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Design and application development of KOMAG-type pulsating concentrators

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Author's affiliations and addresses:

[1] KOMAG Institute of Mining Technology
Pszczyńska 37
44-100 Gliwice, Poland

[2] Institute of Construction and Architecture
Dúbravská cesta 9
845 03 Bratislava 45
Slovak Republic

[3] VSB - Technical University of Ostrava, 17. listopadu 2172/15,
708 00 Ostrava 8, Czechia

*** Correspondence:**

e-mail: dkowol@komag.eu

Daniel KOWOL [1*], Piotr MATUSIAK [1], Martin T. PALOU [2], Jan KIELAR [3]

Abstract:

Coal and mineral raw material processing includes a key stage: improving feed quality and producing products that meet market requirements. One of the most commonly used methods is gravity separation in a pulsating water medium, carried out in jigs and pulsating classifiers. For over 70 years, the KOMAG Institute of Mining Technology has been conducting research on the design and modernization of these devices, developing various types of beneficiation units for different particle-size classes of raw materials, as well as modern control systems. The article discusses the development of KOMAG pulsating beneficiation units, their applications in the coal and aggregate industries, and their use in recovering raw materials from mining waste.

Keywords: Mechanical processing, mineral raw materials, gravity separation, pulsating beneficiation concentrators

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1. Introduction

Hard coal processing constitutes one of the key stages in the production of commercial coal grades. Its primary objective is to improve the quality of the extracted raw material and to obtain quality and quantity parameters of the final products that comply with the final technical and economic unit value (customer requirements).

One of the basic operations in the mechanical processing of mineral raw materials is gravity separation, which enables effective separation of materials composed of particles with different densities. This method is widely used in the beneficiation of coal, metal ores, and non-metallic raw materials. Gravity separation can be carried out in various types of equipment that use different separation media - air, water, or heavy suspension liquids - depending on the type of material, its particle size distribution, as well as the required efficiency and accuracy of separation. The appropriate selection of the separation medium and technological process parameters is crucial for separation efficiency and, consequently, for the quality of the final product and the economics of the entire processing operation.

Due to the widespread application of this method in industrial practice, the KOMAG Institute of Mining Technology has, for many years, conducted research and development focused on the design and improvement of separation equipment. The developed solutions, both in design and technology, are used in domestic and international processing plants.

An example of such achievements is the beneficiation equipment designed 70 years ago and used for density-based separation of mineral raw materials in a pulsating water medium. Over the years, more than 200 technical documents of these devices have been developed at ITG KOMAG. Parallel research conducted at both laboratory and industrial scales has led to continuous improvements in the technical solutions applied.

The article discusses the development of KOMAG-type pulsating beneficiation units, taking into account progress in design solutions and the expansion of their application potential. Directions for equipment modernization and examples of their use under various technological conditions are presented.

2. Characteristics and applications of pulsating concentrators

Beneficiation in pulsating concentrators (jigs) is based on the use of differences in the settling velocities of particles with different densities in water. The processed material is subjected to cyclic loosening in a pulsating water medium, which results in stratification and transport along the screen deck surface toward the separation zone. There, based on measurement signals and control of the product discharge system, the feed material is separated into two beneficiation products: an upper product composed of particles with lower density and a lower product composed of particles with higher density.

A typical pulsating concentrator (jig) consists of working compartments comprising lower and upper boxes (working troughs). The upper boxes of a single jig compartment are equipped with screen decks, working air collectors, a pulsating air distribution system, and beneficiation product discharge devices. The lower boxes, in turn, contain pulsation chambers into which working air is supplied to induce pulsating motion of the water, as well as collectors that supply lower water with an adjustable flow rate [1].

Despite the widespread adoption of heavy-media separators, pulsating jigs remain key devices in the beneficiation of coal and metal ores [2, 3]. They are used, among others, in iron ore processing plants, where they effectively separate feed material in various particle size classes at high separation densities [4, 5]. The jigging process has been extensively tested for manganese, tungsten, tin, iron, and phosphate ores with high MgO content. In China, approximately two-thirds of tungsten ores are processed using this method [6–9].

