FEDERAL STATE BUDGETARY EDUCATIONAL
INSTITUTION OF HIGHER EDUCATION
«NATIONAL RESEARCH OGAREV MORDOVIA STATE UNIVERSITY»

Institute of mechanics and power engineering

The department of heat power engineering systems

APPROVED

Head of department

Prof., Doctor of Technical Sciences

_____________ A. P. Levtsev

« 04 » 06 2019

MASTER'S THESIS

DEVELOPMENT OF ENERGY-EFFICIENT INERTIAL HYDRO-MECHANICAL CONVERTER FOR SPECIAL SMALL SCALE FACILITIES

Author of master's thesis 03.06.2019 A. A. Golyanin

Designation of master's thesis MT - 02069964-13.04.01-03-19

Direction 13.04.01 - Heat power engineering and heat technology

Head of work

Prof., Doctor of Technical Sciences 03.06.19 A. P. Levtsev

(signature)

Normcontrol senior lecturer 03.06.19 A. I. Lysyakov

(signature)

Reviewer

Prof., Doctor of Technical Sciences A. V. Kotin

(signature)

Saransk
2019

FEDERAL STATE BUDGETARY EDUCATIONAL
INSTITUTION OF HIGHER EDUCATION
«NATIONAL RESEARCH OGAREV MORDOVIA STATE UNIVERSITY»

Institute of mechanics and power engineering

The department of heat power engineering systems

APPROVED

Head of department
Prof., Doctor of Technical Sciences
_______ / A. P. Levtsev
« 15 » ___10___ 2017

THE TASK FOR FINAL QUALIFYING WORK
(in the form of master's thesis)

Student: Golyanin Anton Aleksandrovich

1 Theme: Development of energy-efficient inertial hydro-mechanical converter for special small scale facilities

Approved by Mordovia state University № 8135-C from 09.10.2017 year

2 The deadline for the submission of work to the protection of 20.05.2019 year

3 Initial data for final qualifying work state standards, SNiPs, patent database, RD, Textbook.

4 The content of the final qualifying work

4.1 Problems of operation of systems of centralized heat and water supply and review and analysis of centrifugal machines

4.2 Formalization of the model in the language of mathematics

4.3. Description of experimental setup

4.4 Results of experimental studies

Head of works ______ A. P. Levtsev
signature, date — initials, surname

The job has been accepted ______ A. A. Golyanin
signature, date — initials, surname

ABSTRACT

Master's work contains 83 pages, 30 figures, 5 tables, 34 formulas, 38 references.

CONVERTER, GENERAL SPIRAL, ANGULAR SPEED, CONUSIDAL SPIRAL, TORQUE, SHOCKING KNOT, ENERGY OF FLOW.

The subject of the research is a laboratory setup for testing a spiral-type hydromechanical converter.

The object of research of this thesis is MRSU Department of Heat and Power Systems.

The purpose of this thesis is to simulate a laboratory setup for testing a hydromechanical transducer of the spiral type and to evaluate its effectiveness in practical work.

Research methods - comparison, synthesis, modeling, description, experimentation, graphical analysis.

As a result of the research, the prerequisites for creating a flow energy converter, a shock unit, the principle of operation of a power energy converter, a shock unit were considered, and an experimental setup was designed for testing a hydromechanical spiral-type converter.

The degree of implementation is complete.

Scope - in the practical work of National Research Mordovia State University.

Efficiency of development - reduction of electricity consumption losses, reduction of explosion and fire hazard at industrial production facilities.

CONTENTS

INTRODUCTION	6
1 Problems of operation of systems of centralized heat and water supply and review and analysis of centrifugal machines	8
1.1 Problems of using overpressure of working fluids and gases of various technological cycles	9
1.2 Opportunity to convert excess pressure at heat points	12
1.3 Problems of using excess pressure for generating electricity at heat points	13
1.4 Opportunities to convert overpressure of main water lines to electricity	14
1.5 Experience of using vortex engines to create active (reactive) driving forces	15
1.6 Experimental model of Richard Clem energy converter	17
1.7 Experience in creating a centrifugal-vortex energy converter	21
1.8 Justification of the choice of a rational design option	22
2 Formalization of the model in the language of mathematics	23
2.1 Basic concepts of the idea of the Converter of spiral type	23
2.2 The trajectory is a helical line on the cylinder	26
2.3 Trajectory - a helix with a constant pitch on the cone	27
2.4 Preparation of the power circuit of the installation for hydraulics with a description of the individual links	30
2.5 Mathematical transformations of the energy stage 1	32
2.6 Mathematical transformations of the energy stage 2	36
2.7 The characterization energy circuit stage 3	41
3 Description of experimental setup	48
3.1 The prerequisites for creating a shock site	48
3.2 Impact unit with external drive	52

3.3 Operating principle of the impact 54
3.4 Prerequisites for creating a flow energy Converter 55
3.5 Flow energy converter 59
3.6 Principle of operation of the flow energy Converter 61
4 Results of experimental research 64
4.1 Description of the test program 64
4.2 Calculation of the torque of the energy flow converter 65
4.3 Construction of frequency characteristics of the circuit when changing at least three parameters 72
CONCLUSION 78
REFERENCE 80

INTRODUCTION

The relevance of the research topic is that the experimental setup for testing a hydromechanical transducer of the spiral type relates to power engineering, hydraulics and can be used in the field of converting the energy of a fluid flow into rotary motion, with a view to transferring it to an electric generator or accumulating it.

The degree of knowledge of the topic. Many scientists, such as Johann Andreas von Segner, Heron of Alexandria, Victor Schauberger, Leopold Shergyue, Richard Clem, have studied the problem of converting the energy of fluid flow into energy, but this problem has not been studied until the end; there are issues that should be considered and decided to eliminate.

The subject of research of this master's work is an experimental setup for testing a hydromechanical converter of the spiral type.

The object of research of this master's work is the work of Mordovia State University N.P. Ogareva Department of Heat and Power Systems.

The purpose of this work is to increase the energy efficiency of the spiral hydromechanical transducer by using the energy of a compressed stream as a result of its periodic braking.

To achieve this goal in the final qualifying work identified the following tasks:

– drawing up a calculation scheme of forces in a tubular spiral in the form of a cone with a pulsating flow of the working medium;

– development of a mathematical model of a hydromechanical converter of a pulsating flow;

– determination of the optimal design parameters of the hydromechanical energy flow converter;

– develop design documentation for the manufacture of a prototype of a spiral pulse hydromechanical transducer;

– develop a methodology for the energy evaluation of a spiral pulse hydromechanical transducer;

– installation of a laboratory installation of a hydromechanical converter;

– carrying out laboratory tests of the prototype;

– processing and analysis of the results of laboratory tests and verification of the adequacy of the values of the angular velocity and torque obtained on the model.

In this master's work the following research methods were used: comparison, generalization, modeling, description, experimentation, graphical analysis.

The information base for the research was the literary sources and patents of such authors as A. P. Levtsev, A. Makeev, Ya. A. Narvatov, A. Lysyakov, S. Kudashev, V. M. Ivanov, Semkin B.V., Blinov A.A., Volkova T.A.

The novelty of the research lies in the development of an energy-efficient inertial hydromechanical transducer for special small-scale power facilities, which will help reduce power consumption losses, reduce explosion and fire hazards at industrial production facilities, introduce and use this laboratory installation in practice for facilities requiring forced ventilation, such as industrial premises; logistics centers; underground structures where explosive gases can escape.

During the research, the following results were obtained:

– centrifugal machines were considered and their experimental characteristics were analyzed;

– formalization of the model in the language of mathematics;

– a description of the laboratory setup;

– a method for energy evaluation of a spiral pulse hydromechanical transducer has been developed;

– considered the description of the test program;

– the calculation of the torque of the body with a cylindrical spiral,

– graphically analyzed the results of the laboratory setup simulation.

The structure of the work corresponds to the goals and objectives. It includes an introduction, four chapters, and a list of references.

1 Problems of operation of systems of centralized heat and water supply and review and analysis of centrifugal machines

Due to the geographical location in the Russian Federation, a cold climate prevails. Extremely low winter temperatures determine the average annual temperature throughout Russia – 5.5 ° C; our country is the coldest country in the world [28]. This fact shows that for Russia the problem of providing consumers with heat energy is one of the most important state tasks with a pronounced social character, the solution of which involves enormous financial resources. The rational solution of this task determines the sustainable development of the country. This circumstance vividly demonstrates that increasing the energy efficiency and reliability of heat supply systems for our country will always be one of the most urgent national economic tasks. Improving the efficiency and reliability of district heating systems is inextricably linked with the implementation of the Federal Law No. 261-FZ of November 23, 2009 «On Energy Saving and Energy Efficiency Improvement and on Amendments to Certain Legislative Acts of the Russian Federation» and Federal Law No. 190-FZ «On heat supply» dated July 27, 2010.

According to the criteria of thermodynamic efficiency, district heating is the most efficient way to provide consumers with thermal energy [34]. It is known that in systems of centralized heat supply during transportation of the coolant a huge amount of electricity is expended on the drive of the pumps. In particular, in the centralized heat supply system of Moscow, the total installed capacity of network pumps operating only at thermal power plants of Mosenergo, excluding RTS, KTS, small boilers of MOEK and independent producers of thermal energy is about 500 MW [37]. Another product necessary for human activity is water, the need for which is provided on the basis of a well-organized water supply system. The system of centralized water supply is used to distribute the water supply from the source to the conduits under a certain pressure. The presence of several water lines in a single distribution unit, requiring different pressures, necessitates the throttling of individual water lines and, as a result, energy and economic losses.

1.1 Problems of using overpressure of working fluids and gases of various technological cycles

The movement of liquids and gases is carried out in many cases at elevated pressures, due to the need to overcome the hydraulic resistance of pipelines, geodesic markings of pipeline routing and the features of various technological systems. This applies to pipeline systems operating in the fuel and energy complex, as well as in individual sectors of the national economy. The most illustrative are the systems of transporting liquid and gaseous hydrocarbons, heat and water supply, a variety of cooling systems and heat transfer. The overpressure of working fluids and gases of various technological lines and cycles is traditionally throttled, turning into losses and thereby reducing the gross efficiency of such systems. A possible solution to the problem of overpressure in the pipelines is described in [34], where it is intended to use the initial pressure from a source of lower energy to reduce the pressure in the pipelines, and to additionally install booster stations along the entire length of the main network.

At the same time, these losses show a wide range of opportunities for their use in the form of secondary energy resources (VER) on the basis of the recovery process of the partial return of throttled energy for reuse, increasing the efficiency and reliability of the final product. Substantial success in the industrial recovery of excess main pressure of water supply systems, due to significant differences in terrain heights, was achieved by Czech experts [30-33]. The installations created in the SIGMA concern have been successfully operating since the 2000s, transforming the pressure losses into electrical energy. More than 40 installations with a capacity from 5 to 20 kW operate at pressure reduction stations, at which flow meters are located simultaneously. In the water utility system of the city of Prague, recuperative units with a capacity from 45 to 150 kW are installed at the regulatory nodes. All units operate on a network and are built according to the scheme of a generator driven by a network, which makes it possible to further avoid the problem of the quality of the generated electricity.

This approach to the use of VER is very attractive for Russian cities with complex terrain with large elevation differences / 103,104 /. In particular, for Vladivostok, where, due to the large difference in terrain marks, throttled excess pressure on regulators in pumping and throttling substations reaches 30-90 m. Significant recuperation potential exists in direct-flow cooling systems that function, in particular, at power generating facilities (CHP, TPP) / 82 /, in which the cooling water before being thrown into reservoirs and rivers is constantly throttled in order to eliminate the erosion of the coastal part.

Significant energy saving potential due to the use of secondary energy resources is available in water supply and sewage systems [3,20]. In such systems, pumping stations operate with elevated pressures due to an increase in the hydraulic resistance of the piping system over time, fluctuations in the level of fluid in the receiving and pressure tanks, as well as due to inconsistencies in the operation of the pumps of the load network. Recently, there has been a tendency to create ring-type water supply systems [3], in which constant pressure should be maintained throughout the circuit. In such schemes, there is a need for constant throttling (energy loss) of flows at individual points, to which various consumers (microdistricts), characterized by individual parameters, are connected. Large energy-saving potential is in heating systems due to the peculiarities of their construction. Thus, the improvement of the centralized heat supply systems (CCT), which, according to the European Commission [7] as part of the energy strategy for 2011–2020, is the most reliable, economical and environmentally friendly, is the highest priority for providing European consumers with thermal energy. Development and improvement of PTS to achieve and improve their energy efficiency is possible through the use of excess pressure coolant [26, 36]. Such an approach allows not only to realize the technological need to reduce pressure, but also makes it possible to use the potential energy of the overpressure of the working fluid for the production of electrical energy [8, 9, 27, 29], thereby increasing the energy efficiency of the PTS.

One of the most promising areas in the field of energy saving in the transport of natural gas is the recovery of excess pressure energy at the sites of its reduction and consumption [12, 13]. Pressure decreases at the gas control point (PIU), usually by throttling, i.e. The energy of the overpressure of the gas is spent on overcoming the hydraulic resistances and, thus, is irretrievably lost. Reducing the pressure of natural gas with the simultaneous generation of electrical energy can be accomplished in the expander-generating unit (DHA).

Such plants can meet the need for uninterrupted power supply, in particular, for gas distribution stations [4, 11, 15], using the energy obtained by throttling overpressure of gas in main gas pipelines (3.5 - 5 MPa) to the permissible in highways (1.0 -1.2 MPa). In Russia, the first experience of using DGA for hydraulic fracturing was obtained at CHP-21 of Mosenergo [2, 10, 15, 16], where two units with a unit capacity of 5 MW each were installed. World experience shows that the use of DHA to generate electricity when using the excess pressure of the transported gas leads to positive results. The problem of an uninterrupted power supply for gas distribution stations [11], which use different schemes of uninterruptible power supplies, has been solved quite successfully. Technical and economic analysis of the implementation of the schemes of turbogenerator plants with direct communication turbine-generator, using the potentially stored energy of the flow of the transported gas, confirms significant savings in the cost of construction and operation of gas distribution stations. To significantly reduce the capital cost of creating a DSA, it is necessary to use serial equipment adapted to specific operating conditions [17]. The presented analysis of the use of overpressure in gas, heat and water supply systems clearly demonstrates the prospects of this scientific and technical direction for a wide range of systems for the transportation and distribution of gases and liquids.

1.2 Opportunity to convert excess pressure at heat points

One of the highly efficient approaches to using the traditionally lost overpressure is the pressure recovery system [35], which can be installed in the flow or return line of the main heating circuit of the CHP in series with the standard throttle acting as a coolant flow regulator (Fig. 1 and 2).

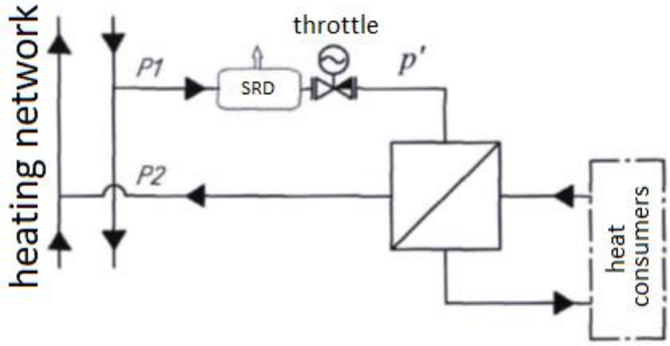

Figure 1 – The option of connecting the SRD in a direct line to the central heating station with an independent heating circuit

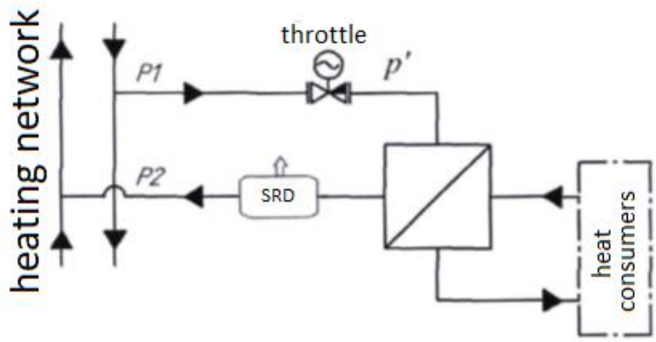

Figure 2 – The option of connecting the SRD in the return line to the central heating station with an independent heating circuit

Such a connection preserves the operability of a regular KZR as a flow regulator, i.e. does not affect the technological mode of operation of the CH. SRD is a hydrodynamic flow regulator, built on the basis of a hydraulic machine, essentially being a mini-hydro [35].

A distinctive feature of such a system is that it is able to provide the required law of flow control through the central heating station, similar to the standard KZR. The sequential inclusion of the SRD with the KZR allows not to change the functional scheme of the elements of the central heating station, to have the opportunity, if necessary, to include in the work the regular KZR, which is constantly in the maximally open position when the SRD operates, practically without providing additional resistance to the working environment. The algorithms incorporated in the automatic control system (ACS) of the DDS allow to provide the required control law and maintain it throughout the entire range of variable costs. The electricity generated at the SRD is sent to the existing power supply network of the central heating station and is spent on its own needs: to drive the central heating pump, hot and coldwater supply, thereby reducing power consumption from the external network and increasing the economy of the central heating station as a whole.

1.3 Problems of using excess pressure for generating electricity at heat points

The use of SRD on a central heating point requires a systematic approach in assessing the effectiveness and feasibility of using such hydrodynamic regulators embedded in the technological cycles of the central heating point.

In addition, it should be noted and issues of work as the DRS, and the system as a whole, in which it is structurally located.

Due to significant changes in coolant flow during the day and seasonal characteristics, the hydraulic turbine of the SRD may fall into the braking region, in which no power generation occurs. The electromechanical part of the SRD and the automation system must ensure high-quality power generation, therefore, the characteristic of the generating device must match the moment characteristic of the turbine, and the ACS must ensure the operability of the SRD and, as a result, the entire TSC with any combination of external and internal control and disturbing influences.

In addition to generating electricity, the work of the SRD at the central heating point is characterized by

firstly, by increasing the reliability of the main heat exchanging equipment, such as plate or shell-and-tube heat exchangers (TA), due to the fact that the pressure is regulated depending on the coolant temperature and prevents cavitation in the TA.

secondly, the resource of work of full-time KZR is significantly increased, since cavitation does not occur during their operation and, as a result, cavitation erosion on the working surfaces of the KZR elements during the movement of the coolant through this device.

Additionally, it should be noted a number of positive qualities when using the SRD at the central heating point: - no additional land allotment is required;

- does not require large one-time investment, because total capacity can be increased gradually - heat substations can be equipped with PSA sequentially one after the other; - does not require the cost of construction and equipment of additional power lines and fuel communications; - no additional fuel quotas and fixed fuel costs are required; - does not require additional costs to ensure environmental safety; - saving of quotas on harmful emissions is ensured; - training of additional highly qualified service personnel is not required; - there are low operating costs.

1.4 Opportunities to convert overpressure of main water lines to electricity

Centralized water supply systems are characterized by a large extent and branching of water lines [38]. In a large settlement, as a rule, there are several sources of water (water intakes) and several distribution nodes (RU), each of which is connected in parallel with conduits to consumers [5]. Due to the real difference in geodesic heights of consumer locations in real-world conditions and due to the different length of highways, the required pressure in parallel conduits differs from each other.

The presence of several water lines in a single switchgear, requiring different pressures, leads to the need for throttling of individual water lines and, as a result, to energy and economic losses.

1.5 Experience of using vortex engines to create active (reactive) driving forces

Positive experiences in this direction by the Austrian inventor and physicist Viktor Schauberger. He is known for his famous self-rotating power generator designs and propulsion designs for aircraft. Years of life of the scientist from 1885 to 1958.

At this point, it makes sense to consider the projects of Viktor Schauberger not from the point of view of ways to create active (non-reactive) driving force, but only from the point of a constructive solution that will be practically useful for the development of new energy sources.

