

Received: March 20, 2015, accepted: April 30, 2015

NUMERICAL ANALYSIS FOR AN OPTIMIZATION OF A POWERED ROOF SUPPORT OPERATING IN HAZARD CONDITIONS OF MINING TREMORS

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Abstract: The article presents an optimization of $\emptyset 0.21/0.16$ hydraulic leg system operating in a powered roof support Glinik 13/25 Pp type, working at longwall 6, seam 501, KWK Bobrek – Centrum - in hazard conditions of mining tremors. The process included numerical modelling and computer software, ANSYS CFX. The optimization allows to achieve an adequate capacity and performance of the hydraulic system which increases workplace safety in the mines. The article provides basic requirements that must be provided in order to conduct an analysis in ANSYS CFX. The software was used to carry out 10 simulations, which allowed to determine an optimal flow for the subject leg.

Keywords: hydraulic leg, performance, hydraulic system, numerical analysis, modelling

1. INTRODUCTION

Currently, 48 % of mining and geological conditions of operating mines are at risk of rockmass tremors (WUG, 2013; GIG 2013). One of the regulations related to safe operation of a powered roof support working in hazard conditions of mining tremors states that: *a powered roof support designed to operate at longwalls exploited in the areas of mining tremors occurrence shall be adapted by yielding to absorb dynamic loads* (Regulation of the Minister of Economy, June 28, 2002). Dynamic impact of rockmass is an effect of layers where tremors occur and are located above operated front. Such impact is transferred through individual strata which generate dynamic

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overload impacting the powered roof support. Its value mainly depends on estimated energy of a tremor, and the distance of a stratum where the tremors occurs and top of the roof. It is defined as n_{tz} coefficient (Biliński et al., 1997).

The selection of the hydraulics for the powered roof support for specific mining and geological conditions is conducted individually for each longwall. The optimization of a hydraulic system in the leg limits expensive and onerous test benches, and improves work safety (Stoiński, 2000).

Numerical modelling and ANSYS CFX software were used to conduct an optimization of Ø0.21/0.16 hydraulic leg (Stoiński and Klabis, 2012) system operating in the powered roof support Glinik 13/25 Pp type, working at longwall 6, seam 501, KWK Bobrek – Centrum - in hazard conditions of mining tremors. The research included characteristics of fluid flow determined through analytical methods, depending on the pressure in the space under the piston, which are determined as relating to volume performance of the control system. Used method allow to model the fluid flowing from the working space of the leg. The model was based on flow channels geometry of the whole hydraulic unit. The article presents results of conducted research, which are characterized by volume capacity which value depends on the pressure in the spacer under the piston that results from clamping velocity.

2. NUMERICAL MODELLING APPLIED TO THE LEG'S HYDRAULIC SYSTEM

Flows determined in the hydraulic system of Glinik-13/25-P-p powered roof support enabled to qualify the roof support as adapted to operate in hazard conditions of mining tremors. The tested Glinik-13/25-P-p powered roof support unit is presented in the Fig. 1.

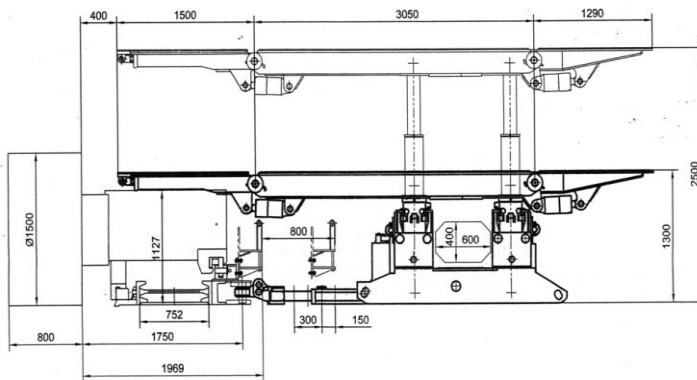


Fig. 1. GLINIK 13/25 P-p powered roof support unit (Operation Manuals of Glinik 13/25 P-p powered roof support)

The analysis was conducted on the basis of numerical modelling based on ANSYS CFX software. The software provides numerical fluid mechanics having significant computing capabilities. This allows to include in the analysis all important conditions resulting from the construction and hydromechanics. Geometric model of the analysed fluid is an element of a whole mathematical object being a basis of a flow simulation. (Doległo et al., 2009).

