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Machinability & Microstructural Analysis of Al-Si Alloys

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ABSTRACT: In the recent years the usage of cast Al-Si alloys components in automotive and marine industries has increased significantly. Such alloys are invariably treated for modification prior to casting to achieve improved properties and performance. Modification results in fine fibrous eutectic silicon which otherwise exists in the form of large plate or needle like morphology. Grain refinement places a crucial role in improving characteristics and properties of aluminum silicon (Al-Si) alloys. In this present investigation modified and grain refined Al-Si alloys are synthesized from commercially available LM 6, LM25 and LM30 alloy using die casting methods. For this alloys Machinability and Microstructure has been carried out.

Keywords: Al-Si alloys, Grain refiner and modifier

I. INTRODUCTION

Use of cast Al–Si alloys as a tribological component in recent years has been expanding widely in military, automobile and general engineering industry. Aluminium–silicon eutectic and near eutectic alloys are cast to produce majority of pistons and are known as piston alloys. Silicon is probably one of the least expensive alloying additions commonly made to aluminium, which improves castability, increases strength to weight ratio, enhances corrosion resistance, decreases the co efficient of thermal expansion and Imparts wear resistance to aluminium [1]. Grain refinement greatly influences the microstructure of the alloy. This affects the properties of castings to a great extent; hence the properties of material improve [3].

Machinability is a term that describes the ease or difficulty with which a metal can be machined. It can be measured by the life of the cutting tool or the material removal rate in relation to the cutting speed used [5]. The good Machinability indicates Good surface finish and integrity, Long tool life, Low surface and power requirements.

Aluminium Alloys. Aluminum is a soft, durable, lightweight, malleable, silverish white metal. Aluminium base alloys find extensive application in Automobile industry, Air craft industry and other general engineering industries due to their good corrosive resistivity and good strength to weight ratio. In recent years aluminium alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. Surfaces of Luminous alloys have a brilliant luster in dry environment due to the formation of a shielding layer of aluminium oxide [6].

Aluminium alloys of the 4xxx, 5xxx and 6xxx series, containing major elemental additives of Mg and Si, are now being used to replace steel panels if various automobile industries. Due to such reasons, these alloys were subject of several scientific studies in the past few years.

Properties of Al Alloys. A wide range of physical and mechanical properties can be obtained from very pure aluminum. The different properties are:

a) Aluminium has a density of about 2.7g/cc which is one third (approximately) the value of steel.
b) Unlike steel, aluminium prevents progressive oxidation by formation of a protective oxide layer on its surface on exposure to air.
c) Aluminium alloys exhibit excellent electrical and thermal conductivities. The thermal conductivity of aluminium is twice that of copper (for the same weight of both materials used).

Turning. Turning is carried out on a lathe that provides the power to turn the work piece at a given rotational speed and to feed he cutting tool at specified rate and depth of cut .here fore three cutting parameters namely cutting speed, feed and depth of cut need to be determined in a turning operation [6]. Whenever two machined surfaces come in contact with one and the other, the quality of the mating parts plays an important role in the performance and wear of the mating parts.

The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as, the machining variables which include:

a) Cutting speed.
b) Feed.
c) Depth of cut.
d) Cutting tool wears,
e) Several other parameters

Machining & Machining Tool Parameters. Machinability is a term indicating how the work material responds to the cutting process. In the most general case good machinability means that material is cut with good surface finish, long tool life, low force and power requirements, and low cost[6,7].

All machine tools must provide work-holding and tool-holding devices and means for accurately controlling the depth of the cut. The relative motion between the cutting edge of the tool and the work is called the Cutting speed [8]. The speed in which uncut material is brought into contact with the tool is called the Feed rate. Means must be provided for varying both.

II. EXPERIMENTAL DETAILS

Procedure for Specimen preparation Using the below process we have prepared the specimens as follows and table 2.1give the details of specimen composition,

a) LM25 with silicon weightage of 7% i.e Hypoeutectic
Al-Si alloy
b) LM6 with silicon weightage of 12% i.e Eutectic Al-Si
alloy
c) LM30 with silicon weightage of 17% i.e Hypereutectic
Al-Si alloy.

