IDEAS CONCERNING THE SAFETY OF HYDRAULICALLY-MECHANIZED SUPPORTED COAL-FACES

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Abstract: Carrying out all the operations related to underground coal mining, in full safety conditions, imply the use of a complex supporting system: this should ensure the optimal conditions needed in the coal exploitation process, as well as the mine working roof control and protection of the coal deposit.

The paper deals with presentation of the structural and operational features of the hydraulic props' drive system, which represent the main force of the elastic elements of the supporting assemblies in the faces, for coal mining: the specifics which ensure the safety level prescribed for both the production activities and the coal deposit have also been identified.

Key-words: face, mining machineries, hydraulic operation, safety

1. INTRODUCTION

The entire underground coal mining process is considered to be safe only if there is a support system to redirect the pressure of the roof. Even if the operation cycles of the face support have a relatively reduced life span, problems related to the support are generally difficult to deal with, due to the requirements imposed by the extremely variable geologic conditions of the mine as well as to the incognizance of all basic data.

Following a series of mining conditions and specific requirements, the hydraulic system which operates the metallic face supports is completely different from the hydraulic systems of other mining machineries, from solving the diagram, to the liquid used as well as from the design and construction of the pumping power pack point of view.

Therefore the powered roof support is composed from a relatively high number

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of shields placed along the face on lengths which may frequently exceed 100 m, each of them being operated by hydraulic cylinders the number of which varies according to the type of support, from 2 to 16; the shielded configuration, of the powered roof support on the length of the wall, from a number of identical shields determines the repetition of the general hydraulic network diagram, belonging to one support shield, composed of the same execution, regulation and distribution hydraulic elements.

The operation reagent supply of the hydraulic cylinders is made by a pumping station usually placed in the main gallery. The operation reagent used is a oil in water fluid 3-5% and it goes from the power pack to each shield through two or three main either flexible or rigid pipes., out of which one is a return pipe: the transport distance may reach up to 500 – 700 m.

Considering the open circulation individual hydraulic props supports, the water in oil fluid supply is made using one power pack foreseen with a single main supply pipe, the operational principle of which excludes the main return pipe to the reservoir and discharges the liquid directly onto the floor during the opening phase.

2. CONSTRUCTIVE AND STRUCTURAL PARTICULARITIES OF FACE HYDRAULIC PROPS

The hydraulic prop, with its bearer function as a result of opposed resistance to geologic pressure generated by the rocks of the roof, is the active element of a metallic face support: either as a part of the powered roof support, or individual, they transmit to the floor of the face through their base the pressure taken from the beam of the roof.

The hydraulic prop (Figure 1) is composed by a force hydraulic cylinder *1* (of a large diameter) operating together with a opening command pilot controlled check valve *2* (with a retention function, therefore called hydraulic lock) and a safety valve *3*, the operational command being given from a distributor *5*; the previously mentioned devices may be either individual or assembled to a hydraulic block and connected to the hydraulic in a single circuit. Considering the powered roof support, the hydraulic props are used in pairs or fours, their command circuit being foreseen with “quality” pressure gauges *4* (specific hydraulic devices, called rod pressure indicators) [1].

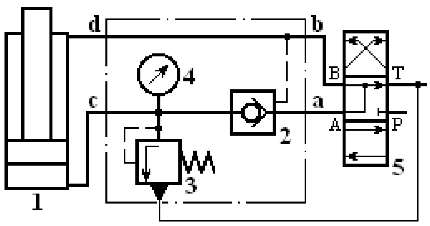

Fig. 1. Hydraulic prop: basic structure

Figure 2 represents the principle hydraulic diagram of the props of a shield with two bearing elements, the reference points having the following significance: *1*- hydraulic cylinders; *2*- hydraulic controlled check valves; *3*- safety valves;*4*- pressure gauges; *5*- distributor; *DPCV*- double pilot controlled check valve.