The software can generate fluid in various ways. Simple geometric shapes can be drawn in the program. More complex shapes of inner space, which outlines are very complicated and sometimes even impossible to be drawn by oneself, may be prepared by the program automatically.

After generating the fluid in the space of the analysed system, it should be determined if the obtained virtual model allows to be sectioned by a plane or planes of symmetry. This will considerably reduce the volume used for discretization, and as a result, it will shorten the time necessary for calculations (Doległo et al., 2009).

ANSYS CFX software is composed of three modules. The use and functionality is presented in the Fig. 2.



Fig. 2. ANSYS CFX modules: CFX Pre-Processor software – modification in geometry, determination of initial conditions, grid generation; CFX Solver - calculations using multigrid technology for solving equations; CFX Post-Processor – presentation of analysis results, possibility to present different variants of solving equations (Doległo, at al., 2009)

The simulation conducted by ANSYS CFX software needs, in terms of physics, the following data:

- physical parameters of the fluid,
- information on additional forces impacting from the outside (e.g. gravity applied to the Navier–Stokes equations),
- inclusion of additional equations which calculate other properties of the flow (energy, turbulence and changes of model parameters, thermal radiation, etc.),
- determination of boundary conditions as sourced applies to the Navier–Stokes equations.

The Fig. 3 presents a numerical model of the fluid in the working space for the hydraulic system protecting the leg from pressure increase.

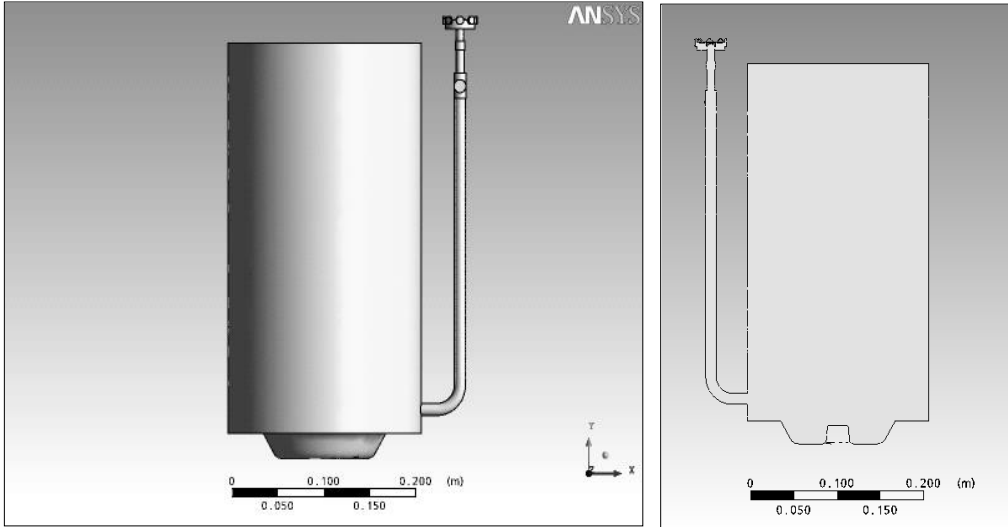


Fig. 3. A numerical model of the fluid in the working space for the hydraulic system protecting the leg from pressure increase: a) view before the division by plane of symmetry b) section view by plane of symmetry (Doleglo et al., 2009)

3. SPATIAL MODEL OF A HYDRAULIC LEG, GLINIK 13/25 P-P ROOF SUPPORT

A spatial model of the hydraulic leg together with the system protecting against loads caused by rockmass was outlined on the basis of data according to the instruction manuals of Glinik 13/25 P-p roof support. Mapped model is presented in the Fig. 4.

Properly constructed model of the fluid system guarantees convergence of the numerical results. A significant element of mapping the phenomena occurring during the flow, is proper discretization of an analysed area. Discretization should be connected with both, estimated fluid characteristics and an algorithm of the Navier–Stokes equation, e.g. such effects as a boundary layer. The Fig. 5 presents mapped system of working fluid of a hydraulic leg in Glinik-13/25-Pp powered roof support operating in hazard conditions of mining tremors located in longwall 6, seam 510, KWK Bobrek – Centrum.

