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KOMAG INSTITUTE OF MINING TECHNOLOGY
Pszczyńska 37, 44-101 Gliwice, Poland

E-mail of Editorial Office: maszynygornicze@komag.eu

Editor-in-Chief: phone: +48 32 2374 600
e-mail: dprostanski@komag.eu or maszynygornicze@komag.eu

Secretary of Editorial Office: phone: +48 32 2374 177
e-mail: rzajac@komag.eu or maszynygornicze@komag.eu

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Technical safety of machinery and equipment in the aspect of the activities of the KOMAG Division of Attestation Tests, Certifying Body

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Andrzej Figiel

KOMAG Institute of Mining Technology, Pszczyńska 37, 44-101 Gliwice, Poland

afigiel@komag.eu

Keywords: technical safety, machinery, conformity assessment, certification, directives, placing of products on the market

Słowa kluczowe: bezpieczeństwo techniczne, maszyny, ocena zgodności, certyfikacja, dyrektywy, wprowadzanie wyrobów do obrotu

Abstract:

One of the areas of activity of the KOMAG Institute of Mining Technology is related to broadly understood ensuring of technical safety. This activity is carried out by the Division of Attestation Tests, Certifying Body, which by carrying out numerous processes of certification, conformity assessments, issuing opinions and expert opinions, contributes to maintaining and increasing the level of technical safety associated with the use of products, mainly machinery and equipment. This article reviews the activities of the Certifying Body, its competences and authorizations and presents how such activities influence technical safety.

Streszczenie:

Jednym z obszarów działalności Instytutu Techniki Górniczej KOMAG jest działalność związana z szeroko rozumianym zapewnieniem bezpieczeństwa technicznego. Działalność tę w Instytucie realizuje Zakład Badań Atestacyjnych Jednostka Certyfikująca, który prowadząc liczne procesy certyfikacji, oceny zgodności, wydawania opinii i ekspertyz przyczynia się do utrzymania i podnoszenia poziomu bezpieczeństwa technicznego związanego ze stosowaniem wyrobów, głównie maszyn i urządzeń. W niniejszym artykule dokonano przeglądu działalności jednostki certyfikującej, posiadanych kompetencji i uprawnień oraz omówiono w jaki sposób taka działalność kształtuje bezpieczeństwo techniczne.

1. Introduction

The requirement of ensuring technical safety and safe working conditions results directly from the Constitution of the Republic of Poland [1], which contains the following statements:

– everyone has the right to safe and hygienic working conditions (Article 66.1),

– public authorities shall protect consumers, users and tenants from actions which threaten their health, privacy and safety and from unfair market practices (Article 76).

Activities related to ensuring safety are carried out by manufacturers, employers, conformity assessment bodies, market surveillance authorities and other specialised inspection bodies, operating within the framework of the legal acts in force.

The basic actions taken to ensure the technical safety of machinery and equipment are [2]:

– design and manufacture of the machine, taking into account the results of the risk analysis and assessment, so that:
  – all the identified hazards have been eliminated or the risks associated with them have been reduced to an acceptable level,
  – the sources of hazards are monitored in the way enabling to prevent a risk increase by initiating preventive measures,

– use of safe working methods and provision of appropriate means of collective protection and personal protective equipment.

The responsibility for technical safety at the stage of design and manufacture of products, placed on the market, primarily belongs to product manufacturers whereas the responsibility for ensuring safe working conditions belongs to employers (users).

The KOMAG Institute of Mining Technology has in its structure a dedicated organizational unit – the Division of Attestation Tests, Certifying Body, which, due to its authorization for several decades, has been participating in the processes of conformity assessment of products requiring the participation of the so-called "third party". The activity of the Division of Attestation Tests, Certifying Body focuses on the assessment of products at the stage of placing them on the market, hence the article discusses primarily the conformity assessment procedures and other activities of the Body supporting manufacturers in the verification of compliance of products with safety requirements at the design and manufacturing stage (Fig. 1).

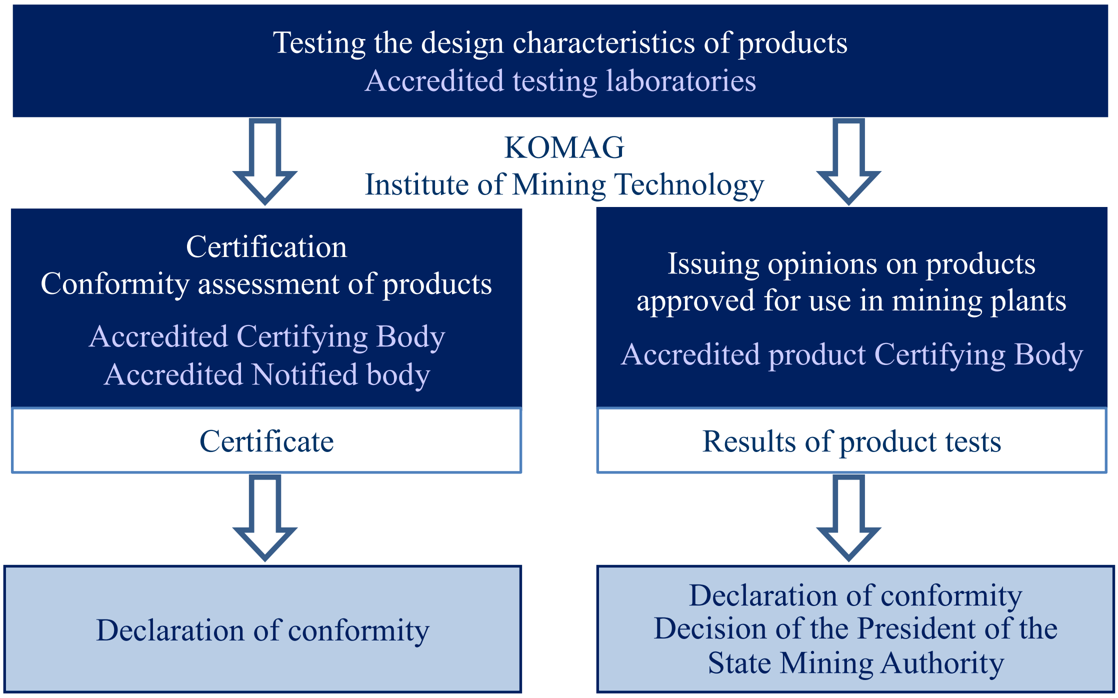

Fig. 1. KOMAG activities in the scope of conformity assessment

With regard to placing products on the market of, understood as making a product available on the market for the first time, the following acts shall apply:

– the Act of 30 August 2002 on the Conformity Assessment System [3] and the Act of 13 April 2016 on Conformity Assessment and Market Surveillance Systems [4], together with the regulations implementing European Union directives issued on its basis, which specify, among others, the essential and additional requirements for products subject to conformity assessment and conformity assessment procedures,
– Law of 12 December 2003 on general product safety [5], which lays down the procedure to be followed concerning products placed on the market where there are no specific other European Union regulations concerning the safety of those products.

The Division of Attestation Tests, Certifying Body carries out assessments of products, mainly machinery and equipment, intended for use in various industries. Products intended for the mining industry, due to specific environmental hazards occurring in mining excavations, are subject to additional assessment procedures and are required to meet additional safety requirements specified in the regulations issued based on the Act of 9 June 2011 - Geological and Mining Law [6].

2. The competences of the Division of Attestation Tests, Certifying Body

The accreditation guarantees reliable, competent, independent and impartial assessment of products with the requirements of reference documents (standards, normative documents, technical specifications) carried out by a certifying body. The condition for obtaining accreditation is meeting the requirements concerning, among others, the organisational structure, resources (personnel, testing capabilities) and management system contained in the PN-EN ISO/IEC 17065:2013-03 Standard [7] and accreditation requirements of the Polish Centre for Accreditation. The Division of Attestation Tests, Certifying Body fulfils all the accreditation requirements, which is confirmed by the accreditation certificate (Fig. 2).

POLSKIE CENTRUM AKREDYTACJI
POLISH CENTRE FOR ACCREDITATION

Sygnatariusz EA MLA
EA MLA Signatory

CERTYFIKAT AKREDYTACJI
JEDNOSTKI CERTYFIKUJĄCEJ WYROBY
ACCREDITATION CERTIFICATE FOR PRODUCT CERTIFICATION BODY
Nr AC 023

Potwierdza się, że: / This is to confirm that:

INSTYTUT TECHNIKI GÓRNICZEJ KOMAG
ZAKŁAD BADAŃ ATESTACYJNYCH – JEDNOSTKA CERTYFIKUJĄCA
ul. Pszczyńska 37, 44-101 Gliwice

spełnia wymagania normy PN-EN ISO/IEC 17065:2013-03
meets requirements of the PN-EN ISO/IEC 17065:2013-03 standard

Akredytowana działalność jest określona w Zakresie Akredytacji Nr AC 023
Accredited activity is defined in the Scope of Accreditation No AC 023

Akredytacja pozostaje w mocy pod warunkiem przestrzegania wymagań jednostki akredytującej określonych w kontrakcie Nr AC 023
This accreditation remains in force provided the Body observes the requirements of Accreditation Body defined in the Contract No AC 023

Certyfikat akredytacji ważny do dnia 09.11.2021 r.
The certificate of accreditation is valid until 09.11.2021

Akredytacji udzielono dnia 10.11.1995 r.
Accreditation was granted on 10.11.1995

DYREKTOR
POLSKIEGO CENTRUM AKREDYTACJI
LUCYNA OLBORSKA

Warszawa, 06 listopada 2017 r.

Fig. 2 Accreditation Certificate for the Division of Attestation Tests, Certifying Body

The accreditation granted by the Polish Centre for Accreditation includes:

- certification of conformity of products in accordance with the standards included in the scope of accreditation No. AC 023, carried out based on type 1a, 1b, 3 and 5 certification programmes according to PN-EN ISO/IEC 17067 [8],
- conformity assessment procedures (modules) requiring the involvement of a notified body as defined in Directives 2014/34/EU [9], 2006/42/EC [10], 2009/48/EC [11],
- issuing opinions on products approved for use in mining plants based on art. 113 sec. 3 of the Act - Geological and Mining Law.

Characteristics and parameters crucial for the product safety are determined based on a documentation analysis, a verification of calculations, inspections and laboratory test results. It should be emphasized that the KOMAG Institute of Mining Technology has its own accredited laboratories (Table 1), whose testing capabilities ensure the performance of tests under the conformity assessment procedures specified in the above-mentioned directives.

Table 1. Accreditation of laboratories and certifying body

	Laboratory of Tests	Laboratory of Applied Tests	Laboratory of Material Engineering and Environment	Division of Attestation Tests, Certifying Body
Management system	PN-EN ISO/IEC 17025:2018-02	PN-EN ISO/IEC 17025:2018-02	PN-EN ISO/IEC 17025:2018-02	PN-EN ISO/IEC 17065:2013-03
Accreditation body	Polish Centre for Accreditation	Polish Centre for Accreditation	Polish Centre for Accreditation	Polish Centre for Accreditation
Accreditation number	AB 039	AB 665	AB 910	AC 023

The competence and practice of the personnel, as well as the infrastructure of the Division of Attestation Tests, Certifying Body allows for additional activities in such areas as a certification of products and quality systems against standards, an assessment of the competence of repair workshops, carrying out technical inspections of products at their work-place, development of technical expert opinions.

3. The activities of the Division of Attestation Tests, Certifying Body

The majority of manufactured products are subject to one or more EU directives containing conditions of placing the products on the market, principles of free trade and a presumption of conformity, conformity assessment procedures, principles of affixing the CE marking, requirements for notified bodies (if such bodies participate in the conformity assessment procedures) and essential safety requirements. Only the products which comply with the essential health and safety requirements, have passed the relevant conformity assessment procedures and are CE-marked may be made available on the EU internal market. In most cases, the conformity assessment procedure(s) is/are carried out by the manufacturer himself. The products which cause the greatest risk are subject to conformity assessment procedures (modules) carried out by the European Commission notified bodies. Such products include the products assessed by the Division of Attestation Tests, Certifying Body, accredited notified body, i.e. equipment and protective systems intended for use in a potentially explosive atmosphere, subject to Directive 2014/34/EU (ATEX), machinery for underground working of the following types: locomotives and brake-vans, hydraulic-powered roof supports, subject to Directive 2006/42/EC (Machinery) and toys, subject to Directive 2009/48/EC (Toys).

The Division of Attestation Tests, Certifying Body, in the framework of its notification, carries out conformity assessment procedures (modules) covering testing and assessment of the product and the quality system applied during its manufacture (Table 2).

Publisher: KOMAG Institute of Mining Technology, Poland

Table 2. Conformity assessment procedures carried out by the Division of Attestation Tests, Certifying Body

Directive	Conformity assessment procedure/module	Document containing the results of product assessment	Document containing the results of the quality system assessment
2006/42/EC	EC type-examination (Module B)	EC type-examination certificate	—
2014/34/EU	EU type-examination (Module B)	EU type-examination certificate	—
	Conformity to type based on internal production control plus supervised product testing (Module C1)	Certificate of conformity	—
	Conformity to type based on quality assurance of the production process (Module D)	—	Notification of quality assurance
	Conformity to type based on product quality assurance (Module E)	—	Notification of quality assurance
	Conformity to type based on product verification (Module F)	Certificate of conformity	—
	Conformity based on unit verification (Module G)	Certificate of conformity	—
	Storage of documentation following Article 13.1(b) (ii) of Directive 2014/34/EU - complement to Module A: Internal production control	Statement of storage	—
2009/48/EC	EC type-examination (Module B)	EC type-examination certificate	—

In addition to the conformity assessment procedures listed in Table 2, the Division of Attestation Tests, Certifying Body carries out other tasks aimed at verifying that a properly identified product, product design or manufacturing process are in compliance with the requirements.

These tasks include:

- issuing opinions on products approved for use in mining plants, such as mining components of shaft hoists (hoisting machines, signalling and shaft communication equipment), slow-speed winches, rope wheels and devices used in underground excavations, in particular rope transport equipment, monorail locomotive, underground funicular railway, passenger carriages, special-purpose carriages, electrical machinery and equipment, switching equipment with a voltage of more than 1 kV AC or more than 1.5 kV DC, communication, safety and alarm systems, and integrated control systems for mining and longwall mining complexes based on Article 113 section 3 of the Act of 9 June 2011 - Geological and mining law, according to document DAC-21 [12] issued by the Polish Centre for Accreditation in cooperation with the State Mining Authority,
- a certification of products under certification programmes 1a, 1b, 3 and 5 described in PN-EN ISO/IEC 17067 Standard within the framework of granted accreditation,
- certification of products according to other programmes, including certification for the registered warranty trademark "B",
- certification of quality management systems according to PN-EN ISO 9001:2015-10 [13],
- an assessment of the ability of workshops to provide overhauls of:
  - powered roof supports and their components based on the Regulation of the Minister of Energy of 23 November 2016 on detailed requirements for the management of underground mining plants [14],

  - machinery and equipment based on own criteria, the fulfilment of which guarantees the conformity of overhauled products with technical documentation and restoration of their performance,
  - explosion-proof equipment based on the criteria specified in the PN-EN 60079-19:2011 Standard [15],
- carrying out technical inspections of the powered roof support sections as part of the assessment of their technical condition after the end of longwall exploitation and before they are built into the next longwall on the basis of the Regulation of the Minister of Energy of 23 November 2016 on detailed requirements for the management of underground mining plants.

4. Conformity assessment in terms of technical safety

The activities of the Division of Attestation Tests, Certifying Body contribute to ensuring technical safety through competent, independent and objective assessment of the conformity of product design with safety requirements at the design and/or manufacturing stage. The assessment, carried out by an independent body, provides objective evidence of conformity of products and processes with the requirements. Certification decisions are made on the basis of tests results from accredited laboratories and inspections as well as audits carried out by competent personnel of the Certifying Body, based on requirements of standards corresponding to the current level of technical knowledge. The assessment of products does not only consist in the verification of constructional characteristics and parameters - the operational manual, given to users together with the product, is also assessed. The content of the operational manual is verified in terms of all the information indispensable for transport, relocation, storage, commissioning, operating, maintenance, decommissioning, disassembly, disposal, as well as emergency procedures, and whether the information clearly identifies the intended use of the product and contains instructions for its correct and safe use; whether it warns of residual risk and hazards associated with prohibited modes of operation. Availability of this information is closely linked to the safe use of products.

5. Summary

For several decades, the KOMAG Institute of Mining Technology has been carrying out activities related to tests and assessments of technical safety of machines and equipment. Current activities of the Certifying Body are carried out on the basis of its own testing facilities, management systems meeting the latest world standards (ISO/IEC series standards) and competent engineering staff. The accreditation of the Polish Centre for Accreditation contributes to the continuous improvement of the product certification programmes and of the management system and it confirms reliability and objectivity of assessment processes. Trust in the activity, carried out by the Certifying Body, is not only a result of the supervision of the national accreditation body but above all, it is a result of technical competence and experience of the staff and ethical principles applied in the Body, confirmed by a strong position of the Certifying Body on the market.

References

[1] Constitution of the Republic of Poland of 2 April 1997 (Journal of Laws of 1997 No. 78, Item 483, of 2001, No. 28, Item 319, of 2006, No. 200, Item 1471, of 2009, No. 114, Item 946).

[2] Figiel A., Tytko A. Monograph of the KOMAG Institute of Mining Technology: System oceny zgodności maszyn i urządzeń górniczych (Conformity assessment of mining machinery and equipment) (2004) 1-135.

[3] Act of 30 August 2002 on the Conformity Assessment System (Journal of Laws of 2019, Item 155).

[4] Act of 13 April 2016 on conformity assessment and market surveillance systems (consolidated text: Journal of Laws of 2019, Item 544).

[5] Act of 12 December 2003 on general product safety (consolidated text: Journal of Laws of 2016, Item 2047).

[6] Act of 9 June 2011 - Geological and Mining Law (Journal of Laws of 2019, Item 868, 1214, 1495).

[7] PN-EN ISO/IEC 17065:2013-03 Conformity assessment. Requirements for bodies certifying products, processes and services.

[8] PN-EN ISO/IEC 17067:2014-01 Conformity assessment. Fundamentals of product certification and guidelines for product certification schemes.

[9] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast), OJ No. L 157, 9 June 2006.

[10] Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast). OJ L 96, 29.3.2014.

[11] Directive 2009/48/EC of the European Parliament and of the Council of 18 June 2009 on the safety of toys. OJ L 170/1, 30.06.2009.

[12] Guidelines DAC-21 Programme for Accreditation of Certification Bodies issuing opinions on products approved for use in mining plants. Issue 1. PCA Warsaw 2014.

[13] PN-EN ISO 9001:2015-10 Quality management systems. Requirements.

[14] PN-EN 60079-19:2019 Explosive atmospheres. Part 19: Equipment repair, overhaul and reclamation.

[15] Regulation of the Minister of Energy of 23 November 2016 on detailed requirements for the management of underground mining plants (Journal of Laws of 2017, Item 1118, Journal of Laws of 2019, Item 1880).

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Innovative Mining Techniques and Technologies - Review of Selected KOMTECH-IMTech 2019 Conference Proceedings – Part 1

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Małgorzata Malec

KOMAG Institute of Mining Technology, Pszczyńska 37, 44-101 Gliwice, Poland

e-mail: mmalec@komag.eu

Keywords: mining, hard coal, mining machines, development

Słowa kluczowe: górnictwo, węgiel kamienny, maszyny górnicze, rozwój

Abstract:

The subject-matter of selected papers, presented at the 20th Jubilee Scientific and Technical Conference KOMTECH-IMTech 2019, are discussed in the article. Special attention is paid to the role of coal in the world and the EU countries. Some information about Mine 4.0 against the characteristic features of Industry 4.0 is given. The article is ended with general conclusions.
Part 1 presents the role of coal in the global economy with special attention being paid to the global energy demand, hard coal production rates, changes in coal demand as well as changes of electric energy sources over the years 2011-2018. A contribution of the KOMAG Institute to development of the Polish mining industry in independent Poland is discussed.

Streszczenie:

W artykule została przedstawiona tematyka wybranych referatów wygłoszonych podczas 20 Jubileuszowej Konferencji Naukowo-Technicznej KOMTECH-IMtech. Szczególną uwagę zwrócono na rolę węgla na świecie oraz w krajach UE. Opisano wkład KOMAG-u w rozwój polskiego górnictwa w niepodległej Polsce. Podano informacje na temat kopalni 4.0 na bazie charakterystycznych cech Przemysłu 4.0. Artykuł został zakończony ogólnymi wnioskami. Część 1 przedstawia znaczenie węgla w światowej gospodarce ze szczególnym uwzględnieniem zapotrzebowania na energię , wielkości produkcji węgla kamiennego, zmian w popycie na węgiel oraz zmian źródeł energii w latach 2011-2018. Omówiono wkład Instytutu KOMAG w rozwój polskiego górnictwa w niepodległej Polsce.

1. Role of coal in the global economy

The role of coal in the world economy with a special emphasis on the role of coal in the EU countries was presented by Janusz Olszowski, President of the Mining Industrial and Trade Chamber. From Fig. 1 it can be clearly seen that the global energy demand increased significantly, in particular over the recent two years.

Publisher: KOMAG Institute of Mining Technology, Poland

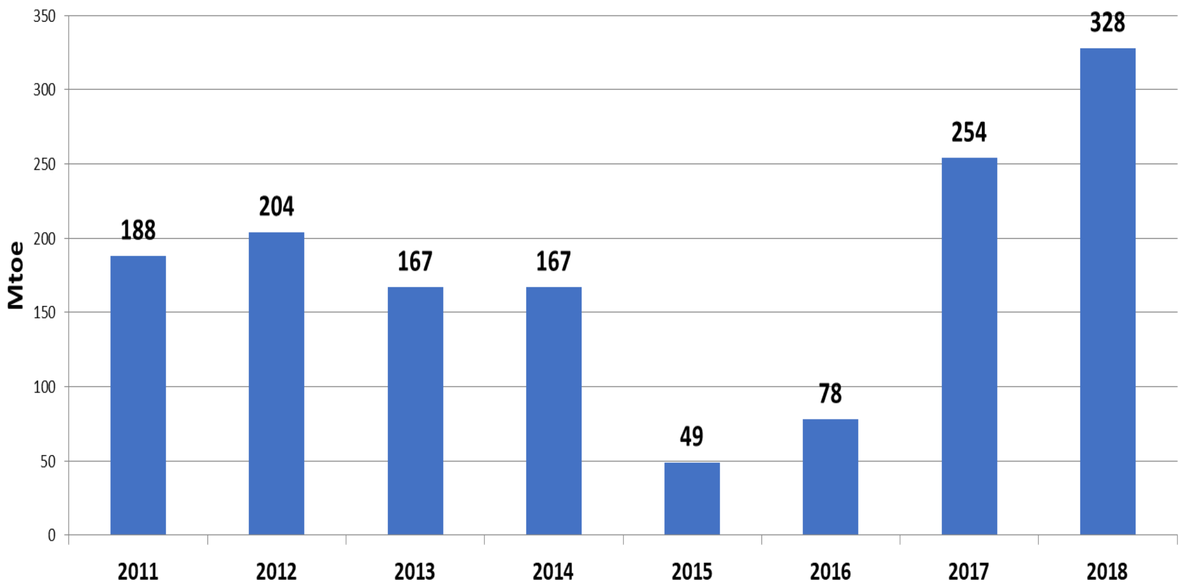


Fig. 1. Global energy demand over the years 2011-2018 [6]

Presenting the role of coal in the global economy, it is worth analyzing a share of different fuels in the world energy mix first of all. The data from the year 2000 and the year 2018 were available, so they were taken for comparison as it is shown in Fig. 2.

