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Mining of thin coal seams using surface-underground methods

Shallow hard coal deposits in the form of seams can be mined using surface-underground methods. These methods are characterized by the exploitation of the deposit from the surface, while the mining process itself takes place underground. The large variability of the mining and geological conditions was the reason for the emergence of many mining methods and systems as well as machines, sometimes used only locally in various parts of the world. The article presents the surface-underground methods used around the world. Attention is paid to unusual and rarely used methods and machines, which are not utilized in Poland for various reasons. The present article discusses mining machines used in the methods of Highwall, Auger, and Punch longwall mining along with their types and varieties.

Key words: *thin coal seams, Highwall mining, Auger mining, Punch longwall mining*

1. INTRODUCTION

The exploitation of mineral deposits starts with the most attractive ones in terms of profitability and technical requirements. In the case of hard coal deposited in the form of seams, thin and highly inclined seams are omitted as long as they are not necessary, especially when there is a combination of both. Thus, in many countries, there is a growing interest in thin and highly inclined seams resulting from their abundance and the need to meet power needs.

Historically, it can be said that the wide range of methods and systems as well as the machines used in the mining of thin coal seams in world underground mining has been significantly limited over the last century [1, 2] and has been reduced to several proven solutions [3–5]. Solutions such as cutters, longwall shearers with a complex and unusual trajectory of cutting tool movement, multi-headed shearers, machines with various positioning and shapes of cutting heads, cavity shearers, plow-scrapers, drills, or active plows are no longer used in most cases. Currently, the most commonly used mining machines are two-headed and two-armed longwall shearers, static coal plows, and milling heading machines. Less frequently

used machines include drilling, drilling-milling machines (Marietta, Ural-20, or Xcel Miners 4-Rotor miners), and cutters. Of course, it should be noted that innovative solutions are still being developed; however, they are either at the design or prototype stage or are niche solutions [3, 5].

Presently, several dozen systems for mining thin seams are known, including ones for highly inclined seams. This article discusses three very interesting methods of exploiting thin seams; namely, Continuous Highwall, Auger, and Punch longwall mining (which are not and have not been used in Poland and are relatively unknown because of their niche use and do not have Polish nomenclature) [6]. The term „Highwall mining” can also be found in the literature as a common system name for both Continuous Highwall and Auger mining. These are systems of surface-underground mining without removing the overburden. The term “surface-underground mining” is aimed at drawing attention to the fact that mining (i.e., underground mining) is performed, but with direct access to the seam from the surface. These systems are used only in seams that are accessible from the surface; i.e., the so-called exposed seams or outcropping seams.

Information on other systems such as longwall, cut and fill, or sublevel caving can be found in the literature [4, 7, 8]. Their mechanization is mostly based on well-known solutions of machines such as roadheaders, drill carriages, loaders, haulers, conveyors, or various solutions of powered supports.

2. THE AUGER MINING METHOD

The auger mining method uses drilling and is the oldest of the surface-underground methods discussed here. It consists of making large-diameter entries using the rotary method at specified intervals (Fig. 1). The spaces left between the entries are support pillars. The cutting head loads the spoil onto the flight, which transports it outside to a scraper or belt conveyor. The method is characterized by low use of the deposit (30–40%); at the same time, it is cheap and enables a quick start and end of an operation.

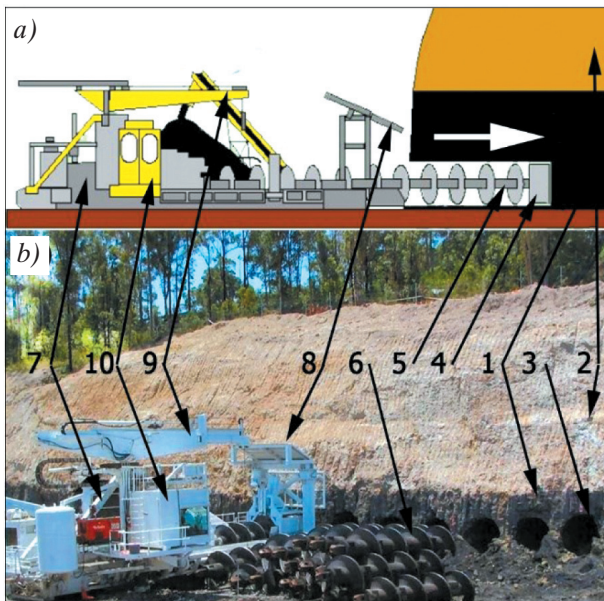


Fig. 1. Auger mining method: a) method scheme;

b) system in operation in Nicholas county, USA

1 – coal deposit, 2 – overburden, 3 – post-mining hole, 4 – cutting head, 5 – helical flange, 6 – shaft sections, 7 – drive, 8 – guard, 9 – crane, 10 – operator's cabin

