Analysis of Defects for Aluminium Copper Bimetal Fabricated By Centrifugal Casting

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Abstract—Centrifugal casting proves to be a promising technique for casting of bimetsals. In such process a pouring basin is there connected to a rotating mold of varying speed. The molten metal gets deposited due to the presence of a centrifugal force of the rotating mold. Bimetals can be defined as a combination of two metals which forms a metallurgical bonding between them constitutes a single piece composite. Bimetals found a wide range of engineering applications like in heat covertures, reformers, reactors, condensers, pumps, radiation tube, furnaces and materials. This paper deals with the casting of Bimetal having Aluminium-copper Interface and the defects which is formed due to certain faulty casting methodology adopted which was due to delay in pouring of molten copper after the solidification of aluminum. This has resulted in an improper metallurgical bond formation at the interface. A defect analysis is done to study the quality of interfacial bond. Also, certain steps are outlined which depicts the proper casting methodology that can be adopted for the successful formation of a metallurgical bonding resulting in formation of bimetsals.

Keywords: - Centrifugal casting, Bimetal, Aluminium-copper Interface, Metallurgical Bond, Defect analysis, SEM analysis

I. INTRODUCTION

With the fast development of recent industry some application requires several properties, but pure metal cannot meet the required properties. Bimetals are a combination of two metals or metal alloys, composed of two separate metals joined together these two metals or metal alloys form two layers which make a metallurgical bond between them and established constitute a single piece bimetal. Aluminum has low density therefore light weight. Also aluminum has high strength and excellent resistance to corrosion, superior malleability good thermal and electrical conductivity are amongst aluminum supreme properties while the copper has corrosion resistance good electrical and thermal conductivity. It is also easy to alloy, easy to get fabricated with metals. The aluminum and copper can be fabricated together to form bimetal which has various engineering applications in chemical industries, petrochemicals, power plants, nuclear power plants and metal mining industries (Copper, Iron, Steel) are the most important usage of bimetal pipes which are fabricated with centrifugal casting. In these industries bimetal pipes are widely used for heat covertures, reformers, reactors, condensers, pumps, radiation tubes, furnaces and materials. This research work provides a thorough understanding of the various defects during the production of aluminum, copper bimetal fabricated through vertical centrifugal casting process. The interest of using and studying bimetals is increasing because of the improvement of sorts they add such as wear resistance, corrosion resistance and cost reduction. Centrifugal casting technique is a cheaper casting method for production of bimetallic by using a cheaper material in place of a highly alloyed material. Vertical centrifugal casting is cylindrical type bodies having ring geometry mold is rotated in vertical axis. Vertical centrifugal casting is suitable for those bodies where the diameter is greater than their length. The process is easy and is accomplished by certain simple steps. First outer metal is poured into the rotating mold. After some gap of time second metal will poured in pouring basin to rotating mould. When first metal has lost the fluidity second metal will be poured into rotating mould through the pouring basin. If the second metal poured earlier than the thickness and composition of second metal will be changed. Also, if second metal will poured late than the first metal, then won’t be a good metallurgical bond between them. Second metal is poured into the rotating mold after some time. After solidification of first metal and before pouring of second metal is calculated by the following expression.

\[ D = k \sqrt{t} \]

where D – thickness solidified, k – Solidification constant, t – time.

During the production of Aluminum-copper bimetal some defects have been outlined. Defects like gaseous porosity, shrinkage holes, hot tears, and macro-segregation. Hot tears are observed to be developed in centrifugal castings for which the highest rotation speeds are used. Longitudinal tears occur when contraction of casting combined with the expansion of the mold, generates hoop stresses exceeding
the cohesive strength of the metal at temperatures in the solidus region. Segregation in centrifugal casting is under various forms of segregation thus pushing less dense constituents at the center. Sometimes casting produce zones of segregated low melting point this caused banding. Some defects due to cause by the pouring time delay and faulty casting methodology. These defects highly affect the quality of casting product. Centrifugal casting is relatively free from defects, better mechanical properties, the production rate is comparatively high and less loss of metal in pouring basin compared to conventional sand casting.

