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Concept of a CDR resonance screen

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Abstract:

Review of existing solutions of resonance screens, including their technical parameters are presented. The following resonance screens are discussed: GHH type, multi-mass ZDR type, GRO-1 type, EGK-2 type, CDR-8 type, etc. On this basis, the strengths and weaknesses of the discussed solutions of resonance screens are identified. Conclusions resulting from the analyzes of the applied solutions were used in KOMAG to develop the concept of the CDR-85K resonance screen. The assumptions made during development of the concept of a new resonance screen solution are presented, and then its structure and principle of operation are discussed. A general drawing of the designed screen with selected parts is provided. The attention was paid to the innovative solutions used in its design.

Keywords: CDR resonance screen, minerals classification

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1. Introduction

Mechanical processing is one of the basic branches of technology for mining the useful minerals. Its task is to refine the extracted raw minerals and prepare them for further use in the form of raw materials, and even to prepare the finished product.

The mineral extracted from the deposit requires preparation, before it is directed to industrial use or for direct sale, consisting in the maximum increase of the useful component content per volume (or mass) unit. Almost all useful minerals, such as hard coal, lignite, iron and non-ferrous metal ores and many others are processed mechanically. Mineral processing, due to their nature, can be divided into the following: preparatory, main, complementary, auxiliary and service [1, 2, 3].

Mechanical classification enables separating the raw material or beneficiation products into the required grain size classes. Mechanical classification is also known as screening. During many years of designing work supported by operating experience, a large number of various design solutions for screens were created. There are two main groups of sieves: screens and grates. This article focuses on resonance screens that belong to the group of vibrating screens [4, 5, 6, 7].

2. Materials and Methods

A resonance screen is a device used in mechanical processing as part of mechanical classification (screening). Technological activities on raw material and processing products are intended to give them such properties that enable their further industrial use.

These types of screens belong to a group of flat screens, the largest group of machines used for screening raw materials and beneficiation products.

The design of flat screens allow, regardless of the dimensions of the openings in the screens, a very high degree of screening accuracy and selecting the characteristics of vibrating motion of the screen box or screen, which enables screening of difficult-to-screen material, i.e. containing a significant amount of the finest grains with a relatively high content of surface water. A significant increase in screening efficiency is also achieved by introduction of new design of screens, especially those self-cleaning from the moist fine grains adhered to them [1, 8, 9].

Design of the screen that would allow reaching the best accuracy of screening, regardless of the assumed quality parameters of the raw material, is not possible. This is because these parameters affect the screening accuracy [10].

It is necessary to increase the vibration frequency of the screen to improve screening efficiency. The forces acting on each grain during the screening process range from 4 to 5 G. Screen structure should be analyzed and simulated during the designing process, together with identification of phenomena appearing during operation [11, 12, 13, 14].

Flat screens, regardless of their design and the drive type, are equipped with practically all the components of a typical screen, i.e. screen boxes properly supported or suspended on a supporting structure, a separate supporting structure with a more or less complex structure, drive and parts transmitting movement from the drive to the sieve box or boxes, or transferring the movement to the sieve (sieves) with stationary sieve boxes [2, 15, 16].

Unlike the other flat screens, resonance screens do not have a rigid connection of drive joints with screening boxes. Only in some designs, connection between joint and the screen box holder was made flexible by rubber cushions or rubber ring inserts. Such elastic inserts were intended only to reduce the load to the drive shaft at the moment of changing the direction of the screen box movement and did not affect the nature of the screen box vibrations or the overall dynamics of the screen movement. However, they made it possible to increase the frequency of screen box vibrations and to achieve a more powerful lift of the screened material layer and its better loosening [1]. The principle of operation of the resonance screens is presented in Fig. 1. The set of rubber bands 3, set in a pendulum motion, drives the upper and lower riddle 1 and 2, which, due to the flexible suspension on leaf rockers, swing in opposite directions. The screening process takes place on the screens installed in the riddle.

