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Determination of Chromite Sands Suitability for Use in Moulding Sands

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Abstract

Using the available analytical methods, including the determination of chemical composition using wavelength-dispersive X-ray fluorescent spectroscopy technique and phase composition determined using X-ray diffraction, microstructural observations in a high-resolution scanning microscope equipped with an X-ray microanalysis system as well as determination of characteristic softening and sintering temperatures using high-temperature microscope, the properties of particular chromite sands were defined. For the study has been typed reference sand with chemical properties, physical and thermal, treated as standard, and the sands of the regeneration process and the grinding process. Using these kinds of sand in foundries resulted in the occurrence of the phenomenon of the molding mass sintering. Impurities were identified and causes of sintering of a moulding sand based on chromite sand were characterized. Next, research methods enabling a quick evaluation of chromite sand suitability for use in the preparation of moulding sands were selected.

Keywords: Chromite sand, Moulding sand, Sintering

1. Introduction

In the casting industry a number of moulding sands are used, but for the production of large steel casting components the most frequently applied are the ones based on chromite sand. This sand is characterized by high refractoriness – above 1750°C, high thermal shock resistance, compressive strength and thermal conductivity [1-6].

Problems related to the availability of raw materials as well as their high price cause that low quality chromite sands appear on the market more and more frequently.

There are two important sources of chromite sands characterized by lower thermo-mechanical properties. The first ones are reclaimed sands [4-7]. Despite the fact that the currently used technologies of thermal and mechanical reclamation of moulding sands allow obtaining chromite sand reclaims whose parameters are similar to those of fresh sands, foundries also use reclaimed sands of low thermo-mechanical quality [5-10]. The second source of chromite sand supplies is raw material after the milling process. In both cases we observe a drop in refractoriness below the temperature of 1100°C as well as resistance parameters lowering properties of moulding sands.

As the problem of moulding sand sintering in the casting process became increasingly common, this phenomenon needed exploring. For this purpose, a number of moulding sands characterized by high quality parameters were examined and compared to moulding sands which underwent sintering during work.

2. Research methodology

As part of the conducted investigations, sands characterized by good thermo-mechanical properties, called reference sands, as well as a two sands which underwent sintering during work were examined. Sands characterized by low thermo-mechanical properties had two sources of origin, they were purchased as a full-value raw material, were assumed to meet high quality requirements and they came from processes of moulding sand reclamation.

Particular physical and chemical properties of chromite sands were determined by the following methods: wavelength-dispersive X-ray fluorescent spectroscopy was used to determine chemical composition; phase composition was determined using X-ray diffraction; a high-temperature microscope was used to determine characteristic temperatures of chromite mixes and grain morphology was observed in a high-resolution scanning microscope equipped with an X-ray microanalysis system.

3. Results and discussion

Table 1.
Chemical composition of chromite sands

	(1) Reference chromite sand	(2) Reference chromite sand	(3) Reclaimed chromite sand	(4) Ground chromite sand
LOI *)	+1.51	+2.06	+1.17	+1.58
SiO_2	0.68	0.46	0.88	0.74
Al_2O_3	14.68	15.04	14.80	15.09
Fe_2O_3 **)	28.25	28.11	28,10	27.94
TiO_2	0.70	0.73	0.69	0.70
CaO	0.05	0.05	0.04	0,06
MgO	9.29	9.23	9.14	9.20
Cr_2O_3	45.68	45.69	45.67	45.63
V_2O_5	0.34	0.34	0.33	0.33
MnO	0.13	0.13	0.13	0.13
NiO	0.11	0.12	0.11	0.11
ZnO	0.09	0.09	0.10	0.09

*) LOI – ignition loss at 1025°C, **) Total Fe converted into Fe_2O_3

Table 2.
Phase composition of moulding sands

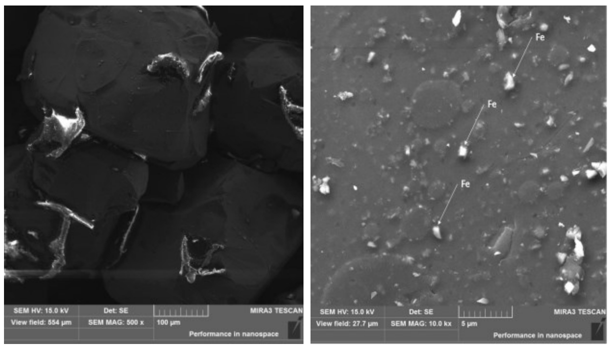
Test sample	Phase composition
Reference chromite sand	$(Fe_{0,51}Mg_{0,49})(Cr_{0,75}Al_{0,25})_2O_4$ - Chromite
Reclaimed chromite sand	$(Fe_{0,51}Mg_{0,49})(Cr_{0,75}Al_{0,25})_2O_4$ - Chromite C - Graphite Additionally, possible traces of the following phases: Fe - Iron $FeAl_2O_3$ - Hercynite $(Mg_{1,56}Fe_{4,39})Si_2O_6$ - Enstatite
Ground chromite sand	$(Fe_{0,51}Mg_{0,49})(Cr_{0,75}Al_{0,25})_2O_4$ - Chromite Fe - Iron FeO - Wustite Fe_2O_3 - Hematite Fe_3O_4 - Magnetite

