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Vibroacoustic Efficiency Evaluation of Anti-Vibration Piping Support for Engineering Systems of Multi-Storey Buildings

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Vibroacoustic Efficiency Evaluation of Anti-Vibration Piping Support for Engineering Systems of Multi-Storey Buildings

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Abstract. The causes of low-frequency noise in high-rise building pipelines are studied. Sources of increased vibration of pipeline systems are identified. The analysis of methods of damping increased vibrations of pipelines is conducted. A description of the pipeline support structures used in the field of building construction and special anti-vibration supports is given. The advantages and disadvantages of the designs of anti-vibration supports of pipeline systems are identified. A method for improving the existing anti-vibration support consisting of all-metal elastic-damping elements pressed from spirals of wire is proposed. An anti-vibration support, consisting of a body and sealed capsules filled with a damping fluid, was developed. The design of the anti-vibration support, which allows adapting to the vibration mode due to the displacement of the pipeline relative to the support body and the redistribution of the damping fluid pressure in the capsules, is presented. The effectiveness of the proposed design support was confirmed experimentally.

1. Introduction
The source of increased vibration, in most cases, is low-frequency pressure pulsations of the fluid, which leads to accelerated destruction of piping systems, equipment and creates low-frequency noise, which has a negative impact on the person. Therefore, methods to reduce vibration of pipelines require comprehensive study [1].

The main causes of the occurrence of fluid pulsations are disturbances of a hydropercussion nature that occur when starting and stopping pump units, opening and closing shut-off and control valves. The causes of increased vibrations cannot be completely eliminated; therefore, it is necessary to develop methods for reducing the vibration of piping systems.

Many studies [2-18] are devoted to the study of vibration damping, but the question remains relevant to this day. Many researchers pay special attention to pipeline supports and their location.

2. Methods
To date, there are different types of supports. They are divided into types depending on two main characteristics [19,20,21]:

1) Mobility:
    a) movable (sliding);
    b) fixed.
2) Installation option:

a) ordinary;
b) suspended.

The fixed supports of the pipeline are designed to firmly fix the pipeline in a certain position and reduce the load, vibration and pulsation. The main type of fastening of the pipeline to the support is welding.

Movable or sliding supports are designed to compensate for the vertical loads of the pipeline. The supports of this design do not interfere with horizontal (longitudinal and transverse relative to the axis of the pipeline) movements of the pipeline arising from the thermal expansion of the walls of the pipeline. The movable supports have a rigid base and a support element that provides horizontal movement of the pipeline, such as a yoke, roller block or a sliding part. Clamp and roller supports allow movement of the pipeline only along its axis. To improve the friction properties of moving parts, special gaskets are installed, for example, paronitic ones [19,20,21].

Suspended pipe supports are of two types: spring and rigid. They are designed to secure the pipeline, compensate for loads on it and reduce vibration. Spring support is used for pipelines, both vertical and horizontal strip [19,20,21].

The supports presented above are mainly designed to compensate for the loads of pipelines and, to some extent, reduce vibrations, but this is insufficient, therefore, a number of researchers [5-10] paid attention to the development of special supports to reduce pipeline vibrations.

The work of Begaevoy Zh. P. [5] is devoted to the development of elastic-damping elements and their application to reduce vibrations of equipment and systems of nuclear power plants.

The forms of natural oscillations and their frequencies can be changed by adjusting the rigidity of the suspensions of the pipeline. Fluctuations of pipelines occur simultaneously in all planes, so the use of supports with the ability to change the stiffness in different directions has its advantages. To realize this possibility, it is proposed in [5] to replace rubber elastic elements with elastic damping elements pressed from spirals with ultrathin wire. The design of the described support is shown in Figure 1.

Figure 1. Support with adjustable stiffness [5].

This method consists in regulating the stiffness of the supports by changing the position of the adjusting sleeves. For various deformations, the required stiffness of the supports is adjusted in different radial directions. This allows you to influence the vibration patterns of the pipeline system, which facilitates the detuning from the resonances of the spatial pipeline systems [5].

In [6], it is also proposed to use a damping element as an anti-vibration gasket. The pipeline is fixed channel element with flanges turned inward, and two metal straps holding the gasket and pipeline.

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In the patent [7] the design of the pipeline support is presented, consisting of a lodgement secured by compression springs with studs inside, where the lower end of the stud is rigidly fixed, and the upper end provides height adjustment. The disadvantages of this support are the absence of the possibility of horizontal movement of the pipeline, does not dampen the vibration of the pipeline arising from the impact of shock loads.

These disadvantages are eliminated in [8]. Anti-vibration support of the pipeline has friction gaskets under the elastic elements, which do not interfere with the possibility of slippage of the stand relative to the base. However, this design supports has a lot of fasteners and elements, which increases the complexity of maintenance and reduces reliability. This deficiency is peculiar to many anti-vibration supports.

