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Objectivation of the Necessity of Structural and Parametric Synthesis of the Hydraulic Drive Of Geokhod

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Abstract. This article considers main systems of a prototype model of geokhod as well as their technical specifications. There are ways distinguished of decreasing the dimensions and the mass of elements of the hydraulic drive. As an optimization tool of structural and parametric parameters of the prototype model of geokhod, there is SimHydraulic simulation considered.

1. Introduction

The exploration of the underground space is an important task in the modern conditions of human life activities. The construction of underground facilities is aimed at the extraction of minerals, at the placement of transport communications as well as objects of urban supply, etc. Among underground facilities there are tunnels. In the publications of authors [1], there are the main tendencies marked concerning the development of tunneling, in particular, there are the following most important tendencies:

– construction of underground facilities using new technologies;
– a wider use of characteristics of rock mass;
– safety increase of tunneling excavation;
– implementation of new mechanized complexes.

As an alternative to modern shield tunneling methods, in publication [2], there is a special technology suggested which basic element is geokhod. In comparison with common tunneling machines, geokhod has several advantages which are based on an absolutely new functioning principle of the aggregate as well as on new functional and structural elements. One of these advantages is the ability to work under any slope angle of the drive working [3].

The structure of recently developed geokhod samples (Figure 1) consists of an executive element of the main forehead, executive elements of head and tail sections, transmission as well as loading system. A distinguishing feature of geokhod consists in the fact that all of the above listed systems function simultaneously, which is why there is a necessity to coordinate their functions. In publication [4], there was a mathematical model elaborated which describes the progressing of a geokhod in the rock mass. It must be mentioned that previously created mathematical models [5] did not take into account the large number of geokhod systems and their diversity. A modular principle of their

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structure, as well as of geokhod in general, showed the need to search for the methods of choosing preferable circuit designs depending on the exploitation conditions of geokhod [6].

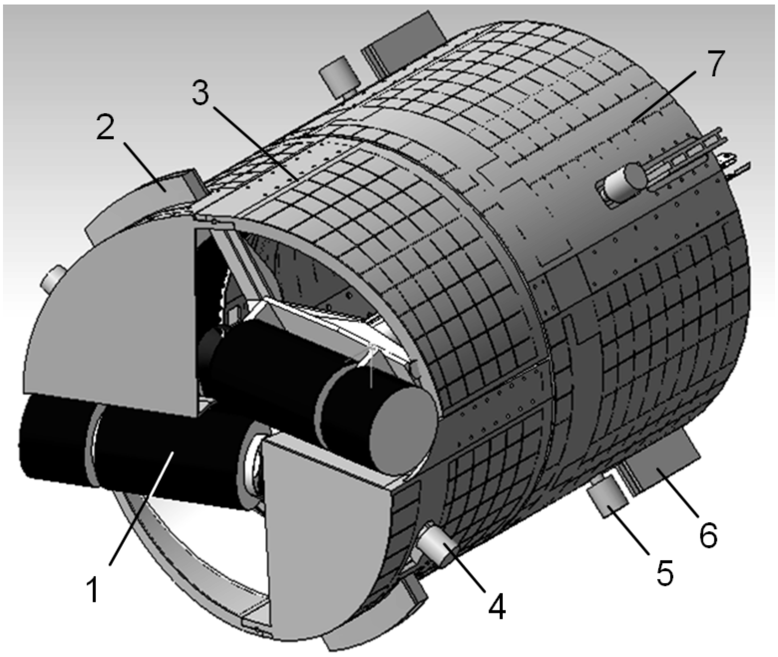

Figure 1. General view of a geokhod prototype model

1 – executive elements of the main forehead; 2 – propelling device; 3 – head section; 4 – executive element of the head section; 5 – executive element of the tail section; 6 – counter-rotating element; 7 – tail section

2. Initial data

Currently, there are not only designing works performed but also manufacturing as well as calculation of economical effectiveness of manufacture of this tunneling machine [7, 8, 9]. According to the scheme of work on the project of geokhod manufacture, researchers of Yurga institute of technology of Tomsk polytechnic university as well as of Yurga mechanical engineering plant have designed a prototype model of geokhod. Main technical specifications of the prototype model are listed in table 1.

