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[54] **SEPARATION OF MAGNETIZABLE PARTICLES**

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[52] **U.S. Cl.** **241/24**

[51] **Int. Cl.** **B07b 4/00**

[58] **Field of Search** 241/19, 24, 30, 52, 241/54, 79, 79.1, 80

[56] **References Cited**

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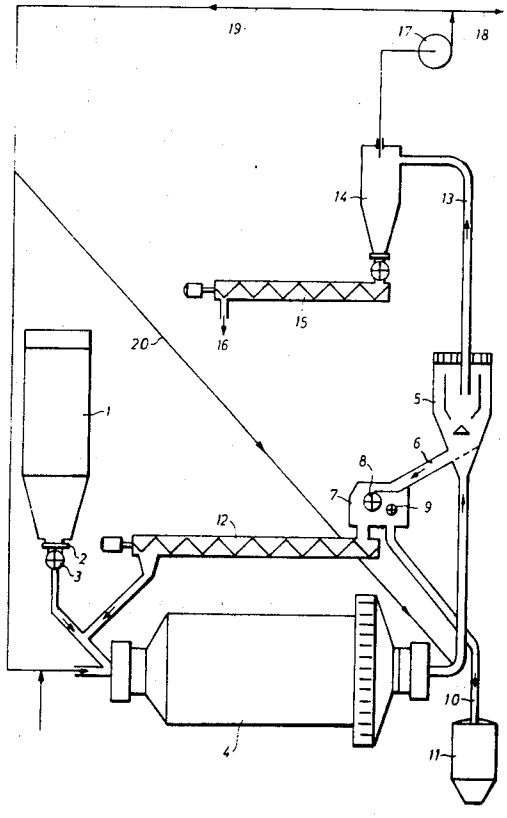
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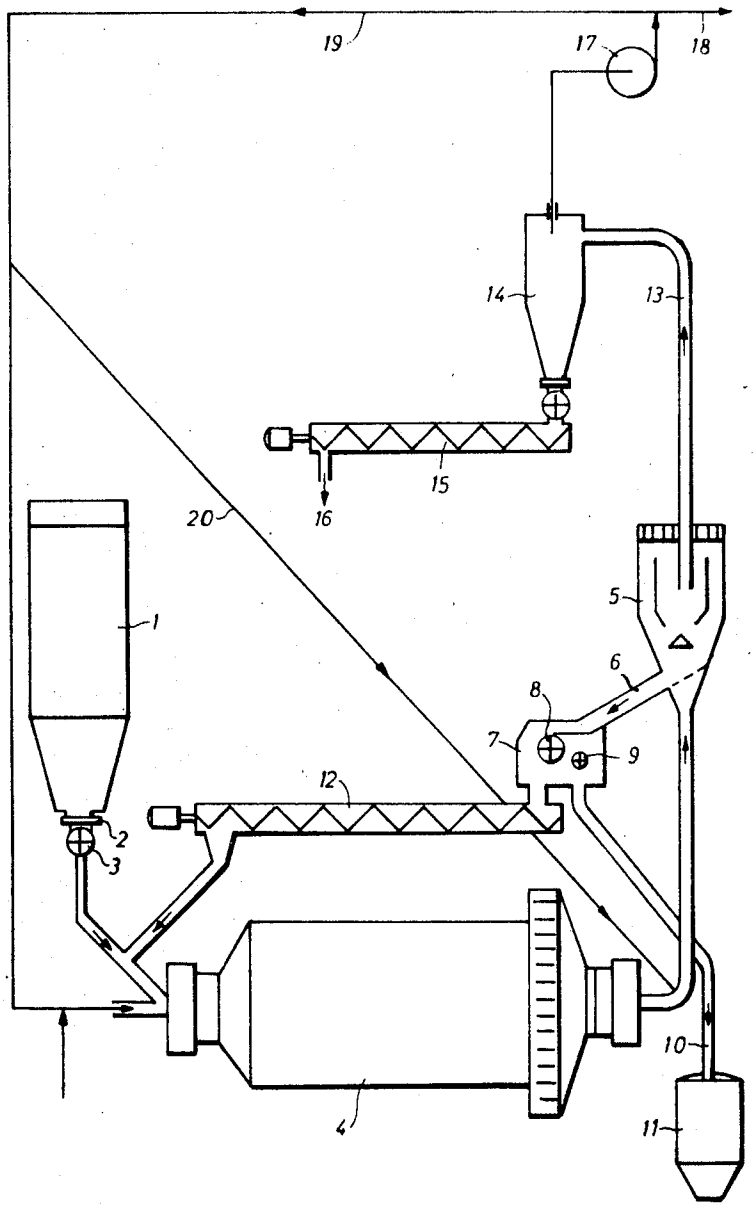
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[57] **ABSTRACT**

