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Study of Machinability and Corrosion Behaviour of Al-Si-Mg Alloy Treated With Master Alloys

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Abstract: Heat treated aluminium Al-Si alloy is widely used in the area of automotive, military, marine, electrical, food and chemical industries. This alloy exhibits high strength property which finds its applications in the corrosion resistance scenario. But the alloy possesses poor mechanical properties and coarse grain structure in as-cast condition. For aluminium castings the properties mainly depend on the microstructure, it is very important to achieve a fine grain structure. Formation of fine equiaxed grains mainly depends on solidification rate, addition of master alloys (Grain refiners), melt agitation and heat treatment. This research work investigates the combined effect of addition of 0.5% of Al-10Ti, 0.2% Al-10Sr and T6 heat treatment on the Machinability and corrosion property of LM25 alloy casting. The properties assessed are Hardness, Machinability, and corrosion rate and microstructure examination. It has been found that Machinability and corrosion properties of LM25 alloy casting have been considerably improved on subjecting the alloy to combined effect of addition of 0.5% of Al-10Ti, Al-10Sr and T6 heat treatment.

***Keywords*: LM25 alloy, Grain refinement, Heat treatment.**

I. INTRODUCTION

Aluminium alloy constitute a significant proportion of lightweight metals used in industry. Al-Si alloys are essential to the automotive, aerospace, marine and engineering applications. Al-Si alloy possesses good physical and mechanical properties. These alloys are light in weight, offers good corrosion resistance, easy to machine, heat treat treatable, excellent castability and have good recycling possibilities [1]. Mechanical properties of these alloys mainly depend on size, shape and distribution of Si particles and Al grains. Al-Si alloy in as cast condition produces coarse α-Al dendrites and needle like eutectic silicon. It is a well known fact that fine equiaxed grain structure gives better mechanical properties and reduces defects in the casting[2]. Fine equiaxed grain structure can be obtained by adding master alloys to the melt in the foundry process [3].

LM25 alloy used in this study is hypoeutectic aluminium. The liquid us temperature of the alloy is 614°C and the solidus temperature is 554°C. The primary aluminium dendrites start to form at 614°C and the binary Al -Si eutectic at 574°C. The LM 25 alloy contains 50 vol.% eutectic phases . The final microstructure is largely determined by eutectic reaction . Eutectic reaction occurs at 574°C as a binary reaction, which results in formation of coarse irregular plate like silicon [1]. This irregular coarse plate like silicon exhibits poor mechanical properties. By adding Na, Sr and Sb in small quantities it is possible modify plate like silicon into fine globular silicon. Consequently exhibiting better mechanical properties [4-9]. Also T6 heat treatment has a positive effect over the mechanical properties including machinability and corrosion resistance [10-13]. Thus an attempt has been made to study the combined effect of addition of Al-10Ti grain refiner, Al-10Sr modifier and T6 heat treatment on Hardness, machinability and corrosion properties of LM25 alloy.

II. EXPERIMENTAL DETAILS

A. Experimental procedure

Composition of alloy used for the work is as follows

Table 1: Composition of LM25 alloy used for the present work

Content	Al	Cu	Mg	Si	Fe	Mn	Ni	Pb	Sn	Ti	Zn
Percent	Rem	0.012	0.380	7.225	0.222	0.024	0.050	0.021	0.013	0.005	0.008

LM25 alloy was melted in an electrical resistance melting furnace to a temperature of 770°C. Degassing was carried out using commercially available Hexachloroethane tablets. Dross was skimmed off and then clean molten metal was transferred to the preheated mould. Mould used for casting process was cylindrical in shape with cross sectional area 20mm dia x 120mm length made up of EN-19 steel. Following treatments were carried out on the molten metal in different stages:

- Without the addition of grain refiner and modifier and without heat treatment. i.e As- cast.
- 0.5% of Al-10Ti grain refiner and 0.2% of Al-10Sr modifier was added.
- Addition of above master alloys in conjunction with T6 heat treatment.

B. T6 heat treatment
Heat treatment process was carried out as per ASTM B917-12 specification [14]. The solution treatment was carried out at 540℃ for 6 hours followed by quenching in still water maintained at 80℃. Then artificial aging was carried out at 155℃ for 5 hours followed by air cooling.

