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DETERMINING THE GEOMETRIC PARAMETERS OF A SHEARED LAYER IN DRILLING OF NONFERROUS METALS AND ALLOYS WITH THE USE OF AXIAL VIBRATIONS

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The problem of determining the kinematic parameters of a vibrodrilling device and the geometric elements of a sheared layer produced in the course of treating nonferrous metals and alloys by drilling with the use of axial vibrations is considered. Relationships between the dimensions of an element of a chip and the frequency of the axial vibrations are found.
Keywords: *metal cutting tool, vibration cutting, nonferrous alloys, neodymium magnets.*

Parts made of nonferrous metals and alloys, such as the elements of fuel equipment, throttles, couplings, spray nozzles, and fuel pumps, are used in the oil-and-gas and chemical branches of industry. These parts often possess deep holes of low diameter (as little as 5 mm) with drilling depth $L \geq 5d$.

Drilling and electro-chemical and electro-erosion broaching are used to create deep holes of low diameter in parts; laser and electron-beam broaching of holes is also used [1].

Vibration drilling, performed with the use of special production equipment, such as vibration exciters (ultrasonic, mechanical, and hydraulic) [2, 3] is among the most promising methods of increasing the productivity of the process of creating holes.

A vibration plant based on permanent magnets (Fig. 1) was created to reduce the cost of treatment.

By comparison with previously known designs, the present plant is distinguished by simplicity of design and the absence of any need for electric power.

Required regimes of processing different materials may be created by varying the number of magnets and the transmission ratio of the planetary transmission [4].

The required amplitude and frequency of the vibrations must be determined in order to calculate the kinematic parameters of a designed vibration excitor. For this purpose, it is necessary to first estimate the parameters of a chip produced in the course of drilling.

The depth of a sheared layer for a twist drill in a single revolution may be numerically set as

$$t = S_{rev}/2,$$

where S_{rev} is the feed rate, mm/rev.

In order to divide a chip into individual segments, the amplitude of the vibrations of a twist drill with two basic cutting edges must be equal to one-half the feed rate S_{rev}. Consequently, the transverse dimension of an element of a chip will be numerically equal to twice the thickness of the sheared layer t.

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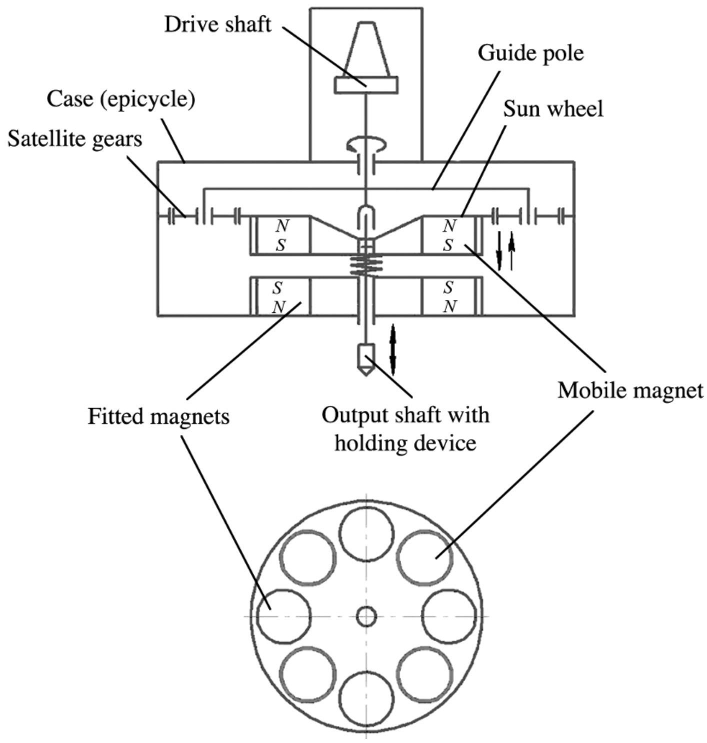

Fig. 1. Schematic diagram of device for vibration drilling.

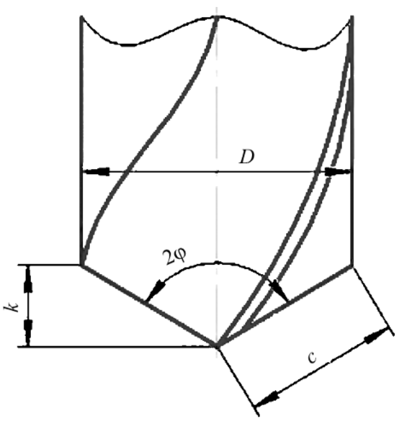

Fig. 2. Axial profile of drill.

To determine the parameters of a sheared layer in vibration drilling, the geometric parameters of the axial profile of the drill must be determined based on the ratio of the sides of a right triangle (Fig. 2),

$$\tan(2\varphi/2) = d/2k,$$

where d is the radius of the drill, mm; k, depth of cutting part of drill, mm; and 2φ, angle of conical cutting part of drill (twice the angle in design).

Consequently,

$$k = \frac{d}{2\tan(2\varphi/2)}.$$

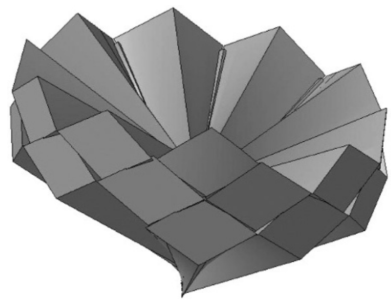

Fig. 3. Visual representation of elements of a chip in vibration drilling.

