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COMPARATIVE STUDY BETWEEN THE ALTERNATIVE USED BY THE IMP TYPE PECCUSSION DRILLS AND THE VERSION USING FLUID ELEMENTS REGARDING THE SUPPLYING, COMMAND AND AUTOMATIC ADJUSTMENT SYSTEMS OF THE INJECTION WATER PRESSURE**BADANIA PORÓWNAWCZE ALTERNATYWNYCH OPCJI: Z WYKORZYSTANIEM WIERTNICZY UDAROWEJ ORAZ Z UŻYCIEM ELEMENTÓW HYDRAULIKI SIŁOWEJ DO ZASILANIA, STEROWANIA I AUTOMATYCZNEJ REGULACJI UKŁADÓW WTRYSKU WODY**

Starting from analyzing of an existing solution regarding the injection water feeding system for the pneumatic rotating and percussion drilling installations, which is included in the structure of the perforator installation (IMP-1 or IMP-2), the paper presents part of a research regarding an original solution of the automatic command and regulate with monostable fluidic elements, with different physical nature jets. This solution is applicable to this drilling installations type, made in Romania.

Keywords: fluidic element, monostable element, automatic adjustment of the injection water pressure, pneumatic rotating drilling installation

Pracę rozpoczyna analiza wykorzystywanego obecnie rozwiązania układu wtrysku wody do pneumatycznej instalacji udarowej, będącej elementem składowym układu perforatora (MP-1 lub MP-2), stanowi ona część badania oryginalnego rozwiązania automatycznego układu sterowania i regulacji z wykorzystaniem monostabilnych ogniw płynnych, generującego różne strumienie. Rozwiązanie to znaleźć może zastosowanie w instalacjach wiertniczych wykorzystywanych w Rumuni.

Słowa kluczowe: ogniwa płynne, elementy monostabilne, automatyczna regulacja ciśnienia wtrysku wody, wiertnicze urządzenie udarowe

1. Introduction

Practical activity show that it is very important to use drilling wet for the galleries dug by drilling-blasting technology. It is recommended to prevent and reduce silicosis illness from the workers. The conventional pneumatic rotary and percussion drills have a central injection

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water system. The water pressure must be less than or equal to the pressure of compressed air. If is not satisfied this condition water is possible to penetrate into the drill, fact what can make damages of the installation. This drills are designed to work in a range of values of the air pressure between 0,4 MPa-0,6 MPa. Because in the underground mining exploitations the injection water from the supply network has variable pressure, depending of the deeps where the work points are, between 0,6 MPa-4 MPa, is necessary to concept a command and automatic regulator distributor of this pressure.

Also, we establish that in some situations, like digging adduction galleries in hydro-technical constructions, because of the network lost head, the water which is provided by water supply network has a pressure lower than 0.4 MPa. In this case the low level of the injection water pressure has insufficient value to achieve the above described functions (Beccu, 1992; Casteel, 1995; Georgescu et al., 1977; Lobontiu, 194605; Praporgescu, 1997; Tuunanen, 1993; Ungureanu et al., 2006; Ungureanu, 2011).

2. Actual solution of alimentation, command and automatic adjustment of the injection water pressure, used by the drilling installations, type IMP-1 and IMP-2

The principle scheme of the pneumatic actuating and the alimentation, command and automatic adjustment of the injection water pressure at the pneumatic rotating and percussion drilling installation is shown in Figure 1.

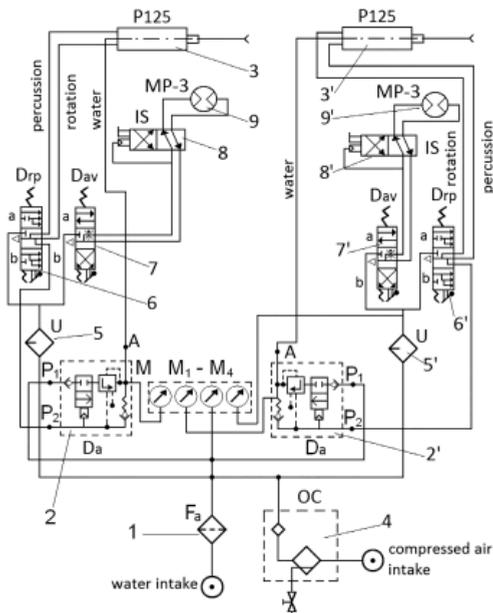


Fig. 1. The alimentation, command and automatic adjustment of the injection water pressure at the pneumatic rotating and percussion drill IMP-2 type (Praporgescu, 1997)

Those two circuits, water circuit and compressed air circuit, are independent function so long as the rotation circuit is powered. Also, when the percussion circuit is powered, than the water circuit is commanded by the air circuit. In this case the water distributors have pneumatic command.

