Improving the quality of hard coal products using the state-of-the-art KOMAG solutions in a pulsating jig node

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Abstract. Hard coal run-of-mine contains a significant amount of waste rock, which must be removed to improve the quality of the extracted raw material. Coal processing is an integral and extremely important part of the production of commercial assortments. Water pulsating jig is one of the basic devices in which the material is separated. The article presents some possibilities of improving the qualitative and quantitative parameters of the beneficiation products due to design changes and control of the jig beneficiation node.

1. Introduction
A proper operation of the jig beneficiation node depends on many factors, but to a large extent it depends on proper selection of cooperating devices. Improperly selected devices result in ineffective work and, consequently, in a limitation of the ability to obtain the desired parameters of the final products, such as losses of combustible substance in the waste product, ash content and a content of harmful sulphur compounds in the concentrate [1].

There are many methods for obtaining the proper quality and quantitative parameters of the products beneficiated in pulsating jigs. Even a distribution of the feed on the surface of the jig feeding device is an important factor that affects the correctness of a beneficiation process in the pulsating jig. Another important factor is a proper selection and operation at correctness of the beneficiated products collecting device. An adjustment of bucket conveyor’s output to the instantaneous load of the dewatered material is an important element of the proper operation of the jig beneficiation node. Operational parameters of the screen deck are the factors having an impact on the water pulsation parameters, and thus the efficiency of the feed separation.

A presentation of a possibility of increasing the jig beneficiation node effectiveness in the scope of technology, design and a control system is the article objective.

2. Feeding the material to the jig
A uniform feed of the material to the water pulsating jig is one of the basic requirements of the beneficiation process. Some disturbances at this stage cause non-uniform loading of the working surface, which results in an decrease of the feed material separation efficiency.

Such conclusions were confirmed by the laboratory tests carried out on the experimental jig at KOMAG. An impact of non-uniform input of the fed material to the jig on the separation efficiency was tested and analysed by changing the feed within granulations 16 – 3 mm as regards its quality and quantity [2,3]. A change in the feed qualitative parameters was obtained by separation of 16 - 3 mm fraction on the 8 mm screen. Thus, it was possible to feed 16 – 8 mm and 8 – 3 mm fractions
separately to the working chamber on the left and right side with a uniform output (Test 1). Non-uniform flow of the feed was obtained by its one-sided introduction to the jig working chamber (Test 2). The test results in a form of beneficiation indexes, shown in Fig. 1, indicate that improper preparation of the feed causes a change of beneficiated products parameters.

![Graph showing the impact of differentiation of feed on the jig inlet on the separation efficiency.](image)

**Figure 1** Impact of differentiation of feed on the jig inlet on the separation efficiency [3].

The tests showed that both a non-uniform in-put of the feed on the inlet width (Test 2) as well as quality non-uniformity (Test 1) significantly reduce the efficiency of the beneficiation process in relation to feed in-put (Test 3).

In the case of improper feed in-put, the probability of unplanned production breaks increases due to an excessive accumulation of material which makes its displacement difficult.

The highest efficiency in material distribution is obtained when using the vibrating devices of the width similar to the width of the jig working bed at the same direction as the feed movement.

Feeders and vibrating screens are the most commonly used devices for feeding the material to jigs. When the directions of material feeding and its moving are the same, the vibrating motion allows distribution and obtaining an input layer of similar height and transportation speed. However, a uniform supply of feeders and vibrating screens with raw coal is required.

A non-uniform distribution of the material along the screen width can be caused by feeding the material at the right angle to the longitudinal screen axis. In this case, despite using the additional guiding components on the transfer chute, the material is not averaged along the screen working surface. A non-uniform distribution of the feed on the screen results in its non-uniformity on the feeding chute of the jig trough.

Use of vibrating feeders with a material distribution function is one of the possibilities enabling to improve the quality of the material feed on the width of the devices in the jig beneficiation node. Feeders of this type (Fig. 2) allow to reduce the length of the feeding devices.
Figure 2 Cross-section of vibrating separator with the central feed and double outlet [1].

3. Solutions of systems for collecting beneficiation process products

Different methods of discharging the heavy fractions from the jig trough surface are used in the design solutions of the systems collecting the bottom product from pulsating jigs. They mainly result from the grain sizes of the feed as well as design assumptions in the aspect of the separation process control or expected load [4].

In the OM fine coal jigs, designed for a beneficiation of the material of grain size distribution $20(30)-0.5(0)$ mm, feedthrough pipes or sliding bolt pipes are used (Fig. 3). A collecting trough, due to which the material layer is increased over the collecting slot, which is the common feature of these solutions.

