USE IN POLISH MINING INDUSTRY HIGH PRESSURE WATER JETS FOR DUST SUPPRESSION

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INTRODUCTION

The most commonly used heading machines in Polish mines AM-50, may be effectively used for rocks of compressive strength R.< or = 60 MPa while only in exceptional cases when the rock has a layered structure that the strength may exceed that value. The trials to apply such heading machines for rocks exhibiting a strength R_c>100 MPa were unsuccessful. Application of heading machines with ripper heads is limited largely by the physico-mechanical parameters of the machined rocks like the uni-axial compressive/tensile strengths and grindability due to the mineral composition as well as the macro-structural properties of the rocks in the body of coal. Deterioration of exploitation conditions and, in particular, the occurrence of hard interlayers result in increased consumption of tools as well as in increased dust production and likelihood of explosion hazard. The latest studies (Klich et al., 1998) indicate that any bluntness of the picks affect significantly the power consumption and, in particular, the specific energy consumption. The relationships between the power consumption, N [kW] or the specific energy consumption index K_u [kWh/m^3] and the speed of advance heading machine for four values of pick's bluntness, S_p [mm] are presented in Fig. 1. The plots evince that the effect of blunting by an increase of the speed of advance, i.e., by an increased depth of machining goes up distinctly which indicates size-reduction of the excavated material leading to increased dustiness. The excavation studies indicate that by a relatively low increase of consumption of a tool the dustiness increases by, respectively, 30 to 70%. It proves that any reduction of consumption of a tool is of great practical value.

Rock excavation by a cutting tool

A precondition for cutting but not crushing is that the angle of application of the tip tool is to be it>0. For a sharp tool of regular geometry, the value of the blunted area may be ignored as well as of the side faces and of the application face contacting the rock. Therefore, the total force acts only on the tool face while the fines in front of the tool are being pressed upwards (Opolski, 1982). Those forces are changing with time as the contact area between the tool and the rock fluctuates due to the breaking away of fragments of different sizes.

Mining with a sharp edge (Fig. 1) due to the fact that the rock's brittleness outweighs its elasticity - does not result in the formation of a continuous chip, as in the cutting of metals, but an output comprising fragments and fines.

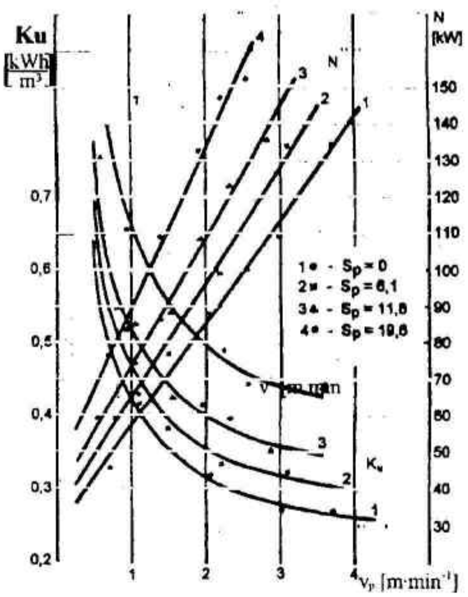

Fig. 1. Power consumption N, and unit energy consumption index K_u as a function of the heading machine advance for the four values of tip's blunt S_p

The machining process with a high-pressure water jet support

According to the model of machining of rock presented above , in front of the tip of the cutting tool there are formed cracks and micro-cracks, whereas for the process of destruction of rock's cohesion, the shear stresses play more decisive role. However, from the application face' side, the most important element in the process of the tool's tip consumption is the friction at the bottom of the formed groove against that face. In machining coherent rocks, the resistance of the rock against cutting is dependent on internal friction as well as on cohesive forces. For coherent rocks the relationship between the shear strength, the internal friction and the cohesion is given by Coulomb's formula (Klich et al., 1998):

$$\tau = \sigma_n^* tg\phi + C \qquad (1)$$

where:

– τ - shear strength (shear stress), N/cm^2

– σ_n - normal stress to the truncation face, N/cm^2

– ϕ - angle of internal friction, ^{0} – C - rock's cohesion, N/cm^2

For rocks with moisture content equal to or higher than the liquid limit, the cohesion is very low, but even a small increase of moisture of the rock causes a drop in cohesive forces. Also, for the rocks in wet state, the internal friction decreases. Thus, for wetted rock, the cutting of rock fragments will arise at a significantly lower level of shear stresses or it appears much faster than for the rocks in the dry state.

One can conceive of further possibilities by the location of one nozzle along the axis of the cutting tool in front or behind the top (Fig. 2) (Klich et al., 1998). For variant A, a high-pressure jet from the nozzle situated in front of the tool is forced directly in the brittle rock zone and wets it, which facilitates the machining process due to the strength drop in the zone. By that variant however there is no certainty that sufficient wetting of the rock from the application face side has already occurred which may cause an increased friction of that face against the rock as if by machining with no support, evolution of large amounts of heat and formation of sparks behind the cutting edge in the groovered cutting.

