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SOK Research Project – Bw-1n gallery drilling test using Bolter Miner and exclusive bolting in Polish conditions

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Abstract:

The article presents the SOK Research Project idea, course and final results. The project was oriented onto an implementation of exclusive bolting in one of the Polish underground coal mines, realized with use of a multifunction Bolter Miner. Until starting that project the Jastrzębska Spółka Węglowa S.A. (Jastrzębska Coal Company J.S.C.) has been using different types of other supports (steel arches as gallery / roadway supports). Previous trials of implementing exclusive bolting in the Polish coal mines in the nineties of the XX century were not successful due to different reasons. In the case of the SOK Research Project, after having conducted detailed geological and mining analyses, a part of the Seam 401 in the Budryk Mine was chosen for tests of exclusive bolting with use of JOY 12CM30 Bolter Miner in the gallery drilling operations. Due to previous experience, gained in the process of exclusive bolting in the Upper Silesian Coal Basin conditions, special attention was paid to bolting designing as well as an installation and monitoring. As the SOK Research Project was the first trial in Poland of gallery drilling using exclusive bolting and Bolter Miner, so it was difficult to predict exact costs and final efficiency results. For all the project participants, i.e. the mining crew, engineers, managers and researchers it was an on-job training in the scope of new technology. The SOK Research Project enabled to gain a lot of new experience and knowledge, leading to guidelines and conclusions which can be useful in the following exclusive bolting implementations with Bolter Miner technology.

Keywords: bolting support, Bolter Miner, test gallery, research project, mining-and-geological conditions, monitoring, advance

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1. Introduction - project assumptions and scope

The SOK Research Project, realized by the Jastrzębska Spółka Węglowa S.A. (Jastrzębska Coal Company), over the years 2017-2020, was oriented onto an assessment of possibilities in the scope of adapting best available techniques and technologies, used in the world mining industry, to increase efficiency of a production cycle. It included a technical dialogue aimed at on identification of the best technical and technological solutions as regards mining operations, haulage of the run-of-mine as well as monitoring of the rock mass [1-8]. Such an approach to the research programme enabled to reach the project objective of implementing exclusive bolting successfully. After having analyzed different mining and geological conditions the Bw-1n test gallery at the Budryk Mine was chosen for a realization of the SOK Research Project. The project itself, but in particular its results, achieved in difficult mining, geological and organizational conditions, turned out to be a technological break-through in the Polish mining industry. The research work within the project concentrated on implementing exclusive bolting in galleries of the Jastrzębska Spółka Węglowa S.A. and on an analysis of a full spectrum of possibilities enabling an application of this technology in the process of gallery drilling and also an extraction of residual parts of deposits. A detailed description of mining-and-geological conditions in the area of the gallery under development included roof, floor and hydrogeological conditions, tectonic faults and natural hazards. Special attention was paid to an installation of the bolting system and its monitoring. It should be highlighted that an implementation of exclusive bolting, realized with use of the Bolter Miner, was a real challenge for all the research project participants, representing leading suppliers of the state-of-the-art technological systems for the mining industry, researchers from the national and international scientific institutes and managers from the leading companies producing minerals in Poland. The project assumptions were based on knowledge and innovations and the final successful results confirmed the JSW'S policy based on a collaboration between science and industry.

After having transported the JOY 12CM30 machine components to the pre-prepared assembly chamber, on 10th October 2019 a realization of the SOK Research Project - Exclusive Bolting started.