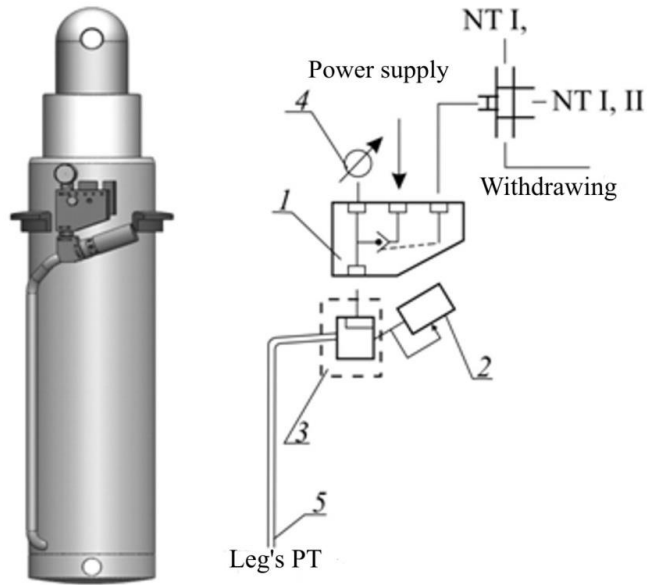


Fig. 4. Leg \varnothing 0.21/0.16 m with optimized control system of support type Glinik-13/25-Pp: 1 – leg block, 2 – working valve (limiting the pressure), 3 –terminal, 4 – pressure gauge, 5 – tube carrying away liquid from leg's working space (Operation Manuals DAGOS control system)

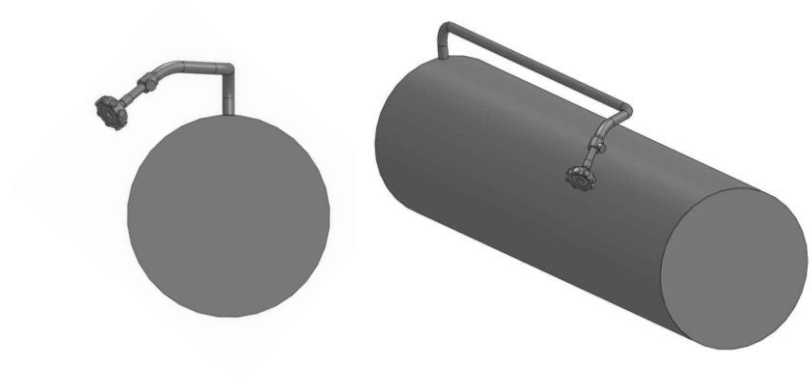


Fig. 5. Working liquid system in hydraulic leg of GLINIK-13/25-Pp powered roof support

The software provides numerical fluid mechanics which has significant computing capabilities. This allows to include in the analysis all important conditions resulting from the construction and hydromechanics (Doległo et al., 2009). It enables to use bidirectional connections to all significant CAD systems. The quality of obtained grid is relevant to accuracy and precision of conducted calculations. It should be characterized by possibly the smallest number of sections and simultaneously should be locally concentrated in the area where variable conditions of fluid flow may occur. The Fig. 6 shows discretization of the analysed numerical model composed of a system including a hydraulic valve and a connecting pipe turn.