II. LITERATURE REVIEW

A proper understanding of defects in the centrifugal casting process has been done by using optical microscope and scanning electron microscopy furnished with EDS system. Investigated that cooling rate increases due to rotational speeds of centrifugal force. Cooling rate increases not only reason of the thin interface but also with increasing nucleation sites result affected the microstructure. EDS analysis shows that interface consists of four discrete layers are Cu2AI, AlCu, AlCu2 continuous layers, Al2Cu precipitates scattering in anomalous eutectic structures and α-Al/Al13Cu anomalous eutectic structure near the Aluminium side. Micro hardness measurements shows that hardness of various phases of Al and Cu decreases for the result of Cu intermetallic phase formation. [5]Experimental investigation of Ti-6Al-4V analyses in the casting defects by vertical centrifugal casting process on graphite moulds, research was done at different vertical centrifugal casting conditions also this investigation shows that this process most suitable for reduction of defect severity. When the mold rotation increases from 0 to 210 rpm, the numerical percentage of defect-visible-specimens start decreasing from 62.4% to 24.8%. When the gravitational coefficient was increased, the quantity of macro pore defects starts decreasing exponentially. But it starts increasing when the mold rotating ratio decreased, more defect is caused when casting was made earlier and longer mold filling path because more inclusions and gas pore will be easily entrapped in alloy melt. So that mold filling process is also influenced the casting process. [6]Fabrication of Al-2Si by centrifugal casting method with different different rotational speed. Investigated that rotational speed affects the final casting. It shows that an optimum speed for reducing the defect in the final cast and found that at lower and extremely high rotational speed, the metal disturbs the position, hence the pattern become irregular. This research also shows that uniform cylinder at optimum speed which is 800 RPM, this optimum speed, the mechanical property of final cast was also improved and forms a fine equated primary alpha-Al grains. At optimum speed, wear rate was reduced and it also decreases more by sliding velocity. [7]Fabricated Copper-Aluminium bimetal by using vertical centrifugal casting and evaluation of Copper-Aluminium interface investigated also optimize metallurgical the interface between the two layers. In the production aluminium copper bimetal two separated furnaces are used for preparation of aluminium melt and copper melt. After that horizontal centrifugal casting used at 800 rpm. During the casting process mold is preheated at 220°C also pouring of second metal time calculated by using chomnief relation. For the microstructures and interface evaluation optical microscope used. Observed by the microscopic images it shows that the bonding percentage of Aluminium -Copper has been increased by decreasing the temperature. The bond percentage found maximum at 200°C and from 700°C to 200°C width has been decreased. SEM type electron microscope used for the analysis of intermetallic phases at the interface and determining the boundary is poly structured or single structure. It was also found that metallurgicalbond
just occurred in length of the tube about 60% to 70 % was interfaced. For the creation of good bond surface of copper should be clean and without oxidise.[8]In this research vertical centrifugal casting used for the fabrication of Aluminium-brass bimetal. First brass bushes preheated at various temperature between 100-400°C and then Aluminium melt with 1.5 and 2.5 melt-to-solid volume ratio casts at rotating speed of 800, 1600, and the centrifugal action of the mold the molten aluminium gets deposited in the 2000rpm respectively. Obtained samples are investigated by using X-ray diffraction analysis (XRD), optical microscope scanning electron microscopy, energy dispersive X-ray spectroscopy. Aluminium-Brass bimetals are successfully prepared by vertical centrifugal casting interface consists of four discrete layers of the Brass side, including first Al3Cu5Zn4, second Al3Cu5Zn3, third Al3Cu precipitates scattering in Al11Zn matrix and fourth α-Al/Al3Cu anomalous eutectic structure near the Aluminium side recorded. At the 1600rpm and 200-300°C preheat temperature range found the optimum result for this bimetal. Also investigated by micro hardness test hardness interface decreases Brass to Aluminium. [9]Fabricated Al-Si alloy and varying the composition of Cu, investigated from various test that what will be the effect of varying amount of Cu in Al-Si alloy. And they found that addition of Cu in Al-12%Si alloy will change the microstructure from rough to fine structure. The mechanical behaviour like (i) tensile strength (ii) yield strength (iii)Vickers hardness is increased while (i) elongation and (ii) reduction area was decreased by increasing the Cu content.[10] In this research investigated the pouring time, shake out time, mold preheat temperature, cooling media and mold rotational speed. Numerical simulation and procast software used for optimization of defects in horizontal centrifugal casting during the production of bimetal rolls.