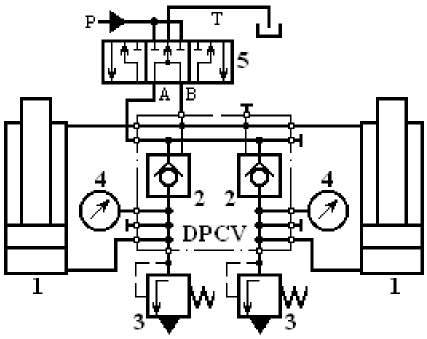

Fig. 2. Basic hydraulic diagram of props from a shield of a powered roof support

The package of the device does not belong to the hydraulic system of the prop but it is integrated in the prop and together with the hydraulic force cylinder forms a complex structure defining the prop. The circuit of the props is integrated in the circuit of the shield and water in oil fluid is supplied to it: the props, usually in pair, as well as other cylinders, are controlled using distributors connected to the main and return pressure pipes of the support complex, resulting therefore a closed type installation supplied by the hydraulic power pack. As a particularity of the safety valve of the prop, is that its outlet is in the atmosphere [2].

3. THE OPERATIONAL INFLUENCE OF A HYDRAULIC PROP ON THE SAFETY WITHIN THE FACE

According to the diagram in Figure 1, the supply of hydraulic props of the powered roof support is made from distributor 5 (turned on the inferior position) through route *a*, the pilot controlled check valve *2* and route *c*. Therefore the pair of props opens requiring the pressure following supply pressure from the power pack.

$$p_{PP} = \frac{2G}{\pi D_C^2 \eta_{mC} \eta_{hP-S}}, \tag{1}$$

where: G is the weight of the beam and the shield of the support, to which the weight of the mobile packages pin-rod of the prop is added, D_C - the interior diameter of the cylinder, η_{mC} - the mechanical coefficient of the cylinder, η_{hP-S} - the hydraulic coefficient of the circuit between the power pack and prop.

Finally, the supporting beam is installed at the roof with a pre-seizure force F_i:

$$F_i = p_{PP\max} \frac{\pi D_C^2}{4}, \tag{2}$$

where p_{PPmax} is the pressure developed by the supply hydraulic power pack under the piston of the prop, depending on the regulation of the safety valve of the power pack.

After the pre-seizure of the prop and cutting-off the liquid supply (distributor on the medium position), valve *2* remains closed, isolating the cavity under the piston. Under the mining pressure of the rocks in the roof, the mobile part of the prop compresses the liquid inside the prop leading to the increase of pressure therefore deforming the walls of the cylinder, and the cylinder developing an elastic descent Δs. When Δs^* value is reached, the pressure inside the cylinder reaches an inlet value $p_{S\max}$ depending therefore on its own safety valve *3*, limiting the force of resistance of the hydraulic prop. This force constitutes the nominal resistance (bearing capacity) force of the prop with the value:

$$F_{\max} = p_{S\max} \frac{\pi D_C^2}{4}; \quad (3)$$

when the safety valve opens a small quantity of operational reagent from the interior of the prop is blown out into the environment. Considering a constant resistance operation the height of the prop continuously decreases depending on the quantity of outlet liquid through the safety valve, while the evolution of pressure under the piston is being followed with the help of the pressure gauge *4*.

In order for the support to advance it is necessary to reduce the mine pressure on the prop. The advancing operation of the powered roof support may be done either by complete reduction of mine pressure on the props of the roof support, by losing the contact of the superior beam with the rocks of the roof, or by partially reducing the mine pressure by reducing the pressure in the cavity of the piston up to a pre-established limit, being able to reduce it using a special valve. In the latter case, the superior beam of the shield, during the advancement, does not lose contact with the roof developing an active support resistance to advancement.

The operation of props may be analyzed using the operational characteristics presented in figure 3. The OABC line represents the opening and pre-tensioning of the prop using force F_t. From point C to D the pressure in the cylinder rises together with the pressure of the mine, and in point D with the ordinate DE, and when $p_{S\max}$, pressure is reached the intermittent opening of the safety valve begins and the prop enters a constant resistance operation: Δs^* represents the elastic descending stroke of the piston corresponding to route C-D. Line EH corresponds to reduce the tension of the prop following with the advancement of the shield and the beginning of a new operational cycle. Considering an advance with active support, the advance of the shield is made on a line parallel to axis t the ordinate of its points being equal to the active resistance developed by the hydraulic prop (ordinate F_a).

