BRAZING OF GRAPHITE/GRAPHITE USING A NEW FILLER TECHNIQUE

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ABSTRACT

Brazing is one of the best methods of graphite to graphite or to metals joining. But the major problem associated with the graphite brazing is the poor wetting by the conventional metal fillers. For this reason, scientists have produced a special filler metal based on active elements which interacts with graphite to form carbides. Also, recently another technique to overcome the wetting problem was introduced by H. Ohmura and T. Yoshida. It included inserting an intermediate layer of pure iron foil inside the copper filler. In the present work, another filler combination of Cu/steel/Cu foils is proposed as new filler technique for graphite brazing. It was found that, it produced a successful joint with a good properties consisted of a columnar phase which resulted from the partially dissolution of iron in molten copper. Additionally, the increasing of brazing time caused reducing the thickness of the steel central layer and increasing the thickness of the columnar phase layers. The X-ray diffraction test was developed that, the joints contained two carbide types, iron and copper free elements.

KEYWORDS: brazing, graphite, ceramic joining, wetting problem, columnar phase

INTRODUCTION

A prime difficulties associating the brazing of graphite to graphite and to common structural metals is that the poor wettability of graphite by conventional metal fillers such as the copper base type. In addition to the general requirements of good brazing alloys such as the low differences in coefficient of expansion between the graphite, the brazing alloys and the structural metals[16]. R.G. Domaly and G. M. Slaughter [17] developed filler alloys to obtain a good joint with acceptable properties. These alloys which contain strong carbide forming elements such as Ti and Zr were found to readily wet and flow on graphite. They appear to be useful in fabricating graphite assemblies for a wide variety of elevated temperature applications, aerospace and nuclear reactors.

Another brazing technique for joining graphite to itself or to metals with conventional filler metals has been developed by H. Ohmura et al [15]. This technique is performed by placing pure iron foil inside the copper filler. During brazing, the columnar phase is formed at both graphite faces and grows towards the iron foil. As a result, both graphite base materials are united by the columnar phase through the iron foil.

This work aims to evaluate a lamellar filler of (copper-low carbon steel-copper) foils as a new technique in the efforts series to overcome the wetting problem accompanied with graphite brazing.
EXPERIMENTAL WORK

Materials used in this investigation were graphite as a substrate material, copper foil (50 μm thickness), and low carbon steel foil (200 μm thickness) as filler metals. Table 1 shows the chemical analysis of copper and steel foils.

Three joint types were employed to evaluate the present filler technique. They were: single butt joint (figure 1a), filler butt joint (figure 2a), and double butt joint (figure 3a). The first type was utilized to study the microstructure, misalignment, and x-ray diffraction test, while the other two types were used for shear testing.

The graphite was cut to the desired dimensions according to the joint design, then the two joint side surfaces were ground with (100, 200, 400, 600, 1200) emery papers.

All joints were fixed by a simple fixture of two sheets of graphite to hold the joint pieces in between and filled with four stainless steel rods (figures 1b, 2b, and 3b).

To keep the brazing process away from an inert atmosphere a stainless steel retort (figure 1c) was employed to hold the brazing samples and fixtures.

After preparation of joints materials, they were assembled in the proper fixtures and inserted in the retort. Then it was sealed and the argon was pumped at 350°C until reaching the temperature of 1150°C, so the joints were held for different times (2, 5, 10, 15, 20, 30 min). Then the assemblies were left to cool in the furnace, and the argon closed at 400°C. Figure (5) illustrates the thermal cycles of these brazing processes.

Figure (6) shows the brazing joint samples of filler and double butt types.

For evaluation the present filler technique, several inspections were performed in this work. They include: a microstructural study with an optical microscope, x-ray diffraction, and shear tests which are divided into the following:

I) Filler Butt Joints Shear Testing

They were inspected by single shear testing using the die shown in figure (7). The assembly of joints with die was held down in the INSTRON compression machine to obtain load-displacement output charts with crosshead speed of 0.5 mm/min.

