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Lining of hydraulic cylinder made of cast iron with copper alloy

Toshinari Yamazaki *, Teppei Shibuya, Cheng Ji Jin, Toshio Kikuta, Noriyuki Nakatani

Faculty of Engineering, Toyama University, 3190 Gofuku, Toyama 930-8555, Japan

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Abstract

A process to line a hydraulic cylinder made of cast iron with copper alloy is developed. In this process, the hollow cylinder was first filled with FeO powder and was heated at a high temperature, which resulted in the removal of the carbon atoms at the cast iron surface that was in contact with the FeO powder. After the FeO powder was brushed away, molten copper alloy was poured into the hollow cylinder held at a high temperature. After cooling, the embedded copper alloy was drilled along its center axis so that the prescribed thickness of the copper alloy may remain. In this study, the temperature and duration of the heat treatment for the decarburization were investigated. The rate of decarburization and the break test of the junction between the copper alloy and the cast iron are discussed.

Keywords: Flake graphite cast iron; Copper alloy; Hydraulic cylinder; Decarburization; FeO; Bonding

1. Introduction

Although it is generally difficult to obtain junction between iron and copper alloy, methods to do so by the self-welding of copper alloy have been devised by several researchers [1,2]. These methods are used to line sliding surfaces of hydraulic iron cylinders with copper alloy [2]. One method for lining the inner surface of an iron cylinder with copper alloy is to pour molten copper alloy into a hole in the heated cylinder. After the cylinder has been cooled, the embedded copper alloy is drilled along its center axis so that the prescribed thickness of the copper alloy may remain. However, when the cylinder is made of cast iron such as flake graphite cast iron or spherical graphite cast iron, both of which include a high concentration of carbon, the copper alloy does not bond to the inner surface of the cylinder. To solve this problem, the present authors attempted to bond the copper alloy after decarburizing the inner surface of a cylinder.

It is difficult to weld flake graphite cast iron or spherical graphite cast iron [3,4]. As a counter measure for this problem, Yamada et al. [5,6] developed a method for decarburizing the surface of cast iron. They studied the decarburization process of spherical graphite cast iron in contact with FeO powder upon heat treatment, and found that the decarburization occurred at a temperature higher than 930 K. According to their discussion, this reaction of decarburization is the process of the formation of CO trough the reaction between the surface carbon and CO_2; CO_2 is formed through reaction between surface carbon and O_2, and O_2 is formed by decomposition of FeO powder.

In this study, copper alloy was shown to bond to the inner surface of a cylinder made of flake graphite cast iron that was decarburized by the method of Yamada et al. [5,6]. The formation of a decarburized layer, observed using scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDX), is also reported.

2. Experimental procedures

Several square chips of flake graphite cast iron with an edge length of 10 mm and a thickness of 5 mm, embedded in FeO powder which filled an iron pot with a capacity of about 20 ml, were heated at 1153, 1203 or 1253 K. After different durations of heat treatment, the chips were removed one by one from the pot. The cross-section of the specimens thus obtained was polished by means of abrasive paper and buffing, and was observed using a scanning electron microscope (Hitachi 3500H) furnished with an energy dispersive X-ray micro-analyzer.

In order to make specimens to use for the investigation of the bonding of copper alloy to cast iron, cast iron cylinders were made using a drill, a lathe turning machine, and a lathe cutting tool. Unless otherwise stated, the diameter and depth of the cylinder hole were 15 and 40 mm, respectively. After being filled up with FeO powder as illustrated in Fig. 1(a), the cylinders were heated for various durations in an electric furnace at a temperature of 1153, 1203 or 1253 K. After cooling to room temperature, the FeO powder in the cylinders was brushed away. Thereafter, the cylinders were filled with borax anhydride as a flux and heated to 1203 K in an electric furnace. At this temperature, the borax anhydride melted because its melting temperature is 1151 K. Immediately

* Corresponding author. Tel.: +81 764456882; fax: +81 764456882.
E-mail address: yamazaki@eng.toyama-u.ac.jp (T. Yamazaki).

