Adding Value by Dry Gravimetrical Sorting of Hematite Ore

By introducing dry gravimetrical sorting as an additional step in the process of ore sorting, it is possible to add value by

1. increasing the average recovery of iron and
2. reducing the amount of low-grade iron ore going into the wet process,

and by doing so, to either increase the total production capacity or reduce the amounts of the tailings. Based on 1 mio t run-of-mine ore per annum, the increased revenue after the implementation of the Allgaier dry gravimetrical sorting can be estimated at 15 mio €, the CAPEX for installing the plant at 5 mio €, and the OPEX cost for running the operation at 1.5 mio €.

Hematite

Hematite is the world's most important iron ore. Today almost all production comes from a few dozen large deposits where significant equipment investments allow companies to efficiently mine and process the ore. Most of the ore is being produced in China, Australia, Brazil, India, Russia, Ukraine, South Africa, Canada, Venezuela, and the United States.

Hematite is mined in some of the largest mines in the world. These mines require investments of billions of dollars, and some will treat over 100 mio t of ore per year. These open-pit mines can be hundreds to thousands of feet deep and several miles across by the time they have been worked to completion.

Crushing, Separation, and Concentration

The ROM ore is usually fed to a dry separation process and then forwarded into a wet process. In some plants the wet process starts right after the initial separation; this might give the desired quality for further processing but wastes a lot of valuable minerals in the rejects.

Mining companies very often have permission from the authorities to deposit specific amounts of solids in the tailings, which quite substantially restricts the total production capacity. In 2020, the United Nations set a new standard for the tailings (water lagoons) process: https://globaltailings-review.org/global-industry-standard/

To increase recovery and save on deposed solids, mining companies are interested in an improved separation of hematite, particularly in the particle sizes between 1 and 15 mm. Current dry separation processes typically raise the iron grade from 45 % in the ROM ore to 55 %, and the following wet stages increase it further up to 68 % in the final product. Higher grades in the feed to the wet stage, like 55 %, could provide a competitive advantage.

Issues

In connection with the initial dry separation, two areas of improvement can typically be identified:

1. Reducing the loss of valuable iron due to insufficient performance of the dry process.
2. Large amounts of low-grade iron ore in the wet process causing unnecessarily high water consumption. This will decrease the total production capacity while at the same time creating extensive additional amounts of sludge or fine solids for further disposal.

Objectives

Hematite (Fe_2O_3) is, in contrast to magnetite (Fe_3O_4), only weakly magnetic and may therefore be less amenable to magnetic separation. In this case, dry gravimetrical separation may be the best possible alternative, especially for particles sizes from 1 to 15 mm. It might also be better than optical sorting that does not work too well at the lower range of these sizes.

Based on extensive tests in pilot-scale, the following opportunity has been identified: Introducing gravimetrical separation as an additional step for particle sizes 1 to 15 mm at the end of the dry section in order to:

1. Increase the iron grade from 46 % to 58 % at a total recovery of 94 %, combining gravimetrical sorting machines working several particle size ranges in parallel with different set-ups (maximum recovery or maximum concentration) before moving further into the wet process
2. Reduce the amount of low-grade iron ore entering the wet process and thereby either increase production capacity or lower the deposit of solids. The total flow might be cut by 35 %, with a consequential iron loss of less than 5 %. The traditional water process generates environmental problems and risks, and it is also more costly.

Our tests, aiming for maximum recovery and maximum grade, have shown that it is possible to define a strategy for the treatment of this ore to reduce the total mass flow to approx. 65 %, while keeping about 95 % of the iron content for further processing.

Dry Gravimetrical Separation

Gravimetrical separation divides the feed into a high-density product (e.g. hematite) and a low-density product (e.g. the gangue minerals) by air fluidization. The feed segregates into a light and a heavy layer which are directed into their respective outlets by applying a combination of vibration and slope.

ALLGAIER GSort

The density separation process is based on a tilted, vibrating deck. An upward air stream passes through this deck, having two important effects on the materials being separated:

- Particles with a lower density will float downwards on a cushion of air, without any contact with the deck,
- Particles with a higher density will remain in periodic contact with the deck and are conveyed upwards by the vibration.

