Roofbolters with compressed-air rotators

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Abstract. The specifications of the most popular roofbolters of domestic and foreign manufacture currently in operation in coal mines are discussed. Compressed-air roofbolters SAP and SAP2 designed at the Institute of Mining are capable of drilling in hard rocks. The authors describe the compressed-air rotator of SAP2 roofbolter with alternate motion rotors. From the comparative analysis of characteristics of SAP and SAP 2 roofbolters, the combination of high-frequency axial and rotary impacts on a drilling tool in SAP2 ensure efficient drilling in rocks with the strength up to 160 MPa.

The cost of underground coal mining is influenced by drilling for rock roofbolters. Low-pressure pneumatic machines (roofbolters) used in Russian coal mines perform rotary drilling with three- (or two-) stage telescopic feed (feeder). Table 1 describes the most popular roofbolters of the domestic and foreign manufacture that are currently in operation in underground coal mines.

Table 1. Compressed-air rotary drilling roofbolters.

| Model   | SBR | RAMBOR | WOMBAT | TYRBO | GOPHER | MQT130 |
|---------|-----|--------|--------|-------|--------|--------|
| Manufacturing country | Russia | Australia | Australia | Great Britain | Germany | China |
| Specifications | | | | | | |
| Rock hardness, MPa | to 80 | to 80 | to 80 | to 80 | to 80 | to 80 |
| Hole diameter, mm | 28–35 | 28–35 | 28–35 | 28–35 | 28–35 | 27–42 |
| Hole length, m | to 3.5 | to 3.5 | to 3.5 | to 3.5 | to 3.5 | to 3.5 |
| Rotation speed, min⁻¹ | 700 | 900 | – | 600 | 850 | 300 |
| Torque, NM | 160 | 245 | 190 | 200 | 170 | 220 |
| Feed force, kN | 7.0 | 9.0 | 7.0 | 6.0 | 6.8 | 8.4 |
| Pressure, MPa | 0.63 | 0.63 | 0.63 | 0.63 | 0.62 | 0.63 |
| Weight, kg | 38 | 44 | 50 | 45 | 49 | 50 |

All of the listed roofbolters possess weak sides:
Rotary method of drilling limits the application area of the machines to rocks with the hardness from 60 to 80 MPa;

Pneumatic rotators exert static torque on the tool, which can shutdown the machine under the increased drag torque connected with the seizure of the drill rod or tool.

Figure 1a shows roofbolter model SAP designed at the Institute of Mining [1, 2]. The machine has been trialed at laboratory and commercial scale, and is recommended for manufacturing. The feature of the machine is the combination of pneumatic rotation and percussion devices which can operate independently and concurrently. The machine can perform rotation, percussion and rotary–percussion drilling if required, which allows application of SAP roofbolter in rocks of different hardness, up to 160 MPa and above. In rock mass with the hardness to 60 MPa, drilling is carried out without an air hammer, which makes the machine lighter and handy in operation.

Tests of SAP show that rotary–percussion drilling rate is 2–3 times higher than rotary drilling rate in rocks with the hardness to 80–160 MPa [1]. Furthermore, in rotary–percussion drilling in rocks with the hardness to 80 MPa, wear of cutter bits is reduced by 3–4 times as against rotary drilling.

A fundamentally new design of the Institute of Mining—SAP2 roofbolter shown in Figure 1b—combines the pneumatic rotator and percussion device as SAP model. The new feature of the design is...
the swinging moving rotors of the rotator [3] that generates high-frequency percussion–rotation moments. Figure 2 depicts cross sections of air channels and rotor lobes of SAP2 roofbolter.

The cross-sections show the body 1, shaft rotor 2 and blades 3 and lobes 4, hammer rotor 5 with blades 6 and lobes 7, distributor 8 interacting with the hammer rotor. The shaft rotor and distributor have air feed lines 9–12 (Figure 2a, the outlet channels are provided but not shown in the figure) and the exhaust holes 13 and 14 (Figure 2b). The blades of the rotors generate pairs of working chambers 15 and 16. The shaft 17 transmits rotary percussion moments to the drilling rod and tool. The shaft also communicates with the impact piston.

SAP2 roof bolter is placed in a mine, the drill tool is pressed to the face by the feeder and the drill rod, and compressed air is then supplied to the impact piston and rotator. The impact piston, via the rod and the shaft, generates axial dynamic impacts on the drill tool.