The switch on command of these is automatic, together with actuating of the pneumatic distributors for the rotation and percussion movement of the drilling installation.

When the percussion device is activating, a command pneumatic signal (that sense this action) is sending to the command and automatic adjustment injection water pressure distributors, which switch on. The water enters in the incorporated pressure regulators of the two pressure distributors. The level of its pressure is set to a value approximately equal to the compressed air pressure and then the water is sending to the injection circuits of the drills.

This solution is suitable for the case with high values of the water pressure in the alimentation circuit (Lobonțiu, 94605, Praporgescu, 1997).

3. Proposed solution for the command and automatic adjustment of the injection water pressure with fluidic element at the drilling equipments type IMP-1 and IMP-2

Analyzing the existent solution for the injection water distributor (Fig. 2), we can see that the problem of the adjustment of the water pressure is not solved (the value of the water pressure to be equivalent with the value of the compressed air). This is the reason to concept an adjustment solution of these parameters based on the fluidic elements.

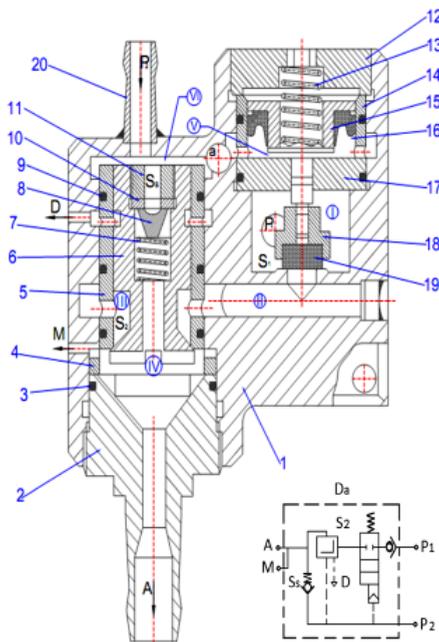


Fig. 2. Distributor for command and adjust the water pressure injection (Praporgescu, 1997)

The command and adjustment action is based on fluidic monostable with attached jet, which function with mixed jets – the feeding jet is liquid (water in this case) and the command jet is air. This new solution is suitable for the case with high values of the water pressure in the alimentantion circuit. The scheme is presented in Figure 3 and it is based on the solution presented in Figure 2. The difference between these two solutions consists on the replacing of the pneumatic distributor by a fluidic monostable.

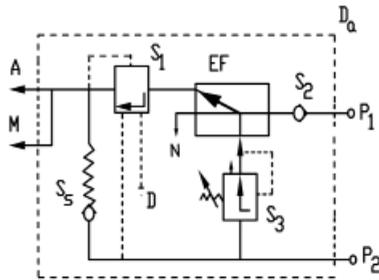


Fig. 3. The command and automatic regulating of the injection water pressure with fluidics elements scheme

The command jet consists in a pneumatic signal obtained by switching the distributor on the position “b”. This position provides the alimentantion of the rotation and the percussive movements of the drilling, thus the percussive and the injection water alimentantion to start and work simultaneous. The decrease of the command jet pressure is providing using the reducing pressure valve S_3 – that an expansion valve.

The wet perforating take place until the command jet action on the liquid power jet, whose switch over it on the opposite receptor channel. At the moment of switch over of the distributor in neutral position, the command disappear and the power jet come back at the beginning position, like wall attached jet (based on Coanda Effect (Bavagnoli, 1968; Florea, 1979) which is evacuated in the distribution network.

Analyzing the solution of the command and injected water pressure automatic regulating distributor (Fig. 2) and the new solution with fluidic element (Fig. 3) we can study the following steps in functioning of the water distributor.

