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Effect of volume ratio of liquid to solid on the interfacial microstructure and mechanical properties of high chromium cast iron and medium carbon steel bimetal

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ABSTRACT

The high chromium cast iron and medium carbon steel bimetal was fabricated by liquid–solid casting technology. The effect of volume ratios of liquid to solid (6:1, 10:1 and 12:1) on the interfacial microstructure and mechanical properties of bimetal was investigated. The interfacial microstructure was analyzed using scanning electron microscope (SEM) and transmission electron microscope (TEM). The shear strength and microhardness in as-cast condition were studied at room temperature. The results show that the volume ratios of liquid to solid affect significantly the interfacial microstructure. When liquid–solid volume ratio was 6:1, the unbonded region was detected in interface region because the imported heat energy cannot support effectively the diffusion of element, whereas, when liquid–solid volume ratios reach 10:1 and 12:1, a sound interfacial microstructure was achieved by the diffusion of C, Cr, Mo, Cu and Mn, and metallurgical bonding without unbonded region, void and hole, etc. was detected. With the increase of liquid–solid volume ratio, the elemental diffusion activity improves, resulting in the increase of width of interface transition region. At the same distance from interface, with the increase of liquid–solid volume ratio, the microhardness is degraded in HCCI, but increased in MCS. The shear strength is also improved with the increase of liquid–solid volume ratio.

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1. Introduction

Bimetallic material has been extensively employed as an advanced functional material in many fields because of its unique physical and mechanical properties [1–3], which can be fabricated by bonding, similar and dissimilar materials [4]. According to the application, the physical and mechanical properties of constituent metals should be considered for choosing sound metals [5]. The wettability, reactivity, phase transformation, melting temperature, thermal conductivity and thermal expansion of constituent metals must be suitable to bond each other. In the current study, the bimetal will be used in wear-resistance and impact-resistance for mineral processing. In view of the above mentioned factors, the bimetal comprises high chromium cast iron (HCCI) and medium carbon steel (MCS). The HCCI was chosen for its high wear-resistance and hardness, whereas the MCS for high strength property to resist impacting. Currently, there are several fabrication methods of bimetal, such as casting [5], diffusion bonding [6,7], rolling [8], extrusion [9], cladding [10,11] and powder metallurgy technology [12]. The casting as a simple, economical and effective method for fabricating bimetal has been confirmed [5], as well as was used in the current study.

The interfacial microstructure between two metals plays a crucial role in determining mechanical properties of bimetal [13], and the interface is formed by the contact of liquid–solid state. The interfacial microstructure can be controlled by modifying the volume ratio of high temperature liquid metal (HCCI) to solid metal (MCS) [14,15], as well as changing the heat energy imported by high temperature liquid metal. The objectives of the present study are to investigate the effect of volume ratio of liquid to solid on interfacial microstructure and mechanical properties of HCCI and MCS bimetal fabricated by sand mould casting, and to achieve the significant information for controlling the interfacial microstructure and improving mechanical properties.

2. Experimental procedure

The high chromium cast iron and medium carbon steel were selected as raw materials to fabricate bimetal by liquid–solid casting technology. The chemical compositions of HCCI and MCS are given in Table 1. The MCS was cut into 20 mm × 20 mm × 50 mm, and each surface was processed by grinding from 320

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Table 1
Chemical compositions of high chromium cast iron and medium carbon steel (wt.%).

Materials	C	Cr	Mo	Mn	Si	Cu	Ti	P	S	Fe
High chromium cast iron	2.31	14.21	1.40	0.60	0.65	0.72	0.15	0.01	0.01	Bal.
Medium carbon steel	0.42	–	–	0.92	0.51	–	–	0.01	0.01	Bal.

to 1200 grit paper and polished with 1 μm alumina, subsequently ultrasonically cleaned in alcohol. The HCCI was weighed according to the volume ratios of liquid to solid metal (6:1, 10:1 and 12:1, respectively), and melt in induction furnace. When the temperature of furnace was raised to 1500 °C and held for 30 min, the molten metal was poured into a sand mould. Prior to pouring, the processed MCS was preheated about 1600 s to 600 °C, and placed into the sand mould. The bimetal was cooled to the room temperature in the sand mould.

The microstructure characterization specimens were cut transversely through the bond, prepared by grinding from 320 to 1200 grit paper and metallographically polished with 1 μm alumina, subsequently ultrasonically cleaned and etched using a reagent of 4% picric acid. The microstructures have been examined using a MeF-3 optical microscope and a JSMT-200 scanning electron microscope. The composition in the transition region was investigated using energy dispersive spectrometry (EDS).