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Jigs are also used for separating plastics, with high efficiency for binary mixtures and fine particles [10, 11]. The jigging beneficiation method has also been validated for recycling electronic waste, end-of-life vehicles, and used household appliances [12–14].

In industrial practice, jigs are used for aggregate cleaning, recovery of mineral and energy fractions from mining waste, and in the recycling of construction materials [15, 16]. They enable the production of high-purity aggregates from recycled concrete, which constitute a full-value substitute for natural aggregates [17, 18].

3. KOMAG-Type Pulsating Concentrators

3.1. Pulsating Jigs for Hard Coal Processing

Pulsating jigs are the basic devices used for hard coal beneficiation in Polish mechanical coal processing plants. KOMAG is currently developing jig designs intended for the beneficiation of hard coal with diversified particle size distributions. These include: OM fine-coal jigs for particles of 20-0(0.5) mm, OS medium-size jigs for particles of 80(50)-0(0.5) mm, and OZ coarse-coal jigs for the 120-20 mm size fraction [1].

Examples of jigs intended for fine coal beneficiation include the OM24 unit installed at the “Zofiówka” Coal Mine (Fig. 1) and the OM15 unit operated at the “Sobieski” Mining Plant. The former is the only Polish jig with a working bed width of 3500 mm.

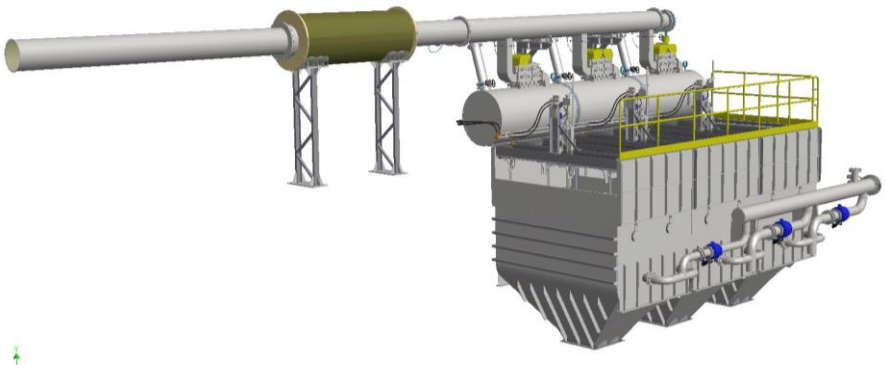

Fig. 1. OM24 fine-coal jig at the Zofiówka Coal Mine [19]

In 2017, as part of the modernization of the Budryk coal mine Processing Plant, six OS18 medium-sized jigs were designed and subsequently implemented for the beneficiation of materials with a maximum particle size of 80 mm, along with two OM20 jigs for secondary beneficiation.

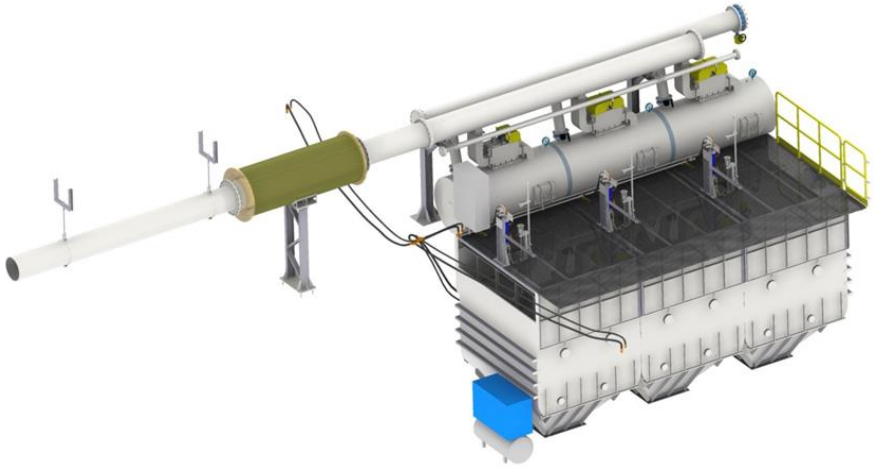

Fig. 2. OS18L medium-size jigs at the “Budryk” Coal Mine [20]

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Subsequent implementations of KOMAG-designed jigs were carried out at the Pniówek Coal Mine (OM24D3E), the Sobieski Mining Plant (OM15), and ZG Eko-Plus Sp. z o. o. (OS4) [1].