At the action of the compressed air feeding distributor, for obtained the rotating and percussive movements, the pneumatic command signal go through the nipple 20 in the cavity VI, and then, after the decreasing of the value of pressure, made by the reducing pressure valve S_3 , actions in the command nozzle of the monostable element. At the opening of the water distributor (represented by the fluidic monostable), the filtrated power jet from the general network, with pressure p_1 is deviated by the command jet and go through the receptor channel in cavity III. The water through the valve S_2 arrives in cavity IV, then exit from device, by outlet 2 (port A) and hose connection, to drill.

The pressure regulator is making by the piston 6, which translated in the bush 5. The conic part of piston forms together the inner part of the bush the pressure regulating valve S_2 (by strangulation flow path). The bush 5 is isolated from the body 1 by three rubber rings. The piston has an axial bore hole where is mounting the sense valve. The sense valve is making by a rubber element 10 fixed on the piston, with screw cap 11 and working element 8, witch is pressed onto

the coil spring seat 7. The screw cap 11 is traversed by an axial channel. The spring 7 is calculated to open the sense valve S_s at a pressure lower than 0.2 MPa.

If the pressure from the water supply network and so cavity IV is greater than pressure value of compressed air from cavity VI begin the progressive closing of valve S_2 by moving the piston 6 up and so strangulation of the water flow section through valve is done. All these make the decreasing of the water pressure in cavity IV at a value close with the air pressure from cavity VI. In all this time the sense valve S_s is closed because of the spring force 7 and of the water pressure from the cavity IV. Through conical valve S_2 (formed as shown in the sleeve 5 and the piston-valve) is realized the strangulation of the path section of the flow water to the drill, in the case when the pressure of water is greater than compressed air pressure for actuating the drill. This strangulation is proportional with the value of water supply network, thus at the drill's entrance the water will have a pressure near the pressure of the compressed air pressure.

During the pressure regulator function the forces which action on the piston-valve 6 will be equilibrate:

$$p_2 \cdot A_2 = (p_1 - \Delta p) A_1 \quad (1)$$

where:

- p_1 — water pressure from network represented by gate P_1 (Fig. 3); ($p_1 = 0.6-4$ MPa)
- p_2 — compressed air supply pressure of the drill represented by gate P_2 (Fig. 3); ($p_2 = 0.4-0.6$ MPa);
- Δp — pressure drop of water passing through the valve S_2
- A_1 — surface area of the piston-valve 6 on the water pressure acting;
- A_2 — surface area of the piston-valve 6 on the compressed air pressure acting.

From the constructive areas A_1 and A_2 are approximately equal (Praporgescu, 1997). If one takes into account the friction force, the two surfaces can be considered equal, so we can consider: $\Delta p = p_1 - p_2$.

Given the expression circulated water flow through a valve stroke "h" of the conical valve and the expression valve passage section for a given race "h", we get the expression race control body, represented by piston-valve 6:

$$h = \frac{Q}{\pi \cdot C_d \cdot d \cdot \sin \frac{\alpha}{2}} \cdot \sqrt{\frac{\rho}{2\Delta p}} \quad (2)$$

where:

- C_d — the flow coefficient ($C_d \cong 0,63 - 0,75$);
- d — inner diameter of the bush;
- ρ — water density;
- α — peak angle of the conical valve.

Equation (2) shows that for increasing values of water pressure (which leads to increased pressure drop Δp), race body control is very much reduced. So, strangling water cross section increases.

In Figure 3 gate A is the water exit to the water supply network, M is the water pressure measure device (manometer), D is the drain circuit and N is the way to the same water supply network.

In the absence of pneumatic command signal, the water power flow jet is return through supply network.

3. About using fluidic element in the proposed control solution

The sensitive flows at amplifications, meaning the fluid flow which changes flow direction, velocity profile and nature of flow, with the help of the secondary or lateral jets, they are mostly used in automatics.

Many investigations and researches performed in the fluid field proved that the achievement of the amplification effect at the fluidic devices it is similar with the electronic magnification (electronic valves, transistors).

The actual orientation of the researches in this field of study, aims to achieve fluidic elements and systems with a minimal energy consumption, a great speed of response, high reliability, safety in operation, a higher level of compatibility with the conventional automation systems, a lower price and many other performances that justify their usage.

So, a command jet, with a lower energy level, is able to modulate, in a large band of frequency, a supply jet with a high energy level.

The bistable and monostable fluidic element, which is a special case of the bistable fluidic device, are two types of fluidic amplifiers, basing in their work, on the principle of jet attachment to solid walls – the Coanda Effect.