The project was conducted in the Bw-1n test gallery, situated in the Seam 401 of the Budryk Mine, at the depth of about 900 metres. It showed that the technology of developing galleries in exclusive bolting systems was safe and that the working was stable. The operations, executed by the teams of miners, were less arduous than in the case of traditional support. The date: 9th November 2020 was the last day of the project duration, so the research project lasted 13 months, during which 1168 metres of the Bw-1n test gallery were drilled [9-12]. The fourth month of the project was particularly difficult due to the problems with an execution of Bend No. 1, changing the direction of drilling the working from the north-eastern to the eastern one. Between the fifth and ninth months of the project realization a straight section of the length of about 800 metres was developed. It should be mentioned that geological conditions deteriorated then. An increase of separations was observed in two measurement points, so a decision about changing the bolting network was taken. In the area of Bend No. 2 the roof conditions deteriorated significantly. Apart from that a local increase of rock layers inclination happened, so it was indispensable to change a location of the designed bend, changing the development direction from the eastern to south-eastern one. A stability of the Bw-1n test gallery was controlled by five stations of convergence monitoring and measurements stands of current control [13]. The conducted tests and monitoring of the rock confirmed a correctness and efficiency of applying exclusive bolting system. During the development period of nine months, the gallery was fully functional and stable. The problems connected with a dynamic increase of roof separations, detected during the sixth month, were solved quickly and efficiently. A change in the bolting network, which will be presented in detail in the following chapters of this article, enabled to continue mining operations without any negative impact on the personnel's safety level.

Down-times and failures, experienced in the development process, were caused by fluctuations of water pressure in the fire-extinguishing pipeline and down-time in the mine central haulage system. Apart from the problems of technical-and-organizational nature, the COVID-19 pandemic had a significant negative impact on the project realization [14].

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In the sixth, seventh and ninth months of the project duration there were down-time periods connected with an introduction of the state of epidemic. In the result of such unexpected circumstances a decrease of daily advances was unavoidable and thus an increase in the project costs happened.

The research-and-development character of the project enabled to conduct series of analyses, an elaboration of best practices and to gain operational experience in the scope of optimum lay-out of machines and devices, designing exclusive bolting system and its installation in deep gassy mines as well as a selection of exploitational materials and monitoring of galleries developed with use of exclusive bolting [15].

2. Materials and Methods

Tasks of the SOK Research Project

The SOK Research Project was started in 2017 by signing the following agreements and contracts:

- 24th March 2017 – Agreement with Joy Global (Poland),
- 20th June 2017 – Agreement with the Główny Instytut Górnictwa (Central Mining Institute),
- 20th April 2018 – Consortium Agreement signed by the JSW Innowacje, JSW S.A., GIG, JOY Global.

A project organizational structure contained the Project Team and the Steering Committee.

Fig. 1 shows the companies taking part in the implementation project of exclusive bolting system and their collaborative links.

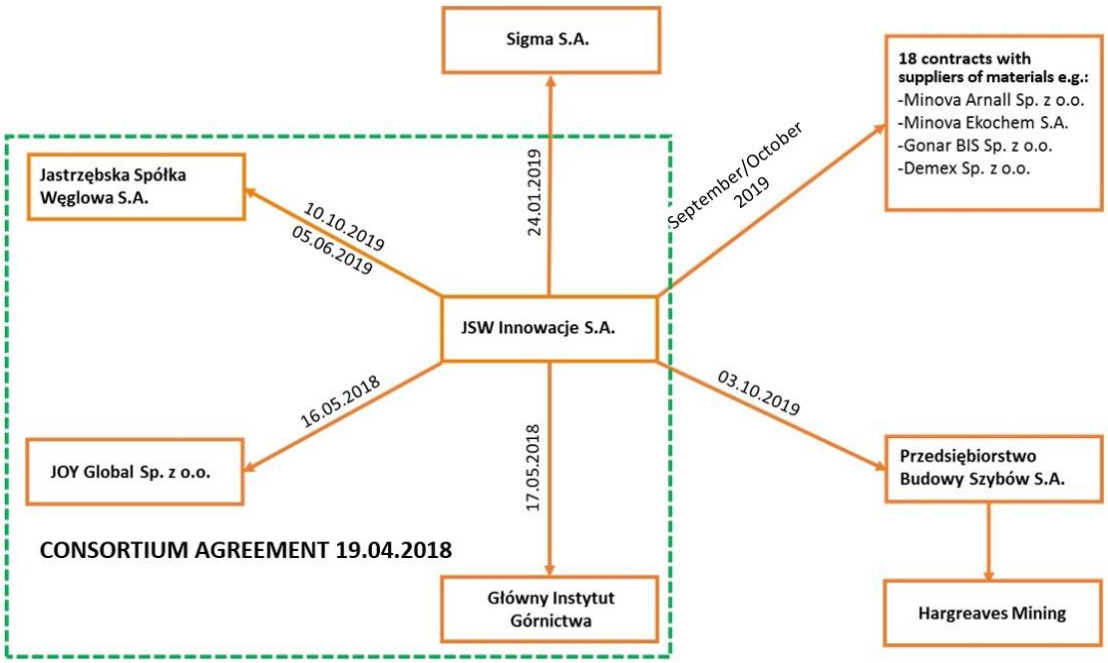

Fig. 1. Companies involved in a realization of the SOK Research Project [1]

