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# Experimental Studies of the SBSH-250MNA-32 Mining Drilling Rig

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**ABSTRACT:** This article discusses the design and principle of operation of a hydromechanical rotator, presents the results of experimental studies of a prototype in the conditions of the Navoi Mining and Metallurgical Combine and recommendations for improving the rotary feed mechanism of a drilling rig of the SBSH-250MNA-32 type.

**KEYWORDS:** drilling rig, reliability, vibration, efficiency, rotary feed mechanism, hydraulic pneumatic accumulator, drilling speed, vibration measuring equipment.

## I. INTRODUCTION

An increase in the productivity of drilling rigs is associated with the intensification of drilling modes, which, in turn, is limited by vibrations of the drilling rig elements, the main source of which is the interaction of the drilling tool with the bottom hole.

In the process of operation of a machine with a rotary feed mechanism (RFM) of the cartridge type, in addition to longitudinal and transverse vibrations, which determine its stability, it becomes subjected to torsional vibrations, the parameters of which are determined mainly by the torsional stiffness of the hexagonal spindle and the drill rod, as well as by electromechanical characteristics rotator drive. At the same time, if one of the natural frequencies of the dynamic drive system of the RFM is close or coincides with the random or deterministic frequency of the component of the spectrum of the external disturbing effect, resonance phenomena may occur, which lead to increased loads, failure and premature wear of the elements of the machine tool metal structures.

In order to avoid such phenomena, the drilling rig operator is forced to work on irrational well drilling modes that reduce the operational productivity of the rig.

## II. METHODOLOGY

Long-term observations of the operation of drilling rigs in different mining, geological and climatic conditions with a number of studies and changes in comments, suggestions and wishes of mining enterprises made it possible to improve the design of rigs. When drilling blast holes in complex structural rock massifs, one of the main disadvantages inherent in the roller cone method of drilling is the increased vibration of the drill string, which forces the operators to operate the rigs at modes that are lower than those specified in the passport.

Vibration causes the formation of fatigue cracks and breakdown of structural elements, leads to failure of the equipment installed on the machine frame, has a harmful effect on the operating personnel and increases the cost of maintaining the machines. With an increase in the power-to-weight ratio and dynamic loading of the drive, energy losses also increase. For example, according to the authors of work [1,2,3] with strong vibrations of the drilling rig, the share of energy expended to create useful torque is 30-50%. As a result, a significant part of the installed drive power of the machine remains underutilized.

The specificity of the operating modes of the machine requires considering its drive not only as a source of mechanical

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energy, but also as an element of the machine, which has a decisive influence on the magnitude and nature of the forces acting in it, reliable and durable operation in vibration-hazardous operating conditions.
One of the main reserves for increasing the efficiency of rotary cutters is the intensification of drilling modes, which is significantly hampered by vibration and dynamic loads arising during the drilling process. Various devices are known for reducing vibrations and dynamic loads in the elements of drilling rigs, both spindle and cartridge schemes: a system for automatic control of drilling modes according to the vibration level, above the bit and above the rod shock absorbers, stabilizers for the drill string.
The use of these devices helps to reduce vibrations and loads in the elements of the drilling rig, however, these devices have not found widespread use due to their low efficiency and reliability.
Their use is mainly aimed at reducing the level of vibration in the vertical plane and there are practically no devices that reduce the horizontal vibrations of the machine.
An important direction in the work on improving the rotary-feeding mechanism of cartridge-type drilling rigs is the introduction of a battery feeding mechanism into the hydraulic circuit, which makes it possible to significantly reduce the level of vibrations of the rig and achieve drilling at forced modes.
An example of the use of such devices can be batteries made in the form of hydraulic cylinders with spring-loaded rods, hydraulically connected to the rod cavities of the feed hydraulic cylinders [4, 5], however, regulation of the stiffness in such batteries can only be performed by replaceable springs, which in a quarry is difficult. Therefore, to protect the liquid and gas from direct contact, in which it is possible for the gas to dissolve in the working liquid, use hydraulic accumulators with an elastic chamber. Hydraulic accumulators with an elastic chamber have absolute tightness, speed and almost complete inertia, the ability to quickly adjust the rigidity by changing the charging pressure of the gas - p0 in their gas cavities and damping due to the dissipation of the energy of the working fluid when passing through the throttle installed at the inlet to the accumulator. Regulating the bit feed rate to the bottom hole with a throttle, the continuity of the flow of the working fluid in the piston cavity (with oscillations of the hydraulic cylinder piston) is ensured by the volume of the working fluid of the accumulator, the hydraulic cavity of which is replenished when the hydraulic cylinder is idle.

