Historical background and development trends of minerals’ processing – conclusions from KOMEKO–IMTech 2019 Conference

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Abstract. The article describes historical background and a few development trends of minerals’ processing on the base of the conclusions drawn during the KOMEKO-IMTech 2019 Conference organized by the KOMAG Institute of Mining Technology last March. The scope of the Conference covered an exchange of information and professional experience among representatives of science and industry technology. Some information about processing techniques and technologies in Soverign Poland are also presented in the article. Special attention is paid to innovative solutions of minerals’ beneficiation machines and equipment, in particular developed at KOMAG for the hard coal mining industry.

1. Introduction
Each March the KOMAG Institute of Mining Technology organizes a scientific and technical conference on innovative and environment - friendly techniques and technologies of minerals’ processing in the aspect of safety, quality and efficiency. This year the 20th KOMEKO – IMTech 2019 Conference was held in Szczyrk, Poland from 25th till 27th March 2019 and it gathered researchers, designers, producers and users of preparation plant machinery and equipment. Due to that an interesting and creative forum of specialists, ready to share their knowledge and professional experience, had a possibility to discuss the present issues as well as development trends of minerals’ processing techniques and technologies. The subject-matter of the conference covered, among others, the following issues:

- Gasification technologies of solid fuels and ecofuels.
- State-of-the-art machines and equipment for processing of minerals.
- Modernization of minerals’ preparation plants.
- Recovery of rare-earth elements from hard coal.
- A development of pulsation jigs, planetary mills and hydrocyclones.
- A recultivation and revitalization of post-industrial areas – coal recovery from waste dumps.

The KOMEKO-IMTech 2019 Conference was really special due to a small jubilee. In fact it was the 20th Conference from the KOMEKO cycle attended by numerous specialists, representing science and industry. It was sponsored by CARBOAUTOMATYKA, OPA CARBO MIFAMA, NORD DRIVE SYSTEMS and OMAG.
2. Development of hard-coal mining industry and of minerals’ processing techniques and technologies in Sovereign Poland (1918-2018).

When Poland regained independence in 1918, it was very important to concentrate on developing its economy, as there were big needs as well as multi-year negligences caused by the war. The government activities were oriented onto Upper Silesia, where different minerals were deposited, mainly hard coal but also iron ore, zinc and lead. Before the first world war 250 thousand workers were employed in the industry and about 200 thousand of them worked in the mining and metallurgical branches of industry. Then there were 67 hard coal mines, 15 mines of zinc ore and 9 mines of iron ore. The hard coal production rate was 43.5 mln tons in 1918.

In the period between the wars the production rate of hard coal in Poland decreased significantly due to an economic crisis. During the second world war the hard coal production rate was only 20 mln tons. After the war, in 1946 the production rate of hard coal reached 51 mln tons. The production top rate was achieved in 1979, when it reached 201 mln tons. However, in 1990 the production rate of 70 coal-mines in operation was 151.3 mln tons.

In 2018 in total 18 coal-mines produced 63.4 mln tons of hard coal and there was a record import of coal in the range of 16.2 mln tons. A development of hard coal processing plants started during the period between the wars. It consisted in a modernization of machines and equipment in the existing preparation plants.

In practice, in all the coal mines, the run-of-mine was directed to preparation plants to be sorted manually. The modernization covered an installation of crushers, screens, washeries and air classifiers. It is important to mention that belt conveyors (which facilitated haulage activities significantly), were introduced then. An electric drive became common.

