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Study of Improvement in Mechanical Properties and Microstructure of LM25 Alloy with the Addition of Grain Refiners / Modifier

Satya Prema
Assistant Professor, Department of Mechanical Engineering, J N N College of Engineering, Shivamogga-577204, Karnataka, India.

Chandrashekharaiah T M
Professor, Research centre, Department of Mechanical Engineering, Kalpataru Institute of Technology, Tiptur - 572 202, Karnataka, India.

Farida Begum P
Assistant Director Town Planning, Karnataka Housing Board, K G Road, Bengaluru - 560009, Karnataka, India.

Abstract
This work is an attempt to study the effect of addition of Grain Refiners (0.2 wt% Al-5Ti-B and 1 wt% Al-3B) and Modifier (0.3 wt% Al-10Sr) to the hypoeutectic Al-Si alloy LM25. Machining tests and Material tests are conducted on the untreated and treated specimen. The results are correlated with the SEM micrographs. It is observed that the hardness, force acceptance and the turning characteristics are unaffected, but wear rate decreases with the addition of grain refiners / modifier to the LM25 alloy samples. There is no change in Torque and Thrust values for 0.3wt% Al-10Sr, but there is improvement in surface roughness by 54.23%.

Keywords: LM25, Grain refiner, Modifier, Hypoeutectic, Microstructure.

INTRODUCTION
The primary characteristics of Al-Si alloys are high strength to weight ratio, excellent castability, good thermal conductivity and resistance to corrosion. Al is the base metal and Si is the alloying element, which is added to get certain desirable properties which are not found in the base metal [1]. Al-Si alloys are classified into three types namely hypoeutectic (≤12%Si), eutectic (12%Si) and hypereutectic (≥12%Si). The machinability of these alloys can be further improved with the addition of grain refiners and modifier.

The hypoeutectic alloy LM25 is used for applications where corrosion resistance and good mechanical properties are service requirements [2]. The Al- Si hypoeutectic alloy with 7% Si (LM25) is used in this study. An effort is made to study the improvement in mechanical properties (turning, surface roughness, torque and thrust) and the material properties (UTM, hardness and wear test) of the LM25 alloy by the addition of grain refiners (0.2 wt% Al-5Ti-B and 1 wt% Al-3B) and modifier (0.3 wt% Al-10Sr). The microstructure of hypoeutectic Al-Si alloys have a large portion of primary α–Al. Reducing the size of the primary α–Al grains which is achieved with grain refinement improves the quality of the casting. Whereas the coarse columnar secondary Si is modified with the addition of modifiers such as Sr. Addition of grain refiner and or modifier to eutectic alloy significantly refines coarse columnar α–Al dendrites to fine equiaxed α–Al dendrites [5]. This is also observed in the present study. Improvement in the mechanical properties such as proof stress, ultimate tensile stress and percentage elongation of the alloys can be achieved with the addition of grain refiner and or modifier [4].

EXPERIMENTAL PROCEDURE
The commercially available hypoeutectic Al-Si alloy LM25 was heated in an induction furnace at 720˚C. The Al-Si melt was degassed with hexachloroethane. A portion of the Al-Si melt was poured into the mould made by graphite and remaining molten alloy is kept back into the furnace. This is the casting of the untreated specimen. In the next step, the estimated amount of Al-5Ti-1B master alloy chips were added to LM25 alloy melt and stirred approximately for about 30sec. After 5 minutes of holding, a part of melt has been poured into the graphite cell mould as in the earlier case, and the specimen was designated for recognition. The same procedure was repeated by adding calculated amount of Al-3B and Al-10Sr to the melt, and the specimen were designated accordingly. The size of the specimen was 25mm diameter and 100mm length. These experiments were conducted without addition of any lubricants or coolant. A total of 4 specimens were obtained as shown in Table I.

Experimental Details
The machining tests conducted on the specimen are Turning with Lathe Tool Dynamometer, Surface Roughness, Torque and Thrust. The Material tests conducted on the specimen are Ultimate Tensile Strength along with % elongation, Hardness and Wear test (constant speed at varying load). And the results are correlated with the micrographs obtained with the electron microscope (SEM).

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Table 1: Prepared sample designation of LM25 alloy

Alloy No.	Grain refiners / Modifier	Weight %
1	Nil (untreated)	As - cast
2	Al-5Ti-1B	0.2
3	Al-3B	1
4	Al-10Sr	0.3

DISCUSSION OF RESULTS

Microstructural Studies

The micrographs obtained with Scanning Electron Microscope (SEM) of the untreated sample and the samples treated with 0.2 wt % Al-5Ti-1B, 1 wt % Al-3B, 0.3 wt % Al-10Sr are shown in Fig.1, Fig.2, Fig.3 and Fig.4 respectively.