The tasks were divided in the following manner:

- JSW Innowacje S.A. – project coordination, realization of scientific-and-research work, organization of the Bolter Miner delivery and other indispensable face equipment as well as organization of materials and measuring instruments deliveries,
- JSW S.A. (Board Office) – project supervision,
- PBSz S.A. – development operations,
- Hargreaves Mining – personnel/machinery operators' training,
- JOY Global – Bolter Miner manufacturer and BM technical service,
- SIGMA S.A. – auxiliary equipment (belt conveyors etc.) manufacturer,

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– Główny Instytut Górnictwa – expert services and bolting research and designing.

Stages of the SOK Research Project

The SOK Research Project was divided into seven stages, including two stages of an assembly and disassembly of the test rig and five stages of the gallery development, in which three stages concerned a development of straight sections and two stages – a development of bends. The project research programme of developing the Bw-1n test gallery in exclusive bolting contained the following tasks:

Task 1: A construction of a test rig in the underground environment and operational conditions, including an assembly of the Joy 12M30 Bolter Miner, face devices and equipment for haulage of the run-of-mine together with an elaboration of reports.

Task 2: Development tests at the test rig in the underground environment and operational conditions during a development of the Bw-1n test gallery to Bend No. 1 together with a preparation of the report.

Task 3: A development of the Bend No. 1 together with driving 70 metres of the Bw-1n test gallery for an installation of the run-of-mine haulage devices according to the technical documentation of the SIGMA S.A., an installation of the run-of-mine haulage devices and a preparation of the report.

Task 4: A realization of planned tests at the test rig in the underground environment and conditions, taking into consideration the conclusions drawn from a development of the second segment of the Bw-1n test gallery and a preparation of the report.

Task 5: A specification of possibilities of the SOK technology at developing the Bend No. 2 together with a development of 70 metres of the Bw-1n test gallery for an installation of the run-of-mine haulage devices according to the SIGMA S.A. documentation, an installation of the run-of-mine haulage devices and a preparation of the report.

Task 6: Development tests conducted at the test rig in the underground environment and underground conditions enabling to demonstrate the technology at driving the third segment of the Bw-1n test gallery and a preparation of the report.

Task 7: An analysis of the current state of the SOK technology and an elaboration of methodology for a liquidation of the test rig in the underground environment and conditions, including a disassembly of the JOY12 CM30 machine, of the face devices and of the SIGMA S.A. run-of-mine haulage devices together with a preparation of the final report on the SOK Research Project.

The research-and-development project started with a selection of the most convenient venue for an assembly of the JOY12CM30 machine. The machine was assembled in the assembly chamber, prepared earlier in the Seam 401 of the Budryk Mine. An operational conformity of all the machine subassemblies was checked [16-17]. A development of the Bw-1n test gallery in the Seam 401 of the Budryk Mine was started in the second month of the project duration. The section of only 65.8 metres of the working was developed due to down-times caused by mechanical failures of the machine and belt conveyors as well as technological reasons such as a construction of a periodical control station.

The third month of the project realization ended at 200 rm of the Bw-1n gallery. It should be highlighted that development operations were sped up significantly and the number of down-time breaks was reduced. An advance of operations in the third month of the project “SOK Research Project” is shown in Fig. 2.

