

Mineral characteristics of dust outlets from rotary furnaces of iron ore works Siderite, Ltd., Nižná Slaná

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Abstract

The paper deals with the mineral and chemical composition of the dust outlets from the rotary furnaces of the iron ore works Siderite, Ltd., Nižná Slaná. The products of dry and wet high gradient magnetic separation were studied with the aim to determine the distribution of mineral phases and chemical components using XRD, AAS and Mössbauer spectroscopy. Maghemite accompanied by siderite was found as a dominant mineral in magnetic products. An occurrence of siderite, quartz, ankerite, sericite and chlorite in non-magnetic products was detected.

Key words: High Gradient Magnetic Separation, siderite roasting, dust outlet, maghemite

Introduction

The iron ore works Siderite, Ltd., Nižná Slaná was the only producer of iron ore in Slovakia. Due to the economic problems its operation was shutdown in August 2008. The run-off-mine ore was subjected to crushing and classifying. The coarser classes were pre-treated using a dry high intensity magnetic separation. Only class with a grain size of 0 – 4 mm was led through bypass and directly added to magnetic product obtained by separation of coarser classes. In such way obtained material has been roasted in the rotary furnaces with the aim to improve the magnetic properties of the main utility Fe-bearing mineral, i.e. siderite. Thus, during magnetizing roasting, siderite was changed into magnetite and/or maghemite with much higher magnetic susceptibility. After cooling the roasted ore was wet ground to a grain size 90 % below 63 μm and subjected to wet low intensity magnetic separation. Magnetic product was filtered and led to pelletizing plant. Final product – blast furnace pellets usually contained 55.4 % of Fe, 3.4 % of Mn and 5 % of SiO_2 (Mihók, 1997; Lukáč, 2002; Hredzák et al., 2008a).

A one of the first reports about magnetic separation and mineral composition of dust outlets from the rotary furnaces studied an influence of low intensity magnetic separator drum revolution on products quality. Thus, from the feed of dust outlet with 35 – 38 % Fe and 13 – 16 % SiO_2 a magnetic product with 41 – 46 % Fe and 8 – 12 % SiO_2 at a mass yield of 59 – 67 % was obtained. Recovery of Fe and SiO_2 into magnetic product attained 72 – 78 % and 36 – 53 %, respectively (Zatko et al., 1979).

Latterly, a detailed research on the application of dry and wet ways of the high gradient magnetic separation was

performed. A dependence of products quality on applied magnetic induction at separation has been studied. The cleaner products were obtained by the wet way. So, from the feed with 26 – 28 % Fe and 16 – 18 % SiO_2 the magnetic products with 44.21 – 45.71 % Fe and 1.20 – 2.55 % SiO_2 at the mass yield of 31.86 – 37.03 % were attained. The recovery of iron and SiO_2 into magnetic products achieved 52.35 – 59.54 % and 2.24 – 5.26 %, respectively (Hredzák et al., 2008b, c).

Methods of experimental work and assessment

The High Gradient Magnetic Separation (HGMS) has been carried out using universal laboratory magnetic separator JONES in a cassette located between its poles. The cassette was lined by two grooved plates made of magnetically soft iron. In such way required induction and gradient of magnetic field were achieved (Hredzák et al., 2008b, c).

The assessment of separation products was performed using classical material balance method. After determination of mass yields the products of magnetic separation were subjected to chemical analyses and volume magnetic susceptibility measuring. Loss on ignition (LOI) at 900 °C and SiO_2 content was assayed gravimetrically. Other elements have been analysed by the atomic absorption spectroscopy using the device VARIAN with accessories: Fast Sequential AAS AA240FS, Zeeman AAS AA240Z 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

Tab. 1

Product	Mass yield [%]	κ	Fe [%]	SiO ₂ [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]	Zn [ppm]	Cu [ppm]
M	38.94	288,921	37.12	12.13	1.95	6.88	0.299	3.67	3.24	1.38	360	150
N	61.06	38,012	21.85	19.89	1.15	18.48	0.219	4.30	2.18	1.81	310	75
feed	100.00	135,711	27.80	16.87	1.46	13.96	0.250	4.05	2.59	1.64	329	104