III. EXPERIMENTAL PROCEDURE

The process of formation of a bimetal can be accomplished by adopting the vertical centrifugal process. The entire flow diagram is depicted in Fig.1. The Aluminium and Copper are first of all heated to their respective melting point temperatures and thus are melted to liquid form. Meanwhile the vertical centrifugal casting machine setup is made ready by preheating the mold to 220°C and coating the pouring basin with graphite. The details about the melting point temperature and the preheating temperatures are given in Figure 2. It is done to prevent sticking of the molten metal to the pouring basin. The process starts with the first of all pouring of the molten aluminium into the rotating mold of the machine. Due to walls of the mold forming a layer which solidifies instantly. The molten Copper is poured into the same after the outer layered aluminium is in semisolid state. It is done so to initialize a good bonding between the aluminium and copper. After the complete solidification of the copper the bimetal is finally prepared. The main challenges that the authors has faced is the pouring of the molten copper right in the semisolid state of the aluminium. It is so because the copper solidifies instantly at a very fast rate.

![Fig.1. Process flow diagram for fabrication of Al-Cu.](image)

After the formation of the bimetal the sample is sent to for testing using optical microscope and SEM type electron microscope for determining the intermetallic phases at the interface and the width of the phases. It can also use for determining whether the boundary is single or poly structured.

Table1. Experimental parameters for bimetallic sample preparation

<table>
<thead>
<tr>
<th>Element</th>
<th>Rotation Speed (rpm)</th>
<th>Pouring Temperature</th>
<th>Mold Preheat Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumini</td>
<td>800</td>
<td>700°C</td>
<td>220°C</td>
</tr>
<tr>
<td>Copper</td>
<td>800</td>
<td>1250°C</td>
<td>220°C</td>
</tr>
</tbody>
</table>
The vertical centrifugal casting machine has 800, 1320, 1980 and 2850 rpm respectively, motor pulley connected to drive pulley.

**IV. RESULT AND DISCUSSION**

Defects present in any casting make the product unacceptable and therefore efforts should be made to either remove it completely or convert it to discontinuity which means defects should be removed to such an extent that the product falls within the tolerance range. In bimetallic casting, the major casting defects are gas porosity, shrinkage defect and pouring metal defect. To study the defects present in the casting and the best way to cast a bimetal, certain testing and evaluation performed. Microstructure and interface evaluation by Optical MicroscopeIn bimetal fabrication, the amount percentage is the most important part to study and thus this evaluation is done. The bonding between metals in centrifugal casting depends upon the rotation speed and pouring temperature. The above image suggests that the bonding percentage is very good and thus the value of the parameters taken for the experiment is up to the mark. During the experiment some values were changed and it showed that less rotation speed and less pouring temperatures do not give good intermetallic bonding which can be seen with naked eyes.

Analysis of Electron Microscope images and EDS

EDS (Energy Dispersive X-Ray Spectroscopy) is done along with SEM (Scanning Electron Microscope) to study the elemental composition of the analyzed volume.

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**Fig.2. Experimental Setup of Vertical Centrifugal Casting**

**Fig.3. Optical Image**

**Fig.4, 5, 6SEM images at X 1500, X2000, X 2500**
The centrifugal casting experiment to fabricate a temperature for the first metal and then pouring second bimetal using Aluminium and Copper is done and following conclusions are drawn. A Bimetal of Aluminium and Copper can be cast using the centrifugal casting method. Casting defects as gas porosity, shrinkage defect and pouring metal defect are the important factors influencing the cast product and can be avoided if metal creates a metallurgical bond with proper quality. If the temperature is too high the intermetallic compounds create at interface between two metal and if the temperature is too low metal oxides glues and cool the second melt and doesn't quiet the surface of two metal and no bond is formed. some factors as mold preheating, controlled pouring of It was found during evaluation of Aluminum-Copper cast metals, rotation speed and solidification time of metals are taken care of. Pouring temperature of metals and rotation speed also influence the bonding of metals at the interface and 800rpm speed and 700°C for Aluminium and 1250°C for Copper can give a good bonding percentage. Effective parameters on the creation of metallurgical bonding between two metals in centrifugal casting were product that in interface shrinkage voids, metal oxides and pure metal bonding region exist, therefore for creating appropriate metallurgical bonds between Aluminum-Copper in centrifugal casting the surface of Copper should be clean without oxides, and
also formed in an oxygen free environment. Evaluated among different parameters specific VI.

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**References**


