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Application of Chromite in the Production of Refractory Coatings

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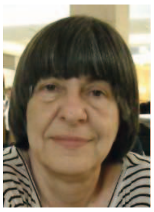

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KEYWORDS

refractory coating, chromite, sand moulds, lost foam casting, image analysis
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ABSTRACT

This work investigated the possibility of developing new chromite-based refractory coatings for hot metal casting applications. The coating composition and rheological properties were optimized by careful choice of binding agents and addition of a suspension maintenance agent in the coating. Different solvents (water and isopropyl alcohol) and casting methods were used in the tests. Chromite was used as refractory filler in both the water- and alcohol-based coating compositions. The chromite was examined by X-ray diffraction analysis and scanning electron microscopy. The chromite shape and grain size were analysed visually with the aid of the OZARIA 2.5 PC image analysis package. Test samples were cast using sand moulds and by the method of expandable patterns using a polymer model, also known as the "lost foam" casting process. The investigation demonstrated that water- and alcohol-based coatings have positive influence on the surface quality, structural and mechanical properties of alloy castings made with both casting processes.

1 Introduction

Refractory coatings for moulds and cores are an integral part of industry casting production. The basic role of ceramic coatings is to provide an efficient refractory barrier between the mould substrate and liquid metal flow during the phases of casting, solidification and final formation of the castings [1]. This ideally provides a smooth and clean surface for the casted component, with no adhered sand or defects due to metal penetration into the mould (e.g. lumps, dents, rough surfaces or other imperfections). Depending on use, contemporary coatings are made from ceramic materials mixed with a solvent and added suspension and binding agents [2–3]. Ceramic coatings enable improvements to existing casting methods and development of new ones, an important example of which is expandable and meltable pattern casting (the "lost foam" casting process and precision investment casting) [4–6].

Coating development involves systematic research to determine optimum coatings and casting methods, and appropriate types of castings for different alloys [7–9]. At the same time, all relevant economic and quality indicators for the casting production should be monitored. Coating properties are strictly defined by standards. It is very important to make the choice, preparation,

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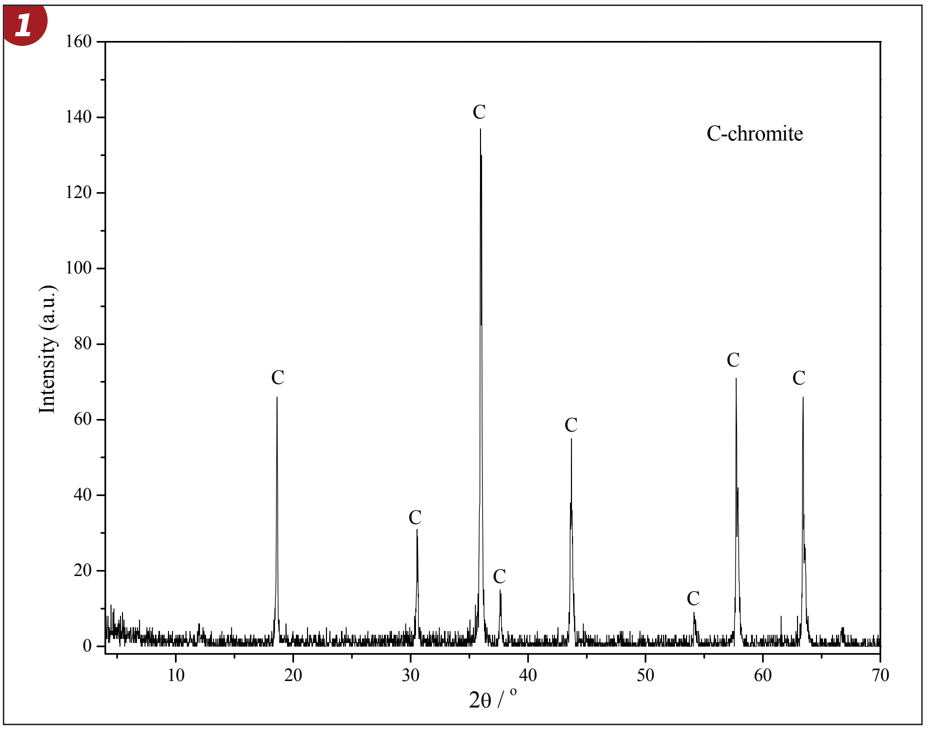

Fig. 1 • **Diffractogram of chromite sample**

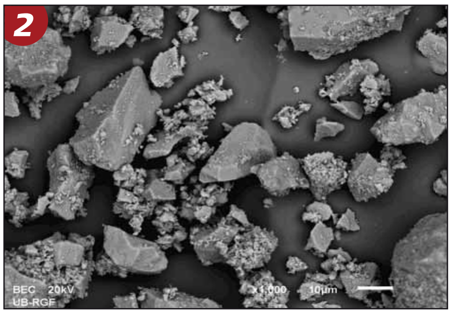

Fig. 2 • **Microphotograph of chromite sample**

and application of coatings under actual foundry working conditions. In this investigation, special attention was applied to the composition of the chromite coatings and to procedures for preparing the coating components [10–13].