However, one should not forget that axial and tangential components of the driving force are usually created in machines of this type, which in turn allows using such a centrifugal machine both as a source of clean energy and as an active (non-reactive) propulsion device for use in aviation , sea, river, road or rail transport.

At the bottom of the structure is a spherical air filter connected to a tap that regulates the flow of air into the system. The generator is connected by a belt drive to the shaft of a Schauberger centrifugal-vortex machine.

The water funnel is connected to the return pipe. With this pipeline, water circulates directly in this funnel.

The museum in Austria preserved the original details of the structures and several models of Schauberger generators. Figure 3 shows an open installation [22].

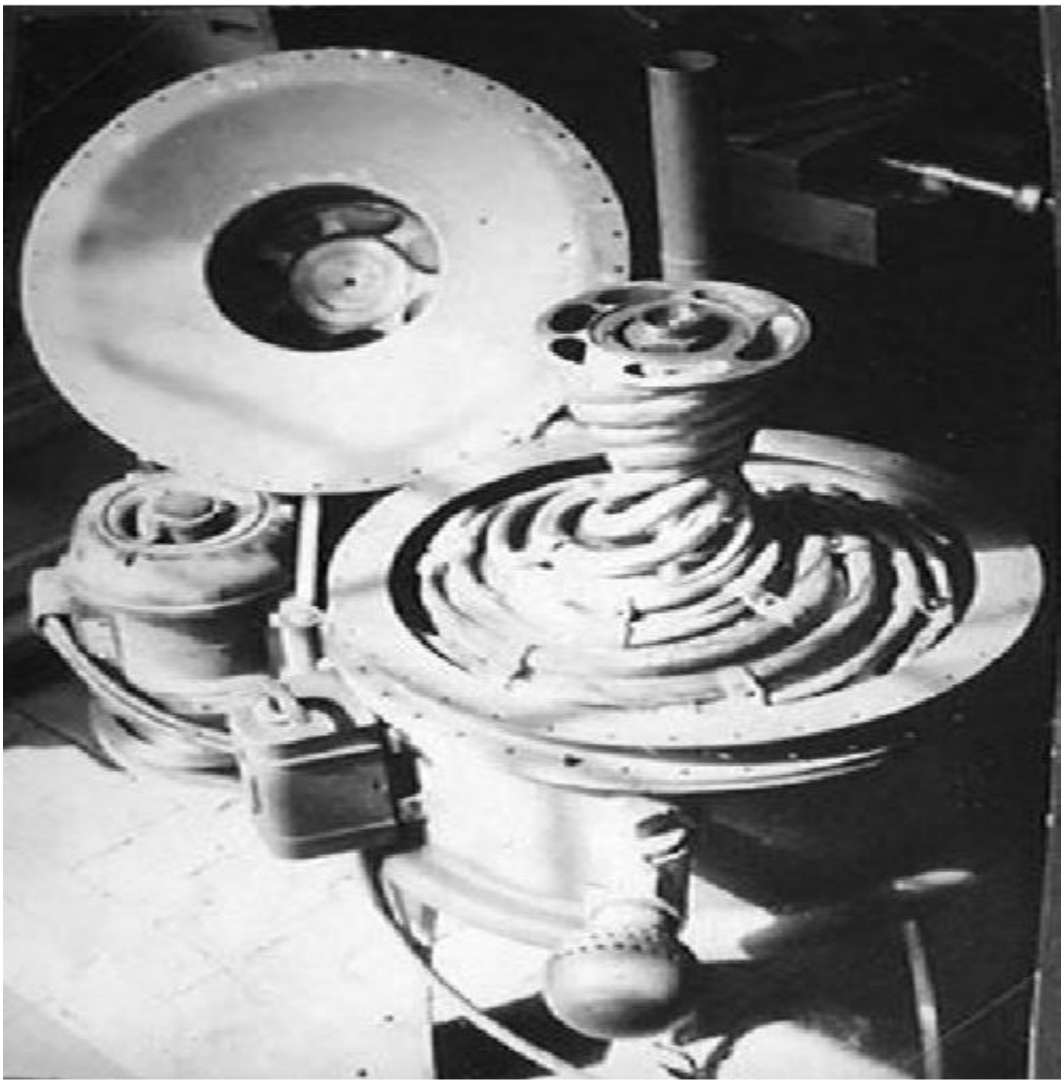

Figure 3 – One of the models of Schauberger generator

The generator model (Figure 3) includes copper tubes, envelopes of a cone. Water enters from the top in the narrow part of the cone. In the description of the operation of this machine, it was noted that, in addition to water, there is always a small amount of air in the copper tubes, and this condition is regarded as necessary for the successful operation of the device. When setting up the machine, it was important to choose, using valves and control valves, the required combination of water and air in the tubes.

Another feature of the nozzle design of the machine is that it uses a microturbine, which does not rotate, but creates rotation of water at the outlet of the tube. This technical solution is widely used by designers of devices in which it is necessary to increase the speed of the jet at the nozzle exit.

As is well known, Schauberger's device, firstly, went into self-rotation mode and, secondly, created a large vertical axial thrust force. During the tests, one of these devices Victor could rise to the air, as a result of which he struck the roof and destroyed part of the building.

Thus, we can conclude that in the developments of Viktor Schauberger there are necessary for designing solutions for creating an elastic working mixture by mixing components such as water and air and reducing hydrodynamic losses.

1.6 Experimental model of Richard Clem energy converter

Richard Clem designed and implemented another well-known example of a technical device that is directly related to this work. Consider this model in more detail.

In 1972, Clem noticed that the hot asphalt sprinkler continued to work after turning off its drive. The axis of this machine was vertical, and the rotor had a conical shape. After these observations, Clem began to research the principle of operation of the machine empirically, which prompted him to create a «Clem motor» (Clem motor). This motor operated by centrifugal force, which in turn created a self-rotation mode.

Figure 4 shows a schematic diagram of such a generator, which can use the centrifugal force created when the liquid mass moves along a conical expanding trajectory, in order to increase the rotor torque.

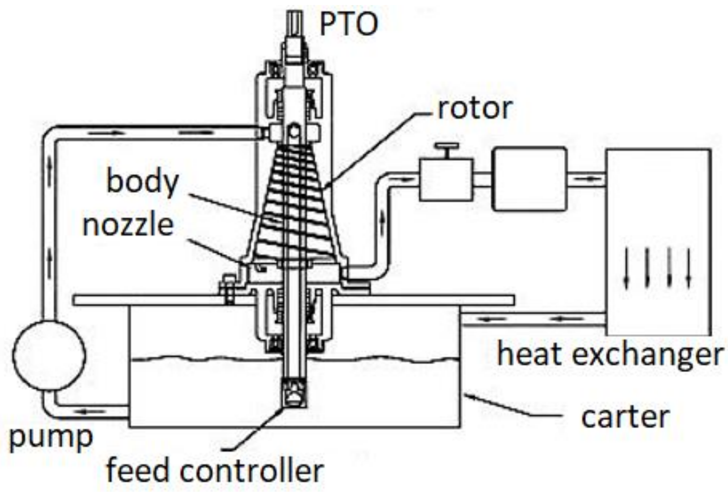

Figure 4 – Schematic diagram of the generator Clem

This is a general idea, without a design research of details, and it has not been tested experimentally. Note that the design includes a heat exchanger.

Figure 5 shows the proposed scheme of this design, and the possible device of the rotor. The tapered rotor is located in the tapered housing, and has spiral channels. These channels, intended for the movement of fluid, run along the cone, and end at its base in the form of nozzles (nozzles).

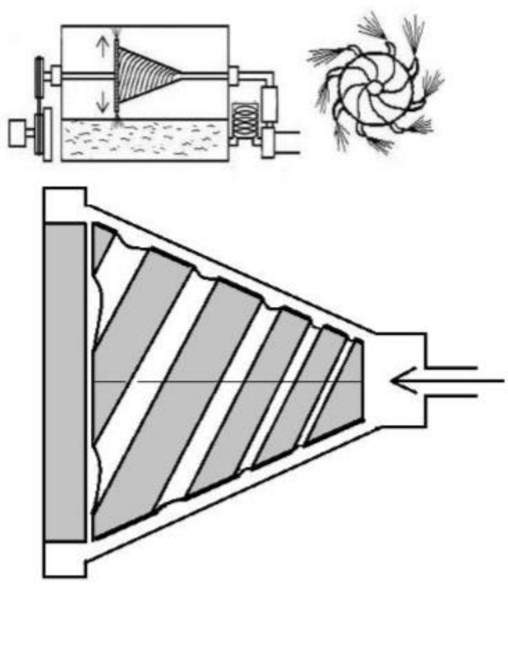

Figure 5 – The principle of operation of the drive Clem. Design option

Recommendations for the design of analog structures will consist in the fact that liquids must be allowed to accelerate independently due to the action of centrifugal force. For this, the spiral along which the fluid must move will have an increase in pitch with increasing radius. Also, the necessary moment will be an increase in the cross section of the channel through which the fluid will flow directly as it approaches the nozzle.

In this work principle there are several factors that affect the performance of the model. One of them is the reactive effect of Segner. Also, these factors can be attributed to the fact that the acceleration of a fluid moving in a spiral, which interacts with the rotor, leads to the fact that the fluid transmits the torque to the rotor. At the entrance to the rotor the speed of the fluid will be equal to the speed of rotation of the rotor. At the site of the trajectory in front of the nozzle, the liquid will move faster than the rotor (the speed increase is due to the centrifugal effect, an analogue of the accelerated fall of the body in the field of force).

At observance of the set conditions the rotor accelerates. When the required speed is reached, the action of the external drive can be turned off, which in turn will cause the machine to switch to the power generator mode.

For optimal use of the kinetic energy of the jet after exiting the nozzle, in the design it is advisable to use inclined reflectors - blades of the turbine impeller.

Thus, in this design can be divided into three main points:

– rotor acceleration occurs due to the reactive Segner effect;

– acceleration of the fluid under the action of centrifugal force on the conditions of increasing the radius of its movement indicates that it begins to move faster than the rotor and subsequently tells it an additional torque, if there is a helical trajectory of the channel along which the fluid moves;

– reactive interaction of the mass of water that has already flown out of the nozzle and «works» with the turbine impeller mounted on the rotor, additionally accelerates its rotation.

A machine was built by Richard Klem, whose principle of operation was based on Mazola edible oil. This was due to the fact that the liquid at work reached a temperature of up to +150 ° C and began to boil.

In the actual Clem design, the fluid was injected into the hollow shaft at a pressure of about 2.106 (N / m2), passed through tight conical channels of the cone and exited through the nozzles. This made the cone rotate. The speed of rotation of the shaft in the design Clem reached 2300 (r / min). A heat exchanger (radiator) was used for cooling.

There is evidence that the first such motor could not withstand the stresses and failed. After upgrading the engine Clem made the motor more durable, since the power of the upgraded motor was 250 kW with a weight of 90 kg. This engine Clem installed on the car and tested his work on the road. However, the battery in the design of the car still was, but it was used only to start the engine and the headlights.

This power plant consisted of a seven-speed pump and a converter. Such a pump was used to supply pressurized oil from the storage to the converter, after which the energy was converted to the force that was used to rotate the motor.

Thus, the principle of operation of this motor was that the working fluid, in this case oil, passed through the channels with acceleration, which led to an increase in the rotating moment of the rotor. After that, it returned to the storage tank and subsequently entered the heat exchanger, and then the cycle continued anew. The converter, in this case the energy converter, acted on the basis of the turbine.

Bendix Corporation (Bendix Corporation) conducted tests for the performance of the Clem engine. Testing consisted in connecting the engine to a dynamometer to measure power, which was generated in the engine, being in the mode of auto-rotation at a power of 250 kW for 9 consecutive days.

As you know, after successful testing, Clem received orders for the production of such machines for a coal company.

After analyzing this model, we can conclude that the feature of using the Clem device shows the important role that the shape of the rotor and heat exchanger plays in the design of the power plant for its introduction into transport.

1.7 Experience in creating a centrifugal-vortex energy converter

Leopold Shergyu proposed a general scheme of a self-rotating hydraulic machine. It is also known as another attempt to create a centrifugal vortex energy converter.

The Sherje machine was not implemented, since the design of this converter revealed significant shortcomings. One of these drawbacks was that the Shergier circuit was generally similar to the design of Richard Clem, but it lacked a tapered rotor.

In the Shergeu design, the working fluid does not have the ability to move faster, with an increase in the rotation radius, because the main part of the rotor has a constant radius.

A rotating moment is created at the bottom of the rotor, since the liquid exits the tubes in the radial direction and then enters the tangential nozzles. In accordance with this, only a small torque is created, since the conical rotor is absent in this construction, and it is one of the main elements in the design of this machine.

Thus, in order to optimize the operation of the structure, it will be important to specify a fluid trajectory such that the radius of rotation of the liquid increases according to the principle of a logarithmic spiral. Such a trajectory of movement can provide the possibility of increasing the radial component of the velocity of the fluid, since it will be influenced by centrifugal force.

In the scheme, there is no conical rotor; therefore, the movement of water in a spiral of constant radius does not ensure the transfer of its kinetic energy to the rotor. It makes sense to consider this solution as a theoretical proposal for the design and layout of the components of a centrifugal type energy converter.

1.8 Justification of the choice of a rational design option

Having studied the problems of insufficient use of the flow of the working environment and the design of centrifugal machines created by other developers discussed in paragraph 1 of this chapter, we can offer a rational option that allows you to implement the theoretical concept of a flow energy converter. The following structural elements should be provided in it: a spiral of conical shape, a cone-shaped base for its fastening. The channels for the movement of the working fluid, the shaft with a partition, for the implementation of the direction of fluid flow in a spiral conical shape.

The purpose of this work is to increase the efficiency of the hydromechanical energy converter of the flow with a tubular coil in the form of a cone, for autonomous sources of energy saving, due to the pulsed flow of the working medium.

To achieve this goal in the final qualifying work identified the following tasks:

– drawing up a calculation scheme of forces in a tubular spiral in the form of a cone with a pulsating flow of the working medium;

– development of a mathematical model of a hydromechanical converter of a pulsating flow;

– determination of the optimal design parameters of the hydromechanical energy flow converter;

– installation of an experimental installation of a hydromechanical converter;

– carrying out laboratory tests of the prototype;

– processing and analysis of the results of laboratory tests and verification of the adequacy of the values of the angular velocity and torque obtained on the model.

2 Formalization of the model in the language of mathematics

2.1 Basic concepts of the idea of the Converter of spiral type

Hydromechanics energy converters (HMPA) was originally developed for steam turbines, and then found application in water-lifting devices. The greatest potential have GMPE with varying flow rates. Recently, interest in GME with a changing flow rate has increased due to another increase in energy prices and primarily for electric energy. While the energy of the flow throttling in many areas is simply not used. A significant leap in the development of such converters was the receipt of significant accelerations of the flow due to its abrupt interruption in modes close to hydraulic shock. However, the possibilities of such converters are still poorly understood. Physical modeling is expensive and time-consuming, while mathematical modeling techniques are continuously being improved.

The relevance of the research topic lies in the fact that a rational combination of physical and mathematical modeling of GMPE with a changing flow rate of cylindrical and spiral type operating in pulse mode will create the basis for calculating their optimal parameters for various applications (in pulsed heat supply systems as a drive fan heaters, mixing pumps, circulation pumps, hot and cold water systems, as drive turbines mini HPP).

The idea of constructing a model of GMPE with a variable flow rate of cylindrical and spiral type, operating in pulse mode, is based on the known laws of fluid mechanics, methods of differential geometry, vector, integral and differential calculus. Structurally, such a Converter is a spiral wound from a pipe, rigidly fixed to the frame, which has the ability to rotate around the vertical axis (Fig.1). The rotation is carried out due to the fact that at each point of such a spiral a force is created, the product of which on the shoulder PM, forms a torque. In this case, the fluid flow is periodically accelerated by generating a hydraulic shock wave with a sharp interruption of the flow by means of a shock node.

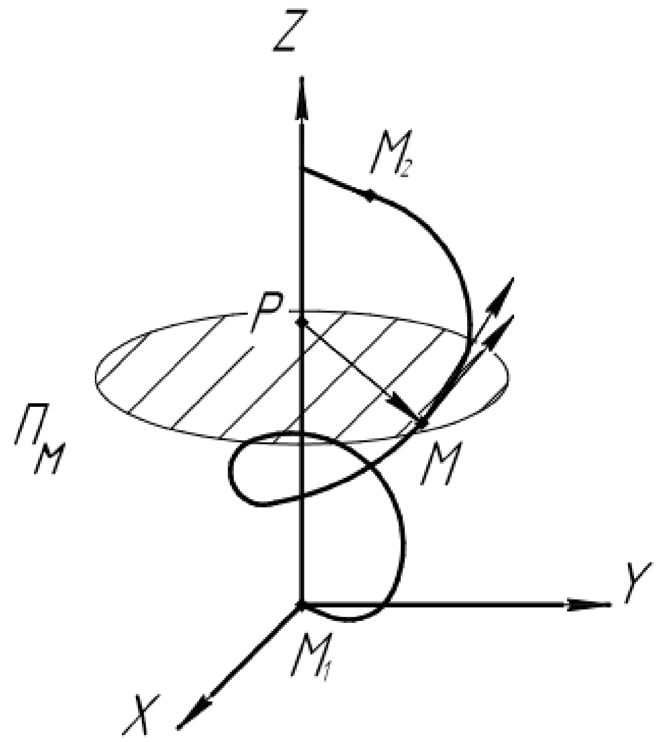

Figure 6 – Scheme of movement of the working environment in a spiral

In a spiral M_1MM_2, rigidly connected to the axis OZ, liquid moves from M_1 at M_2 with a linear velocity $v = v(s)$ at time.

If the speed $v(s)$ constant, then the torque is equal to $\vec{M} = \vec{0}$. This follows from the formula:

$$\vec{M} = J\vec{\alpha}, \qquad (1)$$

where α - the vector of angular acceleration $\left(\vec{\alpha} = \dot{\vec{\omega}}\right)$;

J - moment of inertia (it is an integral character of a body formed by perpendiculars MP to the axis of rotation (Figure 1).

The angular velocity vector will be formed from the formula:

$$\vec{\omega} = \sum_M \vec{\omega}_M, \qquad (2)$$

or through a vector product:

$$\vec{\omega}_M = \left[\overrightarrow{PM}, \vec{v}'\right], \tag{3}$$

where $\vec{v}'$ - the projection on the plane Π_M, angular acceleration vector passing through the point $M \perp OZ \left(\vec{v}' = \overrightarrow{np}_{\Pi_M}\right)$.

The moment of inertia of the spiral is written in the form: $J(t) = \rho\sigma_0 \int_0^m r^2 dm$.

For a constant diameter of the tube we obtain:

$$dm = \rho\sigma_0 ds, \tag{4}$$

where ρ - liquid density;

σ_0 - tube cross-sectional area;

ds - the differential arc length.

The final expression for the moment of inertia of the spiral along its length and angular velocity over time is written in the form:

$$\begin{cases} J(t) = \rho\sigma_0 \int_0^l (PM)^2 ds \\ \vec{\omega}(t) = \int_0^l \left[\overrightarrow{PM}, np_{\Pi_M} \frac{d\vec{r}}{dt}\right] ds = \int_0^l v\left[\overrightarrow{PM}, np_{\Pi_M} \vec{t}\right] ds \end{cases}, \tag{5}$$

It cannot be ruled out that $\vec{\omega}(t)$ constant and variable software t $\vec{\omega}(s,t)$.

The impermanence of the speed is achieved by the impulse of the shock wave with the opposite phase velocity $v_0 \approx 1000$ м/с.

All site M_2M_1 the impulse passes in time:

$$t_0 = \frac{l}{v_0}, \qquad (6)$$

Will continue to review the operation of the pulse only at this time. Thus, the torque is calculated for the duration of one pulse. In the formula (5) the component is assumed to be piecewise constant.

2.2 The trajectory is a helical line on the cylinder

Considering the trajectory of the working medium, made in the form of a cylindrical spiral, it is necessary to determine the angular acceleration, moment of inertia and torque, depending on its basic design parameters. The scheme of action of forces in a cylindrical spiral Converter is shown in figure 7.