The feedthrough pipe is equipped with screens inclined symmetrically towards the collecting trough of rectangular cross-section. A pipe (or angle bar) suspended on moving strings is a component for controlling the degree of feedthrough opening. The bottom product is discharged from the collecting trough through two parallel slots, which can be extended by lowering the pipe (or angle bar) position.

Such a volume control of the discharged material enables to maintain its constant height in the collecting trough. The above mentioned solution is advantageous regarding a stabilization of water pulsating stream flowrate in the products collection zone as well as an accuracy of layer density measurements. Pulsation parameters dependence on a degree of feedthrough slot opening is a disadvantage of this solution [1,5].
A vertical sliding bolt, making the slot opening, is an actuating component in the bottom product collecting system, in which sliding bolt feedthroughs are used. Sliding bolt feedthroughs can be divided into lever ones and straight ones. In the first one a rotation of some system components occurs, whereas in the other one it is a rectilinear movement [1,5,6].

In the OZ grain jigs - (or OS medium-size grain jigs) a collection of the bottom product from beneficiation of coal feeds of grain size distribution 120-20 mm (or 70-0.5 mm) is most often realized with use of key feedthroughs (Fig. 4).

In the above mentioned solution, without the collecting trough, the heavy fraction grains are discharged through a slot placed on the level close to the screen deck surface. The slot appears in the result of simultaneous lifting of the moving threshold equipped with articulating keys and lowering the flap being the screen deck extension. The feedthrough flaps are perforated to ensure pulsating stream flow in the near-the-threshold area and to reduce its flow rate in the collecting slot during the material discharge [1,5].
KOMAG continuously develops designs of jigs and their assemblies. Basing on analyses of operational effectiveness of the solutions used in KOMAG jigs, new designs of the bottom products collecting system were developed both for medium-size grain jigs and coal fines jigs.

In a development of the concept for waste fraction collecting system (Fig. 5a) it was assumed that the system will enable oscillating changes in the collecting slot opening. In the case of the same frequency of its operation as the frequency of water pulsation it can be used for controlling an intensity of water flow through a feedthrough slot to ensure a stable discharge of grains irrespective of their amount. In this solution the floating layer measuring sensor system was mechanically separated from the mechanisms controlling the feedthrough.

In the design solution of the products collecting system intended for medium-size grains, a separation of the bottom product collecting trough from the jig boxes, supplied by pulsating chambers is suggested (Fig. 5b). The screen part of the collecting system situated at the feed in-put side is separated from the jig collecting trough. A supply of this part is realized by a separate pulsating chamber having its own system for controlling the flow of pulsating air and bottom water inflow. The above-mentioned control system is coupled with the controller of the collecting system. Similarly as in the case of the solution for a coal fines jig, the layer floating sensor measuring system is mechanically separated from the feedthrough control components [1,7].

![Figure 5](image.png)

**Figure 5** New solutions of the products feedthrough for (a) coal fines jigs and (b) medium-size grains jigs of KOMAG type [7].

4. **Control of bucket conveyors**

The KOMAG pulsating jigs are equipped with the author’s KOGASTER SSWO system for controlling the jig nod. The system for controlling the speed of bucket conveyors, which dewater jig bottom products, is the most important component of this system.

A changeable load of bucket conveyors operating in the jig nod, resulting from changes in jig feeding rate, a change in density distribution of beneficiated material or in the result of operator’s intervention, is a characteristic feature of their operation. In this case, a speed of the conveyor should be adapted to the load change to prevent against an excessive accumulation of the material in the conveyor discharge zone.

Use of information from the sensors about jig filling degree, feed stream flowrate as well as weight of the feeding belt and feedthroughs opening degree enables to change the rotational speed of the
motor driving the conveyor using the frequency converter. Additionally, the frequency converter informs about the current load of the bucket conveyor [8].

![Control system of the jig node](image)

**Figure 6** Diagram of the bucket conveyor control system.

Such a system enables exceeding the nominal conveyor output by about 20%, in the case of the nod overloading. The instantaneous increase of the conveyor output enables a quicker discharge of the heavy product from the jig.

In the case, when the amount of the bottom product is less than nominal, it is possible to reduce the conveyor speed, at the same time increasing the conveyor life time (Table 1).

| Item | Degree of a bucket filling [%] | Percent of rated power [%] | Energy saving in relation to the rated power [%] |
|------|--------------------------------|-----------------------------|-----------------------------------------------|
| 1    | 0                              | 53.5                        | 46.5                                          |
| 2    | 20                             | 62.6                        | 37.4                                          |
| 3    | 40                             | 71.8                        | 28.2                                          |
| 4    | 60                             | 80.6                        | 19.4                                          |
| 5    | 80                             | 90.0                        | 10.0                                          |
| 6    | 100                            | 100.0                       | 0.0                                           |

5. **Screen deck parameters**

Screen decks of pulsating jigs can be one of the controlling components, which support the systems controlling the compressed air and bottom water inflow during a generation of pulsating motion [9,10]. The clearance between screen decks is one of the most important parameters.