C. Specimen preparation for Microstructure studies
Specimen for microstructure study was prepared as per ASTM E407-2007 specification [15]. A specimen of 18mm height was cut and one surface of the specimen was polished using belt grinder. A series of waterproof emery papers with increasing fineness number to remove the scratches present on the surface. Final polishing was done on a disc polisher using alumina powder until the mirror finish was obtained. The polished specimens were washed in soap solution and distilled water. The specimens were etched using keller's agent for about 2min and the specimen is taken to optical microscopy.

D. Hardness test
Hardness of the LM25 alloy was assessed using Brinell hardness testing machine as per ASTM E10-12 standard [16]. Cross sectional are of the specimen used for this test was 18mm dia x 15mm depth.

E. Machinability test
Experimental work was conducted on Lathe machine. 40mm dia x 100mm length specimen was used for machinability test. The tool and coolant used was Carbide tool and kerosene oil. In this present work Speed, feed and depth of cut were the 3 parameters chosen as the most influencing parameters of cutting force and surface roughness.

F. Corrosion test
Corrosion test was conducted as per ASTM G31-72[17]. 18mm dia x 15mm depth specimens were used for the corrosion test. Salt immersion test was conducted. Hydrochloric acid (HCl) was chosen as the corrosive environment. The specimens were completely immersed in the above corrosive environment and it is weighed after every 24 hours for 4 days.

III. RESULTS AND DISCUSSION

A. Microstructure studies

Figure 1a, 1b and 1c shows the microstructure of LM25 alloy in the absence of grain refiner, modifier and T6 heat treatment. From the figure it can be seen that in the absence of Grain refiner, modifier and T6 heat treatment, the alloy consists of large dendritic structure of α-Al along with uneven distribution of coarse, acicular eutectic silicon in between

Figure 1b shows microstructure of LM25 alloy treated with 0.5% of Al-10Ti grain refiner and 0.2% of Al-10Sr modifier. In the presence of above master alloys a structural change from coarse columnar Al grains to fine equiaxed α-Al can be seen from the structure. Also it can be seen that the eutectic silicon are more even distributed with fibrous structure as compared with the as-cast alloy. Segregation and porosity was not seen in the structure.

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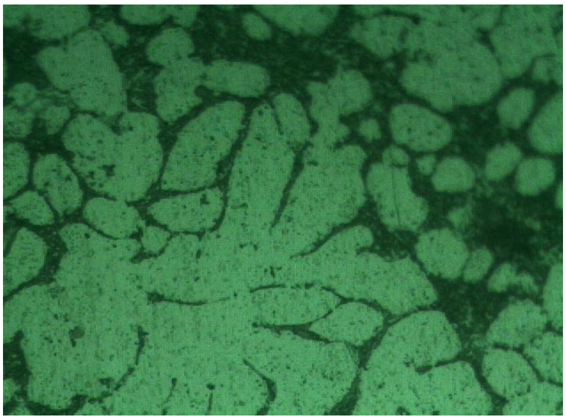
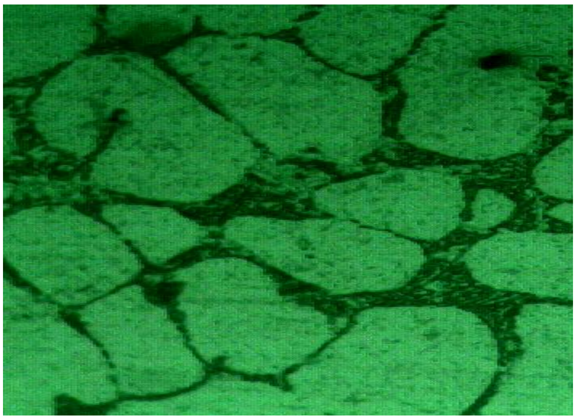
Figure 1c shows the microstructure of alloy subjected to 0.5% grain refiner, 0.2% modifier and T6 heat treatment. From the figure it is clear that the grain size of aluminium is further reduced and eutectic silicon is more fibrous and spherical in shape.