## III. SYSTEM ANALYSIS

The hydromechanical rotary feed mechanism, the installation diagram of which on the SBSH-250MNA-32 drilling rig is shown in Figure 1, is a combined three-stage gearbox with a hydraulic braking system for the carrier of the differential mechanism. Designed to impart torque to the working body when drilling vertical and inclined wells in hard rocks (up to 20 on the scale of Prof. M.M. Protodyakonova - chemical industry and enterprises of the building materials industry, in the entire operating range of rotation speeds of the DC drive motor DVP-52.

**Fig. 1. Drilling rig SBSH-250MNA-32**

The purpose of experimental studies of the SBSH-250MNA-32 machine with a hydromechanical rotator, driven in the conditions of the Urtalik open pit of the Zarmitan mine of the Southern Ore Administration of the Navoi Mining and Metallurgical Combine, is:
a) determination of the effectiveness of reducing the level of vibration of the machine and dynamic loads in the transmission of the rotator due to the introduction of a corrective link;
b) checking the operability and effectiveness of the use as a corrective link of a hydraulic machine with hydraulic pneumatic accumulators, operating in braking mode;
c) establishing the possibility of intensifying drilling modes when using a hydromechanical rotator and determining the area of rational operating parameters;
d) investigation of the efficiency of the gidrofitsirovanny rotary-feeding mechanism based on a hydromechanical rotator;
e) assessment of the influence of torsional vibrations of the rotator transmission on the vertical vibrations of the machine;
f) assessment of the impact of the introduction of a dynamic correcting link into the transmission of the rotator on the tool life;
The result of experimental research should be recommendations for the calculation and design of rotators and rotary-feeding mechanisms with a dynamic correcting link, as well as the choice of volumes and charging pressures of hydraulic pneumatic accumulators [1,3,8].
For a reliable assessment of the performance and efficiency of the use of a hydromechanical rotator, the research program provides for tests in the following stages:
Stage I. Connecting a dynamic correcting link (hydraulic machines with hydraulic pneumatic accumulators, Fig. 2).
The kinematic diagram of the hydraulic rotator (Fig. 1) includes an electric motor 1 (DPV-52), a gear (Z = 40, m = 3) rigidly mounted on its shaft and connected by a cage 3 with a sun wheel 4 (Z = 20, m = 5) differential, epicycle 8 (Z = 82, m = 5) which is rigidly connected to gear 9 (Z = 50, m = 6), which engages with wheel 10 (Z = 50, m = 6), located on the same shaft P -P with gear 11 (Z = 19, m = 10), and engaging with the wheel of the output hexagon 13 (Z = 46, m = 10) through the parasitic gear 12 (Z = 47, m = 10).

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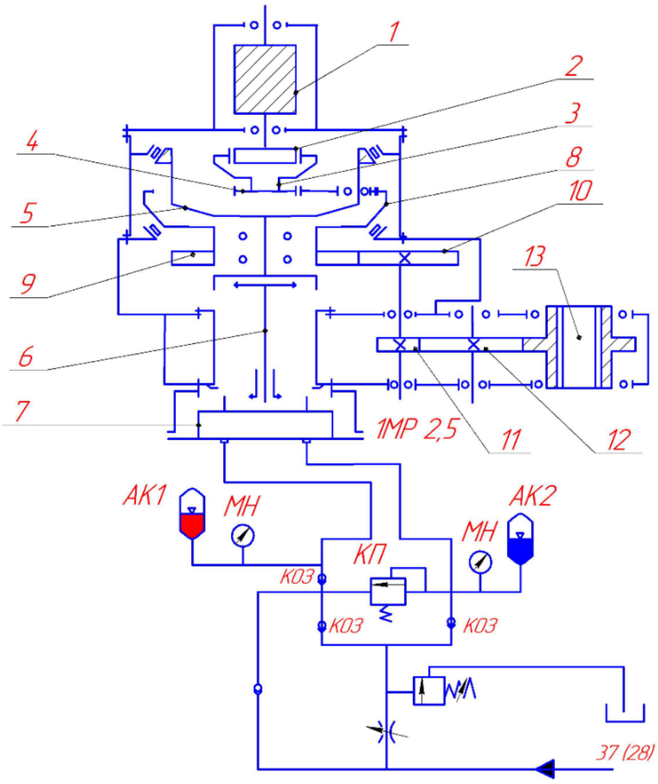

