CONSTRUCTIVE AND CALCULUS PARTICULARITIES FOR THE HYDRAULIC PROPS OF POWERED ROOF SUPPORT

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ABSTRACT. The hydraulic prop represents the supporting element of the metallic individual or powered support of the face, it attaining the yielding strength function as a result of the resistance opposed to the geodetical pressure generated by the roof-rocks at the supported mining work.
The evaluation of the fluid pressure within the prop's hydraulic system and the amount of the volume losses depend on the value of the work pressure, on the precision of manufacturing and on the roughness of the sealing surfaces, also on the wear degree, on the yielding of prop's hydraulic system, on viscosity and on other features of the work fluid.
The paperwork presents the constructive and operating specific features of powered roof support's hydraulic props, as well as their principles of calculus.

КОНСТРУКТИВНИ И ИЗЧИСЛИТЕЛНИ ОСОБЕНОСТИ НА ХИДРАВЛИЧНИТЕ ПОДПОРИ НА МОЩЕН КРЕПЕЖ НА ГОРНИЩЕТО

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РЕЗЮМЕ: Хидравличната подпора представлява поддържащия метален елемент или главната мощна опора, което води до слягане на горнището като резултат от противодействието на геодезичното налягане, което се причинява от покривните скали към изработения минен крепеж.
Изчисляването на налягането на течната среда в хидравлична система на крепежа и количеството на обемните загубите зависят от стойността на работното налягане, от прецизността на производството, от необработената повърхност на водния хидравличен затвор, от степента на износване, от пластичността на поддържащата хидравлична система, от вискозитета и други специфични особености на течностите.
Статията представя конструктивни и експлоатационни специфични детайли на подпорната хидравлична система, както и с принципни особености при изчисляването им.

Introduction

Carrying out in full safety conditions, of all the operation complexes which compose the underground exploitation process may take place only in the conditions of using a supporting system that can ensure the active face roof control. Even if the operating cycles of the active face roof support have a relatively reduced duration, the problems related to support are generally difficult to solve due to exigencies imposed by the mining-geological conditions, that are extremely dynamic and due also to lack of knowledge regarding basis data: the lack of satisfactory defined quantitative relationships having general applicability among the various factors that affect support behavior represents a permanent difficulty when solving the problems imposed both to the designer and the practitioner.

Constructive and operating particularities of the hydraulic props for the powered roof support

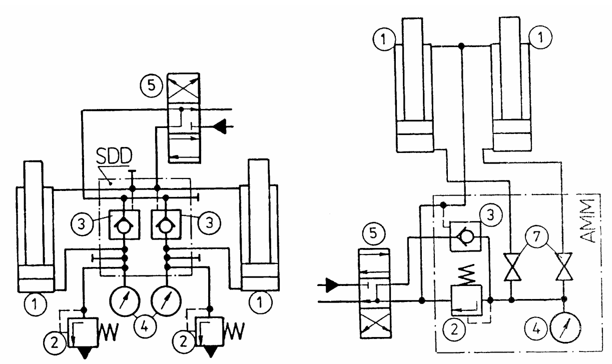
The hydraulic prop represents the active element of the metallic roof support in faces, this fulfilling the bearing strength function, as a consequence of the resistance it opposes to the geodetical pressure generated by the roof rocks in the supported mine working.

The hydraulic props in the powered roof support fulfill the same function as the individual ones: they deliver to the mine working's bottom the pressure taken from the roof through the roof beam, with the difference that pressure delivering is carried out through the powered roof support's bottom plate.

The hydraulic prop consists in a power cylinder that operates commonly with a open controlled unlocking valve (having a retain function – this is the reason it is called hydraulic padlock) and with a safety valve; the operating command being given from a distributor; the mentioned apparatus may be individual or assembled in a hydraulic block and connected with the prop in a sole circuit. In the case of the powered roof support section, the hydraulic props are used in pairs or four at a time.

