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SELECTION OF HYDRAULIC LEG OF MECHANIZED ROOF SUPPORT FOR OPERATION IN HAZARDOUS CONDITIONS OF MINING TREMORS

Abstract

The article presents selection of a hydraulic leg of mechanized roof support which is the main component of its power hydraulics and determines a level of longwall's support capacity and safety. A hydraulic leg is an actuator of double acting type, however, the basic range of work includes compression (support). Selection of its technical parameters for specific mining and geological conditions is extremely important due to the requirements for accommodation of static and dynamic types of loading, as well as strong overloading capabilities. Particularly dynamic loading, as derivative of mining tremors, causes significant technical problem. Loading prognosis for mechanized roof support is based on the model of disturbed strata presented by Bilinski. Additional requirements regarding the flexibility of mechanized roof support which operates in hazardous conditions of mining tremors. This study presents the basic technical features which characterize the construction of a hydraulic leg, together with respective requirements related to mechanized roof support, and thus the construction of its hydraulic legs. Presented assessment method of the prognosed loading for a hydraulic leg ϕ 0.21/0.16 m, equipped with rapid yield valve – as well as without such a valve – designed for operating in hazardous conditions of mining tremors, allows to qualify the utility of the particular leg for dynamic loading cases, which occur the most often. The test trials conducted at testing rig in Central Mining Institute and further analytical flow profile determination for this particular leg have confirmed the correctness of the assumptions adopted in the methods as well as the requirements established in the design process. Due to the results of tests, analysis and consultations it seems to be justifiable to conduct further research and analysis, increasing their range for legs to larger diameters.

Dobór stojaka hydraulicznego zmechanizowanej obudowy ścianowej do warunków zagrożenia wstrząsami górotworu

Streszczenie

W artykule opisano dobór stojaka hydraulicznego zmechanizowanej obudowy ścianowej, który jest głównym elementem hydrauliki siłowej, decydującym o jej podporności i bezpieczeństwie. Stojak hydrauliczny jest siłownikiem dwustronnego działania, jednak podstawowy zakres pracy obejmuje ściskanie (podporność). Dobór jego parametrów technicznych dla konkretnych warunków geologiczno-górniczych jest niezwykle istotny z uwagi na wymagania dotyczące przejmowania obciążeń statycznych i dynamicznych oraz znacznych możliwości przeciążeniowych. Szczególnie obciążenia dynamiczne jako pochodne wstrząsów górotworu stanowią problem techniczny. Prognozę obciążenia zmechanizowanej obudowy ścianowej oparto na modelu górotworu naruszonego według Bilińskiego. Dodatkowe wymagania to dotyczące „upodatnienia" zmechanizowanej obudowy do warunków zagrożenia wstrząsami górotworu. W artykule przedstawiono podstawowe dane charakteryzujące konstrukcję stojaka hydraulicznego wraz z wymaganiami stawianymi dla obudowy zmechanizowanej i tym samym konstrukcji stojaka. Przedstawiony sposób oceny prognozowanego obciążenia stojaka hydraulicznego ϕ 0,21/0,16 m z zaworem i bez zaworu, przeznaczonego do warunków zagrożenia wstrząsami górotworu, pozwala kwalifikować przydatność samego stojaka dla

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występujących najliczniej przypadków obciążeń dynamicznych. Przeprowadzone badania na stanowisku GIG oraz analityczne określenie przepływu stojaka, potwierdziły prawidłowość założeń przyjętych w metodyce oraz wymagań stawianych w procesie projektowania. W świetle przeprowadzonych badań, analiz, konsultacji wydaje się uzasadnione prowadzenie dalszych badań i analiz, zwiększając ich zakres o stojaki z większymi średnicami cylindrów.

