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Research Article

STUDIES ON ALUMINUM SILICON EUTECTIC ALLOY SUBJECTED TO MODIFICATION AND VIBRATION USING MECHANICAL STIRRER

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ABSTRACT

LM-6 alloy is an eutectic alloy of aluminum and silicon as major constituents. This alloy contains 10 to 13% by wt of silicon. This is widely used in automobile and aircraft industries, due to its high strength to weight ratio, excellent corrosion resistance and least expansion nature. These alloys are best suitable for large, intricate and thin walled castings in sand and metal moulds.
Modification is a chemical process adopted to strengthen this alloy. Sufficient literatures are not available to enlighten us the properties of this alloy with modification and modification with vibration using a mechanical stirrer. So the present work is carried out to study the changes in properties of this alloy by modification and modification together with vibration using a stirrer. Stirring is done before pouring in to the mould. Sodium is used as modifier.

Test bars are cast at different conditions and compositions and their properties such as ultimate tensile strength, hardness, and microstructure are studied. All the test bars are made according to British standards. Test results reveal that modification results an overall improvement in the properties. Further vibration through stirring improves the mechanical properties. Stirring time and speed of stirring are also influence the strength of LM6 alloy. Microstructure analysis reveals that fibrous structure is predominant in modification and grain refinement is predominant in stirring.

INTRODUCTION

All industries especially aircraft and automobile industries are presently looking for light metal or alloys having high strength to weight ratio and creep resistant properties. Attempts are still continuing to strengthen these light metal or alloy by different means such as modification, heat treatment, work hardening, grain refining and also by using different casting techniques.
Aluminum alloys are getting popular in high strength to weight ratio applications. LM6 alloy is eutectic alloy of aluminum and silicon. This is widely used in automobiles industries and aircraft industries, due to its high strength to weight ratio, excellent corrosion resistance and least expansion nature these are the best suited for the manufacturing automobile components like piston cylinders and manifold....etc and are also suitable for large intricate and thin walled castings.

In this thesis work an attempt has been made to improve the properties of LM-6 alloys modified with sodium and using vibrations. vibration are produced by using a stirrer. Stirring of molten metal has been done before the solidification of molten metal take place. LM-6 alloy is a eutectic alloy contain 10 - 13% by weight of silicon. This Al-Si alloys can be sand cast, die-cast and suitable for low pressure casting.

Present work is carried out to study changes in the properties of the LM6 alloy with time and speed of stirring with modification.

LM6- Al-12Si

The aluminium-silicon alloys possess exceptional casting characteristics, which enable them to be used to produce intricate castings of thick and thin sections. Fluidity and freedom from hot tearing increases with silicon content and are excellent throughout the range. The resistance to corrosion is very good. LM6 is suitable for Marine 'on deck' castings, water-cooled manifolds and jackets, motor car and road transport fittings; thin section and intricate castings such as housing, motor casings and switchboxes; for very large castings, e.g. cast doors and panels where ease of casting is essential; for chemical and dye industry castings, e.g pump parts; for paint industry, food and domestic castings.(1)

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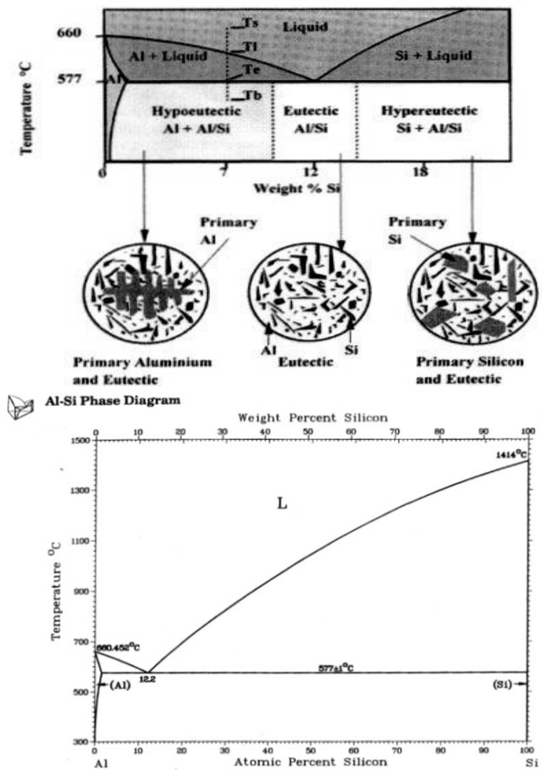