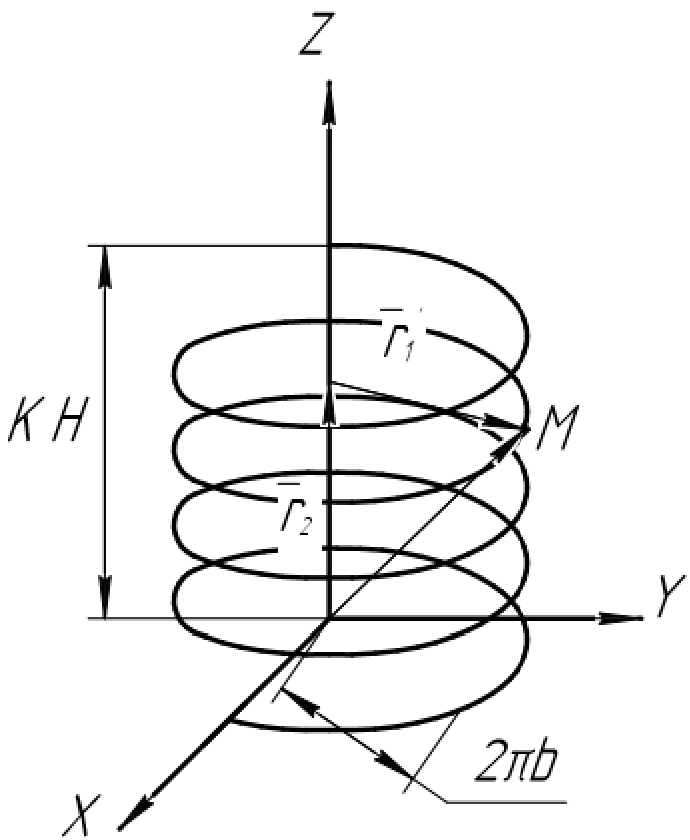

Figure 7 – Scheme of action of forces in a cylindrical spiral Converter

Using the above reasoning, expressions for the angular velocity for the entire spiral are obtained:

$$\bar{\omega} = \int_0^{2k\pi} \omega_M d\varphi = a^2\sqrt{a^2+b^2}\int_0^{2k\pi} v d\varphi = 2k\pi a^2\sqrt{a^2+b^2}\, v(t), \qquad (7)$$

where v - piecewise constant.

The moment of inertia of the body in the form of a cylindrical spiral:

$$J = \rho\sigma_0\int_0^l |\bar{r}_1|^2 ds = \rho\sigma_0\sqrt{a^2+b^2}\cdot a^2\int_0^{2k\pi} d\varphi = 2k\pi\sqrt{a^2+b^2}\cdot a^2\rho\sigma_0 = la^2\rho\sigma_0, \qquad (8)$$

And as a result, the torque as a vector quantity

$$\bar{M} = J\bar{\omega} = l^2a^4\rho\sigma_0\dot{v}(t)\bar{k} = l^2a^4\rho\sigma_0\frac{\Delta v}{\Delta t}\bar{k}, \qquad (9)$$

In expression (9) reversible change of fluid flow rate:

$$\Delta v = v - v_0 = -\tilde{v}_0 < 0. \qquad (10)$$

2.3 Trajectory - a helix with a constant pitch on the cone

Considering the trajectory of the working medium, made in the form of a conical spiral, it is necessary to determine its angular velocity, moment of inertia and torque, depending on the design parameters of the spiral and the parameters of the reverse flow. The scheme of the Converter with a conical spiral is shown in figure 8.

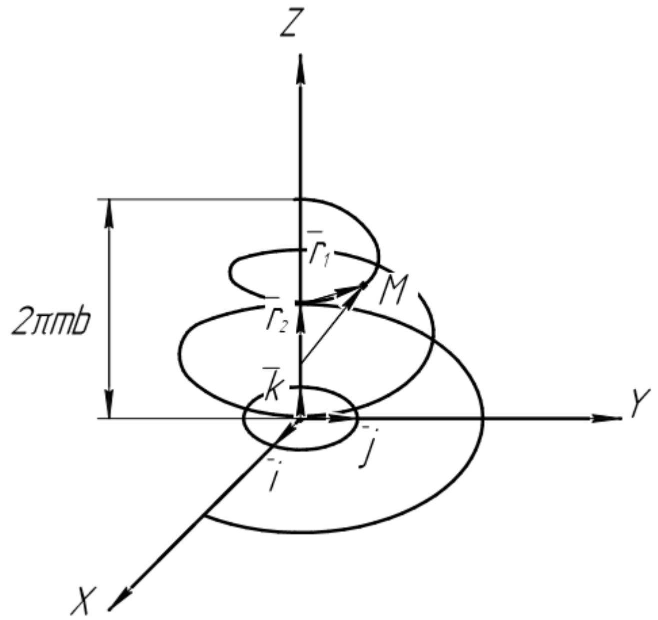

Figure 8 – Converter circuit with conical spiral

By selecting the angle of rotation of the projection of the point on , we obtain the equation:

$$\overline{r}(\varphi)=\overline{r}_1(\varphi)+\overline{r}_2(\varphi), \qquad (11)$$

where $\overline{r}_1(\varphi)=a(2m\pi-\varphi)\overline{e}(\varphi)$;

$\overline{r}_2(\varphi)=b\varphi\overline{k}$.

m - number of turns.

Revolution step:

$$H=2\pi b.$$

Further, using the above reasoning, the expressions for the angular velocity for the entire spiral are obtained:

$$\bar{\omega} = \left(\frac{2m\pi a}{a^2+b^2}\sqrt{a^2+b^2+4m^2\pi^2a^2} + \ln\frac{-2m\pi a+\sqrt{a^2+b^2+4m^2\pi^2a^2}}{\sqrt{a^2+b^2}} \right)\bar{k}\,, \qquad (12)$$

Derivatives of angular velocity:

$$\dot{\bar{\omega}} = a^2\frac{\Delta v}{\Delta t}\left(\frac{2m\pi a}{a^2+b^2}\sqrt{a^2+b^2+4m^2\pi^2a^2} + \ln\frac{-2m\pi a+\sqrt{a^2+b^2+4m^2\pi^2a^2}}{\sqrt{a^2+b^2}} \right)\bar{k} \qquad (13)$$

Calculate the moment of inertia:

$$J = \rho\sigma_0\int_0^l |\bar{r}_1|^2 ds = \rho\sigma_0 a^2\int_0^l (\varphi-2\pi m)^2 ds = \rho\sigma_0 a^2\int_0^{2\pi m}(\varphi-2\pi m)^2\frac{ds}{d\varphi}\cdot d\varphi = \\ \rho\sigma_0 a^2\int_0^{2\pi m}(\varphi-2\pi m)^2\sqrt{a^2+b^2+a^2(\varphi-2m\pi)^2}\,d\varphi \,, \qquad (14)$$

Doing the same operations as before and get the expression for the moment of inertia:

$$J = \frac{\rho\sigma_0\left(a^2+b^2\right)^2}{8a}\left[\frac{\left(a^2+b^2\right)^4 - \left(2m\pi a+\sqrt{a^2+b^2+4\pi^2m^2a^2}\right)^8}{8\left(a^2+b^2\right)^2\left(-2m\pi a+\sqrt{a^2+b^2+4\pi^2m^2a^2}\right)^4} + \right. \\ \left. +\ln\left(\frac{-2m\pi a+\sqrt{a^2+b^2+4\pi^2m^2a^2}}{\sqrt{a^2+b^2}}\right)\right] \,, \qquad (15)$$

The torque for a Converter with a conical helix is determined in the same way:

$$\overrightarrow{M} = J\dot{\bar{\omega}}. \qquad (16)$$

2.4 Preparation of the power circuit of the installation for hydraulics with a description of the individual links

In the course of the research, all the work of the flow energy Converter was divided into 3 stages in order to more accurately understand the nature of the forces arising and more accurately determine the desired parameters on the obtained model.

During the first stage, the valve is opened, which opens the cross section of the supply pipeline, the working medium is fed, resulting in an increase in the flow rate and at this moment the shock valve of the unit, which creates a pulsed flow of the working medium is closed. This process is shown in the energy circuit, which is shown below. The parameters of this circuit are r_1 active resistance of pipe, m_1 масса рабочей these parameters are combined in the first link, which indicates that the valve opens and the working environment begins to pass. The second link is transformative. In the third link r_2 active resistance of pipe, m_2 the mass of the working medium, here shows the closing force of the impact unit.

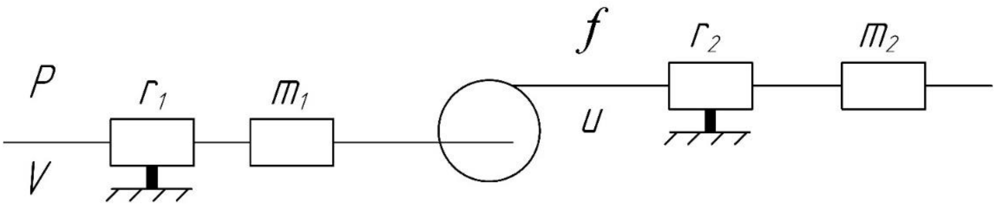

Figure 9 – Energy circuit stage 1

During the second stage, the shock valve of the unit, which creates a pulsed flow of the working medium remains closed, and the flow of the working medium continues its movement with deceleration through the closed system of the experimental sample. The flow of the working medium compresses the gas bubbles in the water, so the kinetic energy is converted into potential compression energy, but it is worth noting that the potential compression energy is not a compliance effect. This process is shown in the energy circuit, which is shown below. This link explains the process, which is described r_1 active resistance of pipe, m_1 working environment weight, l_1 the ductility of the material, the process does not stop, there is a change in pressure, and the expansion of the pipe.

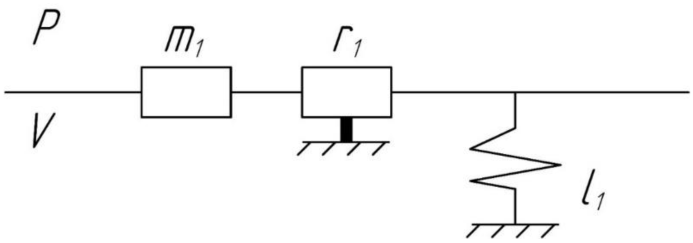

Figure 10 – Energy circuit stage 2

In the course of stage 3, the compression energy obtained by the flow of the working medium, whose kinetic energy has turned into potential energy, creates a reverse flow wave, also the pressure in the system begins to increase, which together leads to the rotation of the shaft of the spiral flow energy Converter. This process is shown in the energy circuit, which is shown below. In this scheme, the first link has l_1 the ductility of the material, r_1 active resistance of pipe, m_1 the mass of the working fluid, this link shows that a reverse wave is created, and the pressure begins to change. The second link is transformative. In the third link, due to the created reverse wave, the rotation of the structure is described and from such parameters as r_2 активное сопротивление трубы, l_2 the ductility of the material and J moment of inertia.

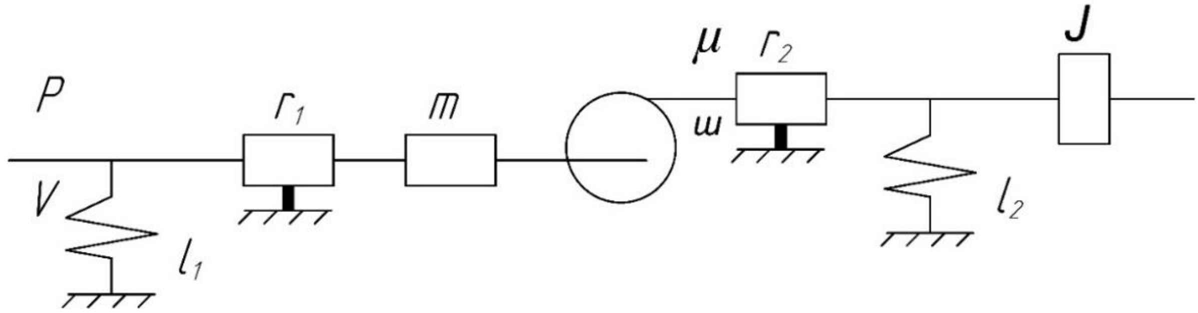

Figure 11 – Energy circuit stage 3

2.5 Mathematical transformations of the energy stage 1

The resulting circuit of the first stage is divided into links. Next, at each level we find the values that affect the basic parameters and change them depending on various factors.

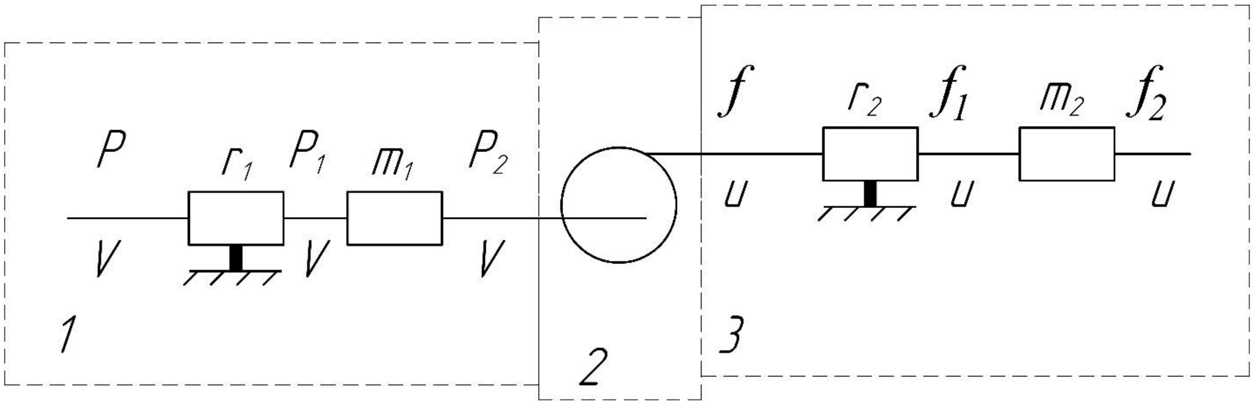

Figure 12 – Energy circuit stage 1 with variable parameters

We get three links in the energy circuit. For each we make a system of equations.

For the first link:

$$\begin{cases} P = r_1 \cdot V^2 + m_1 \cdot \dot{V} + P_2, \\ V = const \end{cases} \qquad (17)$$

For the second link:

$$\begin{cases} f = P_2 \cdot S_p, \\ \upsilon = V / S_p. \end{cases} \qquad (18)$$

For the third link:

$$\begin{cases} f = r_2 \cdot \upsilon + m_2 \cdot \dot{\upsilon} + f_2, \\ \upsilon = const \end{cases}. \qquad (19)$$

We transform the chosen formula (17) into a convenient form for further transformations:

$$\begin{cases} P_2 = \frac{1}{S}\left(r_2\upsilon + m_2\upsilon + f_2\right), \\ V = S\upsilon \end{cases}. \qquad (20)$$

Express the initial parameters are chosen as the final submissions from the formula (20):

$$\begin{cases} P_2 = \frac{1}{S} r_2\upsilon + \frac{1}{S} m_2\upsilon + \frac{1}{S} f_2, \\ V = S\upsilon \end{cases}. \qquad (21)$$

We Express our values through the real and real part of the formula (21):

$$\begin{cases} P_2 = \frac{r_2}{S}\upsilon_0 + \frac{r_2}{S}\bar{\upsilon} + \frac{m_2 \dot{\bar{\upsilon}}}{S} + \frac{1}{S} f_{20} + \frac{1}{S}\overline{f_2}, \\ V = S\upsilon \end{cases}. \qquad (22)$$

Do mathematical transformation of the value:

$$\dot{\bar{V}} = S\dot{\bar{\upsilon}},$$

$$V^2 = S\left(\upsilon_0 + \bar{\upsilon}\right)^2,$$

$$V^2 = S\upsilon_0{}^2 + 2S\upsilon_0\bar{\upsilon}.$$

Through the obtained value we obtain the working equation of the formula (22):

$$P = r_1\left(S\upsilon_0{}^2 + 2S\upsilon_0\bar{\upsilon}\right) + m_1 S\dot{\bar{\upsilon}} + \frac{r_2}{S}\upsilon_0 + \frac{r_2}{S}\bar{\upsilon} + \frac{m_2}{S}\dot{\bar{\upsilon}} + \frac{1}{S}f_{20} + \frac{1}{S}\overline{f_2},$$

$$P = r_1 S\upsilon_0{}^2 + 2r_1 S\upsilon_0\bar{\upsilon} + m_1 S\dot{\bar{\upsilon}} + \frac{r_2}{S}\upsilon_0 + \frac{r_2}{S}\bar{\upsilon} + \frac{m_2}{S}\dot{\bar{\upsilon}} + \frac{1}{S}f_{20} + \frac{1}{S}\overline{f_2},$$

$$P = \frac{m_2}{S}\dot{\bar{\upsilon}} + m_1 S\dot{\bar{\upsilon}} + \frac{r_2}{S}\bar{\upsilon} + 2r_1 S\upsilon_0\bar{\upsilon} + \frac{r_2}{S}\upsilon_0 + r_1 S\upsilon_0{}^2 + \frac{1}{S}\overline{f_2} + \frac{1}{S}f_{20}.$$

Sort the equation in descending order of the series value:

$$P = \left(m_1 S + \frac{m_2}{S}\right)\dot{\bar{\upsilon}} + \left(2r_1 S\upsilon_0 + \frac{r_2}{S}\right)\bar{\upsilon} + \frac{r_2}{S}\upsilon_0 + r_1 S\upsilon_0{}^2 + \frac{1}{S}\overline{f_2} + \frac{1}{S}f_{20}.$$

Replace the obtained coefficients with the parameters:

$$P = a_1\dot{\bar{\upsilon}} + a_2\bar{\upsilon} + a_3 + a_4 + b_1\overline{f_2} + b_2.$$

Equate both sides of equation and get the dependencies:

$$(a_1 S + a_2 + 1)\cdot(\upsilon(S)) = -(b_1 + 1)\cdot(f_2(S)).$$

Get the complex resistance of the circuit:

$$Z(S) = \frac{f_2(S)}{\upsilon(S)} = \frac{a_1 S + a_2 + 1}{-b_1 - 1}.$$

Replace the parameter with the real and imaginary parts of the value:

$$Z(\Omega)=\frac{a_1 j\Omega + a_2 + 1}{-b_1 - 1},$$

$$Z(\Omega)=\frac{f_2(S)}{\upsilon(S)}=\frac{a_1 j\Omega + a_2 + 1}{-b_1 - 1}.$$

Perform mathematical transformations on the complex resistance of the circuit:

$$Z(\Omega)=\frac{(a_2+1)+(a_1 j\Omega)}{-b_1 - 1}.$$

We derive the real part of the complex resistance:

$$U(\Omega)=\frac{(a_2+1)}{-b_1 - 1}.$$

We derive the imaginary part of the complex resistance:

$$V(\Omega)=\frac{(a_1 j\Omega)}{-b_1 - 1}.$$

We obtain the amplitude-frequency function of the energy circuit:

$$A_1(\Omega)=\sqrt{\left(\frac{(a_2+1)}{-b_1-1}\right)^2+\left(\frac{(a_1\Omega)}{-b_1-1}\cdot j\right)^2}.$$

Get the phase-frequency function of the energy circuit:

$$\varphi_1(\Omega) = -arctg\frac{\left(\frac{(a_2+1)}{-b_1-1}\right)}{\left(\frac{(a_1\Omega)}{-b_1-1}\cdot j\right)}.$$

2.6 Mathematical transformations of the energy stage 2

The resulting circuit of the second stage is divided into links. Next, at each level we find the values that affect the basic parameters and change them depending on various factors.