Fig. 1a As-cast specimen **Fig. 1b Grain refined and modified**





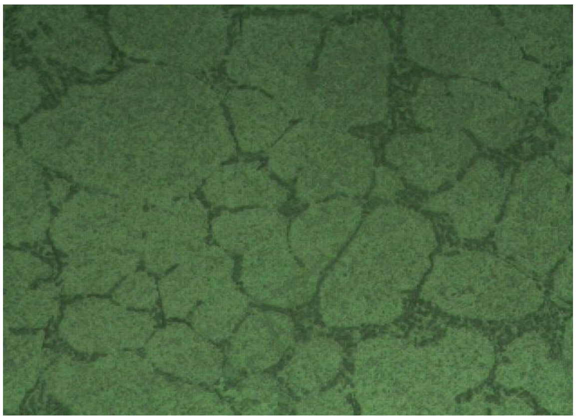


Fig. 1c Grain refined, modified and T6 heat treated

Fig.1 Microstructure of the alloy subjected to various treatments at 500x magnification

B. Hardness test

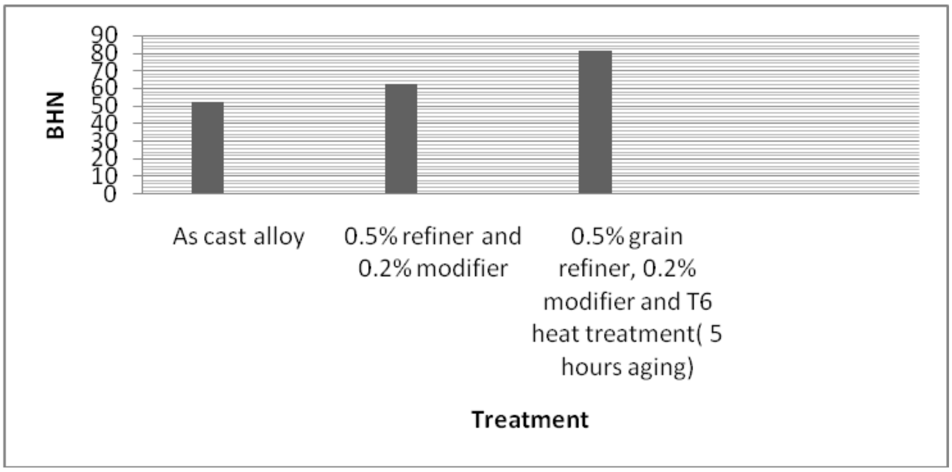


Fig.2 BHN V/s type of treatment made

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Bar chart shows the comparison of hardness values of untreated alloy, alloy treated with 0.5% grain refiner and 0.2% modifier and alloy treated with 0.5% of grain refiner, 0.2% modifier along with T6 heat treatment. There is an improvement of 19.3% of hardness of the alloy with the addition of grain refiner and modifier. Also 56.96% improvement in hardness was observed when the alloy is subjected to simultaneous grain refinement, modification and T6 heat treatment.

C. Machinability

The ease with which a metal can be machined to an acceptable surface finish is generally known as machinability. Commonly used machinability index is tool life, cutting force, power consumption, temperature and surface finish. In the present work surface roughness and cutting force was used as machinability index.

Figure 3a, 3b and 3c shows the effect of turning speed, feed and depth of cut on cutting force of as cast, refined and modified samples and refined, modified and T6 heat treated samples. At all the speed, feed and depth of cut, the cutting force observed was lower in Grain refined, modified and T6 heat treated samples than that of as cast samples. It indicates higher machinability in grain refined, modified and T6 heat treated samples. As cast alloy has Coarse α-Aluminium grains and needle like eutectic silicon. Therefore while turning, higher cutting force was required to machine these hard constituents in the as cast material. Refinement of α-aluminium and eutectic silicon led to requirement of lower cutting force while machining.

One measure of turning process quality is the surface finish. Therefore, surface roughness was considered as another parameter to judge the machinability. Figure 4a, 4b and 4c shows the effect of turning speed, feed and depth of cut on surface roughness of as cast, refined and modified and refined, modified and T6 heat treated samples. Continuous chips were observed in as cast specimens and discontinuous chips in grain refined, modified and T6 heat treated alloy. It is reported that continuous chips results in poor surface finish and discontinuous chips results in good surface finish.

Highest surface finish was observed for the refined, modified and T6 heat treated samples, whereas surface finish of refined and modified sample was in between as cast and refined, modified and T6 heat treated sample.