The most advanced and largest mining machine used in this method is the Auger Miner 1500 (Fig. 2) from Coal Augering Service Pty Ltd. (CAS AM 1500). CAS is an Australian company offering coal mining services using the method of drilling and employs the technology of BryDet, the producer of the

BUA 600 machine for underground drill mining. The diameter range of the cutting heads ranges from $\phi 1200$ to $\phi 1900$ mm. The drilling depth reaches up to 203 m for an individual hole. At the worksite, the machine is set to the appropriate height by means of columns with a pitch of 2600 mm that (in addition to positioning) allows for the drilling of two horizontal holes (one above the other). After making the hole and withdrawing the shaft, the machine moves transversely with the aid of a rolling system made of two guides and a hydraulic mechanism. During assembly and disassembly (drilling, retraction), the flights are transferred with a crane [9].

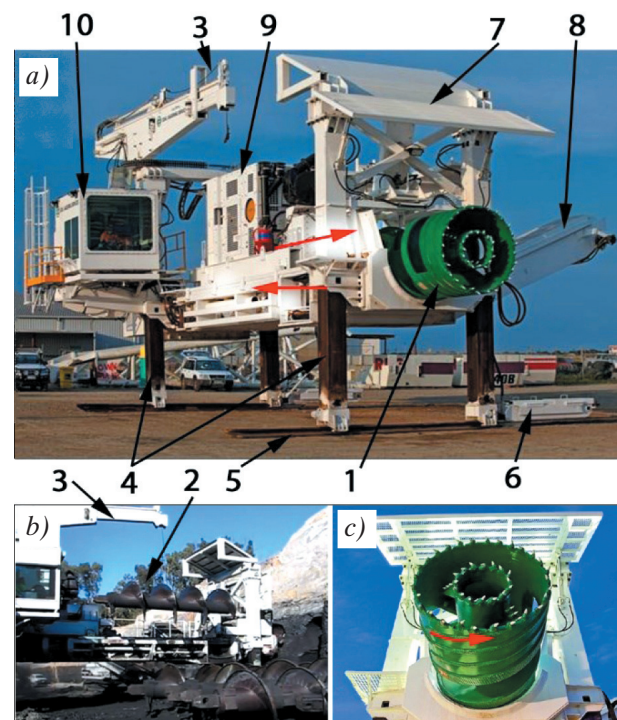


Fig. 2. Auger miner type mining machine: a) CAS AM1500 machine; b) shaft assembly; c) mining head 1 – cutting head, 2 – shaft sections, 3 – crane, 4 – columns, 5 – rolling system beam, 6 – rolling system actuators, 7 – guard, 8 – belt conveyor, 9 – drive, 10 – operator's cabin

Auger machines come in many versions that differ primarily in the diameter of the hole being made as well as the number of heads. The diameter of the holes ranges from $\phi 400$ to $\phi 2500$ mm, and up to three holes can be made at the same time. An example of a machine with the smallest diameter and greatest number of simultaneously made holes is the MCK-GS MUL-T (Fig. 3) by Salem Tool Inc., which can mine a seam with three heads with a diameter of $\phi 400$ mm at the same time. The length of the drilled hole reaches 150 m [10].



Fig. 3. Auger miner: a) MCK-GS MUL-T machine from Salem Tool Inc.; b) drilling with three heads

Machines used for drill mining allow for a very quick start of operation, and apart from providing media and maintenance, they only require an output transport system.

Auger mining technology in the underground version also utilizes the method of drilling, which is used for the exploitation of thin and residual seams. Mining consists of the selective excavation of the seam through large-diameter entries. Pillars are left between the individual entries to support the overburden. Both technology and machines can be found in articles where they are described using the examples of Ukrainian and Czech mining [11, 12].

The BryDet BUA 600 combine is also used for underground mining using the drilling method (Fig. 4). This machine is characterized by an interesting solution consisting of the use of two units: a mining unit and a withdrawing one. Both units work simultaneously, and during drilling and retraction, the shafts are transferred from one hole to the other, which allows us to minimize the shaft storage size and increase efficiency. Changing the distance of both units in relation to one another simultaneously determines the width of the protective pillar. The BUA 600 machine can produce holes with diameters ranging from $\phi 1000$ to $\phi 1800$ mm and up to 80 m in depth.