The laboratory tests, carried out at the KOMAG Institute of Mining Technology on the experimental jig stand, have shown a significant impact of the screen deck clearance on the separation efficiency of the beneficiated material density fractions. The test results proved that use of screen decks of big clearance enables a more efficient separation of lightweight grains of the concentrate fraction of density <1.5 g/cm³ (Table 2). A reduction in screen decks clearance results in an increase of separation effectiveness of hypertrophic grains of density 1.5-1.8 g/cm³ and simultaneously a
reduction of separation effectiveness of the concentrate grains (Table 3). An increase in sizes of screen openings showed the same tendency for the screen decks of the comparable clearance.

Table 2. Share of fraction <1.5 g/cm³ in the concentrate layer [1,9].

| Layer       | Openings Ø4 mm | Openings Ø 10 mm |
|-------------|----------------|------------------|
| Clear ance coefficient, %  |
| 22.8        | 40.4           | 22.8             | 40.4             |
| Share of fraction <1.5 g/cm³ |
| 30 s        | 92.2           | 98               | 98               | 97.9             |
| 45 s        | 94             | 100              | 98               | 98               |
| 60 s        | 96             | 100              | 98               | 100              |

Table 3. Share of fraction 1.5-1.8 g/cm³ in the interlayer [1,9].

| Layer       | Openings Ø4 mm | Openings Ø 10 mm |
|-------------|----------------|------------------|
| Clear ance coefficient, %  |
| 22.8        | 40.4           | 22.8             | 40.4             |
| Share of fraction 1.5-1.8 g/cm³ |
| 30 s        | 89.8           | 80.4             | 71.4             | 64.6             |
| 45 s        | 90             | 82.1             | 73.5             | 64.6             |
| 60 s        | 90             | 84.3             | 70.8             | 65.3             |

As it can be seen from the above tables an extension of beneficiation time increases a separation effectiveness of the concentrate fraction and reduces an output of hypertrophic grains. A reduction of separation effectiveness of hypertrophic grains, after an extension of beneficiation time indicates that apart from the grains density separation a dimensional separation also occurs.

The results of laboratory tests on impact of screen deck parameters on water pulsating movement and separation effectiveness of coal feed indicates that a proper selection of screen decks design parameters, adequate for the technological conditions, have a positive impact on shaping the characteristics of water pulsating flow [10]. A pulsation pitch and flowrate of water lifting stream during a single pulsation cycle reduces with an increase of water flow resistance through the screens in the result of a reduction of their clearance and opening sizes [3,4].

The factors which affect selection of screen deck parameters for the specified pulsating jig are the following:
- density and grain composition of the beneficiated material,
- quantity and quality of the beneficiated products,
- capabilities of the air and water flow control systems,
- methods for control of the bottom product discharge system.

During a beneficiation of the coal feed of grain sizes in class 20-0.5 mm, under water pulsating movement, a part of heavy fraction grains of small sizes is discharged from the working surface through the screen deck openings. This process, which could be used to increase a separation accuracy of coal feed in a wide spectrum of size classes is not controlled at present.
Changing the volume of compressed air fed to the pulsating chambers in relation to the pressure measured in the under-the-screen part of the jig, is one of the possibilities for controlling a volume of the product discharged through the screen openings. A pressure increase in the above mentioned part of the jig due to a thickness increase of heavy fraction grains layer deposited on the screen surface, after exceeding the set value, will cause a periodical, simultaneous and interdependent increase of water pulsating movement rate and of an amount of discharged heavy product [11,12].

6. Conclusions
Beneficiation efficiency in pulsating jigs depends on many factors in the scope of technological and design solutions as well as control system.

To produce commercial products of the required qualitative and quantitative parameters, a pulsating jig requires among others a uniform input of feed and working media (air, water) as well as a precise control of collecting the separation products.

The suggestions of new design solutions or control possibilities of operational parameters in the jig nod, described in the article, are only a part of the issues aimed at reaching a high beneficiation process efficiency.

KOMAG research projects, realized in collaboration with other scientific organizations, universities and manufacturers and especially with end-users enable a continuous development of jigs as well as an implementation of innovative technological and design solutions.

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