Fig. 3a Force V/s `

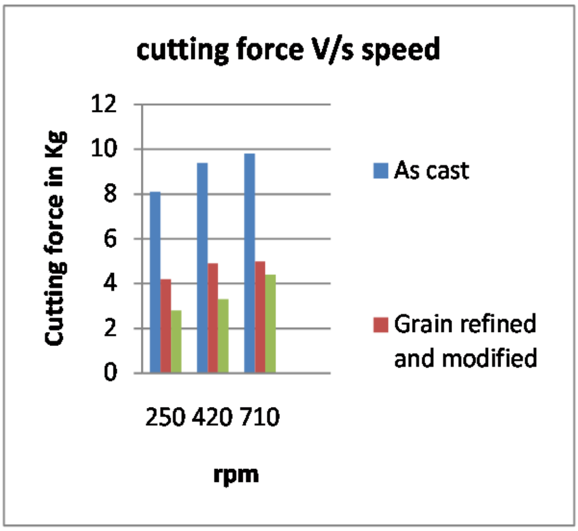

Fig.3b Force V/s Speed

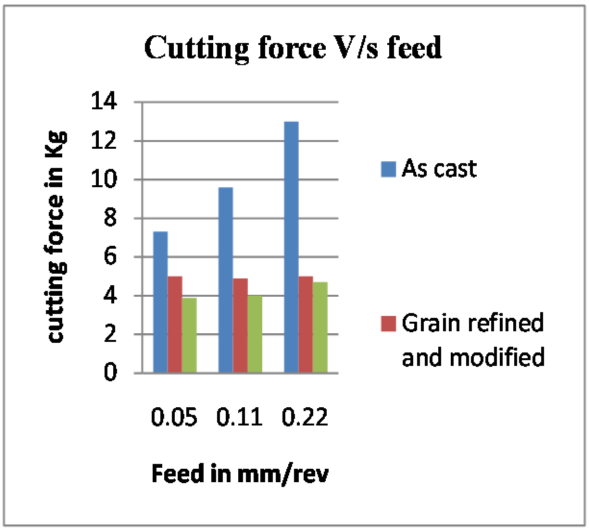

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Fig.3c Force V/s depth of cut