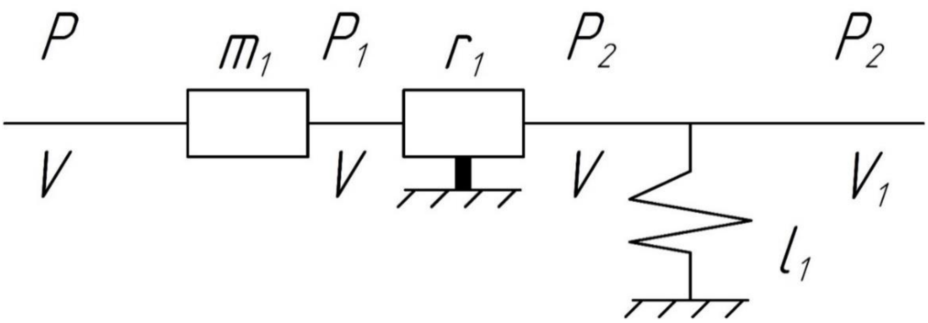

Figure 13 – Energy circuit stage 2 with variable parameters

We get one link in the energy circuit. We make a system of equations.

For the first link:

$$\begin{cases} P = -m_1\cdot\dot{V} + r_1\cdot V^2 + P_2, \\ V = l_1\cdot\dot{P}_2 + V_1 \end{cases}. \tag{23}$$

We make mathematical transformations from the formula (23):

$$\begin{cases} P_0 + \overline{P} = -m_1 \cdot \dot{\overline{V}} + r_1 \cdot (V_0^2 + 2\overline{V}V_0) + P_{20} + \overline{P_2}, \\ V_0 + \overline{V} = l_1 \cdot \dot{\overline{P_2}} + V_{10} + \overline{V} \end{cases} \quad . \tag{24}$$

Select the real and real parts in the formula (24):

$$\begin{cases} P_0 + \overline{P} = -m_1 \cdot \dot{\overline{V}} + r_1 V_0^2 + 2r_1 \overline{V}V_0 + P_{20} + \overline{P_2}, \\ V_0 + \overline{V} = l_1 \cdot \dot{\overline{P_2}} + V_{10} + \overline{V} \end{cases} \quad . \tag{25}$$

From the system of equations, we select the formula (25) over which the transformations will continue:

$$P_0 + \overline{P} = -m_1 \cdot \dot{\overline{V}} + r_1 V_0^2 + 2r_1 \overline{V}V_0 + P_{20} + \overline{P_2}.$$

Do mathematical transformation of the value:

$$V = l_1 \cdot \dot{P}_2 + V_1,$$

$$V = l_1 \cdot \dot{\overline{P_2}} + V_{10} + \overline{V}1,$$

$$V_0 + \overline{V} = V_{10} + (l_1 \cdot \dot{\overline{P_2}} + \overline{V}1),$$

$$(V_0 + \overline{V})^2 = V_{10} + (l_1 \cdot \dot{\overline{P_2}} + \overline{V}1)^2,$$

$$(V_0 + \overline{V})^2 = V_{10}{}^2 + 2V_{10}(l_1 \cdot \dot{\overline{P_2}} + \overline{V}1).$$

Judging from the previous transformations, we can conclude about equality:

$$V_0{}^2 = V_{10}{}^2,$$

$$V_0 = V_{10}.$$

Do mathematical transformation of the value:

$$\overline{V} = l_1 \cdot \overline{\dot{P}_2} + \overline{V}1,$$

$$\dot{\overline{V}} = l_1 \cdot \overline{\ddot{P}_2} + \overline{\dot{V}_1}.$$

Through the obtained value we obtain the working equation:

$$P_0 + \overline{P} = -m_1 \cdot (l_1 \cdot \overline{\ddot{P}_2} + \overline{\dot{V}_1}) + r_1 V_{10}^{\,2} + 2r_1 (l_1 \cdot \overline{\dot{P}_2} + \overline{V}1) V_{10} + P_{20} + \overline{P_2}.$$

Open the brackets in the working equation and make mathematical transformations:

$$P_0 + \overline{P} = -m_1 l_1 \overline{\ddot{P}_2} - m_1 \overline{\dot{V}_1} + r_1 V_{10}^{\,2} + 2r_1 V_{10} l_1 \overline{\dot{P}_2} + 2r_1 V_{10} \overline{V}1 + P_{20} + \overline{P_2},$$

$$P_0 + \overline{P} = -m_1 l_1 \overline{\ddot{P}_2} - m_1 \overline{\dot{V}_1} + r_1 V_{10}^{\,2} + 2r_1 V_{10} l_1 \overline{\dot{P}_2} + 2r_1 V_{10} \overline{V}1 + P_{20} + \overline{P_2}.$$

Sort the equation in descending order of the series value:

$$P = -m_1 l_1 \overline{\ddot{P}_2} + 2r_1 V_{10} l_1 \overline{\dot{P}_2} + \overline{P_2} + P_{20} - m_1 \overline{\dot{V}_1} + 2r_1 V_{10} \overline{V}1 + r_1 V_{10}^{\,2}.$$

Replace the obtained coefficients with the parameters:

$$P = -a_1 \overline{\ddot{P}_2} + a_2 \overline{\dot{P}_2} + a_3 \overline{P_2} + a_4 - b_1 \overline{\dot{V}_1} + b_2 \overline{V}1 + b_3.$$

Equate both sides of equation and get the dependencies:

$$(-a_1 S^2 + a_2 S + a_3 + 1)\cdot P_2(S) = -(-b_1 S + b_2 + 1)\cdot V_1(S).$$

Get the complex resistance of the circuit:

$$Z(S) = \frac{b_1 S - b_2 - 1}{-a_1 S^2 + a_2 S + a_3 + 1}.$$

Replace the parameter with the real and imaginary parts of the value:

$$Z(S) = \frac{b_1 j\Omega - b_2 - 1}{a_1 \Omega^2 + a_2 j\Omega + a_3 + 1}.$$

Perform mathematical transformations on the complex resistance of the circuit:

$$Z(S) = \frac{b_1 j\Omega - b_2 - 1}{a_1 \Omega^2 + a_2 j\Omega + a_3 + 1},$$

$$Z(S) = \frac{\left(b_1 j\Omega - b_2 - 1\right)\cdot\left[\left(a_1\Omega^2 + a_3 + 1\right) - a_2 j\Omega\right]}{\left[\left(a_1\Omega^2 + a_3 + 1\right) + a_2 j\Omega\right]\cdot\left[\left(a_1\Omega^2 + a_3 + 1\right) - a_2 j\Omega\right]}.$$

We make mathematical transformations over the numerator of complex resistance:

$$\left(b_1 j\Omega - b_2 - 1\right)\cdot\left[\left(a_1\Omega^2 + a_3 + 1\right) - a_2 j\Omega\right] = \left(b_1 j\Omega - b_2 - 1\right)\cdot$$
$$\cdot\left(a_1\Omega^2 + a_3 + 1\right) - \left(b_1 j\Omega - b_2 - 1\right)\cdot\left(a_2 j\Omega\right) = a_1 b_1 j\Omega^3 +$$
$$+a_3 b_1 j\Omega + b_1 j\Omega - a_3 b_1 j\Omega - a_3 b_2 - a_3 - b_1 j\Omega - b_2 - 1 - a_2 b_1 j^2\Omega^2 +$$
$$+a_2 b_2 j\Omega + a_2 j\Omega = a_1 b_1 j\Omega^3 - a_3 b_2 - a_3 - 1 + a_2 b_1\Omega^2 + a_2 b_2 j\Omega \quad .$$

We obtain the transformed complex resistance of the energy circuit:

$$Z(S) = \frac{a_1 b_1 j\Omega^3 - a_3 b_2 - a_3 - 1 + a_2 b_1\Omega^2 + a_2 b_2 j\Omega}{a_1^2\Omega^4 + 2a_1\Omega^2 + 2a_1 a_3\Omega^2 + 2a_3 + a_3^2 + 1 + a_2^2\Omega^2}\,.$$

We derive the real part of the complex resistance:

$$U(\Omega) = \frac{\left(a_2 b_1\Omega^2 - a_3 b_2 - a_3 - 1\right)}{a_1^2\Omega^4 + 2a_1\Omega^2 + 2a_1 a_3\Omega^2 + 2a_3 + a_3^2 + 1 + a_2^2\Omega^2}\,.$$

We derive the imaginary part of the complex resistance:

$$V(\Omega) = \frac{\left(a_1 b_1 j\Omega^3 + a_2 b_2 j\Omega\right)}{a_1^2\Omega^4 + 2a_1\Omega^2 + 2a_1 a_3\Omega^2 + 2a_3 + a_3^2 + 1 + a_2^2\Omega^2}\,.$$

We obtain the amplitude-frequency function of the energy circuit:

$$A_2(\Omega)=\sqrt{\left(\frac{\left(a_2b_1\Omega^2-a_3b_2-a_3-1\right)}{a_1^2\Omega^4+2a_1\Omega^2+2a_1a_3\Omega^2+2a_3+a_3^2+1+a_2^2\Omega^2}\right)^2+\left(\frac{\left(a_1b_1\Omega^3+a_2b_2\Omega\right)}{a_1^2\Omega^4+2a_1\Omega^2+2a_1a_3\Omega^2+2a_3+a_3^2+1+a_2^2\Omega^2}\cdot j\right)^2}.$$

Get the phase-frequency function of the energy circuit:

$$\varphi_2(\Omega)=-arctg\frac{\dfrac{\left(a_2b_1\Omega^2-a_3b_2-a_3-1\right)}{a_1^2\Omega^4+2a_1\Omega^2+2a_1a_3\Omega^2+2a_3+a_3^2+1+a_2^2\Omega^2}}{\dfrac{a_1b_1j\Omega^3+a_2b_2j\Omega}{a_1^2\Omega^4+2a_1\Omega^2+2a_1a_3\Omega^2+2a_3+a_3^2+1+a_2^2\Omega^2}}=$$

$$=-arctg\frac{\left(a_2b_1\Omega^2-a_3b_2-a_3-1\right)}{a_1^2\Omega^4+2a_1\Omega^2+2a_1a_3\Omega^2+2a_3+a_3^2+1+a_2^2\Omega^2}\cdot\frac{a_1^2\Omega^4+2a_1\Omega^2+2a_1a_3\Omega^2+2a_3+a_3^2+1+a_2^2\Omega^2}{a_1b_1j\Omega^3+a_2b_2j\Omega},$$

$$\varphi_2(\Omega)=-arctg\frac{\left(a_2b_1\Omega^2-a_3b_2-a_3-1\right)}{\left(a_1b_1\Omega^3+a_2b_2\Omega\right)\cdot j}.$$

2.7 The characterization energy circuit stage 3

The resulting circuit of the third stage is divided into links. Next, at each level we find the values that affect the basic parameters and change them depending on various factors.

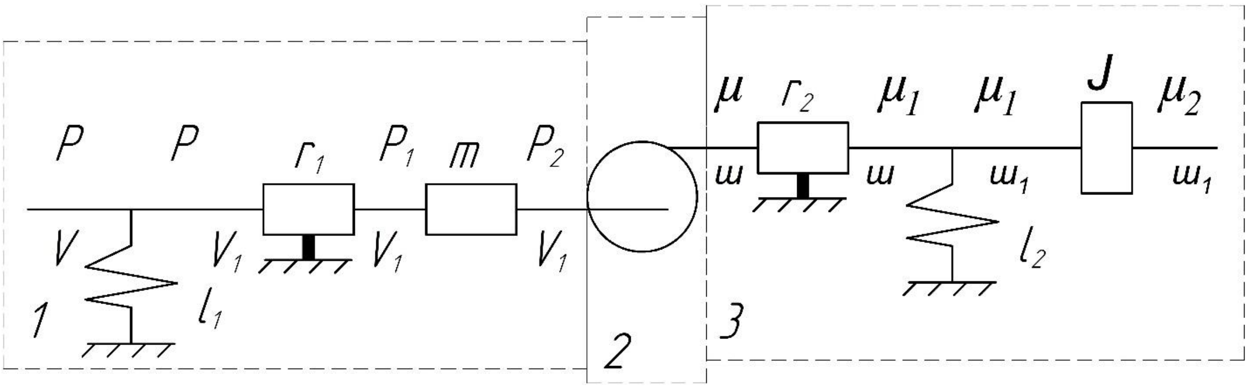

Figure 14 – Energy circuit stage 3 with variable parameters

We get three links in the energy circuit. For each we make a system of equations.

For the first link:

$$\begin{cases} P = r_1 \cdot V_1^{2} + m \cdot \dot{V}_1 + P_2, \\ V = l_1 \dot{P} + V_1 \end{cases} . \tag{26}$$

For the second link:

$$\begin{cases} \mu = P_2 \cdot \dfrac{R}{2} S_p, \\ \omega = V_1 / \left(\dfrac{R}{2} S_p \right). \end{cases} \tag{27}$$

For the third link:

$$\begin{cases} \mu = r_2\omega + J\dot{\omega}_1 + \mu_2, \\ \omega = l_2\dot{\mu}_1 + \omega_1 \qquad . \end{cases} \tag{28}$$

Express magnitude, to further change:

$$2\mu = p_2 \cdot R \cdot S,$$

$$P_2 = \frac{2\mu}{RS},$$

$$\mu = r_2 l_2 \dot{\mu}_1 + r_2\omega_1 + J\dot{\omega}_1 + \mu_2.$$

We perform a mathematical transformation on the value from the formula (28):

$$\mu = r_2 l_2 \dot{\overline{\mu_1}} + r_2\overline{\omega_1} + r_2\omega_{10} + J\dot{\overline{\omega_1}} + \overline{\mu_2} + \mu_{20}.$$

Express magnitude, to further change:

$$\mu = P_2 \cdot \frac{R}{2} S_p \ ,$$

$$2\mu = p_2 \cdot R \cdot S,$$

$$P_2 = \frac{2\mu}{RS} = \mu\frac{2}{RS}.$$

From the data obtained, we Express the main parameter from the formula (26):

$$P_2 = \frac{2}{RS}\left(r_2 l_2 \dot{\overline{\mu_2}} + r_2\overline{\omega_1} + r_2\omega_{10} + J\dot{\overline{\omega_1}} + \overline{\mu_2} + \mu_{20}\right).$$

Expand the brackets of the resulting parameter:

$$P_2 = \frac{2}{RS} r_2 l_2 \dot{\overline{\mu}}_2 + \frac{2}{RS} r_2 \overline{\omega}_1 + \frac{2}{RS} r_2 \omega_{10} + \frac{2}{RS} J \dot{\overline{\omega}}_1 + \frac{2}{RS} \overline{\mu}_2 + \frac{2}{RS} \mu_{20}.$$

Express magnitude, to further change:

$$\omega = V_1 / \left(\frac{R}{2} S_p \right),$$

$$2\omega = V_1 RS,$$

$$V_1 = \omega \cdot \left(\frac{2}{RS} \right),$$

$$P = r_1 \cdot \left(\frac{2}{RS} \omega \right)^2 + m \cdot \left(\frac{2}{RS} \dot{\omega} \right) + P_2.$$

The disclosed brackets and do the math:

$$P = r_1 \cdot \left(\frac{2}{RS} l_2 \dot{\mu}_2 + \omega_1 \right)^2 + m \cdot \left(\frac{2}{RS} l_2 \ddot{\mu}_2 + \omega_1 \right) + P_2,$$

$$P = r_1 \cdot \left(\omega_{10}^2 + \frac{2}{RS} l_2 \omega_0 \dot{\mu}_2 \right)^2 + m \cdot \left(\frac{2}{RS} l_2 \ddot{\overline{\mu}}_2 + \dot{\overline{\omega}}_1 \right) + P_2.$$

From the system of equations, we distinguish the one over which the transformations will continue:

$$P = r_1 \omega_{10}^2 + 2 r_1 \frac{2}{RS} l_2 \omega_0 \dot{\mu}_2 + m \frac{2}{RS} l_2 \ddot{\overline{\mu}}_2 + m \dot{\overline{\omega}}_1 + \frac{2}{RS} r_2 l_2 \dot{\overline{\mu}}_2 +$$
$$+ \frac{2}{RS} r_2 \overline{\omega}_1 + \frac{2}{RS} r_2 \omega_{10} + \frac{2}{RS} J \dot{\overline{\omega}}_1 + \frac{2}{RS} \overline{\mu}_2 + \frac{2}{RS} \mu_{20}.$$

Sort the equation in descending order of the series value:

$$P = m\frac{2}{RS}l_2\ddot{\overline{\mu_2}} + \left(r_1\frac{1}{RS}l_2\omega_0 + \frac{2}{RS}r_2l_2\right)\dot{\overline{\mu_2}} + \frac{2}{RS}\overline{\mu_2} +$$
$$+\frac{2}{RS}\mu_{20} + \left(\frac{2}{RS}J + m\right)\dot{\overline{\omega_1}} + \frac{2}{RS}r_2\overline{\omega_1} + \frac{2}{RS}r_2\omega_{10} + r_1\omega_{10}^2 \quad .$$

Replace the obtained coefficients with the parameters:

$$P = a_1\ddot{\overline{\mu_2}} + a_2\dot{\overline{\mu_2}} + a_3\overline{\mu_2} + a_4 + b_1\dot{\overline{\omega_1}} + b_2\overline{\omega_1} + b_3.$$

Model the resulting coefficients to the parameters and equate both sides of equation and get the dependencies:

$$b_1S + b_2 + 1\left(\Omega_1(S)\right) = -a_1S^2 - a_2S - a_3 - 1\left(M_2(S)\right).$$

Get the complex resistance of the circuit:

$$Z(S) = \frac{\left(\Omega_1(S)\right)}{\left(M_2(S)\right)} = \frac{-a_1S^2 - a_2S - a_3 - 1}{b_1S + b_2 + 1}.$$

Replace the parameter with the real and imaginary parts of the value:

$$Z(S) = \frac{a_1\Omega^2 - a_2j\Omega - a_3 - 1}{b_1j\Omega + b_2 + 1}.$$

The obtained transformed impedance of the energy circuit and carry out mathematical transformation on complex resistance of the circuit:

$$Z_1(S)=\frac{\left(a_1\Omega^2-a_2 j\Omega-a_3-1\right)\cdot\left[\left(b_2+1\right)-b_1 j\Omega\right]}{\left[\left(b_2+1\right)+b_1 j\Omega\right]\cdot\left[\left(b_2+1\right)-b_1 j\Omega\right]}.$$

We make mathematical transformations over the numerator of complex resistance:

$$\begin{gathered}\left(a_1\Omega^2\right)\cdot\left(b_2+1\right)-\left(a_2 j\Omega\right)\cdot\left(b_2+1\right)-a_3\cdot\left(b_2+1\right)-1\cdot\left(b_2+1\right)-\\ \left(a_1\Omega^2\right)\cdot\left(b_1 j\Omega\right)+\left(a_2 j\Omega\right)\cdot\left(b_1 j\Omega\right)+a_3\cdot\left(b_1 j\Omega\right)+1\cdot\left(b_1 j\Omega\right)=\\ =a_1b_2\Omega^2+a_1\Omega^2-a_2b_2 j\Omega-a_2 j\Omega-a_3b_2-a_3-b_2-1-\\ -a_1b_1 j\Omega^3-a_2b_1\Omega^2+a_3b_1 j\Omega+b_1 j\Omega\ .\end{gathered}$$

We make mathematical transformations over the denominator of the complex resistance:

$$\begin{gathered}\left(b_2+1\right)\cdot\left(b_2+1\right)+\left(b_1 j\Omega\right)\cdot\left(b_2+1\right)-\left(b_1 j\Omega\right)\cdot\left(b_1 j\Omega\right)=\\ =b_2^2+b_2+b_2+1+b_1b_2 j\Omega+b_1 j\Omega-b_1b_2 j\Omega-b_1 j\Omega-\\ -b_1^2 j^2\Omega^2=b_2^2+2b_2+b_1^2\Omega^2+1\ .\end{gathered}$$

We derive the real part of the complex resistance:

$$U(\Omega)=\frac{a_1b_2\Omega^2+a_1\Omega^2-a_3b_2-a_3-b_2-1-a_2b_1\Omega^2}{b_2^2+2b_2+b_1^2\Omega^2+1}.$$

We derive the imaginary part of the complex resistance:

$$V(\Omega)=\frac{-a_2b_2 j\Omega-a_2 j\Omega-a_1b_1 j\Omega^3+a_3b_1 j\Omega+b_1 j\Omega}{b_2^2+2b_2+b_1^2\Omega^2+1}.$$

We obtain the amplitude-frequency function of the energy circuit:

$$A_3(\Omega)=\sqrt{\left(\frac{a_1b_2\Omega^2+a_1\Omega^2-a_3b_2-a_3-b_2-1-a_2b_1\Omega^2}{b_2^2+2b_2+b_1^2\Omega^2+1}\right)^2+\left(\frac{-a_2b_2\Omega-a_2\Omega-a_1b_1\Omega^3+a_3b_1\Omega+b_1\Omega}{b_2^2+2b_2+b_1^2\Omega^2+1}\cdot j\right)^2}\ .$$

Get the phase-frequency function of the energy circuit:

$$\varphi_3(\Omega)=-arctg\frac{\left(\dfrac{a_1b_2\Omega^2+a_1\Omega^2-a_3b_2-a_3-b_2-1-a_2b_1\Omega^2}{b_2^2+2b_2+b_1^2\Omega^2+1}\right)}{\left(\dfrac{-a_2b_2\Omega-a_2\Omega-a_1b_1\Omega^3+a_3b_1\Omega+b_1\Omega}{b_2^2+2b_2+b_1^2\Omega^2+1}\cdot j\right)},$$

$$\varphi_3(\Omega)=-arctg\frac{a_1b_2\Omega^2+a_1\Omega^2-a_3b_2-a_3-b_2-1-a_2b_1\Omega^2}{\left(-a_2b_2\Omega-a_2\Omega-a_1b_1\Omega^3+a_3b_1\Omega+b_1\Omega\right)\cdot j}.$$

3 Description of experimental setup

3.1 The prerequisites for creating a shock site

To create the layout of the impact device was considered a few devices generate pulses, the amount of movement of the working environment.