1. INTRODUCTION

A hydraulic leg is an essential element of mechanized roof support, deciding about its safety and operational properties. The hydraulic leg is an actuator of double acting type, however, the basic range of work includes compression (support). Selection of its technical parameters for the specific mining and geological conditions is extremely important due to the requirements for accommodation of static and dynamic type of loading as well as strong overload capacity (Rajwa 2004). Particularly dynamic loading, as a derivative of mining tremors, causes significant technical problems. Important aspects of the leg's design as well as its control system are whether they meet the requirements under the Machinery Directive (PN-EN 1804-2:2010), and they are harmonized with the standards of the BS 1804 (Kasprusz 2007), and further, as a consequence of the Minister of Economy on the safety of paragraph § 440.2 (Kasprusz, Gasztych, Szurgacz 2010). Additional requirements regarding the flexibility of mechanized roof support, operating in hazardous conditions of mining tremors, which – in case of Polish coal mines – are occurring in over 50% of the seams. The report presents procedures regarding the selection of parameters and further related tests of a hydraulic leg, designed for mechanized roof support adjusted to operation in hazardous conditions of mining tremors.

2. REQUIREMENTS FOR MECHANIZED ROOF SUPPORT RESULTING FROM MINING AND GEOLOGICAL CONDITIONS

Basic requirements for mechanized roof support are based on the model of disturbed rocks defined by Bilinski (Biliński, Kostyk, Prusek 1997). Figure 1 presents the model of disturbed rocks.

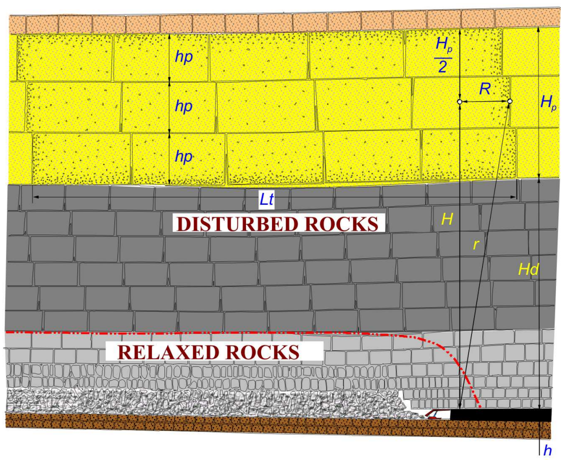

Fig. 1. Model of disturbed rocks acc. Biliński (Biliński, Kostyk, Prusek 1997)

Rys. 1. Model górotworu naruszonego według Bilińskiego (Biliński, Kostyk, Prusek 1997)

The burden of the drift is a consequence of superimposed stratum breaking. This phenomena induces the loadings, which have static and dynamic character. Indicator "g" (called roof stability index) is assigned for hazardous conditions of mining tremors – which applies to the maintenance of the roof (static load). Additionally for conditions the predicted dynamic loading is to be determined by applying of down load factor, assigned as n_{tz}.

Factor n_{tz} is calculated basing on foreseen energy of mining tremor and on vertical distance from the center of the bursting stratum to the drift ceiling (Fig. 2).

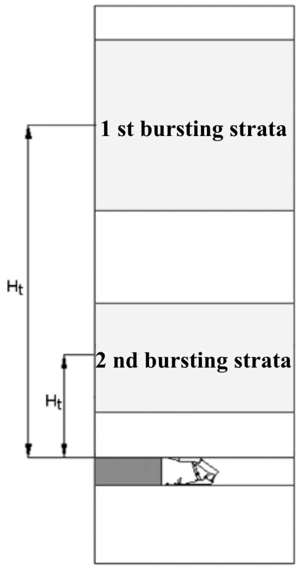

Fig. 2. Method of down load factor n_{tz} calculation

Rys. 2. Sposób obliczenia współczynnika dociążenia n_{tz}

The value of down load factor n_{tz} is calculated from the formula:

- for longwall systems with full caving operation

$$n_{tz} = 1 + \frac{n_{zr}}{0.04 \cdot \left(\frac{H_t}{E_t} \right)^{0.7} + 0.04 \cdot H_t + 0.5} \quad (1)$$

- for longwall systems with back stowing operation

$$n_{tz} = 1 + \frac{n_{zr}}{0.025 \cdot \left(\frac{H_t}{E_t} \right)^{0.7} + 0.025 \cdot H_t + 0.3} \quad (2)$$

where:

n_{zr} – down load factor‘s value depending on operating mode (ranging of 0.3–0.4);

H_t – vertical distance between the center of the layer being probable source of tremor, and the ceiling of the extracted drift, m;

E_t – prognosed energy of miming tremors, MNm.

