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**RESEARCH ABOUT AUTOMATIC ADJUSTMENT SOLUTION OF THE ADVANCE FORCE  
AT THE PERFFUSION DRILLS USING FLUID ELEMENTS**

**BADANIE SYSTEMU AUTOMATYCZNEJ REGULACJI SIŁY POSUWU W WIERTNICACH  
UDAROWYCH Z WYKORZYSTANIEM ELEMENTÓW PŁYNOWYCH**

This paper presents the actual solution used by Secoma Company and part of research regarding a personal solution concerning the implementation of the digital devices in the pressing strength's control of a pneumatic rotating drill, which is included in the structure of the drilling installation. The monostable fluidic 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.

**Keywords:** fluidic element, monostable element, automatic adjustment of the pressing force, advance force, pneumatic rotating drill

W pracy przedstawiono rozwiązanie stosowane przez firmę Secoma oraz omówiono część badań dotyczących rozwiązań w dziedzinie implementacji urządzeń cyfrowych do regulacji siły naporu w obrotowych wiertnicach pneumatycznych będących częścią urządzenia wiertniczego. Zaproponowano użycie mono-stabilnego elementu płynowego, będącego specjalnym urządzeniem zawierającym płyn nieściśliwy jako strugę zasilającą i płyn ściśliwy jako strugę sterującą. Rozwiązanie z wykorzystaniem elementu płynowego daje dodatkowe korzyści w odniesieniu do obecnie stosowanych rozwiązań zawierających komponenty elektryczne, przyczyniając się do poprawy bezpieczeństwa pracy w środowisku niebezpiecznym (w warunkach wysokiej wilgotności, wysokich stężeń metanu, zagrożenia pożarowego, wysokich temperatur), ponadto są one łatwe w użyciu i obsłudze. W celu uzyskania odpowiedniej automatycznej regulacji przy zastosowaniu elementów płynowych testowanych w ramach programu badawczego, ko-

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nieczny był wybór odpowiedniego wzmacniacza plynowego dla prototypu urządzenia, z uwzględnieniem kluczowych wymogów, odnośnie kąta zamocowania do ścian i parametrów geometrycznych.

**Słowa kluczowe:** element plynowy, element monostabilny, automatyczna regulacja siły naporu, prędkość posuwu, pneumatyczne wiertło obrotowe

## 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.

World experience obtained in this domain show as, both in the present time and in the future, that it is preferred the technology by drilling-blasting excavation not using the shearers, at the galleries dug in hard and very hard rocks.

There are many enterprises producing mining equipment, famous by tradition and competitive solutions, which produce a great variety of drilling installations (Atlas Copco, Eimco, Furukawa, Gardner Denver, Ingersol Rand, Secoma, Tamrok, Tampella, Umirom Petroșani 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 drill studies and their performances increase that makes competitive these drilling installations (Beccu, 1992; Hartman, 1958; Mara et al., 1985; Ungureanu et al., 2008).

Basic elements, that determine the characteristics of drilling installations, are represented by the manipulating arms and drill installation. Currently, prevailing compressed air version, but this does not preclude its replacement by hydraulic drill, so realization of a perforated electro- hydraulic installation. Mining equipment manufacturing industry in our country and other countries, made a vast range of equipment for mining work digging. 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 (Almquist & Hamrin, 1993; Cotețiu, 2003; Georgescu et al., 1977; Tuunanen, 1993; Ungureanu et al., 2011).

## 2. Considerations concerning the pressing force control, by adjusting the feed rate of drilling installations equipped with compressed-air 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 control systems

are adaptive in nature as the optimum choice is made during the drilling operation. Also, these systems do not require the continuous supervision of the human operator and can even produce the stopping of the drilling process (Almquist & Hamrin, 1993; Beccu, 1992; Tuunanen, 1993).

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 (Cotețiu, 2003; Georgescu et al., 1977; Hartman, 1958).

The automatic adjustment activity, of all energetically parameters, has results the productivity increase (20%-40%). Also the drill 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 Company concerning the automatic adjustment of the pressing force**

Generally, the pneumatic or hydraulic consummators of a drill installation are: the 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 drill rotation, respectively of the moment of rotation depending on:

- penetration of the drill through inhomogeneous rocks;
- meeting of the some fields where the mineral deposit hardness is very different;
- penetration of the drill through the rocks with various compression resistance;
- entering of the boring bit into the fissures or into the cavities rocks.

That determines the variation of hydraulic engine rotations. Also this leads to changes value pressure circuit.

Secoma Company involved a system, which perceives; with a sensitive device help (installed on the rotating hammer drill engine supply circuit) the pressure variation. Than it sends a steering signal (control signal) for the parameters supply adjustment of the drilling advance mechanism, in fact to its driving motor. Thus results the automatic adjustment of the advance force respectively of the drill feed rate. That features an optimization of the drilling process and we obtain an increase of this productivity operation.