The hydraulic system of the powered roof support comprises mainly the same components as the individual hydraulic props, the difference consisting in the fact that the valve's assembly is not an integrant part of the prop, but represents, together with the power hydraulic cylinder, a complex structure that defines the prop. The prop's circuit it's integrated in the supporting section's own hydraulic circuit ant it is fed with emulsion also: the prop, as well as the other cylinders composing the section, are controlled with their own distributors, that are connected to the main pressure and return pipelines of the supporting complex, resulting a close-type of installation, fed from a pumping station which is called *hydraulic assembly*.

In fig. 1 are shown the hydraulic schemes of the SMA-2 (a) and CMA standard (b) types of powered roof supports; the reference points have the following signification: *1*- hydraulic cylinders; *2*- safety valves; *3*- hydraulically controlled unlocking valves; *4*- manometers; *5*- distributor; *7*- cocks; *SDD*- double unlocking valve; *AMM*- monoblock multiple apparatus.



a. b.

Fig. 1. Hydraulic schemes of the SMA-2 (a) and CMA standard (b) types of powered roof supports

Taking into account the principle of maximum opening accomplished, the powered roof support's props are divided into two categories: a. with one step: b. with two or three steps.

The first category equipped supports used in conditions of seams having medium or big thickness, their maximum openings is attained solely hydraulically, or with mechanical extensions: the extensions are used in cases when the working height of powered roof support attained through the simple cylinder is lesser than the working face's height.

The second category equipped supports for thin and medium thickness seams, lately arising the tendency of using on a larger scale the props having two opening steps, those offering better possibilities of adjusting to the seam thickness variations.

Taking into account the bearing strength at roof load, the powered roof support's props may be:

- High bearing strength props (500 – 3000 kN): it's used a number of one or two or four in one section and they have a large diameter;
- Low bearing strength props (< 500 kN): for the light types of powered roof supports.

The props may be located in any position on the metal construction of supporting sections. When the rod is locked on the beam, it is more protected from a mechanical point of view, but, at closing stroke, there appears the tendency of drawing impurities inside the cylinder; for the mechanical protection of the rod it is frequently used a metal sheath which is useful especially in blasting exploitation working faces.

Compared to traditional supporting sections, where the props stand in vertical or inclined position, the Rheinstahl company carried out an original powered roof support with shield, where the props' function is assumed by two hydraulic cylinders placed horizontally in the section's bottom plate: the cylinders act on the shield through a lever system and they are protected against eccentrical stresses and external damages.

The previous characterization results in the following operating particularities of the hydraulic props in the powered roof support:

- Hydraulic energy feeding is carried out from a pump station located in the main gallery to which the prop is connected in closed circuit;
- Prop's closing, as a consequence of mine pressure, is achieved through releasing the safety valve *2*: in the case of SMA-2 powered roof support, emulsion discharge is performed directly on the working face's bottom, but in the case of CMA-2 the emulsion is directed to return in the assembly's tank.

Hydraulic prop acting suppose accomplishing four different stages:

- *Pre-fastening stage* implies feeding with hydraulic energy through valve *3* for the purpose of placing the roof beam at mine working's roof and of pre-tensioning the props between the roof and bottom of the mine working;
- *Elastic sliding regime* attained as a result of mine pressure load and it acts until the pressure under the piston attains the pre-adjusted value of the safety valve *2*;
- *Steady strength regime* is attained only when the safety valve *2* is operating and it leads to achieving the rated bearing strength of the supporting element;
- *Unloading* of props is performed after unlocking the open controlled valve *3* and props' tension relieving as a result of feeding the annular cavity: after tension relieving the section stepping becomes possible.

The calculus and energetic of the hydraulic prop

The diagram of hydraulic prop operating (Vatavu *et al*. 1999) is shown in fig. 2 and it points out the four mentioned steps.

