APPLICATION OF TUNNEL BORING MACHINES IN THE MINING

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ABSTRACT

In this paper the tunnel boring machines are presented as the possibilities and the limitations for their application in the mining. As well as some world experiences are presented from their application.

1. INTRODUCTION

In development of mine with underground exploitation sometimes some time limitations should be set in relation with the development of the capital drifts which will be used as transportation and ventilation structures. With that we would have faster access to the ore body and its excavation. Because of this fact, necessity of application of the tunnel boring machines, as machines with larger velocity of advancing with respect to that which will be achieved with the method of drilling and blasting operation. As well as these machines do not have limitation with respect to the properties of the working environment.

2. TUNNEL BORING MACHINES

Tunnel boring machines are constructed on such a way to perform two or more operations. Basic operation of these machines is the mechanical drifting specifically on full face of the structure. Under the term 'full face' we define drifting in one rotation of the machine. Second important operation is disposal of dirt from the tunnel face. Also there are some additional operations dependent upon the machine type. These machines in the practice are known as TBM machines.

According to the field of application, these machines can be used in:
- tunnel excavation, no matter of the tunnel type - highway or railway tunnel,
- excavation of mine drifts.

We should mention here that:
- the tunnel boring machines can be used for excavation in straight directions and for small curved directions (this will be supported with technical data of some tunnel boring machines which will be presented bellow),

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- from economical point of view, the tunnel boring machines are economical for lengths larger than 1 km,
- the starting length of the object (about 100 m) usually is excavated on some other way dependent on the working environment (with road header machines or drilling and blasting operations).

The construction of the tunnel boring machines depends on their purpose especially on the working environment. So far plenty of different types of these machines with properties corresponding with the working environment are constructed. Nevertheless, the axes of the mining and engineering objects pass through different materials as well as fractured zones. For this purpose, the TBM machine is constructed on such a way to overcome all of the materials the axis of the object passes through. In order to accommodate specific machine for new project, it is necessary to reconstruct the machine. A challenge is construction of universal machine which will work in any working environment. So far such a machine is not constructed.

It can be said that this type of machines depending on their construction can work in different working conditions e.g. underground-water conditions, fractured rock conditions, clay and sandy conditions etc. Virtually the infinite number of combinations of rock, soil and other conditions which can be included in excavation of the mining and engineering objects cause large difference in the types and the properties of the constructed TBM machines.

The biggest world companies which produce TBM machines are: Robbins (USA), Wirth group – NFM technology (Germany and France), Herrenknecht (Germany), Akkerman (USA) etc. All of these companies have their offices worldwide.

2. 1. Construction details

Generally, the tunnel boring machines consist of several construction parts:
- working part;
- system for disposal of the excavated material;
- metal ring - shield;
- dust control system;
- earth pressure balance system;
- injection system; etc.

**Working part** of the tunnel boring machine is the rotational cutting head. It was mentioned above that this machines excavate on ‘full face’ of the object, what means that the diameter of the cutting head is equal to the diameter of tunnel.
Figure 2.1 Tunnel boring machining with shield: 1 - rotating cutting head with shield; 2 - foam for soil conditioning and stabilization; 3 - screw conveyor; 4 - belt conveyor; 5 - car conveyor; 6 - grout mixing; 7 - backfill grout; 8 - segment concrete; 9 - finish concrete lining if used; 10 - waterproofing membrane (if required).

The cutting head rotates around its own axis. On the cutting head various types of cutting tools can be distributed (Fig. 2.2) depending on the type of the working environment. On one cutting head can be distributed cutting tools of one type or combination of cutting tools from different types depending on the working environment.

To allow effective work of the machine it is necessary to provide: sufficient pressure on the face in order to overcome the resistance of the rock during penetration of the cutting tools and sufficient stability of the machine during the work what means resistance to the torque occurring during the work. The most applied supporting and stabilizing systems are:

1. System consisting of: grippers which are gripped in already excavated part of the object (provide stability of the machine) and hydro cylinders supported on the grippers (provide sufficient pressure). This system can be applied only in stable working environment.