Note: In case of several bursting layers the highest value is applied.

The value of the down load factor, depends on the mining and geological conditions and takes the values within the range of 1.05–1.8 which describes the possibility of down loading of the roof support resulted by mining tremors respectively from 5 to 80% of working capacity.

Assuming that the mechanized roof support is properly matched to the mining and geological conditions with utilizing of the roof stability index, "g" (Biliński, Kostyk, Prusek 1997) in term of support capacity, the dynamic parameters enabling an assessment of roof support loading origin from mining tremors, further optimizing of technical parameters is based on:

- foreseen down loading of mechanized roof support by overburden rocks with respect to working capacity, with utilizing of down load factor n_{tz},
- foreseen speed of drift's tightening, related to n_{tz} factor.

Matching of a hydraulic leg in the range of working capacity follows accordingly to the requirements for stability of the roof (index "g"), while the dynamics as derivative of mining tremors with utilizing of n_{tz} factor. Moreover, in the analysis and matching of a leg in dynamic range comply also cooperative control systems.

For leg's dynamics optimization, complying also controls system, the essential aspect becomes a selection of flow capacity for the system, which protects the yielding leg's space under the piston, as well as keeping the minimum layer (column) of the liquid below the piston.

According to the calculations it is assumed that the actual flow capacity of the hydraulic system should be:

$$Q \geq V_s S_s \cdot 6 \cdot 10^4,\ \mathrm{l \cdot min^{-1}} \tag{3}$$

where:

S_s – protected area, m^2;

V_s – speed of drift's tightening, associated with the factor n_{tz}, ms^{-1}.

The value of flow capacity should ensure the limitation of pressure to the safe value for a leg.

The minimum recommended for the column of liquid in hazardous conditions of mining tremors should be calculated according to the formula:

$$L_{\min} = 0,2\ (l_h + l_m),\ \mathrm{m} \tag{4}$$

where:

l_h – total hydraulic stroke of the leg, m;

l_m – total mechanical stroke of the leg, m; at least of 0.2 m.

3. DESIGN REVIEW OF HYDRAULIC LEGS

A hydraulic leg is an actuator of double acting type, where its basic technical parameter is support capacity. There are single telescopic type or double telescopic type constructions (Doległo, Gil, Stoiński 2009; Kasprusz, Gasztych, Szurgacz 2010; PN-EN 1804-2:2010). In mechanized roof supports are presently utilized hydraulic legs ranging from 0.6 to 5.6 m and yield support capacity is varying from 0.6 to 5.6 MN. Setting pressure does not exceed of 32 MPa and the yield pressure (for a double-stage legs in stage I) is ranging from 28 to 48 MPa. Cylinder bores of the first stage legs are ranging from 0.17 to 0.41 m and the thickness of cylinder's wall from 0.015 to 0.025 m. Typical single telescopic leg's designs are presented in Figure 3, while Figure 4 depicts double telescopic legs.

