EFFICIENCY OF CLEANING SEWER PIPES

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Abstract. As a result of human activity, waste and products that are not suitable for further use are formed, which are mainly disposed of by draining them through networks of urban sewer pipelines, during the operation of which deposits of oils and salts are formed on their walls, the thickness of which constantly increases over time, as a result of which , the pipeline becomes partially or completely clogged, which subsequently becomes a serious environmental and economic problem, and requires large financial and human resources to eliminate them. Therefore, during the operation of sewer networks of urban and residential buildings, both in domestic and foreign practice, various methods of cleaning and restoring sewer pipelines are often used: mechanical, water-air, hydraulic, hydrodynamic, hydrochemical, biological, ultrasonic and others. In order to increase the efficiency of cleaning and restoration of sewer pipelines using ultrasonic vibrations, it is proposed to use the developed new magnetostrictive ultrasonic transducer. This design allows flushing water from sewer lines to be used to cool the ultrasonic converter itself, and then use the heated water to increase the efficiency of the cleaning process. The work proposes a new design of passages in sewer pipelines for relatively powerful, small-sized three-rod magnetostrictive ultrasonic transducers to increase the efficiency of their cleaning, which, in comparison with a two-rod ultrasonic transducer, allows, for given overall dimensions, to increase their output power up to 1.25 times, and for a given power, reduce overall dimensions sizes up to 1.14 times.

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1.Introduction

It is widely known that as a result of human activity and various technological processes, large amounts of waste and products are generated that are not suitable for further use. For their disposal, relatively expensive technologies and means are generally not used, but are simply disposed of by draining them through networks of city sewer pipelines. This leads, in relatively short periods of time, to the rapid formation of oil and salt deposits on their walls, the thickness of which constantly increases over time, as a result of which, as can be seen in Fig. 1, the pipeline section is partially or completely clogged [1-5].

Figure 1. Partially or completely clogged sewer pipes [1-5]

Ultrasonic treatment, due to cavitation, leads to a significant increase in the rate of chemical reactions. Under the action of pulsating bubbles and shock waves, solid phase aggregates are destroyed. Ultrasonic dispersion is successful provided that the stress acting on the particle during the collapse of the cavitation cavity is higher than the actual strength of the crushed materials [6]. In a liquid, ultrasonic waves generate cavitation bubbles, the size of which increases and, as pressure increases, they burst with the release of a large amount of energy [7].

The submersible method of ultrasonic cleaning in washing machines is widely used to remove stubborn contaminants from parts of complex configurations in cases where the required cleaning quality is not ensured by the jet method or when cleaning with detergents developed specifically for submersible washing machines [8].

When using submersible ultrasonic resonators, cavitation fields not only erode dense layers of deposits, but also contribute to the creation of aqueous-hydrocarbon cleaning solutions in a finely dispersed emulsified state. The effectiveness of using ultrasonic treatment to create reverse emulsions makes it possible to make the washing water-hydrocarbon solution heavier with the predominant volume of saline solution representing the dispersed phase. Another advantage of using ultrasonic treatment is the possibility of eliminating the addition of aggressive and often corrosive substances to metal surfaces into cleaning solutions, the effects of which are insignificant in comparison with the dispersive effect of cavitation fields of high-frequency ultrasonic treatment [9,10].

Cleaning such mostly hard-to-reach clogs is very difficult and requires certain considerable financial and human resource costs, this is especially problematic in winter when the entire sewer system can be completely frozen.

Therefore, during the operation of sewer networks of urban, residential buildings and apartments, both domestic and foreign practice provides for periodic cleaning or flushing of their pipelines [1,5,11-14], the effectiveness of which depends on the complexity of the technology, ambient temperature, mentality and culture of people living in these houses. The following are formed in sewer lines: accumulative blockage - from food debris, grease, silt, sand, and other waste; technical blockage - most often occurs when the network is installed incorrectly, the use of small-sized pipes, ice formation on their inner surface and instant blockage - when large foreign objects are thrown into the system, in particular construction waste, which often results. to complete blocking of wastewater movement [1,12-14].