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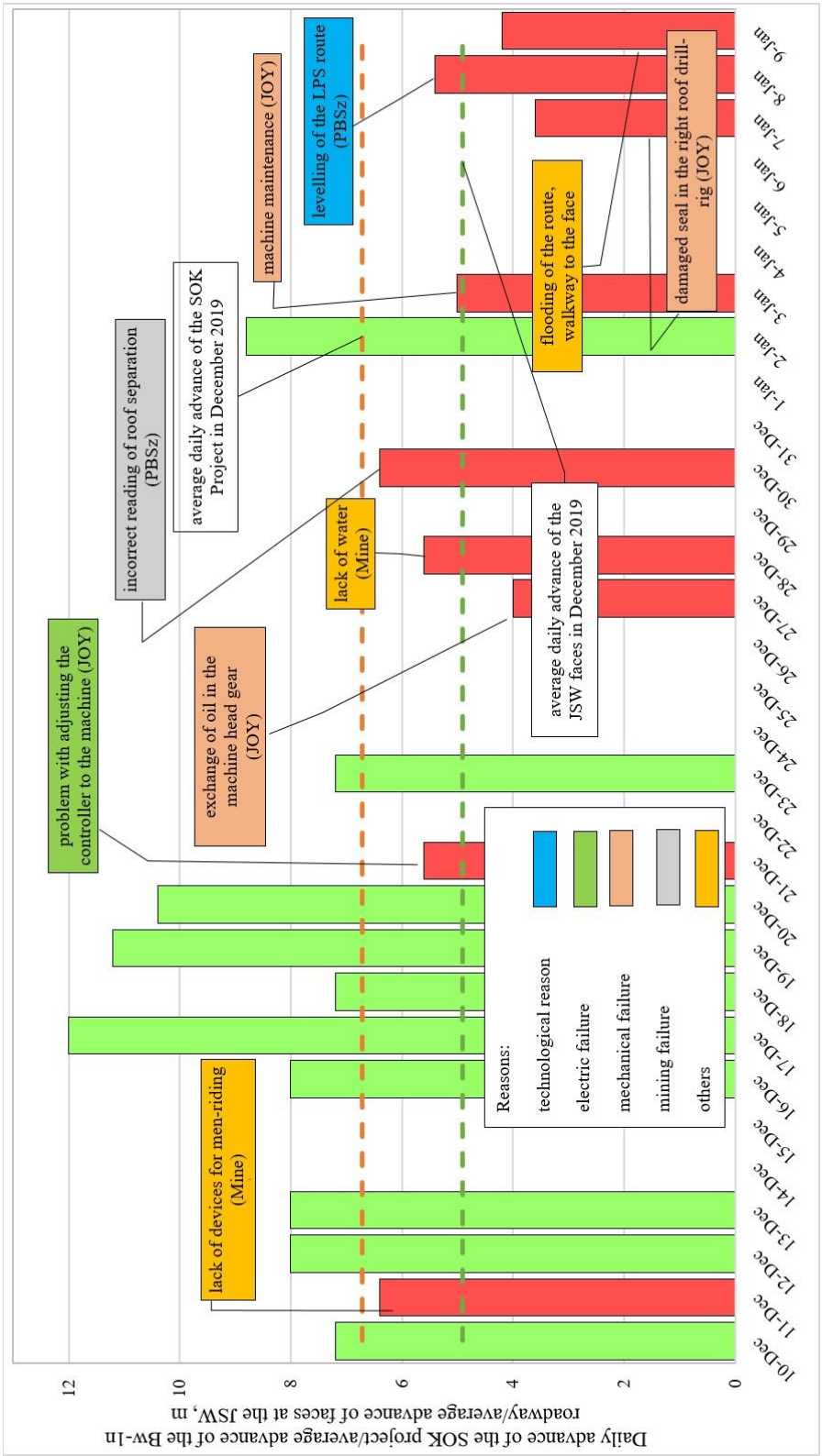

Fig. 2. Advance of operations in the third month of the SOK Research Project duration [5]

An execution of the bend was planned for the fourth month of the project realization. It required an increased amount of labour, especially for a reconstruction of the technical infrastructure and an installation of a bigger number of bolts, including rope bolts.

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The fourth month was ended at 255.2 rm of the Bw-1n test gallery. The machine was withdrawn and an installation of chock supports was started to develop the bend at 210 rm. The working of 6.8 m x 4.2 m was developed until 5th February and then the basic dimensions 5.6 m x 4.2 m were continued, which enabled to increase the daily advance.