The drive power of the drilling unit is 450 kW, and the withdrawing unit's power – 110 kW. The total weight of the machine is 60 Mg and requires a cast 6 m wide and 1.8 m high [13] for installation. Despite its typical underground application, the BUA 600 has been discussed due to its interesting and applicable technical solution in surface mining.

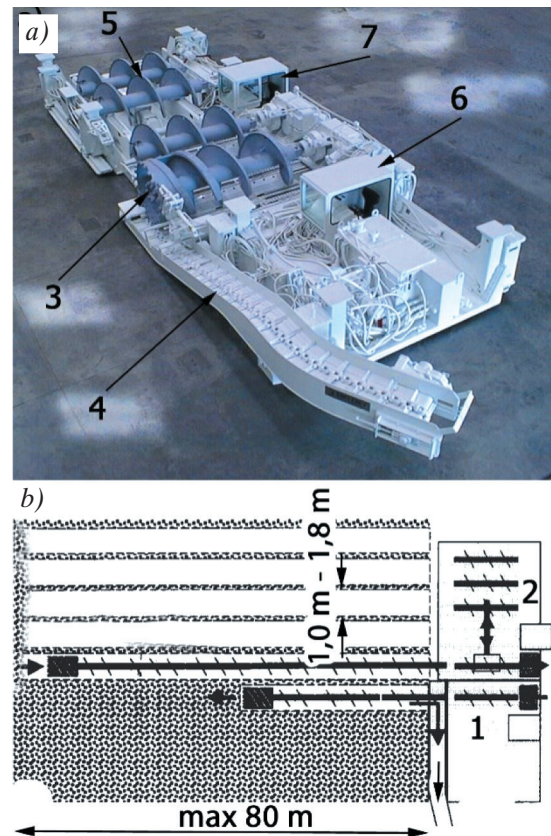


Fig. 4. Auger miner: a) BryDet's BUA 600 machine; b) operation technology
1 – drilling unit, 2 – withdrawing unit, 3 – cutting head, 4 – scraper conveyor, 5 – shaft sections, 6 – drilling unit operator's cabin, 7 – withdrawing unit operator's cabin

3. CONTINUOUS HIGHWALL MINING METHOD

The Continuous Highwall Mining method initially used a mining machine built on the basis of a continuous miner. In newer solutions designed specifically for thin seams, a separate mining machine is used. The method consists of making subsequent galleries separated by protective pillars, which means that the use of the seam varies at around 60%. The spoil is transported outside using double auger conveyors. In both methods (Auger and Highwall), mining takes

place without human intervention at the face, which removes the necessity of using classic ventilation for the excavations and securing the roofs (Fig. 5).

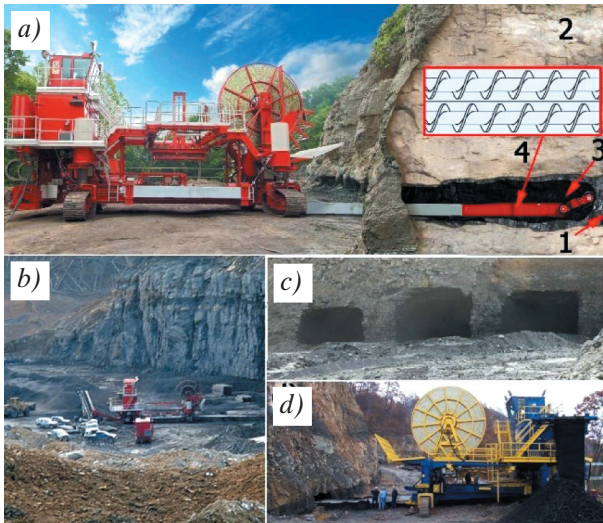


Fig. 5. Highwall mining method: a) method scheme; b) cast equipment along with the Terex SHM miner; c) casts after exploitation in Mingo county, USA; d) AHS American Highwall Systems type mining machine
1 – coal seam, 2 – overburden, 3 – cutting head, 4 – auger conveyor

A machine used in this technology is the CAT HW300, which is technically a Terex SHM miner (Fig. 6).