In practice, various methods of cleaning and restoring sewer pipelines are used [1-5,15-23]:

• mechanical with cylindrical piston pigs made of polyurethane with an additional coating of a fleecy metal cartridge - the cleaning method is used for pipeline diameters of 80–150 mm;

• water-air method, which is used for pipelines with a diameter of 200–250 mm - in the presence of loose rust deposits and the length of the treated area in one pass is up to 2000 m;

• hydraulic based on jet heads or hydrocavitation nozzles - the method can be used for any pipe diameter, while achieving a mirror shine, and at the same time an anti-corrosion internal protective coating can be applied;

• hydrodynamic using high-pressure jets (pressure up to 350 MPa), which allows you to process pipelines with a diameter of up to 400 mm and a length of up to 1200 m in one pass, as well as for cleaning sewer pipelines with a diameter of up to 750 mm, into which the roots of trees and shrubs penetrate;

• hydrochemical, which consists in the use of chemical reagents to remove iron oxides and carbonate deposits from the internal walls of pipelines using specially prepared solutions;

• biological, implemented using foam herbicides, which are pumped into an emptied sewer pipeline and disrupt the normal development of the roots of trees and shrubs, penetrating into open cracks in the pipelines and carried by the flow of water into the nearest inspection wells;

• pulse, which produces a hydraulic shock that destroys deposits on the walls of pipelines - the method is effective for cleaning pipelines with a diameter of up to 300 mm and a length of up to 300 m;

• ultrasonic, which is realized due to ultrasound propagating in a liquid medium or in the material of the equipment being cleaned;

• ice, the basis of which is the use of specially prepared ice to absorb contaminants located on the inner surface of pipes and remove them from the pipeline.

The above methods for cleaning pipelines have certain advantages and disadvantages. The ultrasonic method of cleaning pipelines has currently received limited use, despite such undeniable advantages as low energy intensity, the use of less concentrated cleaning solutions to ensure high quality cleaning without causing damage to the internal surfaces of pipelines [20-22].

As is known [21-25], ultrasonic vibrations (USV) in a liquid medium are created by means of piezoceramic or magnetostrictive ultrasonic vibration transducers. At the same time, piezoceramic ultrasonic transducers provide higher efficiency compared to magnetostrictive ones. - 0.8...0.9 and have a simpler design and low manufacturing cost, and also do not require additional water cooling [21-27]. The disadvantages of piezoceramic ultrasonic transducers include their relatively low specific acoustic power, ranging from 1...2.5 W/cm^2 [20-23,28-30], as well as the need to ensure its high-quality sealing from the liquid medium, since their penetration at best, it will lead to their breakdown; at worst, there will be a short circuit in the output of the ultrasonic testing generator and there will be a possibility of damaging operating personnel with high-frequency electric current. Therefore, to provide the required power needed for cleaning sewer pipelines, bulky composite piezoceramic ultrasonic transducers of the overhead type are used.

Note that magnetostrictive ultrasonic transducers have a much higher specific acoustic power, ranging from 80...120 W/cm^2 [21-23,28-30], but low efficiency. - 0.4…0.5. Therefore, during the operation of magnetostrictive ultrasonic transducers, large losses of electrical energy occur, which leads to heating of both its winding and the magnetic circuit, as a result of which such converters are equipped with an additional water cooling system, which is considered to be its main disadvantage.

In this regard, in the case of using magnetostrictive ultrasonic transducers for cleaning sewer lines, this disadvantage becomes its advantage, since for cleaning pipelines, rinsing water can be used to cool the ultrasonic transducer, and the heated rinsing water can be used to increase the efficiency of the cleaning process. To solve this problem, it is necessary to have powerful, small-sized and through-the-pipe magnetostrictive ultrasonic transducers.

The purpose of the work is to increase the efficiency of cleaning through-flow sewer pipelines using powerful small-sized magnetostrictive ultrasonic transducers.

Methods for manufacturing magnetostrictive ultrasonic transducers. To manufacture single-rod magnetostrictive ultrasonic transducers, rectangular plates are stamped from a tape made of magnetoelastic material, a magnetic circuit package is assembled from them, the end of which is soldered to the waveguide. Gaskets made of heat-resistant electrical insulating material are installed on the magnetic core, onto which the ultrasonic excitation winding is wound [29,30].