The production rate of the biggest sorting plants reached 600 t/h. Cascade washeries, installed in the Bytom and Hohenzollern Mines, were one of several innovative solutions of important character. In the thirties air classifiers were applied in the Bielszowice and Abwehr Mines. Their production rate was from 80 to 100 t/h in the case of grain sizes from 0.5 to 35 mm [1, 5]. A new design solutions concerned the smallest grains. In 1937-1938 the Dębieńsko Mine installed a flotation machine for the first time. It processed 75 thousand tons of concentrate within a year, using two batteries of the total production rate of 25 t/h. It should be noticed that the first washeries in the Upper Silesian mines were implemented twenty years after their introduction in England and in America. In 1946 the coal production rate in Poland was 51 mln tons and the processing capabilities were 19800 t/h. Over the period 1946-1964 some new preparation plans were constructed and several ones were modernized. In total 21 sorting plants, 19 washeries, 3 air classifiers and 6 flotation plants started their operational activity. In the same time 3 sorting plants, 4 washeries and 1 flotation plant were modernized. As the coal production rate was 130.7 mln tons in 1963, so 93% of the run-of-mine could be subject to preparation processes. It should be borne in mind that in 1946 the preparation plants could process 52.3% of the run-of-mine in the sorting plants and washeries [5]. The following years up to 1997 brought a significant progress in the scope of coal preparation plant development, as 53 new plants were built and 23 were modernized. The restructuring activities of the Polish mining industry, undertaken after 1989, had a strong impact on functioning of coal processing plants. Over the period 1989-1997 22 preparation plants were closed down due to a radical reduction of the coal production rate. In 1997 hard coal was mined in 57 mines and 66 preparation plants were in operation, where 66 grain washeries +20 (10) mm, 45 fines washeries 20 (10)-0.5 mm and 22 coal flotation sections 0.5÷0 mm worked [1].

In 1997 the basic technological centres of preparation plants were equipped with machines and equipment presented in Table I [5].
Table 1. Equipment and machines operated in preparation plants in 1997 [5].

| Item | Machines and equipment | Number of machines |
|------|------------------------|--------------------|
|      |                        | in total | domestic | imported |
| 1    | Screens of preliminary classification | 394       | 351      | 43       |
| 2    | Beneficiation equipment for classes +0.5 | 417       | 371      | 46       |
| 3    | Flotation machines      | 86        | 77       | 9        |
| 4    | Dewatering machines     | 916       | 881      | 35       |
| 5    | In total                | 1813      | 1680     | 133      |

At present in 18 hard coal mines there are 40 preparation plants in operation. Among them 33 plants beneficiate steam coal (9 of them beneficiate coal only in the classes above 20 (10) mm, 16 of them – in the classes above 0.1 mm and 8 of them – in the whole grain scope).

Coking coal is beneficiated in 7 coal processing plants within the whole scope of grain sizes. The machines and equipment, used in these processes, include: pulsating jigs, different types of screens, crushers, heavy – medium separators, Reichert spirals, heavy – medium cyclones, hydrocyclones, flotation machines, vibrating screens, and vibrating centrifuges, screen – sedimentation centrifuges, belt presses, filtration presses, pressure filters and disc vacuum filters. At present these technological nodes are automated and visualized.

3. Achievements of KOMAG Institute of Mining Technology in implementing innovative solutions in hard coal preparation plants.

The KOMAG Institute of Mining Technology specializes in designing and testing of machines and equipment for an exploitation as well as processing of minerals. It was established in 1950 and up till now underwent several organizational changes, enabling its adaptation to the market oriented economy. KOMAG has always been active and successful in implementing innovative machinery solutions which are operator and environment friendly [2]. Since 1950 over 1100 technical documentations of machines and equipment, used in mines of minerals in Poland and abroad, have been elaborated. An innovative character of these solutions is confirmed by more than 4400 patents and utility patents granted by the Polish Patent Authority.

Research projects in the domain of minerals’ processing machinery and equipment have been realized since 1955. In this scope of activity KOMAG has extremely efficient solutions as regards DISA separators and pulsating jigs. Over the period 1955-2018 technical documentations of 320 separators and over 200 separators in pulsating water medium, i.e. pulsating jigs [4] have been designed at KOMAG. The present offer includes jigs of KOMAG type such as: OM – fines jigs for grain class 20-(0.5) mm, OS – medium size grain jigs for grain class 80 (50) – 0 (0.5) mm and OZ – grain jigs for grain class 120 – 20 mm. These jigs are operated not only in Poland but also in Argentina, Brazil, China, India, Romania and Vietnam. It is important to realize the fact that modified designs of jigs are also used for a production of aggregates. A list of jigs, designed over the years 1955-2018 and implemented in the Polish hard coal mines and in the aggregates production plants as well as installed abroad, is presented in Table 2.
### Table 2. List of KOMAG type jigs designed over the year 1955 -2018 [4, 6].