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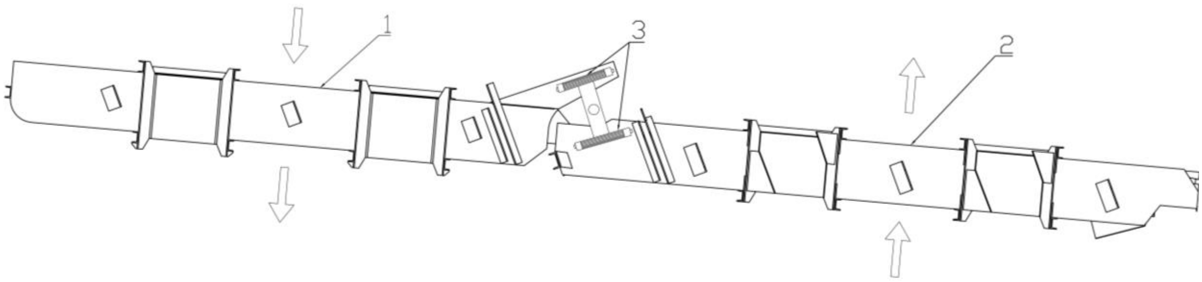

Fig. 1. Principle of operation of resonance screens

Introduction of dynamically balanced vibrating mass systems and flexible (elastic) suspension of the drive unit made it possible to increase vibrations of the screen boxes, as well as to limit the harmful effect of inertia forces on the screen parts and their transfer to the supporting structure of the building. However, in the screens designed in such a way, a significant amount of energy supplied to generate the vibrating motion of the screen boxes is used to overcome inertia forces of accelerated masses of the vibrating system at the moments of constantly changing direction of these boxes fluctuations. Magnitude of these forces is the greater, the larger and heavier the screen boxes and the amount of material fed to them are, and the greater is the stroke of the boxes and the greater the frequency of vibrations (to increase the lifting energy and at the same time accelerate the movement of the screened material layer and increase their efficiency) [1, 11].

The design of resonance screens was developed to solve the problems of dynamic loads and excessive energy consumption needed to overcome the inertia forces in the direction changes/vibrations of the screen boxes, not used for the operation of the screen. Resonance screens belong to the group of flat screens, with the pendulum movement of the screen boxes, therefore, during their working motion, inertia forces also appear, when direction of vibrations of the screen boxes changes [1, 11, 17, 18].

In connection with the work undertaken on a new solution of the resonance screen, several types of resonance screens, differing in design were analyzed in literature.

2.1. GHH resonance screen

The GHH resonance screen (Fig. 2) is a resonance two-mass vibrating system.

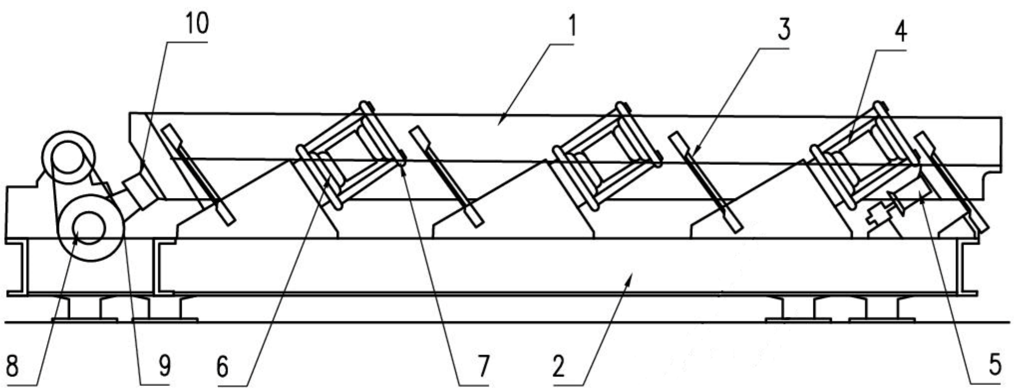

Fig. 2. GHH resonance screen

The horizontal screen box 1 is set on inclined spring slats 3 on a lower steel frame 2 made of profile steel with a closed box cross-section. Three pairs of buffer position limiter 4 are fastened to the screen box. The screen box and the frame vibrate freely in the range close to the stroke of the system of both vibrating masses. When the direction of vibrations changes, the buffer supports hit the elastic rubber cushions in which kinetic energy (as potential energy) is stored. This energy is transferred to the vibrating system after passing the turning points of the vibrating masses.