This method of manufacturing a single-rod magnetostrictive ultrasonic transducer is distinguished by its simplicity of technology, since the excitation winding can be manufactured in the form of a separate ready-made coil, which is immediately installed on the magnetic core. It should be noted that this method of manufacturing magnetostrictive ultrasonic transducers allows the use of waste-free technology for stamping rectangular plates from magnetostrictive material and winding the electromagnetic field excitation coil in a separate automated technological operation. The main disadvantage of such a magnetostrictive ultrasonic transducer is its low efficiency. [29,30]. This is due to the fact that the electrical energy of the windings is converted into the energy of the magnetic field it creates through the magnetic circuit and air space, where there are large magnetic losses, and the efficiency of such converters is within 10...15% [29,30].

The noted disadvantages are absent in the methods of manufacturing two, three or more rod magnetostrictive ultrasonic transducers, in which rectangular holes are cut out in a magnetoelastic rectangular material along its length and in its middle, and after assembling the magnetic circuit package, a window is formed through which the ultrasonic excitation winding is wound onto them [29,30].

The main advantage of manufacturing such two, three or more rod magnetostrictive ultrasonic transducers is that the electrical energy of the ultrasonic excitation winding is converted into the energy of a magnetic field, in which the magnetic flux lines pass in a closed magnetic circuit, as a result of which magnetic losses are significantly reduced, and so on. p.d. of such converters increases to 45...50% [29,30].

2. Methods

Currently, magnetostrictive ultrasonic transducers are manufactured using this method in order to obtain powerful ultrasound for various ultrasonic technological installations, produced in the USA, Germany, Japan, England, Russia, China, etc., which make it possible to obtain ultrasonic testing with a power of up to 10 kW or more. Such magnetostrictive ultrasonic transducers are assembled from a tape made of magnetoelastic material with a thickness of 0.08...0.2 mm, from which rectangular plates of the required width are stamped. Along the length of the plate in its middle, rectangular holes are cut out, the width of which depends on the diameter of the field winding wire. From these plates, a magnetic circuit package of the required dimensions is assembled, the end of which is soldered to the waveguide. Next, gaskets made of heat-resistant electrical insulating material are installed on the magnetic core rods and the ultrasonic excitation winding is wound manually through the resulting windows on the magnetic core.

The main disadvantages of this method of manufacturing ultrasonic magnetostrictive transducers are the presence of windows in the magnetic circuit and the need for manual winding of the excitation winding. At the same time, the presence of windows leads to the complication of equipment for manufacturing plates with rectangular holes, a decrease in the utilization rate of expensive magnetoelastic material and a relative decrease in its power. Losses of magnetoelastic material are in the range of 10...35%, and for magnetostrictive ultrasonic transducers with a power of 350...450 W they are the largest, which leads to an increase in the cost of manufacturing the ultrasonic vibration transducer. The cost also increases due to the need to manually wind the field windings.

The National Polytechnic University of Armenia has developed a method for manufacturing two-rod magnetostrictive ultrasonic transducers, in which rectangular plates are stamped from a tape made of magnetoelastic material, a magnetic circuit package is assembled from them, the end of which is soldered to the waveguide [31]. The magnetic circuit package is divided into two rods of equal thickness; gaskets made of heat-resistant electrical insulating material are installed on them, onto which the ultrasonic excitation windings are wound. A gasket made of heat-resistant electrical insulating material is installed between these windings, the windings are compressed and brought into contact with each other through the gasket, and the free ends of the magnetic core rods are rigidly connected to each other [30]. The main advantage of this method of manufacturing two-rod magnetostrictive ultrasonic transducers is the possibility of using waste-free technology for cutting out rectangular magnetic circuit plates, which is due to the absence of rectangular holes in them. Unfortunately, with the same power, the overall dimensions of the acoustic system manufactured in this way remain relatively large, and with its limited overall dimensions, the ultrasonic sound power emitted by the transducer remains relatively low.