| Production period | Type of jig | Name of coal-mine |
|-------------------|-------------|-------------------|
| 1955 - 1970       | OBM 12, OBM 15, OBSZ15, OBZ 10, OBZ 12 | Anna, Dębieńsko, Knurów, Rydułtowy Export to China, India and Vietnam |
| 1971 - 1985       | ODM 10, ODM 18, ODZ 15, OM 12, OM 12-2, OM-12-3, OM 12-3S, OM 12G3, OM 12 P3, OM 12 L3, OM 18P3, OM 18 L3, OM 24-3, OM 24D, OM 24 BC, OM 24 D3, OZ 18L, OZ 12, OZ 12L, OZ 12 P3, OS 36D3, OZ 36D3, OC8, OC10 | Bogdanka, Borynia, Dębieńsko, Gliwice, Halemba, Knurów, Krupiński, Jankowice, Makoszowy, Marcel, Pniówek, Dymitrow, Rydułtowy, Sośnica, Staszic, Wujek, Szczyciągów, Wawel, Zabrze, Zofiówka, Moszczenica Export to Brazil, India and Romania |
| 1986 - 2014       | OM 8L2e, OM 8L2E, OM10L2E, OM 15 B3E, OM 12P3E, OMPE-3x6.5, OM 18L3E, OM 18P3E, OM 20 P3E, OM 20L3E, OM 24 P4E, OM 24L4E, OM 24D3E, OM 30-3E, OM 18 3x8, OM30 D3E, OS30 D3E, OM 30, OZ 18 L3E, KOD jig | Andaluzja, Anna, Barbara – Chorzów, Bogdanka, Borynia, Budryk, Dębieńsko, Halemba, Jastrzębie, Jasmos, Knurów, Krupiński, Marcel, Pniówek, Rozbark, Rymer, Rydułtowy – Anna, Sośnica, Staszic, Szczyciągów, Wawel, Wujek, Zofiówka Export to Czech Republic and India Budryk – for waste removal from run-of-mine |
| 2003 - 2018       | Pulsating classifiers: K - 100, K – 150, K – 50, K – 80, K – 101, K – 102, K - 151 | KSM in Borzęcin, PPMDKruszbet in Suwałki, PRInż Surowce in Januszkowice, PUHM “M” in Kędzierzyn – Koźle, Żwirownia Bierawa, PRESTO – Emil Potręć, Rokitno, Rent – Pol – Przeczelbie |
| 2014 - 2019       | OM 30, OS18L, OS18P, OM15L, OM 15P, OS 4, OM 20, OM18L, OS 18P, OM 24, OM 15L, OM 15P | Sośnica, Krupiński, Pniówek, Budryk, Zofiówka, ZG „Eko-Plus”, ZG Sobieski |

Research and development projects, realized at the KOMAG Institute within recent years were also oriented onto hydrocyclones, screens and crushers. They concerned not only technical and technological aspects, but their operational safety in particular. One of the hazards, experienced by the personnel of preparation plants, is dust. Four different types of dust control equipment are used:

- **UO type** using a wet dust control method, where water is dispersed by means of fixed and rotational nozzles; the dust control efficiency reaches 99.7%.
- **DCU type**, where a stream of dust laden air contacts with water curtain generated by a rotor, driven by a motor, which acts as a fan forcing the air under control,
LCDU type, where a mechanism of wet dust control connected with labyrinth air flow, is used. Due to frequent and violent direction changes of dust laden air particles, they loose their momentum and are easy to be separated on the water curtain. This dust collector can operate together with axial-flow as well as centrifugal fans, installed in front or behind the dust collector which enables an operation in sucking or combined ventilation systems.

DRU type in which a traditional mechanism of water spraying, connected with a centrifugal separation, achieved due to use of two guide vanes, gives a high efficiency at small resistance to flow.

Another efficient dust control method, developed at KOMAG, consists in an application of spraying equipment in a form of a battery with spraying nozzles which are installed in the areas where dust is generated on transportation routes of the run-of-mine. These installations are supplied with water and compressed air. One of the solutions is the PASAT mist system installed on discharge points of conveyors and on crushers. This system was implemented in the Bolesław Śmialy and Mysłowice - Wesoła Coal Mines. Only recently the NEPTUN system, consisting of seven independent installations, built on five work-places, was implemented in the Bolesław Śmialy Coal-Mine.

4. Examples of modernization activities in hard coal preparation plants.

4.1. Modernization of the Pniówek Preparation Plant
The modernized Pniówek Preparation Plant started its operation in 2017. The beneficiation node consists of 8 fines jigs of OM 15L and OM 15P types (20÷0 mm) shown in Figure 1 and 8 bucket conveyors of B-1000 type shown in Figure 2.

