



(51) International Patent Classification:

B07C 5/34 (2006.01) B07C 5/36 (2006.01)
B07C 5/342 (2006.01)

(21) International Application Number:

PCT/EP2023/059363

(22) International Filing Date:

11 April 2023 (11.04.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

22167772.7 12 April 2022 (12.04.2022) EP

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE,

(54) Title: AUTOMATED BELT SAMPLER FOR SORTING OUT IMPURITIES, METHOD AND USE

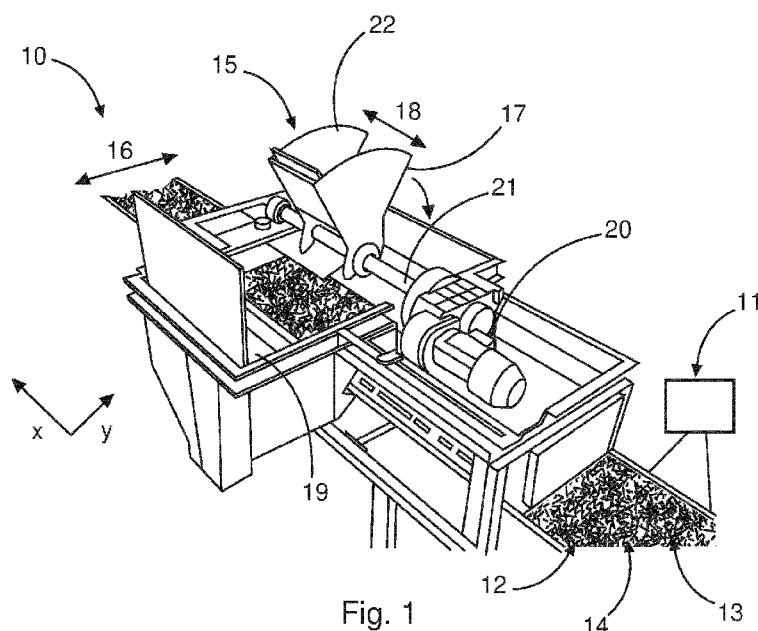


Fig. 1

(57) Abstract: A sorting device for removing of impurities (14) in a stream of a bulk material (13), comprising: a detection unit (11) configured to detect one or more impurities (14) in a stream of a bulk material (13) and to generate corresponding impurity data; a removal unit (15) configured to remove a volume share in the stream of the bulk material (13) based on the impurity data; wherein the volume share comprises at least parts of the bulk material (13) and the one or more impurities (14).

SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN,
GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

AUTOMATED BELT SAMPLER FOR SORTING OUT IMPURITIES, METHOD AND USE

Technical field

The present disclosure relates to a sorting device for removing of impurities in a stream of a bulk material, a method for removing of impurities in a stream of a bulk material, a system for removing of impurities in a stream of a bulk material, a use of a hammer sampler, a plate sampler and/or a band switch arrangement in such a device, and to a use of an optical camera, an XRT system, a NIR system, an EM system and/or a multi-channel laser scanning system in such a device or in such a system.

Technical background

Deposit quality for mineral raw material fluctuates constantly due to inhomogeneities in the deposit. (e.g. black dikes or other silicates). Even though most operations have selective mining and quality control measures in place, some impurities find their way to the plant. The statistic nature of that process results in quality fluctuations. Challenges for sustainable raw materials processing increase. Raw material processing comprises besides mining also a transportation of the raw materials from the mining area to first storage sites. As transportation means conveyor belts are widely used and known in the state of the art. The conveyor belts enable a stream of a bulk material, such as e.g. coal. The quality of such bulk materials is subject to fluctuations.

In view of this, it is found that a further need exists to provide a possibility for a quality control of bulk materials, in particular to provide an efficient and reliable possibility for a quality control of bulk materials.

Summary of the invention

In view of the above, it is an object of the present invention to provide a possibility for a quality control of bulk material, in particular to provide an efficient and reliable possibility for a quality control of bulk materials. These and other objects, which become apparent upon reading the following description, are solved by the subject matter of the independent claims. The dependent claims refer to preferred embodiments of the invention.