Table 1. Main technical specifications

No.	Parameters	Measuring unit	Value
	Mining conditions		
1	Diameter of the drive working in the tunneling	m	3.2
2	Cross sectional area of the drivage	m²	8.4
3	Angle of slope of the drive working	degrees	± 25
4	Hardness of the enclosing rock	units	up to 5
	Technical specifications		

1	Output	m^3/min	up to 0.8
2	Drilling rate	m/h	up to 6
3	Drive types of executive elements		Hydraulic
4	Number of hydraulic cylinders in the module	pieces	16
5	Nominal working pressure	MPa	20
6	Torque of the head module by nominal pressure, minimum	kN·m	1.76e03
7	Gross thrust at the tail module	kN	850
8	Lifting angle of the helical blade of the external propelling device	degrees	8°
9	Mass (without pumping stations)	kg	19,000
10	Installed capacity, minimum	kW	414
11	External diameter of geokhod modules	mm	3,200

The functioning of mining machines in general, and of the geokhod in particular, can be provided by means of power drives of various nature [10]; however, main systems of the prototype model, which perform the progressing of the geokhod down the hole, its crushing and steering along the channel, are driven hydraulically. The distinguishing features of the hydraulic drive of geokhod are high capacity as well as constant simultaneous work of all systems which is typical for recently developed geokhods [11].

The hydraulic circuit diagram of the designed sample of geokhod includes hydraulic drive of the executive element crushing the face, hydraulic drive of the motion of cylinders of the executive element, hydraulic drives of executive elements of off-circuit elements of geokhod's head and tail sections, hydraulic drive of the loading device, hydraulic drive of the transmission. In order to prevent hydraulic lines of geokhod's systems from mutual influence, they are supplied with different pumping units.

The designing of the hydraulic drive is based on the initial data listed in table 2.

Table 2. Initial data

System name	Torque at the output element M, kN·m	Rotation speed of the output element ne_{ee}, min^{-1}	Reduction ratio, u_{red}	Number of hydraulic servomotors i_{hm}, items
Executive element of the main forehead	21.4	30	66.3	2
Executive element of the head section	0.824	130	1	2
Executive element of the tail section	0.39	60	1	4
Loading system		10	15	4
Transmission	1,710	0.1	-	8

The point of departure for the determination of parameters of the hydraulic drive of the geokhod is the calculation of power characteristics of geokhod [12] as well as the necessary capacity of all geokhod systems. Total capacity of the hydraulic drive is determined by equation (1) [13].

$$N_{HS} = \sum_{i=1}^{n} N_{hm} = k_{c.tr} k_{y.tr} N_{tr} + k_{c.ou} k_{y.ou} N_{ou} + k_{c.prou.} k_{y.prou} N_{prou} + \\ + k_{c.lu} k_{y.lu} N_{lu} + \ldots + k_{ci} k_{yi} N_i, \tag{1}$$

$\sum N_{hm}$ – the total sum of power of all hydraulic motors, W.

$k_{c.tr}, k_{c.ou}, k_{c.prou.}, k_{c.lu}, k_{ci}$ – safety factor of hydraulic motor velocity, that of transmission, operating unit of geokhod, propeller operating unit, loading unit, end users i, k_c = 1,1…1,3;

$k_{y.tr}, k_{c.ou}, k_{c.prou}, k_{c.lu}, k_{yi}$ – safety factor of hydraulic motor force, that of transmission, operating unit of geokhod, propeller operating units, loading unit end users i, k_y = 1,1…1,2;

N_{tr} – power, supplied for the drive of transmission hydraulic cylinders, W;

N_{ou}– power, supplied for the drive of operating unit hydraulic motors, W;

N_{prou} – power, supplied for the drive of propeller operating units,

N_{lu} – power, supplied for loading unit drive;

N_i – power of hydraulic motor of end user i.

