


(22) International Filing Date: 30 November 2016 (30.11.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
20159907 1 December 2015 (01.12.2015) FI

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(43) International Publication Date 8 June 2017 (08.06.2017)

(51) International Patent Classification:
G01F 13/00 (2006.01) G01F 11/24 (2006.01)
G01F 1/00 (2006.01) G01F 1/66 (2006.01)
B65G 47/00 (2006.01) G01F 22/00 (2006.01)

(21) International Application Number: PCT/FI2016/050843

(54) Title: A METHOD AND AN ARRANGEMENT FOR DETERMINING THE ORE MASS FLOW OF ORE CONVEYED IN A COMMINUTION PROCESS

Fig. 5

(57) Abstract: The present invention relates to the field of mineral and metallurgical processes, to comminution processing or disintegrating in general and to comminution processing by crushers and tumbling mills, and more particularly to a method and arrangement for determining the ore mass flow of ore conveyed in a comminution process. An arrangement for determining the ore mass flow of ore (11) conveyed in a comminution process according to the present invention comprises an imaging system (12), (20) placed in the vicinity of a conveyor (8), (18), (34), (36), (38), (40), said imaging system (12), (20) measuring 3D reconstruction measurement data (21) for reconstruction of a three-dimensional image profile (32) of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40); and a comminution control block (27) receiving calculated ore mass flow data (23) of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40). The solution according to the present invention provides an accurate determination of the ore mass flow of ore (11) conveyed by a conveyor (8), (18), (34), (36), (38), (40) in a comminution process for controlling said comminution process.
A METHOD AND AN ARRANGEMENT FOR DETERMINING THE ORE MASS FLOW OF ORE CONVEYED IN A COMMINUTION PROCESS

FIELD OF THE INVENTION

The present invention relates to the field of mineral and metallurgical processes, to comminution processing or disintegrating in general and to comminution processing by crushers and tumbling mills, and more particularly to a method and arrangement for determining the ore mass flow of ore conveyed in a comminution process.

BACKGROUND OF THE INVENTION

One of the most common processes in mining and metallurgy is the comminution processing or disintegrating of ore. Comminution is achieved by blasting, crushing and grinding.

Traditionally several different types of belt weighers, such as load cell weighers, weighers based on attenuation of radiation, etc. are used for obtaining tonnage information of ore conveyed in a comminution process.

Belt weighers are, however, somewhat problematic in many circumstances. For example, with retrofit installations the conveyor belt must be shut down for the installation. Typically the installation takes several hours, which is very expensive for an operating production plant. Another problem is the use of the radiation sources in said belt weighers, as this makes the installation problematic and requires a special attention on safety. One further problem with said belt weighers is that they require frequent monitoring of their calibration and possible recalibration.

In general, there are some problems with the prior art solutions for controlling of a comminution process. The problem therefore is to find a solution for determining the ore mass flow of ore conveyed in a comminution process which can provide reliable measurement data and information on the ore mass flow of ore travelling on a conveyer belt from the crusher to the grinding mill with better measurement accuracy and reliability.

There is US patent application publication US 2015/0290654 A1 which discloses a prior art method for controlling a mineral material processing plant and a mineral material processing plant. Furthermore, German patent application publication DE 4240094 A1 discloses a prior art CCD camera system for control of flow on belt conveyor. Furthermore, Japanese patent application publication JP 2000-304523 A discloses a prior art sectional area measur-
ing method of belt conveyor carrying object. Furthermore, PCT patent application publication WO 2014/029493 A1 discloses a prior art method for controlling and/or regulating a volumetric flow rate of a bulk product or bulk products, in particular bulk mineral products, waste products, raw products, or materials, or device for carrying out said method. However, the prior art solutions presented in the above-mentioned patent application documents do not provide a solution for determining the ore mass flow of ore conveyed in a comminution process which can provide reliable measurement data and information on the ore mass flow of ore travelling on a conveyor belt from the crusher to the grinding mill with better measurement accuracy and reliability.

There is a demand in the market for a method for determining the ore mass flow of ore conveyed in a comminution process which method would provide a better controlled and more efficient comminution process when compared to the prior art solutions. Likewise, there is a demand in the market for an arrangement for determining the ore mass flow of ore conveyed in a comminution process which arrangement would give a better controlled and more efficient comminution process when compared to the prior art solutions.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is thus to provide a method and an apparatus so as to overcome the above problems and to alleviate the above disadvantages.

The objects of the invention are achieved by a method for determining the ore mass flow of ore conveyed in a comminution process, which method comprises a step of:

- monitoring the flow of ore conveyed by a conveyor in said comminution process, in which said step of monitoring:
  - 3D reconstruction measurement data for reconstruction of a three-dimensional image profile of said ore conveyed by said conveyor is measured with an imaging system placed in the vicinity of said conveyor, and
- receiving calculated ore mass flow data of said ore conveyed by said conveyor, said ore mass flow data being calculated based on said measured ore 3D reconstruction measurement data.

Preferably, said method comprises a step of calculating said ore mass flow data based on said measured ore 3D reconstruction measurement
data. Preferably, in said step of calculating, a three-dimensional ore image profile of said ore conveyed by said conveyor is calculated. Preferably, in said step of calculating, a volumetric flow of ore conveyed by said conveyor is also calculated.

Preferably, said method comprises a step of calculating control value data for controlling said comminution process based on said calculated ore mass flow data and/or received comminution process data. Further preferably, said control value data is calculated for controlling ore mass feed or water addition or ball addition or pebbles feed in said comminution process.