Table 3.
Bulk density of chromite sand

Sample specification	Bulk density [g/cm^3]
Reference chromite sand	2.95 ± 0.1
Reclaimed chromite sand	2.72 ± 0.1
Ground chromite sand	2.83 ± 0.1

The results of chemical composition (Tab. 1.), phase composition (Tab. 2) and bulk density determination (Tab. 3) did not reveal any significant differences between the examined sands. Mass increment in the process of ignition loss determination, which was different for particular samples, is not a good parameter to characterize the properties of chromite sands.
The ignition loss quoted in the table above is the resultant of iron oxidation from Fe(II) into Fe(III) in chromite and the loss of volatile sands.

Micrographs taken at magnification of 500x (Fig. 1a, 2a, 3) shows that all investigate sands consists the grains with diameter of several hundred micrometers. However on the surface of the grains additional fine specimens are visible. These specimens are few and visible only at high magnification for reference sample (Fig. 1b). The objects are far more numerous for the reclaimed sand (Fig. 2). In the ground chromite sample the specimen are so numerous that are clearly visible at low magnifications (Fig. 3). Microscopic analysis at higher magnification coupled with chemical analysis of microregions revealed that reclaimed and ground chromite sands had micro-particles of iron on the grain surface.



a) b)
Fig. 1. Micrograph of the reference chromite grain surface: a) 500x magnification, SE detector, b) 10000x magnification, SE detector

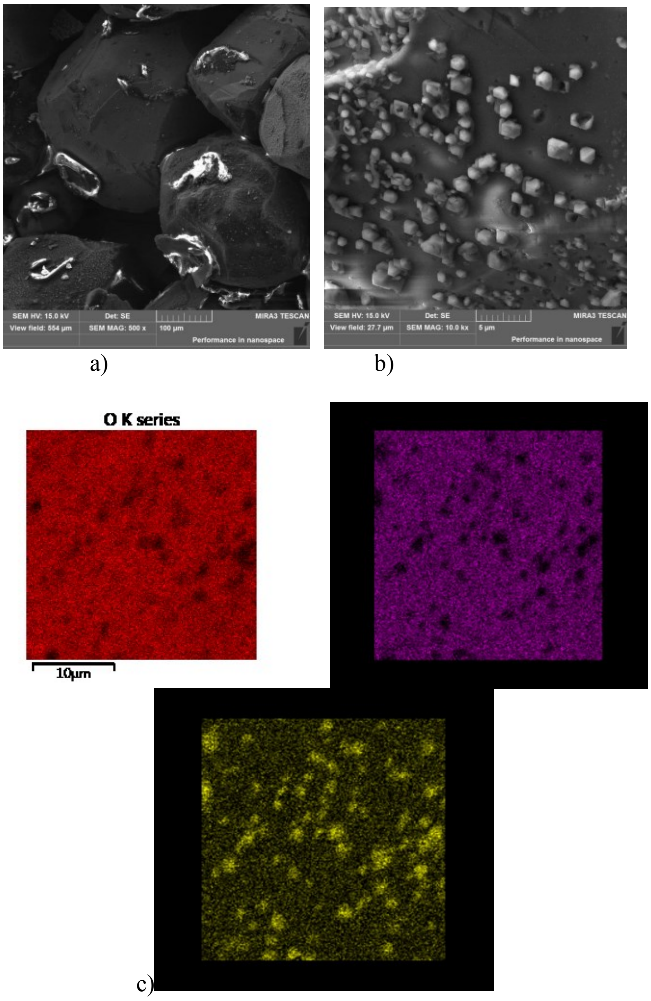


Fig. 2. Micrograph of the surface of the reclaimed chromite grain surface: a) 500x magnification, SE detector, b) 10000x magnification, SE detector c) X ray maps presents distribution of O, Cr, Fe on the on the reclaimed chromite grain surface presented on Figure 2b,

