Determination of Chromite Sands Suitability for Use in Moulding Sands

K. Stec a,*, J. Podwórny a, B. Psiuk a, Ł. Kozakiewicz b
a Institute of Ceramics and Building Materials, Refractory Materials Division, ul. Toszecka 99, 44-100 Gliwice, Poland
b Department of Foundry Engineering, Silesian University of Technology, Towarowa 7, 44-100 Gliwice, Poland
* Corresponding author. E-mail address: k.stec@icimb.pl

Received 29.07.2016; accepted in revised form 03.11.2016

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

|                  | LOI *) | SiO₂ | Al₂O₃ | Fe₂O₃ **) | TiO₂ | CaO | MgO | Cr₂O₃ | V₂O₅ | MnO | NiO | ZnO |
|------------------|--------|------|-------|-----------|------|-----|-----|-------|------|-----|-----|-----|
| Reference sand   | +1.51  | 0.68 | 14.68 | 28.25     | 0.70 | 0.05| 9.29| 45.68 | 0.34 | 0.13| 0.11| 0.09|
| Reclaimed sand   | +2.06  | 0.46 | 15.04 | 28.11     | 0.73 | 0.05| 9.03| 45.69 | 0.34 | 0.13| 0.12| 0.09|
| Ground sand      | +1.17  | 0.88 | 14.80 | 28.10     | 0.69 | 0.04| 9.14| 45.67 | 0.33 | 0.13| 0.11| 0.10|
|                  | +1.58  | 0.74 | 15.09 | 27.94     | 0.70 | 0.06| 9.20| 45.63 | 0.33 | 0.13| 0.11| 0.09|

*) LOI – ignition loss at 1025°C, **) Total Fe converted into Fe₂O₃

Table 2.
Phase composition of moulding sands

| Test sample      | Phase composition                                      |
|------------------|--------------------------------------------------------|
| Reference sand   | (Fe₀,₃,Mg₀,₄,₅)(Cr₁₀,₅,Al₂₀,₃)₂O₇ - Chromite            |
|                  | Cr - Chromite                                          |
|                  | C - Graphite                                           |
|                  | Additionally, possible traces of the following phases: |
|                  | Fe - Iron                                              |
|                  | Fe₃O₅ - Hercynite                                       |
|                  | (Mg₀,₃,Fe₂₀,₃)SiO₅ - Enstatite                          |
| Reclaimed sand   | (Fe₀,₃,Mg₀,₄,₅)(Cr₁₀,₅,Al₂₀,₃)₂O₇ - Chromite            |
|                  | Cr - Chromite                                          |
|                  | C - Graphite                                           |
| Ground sand      | (Fe₀,₃,Mg₀,₄,₅)(Cr₁₀,₅,Al₂₀,₃)₂O₇ - Chromite            |
|                  | Cr - Chromite                                          |
|                  | Fe - Iron                                              |
|                  | Fe₃O₅ - Wustite                                         |
|                  | Fe₇O₉ - Hematite                                        |
|                  | Fe₉O₁₃ - Magnetite                                      |

Table 3.
Bulk density of chromite sand

| Sample specification | Bulk density [g/cm³] |
|----------------------|----------------------|
| 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 chrome 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 chrome sands had micro-particles of iron on the grain surface.

Fig. 1. Micrograph of the reference chromite grain surface: a) 500x magnification, SE detector, b) 10000x magnification, SE detector
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 $\Delta P/P_0$ depending on temperature in a high-temperature microscope. In reference chromium sand sintering takes place at ca. 1450°C (upper graph in Fig. 4). Reclaimed and ground chromite sands sinter 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 foundry 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.

References

[1] Stec, K. (2008). Determining the content of chrome (VI) in raw materials and post-production waste. Ceramika (Ceramics). (102), 189-195. (in Polish)
[2] Stec, K. (2005). Determination of chromium oxide in the ore and chrome refractory materials containing chromium oxide. Ceramika – Polski Biuletyn Ceramiczny (88), 223-22. (in Polish).
[3] Furmanek, J. (2002). Installing the regeneration of molding and core. Archives of Foundry. 2(3), 42-49. (in Polish).
[4] Dańko, J., Dańko, R., Łucarz, M. (2007). The processes and apparatuses for the regeneration of the matrix used molding sands. Kraków, Wydawnictwo Naukowe AKAPIT. (in Polish).
[5] Dańko, J., Holtzer, M. & Dańko, R. (2007). Problems Concerning Reclamation of Used Foundry Sands. Polish Journal of Environmental Studies. 3B(16), 93-9.
[6] Izdebska-Szanda, I., Angrecki, M. & Palma, A. (2013). Recycling of waste moulding sands with new binders. Archives of Foundry Engineering. 13(2), 43-48.
[7] Holtzer, M., Drozyński, D., Bobrowski, A., Mazur, M. & Isendorf, B. (2010). The influence of reclaim on properties of moulding sand with furan resin. Archives of Foundry Engineering. 10(spec.2), 61-64. (in Polish).
[8] Dańko, J., Dańko, R. & Holtzer, M. (2003). Reclamation of Used Sands in Foundry Production. Metallurgy. 42(3), 173-178.
[9] Leidel, D. S. (1994): The influence of sand and binders on reclaimability. Foundry Trade Journal, 3497 (168), 384-387.
[10] Fedoryszyn, A. (1996). The characteristics of grain basis for assessing the quality of the carcass sand moulding. Solidification of Metals and Alloys. 26, 231-238. (in Polish).