The daily advance of the working in the project fourth month is presented in Fig.3.

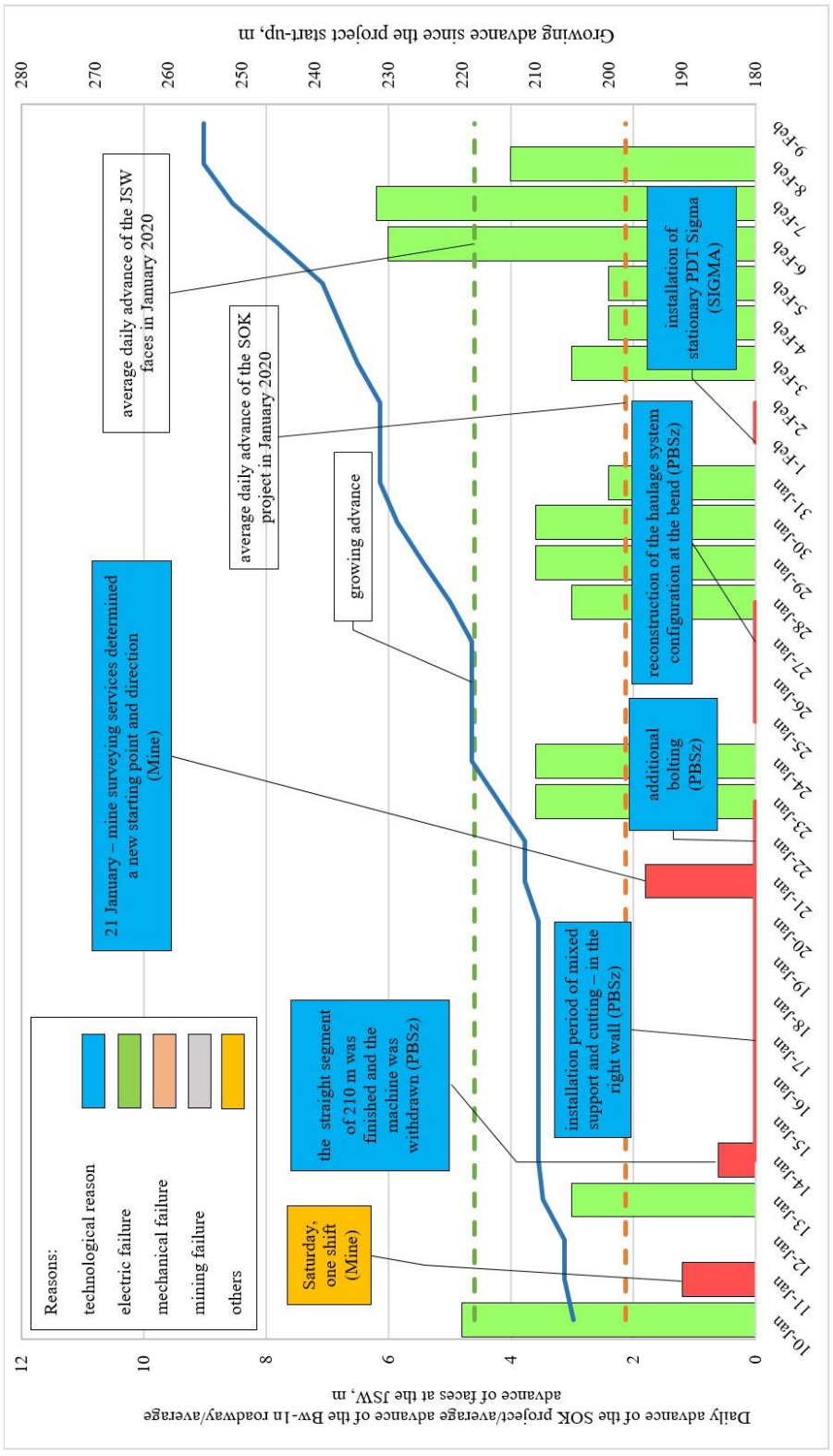

Fig. 3. Advance of operations in the fourth month of the SOK Research Project duration [5]

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The fifth project month ended at 392 rm and the sixth project month - at 556.4 rm of the Bw-1n test gallery. Since 23rd March 2020 an organization of work has been changed due to an introduction of the COVID-19 epidemic state in Poland. The worktime was reduced to 3 working shifts every 24 hours, lasting 6 hours each. Then the daily advances dropped below the average.

