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Short Communication

An investigation of abrasive wear and corrosion behavior of surface repair of gray cast iron by SMAW

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ABSTRACT

In this work, improving the abrasion–corrosion behavior of gray cast iron used in centrifugal pumps was studied. These pumps are usually made of gray cast iron (BS:1452Gr220) and are repaired by Shielded Metal Arc Welding (SMAW). Three different typical welding electrodes including Ni electrode (DIN8563), Carbon Steel electrode (DIN1913), and Hardening electrode (DIN8555) were used to compare the weldability of the base metal. Microstructural differences for three types of electrodes were studied and forming of different phases was analyzed. Corrosion and abrasion tests were conducted and related to welding conditions. Experimental results showed that using Ni substrate electrode reduce the unwanted phases (martensitic and carbides). Furthermore, in comparison with the base metal, the abrasion behavior of all weldments was improved. It was also determined that the carbon steel electrode has a higher corrosion resistance in zero-resistance ammeter (ZRA) test compared to other electrodes.

1. Introduction

Centrifugal pumps are important industrial components that are used to move fluids in petroleum, hydraulic, agriculture, and gas industries. One of the main problems with centrifugal pumps is corrosion and abrasion due to high working speed and corrosive liquids [1–3]. Repair welding is done specially at the inner layer of casing to restore the damaged areas [2–4].

One of the most favorable materials for manufacturing the casing is cast iron. Cast iron advantages are low melting temperature, machinability, low price, and high damping capacity. As a disadvantage, it has poor weldability. On the other hands, welding is one of the most important processes to repair and recover the damage in cast iron instruments. Martensitic phase and brittle iron carbide growth are two main problems of cast irons welding [5–8]. Pouranvari [9] concluded that formation of carbides and martensitic phase in the fusion zone

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are prevented by using the Ni filler material. He also concluded that preheating to 573 K (300 °C) result in forming bainitic HAZ and discontinuous carbides [8]. Also there are other problems associated with welding of gray cast iron. Ghaini et al. [5] showed that residual stresses can control the crack generation during the welding process in ductile cast iron. They also used powder welding process to characterize the kind of crack formed in welding process. He claimed that the cracks in powder welding process are differing in morphology from the cold cracks in the case of arc welding of ductile cast irons [10].

Ebrahimnia et al. [11] have also studied the effect of cooling rate on micro cracks in the heat affected zone (HAZ) of ductile cast iron. They expressed that the cracks generated at interface of graphite and propagate through martensitic matrix.

Winiczenko and Kaczorowski [12] used friction welding of ductile iron with stainless steel. They concluded that friction welding is accompanied by a transport of atoms in both directions across the ductile iron-stainless steel interface. They showed the maximum length of Cr and Ni diffusion in cast iron is 50 μm and the bainitic matrix improves this transition.

Thorntona et al. [13] studied the effect of cryogenic processing on the wear resistance of gray cast iron. They concluded that the wear rate of gray cast iron can improve from 9.1 to 81.4%, due to the depth of cryogenic treatment.

The wear behavior of ductile cast iron was investigated by Fontanari et al. [14]. They have concluded that both the lubrication condition and the microstructure of materials have a strong effect on crack initiation and propagation. They showed that the graphite nodules, as well as the ferritic phase influence the subsurface crack initiation, their preferential propagation and branching [14].

A common method for repair welding of cast iron is shielded metal arc welding (SMAW). This method is rather cheap and easy. In this method, usually carbon steel fillers are used to repair the damaged areas [2–4]. However, using filler materials increases the risk of galvanic corrosion and welding must be performed under controlled condition when the environment is corrosive.

Despite of the influence of welding conditions on abrasion and corrosion behavior of welded cast iron, this issue has not been assessed adequately. Therefore, the main purpose of this work is to investigate the effect of filler materials in SMAW process on tribcorrosion behavior of cast irons. For this reason, three different typical filler metals were used to repair welding of gray cast iron according to standard condition. The microstructures of cross section specimens were studied. Evaluations of different phases were compared for different filler materials after welding procedure. The wear behaviors of the surfaces were recorded using pin-on-disk test. Potentiodynamic polarization measurements and zero-resistance ammeter (ZRA) tests were used to measure the corrosion resistance and galvanic potential of specimens, respectively.

2. Experimental method

Gray cast iron is usually used for manufacturing of centrifugal pumps body (casing). The pumps body in this study were made of cast iron grade BS:1452Gr220. Therefore, the base metal for welding procedure was chosen from this grade. Composition of the base metal (wt%) was Fe-3.20C-2.01Si-0.60Mn. The size of each sample was 100 × 100 × 20 mm^3 and all specimens were prepared before welding by grinding and oil removing. Three different typical filler metals were used to repair welding using shielded metal arc welding process. The type and chemical composition of filler metals are given in Table 1. The condition of welding and the abbreviation of the tests are presented in Table 2. All samples were heated at 573–673 K (300–400 °C) for 15 min before welding to prevent heat shock during welding.

For metallographic examination the section was prepared perpendicular to the weld surface in order to examine the microstructural variation through the weld thickness. Metallographic preparation including grinding and polishing was performed for each specimen and Nital 2% was used for etching.

For investigating the abrasion properties, pin-on-disk test was performed according to ASTM G99 [15]. Tribological tests were carried out in air under a load of 10 N. The other experimental parameters were as follows: sliding speed = 50 m/min; radius = 5 mm; sliding distance = 650 m.

For corrosion test the specimens were sectioned from welding area as well as base metal. Then the cut samples and base metal were grounded by the 320-1200# SiC abrasive paper sequentially and polished by 2.5 μm emery paste. The specimens were mounted with a work area of 0.6 cm^2 before the corrosion test. Experiments were carried out in 3.5% NaCl solution at pH 7.2 at room temperature (300 K (27 °C)) according to the working environment of centrifugal pump (river water).

According to the usual potentiodynamic polarization measurements the base or weld metal was taken as a working electrode and the saturated calomel and platinum plate and counter electrode as a reference. ACM instrument potentiostat (Gill AC) was used in all electrochemical tests.

An initial delay of 60 min was applied for stabilizing in all cyclic potentiodynamic polarization tests. Tafel extrapolation and linear polarization methods (LPR) were used for drawing the cathodic and anodic polarization curves. Each test has been repeated three times to verify the results. Additionally, the galvanic potential and current density of base metal (gray cast iron) and welded specimens has been recorded by built-in zero-resistance ammeter (ZRA). In this test the data was recorded in each 6 h for 24 h and the anode/cathode area ratio was 1/1.

3. Result and discussion

3.1. *Microstructure*

Fig. 1 shows the microstructure of interface, HAZ and welding zone of specimens. The martensitic phase can be seen in HAZ and interface of base metal and E7018 welding metal, (Fig. 1(a and b)). The use of Ni-electrode (CNi7018) prevents martensitic phase formation (Fig. 1c). In this specimen instead of forming hard martensitic phase, the D and E type of graphite phase has been formed in the interface. Formation of brittle carbides and martensitic phases depends on cooling rate and dilution of alloying elements. Previous studies show that