Furthermore, the objects of the invention are achieved by an arrangement for determining the ore mass flow of ore conveyed in a comminution process, which

- said arrangement comprises an imaging system placed in the vicinity of a conveyor, said imaging system measuring 3D reconstruction measurement data for reconstruction of a three-dimensional image profile of said ore conveyed by said conveyor; and that

- said determining arrangement comprises a comminution control block receiving calculated ore mass flow data of said ore conveyed by said conveyor.

Preferably, said imaging system comprises at least one imaging device. Further preferably, said imaging system comprises a structured light source, and a first imaging device of said at least one imaging device is placed at an angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to a line laser source, which first imaging device acquires 3D reconstruction measurement data for three-dimensional reconstruction from said ore conveyed by said conveyor. Further preferably, said imaging system comprises a structured light source, and a second imaging device of the at least one imaging device is placed on the opposite side of said first imaging device, and at an angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to the line laser source, which second imaging device acquires 3D reconstruction measurement data for three-dimensional reconstruction from said ore conveyed by said conveyor.

Preferably, said at least one imaging device acquires 3D reconstruction measurement data for three-dimensional reconstruction from said ore as it is travelling on said conveyor. Alternatively, said at least one imaging device
acquires 3D reconstruction measurement data for three-dimensional reconstruction from said ore as it is exiting said conveyor.

Preferably, said imaging system is attached to a frame structure, to a wall structure or to a ceiling structure in the vicinity of said conveyor. Alternatively, said imaging system is attached to a frame structure or to a supporting structure of said conveyor. Further alternatively, said imaging system is attached to an arm structure or to an articulated arm structure bringing said imaging system in the vicinity of said conveyor.

Preferably, said control block has an input for receiving comminution process data. Preferably, said arrangement comprises at least one calculation block for calculating said ore mass flow data. Further preferably, said at least one calculation block also calculates control value data for controlling said comminution process based on said calculated ore mass flow data and/or received comminution process data. Further preferably, said at least one calculation block calculates said control value data for controlling ore mass feed or water addition or ball addition or pebbles feed in said comminution process.

Preferably, comminution process data includes one or more of the following data: ore mass feed, water addition, ball addition, pebbles feed, grinding mill speed, hardness, density, grinding product size, grinding mill power draw, grinding mill torque, grinding mill bearing pressure and grinding mill charge. Preferably, said arrangement further comprises a data storage block, into which data storage block at least some of the calculated process values, i.e. said ore mass flow data and/or at least some of received comminution process data are stored. Further preferably, at least some of the measured process values are stored to said data storage block.

Preferably, said conveyor has a conveyor belt having a belt width of 50-150 centimeters, preferably 80-110 centimeters. Preferably, said conveyor has a conveying speed of 0.3 to 10 meters per second, preferably 1 to 3 meters per second. Preferably, said conveyor has an ore mass flow in the range of 10 to 5000 tons per hour, preferably 30 to 1500 tons per hour, more preferably 100 to 500 tons per hour. Preferably, said imaging system detects particles having a diameter of 1-1000 millimeters, preferably 5-500 millimeters, more preferably 20-200 millimeters.

BRIEF DESCRIPTION OF THE DRAWINGS
Figure 1 shows a flow diagram of one example of a comminution process according to the present invention;

Figure 2 shows a side view of one embodiment of an arrangement for monitoring the flow of ore travelling on a conveyor belt from the crusher to the grinding mill according to the present invention;

Figure 3 shows a side view of one embodiment of an arrangement for measuring of a three-dimensional image profile of the ore travelling on a conveyor belt from the crusher to the grinding mill of grinding circuit according to the present invention;

Figure 4 shows a backside view of a conveyor belt and a three-dimensional imaging system of one embodiment of an arrangement for measuring of a three-dimensional image profile of the ore travelling on a conveyor belt from the crusher to the grinding mill of grinding circuit according to the present invention;

Figure 5 shows a schematic diagram of one embodiment of an arrangement for determining the ore mass flow of ore conveyed in a comminution process according to the present invention;

Figure 6 shows a schematic diagram of another embodiment of an arrangement for determining the ore mass flow of ore conveyed in a comminution process according to the present invention;

Figure 7 shows a schematic diagram of one embodiment of a screening circuit of a comminution process according to the present invention;

Figure 8 shows one embodiment of an ore mass flow graph diagram of in an arrangement for determining the ore mass flow in a comminution process according to the present invention.

In the following, the invention will be described in greater detail by means of preferred embodiments with reference to the accompanying drawings of Figures 1 to 8.

DETAILED DESCRIPTION OF THE INVENTION

Ore comminution is part of mining and metallurgy processing. When processing material for the selective or collective recovery of valuable material components, the processes concerned are preceded by comminution processing i.e. mechanical crushing, grinding, or disintegration of the material in a manner to free valuable from worthless components. Comminution is particle size reduction of materials. Comminution is achieved by blasting, crushing and
grinding. After comminution the components are then mutually isolated with the aid of known separation methods, this isolation being contingent on differences in color, shape, density or in differences in their respective surface active and magnetic properties, or other properties.

In comminution processing first ore or rock is excavated, broken down or removed by blasting. Blasting is the controlled use of explosives and other methods in mining, quarrying and civil engineering. Typically blasting produces top size particles of several decimeters or more and can to a degree control particle size distribution through a targeted powder factor.

Crushing is particle size reduction of ore or rock materials by using crushing devices i.e. crushers. Crushers e.g. jaw crushers, gyratory crushers or cone crushers are used to reduce the size, or change the form, of materials. In the crushing process the crushing devices hold material being crushed between two parallel or tangent solid surfaces of a stronger material and apply sufficient force to bring said surfaces together. Typically in a crushing process particles having a diameter up to 1000 mm are crushed to particles having a diameter of 5 mm or more.