Tab. 2

Product	Mass yield [%]	κ	Fe [%]	SiO ₂ [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]	Zn [ppm]	Cu [ppm]
M	61.61	214,466	31.04	14.29	1.66	10.74	0.303	4.12	2.84	1.46	360	245
N	38.39	13,146	19.64	25.44	1.07	18.80	0.204	4.71	2.14	1.81	335	85
feed	100.00	137,184	26.66	18.57	1.43	13.83	0.265	4.34	2.57	1.60	350	184

Tab. 3

Product	Mass yield [%]	κ	Fe [%]	SiO ₂ [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]	Zn [ppm]	Cu [ppm]
M	24.97	368,285	48.78	1.85	2.93	1.70	0.220	1.67	3.50	1.47	343	155
N	75.03	37,368	21.52	19.40	1.19	18.43	0.160	4.25	2.12	1.99	377	145
feed	100.00	119,990	28.33	15.02	1.62	14.25	0.175	3.61	2.46	1.86	369	147

Tab. 4

Product	Mass yield [%]	κ	Fe [%]	SiO ₂ [%]	Mn [%]	LOI [%]	As [%]	Al [%]	Mg [%]	Ca [%]	Zn [ppm]	Cu [ppm]
M	36.71	304,699	41.76	4.10	2.64	7.05	0.270	1.97	3.20	1.54	295	157
N	63.29	3,620	18.47	21.86	0.95	18.46	0.215	5.69	1.62	2.10	370	143
feed	100.00	114,152	27.02	15.34	1.57	14.27	0.235	4.32	2.20	1.89	342	148

Tab. 5

[illegible]

Tab. 6

[illegible]

Tab. 7

[illegible]

Tab. 8
Recoveries of components into products of wet magnetic separation at the induction of 0.3T [%]

Product	Fe	SiO ₂	Mn	LOI	As	Al	Mg	Ca	Zn	Cu
M	56.74	9.81	61.72	18.14	42.15	16.72	53.40	29.84	31.62	38.91
N	43.26	90.19	38.28	81.86	57.85	83.28	46.60	70.16	68.38	61.09
feed	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Tab. 9
Evaluation of Mössbauer spectrum of magnetic product obtained at 0.09T by dry way

iron	δ [mm/s]	ΔE_Q (ε) [mm/s]	H [T]	σ_B [T]	I [%]
Fe ²⁺	1.22	1.77		0	18.00
Fe ³⁺ in γ -Fe ₂ O ₃	0.31		48.62	1.19	57.93
Fe ³⁺ in γ -Fe ₂ O ₃	0.48		45.34	3.46	24.07
Sum of iron		100.00			

Tab. 10
Evaluation of Mössbauer spectrum of magnetic product obtained at 0.1T by wet way

iron	δ [mm/s]	ΔE_Q (ε) [mm/s]	H [T]	σ_B [T]	I [%]
Fe ²⁺	1.21	1.74		0	7.87
Fe ³⁺ in γ -Fe ₂ O ₃	0.31		48.69	1.31	59.59
Fe ³⁺ in γ -Fe ₂ O ₃	0.47		45.10	3.51	32.54
Sum of iron		100.00			

conditions: the magnetic field intensity of $300 \text{ A} \cdot \text{m}^{-1}$, the field homogeneity of 0.2 %, the operating frequency of 920 Hz, the range of $-1,999 \cdot 10^{-6} \div +650,000 \cdot 10^{-6}$ SI unit.

The XRD study of magnetic separation products was performed using the device DRON-UM1 with goniometer GUR-8 at following conditions: radiation CuK α , Cu-filter, voltage 30 kV, current 20 mA, step of goniometer 2°/min. The device is equipped by evaluating program developed by PETRA-ARTEP, Ltd., Košice, which operates on the application interface Control WEB2000. A d-spacing was performed using available published data (Beran and Zemmann, 1977; Davies and Evans, 1956; Graf, 1961; Gualtieri, 2000; Hamer et al., 2003; Hazen et al., 1989; Parra et al., 2005; Proust et al., 1986; Reeder and Dollase, 1989; Smith, 1992; Tomita and Sudo, 1971).

