Development of technical solutions for modernization of the rotary feed mechanism of a quarry drilling rig

Rashid Muminov*, *Sherali* Yakhshiev, *Jamshid* Ravshanov, *Zayniddin* Oripov, *Nodirbek* Juraev, and *Mahbuba* Maxmudova

Navoi State Mining and Technology University, Navoi, Uzbekistan

Abstract. This article substantiates and describes the design and operating principle of an electrohydromechanical rotator, presents the results of experimental studies of a prototype, shows ways to reduce dynamic loads and recommendations for improving the rotary-feeding mechanism of a drilling rig of the SBSh-250MNA-32 type. An improved kinematic and hydraulic diagram of an electrohydromechanical rotary-feeding mechanism and installation of a feed pump with a drive electric motor in the machine room of a drilling rig are presented. A design has also been developed for the electrohydromechanical rotary-feeding mechanism of the drilling rig, which can significantly reduce transmission vibrations, increase durability, and, as a result, the productivity of the machine.

1 Introduction

The main directions of economic and social development of the Republic of Uzbekistan provide for the further strengthening and expansion of the country's mineral resource base. Developing coal and gold mining at an accelerated pace using progressive open-pit methods will increase its share in total production by no less than 45%. Reduce the cost of products and work in industry by 4-5% [1,7,9,18,20].

One of the main and very labor-intensive production processes in the country's quarries is the drilling of blast holes. Up to 30% of all costs during mineral extraction are associated with drilling operations.

Both in the Republic of Uzbekistan and abroad, when drilling wells in rocks with a strength coefficient of 6÷20 on the prof. scale. MM. Protodyakonov, the roller-cone drilling method became widespread.

Long-term observations of the operation of drilling rigs, conducting a number of studies and studying the comments of mining enterprises show that when drilling blast holes in complex structural massifs, one of the main disadvantages inherent in the roller-cone drilling method remains increased vibration of the drill string, which forces operators to operate the machines at, underestimated compared to rational ones in terms of drilling speed.

* Corresponding author: rashid_81@mail.ru

Vibration causes the formation of fatigue cracks and breakage of structural elements, leads to failure of equipment installed on the machine frame, has a harmful effect on operating personnel and increases the cost of maintaining the machines. With an increase in the power supply and dynamic load of the drive, energy losses also increase. For example, according to the authors of [2,8], with strong vibrations of a drilling rig, the share of energy spent on creating useful torque is 30÷50%. As a result, a significant part of the installed drive power of the machine remains underutilized.

One of the ways to reduce dynamic loads in drilling rigs is to create fundamentally new designs of rotary-feeding mechanisms that have high safety and vibration-proof properties, ease of execution, reliability and durability.

The developed design of the electro-hydromechanical rotational-feeding mechanism of a drilling rig, which allows, by forming a rational dynamic characteristic of the transmission, to significantly reduce vibrations, increase durability, and, as a consequence, the productivity of the machine [3,7,13,19].

This work is aimed at further improving the electrohydromechanical rotary-feeding mechanism, increasing its reliability and durability.

The electrohydromechanical rotary-feeding mechanism was developed at the Navoi State Mining Institute at the Department of Mechanical Engineering Technology in relation to the SBSh-250MNA-32 drilling rig (2014) (Figure 1). Tests of the experimental sample were carried out in the

conditions of the Navoi Mining and Metallurgical Combine and showed the performance and efficiency of the rotator. The possibility of regulating the speed of the rotator by changing the amount of sliding of the hydraulic machine has been proven.

Fig. 1. Machine SBSH-250MNA-32 with an electrohydromechanical rotary-feeding mechanism.

The high safety properties of the drive have been confirmed [4,10,17,18].

Industrial tests revealed shortcomings in the rotator design, which require the following measures:

- installation of additional seals in the hydraulic machine cover;
- ensuring forced lubrication in the planetary insert of the rotator gearbox;
- ensuring autonomous replenishment of the hydraulic machine;

- development of a hydraulic control unit that ensures operation of the drive in all modes;
- installation of a hydraulic control unit in the machine room;
- installation of pneumohydraulic accumulators on the rear wall of the machine mast and connecting them to the piston and rod cavities of the feed cylinders;
- modernization of hydraulic feed cylinders with low friction seals.