Apparatus and process for the removal of magnetizable particles during grinding of material containing such particles, e.g. grinding of iron-containing titanium ores or slag. The titanium ore, for example, is ground, ground material is pneumatically conveyed to a separator from whence the fines are withdrawn to be treated in conventional manner. The coarse material is subjected to magnetic attraction to remove magnetizable particles and the balance is recycled for further grinding.

5 Claims, 1 Drawing Figure





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SEPARATION OF MAGNETIZABLE PARTICLES

This invention relates to a process for the separation of magnetizable particles, i.e. particles which are attracted by a magnet, from crushed material during the grinding operation.

In the dressing of ores, the components to be recovered are separated from the unwanted components, e.g. from the rock material, during the dressing and enrichment stages from the unwanted components, for example from the rock material, by means of one or more separation processes. Since the ores to be processed in practice, for example iron ores, are, however, almost exclusively highly heterogeneous mixtures of different minerals, clean separation between the rock material and the pure ore is difficult and, for this reason, it is frequently necessary to use several separation processes in succession in order to obtain a useful result.

Accordingly, several techniques in which magnetic separators are used have already been proposed for dressing ores, above all ores of the kind containing iron oxides. The function of these magnetic separators is to separate magnetic components, for example metallic iron or magnetic or magnetizable oxides from the slag or the rock material. So far as the first of these cases is concerned, the following processes for example have been used: the Krupp-Eisenschamm process, the Krupp-Renn process, the SL-RN process and the Esso Fior process (cf. Gmelin-Durrer. Metallurgie des Eisens, 4th Edition, 1968, Vol. 2*a*, page 324 et seq and Vol. 2*B*, pages 137 et seq).

In these processes, the material which has generally been subjected to a reducing treatment is first sifted and then passed over magnetic separators to separate the metallic iron. In some cases, sifting is preceded by an initial size-reduction stage. Unfortunately, all these processes have the disadvantage that, due to the coarse particles still present, a relatively large proportion of magnetizable material remains entrained by the non-magnetizable material.

One exceptional method of dressing is used in the production of titanium slags (cf. Barksdale, Titanium, 2nd Edition, 1966 pp. 201–212). In this case, ilmenite is reduced with carbon to give, in addition to iron, a valuable titanium slag which is used in the production of titanium dioxide pigments. The iron normally accumulates in the form of a melt which can be run off. Relatively coarse, exposed iron particles left behind in the size-reduced slag are removed by magnetic separators. However, the smaller iron particles which are still enveloped in the titanium slag are not entrained in this way and are left behind in the slag. They make up approximately 1 percent by weight of the slag. However, this proportion of metallic iron can promote unwanted reactions during subsequent further processing of the titanium slag.

It is accordingly an object of the invention to provide a process and apparatus for removing magnetizable material from material in which it is embedded.

It is a further object of the invention to provide a process and apparatus for removing iron from coarse-grained titanium materials containing iron.

These and other objects and advantages are realized in accordance with the present invention which provides an apparatus and process by which it is possible to separate magnetizable particles from a material in the course of size-reduction during the grinding operation and in which, after grinding the material is separated into fine material and gravel by centrifugal air separation, and the following separation of the magnetizable particles by a magnetic separator, the gravel-like material is returned to the grinding operation.