Figure 1 phase diagram of Al-Si

Table 1 Chemical composition of LM6 alloy

BS1490	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti
LM6	0.1	0.10	10.0-13.0	0.6	0.5	0.1	0.1	0.1	0.05	0.2

Mechanical properties of Al–Si casting alloys depend not only on their chemical composition but are also significantly dependent on micro-structural features such as the morphologies of the Al rich α-phase and eutectic Si particles.
The mechanical properties of the Al-Si alloy are dependent on the size, shape and distribution of eutectic and primary silicon particles. Like small, spherical, uniformly distributed silicon particles enhance the strength properties of Al-Si alloys (3).

It may be observed that as the amount of silicon in the alloy increases, the strength properties of Al-Si alloys also increase up to the eutectic composition, the hardness increases and the elongation (%) decrease continuously with increasing silicon content (5). This may be largely attributed to the size, shape and distribution of silicon particles in the cast structures up to the eutectic composition. Silicon is present as fine particles and is uniformly distributed in the structure, and hence the strength properties increase. However, when the primary silicon appears as coarse polyhedral particles, the strength properties decrease with increasing silicon content, but the hardness goes on increasing because of the increase in the number of silicon particles (2).

Experiment Details

This thesis analyse the variation on mechanical properties with the stirring action of molten metal, grain refining and modification in LM6 alloy. In the first stage LM6 alloy test bar is casted with and without sodium modifiers and in the next phase of project effect of vibrations on mechanical properties are analysed. Vibrations are produced by using a stirrer. Different vibrating conditions are achieved by varying speed and time of stirring.

The experiment is carried out by varying the stirring time and speed on molten metal before pouring in to the mould. Variation in Mechanical properties and microstructure are studied under each condition in detail. These variations are compared with stirring time and speed. Variation in microstructure level also analysed using electron microscope.
In this first stage the degassed, grain refined and modified molten metal is poured directly into the mould without any stirring.

In second stage the molten metal is hand stirred by using a clay coated (to withstand the temperature) hand stirrer

In third stage the molten metal is stirred by using an electric stirrer .which is run by an electric motor. The time of stirring is varied up to 7min after that the liquid metal starts to solidify. Speed of the stirrer also varied at different stirring time. The test bars produced by different condition is studied for tensile strength hardness and microstructure.

Melting Procedure

1. The crucible is heated and raw materials in the form of ingots are charged As soon as the ingot reaches the pasty condition, cover flux (coveral-2) is sprinkled over it with 5gm/kg
2. The reminder is charge is added and melting is continued by keeping the protective covering flux intact as much as possible
3. When the metal temperature reaches 760 ^{0}c then remove the crucible from the furnace. The melt is then degassed and grain refined on falling temperature.
4. Remove the Surface flux cover to one side and through the cleaned area the degasser tablet is plunge to the bottom of the melt, 0.25%by weight DEGASSER 190 and hold down until the bubbling action ceased –usually 2-3 minutes. The dissolved gases are removed by adding degasser
5. Rabble the surface flux cover into the surface of the melt and skim cleanly and sprinkle COVERALL 5g /kg
6. After degassing , grain refining is done by using NUCLENT 2 tablets with 125g /50kg
7. Modification of the grain structure is done by adding sodium. The flux cover layered at top are then removed and the hot metal is poured in to the mould

Modification

Modification is a treatment used with hypoeutectic or eutectic aluminium-silicon alloys. Modification leads to an extremely high refinement of the aluminium-silicon eutectic during solidification. Aluminium-silicon alloys usually contain a small amount of phosphorus, which produces a granular structure with the formation of aluminium phosphate. Aluminium phosphate stimulates the crystallisation of primary silicon, which is then present in the structure in the form of polyhedral platelets. By contrast, during the classical modification using sodium, the sodium reacts with the phosphorus in the melt to form sodium phosphate.