Elastic rubber cushions 6 are attached to the trestles by threaded bolts 7, enabling their middle positioning in relation to the buffer resistance 4. The rubber cushions are fixed in special mountings for plates, the position of which is determined by nuts on the bolts 7. Total width of both slots is slightly smaller than the stroke of the screen box.

The screen box is coupled to the frame 2 with an elastic rubber cushion 5. The drive motor set on the frame 2 drives the cranked shaft 8 with a system of V-belts, on which the drive couplings 9 are placed. These links are connected to the screen box by double-sided elastic rubber cushions 10. This system is known as a free coupling. The vibrating frame 2 is set on the foundation on sets of elastic rubber cushions, allowing it to vibrate freely.

These types of screens are designed with a screen working width from 1000 to 2200 mm and the length from 4500 to 7500 mm [4].

2.2. ZDR multi-mass resonance screen

ZDR screens are marked by high efficiency, low power consumption, high screening efficiency due to good loosening of the screened material layer and negligible dynamic impact on the building.

Diagram of ZDR resonance screen is shown in Fig. 3.

Its design consists of two screen boxes 1 and 2 placed on sets of elastic slats 3 on two separate frames 4 and 5, balancing weight of the screen boxes. The frames are set on elastic rubber rings 6 and 7 and additionally fixed to the base by sets of springs 8 and 9, bent in the shape of the letter S. The arrangement of these springs provides additional protection of the entire vibrating system against excessive vibrations. Screen boxes and the frame are additionally coupled with flexible couplings 10 and 11. Each screen box is equipped with two pairs of sets of elastic rubber rings 12 and 13, built into trestles 14 and 15 fixed to the frames. The rubber ring assemblies rest against buffers 16 attached to the screen boxes. Stroke of the boxes is limited by rubber bumpers 17.

The motor 18 drives the shaft on which the eccentrics are wedged through the V-belt transmission. Driving connectors 19 are bearing mounted on the eccentrics and are connected to the first screen box via flexible couplings, which make it swing. The first frame is set in motion by the dynamic action of the eccentric shaft thereon. The first oscillating system sets the second screen box and the second frame into motion via clutch links 10 and 11. Stroke of the screen boxes is determined by pre-compressing the rubber ring assemblies and selecting the radius of the eccentrics.

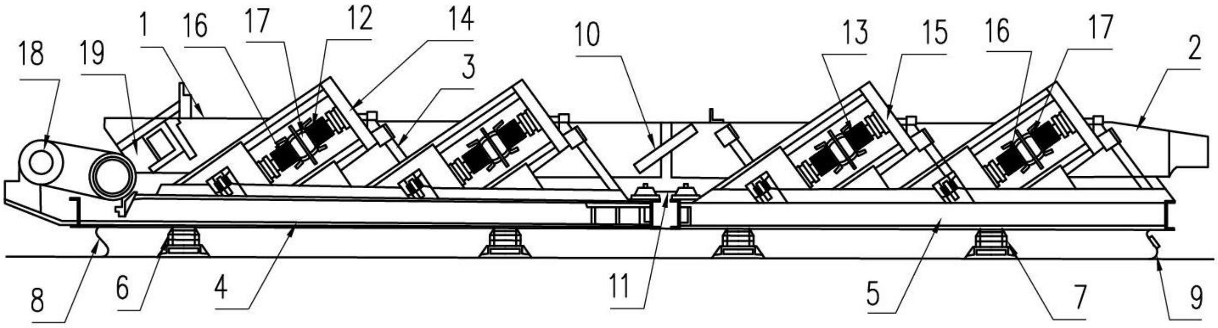

Fig. 3. ZDR resonance screen

ZDR screens are designed in two different sizes, with a screen box width of 1800 and 2000 mm, and with a screen working surface of 17 and 21 m^2. They have a capacity of 300 and 350 t/h. The screen boxes vibrate at a frequency of 800 cycles per minute with an amplitude of 16 mm. The screens are powered by motors with a power of 13 and 17 kW [5].