The use of anti-vibration supports will reduce pipeline vibrations, which will increase the service life of technological systems and reduce the likelihood of various negative consequences of pipeline vibrations.

3. Results

The main disadvantages of the method proposed in [5] are the complexity of the design, limited functionality and the need to detuning from the resonance by a special adjustment manually. The remaining anti-vibration supports considered have similar disadvantages. Therefore, there is a need to improve the existing structures of anti-vibration supports or to develop new ones.

The task of the proposed support design is the adaptation of elastic elements to the resulting vibration and, therefore, automatic detuning from resonant modes. To this end, it is proposed to replace the elastic-damping elements extruded from the spirals of the ultra-thin wire with hermetic capsules made of plastic material with a damping fluid. The design of the proposed support is presented in Figure 2.

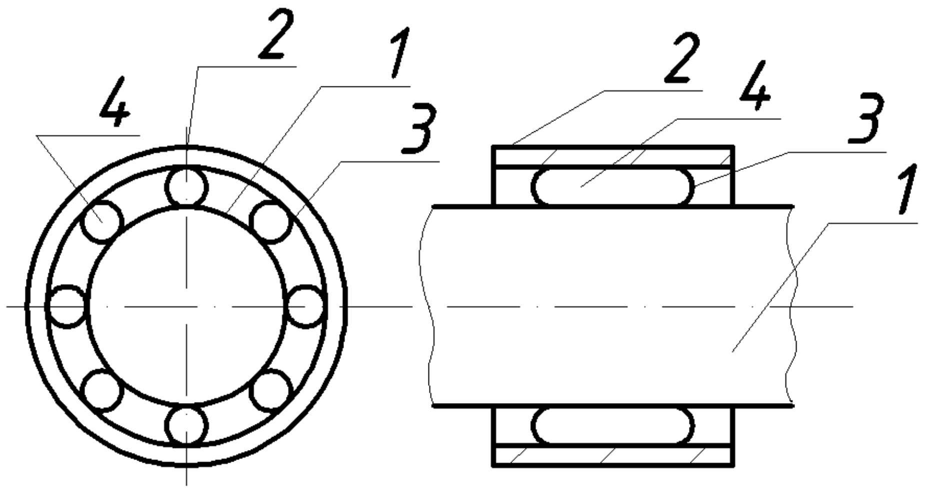

Figure 2. Anti-vibration pipe support.

The anti-vibration support consists of a collapsible body 2, sealed capsules 3 of plastic material, a damping fluid 4. Capsules 3 are fixed between body 2 and pipeline 1. When vibration occurs, an asymmetrical displacement of pipeline 1 relative to the support body 2 occurs. In this case, there is a “flow” without slipping capsules 3 between the pipeline 1 and the casing of the support 2. The flow of the capsule is accompanied by a change in its shape, due to the asymmetry of the emerging vibration forces. Consequently, a redistribution of the pressure of the damping fluid in the capsule occurs, which leads to rapid changes in the rigidity of the support in different directions and does not allow resonance to appear. Thereby an automatic detuning of the resonant mode occurs. When the vibration mode changes, the anti-vibration bearing adapts to the new mode by displacing the pipeline 1 relative to the support body 2 and redistributing the pressure of the damping fluid in the capsules.

The experiment showed the effectiveness of this design. The experiment was carried out on a special stand consisting of a pipeline with an outer diameter of 57 mm and a wall thickness of 3.5 mm. The pipeline is a circuit that includes a pump and valves. The calculated frequency of natural oscillations was 25.6 Hz, which was confirmed by an experiment with a rigid attachment of the pipeline contour (at this frequency, the pipeline experienced maximum vibrations). An experiment conducted under similar conditions with mounting the pipeline on the proposed supports showed a decrease in the oscillation frequency and the absence of resonant modes of the system. The change in the oscillation frequencies during the experiment confirms adaptive changes in the rigidity of the supports during operation and automatic detuning from the resonant modes.

4. Conclusion

1. The presented technical and economic analysis of anti-vibration supports revealed their advantages and disadvantages. The advantages include high friction and anti-vibration properties of the supports. The disadvantages of the presented supports include the absence of automatic detuning from resonant modes, which leads to increased maintenance costs, design complexity and relatively high cost of the products as a whole.
2. The presented design of an anti-vibration support has a simple design which does not need manual detuning from a resonance. The proposed anti-vibration bearing allows you to adapt to the vibration mode due to the displacement of the pipeline relative to the support body and the redistribution of the pressure of the damping fluid in the capsules.
3. To determine the optimal properties of the damping fluid requires a series of experiments for different diameters of pipelines.
4. The use of a support consisting of capsules with a damping fluid for automatic detuning from resonance modes is highly effective. Adaptive detuning from resonance during operation expands the possibilities of using this support and significantly reduces the cost of its operation.
5. The use of the proposed anti-vibration support to reduce the vibration of engineering systems of high-rise buildings will lead to an increase in the service life of engineering equipment, a decrease in the noise level and an increase in the comfort of living.

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