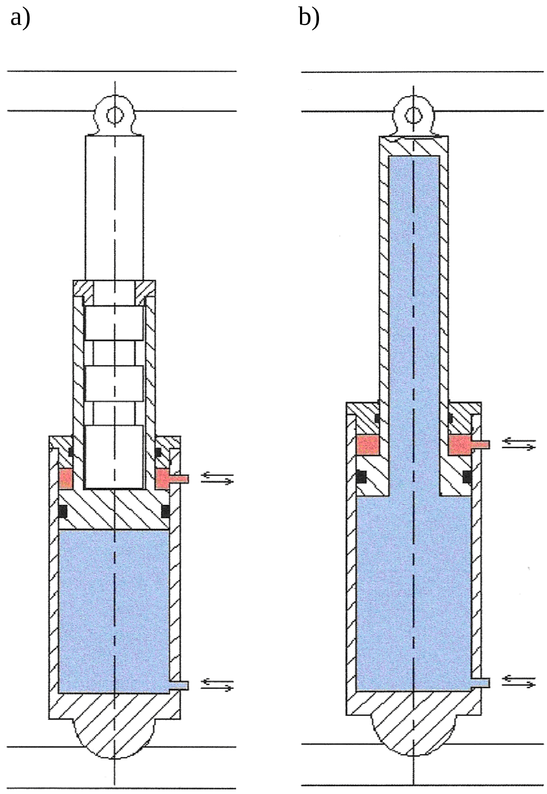

Fig. 3. Examples of single telescopic hydraulic legs used in mechanized roof support: a – with mechanical extensions, b – with fluid within the piston rod

Rys. 3. Przykładowe stojaki hydrauliczne jednoteleskopowe, stosowane w zmechanizowanych obudowach ścianowych: a – z przedłużaczem mechanicznym, b – z cieczą w tłoczysku

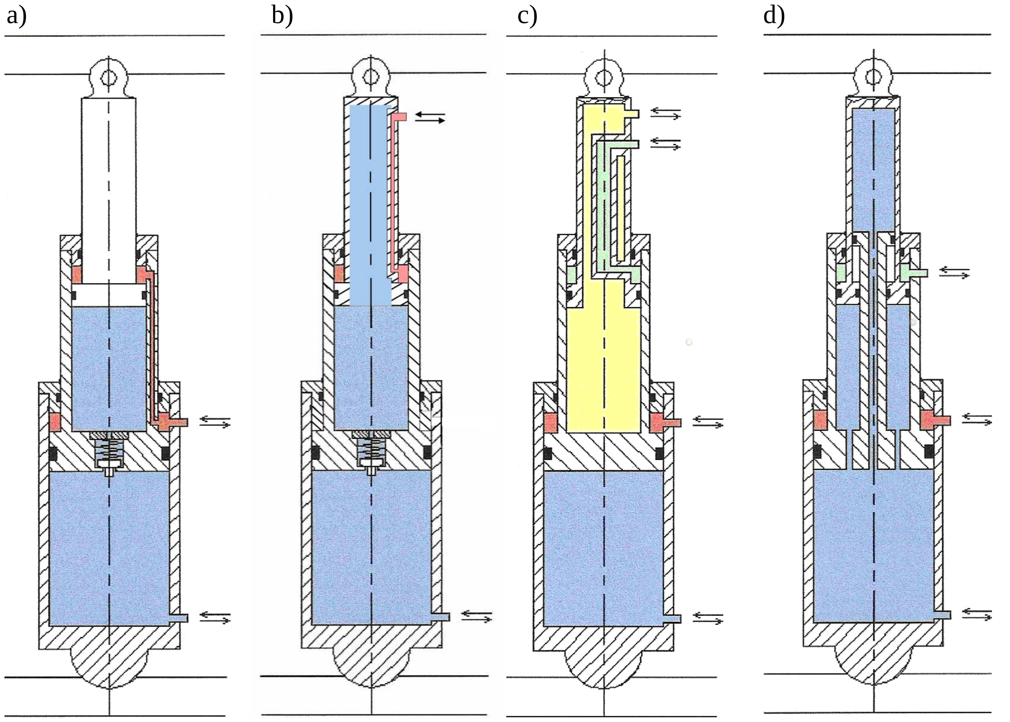

Fig. 4. Examples of double telescopic hydraulic legs utilized in mechanized roof supports with: a – a bottom check valve with bored second stage rod, b – a bottom valve with fluid within the piston rod, c – a hydraulic extension rod with fluid within the piston rod powered from the top, d – an internal rod