2.3. GRO-1 triple-mass resonance screen

The group of resonant screens also includes a box resonance screen in a triple-mass system, shown in Fig. 4.

The screen boxes 1 and 2 are positioned horizontally on the swing rods 3 on a joint frame 4, which is equivalent to the mass of both screen boxes. The frame is set on a foundation on elastic rubber cushions 5, enabling the frame to vibrate in resonance with the screen boxes.

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In the trestles 6 fixed to the frame, groups of rubber rings 7 are mounted, resting on the support 8 fixed to the screen box. Beneath both sets of rubber rings, rubber buffers 9 are fixed, limiting the stroke of the screen box. The motor drives the eccentric shaft 11 through a belt transmission. The eccentrics bear the drive connectors 12, connected to the screen box with a double-sided set of rubber rings 13. Drive connectors 12, connected to the screen box by a double-sided set of rubber rings 13, are fixed on the eccentrics.

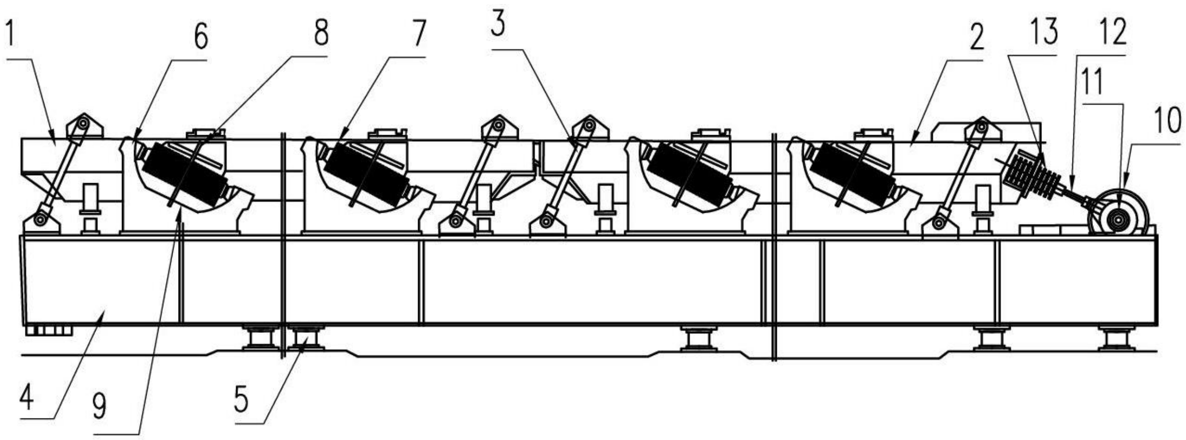

Fig. 4. GRO-1 triple-mass resonance screen

This screen is intended mainly for coal dewatering with a maximum grain size of 0 to 25 mm and for mud dewatering. Working width of GRO-1 screen is 2000 mm with a total length of 8000 mm and an active area of 15 m^2. The screen boxes vibrate at a frequency of 700 to 800 cycles per minute with an amplitude of 6 to 8 mm. Capacity of the screen used for coal dewatering is 100 t/h, and for mud dewatering it is up to 40 t/h. For drainage, wedge wire screens with a slot width of 0.25 to 1.0 mm are used [4].

2.4. EGK-2 two-mass resonance screen

The resonance screen shown in Fig. 5, equipped with an inertial drive, forcing the elliptical movement of the vibrating masses is another considered solution. Screen box 1 is fixed on the sets of helical springs 2, mounted on the supporting frame 3 of the screen. On both sides of the screen box there are counterweights 4, creating a system that vibrates with the screen box called the drive yokes. These counterweights are suspended by the levers 5 on the supports 6 of the screen box. Between the supports 6 and the handles 7 of the counterweights, elastic sets of rubber rings 8 are inserted perpendicular to the lever 5. These sets accumulate kinetic energy of the vibrating masses and transfer it to the vibrating system at the turning points. The drive shaft 9 is mounted in counterweights and a weight 10 is wedged on its external pivot, creating the inertial drive of the screen. Drive system of the screen consists of a motor, a belt transmission with V-belts and an intermediate shaft connected with a clutch to the drive shaft 10.