Modification leads to a significant improvement in strength and ductility, Sodium is one of the most effective modifiers.

Additives

Along with modifying agents, we used other additives to get sound casting. These are Coverall flux (containing various salts likes' alkalis' chlorides and alkali fluorides) is used to prevent oxidation of molten metal.

Grain refiner is used to produce 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. In this work, 'Degasser 190' tab is used (2)

Fluxing

Mixtures of various salts which is used as cover fluxes forms a layer on the molten liquid protects it from oxidation and reaction with gases in atmosphere. Alkaline chlorides and various fluorides constitute the composition of Cover fluxes.

Degassing

The Degasser in the shape of tablet is added to the hot metal to prevent the gas absorption in it. The degasser contains chemicals in it decomposes and release gas bubbles in the hot metal. The most popular degasser is hexachloethanec2cl2 (Degasser 190) which are quite suitable for small melts.(2)

Grain Refinement

In the present work grain refining has been done with master alloy consisting of Aluminium, Titanium and Boron. From the studies it is clear that a greater number of nuclei will allow more grains to form resulting in a fine grain size. Hence addition of effective nuclei is done by chemical grain refinement. Titanium diboride and Titanium aluminide which are added to the hot metal soon start the formation of Aluminium grains. Thus this grain refinement provides fine porosity, shrinkage distribution and reduces hot tearing. The grain refiner is added at a rate of 2.5gms/kg.

Figure 2 pouring of molten metal

Pouring Molten Metal

Place the Mould in a sand bed for pouring molten metal. In this project work Al-Si Eutectic alloy is used as molten metal. Molten metal treated with chemicals and modified with sodium is poured in to the mould cavity through the runner, in stir casted test bars the molten metal in the crucible is stirred before pouring

Test Bar Preparation

Test bar pattern and rectangular box is made according to ASTM specification. Top portion of the test bar act as runner Fig shows the test bar with full dimensions. The enlarged head will act as riser during solidification and as runner pouring and compensate the volumetric shrinkage (9).

Figure 3 Test bars

RESULTS AND DISCUSSIONS

Test bar castings have been produced with by varying the stirring time and speed. Stirring is done before pouring to mould. Test bars are also produced with and without modification to study the effect of modification. The details of investigation are given below and discussed.

Tensile Strength

Tensile strength is measured by using universal testing machine (UTM). Load is applied on the test bar and failure of specimen will occurs at ultimate tensile load. Test bar for tensile test are made as per the ASTM standard. Tensile strength varies with stirring time and speed. Tensile strength increased with the time of stirring increasing.

In unmodified Al-Si alloy, silicon is in the form of plates like structure with sharp edges. So whenever there is a formation of crack, it will propagate at a faster rate due to additional load.

By treating the alloy with modification silicon structure become fibrous. Fibrous structure of silicon contributes higher ultimate tensile strength and hardness.

Due to agitation by stirring cause wavy nature of metal flow results in grain refinement due to quick formation of seed nuclei in several sites.

This is in turn brings grain refinement and thereby increase the tensile strength. With increase in stirring time and speed ultimate tensile strength also increases.

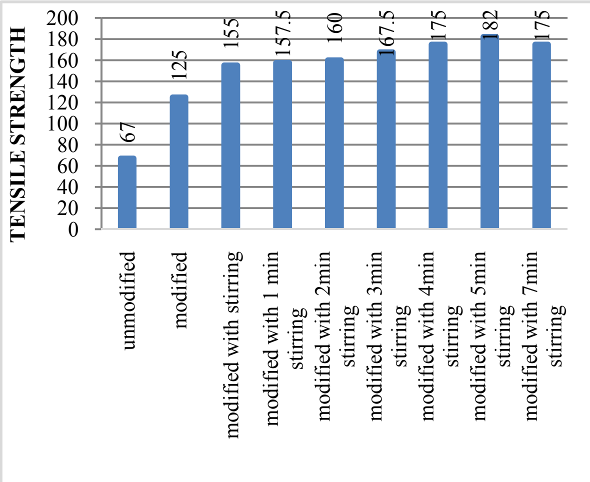

Figure 4 Graph of tensile strength variation with stirring time.