The process according to the invention can be used with advantage during the dressing of materials which on the one hand contain magnetic or magnetizable components and which on the other hand have to be subjected to a size-reduction operation for dressing. For example, mixed ores containing magnetic or magnetizable constituents can be separated and dressed by this process. The process according to the invention is also suitable for enriching titanium-containing materials such as for example rutile or ilmenite. Thus, the process can be used for example to separate two minerals occurring naturally alongside one another, as is the case for example with the non-magnetic rutile and the weaky magnetic ilmenite. It is possible in this way to remove the last traces of metallic iron from titanium slags of the kind obtained by reducing ilmenite with carbon.

In principle, only a size-reducing machine, a machine for separating coarse and fine material and a magnetic separator are required for carrying out the process.

Size-reduction of the material is generally carried out in grinding machines, for example hammer mills, centrifugal mills, pounding mills, disc attrition mills, pendulum mills, ball mills, tube mills, wet mills, percussion mills or vibration mills.

Tubular mills or ball mills are particularly suitable. The grain size of the material discharged from the mill in the process according to the invention should best be between about 5 microns and 400 microns.

Separation into fine material and gravel can be carried out for example in sifting machines or separators. Separators such as for example centrifugal separators, centrifugal air separators or reversing separators, are particularly suitable. The size-reduced material can actually be pre-separatred in the mill itself by means of a stream of air circulating inside it. Depending upon the intensity of the air stream flowing through the mill, a material of suitable grain size distribution is discharged from the mill. This material passes with the carrier air into a separator in which it is separated into fine material and gravel. By suitably establishing the conditions for the centrifugal or flow separator to be used, for example, it is possible accurately to adjust the grain-size limit between fine material and gravel for the particular grain sizes requires. At the same time, a high degree of sharpness in separation is obtained. Depending upon the setting of the separator, the grain size of the fine material is between about 5 and 120 microns and the grain size of the gravel is accordingly between about 30 and 400 microns, the fine material and gravel being separated with sufficient definition at a corresponding grain size which is between about 30 and 120 microns.

In addition to the coarse-grained particles, the particles of higher specific gravities are also enriched to a considerable extent in the gravel. Due to their inferior grinding properties and their greater density, the ore components are predominant in the gravel in the working up of minerals, whereas the iron is predominant in the gravel in the working up of reduced materials. The components enriched in this way in the gravel are then separated by means of magnetic separators. Separation into fine material and gravel can be carried out either

continuously or in stages. The materials to be dressed may be wet can actually be dried in the same installation by heating the air stream with a hot gas introduced into it, as is done in conventional combined grinding and drying machines. This makes magnetic separation much easier, above all in cases where strong magnetic fields are used.

Both weak magnetic field separators and also strong magnetic field separators can be used as the magnetic separators. The weak-field magnetic separators have the best separating effect, their superiority increasing with decreasing grain size.

A preferred embodiment of the process according to the invention is described in the accompanying drawing which is a schematic flow sheet of a process for the dressing of titanium slag.

In the FIGURE, the reference **1** denotes a feed hopper, the reference **2** a rotary-table feeder, the reference **3** a ball valve, the reference **4** a tubular mill, the reference **5** a separator, the reference **6** a gravel return to a magnetic separator **7**, the reference **8** the surface of a drum, the reference **9** a brush roller, the reference **10** a pipe to a supply container **11**, the reference **12** a return screw for the gravel, the reference **13** a feed pipe, the reference **14** a cyclone separator, the reference **15** a conveyor screw and the reference **16** a supply to a container for fine material; **17** is a fan, **18** a dust filter and **19** and **20** are feed pipes.