Screening is typically carried out after crushing. In screening the ore is passed through a number of screens in a screening station. The screens in a screening station have openings or slots that continue to become smaller and smaller. Screening is used to produce different ore products based on an ore size range.

Grinding is particle size reduction of ore or rock materials in grinding mills such as tumbling, roller, or various types of fine grinding mills which can be arranged in either a vertical or horizontal orientation. In hard rock mining and industrial mineral operations the demands for rotating mineral and metallurgical processing equipment such as grinding mills are very high both in terms of grinding efficiency and energy consumption. Typically in a grinding process particles of a diameter as large as 150mm or more are ground to particles having a diameter of sub-millimeter size or smaller, depending on whether a series of staged size reduction in different types of mills is employed, and depending on the type of mill and its operational setting. This conventional grinding of materials results in considerable wear on sacrificial liners installed inside the mechanical framework of the mill, due to the hardness and associated friction of the rock concerned, therewith also resulting in considerable costs for the provision of such grinding bodies.
Comminution processing equipment such as grinding mill is typically very large, having a diameter of several meters. Grinding mills may be trunnion-supported or shell-supported. Trunnion support is the most common way of supporting a mill in a mineral processing application, especially in very large grinding mills. Shell-supported grinding mills are more compact, occupy less floor space and require simpler foundations than comparable trunnion-supported grinding mills.

Coarse ore particle grinding mills are commonly either autogenous (AG) or semi-autogenous (SAG) grinding mills designed for grinding of primary crushed ore. Autogenous grinding mills are so-called due to the self-grinding of the ore. In an autogenous grinding mill a rotating drum throws ore in a cascading motion of the mill content (charge) which causes impact breakage by larger rocks and compressive grinding of particles below the charge surface. In autogenous grinding the actual material itself, i.e. the material to be ground, forms the grinding media.

Semi-autogenous grinding mills are similar to autogenous mills, but utilize grinding media e.g. steel grinding balls to aid in grinding. Impact and attrition between grinding balls and ore particles causes grinding of coarse particles into finer particles. Semi-autogenous grinding mills typically use a grinding ball charge of 8 to 21%, sometimes the total charge may be higher. Autogenous and semi-autogenous grinding mills are generally used as a primary or first stage grinding solution. They are primarily used at gold, copper and platinum mines with applications also in the lead, zinc, silver, alumina and nickel industries.

Ball mills are tumbling mills like SAG and AG mills, but are typically employed in a comparably fine grinding duty, often as a second stage behind SAG and AG mills. Like SAG mills, they use steel balls as grinding media, albeit of smaller diameter than SAG mills.

Autogenous and semi-autogenous grinding mills are characterized by their large diameter and short length as compared to ball mills, which are typically long with a smaller diameter. Tumbling mills are typically driven by ring gears, with a 360° fully enclosing guard. The inside of comminution equipment such as a tumbling mill is lined with sacrificial liners. Mill liner materials typically include steel, cast iron, solid rubber, rubber-steel composites or ceramics. Mill liners include lifters, e.g. lifter bars to lift the material inside the mill, where it then falls off the lifters onto the rest of the ore charge.
Comminution processing equipment that is provided with internal lifters is subject to changes in performance due to the change in liner shape caused by abrasive wear. For example, in autogenous grinding mills or semi-autogenous grinding mills the feed to the mill also acts as a grinding media, and changes in the feed have a strong effect on the grinding performance. Change in the feed properties, i.e. change in the feed parameters is a normal phenomenon that needs to be considered in controlling the comminution processing equipment.

Mineral deposits rarely have a homogenous structure or a homogenous mechanical strength. In regard to the feed parameters of a grinding process, the ore properties such as hardness, particle size, density and ore type also change constantly and this makes the control of the grinding process difficult, e.g. a constantly varying energy input is required.

The comminution process of a grinding mill is typically controlled on the basis of mill power draw as a grinding process parameter, yet power draw is sensitive to changes in feed parameters and mechanical properties of the grinding process and is often not a suitable indicator of grinding conditions inside the mill. Another grinding process parameter is the measurement of mill charge mass.

The knowledge of mass of different materials that are transported on a conveyor belt is a very important measure in a comminution process and in industry.

It has been discovered that in an optimal grinding process control the measured grinding process parameters such as e.g. power draw, torque, bearing pressure, product size and mill load mass and also degree of fullness as percentages of mill volume would also require the knowledge of ore mass flow in a grinding process. As the grinding process control has a proper knowledge of both the measured grinding process parameters and the ore mass flow of the grinding process it can carry out calculations for calculating of the degree of fullness in the mill as percentages of the mill volume and for determining grinding control parameters for controlling the grinding process such as e.g. mass feed, water addition, circulated pebbles, ball addition and speed.

Moreover, there may be intensive variations in the load density as well as significant variations in liner weight due to wear, in which case changes in the mass do not necessarily result from changes in fill level i.e. the grinding mill charge as percentages of mill volume. Fill level of the mill expressed as
percentage of mill volume is a quantity that is very stable, descriptive and useful as an indicator in regards the state of the mill and therefore its efficiency.

The present invention relates to a method and arrangement for determining the ore mass flow of ore conveyed in a comminution process, which provides a better controlled and more efficient comminution process when compared to the prior art solutions. In the solution for determining the ore mass flow in a comminution process according to the present invention there is no need for frequent monitoring of calibration and possible recalibration. The solution for determining the ore mass flow in a comminution process according to the present invention provides a more accurate measurement from the ore mass flow within a very broad measurement range.

In a comminution process according to the present invention the density of used ore is known and stable enough. In the present invention the ore mass flow of ore conveyed in a comminution process is determined based on the volumetric flow of ore. There are several 3D measurement devices that can be used to produce data for a 3D representation of ore conveyed on a conveyor in a comminution process.