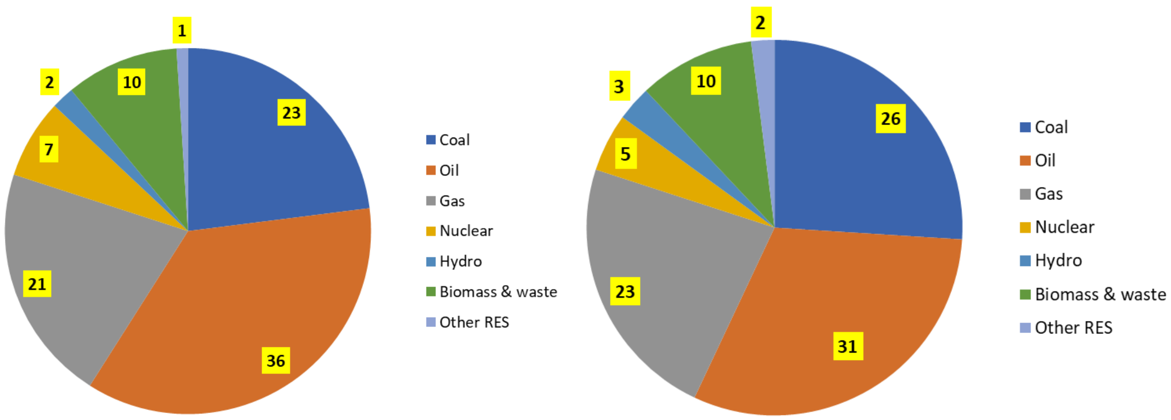


Fig. 2. Share of fuels in the global energy demand in 2000 and 2018 [7]

Bearing in mind the figures, reflecting the global energy demand, the hard coal production rates should be taken into consideration. They seem to be stable over the period under analysis, i.e. the years 2010-2018, as it can be seen in Fig. 3.

Publisher: KOMAG Institute of Mining Technology, Poland

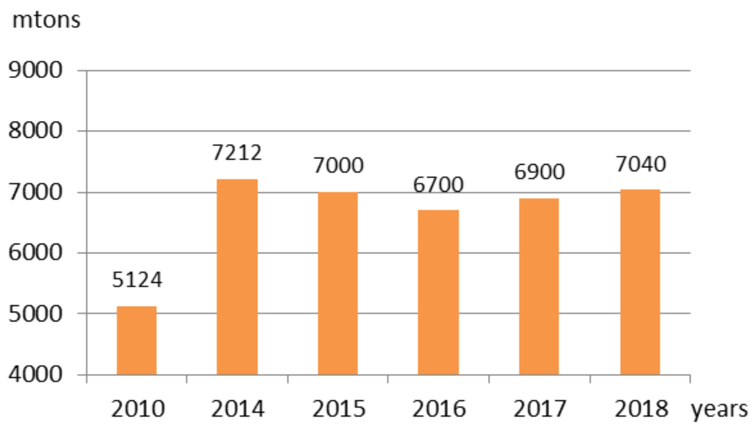


Fig. 3. Global hard coal production rates over the years 2010-2018 [6]

It should be highlighted that the global production rates in 2018 in comparison with 2017 show the increase of 2.5%, i.e. 7.04 billion tons. A significant increase can be seen in China, Indonesia, India and Russia but a decrease occurs in the USA, Columbia, Canada and EU countries. Due to climate changes and anti-coal campaigns the coal demand shows a decreasing trend starting in 2014 as it can be seen in Fig. 4.

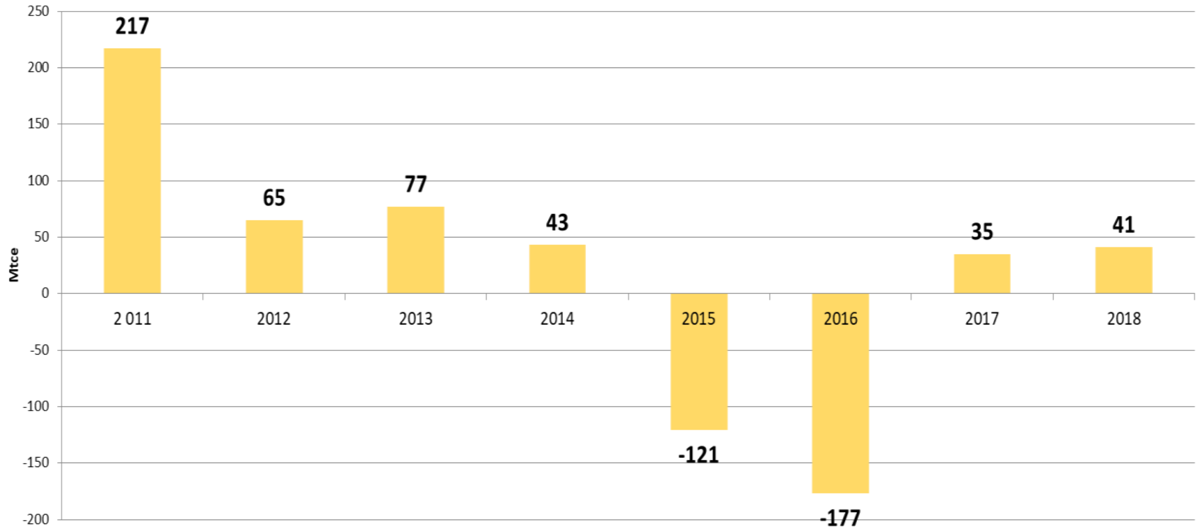


Fig. 4. Changes in coal demand over the years 2011-2018 [6]

In 2018 the production rate of electric energy in the world reached 26615 TWh and it is important to highlight the fact that 64% of electric energy was generated from fossil fuels and 26% - from renewables. However, 23% of energy was generated from gas, 19% - from hydro and others, 10% - from nuclear sources, 7% - from photovoltaics and wind as well as 3% - from oil. As regards the EU countries in 2018 the electric energy production rate reached 3282 TWh. However, 40.5% of electric energy was generated from fossil fuels and 34.3% - from renewables, being more precise 23.8% - from renewables and others, 10.5% - hydro, 25.2% - nuclear sources, 18.9% gas, 20% - coal and 1.6% from oil. These data were published in the BP Statistical Review of World Energy 2019. In Fig. 5 changes of electric energy sources in 2018 against 2017 are shown.

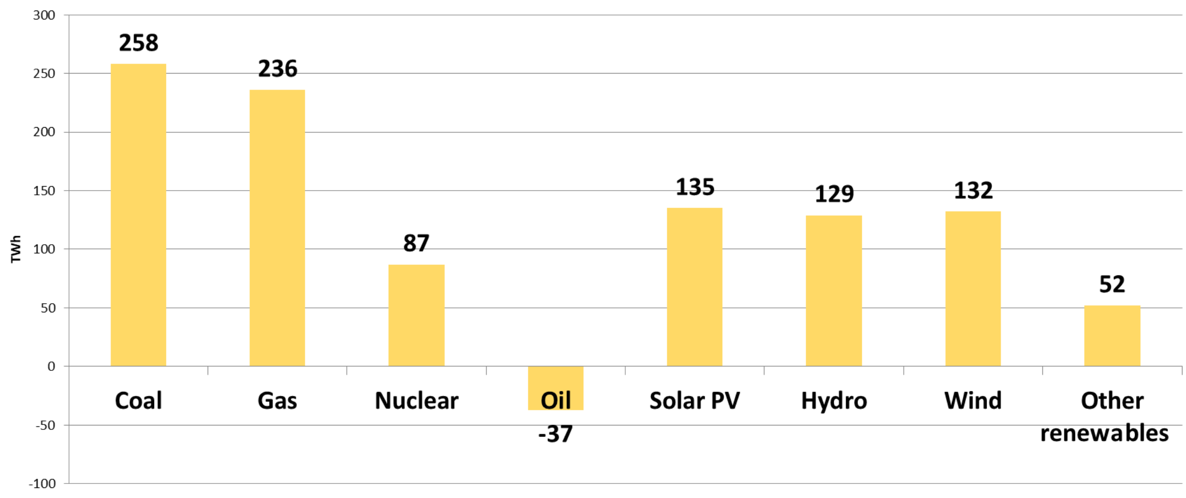


Fig. 5. Changes in electric energy sources in 2018 against 2017 [7]

More detailed conclusions can be drawn after having analyzed the production rates of hard coal and lignite as well as an import in EU countries in 2018 (Fig. 6).

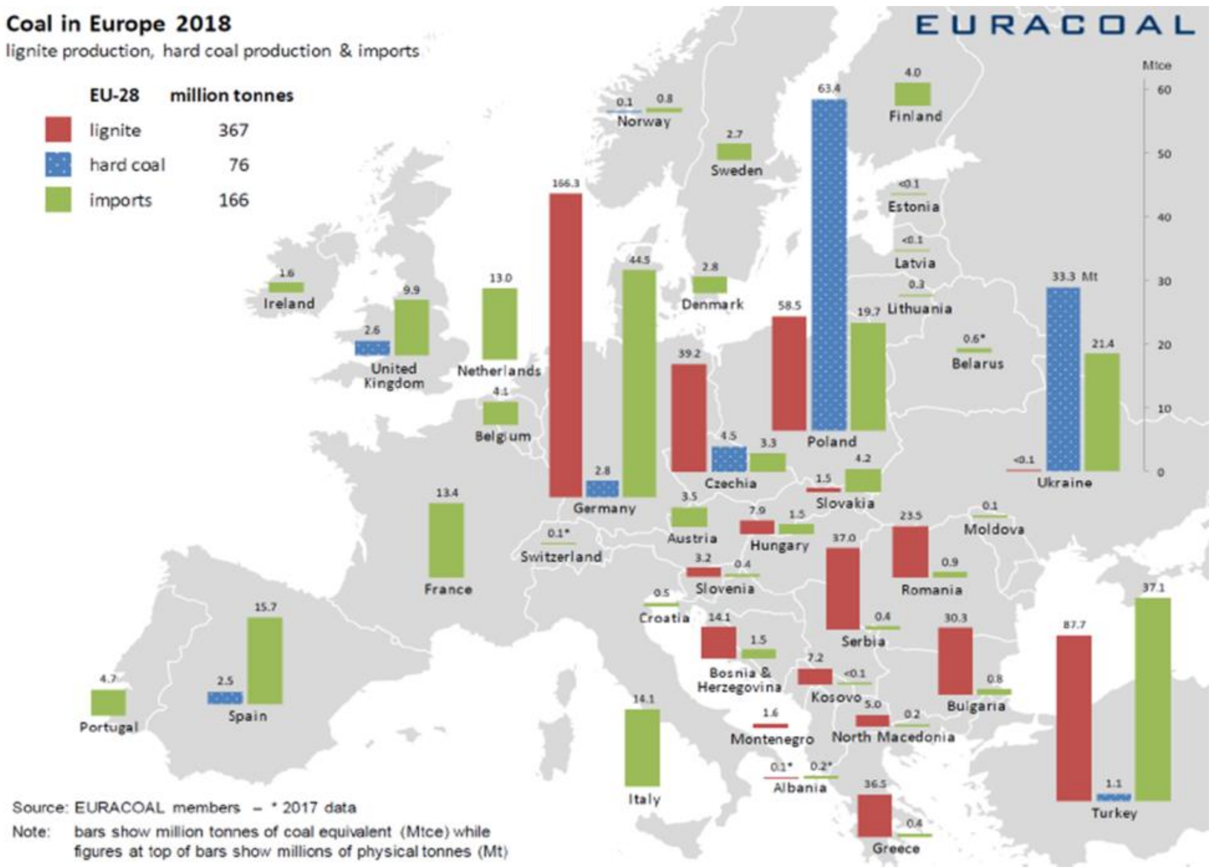
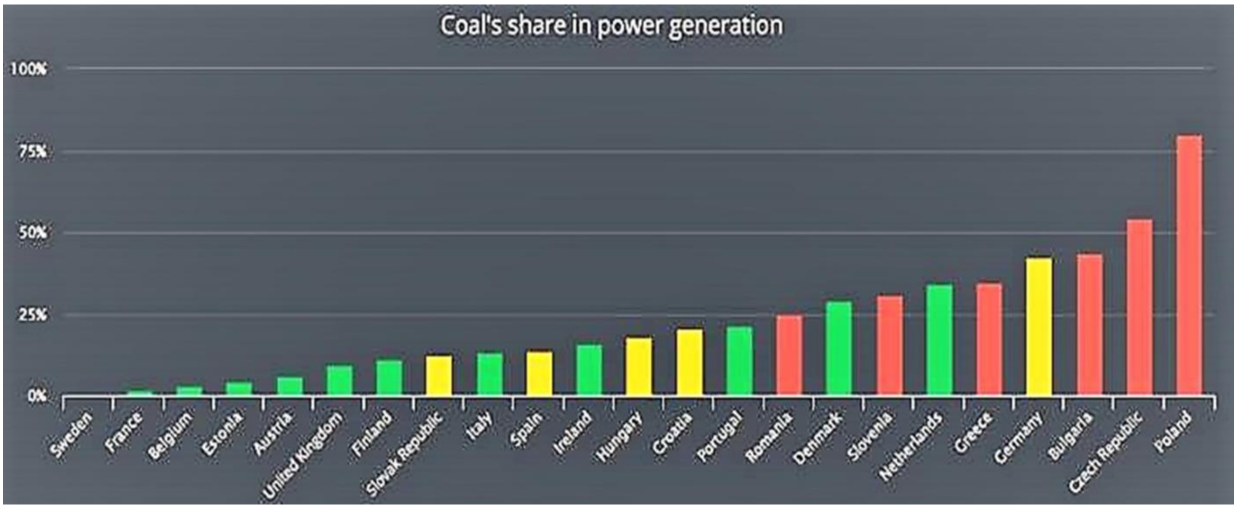


Fig. 6. Coal in Europe in 2018 [8]

Plans for eliminating coal from the energy mix in EU countries are shown in Fig. 7.



Announced elimination of coal Discussions about eliminating coal No discussions about eliminating coal

Fig. 7. Planned eliminations of coal from energy generation processes [6]

According to the latest political announcements till the year 2030 28% of the existing coal-fired power plants will be closed down. Germany intends to reduce the power of coal-fired plants to 17 GW till 2030. The next step will consist of a total elimination of electric energy, generated from coal, till the year 2038. After having analyzed the information, given in Mr. Olszowski's presentation, it should be highlighted that over the years 2000-2018 the global hard coal production increased from 3639 m tons to 7040 m tons. During the same period, electric energy production from coal increased from 1066 TWh to 2024 TWh. Reduced production of coal in the USA and Western Europe was compensated by an increase of coal production in China, India and South-Eastern Asia. In total 40% of the global electric energy is generated from coal.

At present 78 countries use coal for generating electric energy, whereas in 2000 there were only 66 countries. According to the latest information, given by politicians, in the near future 16 countries are going to join the group of coal users for electric energy production. A survey of the present global economy as regards sources of energy and forecasts of coal demand indicate clearly that coal will not be completely eliminated from the energy mix and for many years to come it will be an important source of energy. However, the majority of West European countries plan to eliminate coal as an energy source over the years 2022-2030, except for Germany which plans to achieve that objective in 2038. In the East European countries, the coal demand is on a stable level and most of these countries do not plan to eliminate coal from the energy mix. The countries, which are non-EU members, such as the Balkans and Turkey, plan development of coal-fired power plants.

2. The hard coal mining industry in Silesia, Poland

Tomasz Rogala, President of Polska Grupa Górnicza (PGG), Polish Mining Group and of EURACOAL, the European Association for Coal and Lignite highlights the importance of the coal industry's value chain and progress in clean coal technologies. It is worth mentioning the triangle of values and challenges: technology, society and economy. The problems resulting from the restructuring process of the hard coal mining industry are extremely difficult in Silesia. In 2019 200 thousand jobs in Silesia were related to coal and these jobs paid 50% more than the average salary in the region. 719 million Euros of fiscal payments were transferred to the central government and 181 million Euros per year are spent by the PGG on machines and equipment. An implementation of the carbon capture and storage (CCS) processes gives positive results. The same concerns clean coal technologies (CCT). At present, the PGG is involved in the projects oriented onto coal gasification as an alternative to conventional combustion processes and is, therefore, supporting the EU's circular economy as shown in Fig. 8. presenting Carbon Capture and Utilisation – CCU.

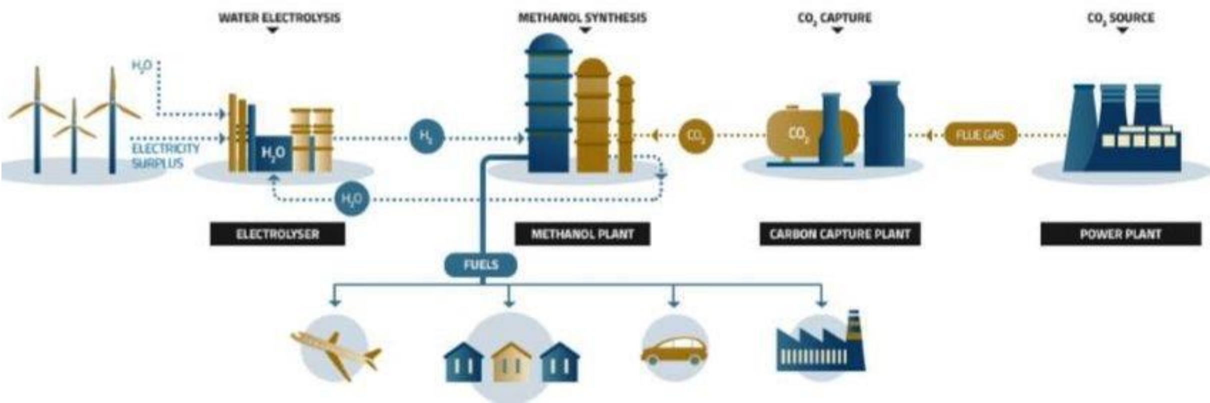


Fig. 8. Circular economy – coal power plant and carbon capture and utilization [9]

The picture of the decarbonisation process in Poland does not seem to be pessimistic. In the year 2000, there were 42 operating coal mines in Silesia, which accounted for 10% GDP. In 2018 20 coal mines were still operating (Fig. 9). As the ultimate goal for all the European regions is to achieve a zero-emission economy by 2050, then a significant number of areas will be abandoned or degraded unless appropriate action is taken. According to Jan Bondaruk, Deputy Director for Environment at the Główny Instytut Górnictwa (GIG), Central Mining Institute, Poland, this process should not be perceived as a disaster but as a chance. Post-mining can be a key economic asset for the circular economy, for geothermal energy from mine water, post-mining infrastructure as well as cultural and leisure services.

Fig. 9. Transition pathway in Silesia, Poland [9]

Researchers have started to promote a smart closure of mines to reuse these newly abandoned areas in the most sustainable way, analyzing different scenarios. The ecosystem restoration seems to be crucial. There is an enormous potential for creating a new value chain, but as it is not yet a mainstream practice, no information is available on the cost-effectiveness of land rehabilitation. However, a realization of several projects confirms efficient and cost-effective restoration processes that respect the ecosystem and biodiversity and directly or indirectly benefit local authorities and society.

3. Technological achievements of the coal sector during 2011-2017 are as follows:

- Automation and digitalization in coal mines (integrated ICT technologies in coal mines, e.g. new sensor technologies, mine power engineering and real-time process reconciliation).
- Health and safety (an implementation of devices for dust control and ventilation-on-demand, gas control and novel rescue devices).
- Protection of the environment (mine water usage, environmental monitoring, land reclamation and restoration).
- Sustainable coal technologies (capturing CO_2, implementation of emission reduction systems – smart control and sensors, co-firing coal with solid waste or biomass).
- Improvement of the coal use (optimized systems for the preparation of coking fuel blends, co-processing and an improvement on catalysts in coal liquefaction, development of novel porous carbon materials).
- Alternative use of coal-security of energy supply (underground coal gasification, production of syngas, simplified gas cleaning, methanol or Fischer-Tropsch-fuels).

4. Coal challenges and recommendations

Presenting the future of the coal sector, it is indispensable to highlight the efforts which should be made to increase social acceptance and awareness of the sector. All the energy-intensive industries agree on the need to further develop clean technologies to reduce their carbon footprint. The push towards technology-intensive mining practice to increase mining stability is specific to the coal sector. Post-mining and land restoration continue to challenge the coal industry. The sector also explores alternative use of coal areas for renewables, while increasing the value of coal products (e.g. gasification and integrated hydrogen production). It should be borne in mind that digitalization and the digital transformation challenge the coal industry and provide an opportunity to improve the sector.

Coal challenges for the next decade include:

- Clean Coal Technologies reducing the carbon footprint.
- Technological leadership towards sustainable mining.
- Alternative use of coal areas for renewables.
- Valorisation of coal products.
- Mine reclamation, land restoration and post-mining activities.
- Digital transformation.
- Workforce development.

The recommendations, suggested by Elisabeth Clausen and Nicholaos Koukouzas who are experts representing the Research Fund for Coal and Steel, are as follows:

- Carbon capture, utilisation and storage (CCUS) in other energy-intensive industries.
- Geothermal, pumped hydroelectric storage, energy storage, photovoltaics, wind.
- Coal gasification, integrated hydrogen production, methanol production.
- New methods and approaches for mine closure, long-term stability and safety.
- Clean coal technologies by automation and digitalization, advanced mining technologies.
- Skills, knowledge management, lifelong learning education, re-employment, social awareness and acceptance.

5. Contribution of KOMAG to development of the Polish mining industry in independent Poland

5.1. KOMAG scope of activity

At present KOMAG Institute of Mining Technology is one of the preferred providers of innovative technologies in the domain of mining machines and equipment for winning and beneficiation of minerals, in particular hard coal. KOMAG specializes in designing, testing, assisting and implementation of highly productive and reliable machines. Its history dates back to 1950. Over the period of nearly seventy years of the activity, it changed its name and organizational scheme several times, but it was always oriented onto designing, testing and implementing mining machines which are operator and environment friendly. Safety, reliability and productivity have always been key drivers of innovative solutions offered to mining machinery producers and end-users in mines. Since 1950 over 1100 technical designs of mining machines and equipment, implemented in Polish and foreign mines, have been developed. An innovative character of technical and technological solutions is confirmed by 4400 patents and utility patents granted to KOMAG over the period of its activity [4].

Describing a contribution of KOMAG to the development of the Polish mining industry in independent Poland, it is indispensable to give some historical facts.