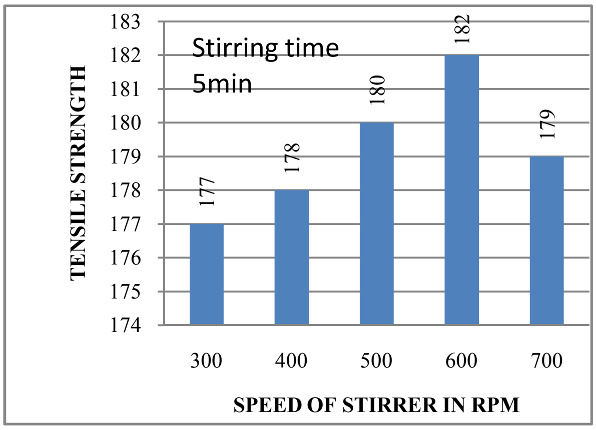

Figure 5 variation in tensile strength with speed

Hardness

Rockwell hardness number for the specimen is checked with 1/16" steel ball indenter. The average value is taken and graph is plotted. Modification of metal with sodium improves hardness about 30%. Hardness number increase with the time of stirring action up to a limit. Stirring improves the hardness up to 5min and it decrease at 7min it may due to solidification. 5min stirred test bar shows the maximum hardness.

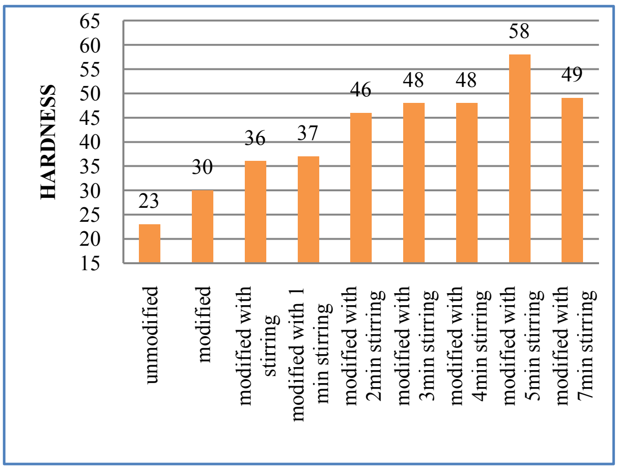

Figure 6 graph of hardness variation with stirring time

Microstructure

From microstructure analysis, it is found that in unmodified form silicon appears as course flakes as shown in fig:7 although modification does not actually refines the grain size significantly. Modification breaks up this needle like structure within the grains and enables the fine fibre of silicon to segregate out of the aluminum.

In unmodified LM6 alloy silicon dendrites are present unevenly and it contains larger grains compared to modified alloy. When the stirring action of the molten metal increases the grains are getting finer and equiaxed. Silicon particle are uniformly distributed over the metal. In modified LM6 casting dendrites of silicon particles are broken up into small particles as shown in fig 8. When the stirring time increases fine grains of equiaxed shape is produced as shown in fig 9. Further increase in stirring time increases grain refinement as shown in fig 10 and fig 11.

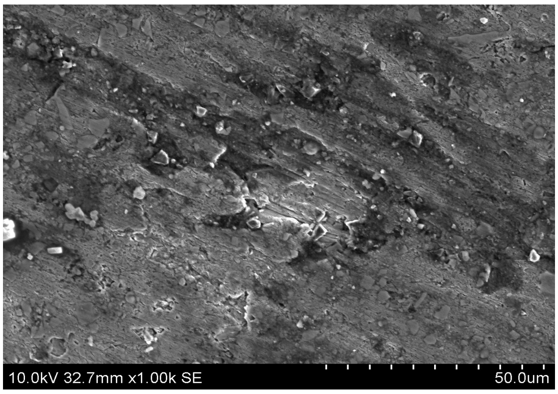

Figure7 Unmodified casting (plate like structure).