The diagram OABCDEH representing the load variations of the prop (in the same time and under interior pressure of the cylinder) during a cycle (t_{cycle}) considering a constant descendant speed of the rocks of the roof constitutes a nominal operational characteristic of the prop.

Following the research made underground regarding face supports it has been determined that in most of the cases the real operational characteristic may deviate from the nominal movement presented in figure 3.

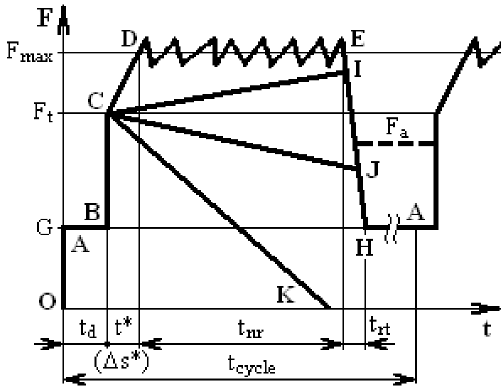

Fig. 3. The operation of hydraulic props

The nominal operational characteristic is developed on the hypothesis that the hydraulic circuit of the prop is perfectly sealed; in reality there are a series of internal liquid loses. If there are small micro-losses, pressure increase in the piston slows down in such a way that before the decrease of tension of the prop the real resistance is smaller than the nominal bearing coefficient F_{max} (line CI). If there are larger micro-losses, before the discharge of the real resistance of the prop may be smaller than the pre-tensioning force F_t, and the form of this characteristic will be OABCJH. In case of high losses there is a premature discharge of the prop from the mine pressure in point K, the characteristic turns into OABCK.

The consequence that the decrease of resistance of the hydraulic prop, to total disappearance, is the disturbance of the balance of the rocks in the roof, resulting therefore in their caving or crumbling, making it harder for the shields to operate normally, affecting as well the safety conditions of the face.

During the use of the powered roof support inlet pressure decrease situations may appear when the safety valve is operating (due to nitrogen loss or weakening of the spring), meaning thus the decrease of operational resistance of the hydraulic prop: the effect is the destruction of the integrity of the rocks of the roof.

The pre-tensioning of the hydraulic prop depends on the value of the maximum pressure developed by the power pack within the pipes of the powered roof support. In practice, using a manual control of the shield, the possibility to turn the distributor and disconnect the supply of the hydraulic prop appears before the pressure created by the pumping station even determines the pre-tensioning force, consequently leading to the increase of the period of time before the hydraulic prop goes into a constant resistance operation worsening the support of the rocks in the roof especially in the space next to the face.

An important problem in carrying out the bearing function in best conditions of props inside the face is the adequate use of safety valves, the outlet capacity of which has to be in perfect correlation to the characteristics of the rocks in the roof of the face, consequently avoiding the swelling of the cylinders even bursting in cases of high speeds of the roof's descent.

The changing capacity of the safety valves depends of how the liquid is evacuated when it opens. Therefore, the changing capacity of the safety valves that evacuate the liquid in the environment is not influenced by the counter-pressure developed in the return pie (e.g. nitrogen valves), while the valves connected to the return pipe the pressure in the circuit influences their opening and their flow. Together with the accidental increase of the counter-pressure the changing capacity reduces, and when reaching a certain value the counter-pressure disappears, consequently the opening pressure changes substantially.

4. CONCLUSIONS

The resistance of the prop is fundamental in maintaining the balance of the rocks in the roof, resulting in a normal operation of the support shields, consequently ensuring the safety conditions inside the mine.

Considering the improvement of the interaction of the support with the rocks in the roof it is very important that the real operational characteristics be close to the nominal established ones for the given operational conditions. It is required as much as possible of the required pre-tensioning of the hydraulic prop to be as close to the value of the nominal resistance; the value of the initial pre-tensioning is obtained by regulating the maximum pressure developed by the pumping station.

The information regarding the dynamic behavior of safety valves correlated to the characteristics of the rocks of the roof is an essential condition in order to have a normal operation of the hydraulic props as well as ensuring the required safety level in a face.

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