Equipment for improving the quality of finishing processing in floating workshops

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Abstract. The article discusses the results of research and development in the direction of modernization of technological equipment for high-quality processing of parts in floating workshops by increasing vibration resistance and reducing harmful effects from the external environment (sea waves) and neighboring operating equipment. Traditional vibration isolation mounts of machines cannot be used in floating workshops due to their loss of functioning under the conditions of the floating base pitching and horizontal displacements under its influence. New effective constructive options for the vibration protection device of precision machines and supports with active vibration isolation are described, which allow automatic control of damping of the vibration isolating support of the machines under various types of external influences.

1. Introduction
Currently, for the bases installation of high-precision, vibration-sensitive machines, as well as many general-purpose machines, preference is given to elastic vibration isolating supports. With this method of installation, the installation of the machine is carried out many times faster, the quality of the machined surfaces on precision machines is improved, noise and dustiness of the air in the workshops are reduced. Such supports are very convenient when installing machines on the floors of the upper floors of buildings, or when rearranging machines in connection with a change in the technological process, etc.

Supports of various designs are produced in Russia and abroad. Most often - these are: rubber-metal supports of increased flexibility, located on the floor of the workshop; pneumatic series "L" and "K"; series "M" - for coordinate measuring machines and grinding equipment.

The machines can also be installed on a foundation concrete block connected to the bed, which is supported by rubber mats; on a foundation block supported by spring supports and dampers. In such installation options, the basis for the elastic supports are concrete boxes founded on the ground or floors [1, 2]. The choice of elastic elements in this case is significantly difficult, and with insufficient careful selection or when changing the operating mode of the machine, elastic elements can even cause an increase in vibration. In cases where it is required to reduce the roughness of the processed surface, the most rational options can be foundations with spring vibration isolation using coil springs, cable, spiral cable and cable rubber vibration isolators, as well as mats and gaskets spiral cable, rubber elastomeric and rubber.

This foundation improves the accuracy of the grinding machine installed on soft ground, protecting the supporting system from possible vibrations and deformations.
The use of various elastic supports (Figure 1, a-h) allows obtaining different natural frequencies of vertical vibrations of the machine $f_0$:

1) for $f_0 \geq 25$ Hz - gaskets made of rubber, cork, felt, plastics, etc.;
2) for $25$ Hz $\geq f_0 \geq 10$ Hz - rubber and rubber-metal bearings in which rubber works in compression;
3) $10$ Hz $\geq f_0 \geq 5$ Hz - rubber-metal supports, in which rubber works in shear, supports from a volumetric metal mesh;
4) for $f_0 \leq 10$ Hz - spiral or sheet steel springs.

The natural frequency $f_0$ is determined by the formula \[ f_0 = 5 \sqrt{\frac{k}{\Delta_{st}}}[Hz] \]

where $k$ is the ratio of the stiffness of the support during vibrations to the stiffness under static loading (dynamic coefficient); $\Delta_{st}$ - static deformation of the supports from the weight of the machine.

The wrong choice of vibration-isolating supports can lead to increased vibrations if it turns out that $f_0$ and the frequency of the disturbing force $f$ are close. To ensure passive vibration isolation (i.e., isolation of the machine from vibration of the base) of high-precision, including grinding machines, the $f$ values must be determined as a result of special studies, not excluding the possibility of improving the structures of existing vibration-isolating supports and the development of fundamentally new, more rational options for their execution. With an elastic installation, the machine is isolated from the external environment. At the same time, the influence of external disturbances on the performance of the machine is less, but the level of displacements and oscillations from disturbances acting in the machine is greater.

Figure 1. Vibration isolation devices of modern machines:
(a), (b) - vibration isolators with spiral springs; (c), (d), (e) - cable, spiral cable and cable rubber vibration isolators; (f), (g), (h) - spiral-rope, rubber-elastomeric and rubber mats and gaskets

(a) (b) (c) (d) (e) (f) (g) (h)
Different installation methods provide different degrees of machine sensitivity to base vibrations and disturbances in the machine. The lower the natural vibration frequencies, determined by the stiffness of the supports and the mass of the system, the higher the degree of vibration isolation. At the same frequencies of natural vibrations of the system, the greater the mass of the system and the stiffness of the supports, the lower the level of vibrations caused by the operation of the machine mechanisms. In accordance with this, the most effective, but also the most expensive means of vibration isolation used for particularly precise machines are foundations on springs, and the cheapest, providing a satisfactory degree of vibration isolation for most medium-sized machines, are elastic vibration isolating supports [4].

2. Main part

However, none of the above types of vibration-isolating supports and devices is acceptable in floating workshops for precision machine tools due to the features of operation under significant external influences and the possibility of horizontal displacements of equipment when the floating base is pitching.