Mechanical properties of as-cast specimens were surveyed according to the shear properties and hardness at room temperature. The bimetal sample was machined for preparing shear test sample with 8 mm × 8 mm × 10 mm. An Instron tensile testing machine was used for the shear tests at a speed of 0.5 mm/min. Microhardness measurements were carried out on a microhardness tester using a 100 g load for 15 s.

3. Results and discussion

3.1. Interfacial microstructure

The typical interfacial microstructures of as-cast samples are shown in Fig. 1. The low magnification of interfacial microstructure in bimetal containing volume ratio of 6:1 is presented in Fig. 1(a), and high magnification is indicated in Fig. 1(b). It is obvious from Fig. 1(a) that the long unbonded regions at the interface of that were found, and short unbonded region also was detected as shown in Fig. 1(b). It is illustrated that the interface cannot form desired metallurgical bonding, whereas, the interfacial microstructures with

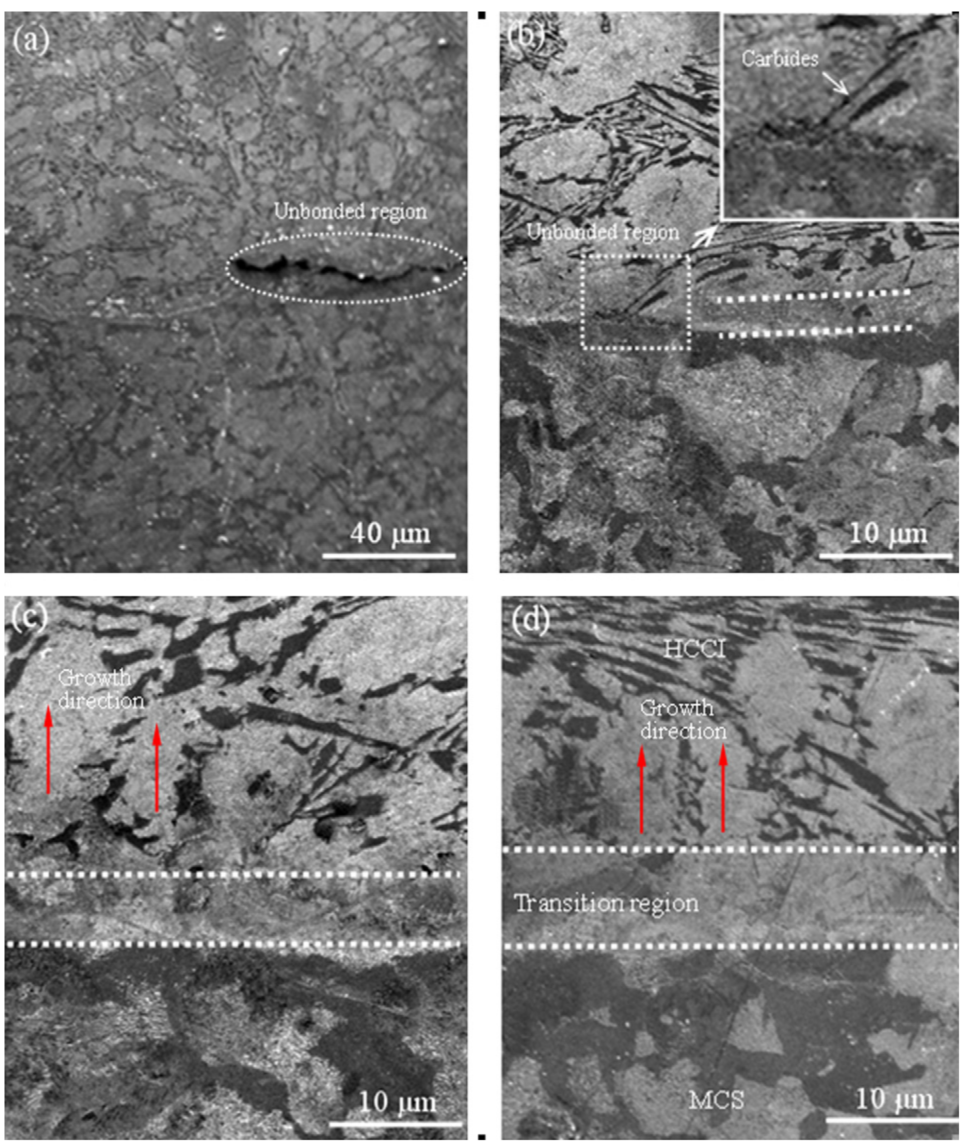

Fig. 1. Typical interfacial microstructures of as-cast samples: (a) low magnification of interfacial microstructure in bimetal containing volume ratio of 6:1, (b) high magnification of interfacial microstructure in bimetal containing volume ratio of 6:1, (c) 10:1 and (d) 12:1.

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