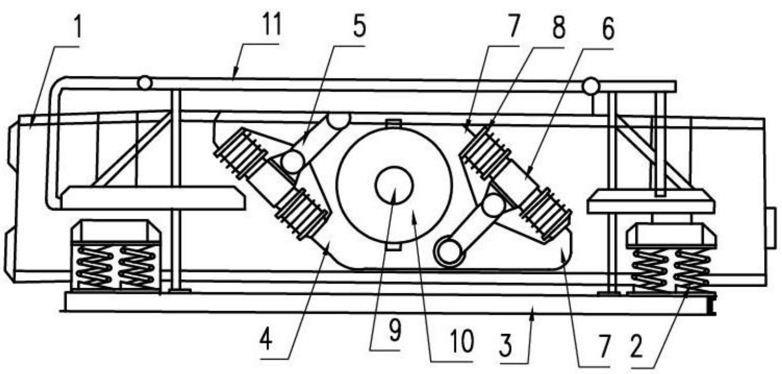

Fig. 5. EGK-2 resonance screen

Pipeline system 11 supplies water to showers used for product desludging.

This typical two-mass system vibrates in a scope close to resonance. The elliptical vibrations have a large axis of the ellipse directed in the axis of elastic rubber rings, while the small axis is directed in the direction of lever 5, and the system of resonant vibrations is in the direction of the large axis of the ellipse (the ellipse axis size ratio is 3:1).

Resonance screens of this type are built in four versions intended for screening fine-grained material (EFK), medium-grained (EGK), coarse-grained (EGS) and as heavy ESL-type screens. The vibration amplitude in these screens is 4 to 5, 5 to 7.5 and 7.5 to 10 mm, respectively, at a frequency of 1030, 850 and 730 vibrations per minute. These screens are designed with a sieve working width from 1000 to 2500 mm and its length from 2000 to 6000 mm. The drive is powered by motors of a power from 3 to 22 kW [4].

2.5. CDR-43 two-mass resonance screen

The resonance screen with one on top of the other arrangement of screen boxes directed at inclination of screens in the opposite directions, shown in Fig. 6, can also be included to the analysed screens.

Screen boxes 1 and 2 are suspended on sets of inclined elastic slats placed on the supporting structure 3 of the screen. Each screen box is equipped with two pairs of flexible sets 4. Swinging motion of the screen boxes is generated by shaft 5 through two-armed levers 6 and flexible couplings 7. The shaft 5 is driven by a motor and gears, not shown in the drawing.

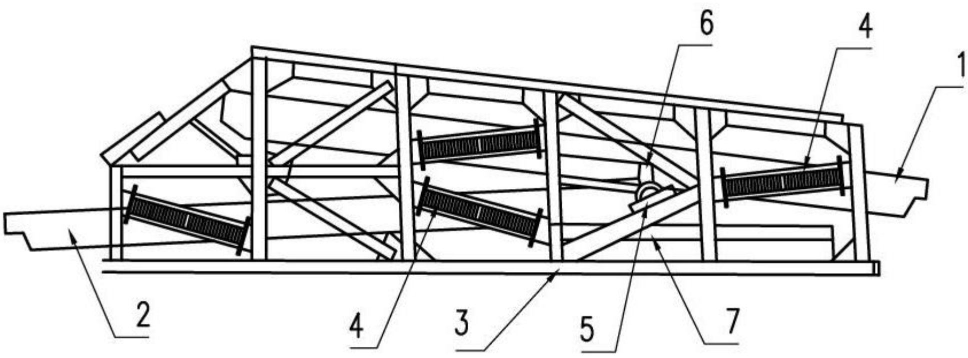

Fig. 6. CDR-43 resonance screen

Working width of the screen box is 1800 mm with an active screen area of 20.2 m^2. The nominal capacity of the screen for coal is 160 t/h with a maximum capacity of up to 200 t/h. An 18.5 kW motor is used to drive the screen. Stroke of the screen boxes is from 38 to 42 mm at a frequency of 400 cycles per minute. The permissible feed water content is 6% [4].