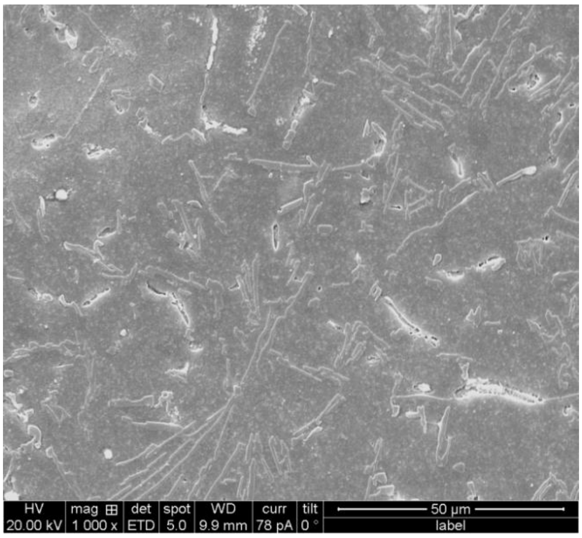

Figure 1: Untreated alloy – LM25

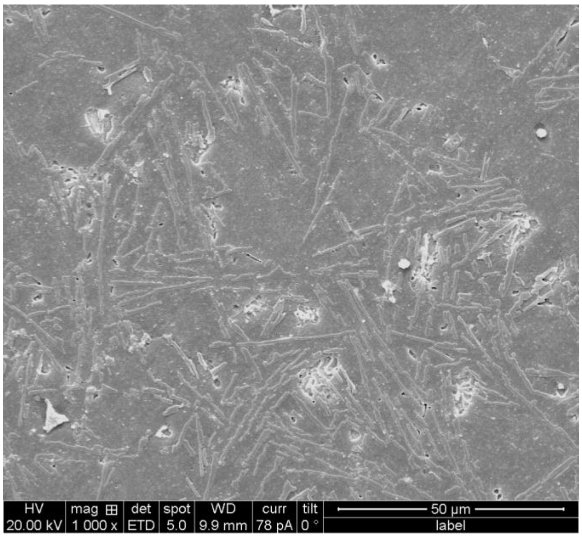

Figure 2: LM25 alloy treated with 0.2 wt% Al-5Ti-1B

LM25 is a hypoeutectic alloy with 7% Si content. The α - Al phase is visible in Fig.1 micrograph of untreated LM25 alloy. The inter dendrite arm spacing of α – Al dendrites is reduced by grain refinement and eutectic Si particles are spheroidized after modification [5]. This may be observed in Fig.2, Fig.3 and Fig.4.

The micrograph in Fig.2 of LM25 alloy treated with the addition of 0.2 wt% Al-5Ti-1B shows uniform distribution of dendritic α - Al.

Whereas in the micrograph in Fig.3 of LM25 alloy treated with 1 wt% Al-3B the dendritic α – Al is reduced.

