Effect of sliver filler metal alloy on bonding structure for brazing Ni270 to Ductile cast iron

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Abstract: Diffusion brazing mechanism of two dissimilar alloys Ni 270 and Ductile cast iron (DCI) by BAg-5 and BAg-7 filler metal with bonding time of 10 min was investigated. Shear strength test was performed to evaluate mechanical properties. The bonding phase for joining side nickel by using the two type of filler metal alloy BAg-5 and BAg-7 is the NiCu phase with shear strength about 70 Mpa, and the bonding phase for joining side ductile cast iron by using the two type of filler metal alloy BAg-5 and BAg-7 is the Fe3Si and SiC phase with shear strength about 40 Mpa. The joining of nickel 270 plate and ductile cast iron by using BAg-5 filler metal alloy shows an Eutectic structure at the middle of filler zone, which lead to great affinity between nickel element with copper. The optimum shear strength of 43 MPa was achieved for the bond made by BAg-7 filler metal.

1. Introduction

Many products are assembled from two or more individual components that are often permanently joined to produce structurally sound assemblies[1]. Due to Ni 270 their good mechanical properties, weldability and excellent resistance to many corrosive environments in a range of media, including seawater, hydrofluoric acid, sulfuric acid, and alkalis, used for marine engineering, chemical and hydrocarbon processing[2,3]. Ductile iron (DCI) possesses much of the strength and ductility of steel. In ductile iron, this graphite is converted into spheroids that minimize the notch effect and thereby produce a product combining the strength and ductility of cast steel with the low cost, wear resistance, and damping characteristics of cast iron[4]. So, we will be welding Ni 270 to ductile cast iron for this property, which we don’t find them in DCI. Joining of Ni 270 and DCI are so difficult by conventional fusion welding methods because there are great differences in the performance and physical behaviors of these two materials. Therefore, a considerable attention has been paid to achieve a sound joint by advanced joining processes like diffusion bonding, laser. Both filler metal alloys used in brazing process were solid rods, rolled to thickness about (90-150) µm as a ribbon. Butt joint types were used to braze specimens.

The brazing filler metal was pre-placed in between the two faying surfaces of butt joint with same direction of abrading. Sufficient quantity of filler metal must be applied to the base metal surfaces. Then, they were held in a fixture to keep the joint without any movement before and after the assembly had inserted inside the furnace as shown in Fig (1). Welding and transient liquid phase bonding and brazing. The term brazing is defined as a group of joining processes wherein coalescence is produced by heating to a suitable temperature and by using a filler metal having a liquids temperature above 470°C and below the solidus of the base metals. In brazing, metallic parts are joined by a non-ferrous filler metal or alloy. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction [5]. Among them, brazing has been chosen as one of...
main techniques for Ni270/DCI bonding. studied induction brazing characteristics of Ni270 to DCI using an Ag-based filler metal BAg-5 and BA-7[6].

![Figure 1. Schematic of the sample fixture](image)

2. Experimental procedure

2.1. Materials and brazing process

BAg-5 and BAg-7 foil with the thickness of 150 μm was used as the filler metal to join Ni270 to DCI. The accurate chemical composition of base alloys and filler metal is given in Table (1,2). At first, Cubic specimens (10 mm x10 mm x10 mm) were sectioned from the root part of the blade using wire cutting process. The specimens were ground in consecutive steps emery paper to be ready for diffusion brazing process. Surface preparation for brazing for Ni 270. The nickel oxide film is removed by grinding the surfaces using emery papers with a grid of 200,400,800,1000 and 1500 . Finally, specimens are washed with distilled water, while DCI chemical Treatment cleaning used to remove free graphite by components are generally immersed for 15 minutes in a fused 50:50 solution of sodium and potassium nitrate salts. The temperature of the salt bath is kept at 662° to 752°F (350° to 450°C) by external heating. The surface graphite is oxidized by the salts, leaving the metal with a light film of iron oxide over it. The samples are then cooled and washed. This is followed by pickling for about one minute in a 10% by volume solution of commercial hydrofluoric acid (50-60% strength) to remove the iron oxide film[7]. Finally, specimens were washed by distilled water and dried. Diamond finish. The chemical etchant for the was used for revealing the metallographic structure of the bond and the adjacent base metals was Remington A etch (10ml HF, 10ml HNO3, 30ml Glycerin)[10]. The brazed samples were mainly characterized for microstructure view by using optical microscopy (OM), the mechanical properties assessment by single shear test. The SEM test was carried out supplemented for fracture assessment. Then X-ray diffraction examinations were used to investigate the type of interlayer bonding phases.

| Elements Materials | C %  | S %  | P %  | AL % | CR % | Ni % | Other |
|--------------------|------|------|------|------|------|------|-------|
| Actual chemical composition to Ni270 | 0.028 | 0.0046 | 0.0117 | 0.0071 | 0.0028 | 99.94 | …. |
| Actual chemical composition to DCI | 3.76 | 0.30 | 2.30 | 0.02 | 0.045 | 0.02 | Balance |
Table 2. Chemical composition and melting ranges of filler metals used [6]

| Filler Type | Composition Wt. % | Melting Range °C | Brazing Temperature Range °C |
|-------------|------------------|------------------|-----------------------------|
| BAg-5       | Ag 46, Cu 31, Zn 23 | 663   | 743 | 743-843 |
| BAg-7       | Ag 57, Cu 23, Zn 15, Sn 5 | 618   | 652 | 652-760 |

2.2. Microstructure evaluation

For evaluation of the microstructural changes. It is known that a typical diffusion brazing joint consists of the bonding zone (I), diffusion zone (II) and substrate zone (III), the bonding zone here is composed of what’s called as a thermally solidified zone (ASZ), which is formed as a result of the residual liquid solidifies in the joint. Further away from the joint centerline, the liquid\solid transition reaction layer is formed between the filler and the base metal. These reactions result from dissolution and inter-diffusion. Consequently, form what is known as the bonding line and diffusion affected zone (DAZ) denoted by (II), as shown in figure(2). The brazed joints were sectioned transversely to the bond line, ground and polished to .