2.6. CDR-8 resonance screen

The last presented solution (Fig. 7) is a screen with the screen boxes 1 and 2 arranged in one after the other position. These boxes are suspended on the structure 3 placed on a system of elastic slats.

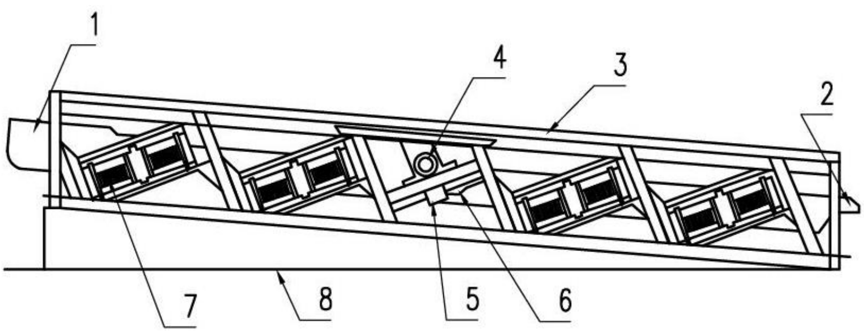

Fig. 7. CDR-8 resonance screen

The drive shaft 4 is installed in the middle of the screen length, driving the end section of the first screen and the initial section of the second screen box with the levers 5 and a flexible coupling 6. Each box is equipped with two pairs of elastic assemblies 7 arranged perpendicular to the direction of the elastic slats. Screen boxes are driven by a motor and gearbox. A screen of this type requires an additional wedge-shaped structure 8. Table 1 shows the currently used variants of CDR-8 screeners.

These screens are manufactured in four sizes with the working width of the screen box from 1600 to 2200 mm and with the working area of the screens from 14 to 19.5 m^2. Nominal and maximum capacities (for coal) are from 145 (180) to 330 (390) t/h. The screens are powered by motors with the power of 15, 18.5 and 22 kW. Screen boxes vibrate at a frequency of 400 cycles per minute with a pitch of 38 to 42 mm [6].

2.7. Strengths and weaknesses of the analyzed solutions of resonance screens

The strengths are as follows. The existing solutions of resonance screens are highly efficient. Moreover, the screening process is of high accuracy. The screens have a low power demand needed to generate the working movement of the riddle.

Weaknesses of the screens are that they emit noise during their operation and require very careful and systematic control and adjustment, especially the flexible assemblies. Flexible assemblies require a very even initial stress of both their halves, because this determines the identical amount of kinetic energy transferred in both directions of the screen box movement and the transition of the entire system to work in resonance. It can be troublesome to systematically control the wear of all elastic components (aging of rubber rings and buffers), correct cooling of rubber elastic assemblies, selection of lubricants, etc. The problem may arise during the repairs, when it is necessary to pay special attention to keep the masses of the screen boxes and vibrating frames in multi-mass screens unchanged [19, 20].

3. Results

Resonance screens used in industry still have many disadvantages and do not always meet the users requirements. Due to the interest of the mining and metallurgy industry in resonance screens for coke classification and lack of such design solutions, research work was undertaken at KOMAG to develop a new design of CDR-85K (K – coke) resonance screen.

3.1. Design assumptions

The CDR-85K resonance screen is intended for the initial as well as final classification of each assortment of coal and coke. This version is designed for coke classification in the metallurgical industry. The only difference is a modification of the height of the side panels and the upper and lower riddle. The necessary modification results from the coke weight density (twice as low as that of coal), which translates into efficiency of the device.

The CDR-85K screen, depending on the screens used, in terms of material (rubber or steel screens) and screen mesh, can be successfully used for material classification in the range of 120-0 mm. The classification process can be dry or wet with a spraying system which prevents clogging of the screen mesh.

The use of successive riddles, combined with the possibility of setting the screen at a selected angle (horizontally - 0°, inclined to - 5°), enables the selection of the assumed capacity of the device.

Technical parameters of the designed CDR-85K resonance screen are presented in Table 1.

Table 1. Technical characteristics of CDR-85K screen [21]

Specification	Unit	Value
Output	t/h	300
Working area of metal screen	m^2	18,6
Number of strokes in the riddle	min^{-1}	400
Pitch of riddle	mm	40
Inclination angle	°	5
Total weight	kg	14437

The assumed characteristic was developed on the basis of a literature analysis and guidelines for a metallurgical plant. The screen is used to separate coke of a grain size 80-0 mm into an upper product (80-30 mm) and a bottom product (30-0 mm), with a output of 300 t/h [21].

3.2. Design and operation of CDR-85K resonance screen

The design of CDR-85K resonance screen includes the following assemblies:

- upper riddle,
- lower riddle,
- screen frame,
- pendulum gear,
- tension frame,
- pendulum lever,
- rubber band assembly,
- drive frame,
- drive.

The main components of the CDR-85K resonance screen (Fig. 8) are the upper riddle 1 and the bottom riddle 2, fixed to the screen frame by rubber springs 18, 19, 20. A pendulum reducer 5 and an electric motor N=22kW, 6 are fixed on the drive frame 4. The electric motor drives the shaft 2200/20 12 through a flexible coupling 9, a pendulum reducer and a fixed coupling 10, setting it in a swinging motion together with the pendulum levers 13 located on both sides and the elastic couplings of rubber bands fixed in them 16. At equal distance from the centre of each lever arm 13 a set of rubber bands 16 is fixed, elastically coupling the riddle 1, 2 with the drive. The pendulum levers 13 are rigidly fixed on the main shaft 12 at a distance slightly greater than the width of the riddle. The pendulum reducer 5 is used to convert the rotational movement of the motor into the swinging movement of the shaft 12. In the CDR-85K screen, the main shaft 12 is supported on one side by a roller bearing 11 placed on the machine frame. Tensioning frame 14 and flat hanger 15 tension and fix the rubber springs 18, 19, 20. The tensioning frame consists of two tensioning bolts connected by plates to which one side of the spring set is screwed, and the other side is fixed in the spring foot of the riddle. Each tensioning frame includes two spring sets. For one riddle 1 and 2 there are 4 tension frames 14 – two on each side of the riddle.

The principle of operation of the screen is based on appropriate tension and swinging of the set of rubber belts 16 drive both riddles 1 and 2, which, thanks to the elastic suspension on leaf rockers, make a reciprocating oscillating motion with a stroke limited by four sets of rubber springs suitably tightened and fixed to the machinery frame. Screening takes place on a metal screen s=30 mm 21, which is fixed on the upper riddle 1 and on the lower riddle 2.

The basic flexible components of the CDR-85K resonance screen are:

- flexible couplings of rubber bands 16 connecting the riddle with the drive,
- elastic, resilient components, installed between the screen boxes and the screen supporting structure, limiting the stroke of the screen boxes 18, 19, 20.

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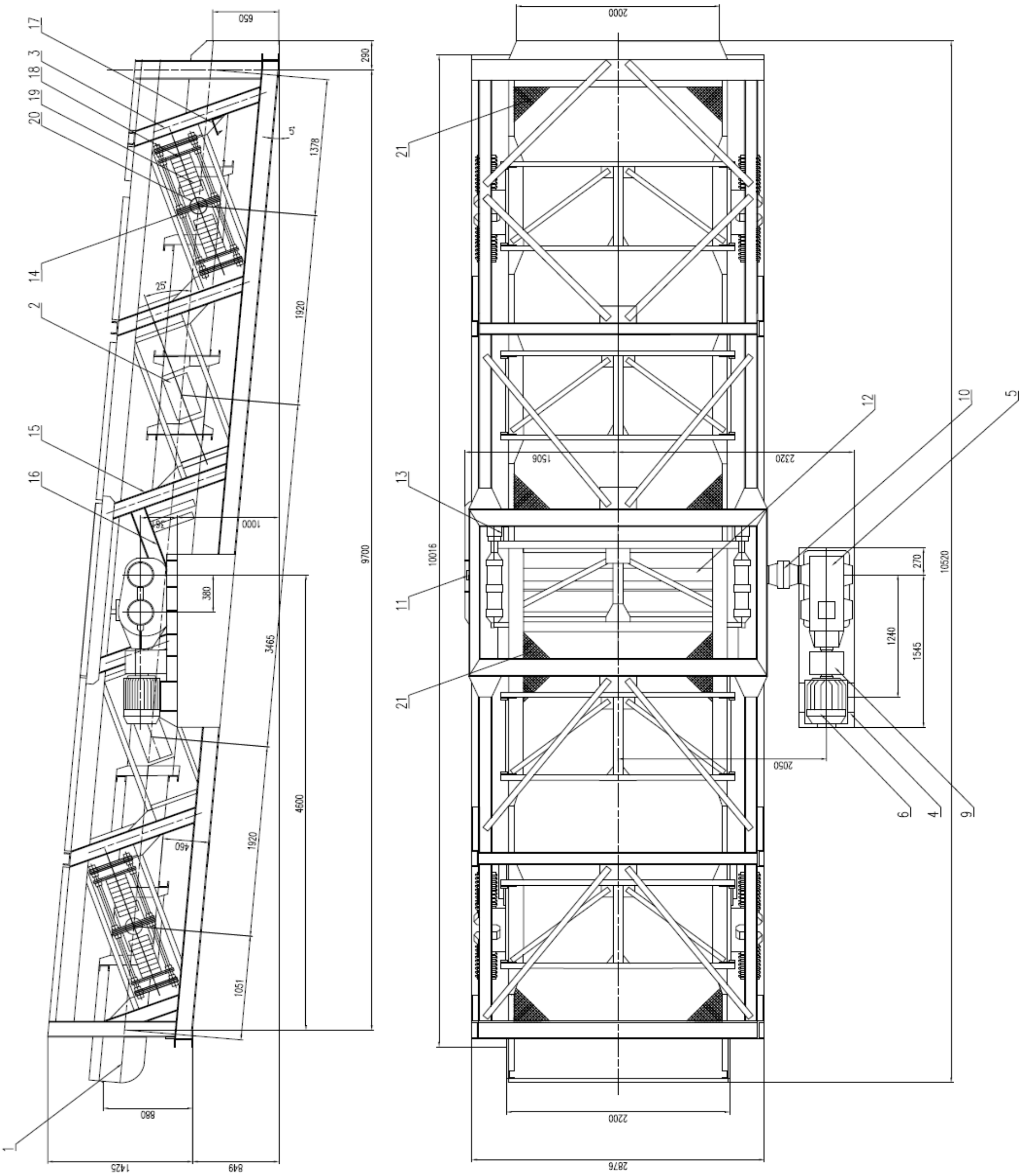

Fig. 8. Preliminary design of the 85K resonance screen [21]

3.3. Innovative design

A number of new and innovative solutions will be used in the developed solution listed below:

- drive system of the resonance screen for the use of a state-of-the-art pendulum reducer with an electric motor N=22 kW is provided. This solution will reduce electricity consumption and increase the durability of the drive compared to the old reducer. It will also allow to replace HK400/22 part-turn gearboxes manufacture of which has been discontinued. The designed system will be replaceable with the existing solutions and possible to use in operating screens,
- new rubber springs for the screen suspension were developed,
- in order to increase the screening capacity, larger clearances were applied and the sides of the screen were raised,
- screen decks are made of a material that has a tendency to self-cleaning, which will allow for higher system efficiency,
- anti-corrosive coatings are applied to screen components,
- the screen riddle is equipped with abrasion-resistant materials.

The design of the device has now been completed. Subsequently, it is planned to develop the technical documentation of the screen and make a prototype.

4. Conclusion

Due to the unavailability of CDR resonance screens on the market and the interest of the mining and metallurgy industry in modernization of classifying nodes based on this type of screen, KOMAG has developed a design of a new CDR-85K resonant screen.

The applied design solution of the CDR-85K resonant screen will provide a very high screening accuracy and such a characteristic of the vibrating motion of the screen box that will enable screening of difficult to screen material, which may have a large amount of the finest grains, at the same time having a high content of surface moisture.

Moreover, in order to ensure a constant and high screening efficiency, the screens with ability to self-clean from the grains adhered to them, were used.

The developed innovative solution in relation to the existing designs of this type will allow to increase the functionality and durability of the design.

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