5.2. Historical facts about the Polish hard coal mining industry after regaining independence

In his presentation, Prof. Aleksander Lutyński from the KOMAG Institute of Mining Technology concentrated on the past and present history of the mining industry in Poland. In 1918 there were two industrial regions in Poland. In the result of the plebiscite, Poland obtained 52 hard coal mines. After World War II, based on the Act dated 3rd January 1946 all the mines became state-owned [5]. In 1946 the annual hard coal production rate was 51 m tons, but the top production rate in the amount of 201 m tons was achieved in 1979. Over a period of 100 years of techniques and technologies of winning coal changed. These changes concerned exploitation systems, cutting methods, run-of-mine haulage and transportation of men and materials as well as beneficiation processes. In 1950 longwall, contour, deep-web shearers were introduced. At the end of 1957, the first shallow web shearer better suited to Polish coals was applied. In 1970 529 longwall shearers were in operation in the Polish mines. Simultaneously manual loading of the run-of-mine was replaced by mechanical loading [6]. In 1969 79% of the run-of-mine in longwall faces were loaded mechanically, but in roadways – only 28%. In the following years, loaders which eliminated manual loading of the run-of-mine were implemented. In 1946 90% of workings were supported with wooden supports, but in 1970 – 70% of workings were equipped with steel supports, in total 3000 longwall roof support units. Two mechanized longwall systems were in operation: ASI and BESTA, composed of powered roof supports, longwall shearers, scraper conveyors, supply power packs, signalling equipment and remote control systems. Further development of machines and equipment caused the implementation of full mechanization of coal exploitation processes, including loading as well as horizontal and vertical transportation. During the between-the-wars period, mechanical preparation of the run-of-mine was used on a large scale. In general, 80% of the run-of-mine was subject to separation according to the grain sizes in sorting plants [2]. Within the years 1946-1964 21 sorting plants, 19 washeries, 3 pneumatic separation plants and 6 flotation departments were constructed and 3 sorting plants, 4 washeries and 1 flotation department were developed. In 1963 130.7 m tons of the run-of-mine was produced and about 93% of it was subject to beneficiation processes [1, 3]. Activities oriented onto an improvement of productivity were accompanied by the activities oriented onto an improvement of miners' work safety. In 1997 66 preparation plants beneficiated coal from 57 mines. At present 40 preparation plants are in operation in 18 hard coal mines [5]. A radical improvement was confirmed by fatal accidents coefficient for a million tons of mined coal. In 1946 570 miners lost their lives, whereas in 2018 – 0.24.

6. Conclusions

- Presenting the role of coal in the global economy, it is worth analyzing a share of different fuels in the world energy mix – in 2018 26% of energy was generated from coal.
- In 2018 a significant increase in coal production rates can be seen in China, Indonesia, India and Russia but in the USA, Columbia, Canada and EU countries a decrease occurred.
- Analyzing the role of coal in the Polish economy, the whole value chain should be taken into consideration as well as the triangle of values and challenges: technology, society and economy.
- Technological achievements of the coal sector are oriented onto automation and digitalisation, health and safety, protection of the environment, sustainable coal technologies, improvement of the coal use and alternative use of coal in the aspect of energy supply.
- The ecosystem restoration seems to be crucial in the process of smart closure of mines.
- KOMAG had a fundamental impact on the development of the Polish mining industry in independent Poland.
- An implementation of the state-of-the-art mining machines and equipment, designed at KOMAG, enabled the Polish mining industry to be the world leader of the coal production rates.

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A new design solution for reducing the impact of transported rock on belt conveyors in mining

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Horst Gondek[1], Jiří Pokorný[2], Daniel Boháč[3], Jiří Kolman[4]

[1] Vysoká škola báňská – TU Ostrava, Třída 17. listopadu 15, 708 32 Ostrava-Poruba, Česká republika
e-mail: horst.gondek@vsb.cz
[2] Vysoká škola báňská – TU Ostrava, Třída 17. listopadu 15, 708 32 Ostrava-Poruba, Česká republika
e-mail: jiri.Pokorny@vsb.cz
[3] DvB-AF,s.r.o.,Meleček 227,Žimrovice, 747 41 Hradec nad Moravici, Česká republika
[4] Severočeské doly, a.s. Doly Bílina, Důlní ul. 375/89, 418 29 Bílina, Česká republika
email: kolmanj@sdas.cz

Keywords: belt conveyor, conveyor belt, impact stool, impact stool dynamics, damping coefficient

Słowa kluczowe: przenośnik taśmowy, taśma przenośnika, stół impaktowy, stół uderzeniowy, współczynnik tłumienia

Abstract:

As we are increasingly focusing on the economy of mining, researchers are constantly trying to find new technologies to improve existing machines to be more efficient and less perishable. Such actions allow mining companies to save money in all of the mining processes. The authors focused on the transport of materials and how to improve it. The most frequent problems in this matter are caused by the destruction of conveyor belts. The cost of repairs is estimated at about half a billion crowns in the Czech Republic. That is why engineers are working on reduction of the rock impact force on the conveyor belt. The paper deals with the issue of reducing the passage of conveyor belts by proposing a new solution to the impact stand, which will considerably reduce the number of conveyor belt breaks.

Streszczenie:

Zwracając uwagę na ekonomikę wydobycia, nieustannie trwają badania poszukujące nowych technologii ulepszających istniejące maszyny i urządzenia, by były one bardziej wydajne i mniej wadliwe. Takie działania pozwalają firmom górniczym oszczędzać pieniądze we wszystkich procesach wydobywczych. Autorzy skupili się na transporcie materiałów i tym, jak go poprawić. Najczęstsze problemy w tej kwestii są spowodowane zniszczeniem taśm przenośnikowych. W Czechach koszt napraw szacowany jest na około pół miliarda koron rocznie. Dlatego inżynierowie pracują nad zmniejszeniem siły uderzenia skały w taśmę przenośnika. W artykule poruszono kwestię zmniejszenia awaryjności taśm przenośnikowych w miejscu przesypu, proponując nowe rozwiązanie stołu udarowego pochłaniającego energię uderzenia, który znacznie zmniejszy liczbę zerwań taśmy przenośnikowej.

1. Introduction

From the results of the measurements [1, 2, 3, 4] and the verification of the dynamics of impact bed with impact bars follow the result that for the further improvement of the impact bed must be rearranged at least one supporting element and on the frame stand of the impact bed must be assigned at least one connection piece which one end is connected to the support part by the holder and the other end is movably connected to the frame stand of the impact bar. This increases the efficiency of the impact bar and at the same time converts the impact bed construction into multiple springing with an effort to achieve a flexible attachment at all points of the fixed attachment parts of impact bed, including the attachment itself to the conveyor frame. This solution is illustrated in fig.1, 2, 3 and 4.

2. Description of a proposed impact bed

The new impact bed [4] is composed of an impact bed frame containing a vertical, to the belt movement cross-established frame stands which contain a device for flexible attachment to the belt conveyor frame. Stands are set approximately upwardly in the form of an open gutter which concave side contains a plurality of support parts. There is at least one flexible bar attached to each support part. The improvement is based on the fact that between at least one supporting part and the impact bed frame stand is associated a minimum of one connecting part, the first end of which is secured by the holder of the support part to the support part and the second part, which is opposite to the first end of the fastener part, is movably attached to the frame stand of the impact bed. The second part of the fastener part is then movably connected to the stand through with it connected top plate and bottom plate, which are positioned one above the other with a gap and at the same time, the connecting part is connected through holes in the upper and lower plates of the stand. To the first end of connecting part is assigned at least one (first) springing tool which is set up so it is in touch with firstly its adjacent side with an inner surface of support frame holder and secondly its opposite side with the top surface of support frame top desk. To the second end of connecting part is assigned at least one (second) springing tool which is set up so it is in touch firstly its adjacent side with supporting surface second end of connecting part and secondly its opposite side with a lower surface of impact bed support frame´s lower desk. The connecting piece is connected to the support part so, between the inner surface of the holder, at least one first springing tool and the upper surface of impact bed support frame´s upper desk and also between supporting surface of the second end of connecting part, at least one-second springing tool and the lower surface of impact bed support frame´s lower desk is created connection with preload.

In the new design is a support frame of impact bed formed by two sidewalls which are established parallelly beside each other with a gap which allows established connecting part between sidewalls. To the stable securing of support parts establishing, carrying impact bars, are sidewalls of the support frame in a perpendicular direction to the upper desk mounted with a group of cross members whose number is one more than several assigned support pieces.

Each support piece is established in the area between two cross members. For the secure possibility of linear sliding movement of support piece in the area between two cross members there and back, is the inner distance between two beside cross members minimum or more than is the width of support piece in its cross-section. Frame stand construction´s stiffness is preferably secured by that both sidewalls, upper desk of frame stand, lower desk of frame stand and the cross beams are together connected, so they form welding piece. For the right function of an impact, the bed is also advantageous when the holes in the upper frame stand desk and the lower frame stand desk between two sidewalls are situated in one axis above each other.

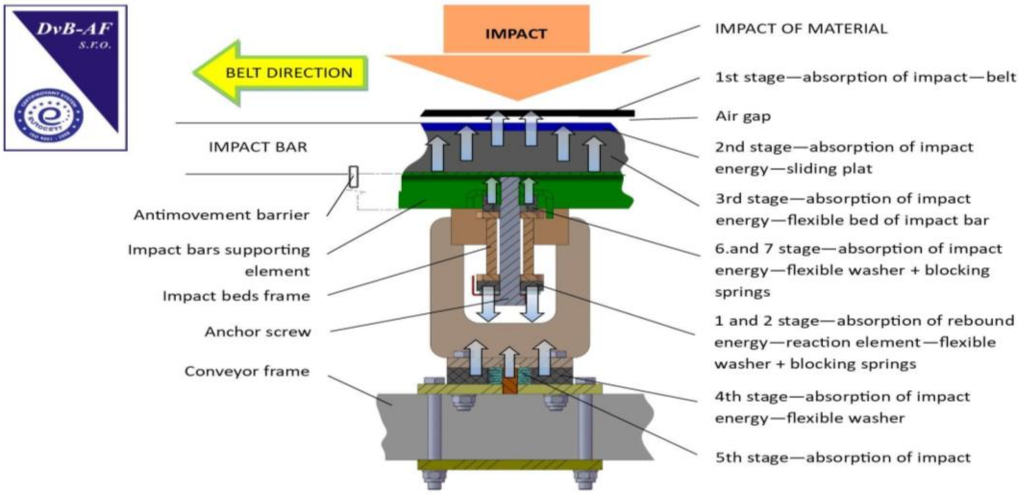

Fig. 1. Force load scheme acting on the impact bed [1]

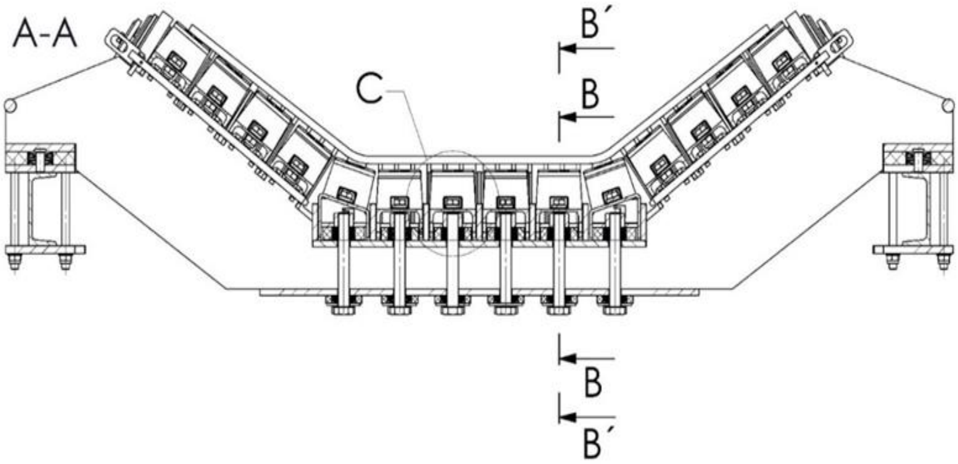

Fig. 2. Cut of impact bed [4]

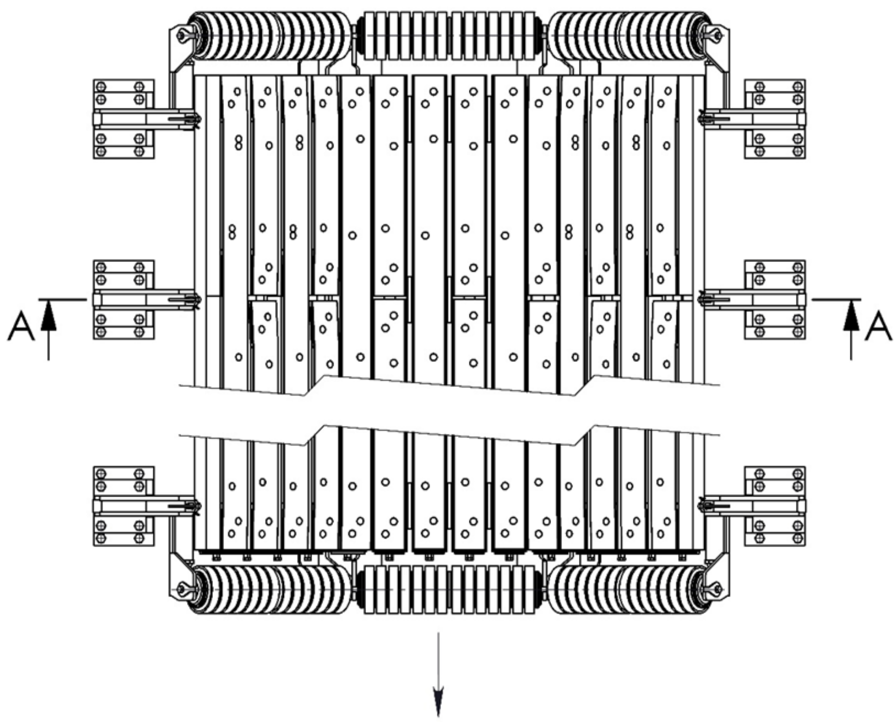

Fig. 3. Ground plan of impact bed [4]

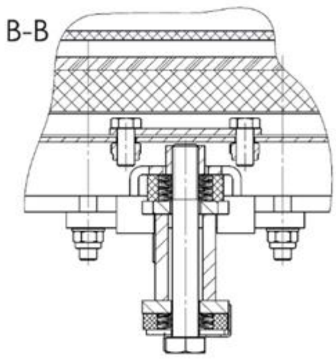

Fig. 4. Cut of impact bed ´s absorbing part [4]

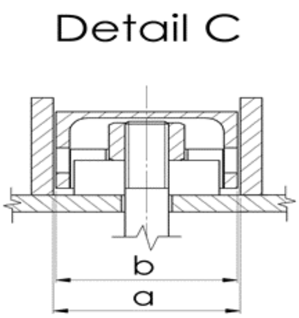

Fig. 5. Cut of holder [4]

3. Determination of the damping coefficient of absorbing block

As it can be seen from the theory of material impact on the impacted place, for determining of damping force the damping coefficient is deciding [2]. This coefficient shows us the size of damping for impact bed. For a quality appraisal of the impact bed, it is necessary to decide this figure.

3.1. Measuring of damping coefficient on impact bed absorber [2]

The proposed procedure for determining the damping coefficient is based on the deformation of the block of material induced by the fall of the weights (fig. 6). The block is connected on the bottom side with a massive base plate and on the top side is connected with the desk where the weights fall. The weight of the desk is smaller than the weight of the weights.

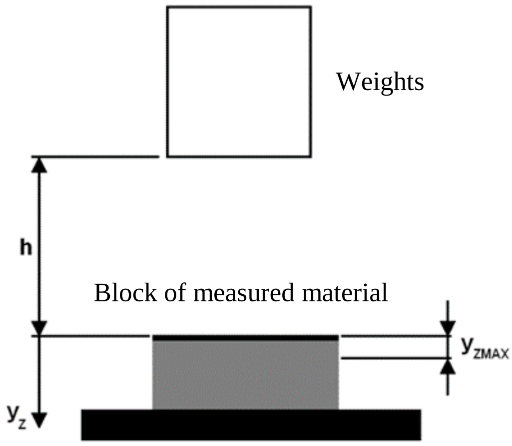

Fig. 6. *Scheme of measuring systems*

After falling off the weights from known heights the measured block will be pressed. When will be the maximum deformation is reached the deformation stops and then the weights will go up. If we know the stiffness of the material of the block, the damping parameters (coefficient of linear damping, coefficient of viscous damping) will be given from measuring of geometric variable: the start height of weights above the desk and maximum compression of the block.

In the phase of material compression the movement of the weight is described by motion equation:

$$(m_z + m_M) \cdot \ddot{y}_z + b_M \cdot \dot{y}_z + k_M \cdot y_z = (m_z + m_M) \cdot g \tag{1}$$

m_z is the weight of weights, m_M is the weight of the measured block, b_M is coefficient of material linear damping, k_M is stiffness, g is gravitational acceleration, y_z is a shift of the weights (compression of a block) and ($\dot{y}_z$), ($\ddot{y}_z$) means the first and the second derivative.

The solution of the motion equation (1) in prerequisite under critical damping is:

$$y_z = C_1 \cdot e^{-\delta t} \cdot \sin(\Omega_t \cdot t + C_2) + y_G \tag{2}$$

C_1, C_2 are integration constants, δ is subsided coefficient, Ω_t is own circular frequency of subdued oscillation, t is time and y_G is particular integral. It can be set an estimate by the form of the right side of the motion equation (1):

$$y_G = \frac{(m_Z + m_M) \cdot g}{k_M} \tag{3}$$

For own circular frequency of subdued oscillation is:

$$\Omega_t = \sqrt{\Omega^2 - \delta^2} \tag{4}$$

where Ω is own circular frequency of unsubdued oscillation of the system

$$\Omega^2 = \frac{k_M}{m_Z + m_M} \tag{5}$$

A relation for movement speed of the weights is set by a derivative of relationship (2) for deviation by time

$$\dot{y}_Z = -\delta \cdot C_1 \cdot e^{-\delta t} \cdot \sin(\Omega_t \cdot t + C_2) + C_1 \cdot \Omega_t \cdot e^{-\delta t} \cdot \cos(\Omega_t \cdot t + C_2) \tag{6}$$

Integration constants C_1, C_2, coefficient of desaturation δ and stopping time of the movement is set from additional conditions:

$$y_Z(0) = 0 \tag{7}$$

$$\dot{y}_Z(0) = v_0 \tag{8}$$

$$y_Z(t_Z) = y_{ZMAX} \tag{9}$$

$$\dot{y}_Z(t_Z) = 0 \tag{10}$$

v_0 is impact speed of the weights to the block of measured material, y_{ZMAX} marks its maximum compression.

After being put into relationships (6) – (9) to (2) and (5) is obtained set of four non-linear algebraic equations, where the unknowns are C_1, C_2, δ and t_Z

$$C_1 \cdot \sin(C_2) + y_G = 0 \tag{11}$$

$$-\delta \cdot C_1 \cdot \sin(C_2) + C_1 \cdot \Omega_t \cdot \cos(C_2) = v_0 \tag{12}$$

$$C_1 \cdot e^{-\delta t_Z} \cdot \sin(\Omega_t \cdot t_Z + C_2) + y_G = y_{ZMAX} \tag{13}$$

$$-\delta \cdot \sin(\Omega_t \cdot t_Z + C_2) + \Omega_t \cdot \cos(\Omega_t \cdot t + C_2) = 0 \tag{14}$$

Impact speed of the weights to the block of measured material from the height h in the absence of air resistance is given by the relationship:

$$v_0 = \sqrt{2\, g \cdot h} \tag{15}$$

For the coefficient of viscous damping η_V and the linear damping factor are valid

$$\eta_V = \frac{2 \cdot (m_Z + m_M) \cdot \delta}{k_M} \tag{16}$$

$$b_M = \eta_v \cdot k_M \tag{17}$$

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Block stiffness of measured material is determined from the measurement of its deformation with known weight, for example under a load of own weights which are placed on it:

$$k_M = \frac{m_Z \cdot g}{\Delta_G} \tag{18}$$

The damping viscosity coefficient is then determined from measuring the impact height of the weights *h* and the maximum compression of the block of the measured material y_{ZMAX}

The solution of the motion equation (3.1) assuming supercritical damping has the form

$$y_Z = C_3 \cdot e^{\lambda_1 t} + C_4 \cdot e^{\lambda_2 t} + y_G \tag{19}$$

where C_3, C_4 are integration constants and λ_1, λ_2 are roots of the characteristic equation

$$\lambda_1 = -\delta - \sqrt{\delta^2 - \Omega^2} \tag{20}$$

$$\lambda_2 = -\delta + \sqrt{\delta^2 - \Omega^2} \tag{21}$$

y_G is the particular integral estimated by the shape of the right-hand side of the motion equation (3.3)

The equation for the speed of movement of the weight is determined by the derivative of the equation (3.19) for deviation by time

$$\dot{y}_Z = \lambda_1 \cdot C_3 \cdot e^{\lambda_1 t} + \lambda_2 \cdot C_4 \cdot e^{\lambda_2 t} \tag{22}$$

The integration constants C_3, C_4, the decay coefficient δ and the stopping time of the weight shall be determined from the additional conditions (7) - (10). Substituting them into formulas (21) and (22), a set of four non-linear algebraic equations is obtained, where they are unknown with respect to (20) and (21) C_3, C_4, δ and t_Z.

$$C_3 + C_4 + y_G = 0 \tag{23}$$

$$\lambda_1 \cdot C_3 + \lambda_2 \cdot C_4 = v_0 \tag{24}$$

$$C_3 \cdot e^{\lambda_1 t_Z} + C_4 \cdot e^{\lambda_2 t_Z} + y_G = y_{ZMAX} \tag{25}$$

$$\lambda_1 \cdot C_3 \cdot e^{\lambda_1 t_Z} + \lambda_2 \cdot C_4 \cdot e^{\lambda_2 t_Z} = 0 \tag{26}$$

The speed of impact of the weight on the measured block is given by (15). The viscosity damping coefficient η_V and the linear damping coefficient b_M are then determined from formulas (16) and (17).

The viscosity damping coefficient is in both cases calculated from the measurement of the height of the weight h and the maximum compression of the y_{ZMAX} material block. For damping to be subcritical (weak), it must apply:

$$\delta < \Omega \tag{27}$$

For supercritical (strong) damping is valid

$$\delta < \Omega \tag{28}$$

4. Conclusion

Problems of mathematical modelling of rock impact on the conveyor belt, are not a simple matter at all. Here we have to make a certain simplification because the issue of dynamics is very complicated and practically we are not able to include all the factors influencing the excited oscillation in the calculations. It is also very problematic to determine the correct modulus of the conveyor belt elasticity, the coefficient of viscous damping of the belt material and other factors. Also, the measurement problem of the impact bed shock absorber coefficient is not as simple as expected, and despite the utmost effort to achieve accurate results, it has not been succeeded. On the other hand, in cooperation with other experts, we measured the impact bed vibration, both on an excavator with a classic impact spot with garlands and a new solution with impact bed with impact bars. Even here we have some things that are directly related to practice. Further progress should go through the improvement of impact silencer even though there have been no defects in this part of the device during the two-year operation. The research should also continue to reduce the weight of the impact bed and by the construction solution of the newly designed absorbing parts.