II) Double - Butt Joints Shear Testing

The double butt joint shear tests were carried out using the die shown in figure (8). The assembly of the graphite joints with die was held down in the INSTRON compression machine at the same previous crosshead speed.

RESULTS AND DISCUSSION

I) Microstructural Evaluation

Figure (9) contains a micrograph of graphite/graphite joint brazed at 1150°C and holding time of 2.5 min. It shows an ideal joint consisting of three zones: graphite substrate, columnar phase, and steel center. In figure (10) other observations from the same joint conditions. They develop uneven thicknesses of columnar phase and steel layer in the same micrograph and in different micrographs. This inhomogeneity in layer thicknesses may be attributed to many factors such as: unequal pressure applied by four bolts, the change of pressure at elevated temperatures due to the base occurring by expansion, and heterogeneous distribution of temperature in the retort.

Figure (11) contains a combination micrographs of before brazing assembly (Graphite-Cu-Cu-Graphite), and after brazing the (same joint). It shows a high reduction in the steel layer thickness and growth of columnar phase through all of the copper, graphite and part of steel layers. The effect of brazing time on the phase change and interface movement of both filler and base materials is shown in figure (12). The steel layer reduced in thickness and the columnar phase initiated and expanded through the copper layers, graphite substrates and central steel layer with increasing time. So at 2.5 min, the large thickness of steel layer is clear, but at 30 min of brazing time it has almost reduced. An important observation is the agression of the graphite which is transferred into the columnar phase towards the iron. This agression increased clearly with increasing time.

II) X-Ray Diffraction

X-ray diffraction were carried out for five specimens in different brazing times (2.5, 5, 10, 15, 30 min) as shown in figure (13). The room dedication is that the predominant existence of two iron carbide phases (Fe3C, FeC), which indicates a clear diffusion and interaction between the graphite and the iron atoms across the two liquid copper layers. Also, the charts assessed the presence of both free copper and iron in the joints at all brazing times except at 30 min, so they disappeared completely. The poor sensitivity of the instrument reduced an opportunity of identification of a columnar phase and intermetallic compounds peaks in the charts.
CONCLUSIONS
1-The present filler technique succeeded in producing an excellent joint.
2-The limited copper played as a path to the carbon atoms to move towards the steel center and formation of iron carbides.
3-The best brazing time was (15 min.) at 1125°C a brazing temperature, which gave a maximum shear strength.
4-The maximum hardness was at the center of the joints.

REFERENCES
Table (1) The chemical composition of copper and steel foils

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<th>AI</th>
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*Balances are Ca and Fe

Figure (1)  a- The joint design and dimensions of single butt joint  b- The fixture of the single butt joint

Figure (2)  a- The joint design and dimensions of fillet butt joint  b- The fixture of the fillet butt joint

Figure (3)  a- The joint design and the dimensions of double butt joint  b- The fixture of the double butt joint
Figure (3) the rotor which used in brazing processes

Figure (5) Thermal cycles of brazing processes

Figure (6) a A photograph of brazed fillet butt joint samples  b A photograph of brazed double butt joint samples

Figure (7) A die of fillet butt joint shear testing  Figure (8) A die of double butt joint shear testing
Figure (9) A microstructure of the joint at brazing conditions; 1125°C for 2.5 min

Figure (10) Microstructure of joints of same brazing conditions; (1125°C for 2.5 min.)
Figure 11: The variation in microstructure before and after brazing.
Figure (13): The charts of X-ray diffraction show the evaporation of different baking times: a) 15 min, b) 30 min, c) 60 min, d) 120 min, e) 30 min.

Basrah Journal for Engineering Sciences / 2009
Continuous of previous figure (11)
Figure (14) The effect of brazing time on max. shear strength of single butt fillet joints.

Figure (15) A photograph of fractured single butt fillet joints.

Figure (16) The effect of brazing time on max. shear strength of double butt joints.

Figure (17) A photograph of double butt joints.