The room-temperature Mössbauer spectroscopy measurements were made in transmission geometry using a conventional spectrometer in a constant acceleration mode. A ⁵⁷Co/Rh gamma-ray source was used. The velocity scale was calibrated relative to ⁵⁷Fe in Rh. A proportional counter was used to detect the transmitted gamma-rays. Mössbauer spectral analysis software RECOIL (Lagarec and Rancourt, 1998) was used for the quantitative evaluation of the spectra. The spectra were fitted using the Voigt-based fitting method providing distributions of hyperfine parameters.

Results and discussion

The products of magnetic separation obtained at the lowest and the highest values of magnetic induction were subjected to mineralogical study. The qualities of studied products and recoveries of observed components into separation products are introduced in Tables 1 – 4 and 5 to 8, respectively (where κ – volume magnetic susceptibility in 10^{-6} SI units, LOI – lost on ignition, M – magnetic product, N – non-magnetic product). The XRD patterns are shown in Figs. 1 – 8, where used abbreviations mean (Hovorka and Spišiak, 1984): Magh – maghemite γ (gamma)-Fe₂O₃, Sdr – siderite FeCO₃, Qtz – quartz α (alpha)-SiO₂,

Ank – ankerite Ca(Fe⁺⁺, Mg, Mn)(CO₃)₂, Ser – sericite and Chl – chlorite.

The Mössbauer spectra of magnetic products obtained at the lowest magnetic induction are illustrated in Figs. 9 to 10. An interpretation of Mössbauer spectra is given in Tables 9 – 10.

As it is shown in Tables 1 – 4 the cleaner magnetic products were obtained using wet way magnetic separation. Generally, the iron content is higher by 10 %, the SiO₂ content and LOI values are lower by 10 % and 3 – 5 %, respectively. A relatively high iron content in non-magnetic product and a low iron recovery into magnetic product advert to the iron loss in non-magnetic product.

These losses explain the results of mineralogical analyses. In all magnetic products, especially in those, which were obtained using the induction of 0.3T. The maghemite is accompanied by siderite. Thus, siderite not only lowers the Fe content in magnetic products as a carrier CO₂ in its lattice (as a LOI in chemical analysis), but also it is the cause of Fe losses in non-magnetic products due to its low magnetic susceptibility.

Firstly, with regards to low iron content in magnetic products, as it implies from the Table 9 in the case of the cleanest magnetic product obtained by dry way at 0.09T an 82 % of the total iron is bonded in the structure of maghemite. The rest of iron as a bivalent one is fixed in other minerals, above all in siderite, which was approved by XRD analyses. Similarly, as to magnetic product achieved using the wet way of separation, a share of iron in maghemite attains of 92.13 % (Tab. 10).

Secondly, with respect to iron losses siderite in all non-magnetic products was determined as a dominant mineral accompanied by quartz, sericite and ankerite.

Conclusion

The research on mineral composition of magnetic separation products at dust outlets upgrading was carried out with the purpose to determine the mineral phase distribution and to verify the conversion of siderite to

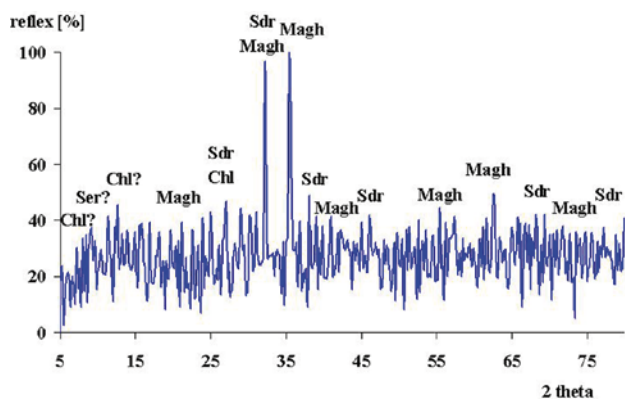


Fig. 1. XRD pattern of magnetic product obtained at 0.09T by dry way.