![Figure 2. Optical micrograph of two samples (a) brazed by BAg-5 filler metal alloy, (b) brazed by BAg-7 filler metal all](image)

2.3. Mechanical tests

Single shear test was executed by tensile at room temperature to find the strength of the joints. The result of the shear was, 38 and 43 MPa. It can be clearly noticed the shear strength of the joints bonded by BAg-7 higher than the joints bonded by BAg-5, as a result of the ease of movement of copper for the bonding interface zone when bonded by BAg-7, and difficulty moving the copper for interface zone when bonded by BAg-5 filler metal . The shear strength for brazed CI to CI was ≈ 40 Mpa. This means that the shear occurred on the side of CI and it did not happen on the side of nickel, because when we brazed Ni to Ni the shear strength was ≈ 70 Mpa as shown in Fig (3).
3. Results and discussion

In case of side nickel bond, the silver (Ag) in general be stay at the mid filler zone, which means don’t moves to the bond zone or the interface between the filler metal and base material. And from that all element will be transfer through that. While the Cu element will be shearing the bond zone and the Zn in less with the Ni will be creating the bond phase or interface as show in figure (4). In this case only four elements (Ag, Cu, Zn, and Ni) will be executed at the joint, so it's easy to identify the bonding phase. But of the bonding phase of side DCI will be difficult to identifying the bonding phase because there are more the elements are present at the bonding and its around zones (Fe, C, Si, Ni, Mn, Cr, Al, S, P, Ag, Cu, Zn, and Sn). The brazing joint of Ni to Ni by using the two types of filler in this work, the figure (5) show, that silver element remain at the filler matrix (or not migrate to the interface). While Zn migrate far away the interface. The Ni–Cu phase dominated the interface as show at the figure (4 and 5). The figure (2) showing in clear picture the bonding reaction. The use of BAg-5 filler metal will help to represent a eutectic structure between Ag and Cu. While the use of filler type BAg-7 will not, as clearly be observed in figure (5) the elements Cu and Ni. The figure (6) pointing out to two phases one of them controlled by silver (Ag) phase I, the second should be controlled by copper phase II. The bonding phase should by at the phase II. XRD of this joint explain that in figure (7 and 8) the bonding phase is CuNi. For DCI side, the XRD output show identically between the two type of filler as in figures (9 and 10). The phases that responsible for bond at the cast iron side are Fe3Si, SiC, and the appearing of Fe, Ag, and Cu, which were showily appear at figure (9), which is the close layer to the bonding phase. The bonding phase of NiCu showing about 70Mpa in shear strength while the bonding phase of Fe3Si showing about 40Mpa.
Figure 4. Energy dispersive spectroscopy (EDS) line scan for: a) specimen CI to CI bonded using BAg-5 filler metal, b) specimen CI to CI bonded using BAg-7 filler metal, c) specimen Ni to Ni bonded using BAg-5 filler metal, d) specimen Ni to Ni bonded using BAg-7 filler metal, e) specimen Ni to CI bonded using BAg-5 filler metal and f) specimen Ni to CI bonded using BAg-7 filler metal.
Figure 5. EDS micro-points analyses a) specimen bonded using BAg-5 filler metal, and b) specimen bonded using BAg-7 filler metal.
Figure 6. SEM image of two samples (a) brazed by BAg-5 filler metal alloy, (b) brazed by BAg-7 filler metal alloy.

Figure 7. Layer XRD Pattern bonded by Bag-5 side nickel a) Layer (I) XRD Patterns, b) Layer (II) XRD Patterns
Figure 8. Layer XRD Pattern bonded by Bag-7 side nickel a) Layer (I) XRD Patterns, b) Layer (II) XRD Patterns

Figure 9. Layer XRD Pattern bonded by Bag-5 side cast iron a) Layer (I) XRD Patterns, b) Layer (II) XRD Patterns
4. Conclusion
1. It is possible to use furnace brazing of Ni 270 to Ni 270, CI to CI and Ni 270 to CI with different two filler alloys of Ag-Cu.
2. The side bonding phase for joining nickel by using the two type of filler metal alloy BAg-5 and BAg-7 is the NiCu phase with shear strength about 70 Mpa.
3. The side bonding phase for joining ductile cast iron by using the two type of filler metal alloy BAg-5 and BAg-7 is the Fe3Si and SiC phase with shear strength about 40 Mpa.
4. The searching about moving elements at the joint may help in seeking of the bonding phase.
5. The joining of nickel 270 plate and ductile cast iron by using BAg-5 filler metal alloy shows a eutectic structure at the middle of filler zone, which lead to great affinity between nickel element with copper.
6. Maximum shear strength obtained is 38 MPa when bonded Ni 270 to CI with BAg-5 filler metal and 43 MPa with BAg-7 filler metal.

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