According to the present embodiment a three-dimensional image profile of the ore travelling on a conveyor belt is acquired by using a 3D camera (3D, three-dimensional) for scanning or photographing said ore travelling on a conveyor belt. There are several 3D technologies that can be used to obtain the 3D image profile. One approach is to use a system consisting of a line laser source and a digital imaging sensor, such as e.g. a CCD imaging sensor (CCD, Charge-Coupled Device) or a CMOS imaging sensor (CMOS, Complementary Metal-Oxide-Semiconductor).

Figure 1 shows a flow diagram of one example of a comminution process according to the present invention. A comminution process according to the present invention comprises the process blocks for a crushing circuit 1, a screening process 2 and a grinding circuit 3. In a comminution process according to the present invention the crushing circuit process block 1 is carried out first. In the crushing circuit 1 the ore or rock material is crushed between two solid surfaces of a stronger material. In crushing the particle size of ore is substantially reduced. The crushing circuit 1 produces crushed ore for the screening process 2.

In screening process block 2 the ore is passed through a number of screens in a screening station. The screens in a screening station have open-
ings or slots that continue to become smaller and smaller. In screening different ore products based on an ore grade or an ore size range are produced.

After the screening process 2 the crushed and screened ore is forwarded to the grinding circuit process block 3. In the grinding circuit 3 the ore or rock material is ground in a grinding mill such as e.g. a tumbling mill, roller mill or a fine grinding mill. In the grinding circuit 3 the particle size of ore is reduced. Typically in a grinding circuit process block 3 particles of a diameter as large as 150mm or more are ground to particles having a diameter of sub-millimeter size or smaller.

Figure 2 shows a side view of one embodiment of an arrangement for monitoring the flow of ore travelling on a conveyor belt from the crusher to the grinding mill according to the present invention. The presented ore monitoring arrangement shows a conveyor belt 4 travelling clockwise from the crusher to the grinding mill. The conveyor belt 4 is first being fed ore 5 from the crusher, thereafter conveyor belt 4 conveys the ore 5 from left to right to the feed of the grinding mill.

In the presented ore monitoring arrangement of Figure 2 there is a laser measurement unit 6 for measuring the surface height of ore travelling on a conveyor belt. The laser measurement unit 6 according to the present invention comprises a laser light source and a laser measurement receiver. The laser light source of the laser measurement unit 6 generates laser light pulses towards the ore 5 travelling on a conveyor belt 4 from the crusher to the grinding mill. The generated laser light pulses reflect back from the surface 7 of the ore 5 travelling on the conveyor belt 4.

Figure 3 shows a side view of one embodiment of an arrangement for measuring of a three-dimensional image profile of the ore travelling on a conveyor belt from the crusher to the grinding mill of grinding circuit according to the present invention. The presented three-dimensional image profile measuring arrangement shows a conveyor belt 8 travelling clockwise from a crushing circuit 9 to the grinding mill of grinding circuit 10.

In the presented embodiment of the three-dimensional image profile measuring arrangement according to the present invention the conveyor belt 8 is first being fed ore 11 from the crushing circuit 9, thereafter conveyor belt 8 conveys the ore 11 from left to right to the feed of the grinding mill of grinding circuit 10. The presented three-dimensional image profile measuring arrangement also comprises a three-dimensional imaging system 12 placed above the
conveyor belt 8, said three-dimensional imaging system 12 comprising a structured light source, e.g. a line laser source 13, and at least one imaging device 14, 15.

The line laser source 13 of the three-dimensional imaging system 12 generates a laser line and draws a coherent light line on the ore 11 travelling on the conveyor belt 8 from the crushing circuit 9 to the grinding mill of grinding circuit 10. The generated laser light reflects back from the surface 16 of the ore 11 travelling on the conveyor belt 8.

In the presented embodiment of the three-dimensional surface profile measuring arrangement according to the present invention a first imaging device 14, e.g. a CCD imaging sensor 14 or a CMOS imaging sensor 14, of the at least one imaging device 14, 15 is placed in the angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to the line laser source 13. The first imaging device 14 of the at least one imaging device 14, 15 is constantly acquiring measurement data for three-dimensional reconstruction from the ore 11 travelling on the conveyor belt 8. The reflected laser line reflected back from the surface 16 of the ore 11 and is detected in the three-dimensional reconstructions taken by said first imaging device 14. For example in one three-dimensional reconstruction representing one cross-section of said ore 11 travelling on the conveyor belt 8, the location of the laser line may be identified by machine vision algorithms and transformed to the real height of the ore bed for said cross-section.

As the conveyor belt 8 is moving, and the speed of the conveyor belt 8 is known, consequently an enhanced volumetric flow and a three-dimensional image profile of the ore 11 travelling on the conveyor belt 8 is obtained. The 3D profile image obtained using the presented principle i.e. triangulation principle, will inherently include also the shadow areas in the 3D image profile that cannot be detected by the camera. To reduce this effect two cameras can be used.

In the presented embodiment of the three-dimensional surface profile measuring arrangement according to the present invention there is also a second imaging device 15, e.g. a CCD imaging sensor 15 or a CMOS imaging sensor 15, of the at least one imaging device 14, 15 is placed at the opposing side to said first imaging device 14, and in the angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to the line laser source 13. Also the second imaging device 15 of the at least one imaging de-
vice 14, 15 is constantly acquiring measurement data for three-dimensional reconstruction from the ore 11 travelling on the conveyor belt 8. The reflected laser light line reflected back from the surface 16 of the ore 11 and is detected in the three-dimensional reconstructions taken by said second imaging device 15.