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Analysis of effort of lifting eye fixation in the tilt cylinder in the powered roof support's gob shield

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Marek Jaszczuk[1], Józef Markowicz[1], Stanisław Szweda[2a]

[1] Silesian University of Technology**,** Faculty of Mining, Safety Engineering and Industrial Automation, Akademicka 2A, 44-100 Gliwice, Poland
[2] KOMAG Institute of Mining Technology, Pszczyńska 37, 44-101 Gliwice, Poland

[a] e-mail: : sszweda@komag.eu

Keywords: gob shield, damage, FEM (Finite Element Method) model

Słowa kluczowe: osłona odzawałowa, uszkodzenie, model MES (Metoda Elementu Skończonego**)**

Abstract:

Cases of damage to the lifting eye fixation in the tilt cylinder of a gob shield during operation of powered roof support is discussed. Using the FEM model of the gob shield, the lifting eyestrain was assessed, both in conditions of the discussed longwall panel as well as in the most adverse load. The probable cause of the damage has been determined as well as a suggestion to modify the design of lifting eye fixation in the tilt cylinder is analysed.

Streszczenie:

Omówiono przypadki uszkodzenia mocowania ucha podpory stropnicy w osłonie odzawałowej, powstałe w trakcie użytkowania sekcji. Korzystając z modelu MES osłony oceniono wytężenie ucha, zarówno w warunkach rozpatrywanego wyrobiska ścianowego, jak również przy najbardziej niekorzystnym przypadku obciążenia. Określono przypuszczalną przyczynę powstałych uszkodzeń oraz przeanalizowano propozycję modyfikacji postaci konstrukcyjnej mocowania ucha podpory stropnicy.

1. Introduction

Powered roof support are assumed to be the machines having a significant impact on safety of workplaces and technological processes in the mine longwall panel [3]. That is why their use in a longwall panel is conditioned by meeting the safety requirements provided in the harmonized standard [8]. Powered roof support designing processes and its proper selection to local mining and geological conditions require determination of static and dynamic loads acting on the roof support[1, 4, 9, 10]). In the case of already used roof supports, the operational parameters and technical conditions are assessed [7]. Before another use of powered roof supports in the longwall panel, their technical condition is inspected and assessed [2, 11]. However, despite the above-mentioned procedures there are some incidents of damages to the roof support components.

Analysis of effort of the lifting eye fixation in the tilt cylinder of a gob shield in the aspect of reported accidents of its damage as well as suggested changes to design of its fixation in a gob shield within the range of installation height from 1.4 m to 3.2 m, is the paper subject. Positive results of testing the powered roof supports means that they meet all standard requirements. The reported incidents of damages to welds connecting the tilt cylinder'slifting eye with the gob shield sheeting forced both roof supports users and manufacturers to undertake actions aiming at determination the damages reasons and elimination of future damages to the lifting eye fixation in the tilt cylinder of a gob shield.

2. Analysis of damages to the lifting eye fixation unit in the tilt cylinder of a gob shield

The discussed damages to welds connecting the tilt cylinder's lifting eye with the gob shield sheeting were reported at the beginning of the longwall panel of symbol B. A set of 156 line roof supports and 6 end supports made a longwall supporting system.

Longwall of length 250 m was located at depth 1035 ÷ 1065 m. Seam thickness, depending on number and thickness of interlayers and degree of seam erosion and change in the range from 1.7 m to 2.9m, while at the longwall panel beginning it was 2.5 m. Due to natural hazards, the seam in "B" longwall panel was classified to:

- I degree of water hazard,
- class B of coal dust explosion hazard,
- IV category of methane hazard,
- Partly to the category of coal and rocks burst hazard.

Already at the second week of longwall mining, damage to the gob shields in two roof supports were reported. After a month damages to the welds connecting the eye system of the tilt cylinder with a gob shield sheathing sheet were found in the next four roof supports. The damaged welds were marked. Based on a visual inspections it was found that length of damaged welds did not change. Sample weld damages are presented in Fig. 1 and 2.

Fig. 1. Damages to the welds connecting the lifting eye system of the tilt cylinder with a gob shield sheathing sheet [12]

Fig. 2. Damaged welds in the gob shield of roof support No. 135[12]

Damaged gob shields were successively replaced and inspected to check condition of welds connecting the lifting eye attachment of the tilt cylinder with top plate (Fig. 3). It was found that all welds were made in accordance with the documentation.

Analysing the nature of the sheathing sheet and tilt cylinder's lifting eye's welds deformation, it can be concluded that they were caused by the force of pressure in the under-piston area of the tilt cylinder. In this case the tilt cylinder is compressed.

For a longwall height of 2.50 m, the roof support convergence results in an increase in the length of the tilt cylinder. For example, reducing the height of the roof support from 2.50 m to 2.46 m results in an extension of the tilt cylinder from 1140 mm to 1147 mm. In this case, the cylinder is stretched. It means that the observed damages did not happen during the realization of the roof support basic function related to taking over the load caused by the pressure of floor rocks. During typical manoeuvring of the roof support, the piston area of the tilt cylinder may be an active space, but then the pressure in this area is equal to the supply pressure.

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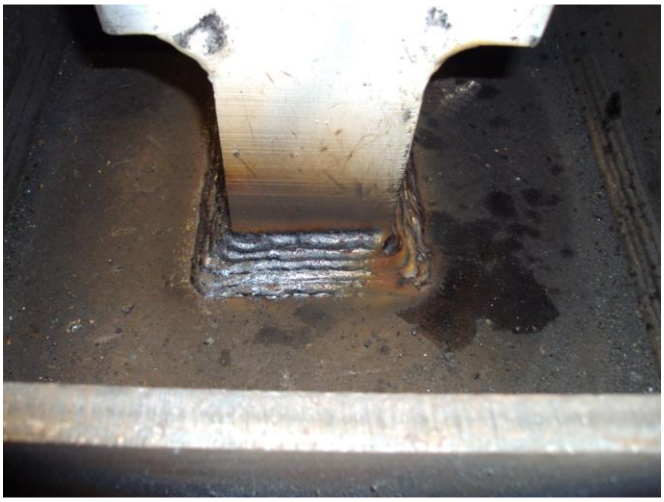

Fig. 3. Weld connecting the base of tilt cylinder's lifting eye fixation system with a gob shield top plate [12]

Theoretically, during the implementation of non-standard auxiliary functions of roof supports, it is possible to create operating pressure in the under-piston area of the tilt cylinder. Therefore, it is necessary to check the effort of fixation of the tilt cylinder's lifting eye in the case when this cylinder is stretched by a force of 703.7 kN, resulting from the working pressure in the under-piston area.

3. Determination of the effort of the tilt cylinder's lifting eye system at the load as in the real operational conditions

In cooperation with KOPEX Group factories, effort and deformation of lifting eye system in the tilt cylinder of the powered roof support were calculated using the FEM method.

The geometric model of the gob shield, for which numerical simulations were performed, is presented in Fig. 4. The assumed finite elements mesh, consisting of 237224 knots and 53 539 elements, was densified in the area covering the tilt cylinder's lifting eyes as well as in the metal sheets for attaching this lifting eye to the other components of the gob shield.

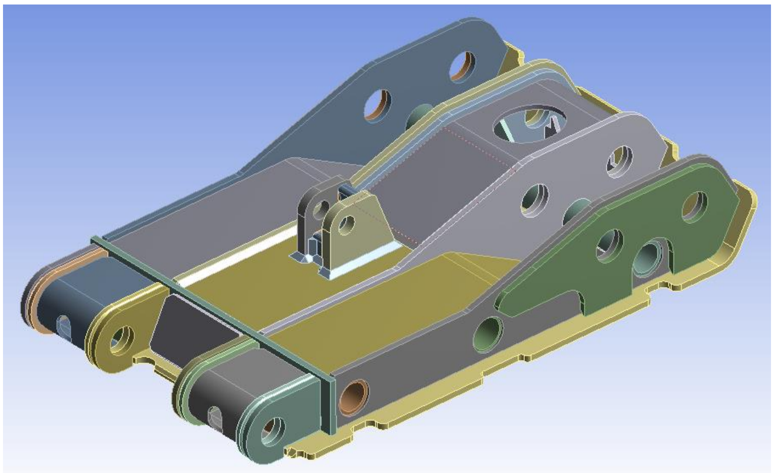

Fig. 4. Geometric model used in numerical simulations[6].

Elastic-plastic material characteristics with linear strengthening was assumed in numerical calculations (Fig. 5). The following material properties were applied in the model:

- Young modulus - $2\ 10^5$ MPa
- Poisson number – 0.3
- flow stress Re = 400 MPa
- strengthening module - $2\ 10^3$ MPa.

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The purpose of the numerical simulations was to assess the impact of force in the tilt cylinder on lifting eyeeffort. Therefore, the strain on the sheathing caused by the forces in the rotational pairs connecting it with other roof support components was treated as a "zero" reference level when assessing the impact of force in the tilt cylinder on the change in strain of the system for fixation of lifting eye to the gob shield.

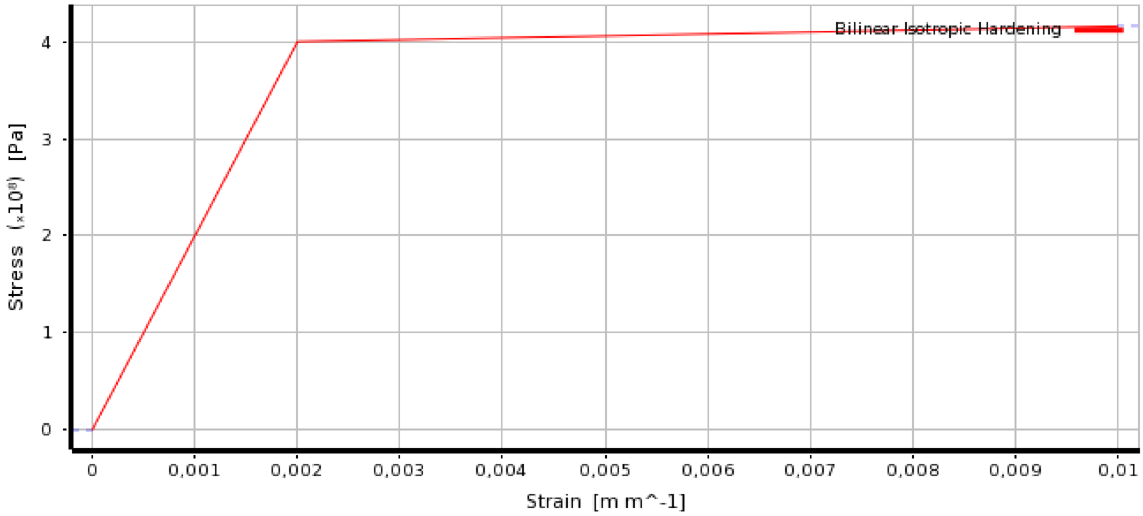

Fig. 5. Elastic-plastic characteristic of the material [6]

Supporting method and load to the gob shield is presented in Fig. 6.

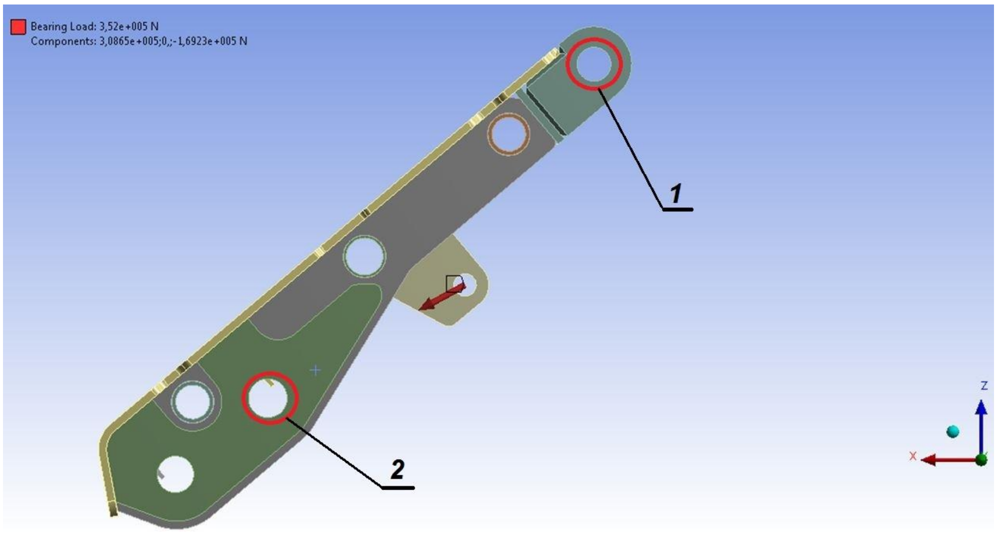

Fig. 6. Supporting method and load to the gob shield [6].

Cylindrical support was applied in eyes of the hinges connecting the gob shield with the canopy (point 1 Fig. 6) to enable rotation of the gob shield around hinges axles and in the eyes of hinges connecting the gob shield with the front links (point 2 Fig. 6), the cylindrical support with a possibility of gob shield rotation around the hinges and moving along the hinges was used.

Using the computer program OStO v.4.0 for analysis of static load to the powered roof support [5], the angle between the tilt cylinder axis and surface of the gob shield top sheet, at height 2.5 m, equal to $11.5^0$was determined, so it was possible to settle the resultant force components during feeding the under-piston area of the tilt cylinder. In the global coordinates system given in Fig. 6, at the resultant force in the tilt cylinder equal to 703,7 kN, the force acting on each eye of the tilt cylinder has the following components:

$$F_x = 308.649 \text{ kN} \qquad F_y = 0 \qquad F_z = -169.233 \text{ kN}$$

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In Fig. 7 distribution of the equivalent stress on the deformed model the eye and base is presented. The scale of the equivalent stresses was set in such a way that places in which the equivalent stress is higher than the yield point are marked in red.

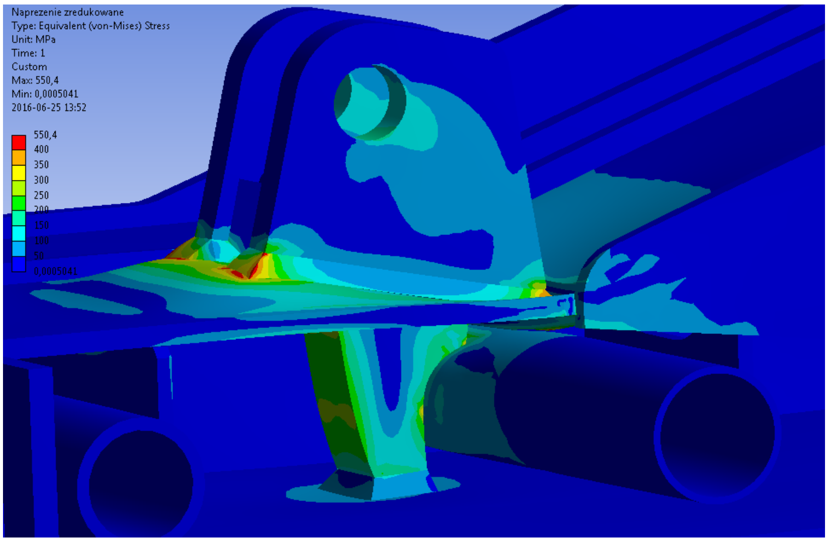

Fig. 7. Distribution of equivalent stress of the deformed model [6]

The analysis of the obtained results showed that there are local concentrations of equivalent stress, especially in the elements that model the welds as well as at the point between the welds and the sheathing sheets. To some extent, the local build-up of stress above the yield point results from the specificity of the calculation method used. Simplification of the geometric form of welds (no rounding radius when passing from one plane of the weld to another) resulted in creation of edges that are not present in the real object, which generates additional stress build-up in the vicinity of the edges.

The maximum equivalent stress in the base is lower than the stress at the yield point. It was also found that the equivalent stress is lower than the yield point, except for the weld edges and the edge of the weld transitions into the material of joined sheets.

Local equivalent stress above the yield point, and the associated permanent deformation, can cause cracks in the case of periodically variable loads and a high number of load cycles. Hence, Fig. 8 presents a distribution map of the highest main stress. The fatigue process is initiated in areas where the value of such stress is the highest.

To summarise the discussion concerning the analysis of stress and deformation in the eye of the tilt cylinder fixation system, it was found that under the conditions of roof support operation in Longwall B, local permanent deformation may appear. Due to the fact that they can occur in a small area, they should not lead to a deterioration of the roof support's functionality as a result of collision of the tilt cylinder against the lifting eye. It should be noted that the stress and deformation analysis in the area under consideration took into account the load resulting from the forces occurring in the tilt cylinder, neglecting the stress in the gob shield, caused by internal forces in the turning pairs of the roof support.

The most unfavourable load to the eye will occur when the bending moment acting on the lifting eye being a support is the highest. Assuming that the force in the tilt cylinder is nominal, it will take place when the angle between the tilt cylinder and the surface of the top plate of the gob shield is the smallest.

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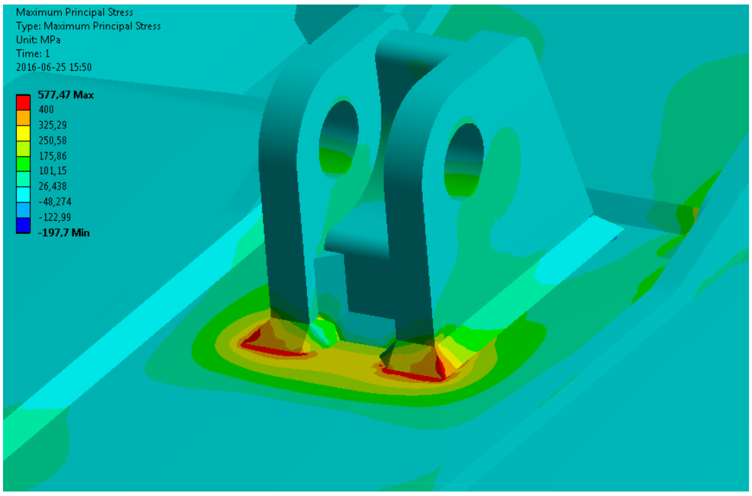

Fig. 8. Distribution of maximum main stress [6]

Using the OStO v.4.0 [5] software for analysis of static load to the tilt cylinder, a change of the angle between the axis of the tilt cylinder and the surface of the top plate of the gob shield was analysed as a function of a roof support height. This angle was found to be the lowest at the roof support height 1.6 m and was 2.95o. With a resultant force in the tilt cylinder equal to 703.7 kN, the force consisting of the following components acts on each lifting eye of the tilt cylinder:

Fx = 280.058 kN Fy = 0 Fz = -213239 kN

The eye support and load model for a section height of 1.6 m is shown in Fig. 9.

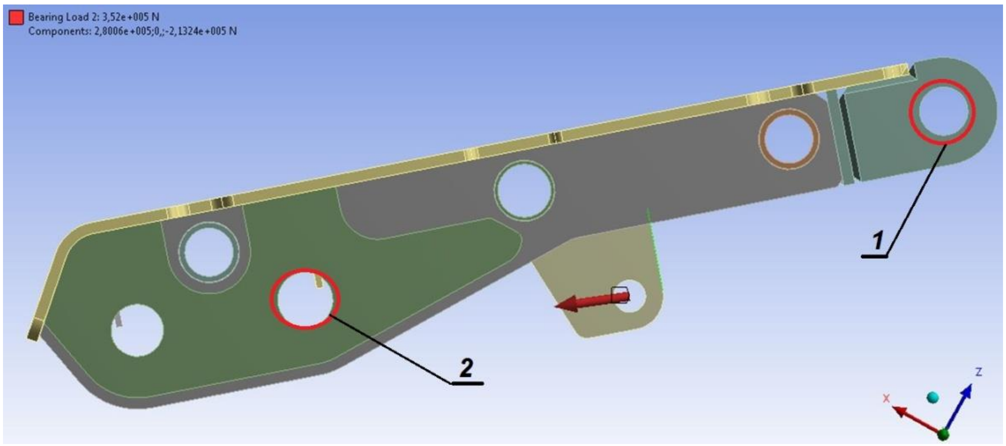

Fig. 9. Eye support and load model for a roof support height of 1.6 m [6].

As a result of the analysis of the gob shield's FEM model, it was found that in the analysed case of load, the level of stress in the tilt cylinder unit components is slightly higher compared to the load variant corresponding to a roof support of height 2.5 m. The displacements and maximum main stress are also slightly higher [6].

4. Analysis of fixation of tilt cylinder's eye of modernized design

The manufacturer modified a design of tilt cylinder's eye fixation to the gob shield to avoid its damage.

Geometric model of the gob shield with the modernized tilt cylinder's eye unit is presented in Fig. 10. Additional covers for the sheathing sheets as well as the supporting sheets between the eye and cover were used around the eye to strengthen the analysed fixation system. The finite elements mesh, made of 325447 nods and 79315 elements, was concentrated in the area covering the tilt cylinder's eye and in the sheets fixing the eye to other components of the gob shield including the sheathing sheets of the gob shield.

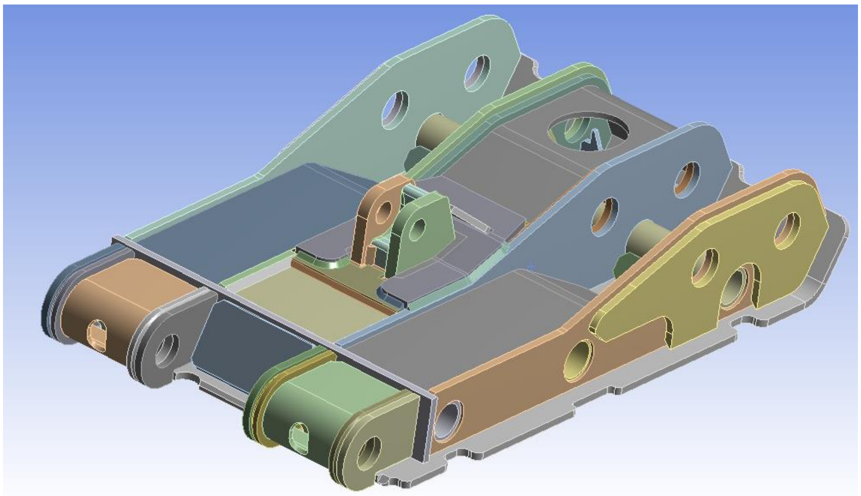

Fig. 10. Geometric model of the gob shield with modernized design of tilt cylinder’s eye fixation system [6]

Numerical simulations and analysis of effort of tilt cylinder’s eye fixation system in the gob shield were made for the most adverse case of load to the eye, that is for the loads in the case of loads existing at roof support height 1.6 m. Supporting and load conditions to the gob shield are presented in Fig. 9.

Distribution of equivalent stresses for the modernized design of the gob shield is presented in Fig. 11.The scale of the equivalent stress was set in such a way that places of the gob shield in which the equivalent stress is higher than the yield point are marked in red.