Down-time was caused by failures of the main haulage system, a failure of the machine roof drill-rig, of its cutting head, a failure of the water flow in the machine and also lack of water and pressure jumps in the fire pipeline.

The seventh month of the project duration enabled to reach 689.2 rm of the Bw-1n test gallery. When the COVID-19 restrictions were annulled and four-shift system was returned a daily advance increased. The down-time was mainly caused by mechanical failures, an extension of the run-of-mine haulage route and the machine sinking in weak floor rocks.

The eighth month of the project duration ended at 903.2 rm of the Bw-1n test gallery. The average daily advance reached 9.70 metres, whereas in the case of other faces developed with use of conventional technology - 5.14 metres. It is worth highlighting that the concentrated bolting network was installed. It should be borne in mind that when better roof conditions occur, the daily advance can be even greater. The down-time was caused by failures of the main haulage system, of the SIGMA conveyor, a voltage decay in the grid, exceeded methane concentrations as well as lack of water in the fire pipeline.

The ninth month enabled to reach 1015.4 rm of the Bw-1n test gallery. The advance was extremely limited because of severe restrictions in the Upper Silesian Region due to a big number of the COVID-19 cases. The development operations were conducted during single shifts in June. However, at the beginning of July normal operation of the Budryk Mine started. The daily advance in June was 6.22 metres. Some mechanical failures were recorded but they were rare. Initially, it was planned to make the second bend, but due to delays it turned out impossible.

The tenth month of the SOK Research Project realization ended at 1059.4 rm of the Bw-1n test gallery. The advance was reduced due to a sudden change of mining-and-geological conditions, mainly due to an increase of the Seam 401 inclination angle to about 15° which made a continuation of the development operations practically impossible, so the machine was withdrawn and installed in the new location of the bend. An average daily advance in July was only 3.49 metres. An average daily advance in the project accounting period was 2.01 metres [18-19].

In Fig. 4. A growing advance rate of the Bw-1n test gallery development, over the period of 10 months of the SOK Exclusive Bolting, is presented.

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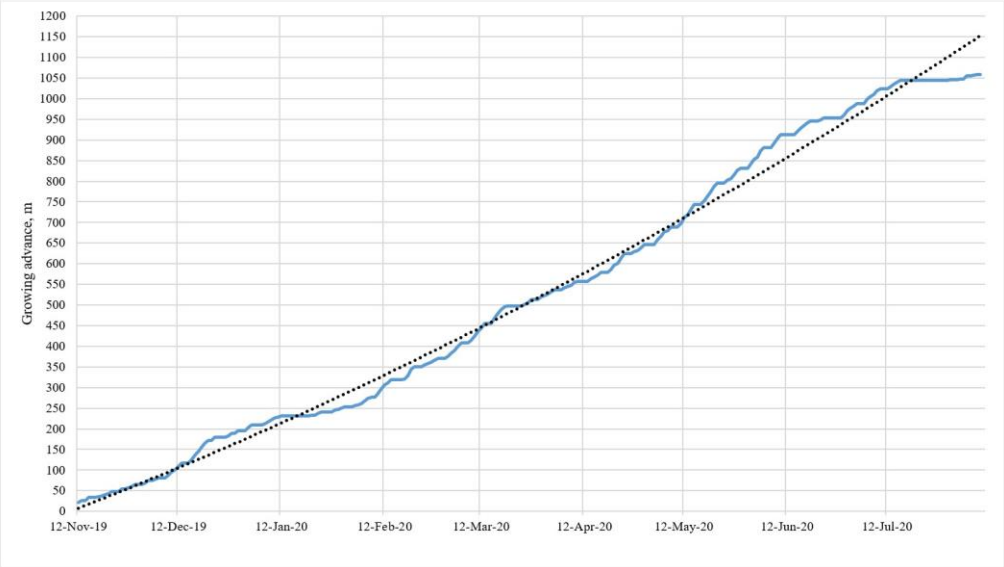

Fig. 4. Cumulative advance of the Bw-1n test gallery development over the period of ten months [5]

3. Assessments, comments, conclusions and recommendations

Having analyzed a series of machines of Bolter Miner type available on the market, including possibilities of their use in the mining-and-geological conditions of the JSW S.A. mines, the Bolter Miner of JOY12CM30 was chosen.