In the present embodiment the imaging devices 14, 15 may be any types of regular imaging devices 14, 15, e.g. based on digital imaging technology. Digital imaging technology is a technology utilizing sensors, e.g. containing grids of pixels, and is widely used in professional, medical, and scientific applications where high-quality image data is required such as in digital cameras, in optical scanners, in video cameras and in light-sensing devices.

Furthermore, in the present embodiment the ore is travelling on a conveyor leading directly to a grinding mill. Also in the present embodiment the imaging devices are positioned for acquiring measurement data for three-dimensional reconstruction from the ore as it is travelling on a conveyor leading to a grinding mill. However, in an alternative embodiment of the present invention, said comminution process may have several conveyors, screening stations and storage bins. Likewise, in an alternative embodiment of the present invention, said at least one imaging device is acquiring measurement data for three-dimensional reconstruction from said ore as it is travelling on any conveyor in a comminution process or exiting any conveyor in a comminution process.

Figure 4 shows a backside view of a conveyor belt and a three-dimensional imaging system of one embodiment of an arrangement for measuring of a three-dimensional image profile of the ore travelling on a conveyor belt from the crusher to the grinding mill of grinding circuit according to the present invention. In the presented embodiment of the three-dimensional image profile measuring arrangement according to the present invention the conveyor belt 8 conveys the ore 11 from the crushing circuit to the feed of the grinding mill. The presented three-dimensional image profile measuring arrangement comprises a three-dimensional imaging system 12 placed above the conveyor belt 8, said three-dimensional imaging system 12 comprising a structured light source, e.g. a line laser source, and at least one imaging device. The line laser source of the three-dimensional imaging system 12 generates a laser line and draws a coherent light line on the ore 11 travelling on the conveyor belt 8. The generated laser light reflects back from the surface of the ore 11 travelling on the conveyor belt 8.
In the presented embodiment of the three-dimensional surface profile measuring arrangement according to the present invention a first imaging device of the at least one imaging device is placed in the angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to the line laser source of the three-dimensional imaging system 12. The first imaging device of the at least one imaging device is constantly acquiring measurement data for three-dimensional reconstruction from the ore 11 travelling on the conveyor belt 8. The reflected laser line reflected back from the surface of the ore 11 and is detected in the digital images taken by said first imaging device. As the conveyor belt 8 is moving, and the speed of the conveyor belt 8 is known, consequently an enhanced volumetric flow and a three-dimensional image profile of the ore 11 travelling on the conveyor belt 8 is obtained.

Furthermore, in the presented embodiment of the three-dimensional surface profile measuring arrangement according to the present invention there may also be a second imaging device of the at least one imaging device, which second imaging device is placed at the opposing side to said first imaging device, and in the angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to the line laser source of the three-dimensional imaging system 12.

Figure 5 shows a schematic diagram of one embodiment of an arrangement for determining the ore mass flow of ore conveyed in a comminution process according to the present invention. The presented embodiment of an arrangement for determining the ore mass flow in a comminution process according to the present invention comprises a crushing circuit 17, a grinding circuit 19 and a conveyor 18 conveying ore from the crushing circuit 17 towards the grinding circuit 19.

The arrangement according to the presented embodiment also comprises an imaging system 20 for measuring 3D reconstruction measurement data 21 for reconstruction of a three-dimensional image profile of the ore before entering said grinding circuit 19. The imaging system 20 monitors the flow of ore conveyed in said comminution process. The imaging system 20 of the presented embodiment is placed in the vicinity of said conveyor 18. In the presented embodiment said imaging system 20 measures said 3D reconstruction measurement data 21 from ore conveyed by said conveyor 18 and forwards said measured 3D reconstruction measurement data 21 to an ore mass flow calculation block 22.
In said ore mass flow calculation block 22 ore mass flow data 23 is calculated. The ore mass flow calculation block 22 forwards said ore mass flow data 23 towards a control block 27 of the arrangement according to the presented embodiment.

The arrangement according to the presented embodiment also comprises a separate control value data calculation block 24 for calculation of control value data 26 and for forwarding said calculated control value data 26 to said control block 27. The control value data calculation block 24 according to the presented embodiment receives said ore mass flow data 23 from said ore mass flow calculation block 22. The control value data calculation block 24 also receives comminution process data 25 from said grinding circuit 19. The comminution process data 25 may include one or more of the following data: mass feed, water addition, ball addition, pebbles feed, grinding mill speed, hardness, density, ore specific gravity, elemental analysis, ore grade, grinding product size, grinding mill power draw, grinding mill torque, grinding mill bearing pressure and grinding mill charge.

In the arrangement according to the presented embodiment said control value data calculation block 24 calculates control value data 26 based on the received data and forwards said calculated control value data 26 to said control block 27. The control value data calculation block 24 may also forward the received ore mass flow data 23 and/or the received comminution process data 25 along with said calculated control value data 26 to said control block 27.

The control block 27 according to the presented embodiment receives said calculated control value data 26 and may also receive said ore mass flow data 23 and/or said comminution process data 25 along with said calculated control value data 26. The control block 27 controls the crushing circuit 17 and/or the grinding circuit 19 by e.g. by sending control signalling and/or data signalling 28, 29 to the crushing circuit 17 and/or to the grinding circuit 19. In an alternative embodiment, said control value data calculation block 24 may be integrated into said control block 27. Furthermore, in an alternative embodiment, said ore mass flow calculation block 22 and said control value data calculation block 24 may both be integrated into said control block 27.

The control block 27 according to the presented embodiment may control e.g. grinding mill speed and/or mass feed and/or water addition and/or
ball addition and/or pebbles feed to a grinding circuit 19 of said comminution process based on said received ore mass flow data 23.

