ALUMINIUM BIMETAL STRUCTURE PRODUCTION
BY LOST FOAM CASTING WITH LIQUID-LIQUID PROCESS

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Abstract: Numbers of both ferrous and non-ferrous bimetal productions and applications have been increased due to useful advantages. Bimetal fabrication techniques and procedures are developing and getting various. Liquid metal based techniques are in basic bimetal fabrication methods which have two types; liquid-solid and liquid-liquid processes. Lost foam casting technique can be successfully employed for both liquid-solid and liquid-liquid bimetal composite productions. In this work, A380 and A2014 aluminium alloys were used to produce bimetal structure by conventional lost foam casting with liquid-liquid process. There are two main principles of liquid-liquid process. First, both alloys are joined in liquid phase and solidified and second, crucibles tilting are carried out synchronously at the same time. HB hardness of the cast specimens were measured and micro structure of the joint field were observed.

Keywords: BIMETAL, LOST FOAM CASTING, LIQUID-LIQUID COMPOSITE

1. Introduction

Bimetallic material has been extensively employed as an advanced functional material in many fields because of its unique physical and mechanical properties, which can be fabricated by bonding, similar and dissimilar materials. According to the application, the physical and mechanical properties of constituent metals should be considered for choosing sound metals [1-6].

The Evaporative Pattern Casting process, which employs expanded polystyrene pattern placed in unbonded silica sand, is increasingly gaining popularity in the foundry industry. The great innovative potential of the EPC process was first recognized in the 1980 in the USA and Japan. This process offers many benefits such as flexibility in design configuration, reduced development time, cost and reduction or elimination of machining [7-9].

Xiaofeng et al. were reported a liquid-liquid composite process based on lost foam casting. In their work, bimetal liners from high chromium white cast iron and carbon steel composite were fabricated. Moreover, researchers were worked on Al/Mg liquid-solid bimetal castings with conventional sand mould and lost foam process [10-12].

In this study, fabrication of aluminium bimetal structure with A380 and A2014 alloys is investigated.

Table 1: Chemical compositions of aluminium alloys (wt%)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Fe</th>
<th>Si</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ni</th>
<th>Ti</th>
<th>Pb</th>
<th>Sn</th>
<th>Cr</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>A380</td>
<td>1.0</td>
<td>7.5-9.0</td>
<td>3.0-4.0</td>
<td>0.5</td>
<td>0.30</td>
<td>1.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
<td>Bal.</td>
</tr>
<tr>
<td>A2014</td>
<td>0.7</td>
<td>0.5-1.2</td>
<td>3.9-5.0</td>
<td>0.4-1.2</td>
<td>0.2-0.8</td>
<td>0.25</td>
<td>-</td>
<td>0.15</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
<td>Bal.</td>
</tr>
</tbody>
</table>

2. Experimental Procedure

In the experimental work, conventional process steps of the lost foam casting method were followed. Prismatic foam patterns in dimensions with 60 mm in length, 25 mm in width and 10 mm in height were cut out from an EPS board in the density of 20 kg/m³.

Two identical prismatic foam patterns were joined overlap with 20 mm from one of their ends, by using a thermoplastic adhesive. Also, these patterns were connected to foam sprue parts from other ends. Also the heights of these foam sprue parts are the same. Assembled pattern was coated with special refractory pattern paint (ASK Chemicals Polytop FS 6) and dried 24 hours at room temperature. After coating had dried, pattern was settled into the steel flask and embedded under vibration using loose silica sand with an average grain size of 55 AFS (240 µm).

A2014 and A380 aluminium alloys were melted in two different electrical furnaces using clay graphite crucibles at 730 °C and 830 °C, respectively. Chemical compositions of the alloys are given in Table 1. A380 was poured into the bottom and A2014 was poured into the top part at the same time. Schematic illustration of the casting process is seen in Figure 1.

After solidification, the cast part was got out from the sand and sectioned for metallographic preparation and characterization. Grinding was performed using water cooled silicon carbide papers of 180, 240, 320, 400, 600, 800, 1000 and 1200. Moreover, the samples were polished using Al2O3 and diamond paste. Both optical microscope and SEM analyses were performed.

Also, mechanical properties of specimen were investigated with Brinell Hardness test.

3. Results and Discussion

Lost foam casting with liquid-liquid process is promising method for fabrication of aluminium bimetal structures. During the experiments, A380 casting aluminium alloy was poured at 730 °C because of its high fluidity and A2014 wrought aluminium alloy was poured at 830 °C because of its low fluidity. Also, EPS foam parts in 60 mm length were cut and their contact width for bimetal formation was considered in 20 mm length at the ends. Moreover, A380 aluminium alloy followed long path and A2014 aluminium alloy followed short path. Casting can be seen in Figure 2.
Light microscope images of the bimetal structure can be seen in Figure 3. Typical unmodified as cast microstructure of A380 aluminium alloy is seen. A380 is a hypoeutectic Al-Si casting alloy and eutectic Si needles can be seen clearly. Moreover, α-Al phase is seen clearly in A2014 microstructure. Also, bimetal interface is clear and free from any vacancies.

In Figure 4 SEM micrographs of the bimetal zone is seen in different magnifications. According to SEM images, interface zone includes eutectic Si needles in large amount which comes from

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**Figure 1:** Schematic illustration of the casting process

**Figure 2:** Photographs of the casting

**Figure 3:** Microstructure of cast aluminium alloys and bimetal interface zone with different magnifications
A380 alloy mapping analysis was carried out on the interface zone and result is given Table 2.

EDS mapping analysis has given probable amounts of Al, Si, Cu, Zn and Mg in the interface zone. According to chemical compositions of the A380 and A2014 aluminium alloys, migration of Si from A380 alloy and migration of Mg from A2014 alloy were occurred to interface zone. Also, migration of Cu and Zn were occurred to interface zone from both of the alloys.

Table 2: EDS mapping analysis of bimetal interface zone (wt%)

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>15.619</td>
</tr>
<tr>
<td>Cu</td>
<td>9.754</td>
</tr>
<tr>
<td>Zn</td>
<td>9.265</td>
</tr>
<tr>
<td>Mg</td>
<td>0.945</td>
</tr>
<tr>
<td>Al</td>
<td>Bal.</td>
</tr>
</tbody>
</table>

Brinell hardness tests were carried out on the specimens with 2.5 mm tip diameter and 62.5 kg load. Transition hardness distribution curve between constituent alloys is given in Figure 5.

Average Brinell hardness measurements of A380 alloy, interface and 2014 alloy are 98±1 HB, 100.67±8 HB and 83±2 HB respectively. Hardness value of A380 alloy is higher than A2014 alloy due to the high Si and Cu content. Interface hardness value is higher than A380 and A2014 alloys due to Si needles. Moreover, fine intermetallic precipitates were formed at interface because of rapid cooling during solidification.

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4. Conclusion

Usage and fabrication of bimetal is increasing. Conventional materials cannot provide the properties that service conditions are required. In this regard, bimetals are getting alternative materials instead of the conventional materials. In this study, liquid-liquid process was used to fabricate bimetal. A380 and A2014 aluminium alloys were used in experiments and alloys were connected by lost foam casting process with using synchronous double-crucible pouring method. Specimens were characterized by optical microscope and SEM analysis. Moreover, hardness test was applied to determine the bimetal properties. Characterization studies show that two alloys were connected with a transition zone which is called interface and this zone consist of mixture of both constituent alloys.

5. References