Regarding the rotator, compressed air, along the air feed lines 9–12 (Figure 2a) in turns enters the pairs of working chamber 15 or 16 while the neighbor pairs 16 or 15 are connected to the atmosphere via the outlet channels and exhaust holes 13 and 14 (Figure 2b). Compressed air influence the blades 6 of the hammer rotor 5 and makes it carry out alternating motions relative to the shaft rotor 2 that is kinematically connected to the body by means of a free wheel unit (not shown in Figure 2). The alternating feed of compressed air in the pairs of the working chambers 15 and 16 is performed by the distributor 8.

At the end of the power stroke (clockwise) of the hammer rotor 5 (Figure 2), its lobes 7 collide with the lobes 4 of the shaft rotor 2, and the rotary percussion moment is transmitted, via the shaft 7 and the drill rod, to the rock-breaking tool. At the end of the idle motion (counterclockwise) of the hammer rotor, collision of the lobes is eliminated. The hammer rotor is stopped by compressed air and this soft impulse (reactive torque) is taken by the body 1 via the free wheel unit. Owing to comparatively high inertia moment of the body, as well as weight and length of the attachment with the control levers, vibration is not transferred to a miner’s hands.

The pneumatic rotor using alternating motion of rotors is self-adjustable. In case of a low resistant moment on the rock-breaking tool and rod, they rotate at the maximum speed under the action of moments due to the pressure exerted by compressed air on the blades 3 of the shaft rotor 2 from the side of the working chambers 16 while the collision between the lobes 7 and 4 of the hammer rotor and shaft rotor is absent. In case of the high resistance moment, up to the seizure of the rock-breaking tool and rod, the air-driven rotator performs percussion mode, which liberates the tool and rod and allows the drilling process to be continued.

Table 2 compares SAP and SAP2 models; the analysis of the specifications yields some advantages of SAP2 roofbolter over SAP model:

— axial impacts and rotary–percussion torques intensify drilling;
— self-adjustable rotator in case of low loading allows no-impact moderate mode of operation and increment in torque on the tool under increasing resistance moment;
— capability of the rotator to operate at the complete shutdown of the drill rod unit it is recovered;
— smaller air consumption;
— no reducer is required;
— smaller weight.

Conclusion
The specifications of the most popular domestic and foreign roofbolters currently in operation in coal mines have bee discussed.

The authors describe SAP and SAP2 roofbolters designed at the Institute of Mining and present the pneumatic rotator using alternating motion of rotors.

The comparison of the specifications of SAP and SAP2 roofbolter shows that the axial rotary–percussion mode of drilling in SAP2 roofbolter combines high-frequency axial impacts and high-frequency rotary–percussion attacks on the rock-breaking tool, which ensures efficient operation of the machine in rocks with the hardness up to 160 MPa.
### Table 2. Specifications of roofbolter models.

| Roofbolter model | SAP                  | SAP2                |
|------------------|----------------------|---------------------|
| **Description**  |                      |                     |
| Drilling mode    | Rotary–percussion    | Axial rotary–percussion |
| Rock hardness, MPa | to 160              | to 160              |
| Hole diameter, mm | 28–30               | 30–32               |
| Hole length, m   | to 4.0              | 1.5–3.0             |
| Feed force, kN   | 5.7                 | 5.7                 |
| **Rotator actuator** |                      |                     |
| *Pneumatic*      | Rotation             | Alternating motion rotors |
| Rotation speed, m⁻¹ | 2500                | 0–210               |
| Air pressure, MPa | 0.4–0.63            | 0.4–0.63            |
| Air flow rate, m³/min | 3.0–4.0            | 1.5–3.0             |
| Torque on rotor, Nm | 13.6               | 100–300             |
| Rotary percussion frequency, Hz | -         | 16–24               |
| Power, kW        | 3.6                 | -                   |
| Weight, kg       | 11                  | 18                  |
| *Reducer*        | Planetary–cylinder  | Absent              |
| Reduction ratio  | 10                  | -                   |
| Weight, kg       | 11.8                | -                   |
| Rod rotation speed, min⁻¹ | 0–250            | 0–210               |
| Torque on rod, Nm | 136                 | 100–300             |
| **Air hammer:**  |                      |                     |
| Blow energy, J   | 35                  | 35                  |
| Axial blow frequency, Hz | 30              | 30                  |
| Air flow rate, m³/min | 1.58              | 1.58                |
| Weight, kg       | 6.9                 | 6.9                 |
| Weight without drilling rods, kg | 60           | Not more than 500  |

**References**

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