2. System consisting of hydraulic pressure suits uniformly distributed at the outer edge behind the machine supported by already set steady or temporary support. On this way the necessary pressure on the face and the stability of the machine are provided. This system can be applied during work in weak, fractured, and non bonded rock material.
Besides cutting tools, on the cutting head special holes are distributed through which the excavated material passes. This material falls down in the extraction room and continues into transportation system which can be screw conveyor or belt conveyor. How will the transport continue depends on the project solution so it can continue with a belt conveyor or with railway transport (Fig. 2.1).

Depending on the machine type, it can be with shield (single or double) or without shield. The shield is in form of metal protection ring with thickness 5 – 120mm and it has double role, to protect the machine from sudden ground destruction and temporary to hold the excavated space. Historically, non mechanized shields are ancestors of the tunnel boring machines. Depending on the work conditions some supporting can be done if the excavation is in stable environment, but in weak environment it is possible concrete segments to be added in the shield so after its advancing, the space between the concrete segments and the excavation is filled usually with injected bentonit or cement pulp (Fig. 2.1).

Regardless the cutting tools, which the tunnel boring machines use, the excavation in the rock materials is accompanied with a dust appearance. Because of this, the tunnel boring machines have a system for dust control which treats the dust with water under pressure sprayed on micron drops (water fog) using special nozzles.

In the practice, the machines with built system for earth pressure balance are known as EPB shields (Earth Pressure Balance) and they are used for work in low cohesive and non cohesive environments. To provide stable face and to respond properly to the variable underground
pressure, this system uses a part of the excavated material, treats it with special additive – foam, converting the material in soft land. So prepared suspension creates necessary pressure and provides more stable working regime of the machine.

3. APPLICATION OF THE TBM MACHINES IN THE MINING

As was mentioned above the tunnel boring machines are used in the mining for excavation of drifts, as machines with much higher advancing speed compared with the one which can be achieved with drilling and blasting methods, and as machines which do not have limitations regarding the properties of the working environment as in case of road header machines.

An example for application of the tunnel boring machines in the mining is the project realized in the copper mine, located 11km on west of San Manuel, Arizona. For faster opening of new ore body, it was necessary to excavate two drifts on different levels with length of 12,800m each (Fig. 3.1). For this purpose a tunnel boring machine with excavating diameter of 4.62m constructed by Robbins has been used. Thirty three cutting disks with diameter 432 mm have been distributed on the cutting head. The installed power on the cutting head was 1,259KW and the variable circular speed was in interval 4 to 12 min⁻¹. The machine had minimum radius of rotation equal to 105 m and total weight 225 tons (Fig. 3.2).

The axes of the drifts pass through terrain consisting of: quartz monzonite with uniaxial pressure strength of 150 to 180 MPa which on many locations was cut by the ore body, dacitic andesitic, clays, as well as fractured rocks captured by hydrothermal metamorphism. During the work some problems occurred as gluing of clay on the cutting head and difficulties about the maintenance of the rotation of the cutting head in soft and fractured rocks. To overcome these problems, the following changes were made:
- the distances among the cutting tools were increased, which provides increase of the space for receiving and disposal of the excavated material,
- the circular speed of the cutting head was decreased from 12 to 9.3 min⁻¹, which provides decrease of the torque for 29% providing more efficient work in weak and fractured rock,
- changes were made in the support and the protection of the machine for providing stability.

After these changes of the machine, an average advancing speed of 678 m/month was achieved. The maximum advancing speed of 831 m/month was achieved.

CONCLUSION

From the presented data for the TBM machines, as well as the data for their application in the mining, it can be concluded that these machine types should be used in the mining for excavation of capital drifts providing faster excavation of these objects.

The tunnel boring machines are machines with very high advancing speed and machines which do not have limitations with aspect of the working environment.

REFERENCES

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