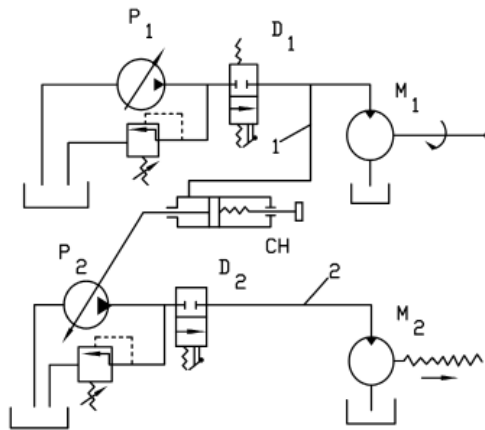


Fig. 1. The automatic adjustment schema of the advance force made by Secoma (Beccu, 1992)

Figure 1 represents a part of 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;
- $D_1, D_2$  are two directional control valves;
- $M_1$  is the rotary hydraulic motor for drill's drive rotation mechanism;
- $M_2$  is the rotary hydraulic motor for drill's drive advance mechanism;
- CH is the hydraulic cylinder, as a sensitive device.

At the unloaded start, the sensitive device CH regulates the capacity of the controlled-volume pumps  $P_2$ , which adjusts the revolution speed of the drill's advance motor  $M_2$ . Entering of the rotary hydraulic motor  $M_1$  is connected with the sensitive device CH through hydraulic circuit 1. The load on the rotary hydraulic motor  $M_1$  increases and the pressure at the sensitive device CH increases too when the drill 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 hydraulic motor  $M_2$  and the feed rate of the drill.

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 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 can not displace both ways. It is necessary to displace the drill rotary hydraulic motor  $M_2$  (Figure 1) with other type. It is recommended a reversing rotary hydraulic motor  $M_2$  (Figure 2). It provides both a drill feed motion through the working face and the return motion, function of necessities.

Figures 2 and 3 present the personal proposed solutions. Using other type of drill rotary hydraulic motor  $M_2$  that 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

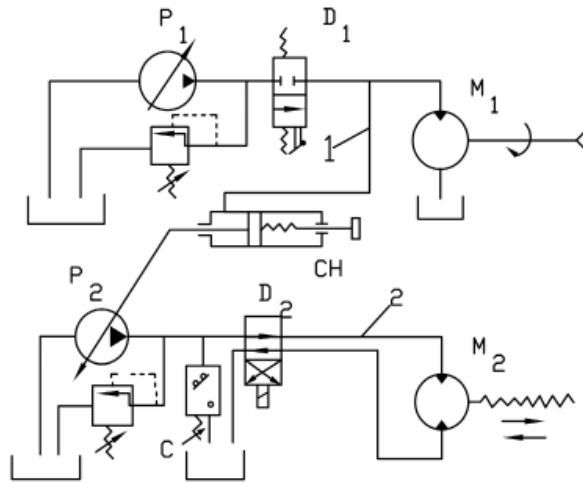


Fig. 2. The automatic adjustment schema of the advance force, with hydro-electrical switch element, based on the simplified hydraulic schema made by Secoma (Beccu, 1992)

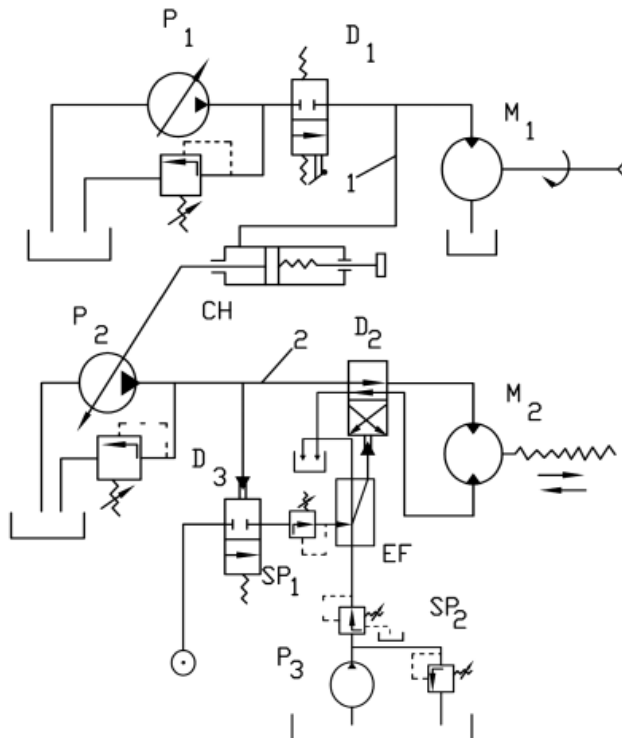


Fig. 3. The automatic adjustment schema of the advance force, with fluidic elements, based on the simplified hydraulic schema made by Secoma

fluidic element type; it needs also an air source, expansion valves  $SP_1$  for air pressure and expansion valves  $SP_2$  for oil pressure. With increasing load on the hydraulic motor  $M_1$ , driven by increased torque drill resistant, the circuit 1 pressure increase and sensitive device CH increase too, which command lower flow pump  $P_2$  and thus reduce the revolution speed of the drill rotary hydraulic motor  $M_2$ . The feed rate of the drill decrease too.

