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HIGH GRADIENT MAGNETIC SEPARATION OF DUST OUTLETS COMING FROM ROTARY FURNACES OF THE IRON ORE WORKS SIDERIT, Ltd. NIŽNÁ SLANÁ

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Abstract

The contribution describes the results of high-gradient magnetic separation of dust outlets from rotary furnaces collected in electrofilter. The separation was performed by the both ways, the dry and wet ones at a magnetic field induction in the range from 0,09 to 0,30 T. As to main components, the dust outlets contain 26–28 % of Fe, 16–18 % of SiO_2 and 1,50–1,65 % of Mn.

Under application of dry way growing induction of field results in an increasing of mass yield into magnetic product from 35 % to 66 %, iron and manganese contents gradually decrease from 35 % to 31 % and from 1,92 % to 1,72 %, respectively. The content of SiO_2 enhances from 11 % to 12 %. The recoveries of main components into magnetic product grow together with increasing of magnetic field induction, namely for iron from 44,75 % to 76,13 %, for manganese from 44,36 % to 75,36 % and for SiO_2 from 22,42 % to 46,54 %.

Similarly, as to wet way of separation, growing induction of magnetic field also results in enhancement of magnetic products mass yields, i.e. from 31,86 % to 37,03 %. Iron and manganese contents in magnetic product decrease from 45,71 % to 44,21 % and from 2,74 % to 2,71 %, respectively. The SiO_2 content increases from 1,20 % to 2,55 %. The recoveries of iron and manganese enhance together with a growing of magnetic field induction from 52,35 % to 59,54 % and from 54,03 % to 61,68 %, respectively, but recovery of SiO_2 only from 2,24 % to 5,26 %.

Thus, under application of dry way of separation the higher recoveries of utility components, namely iron and manganese, into magnetic product can be achieved. On the other hand, wet way of separation enables to attain at lower recoveries of utility components cleaner magnetic product, i.e. higher contents of iron (by 10 %) and manganese and also by 10 % lower content of SiO_2.

Key words: *HGMS, iron ore, dust, rotary furnaces, magnetic separation.*

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1. Introduction

The iron ore works Siderite, Ltd. Nižná Slaná is only one producer of iron ore in Slovakia. The mining field of the company is located in the southeast part of the Slovak Ore Mts. and it consists of two near one another placed deposits (their distance is about 2.500 m), namely Manó and Kobeliarovo.

The ore from the first of one contains in the average 33,5 % of Fe, 2,18 % of Mn, 8,5 % of SiO_2, 0,001–0.2 % of As, 0,001–0,03 of Pb, 0,002–0,009 % of Zn and 0,5–1.5 of S. The average quality of ore from the Kobeliarovo deposit is as follows: 33,98 % of Fe, 1,71 % of Mn, 3,71 of SiO_2 and 0,02 % of As [1]. The ores from the both deposit are characterized by fine intergrowth of utility minerals and gangue.

The company exploits siderite ore by underground method, namely sublevel caving. The run-off-mine ore is subjected to crushing and classifying. The coarser classes are pre-treated using a dry high intensity magnetic separation. Only class with a grain size of 0–4 mm is led through bypass and directly added to magnetic product obtained by separation of coarser classes. In such way obtained material is roasted in rotary furnaces with the aim to improve the magnetic properties of main utility Fe-bearing mineral, i.e. siderite. Thus, during magnetizing roasting, siderite is changed into magnetite and/or maghemite with much higher magnetic susceptibility. After cooling the roasted ore is wet ground to a grain size 90 % bellow 63 μm and subjected to wet low intensity magnetic separation. Magnetic product is filtered and led to pelletizing plant. Final product – blast furnace pellets usually contain 55,4 % of Fe, 3,4 % of Mn and 5 % of SiO_2 [2].

Currently, an annual production of ore is running about 720.000 tons. Subsequently, 320.000 tons of blast furnace pellets are made from the ore [3]. Maximal annual production, i.e. 1.010.365 tons of ore and 447.810 tons of pellets, was attained in 2000 [4].

Recently, the Institute of Geotechnics SAS Kosice cooperates with iron ore works Siderit, Ltd. Nižná Slaná in the research, which is focused on the application of magnetic separation in processing of dust outlets from rotary furnaces collected in electrofilter with the aim to improve of final products quality and raw material management of the works. Coming from data introduced in contribution [5], total amount of collected dust is about of 44.000 ton per year.