Rys. 4. Przykładowe stojaki hydrauliczne dwuteleskopowe, stosowane w zmechanizowanych obudowach ścianowych: a – z zaworem dennym z nawierconym rdzennikiem II stopnia, b – z zaworem dennym z cieczą w tłoczysku, c – z przedłużaczem hydraulicznym z cieczą w tłoczysku zasilany od góry, d – z rdzennikiem wewnętrznym

The legs preferred for hazardous conditions of mining tremors are single telescopic type (according to Figure 3) items b and c. On the contrary, double telescopic type (according to Figure 4) are positions b and c. Furthermore the requirements regarding design of a leg for hazardous conditions of mining tremors are as follows:

- keeping the highest possible liquid column in the entire range of PT work,
- being designed to enable attachment of the rapid valves with high flow capacities,
- with overload factor's value as high as possible (2).

4. ADDITIONAL TESTS OF HYDRAULIC LEG ϕ 0.21/0.16 m UTILIZED IN MECHANIZED ROOF SUPPORT

It is assumed that the leg must meet the requirements arising of harmonized standards BS EN 1804, and in addition to § 440 paragraph 2 of the Decree of the Minister of Economy on work safety and hygiene (Rozporządzenie 2006). Additional requirements are included in the project procedures for longwall roof supports and confirmed by prototypal research. Additional studies of a leg include:

- cooperation of legs and hydraulic valves for the speed of leg clamping 2, 10, 100 mm/min (PN-EN 1804-3:2010),
- the dynamic test by mass stroke according to the principles included in the Polish standard PN-G-15537:1999 (withdrawn after Polish accession to the EU structures) (PN-EN 1804-3:2010),
- study of the flows with a valve foreseen for particular mining and geological conditions (Biliński, Kostyk, Prusek 1997);

in addition with the entire roof support are checked:

- the minimum of liquid PT for a minimum operating range of the roof support,
- self arousing of the hydraulic systems cooperating with a leg during closing of the roof support (PN-EN 1804-3:2010).

This report includes the only selected research with mass stroke and the flows assignment in hydraulic system equipped with a valve class III (PN-EN).

4.1. Example test with mass stroke with valve type SP10

The rig for dynamic tests by mean of stroking mass with specialized instrumentation is presented on Figure 5.

a) b)

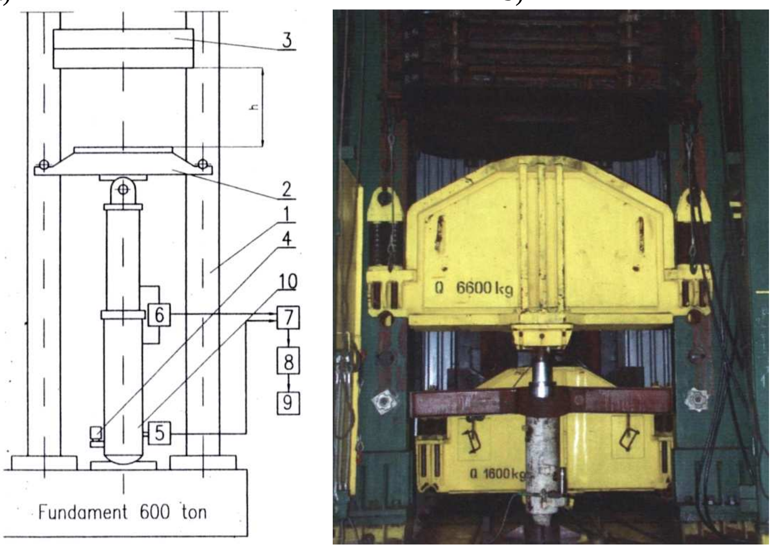

Fig. 5. Rig for dynamic testing of a hydraulic leg mass by impact: a – layout of the post, b – design of the post description; 1 – guides of impact mass, 2 – traverse beam, 3 – beater, 4 – sluice valve, 5 – pressure transducer, 6 – track transducer, 7 – measuring signal amplifier, 8 – PC, 9 – printer, 10 – tested leg

