

Developments in separation by sorting

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Abstract

This article presents a review of the evolution of the sorting process in recent years. The process is no longer exclusively dependent on optical properties. The old sorting practice and the modern equipment are described. Different properties such as shape, natural radiation, laser and X-ray fluorescence, gamma and infrared rays absorption, magnetic resonance used today are introduced. Analytical methods processed in real time are also used. The use of artificial intelligence, instrumentation and computation makes sorting today a very trustworthy and sophisticated separation method. It is performed dry. Its great limitation is processing capacity, but manufacturers are making efforts to overcome this limitation.

Keywords: Sorting, Optical, Shape; Other Properties.

1 Introduction

Separation by sorting is the most immediate method to sort different species.

Many residential buildings have selective trash collection. Every day, in places where there is dry garbage municipal collection, paper and other recyclable items collectors sort cans, bottles, and paper for recycling. They are sorting the different materials.

2 Sorting practice historical cases

I believe that optical (visual) sorting is the oldest and surely the simplest separation method for minerals also. Figure 1 shows its manual application to the separation of building and demolition residues (BDR) (separation for reuse in civil construction) and domestic garbage selection.

Figure 2 shows the separation of waste from ore after primary crushing in a preparation plant. It is an old picture, as operators do not use any individual protection equipment. Waste crushes coarser than the ore. So, it is easy to eliminate part of this undesirable material as it is retained over the grizzly. In such an operation, we are not using the visual aspect of the particles to separate them, but the size segregation.

In World War II, the Brazilian Northeast region was a source of different strategic ores for the USA. There were manual mines (“garimpos”) for scheelite and columbite-tantalite. Scheelite is photoluminescent to ultraviolet light. Manual miners used special lamps and completed the separation at night. Columbite and tantalite build a complete continuous series from pure columbite to pure tantalite. Sales values change as a function of the predominant mineral. It is difficult to distinguish them, as they have the same density, color, hardness and brightness.

The always remembered late engineer Gildo Sá used to tell the story of a miner who was able to separate stones richer in tantalum or niobium according to the temperature sensation in his hand: one of the species had a greater specific heat and gave his hand a freezing sensation [1].

So, besides color and brightness, other properties have always been used to identify and sort mineral species. The present reflection tries to bring to our readers other properties recently introduced to sort minerals (and other materials) and to show how the introduction of analytical or physical methods, plus the use of sophisticated computational crafts, took a simple separation method and upgraded it to a high trustability level.

The objective of this reflection is to stress how the mineral industry had a dynamic answer to the challenges offered by increasingly poorer and more difficult ores, to the challenge of dry processing to avoid the use of tailing dams, as well as the incorporation of the most recent developments of instrumentation and artificial intelligence to the equipment.

3 Optical sorting

Figure 3 shows an optical sorter scheme.

Ore, carefully washed, is fed to a vibratory feeder (1) in a single layer over a belt conveyor (2). This conveyor has a known and carefully controlled speed. A light source (4) or a detector for brightness or shape (3) scans the layer over the conveyor, registers each particle’s properties and location and sends this information to a processor (5) which identifies each particle and its position on the belt and sends a command to the blower inside a valve bar (6). In this figure they are air blowers that, according to the received

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BDR



Urban garbage

Figure 1. Manual sorting (personal files).

instruction, allow the particle to follow its descending path and fall onto launder (7) or blow it to fall onto launder (8).

I do not want to detail instruments or color identification. Figure 4 shows one of the many used systems, RGB, the same one used in most of our cell phones. It uses three basic colors and combines them into seven different colors.

In a previous calibration step, different mineral (or chemical) composition particles are identified, and the processor is told about which flux (7) or (8) to send, according to the color proportion in each particle.

4 Other mineral properties used for sorting

Analytical technique development has been great in recent years. “Online” and “real time” analyses are today a successful reality. Many plant supervisory systems use them to correct, at each moment, a circuit, or even a complete plant operation. These same instrumental techniques are now used in the design of a new generation of sorters.

It is important to call the reader’s attention to the fact that the pure optical sorting demands careful washing and cleaning of the particle’s surface. For penetrating methods, like infrared rays or gamma rays, this is irrelevant.

Infrared rays heat each one of the particles. A temperature sensor, able to measure particle by particle temperature, will quantify the amount of the greater thermal capacity species in each one of the particles. One must remember that a previous calibration and identification class by class (similar to that described for color calibration) has been made.

Table 1, adapted from Valery [3], shows the properties used at the publication time, answering time, and other pertinent information.

In the next items, some applications of these modern sensors are presented. This way, sorting is, today, a sophisticated, safe and trustworthy separation method. It is performed dry. Its great limitation is processing capacity, but manufacturers are making efforts to overcome it by building greater units.



Figure 2. Crushed ROM manual sorting (personal files).