At the exit of the supply nozzle, the power jet meets an auspicious geometrical structure for his attachment to the solid wall. So, in the corresponding receiving canal (R_2) it obtains a pressure signal and a flow signal.

Their values are established by the supply pressure (p_a) level and by the geometrical structure. In subtend receiving canal (R_1) the achieve flow is null. We achieve the first stable state.

If we apply a command jet in the control nozzle that determine the switch of the power jet in subtend receiving canal (R_2) (Bavagnoli, 1968; Florea, 1979).

The power jet returns in the receiving canal (R_2) if the geometrical structure is asymmetrical (Fig. 4) and the command jet disappears. We obtain again the initial stable state. The monostable fluidic device is a decision element.

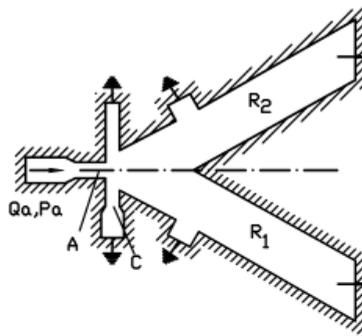


Fig. 4. Monostable fluidic amplifier (Florea, 1979)

To calculate the angle of the wall for the bistable fluidic device we can study few steps using the following nomenclature:

Nomenclature:

M_a — weight flow rate of the power jet;

M_c — weight flow rate of the command jet;

V_a — speed of the power jet;

V_c — speed of the command jet;

S_a — section of the supply nozzle;

S_c — section of the command nozzle;

h — deep of the monostable fluidic element;

b_a — breadth of the supply nozzle;

b_c — breadth of the command nozzle;

p_a — supply pressure;

p_c — command pressure;

β — receiving nozzles' medium angle between the symmetrical axis for the bistable element.

Was used the low of conservation of momentum. There results:

$$V_c = \frac{M_c \cdot V_c}{M_c + M_a}; \quad V_a = \frac{M_a \cdot V_a}{M_c + M_a} \quad (3)$$

The relation between V_a and V_c can be expressed that:

$$\operatorname{tg}\beta = \frac{V_c}{V_a} \quad (4)$$

The weight flow rate is $M = \rho SV$. So, was obtained $MV = \rho SV^2$.

Introducing the relation (2) and (3) into (4) there results:

$$\operatorname{tg}\beta = \frac{\rho_c \cdot S_c \cdot V_c^2}{\rho_a \cdot S_a \cdot V_a^2} \quad (5)$$

where:

$$S_c = h b_c; \quad S_a = h b_a \quad (6)$$

We obtain:

$$\operatorname{tg}\beta = \frac{\rho_c \cdot b_c \cdot V_c^2}{\rho_a \cdot b_a \cdot V_a^2} \quad (7)$$

But $p = \rho \frac{V^2}{2}$ is the kinetic head (dynamic pressure). From this last relation we can express:

$$V_c^2 = \frac{2p_c}{\rho_c} \quad \text{and} \quad V_a^2 = \frac{2p_a}{\rho_a} \quad (8)$$

Introducing the relation (8) into (7) there results:

$$\operatorname{tg}\beta = \frac{b_c p_c}{b_a p_a} \quad (9)$$

That is available in the case when the supply and command jets have the same physical nature. Respectively:

$$\delta' \cong \beta = \arctg \frac{\rho_c b_c P_{c1,2}}{\rho_a b_a P_a} \quad (10)$$

That is available in the case when the monostable fluidic element works with different physical nature jets (Florea, 1987).

Taking account by the technical recommendations in their manufacturing (Florea, 1979), and also by the fact that the special fluidic device, theoretically and experimentally studied, has a geometrical structure inspired by an amplifier design for supersonic compressible fluids, studied by Bavagnoli (Bavagnoli, 1968), was established few design supplementary indications.

The supply nozzle is the most important source of perturbation in the work of the fluidic amplifier. Therefore, the negative effects can be eliminated using longer power canal. ($l_a \geq 5b_a$). So, for the experimentally model, was adopted $l_a = 20$ mm, with a splay exit and 28° angular spread. The radius of curvature to the interaction room wall must be at the best hand ($R = 2$ mm).