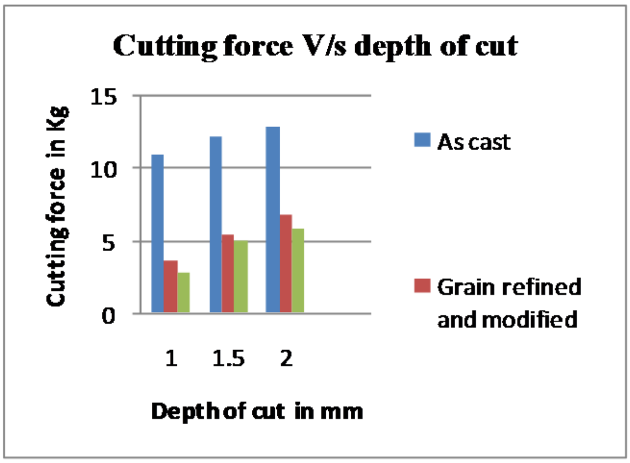

Fig 3 Cutting force at varying speed, feed and depth of cut

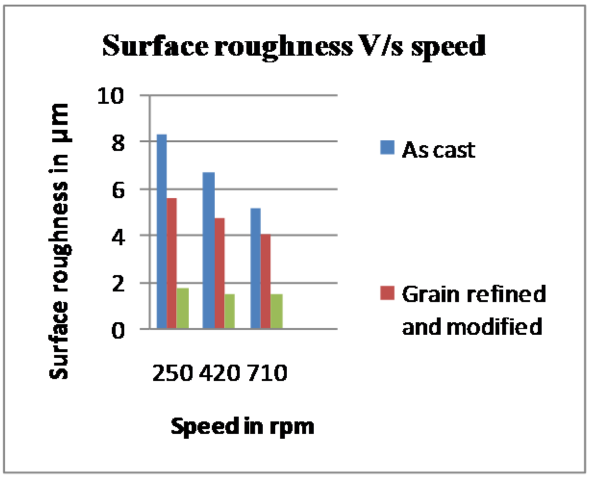

Fig. 4a Surface roughness V/s speed

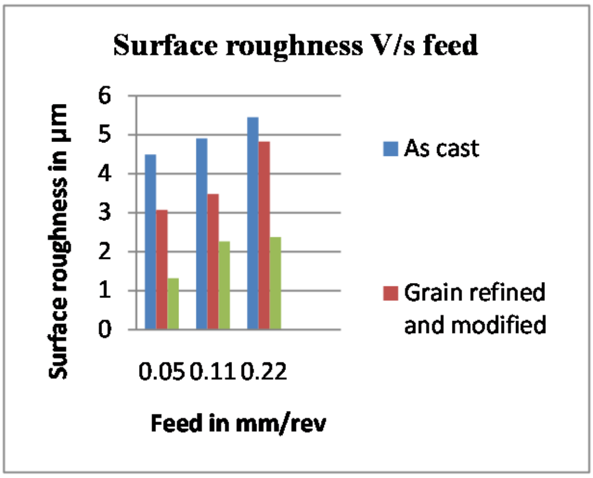

Fig. 4b Surface roughness V/s feed

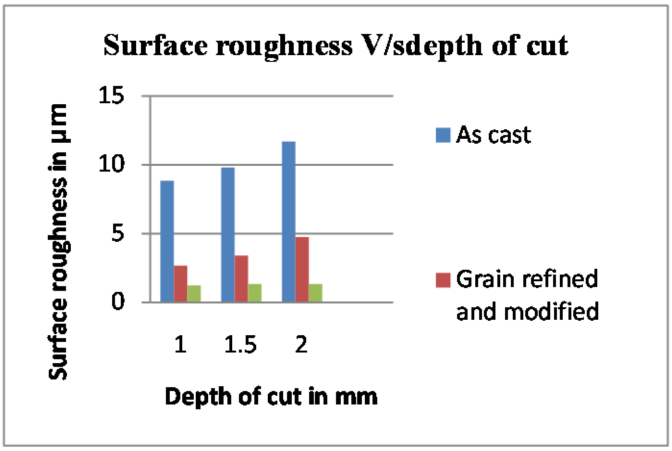

Fig 4c Surface roughness V/s depth of cut

Fig.4 Surface roughness of the alloy subjected to various treatment

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D. Corrosion test

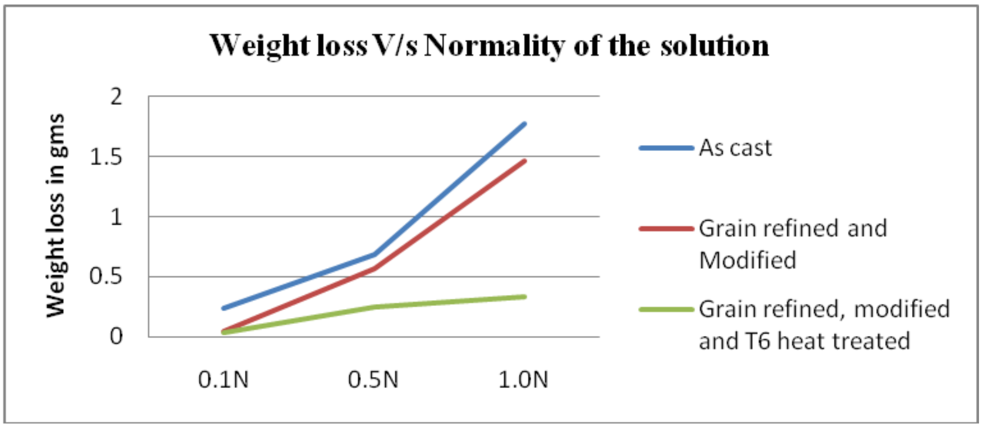

Fig. 5 Weight loss V/s normality of the solution

Figure 5 shows the relationship between weight loss and the normality of the solution. It can be seen that as the normality increases, weight loss also increases. Also there is considerable reduction in weight loss in refined and modified alloy and a significant reduction in weight loss in refined, modified and T6 heat treated alloy when compared to as- cast alloy. This is due to the increment in the number of grains in the grain structure.

IV. CONCLUSION

1. Unrefined as cast specimen comprised of coarse aluminium matrix and plate/needle like Si particles.
2. Addition of Al-10Ti grain refiner refines coarse columnar α-Al dendrites to fine equiaxed α-Al dendrites.
3. Modification refines the eutectic silicon and changes its morphology.
4. Maximum hardness of 81.62 BHN is observed in the specimen when it is subjected to combination of 0.5% of Al-10Ti, 0.2% of Al-10Sr and T6 heat treatment. An improvement of 56.96% is observed
5. Reduction in cutting force and surface roughness was observed due to the combined effect of addition of 0.5% Al-10Ti, 0.2% Al-10Sr and T6 heat treatment
6. Reduction in weight loss was observed due to the combined effect of addition of 0.5% Al-10Ti, Al-10Sr and T6 heat treatment.

V. FUTURE SCOPE

- Work-tool interface temperature and chip morphology could be used to assess machinability.
- Machinability index could be estimated.
- Corrosion inhibitors or corrosion accelerators could be added to the solution while assessing corrosion property.

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