On the decks of floating workshops, as a rule, fixation of the machines is provided by a foundation (Figure 2, a, b), which does not guarantee a sufficient level of vibration isolation due to significant vibrational influences from both external equipment and the external environment through the floating base and the deck surface.

![Figure 2: Examples of equipment installed on the foundations and ridgepoles on floating workshop](a) - horizontal boring machine; (b) - flat grinding machine SPC-20c

The traditional vibration isolation mounts of the machines, analyzed earlier, cannot be used in floating workshops due to the impossibility of their functioning in conditions of the floating base pitching and horizontal displacements under its influence.

Taking into account the theoretical and experimental research carried out at Sevastopol State University, a vibration-isolating device has been developed (Figure 3, a). It allows, on the basis of tested samples of vibration-isolating supports (Figure 3, b) and a vibration-isolating device (Figure 3, c), adapted to the conditions of floating workshops, to provide automatic vibration protection of the grinding machine [5, 6].

A metal-cutting machine for precision machining (circular, flat grinding, boring, etc.) is installed on the common deck surface of the machining section of the floating workshop on four vibration-isolating supports 1 [7], made in the form of a base with a rubber element and installed in the axial hole a cylinder with a working fluid, a piston with a rod 2, located and fixed in the holes of the frame 3 of the machine 4 (Figure 3, a). Vibrations influence the machine bed 4 and transmitted through the support 1 to the cylinder with the rod 2, which provide vibration damping, that is, mechanical and
hydraulic damping. To prevent shifting of the machine, the upper part of the rod 2 is pressed by the clamp 5, placed on the axis 6 of the rack 7. The rear part of the clamp 5 interacts with the rod 8 of the anti-vibration hydraulic cylinder 9, fixed on the surface 10 of the deck together with the rack 7. The lower chamber of the anti-vibration hydraulic cylinder 9 is connected with hydraulic pump 11, powered by an asynchronous electric motor 12. However, external influences are not constant in terms of both frequency and amplitude. To eliminate the harmful effect of these vibrations on the machining process, in particular, to reduce waviness during grinding of parts, vibration sensors 13 installed on the guides of the bed 3 convert vibrations into electrical signals, which are transmitted through an analog-to-digital converter (ADC) to the input of the ArduinoUNO programmable logic controller. The specified controller through a digital-to-analog converter (DAC) and amplifier (A), as well as an Altivar frequency converter (FC), by adjusting the speed of the electric motor 12 and pump 11, respectively increases or decreases the pressure in the counter-flow cavity of the anti-vibration hydraulic cylinder 9, thereby increasing or decreasing the stiffness of the vibration-isolating support by acting through the clamp 5 on the rod 2. The ArduinoUNO controller is adjusted in such a way that when the vibration sensors 13 appear at the output of low-frequency high-amplitude vibrations that go beyond the calculated (normal), corresponding output signals are generated controller, allowing to increase the rigidity of the vibration mount by increasing the pressure of the working fluid in the anti-vibration hydraulic cylinder 9 by increasing the pressure in the pressure pipe from the pump 11 with the 12 electric motor and the Altivar.

Figure 3. Diagram of a device for automatic vibration protection of a machine in a floating workshop: (a) based on vibration-isolating supports (b) and a vibration-isolating device (c)
The developed devices allow:
- to provide automatic control of damping of the vibration-insulating support of a metal-cutting machine under external influences, including influence of water surface;
- to improve the dynamic qualities of the machine and the reliability of its vibration protection when working in floating workshops;
- to provide the ability to adjust the control actions on the stiffness of vibration isolating supports in a wide range by using the modern ArduinoUNO platform, which has 14 digital inputs and 6 outputs, a crystal oscillator, a USB connector, a power connector, an ICSP connector and a reset device;
- to improve the quality of parts processing by reducing the errors of their shape, reducing the roughness and waviness of the surface by reducing vibration effects, the damping of which is facilitated by a vibration-insulating mechanical-hydraulic support with automatic stiffness control depending on signals from vibration sensors located at a small distance from working area of the machine.

3. Conclusion
Thus, as a result of the research and development, effective options for the construction of automatic vibration protection devices for precision machines were obtained [8, 9], which make it possible to automatically control the damping of the vibration isolating support of the machines under external influences, including from vibrations of the water surface and neighboring operating equipment. The proposed devices make it possible to improve the quality of parts processing [10], by reducing the errors of their shape, reducing the roughness and waviness of the surface by reducing vibration effects, the damping of which is facilitated by a vibration-insulating mechanical-hydraulic support with automatic stiffness control depending on the magnitude of the signals of vibration sensors located at a small distance from working area of the machine.

In further developments, one should take into account the need for additional equipment of such machines with special ridgepoles in the form of rods with damping elements attached to the bed and deck. In addition to the measures proposed above, in the conditions of floating workshops, it is possible to use high-precision CNC machines equipped with adaptive control systems built on the basis of optimal models with a stochastic process controller.

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