**Fig. 2. Schematic diagram of the hydromechanical rotator of the SBSH-250MNA-32 drilling rig.**

- choke DP with unloading valve KP, installed between the feed line of the hydraulic system and check valves KO1 and KO2, designed to maintain the required pressure and flow in the drain line of the brake hydraulic machine 7.
Stage II. Rotator operation without dynamic correcting link (purely mechanical transmission).
In this case, it is necessary that the machine during the test period worked in identical rock and geological formations.
To meet these requirements, the design of the prototype rotator provides for the installation and dismantling of the IMP2.5 hydraulic motor, as well as its connection to the pressure line of the supply hydraulic cylinders without disassembling the main gearbox and the valve body [4,8].
The main criteria for evaluating the efficiency of the hydromechanical rotator are the level of dynamic accelerations of the drilling rig, the drilling speed and productivity, on the basis of which a set of parameters to be measured and recorded has been determined:
- the name and strength of the developed rocks;
- the amplitude of the machine tool acceleration in the vertical plane;
- the amplitude of the machine tool acceleration in the horizontal plane, along the longitudinal and transverse axes of the machine;
- current of the drive motor;
- voltage of the drive motor;
- pressure in the pressure head and drain lines of the hydraulic machine;
- rotational speed of the drill string or transmission element located in the kinematic target after the planetary gear;
- pressure in the piston cavities of the hydraulic cylinders for feeding the drilling string;
- feed rate of the drill string;
- durability of roller cone bits and the nature of wear;
- productivity of the machine.
All measurements are carried out using equipment.
1. Registration of all parameters is performed with VIBXPERT II (Topaz and Quartz).

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2. The electrical parameters of the drive motor are measured and recorded according to generally accepted schemes without the use of special sensors.
3. Drillstring RPM and feed rate are measured with VIBXPERT II (Topaz and Quartz).
The pressures in the main lines are measured using telemetric pressure sensors TMD-100, TMD-I50, TMD-250 [11,12].
Accelerations on the machine frame are measured using VIBXPERT II sensors (Topaz and Quartz) of a set of vibration measuring equipment with a vibration transducer and an epograph vibration sensor.
Parameter change control $I_{ав}$, $V_{cm}$, $V_{ав}$, $P_{oc}$ It is carried out according to the dial gauges installed in the driver's cab of the drilling rig, and after the pressure change in the hydraulic machine lines - according to the MH1, MH2 pressure gauges installed on the hydraulic unit.
Variable parameters during the experiment are:
- rotation frequency of the stave. Change range 50 ÷ 150 rpm
- axial force. Change range 10 ÷ 24 ts;
- charging pressure of the hydraulic accumulator installed in the high pressure line of the hydraulic machine. Range of change 0,3÷0,9 $P_{ном}$.
The largest number of measurements should be made when the rotation speed of the stack is more than 100 rpm. and axial pressure of more than 20 tf for reliable substantiation of the possibility of drilling at forced modes [6,7,8].
The research program includes work carried out in the factory and open pit conditions.
The following works are performed in the factory (laboratory) conditions:
- preparation and calibration of telemetric pressure sensors, and manufacture of the corresponding hydraulic fittings;
- static calibration of DUS-5 sensors of the VIBXPERT II vibration measuring equipment set (Topaz and Quartz);
- installation and calibration of circuits for measuring and recording the voltage and current of the electric motor of the rotator drive and the feed rate of the drill string;
- calibration of VIBXPERT II (Topaz and Quartz) for measuring the rotational speed of the drill string;
- development and manufacture of VIBXPERT II attachment points (Topaz and Quartz) and DUS-5 sensors.
In the open pit conditions at the first stage of testing, the following works are envisaged:
- installation of the rotator and valve body on the SBSh-250MNA-32 machine;
- connection of the valve body and hydraulic motor IMP2.5 to the hydraulic system of the machine;
- Installation of VIBXPERT II (Topaz and Quartz), acceleration and pressure sensors;
- connection of measuring and recording equipment to the electrical circuit of the machine control panel;
- verification and final calibration of measuring and recording equipment.
The second stage involves the installation of a locking flange on the intermediate shaft of the transmission instead of the hydraulic motor IMP2.5, thus fixing the intermediate shaft motionlessly relative to the rotator housing.
At each stage, at one of the selected modes, together with the Navoi Mining and Metallurgical Combine, it is carried out in accordance with the generally accepted procedure for recording vibration parameters.
Experiment order:
1. Measurements and recording of parameters during the drilling of one well are carried out:
- when drilling;
- when drilling with the second rod;
- at the end of drilling to the full length of the stave;
2. In the process of recording one implementation, the oscilloscope records in the diary of observations of the control indications of the dial gauges in the driver's cab and on the hydraulic unit, as well as the shift performance of the drilling rig [1,5,8].
Industrial tests of the hydromechanical rotator of the SBSH-250MNA-32 drilling rig were carried out at the Urtalik quarry of the Zarmitan mine of the Southern Mining Administration of the Navoi Mining and Metallurgical Combine. A control cluster of wells was drilled with a distance of 7m between them, a depth of up to 23m along sheathed serpentinite with asbestos cuts with a strength coefficient on the scale of prof. M.M. Protodyakonova f = 10 ÷ 18. Drilling was carried out using TP-215.9 pin bogs.
When investigating the efficiency of the hydromechanical rotator, drilling was carried out in the entire range of modes provided by the technical characteristics of the rig. The axial load was maintained within 6-14t, which was optimal when drilling with a 215.9mm bit in the above rocks.
The rotational speed of the drilling tool was varied from 60 to 158 rpm. Vibration measurements were made with a set of vibration measuring equipment of the VIBXPERT II type (Topaz and Quartz) or VI6-6TN. The registration of pressure

