FLUID ELEMENTS AND THEIR TECHNICAL APLICATION
FOR THE AUTOMATIC ADJUSTMENT OF THE ADVANCE FORCE
AT THE PNEUMATIC ROTATING HAMMER DRILLS

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Abstract:
This paper presents the actual solution used by Secoma Enterprise and a new solution concerning the implementation of the digital devices in the pressing strength’s control of a pneumatic rotating hammer drill, which is included in the structure of the drilling installation. The monostable element, which was proposed to be used, is a special device, with an incompressible fluid as supply jet and compressible fluid as command jet.

The fluidic command proposed solution presents superior advantages given the existing variants and the automation solutions with electronic components. This is due to the higher security in hostile work environments (moist environment, with high methane gas contents, with fire danger, with high temperature) of their high feasibility and maintenance.

For the practical achievement of the automated regulation with fluidic elements, of the type tested in the experimental plan, it is necessary to choose a monostable fluidic amplifier for the prototype device, which respects several clear conditions regarding wall attachment angle and geometrical parameters.

Key words: monostable element, automatic adjustment of the pressing force, advance force, pneumatic rotating hammer drill

1. Introduction
The increase process of the production mines capacity determines a great development of the extractive industry in generally. That process involves the continuous integration of the technical progress elements concerning the technologies modernization which needs this industry.

The experience obtained in this domain relives that it is preferred the firing - drilling hoeing technology not using the shearsers, both in the present time and in the future, at the drifting operation into the strong and very strong rocks.

There are many enterprises producing mining equipment, famous by tradition and competitive solutions, which produce a great variety of drilling installations (Atlas Copco, Ingersol Rand, Eimco Secoma, Tamrok, Gardner Denver, Furukawa, Umirom Petroșani Romania, Unio Satu-Mare Romania and many others).

Because the drilling installation made by the foreign enterprises are very expensive, than, the actual researches are orientated to the drilling installations improvement direction and their energetically optimization.
Also they are many preoccupations regarding hydraulic hammer drill studies and their performances increase that makes competitive these drilling installations.

Necessity of the continue drilling speed increase, the drifting profile size and shape, the nature of rocks, the utilization domain extension, the during functionary increase, utilization coefficient increase too, the automation of the displacement method produces permanently constructive and functional changes of the drilling installation [1], [2], [5], [6], [7].

2. Appreciation concerning the pressure force control, by adjusting the advance speed at drilling installations equipped with pneumatic rotating hammer drills

In order to obtain the best conditions of work and avoid the drill blockage, one of the most frequent damage, which takes time for repairing, different systems of automation were conceived for the operations of the drilling installation. With their help, the force of advance, respectively the speed of the advance mechanism may be adjusted depending on necessities. By adjusting these parameters, their values are maintained within the limits of obtaining efficiency and increased productivity, if the work quality and the imposed safe are complied with. These systems do not require the continuous supervision of the human operator and can even produce the stopping of the drilling process [1], [2], [7].

The automation systems of the drilling conditions adjustment are divided in two groups:
   a. Systems which function after curves of optimal variation of the drilling parameters, depending on rock characteristics, curves preliminarily established on the basis of some researches;
   b. Automatic search systems for optimal parameters after a given criterion, called adjusting systems.

The automation adjusting systems are the most used, because they don’t require preliminary researches of conditions, because the choice of the optimal conditions is made during the drilling period. These systems have the role to set off due to the additive and parametrical disruptions that interfere during the drilling process, so that the different performances can be attained (production cost, productivity, the usage of a rational charge from the point of view of the loads and the drilling installation). In this sense, the adjusting system identifies the disruptive sizes of the drilling process by measuring the drill rotation, the moment of the turn, the supplying pressure of the advance rotating engine and corrects the advance forces size and direction, or adjusts the energy and frequency of the percussion through the variation of the mechanism piston run [3], [4], [5], [7].

The automatic adjustment activity, of all energetically parameters, has results the productivity increase (20%-40%). Also the drill steal head consumes decrease (30%-50%) because using the automatic adjustment of the advance force, for samples, it avoids its blocking into the working face.