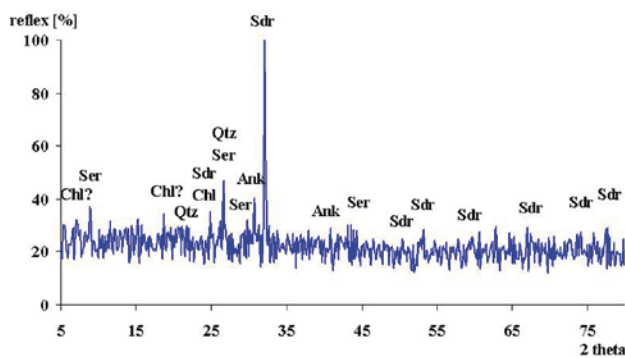


Fig. 2. XRD pattern of non-magnetic product obtained at 0.09T by dry way.

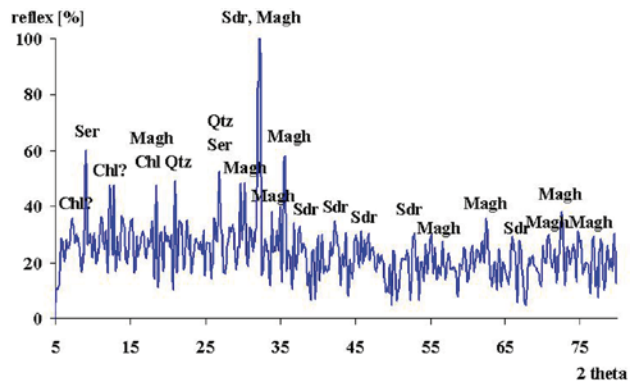


Fig. 3. XRD pattern of magnetic product obtained at 0.3T by dry way.

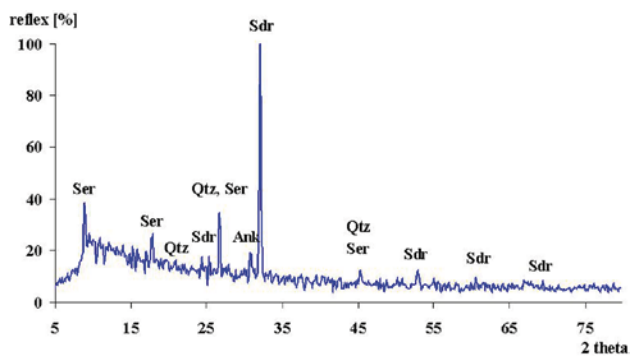


Fig. 4. XRD pattern of non-magnetic product obtained at 0.3T by dry way.

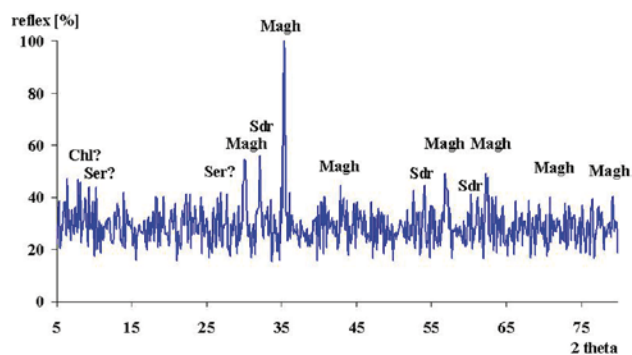


Fig. 5. XRD pattern of magnetic product obtained at 0.1T by wet way.

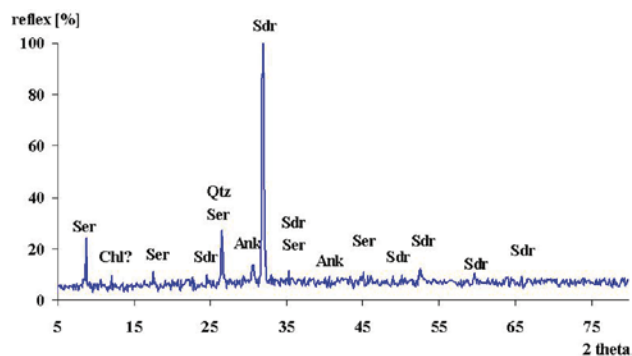


Fig. 6. XRD pattern of non-magnetic product obtained at 0.1T by wet way.