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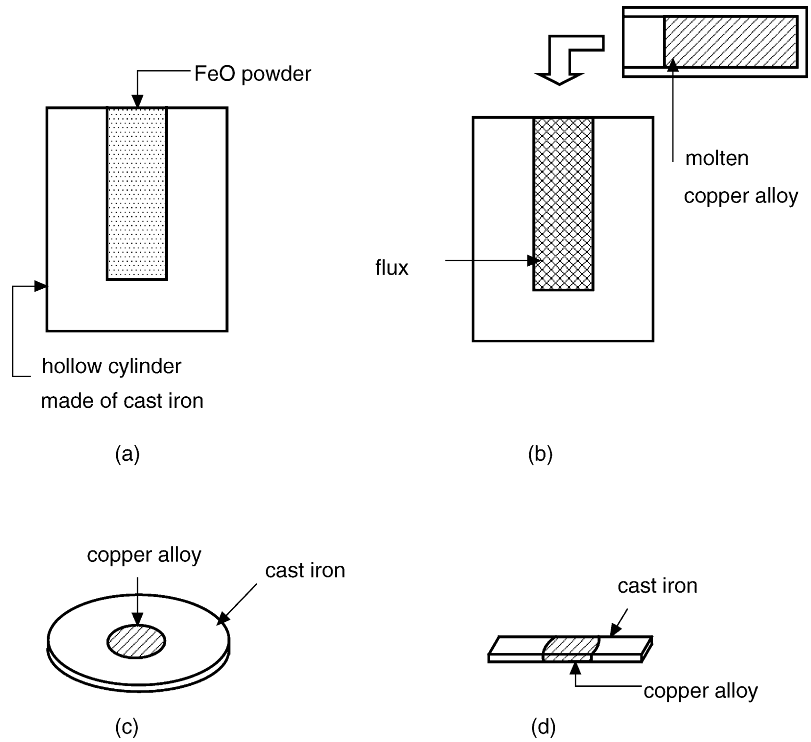

Fig. 1. Process of the fabrication of the specimen for the observation of the interface between the cast iron and the copper alloy as well as the break test. (a) Heat treatment of the cylinder filled with FeO powder. (b) Pouring of molten copper alloy into the cylinder filled with molten borax anhydride. (c) Disk specimen cut out of the cylinder embedded with copper alloy. (d) Strip specimen cut out of the disk specimen.

after the heated cylinders were removed from the electric furnace, molten copper alloy of a composition of $Cu_{0.87}Sn_{0.08}Pb_{0.03}Ni_{0.02}$ heated at 1523 K was poured into the cylinders, as illustrated in Fig. 1(b). When the molten copper alloy was poured in, it caused the molten flux to all spill out from the cylinder, because the density of the borax anhydride is smaller than that of copper alloy. Here, it should be noted that the process, from decarburization to the injection of molten copper alloy, was carried out in air. After cooling, disks 2 mm thick (Fig. 1(c)) were cut out from the cylinders embedded with copper alloy, and then strip specimens 44 mm long and 6 mm wide (Fig. 1(d)) were cut out from the disks. After the strip specimens were polished by means of abrasive paper and buffing, the structure of the interface between the cast iron and copper alloy was observed using SEM and EDX. The strip specimens were also examined using a tensile stress tester.

3. Results and discussion

When molten copper alloy is poured into a cylinder made of cast iron without decarburization, the two substances do not bond to each other. Thus, after the cast iron and the copper alloy are cooled to room temperature, they can rather easily be separated. Fig. 2 shows an example of the inner surface of the cast iron cylinder with an inner diameter of 80 mm and a depth of 20 mm, and the copper alloy which was separated from it. The cast iron is on the left side, and the copper alloy on the right side. Note that after being removed from the cast iron, the copper alloy was placed upside down. Both the surface of the cast iron and that of the copper alloy were smeared. It was observed that many holes with diameters between 0.1 and 3 mm were on the surface of the copper alloy. These holes were considered to be a trace of the blowout of carbon oxide formed through the reaction between the carbon atoms at the surface of the cast iron and the oxygen atoms in air. On the basis of this idea, we expected the copper alloy to bond to the cast iron decarburized at the surface.

Fig. 3(a) and (b) shows the SEM image and EDX carbon distribution image around the decarburized layer formed by heat treatment at 1203 K for 2 h, respectively. From these figures, the decarburized layer was found to be about 150 μm thick. Fig. 3(c)

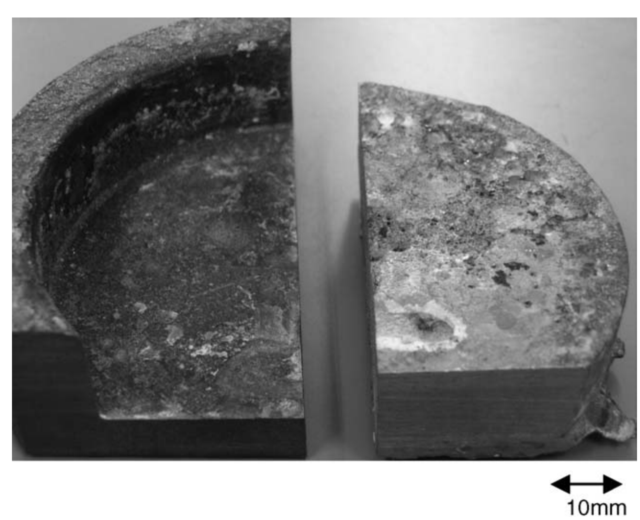

Fig. 2. Surface of the cast iron and the copper alloy, which could not be bonded to each other. Note that the cylinder was cut away to separate the copper alloy from the cylinder. The cast iron is on the left. The separated copper alloy is placed upside-down on the right.