Its cutting weight was from 2.2 to 4.9 m, cutting width – from 4.6 to 5.4 m and its weight – 85000 kg. The minimal roof opening before the web was 2.0 (1.0) m.

Fig. 5 presents a view of the JOY12CM30 Bolter Miner implemented in the Budryk Mine.

Fig. 5. A view of the JOY12CM30 Bolter Miner [16]

In the initial version 6 bolts in the roof and in the walls were accepted. In the case of the project basic variant of 14 bolts, the achieved advance varied from 15 to 30 rm (Fig. 6).

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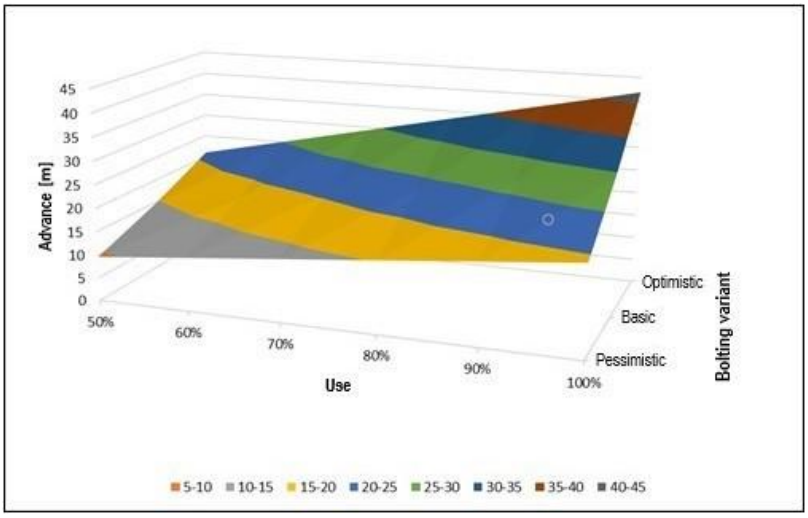

Fig. 6. Relationship between advance and bolting variant

The analysis concerned the cutting and bolting cycle in relation to the number of bolts and their spacing. A conservative approach was assumed as regards time consumption – on the level of 50%. From Fig. 7 it can be seen that in the case of increased number of bolts the SOK Research Project is efficient economically.

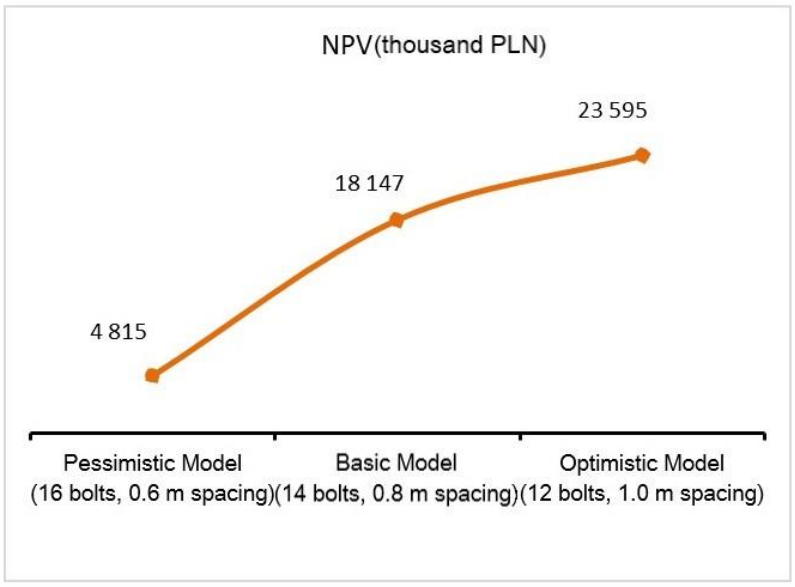

Fig. 7. Economic efficiency of the SOK Research Project

Even if the number of bolts is increased to 10 in the roof and 8 in the walls and the spacing is reduced to 0.6 m the economic efficiency is still positive.

