Ceramic Particles Reinforced Ductile Iron Prepared by Lost Foam Casting and Its Properties

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Abstract: Based on the integrated composite addition technology of ceramic particles and Fe powder foam preform, ceramic particle reinforced ductile iron materials were prepared by lost foam casting, and the effect of TiC ceramic particles on the microstructure, mechanical properties and friction and wear behavior of ductile cast iron were studied. The results show that the heterogeneous nucleation of cementite can be enhanced by using TiC particles (1~5 μm) as the reinforcement phase, and the content of pearlite in ductile iron increases. The tensile strength and hardness of ductile iron increase with the increase of TiC content, while the elongation decreases. The wear mechanism changes from adhesive wear to abrasive wear. When the addition of TiC is 1wt. %, the strength of ductile iron reaches 498MPa and the elongation is 18.1 %.

Keywords: ductile iron composites; ceramic particles; mechanical properties

1 Introduction

Ductile iron is widely used in structural parts due to its excellent mechanical properties such as strength and plasticity. For some ductile iron castings, e.g., hubs, gears and crankshafts, etc., in addition to the need for good strength and toughness, the wear resistance is often their assessment index as well [1]. Adding hard insoluble ceramic particles to alloy materials, that is, based on the dispersion strengthening method, can generally improve the strength, hardness and wear resistance of the alloy simultaneously [2], which provides a new way for the development of wear-resistant ductile iron. Research indicates that the addition of 0.5 wt.% CeO_2 can make the austenitic ductile iron have 452 MPa ultimate tensile strength, 14.4 % elongation and 85 % wear volume reduction [3]. However, the inherent density difference, wettability and reaction problems between molten iron and ceramic particles make it difficult to achieve a good combination between the two by using traditional casting methods to prepare composite materials, and it is also difficult to achieve uniform distribution of ceramic particles [4]. Therefore, it is imperative to develop new technologies that can maturely prepare ductile iron / ceramic particles composites. Hence, in this study, a method for preparing ductile iron / ceramic particle composites by Fe powder / foam preform and lost foam casting technology was proposed, and the TiC particles was used as the reinforced phase to add into ductile iron. The variation trend of microstructure and mechanical caused by TiC ceramic particles are evaluated.

2 Experimental procedure

The preparation process of ceramic particles reinforced ductile iron is shown in Figure 1. The iron powder with a size of about 5 μm and the TiC (1~5μm in size) ceramic particles with the expected addition amount were ground together to form a mechanical mixture by high-energy ball milling. Then the mechanically mixed Fe/TiC powder was mixed with EPS beads and foamed together to prepare foam preform for lost foam casting. After which the foam preform was embedded in the molding sand and awaited pouring under negative pressure. Pig iron, scrap steel, carburant and ferrosilicon were used as raw materials for smelting molten iron, and they were melted using a induction melting furnace. Spheroidization and inoculation were carried out in ladle by punching method, and the smelting temperature of molten iron is about 1500 °C. Then the molten iron in the ladle is poured into a sand mold containing prefabricated foam, and the pouring temperature is about 1380°C. After solidification and cooling, the sanding was carried out and the ductile iron ingot was obtained.

The metallographic samples, tensile performance samples and wear test samples were cut from the ingot. The 4% nitric acid alcohol solution was used to corrode the metallographic sample. Microstructure of the TiC ceramic particles reinforced ductile iron were analyzed using the OLS4100 laser scanning confocal microscope (LSCM) and the TM3030 scanning electron microscope (SEM). The tensile properties of the samples were tested using an E45-305 microcomputer-controlled electronic universal testing machine (MTS) at the speed of 1 mm/min. The wear resistance of the ductile iron was analyzed by reciprocating friction of WC balls at a speed of 5 mm/s for 90m under a load of 50 N on an MFT-5000 multi-function tribometer. The surface morphology of wear test samples after wear was observed using the OLS4100 LSCM.