When designing the hydraulic drive of the prototype model of geokhod, it is necessary to judge from the principle of performance assurance of geokhod systems taking into account increased safety factors. Thus, an increased power reserve of geokhod systems is guaranteed which compensates possible designing errors and allows to carry out tests of the prototype model under critical loads.

However, such approach is unacceptable when designing production samples because the increase of capacity of hydraulic drives results in the increase of hydraulic fluid consumption which leads to the increase of volume of the hydraulic tank as well as the mass and dimensions of hydraulic units and valves. These factors make it impossible to place a pumping station inside the geokhod in case of necessity. Thus, the factors of assurance, the value of which is mostly determined by the experience of designing of hydraulic drives, in geokhod's case, demand a scientific objectivation.

3. Results and discussion

In order to achieve the assigned task, it is necessary to simulate the drive's work in the conditions imitating close to real. The library SimHydraulics of Simulink environment of the Mathlab system allows not only to receive quite exact simulation results of hydraulic systems, it also makes it possible to correct corresponding parameters based on the results of real tests. A distinguishing feature of this library consists in the fact that the applied units are represented by ready-to-use standard components of hydraulic drives. This accelerates the simulation process and makes it easier [14, 15, 16], while a wide list of units helps simulate almost any kind of hydraulic systems.

The hydraulic circuit diagram of geokhod's transmission includes two groups of hydraulic cylinders, eight pieces in each. The hydraulic fluid for a forward stroke and an idle run is delivered from different pumping units. The delivery of the hydraulic fluid is performed by means of a six-line three-position hydraulic distributor. The simulation of the transmission in the environment SimHydraulics, like any other hydraulic scheme with hydraulic cylinders, has its own peculiarities. When building a diagram from Simscape library, you should pick the proper element (in this case a double-acting hydraulic cylinder) and connect it with the distributor by means of hydraulic lines (Figure 2). In the units' parameters, you can define the technical specifications of the hydraulic cylinder and other units. Then, you must connect the hydraulic cylinder with the units of fixed bearings and simulate the load at the piston. For this, "Mass", "Translational spring", and "Translational damper" units are used. In order to measure the motions of the piston, unit "Ideal Translational Motion Sensor" is used, whereas, in order to display measured values, this unit is connected with a virtual oscillograph (unit "Scope"), and the signal transmitted is previously transformed from Simulink signal into the necessary physical quantity by means of the unit "PS S Simulink Converter".

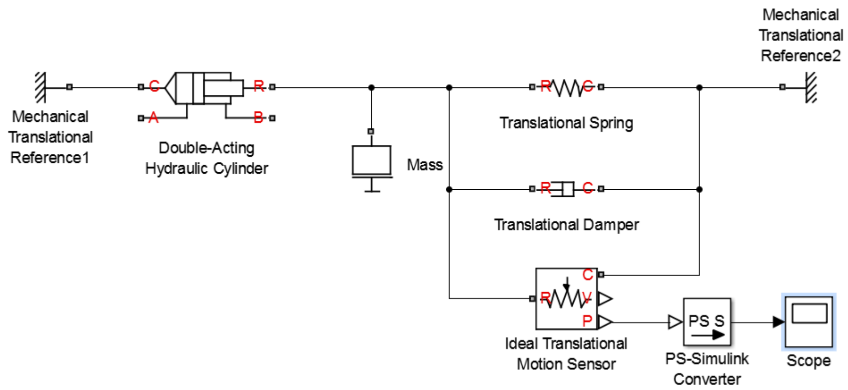

Figure 2. Simulation example of a double-acting hydraulic cylinder

As it has already been mentioned before, the transmission of the geokhod consists of two groups of hydraulic cylinders, eight items in each. This is why, in order to decrease the workload of the model, several units can be united into one subsystem. In Figure 3, such subsystems (HC1…HC16) combine hydraulic cylinder units, fixed bearings, load imitating units at piston as well as the units that allow to measure the motion of pistons.

