**DEVELOPMENT OF SOFTWARE FOR MODELING THE DYNAMIC SYSTEM OF A BORING MACHINE IN CONDITIONS OF INTERRUPTED CUTTING**

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The vibration of the tool during a thin boring affects the precision of the geometric form and the quality of the processing surface.

In this case, relatively low-frequency oscillations of the tool to in a greater degree affect the appearance of the shape error and the formation of volatility, and high-frequency oscillations affects the formation of surface roughness.

The practice of using existing methods of supplication the vibration of the tool has shown that these methods do not allow to provide requirements for processing quality.

The detail with a continuous opening of the gap was considered (Fig. 1). The scheme of boring the hole with a continuous gap (Fig. 2) was represented by a single-mass oscillation system whose oscillations are described by a nonuniform differential equation with constant coefficients.

The motion of a linear system is described by a differential equation.

$$m\ddot{y}(t) + \mu\dot{y}(t) + ky(t) = P(t) \qquad (1)$$

here *m* – reduced mass; $\mu$ – reduced damping coefficient; *k* – reduced rigidity of the system; *P(t)* – disturbing force.

The specificity of the solvable problem is that the perturbing force is a non-harmonic, but a piecewise constant function graphically which can be represented as the periodic action of rectangular pulses (Fig. 3).

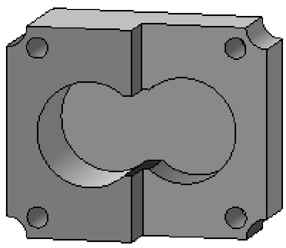


Fig.1 Detail with continuous gap opening

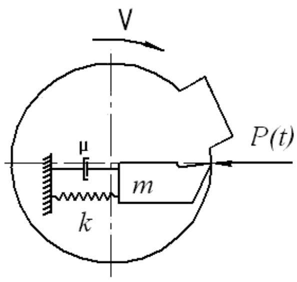



Fig.2 Boring scheme

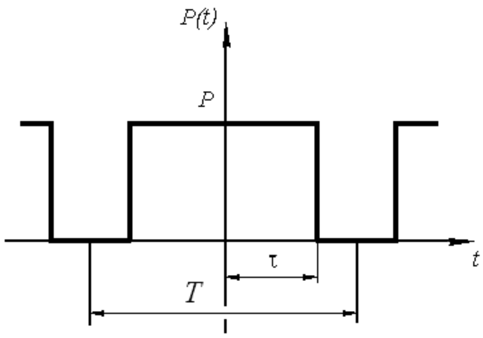



Fig.3 Schedule for periodic disturbing force

Such a form of perturbing force can be presented in the form of a Fourier trigonometric series.

$$P(t) = \frac{P\tau}{2T} + \frac{2P}{\pi}\sum_{i=1}^{\infty}\frac{1}{i}\sin\left(\frac{\pi i\tau}{T}\right)\cos\left(\frac{2\pi it}{T}\right) \qquad (2)$$

here $i$ – harmonic number; $2\tau$ – cutting time; $T$ – period of disturbing force; $P$ – radial component of cutting force.

Using the method of variation of arbitrary constants, the solution of equation (1) will be sought in the form (3), which corresponds to the solution of a homogeneous equation.

$$y(t) = C_1(t)e^{-\varepsilon t}\sin(\omega t) + C_2(t)e^{-\varepsilon t}\cos(\omega t) \tag{3}$$

$$\varepsilon = \frac{\mu}{2m};\ \omega = \sqrt{\frac{k}{m} - \frac{\mu^2}{4m^2}};\ p = \frac{2\pi}{T}$$

here $C_1(t)$ and $C_2(t)$ – in this case the variables; $\varepsilon$ – damping system; $\omega$ – own frequency; $p$ – frequency of disturbing force.

After a series of transformations, we obtain a mathematical model of the oscillations of a system that is under the influence of pulses of cutting forces that follow the gap between them.