It is worth bearing in mind that advances possible to be achieved, with use of the Bolter Miner, are greater than an average advance achieved with a use of a road-header and chock supports (6.0 m/day) already at 20% of the BM system available time (Fig. 8).

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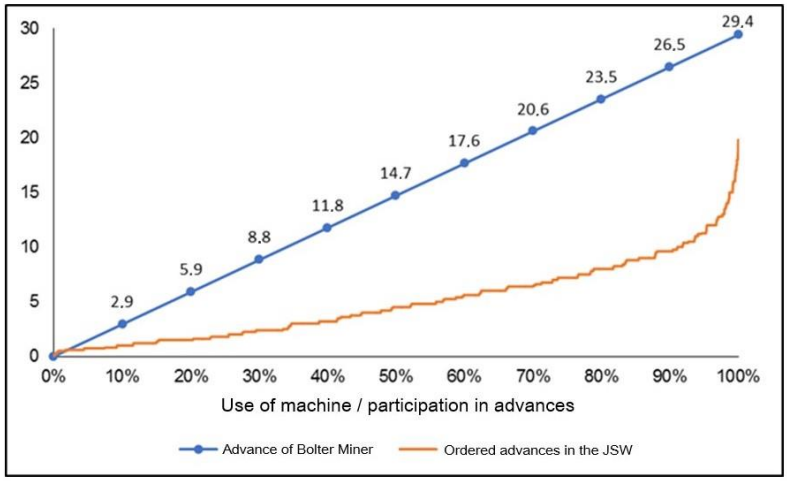

Fig. 8. Relationship between the working development advance and the degree of the 12CM30 Bolter Miner use in relation to advances achieved at JSW S.A. with use of conventional method of developing roadways with roadheaders

The SOK Research Project results confirmed a possibility of using exclusive bolting in the conditions of the test gallery developed with the Bolter Miner. Different, than initially forecasted, mining-and-geological conditions caused that it was indispensable to change the bolting system design project which had an impact on the number and length of the applied bolts and thus extended the time of bolting roof and walls in one working cycle. The mechanical strength of rocks was lower than that one predicted by geological-and-surveying staff of the Budryk Mine, so it was indispensable to change the bolting network.

A big disadvantage also concerned the Bolter Miner sinking in the floor. An occurrence of sphaerosiderite lenticles of the compressive strength reaching 85 MPa was a probable reason of a serious failure – a damage to the cutting head. The run-of-mine transport system, consisting of stationary belt conveyors (Bogda), belt conveyors (Boa) and Sigma belt feeder suspended to the machine, was unreliable operationally.

According to the operational manual, the 12CM30 machine is designed for cutting rock of the Rc which does not exceed 60 MPa [16]. An essential technical element of the system includes a sub-system for a transportation of personnel and materials to the face. It should also be mentioned that a peripheral location of the Bw-1n test gallery caused decays in electric energy supplies and pressure drops of technological water which caused breaks in cutting and/or bolting operations. Another crucial factor, having a direct impact on development results, included personnel's work time. In the case under consideration it was about 5 hours in the 4-shift system, whereas in Australia it varies from 10 to 12 hours, in China and Russia – 8 hours.

In the result of the SOK Research Project realization repeatable failures of the power hydraulic system were experienced e.g. damage to hydraulic hoses during drilling-and-bolting operations. There were leakages of oil due to damage of seals. In the water system mechanical failures of flowmeters occurred.

However, the final conclusions, which can be drawn on the basis of the SOK Research Project analysis, authorize to state that an application of the gallery development with use of the Bolter Miner, enabling an installation of exclusive bolting, gave positive results. This technology has a big potential in terms of efficiency improvement as well as in terms of development advance in relation to the results achieved in the Bw-1n test gallery, developed in the Seam 401 of the Budryk Mine.

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