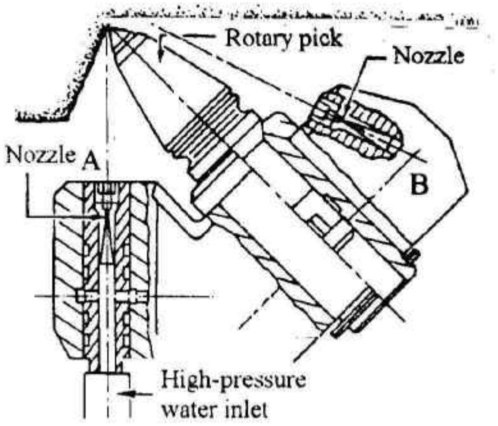

Fig.2. Scheme of possible supports for rotary pick by use of a high-pressure water .jet

Such a possibility is reduced to zero when using variant B and directing the high-pressure jet from the rear of the tool directly into the groove behind the cutting edge. By wetting of the bottom and the sides of the formed groove any possible spark will be extinguished at the nucleation step. Also, the wetting of a rock results in a drop of the coefficient of friction of the rock against the tool walls, and thus it lowers tool consumption. By increased assistance of pressure jet, the so called "water film" (a thin layer of water or even damp) may be formed. The film will reduce additionally tool consumption. In that case, however, beside the limited consumption and the protection against spark formation, there is a limited possibility of wetting of the rock in front of the tool and of making rock's machining easier.

For technical reasons, the distance of the nozzle to the rock surface, particularly for radial tools, may be higher for that variant but should not exceed 70 mm.

Tests performed on a high-pressure support of cutting tools

As early as 1978, in England a prototype was designed of a heading machine Dosco Mk-2A equipped with a supporting system for the process of machining by means of a high-pressure water jet (Kalukiewicz, 1997). Also, Anderson Strathclyde Company designed a supporting system based on a heading machine of type RH-22. From 1981, systematic tests were performed of those heading machine prototypes under mine conditions.

About 100 heading machines from Anderson

Strathclyde worked in English and American mines cutting tunnels in the rocks of about 120 MPa strength. Working on the machines for hydromechanical mining, Anderson Strathclyde Company produced RH-25 heading machine with a longitudinal head supporting simultaneously the operation of all cutting tools. The manufacturer emphasized, apart from many operational advantages, almost a complete suppression of dust in the mine face, a lowered risk of spark ignition, an increased lifetime of the tools as well as the possibility of machining hard rocks and interlayers.

At Bergbau Forschung GmbH in Essen, on the base of the outrigger of a Westfalia-Lnen heading machine, some tests were performed on a high-pressure water jet support of operation of the transverse head. The nozzles of the head were supplied, segmentally by a special complex valve distributor controlled by rotation of the head. Unlike the English heading machines - where the jet overtook the cutting tool - the Germans used also another variant with the nozzles situated at the back of the tool. However, no major supporting effects were achieved, except of an increased sprinkling and cooling of the tool.

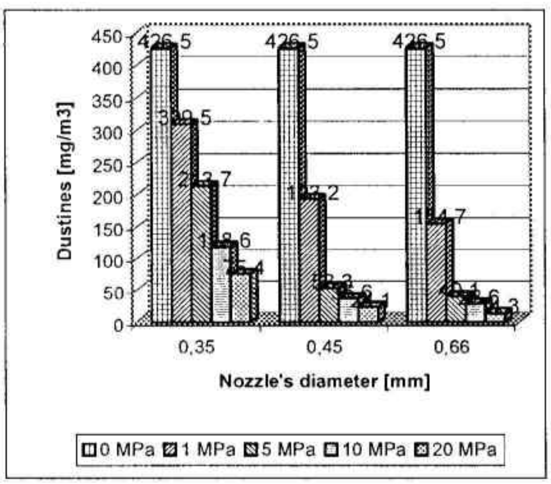

Fig.3. Dustiness by machining of an artificial concrete sample with a longitudinal experimental organ as a function of jet's pressure and nozzle's diameter

At the University of Mining and Metallurgy, Cracow, a similar research study was performed as well (Kalukiewicz, 1997). The subject of that study was a special purpose designed longitudinal hydromechanical cutter placed on the arm of an AM-50 heading machine equipped with a special gear attachment which allowed for overlapping of the cone of the organ axis with the arm axis. By this way, some problems were avoided with the sector control of water supply to individual nozzles and with the application of a simultaneous supply of the nozzles at the all tools of the organ. Installed on a experimental stand the organ was equipped with 42 rotational knives supported by 42 water nozzles, which were situated on the organ's body in such a way, that the water jets knocked the body of coal a distance of 2 mm from the tool tip. The study was performed to compare purely mechanical machining with a water jet support (hydromechanical machining). In the course of all the experimental tools measurements were made, at a distance of about 1 m behind the organ, the level of dustiness evolved during machining of a concrete block modeling the body of coal as well as the power consumption of the heading machine drive head electric motor, the speed of the organ's displacement etc. Consecutive measurements were performed for different values of such parameters like the pressure of the water supply, at nozzles, the diameter of nozzles and the depth of rock machining. The pressures p of the water supplying the, nozzles Was varied from 1,0 to 20,0 MPa and the nozzle diameters of 0,35, 0,45 and 0,6 mm were used. The averaged results from the dust measurements are presented in Fig. 3. The diagram demonstrates that a dramatic drop in levels of dustiness was achieved by Water pressure of an order of 10-20 MPa, which matched the valu6s of power consumption of the water supply system, depending on the nozzle diameters, from 10,6 to 12,23 kW. These are relatively low of less power input and small aggregates of adequate operational parameters may be constructed and installed even on a small heading machine.