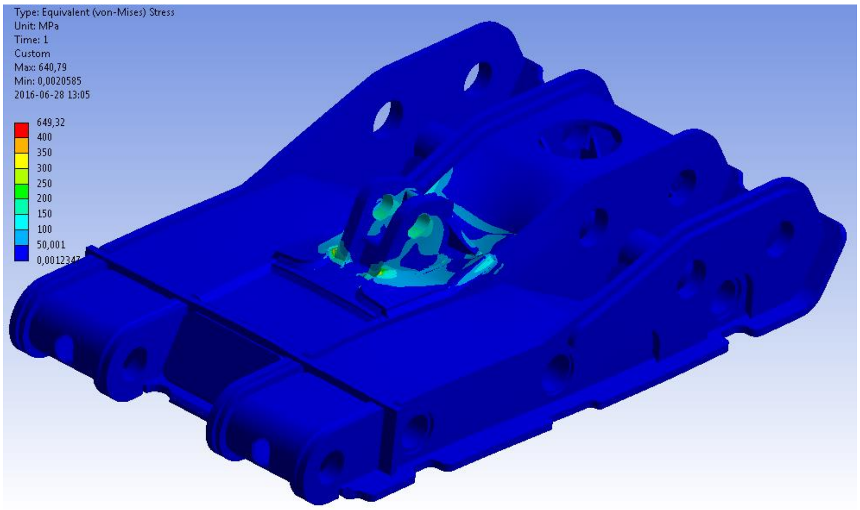

Fig. 11. Distribution of equivalent stress in the eye unit after modernization

The level of effort of the gob shield’s eye unit after design changes significantly decreased. Although the maximum equivalent stress is still high but it occurs locally at the place of connecting the eye with the covering sheet. In this area, welds were modelled in a simplified way. The end of the solid modelling the V-type weld with a vertical plane and the lack of rounding radii at the transition of one weld plane to the other caused that in this area there were geometric notches that do not appear in the real object. The simplification of the geometrical form of welds meant that additional stress

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concentration was obtained in these areas, which would not occur in the real object. This fact should be taken into account when further interpreting the simulation results.

Excluding the areas, where the notches appear in the result of simplified modelling, it can be concluded that the equivalent stress is significantly below the yielding point (Fig.12).

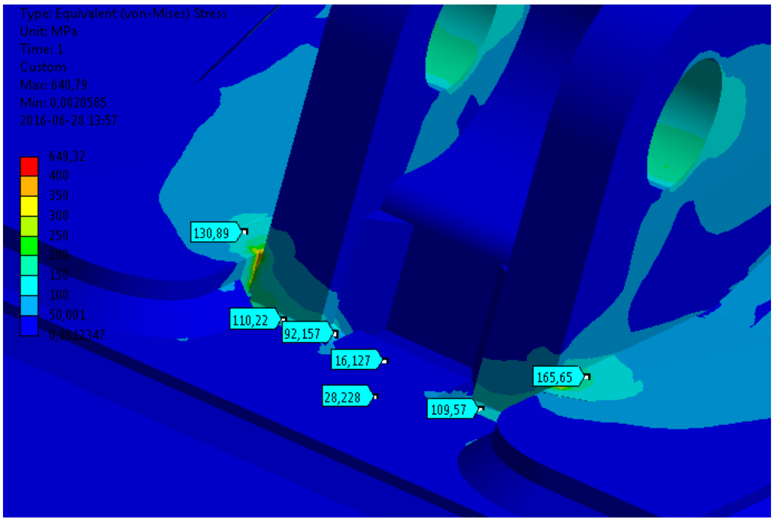

Fig. 12. Equivalent stress in the selected model elements [6]

Distribution of the highest stress in the tilt cylinder's eye unit is presented in Fig.13.

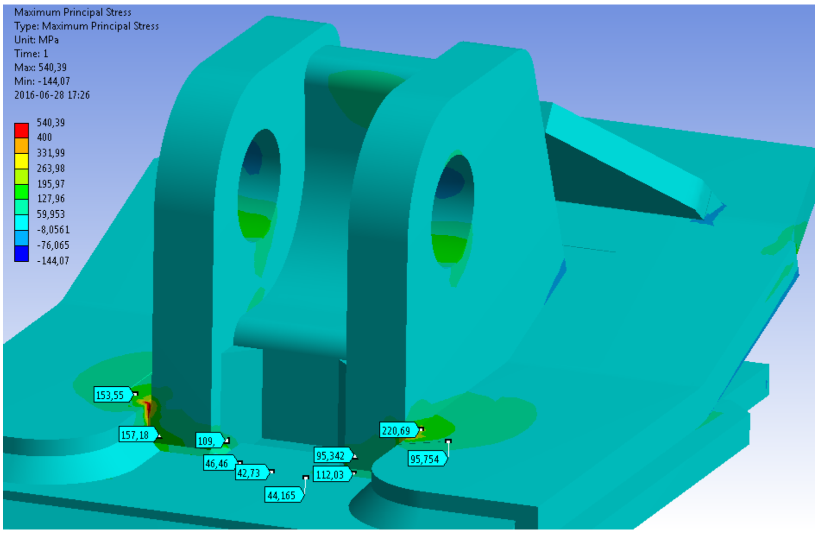

Fig. 13. Distribution of maximum main stress [6]

When analysing the effort of tilt cylinder's eye unit for the gob shield, it can be concluded that change in the design of this unit caused significant reduction in the effort level. Concentration of stress in geometric notches are mainly caused by simplifications associated with modelling of welds. Maximum displacement of the eye was reduced by almost three times. Also, maximum main stress was significantly reduced.

5. Conclusions

Numerical simulation of the effort of tilt cylinder's eye in the gob shield was carried out for three variants: a load corresponding to the conditions of the roof support operation, the most unfavourable load case of this unit before modernization, and for the modernized design in the most adverse load case.

It was found that under the conditions of using the roof support in the "B" longwall, local concentrations of equivalent stress with values above the stress at the yield point may occur in the eye area. This could lead to slight permanent deformations. Due to the small area in which these deformations may occur, they should not cause deterioration of the roof support functionality as a result of collision movement of the tilt cylinder relative to the eye. In the aspect of damages observed in this longwall, it can be assumed that they arose as a result of adverse circumstances such as random ear overload or/and manufacture errors.

After design changes consisting in implementation of additional covers, the effort of gob shield's lifting eye unit significantly reduced. Excluding the areas, where the notches appear in the result of simplified modelling, it can be concluded that the equivalent stress is significantly below the yielding point. Thus, it can be concluded that the analysed change to the design of tilt cylinder's eye of a gob shield is reasonable.

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Mechanization of reinforcing gate supports in the zone of longwall inlet

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Marek Szyguła[1a], Krzysztof Mazurek[1]

[1] KOMAG Institute of Mining Technology, Pszczyńska 37, 44-101 Gliwice, Poland

[a] e-mail: mszygula@komag.eu

Keywords: mining, gate, gate support, crossing between longwall and gate, powered roof support

Słowa kluczowe: górnictwo, chodnik przyścianowy, obudowa chodnika, skrzyżowanie ściany z chodnikiem, podciąg, obudowa zmechanizowana

Abstract:

Known and used methods of reinforcing the load-bearing capacity of gates in the zone of crossing between longwall and gate are presented in the article. Characteristic features of equipment (special support unit), used in this zone are discussed. A new design of a special support, eliminating basic disadvantages of present solutions, are proposed.

Streszczenie:

W artykule przestawiono znane i stosowane sposoby wzmacniania nośności obudowy chodników przyścianowych w strefie skrzyżowania ściany z chodnikiem. Omówiono charakterystyczne cechy urządzeń (sekcji obudowy specjalnej) stosowanych w tym rejonie. Zaproponowano nową konstrukcję obudowy specjalnej eliminującą podstawowe wady dotychczasowych rozwiązań.

1. Introduction

In the Polish hard coal mining industry the crossing between longwall and gate is an area of concentrated activities connected with a longwall advance. It mainly results from a fact of using support arches in the gate and a need of disturbing a continuity of this support, exactly in the zone of the longwall inlet. The side-wall elements of gate support must be removed to enable pushing out the armoured face conveyor drive to the gate. In this case it is needed to additionally reinforce the gate support in this zone [1]. A fragment zone displacement of disassembled side-wall arches, requiring a necessity of continuous rebuilding of reinforcements of gate supports, causes significant difficulties. These activities, performed in exceptionally difficult conditions, are mechanized only to a small extent. A labour consumption, connected with maintaining the crossing between longwall and gate, often takes over 30% of the time spent on a realization of all the jobs, done in the longwall, and it is the decisive factor about the longwall production capacity [3]. Simultaneously the crossing between longwall and gate is an area of increased rock mass impact [2], which is an additional decisive factor about the safety of miners working there at a continuous reconstruction of gate arches, connected with a longwall advance. In the zone of crossing between longwall and gate the biggest number of accidents happens. In the result a maximal reinforcement of the support of the crossing between longwall and gate is attempted. Mining, geological and mechanization factors force a use of different systems of gate support reinforcements [12. 13]. So called steel binders connecting the set with disassembled side-wall elements and the full set (Fig. 1) are used most frequently.

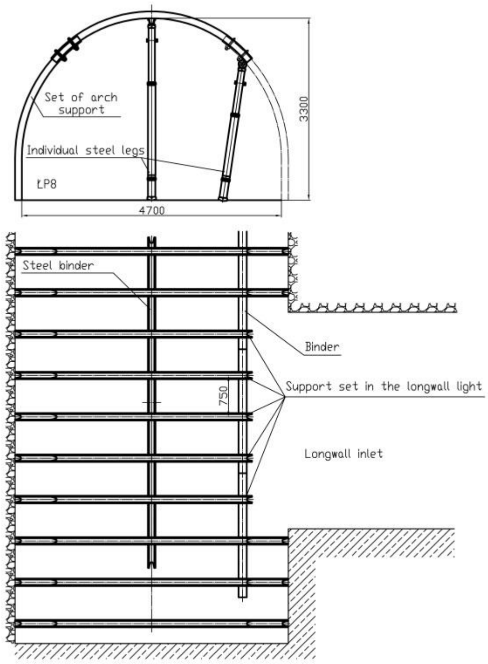

Fig. 1. Most frequently used method of reinforcing gate support [Authors' elaboration]

The binders are supported with individual legs and their presence in the crossing zone impedes not only the miners' passage but also a relocation of machines, in particular of the conveyor, when the longwall advances. In difficult geological conditions all the sets of arch supports are supported. A construction of binders and their advance requires an employment of a bigger number of employees in the most dangerous zone of the longwall. Significant difficulties, connected with a construction of the gate support reinforcement, in particular with its advance together with an advance of the longwall, caused a need of searching methods of mechanizing the activities connected with a reinforcement of the gate support in the crossing zone.

2. Mechanization of activities in the area of the crossing between longwall and gate – a present situation

Bigger and bigger production capacity of longwall systems causes that the cutting machine must wait for a reconstruction of the crossing zone at the longwall face end. Due to that some attempts to mechanize the activities, connected with ensuring a right protection of this zone, are undertaken [15]. The most frequently used solution consists in conducting in the gate a self-advancing mechanized crossing support unit. This unit is raised under the basic gate support, but its canopies reach outside the zone of disassembled side-wall arches.

The mechanized crossing support unit was applied at the Marcel Mine at the turn of 1990 and 1991 for the first time in Poland (Fig. 2).

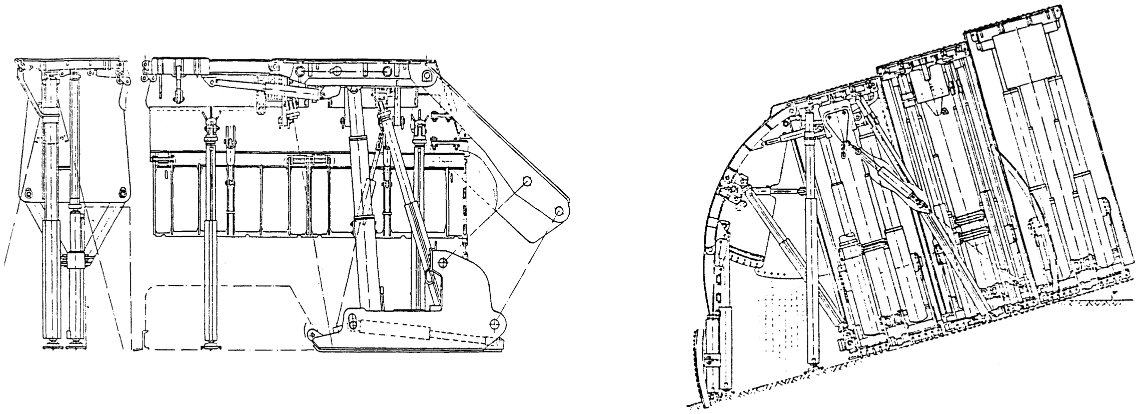

Fig. 2. Crossing support unit applied in the Marcel Mine [4]

The unit was designed at KOMAG as a modification of the FAZOS-22/44-Oz extreme support unit. It was a four-leg unit with an elongated sequence of canopies, enabling to support the gate roof in the longwall light and the roof before the longwall face. The canopies were equipped with arched side shields, deflected with rams, shielding the gate side-wall. A correct operation of this unit required an elimination of the gate arch support set before the sequence of canopies of a mechanized unit. An application of this type design enabled to install powered roof support units at the fool length of the longwall face together with the gates. Difficult conditions, occurring in the longwall face, in particular the longwall inclination and changes of its length did not make it possible to eliminate the arch support set in front of the unit and it was impossible to conduct the support unit in the gate axis. After a disassembly of arched side shields the unit was used as the first support unit in the longwall face.

In 1993, at the Staszic Mine the first three-segment mechanized crossing support 6l420T (Fig. 3), delivered together with other equipment of the longwall system by the MECO International Company, was applied. Each of the three segments, stabilized by the lemniscate system was equipped with two legs. The front legs of all the segments were additionally stabilized, in relation to the bases, with special clamping rings.

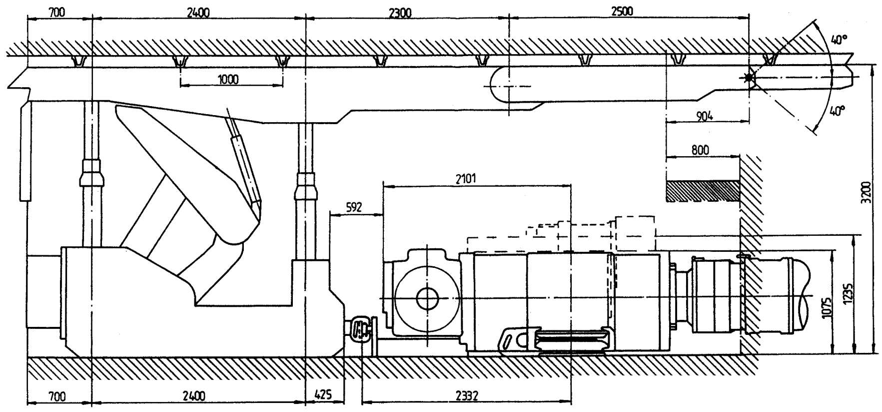

Fig. 3. 6L420T crossing support unit by MECO International [4]

This unit became a prototype of new designs of the mechanized crossing support units based on three segment, enabling a self-advance of the unit and when it is possible a collaboration with the conveyor drive base. Such a collaboration is possible when the conveyor drive is located in the gate. A majority of new solutions of mechanized crossing support units has a three-segment construction. A few construction designs of this type unit were developed by the leading producers of powered roof support units in Poland (GLINIK, FAZOS, TAGOR) [6 , 9] . Similar solutions are used in the world mining industry [5 , 14 , 16].

The main disadvantage of units, modelled after the MECO support, is their small longitudinal stability. A big weight of the canopy sequence, pulled out far to the front, at heavy components of the lemniscate system, located among the legs makes the unit tilt to the front during the advance. Not before raising the unit in the gate, the whole construction is stabilized and active supporting of the gate support by the front deflecting canopies is possible.

Aiming at an elimination of the disadvantage, known already from the three-segment mechanized crossing support unit, in 1995 at the KOMAG Institute the KSK-18/37-Pz unit (Fig. 4) with the lemniscate system, situated behind the rear row of hydraulic legs which had a very advantageous impact on the weight distribution and thus on the unit stability, was designed.

Fig. 4. KSK-18/37-Pz mechanized crossing unit [15]

The lemniscate stabilization unit connected the unit external segments with a joint gob shield and a rear connector. A stability of the central segment was ensured by hydraulic rams connecting its main canopy with the main canopies of external segments. The external segments had two hydraulic legs each, supporting the main canopies. In the central segment three legs were installed; two of them supported the main canopy, but the third one – the rear canopy. The main canopies of external segments were equipped with the deflecting – advancing canopies and front canopies supported with rams. The KSK-18/37-Pz support unit was subject to operational tests at the Zofiówka Mine and it was also operated at the Mysłowice-Wesoła Mine.

Taking into consideration the experience resulting from the tests of the KSK-18/37-Pz unit at the KOMAG Institute in 1996, the GSW-17/36-Pz unit (Fig. 5) was designed. It was a for-going modification of the previous design. The advancing canopies were eliminated which simplified the design significantly. The canopies of similar construction and of the same length were used in all the segments. The main canopies were elongated considerably obtaining a bigger load-bearing capacity in the distance of about 2000 mm before the front legs, whereas in the KSK-18/37-Pz unit the deflecting canopies of a small load-bearing capacity were installed. Longer deflecting and front canopies were assembled in the GSW-17/36-Pz support unit which enabled to protect the gate at the bigger length. In the central segment the leg, supporting the rear canopy, was eliminated and a ram was applied instead. The unit could be self-advanced or in connection with the conveyor drive base. It could also support the drive advance, unfortunately this construction has not been implemented.

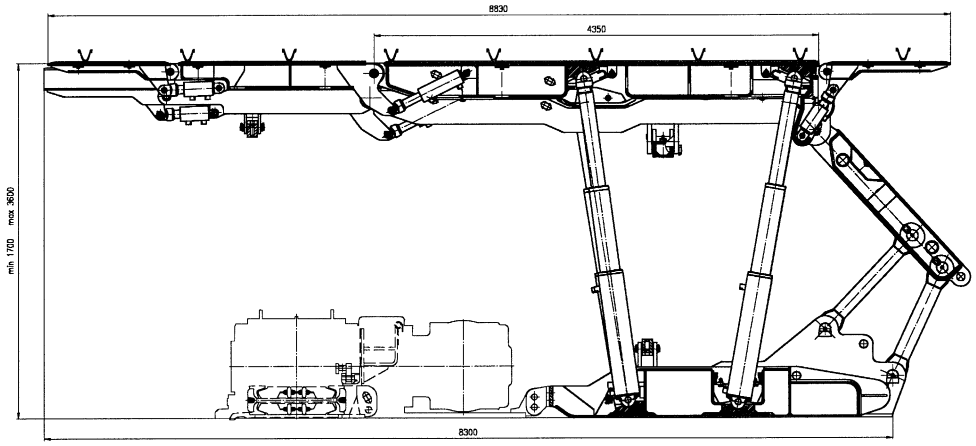

Fig. 5. GSW-17/36-Pz mechanized crossing support unit [15]

Three-segment unit with a stabilizing lemniscate system, located among the legs, is the only type of the mechanized crossing support, used at present. Some other constructions of different types also appeared, i.e. constructions of FZOŚ FAZOS S.A. and Główny Instytut Górnictwa (Central Mining Institute), POS-V9 (Fig. 6) made in 1998 and implemented for operational tests in the Wujek Mine [7]. A unit of this support consisted of two sequences of supporting beams, supported with legs and hung on a sequence of track beams through arms and trolleys. The track beam was fitted to the gate support set with holders adapted to a given type of sections. The supporting beams consisted of three parts: front, central and rear ones. The rams, used for a support unit advance, were situated among these parts. Two parts of canopies were always raised by the legs during the advance and the third one was advanced with use of the track beam. The basic disadvantages of this construction included a necessity of constructing a special track beam along the gate axis, lack of the gate support at the length of the advancing canopy part which was performed within a given moment and impeded conducting of the support in the non-linear gate.

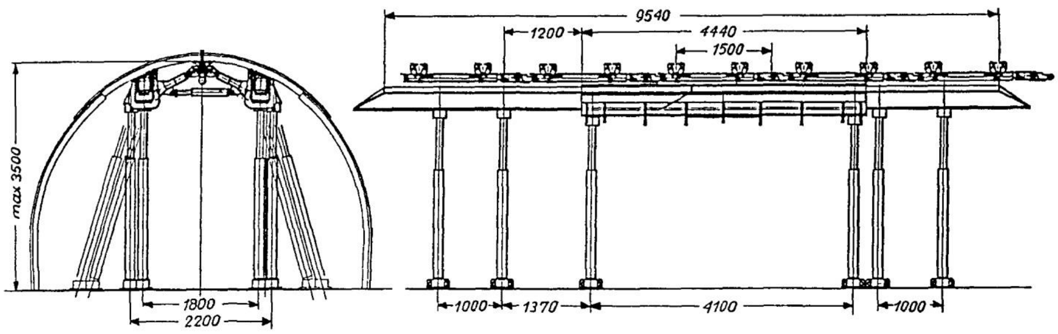

Fig. 6. POS-V9 chock crossing support [7]

A three-segment unit was also designed at the KOMAG Institute (Fig. 7). It was modelled after the first units of this type due to an appearing demand from mines which needed this type of units.

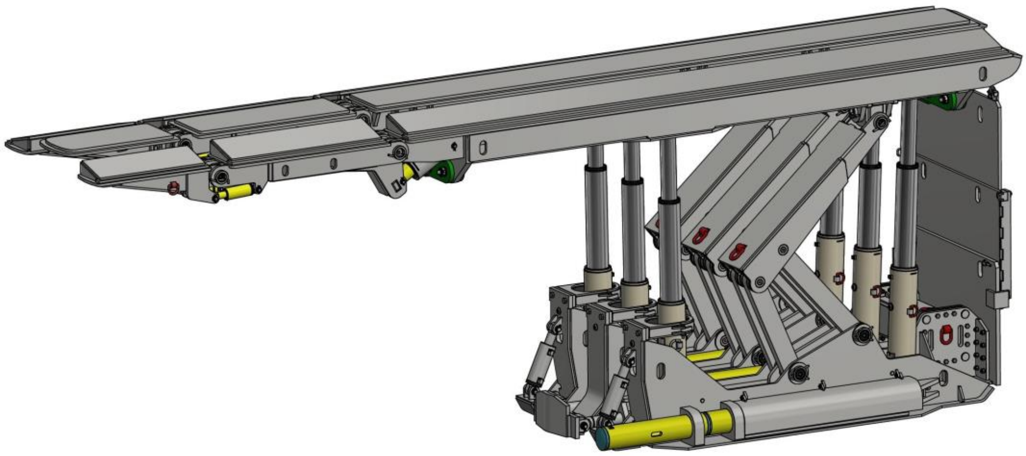

Fig. 7. Model of mechanized crossing support unit [Authors' elaboration

Several solutions, increasing functionality and stability, were used in this unit. In comparison with other units of this type a new unit has a lighter construction.