Over the years, all main assemblies of the jigs have undergone design modifications, including, among others, pulsating air distribution systems, measurement systems, and product discharge systems, as well as screen decks.

In the early 1980s, modern disc valves replaced the rotary pulsation valves previously used in KOMAG-type jigs. The application of these solutions enabled modulation of the pulsation cycle, thereby directly improving the stratification effectiveness of the processed material. In subsequently implemented jigs, further modifications were made to the pulsating air distribution systems, notably reducing the pneumatic actuator control system's sensitivity to contamination of the air supply (Fig. 3).

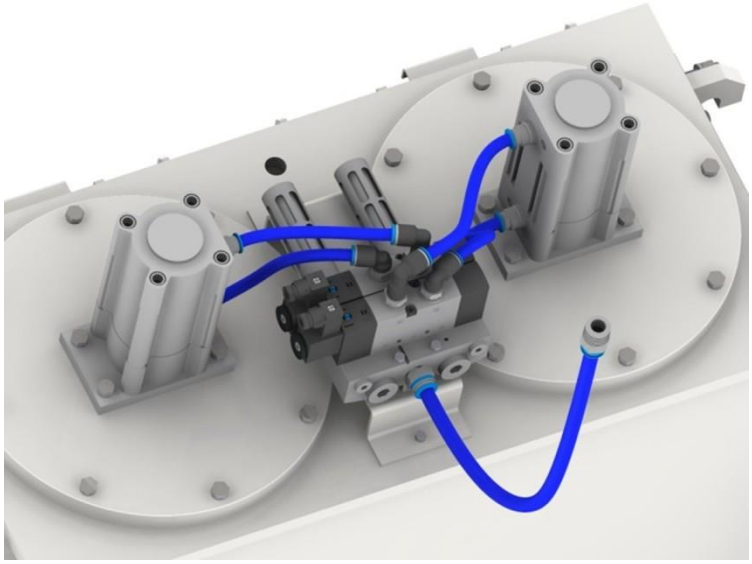

Fig. 3. KOMAG-type pulsation valve [19]

The design solutions for product discharge systems depend primarily on the feed particle size and the design assumptions regarding the degree of control over the separation process. The slide-gate discharge systems used in older fine-coal jigs (OM) were replaced in newer jigs by systems with a slide gate as the closing element. This design extends the active area of the working deck and reduces disturbances of the material bed in the product discharge zone (Fig. 4).

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Fig. 4. Slide-gate discharge system [19]

An extremely important and integral component of a pulsating jig is its control system, which governs and optimizes its operation. However, effective execution of the beneficiation process in a jig requires an appropriate control system for the entire jigging node, which, in addition to the main device, includes the feed supply system and systems for the discharge and dewatering of the beneficiation products.

As a result of the work of ITG KOMAG specialists, the KOGA SSWO system was developed and implemented at several mining plants, including the Sośnica, Zofiówka, and Budryk coal mines, as well as the Sobieski Mining Plant. Among its many functions, the KOGA SSWO jigging node control system controls the water pulsation process, automatically controls beneficiation product discharge, controls bucket elevator speeds, and measures and records monitored operating parameters [19].

3.2. Application of pulsating classifiers in the natural aggregate cleaning process

Based on many years of experience in designing pulsating jigs for coal beneficiation, a new device structure was developed to produce sand and gravel while simultaneously removing organic and mineral impurities. The result of these efforts was the development of the K-100 pulsating classifier, an innovative solution enabling the production of aggregates that meet the required quality standards.