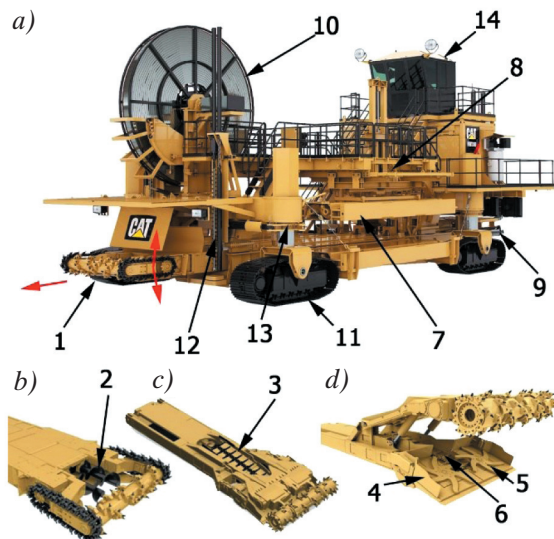


Fig. 6. HW300 CAT miner: a) miner, modules; b) XLPCM; c) LPCM; d) high

1 – cutting head, 2 – auger conveyor, 3 – scraper conveyor, 4 – loading spade, 5 – centrifugal loading arms, 6 – scraper conveyor, 7 – pushbeam, 8 – gantry crane, 9 – feed system actuators, 10 – cable drum, 11 – caterpillar, 12 – anchor, 13 – column XII, 14 – operator's cabin

The HW300 miner is a powerful machine with a total power of 1600 kW and weighing 250 Mg in the lightest configuration, which carries out the mining process to a depth of up to 300 m. After having been set in the right position, the machine is stabilized with two anchors. The mining is carried out with a cutting module pushed into the face by the feed system by means of hydraulic actuators with a pitch of 6.8 m. Pushbeams with a length of 6 m are simultaneously the hull of the double auger conveyor and are transported during assembly and disassembly using a gantry crane. As with the front progresses, all cables are unwound from the cable drum [14].

The HW300 miner has four compatible cutter modules used depending on the thickness of the seam:

- XLPCM – ultra low module – cutterhead diameter $\phi 648$ mm, cutting height from 711 to 1549 mm, cutting width 2946 mm, weight 23.1 Mg,
- LPCM – low module – cutterhead diameter $\phi 648$ mm, cutting height from 762 to 1575 mm, cutting width 2946 mm, weight 23.1 Mg,
- Mid – medium module, partly outranging thin layers – cutterhead diameter $\phi 965$ mm, mining height from 1200 mm to 3060 mm, cutting width 3505 mm, weight 42.8 Mg. Equipped with an additional scraper conveyor.
- High – high module, completely outranging thin seams – cutterhead diameter $\phi 965$ mm, mining height from 2400 mm to 4494 mm, cutting width 3505 mm, weight 48.5 Mg. Equipped with a loading spade with centrifugal loading arms and an additional scraper conveyor.

The HW300 harvester moves on four caterpillar trolleys fixed to the columns that allow for changing the height of the cutter module in relation to the floor and turning the machine as well as driving transversely. The machine is more than 20 m long, almost 12 m wide, and almost 9 m high [14].

Highwall mining machines are also available in the AHS version from American Highwall Systems. AHS harvesters are suited for exploiting seams with a dip of up to 30° and undulate deposits (Fig. 6d) [15].

An interesting variant of the Highwall mining system is the ADDCAR system from UGM ADDCAR Systems, LLC (Fig. 7). The ADDCAR system is used in the same way as the HW300 and is designed for exploiting seams within a range of 0.76 m to 8.54 m in height and approximately 3.5 m wide. As a mining machine, one of the CAT or Joy continuous miners is

used. It is also possible to use a roadheader with point cutting. However, in each case, a special design of the combine is required, adapted to be compatible with the ADDCAR system.