Three-segment units containing a lemniscate stabilization system, are characterized by a significant weight reaching ewen 90000 kg [6]. The front parts of this type units, supporting the gate support along the longwall light and on the segment before the longwall light, has a small load-bearing capacity in comparison with the rear part. A mechanized crossing support is indeed an additional support of the crossing zone but in the longwall light, at disassembled side-wall arches, it should be treated as basic support. Besides, in front of the longwall light an increased impact of the rock mass on the gate arch support occurs and exactly in this zone a bigger load-bearing capacity of additional support is needed [11]. In 2001 and 2002 some tests of forecasted loading of the additional support reinforcing the gate support in the crossing zone with the longwall [15] were conducted. One of available monitoring methods of the gate support was applied [8, 10]. The load, transmitted to the additional support through the set of the arch support in the gate, was measured during longwall mining operations. Binders clamping the canopy elements of a few adjacent arch support sets were used on the crossing of the longwall and gate, and the following sets were supported by individual hydraulic legs of SHC type. The pressure, reflecting the load transmitted by the arch support under clamping, was recorded. Setting of legs was started in the distance of about 10 m before the wall and the measurements were conducted until the longwall passed the measurement segment. The test results showed that the load transmitted by the arch support set to a measurement leg increased when the longwall was getting nearer and nearer, reaching the biggest values at the length of 3÷4 sets before the zone of disassembled side-wall elements of the set. A reduction of load on a few sets with disassembled side-wall elements occurred in the longwall light and then a following load increase was experienced, when the goaf zone was getting nearer and nearer to the measurement leg (Fig. 8). The gate behind the longwall was liquidated.

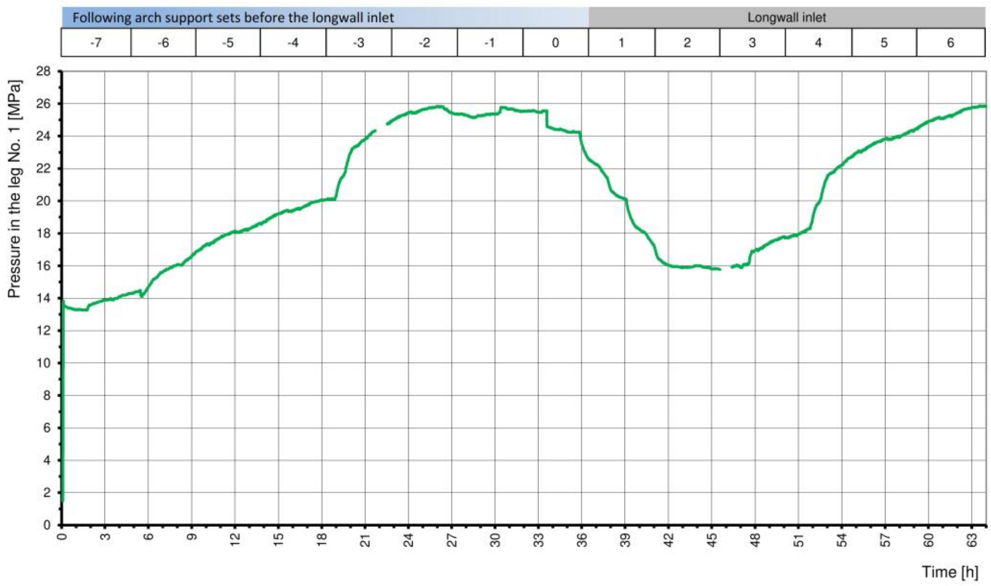

Fig. 8. Course of pressure in the measurement leg [15]

In Fig. 9 a graph of load-bearing capacity of individual canopies of the three-segment unit is shown for a comparison. In Fig. 9 individual sets are marked with the numbers in accordance with the numbers accepted at the graph shown in Fig. 8. The units of this type have the smallest load-bearing capacity exactly in the zone, where a big one is most needed. It should be assumed that in extreme cases the set of gate support before the longwall light may be clamped. In the result, despite having a heavy unit of a powered roof support unit on the crossing, it is not possible to resign from an additional reinforcement of the gate support before the powered unit.

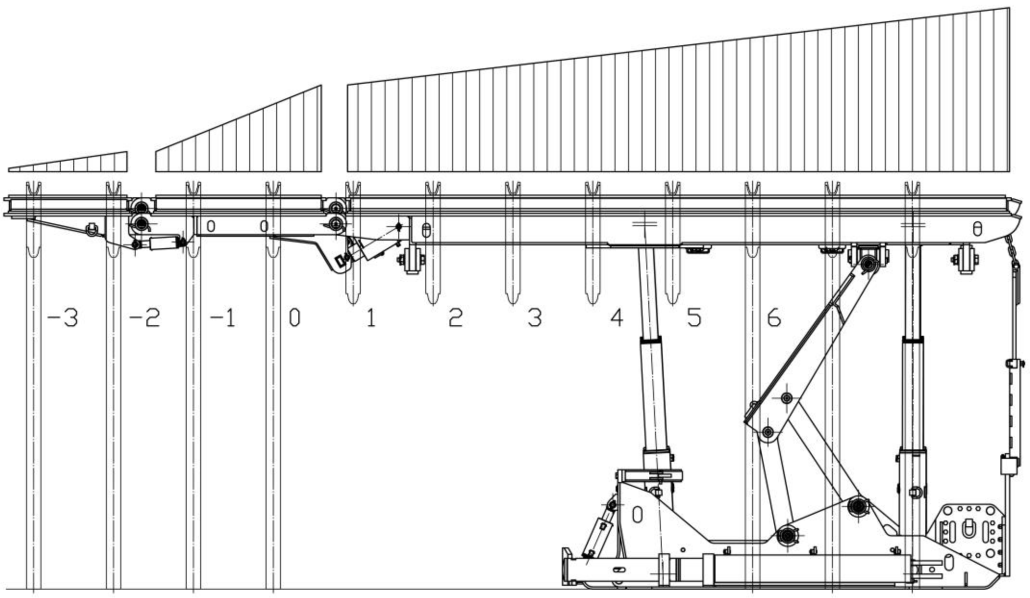

Fig. 9. Comparison of load-bearing capacity of individual canopies in a crossing support unit [Authors' elaboration]

3. New concept projects

All figures, charts, schematics, and photographs should be named as figures in the text and numbered consecutively with Arabic numerals. Each figure should have a brief caption describing it and, if necessary, a key to interpret the various lines and symbols on the figure.

Knowing the basic advantages and disadvantages of the methods of the gate reinforcement in the zone of the crossing with longwall, used at present, some research and development work was undertaken at the KOMAG Institute to elaborate a new construction, having the advantages of the former solutions and at the same time eliminating the disadvantages. For a new design solution it was accepted that a set of canopies should ensure a uniform support of the gate support in the zone of crossing between longwall and gate, incorporating also the segments before and behind the longwall light. The equipment should be self-advancing, of a light construction and it should be possible to operate it in a non-linear gate. No supporting legs should be installed along the longwall light, and the legs themselves cannot impede the miners' passage and cannot collide with other equipment located in the crossing zone.

Taking into consideration the accepted assumptions, it was rejected to follow the existing three-segment construction of a very big weight. It was assumed that the components, having contact with the gate support set (canopies), should be in the number of three. Only such an assumption enables a continuous support of the set during an advance (walking) of the construction. It was also assumed that the canopy beams should cover full length of the whole crossing zone and should be supported with legs at the ends, outside the longwall light. In the case of such an assumption the canopies (sequence of canopies) should have the length of about 7500 mm.

The equipment (self-advancing binder), whose central canopy is situated in the gate axis, was designed. The canopy is equipped with a symmetrical bracket of the legs and with the clevises for deflecting the legs (Fig. 10). At the bracket both sides there are rollers which make support points for the lateral canopies during their advance.

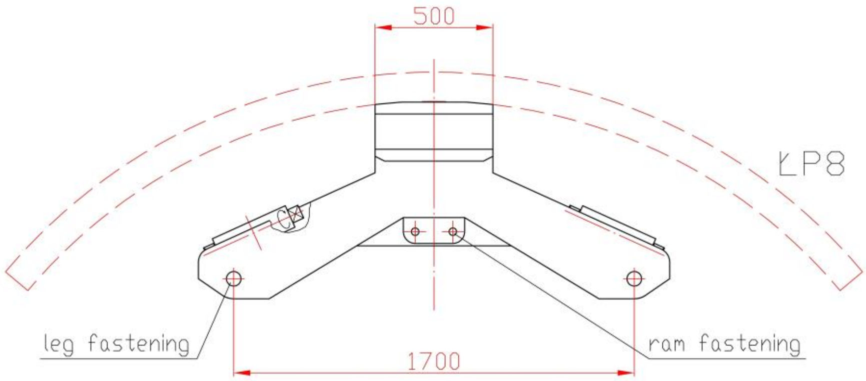

Fig. 10. Central canopy of the binder [Authors' elaboration]

The lateral canopies connected with a joint bracket being also a support for the legs, are situated at both sides of the central canopy. The bracket is equipped with clevises of rams for deflecting the legs. An assembly of lateral canopies for the ŁP8 profile is shown in Fig. 11. Due to shape differences of different size ŁP sets, the lateral canopies are installed on the bracket in a self-aligning way, with a possibility of its adjustment to the shape of canopy set element.

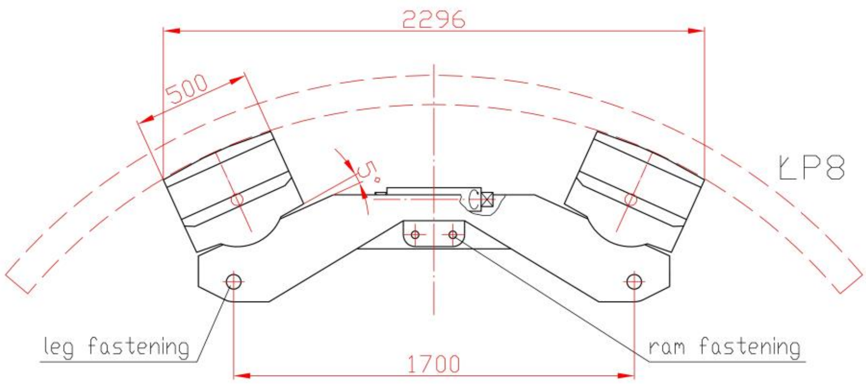

Fig. 11. Assembly of lateral canopies of the binder adapted to ŁP8 set [Authors' elaboration]

The central canopy and the assembly of lateral canopies, equipped with hydraulic legs, are situated on the bases forming two assemblies connected with the self-advancing ram (Fig. 12).

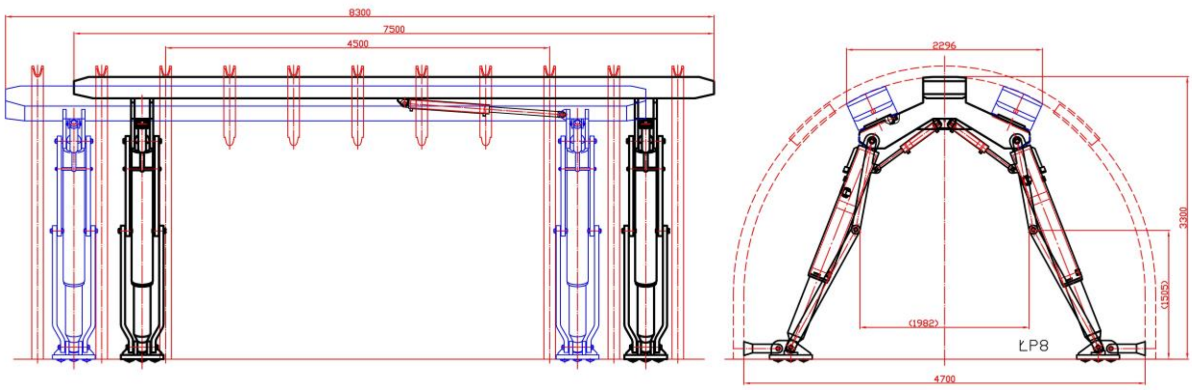

Fig. 12. Collaboration scheme of binder assemblies with gate support set [Authors' elaboration]

During the support of the arch support set the canopies of the binder are raised with eight hydraulic legs – four legs for the central canopy and four legs for the assembly of lateral canopies. During an advance e.g. of the central canopy, its legs are lowered and the canopy lowers till it leans on special rolling elements of the brackets of lateral canopies. A further lowering of the legs causes their raising together with the bases. After the legs are raised, it is possible to correct an angle of their position, controlling the rams operating together with special connectors. These connectors reduce a risk of generating lateral forces in the legs. In the consecutive step it is possible to advance the central canopy to the front together with the legs and the ram connecting the central canopy with the bracket of lateral canopies. In the same way an advance of the assembly of lateral canopies, together with the legs, is realized. Fig. 13 shows a construction and elements forming a support for the canopies of the binder. Special bases of the legs, increasing the surface of their leaning on the floor, are equipped with stabilizers which facilitate proper positioning of the legs in the gate. Each stabilizer leans on a few adjacent side-wall elements of the gate support set.

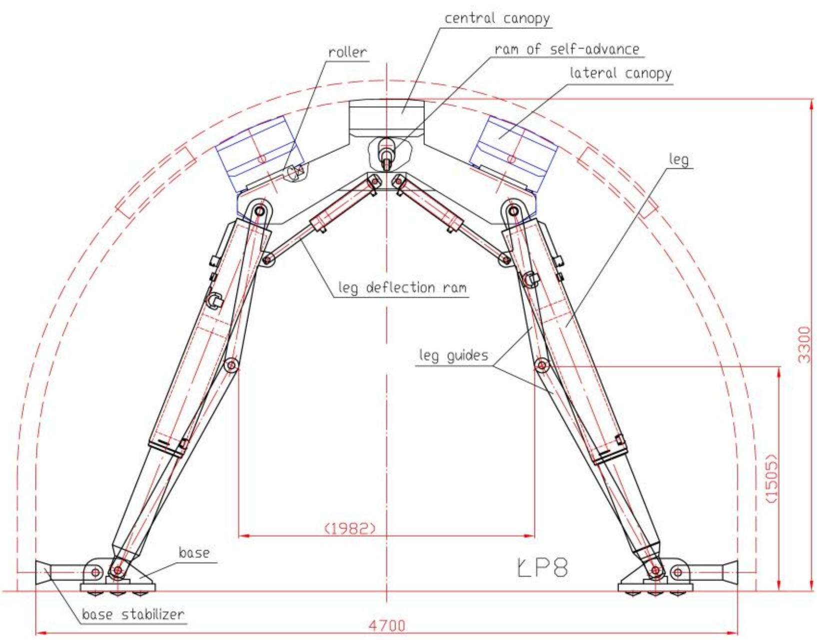

Fig. 13. Construction of assemblies supporting the binder canopies [Authors' elaboration]

A construction of the binder enables an application of an additional mechanism facilitating a removal of the following elements of side-wall sets of the gate support. To realize this task the lateral canopies are equipped with clevises for fastening the rams, which enable to tear out the side-wall

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element of gate support from the floor (Fig. 14) using a chain with an appropriate holder. This operation is one of difficult ones, but indispensable to be performed in the crossing zone. At present no dedicated equipment is used for its assistance.

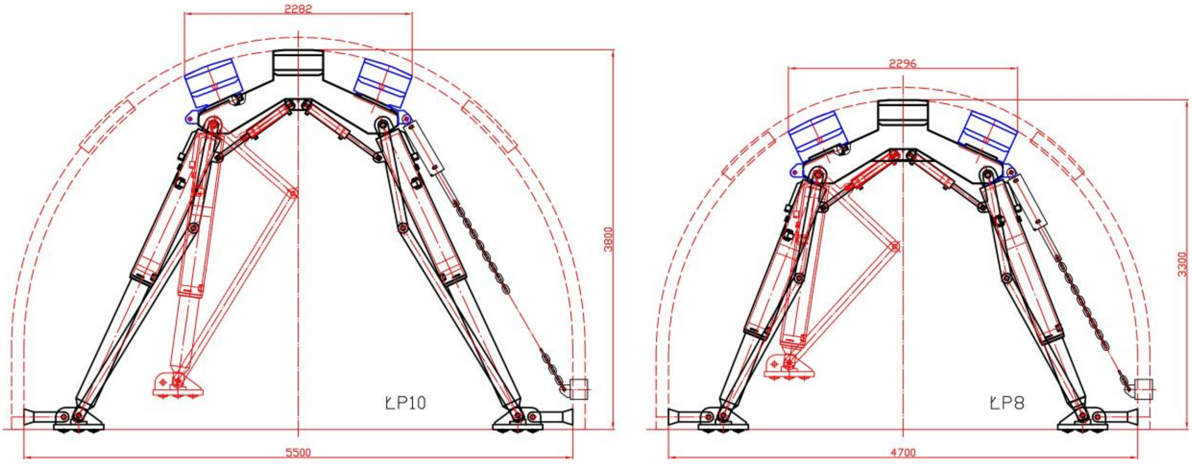

Fig.14. Adaptation of the binder for a removal of elements of gate support set [Authors' elaboration]

To ensure a correct collaboration of the binder with the gate support set at an unavoidable non-linear course, a possibility of dividing individual canopies into parts is introduced. Interconnections of these parts, enabling a minor deviation of their axes, facilitate an advance of the binder along the gate.

4. Summary

The KOMAG Institute of Mining Technology has been developing the design of powered roof supports for many years. In the first development stage it was the only supplier of technical documentation for a production in the Polish mines and in a certain period also a production on foreign markets (Russia, China, India, Hungary). The basic solutions of the FAZOS-12/28-Oz and GLINIK-08/22-Oz powered roof supports were developed just at KOMAG. Similarly as in the case of mechanizing the crossing zone of the longwall and gate, the first construction of the mechanized crossing support unit in Poland was generated at KOMAG.

In the article a new approach to solving problems, related to maintaining the overall dimensions and the load-bearing capacity of the gate in the direct vicinity of the extracting longwall, is presented. The suggested solution enables a significant reduction of time indispensable for a reconstruction of equipment on the crossing when the longwall advances and thus to reduce or even eliminate the cutting machine down-time at the face ends. An additional advantage of the offered equipment consists in aiding a disassembly of the side-wall elements of the gate support in the longwall light.

In the designing processes of powered roof support units the KOMAG specialists use the latest versions of the CAD Autodesk Inventor software and advanced computational software based on the FEM method. They enable to elaborate and check basic parameters of designed constructions already at the designing stage.

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Use of state-of-the-art jigs of KOMAG type for a beneficiation of coking coal

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Piotr Matusiak [1a], Daniel Kowol [1]

[1] KOMAG Institute of Mining Technology, Pszczyńska 37, 44-101 Gliwice, Poland

[a] e-mail: pmatusiak@komag.eu

Keywords: coal mining, mechanical processing, pulsatory jig, jig beneficiation node

Słowa kluczowe: górnictwo, przeróbka mechaniczna, osadzarka pulsacyjna, węzeł wzbogacania osadzarkowego

Abstract:

The present beneficiation technology, used in the Mechanical Coal Preparation Plant at the Budryk Mine is assessed in the article. A description and a schematic diagram of the beneficiation node before its modernization are inserted. The industrial test results of pulsatory, medium-size-grain jigs are presented. The modernization scope of the jig node with use of new pulsatory jigs of KOMAG type is described and a new technological scheme is discussed. The effects of implementing new beneficiation systems in the modernized plant are given.

Streszczenie:

W artykule oceniono dotychczasową technologię wzbogacania stosowaną w zakładzie przeróbki mechanicznej węgla w KWK „Budryk". Zamieszczono opis i schemat osadzarkowego węzła wzbogacania przed jego modernizacją. Przedstawiono wyniki przemysłowych badań osadzarek pulsacyjnych średnioziarnowych. Omówiono zakres modernizacji węzła osadzarkowego z zastosowaniem nowych osadzarek pulsacyjnych typu KOMAG, przedstawiono nowy schemat technologiczny. Omówiono efekty wdrożenia nowych systemów wzbogacania w zmodernizowanym zakładzie.

1. Introduction

For several dozen years the KOMAG Institute of Mining Technology has been designing jigs for a beneficiation of different grain classes: OM-fines jigs for grain sizes 20-0(0.5) mm, OS-medium-size-grain jigs for grain sizes 80(50)-0(0.5) mm and OZ- grain jigs for grains 120-20 mm.

Their construction is modernized permanently starting from the mechanisms generating a pulsatory motion, through the kind and way of fixing sieve decks, the shape of pulsatory chambers and ending with the ways of collecting beneficiation products [1,2,3,4,5]:

Research work, concerning gravitational beneficiation with particular attention paid to pulsatory jigs, is also conducted and it enables to improve their operation permanently, both in the scope of beneficiation efficiency as well as reliability [6,7,8,9].

Highly productive and precise control of the raw material supply, of shaping the pulsatory motion and of collecting the beneficiation product is ensured by the SSWO KOGA control system of the jig node, developed at the KOMAG Institute [10,11,12,13,14].

A modernization of the jig node in the Mechanical Coal Preparation Plant at the Budryk Mine for a beneficiation of coking coal, with use of new pulsatory jigs of KOMAG type, is presented in the article.

2. Technology of jig beneficiation – condition before modernization

Mechanical Coal Preparation Plant at the Budryk Mine had three pulsatory jigs for a beneficiation of coal feed, including two double-trough OS36D3E jigs and one single-trough OM24L4E jig [15,16]. Initially, all the jigs were equipped with the SSO electronic control system made by the BGG

Automation Plant. In recent years, before the modernization started, the BGG control systems were gradually replaced by the KOGA system developed at the KOMAG Institute [17,18,19].

The material of grain sizes 60(80)-12(0) mm, obtained in the results of a classification on four PWE1-2,6x6 screens, was fed to the OS36D3E jig (Fig.1). The bottom product could be directed to the raw fines tank, energy mix tank or to dumps.

Fig. 1. OS26D3E medium-size-grain jig

The screen top product, was delivered to the OS36D3E jigs through the area sieves, playing a role of a navigable trough, in the area of which the top water sprays were installed.

A characteristic feature of the above mentioned equipment is a supply of both working troughs with pulsating air through common air collectors.

The jigs were equipped with key culverts of the "heavy" product. The culverts of this type, in contradistinction to the solutions used in fines jigs, do not posess a collecting channel and the heavy material is collected from the working chamber through a slot situated on the level close to the surface of sieves in the working trough.

Each of the above mentioned jigs, used for a three- product beneficiation, had three bucket conveyors, from which two were used for dewatering of waste product (one for each trough) and one conveyor – for dewatering of intermediate product. The waste product, after its dewatering in bucket conveyors, was directed to the collecting belt.

The intermediate product, after its dewatering in a bucket conveyor, was directed to the PWP1-2.6x5.25 screen equipped with sieves of ø10 mm mesh. The top product, after having been crushed in the UP 1500x1000 crusher, combined with the bottom product of the above mentioned screen, was the feed to the OM24L4E jig. The concentrate product was directed to preliminary dewatering and a classification on the PWP1 2.6x4.65 screen, equipped with the sieves of ø20 mm mesh. The bottom product of the screen was subject to dewatering on the BISO 2800 sieves and WOW 1.3 vibratory drainers.