2.1. Analysis of the solution used by Secoma Enterprise concerning the automatic adjustment of the pressing force at the pneumatic rotating hammer drills

Generally, the pneumatic and hydraulic consummators of a hammer drill installation are: the hammer drill with its percussion and rotation mechanisms, respectively the pneumatic or hydraulic engine of the advance system.

In the drilling process time the variation of the hammer drill rotation, respectively of the moment of rotation depending on:
   - penetration of the hammer drill through inhomogeneous rocks;
   - meeting of the some fields where the mineral deposit hardness is very different;
   - penetration of the hammer drill through the rocks with various compression resistance;
This productivity operation.

Figure 1 represents the automatic adjustment hydraulic schema of the advance force function by the revolution speed of the drill rotating motor, made by Secoma.

- $P_1$, $P_2$ are two controlled-volume pumps;
- $M_1$ is the drill steel rotating driving motor;
- $M_2$ is the drill steel advance mechanism of the driving motor;
- $CH$ is the hydraulic cylinder, as a sensitive device;

At the no-load run, the sensitive device $CH$ regulates the capacity of the controlled-volume pumps $P_2$, which adjusts the revolution speed of the drill rotating motor $M_2$. Entering of the rotating driving motor $M_1$ is connected with the sensitive device $CH$ thru hydraulic circuit 1. The load on the rotating driving motor $M_1$ increases and the pressure at the sensitive device $CH$ increases too when the drill steel advances in the working face. The sensitive device $CH$ commands the decrease of the capacity of the controlled-volume pump $P_2$; respectively reduce the revolution speed of the drill rotating motor $M_2$ and the advance speed of the drill steel.

In time that the circuit 1 pressure increase, the capacity of the controlled-volume pump $P_2$ decreases until the interruption of the supply drill rotating and advance motor $M_2$. But the minimal value of obtained pressure is not enough for the drill rotating motor $M_2$ reversing.

In this situation is necessary that the drill rotating motor $M_2$ can be a reversing motor. But the Secoma schema not contains this kind of motor, an unfavorable characteristic of this schema. So, the drill steel can not displace both ways. It is necessary to displace the drill rotating motor $M_2$ (fig. 1) with other. It is recommended a reversing rotating motor $M_2$. It provides both a drill steel feed motion thru the working face and the return motion,
Figures 2 and 3 present the proposed solutions. Using other type of drill rotating motor \( M_2 \) requests some adjustments of Secoma schema.

- For the figure 2 schema there are: utilization of a directional control valve \( D_2 \), with electric control and a hydro-electrical switch element \( C \).
- For the figure 3 schema there are: utilization of a directional control valve \( D_2 \), with hydraulic control and a new directional control valve \( D_3 \), utilization of a monostable fluidic element type; it needs also an air source, two expansion valves \( SP_1 \) and \( SP_2 \).

The pressure in the circuit 1 and at the sensitive device \( CH \) increase too then the load increases on the hydraulic motor \( M_1 \), which is determined by the increase of the drill steel load torque. Sensitive device \( CH \) commands decrease of the capacity of the controlled-volume pump \( P_2 \), respectively reduce the revolution speed of the drill rotating motor \( M_2 \). The advance speed of the drill steel decrease too.

While the circuit 1 pressure increases, the capacity of the controlled-volume pump \( P_2 \) decreases. That determines the decrease supply pressure of the drill rotating motor \( M_2 \) too. In this situation, the hydro-electrical switch element \( C \) commutes the directional control valve \( D_2 \) into position which determines the rotating reverse of the drill steel advance mechanism of the driving motor \( M_2 \) and the retracting of the drill steel from the working face too.

In this moment the load and the drill steel load torque on the rotating driving motor \( M_1 \) decreases, its revolution speed increases, so the circuit pressure 1 decrease. Consequently the sensitive device \( CH \) determines the capacity of the controlled-volume pumps \( P_2 \) increase. Therefore, the supply pressure of the drill steel advance mechanism of the driving motor \( M_2 \) increases too. The drill steel advances to the working face results that the directional control valve \( D_2 \) returns to the initial position.

