STUDIES ON ALUMINIUM-SILICON EUTECTIC ALLOY CASTING AND DESIGN APPROACH OF ITS GATING SYSTEM

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ABSTRACT

LM-6 alloy, an eutectic alloy of aluminium and silicon is widely used in automobile industries and aircraft industries due to its high strength to weight ratio, high wear resistance, corrosion resistance etc. In this project work, to improve the mechanical properties of LM-6 alloy such as tensile strength, hardness and percentage elongation, modification treatment is carried out along with grain refinement, fluxing and degassing. Modification is a treatment of metal in molten condition which leads to the formation of fine grain structure improves the mechanical properties of the metal. Therefore LM-6 alloy can be strengthened by modification. Also, comparison of these properties of LM-6 alloy with modification and without modification are carried out and methods for the proper design of gating system and riser for the casting using Modulus method are taken up. Also flowchart for this casting design for computer programming are developed. Also defects analysis is made on the casting section and is reported. Experimental investigation reveals that modification treatment improves the mechanical properties of LM-6 alloy.

Keywords: Sand Casting; LM 6 Alloy; Properties.

I. INTRODUCTION

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or taken out of the mold to complete the process. Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material.

All industries, especially aerospace and automobile industries are presently looking for light metals or alloys having good mechanical properties such as high strength to weight ratio, ductility,
hardness, corrosion resistance, creep resistance etc. So attempts are continuing to improve these properties to the light metals such as Aluminium alloys. Aluminium has a density of 2.7g/cc and Silicon has 2.3g/cc. Therefore by using alloys of these two metals, there will be no weight loss. It is one of the main advantages of these alloys. Aluminum-silicon alloys are characterized by their low specific gravity which can vary slightly alone below the specific gravity of pure Aluminum depending on their major alloying elements. In addition to their light weight, other advantages of Aluminum Casting alloys include creatively low melting temperature negligible gas solubility with the exception of hydrogen, excellent castability especially near the eutectic composition of 11.6 percent, good machinability and surface finish, good corrosion resistance, and good electrical and thermal conductivity. Aluminum-silicon eutectic alloys having medium strength to weight ratio with relatively low hardness and elastic limit.

In this thesis work, because of these advantages LM 6 alloy which is a hypoeutectic alloy of Aluminium-Silicon alloys having 11.6% Si. Also, an attempt has been made to improve the strength and hardness of the Aluminum-silicon eutectic alloy, through temporary modification by Alkali metals such as Sodium. The microstructure of Aluminum silicon alloys depend strongly on the composition and the casting process. Unmodified aluminum –silicon eutectic alloy contains the silicon phase in the form of large plates with sharp sides and ends (Acicular silicon) Chemical modification dramatically alter morphology of the eutectic silicon. Grain refiners are added to Aluminum-silicon alloys to produce a fine equiaxed grain structure. Grain refinement improves resistance to hot tearing, decreases porosity and increase mass feeding. As a result, a grain refined Cast part is more homogeneous with better casting soundness and increased mechanical properties. This work concentrates on design of its gating system also.

Aluminum –Silicon eutectic alloys are suitable for engine parts (manifolds, casings), Pistons of I.C. engines, pulleys and sieves, marine castings, switch boxes and generally where corrosion resistance and ease of castings are essential. They can be sand cast, die cast both gravity and pressure-and are very suitable for low pressure casting.

II. EXPERIMENTAL DETAILS

A. Equipments Used

1. Furnace for melting
   Electrically Operated high temperature furnace is used.
   The maximum temperature of furnace is 1150°C and the thermocouple is K type sensor.

B. Materials used

1. Green sand
   LM-6 alloys can be cast satisfactorily in green and moulds with natural mounding sand. It is having permeability and fairly low green strength, which is best suited for these alloys. The properties of the moulding sand used are as follows.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Fineness</td>
<td>AFS NO: 60</td>
</tr>
<tr>
<td>Clay content</td>
<td>5%</td>
</tr>
<tr>
<td>Moisture</td>
<td>6%</td>
</tr>
<tr>
<td>Green Compression strength</td>
<td>1kg/cm²</td>
</tr>
</tbody>
</table>
2. Chemicals Used

The following chemicals are added to obtain the defect free castings.