2 Experimental

To properly choose a ceramic coating, familiarity is necessary with the physico-chemical phenomena and thermodynamic changes occurring on the liquid metal-mould boundary during inflow, cooling and solidification of castings.

Chromite was applied as a refractory coating filler due to its high melting temperature, low heat spread coefficient, absence of reaction with liquid metal, and non-production of gases when in contact with liquid metal. The chromite applied as filler in the coatings was tested by X-ray diffraction analysis (Philips model PW1710 X-ray diffractometer) and scanning electronic microscope (JEOL JSM-6610LV). SEM microphotographs were used to analyse the distribution of refractory filler particles. Particle sizes and shape factors were measured with the OZARIA 2.5 application software package.

An agent was chosen based on the size and shape of the chromite particles to perfectly bind the filler elements together and secure good adhesion of the particles to the surface of the sand mould or polymer model used in the casting techniques. Two types of coatings were prepared. In the Type A coating, alcohol was used as a liquid solvent. The solvent used in Type B was water. The suspension temperature, one of the process parameters important in production of refractory coatings, was 25 °C. The coating compositions, including solvents, binding agents and other additives, and the chromite particle size and optimal density of each refractory coating suspension are given in Table 1.

Coatings were applied to previously prepared sand moulds, as well as on a polymer model made of polystyrene. The coatings were dried as follows:

- For the water-based coating, the first layer was dried for 2 h and a second (final) layer was dried for 24 h. The coating thickness on the mould/model after drying was 0.5 mm.
- The alcohol-based coating was burned after its application on the mould/model. The thickness of the coating after drying was 1 mm.

The test castings were shaped in the form of plates with dimensions of 200 mm × 50 mm × 20 mm. For sand casting, a mould mixture was prepared with 3 mass-% bentonite and

Table 1 • **Compositions of refractory coatings Type A and Type B**

Coating	Composition		Grain size / µm	Content / mass-%
Type A	Refractory filler	Chromite ($FeCr_2O_4$)	20–35	90
	Binding agent	Colophonium ($C_{20}H_{30}O_2$)	–	3
	Additive	Bentone 25	–	1
	Solvent: isopropyl alcohol (C_3H_8O)			
Optimal density of refractory coating Type A in suspension: 1900 kg/m^3				
Type B	Refractory filler	Chromite ($FeCr_2O_4$)	25–35	95
	Binding agent	Bentonite ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) Carboxymethyl cellulose (CMC)	– –	3 0.5
	Suspension maintenance agent	– Dextrin ($(C_6H_{10}O_5)_n$) – Klucel hydroxypropylcellulose (HPC)	– –	1 0.5
	Solvent: water			
Optimal density of refractory coating Type B in suspension: 2000 kg/m^3				