2.2. Analysis of the fluidic variant concerning the automatic adjustment of the pressure force at the pneumatic rotating hammer drills

The theoretical and experimental study made the fluidic amplifier of bistable fluid, that has the Coandă effect at the basis of its functioning, opened certain perspectives concerning its utilisation possibilities in the schemas of automatic adjustment of the advance force. This one has a construction based on an amplifier model for supersonic compressible fluids, studied by F. Bavagnolli. Its particularity consists in the fact that it uses in operating liquid supply jet and compressible fluid as command jet [3].

The experimental researches it was observed that the presence of the command jet determines only a partial commutation of the power jet, and the loss of the command does not lead to the memorising of the useful signal in the opposite canal, but to a symmetrical flow on
the two receiving canals. The described operation characterises rasher a monostable fluid element, a particular case of the bistable element. This explains the reason why we recommend the monostable utilisation in the proposed implementation solution.

In the second proposed solution (figure 3), the hydro-electrical switch element C is changed with a directional control valve D₃ (with hydraulic control on side and spring control on other side) and a monostable fluidic element EF implementation. The compressed air pressure as command or control jet, respectively the pressure of the supply jet is reduced to the wanted values with the expansion valves SP₁ and SP₂. In its turn, the monostable fluidic element EF controls, in a hydraulic way, the directional control valve D₂.

In this case, the algorithm logic of the described phases, in the figure 2 schema functionaries, repeat.

During the usage of the fluid amplifier of monostable type (with mixed jets or the same nature), as automatic adjusting elements in the pneumatic circuit of the drilling installation, some difficulties appear, due to the fact that they are sensitive to the sonorous oscillation, to the flow and pressure variation, which may appear in the supply networks with compressed air. These problems can be solved by a sufficient screening and equipping of the installation with a buffer reservoir of compressed air, with fluctuations standardisation role.

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 utilisation was proposed, particular case of the bistable studied in the experimental attempts. A correction must be imposed.

In case we use mixed jets results:

\[ \tan \theta = \frac{\rho_c \cdot b_c \cdot p_c}{\rho_a \cdot b_a \cdot p_a} \]  
(1)

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

\[ \tan \theta_1 = \frac{\rho_{air} \cdot b_{c1} \cdot p_c}{\rho_{oil} \cdot b_{a1} \cdot p_a} \]  
(2)

For the monostable prototype we obtain:

\[ \tan \frac{\beta_2}{2} = \frac{\rho_{air} \cdot b_{c2} \cdot p_c}{\rho_{oil} \cdot b_{a2} \cdot p_a} \]  
(3)

Results:

\[ \tan \frac{\beta_1}{2} = \frac{b_{c1}}{b_{a1}} \cdot \frac{b_{a2}}{b_{c2}} \]  
(4)

Nomenclature:
- \( b_a \) - breadth of the supply nozzle;
- \( b_c \) - breadth of the command nozzle;
- \( p_a \) - supply pressure;
- \( p_c \) - command pressure;
- \( \beta \) - medium angle between symmetrical axis of the experiment tested bistable fluidic element receiving nozzles.

For the monostable prototype with a medium angle of 14°, the imposed conditions are: \( b_{a2} \cong 2b_{c2} \) (when the third fluidic element has \( b_{a1} = 1\text{mm}, b_{c1} = 1\text{mm} \), \( \beta_1 = 28^0 \)) and \( \beta_2 = 28^0 \).
3. Conclusions

✓ The solution proposed does not exclude the possibility of using a fluid element with jets of the same physical nature (liquid – liquid or gas – gas), which presents stability and better performances during the operation.

✓ In this paper is presented the solution used by Atlas Copco, and also an original solution of automatic adjustment of the advance force, with fluid elements, at the pneumatic rotating hammer drills.

✓ The solution of fluidic command proposed presents superior advantages to the existing variants, as well as to the automation solutions with electronic components, due to: the safety in operation in hostile environments (explosive and wet atmosphere, as high temperatures). For the practical realisation of an automatic adjustment with fluidic element of those tested within the experimental programme type, for the monostable fluidic amplifier prototype must be chosen a medium angle $\beta = 14^\circ$, and complying with the condition $b_{\alpha 2} \geq 2b_{\alpha 2}$ [3].

✓ In the practical realisation of the proposed variants for the automatic adjustment of some seizures 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.

REFERENCES