3. Results and Discussion

Development of powerful small-sized three-rod magnetostrictive ultrasonic transducers. The problem was solved as follows. A package of magnetic circuit, assembled from rectangular plates made of magnetoelastic material, was divided not into two, but into three rods, resulting in the formation of a middle, one might say, central rod, and two adjacent outer cores of the magnetic circuit (Fig. 2) [31,32]. In this case, the thickness of the middle rod is taken to be twice the thickness of the outer rods, which makes it possible to obtain a three-rod magnetostrictive ultrasonic transducer. As a result, after rigidly connecting the free ends of the three rods using rivets 9 through insulating bushings 8 (Fig. 2), it is possible to obtain a three-rod magnetostrictive ultrasonic transducer with a uniformly distributed magnetic flux throughout the magnetic core.

This solution also ensures a uniform magnetic flux over the entire cross-section of the magnetic core package. In Fig. Figure 3 shows a three-rod magnetostrictive ultrasonic transducer assembled using the proposed method. Another distinctive feature of the proposed method for manufacturing three-rod magnetostrictive ultrasonic transducers from known analogues is that instead of manual winding, it becomes possible to mechanically wind the excitation winding of the ultrasonic transducer, which makes it possible to manufacture it in the form of a separate coil, wound automatically in a separate technological operation. This reel can be immediately installed on the middle rod without any problems. As a result, the manufacturing technology of a three-rod magnetostrictive ultrasonic transducer is simplified.

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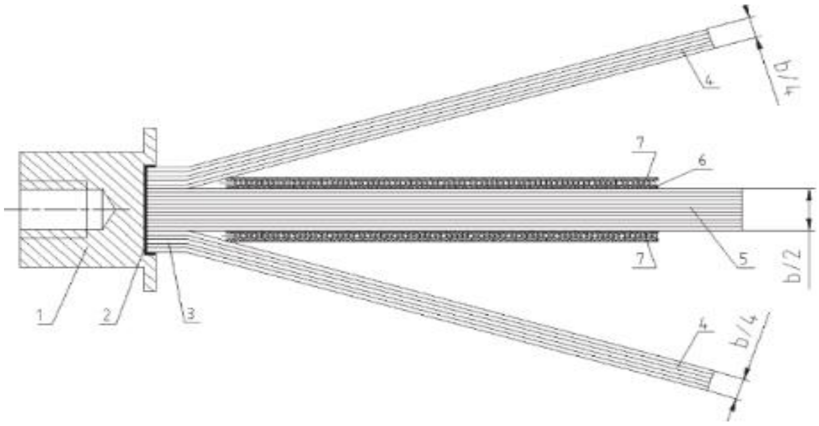

Figure 2. Scheme of dividing the magnetic core package into separate rods.

In the Fig.2: *1 - ultrasonic waveguide, 2 - place of soldering of the magnetic core package to the waveguide, 3 - sheets of magnetostrictive material, 4 - outer rods of the magnetic core package, 5 - central rod of the magnetic core package, 6 - insulating spacers, 7 – field winding coil.*

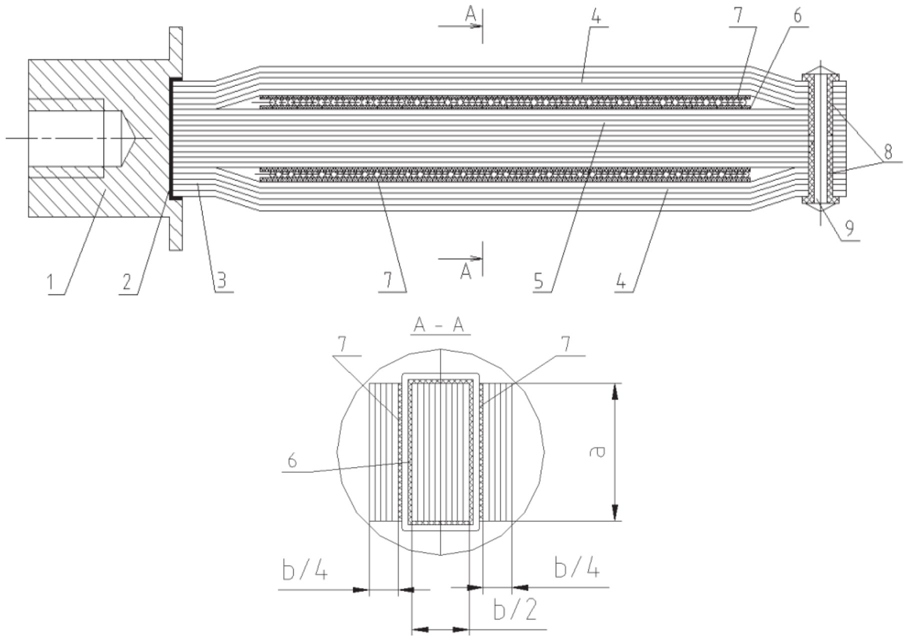

Figure. 3. Assembled three-rod magnetostrictive ultrasonic transducer.