Design and construction of the hydromechanical organ at AGH, Krakow

The reduction of dust levels and improvement of work safety dictated that internal sprays using lower pressures, not exceeding 20 MPa, which are being applied in a majority of heading machine and in many countries the application of internal spraying is one of the preconditions for acceptance of such machines. Manufacturers offer different solutions as to the location of the nozzle relative to the tip and the pressures and jet configuration. However, the use of higher pressures, low water consumption, meets some obstacles. The first of them is due to the energy balance, the other one is the apprehension on the introduction at the mine face of an excess water - in, the form of a water fog at that - as reduction of nozzle diameters leads to lowering of the system reliability.

The third obstacle is the difficulty of supplying a robust distributor for the water supply at an acceptable cost to the user. The distribution system, i.e., water supply directed only to the tip operating in the cutting zone, is essential in the case of a transverse cutting organ while for, a longitudinal organ it lowers water consumption to almost half of the total water supplied to the mine face.

The results of these studies as well as the demands of customers, and in particular the foreign ones, and in the face of competition of foreign companies in Polish market, prompted one of the Polish manufacturers of heading machines, Zaklady Naprawcze "Remag" (Overhaul Plant "Remag") with the cooperation of CMG "Komag" as well as with Mining Machinery Faculty at University of Mining and Metallurgy to design a method of hydraulic jet assisted machining applied to heading machines produced by them.

The final design was constructed, applied to a KR-150 heading machine (Fig. 4) produced by ZN "Remag" in Katowice (Kalukiewicz, 1997). A view of the heading machine's cutting organ during tests on the surface is shown in Fig. 5. The heading machine was subjected to tests in a heading of KWK "Boleslaw Smialy" mine.

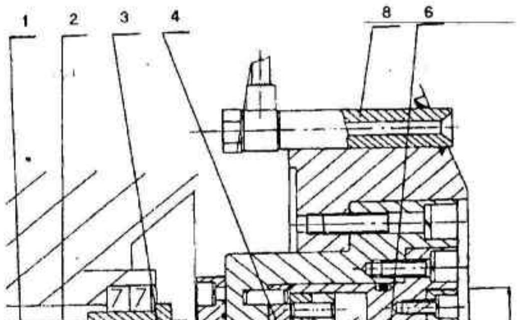

Fig. 4. Sector divider of KR-150 heading machine:

1 - cage of a planetary gear (non-revolving part), 2 - connector, 3 - clutch, 4 - rotational plate, 5 - sector plate (non-rotational), 6 - pressure system (differential), 7 - water pipes,

8 - sleeve for water supply to tool's hold

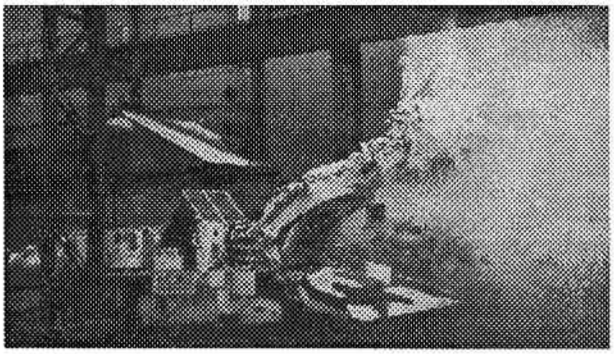

Fig. 5. Tests of KR-150 (REMAG) heading machine organ with internal high-pressure sector spray

In Polish mine industry, there are over 400 unit of light weight (about 24 tones) AM-50 heading machines are operating together with their development variants. The construction of heads and machining organs by these heading machines is adjusted to low-pressure external sprays. It is extremely difficult therefore to introduce high-pressure internal spray systems. Alter numerous trials, success was achieved in designing for AM-50 heading machine a correctly operating timing-gear sector system and water distributor. The current research is aimed at improvement of the life of water rotational seals as well as at evolving a system of easy-to-clean water nozzles.

SUMMARY

The results presented in this study on rocks machining by cutting tools with the assistance of a high-pressure water jet allow one to conclude that this method of machining is very effective vis-a-vis reduction of dust levels (Fig. 3). Moreover, it lowers operational costs due to reduction of cutting tool consumption. It is worth noting that the application of the individual sprays to the tool contacting the rock gives much better results than for the typical case of external spray with substantial lower water consumption. By external spray of machining organs, the volume of water goes up to 120 dm^3/min while by individual, i.e., internal spray on the organ, the water consumption may be limited to 30 dm^3/min. It is expected that cutting systems with high-pressure water supply to individual tool fixtures will emerge as a standard solution in the near future.

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