One of the first reports [6] about magnetic separation of dust outlets from rotary furnaces studied an influence of magnetic separator drum revolution on products quality. The applied dry low intensity magnetic separator of own design was under cover of drum equipped by permanent magnets. The magnets were located in order to achieve alternating magnetic polarity of magnetic field. Moreover, drum and rotor had contrary rotation. All these structural designs were proposed with the aim to prevent mutual aggregation of magnetic and non-magnetic particles. Thus, from the feed of dust outlet with 35–38 % of Fe and 13–16 % of SiO_2 a magnetic product with 41–46 % Fe and 8–12 % SiO_2 at a mass yield of 59–67 % was won. Recovery of Fe and SiO_2 into magnetic product attained 72–78 % of Fe and 36–53 % SiO_2, respectively.

Current research deals with the application of dry and wet ways of high gradient magnetic separation. In comparison with previous reference the feed of dust outlet had lower quality, i.e. 26–28 % of Fe and 16–18 % SiO_2.

2. Magnetic separator and assessment methods description

Magnetic separation has been carried out using universal laboratory magnetic separator the JONES model (Fig. 1), in cassette located between its poles. The cassette was lined by two grooved plates made of soft iron. In such way required induction and gradient of magnetic field were achieved (Fig. 2 and 3).

The dry way of separation was realised at four values of magnetic induction, namely 0,09, 0,15, 0.20 and 0,30 Tesla. The wet one was carried out at three values, i.e. 0,1, 0,2 and 0,3 Tesla.

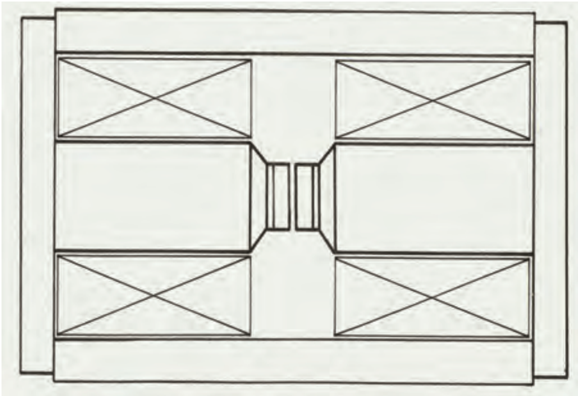

Fig. 1. Design of universal laboratory magnetic separator of JONES model

Fig. 2. Cassette

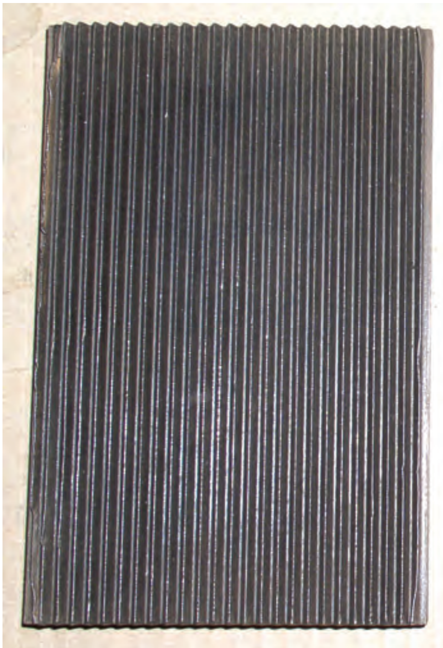

Fig. 3. Grooved plate made of soft iron

After determination of mass yields the products of magnetic separation were subjected to chemical analyses and volume magnetic susceptibility measure-ing. Loss on ignition at 900 ºC and content of SiO_2 were determined by gravimetric analysis. The other chemical components were assayed by atomic absorption spectroscopy (AAS) using the device VARIAN AA240FS with accessories: Zeeman AAS240Z with Programmable Sample Dispenser PSD120, Graphite Tube Atomizer GTA120 and Vapor Generation Accessory VGA-77.

The volume magnetic susceptibility was measured using the Kappabridge KLY-2, Geofyzika Brno at following conditions: the magnetic field intensity of 300 $A.m^{-1}$, the field homogeneity of 0,2 %, the operating frequency of 920 Hz, the range of $-1.999\ 10^{-6} \div +650.000 10^{-6}$ SI unit [7].

The assessment of separation product was performed using classical material balance method according to general balance equations [8, 9].

3. Results of magnetic separation

The quality of magnetic separation products obtained by dry way is presented in Tables 1-4. Calculated recoveries/ distribution of chemical components into products of dry magnetic separation are in Tables 5-8. Similarly, the quality of magnetic separation products obtained by wet way is introduced in Tables 9-11. The recoveries/distribution of chemical com-ponents into products of wet magnetic separation is in Tables 12-14.

The quality of feed was calculated on the basis of analysed separation products using the method of material balance. Iron content is presented as total iron content.