Taking into account these requirements, the electrohydromechanical rotary-feeding mechanism of the SBSh-250MNA-32 drilling rig was modernized.

2 Materials and methods

The electrohydromechanical rotary-feeding mechanism of the SBSH-250MNA-32 drilling rig is a reversible planetary three-stage helical 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. Protodyakonov) with a roller bit to a depth of up to 40 m in open-pit mining of ferrous and non-ferrous metallurgy, as well as in mining and chemical quarries industry and enterprises of the building materials industry, over the entire operating speed range of the DC drive electric motor DPV-52 (Figure 2) [5,6,11,18-20].

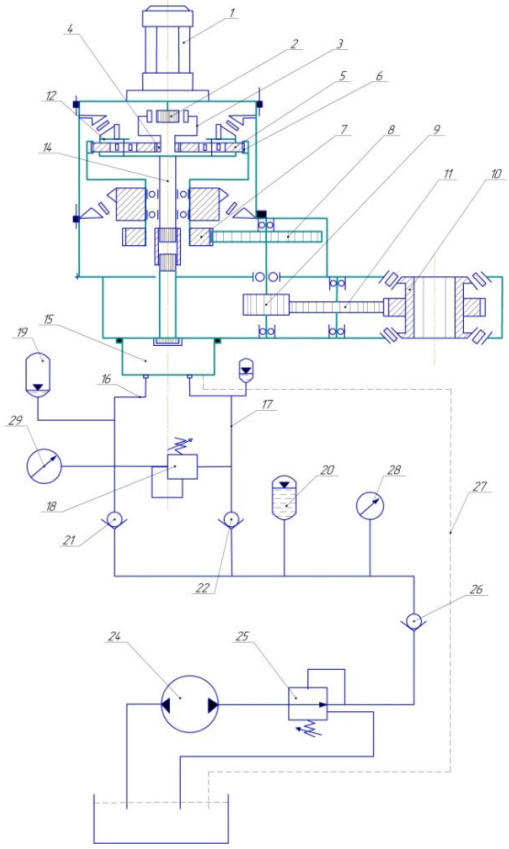

Fig. 2. Improved kinematic and hydraulic schemes of the electrohydromechanical rotary-feeding mechanism of a drilling rig.

The developed new design of the rotary-feeding mechanism, the kinematic and hydraulic diagram of the machine (Figure 2) gives it the properties of a hydraulic drive and allows you to significantly change the dynamic characteristics of the entire drilling rig during setup and operation, as well as gain new advantages over the traditional hydraulic drive, namely:

- absence of double energy conversion;
- direct savings on the installed power of hydraulic machines (approximately doubled);
- a sharp increase in the service life of hydraulic machines (up to an order of magnitude) due to their operation in braking mode.

The hydraulic machine of the electrohydromechanical rotation-feeding mechanism performs the functions of a hydraulic spring, and in the case of using pneumohydraulic accumulators, a pneumohydraulic spring with rigidity and damping adjustable within the required (quite wide) limits [1,15,16,19].

3 Results and discussion

The electrohydromechanical rotary-feeding mechanism of the drilling rig, the kinematic diagram of which is shown in Figure 2, includes an electric motor 1 (DPV-52), a gear 2 (z=20, m=6), rigidly mounted on its shaft and connected by a holder 3 with the sun wheel 4 planetary gears, satellite 5, epicyclical gear 6 (z=82, m=5), rigidly connected to gear 7 (z=50, m=6). Gear 7 is in mesh with wheel 8 (z=50, m=6), on the shaft of which gear 9 (z=19, m=10) is fixed, which engages with wheel 10 (z=46, m=10) through idler gear 11 (z=47, m=10). The planetary gear carrier is connected through a gear coupling and shaft 14 to the rotor of the brake hydraulic machine 15 (IMP 2.5), and the body of the hydraulic machine is rigidly connected to the housing of the rotator gearbox. The hydraulic circuit of the electrohydromechanical rotary-feeding mechanism ensures its reliable and smooth operation both during startup and during various drilling modes. The main elements of the hydraulic system are [4,12,14,18]:

- radial piston hydraulic machine 15 with high pressure line 16 and make-up line 17;
- safety valve 18, installed between the lines 16, 17 of the hydraulic machine 15, and serving to protect the electric drive of the rotator and its transmission from overload by limiting the pressure in the hydraulic machine 15 in stop mode;
- a pneumatic-hydraulic accumulator 19 installed in the line 16 of the hydraulic machine 15, designed to provide the required dynamic characteristics of the hydromechanical rotator in various modes of its operation;
- pneumatic-hydraulic accumulator 20, installed in the common make-up line 23 and ensuring the operation of the rotator in starting modes;
- check valves 21, 22 installed in front of lines 16, 17 of hydraulic machine 15, designed to prevent fluid flow between lines 16, 17, bypassing hydraulic machine 15 and valve 18, as well as to ensure reliable operation of the rotator during reverse rotation and increasing pressure in line 17;
- a make-up pump that replenishes fluid losses associated with leaks in the hydraulic machine;
- support valve 25, installed after pump 24 and providing pressure in line 23 equal to 100÷150 MPa;
- check valve 26, installed after valve 25 and preventing discharge of the hydraulic cavity 20 when pump 24 is turned off;
- drainage pipeline 27 of hydraulic machine 15 [7,10,13,19,20].

The specific pipeline of the planetary insert and hydraulic machine IMP-2.5 on the housing of the rotator gearbox of the SBSh-250MNA-32 machine, as well as the placement of the hydraulic control unit with the feed pump in the engine room are shown in Figure 3.

Fig. 3. Installation of a feed pump with a drive electric motor in the engine room of the SBSH-250MNA-32 drilling rig.

Operation of the electrohydromechanical rotary-feeding mechanism. The rotation-feeding mechanism is started as follows. The feed pump 24 is turned on, supplying working fluid to lines 16, 17 of the hydraulic machine 15, and the hydropneumatic accumulator 20 is filled. The drive is ready for operation. The electric motor 1 of the rotator is turned on and the rotation of its shaft through gear 2 and cage 3 is transmitted to the sun wheel 4 and the satellites 5 of the planetary gear, the carrier of which 12 is connected through a gear coupling and shaft 14 to the rotor of the hydraulic machine 15 operating in braking mode. The satellites 5 transmit rotation to the epicyclic wheel 6, rigidly connected to the gear 7. Further rotation through the gearing 7, 8, 9, 11, 10 is transmitted to the output hexagon, chuck and drill rod.

When the drill string is fed to the bottom, the shaft 14 connecting the planetary gear carrier 12 with the rotor of the hydraulic machine 15, under the action of the reaction torque, tends to turn the rotor of the hydraulic machine 15 in the direction of supplying fluid to the line 16 [1,16,17,20].

In the lines 16, 17 of the hydraulic machine 15, check valves 21 and 22 are installed, respectively, which are activated when the pressure increases. When the rotor of the hydraulic machine 15 turns, the pressure in the line 16 increases and the reaction torque on the carrier 12 is balanced. The pneumohydraulic accumulator 19 connected to line 16 allows for a smooth change in load and provides regulation of the rigidity characteristics of the drive. Damping of torsional vibrations of the drill string and transmission is carried out due to hydraulic losses in the pipelines and hoses connecting the accumulator 19 and the hydraulic machine 15 [4,7,10,12,14,18].

Leaks in the hydraulic machine 15 cause a slight decrease in the rotation speed of the drill string, not exceeding 0.1%. Leaks are carried out by the make-up pump 24. The pneumohydraulic accumulator 20, installed in the feed line 23, ensures the operation of the hydraulic machine 15 during reverse and rotator loads. When the rotator is overloaded due to sludging of the well, the drilling rod slows down rotation, at the same time the pressure in

the line 16 of the hydraulic machine 15 increases to the setting level of the safety valve 18 connecting the lines 16 and 17 and the rotor of the hydraulic machine 15 and, accordingly, the carrier 12 of the planetary gear begin to rotate at speed , proportional to the rotation speed of electric motor 1, and the torque developed by the rotator on the drill string does not exceed the specified values. The drilling string stops and the drive motor 1 is turned off.

4 Conclusion

Thus, the use of an electrohydromechanical rotator with rational dynamic parameters is an effective means of minimizing dynamic loads in the working body, drive and metal structure of a drilling rig. An electrohydromechanical rotational feed mechanism has been developed and tested, which is a fundamentally new design of the actuator drive transmission and a modernized feed mechanism.

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