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A NEW FULL COLOUR ORE SORTER FOR ROCKS TOO SMALL TO HAND SORT

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ABSTRACT: Throughout history hand sorting of ores has been common practice. The introduction of automatic ore sorting machines over the past 30 years has succeeded in reducing sorting costs and improving product quality when treating industrial minerals and gold ores. However, there remained the problem of economic treatment of rocks that are smaller than 25 mm in size, and the difficulty of identifying and separating rock by colour.

This paper outlines the basic operating principles of successful optical sorters - good feed preparation, stable feed presentation, collection of optical data, decision making and effective separation of the selected rocks. A new colour sorter is discussed in relation to these principles. Some unique features introduced with this new sorter are described in detail. They include a catenary feed belt, high-resolution tri-chromatic cameras, high-speed data processing and rapid response air jet valves. With these, user gains the economic advantage of effectively treating greater throughputs of small rocks down to about 6 mm in size. Rocks can be sorted by subtleties of colour which are beyond the capability of the human eye.

This new sorter has been demonstrated to produce excellent separations on a range of materials including limestone, spodumene, talc, quartzite, fused alumina, emeralds down to 2 mm in size, and scrap metals.

1.INTRODUCTION

The new Model 700 optical ore sorting machine from OSNA Equipment Inc. (Ore Sorters of North America) offers mineral processors the benefits of economic sorting of ore at a size range from 40 mm down to about 6 mm (and even 2 mm for valuable items such as gemstones). This is much smaller than is practical by hand. The machine achieves full colour sorting by using the latest in charge coupled device (CCD) colour cameras and high-speed computer technology.

2. HISTORY

Automatic ore sorting has developed in parallel with food sorting technology. It has been commercially in use and in various stages of technical development for about 30 years. Several sensing techniques have been developed, the most popular being X-ray fluorescence for use in the diamond industry, photometry to separate light coloured from dark coloured rocks (usually industrial minerals) and a radiometric system for uranium ore. The most successful ore sorter in commercial use over the past 20 years is the Model 16 laser-based photometric sorter produced by the international group of Ore Sorters Ltd. This machine has been improved over the years and used for sorting magnesite, limestone, dolomite, talc, feldspar, spodumene, metal sulphides, wolframite and gold ores. There has, however, always been the problem of achieving an economic treatment of rocks smaller than 25 mm in size, and the difficulty of identifying and separating rock by colour. These problems have been overcome in the new Model 700 sorter.

3.0PERATING PRINCIPLES OF ORE SORTERS

An automatic sorter comprises a sensing and data processing system, which recognizes the material to be sorted, surrounded by a mechanical handling system, which presents the material to the sensor and later physically sorts it into two products. Sorter design can be considered as comprising the following five sub-systems:

3 1 Feed preparation

A prerequisite for efficient sorting is the preparation of the feed material to allow optimum performance of the sorter functions. Material must be screened into the size fractions suitable for the machine, and washed to remove fines, which would otherwise mask the appearance of the rock and generate false optical data. Wet rocks present the most consistent appearance to the sorter and moisture enhances the reflectance of the ore. The use of closely sized feed improves the sorter performance by allowing a more accurate determination of the exact position of a rock within the optical scan. This is because the data is collected by viewing the rock stream at an acute angle to the vertical line of scan. Consequently the top of a large rock can appear to be in the same lateral position across the scan as a more distant small rock If the air ejector system is set to open valves in the position of the large rock it will fail to eject the smaller rock, since that would be further away from the camera. Rock size range also affects the positioning of the ejector valves. The ejector manifold must be adjusted to allow a safe clearance above the top of the largest rock in the feed whilst it is in its free flight trajectory. If the feed size range is large the ejector valve will be positioned too far from the smaller rocks to ensure accurate deflection by the air jet

3 2 Stable feed presentation

Rocks must arrive at the sensing system in a single layer, but separated from one another, in order to measure the optical properties of each one individually. This is achieved by feeding at a steady controlled rate from a storage bin via a vibrating feeder The rocks must be stable when they pass through the optical scanning system to ensure that correct optical measurements are taken. They must have a stable and controlled launch and free-flight trajectory to ensure that they are all able to pass over a product splitter and are in the correct pre-determined position for ejection of the selected rocks.

3.3 Optical data collection

The ore must pass through a scanning system as a single layer of separated rocks. Reflected light from each rock is detected at light sensitive devices to generate the optical data. The pattern of light is broken up into a series of picture elements (pixels) and transmitted as electronic signals to the processor.

3.4.Decision making

An electronic processor must analyze data and make a decision whether to allow the rock to continue in its trajectory or be diverted by air jets. The processor is programmed with data collected from typical minerals and rock types occurring in the ore body that is to be sorted. Settings are chosen for light reflectance signals that identify the different rock types and characteristics. During sorter operation the processor compares measurements from each rock against these set points, and makes the decision regarding the operation of the air jets. The processor determines the size of the rock and its relative position in order to activate the ejection system at the right time and place.