Rys. 5. Stanowisko do dynamicznych badań udarem masy stojaków hydraulicznych: a – schemat stanowiska, b – wygląd stanowiska; 1 – prowadnice masy udarowej, 2 – trawersa, 3 – masa udarowa (bijak), 4 – zawór upustowy, 5 – przetwornik ciśnienia, 6 – przetwornik drogi, 7 – wzmacniacz sygnałów pomiarowych, 8 – komputer PC, 9 – drukarka, 10 – badany stojak

The tested leg is expanded between the traverse beam and the foundation with setting capacity, and subsequently loaded by stroke freely falling mass. Expanding and collapsing of the leg is caused by hydraulic fluid from the pump station. The test under mass stroke is conducted at the yield space being cut off from the hydraulic supply system (pumps). Measurement and recording of chosen physical parameters, which are essential to evaluate the dynamics of the leg, are performed using specialized equipment.

The leg and hydraulic system were tested by stroking mass in the Central Mining Institute (PN-EN 1804-3:2010). The results are included in Figure 6. The purpose of this study was to examine, on the basis of the rig of research, the dynamic resistance of a hydraulic leg ϕ 0.21/0.16 m equipped with a hydraulic valve type SP-10 as well as without the valve.

The dynamic test of a leg's hydraulic resistance ϕ 0.21/0.16 m without a valve and with a mounted hydraulic valve type SP-10, was conducted acc. to an accredited test procedures of Central Mining Institute No. PB-OD 01: 'Study of the dynamic resistance of hydraulic legs of mining mechanized roof support'.

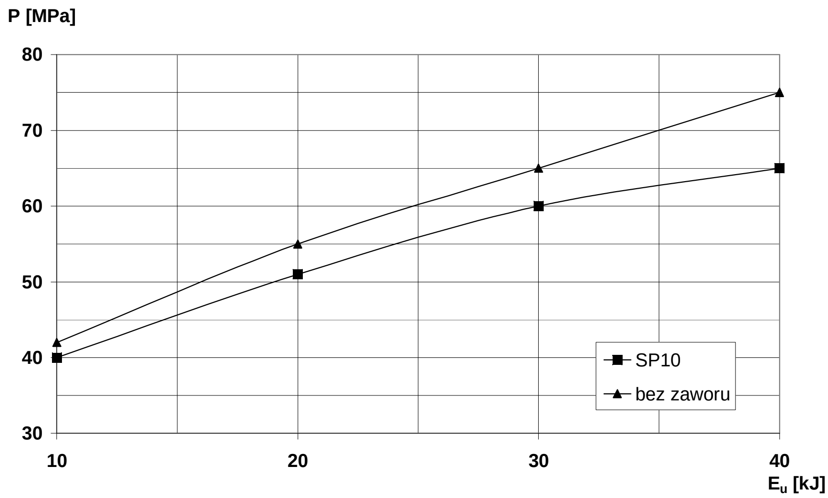

Fig. 6. Characteristics of $P_{max} = f(E_u)$ – results of testing leg ϕ 0.21/0.16 m by stroking mass

Rys. 6. Charakterystyka $P_{max} = f(E_u)$ – wyniki badania udarem masy stojaka ϕ 0,21/0,16 m

4.2. Example method for determination of flow character of a leg with valve ϕ 0.21 SP10

Flow assessments were made with the analytical method using ANSYS CFX (Doległo, Gil, Stoiński 2009; Stoiński et al. 2010). Figure 7 presents a diagram of a leg with the valve. Calculation of volume flow performance was based on a model made in 3D, developed on the basis of the documentation of a leg, a valve and terminal leading the working fluid to the valve. Figure 8 presents a graphically designed demonstration method of determining flow characteristics of the valve and the leg.