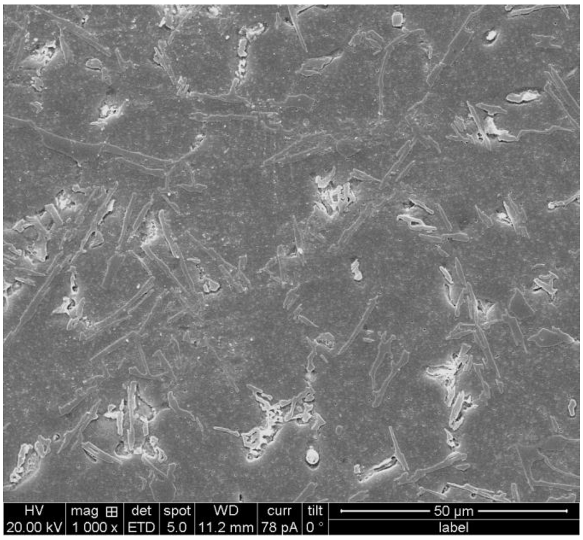

Figure 3: LM25 alloy treated with 1 wt% Al-3B

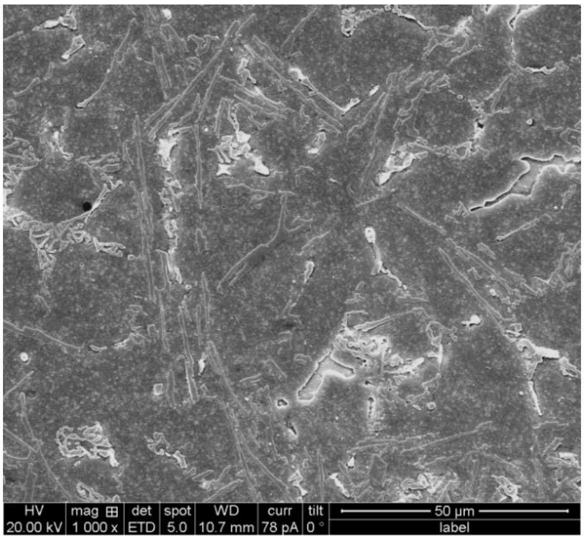

Figure 4: LM25 alloy treated with 0.3 wt% Al-10Sr

Results

Mechanical Properties

Turning with Lathe Tool Dynamometer:

The Lathe machine used was high accuracy heavy duty lathe machine having 112-1800 rpm of spindle speed and 1 H.P motor. The experiment was conducted by giving a constant feed and speed N=770rpm, the depth of cut was 2 mm with 5° rake. The following graph in Fig.5 shows force values in X, Y & Z directions in KN v/s alloys of LM-25.

It was noted that untreated LM25 alloy sample has indicated better force acceptance and good turning characteristics. The microstructure of untreated LM25 alloy in Fig.1 has almost uniformly distributed secondary Si phase. With the addition of the grain refiners the primary α Al phase is further grain refined, whereas the addition of Al-10Sr modifies the secondary Si particles as shown in Figure4.

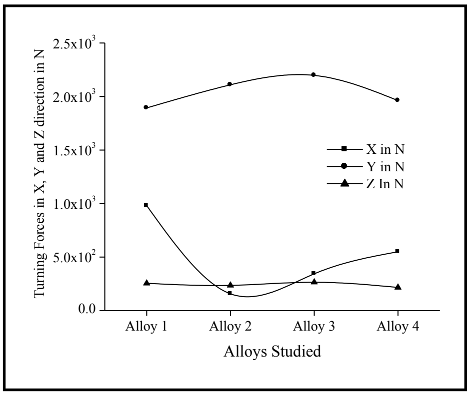

Figure 5: Force measurement of LM-25 alloy samples

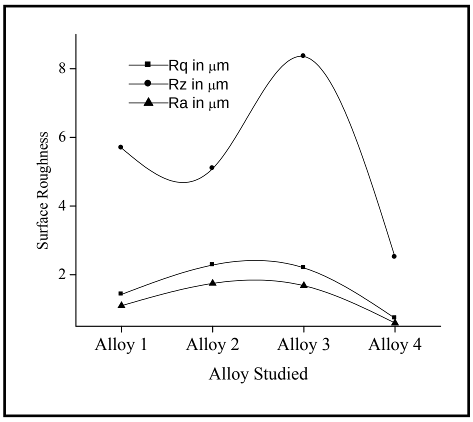

Figure 6: Surface roughness measurement of LM-25 alloy

Surface Roughness:
The turned surfaces of the samples were tested for study of Surface roughness and Ra values of surface measurement were noted. Fig.6 indicates the surface measurement values Ra, Rq and Rz in µm v/s sample no. of LM-25 alloy. The addition 0.3 wt. % of Al-10Sr to the LM-25 alloy has improved the surface finish as compared to other grain refiners and modifier.

Torque and Thrust:
The readings of the drill tool dynamometer are shown in Fig.7 and Fig.8. It is observed that the variation in torque is very less and it can be seen that LM-25 alloy grain refined with 1 wt.% (Al-3B) is sustaining higher thrust value compared to other samples. Hence LM-25 grain refined with 1 wt.% (Al-3B) can be considered for the drill operation.