3.5. Rock separation

The separation system consists of a manifold housing a number of high-speed valves fitted across and above the stream of rocks. When the processor establishes that a particular rock should be ejected, a signal is sent and the appropriate valve or valves open for the required time allow ing a high-energy blast of air to divert the rock from its normal trajectory Diverted and normal trajectory rocks are collected on either side of a product splitter in separate chutes.

In order to make the machines as user friendly as possible, sufficient warnings and interlocks are built in to enable relatively unskilled plant personnel to successfully operate the sorters without continual reference to highly trained technicians These machsies are designed to be fail-safe in operation such Aat an event that may potentially damage them results in an automatic shutdown. Warnings indicate the location of the problem and signal the operator that action is required.

4. DESIGN FEATURES

The new Model 700 optical sorter incorporates the following innovative features:

4.1 Catenary shaped feed belt

A unique, loose fitting conveyor belt is draped to take the shape of a catenary. The ore particles are accelerated by gravity as they fall from a vibrating feeder, almost reaching the belt speed of 3 m/s before they are collected by the belt at a very shallow contact angle, minimizing abrasion and wear on the belt. Centrifugal force presses the rocks against the belt's catenary profile. The rocks do not bounce or roll, and all travel at belt speed in the linear direction of belt travel, ensuring that a stream of stable rocks is launched in a narrow spread of trajectories from the belt through the scanning and separation areas. A simple tensioning system keeps the belt tracking correctly.

4 2 Colour cameras

Tri-chromatic cameras separate red, green and blue using sequential dichroic elements, i.e. filters that select- specific range of frequencies. These colour cameras process 8 bits in each of the three colours, or 24 bits in total making 16.7 million or $(2)^{24}$ colour combinations. Such subtlety of colour is beyond the capability of the human eye. The camera's CCD array scans 4000 times per second. At a feed belt speed of 3 m/s, the scan width in the dire^ion of travel is 0.75 mm. Since 2000 readings ai^ taken across the 1.5 m width of the s,an, *— sorter achieves a pixel resolution of 0.75 mm ' /5 mm. Camera design is very rugged, using lens, locked in rigid barrels, machined towers and mechanical bonding to prevent loss of alignment. The video image is sent to the data processing via fiberoptic cable

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The collection of optical data by colour cameras requires bright and consistent lighting of the scanning area. Nine very high output long-life fluorescent lamps are used to achieve the necessary level of illumination. These lamps are specially made for the new sorter to ensure the same light output across the complete 1.5 m width of the scanning area. They are calibrated on the sorter, and the output can be varied to achieve optimum separation. The lamps are installed as groups of three, and enclosed in tough polycarbonate tubes to protect against breakage. Two further lamps are used as a background for product references. A filter, typically blue, is placed over the reference lamps to create a distinct background colour against which to view the rock. Blue is used because it is different from most rocks allowing the sorter to easily identify images of separate pieces of rock from the background. The colour of the background filter can be changed if required.

4 4. Camera positions

Opposite pairs of cameras are positioned above and below-the scanning area in a tilted-X formation such that both sides of each rock are observed whilst placing the cameras away from danger of impact. A pair of cameras covers one half of the scan width. The cameras are installed behind shatter proof glass windows, in a dry, air-conditioned environment. Camera vision stays clear and illumination levels are maintained by automatic washing of the windows and lights with clean water.

4 5 Data processor and software

Decision making and air jet operation is controlled by a high-speed Pentium-based processor, allowing the ejectors to be close to launch point and scan line for greater separation accuracy. The processor is programmed after collecting images of known minerals and rock types. The user selects and stores in memory those pixels from these images that represent characteristic colours from each rock type. This data can be considered as a cloud of points in a 3-dimensional array with intensity of red, green and blue as the axes. The data collected from each rock during sorter operation is then compared with the representative arrays as the basis for the colour sort decision. If there are pixels on a rock which fall within a colour array that was selected for ejection then an air valve may be activated to eject that rock. The program software can be used to manipulate the data to grow or shrink the data cloud in order to increase or decrease the sorter sensitivity to the selected colours. Separation difficulties will occur if the colour arrays of different rock types overlap and one type is selected for ejection and the other is not. Setting the minimum number of contiguous pixels, i e. area, on a rock that must fall within the colour cloud of data controls the final sort decision. Only when' that set point is exceeded will a signal be sent to the air jet valves to eject that rock from the stream. Finally, the processor determines the size, shape and position in space of each rock to be ejected. This information determines which air ejection valves to fire and when Different machine settings can be saved for future use to save time when switching feed material or product grade. The processor system also automatically checks for and displays any errors for immediate operator attention.

4 6 User interface

A flat panel touch screen is used as interface between user and data processor to eliminate the need for operators with computer skills. The sorter controls are easy to' set up and operate, with simple, easy to understand graphics and symbols, allowing fast adjustment for colour sensitivity and area set point. The operator's access to the data processing is restricted to different security levels by a system of customer selected passwords.