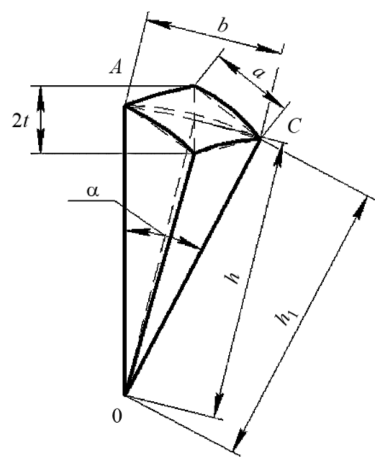

Fig. 4. Geometric parameters of an element of a chip.

The length of the cutting edge of the drill c (mm) is determined by the formula

$$c = \sqrt{\frac{d^2}{2 - 2\cos 2\varphi}}.$$

Under the effect of the periodic constant oscillations created by the vibration excitor, the drill divides the chip into segments, which makes it possible to remove the elements of the chip without halting the drilling process.

Setting the number of axial oscillations that the drill may experience under the effect of vibrations in a downward transit of the cutting part of the drill equal to k (in a mathematically idealized form), we obtain the following form of the elements of a chip (Fig. 3).

We then determine the geometric parameters of the elements of a chip (Fig. 4):

$$\alpha = 360°/n_k,$$

where n_k is the number of oscillations of the drill in a single revolution.

Assuming that the form of an element of a chip is close to that of a regular pyramid, the height of an element of a chip h (mm) may be determined from the formula

$$h = D/(2\cos\varphi).$$

The lateral side of an element of a chip may be expressed by the formula

$$h_1 = \sqrt{h^2 + (b/2)^2}.$$

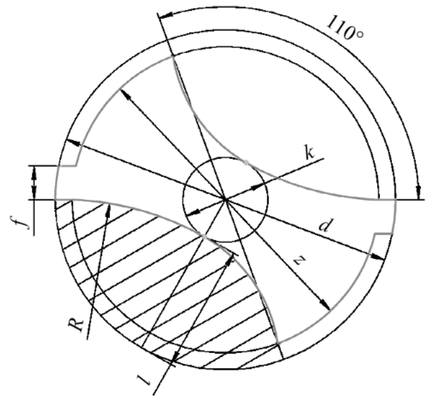

Fig. 5. Cross-sectional profile of drill.

The transverse dimension b (mm) may be found as follows:

$$b = \sqrt{(h^2 - h_1^2)/2}.$$

The dimension b is decisive for assuring removal of the elements of a chip out of the cutting zone; that is, the possibility of placing an element of a chip in the groove of the drill (Fig. 5) and its extraction from the cutting zone depend on the magnitude of b.

If the dimension l is considered decisive for possible placement of an element of a chip with transverse dimension b, the following relationship is found:

$$b = D\sqrt{\frac{1-\cos(360°/V)}{1-\cos 2\varphi}}, \quad b < l.$$

In turn, the magnitude of l may be determined with acceptable error from the formula

$$l = (d - K)/2.$$

Consequently,

$$D\sqrt{\frac{1-\cos(360°/V)}{1-\cos 2\varphi}} < \frac{d-K}{2}.$$

Following transformation of the formula, we obtain

$$V = \frac{360°}{\arccos(1-(2-2K/D)^2 \sin^2\varphi)}.$$

The parameter V determines the degree of fragmentation of a chip into elements and may be used to arrive at a preliminary estimate of the probability of successful removal of an element of a chip from the processing zone in the course of deep drilling of alloys made of nonferrous metals.

Depending on the selected design of a drill (ordinary or enlarged core K), the dimension of an element of a chip may vary within a certain range. Since processing with the use of vibrations is proposed, let us also consider a variant of processing by drills with enlarged core [5]. Based on the parameters of drills (GOST 4010–77), dependences of the possible magnitude l of an element of a chip on the parameters of the drill may be obtained and, correspondingly, the minimal number of elements of a chip in a single revolution of the drill determined (cf. Table 1).

Consequently, shattering of a chip into at least 8–9 parts in a single revolution of the drill (depending on the diameter of the hole) is necessary to form a chip with magnitude l of its elements not greater than the design values.

TABLE 1. Parameters of Drills (GOST 4010–77) of Diameter 1–5 mm and Elements of Chips

Parameter	Value								
With enlarged core									
Diameter of drill d, mm	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Dimension of core k, mm	0.28	0.37	0.47	0.56	0.63	0.71	0.8	0.85	1.0
Transverse dimension of chip groove l, mm	0.35	0.57	0.77	0.97	1.19	1.39	1.6	1.83	2.0
Number of elements in revolution of drill, n	8.98	8.27	8.21	8.09	7.91	7.88	7.85	7.74	7.85
With normal core									
Diameter of drill d, mm	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Dimension of core k, mm	0.22	0.28	0.35	0.4	0.5	0.55	0.64	0.7	0.75
Transverse dimension of chip groove l, mm	0.39	0.61	0.83	1.05	1.25	1.48	1.68	1.9	2.13
Number of elements in revolution of drill, n	8.05	7.73	7.6	7.48	7.54	7.45	7.48	7.44	7.39

Thus, the required frequency of vibrations of the newly designed vibration excitor based on permanent magnets – not less than nine pulses in a single revolution of the drill – has been determined; moreover, to form the structure of the process of extracting a chip in a spiral (cf. Fig. 3) with shift in the step of the placement by one-half an element of a chip, the number of elements must be a multiple of 0.5 (whence removal of the elements of a chip will proceed uniformly with each revolution).

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