The Allgaier GSort (Figs. 1–4) has the possibility to adjust many running parameters individually, quickly, and easily, ensuring that the machine is always perfectly tuned for the materials

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Fig. 1 Allgaier GSort

Fig. 2 Trial Plant (GSort visible in the back)

being separated. This high precision is achieved by adjusting the following parameters:

- Flow and air speed distribution
- Overflow flap height
- Inclination of the table
- Vibration frequency

This flexible configuration ensures that a large range of materials can be processed.

For a specific product mix the production capacity depends on the difference in material density. The treatment of the exhaust air takes place via cyclones or bag filter systems, which separate air and dust. The cleaned air is extracted by a fan.

Added Value

The improved iron and mass balances in Table 01 can be achieved by using specific strategies for each size fraction, for example:

- For fraction 1–2 mm: two stages; in the first using the setup for maximum concentration and feeding its rejects (light fraction) to the second, aiming again for concentration
- For fraction 2–4 mm: only one stage for maximum concentration
- For fractions 4–7 mm and 7–15 mm: first stage for maximum recovery, followed by secondary crushing and screening stage (to achieve more liberation) and then fed to the 1–2 mm and 2–4 mm processes

Table 1 lists the examples of a possible overall iron- and mass-balance with an explanation which strategy was used during the trials, running either for maximum concentration (A) or maximum recovery (B). It should be noted that the contribution of sizes 4 to 15 mm to the „process outlet“

Tab. 1 Summary

100 t/h infeed flow

	Infeed		Process 1	Heavy outlet		Light outlet		Process 2	Heavy outlet		Light outlet		T/h outlet total	% recovery	T/h iron net
Fraction	t/h	t/h iron eq.		t/h	t/h iron eq.	t/h	t/h iron eq.		t/h	t/h iron eq.	t/h	t/h iron eq.			
1–2 mm	62.00	34.08	A	33.68	22.90	28.32	11.17	A	15.38	9.41	12.93	1.76	49.07	94.84 %	32.32
2–4 mm	13.00	5.43	A	6.94	4.36	6.06	1.07						6.94	80.31 %	4.36
4–7 mm	18.00	4.24	B	7.62	3.53	10.38	0.71	(*)+A	6.03	3.35	1.59	1.94	6.03	79.00 %	3.35
7–15 mm	7.00	2.30	B	3.85	2.10	3.15	0.21	(*)+A	3.04	2.07	0.80	1.29	3.04	89.90 %	2.07
Total	100.00	46.05											65.08	91.42 %	42.10

Process A: GSORT adjusted to obtain maximum concentration.

Process B: GSORT adjusted to obtain maximum recovery of iron, that means the reject will not have more than 5 % of iron

(*)+A: Crushing and process as 1–2 or 2–4 after screening looking for maximum concentration.

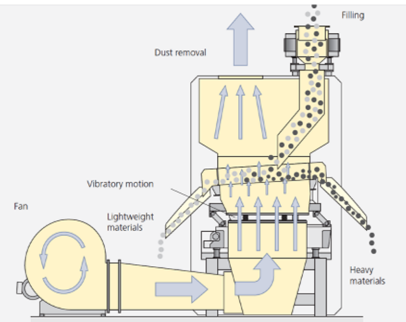

Fig. 3 Sketch of the entire machine

are given in their respective rows, although they joined the sizes 1 to 4 mm after secondary crushing.

Plant Equipment and its Costs

Fig. 5 shows the concept layout: a dedicated Allgaier GSort for each of several size fractions. Stockpile (A), dosing conveyor belt (B), coneyor belt (C), GOSAG distribution feeder (D), Mogensen sizer (E), Allgaier GSort for fine/medium/coarse fraction (F, G, H), rejects belt (I), rejects (J), extraction conveyor belts (K), coarse/medium/fine stock pile (L, M, N), extraction cyclones (or filters) (O), dust from cyclones or filters (P), extraction fans (Q).

A few assumptions are made in this calculation: The ROM ore moisture is low enough for screening at 1 mm (max. 1–2 % of moisture required). Otherwise a separate dryer for the fine fractions would be required. The average world market price for iron ore concentrate may change, for simplicity we considered a value of 100 $/t, e.g. China import Iron Ore Fines 62 % FE spot (CFR Tianjin port).