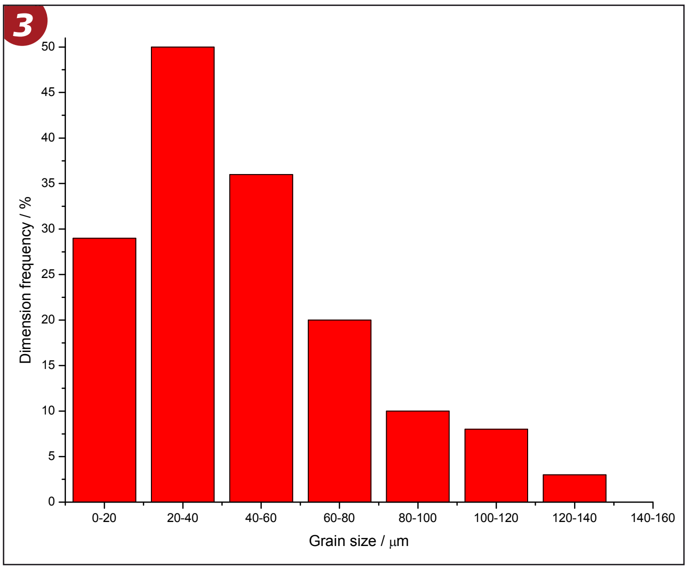

Fig. 3 • **Histogram of chromite particle sizes**

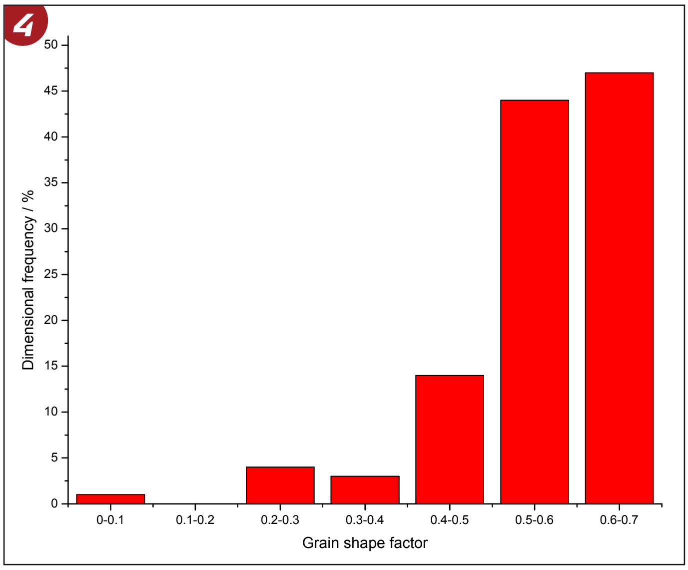

Fig. 4 • **Histogram of chromite particle shape factors**

0.5 mass-% dextrin added to 0.17 mm mean grain size quartz sand. The refractory coating was applied to the sand moulds by brush. For the "lost foam" casting process moulds, dry quartz sand with mean grain size of 0.25 mm was used. Evaporable models were made of polystyrene with density of 20 kg/m^3. The refractory coating was applied to polymer moulds by immersion in a tank and painting of the lining with a brush. Fe-C alloy was used as the casting material. The metal temperature was between 1250–1350 °C. A skimming agent and aluminum granules for deoxidation were used during casting.

3 Results and discussion

An X-ray diffractogram of the chromite sample used in the investigation showed a prevailing presence of chromite, as was expected. The XRD is given in Fig. 1.

SEM microstructure analysis of the chromite showed larger particles having mostly uniform size, accompanied by additional smaller-sized particles. The morphology of the particles was uniform. The bigger particles were elongated and angular-shaped. Smaller particles formed clusters by merging with each other or with bigger particles. The SEM microphotograph is presented in Fig. 2.

The particle size and shape profile of the coating material was analysed using OZARIA 2.5 PC software. A histogram of the chromite particle sizes is given in Fig. 3. The mean particle size was observed to be approx. 40 µm. The upper particle size limit was 140 µm, but the percentage of particles of that size in the investigated sample was less than 2.5 mass-%. It is reasonable that these angular-shaped particles of various grain sizes would form a uniform and consistent layer coating the sand mould and polystyrene model surfaces due to favourable space-fill interrelations between the particles. To achieve the best sedimentary stability of the coating suspension, 20–35 µm filler particles were used. It was expected that smaller particles would create less visible debris and the suspension would be faster and more easily homogenized. Smaller filler particles also cover the coated mould and model surfaces more evenly and thoroughly.

An analysis of the chromite particle shapes is given in Fig. 4. The OZARIA 2.5 analysis identifies particle sizes that range over the interval from 0 to 1 as follows:

- shape factor 0 corresponds to a needle shape
- 0–0.2 is a needle-like shapes with sharp angles
- 0.2–0.4 for a sub-needle shape
- 0.4–0.5 for a sub-angular shape
- 0.6–0.8 for sub-oval shapes
- 0.8–1 for spherical shapes, and
- 1 represents a circle.

Most of the particles had sub-angular (0.4–0.5) and sub-oval (0.6–0.8) shapes.

According to our estimates, the refractory filler particles of various sizes and different shapes (ranging from small sub-angled shapes to larger sub-oval particles) should form a uniform coating layer on the mould and model surfaces. This is due to mutual harmony of their different sizes and shapes. The angled sides of the larger particles "lock" together to form the coating substrate, while any empty inter-grain spaces are filled by smaller particles. Good overall interaction between the particles produces a positive result.

4 Conclusion

Use of coatings based on chromite in a sand mould or "lost foam" casting process can enable castings with improved quality. Coatings prepared with density 1900–2000 kg/cm^3 were applied in double layers and dried, forming constant, thin coverings on both sand moulds and polymer models. The coatings provided good gas permeability, enabled fast liquid metal cooling in the mould and formed a tiny-grained cast structure. Application of thinner coating layers also induced a reduction of porosity in the castings. These conclusions are expected to be confirmed by ultrasonic tests and by mechanical properties testing of the castings in further investigations.

Successful application of chromite refractory coatings in sandy mould and "lost foam" casting processes depends crucially on appropriate casting procedures, rheological properties of the coatings, and on the coating sediment characteristics and stability. The results of this investigation show that careful optimization of coating compositions and their preparation procedures can have positive effects on casting quality. Coatings designed on an alcohol base are recommended for casting into sand moulds, while water-based coatings are more appropriate for polymer models used in the "lost foam" procedure. Water-based coatings are by far the more economical choice and are also safer to work with.

Acknowledgments

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