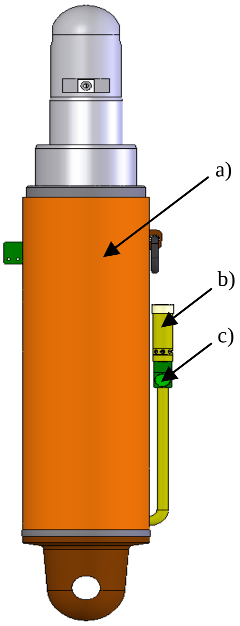

Fig. 7. Layout of the analyzed double telescopic leg ϕ 0.21/0.16 m with a valve and its connection

Rys. 7. Schemat poglądowy analizowanego stojaka dwuteleskopowego ϕ 0,21/0,16 m z zaworem i przyłączem

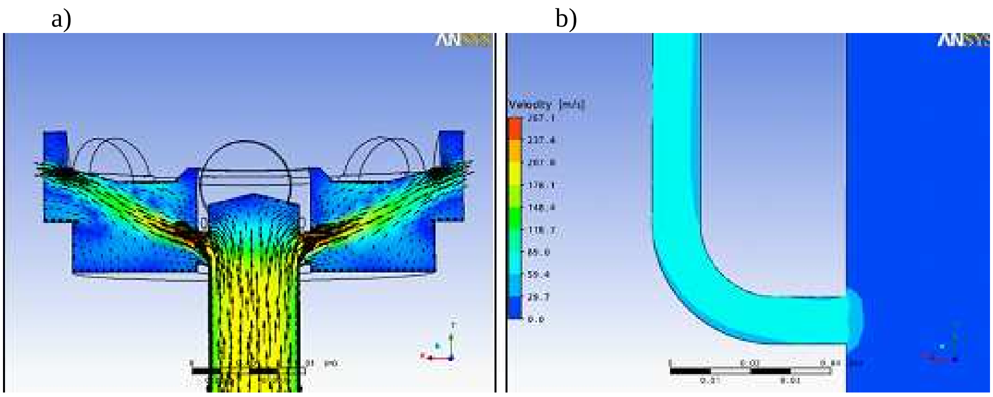

Fig. 8. Example method to determine characteristics of a leg ϕ 0.21 m flow using ANSYS CFX programme: a – speed layout of the fluid in the valve, b – speed layout of the fluid in the valve connection

Rys. 8. Przykładowy sposób wyznaczania charakterystyki przepływu stojaka ϕ 0,21 m z zaworem typu SP10 z wykorzystaniem programu ANSYS CFX: a – rozkład prędkości cieczy w zaworze, b – rozkład prędkości cieczy w przyłączu zaworu

5. CONCLUSION

A hydraulic leg deciding about capacity and safety should be optimized with accordance to the real conditions of the roof support's operation and mentioned matching is to be confirmed by the relevant research. The process of the design optimization should be adjusted to the dynamic characteristic of a leg.

The report presents basic data characterizing construction of a hydraulic leg, along with respective requirements related to mechanized roof support and simultaneously for the hydraulic leg. The optimization of hydraulic legs is a crucial aspect of increasing safety during the operation.

Presented assessment method of the prognosed loading for a hydraulic leg ϕ 0.21/ 0.16 m equipped with rapid yield valve – as well as without such a valve – designed for operating in hazardous conditions of mining tremors, allows to qualify the utility of the particular leg for dynamic loading cases, which occur the most often.

The test trials conducted at testing rig in Central Mining Institute and further analytical flow profile determination for this particular leg have confirmed the correctness of the assumptions adopted in the methods as well as the requirements established in the design process.

Due to the results of the tests, analysis and consultations it seems to be justifiable to conduct further research and analysis. The research are mainly conducted by Central Mining Institute and particular companies, as additional research which increase their range. It has got certain influence on meeting the requirements of support and on equipment of the legs in appropriate safety devices.

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