According to a first aspect of the present disclosure, a sorting device for removing of impurities in a stream of a bulk material is provided, comprising: a detection unit configured to detect one or more impurities in a stream of a bulk material and to generate corresponding impurity data; a removal unit configured to remove a volume share in the stream of the bulk material based on the impurity data; wherein the volume share comprises at least parts of the bulk material and the one or more impurities.

The term impurity, as used herein, is to be understood broadly and relates to any deviation of a bulk material from an ideal bulk material. An impurity may comprise material deviation, e.g. an iron, a silicate instead of a desired stone (e.g. amphibolite or calcite). A material deviation may comprise an individual element, such as a copper, in a bulk of calcite or amphibolite. A material deviation may comprise another material enclosed from a bulk material (e.g. iron inclusion in a calcite). An impurity may comprise a size deviation. An impurity may comprise a form deviation or shape deviation. Bulk

material may comprise a mineral-based raw material or industrial minerals such as calcite, dolomite, gypsum, talc, clay, flint, primary ores (e.g. iron, copper, tin). The term stream, as used herein, is to be understood broadly and relates to any kind of flow of a bulk material. The stream of bulk material may be continuous or intermittent. The stream of bulk material may comprise a constant or dynamic stream rate (e.g. volume per second, weight per second, or area per second, objects per second) of bulk material. The stream rate may depend on a speed of a conveyor belt. The stream rate may comprise values of 1 to 100 tons per hour or 1.5 to 150m³ per hour. The stream of bulk material may comprise a constant cross section. The term volume share, as used herein, relates to a volume share of the stream of bulk material. The volume share of the stream of bulk material may comprise an entire cross section of the stream of bulk material and a certain length. The volume share of the stream of bulk material may comprise a part of the cross section of the bulk stream and a certain length. The certain length may depend on a dimension of a removal means. The volume share may be constant or variable. The volume share in general relates to a volume which is bigger than one element of the bulk material. The volume share may comprise a dimension of a removal means and a width and/or height of a bulk stream. The term removal unit, as used herein, is to be understood broadly and relates to a mechanical unit configured to remove a volume share of a stream of bulk material. The removal unit may comprise as removal means a removal panel (e.g. a hammer sampler), a flap (e.g. a plate sampler), or a removal blow-out nozzle. The removal unit may comprise a hydraulic drive, pneumatic drive, electromechanical drive. The removal unit may be arranged adjacent to a stream of a bulk material. The term detection unit, as used herein, is to be understood broadly and relates to a measurement device configured to detect one or more impurities in a stream of a bulk material. The detection unit may comprise a measurement device. The detection unit may comprise a radiation source and a corresponding detector. The detection unit may be one of the following: X-ray system (e.g. XRT), optical measurement system (e.g. camera), NIR system, a thermal system. The term impurity data, as used herein, is to be understood broadly and relates to any data indicative for an impurity in a stream of a bulk material. The impurity data may comprise a position of an impurity in a stream of a bulk material, a volume of an impurity, a distribution of impurities in a stream of a bulk material, an identification of an impurity (e.g. stone, ore, and mud). There may be different impurities in a stream of a bulk material (e.g. wood, plastics, blasting wires in a stream of a calcite; or e.g. gangue material (e.g. dikes, silicates, graphite in carbonate ores). The removal unit and the detection unit may comprise communication interfaces for a communication between them. The communication may be wired (e.g. Ethernet, Profibus) or wireless (e.g. WIFI).

The invention is based on the finding that impurities in a stream of a bulk material lead to a quality decrease of the bulk material. This may further lead to decreased quality and quality fluctuation in processing the bulk material. In case an impurity is detected in a stream of a bulk material, it is in dependency of the bulk material difficult to remove only the detected impurity (e.g. by means of an automated gripping unit). E.g., a gripper unit may not grip the impurity due its shape, weight, size, or to a quite difficult and error-prone prediction of an exact position of the impurity. E.g. the gripper unit may not be able to grip the impurity as it is partly hidden by the bulk material. E.g. a Y-divider may not remove the detected impurity since it cannot be installed on top of a belt. E.g. a pneumatic extraction may not remove the detected impurity since it is no single particle extraction possible. A further

challenge is the speed of the stream of the bulk material as the impurity should be removed during the transportation of the bulk material (i.e. stream of bulk material) in order to maintain the transportation process. A further problem are rough environmental conditions that do not enable a usage of filigree removal units, such as hexapod robot grippers or the like. The invention proposes to solve these