Consider one of these devices, which is taken as an analogue of the shock node. This analogue is shown in figure 15.

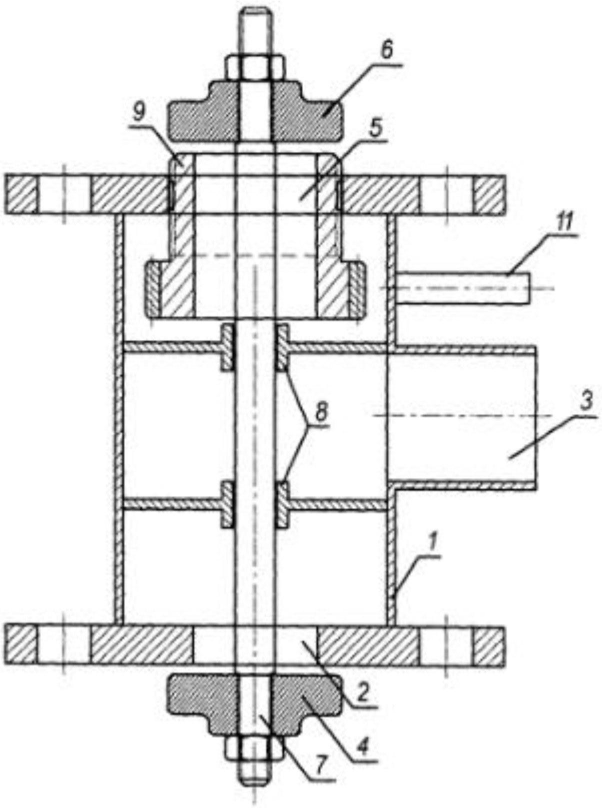

Figure 15 – The design of the impact site

The shock Assembly comprises a cylindrical body 1 with an inlet 2 and an outlet 3 holes, as well as a shock valve 4. Above the second inlet 5 is the second shock valve 6.

The inlet holes 2 and 5 are made coaxially along the centering rod 7 installed in the cylindrical housing 1 on the sleeves 8 with the shock valves 4 and 6 rigidly fixed at its ends.

In the second inlet 5 screwed movable seat 9, 10 worm gear associated with the adjusting screw 11.

The work of the shock node is as follows. The flow of liquid is made from one source simultaneously in both inlet openings 2 and 5. The distance between the shock valves 4 and 6 is greater than the distance between the inlet ports 2 and 5 by the valve stroke.

With the full opening of one inlet, the second is completely closed, i.e. with one of the shock valves» raised», the second is tightly adjacent to the movable seat 9.

When the inlet is open, water, passing through it, acts on the open shock valve, causing it to close and create a hydraulic shock. And since the shock valves 4 and 6 are rigidly connected with each other by means of a centering rod 7, the movement of one of them leads to the movement of the other, i.e. the complete closure of one of them leads to the full opening of the other. And the process is repeated in the same sequence for another shock valve, etc.

Thus, this design, which is shown in figure 17, is able to independently support the process of closing and opening the shock valves 4 and 6. The stroke of the shock valves 4 and 6 is regulated by the adjusting screw 11, during the rotation of which the torque is transmitted by means of a worm gear 10 to the movable seat 9 screwed into the second inlet 5.

When the movable seat 9 rotates, its translational motion is provided, increasing or reducing the stroke of the shock valves 4 and 6.

The disadvantages of the known design of the shock unit are its relatively low stability at low flow rates of the working medium, as well as the violation of the phases of the alternate opening of the shock valves during operation of the device [24].

Next, we consider the design, which is its component and the principle of operation of the shock node on the basis of figure 16.

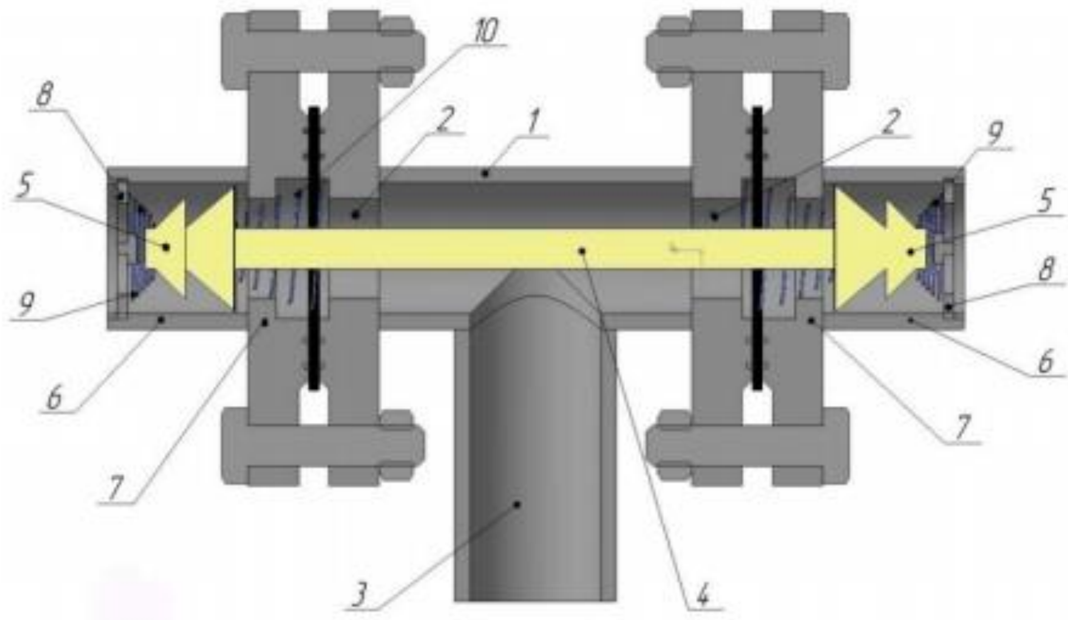

Figure 16 – The design of the impact site

The shock Assembly includes a housing 1 with two inlet 2 and outlet 3 holes, a centering rod 4 with shock valves 5 rigidly fixed at its ends, two guide bushings 6 with seat 7, two locking rings 8, two return springs 9 and two conical springs 10.

The impact Assembly works as follows. Preliminary adjustment of the shock unit is carried out, which consists in the selection of the stiffness of the return 9 and conical 10 springs in such a way that the different lifting height of the shock valves 5 relative to the seats 7 is provided. For this purpose, return springs 9 are fixed in guide bushings 6 by means of locking rings 8, providing access to the specified settings.

Then the input channels 2 and the output channel 3 of the housing 1 are hydraulically connected to the supply source of the working medium and its receiver (not indicated in the drawing). In this case, the working medium enters the inlet channels 2 in series through the guide bushings 6 with seat 7, bypassing, at the same time, the shock valves 5, rigidly fixed to the centering rod 4 and installed between the return springs 9 and the conical springs 10, and then leaves the housing 1 through the outlet 3.

Since the initial setting between the inlet 2 and outlet 3 holes of the housing 1 was provided by the difference of hydraulic heads, the shock valve 5 will be shifted to close in the inlet 2 channel with a large hydraulic resistance, and the second shock valve 5 in the corresponding inlet 2 channel, by means of the centering rod 4, will ensure its full opening.

As a result of closing one of the inlet channel 2 of the working environment of the shock valve 5 in the corresponding guide bushing 6 will occur hydraulic shock, the energy of which is used depending on the area of application of the impact device. Then, the working medium will flow into the outlet channel 3 of the housing 1 of the shock unit through another, open, inlet channel 2 and, with a sufficient (steady-state) flow rate, will entail the shock valve 5 to close, and in the corresponding guide sleeve 6 the desired hydraulic shock will occur.

Then the process of generating pulses of the amount of motion of the working medium in the guide bushings 6 will occur automatically alternately until there is a supply of working fluid through the design of the shock unit.

The disadvantages of the known solution are the relatively slow closing of the shock valve, as well as the inability to control the moment of generation of pulses of the amount of motion of the working medium without changing its flow through the shock node [24].

3.2 Impact unit with external drive

In modern systems of heat and water supply, to improve the technical and economic indicators, offers many options for their optimization.

One of these solutions is the use of locally generated pulses of the amount of motion of the working medium.

In water supply systems, according to the principle of operation of the hydraulic RAM, these pulses of the working environment are used to provide water to consumers [6].

In heat supply systems, periodic local water hammer is used to intensify heat transfer [18], to implement the conditions for self-cleaning of the coolant circulation surfaces of heat power equipment, as well as to organize the mixing of different temperature coolant flows and the transformation of the head, for example, the heat network into the head of the heat consumption system [1, 23].

A tool for generating pulses of the amount of motion of the working medium are shock nodes (flow pulsators), which are installed in the water and heat supply system according to a certain scheme, which is determined by the scope and purpose of the devices.

Currently, there are a large number of technical solutions for flow pulsators, which causes some difficulties in the case of their choice for practical use.

Currently, a useful model has been developed – a Shock node. It belongs to the field of hydrodynamics, hydraulics and mechanical engineering, where it can be used in devices for various purposes that use the effect of hydraulic shock, as well as heat supply, where it can be used to create a pulsed motion of the liquid in relation to the intensification of heat exchange in heat power plants [19].

To create a pulsating flow of the working medium passing through the flow energy Converter, a shock unit is installed, the drawing of the model is made in The COMPASS - 3D program (in accordance with figure 17).

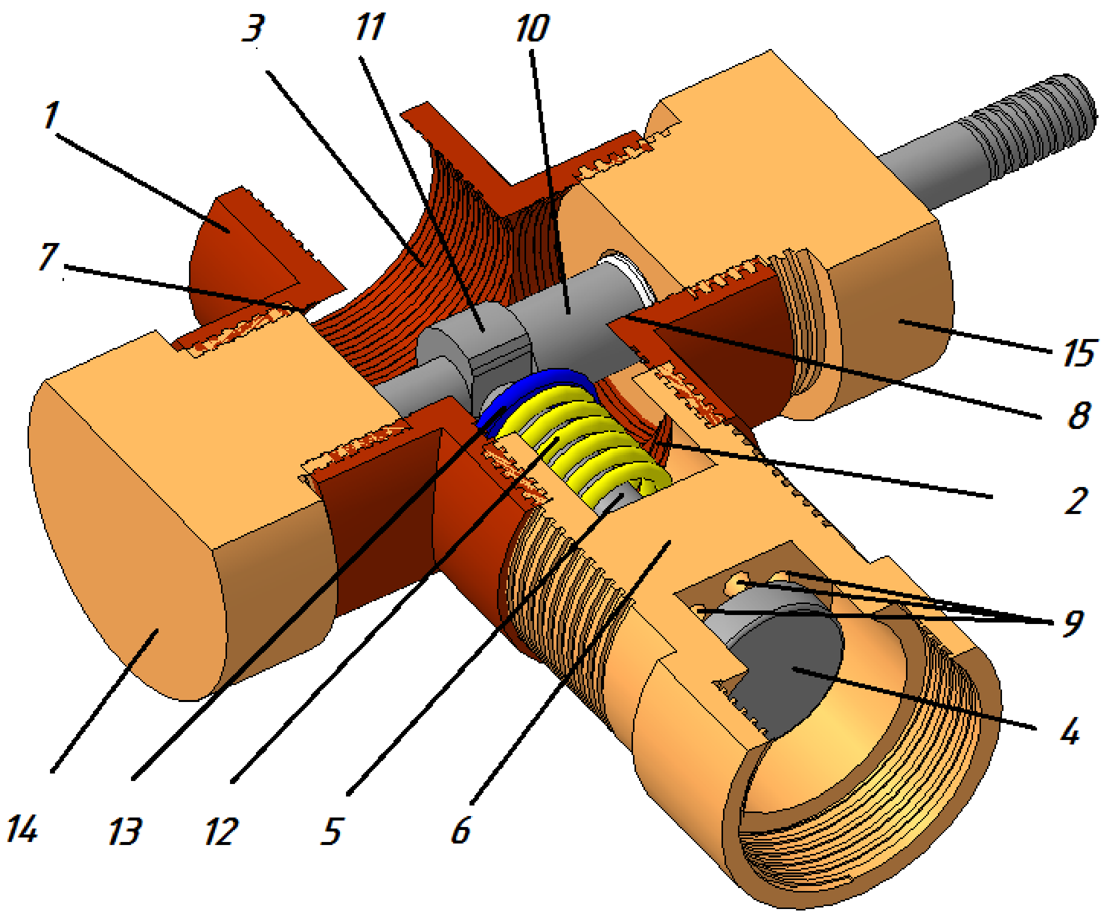

Figure 17 – the design of the impact site

The impact unit includes a hollow body 1 with an input 2 and an output 3 holes for the expiration of the working medium. Shock valve 4, rigidly fixed to the rod 5, mounted in the sleeve 6 with the possibility of reciprocating.

Two additional coaxial holes 7 and 8 are made in the floor of the housing 1. The sleeve 6 is made with through channels 9 for the expiration of the working medium along the rod 5.

The design additionally contains a shaft 10 with a Cam 11, a spring 12, a locking ring 13, a centering plug 14 and a guide sleeve 15. The sleeve 6 is rigidly connected to the inlet 2 of the hollow body 1.

The shock valve 4 is located at the inlet of the working medium to the through channels 9 of the sleeve 6. The spring 10 is mounted on the rod 5 and fixed to it by the locking ring 13 from the outlet of the working medium from the through channels 9 of the sleeve 6.

The shaft 10 is installed inside the hollow body 1 with the possibility of rotational movement, where one end of the shaft 10 is inserted into the centering plug 14 fixed in the first additional hole 7 of the hollow body 1, and the second end of the shaft 10 is removed from the hollow body 1 through the guide bushing 15 installed in the second additional through hole 8 of the hollow body 1.

The Cam 11 of the shaft 10 is connected to the rod 5 with the possibility of converting its rotational-sliding motion into a reciprocating motion of the rod 5.

3.3 Operating principle of the impact

The impactor works in such a way that the free end of the sleeve 6 is first connected to the source (not specified in the drawing) of the working medium supply, and the outlet 3 to the receiver (not specified in the drawing) of the working medium. The shaft 10 from the outside of the hollow body 1 is connected to the source of rotational motion (not specified in the drawing), which to be able to control the pulse generation frequency of the amount of motion of the working medium must be able to change its own speed. For example, it can be an electric motor whose shaft speed is controlled by a frequency Converter (not shown in the drawing), etc.

This method ensures the rotation of the shaft 10 in the centering plug 14 installed in the first additional hole 7 of the hollow body 1, and the guide sleeve 15 installed in the second additional hole 8 of the hollow body 1. When this occurs, the rotation associated with the shaft 10 of the Cam 11. After that, the working medium is fed through the hollow body 1 from its source to the receiver.

When the Cam 11 rotates, which is made in the form of an involute, the reciprocating motion of the rod 5 in the sleeve 6 is provided and the opening and closing of the through channels 9 in the sleeve 6 by the shock valve 4, which is rigidly fixed to the rod 5. The closing of the shock valve 5 is facilitated by the impact of the spring 12 on the tension, which is installed on the rod 5 with the help of the locking ring 13, as well as the high-speed head of the working medium.

Thus, the working medium entering the sleeve 6 passes through the through channels 9 at the open position of the shock valve 4 and enters the inlet of the working medium 2 of the hollow body 1, and then leaves it through the outlet 3. In this case, the acceleration of the working medium is provided for the subsequent creation of an impulse of the amount of its movement. At the time when the spatial position of the Cam 11 will provide the possibility of closing the through channels 9 in the sleeve 6 by the shock valve 4, there will be a hydraulic shock, the energy of which can be used depending on the application of the shock unit.

After the spatial position of the Cam 11 at the rotation of the shaft 10 will ensure the subsequent opening of the through channels 9 in the sleeve 6 by the shock valve 4, the process of generating hydraulic shock will be repeated in the sequence described above.

When applying the proposed technical solution:

– increases the stability of the shock unit, since the opening and closing phase of the shock valve determines only the position of the Cam when the shaft rotates and does not depend on the flow of the working medium;

– provides the ability to control the frequency of pulse generation of the amount of motion of the working medium, regardless of its flow through the device;

– the task of obtaining a predetermined value of pressure increase at the time of hydraulic shock in the working environment with a wide range of changes in its flow rate.

3.4 Prerequisites for creating a flow energy Converter

Consider the utility model shown in figure 18. It was used as a prototype to create the first version of the flow energy Converter.Consider the utility model shown in figure 18. It was used as a prototype to create the first version of the flow energy Converter.

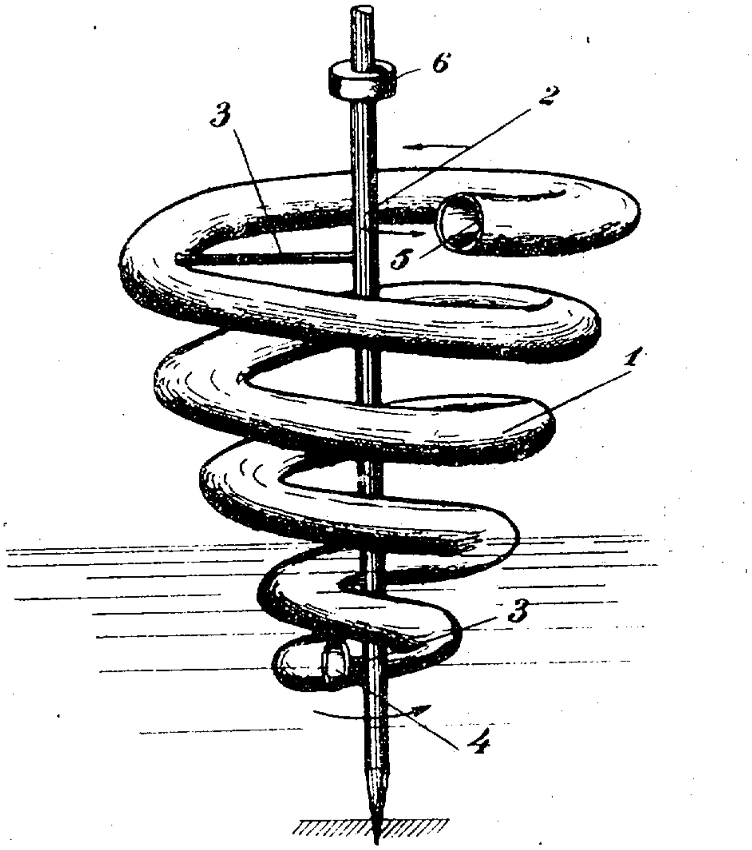

Figure 18 – The design of the scroll pump

The proposed design of the spiral pump shown in figure 18 is a tubular spiral 1 in the form of a cone mounted on the axis 2 by means of spokes 3, with an inlet channel 4 and an outlet 5, or any other method used in technology. Rotation occurs through the pulley 6.