Furthermore, in the present embodiment the ore is travelling on a conveyor towards a grinding mill. However, in an alternative embodiment of the present invention, said comminution process may have several conveyors, screening stations and storage bins. Likewise, in an alternative embodiment of the present invention, said at least one imaging device is acquiring measurement data for three-dimensional reconstruction from said ore as it is travelling on any conveyor in a comminution process or exiting any conveyor in a comminution process.

Figure 6 shows a schematic diagram of another embodiment of an arrangement for determining the ore mass flow of ore conveyed in a comminution process according to the present invention. The presented another embodiment of an arrangement for determining the ore mass flow in a comminution process according to the present invention comprises a crushing circuit 17, a grinding circuit 19 and a conveyor 18 conveying ore from the crushing circuit 17 towards the grinding circuit 19.

The arrangement according to the presented another embodiment also comprises an imaging system 20 for measuring 3D reconstruction measurement data 21 for reconstruction of a three-dimensional image profile of the ore before entering said grinding circuit 19. The imaging system 20 monitors the flow of ore before it enters said grinding circuit 19 of said comminution process. The imaging system 20 of the presented embodiment is placed in the vicinity of said conveyor 18. In the presented embodiment said imaging system 20 measures said 3D reconstruction measurement data 21 from ore conveyed by said conveyor 18 and forwards said measured 3D reconstruction measurement data 21 to a three-dimensional image profile calculation block 30.

In the arrangement according to the presented another embodiment said three-dimensional image profile calculation block 30 also receives conveyor speed 31 from the conveyor 18. The three-dimensional image profile calculation block 30 then consequently obtains a three-dimensional image profile 32 of the ore travelling on the conveyor 18 based on the received measured 3D reconstruction measurement data 21 and the received conveyor speed 31. Thereafter, said three-dimensional image profile calculation block 30 forwards said measured 3D reconstruction measurement data 21 including
said three-dimensional image profile 32 of the ore to an ore mass flow calculation block 22.

In said ore mass flow calculation block 22 ore mass flow data 23 is calculated. The ore mass flow calculation block 22 forwards said ore mass flow data 23 towards a control block 27 of the arrangement according to the presented another embodiment.

The arrangement according to the presented another embodiment also comprises a separate control value data calculation block 24 for calculation of control value data 26 and for forwarding said calculated control value data 26 to said control block 27. The control value data calculation block 24 according to the presented embodiment receives said ore mass flow data 23 from said ore mass flow calculation block 22. The control value data calculation block 24 also receives comminution process data 25 from said grinding circuit 19. The comminution process data 25 may include one or more of the following data: mass feed, water addition, ball addition, pebbles feed, grinding mill speed, hardness, density, ore specific gravity, elemental analysis, ore grade, grinding product size, grinding mill power draw, grinding mill torque, grinding mill bearing pressure and grinding mill charge.

In the arrangement according to the presented another embodiment said control value data calculation block 24 calculates control value data 26 based on the received data and forwards said calculated control value data 26 to said control block 27. The control value data calculation block 24 may also forward the received ore mass flow data 23 and/or the received comminution process data 25 along with said calculated control value data 26 to said control block 27.

The control block 27 according to the presented another embodiment receives said calculated control value data 26 and may also receive said ore mass flow data 23 and/or said comminution process data 25 along with said calculated control value data 26. The control block 27 controls the crushing circuit 17 and/or the grinding circuit 19 by e.g. by sending control signalling and/or data signalling 28, 29 to the crushing circuit 17 and/or to the grinding circuit 19. In an alternative embodiment, said control value data calculation block 24 may be integrated into said control block 27. The control block 27 according to the presented another embodiment may control e.g. grinding mill speed and/or mass feed and/or water addition and/or ball addition and/or peb-
bles feed to a grinding circuit 19 of said comminution process based on said received ore mass flow data 23.

Furthermore, in the present embodiment the ore is travelling on a conveyor towards a grinding mill. However, in an alternative embodiment of the present invention, said comminution process may have several conveyors, screening stations and storage bins. Likewise, in an alternative embodiment of the present invention, said at least one imaging device is acquiring measurement data for three-dimensional reconstruction from said ore as it is travelling on any conveyor in a comminution process or exiting any conveyor in a comminution process.

Figure 7 shows a schematic diagram of one embodiment of a screening circuit of a comminution process according to the present invention. The presented embodiment of a comminution process according to the present invention comprises a crushing circuit 33 and a screening circuit, said screening circuit comprising a screening station conveyor 34 and a screening station 35. In the presented embodiment of a comminution process according to the present invention ore is crushed in the crushing circuit 33 and conveyed to the screening station 35 via the screening station conveyor 34.

The screening circuit of a comminution process according to the present invention comprises a fine ore storage bin 37, a pebble ore storage bin 39 and a lump ore storage bin 41. The screening circuit also comprises a fine ore conveyor 36, a pebble ore conveyor 38 and a lump ore conveyor 40.

In the presented embodiment of a comminution process according to the present invention ore is screened in the screening station 35 and the screened ore is distributed from the screening station 35 to the responsible conveyor, i.e. screened fine ore to said fine ore conveyor 36, screened pebble ore to said pebble ore conveyor 38 and screened lump ore to said lump ore conveyor 40. Respectively, said fine ore conveyor 36 conveys the screened fine ore to said fine ore storage bin 37, said pebble ore conveyor 38 conveys the screened pebble ore to said pebble ore storage bin 39 and said lump ore conveyor 40 conveys the screened lump ore to said lump ore storage bin 41. In the screening station 35 of the presented embodiment the screened oversize ore 42 is typically returned back to the crushing circuit 33.

The comminution process according to the present invention may also comprise a system for monitoring the flow of ore, said monitoring system comprising an imaging system, and said imaging system measuring 3D recon-
struction measurement data 21 for reconstruction of a three-dimensional image profile of said crushed ore being conveyed to said screening station 35.