The device design was developed within the framework of the targeted project No. 6 T07 045 2001 C/5462 entitled “Installation for the production of washed natural aggregates – a pulsating classifier for natural aggregates”, co-financed by the State Committee for Scientific Research. Its prototype was installed in 2002 at the “Dębówko” aggregate mine, belonging to Szczecińskie Kopalnie Surowców Mineralnych S.A. [21].

The pulsating classifier consists of a set of working chambers with a total area of 4 m², with a screen deck installed in the upper part on which material separation takes place. The device is equipped with a rotary discharge unit with a scraper for the higher-density product and an overflow

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trough for the lower-density fraction. The pulsating motion is generated by a pneumatic system comprising a blower, air tank, pulsator valves, compressor, and water supply system. An electronic control system allows adjustment of process parameters, such as pulse frequency and scraper speed, to adapt them to the type of material being processed and the load.

In accordance with the schedule of the targeted KOMAG project, the first two units were commissioned in 2005 at the KSM Sp. z o.o. gravel pit in Borzęcin (CEMEX Polska) (Fig. 5) and at the Aggregate and Prefabricate Production Plant in Suwałki (PPMD Kruszbet S.A.).

Fig. 5. Pulsating classifier K-100 in Borzęcin [16]

Subsequent K-100 units were commissioned at the PRInż. Surowce Sp. z o.o. gravel pit in Januszkowice and at the Concrete Production Plant in Zdzieszowice (PUH "M+" Sp. z o.o. in Kędzierzyn-Koźle).

Subsequently, a K-150 classifier was installed at the Bierawa gravel pit (CEMEX Polska). To accommodate the increased capacity of 150 t/h, the rotary discharge unit for the gravel product was redesigned (Fig. 6). At the Rokitno gravel pit (K-80), the next unit was equipped with a control system that allows the selection of operating parameter sets tailored to different feed particle size ranges in order to improve the efficiency of carbonate particle removal.

Fig. 6. Pulsating classifier K-100 in Bierawa [16]

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The classifier's design was continually improved. In 2010, a modernized pulsating classifier, K-101, was developed. Among other updates, the pulsation valve was modified, allowing independent control of the working air supply system. A new classifier operating algorithm was also implemented, a more effective silencer was installed on the working air outlet, and the product discharge device was upgraded. Additionally, an alternative solution for the cleaned aggregate discharge system was introduced by installing a flexible scraper in the discharge unit, which increases the maximum particle size of the feed to 32 mm (Fig. 7).

Fig. 7. Flexible scraper of the discharge unit [22]

Due to the need to adapt the device for operation at lower capacity, a K-60 classifier was developed in 2012, featuring a screen deck width reduced by half compared to the K-100/K-101 classifiers [23].

The Institute also developed a new version of the pulsating classifier, called the membrane classifier (Fig. 8). The main design goal was to reduce the number of components needed for basic functions, such as generating feed pulsation and transporting and discharging the products. The aim was to lower manufacturing, equipment, and subsequent operating costs. In this design, the pulsating motion of the processed material is produced by a bellows pulsator, which includes a pneumatic actuator and a series of bellows connected in sequence by bolted elements, shaped flanges, and spacer rings (Fig. 8) [24].

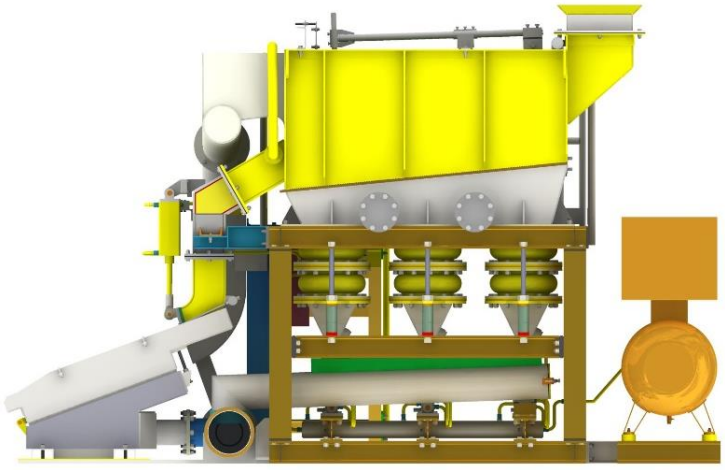

Fig. 8. Membrane pulsating classifier [24]

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3.3. Use of pulsating classifiers in the separation of mining waste

Further design modifications enabled the classifier to be used for the recovery of mineral raw materials from post-mining waste dumps. As a result, the device has found application not only in natural raw material processing plants but also in waste management and resource recovery activities.