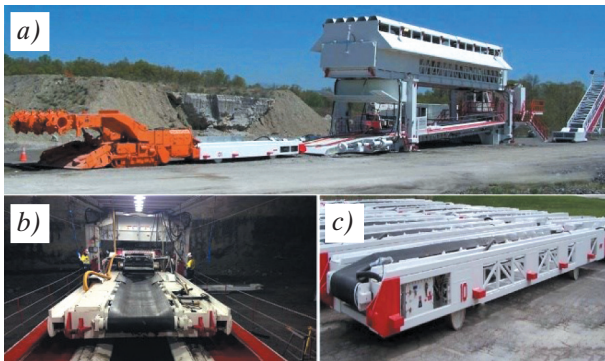


Fig. 7. ADDCAR system machines: a) complex; b) transfer module assembly; c) transfer modules

The system is available in two varieties – Broad and Narrow Bench Highwall, with different maximum thicknesses of the seam and lengths of the gallery. The key feature of the ADDCAR system is the use of modules constituting independent cooperating belt conveyors. The 12.5-meter-long modules have a wheel chassis as well as their own drive and control systems. The modules that are added during operation are connected mechanically and electrically. The system allows for the extraction of coal along a 488-meter-long gallery. An undeniable advantage of using belt conveyors is the significantly lower spoil degradation as compared to transport by auger conveyors [16].

4. PUNCH LONGWALL MINING METHOD

The Punch longwall mining method (Fig. 8) consists of the extraction of seams, which are made available directly from the surface by making access excavations, using the longwall system. The excavations can be parallel or perpendicular to the direction of the longwall system's progress, in which case, the direction of exploitation is parallel to the excavations or is perpendicular to the boundary of the mining area towards the excavation. Protective pillars are left between consecutive fields. The wall equipment is an automated longwall system [8, 17]. The use of automated longwall systems allows for the mining of seams of varying thickness and allows for obtaining a high (approximately 90%) extraction of the deposit.

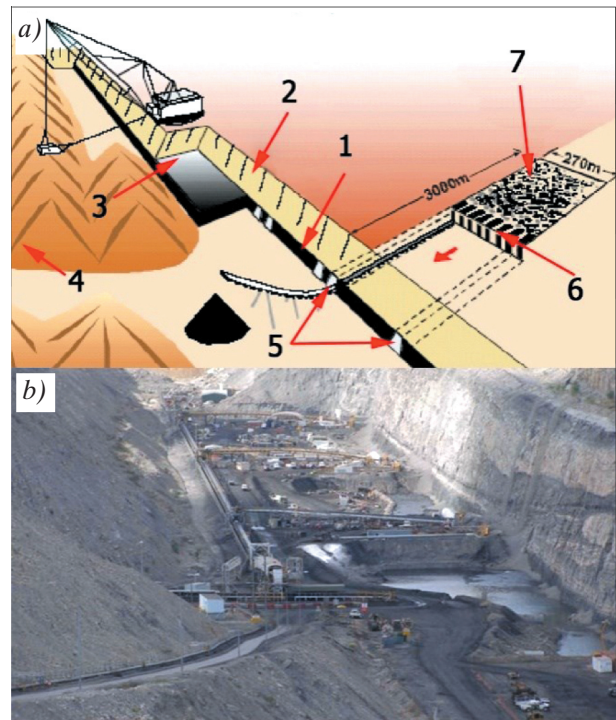


Fig. 8. Punch longwall mining: a) method scheme; b) Broadmeadow mine in Australia
1 – coal seam, 2 – overburden, 3 – excavation, 4 – spoil tip, 5 – longwall galleries, 6 – longwall system, 7 – goaf

In surface-underground methods, creeping scraper conveyors are also used. These are solutions involving remotely controlled machines that can traverse excavations that are located in varying configurations with reference to one another, combining a mining machine with a subsequent means of hauling. Such solutions enable the use of various mining machines integrated with the conveyors.

5. CONCLUSIONS

The exploitation of thin and highly sloping seams, takes place using different methods and machines depending on many factors. Over the years, various mining machines have been used, although only a few proven solutions have remained. However, local conditions contributed to the development of mining methods and the machines they employ that are utilized on a small scale in various parts of the world. The review of methods, systems, and mining machines presented in the article and the literature [5–8] indicates their great diversity. The machines presented in the article have been developed and used for many years. Despite the large variety of methods,

the technique of mining is reduced to either milling or drilling. Depending on the method used and the possible need to protect the area above the excavations, the rate of deposit extraction varies from 30–40% for the Auger mining method, 60% for the Highwall mining method, and around 90% for the longwall systems.

The article focuses on machines not used in Poland in the aspect of thin coal seams. The lack of their utilization in the country is due to the lack of favorable mining and geological conditions and the lack of exploitable shallow or exposed deposits.

All of the methods presented are also used for the mining of medium and thick seams. In those cases, the mining machine is characterized by a larger mining height. The only exception is the drilling method where the maximum diameter of the head is $\phi 2500$ mm and the holes are made in two rows vertically.

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