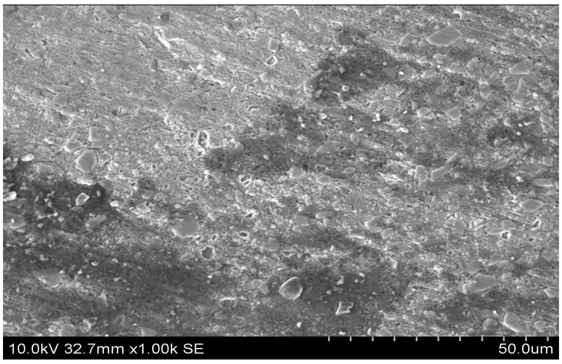

Figure8 Microstructure of LM6 alloy modified with sodium (Fibrous structure)

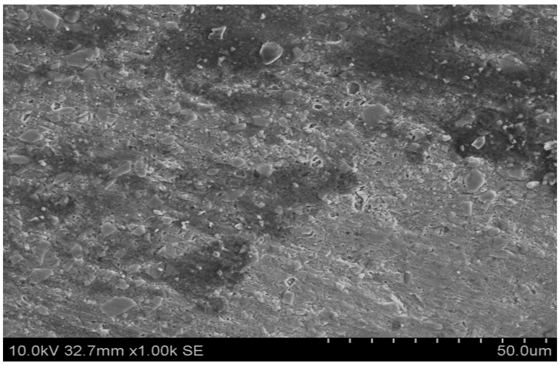

Figure9 1 min stirr casting

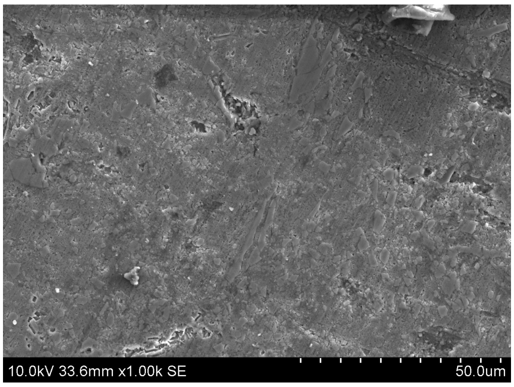

Figure 10 2 min stir casted specimen

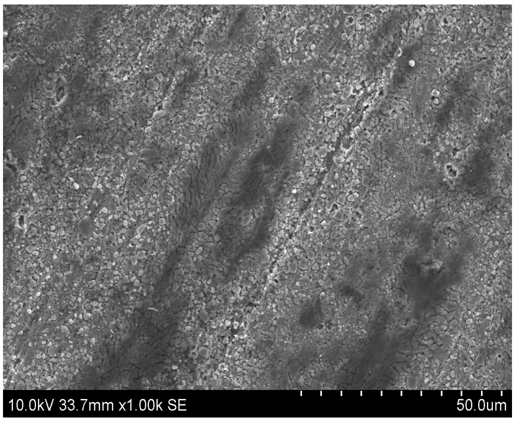

Figure 11 4 min stir casted specimen

Microstructure analysis reveals that fibrous structure is predominant in modification and grain refinement is predominant in stirring.

CONCLUSIONS

Mechanical properties and microstructure of the LM6 alloy under modification and subjected to mechanical vibration using stirrer are analysed and following are the conclusions.

1. Modification treatment with sodium compound increases all properties such as UTS, toughness, hardness.
2. When stirring time increases the mechanical properties are also improved and finer grains are obtained.
3. Modification and stirring enhances tensile strength and hardness. It is found that stirring action on the metal cause fine equiaxed grains and silicon particles are distributed uniformly.
4. Stirring time and speed of stirring also influence the mechanical properties of LM6 alloy
5. Microstructure analysis reveals that fibrous structure is predominant in modification and grain refinement is predominant in stirring.

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