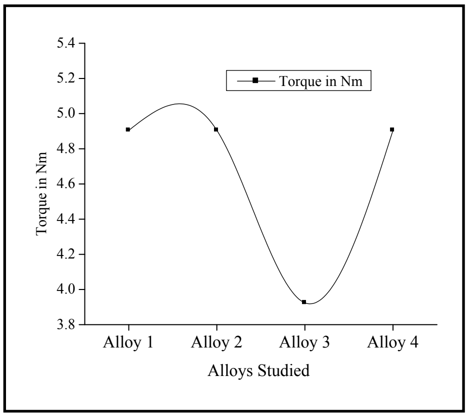

Figure 7: Torque values of LM-25 alloy samples

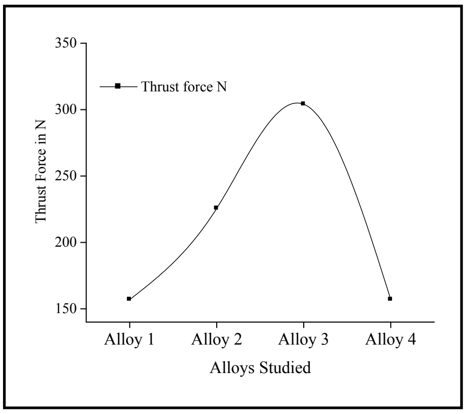

Figure 8: Thrust values of LM-25 alloy samples

MATERIAL PROPERTIES

Ultimate Tensile Strength alongwith % elongation: Machined samples were used to conduct the tensile test on each sample using UTM at room temperature. Fig.9 shows the variation of ultimate tensile strength versus samples with different grain refiners and modifier. Results clearly show that addition of grain refiners / modifier improves the UTS of LM25 alloy. This is due to the grain refinement of eutectic silicon.

Hardness:
Vickers micro hardness test was used to evaluate the hardness of the samples. The specimens were cut out from each cast sample by lathe turning process. A force of 10N was applied to carry out the hardness test. Fig.10 represents the variation in hardness of samples evaluated at a load of 10 N with samples of different grain refiners of LM25 alloy. Untreated LM25 alloy has high hardness value and no significant improvement is observed with the addition of grain refiners and modifier. This can be related with untreated LM25 alloy sample indicating better force acceptance and good turning characteristics.

Wear test (constant speed at varying load):
The tests were carried out by using a Ducom Pvt. Ltd., Bangalore make, pin-on-disc test apparatus. The wear tests

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were conducted under dry sliding condition on the prepared alloy samples with varying weight percentage of grain refiners and modifier. The tests were carried on 6mm diameter, 25 mm long specimens against a rotating EN-32 steel disc with hardness of 63Rc. The frictional force and wear were noted with the help of electronic sensors.

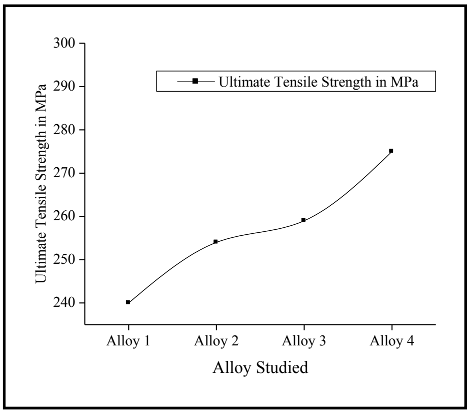

Figure 9: Variations in Ultimate Tensile Strength of LM-25 alloy samples

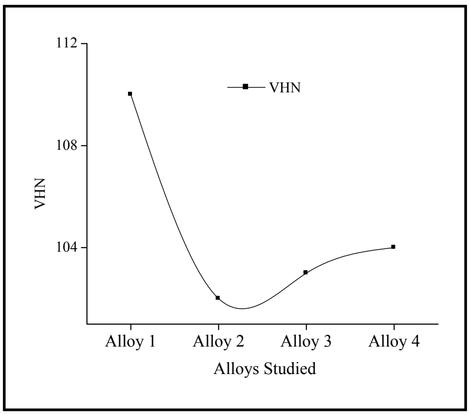

Figure 10: Variations in Hardness of LM-25 alloy samples

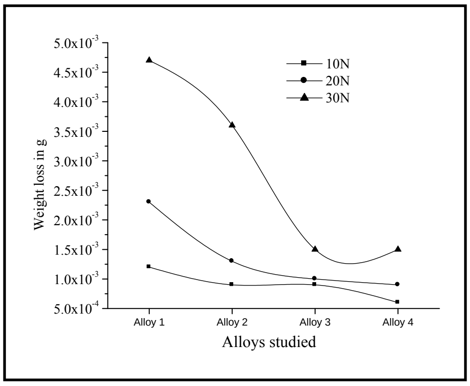

Figure 11: Effect of grain refiners on wear of LM-25 alloy samples

These two parameters were measured as a function of load and sliding distance. For each type of sample, tests were conducted at three different nominal loads (10N, 20N, 30N) keeping the sliding speed fixed at 1.4 m/s. Wear tests were carried out at room temperature without lubrication for 3 min. Interestingly, it is observed that the wear rate decreases with the addition of grain refiners and modifier to the base metal LM25 as per Figure 11.

CONCLUSION

Untreated LM25 alloy has high hardness value and also better force acceptance and good turning characteristics. Wear rate decreases with the addition of grain refiners and modifier. There is no change in Torque and Thrust values for 0.3wt% Al-10Sr, but there is improvement in surface roughness by 54.23%.

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