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changes in the falling mechanism and in the lines of the IMP2.5 hydraulic machine was carried out by a pressure sensor of the TMD and TMG types. The registration of the number of revolutions of the drilling rod and the engine was carried out by VIBXPERT II (Topaz and Quartz) type TMG-Z0, The recording of the readings of the sensors was carried out at certain intervals of the drilling depth on the first, second and third rods, in connection with which a complete coincidence of physical and mechanical properties of drilled rocks in all wells at the time of recording the parameters with an oscilloscope [8].

During the tests, 24 modes were recorded, of which II without a hydraulic machine with a rigidly fixed planetary carrier, and 13 with a hydraulic machine, the shaft of which is connected to the planetary carrier, and the lines are equipped with pneumatic accumulators.

Preliminary analysis of VIBXPERT II (Topaz and Quartz), fragments of which are shown in Fig. 3, 4, 5 showed that when a hydraulic machine rotator was introduced into the transmission, in the lines of which hydro-pneumatic accumulators were installed with the values of stiffness and damping parameters established in an analytical study, the nature of the change in the parameters under study changed dramatically.

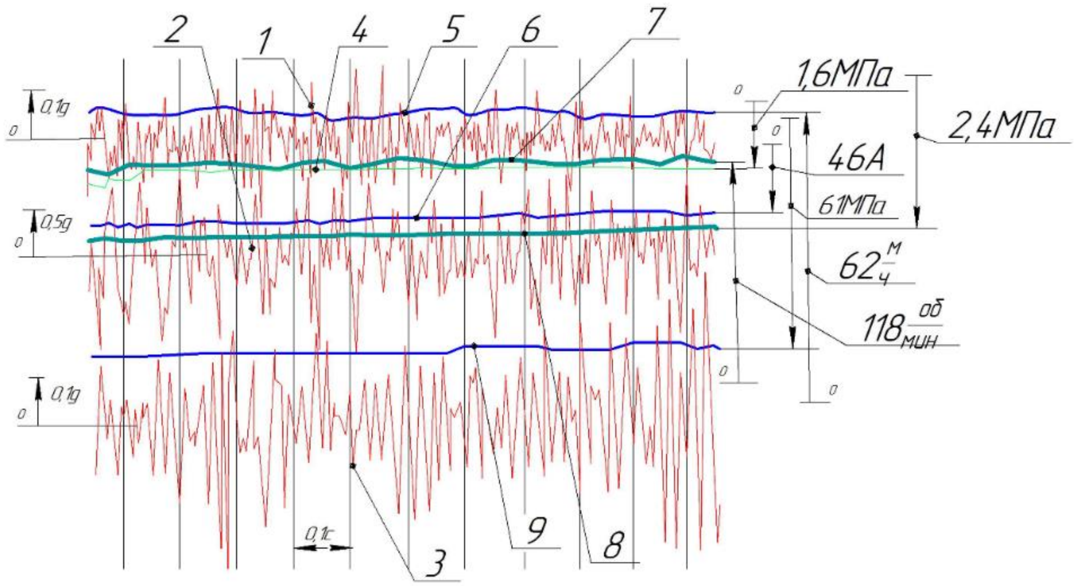


**Fig. 3. VIBXPERT II drilling rig operation before installing the hydromechanical rotator 1 - acceleration in the horizontal plane (along the frame); 2 - acceleration in the vertical plane; 3 - acceleration in the horizontal plane (across the frame); 4 - pressure in the piston plane of the feed hydraulic cylinder; 5 - drilling speed; 6 - motor current; 7 - speed of rotation of the stave; 8 - pressure in the make-up line of the hydraulic machine; 9 - pressure in the pressure line of the hydraulic machine.**

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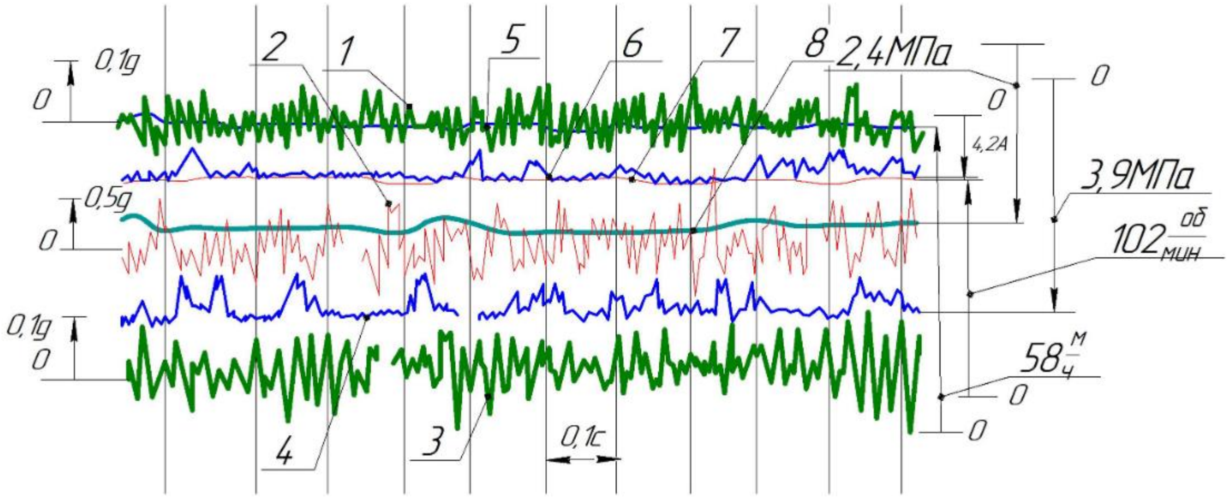


**Fig. 4. VIBXPERT II drilling rig operation after installing the hydromechanical rotator 1 - acceleration in the horizontal plane (along the frame); 2 - acceleration in the vertical plane; 3 - acceleration in the horizontal plane (across the frame); 4 - pressure in the piston cavity of the feed cylinders; 5 - drilling speed; 6 - motor current; 7 - speed of rotation of the stave; 8 - pressure in the make-up line of the hydraulic machine.**