The action of the spiral pump is as follows: the axis 2, with a tubular spiral 1 attached to it, is rotated by means of a pulley 6 or by some other method practiced in the technique. During the rotation of the spiral 1 in the hole 4 will enter the water.

Due to the conical shape of the tubular spiral, which develops during the rotation of this spiral of centrifugal force and the rarefaction of air at the outer end 5, facing the opposite rotation, the water will rise inside the tubular spiral as if on an inclined plane and pour out from the end 5 of the pipe 1.

The number of tubular spiral cones on the same axis can be different, and the holes for pouring can be arranged in mutually diametrically opposite directions, in order to uniformity of work. The end 4 can have a bell, the Axis 2 can be installed with a conical spiral, both in vertical and inclined position, and the whole system can be suspended to the vertical shaft, and in this case the lower support of the axis 2 is not required. It is also possible to install this tubular spiral cone with the base down.

The spiral pump, characterized in that the turns of the pipe 1, in the direction from the inlet 4 to the outlet 5, have gradually increasing radii, and the connection of the pipe with the rotating shaft 2 is made by means of spokes 3.

The disadvantages of the prototype is the impossibility of reversibility of the conversion of the raised fluid flow into mechanical energy [25].

The first laboratory sample was the energy Converter of the working medium, into mechanical energy, the drawing of the model is made in the COMPASS - 3D program (in accordance with figure 19).

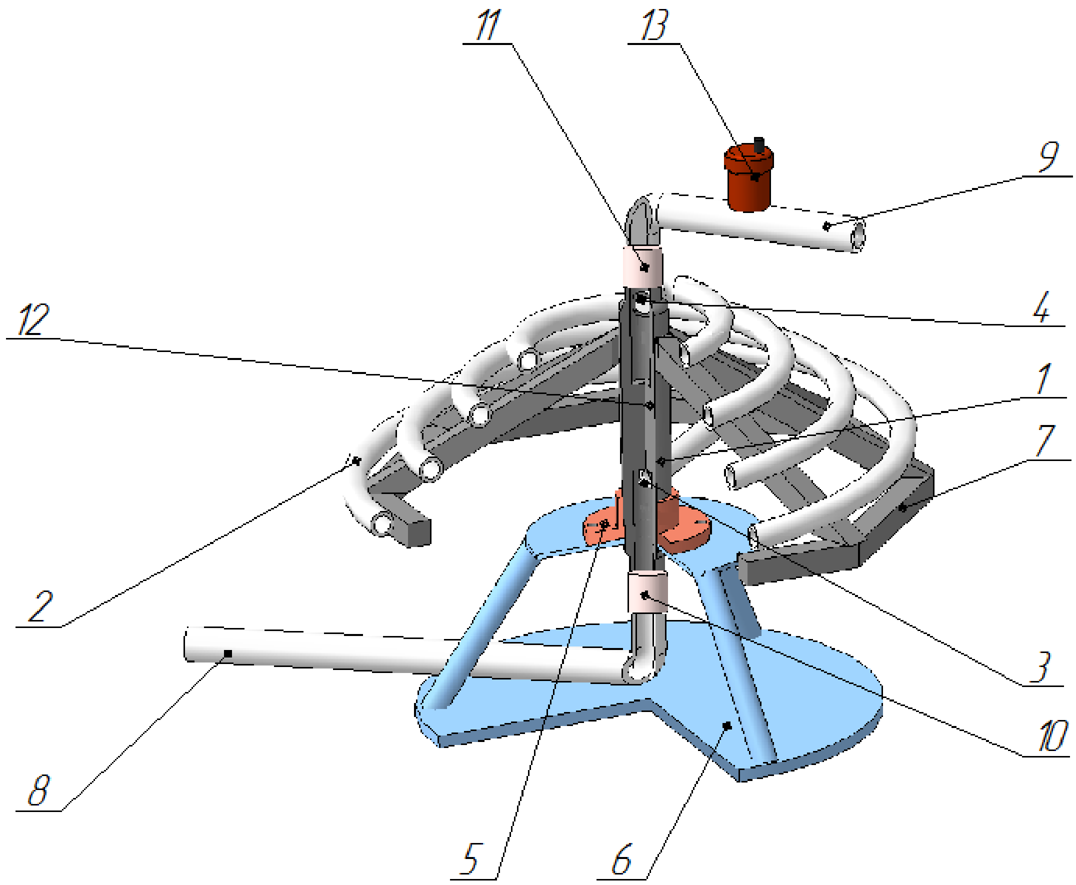

Figure 19 – Flow energy Converter design

The flow energy Converter includes a shaft 1, a tubular spiral of conical shape 2, having an input channel 3 and an output channel 4.

The shaft 1 is pressed into a thrust bearing 5, which is fixed rigidly to the rack 6, also a cone-shaped base 7 is rigidly fixed to the shaft 1, to which a tubular spiral of conical shape 2 is attached.

The inlet 8 and outlet 9 nozzles of the working medium are connected through swivels 10, 11 with shaft 1 to create the possibility of rotational movement of the design.

The flow energy Converter works as follows. Initially, the shock unit is adjusted, which consists in the selection of periodic reciprocating movements of the valve, to create a certain periodicity of pulsation of the liquid velocity. The pulsating flow of the working medium enters the inlet pipe 8 of the working medium and through the inlet channel 3 enters the tubular spiral of conical shape 2, then leaves it through the outlet pipe 9 of the working medium, passing through the outlet channel 4, a shock node is installed on the outlet pipe 9 of the working medium (the shock node is not shown in the drawing), necessary for the pulsating flow of the liquid. To direct the flow of liquid into a tubular spiral of conical shape 2, a special device 12 is provided in the shaft 1. The inlet and outlet nozzles 8, 9 of the working medium are connected to the shaft 1 by means of hinge joints 10, 11. At a certain frequency of the pulsating fluid flow, in a tubular spiral of conical shape 2 fixed on a cone-shaped base 7, due to the conical shape, a centrifugal force and a tangential acceleration component arise, the resultant of which creates a torque and drives the shaft into rotation. As a result, the potential energy of the liquid flow passes into the kinetic energy of rotation of the shaft 1. The shaft 1 itself is pressed into a thrust bearing 5 to realize the rotational energy, which in turn is rigidly fixed to the rack 6. To remove air from the cavities of the system, a trigger 13 is provided. The amount of energy produced depends on the amount of pumped working medium passing through the flow energy Converter and the speed of the shock unit. To increase the productivity of this installation, it is necessary to increase its size and the volume of supply of the working environment.

3.5 Flow energy converter

The invention relates to the fields of hydraulics and hydro-gas dynamics, where it can be used to convert the energy of the fluid flow motion into the rotational motion of various mechanisms, as well as to heat power engineering, where it can be used to drive the fan of calorific installations. The experimental installation of the flow energy Converter is shown in figure 20. The drawing of the model is made in the program COMPASS - 3D.

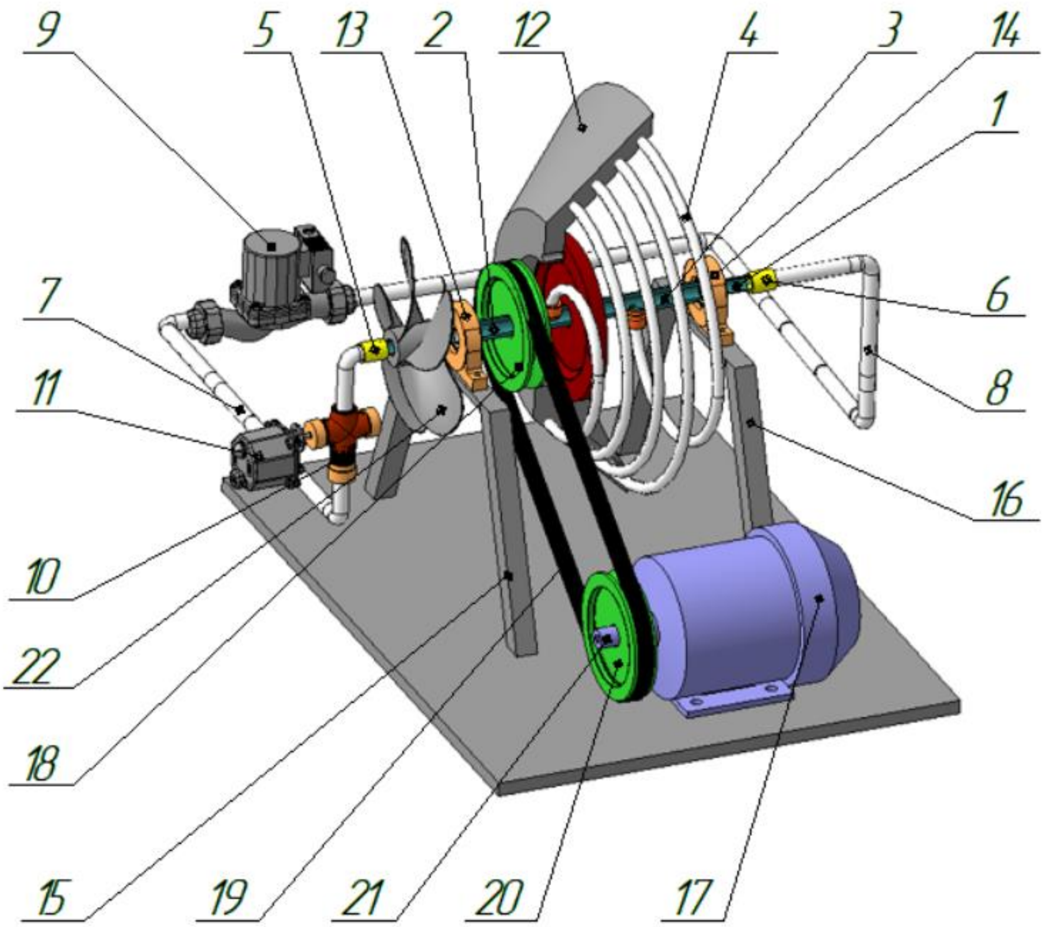

Figure 20 – Flow energy Converter design

The essence of the invention lies in the fact that the flow energy Converter includes a shaft, a tubular spiral of conical shape, with the shaft pressed in bearings that are rigidly fixed to the racks, also to the shaft is rigidly fixed a conical base, to which in turn is rigidly attached a tubular spiral of conical shape, with the inlet and outlet channels of the working medium connected to a tubular spiral of conical shape, and through the hinge joints are connected respectively to the inlet and outlet of the working medium, which in turn are connected to the suction and discharge pipelines of the centrifugal pump, forming a closed hydraulic circuit, the shock unit is connected to the electric drive and installed in the suction pipe section, additionally contains a second bearing and a second rack, a impeller with blades, an electric motor with a shaft, a drive pulley, a driven pulley, and a drive belt, with the impeller with blades and a driven pulley mounted on the shaft, the drive pulley mounted on the motor shaft mounted on the rack, the leading and driven pulleys are connected to each other by means of a drive belt, and the cone-shaped base is made monolithically with a tubular spiral of conical shape, having two isolated cavities from the inlet and outlet of the working medium, the inner sides of which are connected through a tubular spiral of conical shape, and the outer through the hinge joints are connected to the suction and discharge pipelines of the centrifugal pump, forming a closed hydraulic circuit, while in the section of the suction pipeline there is a shock unit with an electric drive, the tubular spiral of conical shape is made monolithically with a cone-shaped base rigidly connected to the shaft, which is mounted in bearings resting on racks and connected to the starting motor by means of a driven pulley rigidly fixed to the shaft, a drive belt and a drive pulley pressed onto the motor shaft, and a impeller with blades is rigidly fixed to the shaft.

The flow energy Converter includes a shaft 1 having inlet channels 2 and outlet 3 of the working medium, the inner sides of which are connected through a tubular spiral of conical shape 4, and the outer through the hinge joints 5 and 6 and the inlet pipes 7 and outlet 8 of the working medium are connected to the suction 9 and discharge 10 pipelines of the centrifugal pump 11, forming a closed hydraulic circuit. In the section of the suction pipeline there is a shock unit 12 with an electric drive 13, a tubular spiral of conical shape 4 is made monolithic with a conical base 14 rigidly connected to the shaft 1, which is mounted in bearings from the inlet 15 and outlet 16 of the working medium, based on the racks from the inlet 17 and the inlet 18 of the working medium. The shaft 1 is connected to the starting motor 19 by means of a rigidly fixed driven pulley 20, a drive belt 21 and a drive pulley 22 pressed onto the motor shaft 23. Also the shaft 1 is rigidly fixed to the impeller blades 24.

3.6 Principle of operation of the flow energy Converter

The flow energy Converter works as follows. First filled with a closed hydraulic circuit of the working environment, including channels of input 2 and output 3 of the working environment, drilled in the shaft 1, the tubular conical helix shape 4, swivel 5 and 6, the nozzles inlet 7 and outlet 8 of the working environment, suction and discharge 9 10 piping, a centrifugal pump 11, the striking unit 12. Then the centrifugal pump 11 is started from the electric network. When the steady-state speed of the centrifugal pump 11 is reached, the shock unit 12 is started from the electric drive 13, while the shock unit 12 sharply interrupts the flow of the working fluid with the creation of a hydraulic shock. In this case, the working fluid impulsively moves according to the following scheme: a centrifugal pump 11, a suction pipe 9, a shock node 12, an outlet pipe 8, a hinge joint 6, an outlet channel 2 of the working medium, a tubular spiral of conical shape 4, an inlet channel 3 of the working medium, a hinge joint 5, an inlet pipe 7, a discharge pipe 10.

With a sharp operation of the shock node 12 in a closed hydraulic circuit of the flow energy Converter, its kinetic energy (direct wave of the water hammer), repeatedly increases the pressure before the shock node 12, elastically deforms the walls of the pipe in front of it, that is, accumulates the potential energy of pressure and compression), the accumulated potential energy is released with the reverse wave of the water hammer with a change in the flow rate (passes into the kinetic energy of the flow), which is accompanied by a change in the acceleration of the flow, the tangential component of which creates a force and torque in a tubular spiral of conical shape 4 rigidly connected to the conical base 14 and the shaft 1, while the shaft 1, with each interruption of the flow, makes a sharp turn in the bearings from the inlet 15 and outlet 16 of the working medium, based on the racks from the inlet 17 and the inlet 18 of the working medium at a certain angle. When the starting motor 19 is switched on, it will transmit additional rotational motion from the drive pulley 22 rigidly fixed to its shaft 23 through the drive belt 21 to the driven pulley 20 rigidly connected to the shaft 1. When untwisting the shaft 1 to a stable speed of its rotation from the starting motor 19, it is turned off, and its further rotation will be maintained by supplying energy from the closed hydraulic circuit and consumed as a useful work, consisting in the drive of the impeller with blades 24 and losses in bearings and air. The energy in the hydraulic circuit is supplied to the centrifugal pump 11 from the electrical network.

The amount of transmitted energy from a closed hydraulic circuit depends on the flow rate of the pumped working fluid and the frequency of its pulsations. The frequency of pulsations is from 0.5 to 3 Hz. With the increase in the frequency of pulsations, the value of the transmitted energy from the closed hydraulic circuit increases.

In the course of the research, it can be concluded that as a result of the use of this design, the flow energy Converter uses the working environment completely, does not require the constant presence of maintenance personnel, can be used for power supply of Autonomous consumers, while the device is simple to manufacture and has a long life of use.

Thus, the principle of operation of the shock unit, which directly has a significant value in the work of the flow energy Converter, was considered. In this case, the flow energy Converter works by means of pulses, which creates a shock node.

As can be seen from the above material, there are various variations in the presentation of these utility models, both prototypes and analogues, but they all have their own distinctive characteristics, their disadvantages and useful additions to existing devices. Each of the scientists has made a huge contribution to the development of useful models. Time does not stand still and each time there are various innovations that greatly simplify the work of laboratory facilities, making them more economical while increasing their efficiency.

4 Results of experimental research

4.1 Description of the test program

Installation of a laboratory installation consists in the assembly of structural elements, such as:

– metal carcass;

– cone-shaped spiral, curled from metal-plastic pipe, Ø25mm;

– pulleys of different diameters;

– drive belt;

– Electrical engine;

– bearings with a seat, Ø32mm;

– shaft, Ø32 mm;

– inlet pipes made of polypropylene, Ø25 mm;

– drain valve, mounted in the pipe outlet of the working environment;

Impact node is installed in the network after the energy flow converter, the rotation of which is carried out due to the operation of the 12V engine.

After assembly, the installation is mounted in the network to supply the working environment. The tests are carried out several times, with changes in the flow rate of the working medium, the number of revolutions of the electric motor and the rotation of the roller of the impact unit.

At the end of the test, the data obtained are recorded in a table for further processing. A photograph of the mounted installation is shown in Figure 21.

Figure 21 – Mounted design of the energy flow converter

4.2 Calculation of the torque of the energy flow converter

In this section, we present the results of modeling torque and body with a cone-shaped spiral.

Table 1 shows the parameters for calculating the torque of the body with a cone -shaped helix, where:

a,m = 0,01035; m,m = 4; b,m = 0,00517; σ_0,m^2 = 0,00011; Δt = ,1

were identified as a result of mathematical modeling.