4.7 Air jet valves

A line of 256 air jet valves firing through nozzles at 6 mm spacing across the 1.5 m width of the sorter's scanning area removes selected rocks by blasting at the centre of each particle. High-speed data processing allows the air jets to be positioned only 130 mm from the point of rock launch from the belt. Therefore, rocks can be separated before they have time to diverge from the expected trajectory. Highly accurate separation of small particles is achieved with air pulses that can be as small as 1 ms. Since the rocks travel 3 mm in 1 ms the cycle time of the valves limits the smallest size that can be effectively separated. The expected operating life of a valve is 250 million cycles, or more than 2 years. The manifold is easily adjustable for angle and height above the rock stream and distance from scan line to optimize the separation for different feed particle sizes. The air jet timing and number of valves that open concurrently is pre-set by the operator to suit the size range of the feed material. A built-in microphone and the dedicated software are used to automatically determine the characteristic response time of each valve and tune it to achieve optimum results. Air consumption is approximately 50 m^3/t of rock blasted at 400 kPa pressure. Compressed air represents the majority of the operating cost of the sorter.

4.8. Machine design (excluding feeder)

Ail of the sensitive components are completely enclosed in a single sealed, air-conditioned environment for protection against the heat and humidity of the plant, and provide for structural stability and strength of installation. The user interface is built into the side of this enclosure minimizing cable runs and eliminating the need for a separate control console room. A standard sorter with 1.5 m scanning width has overall dimensions of 2.5 m long by 2.7 m wide by 2.4 m high. The small machine "footprint" provides a minimal occupation of space and low cost easy installation. Repairs can be made quickly by replacement of modular parts.

5. BENEFITS

The innovative features of the new Model 700 sorter offer benefits of true colour sorting at smaller rock sizes with greater accuracy and at higher throughputs than were previously economically possible. True colour sorting is achieved by using tri-chromatic cameras supported by a state-of-the-art computer and dedicated software. Sorting of particles down to 2 mm can be accomplished because of the fast scanning rate and high resolution of the CCD cameras, and the rapid cycle times possible on the air jet valves. Sorting accuracy is improved by ensuring the stability of the rock in flight within the scanning area and an all around view provided by placing cameras above and below the rock stream. High-speed data processing ensures that the rocks can be hit by air jets whilst in their pre-determined positions in flight. Rapid cycle time valves ensure that only the correctly selected rocks are ejected

Sorting machine throughput is limited by the time taken to sense, compute and make decisions concerning streams of separately spaced rocks. Sorter capacity is a function of the particle size distribution of the feed, since a single layer of small rocks on the feed belt is a smaller feed rate than a single layer of larger rocks Typical ore throughputs relate closely to the average size of the rock to be treated. A simple rule of thumb for the Model 700 sorter is 1 t/h for each mm in size of the rock, for example 15 t/h for rock of average size 15mm (say 10 to 20 mm size range). This high throughput is achieved by the high-speed data processing and rapid acting air valves, and the use of the catenary belt design which allows rocks to be fed at 3 m/s whilst maintaining their stability.

6. APPLICATIONS

The economic benefits offered to aie mineral processor from using the Model 700 optical sorter can be found in the following applications most relevant to the industrial minerals fie! 1:

- the separation of rock in the size range from 40 mm down to 2 mm where the only physical difference between the valuable and waste fractions is appearance, with the consequent elimination of loss of ore, that was previously too fine for hand sorting, and the potential to recover old dumps of such ore.
- the detection of features on rocks down to about 1 mm in size that can be used for the separation of the valuable from waste fractions. Such detection can be achieved more precisely in terms of colour than the human eye, and with no loss of efficiency due to operator fatigue.

- the removal of fine waste at an early stage in the process before other costly operations such as transportation to a distant plant, comminution, high-intensity magnetic separation, or the need . for environmentally unpopular processes involving chemicals.

  improved quality control of the final product by eliminating waste material from the fine ore.
- the use of less plant space and lower labour costs than required by hand sorting.

Specific economic applications of the new sorter can only be determined case-by-case, and depend on the value added to the product by achieving a higher quality and the possible savings in subsequent operations. Excellent separations have been demonstrated on a range of materials including limestone, spodumene, talc, quartzite, fused alumina, emeralds, and scrap metals, ft is expected that similar results can be achieved on materials that are already being sorted at coarser sizes using Model 16 sorters such as magnesite, dolomite, feldspar and gold ores.

7. SUMMARY

The basic sorting machine operating principles that were developed at Ore Sorters Ltd. and culminated in the successful Model 16 laser-based photometric sorting machine, have been incorporated in the new Model 700 optical sorter from OSNA Equipment, Inc. The Model 700 includes innovative features such as a catenary shaped feed belt, high-intensity lighting, CCD colour cameras positioned above and below the rock, high-speed decision making with a simple user interface, and rapid-action air jet valves, all enclosed in a single housing. These features offer the user the benefits of full colour sorting at smaller rock sizes with greater accuracy at higher throughputs than were previously possible. The economic benefits are particularly relevant to the industrial minerals industry to recover fine ore that was previously discarded, recover valuable pieces that were previously lost, reduce subsequent costs by the early elimination of waste, improve final product quality, and reduce process costs. Specific separations that have been successfully demonstrated include limestone, spodumene, talc, quartzite, fused alumina, emeralds, and scrap metal.