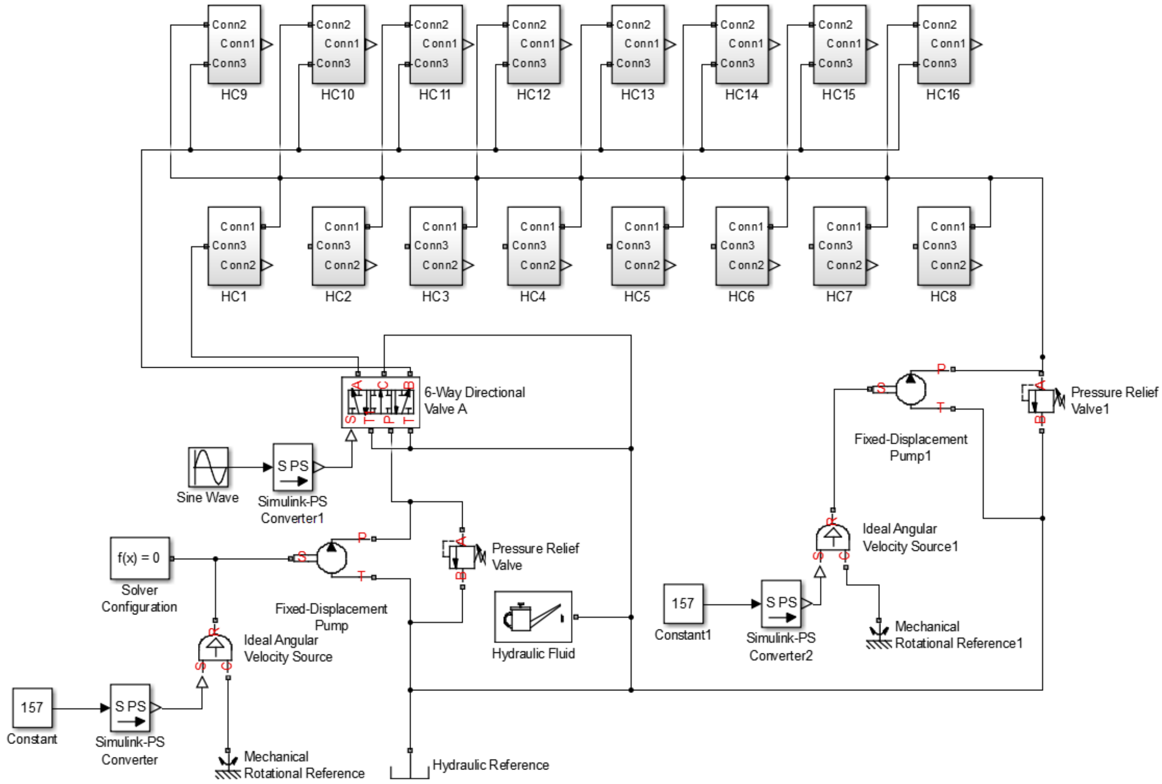

Figure 3. SimHydraulics model of geokhod transmission

Having entered the necessary parameters into the units, you can simulate the function of the transmission in various situations, e. g. to test its functioning when some of the elements fall out. It must be mentioned, that the simulation results in Simulink system can be only approximate and demand an adequacy test in experimental conditions which is, on the other hand, typical for other models as well [17].

4. Conclusions

In spite of the performed work on the search for means of decreasing the dimensions of basic elements of the pumping station, there are still open issues of determination of rational parameters of other elements of the hydraulic system of geokhod as well as structural optimization of the function of the whole hydraulic drive of geokhod, and the creation of basics of its automatic regulation system. For a comprehensive research of the hydraulic drive of geokhod, it is necessary to perform following actions: to research the sensitivity analysis of output characteristics to the changes of drive parameters, to determine extreme values of output characteristics, to conduct a statistical analysis of the drive, to determine permissible deviations of the parameters of the hydraulic drive from predefined values, and to evaluate the working capacity of the hydraulic drive in case of fall-out of its separate elements.

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