5 problems by combining a detection unit with a robust removal unit, wherein the removal unit does not pick and remove single detected impurities. Instead, the removal unit removes a complete volume share of the stream of bulk material, wherein the volume share encloses the single detected impurities and bulk material. The proposed removal unit is in general used for representative sampling and not for sorting out impurities. The invention proposes to combine two existing devices (i.e. removal unit

10 and detection unit) to solve the described problem. This may be advantageous as it may enable a reliable and an efficient quality control of a stream of a bulk material. This may improve a quality of raw material mining due improved raw material (i.e. bulk material) conveyance. This may further improve the overall quality as well as the homogeneity of the material stream.

In an embodiment, the stream of the bulk material may be a conveyor belt stream or a free

15 falling stream. The conveyor belt stream may be horizontal or slightly inclined. The conveyor belt may comprise different belt widths (e.g. 1m, 1.5m). The conveyor belt may be operated at different velocities. The free falling stream may connect different levels in a transport route of a stream of a bulk material. In other words the free falling stream may be a fall section.

In an embodiment, the volume share may be defined by a cross section of the conveyor belt or

20 the free falling stream, in particular by a width of the cross section of the conveyor belt or by a width and a height of the free falling stream.

In an embodiment, the volume share may be defined by one or dimensions of a removal means of the removal unit. The removal means may be a removal panel (e.g. a hammer of a hammer sampler) with a width and a height. The removal means may be a fall flap (e.g. a plate sampler with a

25 plate width and a plate height or plate length) with a width and a height.

In an embodiment, the impurity data may comprise a position of the one or more impurities within the stream of the bulk material and a corresponding time stamp. Based on the position and the time stamp, the removal unit may determine by a known speed of the stream of the bulk material the time for removing the volume share comprising the one or more impurity. The position of the one or

30 more impurities may be described in one or more Cartesian coordinates (e.g. a line coordinate, or x and y coordinate, wherein y refers to width of the conveyor belt and x to the position in moving direction of the conveyor belt) of for example the conveyor belt. This may be advantageous in order to determine accurately the corresponding volume share to be removed. This may further be advantageous as for example two or more impurities may be removed in one removal step with the

35 removal unit.

In an embodiment, the removal unit may remove the volume share demand-oriented on the basis of the impurity data and on a speed information of the stream of the bulk material. The speed information may be derived from the speed of the conveyor belt or the gravity in a free falling stream. The term demand-oriented, as used herein, means that the removal unit only removes a volume share

40 if it detects an impurity. This may be advantageous in terms of efficiency.

In an embodiment, the removal unit may be a hammer sampler, a plate sampler and/or a band switch arrangement. This may be advantageous as the hammer sampler, the plate sampler and the band switch arrangement are each robust and cost-effective in comparison to pick robots. The hammer sampler may be arranged adjacent to or above a conveyor belt. The hammer sampler may normally swipe cross sections from a moving conveyor belt in a predefined interval. The combination with a determination unit (e.g. an optical system, an illumination and an optical detector) may replace the predefined interval and activate the sampling when one or more impurities (e.g. color differences between bulk material and impurity) are detected. Therefore the purpose of the hammer sampler is no longer the sampling itself but the removal of the one or more impurities from the stream of bulk material. The hammer sampler is one of the so called cross belt sampler with a hammer (i.e. removal panel) for sampling. The plate sampler has a fall flap which opens in order to remove the volume share of impurities. The plate sampler is implemented in the conveyor belt. The band switch ejects the volume share in another direction (e.g. to another conveyor belt or a waste box). Hammer sampler, plate sampler and band switch arrangement have each in common that they are normally used for periodical sampling of the bulk material. Each of them is normally not used for removal of single impurities in a stream of bulk material. However, these removal units are normally already implemented in a transportation system. This may be advantageous in terms efficiency as a second use of an already existing mean is advantageously provided.

