Automatic system to control hydraulic drill operation

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Abstract. Under consideration is the operation principle of the automatic control system to manage the drilling modes in terms of variable rocks in view to increase the cutting tool durability, to lower drilling costs, and to improve the new-made hole quality. The modern requirements for drilling processes imply automation of the control processes as it is impossible to achieve the above goals with manual control of a drilling machine. Automation rests on the use of high-speed automatic systems, capable to provide automatic prompt changeover from one mode to another, along with routine adjustment of drilling modes.

1. Introduction
Drilling is a routine, but cost process in the mining industry. Moreover, it is actually known as a complicated method requiring high professional skills of workers and operators, responsible for quality and production cost of hole-making [1, 2]. Thereto, the production cost of hole making depends on a variety of other factors: drilling mode, factor of drilling machine utilization, its performance, durability of a tool. The drilling regimes: drill feed rate, drill rotation velocity, air hammer blow frequency, etc. are prime drilling parameters constituting operation life of the tool, and its capacity utilization factor [1, 2].

A drilling mode is computed and prescribed based on physical-and-mechanical properties of a rock mass to be drilled, but not always they match it because of a variability of rock properties especially in making long-length holes. The high-class skills of the drill operator imply just-in-time detection of variations in rock properties, proper adjustment of a drilling mode. The human factor does not always guarantee a success, durability of the tool can fail and lead to an accident; and in both cases production cost of hole making increases with a respective violence of hole quality.

The modern requirements for drilling velocity and hole-making grade became more rigorous and the conventional control of drill operation got really impracticable. The application of automatic system for control and adjustment of principal drilling parameters acquires a profound actuality [2].

Automation of drilling techniques as a many-years advance resulted in a good variety of available approaches and methods to adjust drilling modes. However the processor control systems with sophisticated tuning components often fail to meet present-day demands for speed performance. All the above provides the sound grounds to develop so called two-circuit automatic systems.

2. Automatic control system layout
The investigation into modern hydraulic drill machines with automatic control functions revealed that automation means for their hydraulic systems are only adjustable oil pumps to provide delivery control. The adjustable oil pumps have less operational life at higher cost as compared to uncontrolled pumps, so in a number of applications the adjustable pumps are economically unsound. Besides,
delivery control in hydraulic systems often has a negative effect on a fluid flow rate in all the hydraulic lines, thus appreciably increasing an inertia capacity and transition time of the system [2, 3]. Throttle control eliminates the above cited drawbacks and provides speedy response of the automatic system [4, 5].

A novel automatic system to optimize drilling control is developed to drill expendable wells (Figure 1). The specific optimal tool feed, its rotation velocity, the impactor actuation moment are adjusted by three automatic fluid-flow-rate controllers 13, 14, 15.

The operation principle of the automatic control system runs as follows: internal combustion engine 1 drives concurrent rotation of three oil pumps 2, 3, 4. Pump 2 supplies a working fluid to hydraulic line of the percussion device 18, where automatic fluid-flow-rate controller 13 is mounted to vary energy and impact frequency. Percussion device 18 is actuated automatically when rotation torque reaches a certain value at drill tool and is intended to break hard rock. Pressure reducing valve 11 is a component of regulator 13, and is connected to its inlet and outlet lines and functions to eliminate pressure difference in a regulator and overflow of a fluid excess into a bin under throttling.

Pump 3 supplies the working fluid to hydraulic line of motor 16 rotating the drill tool. Distributer 8 provides reverse rotation of motor 16, fluid-flow controller 14 varies its rotation velocity.

Pump 4 rotates motor 17 to feed the drill tool, includes distributor 9 and fluid-flow regulator 15. Motor 17 generates velocity and drill feed force.

![Figure 1. Principal diagram of automatic control of hydraulic drill operation: ICE—internal combustion engine.](image)

When hydraulic pumps 3, 4 rotate, the working fluid is fed to fluid distributors 8 and 9, responsible for rotation direction of hydraulic motors of rotating and feeding mechanisms of the drill tool. Working fluid through pump 2 is supplied to fluid-flow regulator 13, where fluid is backed due to closed space. Each fluid-flow distributors 8 and 9 have two outlet hydraulic channels; one from each distributor is connected to fluid-flow distributors 14 and 15, these channels are responsible for the working drilling moments. Other two channels are responsible for secondary operations, such as pulling out of a drill string or demounting of a drill machine.
Control of sleeve valve of fluid-flow distributors 13, 14 and 15 is performed by pump pressure mains, connected to air pressure line of motor 16 of drill-tool rotation device. Sleeve valves are tuned in such a way that if pressure in the line under their control starts to grow the sleeve lines move to the left side; thereto regulator 15 diminishes fluid flow rate, while regulators 13 and 14 increase it.

In the drilling process the pressure generated in the control lines characterizes the torque moment on the drill tool. This pressure moves sleeve valves 13, 14 and 15 in the preset positions providing the design drill modes. Given that hardness of drilled rock varies, let, to a higher value, then the torque moment on the drill tool increases; this leads to increase in pressure in control main lines and position of sleeve valves of fluid-flow regulators changes. Hereupon, sleeve valves of regulators 14 and 15 start to move to the left, so the rate of drill feed lowers, but its rotation velocity grows. Sleeve valve of regulator 13 remains in the previous position, because it is tuned to move under pressure higher than that in sleeve valves of regulators 14 and 15. Assuming that hardness of the rock to be drilled continues to vary to higher level and pressure in the control channels reaches such values that the sleeve valve of regulator 15 moves to close the fluid-supply channel, and the tool feed is cancelled. However the sleeve valve of regulator 14 maximally opens fluid-supply channel and the tool rotation will be maximum high; regulator 13 opens and actuates percussion mechanism to break hard rocks.

To conclude, the new-proposed automatic system has the range to adjust drilling modes of three executive members of the drill machine and after all provides transition from one kind of drilling to another.

3. Conclusions
1. Advantage of throttle adjustment of a drilling mode is substantiated.
2. The automatic system is developed to control the hydraulic drill operation modes.
3. The development of such automatic systems enables to improve drill durability, to lower an accident risk in drilling operation to higher the drilling performance and quality of new-made holes.

References
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