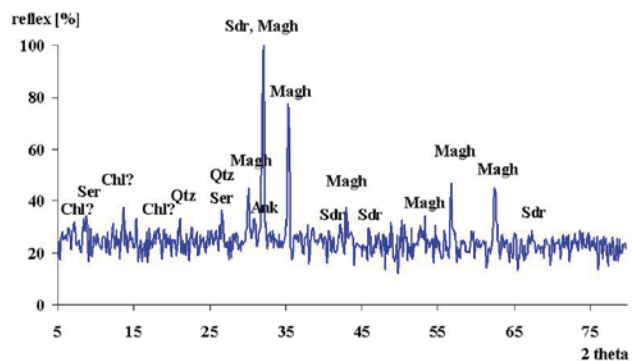


Fig. 7. XRD pattern of magnetic product obtained at 0.3T by wet way.

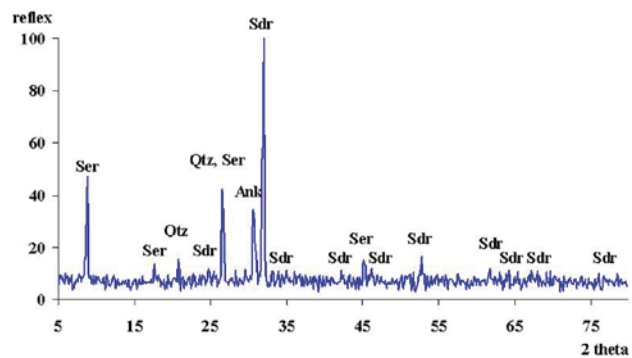


Fig. 8. XRD pattern of non-magnetic product obtained at 0.3T by wet way.

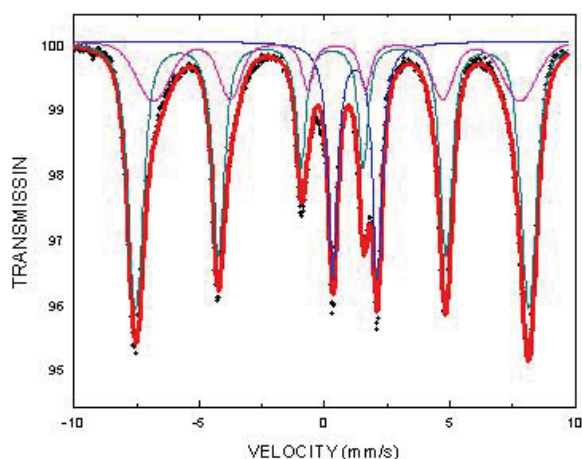


Fig. 9. Mössbauer spectrum of magnetic product obtained at 0.09T by dry way.

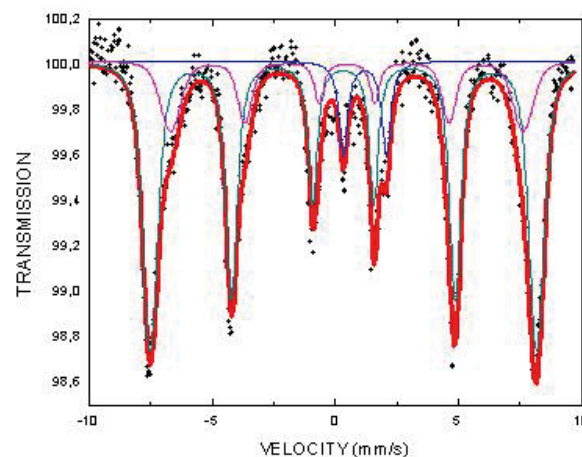


Fig. 10. Mössbauer spectrum of magnetic product obtained at 0.1T by wet way.

magnetic phases. Thus, chemical analyses, XRD study and Mössbauer spectroscopy were performed.

From viewpoint of Fe-concentrate quality it was proven that wet way of separation is preferable to dry one. In this way prepared magnetic products has higher iron content by 10 % and SiO_2 content was lower by 10 %.

The XRD study and Mössbauer spectroscopy confirmed the occurrence of siderite, which causes the unfavourable parameters of separation process. So, to prepare an iron concentrate of commercial quality and to prevent the iron losses in tailings it is needed the thermal pre-treatment of dust outlet aimed at the dead roasting of CO_2 , i.e. the total conversion of siderite to magnetic phase such as maghemite and/or magnetite.

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