![Figure 1. OM 15 Fines jig](source: KOMAG).
Figure 2. B-1000 Bucket conveyor [source: KOMAG].

Figure 3. Jig node control system of KOGASTER type [source: KOMAG].

The jig node, shown in Figure 3 is controlled by the KOGASTER system developed at the KOMAG Institute.

Figure 4. Modernized preparation plant at Pniówek Coal Mine.
It is important to emphasize the fact that in the case of the Pniówek Mine four two-trough jigs (Figure 4) were replaced by eight one-trough jigs of OM 15 type which facilitated the control possibilities of the beneficiation process.

4.2. Modernization of the Budryk Preparation Plant

The modernized Budryk Preparation Plant started its operation in 2018. The beneficiation node consists of 6 medium-size grain jigs of OS 18 (L and P) (70—2 mm) type, shown in Figure 5, 2 fines jigs OM 20 (12-0 mm) type, shown in Figure 6, and 14 belt conveyors of B-1000 type (Figure 7).

Figure 5. OS 18 medium-size grain jig [source: KOMAG].

Figure 6. OM 20 fines jig [source: KOMAG].

Figure 7. B-100 Bucket conveyor [source: KOMAG].
The jig node is controlled by the KOAGASTER system developed at KOMAG. It is shown in Figure 3.

Due to a modernization of the Budryk Preparation Plant it was possible to beneficiate coal of two types: 34 and 35, using two independent systems.

4.3. Modernization of the Sośnica Preparation Plant

The KOAGASTER SSWO system [3, 7] at the Sośnica Preparation Plant controls an operation of two OM 30 fines jigs for a three-product beneficiation of the run-of-mine in the grain class 20-0 mm. Three B-1000 bucket conveyors of an increased bucket capacity up to 120 cm$^3$ are installed. An implementation of new machines and equipment enabled to increase a supervision of the beneficiation process and to improve an efficiency of the run-of-mine separation in the jig node.

The structure of the jig node control system as well as the measured parameters [3] are shown in Figure 8.

![Figure 8. Structure of the jig node control system [3, 7, 8].](image)

An automatic control of the hard coal beneficiation process in jigs is realized by:
- collecting data on the object condition,
- data processing enabling to take decisions concerning the process control,
- adjusting and taking corrective measures.

The control system, installed in the Sośnica Mine, is enables a control of the speed of the bucket conveyors, adapting their capacity to current loading [7, 9].

An installation of the KOAGSTER SSWO control system, elaborated at the KOMAG Institute, contributed to an increase of the Sośnica Preparation Plant efficiency and reliability.

4.4. Modernization of the Sobieski Preparation Plant.

In 2019 the jigs for the Sobieski Preparation Plant will be commissioned. The modernized beneficiation node consists of two fine coal jigs OM15L and OM15P for the grain class of 30-2 mm at the maximum capacity of 320 t/h each. They will replace two compartment Allmineral jigs. The
OM15 jigs will benefit three products. Modern WZL1 2.8x6.0 screening machines for separating the material below 2 mm are shown in Figure 9.

![WZL1 2.8x6.0 screening machines](image)

**Figure 9.** WZL1 2.8x6.0 screening machines installed at the Sobieski Preparation Plant [source: KOMAG].

5. Conclusions

- The technical and technological changes implemented in minerals’, mainly hard coal preparation plants over the period of a hundred years of the Poland’s sovereignty, contributed to a rapid development of the mining industry in Poland.
- A modernization of the existing and a construction of new preparation plants were realized with a close collaboration with the researchers from the KOMAG Institute of Mining Technology.
- Within the period of nearly 70 years of activity in the domain of designing and testing of mining as well as preparation plant machinery and equipment KOMAG researchers elaborated over 1100 technical documentations being the basis for manufacturing the machinery used in Poland and abroad (Argentina, Brazil, China, India, Romania and Vietnam).
- An innovative character of the KOMAG technical and technological solutions is confirmed by more than 4400 patents and utility patents granted by the Polish Patent Authority.
- Research and development projects, realized at the KOMAG Institute within recent years, concerned not only technical and technological aspects, but also widely understood operational safety, in particular dust control.
- As far as modernization activities in hard coal preparation plants are concerned three examples are given: Sobieski, Budryk and Sośnica Coal Mines, but special attention is paid to the KOGASTER jig node control system developed at KOMAG.

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