5 Industrial use of sorting

My interest in sorting started with waste and coal separation in an African mine. Mine design was very poor and the same equipment was specified both to remove overburden and to mine coal. The result was: as the waste volume is much greater, the big mining equipment did not have the necessary selectivity to dig coal, resulting in a waste contaminated with coal, and also in coal contaminated with waste. As the blocks are great and the flow rates great too, it was impossible to pre-concentrate coal and waste by conventional methods. Another preparation plant would be necessary! Hence the idea of using sorting. But fine coal dirties all particle surfaces and makes it impossible to distinguish, visually, a coal from a waste particle.

Tests on the coal stream to the plant after crushing showed the feasibility of using X-ray sorters but the enormous demanded capacity made its application unfeasible.

Figure 5 shows different color sorting application results.

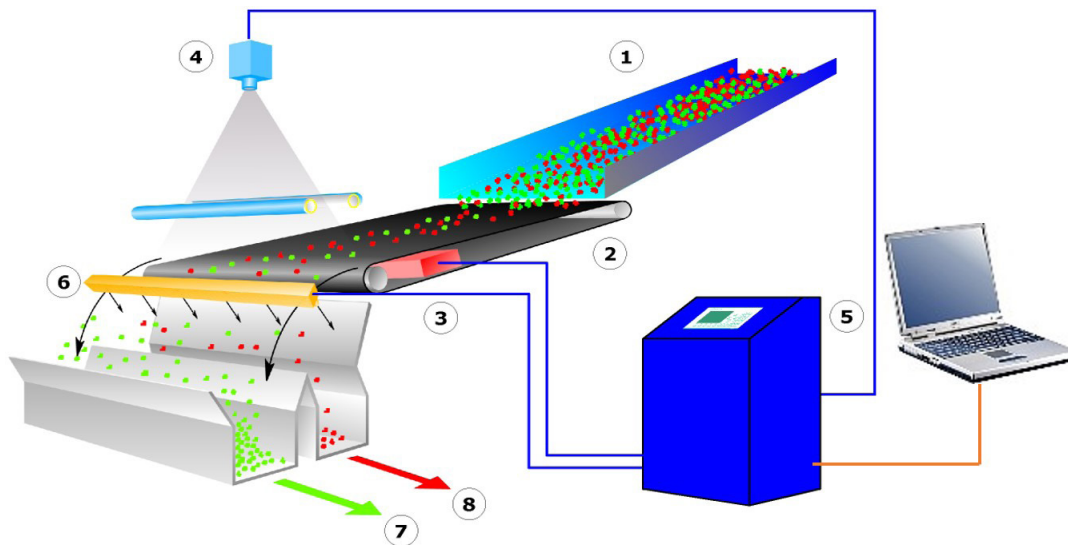


Figure 3. Optical sorter scheme [2].

Table 1. useful properties for sorting.

sensor type	used property	application	stage of evolution	answering time	penetration
light	reflexion, absorption, transmission	diamonds, industrial minerals, metallic minerals and gold	separation	real	surface
radiation	natural radiation	radioactive minerals	separation	real	internal
photometric	reflection, absorption (monochromatic)	industrial minerals and diamonds	separation	real	surface
X-ray fluorescence	secondary emission	diamonds	separation	real	surface
laser fluorescence	photon emission spectroscopy	many	separation	real	surface
Infrared rays	thermal capacity	basic metals and industrial minerals	recycling	real	surface
X-ray transmission	X-ray absorption (atomic number)	basic and precious metals, industrial minerals, fuels and diamonds	separation	real	partially penetrating
infrared spectroscopy	reflection, absorption	basic metals and industrial minerals	recycling	real	surface
PGNAA	activated gamma radiation	limestone, iron and basic metals	only measurement	minutes	penetrating
PFTNA	neutron activation analysis	basic metals, magnesium, silicon, carbon and water	only measurement	minutes	penetrating
LIBS	laser spectroscopy	many	many	real	surface
electromagnetic	conductibility and permeability	basic metals	separation	real	penetrating
magnetic resonance	radio frequencies detection	chalcopyrite	separation	seconds	penetrating
Foucault currents	induced magnetic field	metals recycling	separation	real	penetrating

PGNAA = pulsed gamma neutron activation analysis; PFTNA = pulsed fast thermal neutron analysis; LIBS = laser induced basic spectroscopy

Figure 6 shows nickel ore preconcentration using inductive sensor separator results.

In metals waste recycling modern sorting found a fertile field of use. Figure 7 shows metallic waste sorted via optical sorting and Figure 8 via inductive sensor.

In any civil work demolition product, there are many high strength coarse particles like gravel or structural concrete. They can be reused to replace natural gravel in new constructions. Also, there are both natural sand and that resulting from crushing. But there are also noxious materials