While the circuit 1 pressure increases, the flow pump  $P_2$  decreases. That determines the decrease supply pressure of the drill rotary hydraulic 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 advance mechanism of the driving motor  $M_2$  and the retracting of the drill from the working face too.

In this moment the load and the drill load torque on the rotary hydraulic motor  $M_1$  decreases, its revolution speed increases, so the circuit pressure 1 decrease. Consequently the sensitive device CH determines the flow pumps  $P_2$  increase. There for, the supply pressure of the drill advance mechanism of the driving motor  $M_2$  increases too. The drill 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 compressed – air drills

The theoretical and experimental study made on the bistable fluid amplifier, that has the Coanda effect at the basis of its functioning, opened certain perspectives concerning its utilization 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 (Bavagnoli, 1968; Cotețiu, 2003; Florea & Dumitrache, 1979).

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 memorizing of the useful signal in the opposite canal, but to a symmetrical flow on the two receiving canals. The previous described operation characterizes rasher a monostable fluid element, a particular case of the bistable element. This explains the reason why we recommend the monostable fluid utilization in the proposed implementation solution that a technical application of the experimented fluid element.

In the second proposed solution (Fig. 3), the hydro-electrical switch element C is changed with a directional control valve  $D_3$  (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  $SP_1$  and  $SP_2$ . In its turn, the monostable fluidic element EF controls, in a hydraulic way, the directional control valve  $D_2$ . In this case (Fig. 3) 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 standardization 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 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:

$$\operatorname{tg} \beta = \frac{\rho_c \cdot b_c \cdot p_c}{\rho_a \cdot b_a \cdot p_a} \quad (1)$$

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

$$\operatorname{tg} \beta_1 = \frac{\rho_{air} \cdot b_{c1} \cdot p_c}{\rho_{oil} \cdot b_{a1} \cdot p_a} \quad (2)$$

So, for the monostable prototype we obtain:

$$\operatorname{tg} \frac{\beta_2}{2} = \frac{\rho_{air} \cdot b_{c2} \cdot p_c}{\rho_{oil} \cdot b_{a2} \cdot p_a} \quad (3)$$

Results:

$$\frac{\operatorname{tg} \beta_1}{\operatorname{tg} \frac{\beta_2}{2}} = \frac{b_{c1}}{b_{a1}} \cdot \frac{b_{a2}}{b_{c2}} \quad (4)$$

Nomenclature:

- $b_a$  — breadth of the supply nozzle;
- $b_c$  — breadth of the command nozzle;
- $p_a$  — supply pressure;
- $p_c$  — command pressure;
- $\beta$  — receiving nozzles' medium angle between the symmetrical axis (fig. 4) for the bistable element.

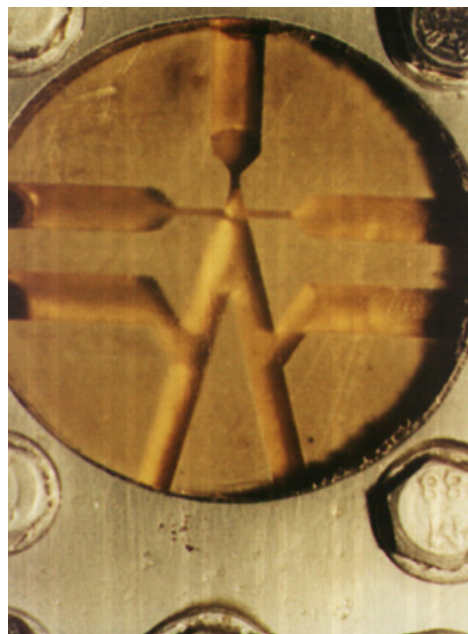


Fig. 4. Experimental bistable fluid element

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

### 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 Secoma Company, and also an original solution of automatic adjustment of the advance force, with fluid elements, at the compressed – air drills.

For the practical realization of an automatic adjustment with fluidic element of those tested within the experimental programmer type, for the monostable fluidic amplifier prototype must be chosen a medium angle  $\beta = 14^\circ$ , and complying with the condition  $\beta_{a2} \cong 2\beta_{c2}$ .

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).

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