In turn the screen top product, after having been crushed in the UP 1500x1000 crusher, could be combined with the products of centrifuges under dewatering or become a separate commercial product.

The OM24L4E jig was used for a secondary beneficiation of the crushed intermediate product obtained from the OS36D3E.

The waste product, from the first two compartments, after having been dewatered in the bucket conveyor, was directed to a collecting belt conveyor.

The "heavy" product of the last jig compartment, after its dewatering in the bucket conveyor, could be combined with the concentrate product or directed for a generation of energy mixes.

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The concentrate product was subject to a two-stage dewatering on the OSO 2400 sieve and on two WOW 1.3 drainers.

A simplified scheme of the jig beneficiation node at the Budryk Mine before the Plant modernization is presented in Fig.2.

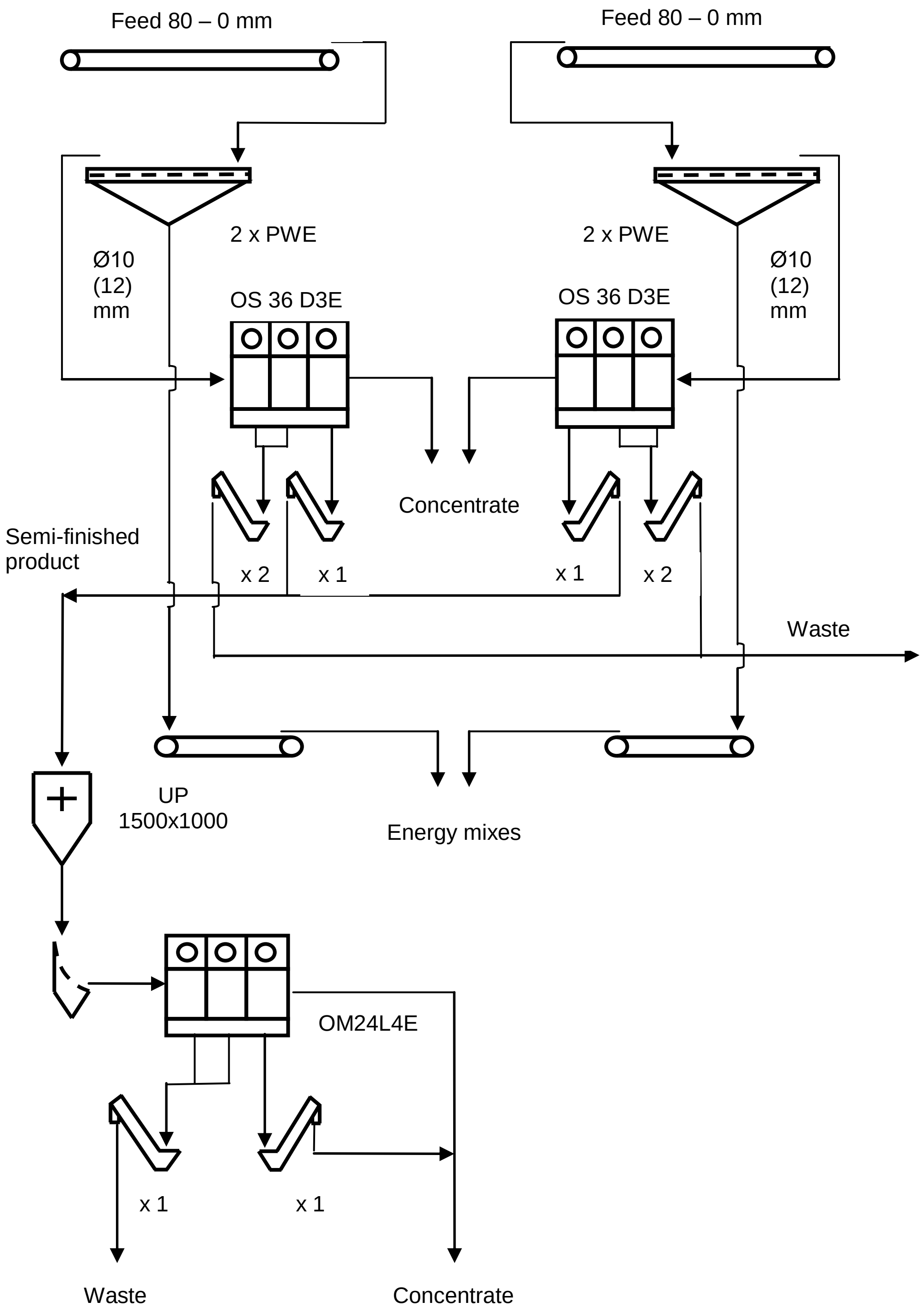

Fig. 2. Simplified scheme of the jig beneficiation node at the Budryk Mine before its modernization

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3. Industrial tests of OS36D3E pulsatory, medium-size-grain jigs

One of the essential issues in the jig beneficiation process is dynamics of shaping density layers of the material under beneficiation (bed) in the jig working trough and its impact on the beneficiation process effectiveness [20,21].

The tests in this scope were conducted in the OS36D3E medium-size-grain pulsatory jig, installed at the Budryk Mine, used for a three-product beneficiation of material in the grain class 60(80)-12(0) mm. Within the framework of tests point samples of the jig bed, embracing the whole bed layer, were taken. These samples were taken in the first and second parts of each jig compartment in three layers which were next subject to density analysis in heavy liquids of density 1.5 g/cm^3 and 1.8 g/cm^3.

In Table 1 the analysis results of the layer adjacent to the sieve in individual working compartments are listed.

Table 1. Parameters of the layer adjacent to the sieve in the jig working compartments

Fraction density, g/cm^3	**Compartment I, %**		**Compartment II, %**		**Compartment III, %**	
	Part I	Part II	Part I	Part II	Part I	Part II
> 1.5	99.0	93.9	93.4	88.2	98.5	89.4
> 1.8	96.0	86.9	89.0	75.1	88.3	69.5
1.5 – 1.8	3.0	7.0	4.4	13.1	10.2	19.9

The analysis of test results showed that in the following jig compartments, which were characterized by higher and higher threshold and heights of the layer adjacent to the sieve, an increase in the layer parameters' differences occurred.

On the contrary to a uniform gravimetric composition of the layers adjacent to the sieve in Part I of the compartment, in Part II (in which measurement points were situated close to the separation/collection sphere) the output of fraction >1.5 g/cm^3 and >1.8 g/cm^3 was significantly smaller.

During these tests the measurements of the bed density distribution, using experimental floats together with recording a location of the bottom product culvert, were taken. The test results are listed in Table 2.

A comparison of boundary densities of floats in the I and II waste compartments, whose exceeding caused their falling down towards the collecting slot, showed that the float density in Compartment I was smaller than in Compartment II despite collecting bigger and heavier grains.

Twice bigger height of the threshold in Compartment II, on the contrary to Compartment I limited the effect of "sucking in" the grains by the culvert collecting slot.

The effect, mentioned above, resulted among others from a specificity of key culverts construction used in the jigs under testing.

The conditions occurring in Compartment I required a quick reaction of control systems to bigger changes in location of the layer under separation to maintain a stable waste product as regards its quality.

Table 2. List of recorded parameters for the following jig compartments

Float	Compartment I, %	Compartment II, %	Compartment III, %
Limiting density, g/cm^3	1.525	1.825	1.425
Height (H) of separating layer, cm	42.30	33.40	27.50
Culvert	Compartment I, %	Compartment II, %	Compartment III, %
Mean opening, %	55.6	44.7	34.0
Scope of changes, %	71.1	24.2	25.9
Frequency of changes, pulsation cycles	12.0	25-50	20.0

A design solution of key culverts and of pulsatory chambers, used in the OS36D3E jig under testing, caused that the amount of collected heavy product was dependent on both the opening size of the culvert slot as well as on the intensity of pulsating water stream flowing through the slot. An impact of the second factor was the bigger, the smaller the threshold height. In this case a partial loss of control over an operation of collecting the heavy product was experienced, which could cause losses of combustible substance (coal) in the waste product.

Basing on the test results, it can be stated that it is purposeful to limit the water flow through the culvert to obtain a control increase over an operation of collecting the heavy product and in effect to increase a separation effectiveness. For the grain scope under beneficiation, it can be realized due to an application of a new design solution of the culvert for heavy products.

It is required to ensure a uniform distribution of working air in the pulsatory chambers through an application of independent feeding of jig's working troughs to increase stability of water flow in a pulsatory motion.

Besides, violent density changes, which forced a quick reaction of control systems, were demonstrated.

4. Modernization of jig beneficiation node at the Mechanical Coal Preparation Plant at the Budryk Mine

4.1 OS18 medium-size-grain jigs

In the framework of the modernization two OS36D3E double-trough jigs, used hitherto, were exchanged for six OS18 single-trough medium-size-grain jigs of KOMAG type. The rated capacity of each jig, having the working surface of 18 m^2, was determined on the level of 250 t/h [15].

New, three-compartment jigs were designed for a beneficiation of the feed in grain class 80-0.5 mm and its separation into three products: concentrate, semi-product and waste.

Dewatering of beneficiation products is conducted in the way used hitherto, i.e. the concentrate product – on screens, and then the bottom product – on the OSO sieves and vibratory centrifuges, however the semi-product and the waste product – in bucket conveyors.

The pulsatory motion in the jig is generated by pneumatically controlled disk valves and an application of electronically controlled pulsation cycle, using working air supply at the pressure of 0.03-0.035 MPa and its consumption up to 110 m^3/min.

A consumption of bottom water is assessed at 600 m^3/h (with a possibility of its control) at the pressure of 1-1.2 bar.

The collecting system of heavy products (waste, semi-products), made of stainless steel, is hydraulicly supplied at the installation required pressure on the level of 50 bar.

A new design solution of the product culvert of a damper type, was implemented in the OS18 medium-size grain jigs.

The OS18 medium-size grain jig of KOMAG type is presented in Fig. 3.

Ten bucket conveyors (Fig.4) of bucket width equal to 1000 mm were installed in the modernized jig node.

Six of them were planned for dewatering of waste products and four – for dewatering of semi - products.

The length of conveyors for dewatering waste products was 18 m, at the inclination angle of 60^o. In the case of the conveyors for dewatering of the semi-product their length was 20 m, at the inclination of 65^o.

The capacity of the installed bucket conveyors, both for the waste and the semi-products was 220 t/h at the power of the main driving motor equal to 30 kW.

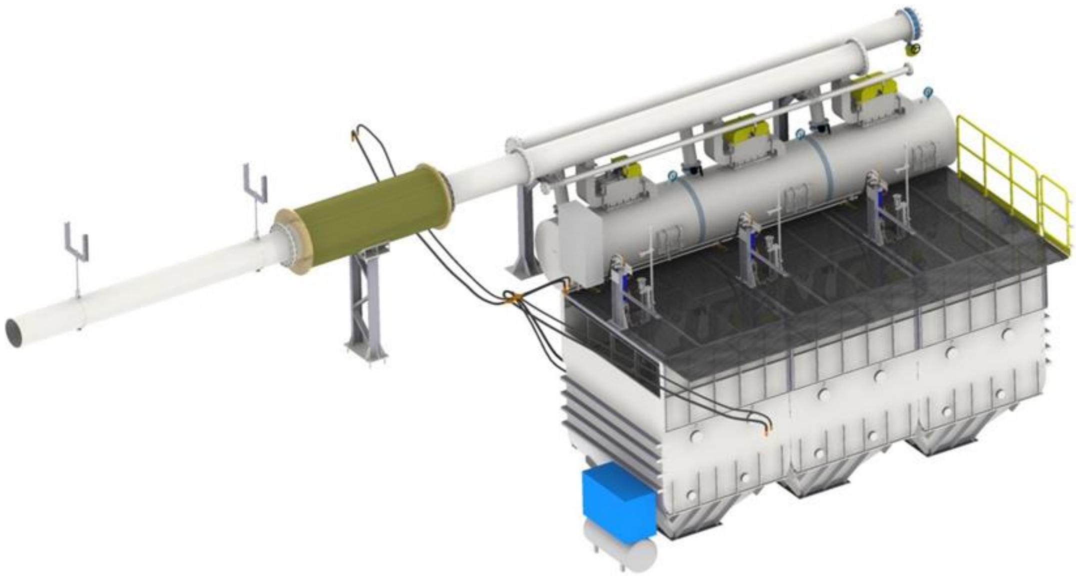

Fig. 3. OS18 medium-size grain jig of KOMAG type

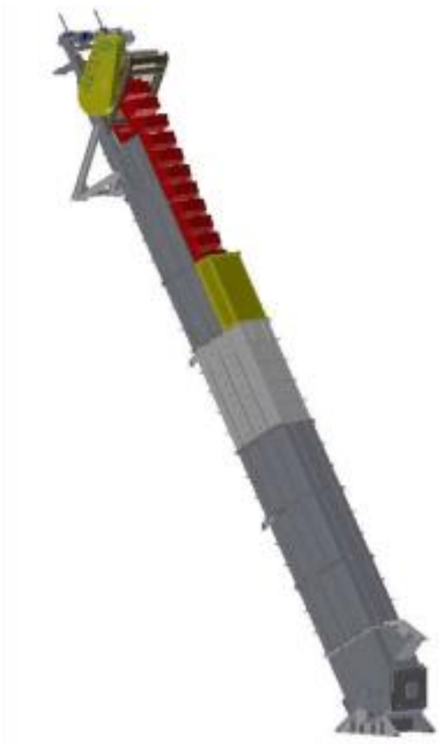

Fig. 4. B-1000 bucket conveyor

4.2 OM20 fines jigs

The modernized node of fines feed jig beneficiation is composed of two secondary, single-trough OM20 fines jigs of KOMAG type. The rated capacity of each jig, of the working surface equal to 20 m^2, was determined to be 250 t/h 16].

One of the OM20 jigs was installed in the place, where the OM24L4E jig used to be operated. The other one was located in the place of the FTC vacuum filters used so far for dewatering of the flotation concentrate. At present their role was taken over by sedimentation-sieve centrifuges.

New three-compartment jigs are used for a beneficiation of the feed in the grain class 12-0 mm and its separation into three products: concentrate, semi-product and waste. The semi-product from new OS medium-size-grain jigs, crushed below 12 mm on the UPK 1500x1000 crushers, will be the feed, similarly as in the system before modernization.

Dewatering of beneficiation products is conducted in the same way as it has been done so far, i.e. the concentrate product – on OSO sieves and vibratory centrifuges, however the semi-product and waste product – in bucket conveyors.

The pulsatory motion in the jig is generated with use of pneumaticly controlled disk valves and an application of electronicly controlled pulsation cycle, using the working pressure supply of 0.03 MPa pressure and at its consumption up to 100 m^3/min.

A consumption of bottom water is assessed for 450 m^3/h (with a possibility of its control) at the pressure of 1-1.2 bar.

A system of heavy products collection (waste, semi-products), made of stainless steel, is hydraulicly supplied at the required installation pressure of 50 bar.

The OM20 fines jig is presented in Fig.5

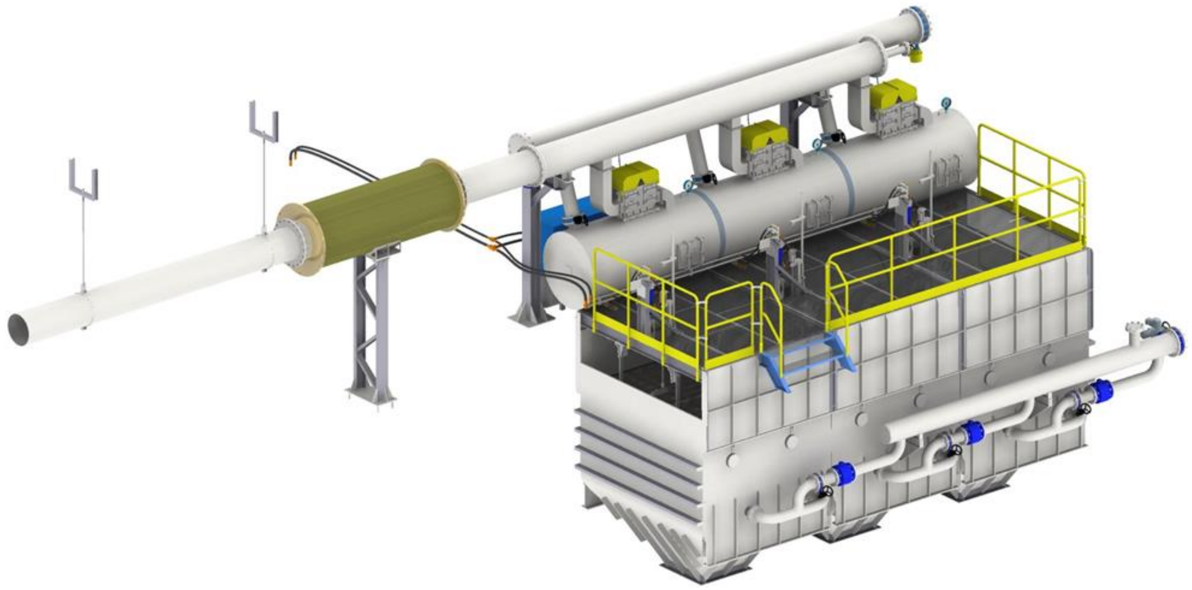

Fig. 5. OM20 fines secondary jig of KOMAG type

In the modernized jig node four bucket conveyors are used-two of them for one OM20 jig. The width of the buckets is 1000 mm.

Each jig is equipped with one conveyor for dewatering of the waste product and one-for dewatering of the semi-product.

The length of the conveyors for dewatering of the waste products is 21.5 m, at the inclination angle of 62^o. In the case of the conveyors for dewatering of the semi-product their length is 19 m, at the inclination of 71^o.

The capacity of the bucket conveyors both for the waste and for the semi-product is 220 t/h at the main drive motor power equal to 30 kW

4.3 Modernized jig beneficiation node

The modernized jig beneficiation node (Fig.6 and 7) was designed in 2017 and a start-up of the first system took place in 2018.

It consists of:

- 6 OS18 medium-size-grain jigs (L and R) (80-0.5 mm),
- 2 OM20 fines jig (12-0 mm),
- 14 B-1000 buckets conveyors.

The modernized node consists of two systems for beneficiating the medium-size-grain feed, which gives a possibility of independent beneficiation of different types of coal (types: 34 and 35) in each of the above mentioned systems. Both systems are composed of three OS18 jigs.

Several new design solutions are implemented in the jigs to increase a control of the beneficiation process and to increase an effectiveness of the beneficiated material separation. New medium-size-grain jigs were designed as single-trough units with independent control, feed and media (water, air) supply. This solution enables to increase a control and a stabilization of the pulsatory motion parameters, being a factor which, to a big extent, decides about beneficiation effectiveness.

The applied culverts of damper type for heavy products increase a control in the collecting zone and a stabilization of the products collecting operation. A secondary beneficiation in the OM20 jigs of the parting material from the medium-size-grain jigs, crushed in the UPK 1500x1000 crushers below 12 mm, enables to maximize production rates.

The jig beneficiation nodes, installed at the Budryk Mine are equipped with the authors' KOGA control system. It is constructed on the base of a free-programmable controller which ensures monitoring of operation and a control of the jig node operational correctness, automatic, emergency switch-off and remote, manual, sequence stop and start of the jig and of the devices operating together with it.

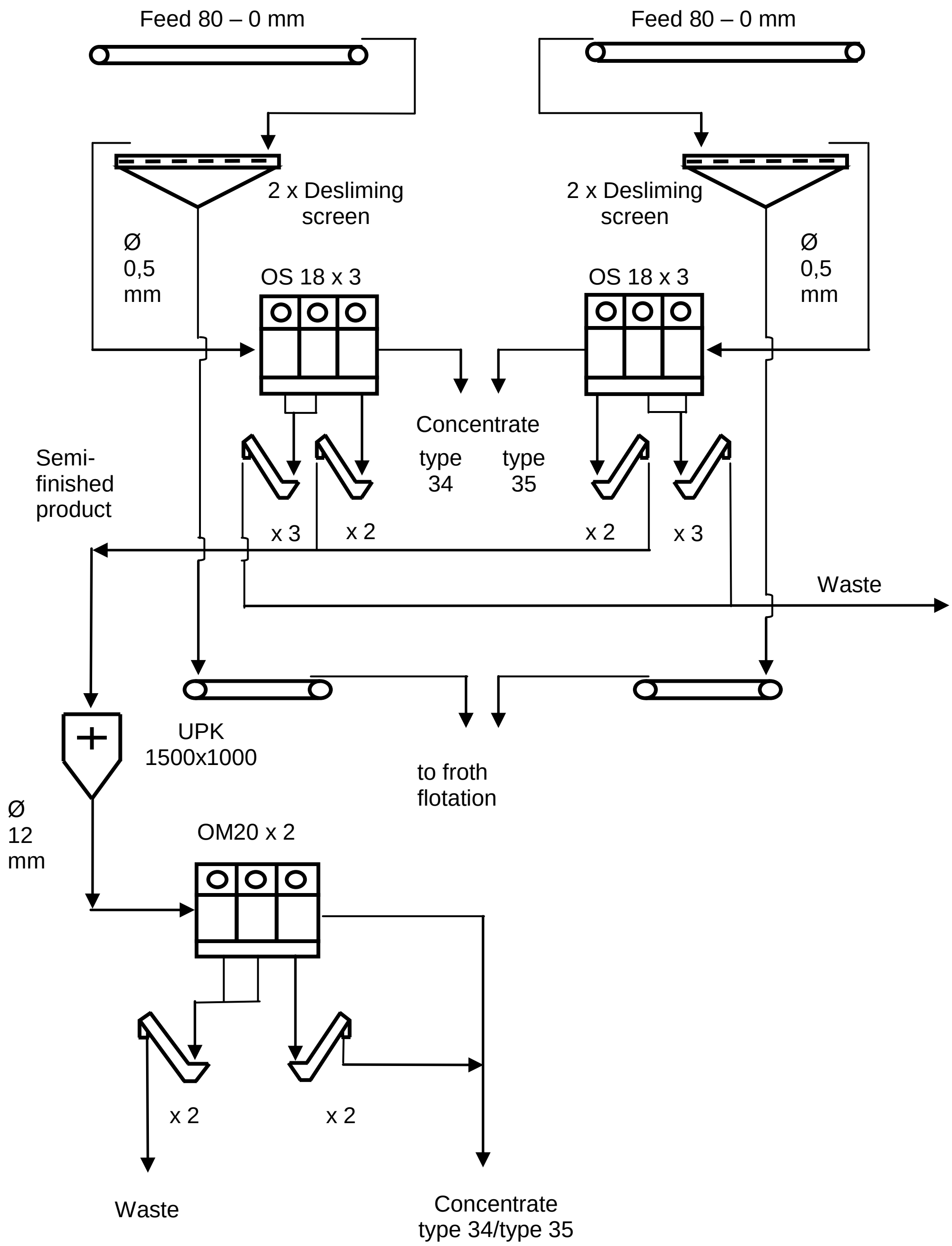

Fig. 6. Simplified scheme of the jig beneficiation node at the Budryk Mine after modernization

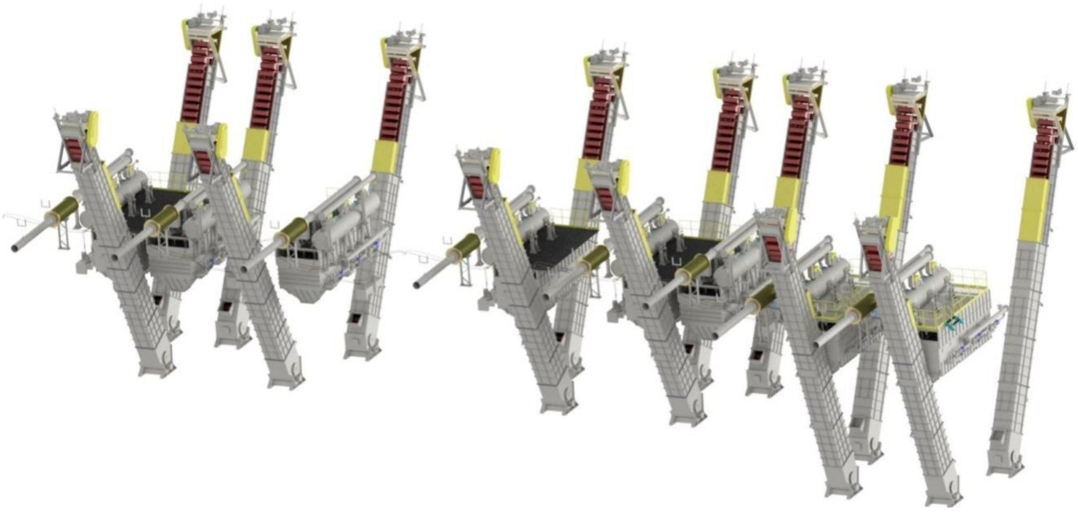

Fig. 7. Beneficiation node at the Budryk Mine after modernization

5. Summary

The results of technological tests, conducted by the KOMAG specialists in the Mechanical Coal Preparation Plant of the Budryk Mine in 2011, indicated a necessity of introducing technological and design changes of the beneficiation node to improve parameters of beneficiation products. Within the framework of the plant modernization, basing on the design project elaborated at the KOMAG Institute of Mining Technology, six OS18 medium-size-grain jigs and two OM20 fines jigs together with dewatering bucket conveyors in the number of fourteen, were installed. The jigs were equipped with the innovative KOGA control system developed at the KOMAG Institute.