For the achievement of a fluidic amplifier, which is commanded through the pressure power of the control jet, it is necessary an adequate input impedance. This purpose is obtained using more breadth command nozzle, which also serve to achieve a good pressure gain. Thus, the optimal condition can be written:

$$\left(\frac{b_c}{b_a} \right)_{optimal} \rightarrow maximum \quad (11)$$

It was observed that for the too broad command nozzle appears fluid dynamics effects, which can't be control. Those deteriorate, a little, the fluidic amplifier's performances (Florea, 1979). There recommends:

$$(b_c)_{optimal} = (1 \div 3)b_a \quad (12)$$

Was adopted $b_c = 1$ mm. Determination of the optimal distance between the extremity's command jet is recommended in (Florea, 1979). There results:

$$(d_c)_{optimal} = (2,5 \div 3)b_a \quad (13)$$

That is recommended when we respect the condition that the supply jet isn't intercept by the command nozzle. At the monostable fluid device, one of the two command nozzle of the model which was used is cut. Was adopt $d_c = 2,5$ mm.

Because pursue a good operating and high performances of the fluidic amplifier, meaning that is experimental possibly under 15° for the wall angle, this value will limited at:

$$|\alpha| \leq 15^\circ \quad (14)$$

For a maximum pressure gain coefficient ($K_p = \text{maxim}$), there results:

$$\frac{l_s}{b_c} \rightarrow l_s \quad (15)$$

That means the positioning of the receiving nozzle right behind the command nozzle. Taking account by the recommendations in the used references (Florea, 1979), there results:

$$l_s \text{ optimal} = (8 \div 12) \cdot b_a \quad (16)$$

Was adopted $l_s = 12,5$ mm. The breadth of the receiving nozzle was adopted basing on the recommendations presented in (Florea, 1979). So, $b_e = 3$ mm.

Experimentally was established the relation between wall angle's value (β) and supply pressure's value, which assures a good stability of the attach jet and a good work of monostable fluid element. So, was studied three fluidic elements and the supply pressure's variation domain was limited into 1,3÷28 bar. In the experiments made upon three fluid elements, it was not taken into account the fact that, in the automatic adjustment solution presented, the fluid monostable utilization was proposed, particular case of the bistable studied in the experimental attempts. So, a correction must be imposed. In case we use mixed jets results from relation (10) that:

$$\text{tg}\beta = \frac{\rho_c \cdot b_c \cdot P_c}{\rho_a \cdot b_a \cdot P_a} \quad (17)$$

For the amplifier fluidic element model used in the experimental plan results:

$$\text{tg}\beta_1 = \frac{\rho_{air} \cdot b_{c1} \cdot P_c}{\rho_{oil} \cdot b_{a1} \cdot P_a} \quad (18)$$

So, for the monostable prototype we obtain:

$$\text{tg} \frac{\beta_2}{2} = \frac{\rho_{air} \cdot b_{c2} \cdot P_c}{\rho_{oil} \cdot b_{a2} \cdot P_a} \quad (19)$$

Results:

$$\frac{\text{tg}\beta_1}{\text{tg} \frac{\beta_2}{2}} = \frac{b_{c1}}{b_{a1}} \cdot \frac{b_{a2}}{b_{c2}} \quad (20)$$

For the monostable prototype with a medium angle of 14° , the imposed conditions are: $b_{a2} = 2,132 \cdot b_{c2}$ (when the third tested fluidic element has $b_{a1} = 1$ mm, $b_{c1} = 1$ mm, $\beta_1 = 28^\circ$ and $\beta_2 = 28^\circ$.)

5. Conclusions

- The proposed solution has advantages on the existing solutions and on the electronically solutions because:
 - functioning in a great security in dangerous atmosphere (explosion and fire conditions), dust, wet, high temperatures;
 - give a greater reliability of the fluidic elements than other solutions.
- Because the experimental testing was made on the bistable fluidic elements, and the proposed solution use the monostable fluidic elements we need make a correction. For

the prototype of the monostable element we choose an average angle for inclination of the wall about 14° and we have to respect the condition: $b_{a2} \cong 2b_{c2}$.

- In the practical realization of the proposed variants for the automatic adjustment of some parameters characteristic to the perforation process, with the help of the fluidic elements may appear some difficulties. This depends first of all on the solving of the problems concerning their sensitiveness to sonorous oscillations, to flow and pressure variations from the system, and especially on the economical and financial availabilities of the beneficiaries from the mining industry.

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