Furthermore, said monitoring system may also comprise an imaging system measuring 3D reconstruction measurement data 21 for reconstruction of a three-dimensional image profile of said screened fine ore being conveyed to said fine ore storage bin 37 and/or an imaging system measuring 3D reconstruction measurement data 21 for reconstruction of a three-dimensional image profile of said screened pebble ore being conveyed to said pebble ore storage bin 39 and/or an imaging system measuring 3D reconstruction measurement data 21 for reconstruction of a three-dimensional image profile of said screened lump ore being conveyed to said lump ore storage bin 41. The screening circuit of a comminution process according to the present invention may also comprise ore mass flow calculation block calculating said ore mass flow data based on said measured ore 3D reconstruction measurement data 21.

Figure 8 shows one embodiment of an ore mass flow graph diagram in an arrangement for determining the ore mass flow in a comminution process according to the present invention. The presented embodiment of a graph diagram 43 shows the ore mass flow data of ore which has been calculated based on the measurement data of ore, said measurement data measured by the imaging system of the arrangement according to the present invention.

In the presented graph diagram 43 the ore mass flow data calculated from the ore measurement data is shown as a function of time. The height of the presented graph diagram 43 indicates a mass flow during a specific time. One such mass flow 44 during a specific time interval is shown in the presented graph diagram 43.

The arrangement for determining the ore mass flow in a comminution process according to the present invention may control the crushing circuit by producing crushing control signalling for controlling the crushing process control parameters, that is, by e.g. controlling the screen control and/or the vibrating feeder control so that the desired crushing process output i.e. out coming rock size distribution is sought.

The arrangement for determining the ore mass flow in a comminution process according to the present invention may control the grinding circuit by producing grinding control signalling for controlling the grinding process control parameters so that the desired grinding process output is sought.
In a typical grinding circuit control it is typical to keep the mill charge or the filling of the grinding mill at the constant level by controlling the feed to the mill. As an indication of the filling, the mill power draw and mill bearing pressures are often used. This typical approach works relatively well in case the hardness, the density, and the size distribution of the feed are constant. Unfortunately all of these variables are unknown and changing continuously. With the obtained ore mass flow data according to the present invention it is possible to assess these disturbances in the grinding circuit control and take the necessary action.

Conventional belt weighers are quite problematic in many circumstances. In many installations, e.g. with retrofit installations the conveyor belt must be shut down for the installation. The conventional belt weigher installation takes several hours, which is very expensive for an operating production plant. Another problem is the use of the radiation sources in the conventional belt weighers, as this makes the installation problematic and requires a special attention on safety. One further problem with the conventional belt weighers is that they require frequent monitoring of their calibration and possible recalibration.

The arrangement for determining the ore mass flow in a comminution process according to the present invention can be easily installed without ever stopping the conveyor belt. This brings substantial savings in an operating production plant. In the solution for determining the ore mass flow in a comminution process according to the present invention there are no radiation sources used, which makes the installation easier and the use safer. Furthermore, in the solution for determining the ore mass flow in a comminution process according to the present invention there is no need for frequent monitoring of calibration and possible recalibration. There are no calibration drift problems.

The solution for determining the ore mass flow in a comminution process according to the present invention provides a more detailed view of the entire comminution process with a thorough knowledge of the ore travelling on a conveyor belt from the crusher to the grinding mill. This enables a substantially better control of a comminution process.

By achieving a substantially better control of a comminution process in general; also the crushing process and more importantly the grinding pro-
cess can be better and more efficiently controlled. This brings a lot of savings through more efficient use of energy and process ore.

With the help of the solution according to the present invention the manufacturers of comminution process equipment will be able to provide comminution process equipment arrangements with having more reliable measurement data and information on the ore mass flow of the ore travelling on a conveyor belt from the crusher to the grinding mill of grinding circuit with better measurement accuracy and reliability. The solution according to the present invention may be utilised in any kind of comminution process equipment.

It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.
CLAIMS

1. A method for determining the ore mass flow of ore (11) conveyed in a comminution process, said method comprising a step of:
   - monitoring the flow of ore (11) conveyed by a conveyor (8), (18), (34), (36), (38), (40) in said comminution process,

characterized in that in said step of monitoring:
   - 3D reconstruction measurement data (21) for reconstruction of a three-dimensional image profile (32) of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40) is measured with an imaging system (12), (20) placed in the vicinity of said conveyor (8), (18), (34), (36), (38), (40), and in that said method comprises a step of:
      - receiving calculated ore mass flow data (23) of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40), said ore mass flow data (23) being calculated based on said measured ore 3D reconstruction measurement data (21).

2. A method according to claim 1, characterized in that said method comprises a step of:
   - calculating said ore mass flow data (23) based on said measured ore 3D reconstruction measurement data (21).

3. A method according to claim 2, characterized in that in said step of calculating, a three-dimensional ore image profile of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40) is calculated.

4. A method according to any one of claims 2 to 3, characterized in that in said step of calculating, a volumetric flow of ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40) is also calculated.

5. A method according to any one of claims 2 to 4, characterized in that said method comprises a step of:
   - calculating control value data (26) for controlling said comminution process based on said calculated ore mass flow data (23) and/or received comminution process data (25).

6. A method according to claim 5, characterized in that said control value data (26) is calculated for controlling ore mass feed or water addition or ball addition or pebbles feed in said comminution process.
7. An arrangement for determining the ore mass flow of ore (11) conveyed in a comminution process, characterized in that
- said arrangement comprises an imaging system (12), (20) placed in the vicinity of a conveyor (8), (18), (34), (36), (38), (40), said imaging system (12), (20) measuring 3D reconstruction measurement data (21) for reconstruction of a three-dimensional image profile (32) of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40); and that
  - said determining arrangement comprises a comminution control block (27) receiving calculated ore mass flow data (23) of said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40).