From the supply hopper **1**, the crude material runs continuously through the rotary-table feeder **2** and the ball valve **3** into the tubular mill **4** which is partly filled with steel balls of different diameter. The crude material is then ground by rotation of the mill. By means of a vigorous air stream which is passed through the mill, material which has already been size-reduced therein is pre-separated and delivered pneumatically to the separator **5**. The coarser-grained and specifically heavier material is separated in the form of gravel in known manner in the separator **5**. Through the exact setting of the fittings in the separator and by carefully maintaining the rates of air flow, the grain size limit at which separation between fine material and gravel is to take place is determined with precision. The gravel passes as return feed **6** to the magnetic separator **7** where the material to be separated is scattered on to the magnetically induced and rotating drum surface **8**. Whereas the material which is not to be magnetized is immediately repelled by the rotating drum and then carried back into the mill by the gravel return screw **12**, the magnetizable material temporarily adheres to the drum and is removed from the drum at the opposite side by a brush roller **9**. The magnetizable constituents obtained are continuously delivered through the feed pipe **10** to a container **11**.

The fine material **13** separated in the separator (the oxidic constituents in the reduction of ore, the rock material in the dressing of ore) is separated from the carrier air in a cyclone separator **14** and introduced by the conveyor screw **15** into the fine material supply line **16** for transport to a container (not shown). The carrier air is drawn away by the mill fan **17**, some of it being returned to the mill system. The rest of the air passes through the dust filter **18** into the atmosphere. Some of the recycle air **19** can be branched off before the mill, being recombined with the product stream as a by-pass **20** at the end of the mill. This assists pneumatic delivery of the material discharged in known manner and provides for the necessary wind velocity in the separator. The quantity of gravel accumulating in the separator can be predetermined by suitably distributing the quantities of air passing through the mill and through the by-pass. By virtue of this measure, coupled with the setting of the separator, it is possible to determine the continuously accumulating quantity of gravel which passes over the magnetic separator so that the efficiency with which the magnetizable components are separated is also governed thereby.

The process according to the invention is illustrated in the following Examples:

EXAMPLE 1

Most of the metallic iron present in a titanium slag containing up to 1 percent of metallic Fe was removed in order to avoid difficulties during further processing.

a. Removal from the unground titanium slag by means of a drum-magnet separator (drum rotating at 150 r.p.m.)

	Ti slag used non-ground	Non-magnetic fraction	Magnetic fraction
Weight [kg]	30.000	29.875	0.125
% by weight	100.0	99.6	0.4
Grain distribution			
>300μ	68.3%	67.8%	82.1%
300–200μ	7.8%	8.7%	5.0%
200–150μ	5.7%	6.0%	3.0%
150–100μ	6.2%	6.3%	2.9%
100–60μ	4.6%	4.7%	2.1%
60–40μ	2.8%	2.2%	1.4%
40μ	4.6%	4.7%	3.5%
Analysis			
% TiO_2	70.4	70.6	21.6
% Fe metal	0.81	0.6	51.7
Weight Fe metal	0.243 kg	0.178 kg	0.065 kg
% output of Fe metal			27%

b. Removal from the gravel return of the grinding machine by means of a drum-magnet separator (drum rotating at 176 r.p.m.)

	Gravel return used	Non-magnetic fraction	Magnetic fraction
Weight [kg]	25.660	27.735	0.925
% by weight	100.0	96.4	3.6
Grain distribution			
>150μ	18.2%	16.7%	31.4%
150–100μ	19.7%	20.6%	10.2%
100–60μ	33.8%	35.4%	20.3%
60–40μ	13.1%	14.5%	13.3%
>40μ	15.2%	12.8%	24.8%
Analysis			
% TiO_2	70.1	71.0	4.5
% Fe metal	3.48	0.23	90.60
Weight of Fe metal	0.894 kg	0.057 kg	0.837kg
% output of Fe metal			93.7%

c. Removal from the fine material by means of a magnetic separator

	Fine material used	Non-magnetic fraction	magnetic fraction
Weight [kg]	5.534	5.490	0.044
% by weight	100.0	99.2	0.8
Grain distribution			
> 40μ	16.3%	16.1%	15.4%
< 40μ	83.7%	83.9%	84.6%
Analysis			
% TiO_2	70.6	70.9	39.2
% Fe metal	0.67	0.34	41.3
Weight of Fe metal	0.037 kg	0.019 kg	0.018 kg
% output of Fe metal			49%