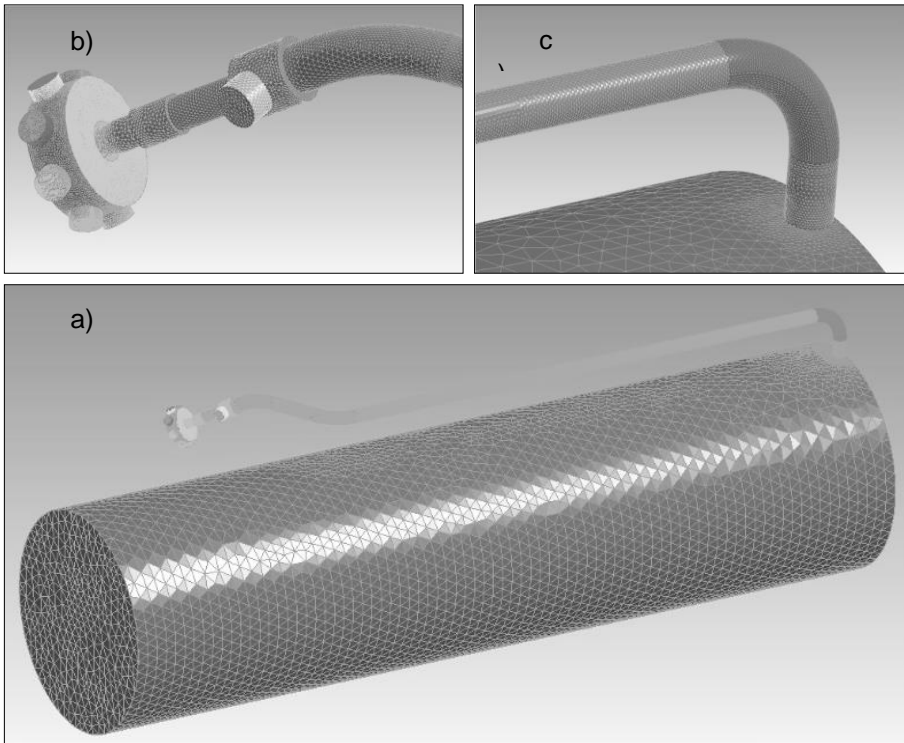


Fig. 6. Discretization of numerical model:
a) the analyzed system b) hydraulic valve c) connecting pipe turn

The Fig. 7 presents the results, in a graphic form, as a section plane running through the model hydraulic system with variable inflow pressure and free outflow of the fluid from outlets of the valve.

Presented pressure distribution shows that stable pressure, equal to estimates in-flow pressure, occurs in the space of the cylinder. Decrease of the pressure was observed in the hydraulic valve as well as in an outflow tube transporting working fluid from the space under the piston of the leg.

Change in the flow velocity, similarly to pressure, is visible outside the cylinder's chamber. Typical changes in flow velocity are noticeable in the hydraulic valve itself, and in the areas where the stream changed its direction.

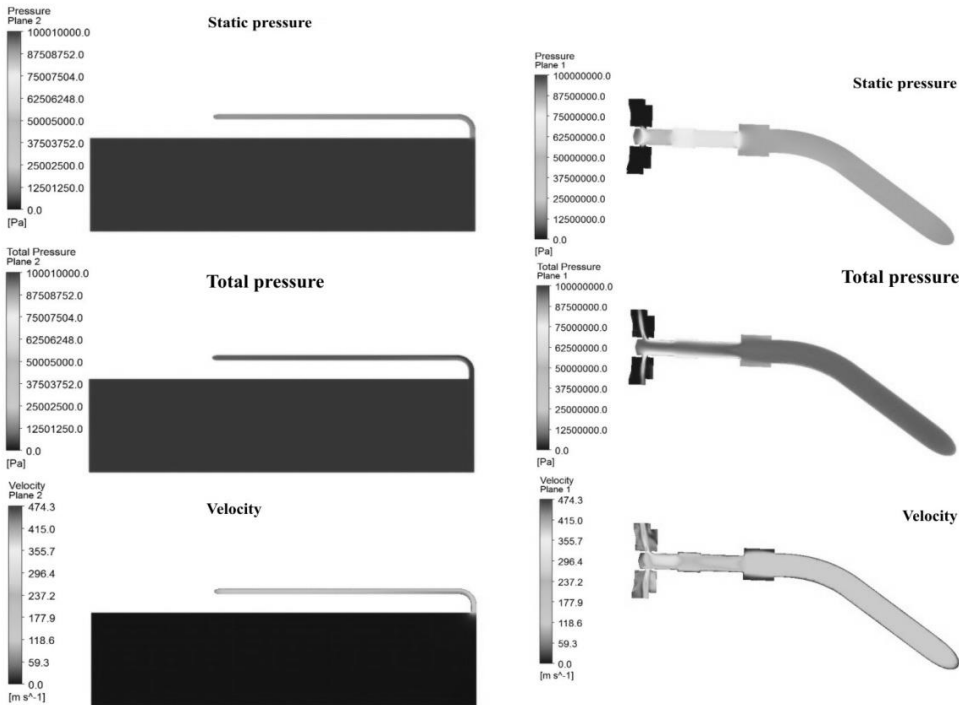


Fig. 7. Static and total pressure, and velocity of the analyzed system. Data used in this article come from borehole measurements in Winna Góra 1 (WG1) well, which is located nearby Poznań City in Wielkopolskie district