8. An arrangement according to claim 7, characterized in that said imaging system (12), (20) comprises at least one imaging device (14), (15).

9. An arrangement according to claim 8, characterized in that said imaging system (12), (20) comprises a structured light source, and that a first imaging device (14) of said at least one imaging device (14), (15) is placed at an angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to a line laser source (13), which first imaging device (14) acquires 3D reconstruction measurement data (21) for three-dimensional reconstruction from said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40).

10. An arrangement according to claim 9, characterized in that said imaging system (12), (20) comprises a structured light source, and that a second imaging device (15) of the at least one imaging device (14), (15) is placed on the opposite side of said first imaging device (14), and at an angle of 0-150 degrees, preferably 15-60 degrees, more preferably 30-40 degrees compared to the line laser source (13), which second imaging device (15) acquires 3D reconstruction measurement data (21) for three-dimensional reconstruction from said ore (11) conveyed by said conveyor (8), (18), (34), (36), (38), (40).

11. An arrangement according to any one of claims 7 to 10, characterized in that said at least one imaging device (14), (15) acquires 3D reconstruction measurement data (21) for three-dimensional reconstruction from said ore (11) as it is travelling on said conveyor (8), (18), (34), (36), (38), (40).
12. An arrangement according to any one of claims 7 to 10, characterized in that said at least one imaging device (14), (15) acquires 3D reconstruction measurement data (21) for three-dimensional reconstruction from said ore (11) as it is exiting said conveyor (8), (18), (34), (36), (38), (40).

13. An arrangement according to any one of claims 7 to 12, characterized in that said imaging system (12), (20) is attached to a frame structure, to a wall structure or to a ceiling structure in the vicinity of said conveyor (8), (18), (34), (36), (38), (40).

14. An arrangement according to any one of claims 7 to 12, characterized in that said imaging system (12), (20) is attached to a frame structure or to a supporting structure of said conveyor (8), (18), (34), (36), (38), (40).

15. An arrangement according to any one of claims 7 to 12, characterized in that said imaging system (12), (20) is attached to an arm structure or to an articulated arm structure bringing said imaging system (12), (20) in the vicinity of said conveyor (8), (18), (34), (36), (38), (40).

16. An arrangement according to any one of claims 7 to 15, characterized in that said control block (27) has an input for receiving comminution process data (25).

17. An arrangement according to any one of claims 7 to 16, characterized in that said arrangement comprises at least one calculation block (22), (24), (30) for calculating said ore mass flow data (23).

18. An arrangement according to claim 17, characterized in that said at least one calculation block (22), (24), (30) also calculates control value data (26) for controlling said comminution process based on said calculated ore mass flow data (23) and/or received comminution process data (25).

19. An arrangement according to claim 18, characterized in that said at least one calculation block (22), (24), (30) calculates said control value data (26) for controlling ore mass feed or water addition or ball addition or pebbles feed in said comminution process.

20. An arrangement according to any one of claims 16 to 19, characterized in that comminution process data (25) includes one or more of the following data: ore mass feed, water addition, ball addition, pebbles feed, grinding mill speed, hardness, density, grinding product size, grind-
ing mill power draw, grinding mill torque, grinding mill bearing pressure and
grinding mill charge.

21. An arrangement according to any one of claims 7 to 20, characterized in that said arrangement further comprises a data stor-
age block, into which data storage block at least some of the calculated pro-
cess values, i.e. said ore mass flow data (23) and/or at least some of received
 comminution process data (25) are stored.

22. An arrangement according to claim 21, characterized in that at least some of the measured process values are stored to said data
storage block.

23. An arrangement according to any one of claims 7 to 22, characterized in that said conveyor (8), (18), (34), (36), (38), (40) has
a conveyor belt having a belt width of 50-150 centimeters, preferably 80-110
centimeters.

24. An arrangement according to any one of claims 7 to 23, characterized in that said conveyor (8), (18), (34), (36), (38), (40) has
a conveying speed of 0.3 to 10 meters per second, preferably 1 to 3 meters
per second.

25. An arrangement according to any one of claims 7 to 24, characterized in that said conveyor (8), (18), (34), (36), (38), (40) has
an ore mass flow in the range of 10 to 5000 tons per hour, preferably 30 to
1500 tons per hour, more preferably 100 to 500 tons per hour.

26. An arrangement according to any one of claims 7 to 25, characterized in that said imaging system (12), (20) detects particles
having a diameter of 1-1000 millimeters, preferably 5-500 millimeters, more
preferably 20-200 millimeters.
INTERNATIONAL SEARCH REPORT

INTERNATIONAL APPLICATION No.
PCT/FR2016/050843

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01F13/00 G01F22/00
G01G 01/00 G01B 11/24
G01F22/00

B. ADDITIONAL INFORMATION

According to International Patent Classification (IPC), the following additional classification symbols have been included:

G01F13/00
G01F22/00

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
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<th>Category</th>
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<th>Relevant to claim No.</th>
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<td>X</td>
<td>wo 90/02318 AI (VICTORIA ELECT COMMISSION [AU]) 8 March 1990 (1990-03-06) page 1, line 16 - line 35 page 4, line 13 - line 14 figure 1 page 6, line 12 - line 14 page 4, line 38 - page 5, line 2 ----</td>
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Further documents are listed in the continuation of Box C.

*C* Special categories of cited documents:

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Date of the actual completion of the international search:

23 February 2017

Date of mailing of the international search report:

02/03/2017

Name and mailing address of the ISA:

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Authorized officer:

Regert, Tamas
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