Table legend: M – magnetic product, N – non-magnetic product, LOI – lost on ignition, κ – volume magnetic susceptibility [10^{-6} SI unit]

Table 1. Products quality of dry magnetic separation at the induction of 0,09 T

product	yield [%]	κ	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	35,23	285.525	34,92	11,13	1,92	7,61	0,264	3,50	3,08	1,45
N	64,77	61.167	23,45	20,95	1,31	17,33	0,210	4,12	2,36	1,78
feed	100,00	140.202	27,49	17,49	1,52	13,91	0,229	3,90	2,61	1,66

Table 2. Products quality of dry magnetic separation at the induction of 0,15 T

product	yield [%]	κ	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	50,43	254.962	33,31	11,54	1,87	8,83	0,289	3,73	2,87	1,50
N	49,57	35.853	22,00	23,34	1,23	18,41	0,201	4,34	2,24	1,76
feed	100,00	146.350	27,70	17,39	1,55	13,59	0,245	4,03	2,56	1,63

Table 3. Products quality of dry magnetic separation at the induction of 0,20 T

product	yield [%]	K	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	55,35	239.363	31,14	12,39	1,81	9,42	0,280	3,67	2,86	1,50
N	44,65	21.488	20,14	23,72	1,17	18,59	0,206	4,40	2,15	1,77
feed	100,00	142.072	26,23	17,45	1,52	13,51	0,247	4,00	2,54	1,62

Table 4. Products quality of dry magnetic separation at the induction of 0,30 T

product	yield [%]	κ	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	65,67	212.518	30,79	11,89	1,72	11,06	0,245	3,73	2,66	1,59
N	34,33	11.984	18,47	26,13	1,07	18,28	0,193	4,55	2,07	1,90
feed	100,00	143.674	26,56	16,78	1,50	13,54	0,227	4,01	2,46	1,70

Table 5. Recoveries of components into products of dry magnetic separation at the induction of 0,09 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	44,75	22,42	44,36	19,28	40,61	31,60	41,51	30,70
N	55,25	77,58	55,64	80,72	59,39	68,40	58,49	69,30
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 6. Recoveries of components into products of dry magnetic separation at the induction of 0,15 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	60,64	33,47	60,73	32,79	59,40	46,65	56,59	46,44
N	39,36	66,53	39,27	67,21	40,60	53,35	43,41	53,56
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 7. Recoveries of components into products of dry magnetic separation at the induction of 0,20 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	65,71	39,30	65,72	38,58	62,75	50,83	62,25	51,23
N	34,29	60,70	34,28	61,42	37,25	49,17	37,75	48,77
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 8. Recoveries of components into products of dry magnetic separation at the induction of 0,30 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	76,13	46,54	75,46	53,65	70,83	61,06	71,08	61,55
N	23,87	53,46	24,54	46,35	29,17	38,94	28,92	38,45
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 9. Products quality of wet magnetic separation at the induction of 0,1 T

product	yield [%]	κ	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	31,86	355.536	45,71	1,20	2,74	3,44	0,308	2,02	3,61	1,34
N	68,14	10.876	19,45	24,50	1,09	18,29	0,255	5,78	1,92	2,19
feed	100,00	120.679	27,82	17,08	1,62	13,56	0,272	4,58	2,46	1,92

Table 10. Products quality of wet magnetic separation at the induction of 0,2 T

product	yield [%]	κ	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	33,86	339.576	45,19	2,15	2,73	4,02	0,295	2,13	3,36	1,64
N	66,14	4.541	18,36	25,55	1,00	18,35	0,260	5,69	1,79	2,11
feed	100,00	117.969	27,44	17,63	1,59	13,50	0,272	4,48	2,32	1,95

Table 11. Products quality of wet magnetic separation at the induction of 0,3 T

product	yield [%]	κ	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	37,03	313.030	44,21	2,55	2,71	6,29	0,285	2,04	3,28	1,63
N	62,97	3.536	17,67	26,99	0,99	17,88	0,264	6,08	1,79	2,23
feed	100,00	118.144	27,50	17,94	1,63	13,59	0,272	4,58	2,34	2,01

Table 12. Recoveries of components into products of wet magnetic separation at the induction of 0,1 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	52,35	2,24	54,03	8,08	36,09	14,04	46,78	22,24
N	47,65	97,76	45,97	91,92	63,91	85,96	53,22	77,76
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 13. Recoveries of components into products of wet magnetic separation at the induction of 0,2 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	55,75	4,13	58,29	10,08	36,74	16,08	49,00	28,46
N	44,25	95,87	41,71	89,92	63,26	83,92	51,00	71,54
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Table 14. Recoveries of components into products of wet magnetic separation at the induction of 0,3 T

product	Fe [%]	SiO_2 [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]
M	59,54	5,26	61,68	17,14	38,83	16,48	51,87	30,06
N	40.,46	94,74	38,32	82,86	61,17	83,52	48,13	69,94
feed	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

4. Discussion and conclusion

From results in above presented tables, it is possible to deduce, that successive increasing of magnetic field induction in separating zone showed the following dependences with regard to Fe concentrate:

- increase of mass yield into magnetic product,
- decrease of volume magnetic susceptibility of magnetic product,
- reduction of iron, manganese and magnesium content in magnetic product,
- rise of SiO_2 content and LOI in magnetic product,
- increase of recoveries of all observed chemical components into magnetic product.