In the Fig. 3; a - three-rod magnetostrictive ultrasonic transducer: *1 - ultrasonic waveguide, 2 - place of soldering of the magnetic core package to the waveguide, 3 - sheets of magnetostrictive material, 4 - outer rods of the magnetic core package, 5 - central rod of the magnetic core package, 6 – insulating gaskets, 7 – field winding coil, 8 – insulating bushings, 9 – rivets.*

Calculations have shown that the above method of manufacturing relatively powerful, small-sized three-rod magnetostrictive ultrasonic transducers allows, in comparison with a two-rod ultrasonic transducer, with given overall dimensions, to increase their output power up to 1.25 times, and for a given power, to reduce overall dimensions to 1.14 times. Such an ultrasonic transducer will not only improve the cleaning efficiency, but also the quality of the work performed and reduce the time required to complete the work, eliminating labor-intensive methods of mechanical and environmentally hazardous chemical cleaning.

Taking into account the above, relatively powerful, small-sized three-rod magnetostrictive converters with an ultrasonic concentrator have been developed, intended for cleaning sewer pipelines (Fig. 4), the axial dimensions of which are determined using known methods for calculating waveguides and ultrasonic concentrators [21-23, 29].

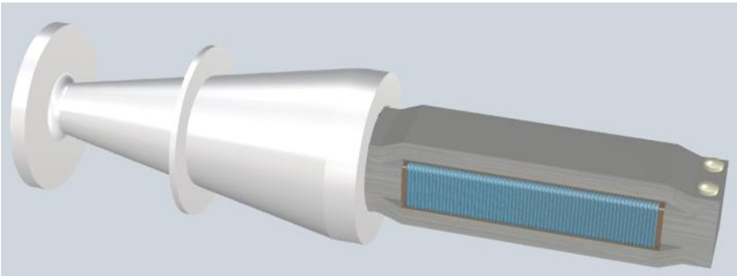

Figure. 4. 3D model of a three-rod magnetostrictive transducer with an ultrasonic concentrator.

When ultrasonic treatment of the internal surfaces of clogged pipelines, it is necessary to take into account the following factors: pipeline material, method of internal pipeline treatment, chemical composition of the supplied liquid and deposits on the pipeline surfaces, thickness and structure of deposits, etc. [26]. An important parameter influencing the efficiency of the cleaning process is the intensity of ultrasound, which depends on the type of product being cleaned, the nature of the contamination, the washing liquid, etc. Depending on the type of contamination, it is advisable to use the following intensity values: up to 1–3 W/cm2 - for easily removable contamination (oil and fat during mechanical processing of products, sediments soluble in washing liquid, fluxes, etc.); from 3 to 10 W/cm2 – for contaminants such as polishing and lapping pastes, physical contaminants and lubricants rolled during pressure treatment, polymerized lubricants, etc.; over 10 W/cm2 – for difficult-to-remove contaminants (varnish films, etching sludge, etc.) [33].

4. Conclusions

1. Relatively powerful, small-sized three-rod magnetostrictive transducers with an ultrasonic concentrator have been developed, intended for cleaning sewer pipelines.
2. It has been established that the developed method for manufacturing relatively powerful, small-sized three-rod magnetostrictive ultrasonic transducers allows, in comparison with a two-rod ultrasonic transducer, with given overall dimensions, to increase their output power up to 1.25 times, and for a given power, to reduce overall dimensions to 1.14 times.

3. Theoretical calculations show that the use of a three-rod magnetostrictive transducer with an ultrasonic concentrator will increase the efficiency of cleaning sewer pipelines by up to 10% and reduce the time required for their implementation.

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