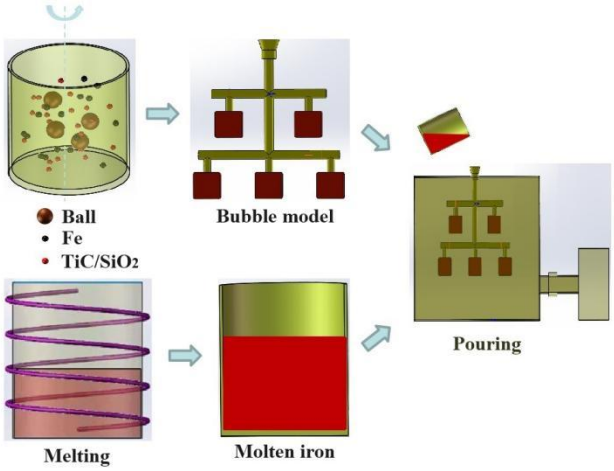

Fig. 1. Process diagram of preparing ceramic particle reinforced ductile iron by lost foam casting method.

3 Result and discussion

Microstructural characterization

Fig.2 shows the effect of TiC ceramic particles on the microstructure of ductile iron. With the addition of TiC, the pearlite content in the matrix increases significantly, and the value for ductile iron without TiC addition is 0.63%, while 10.75% for ductile iron with the TiC addition of 1%. In addition, the addition of TiC will lead to a decrease in the spheroidization rate of graphite. The pearlite exhibits a typical lamellar structure with cubic TiC particles distributed in it, and the TiC particles are well combined with the cementite in the pearlite. However, no obvious TiC particles were found in the ferrite matrix. The phenomenon indicates that TiC can be used as the heterogeneous nucleation of cementite, which promotes the increase of pearlite in ductile iron [5].

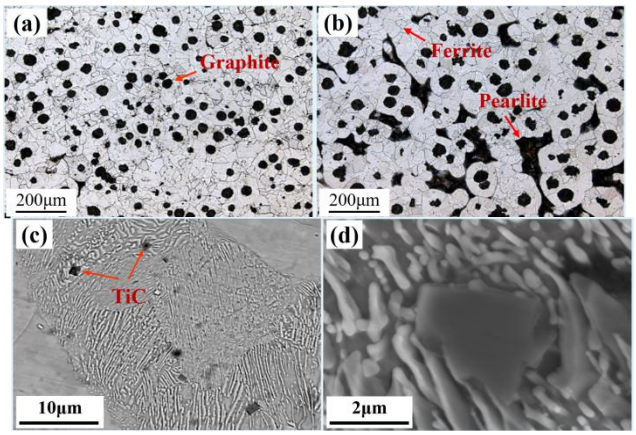

Fig. 2. the effect of TiC ceramic particles on the microstructure of ductile iron, in which (a) is the ductile iron without TiC, (b) is the ductile iron with the TiC addition of 1.0wt.%, (c) is the distribution of TiC in the ductile and (d) is the enlarged TiC particle.

Microstructural characterization

Fig.3 shows the effect of TiC addition on strength and elongation of ductile cast iron. With the increase of TiC content, the strength of ductile iron tends to increase gradually, while the elongation decreases gradually, which are mainly related to the increase of pearlite proportion caused by TiC addition. When the addition of TiC is 1 wt.%, the tensile strength of ductile iron is 498MPa, and the elongation is 18.1%.

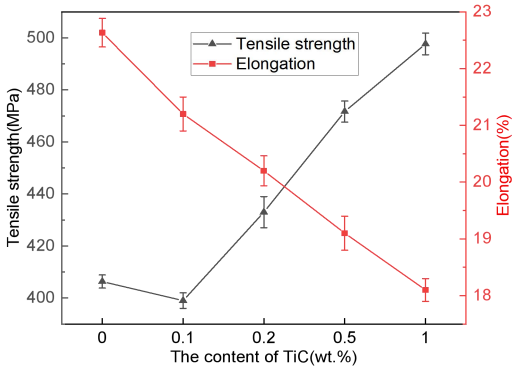

Fig. 3. Effect of TiC addition on strength and elongation of ductile cast iron

4 Conclusion

In this work, prefabricated foams were prepared by co-foaming of Fe powder / TiC ceramic particles obtained by high-energy ball milling and EPS beads. Then TiC / ductile iron composites were prepared by lost foam casting technology. TiC ceramic particles are uniformly dispersed in the pearlite of the matrix structure of ductile iron, and increases the proportion of pearlite in the ductile iron, which is related to the fact that TiC can be used as the core of heterogeneous nucleation of cementite. The increase of TIC content leads to the increase of pearlite content in ductile iron, resulting in the increase of strength and the decrease of elongation of ductile iron.

Acknowledgments

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