Increased revenues with gravimetrical sorting:

- In this special case, we increased the total net iron production in the wet processing plant from 46 t/h per 100 t/h feed to 65 t/h per 100 t/h, due to the reduction of the inert flow. (The basis was 46 % of iron without gravimetrical sorting vs 42 % of iron after gravimetrical sorting but with only 65 % of the flow!)
- For any other case, it remains to be decided whether a reduced amount of low-grade iron ore going into the wet process (and thereby increasing production capacity) or a lower amount of fine solids going for deposit is the more desirable solution.

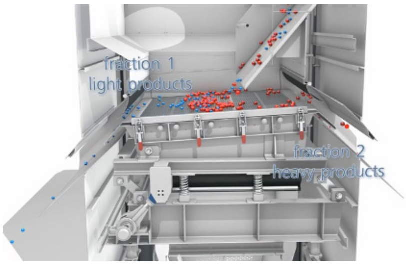

Fig. 4 Separation of light particles (blue) from heavy particles (red)

With a budgetary iron ore concentrate price of 100 $/t, this means that, for each hour of production, an added value of 1900 $/h is being generated – more than 15 mio $ per year.

Budgetary Capital Expenses (CAPEX) for

- Process equipment (eight Allgaier GSort, Mogensen sizer, distribution feeder, crusher, cyclones or bag filters, control panel, hoppers, conveyor belts; but excluding steel structure, civil works, etc.)
- Optional dryer for 65 t/h
- Project management, engineering and purchasing
- Transport
- Installation and commissioning

This investment amounts to around 5 mio € (based on 2021 prices and of course depending on more conditions). It includes the optional dryer for 65 t/h for fine fractions.

Budgetary Annual Operating Expenses (OPEX)

- Two operators per shift, 1.0 mio €
- Energy about 600 kW, 0.3 mio €
- Spare parts, 0.2 mio €
- Additional energy if a dryer were required

The yearly operating total budget costs are at around 1.5 mio €

Other non-monetary additional benefits considered are

- a higher recovery from excavated ore and
- less environmental impact from solids deposits
- and/or increased production capacity

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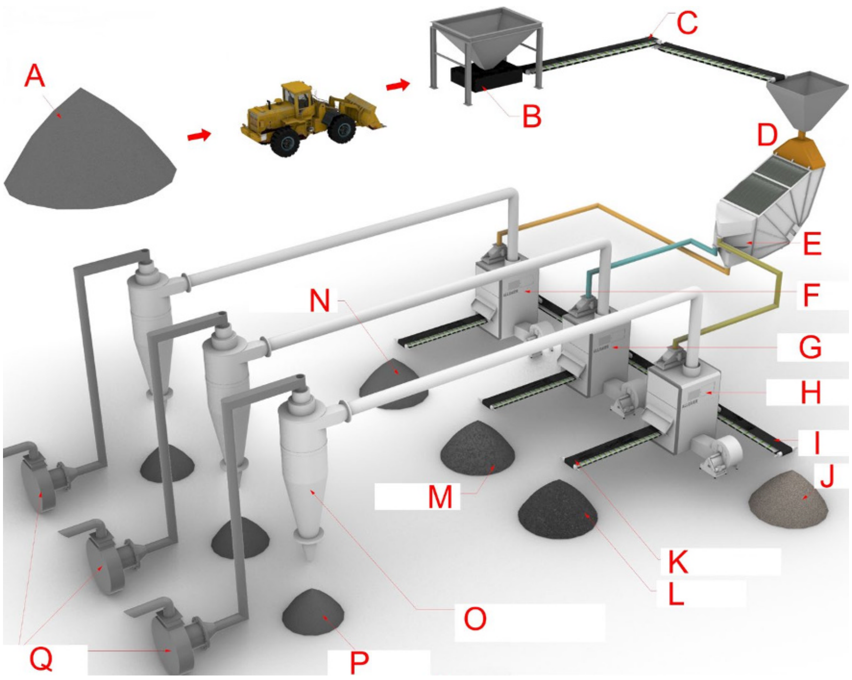

Fig. 5 Concept layout