EXAMPLE 2

The effectiveness of magnetic separation following enrichment of the Fe metal in the gravel return of the

grinding machine by adjusting the separator accordingly is demonstrated in the following Examples. A titanium slag containing 0.7 percent of Fe metal was ground in a continuously fed industrial grinding and drying machine. Drum-magnet separators were used for magnetic separation. In each case, the drums rotated at 180 r.p.m.

	a	b
Ratio by weight of gravel return to fine material	2.2-fold	0.15-fold
Fe metal in the unground titanium slag	0.7%	0.7%
Fe metal in the gravel return	3.4%	4.8%
Enrichment of the Fe metal content in the gravel return	4.9-fold	6.9-fold
Fe metal in the magnetic fraction	58.8%	76.4%
Enrichment of the Fe metal content in the magnetic fraction as against the starting slag	84-fold	107-fold
Fe metal in the fine material	0.20%	0.18%
% output of Fe metal	72%	75%

EXAMPLE 3

After suitable pre-separation, a mixture prepared from ilmenite ore and rutile sand (grain sizes between 60 and 200μ) was divided into two fractions by a single magnetic separation:

	Ilmenite ore	Rutile sand
Loose weight	2.61 g/cc.	2.48 g/cc.
Mixture: 100 parts by weight of starting mixture made up of	65 parts	35 parts
Magnetic separation: (a) 72 parts by weight of magnetic fraction made up of	64 parts by weight = 89%	8 parts by weight = 11%
(b) 28 parts by weight of non-magnetic fraction made up of	1 part by weight = 4%	27 parts by weight = 96%

The results of chemical analysis in each case were as follows:

	Ilmenite	Rutile	Mixture	Magn. fraction	Non-magn.
		oresand	65 Ilm: 35 Ru.	89% ilmenite ore	fraction 96% Ru-sand
% by weight of TiO_2	50.39	6.1	66.8	55.2	93.2
% by weight of total Fe (present in the form of iron oxides)	35.70	28	23.4	31.9	1.8

It will be appreciated that the instant specification and examples are set forth by way of illustration and not limitation and that various modifications and changes may be made without departing from the spirit and scope of the present invention.

What is claimed is:

1. In the process of grinding of a material, high in titanium dioxide and low in iron, containing magnetizable particles to effect size reduction, the improvement which comprises pneumatically separating from the ground product a fraction of particles from between 5 to 400 μ, separating this fraction by centrifugal air separation into titanium dioxide enriched particles of between 5 and 120 μ and iron enriched coarse particles of between 30 and 400 μ, collecting the titanium dioxide enriched fines, subjecting the iron enriched coarse material to magnetic forces to separate the magnetizable particles from the balance of the coarse material, and returning such balance for further grinding.

2. Process according to claim **1,** wherein the initial material is wet and pneumatic separation is effected with warm air, whereby the fines are dried prior to collection.

3. Process according to caim **1,** wherein the starting material comprises an iron-containing titanium material.

4. Process according to claim **3,** wherein said titanium material comprises a titanium ore.

5. Process according to claim **3,** wherein said titanium material comprises a slag from the reduction of titanium ore.

* * * * *

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UNITED STATES PATENT OFFICE F. 1908

CERTIFICATE OF CORRECTION

Patent No. 3,754,713 Dated August 28, 1973

Inventor(s) Gerhard Kienast et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 5, lines 40 and 41, cancel in their entirety.

Col. 6, rewrite table at top of page to read as follows:

	Ilmenite ore	Rutile sand	Mixture 65 Ilm: 35 Ru.	Magn. fraction, 89% ilmenite ore	Non-magn fraction, 96% Ru-sand
% by weight of TiO_2	50.3	96.1	66.8	55.2	93.2
% by weight of total Fe (present in the form of iron oxides)	35.7	0.28	23.4	31.9	1.8

Signed and sealed this 17th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents