupling 6 is transmitted to the output shaft 7, where the magnets are placed 8. During rotation of output shaft the magnets interact with placed in the magnetic bodies 9, 10 magnets 11, which are placed in such a way to hold inversed polarity toward the magnets 8 placed at the output shaft 7. During interaction there occur vibrations, the frequency of which is determined by the amount of magnets 8 in the output shaft 7 and magnets 11 in the magnetic bodies 9, 10.

Vibration force is regulated by the distance between magnets 8 of output shaft 7 and magnets 11, 12 located in the magnetic bodies 9, 10, which are being regulated by means of screw on the body 1 and housing cover 2 the device for vibrational drilling and magnetic bodies 9, 10. Vibration amplitude is limited by adjusting screw nut 13, where the bearing is located 14 with the possibility of axial movement and between adjusting screw nut13 and output shaft 7 there located axial bearings 15,16,17,18, between which there located springs 19, 20 for damping of strokes between output shaft 7 and adjusting screw nut 13.

In such a way imposition of axial vibrations may considerably increase drilling rate in the billets made of titanium alloy, but cyclic loads, which influence significantly tool durability, should be considered during stress calculation of rotary cutting tools. In this connection the questions concerning the purpose of vibration modes during drilling [3] should be considered, herein the fundamental parameter is the force of applied axial vibrations of the tool, which may be determine as the difference between critical load of the drill and cutting thrust force.

Analysis of calculation methods of metal-cutting tool for stiffness during drilling showed that for calculation of critical force of the drill it is effective to apply the dependence

$$[P]_{o.} = \frac{\pi^2 \cdot E \cdot J_{\min}}{(\mu \cdot l_{вс})^2} \qquad (1)$$

where μ- is the length reduction factor; l_{dr}– drill range, mm; E - elastic module of drill material, Н/мм^2; J_{min}– minimum torque of inertia of drill section, мм^4. According to this dependence, critical axial force during drilling for various drill diameters was determined.

According to the source [4], axial cutting force during drilling is determined by dependence:

$$P_{кр} = C_p \cdot D^{q_p} \cdot S^{y_p} \cdot k_p \qquad (2)$$

where C_p, q_p, y_p are the coefficients and exponents of power for calculation of axial force during drilling and boring ; *D* – drill diameter, mm*; S* – averaged value of tool supply, mm/r; k_p-- compensation factor, which considers the influence of mechanical properties of the material on the cutting force.

Dependency diagrams of critical load and axial force during drilling are represented in the figure 2-3. For convenience of results report, the range of drill diameters was divided into 2 parts (1-5 mm) (5-20 mm).

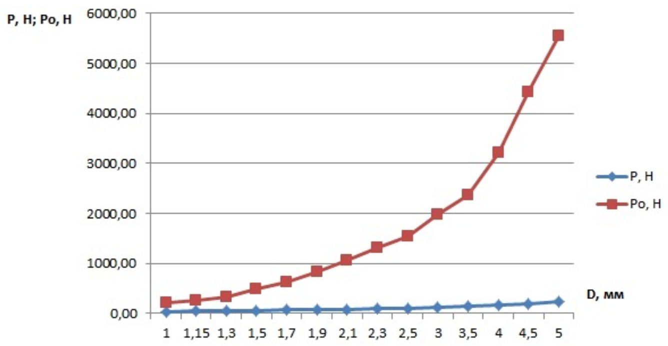

Figure 2. Dependency diagrams of critical load and axial force for the diameters from 1 to 5 mm during drilling: P – critical force during drilling; P_o –axial force during drilling.

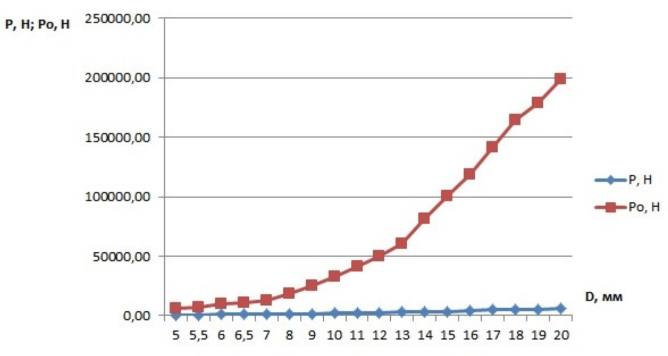

Figure 3. Dependency diagrams of critical load and axial force for the diameters from 5 to 20 mm during drilling: P – critical force during drilling; P_o –axial force during drilling.

In such a way, we obtained the range and maximum value of acceptable vibration forces.

Fulfilled calculation will allow to choice the parameters during vibrational drilling taking into account the rigidity of rotary cutting tools. Knowing of the form and magnetization intensity of permanent magnet allows to replace it with equivalent system of magnetizing electric current for calculations. Such replacement is possible both during calculation of magnetic-field patterns and during calculation of forces, which affect the magnet from the side of external field.

The scheme of interaction of permanent magnets is represented in the figure 4.

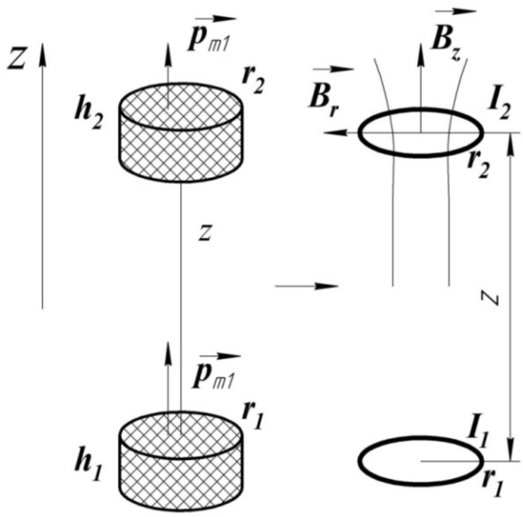

Figure 4. The scheme of interaction of permanent magnets

Let us fulfill the calculation of interaction of two permanent magnets. Let the magnets have cylindrical form, their radii are marked as r_1 and r_2, thicknesses h_1, h_2, magnet axes coincide, the distance between magnets are denoted as *z*, and it is considered to be larger than the magnets size.

Appearance of the interaction force between magnets is explained by traditional way: one magnet creates magnetic field, which affects the second magnet.

For calculation of the interaction force we will mentally replace the magnets with uniform magnetization J_1 and J_2 by circular current loop, flowing along the side face of cylinders.

Current strengths we will express in terms of magnetization intensity of magnets and their radii are equal to magnet radii.

$$I_{1,2} = J_{1,2} \cdot h_{1,2} \qquad (3)$$

Let us decompose the induction vector $\vec{B}$ of magnetic field, which is being created by the first magnet in the area of location of the second magnet, into the two parts: axis $\vec{B_z}$ directed along the magnet axis and radial $\vec{Br}$ - perpendicular to it.

To calculate joint force, affecting the ring, it is necessary to divide it into small elements $I\Delta l$ and to sum Ampere forces, affecting each element.

As the suggested system has axial symmetry, then the module of radial component is permanent in all points of ring current of the second magnet. Consequently force projection affecting the second magnet taking into account the left-hand rule is determined under the formula:

$$F = -I_2 \cdot B_r \cdot l = -I_2 \cdot B_r \cdot 2\pi \cdot r^2 \qquad (4)$$

Positive direction of the force corresponds to the sticking of magnets, positive current - anti clockwise.

Magnetic field, which is created by the first magnet, is equivalent to the field of circular current loop, Laplace's law and superposition theorem allow to calculate field density $\vec{B}$, created by arbitrary system of electric currents in the space arbitrary point. Within the limits of made approximations (z << r, h), axial component of the field is determined under the formula:

$$B_z = \frac{\mu_0 \cdot p_{m1}}{2\pi \cdot (r^2 + z^2)^{\frac{3}{2}}}, \qquad (5)$$

where

$p_{m1} = I_1 \cdot S_1 = J_1 \cdot h_1 \cdot \pi \cdot r_1^2 = J_1 \cdot V_1$ – magnetic moment of the first magnet;

V – magnet volume, м^3;

μ_0 – magnetic constant.

Radial component of the field we will find with the help of magnetic flow, in the place of location of the second circular contour under the following formula:

$$B_r = -\frac{r_2}{2} \cdot \frac{\Delta B_z}{\Delta z} = \frac{\mu_0 \cdot p_{m1}}{4\pi \cdot z \cdot (r^2 + z^2)^{\frac{3}{2}}} \cdot r_2 \qquad (6)$$

Inserting the expression for radial component of the field, we will obtain the formula for calculation of force of interaction of two magnets in the considered case:

$$F = -I_2 \cdot 2\pi \cdot r_2 \cdot B_r = \frac{\mu_0 \cdot p_{m1} \cdot p_{m2}}{2\pi \cdot z \cdot (r^2 + z^2)^{\frac{3}{2}}}$$

(7)

where

$p_{m2} = I_2 \cdot S_2 = J_2 \cdot h_2 \cdot \pi \cdot r_2^2 = J_2 \cdot V_2$ – is the magnetic moment of the second magnet.

Mathematical manipulation given in this article allowed to computerize the calculation of parameters of device setting to provide the conditions for forming of holes with imposition of vibration.

Screenshot of program window, which allows to calculate technological parameters during drilling with impositions of vibrations, is represented in the figure 4.

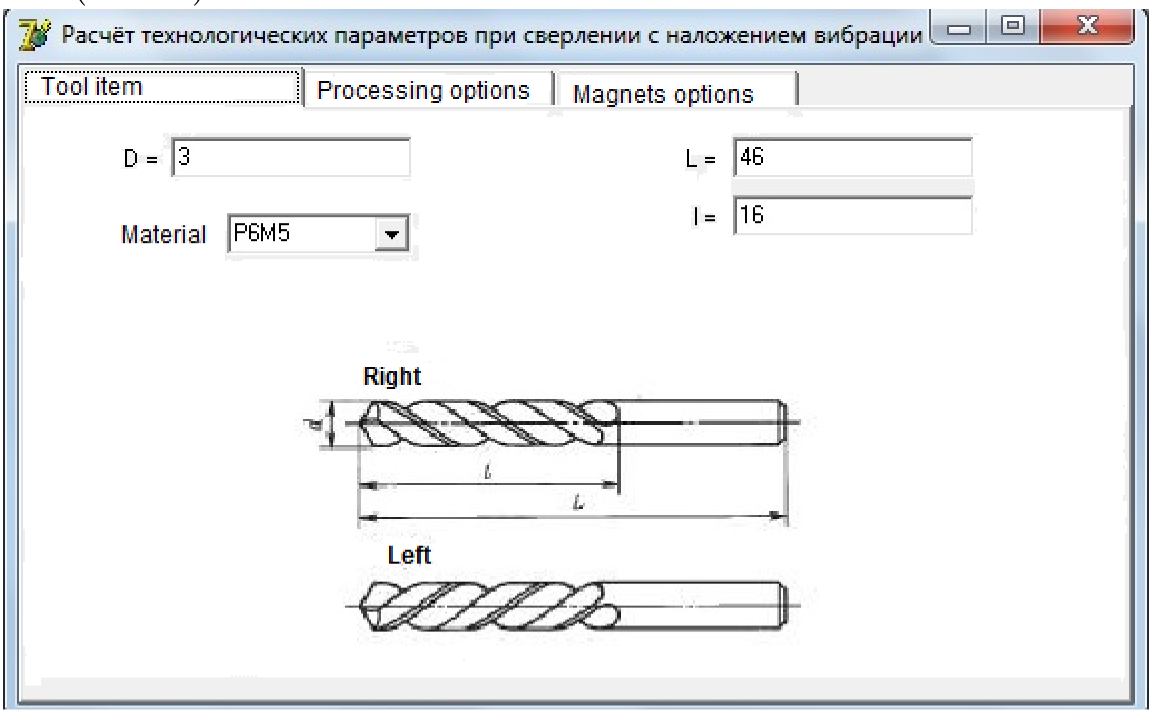

Figure 4. Interaction pattern of permanent magnets

In the first dialog window there inputted parameters of cutting tool. Further processing options are entered. In the third dialog window there inserted magnet options, after this there activated calculation process to obtain resulting data.

The article considers the new construction of vibro-drilling drivegear, which is distinguished by high processibillity and generality, this will allow to reduce the quantity of passes during drilling and increase processibillity up to 10-15%. The range of permissible axial forces of vibration is defined in order to provide efficient parameters of cutting. The formula for determination of the distance between magnets depending on the vibration force, which allows to computerize the calculation of setting of suggested device, is obtained, this will reduce time spending on technological preparation of drilling process.

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