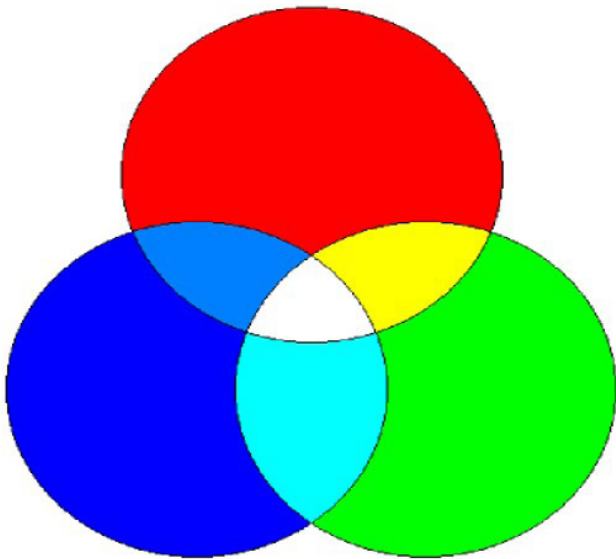


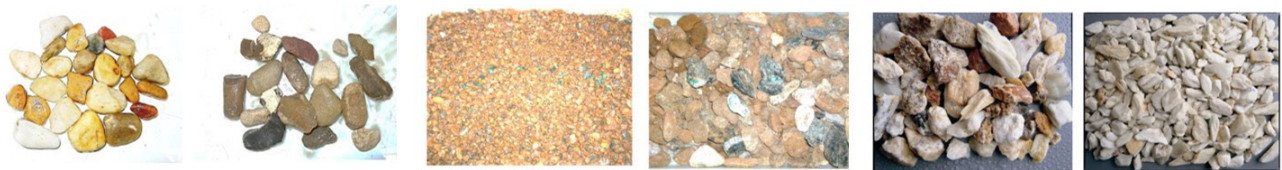
Figure 4. Color analysis – three basic colors and four combinations [2].

such as gypsum and asbestos. Conventional separation methods are jigging and tabling. But water consumption is great. So it is, this way, a fertile field for the use of sorting.

6 Sorting in Brazil

Figure 9 shows the distribution of one of the sorter manufacturers (Steinert) all over the world, by raw material, and the diversity of materials processed. This same company sold around 18 equipment units in Brazil.

An innovator case was Vazantes’ nickel mine one. Nexa bought a sorter, 40 t/hr capacity, working by transmittance. They started laboratory tests, followed by industrial tests processing 17,500 ROM tons in 2019 [4]. Today, an industrial installation has been erected. The ore sorter is 1 m wide and handles around 60 t/hr of feed. A second sorter will come into operation next year, 2 m wide, processing 120 t/hr[?].



Quartz (transparency)

Emeralds (color)

Quartz (color)

Figure 5. Purely optical separation [2].



Feed

Concentrate

Tails

Figure 6. Inductive sensor separation [2].



Feed

Copper and brass

Aluminum

Figure 7. Metals separation via optical sorting [2].



Figure 8. Metals separation via inductive sensing [2].

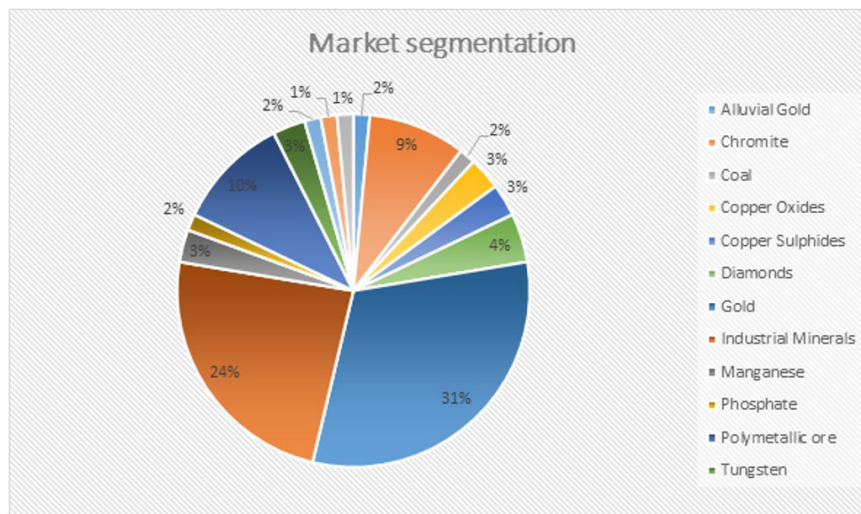


Figure 9. Raw ores sorted.

This preconcentration operation eliminated the circulating load in crushing. The concentration plant performance increased by around 89%. Waste rejected before coming into the plant was around 42% [4].

The success of such an operation decreased the demand for grinding. Using the same grinding circuit, the tailings of the Aroeira tailings dam started to be recycled, thus decreasing this environmental passive [5].

Also, 0,5 Mt of marginal ore (grade < 3,23% Zn) will be added to the reserves. It is estimated that ca. 40% of feed mass will be removed and that Zn recovery will be greater than 90%.

Ferbasa is an important ferrochrome producer. It used hand sorting to sort lump or, high chromite grade, from

disseminated ore that demands concentration. 6 ore sorters were installed processing 120 t/hr of -3+1" or 180 t/hr of -5+2" ore. Enrichment reached 30 times on the feed grade with recoveries over 90%.

7 Conclusion

Sorting separation evolved from the basic optical sorter and today makes use of many different chemical and physical properties of minerals. The introduction of different sensors associated with artificial intelligence techniques and electronic devices makes it a very trustable technology.

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