- Coverall flux (containing various salts like alkalies chlorides and alkali fluorides) is used to prevent oxidation of molten metal.
- Grain refiner are used to produced a fine grain structure. Grain refinement improves resistance to hot tearing, decreases the porosity and increases mass feeding. In this work, ‘Nucleant-2’ grain refiner is used.
- Degassing agents are added to the alloy to remove the dissolved gases.

3. Modifier used

In this experiment, only sodium modifier is used.

Sodium modifier: The process of adding modifier to a melt involves the dissolution of the modifying agent and its subsequent dispersal throughout the body of melt. Commonly, NaF salts or NaCl salts are used. The modifiers to be added after grain refinement and degassing at about 710°C and to be stirred gently for a minute and leave the melt in the crucible for 3 to 4 minutes to settle down before pouring into the mould.

C. Processes Involved

1. Modification

Modification is such a treatment of metal in a liquid state which leads to the formation of fine crystal grains for the improvement of mechanical properties of the casting. Modification also reduces the tendency to hot cracks and homogenize the castings. Of all of these sodium is the most effective in producing a fine, uniform, fibrous structure.

2. Fluxing

Purpose:
- To remove dissolved hydrogen from the melt.
- To separate dross from the melt.
- To entrap dross

3. Grain Refinement

Grain refiner produces fine grain structure for these alloys. The grain refinement improves feeding characteristics and fluidity. This treatment reduces the incidence of shrinkage unsoundness in the castings and other defects.

4. Degassing

In conventional melting practices it is not possible to prevent gas absorption completely into the molten metal. Gas absorption can be reduced by taking measures like (1) using dry tool (ii) preheating the charge and (iii) pre heating the flux compounds. To remove the absorbed gases mainly hydrogen which is generated through decomposition of moisture, degassing operation has been carried out with degasser 190 (hexa dichloro ethane). Since degassing not only removes the
harmful gases but also removes sodium as well and hence destroys modification. So, modification is proceeded by degassing.

D. Pattern Used

Test bars are made up of wood to study the properties of castings. These are moulded in green sand and pouring temperature is maintained at 710°C. At the start of the pouring the mould is held at an angle about 45° C from vertical and then brought to the upright position as the head fills pouring is carried out steadily and over a period not less than 10 seconds to avoid turbulence. The pattern is made in accordance with British standard specification and universally adopted to study the properties of as cast castings. Design of test bar pattern is such that the enlarged portion will act as a runner during pouring of molten metal into cavity. It will also work as riser during shrinkage during solidification.

E. Experimentation

There are two stages involved:

1. Stage 1
   This is the initial stage at which LM-6 alloy is melted and adding enough amount of flux. This molten metal is grain refined and degassed after adding enough amount of flux. When the required temperature is obtained it is poured into the mould box. After the solidification, the casting is taken out and tested for various properties. These properties are taken as the reference. This is the stage for unmodified LM-6 alloy.

2. Stage 2
   In this stage, modification is carried out by varying the amounts of modifying agent. Modification is carried out for modifying compound amounts ranging from 0.5 to 2 percent by weight of modifying agent. Modifying agent consists of sodium salts is added to the molten metal just before pouring into the moulds. The amounts are 0.50, 1.0, 1.5, 2.0% by weight. Metal with varying amounts of modifier is poured at 700°C to the mould cavities made of green sand and after solidification the castings are machined to get different test specimens like tension test bar, specimen for hardness test and percentage elongation are obtained from this tension test specimen.

F. Tests

There are three tests carried out.