In practice, to compensate for flexural oscillations, the structure of the borshers with elastic elements is used (Fig. 4), which provides, along with the high quality of the processing of the reduction of shock overload, acting on the tool.

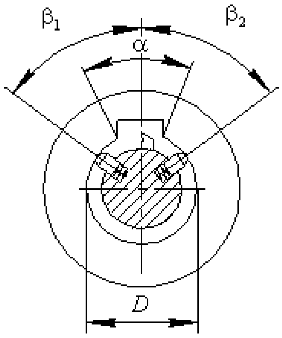



Fig.4 Constructive scheme of boring bar with elastic elements

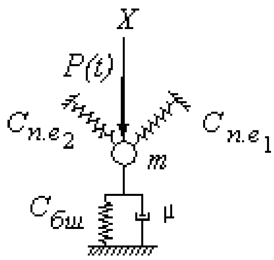



Fig.5 Calculating scheme

The accuracy and quality of processing by such borschtangs is achieved through the choice of structural parameters, namely, the stiffness of the elastic elements $C_{n.e}$ and the angle of the placement of the elastic elements relative to the β cutter, at which the amplitude of oscillation of the borscht will be the smallest, in comparison with the boring by standard borshtagami. Thus, the problem of choosing the optimal structure of the bartenders, namely, the values and β, at which the amplitude of oscillations $A$ does not exceed the amplitude $A1$, arises when boring the intermittent holes with birstangs without elastic elements.

For this purpose, a single-mass oscillation system described by a nonuniform differential equation with variable coefficients was considered.

$$m\ddot{x}(t) + \mu\dot{x}(t) + C_{n.e}(t)x(t) = P(t) \tag{4}$$

The specificity of the solved is a periodic change not only of the perturbing force $P(t)$, but also of the stiffness of $C_{n.e}(t)$ for one tool turning, so the dynamic system becomes a system with variable characteristics.

To solve this equation, we used a numerical method, a finite difference method. The original differential equation is replaced by the difference equation. In this case, the function describing the fluctuations *x(t)* was replaced by the approximate function *X(t).*

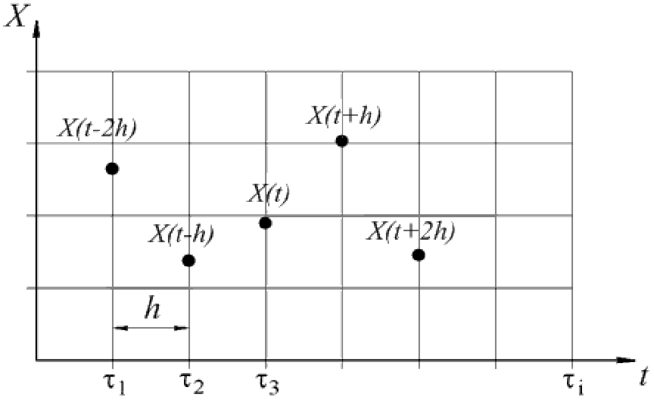



Fig. 4 Interpolation problem scheme

Approximation of the first derivative:

$$\dot{x}(t) = \frac{X(t) - X(t-h)}{h} \tag{5}$$

Approximation of the second derivative:

$$\ddot{x}(t) = \frac{X(t+h) - 2X + X(t-h)}{h^2} \tag{6}$$

After replacing the derivatives, in the initial differential equation (4), the algebraic expressions (5) and (6) obtained the equation of the form:

$$X(t+h) = \left[\frac{P(t)}{m} - \frac{X(t-h)}{h^2} - X(t)\left(\frac{k}{m} - \frac{\mu}{mh} - \frac{2}{h^2}\right)\right] \Big/ \left(\frac{1}{h^2} + \frac{\mu}{mh}\right) \tag{7}$$