The designed device, the K-102 pulsating classifier intended for the separation of material with a particle size range of 35-3(0) mm, was commissioned in autumn 2015 at the Central Coal Waste Dump in Przezchlebie (Fig. 9).

Fig. 9. Pulsating classifier K-102 in Przezchlebie [24]

Repeated industrial tests have confirmed that applying the gravity beneficiation method to mining waste in the K-102 pulsating classifier produces two full-value products. The high-density product, containing trace amounts of organic matter, can serve as an alternative aggregate with various applications. The second product, which has high calorific value and low ash content, is an energy coal concentrate [24, 25].

Subsequent implementations focused on further development of the device, primarily its control system. The K-102 No. 2 classifier, commissioned in 2016, was equipped with a proprietary ITG KOMAG control system.

The implementation of an integrated control system for the entire processing node enabled the achievement of a number of benefits, including:

- optimization of equipment operation by adjusting capacity to the current classifier load,
- reduction of electrical energy consumption,
- extended service life of actuating components under variable load conditions,
- expanded capabilities for process monitoring and documentation,
- reduction in the number of downtimes,
- easy system expandability,
- centralized access to data from a single location [16].

In the K-102 No. 3 classifier commissioned in 2017, the KOMAG-type control system was enhanced with algorithms for analyzing pulsation, classifier load, blower operating statistics, and the rotary scraper discharge unit [24].

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Fig. 10. Pressure sensor installed in the air chambers of the working compartment [16]

In 2025, a new version of the classifier was developed - a prototype of the mobile mining waste separation system S-100 (Fig. 11), which constitutes one of the significant outcomes of the project "New technology for hydrogen and geopolymer composites production from post-mining waste" (H2GEO), co-financed by the Research Fund for Coal and Steel and the Ministry of Science and Higher Education. The main objective of the project is the development of a comprehensive technology for the processing of post-mining waste dumps.

Fig. 11. Prototype of the mobile mining waste separation system S-100 [26]

In the new solution, a number of design modifications were introduced that will improve the device's efficiency and reliability and facilitate maintenance and adjustment activities. These include, among others:

- a labyrinth seal and a flushing system in the design of the rotary discharge unit,
- a valve island in the pulsating air generation system,
- improved mounting of the screen deck,
- a redesigned air tank geometry [26].

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5. Summary

The development of pulsating concentrators at the KOMAG Institute of Mining Technology includes both structural improvements and the implementation of advanced control systems across the entire jigging node. These improvements affect all essential components of the equipment, including screen decks, product discharge systems, pulsation valves, and working chambers, enabling increased separation efficiency and the production of high-purity products of consistent quality.

Simultaneously, integrated automation and monitoring systems are being developed to enable continuous control of process parameters. Advanced control algorithms allow for dynamic optimization of unit operation, resulting in reduced energy and water consumption, improved process stability, lower failure rates, and extended service life of actuating components.

The design and technological solutions used in KOMAG pulsation jigs enable efficient beneficiation of hard coal, resulting in the production of high-quality coal concentrates, cleaned natural aggregates, and the recovery of mineral resources from mining waste. The coal and mineral fractions separated during this waste processing can serve as valuable raw materials for additional use, including in energy processes like gasification and in material applications such as geopolymers.

The latest devices, including the innovative S-100 classifier developed within the H2GEO project, set the direction for further modernization of pulsating jigs. They are characterized by increased reliability, higher operational efficiency, and improved ergonomic design. Additionally, they allow flexible adjustment of process parameters to meet changing technological conditions, paving the way for even more precise separation of materials with diverse physicochemical properties.

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