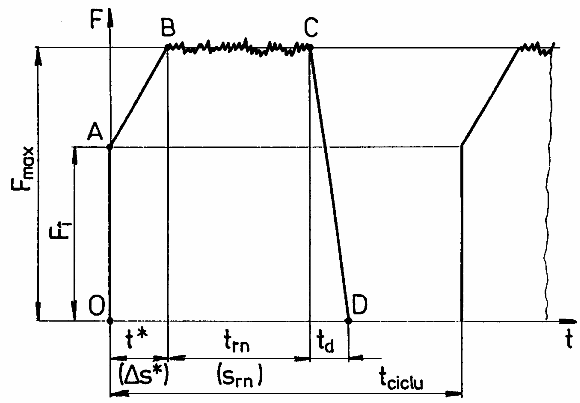


Fig. 2. The diagram of hydraulic prop operating

As a result of feeding with pressurized liquid, the individual hydraulic prop extends and develops the opening force $F_{ds} \in$ (0A),

$$F_{dS} = F_P - F_{fS} = F_P \cdot \eta_{mS}, \quad (1)$$

that is required for uplifting towards the roof the prop's telescope and the roof beam, which are components with constant weights:

$$F_{dS} = G_G + G_T = ct \quad (2)$$

in formula (1) F_P represents the force developed by the piston having the D_S diameter when acting the feeding pressure p_S, $F_P = \pi D_S^2 \cdot p_S / 4$, F_{fS} – the inner friction force due to the piston's sealing system, proportional to the feeding pressure, $F_{fS} = f(p_S) \neq ct$ şi η_{mS} is the mechanic efficiency of the prop.

In order for the piston to develop the force F_{dS}, the pump must generate the pressure

$$p_P = \frac{p_S}{\eta_{hPS}} = \frac{4(G_G + G_T)}{\pi D_S^2 \eta_{mS} \eta_{hPS}}, \quad (3)$$

where η_{hPS} represents the hydraulic efficiency of the pump-prop connecting circuit.

When the prop places the roof beam on the roof, the feeding pressure attains the value p_{maxP} that is regulated through the adjustment of the safety valve in the feeding hydraulic assembly, for which the force developed in the prop means in fact prop's pre-fastening force:

$$F_{iS} = \frac{\pi D_S^2}{4} p_{max\,P}. \quad (4)$$

On the operating characteristic shown in fig. 2, the ordinate OA corresponds to pre-locking force, and a point that is inferior to A corresponds to the opening force.

After the hydraulic prop pre-locking with the force F_{iS} and after feeding cut off, the one way/sense valve *3* (fig. 1) closes the cavity under the prop's piston. Mine pressure acting generate the lowering of roof rocks level: this results in increased pressure under the piston, elastic compression of the emulsion column and cylinder walls swelling, and the piston carries out an elastic withdrawal having the stroke Δs^*. The value of elastic slide of piston is given by the sum of two components,

$$\Delta s^* = \Delta s_E + \Delta s_C, \quad (5)$$

the first due to elastic compression of the emulsion column under the piston and the other due to the increased diameter of the cylinder as the result of the elastic deformation of the wall.

The regime of strength elastic increase determines the time t* needed to attain the rated strength after prop pre-locking,

$$t^* = \Delta s^* / v_c, \quad (6)$$

where v_c is the mean value of lowering speed of roof rocks; during this interval, the force developed by the piston increases at the value F''_P, and the resistance opposed by prop to the roof rocks increases at the value F_{maxS} (segment AB).

When value Δs^* is attained, the pressure under the piston reaches the value p_{maxS} – which ensures the prop's safety valve entering into operation. Beginning from this operation moment, it passes into the steady strength regime, the prop develops the maximum force, named nominal strength, this corresponds to the segment BC and the formula:

$$F_{max\,S} = F''_P + F_{fS} = \frac{\pi D_S^2}{4\eta_{mS}} p_{max\,S}; \quad (7)$$

in this situation, the mechanic efficiency η_{mS} is constant, due to the fact that it depends on the value of the pression developed under the piston, that is settled through the adjustment of the safety valve *3* (fig. 1).

The work regime that allows developing the nominal strength is reached as a result of intermittent operating of safety valve *3*. When operating in steady strength regime, which corresponds to period t_m, the prop's height decreases with a value determined by the amount of emulsion evacuated from the cavity under the piston through the safety valve, the mobile assembly will perform the stroke s_m.

In order for the support to step, it is necessary to unload the hydraulic props: in this phase of the work technology, the prop is unstressed by its load, usually by forced lowering of the mobile assembly, the operation (segment CD) being carried out in the time t_d; after support stepping, the prop is extended and the cycle shown repeats.