Thus, the cleanest magnetic product, i.e. with the highest content of Fe and Mn, and the lowest content of SiO_2 was won at the lowest value of magnetic field induction. In successive steps increasing of induction and thereby mass yield resulted in gradual contamination of Fe-concentrate by ballast components, represented by SiO_2 and Al, naturally, firstly by these, which are intergrown with utility components. Vein quartz, various shales, lydite and other accompanying rocks occurring in the deposit can be considered as the carriers of gangue components. Similarly, the mass yield increasing resulted in the enhancing of utility components recovery, but at the expense of Fe-concentrate quality.

As to obtained Fe-concentrates and their parameters, a large amount of tabular data can be recapitulated as follows:

1) dry way of magnetic separation:

- mass yield of Fe- concentrate 35,23 – 65,67 %,
- Fe content 34,92 – 30,79 %,
- Mn content 1,92 – 1,72 %,
- SiO_2 content 11,13 – 12,39 %,
- Fe recovery 44,75 – 76,13 %,
- Mn recovery 44,34 – 75,46 %,
- SiO_2 recovery 22,42 – 46,54 %.

2) wet way of magnetic separation:

- mass yield of Fe- concentrate 31,86 – 37,03 %,
- Fe content 45,71 – 44,21 %,
- Mn content 2,74 – 2,71 %,
- SiO_2 content 1,20 – 2,55 %,
- Fe recovery 52,35 – 59,54 %,
- Mn recovery 54,03 – 61,68 %,
- SiO_2 recovery 2,24 – 5,26 %.

Finally, it can be stated, that dry way of separation resulted in higher recoveries of utility components, i.e. Fe and Mn into Fe-concentrates. On other hand the cleaner Fe-concentrates, Fe content higher by 10 %, Mn content higher by 1 % and SiO_2 content lower by 10 %, were won using wet way of separation.

It was also proven that recoveries of iron and manganese into magnetic products achieve almost the identical values at the same condition of separation and that is feature at magnetic separation of raw and/or roasted ore from Nižná Slaná deposit. This fact indicates isomorphous replacement of iron and manganese in utility minerals lattices, namely siderite and ankerite, in given mining field.

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6. References

1. Boláček O., Mihók J., Iron Ore Works, Nižná Slaná, 1994. In: P. Grecula et al.: Mineral deposits of the Slovak Ore Mountains, Vol. 1., the 1st edition, Geocomplex, Bratislava, (1995), 834.

2. Hredzák S., Lovás M., Jakabský Š., Gešperová D., Balog M., Distribution of heavy metals in the products of magnetic separation of siderite ore from Nižná Slaná. In: Chemické Listy – Chemical Papers, Vol. 102, (2008), 830–833.

3. Investment project: Innovation of technological process of the Siderit, Ltd. Nižná Slaná and development of reserves of the Nižná Slaná – Manó – Kobeliarovo deposit, Attachment 3 (in Slovak).

4. Lukáč S. Raw material base and state of mine and processing equipment in works Siderit Nižná Slaná. In: Acta Montanistica Slovaca Vol. 7, (2002), No. 4, 227-230 (in Slovak).

5. Bernáth J., Reduction of energy consumption at roasting of siderite ore in rotary furnaces. In: Proc. of the 4th scientific technical conference „Mining, mineral processing and environment in the region Upper Gemer“, Slovak Mining Society at the Siderit, Ltd. Nižná Slaná, Nižná Slaná 2008, pp. 47–60 (in Slovak).

6. Zaťko S., Jakabský Š., Bakoš J., Rusnák J., Research on possibilities of utilisation of dust collected in electrofilter in mineral processing plant Nizna Slana. Running informative report to department task No. RC 1-06-0250 "Optimisation of running-in operation of mineral processing plant in Nižná Slaná", Mining Institute of the SAS, Košice, (1979), 29 pages (in Slovak).

7. Kappabridge KLY-2. Instruction manual for magnetic susceptibility bridge, Geofyzika Brno.

8. Špaldon F., Mineral Processing. ALFA/SNTL, Bratislava/Prague, (1986), 484 pages (in Slovak).

9. Lukáč J., Physical methods of separation, BF TU Košice, 1993, 215 pages (in Slovak).