In an embodiment, the detection unit may be an optical camera configured to determine color differences between bulk material and impurities. The optical camera may be arranged above or adjacent to the stream of the bulk material. The optical camera may continuously detect single impurities. The detection unit may be trained with ideal bulk material, e.g. a color of ideal bulk material (e.g. black). Any deviation from the ideal color may lead to a detection of an impurity. The detection unit may comprise a look up table comprising color values for ideal bulk material and/or color thresholds for ideal bulk material. Based on a comparison of the measured color value with a color threshold for an ideal bulk material in the look up table an impurity may be determined. The optical camera may be a single entity or distributed on several optical camera sensors (e.g. RGB sensor, RGB-D sensor). This may be advantageous in terms of a reliability, robustness, and efficiency.

In an embodiment, the detection unit may be an X-ray transmission system, XRT system, a Near Infrared system, NIR system, electromagnetic sensor system, EM system and/or a multi-channel laser scanning system. The X-ray transmission system may be arranged below the conveyor belt. The XRT system may detect impurities within a stream of a bulk material (e.g. flint in chalk) and not only on the surface. This may advantageously increase the efficiency of the quality control. The NIR sensor may advantageously be used for biological bulk material such as cereals or the like. The NIR sensor may be used detect impurities within the stream of the bulk material. The NIR sensor is in comparison to the XRT not harmful to health.

A further aspect relates to a method for removing of impurities in a stream of a bulk material, comprising the steps: detecting one or more impurities in a stream of a bulk material; generating corresponding impurity data; removing a volume share in the stream of the bulk material based on the impurity data; and wherein the volume share comprises at least parts of the bulk material and the one or more impurities.

In an embodiment, the method may be provided, wherein the volume share is defined by a cross section of a conveyor belt or a free falling stream, in particular by a width of the cross section of the conveyor belt or by a width of the free falling stream.

5 A further aspect relates to a system for removing of impurities in a stream of a bulk material, comprising: a device for removing of impurities in a stream of a bulk material as described above; and a conveyor belt configured to convey the bulk material.

In an embodiment, the system may comprise a falling system configured to provide a free falling stream of the bulk material. The falling system may be used to connect different levels in a transport system.

10 A further aspect relates to a use of a hammer sampler, a plate sampler and/or a band switch arrangement in a device according described above or in a system above.

A further aspect relates to a use of an optical camera, an XRT system, a NRT system, EM system and/or a multi-channel laser scanning system in a device as described above or in a system described.

15 **Brief description of the drawings**

In the following, the present disclosure is described exemplarily with reference to the enclosed figures, in which

Figure 1 is a schematic view of a system according to an embodiment of the present disclosure; and

20 **Figure 2** is a schematic view of a method according to an embodiment of the present disclosure.

Detailed description of embodiments

Figure 1 is a schematic view of a system 10 according to an embodiment of the present disclosure. The system 10 is used for removing of impurities in stream of a bulk material 13. The system 10 comprises a sorting device for removing of impurities 14 in a stream of a bulk material and a conveyor belt 12 configured to convey the bulk material 13. The sorting device comprises a detection unit 11 and a removal unit 15. The stream of bulk material 13 is in the present example provided by the conveyor belt 12. The sorting device comprises a detection unit 11 configured to detect one or more impurities 14 in a stream of a bulk material 13 and to generate corresponding impurity data. The detection unit 11 is arranged above the stream of the bulk material 13. The detection unit 11 is in the present example an optical camera, in particular a RGB camera. Alternatively the detection unit 11 may be for example a XRT system, which may be arranged below the conveyor belt. Alternatively the detection unit 11 may be for example a NIR system, an EM system and/or a multi-channel laser scanning system. The detection unit 11 may comprise for example two or more of the given examples. The detection unit comprises a control (e.g. CPU) configured to evaluate measurement data from the optical camera and to determine impurities by determining a property difference between the bulk material and the impurities. The control further generates based on the determined impurities impurity data. The impurity data may comprise a position of the one or more impurities within the stream of the bulk material and a corresponding time stamp. The position of the one or more impurities may be described in one or more Cartesian coordinates (e.g. line or x and y

coordinate, wherein y refers to a width 16 of the conveyor belt 12 and x to the position in moving direction of the conveyor belt 12) of for example the conveyor belt 12. The detection unit 11 comprises a communication interface (not shown), in the present example a WIFI interface configured to communicate with the removal unit 15. The detection unit 11 transmits by means of the WIFI interface the generated impurity data to the removal unit 15. The removal unit 15 is part of the sorting device. The removal unit 15 is in the present example a hammer sampler which is arranged above or around the conveyor belt 12. The hammer sampler comprises a control (not shown), a hammer 17 as removal means, a drive 20 (e.g. an electromechanical drive, a hydraulic drive or a pneumatic drive) and a pinion shaft 21. The hammer 17 is arranged at the pinion shaft 21. The hammer 17 swings over the surface of the conveyor belt 12 and removes all bulk material which is between an opening 22 of the hammer 17. The volume share in general contains one or more detected impurities (e.g. a stone) and also bulk material (e.g. coal). Alternatively the removal unit may be a band switch or a plate sampler. The removal unit 15 comprises a communication interface, in the present example a WIFI interface (not shown), configured to communicate with the detection unit 11. The communication between the detection unit 11 and the removal unit 15 may alternatively be provided by means of Ethernet or Profibus. The communication between the detection unit 11 and the removal unit 15 may be wired or wireless. The removal unit 15 is configured to remove a volume share in the stream of the bulk material based on the impurity data. The removal unit 15 uses the impurity data and a speed information of the conveyor belt 12 in order to remove the volume share demand orientated. The speed information of the conveyor belt is indicative for a speed of the stream of the bulk material. The speed information may be transmitted to the removal unit 15 from a control of the conveyor belt 12 or from a speed measurement device that is arranged at the conveyor belt 12. In other words, in case the detection unit 11 detects an impurity and generates corresponding impurity data, the removal unit 15 removes based on the received impurity data a volume share containing the impurity from the stream of the bulk material. If there is no impurity detected, the removal unit does not remove a share of volume of the stream of the bulk material. The volume share is in the present example defined by a cross section of the conveyor belt 12. In particular the volume share is in present example defined by the width 16 of the cross section of the conveyor belt 12. Alternatively in a free falling system the volume share may be defined by the width and/or height of the cross section. The volume share is in the present example further defined by a dimension of a removal means of the removal unit 15, in particular in the present example by the width 18 of the hammer 17 of the hammer sampler 15. In the present example the hammer 17 removes all bulk material on the surface of the conveyor belt 12 that is within an opening 22 of the hammer 17 when the hammer swings across the surface of the conveyor belt 12. The so removed bulk material is transported to a disposal opening 19.

Figure 2 is a schematic view of a method according to an embodiment. The method is used for removing of impurities in a stream of a bulk material. The method comprises the following steps. In a step S10 one or more impurities are detected in a stream of a bulk material. In a step S20 based on the detected impurities corresponding impurity data is generated. Step S10 and step S20 may be carried out by the detection unit 11. Step S10 and step S20 may alternatively be carried out by a processor that is in communication with the detection unit 12. The processor may be on a single hardware unit or distributed on two or more hardware units (e.g. a cloud server, a workstation or the

like). The method further comprises the step S30 removing a volume share in the stream of the bulk material based on the impurity data, wherein the volume share comprises at least parts of the bulk material and the one or more impurities. Step S30 may be carried by the of removal unit 15.

Alternatively step 30 may be carried out by the processor described above which is in communication
5 with the removal unit 15.

The present disclosure has been described in conjunction with a preferred embodiment as examples as well. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed invention, from the studies of the drawings, this disclosure and the claims. Notably, in particular the steps S10 to S30 can be performed in any order, i.e. the present
10 invention is not limited to a specific order of these steps. Moreover, it is also not required that the different steps are performed at a certain place or at one place, i.e. each of the steps may be performed at a different place using different equipment/data processing units. In the claims as well as in the description the word "comprising" does not exclude other elements or steps and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of
15 several entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

Reference signs

20	10	system
	11	detection unit
	12	conveyor belt
	13	bulk material
	14	impurity
25	15	removal unit
	16	width of cross section of conveyor belt
	17	removal means
	18	width of removal means
	19	disposal opening removal unit
30	20	electromechanical drive
	21	pinion shaft
	S10	detecting one or more impurities in a stream of bulk material
	S20	generating corresponding impurity data
	S30	removing a volume share in the stream of bulk material based on the impurity data

Claims

1. A sorting device for removing of impurities (14) in a stream of a bulk material (13), comprising:
a detection unit (11) configured to detect one or more impurities (14) in a stream of a bulk
5 material (13) and to generate corresponding impurity data;
a removal unit (15) configured to remove a volume share in the stream of the bulk material
(13) based on the impurity data;
wherein the volume share comprises at least parts of the bulk material (13) and the one or
10 more impurities (14).
2. The sorting device, wherein the stream of the bulk material (13) is a conveyor belt (12) stream
or a free falling stream.
3. The sorting device according to claim 2, wherein the volume share is defined by a cross
15 section of the conveyor belt (12) or the free falling stream, in particular by a width (16) of the cross
section of the conveyor belt (12) or by a width and a height of the free falling stream.
4. The device according to any of the preceding claims, wherein the volume share is defined by
one or dimensions (18) of a removal means (17) of the removal unit (15).
- 20 5. The device according to any of the preceding claims, wherein the impurity data comprise a
position of the one or more impurities (14) within the stream and a corresponding time stamp.
6. The device according to any of the preceding claims, wherein the removal unit (15) removes
25 the volume share demand-orientated on the basis of the impurity data and on a speed information of
the stream of the bulk material (13).
7. The device according to any of the preceding claims, wherein the removal unit (15) is a
hammer sampler, a plate sampler and/or a band switch arrangement.
- 30 8. The device according to any preceding claims, wherein the detection unit (11) is an optical
camera configured to determine color differences between bulk material (13) and impurities (14).
9. The device according to any preceding claims, wherein the detection unit (11) is an X-ray
35 transmission system, XRT system, a Near Infrared system, NIR system, electromagnetic sensor
system, EM system and/or a multi-channel laser scanning system.
10. A method for removing of impurities (14) in a stream of a bulk material (13), comprising the
steps:
40 detecting one or more impurities (14) in a stream of a bulk material (13) (S10);
generating corresponding impurity data (S20);

removing a volume share in the stream of the bulk material (13) based on the impurity data (S30), and

wherein the volume share comprises at least parts of the bulk material (13) and the one or more impurities (14).

5

11. The method according claim 10, wherein the volume share is defined by a cross section of a conveyor belt (12) or a free falling stream, in particular by a width of the cross section of the conveyor belt (12) or by a width of the free falling stream.

10 12. System (10) for removing of impurities (14) in a stream of a bulk material (13), comprising:
a device for removing of impurities (14) in a stream of a bulk material (13) according to any of the claims 1 to 9; and
a conveyor belt (12) configured to convey the bulk material (13).

15 13. System according claim 12, further comprising a falling system configured to provide a free falling stream of the bulk material (13).

14. Use of a hammer sampler, a plate sampler and/or a band switch arrangement in a device according to one of the claims 1 to 9 or in a system according to the claims 12 or 13.

20

15. Use of an optical camera, an XRT system, a NIR system, EM system and/or a multi-channel laser scanning system in a device according to one of the claims 1 to 9 or in a system according to the claims 12 or 13.

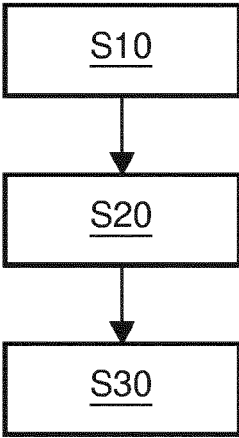
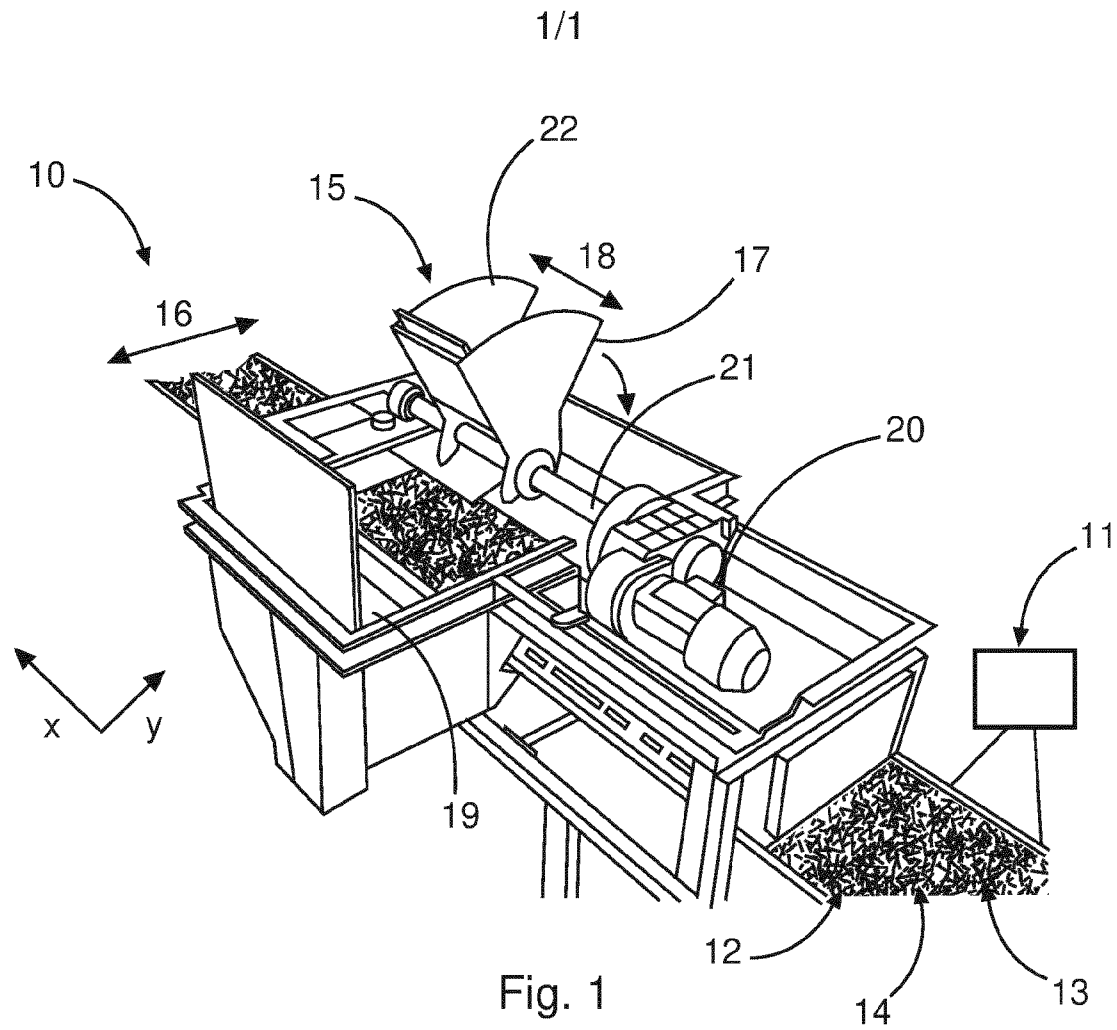


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/059363

A. CLASSIFICATION OF SUBJECT MATTER

INV. B07C5/34 B07C5/342 B07C5/36

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 0 377 478 A1 (HEUFT QUALIPLUS BV [NL]) 11 July 1990 (1990-07-11) figures -----	1-6, 8, 10-13 7, 9, 14, 15
X A	WO 2008/056465 A1 (SUMITOMO METAL MINING CO [JP] ET AL.) 15 May 2008 (2008-05-15) figures -----	1-7, 9-15 8
X A	DE 10 2013 104740 A1 (DORNIER GMBH LINDAUER [DE]) 13 November 2014 (2014-11-13) figures -----	1, 4-7, 10, 13 2, 3, 8, 9, 11, 12, 15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

1 June 2023

Date of mailing of the international search report

12/06/2023

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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