The graph OABCD is named the ideal operating characteristic of the hydraulic prop and, if admitted the lowering speed of roof as a constant, then its surface express the resisting activity of the hydraulic prop towards the roof rocks lowering.

It must be taken into account the fact that, in most cases, the real operating characteristic may differ from the ideal one shown in fig. 2. The main causes that may determine deviations from nominal values are the following:

- The ideal operating characteristic is founded on the hypothesis that the prop's hydraulic circuit is perfectly sealed. In reality, in the circuit may occur volumic losses at the valves and the sealing gaskets on the prop's piston: occurrence of these losses may significantly alter the operating characteristic form, decreasing the real prop resistance towards roof rocks lowering, up to even entirely unload the mine pressure. Diminishing up to total loss of prop resistance has consequences in altering the roof rocks consistency, that leads to rock falls and crumbling;
- Having a crumbled layer of coal and rock under the bot-

tom plate and especially over the roof beam significantly alters the operating characteristic of the prop, leading to a elastic sliding regime to develop following a straight line AB which is more inclined: by this, the prop nominal working period is diminished and, in certain cases, the prop may not develop the nominal working strength, respectively the conditions needed for the safety valve to operate may not be fulfilled;

- In the situation of diminishing the safety valve's operating pressure, its arc characteristic altering results in a decreased working resistance, and the effect of affecting the roof rocks integrity;
- Changing the work cycle time t_{ciclu} influence the real resistance curve of the prop. For a special dynamics of exploitation, the work cycle time in the working face may become smaller than time t*, the hydraulic prop working only in elastic strength regime, its unloading takes place without reaching the nominal strength: this type of real characteristic reduces support's efficiency towards the possibilities of use;
- The initial pre-tensioning of the hydraulic prop depends on the value of maximum working pressure developed by pump in the support's pipes: when prop opening is manually controlled arises the possibility that the worker may interrupt prop feeding before the pressure enables the pre-locking force to develop. In this situation, the period up to entering the constant strength regime increases and, as a result, the roof rock supporting is deteriorating, especially in the work space near the face; a control of correct initial tensioning may be carried out following indications on a manometer.

From the point of view of improving the interaction between the support and the roof rocks it's advisable that the hydraulic prop's pre-tensioning to get as near as possible to the value of the nominal working strength. For the supports used in mine exploitations in our country, the pressures of feeding the hydraulic props vary between 15 up to 30 MPa.

Fulfilling the bearing strength function suppose that actuating the safety valve shall be carried out at a pressure 20% greater; also, it's particularly important the type of safety valve adequate to the characteristics of the rocks in the face roof, thus avoiding, in cases of great speeds of roof lowering, swelling of prop cylinder walls and even break down of cylinders or of other parts of the hydraulic circuit up to valve. It results that working of this valve is done in specific conditions, completely out of common, reason for which there are imposed to it certain requirements, unwitnessed in working of other safety valves used in the hydraulic drive systems. (Patrascu and Vatavu, 1997)

The working regime specific for long term operating of the safety valve in the hydraulic props is the one which can ensure the smaller and the most even lowering of roof rocks, with a mean speed value of a few millimetres per hour, thus determining the smallest flow evacuated.

Conclusions

Ensuring a normal and efficient working of the support supposes the pre-locking force of the hydraulic props to have a value as closest as possible to the one of the force developed during the nominal strength regime: increasing the maximum feeding pressure reduces the difference between the operating pressure of the safety valve and accordingly reduces the value of elastic sliding Δs^* and time t* to pass into the constant strength regime, by this radically improving interaction between support and face roof.

Choosing the safety valve in close correlation with the roof rocks characteristics has a special importance, since, in the rock-support system, it determines, on one hand, the resistance opposed by prop at roof lowering, and, on the other hand, it ensures the integrity of roof rocks.

The principles of calculus presented allow the assessment of dynamic parameters both those at feeding and those developed, fact that allows a general evaluation of the energetical performances of the hydraulic props, respectively for the support.

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