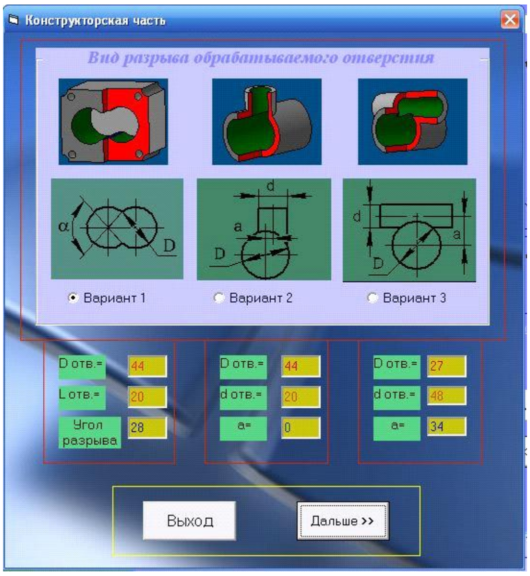
here $h$ – step of the difference scheme.

Thus, the value of the approximate function *X(t+h)* can be calculated for any time t depending on the values of this function for the two previous iterations *X(t)* and *X(t-h).*

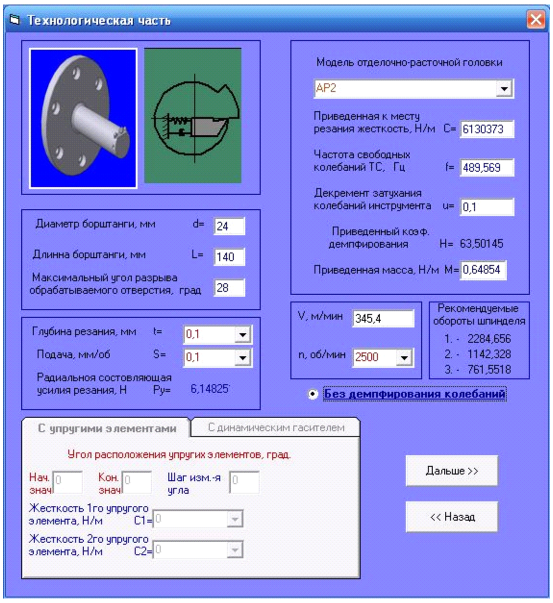
It should be noted that the problem of numerical determination of the derivative is associated with the procedure for choosing the value of *h*, which is far from obvious. Therefore, in each case, additional steps are needed to test the correctness of the choice of the step for numerical differentiation.

The calculation of the bending oscillation amplitudes of the bartenders requires a large number of calculations and without the use of computers is not feasible. Therefore, a program of calculation in the programming language *C++* was developed.

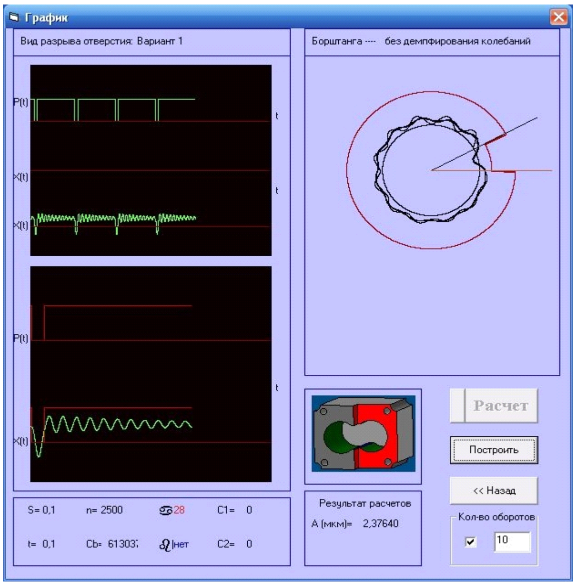
The developed program allows to determine the value of the amplitude of the oscillation of the tip of the boring cutter, even at the stage of development of the technological process of processing parts with interrupted holes. The program also calculates the cutting modes and cutting efforts, but does not require additional software.



a) Window - "Design part"



b) Window - "Technological part"



c)Window - "Graphics"

Fig. 5 The program mathematical modeling of boring

## References


1. Динамика станков. / В.И. Попов, В.И. Локтев – К. : Техніка, 1975. –136 с.