Table 1 – Parameters for modeling the moments of inertia of the body with a cone-shaped helix

a ,м	m ,м	b ,м	σ_0 ,м^2	Δt
0,01035	4	0,00517	0,00011	1,1

The ratio of the length of the initial turn of the cone-shaped spiral to the product and the number of turns was determined by the formula derived in Chapter 2 of this work:

$$a = \frac{\tilde{a}}{2\pi m}, \tag{29}$$

where $\tilde{a}$ - the length of the initial coil, m;

m - the number of turns of the cone-shaped spiral.

$$a = \frac{0,26}{2 \cdot 3,14 \cdot 4} = 0,01035\, m.$$

The ratio of the step of a cone of the cone-shaped spiral to was found from the expression derived in Chapter 2 of this work:

$$b = \frac{H}{2\pi}, \tag{30}$$

where H - coil pitch, m.

$$b = \frac{0,032}{2 \cdot 3,14} = 0,0051\, m.$$

The length of the spiral trajectory, along which the working medium performs its movement, was found according to the formula derived in Chapter 2 of this work:

$$l=\frac{a^2+b^2}{2a}\cdot\left(\frac{2m\pi a}{a^2+b^2}\sqrt{a^2+b^2+4m^2\pi^2a^2}-\ln\frac{-2m\pi a+\sqrt{a^2+b^2+4m^2\pi^2a^2}}{\sqrt{a^2+b^2}}\right), \qquad (31)$$

where a - the ratio of the length of the initial turn of the cone-shaped spiral to product by the number of turns, m;

b - the ratio of the pitch of the cone-shaped spiral to 2π, m;

m - the number of turns of the cone-shaped spiral.

$$l=\frac{0,01035^2+0,0051^2}{2\cdot 0,01035}\cdot\left(\frac{2\cdot 4\cdot 3,14\cdot 0,01035}{0,01035^2+0,0051^2}\times\right.$$
$$\times\sqrt{0,01035^2+0,0051^2+4\cdot 4^2\cdot 3,14^2\cdot 0,01035^2}-$$
$$\left.-\ln\frac{-2\cdot 4\cdot 3,14\cdot 0,01035+\sqrt{0,01035^2+0,0051^2+4\cdot 4^2\cdot 3,14^2\cdot 0,01035^2}}{\sqrt{0,01035^2+0,0051^2}}\right)=3,3\,m.$$

The moment of inertia of the body with a cone-shaped spiral is according to the formula derived in Chapter 2 of this work:

$$J=\frac{\rho\sigma_0\left(a^2+b^2\right)^2}{8a}\left[\frac{\left(a^2+b^2\right)^4-\left(2m\pi a+\sqrt{a^2+b^2+4\pi^2m^2a^2}\right)^8}{8\left(a^2+b^2\right)^2\left(-2m\pi a+\sqrt{a^2+b^2+4\pi^2m^2a^2}\right)^4}+\right.$$
$$\left.+\ln\left(\frac{-2m\pi a+\sqrt{a^2+b^2+4\pi^2m^2a^2}}{\sqrt{a^2+b^2}}\right)\right], \qquad (32)$$

where a - the ratio of the length of the initial turn of the cone-shaped spiral to product by the number of turns, m;

b - the ratio of the pitch of the cone-shaped spiral k, m;

m - the number of turns of the cone-shaped spiral;

σ_0 - section of the pipe from which the cone-shaped spiral is made, m^2;

ρ - working medium density ($\rho = 999{,}841$ kg/m^3).

$$J = \frac{999{,}841 \cdot 0{,}00011\left(0{,}01035^2 + b^2\right)^2}{8 \cdot 0{,}01035} \times$$

$$\times\left[\frac{\left(0{,}01035^2 + 0{,}0051^2\right)^4 - \left(2 \cdot 4 \cdot 3{,}14 \cdot 0{,}01035 + \right.}{8\left(0{,}01035^2 + 0{,}0051^2\right)^2\left(-2 \cdot 4 \cdot 3{,}14 \cdot 0{,}01035 + \right.}\right.$$

$$\frac{\left. + \sqrt{0{,}01035^2 + 0{,}0051^2 + 4 \cdot 3{,}14^2 \cdot 4^2 \cdot 0{,}01035^2}\right)^8}{\left. + \sqrt{0{,}01035^2 + b^2 + 4 \cdot 3{,}14^2 \cdot 4^2 \cdot 0{,}01035^2}\right)^4} +$$

$$\left. + \ln\left(\frac{-2 \cdot 4 \cdot 3{,}14 \cdot 0{,}01035 + \sqrt{0{,}01035^2 + 0{,}0051^2 + 4 \cdot 3{,}14^2 \cdot 4^2 \cdot 0{,}01035^2}}{\sqrt{0{,}01035^2 + 0{,}0051^2}}\right)\right] = 0{,}169\ m.$$

The angular velocity of the body with a cone-shaped spiral is found according to the formula derived in Chapter 2 of this work:

$$\dot{\vec{\omega}} = a^2 \frac{\Delta v}{\Delta t}\left(\frac{2m\pi a}{a^2 + b^2}\sqrt{a^2 + b^2 + 4m^2\pi^2 a^2} + \ln\frac{-2m\pi a + \sqrt{a^2 + b^2 + 4m^2\pi^2 a^2}}{\sqrt{a^2 + b^2}}\right)\bar{k}, \qquad (33)$$

where a - the ratio of the length of the initial turn of the cone-shaped spiral to product by the number of turns, m;

b - the ratio of the pitch of the cone-shaped spiral to 2π, m;

m - the number of turns of the cone-shaped spiral;

$\bar{k}$ - unit vector ($\bar{k} = 1$)

Δv - the speed of movement of the working medium during the pulse, m/s.

Δt - number of revolutions of the impact roller, s;

$$\dot{\varpi} = 0,01035^2 \frac{995}{1,1}\left(\frac{2\cdot 4\cdot 3,14\cdot 0,01035}{0,01035^2+0,0051^2}\sqrt{0,01035^2+0,0051^2+4\cdot 4^2\cdot 3,14^2\cdot 0,01035^2}+\right.$$

$$\left.+\ln\frac{-2\cdot 4\cdot 3,14\cdot 0,01035+\sqrt{0,01035^2+0,0051^2+4\cdot 4^2\cdot 3,14^2\cdot 0,01035^2}}{\sqrt{0,01035^2+0,0051^2}}\right)\cdot 1=$$

$$=48,61 rad / s.$$

The body torque with a cone-shaped spiral is found according to the formula derived in Chapter 2 of this work:

$$\bar{M} = J\bar{\varpi}, \qquad (34)$$

where J - body moment of inertia with a cone-shaped helix, kg·m^2;

$\bar{\varpi}$ - angular velocity of the body with a cone-shaped helix, rad/s.

$$\bar{M} = 0,169\cdot 48,61 = 8,22\,Н\cdot м.$$

Figure 22 shows the dependences of body torques, in which the trajectory of the working medium is made in the form of a cylindrical spiral, on parameters such as:

– the length of the trajectory of the cylindrical spiral l, m;

– section of the pipe from which the cylindrical spiral is made σ_0, m^2;

– lifting step of a cylindrical spiral k, m;

– the radius of the coil of a cylindrical spiral a, m;

– the number of revolutions of the roller of the shock unit Δt, s;

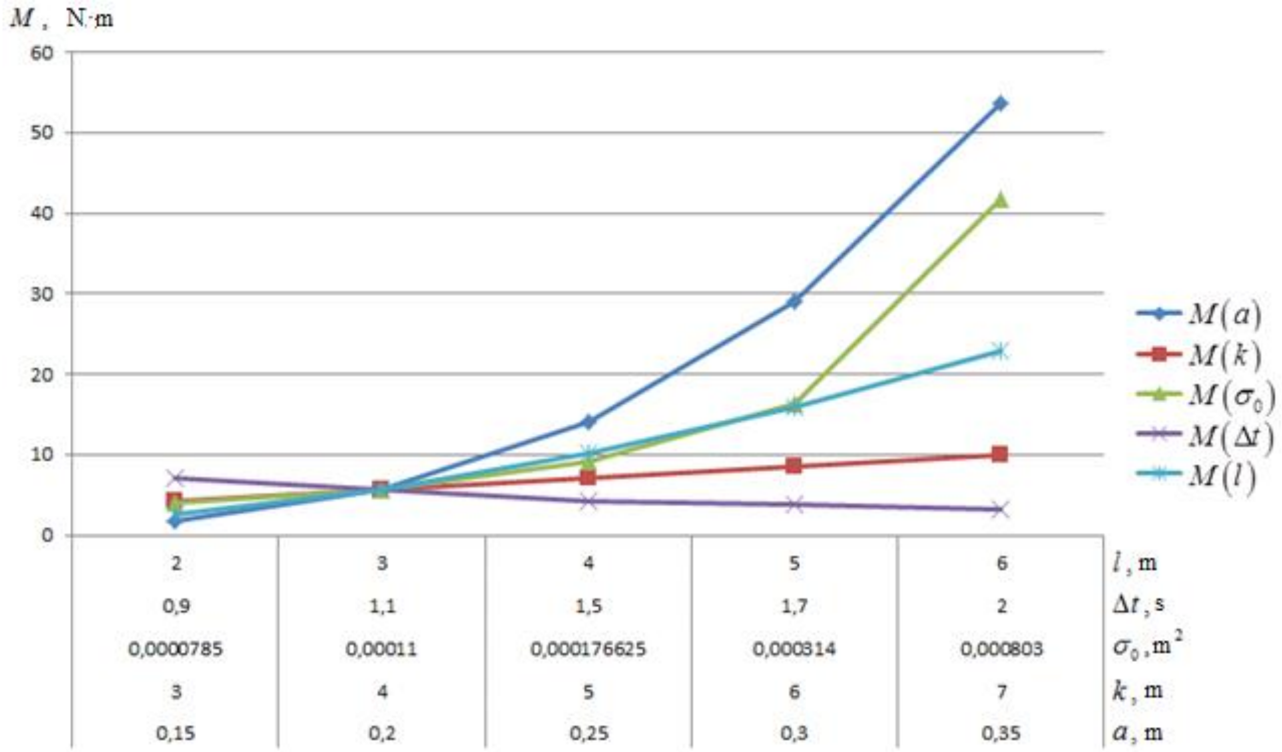

Figure 22 – Dependence of body torques with a cylindrical spiral on the main indicators

As can be seen from this figure, the radius of a turn of a cylindrical spiral has the greatest influence on the amount of body torque. a , m. Judging by the dependence $M = f(a)$ it can be concluded that with an increase in the radius of the coil of a cylindrical spiral 2 times, there is a large-scale increase in the body's rotational moment, more than 10 times.

Analyzing dependencies $M = f(l)$, $M = f(k)$ and $M = f(\sigma_0)$, positive dynamics of body torque growth are also observed, with increasing parameters: the length of the trajectory of the cylindrical helix, m, the lifting step of the coil of the cylindrical helix k, m and section of a pipe from which the cylindrical spiral is made σ_0, m^2.

Considering the change in body torque from the number of revolutions of the impactor roller $M = f(\Delta t)$, an inverse dependence of the parameters is observed, thus, with an increase in the number of revolutions of the impactor roller Δt, m in 2 times, the torque of the body will tend to decrease, almost 2 times.

Figure 23 shows the dependence of the torques of the body, in which the trajectory of the passage of the working medium is made in the form of a cone-shaped spiral from the moments of inertia obtained in Figure 22, with $\omega = const$.

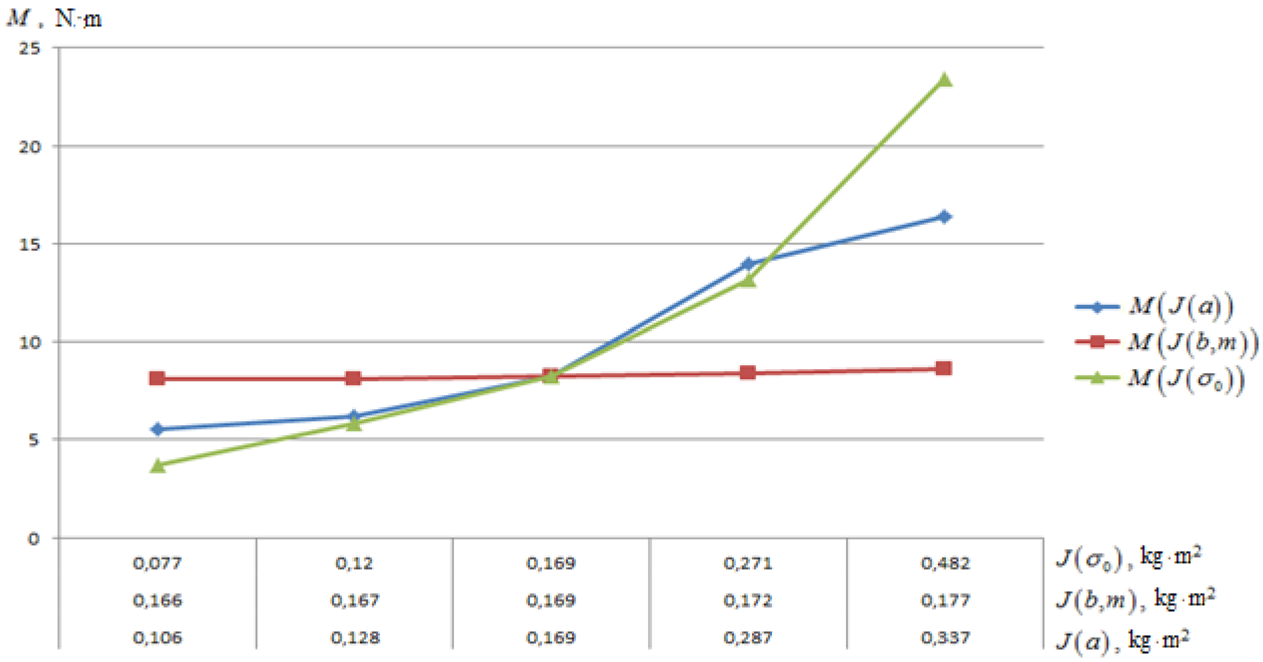

Figure 23 – The dependence of the torsional moments of the body with a cone-shaped spiral from indicators

On the charts $M = f\left(J\left(\sigma_0\right)\right)$ and $M = f\left(J\left(a\right)\right)$ an increase in body torque is observed, with an increase in the moments of inertia. From the graph $M = f\left(J\left(b,m\right)\right)$, it is seen that with an increase in the moment of inertia, the torque of the body increases in a relatively small range.

Figure 24 shows the dependence of the torques of the body, in which the trajectory of the passage of the working medium is made in the form of a cone-shaped spiral from the angular velocities obtained in Figure 22, with $J = const$.

The results of the obtained torsional moments of the body with a cone-shaped spiral, with $J = const$.

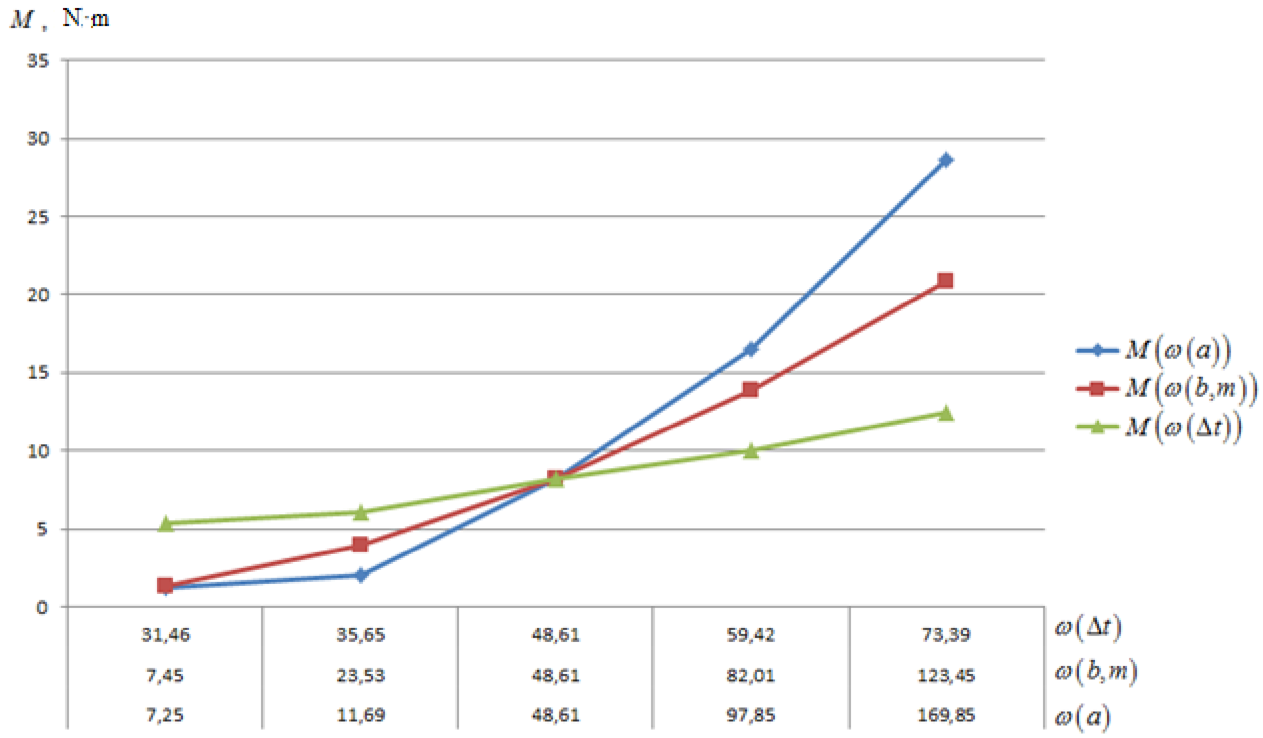

Figure 24 – Dependence of body torques with a cone-shaped spiral from the main indicators

The greatest effect on torque has a parameter. Also, the positive dynamics of torque growth show dependencies $M = f\left(\omega(\Delta t)\right)$ и $M = f\left(\omega(b,m)\right)$

4.3 Construction of frequency characteristics of the circuit when changing at least three parameters

After all the energy circuits were found integrated resistance, the amplitude – frequency characteristic, phase – frequency characteristics, will be sold with graphs that will clearly shows which parameter is affected to a greater or lesser extent on one or another dependency.

Several specific input parameters are accepted, with the help of which the simulation will take place Values may vary depending on our goals. All values will be listed in table 2.

Table 2 – Values for constructing frequency characteristics

m_1, kg	m_2, kg	l_1, mm/kg	l_2, mm/kg	r_1, N	r_2, N	R, m	S, m	J, kg·m^2	P, kPa
10	7	0,21	0,29	120	25	0,7	0,02	140	500

Dependency graphs are plotted based on the input values. For the best perception of graphs values are taken only those that affect the dependence. The values obtained for the first stage of the energy circuit are shown in table 3.

Table 3 – value amplitude frequency response for energy circuit stage 1

Ω	A_1 (Ω)	Ω	φ_1 (Ω)
1	7,310945	1	0,350413
3	20,75232	3	0,121235
6	41,27637	6	0,060841
9	61,85094	9	0,040588
12	82,43821	12	0,030449
15	103,0306	15	0,024362
18	123,6255	18	0,020303
21	144,2218	21	0,017403
24	164,8191	24	0,015228
40	274,6781	40	0,009137

After obtaining certain parameters, the graphical dependences of the obtained dependences of the frequency characteristics and the technical result of this installation scheme are made, the data are presented in figures 22 and 23.

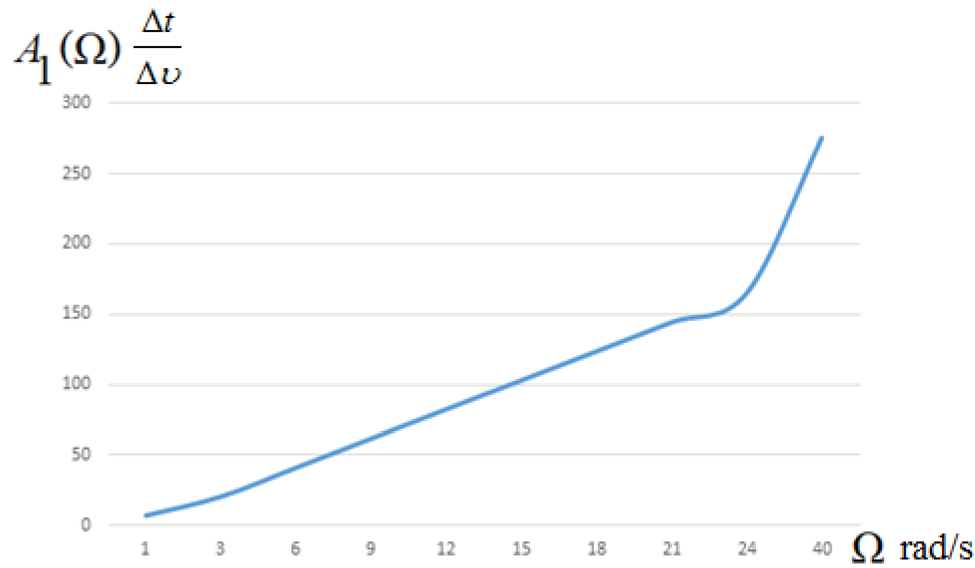

Figure 25 – Amplitude frequency responce energy circuit stage 1

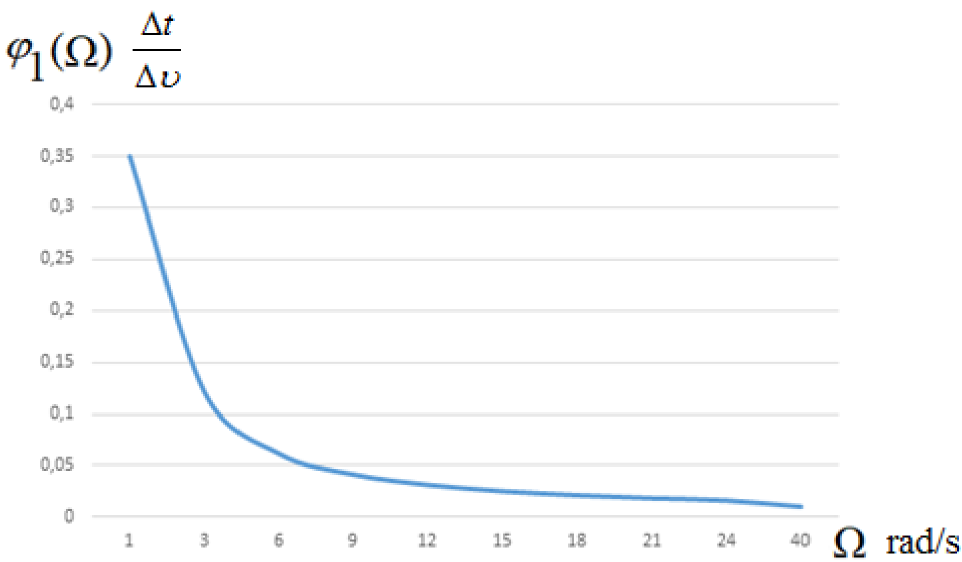

Figure 26 – Phase frequency response energy circuit stage 1

For power circuits of the second and third stage calculations are conducted similarly, and are written in tables 4 and 5. A graphical view is presented in graphs 24-27.