1. Ultimate Tensile strength is found out using universal testing machine. Tension test specimen is obtained from test bar casting which is machined as per BS1490 specification.
2. Percentage elongation is also found from tension test specimen using universal testing machine.
3. Brinell hardness number is found out using Brinell hardness test. Specimen is obtained by cutting a section from test bar specimen. It is denoted by BHN and given by the equation:

   \[ BHN = \frac{2P}{\pi D(D^2-d^2)^{1/2}} \]

   \( P = \) applied load=250kgf, \( D = \) diameter of indenter =5mm, \( d = \) diameter of indentation in mm
G. Method of Designing gating system and risering using Modulus method

According to Chvorinov’s rule, the sections of a casting which have a higher modulus (volume: surface area ratio) will freeze last, while those sections with a lower modulus value will freeze earlier.

\[(V/A)_{\text{riser}} > (V/A)_{\text{casting}}\]

H. Defects in Test bar casting

A casting defect is an irregularity in the metal casting process that is very undesired. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated. They are broken down into five main categories: gas porosity, shrinkage defects, mold material defects, pouring metal defects, and metallurgical defects. The shrinkage defects involved are pipes, caved surfaces. Gas porosity defects include blow holes, pin holes, micro and macro porosities. Finally defects in this section are found out.

III. RESULTS AND DISCUSSIONS

I. The results are shown in table 1:

<table>
<thead>
<tr>
<th>Properties</th>
<th>% by wt of Na (Modifying agent )</th>
<th>Unmodified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>1.00</td>
</tr>
<tr>
<td>Tensile Strength in N/mm²</td>
<td>79.72</td>
<td>115.53</td>
</tr>
<tr>
<td>Hardness (BHN)</td>
<td>51</td>
<td>53</td>
</tr>
<tr>
<td>Percentage Elongation in %</td>
<td>3.9</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Table 1: Properties of LM 6 alloy

1. Strength

From experiments conducted without modification, it is observed that the optimum ultimate tensile strength of unmodified alloy is found as 68.10 N/Sq.mm. From the experiments with modification the ultimate tensile strength is found increasing to a maximum of 131.26 N/Sq.mm at 1.5 per cent by weight sodium modifier. This increase is a very significant one, need for components for engineering applications. Table 1 gives these results and figure 1 shows the relation between percentage of sodium modifying agent and ultimate tensile strength in N/mm².
2. Percentage elongation

The values obtained are given in table 1 and the figure 2 shows the relation between percentage by weight of Na modifying agent and % elongation. A similar variation is also observed for percentage elongation and it is noted that percentage elongation is 2.15% for unmodified alloy and after modification the maximum value is found to be 7.8 percent at an addition of 1 percent by weight of sodium modifier.

3. Hardness

The values observed are given in table 1 and the relation between percentage by weight of sodium modifying agent and hardness in BHN is shown in figure 3. From the experiments, Brinell Hardness for unmodified alloy is found to be 42 BHN (5 mm diameter ball, 250kgf load) and for modified alloy is 57 BHN at 1.5 percent by weight sodium modifier.
4. The defects found in casting section are blowholes. Modification reduces the defects in castings. It is evident from the figure 1 that as strength increases defects are found to be less in number. After 1.5% of modifier addition, no effects are analysed because after 1.5 %, sodium acts as filler material.

5. Method of designing gating system and risering using modulus method are reported.

IV. CONCLUSIONS

From the experiments conducted to study the effect of modification on the mechanical properties of LM-6 alloy, following conclusions are made.

- Ultimate tensile strength is max at 1.5g/kg modifier addition and after that it decreases. Therefore modification increases the strength.
- Brinell hardness value is max at 1.5g/kg for modified casting and after that it decreases.
- Percentage Elongation is max at 1g/kg and after that it decreases.
- Methods for designing the gating system and riser using Modulus method are reported.
- The defects that are found on the casting section are identified.

Therefore, it is concluded that the modification treatment improves the mechanical properties of Aluminium-Silicon Eutectic alloy and reduces the defects occurred in casting.

REFERENCES