The solution implemented in the medium-size-grain beneficiation node, consisting in a division of the jigs into two systems (three jigs in each of them), enabled a simultaneous, independent beneficiation of coal (types:34 and 35) or an operation of only one system.

An implementation of new design solutions in the modernized beneficiation node enables a more effective realization of the beneficiation process and it enables to maximize a production of high-quality coal concentrates.

An additional factor, maximizing the process capacity, is a recovery of coal grains from the parting product being beneficiated in the secondary OM20 fines jigs.

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Tests of Reversion Filter of KOMAG Design

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Krzysztof Nieśpiałowski

Affiliation: KOMAG Institute of Mining Technology, Pszczyńska 37, 44-101 Gliwice, Poland

e-mail: kniespialowski@komag.eu

Keywords: hydraulic liquid, filter, reversion filter, test

Słowa kluczowe: ciecz hydrauliczna, filtr, filtr rewersyjny, badanie

Abstract:

In technological systems of many industry branches including the hard coal mining industry, water indispensable for washing, transport of materials, cooling or driving and controlling an operation of equipment, is used. Quality parameters of water have a direct impact on life of the equipment supplied with it. In many cases they have a decisive impact on a technological process. Water quality can be increased by a correct filtration with use of filters operating in a continuous way (without operators), which are subject to verification tests as regards their functionality and operational safety before their delivery to a customer.

Streszczenie:

W ciągach technologicznych wielu gałęzi przemysłu, w tym w górnictwie węgla kamiennego, wykorzystuję się wodę, niezbędną do płukania, transportu materiałów, chłodzenia czy napędu i sterowania pracą urządzeń. Parametry jakościowe wody przekładają się bezpośrednio na żywotność zasilanych przez nią urządzeń. Niejednokrotnie mają decydujący wpływ na proces technologiczny. Jakość wody może być podniesiona poprzez właściwą filtrację, z zastosowaniem filtrów pracujących w sposób ciągły (bezobsługowy), które przed dostarczeniem do klienta poddawane są badaniom weryfikującym pod względem funkcjonalności i bezpieczeństwa pracy.

1. Introduction

Different types of filters are used in every branch of industry where liquid or air is a working medium. They can be equipped with paper, textile, plastic or steel cartridges. In turn they can be woven, interlaced or made of wire wound on a supporting structure (slotted cartridges). Filters with slotted cartridges, due to their easy cleaning are widely used and they are divided into two basic groups:

- linear – assembled in the supply hose – their cleaning requires switching off the supply and thus interrupting the filtration process,
- with internal cleaning, using a scraping element or reversion rinsing with filtrate stream. The cleaning process can by conducted automaticly or manually, basing on the information about the pressure difference on the filter inlet and outlet.

Filters of the second group are mainly used in the systems of continuous operation. It is not necessary to switch off the equipment to exchange a cartridge, but only short rinsing with the reverse stream is required, so these filters are widely used in:

- conventional power stations for purifying water cooling generators and thus extending the operational time of slide bearings of turbines shafts in water-power plants,
- heat and power generating plants for a protection of heat exchangers through their protection against their chocking and wear,
- chemical industry for a purification of process water,

- metallurgical industry for pressure cleaning of castings made of moulding sand and for cooling iron blast furnaces and rolling mill lines,
- technology of drinking water treatment as filters of preliminary purification,
- environmental protection technology for dewatering of sludges before their sterilization with ultra-violet rays in the process of reverse osmosis or in the process of membrane filtration,
- papermaking industry for supplying water spraying nozzles on paper sieves,
- mining industry in hydraulic installations supplied with emulsion and in water spraying and water-and-air installations of cutting drums of shearers, roadheaders and other systems reducing dust in the run-of-mine haulage processes [1,2,3].

Specific environmental conditions, which occur in the mining industry, force a use of big amounts of water (for spraying and cooling of equipment) and of emulsion (for supplying powered roof support units). The quality of water, delivered to machines and equipment, has a significant impact on their reliability and life which affect an increase of operational safety, a reduction of down-time and a reduction of service and maintenance costs [4,5,6,7,8]. A filtration of the above mentioned media is often conducted with use of filters with slotted cartridges. A construction of this equipment enables their cleaning without a need of their disassembly (self-cleaning filters called reversion ones). A big demand of the mining market for this type of filters (offered by foreign companies so far) caused a start of their production by domestic producers. However, high requirements of their users caused a development of filters' control systems, from manual to automatic. The reasons, described above, made the specialists from the KOMAG Institute undertake an elaboration of the slotted filters' series of types in the scope of operational pressure values from 4 to 40 MPa and capacities from 80 $dm^{3/}$min to 60 dm^3/min, basing on professional experience and an observation of slotted filters' operation in hard coal mines. These filters, ensuring high technical parameters, can be controlled manually (small units) or automaticly.

The significance of manual control at big flows and big operational pressures consists in generating a big force for a valve recontrol. Filters, operated in an automatic cycle, are deprived of this disadvantage and they do not require any supervision from the operator's side.

The equipment, described above, after its full completion, is subject to verification tests which mainly consist in checking the manufacture quality, a determination of flow resistances as well as in conducting functionality, leaktightness and strength tests. Below some tests of a chosen filter item, controlled manually, are described.

2. Test of high pressure WFR-250/40 reversion filter

High pressure WFR-250/40 reversion filter of KOMAG design, produced by the Elektron Company from Bytom, was subject to test (Fig. 1). It is designed for a filtration of water and of water-in-oil emulsion. It is two-chamber equipment, enabling a reverse cleaning of cartridges without a necessity of interrupting a filtration and a disassembly of filtration cartridges. Its construction ensures a safe application in underground mine workings, in which methane or coal dust explosion hazard may occur.

The filter is characterized by the following basic parameters:

- flow rate 250 dm^3/min,
- working pressure 40 MPa,
- max. liquid temperature 50^{o}C,
- filtration 50 μm (100 μm, 200 μm).

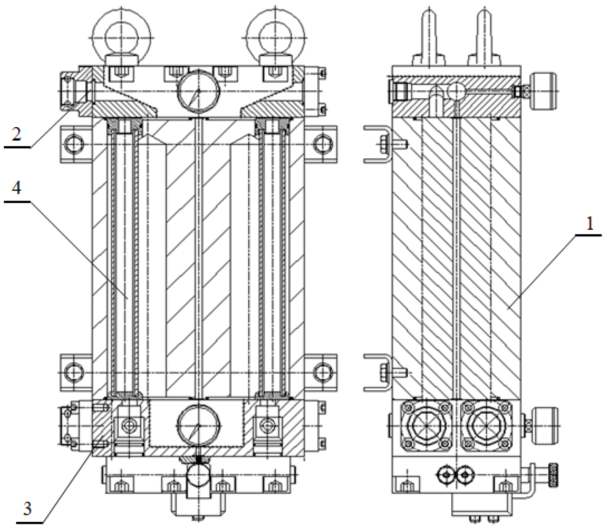

Fig. 1. WFR-250/40 reversion filter
1 – housing, 2 – supplying plate, 3 – flow plate, 4 – filtration cartridge

The filter was subjects to tests at the KOMAG test rig to check its operational correctness and also its manufacture correctness, as both of them are interconnected. These tests incorporated:

- a determination of flow resistances through a high-pressure reversion filter with filtration cartridges,
- a determination of flow resistances through a high-pressure reversion filter without filtration cartridges,
- functionality test during the filter operation:
  – a filtration of the left chamber and a regeneration of the right chamber,
  – a filtration of the right chamber and a regeneration of the left chamber,
- a test of static loading for the pressure of:
  – 40 MPa, i.e. p_{nom} (test of leaktightness),
  – 60 MPa, i.e. p_{nom} x 1.5 (strength test).

A view of the filter on the test rig is shown in Fig. 2.

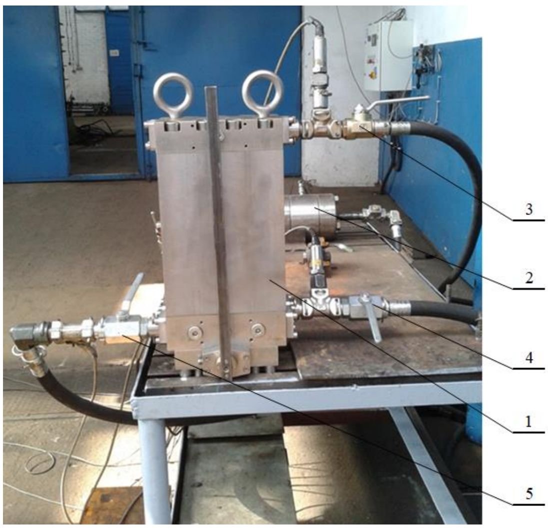

Fig. 2. WFR-250/40 reversion filter on the test rig
1 – filter, 2 – measurement turbine, 3, 4, 5 – hydraulic hoses (respectively: inflow of contaminated liquid, outflow of filtered liquid, outflow of contaminants) with installed pressure transducers and cut-off valves

First of all the filter was subject to tests connected with a measurement of flow resistances. Two tests were conducted, for the filter equipped with filtration cartridges (Fig. 3) and with no cartridges (Fig. 4). The measured pressure drop during the first test was Δp = 1.13 MPa at the flow rate Q = 104.6 dm^3/min. During the second test the measured pressure drop was Δp = 1.06 MPa at the flow rate Q = 103.15 dm^3/min.

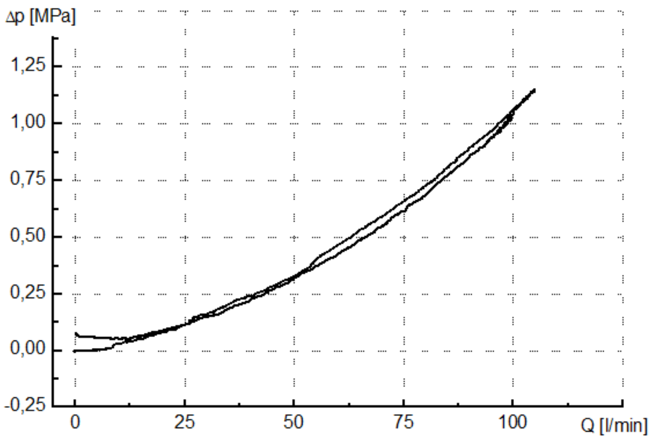

Fig. 3. Graph of flow resistances through the filter with filtration cartridges

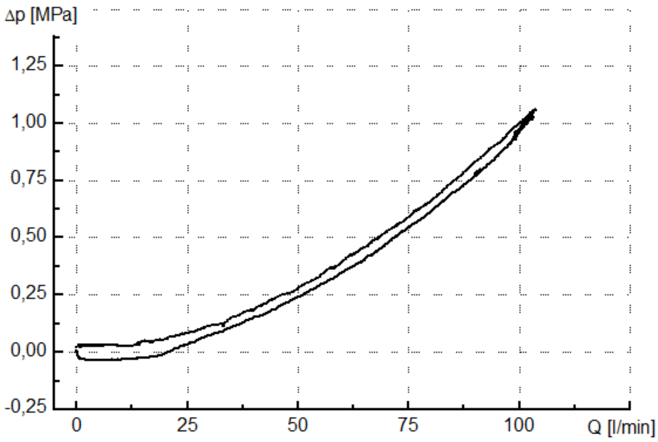

Fig. 4. Graph of flow resistances through the filter without filtration cartridges

Basing on the conducted tests, it was concluded that a construction of the filter meets the design requirements in the scope of liquid flow resistances. The pressure drops during the flow through filtration cartridges were minor and comparable with the pressure drops during the liquid flow through the chamber without any installed cartridges. It confirms a correct selection of the filtration surfaces of cartridges. The next test was the functionality test. It consisted in conducting filtration in both filtration chambers, manual switching of the filter operation into the rinsing mode of one chamber cartridge and then a manual recontrol into the mode of rinsing the other chamber cartridge. An exemplary graph in the case of a filtration through both chambers is shown in Fig. 5.

Due to the fact that the outflow from the filter was not loaded (a direct overflow to the tank), the filtration pressure (course in the graph is marked in black) in each case had the value close to 1 MPa, resulting from flow resistances. The regeneration pressure (in red) had a similar value. In the graph the moment of the valve opening and closing, in the line supplying the filter (in blue), can be clearly seen.

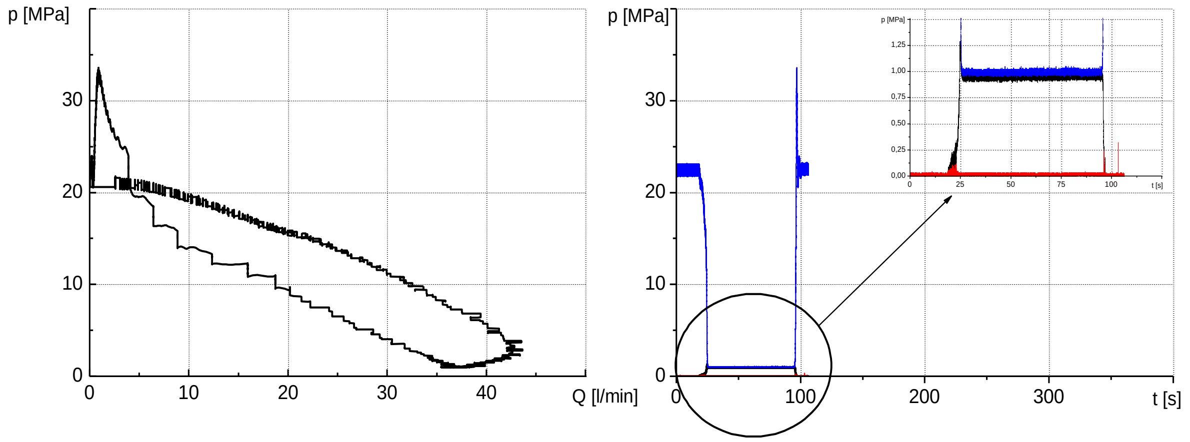

Fig. 5. Graph of pressure in the function of time during the functionality tests. A simultaneous filtration of both filtration subassemblies: in blue – supply pressure, in black – filtration pressure, in red – regeneration pressure

Fig. 6 shows a filtration process with one chamber, whereas the other one is being rinsed (regenerated). In this case a clear increase of regeneration pressure (in red) and the moment of the valve opening and closing, in the line supplying the filter (in blue), can be noticed.
In this case the conducted tests also confirmed the design correctness, switching of the direction of filtration/regeneration did not cause any problems and the flow resistances were similar to those obtained in the former test.

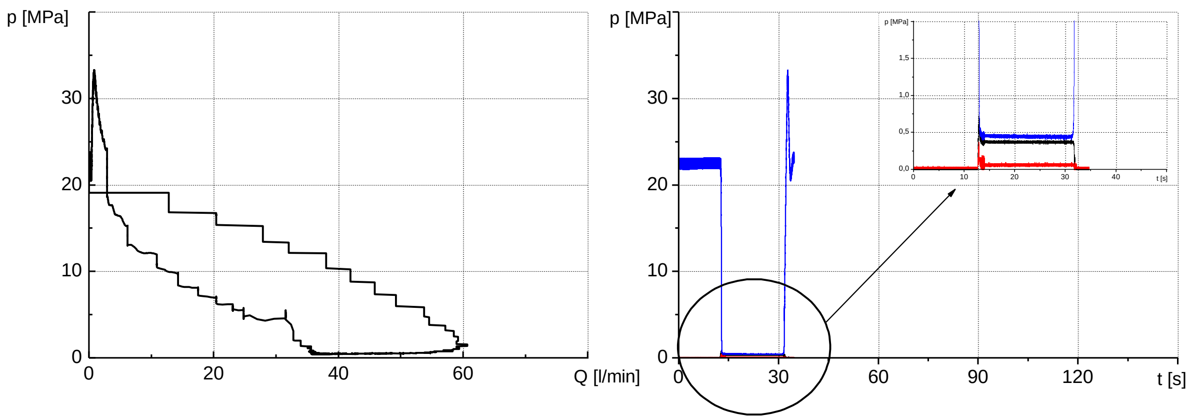

Fig. 6. Graph of pressure in the function of time during the functionality tests – filtration of right chamber and regeneration of left one: in blue – supply pressure, in black – filtration pressure, in red – regeneration pressure

The last test included filter leaktightness and strength tests. During the filter loading with nominal pressure, an outflow of the sealing from the space between the housing and the flow plate (Fig. 7) was noticed. An analysis of the filter housing screw joint with the plates: supply and flow ones showed that such a condition was caused by using stainless screws of class A2, for which the elongation strength limit is Rm = 700 MPa but the yield point is Re = 450 MPa.

Fig. 7. A view after unsealing the filter 1 – housing, 2 – flow plate, 3 – sealing

The screws were exchanged for stronger ones (class 12.9), whose Rm = 1200 MPa and Re = 1080 MPa and screwed home with the moment appropriate for them. During the following test (of leaktightness and of strength) no leakage of filtrated liquid was noticed, what is presented in a form of graphs in Fig. 8 and 9.

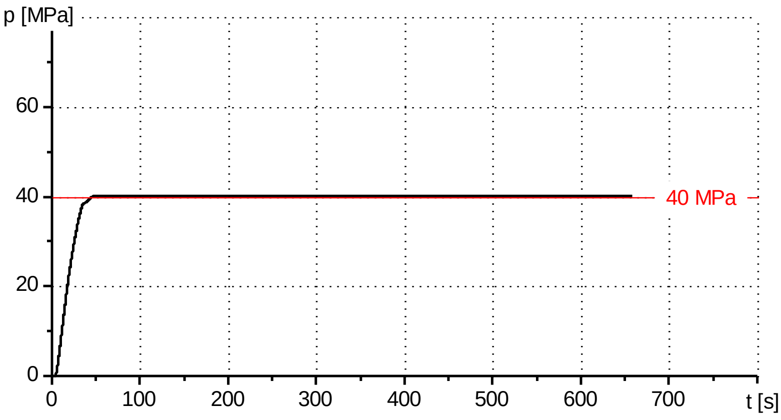

Fig. 8. Test of leaktightness – nominal pressure

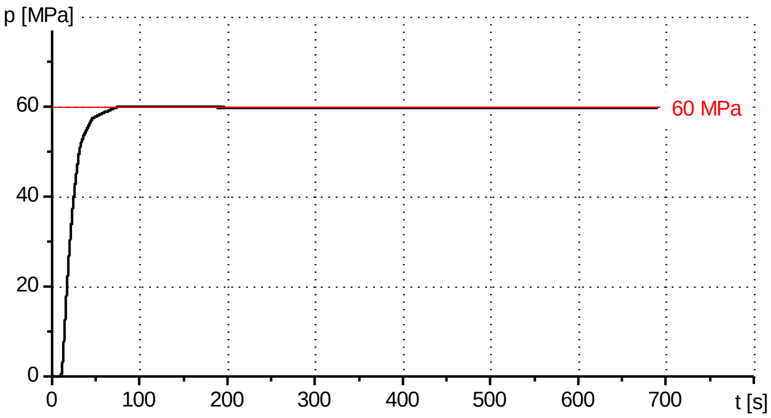

Fig. 9. Strength test – nominal pressure x1.5

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3. Summary

Three thematic groups work in the Division of Machines and Equipment at the KOMAG Institute of Mining Technology. One of them deals with hydraulic issues. It realizes projects oriented onto widely understood power hydraulics. Concepts, projects and technical documentations of machines and equipment to which belong, among others, reversion filters discussed before, are elaborated. These filters, designed for a filtration of water and of water-in-oil emulsion, are widely used in many branches of industry, including the hard coal mining industry. Exactly there, they are used in technological systems connected with the production. They purify water from mechanical pollutants. Among others this water is used in cooling systems of electric motors and high power gear – boxes, spraying systems or as regards emulsion – power roof support units.

Big experience enables to conduct research work connected with hydraulic supply systems and to offer assistance during assembly operations and start-up of machines and equipment constructed on the base of the authors' technical documentation. A close collaboration with the KOMAG laboratories, having test rigs enabling to conduct a broad tests' spectrum of systems, subassemblies and assemblies of power hydraulics for machines in series production and experimental prototypes, facilitates an implementation of safe machines and equipment.

The tests of one of the products, made according to the KOMAG technical documentation, are presented in the article. The conducted tests confirmed a correctness of the design. Drops of pressure during a regeneration of the filter cartridges were minor, which certifies a right selection of filtration surfaces. Only during the test of leaktightness an outflow of the sealing was noticed which was caused by an application of improper screws fixing the flow plate to the housing block. An exchange of screws, for stronger ones mechanically, eliminated the problem and a repeated test of leaktightness did not cause any liquid outflow from the equipment. The strength test, which was conducted by loading the filter with the pressure equal to 1.5 x nominal pressure was also successful which certifies the fact that the filter is efficient and can be exploited safety.

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