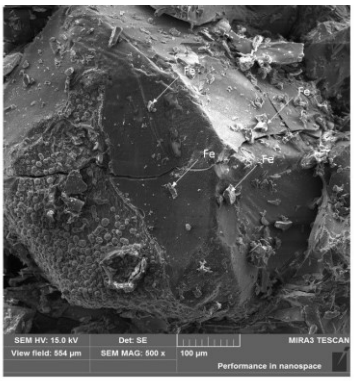


Fig. 3 Micrograph of the surface of the ground chromite grain, with Fe particles on the surface (500x magnification, SE detector)

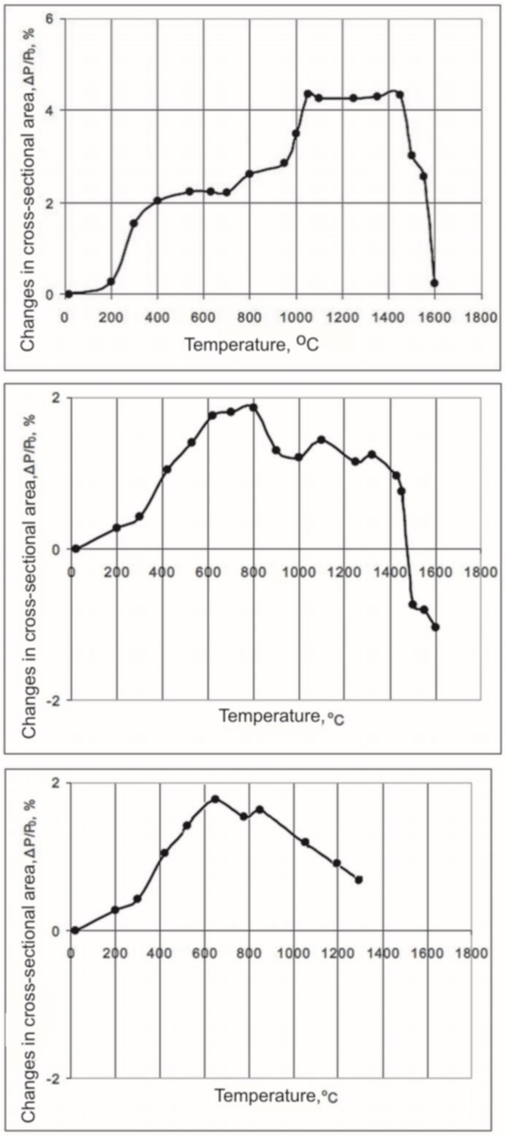


Fig. 4. Graphs of characteristic temperatures of chromite sands determined in a high-temperature microscope, a) reference chromite sand, b) reclaimed chromite sand, c) ground chromite sand.

Identification of submicroscopic particles of iron was shown for the surface of the reclaimed chromite sand grain (Fig. 2b). The iron particles possibly partially oxidised had the size of ca 1-2μm. The presence of Fe particles on the chromite surface resulted in the lowering of chromite sand refractoriness by ca 650°C, which has been shown in Figure 4, presenting the results of determination of changes in the chromite sand sample cross-section area ƛP/P_0 depending on temperature in a high-temperature microscope. In reference chromium sand sintering take place at ca. 1450°C (upper graph in Fig. 4). Reclaimed and ground chromite sands sinters at ca. 800°C and 650°C respectively (middle and lower graph in Fig. 4).

The presence of small iron particles in the reclaimed chromite sand was most probably due to a drop in the effectiveness of the reclamation process, and in the case of ground sands the impurities came from steel balls applied in mills.

4. Conclusions

Difficulties related to the availability of raw materials as well as their high price cause that moulding sands subjected to reclamation or contaminated with Fe particles in the grinding process are used more and more frequently. Irrespective of the origin of impurities, the phenomenon of grain sintering is observed during the work of the above mentioned sands. At elevated temperatures, Fe particles filling the spaces between chromite grains most probably trigger the formation of liquid phase, which increases the mix sinterability.

A sintered moulding sand changes its volume as well as the thermal properties of the mould, which is an unfavourable phenomenon. The stability of both factors influences the quality of moulds. Additionally, removal of the sintered moulding sand from the casting is extremely burdensome, considerably extending the time and increasing the costs of steel castings. For this reason, it is crucial to control the quality of chromite sand before it is allowed for use. The most effective method of determining the suitability of chromite sands for use in founding is to determine their characteristic temperatures, i.e. sintering, softening and flowing in a high-temperature microscope. This method provides a fast and simple way of verifying the producer’s declarations regarding the quality of the supplied material. If mixes containing reclaimed chromite sand are used in foundries, a high-temperature microscope allows fast evaluation of the effectiveness of the conducted reclamation, which prevents the problem of moulding sand sintering in the process of steel casting.

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