Table 4 – Value amplitude frequency response for energy circuit stage 2

Ω	A_2 (Ω)	Ω	φ_2 (Ω)
1	4,743459	**1**	0,115288
2	4,395554	**2**	0,036075
3	5,349654	**3**	-0,01693
4	5,765441	**4**	-0,00874
5	5,72026	**5**	-0,00494
6	5,458158	**6**	-0,00303
7	5,11821	**7**	-0,00198
8	4,766228	**8**	-0,01762
9	4,4306	**9**	-0,00097
15	2,985063	**15**	-0,00022

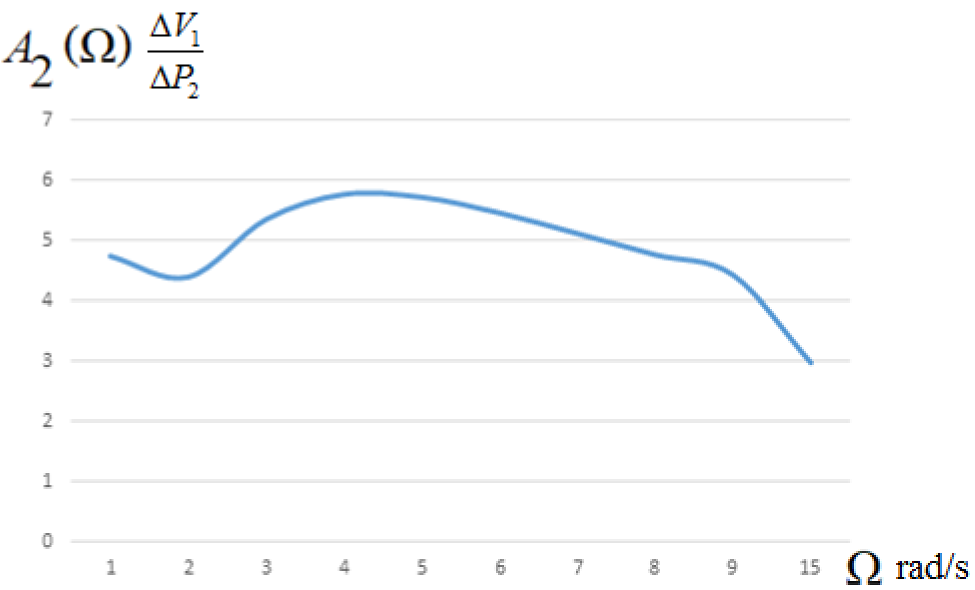

Figure 27 – Amplitude frequency responce energy circuit stage 2

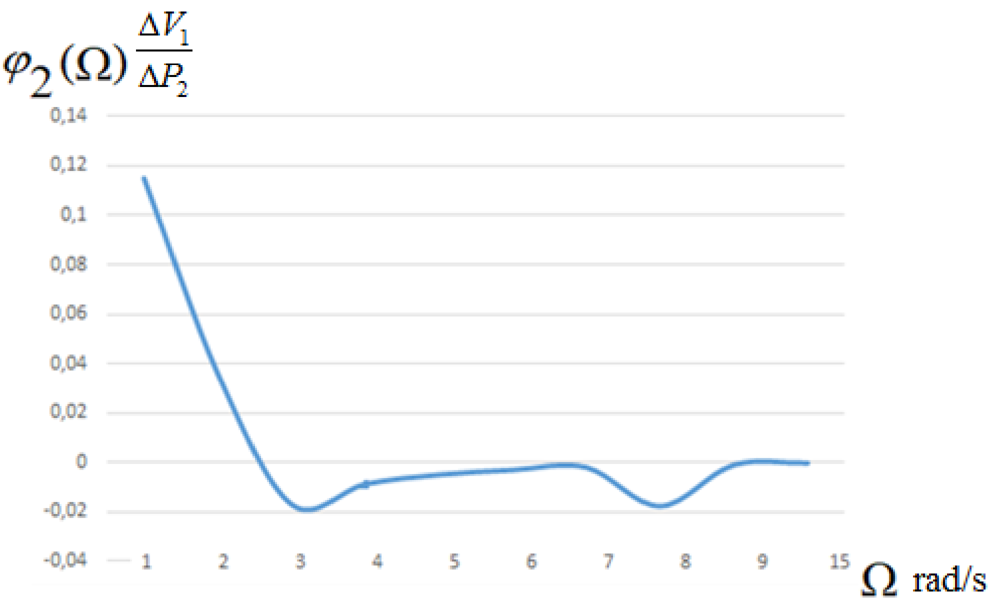

Figure 28 – Phase frequency response energy circuit stage 2

Table 5 – value amplitude frequency response for energy circuit stage 3

Ω	$A_3(\Omega)$	Ω	$\varphi_3(\Omega)$
6,5	1,212492906	6,5	6,86394E-10
7	1,305904435	7	5,50314E-10
8,5	1,586138088	8,5	3,08206E-10
9	1,679549021	9	2,59802E-10
9,5	1,77295983	9,5	2,21019E-10
10	1,866370526	10	1,89582E-10
10,5	1,959781119	10,5	1,63832E-10
11	2,053191619	11	1,4254E-10
11,5	2,146602035	11,5	1,24781E-10
20	3,734571355	20	2,37726E-11

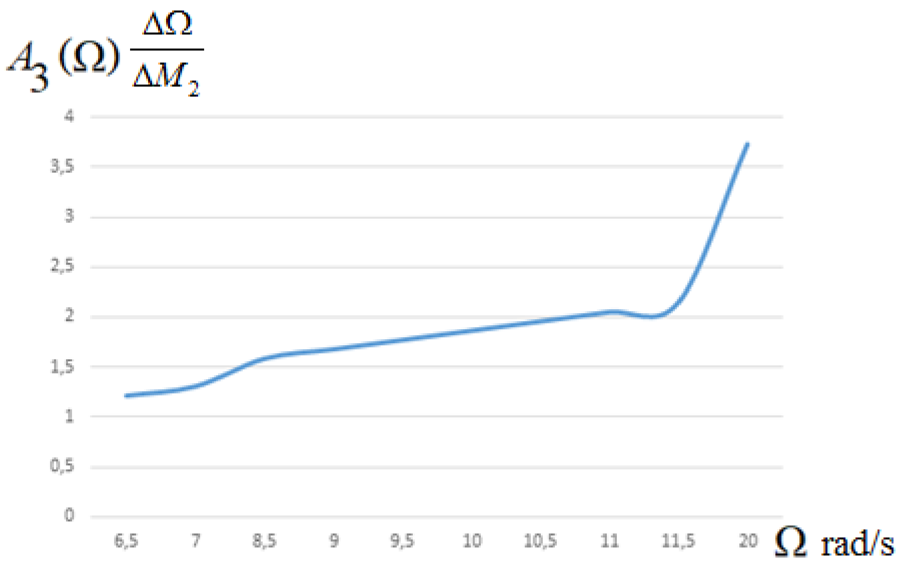

Figure 29– Amplitude frequency responce energy circuit stage 3

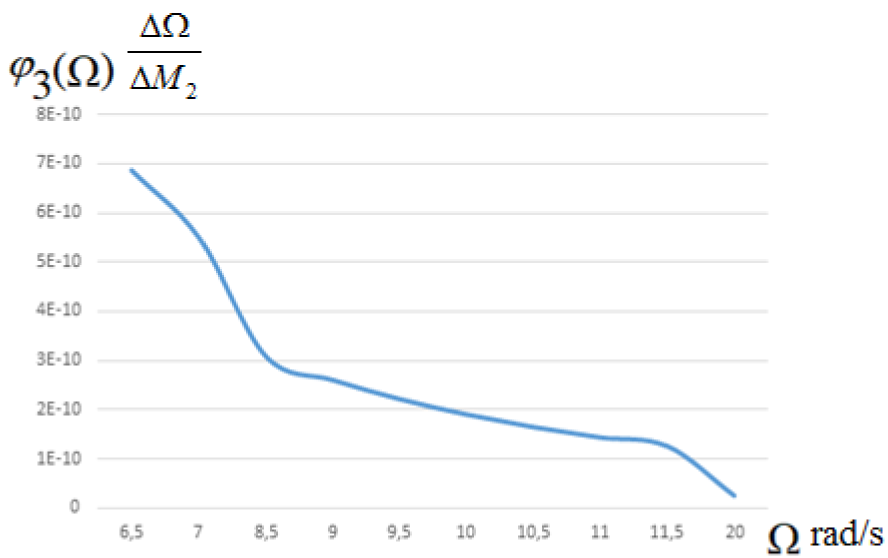

Figure 30 – Phase frequency response energy circuit stage 3

Judging by the obtained graphs, it can be concluded that in the energy circuit of the first stage the indicators are directed upwards. This is due to the fact that there is a dependence of the flow of the working medium and the rotation of the shock node, from this dependence it can be concluded that the more rotations of the shock node, the higher the value obtained.

CONCLUSION

The purpose of this bachelor's work was to increase the energy efficiency of a spiral hydromechanical transducer by using the energy of a compressed stream as a result of its periodic inhibition.

Assessment of the completeness of the solution of the tasks:

– analysis of the structures of hydromechanical converters, which ensure the reduction of their energy efficiency, was carried out;

– an experimental sample of a spiral hydromechanical energy converter with a pulsed flow was developed and tested;

– theoretical dependences of the angular velocity, torque, on the design parameters and modes of operation of the spiral hydro–mechanical converter with a pulsed flow were obtained;

– developed design documentation for the manufacture of a prototype of a spiral pulse hydromechanical transducer;

– a method for energy evaluation of a spiral pulse hydromechanical transducer has been developed;

– tests of a prototype of a spiral pulse hydromechanical transducer were carried out, and experimental dependencies of the angular velocity, torque, on the design parameters and modes of its operation were obtained;

During the development of the experimental installation, a reduction in energy consumption losses, a reduction in explosion and fire hazards at industrial production facilities, which in turn will increase the efficiency of the present invention and reduce its costs in production, was achieved.

During the research of an experimental setup for testing a spiral-type hydromechanical transducer, parameters were determined that became the basis of mathematical modeling.

In the simulation, the formulas for finding the torque of the cone-shaped spiral are derived.

modes of its operation were obtained. It is established that the energy characteristics of a prototype spiral pulse hydromechanical transducer;

- amplitude-frequency characteristics and phase-frequency characteristics were obtained.

During the development of the experimental facility, a reduction in energy loss was achieved, which in turn would increase the effectiveness of the present invention and reduce its production costs.

In the study of an experimental setup for testing a hydromechanical converter of the spiral type, parameters were determined that became the basis of mathematical modeling.

In modeling, formulas are obtained for determining the torque of a cone-shaped helix.

Considering the energy chain of the first stage, the amplitude - frequency characteristic is directed upwards. This is due to the fact that there is a dependence of the flow of the working fluid and the rotation of the impact site.

According to the diagram of the dependence of the energy chain of the second stage, we can conclude that we have obtained a peak value of $\Omega = 4.5$, which means that the experimental sample will work best under these conditions.

Considering the dependence of the energy contour of the third stage, we can say that with the growth of parameters, the indicators lead to an increase in efficiency.

According to the diagram of phase-frequency characteristics, the dependences of all three energy circuits, leading to a decrease in the parameters, are determined.

03.06.2019

REFERENCE

1) A.N. Makeev Pulsed heat supply systems for public buildings / A.N. Makeev, A.P. Levcev // Regional architecture and construction. - Penza, 2010. - №2 (9). - p. 45–51.

2) Agababov B.C. Influence of the expander-generator units on the thermal efficiency of thermal power plants. Abstract for the competition. step. doc those. Sciences, MEI, 2003.

3) B. Leznov. Methods for assessing the effectiveness of the use of a controlled electric drive in water and sewage pumping installations - Moscow: Mashinostroenie, 2011. - 88 seconds.

4) Bukharkin, E. N. To optimizing the expander scheme of using the overpressure of the main gas / E. N. Bukharkin // Energy Saving and Water Treatment. - 2011. - N 1. - p. 57-59.

5) Fernwarmeversorgung steigt 2010 kraftig. // Euroheat and Power. -2011.- T.40, N 7-8, -p. 22.

6) Hydraulic ram and ram installation / V. M. Hovsepyan; reviewer prof. S. S. Rudnev. - M.: «Mechanical Engineering», 1968. - 124 p.

7) Intelligente Stadte brauchen Femwarme. // Euroheat and Power. -2010.- T.39, N 12.-p. 18.

8) Ivanov A.S. Development of an energy recovery system based on an asynchronous generator. Abstract for the competition. step. Cand. those. Sciences, MEI, 2012.

9) Ivanov A.S., Kotelenets N.F. The use of overpressure in district heating systems for the production of electric energy. //Energy safety and energy saving №3, 2009.

10) Kulichikhin V.V., Lazarev L.Ya., Chizhov V.V., Savenkov V.F. Methods and results of the research of the characteristics of the expander-generating unit. Vestnik MEI, No. 4, 2001, p. 19-24.

11) Kulichikhin V.V., Lazarev L.Ya., Chizhov V.V., Savitsky A.I. Utilization of the potential energy of compressed natural gas at gas distribution stations // Proceedings of the 2nd International Symposium on Energy, Environment and Economics. KF MEI, Kazan, September 7-10, 1998, pp. 281-284.

12) Kulichikhin V.V., Lazareva O.O. The current state of application of turboexpanders // Heat News, №10, 2010, pp.28-30.

13) Kulichikhin V.V., Lazareva O.O. The use of overpressure of natural gas in industrial enterprises // Reliability and safety of energy, №2, 2010, p.48-54.

14) Kulichikhin V.V., Parygin A.G., Volkova T.A. Improving the efficiency of centralized heat supply through the use of excess main pressure // New in the Russian electric power industry, № 12, 2011, p. 5-10.

15) Kulichikhin V.V., Savenkov V.F. The main results of tests of the expander-generator unit // Energy Saving and Water Treatment, No. 2, 2001, p. 18-24.

16) Kulichikhin V.V., Zroychikov N.A., Astashkin A.V., Galas I.V. Ecological technology for gas-oil power plants // Proceedings of the Academy of Industrial Ecology, №2, 2003, p. 15-20.

17) Kulichikhin V.V., Zroychikov N.A., Astashkin A.V., Lazarev L.Ya., Chizhov V.V. Efficiency, overall performance and design schemes of turboexpanders // Energy Saving and Water Treatment, No. 2, 2003, p. 13-20.

18) Levtsev A.P., Kudashev S.F., Makeev A.N., Lysyakov A.I. Influence of the pulsed flow regime of the coolant on the heat transfer coefficient in the plate heat exchanger of the hot water supply system // Modern problems of science and education. - 2014. - № 2; URL: www.science-education.ru/116-12664 (access date: 10.25.2015).

19) Levtsev, A.P., Makeev, A.N., Makeev, N.F., Narvatov, Y.A., Golyanin, A.A. Review and analysis of the structures of impact valves for creating a hydraulic shock // Modern problems of science and education. -2015. -№ 2.

20) Leznov B.S. Energy saving and adjustable drive in pump and blower installations. - M.: Energoatomizdat, 2006.- 360 p.

21) Maksimov S.F., Surmilin A.D., Arefyev K.Yu. Analytical review and assessment of the energy efficiency of using various turbogenerator sources of electricity for GDS. // Space rocket propulsion systems. -M.: Diona, 2010. -p. 91-92.

22) Pat. 117749 Österreich. Strahlturbine / Viktor Schauberger. - erklärt 08/19/1926, veröffentlicht 07/25/1929.

23) Pat. 2423650 Russian Federation, IPC F24D 3/00. Method of heat supply / A. N. Makeev, A. P. Levcev. - № 2010112729/03; declare 04/01/2010; publ. 07/10/2011, Bull. No. 19

24) Pat. 2558740 Russian Federation, IPC F15B 21/12. Impact site / A.P. Levtsev, A.N. Makeev, S.N. Makeev, S.I. Khramov, S.F. Kudashev, A.M. Zyuzin, Ya.A. Narvatov. - No. 2014107201/06; declare 02/25/2014; publ. August 10, 2015, Bull. No. 22.

25) Pat. 3039 Union of Soviet Socialist Republics, IPC F04D 1/04. Spiral pump / D.I. Trembovelsky. - № 5315; declare 11/16/1925; publ. 05/31/1927.

26) Patent of the Russian Federation No. 2452899 / V.A. Ryzhenkov, A.V. Volkov, A.G. Parygin, and others. System of recovery of excess main pressure in heat points of heat supply networks // Byul. Inventions. 2012, № 16.

27) Pugovkin, EG. Increasing the Efficiency of Recovery Systems for Excess Line Pressure, Created on the Basis of Line Pressure: Master's Thesis, Nat. researches Univ. «MEI». - M., 2012.-150 p.

28) Russia in the World around Us - 2008. Sustainable Development: Ecology, Politics, Economics: Analytical Yearbook / Ed. ed. N.N. Marfenin; under the general editorship of N.N. Marfenina, S.A. Stepanova. - M.: Publishing house MNEPU, 2008.

29) Ryzhenkov V.A., Volkov A.V., Parygin A.G. Ways to improve the efficiency of operation of heat supply systems of large cities in modern conditions. // Tez. report Scientific-practical conference ≪Main problems and mechanisms of implementation of the program «Housing and public utility complex modernization» ≫ -Yaroslavl, November 1-2, 2006.

30) Shoukal I et al. Research and development of an intelligent energy recovery system. // TP 3212/08 Research Report. ≪SIGMA≫ Research Institute (Czech Republic), 2008.

31) Shoukal I. et al. Research and development of an intelligent energy recovery system. // Research report TP 3202/07. SIGMA Research Institute (Czech Republic), 2007.

32) Shoukal I., et al. Research and development of an intellectual energy recovery system. // Summary FT-TAZ / 160, TP 3228/09. SIGMA Research Institute (Czech Republic), 2009.

33) Shoukal I., et al. Research and development of an intelligent energy recovery system. // Annual report of a project decision. SIGMA Research Institute (Czech Republic), 2006.

34) Sokolov E.Ya. Heat and heat networks: A textbook for university students enrolled in the direction of «Thermal Engineering». 9th erased. ed. - M .: Publishing house MEI, 2009.

35) The system for recovering the overpressure of the main water and heat supply networks. The patent of the Russian Federation № 2239752.

36) Timonova M.N., Biktasheva R.A. The potential of the energy of the overpressure of the main networks of water and heat supply. // ≪International Research Journal≫, Series Technical Sciences≫, June, 2013.

37) Volkov A.V., Pankratov S.N. On the residual resource of vane pumps // предприятияEnergy service of the enterprise ≫, 2006, № 4, p. 36-38.

38) Water supply. Drainage. Equipment and technology / Handbook. -M.: LLC Stroyinform, 2006.