4. RESULTS

The Tab. 1 includes results obtained during ten simulations conducted for variable pressure, every 10 MPa, in the range of 0 to 100 MPa. Characteristics of fluid flow were determined on the basis of the results and are determined as relating to volume performance of the control system.

The objective of the simulation was to determine an optimal flow for the subject leg. The Tab. 1 shows a simulation No. 3, where the volume capacity of the hydraulic system reached $Q=393.7 \text{ lmin}^{-1}$ with 30 MPa pressure. Such result is the most beneficial for Glinik-13/25-Pp powered roof support operating in mining and geological conditions of longwall, 6, seam 510, KWK Bobrek – Centrum. The Fig. 8 shows volume performance of the analysed hydraulic system obtained by ten simulations.

Table 1. Results of a numerical analysis of relation between pressure and volume performance of a hydraulic system

Parameter	1	2	3	4	5	6	7	8	9	10
P, MPa	10	20	30	40	50	60	70	80	90	10
Q, lmin^{-1}	227.8	322.3	393.7	457.5	509.9	561.0	604.2	645.3	683.4	725.4

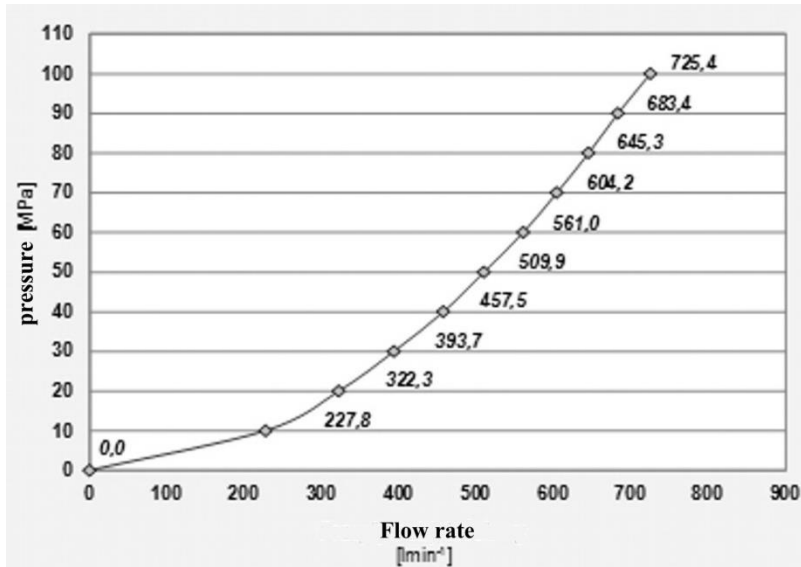


Fig. 8. Volume performance characteristics of the analyzed hydraulic system

5. CONCLUSION

Mining works conducted in hazard conditions of mining tremors set high requirements for manufacturers producing powered roof supports in terms of design and testing. The subject hydraulic system of the leg in the powered roof support showed that it has capabilities to transfer dynamic loads caused by a tremor.

The numerical method allowed to model flows of fluid stream running out of the space under the piston. The model included a pressure relief valve and fluid provided to the valve. The calculations determined volume characteristics depended on pressure under the leg's piston.

The article presents an optimization of the control system of 0.21/0.16 leg mounted in Glinik-13/25-Pp powered roof support operating at longwall 6, seam 510, KWK Bobrek-Centrum, in hazard conditions of mining tremors. The research included characteristics of fluid flow determined by the numerical method and ANSYS CFX software, depending on the pressure in the space under the piston, which are determined as relating to volume performance of the control system.

According to tests results carried out on proposed hydraulic system, the measures protecting the leg against damages are correct and accurate. The hydraulic system of a leg was also subject to pile driving testing. The results confirmed the correctness of assumptions applied to the method and of the requirements of the design process.

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