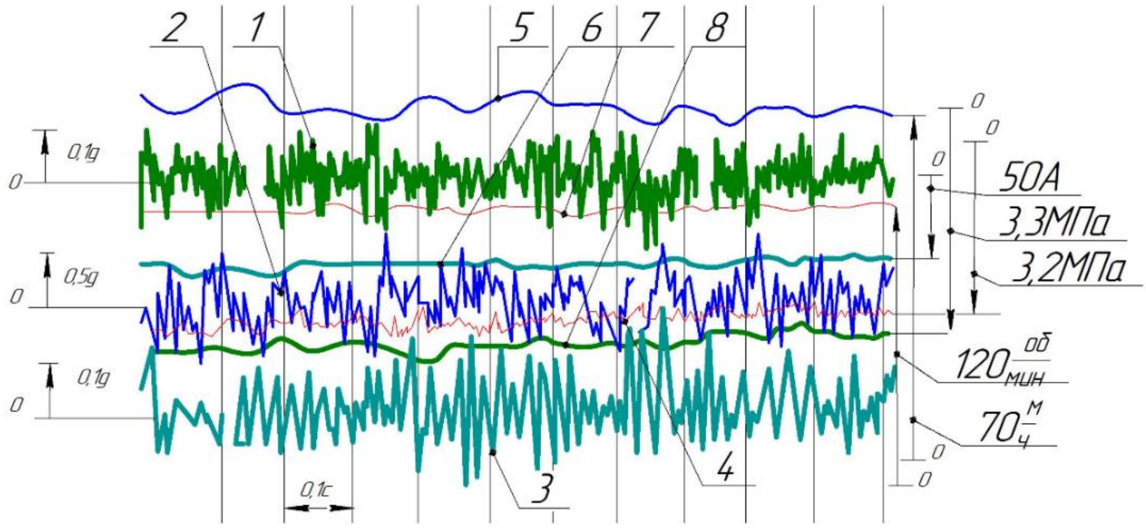


**Fig 5. VIBXPERT II drilling rig operation after installing the hydromechanical rotator 1 - acceleration in the horizontal plane (along the frame); 2 - acceleration in the vertical plane; 3 - acceleration in the horizontal plane (across the frame); 4 - pressure in the piston cavity of the feed cylinders; 5 - drilling speed; 6 - motor current; 7 - speed of rotation of the stave; 8 - pressure in the make-up line of the hydraulic machine.**

The process of changing vibration accelerations began to be rather random, non-periodic in nature, and fluctuations occur mainly due to the heterogeneity of the developed mountain range.

Maximum values of vibration acceleration of the base of the mast in the vertical plane $Q^{z}_{\text{верт}}$ before the installation of the hydraulic machine are (Fig. 3) 0.2 ÷ 0.9g; when working with a hydraulic machine (Fig. 3.5) - 0.2 ÷ 0.5g at the same torque generated by the electric motor, rotation speed and feed force of the drill string.

Similarly, in the horizontal plane (across the machine frame) (Fig. 3), in the first case, they are 0.06 ÷ 0.27g, and in the second case, 0.04 ÷ 0.1g.

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When working without a hydraulic machine, vibrations with frequencies of 2 are pronounced; 6.4; 58Hz horizontal and 1.1; 2; 16; 71Hz in the vertical plane. When drilling with a hydraulic machine, there are no frequencies of 2 Hz in the horizontal plane and 1.1 and 2 Hz in the vertical plane, which allows us to conclude that the natural frequency of the rotator is shifted to the lower frequency range due to the introduction of additional compliance and a decrease in the response of the system to disturbing influences in the frequency range from 1 to 2Hz.
Characteristic is the relative change in the engine load current (curve 6) and the pressure in the pressure line of the hydraulic machine (curve 9) before the installation of the hydraulic machine and the pressure in the make-up line (curve 8) after the installation of the hydraulic machine. As the current increases, the pressure decreases and vice versa, which is explained by the fact that at the moment of increasing the load on the drilling rod and the corresponding increase in the motor current, the hydraulic machine turns, which causes a decrease in the pressure in the make-up line. The load change frequency is 1.8-2.6Hz, which corresponds to the rotational speed of the drill string $n_{cm}$= 108÷156rpm At the same time, the frequency of oscillations of the drilling speed is 5.4 ÷ 7.8 Hz, which corresponds to three times the rotational speed of the drill string, due to the rolling cutter along the three wave bottom.

## IV. CONCLUSION

Thus, the introduction into the mechanical transmission of the rotator of a pliable dynamic link in the form of a hydraulic machine with hydraulic pneumatic accumulators with a stiffness adjustable over a wide range made it possible to significantly reduce the natural frequency of the drive and, thus, to realize the mismatch between the natural and disturbing frequencies. As a result of this, a decrease in the amplitudes of vibration accelerations was achieved with the same load of the electric motor of the rotor by 25 ÷ 44% in the vertical and by 33 ÷ 62% in the horizontal planes.

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