Specimen Preparation. The aluminium silicon alloys were melting in the graphite crucible in a high frequency induction furnace (10kW, Max. Temperature 1300°C) and the melt were held at 720°C in order to attain homogeneous composition. The molten metal was degassed with 1% solid Hexa-chloroethane (C2Cl6) salt.

The weighed salt packed in an aluminium foil was added and the melt was stirred with a Zircon coated iron rod for uniform mixing. After completion of the reaction times the residual amount of molten flux present at the top of the melt was removed. Then the melt were added with suitable amount of grain refiners and/or modifiers or primary Si refiner and were held for 5 min and then poured into a graphite mould and allowed to cool refer figure 2.1.1 to 2.1.6.

Specimen is machined in lathe for final specimen preparation for surface roughness analysis and SEM analysis by using Grinding and Polishing machines refer figure 2.1.7 to 2.1.8.

Table 1: Grain refiners and modifiers used for base metal.

Alloys	Group Number	Additives	Quantity used	Remark
LM 6	1st	As Cast	-	
	5th	Al-3B	0.55%	Grain refiner
	7th	Al-10Sr	0.3%	Modifier
	10th	(Al-3B)+(Al-Sr)	(0.55%+0.3%)	(Grain refiner +Modifier)
LM 25	12th	As Cast	-	
	14th	Al-3B	0.55%	Grain refiner
	15th	Al-10Sr	0.3%	Modifier
	18th	(Al-3B)+(Al-Sr)	(0.55%+0.3%)	(Grain refiner +Modifier)
LM 30	16th	As Cast	-	
	17th	Al-Cu	3.15%	Primary Si refiner

Table 2.1 Grain refiners and modifiers used for base metal

III. EXPERIMENTAL RESULTS

A. Surface Roughness

In order to evaluate the effect of surface roughness on surface quality, measurements were taken at three different locations in longitudinal direction. In collecting the surface roughness data of the experimental sample with the talysurf series 2, three measurements are taken along the axis for each experimental sample. So a total of 99 measurements were taken on machined surface. The surface roughness (Ra) value was calculated on each machined surface for different speeds and depth of cut.

The graph 3.1shows the surface roughness varies with the cutting speed keeping all other parameters constant.

Figure 2.1.1 Induction heating machine

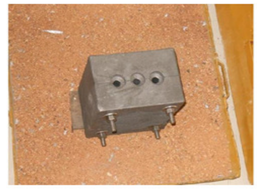


Figure 2.1.3 Graphite mould used for casting

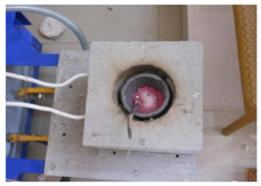


Figure 2.1.2 Furnace with molten metal

Figure 2.1.4 Degasification

Figure 2.1.5 Pouring and solidification

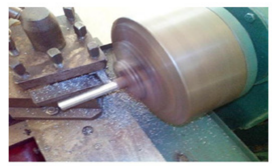
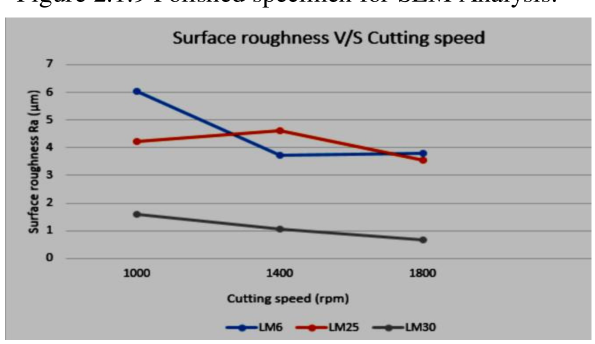


Figure 2.1.7 Specimen preparation on lathe

Figure 2.1.6 Casted specimen

Figure 2.1.8 Final component for surface

Figure 2.1.9 Polished specimen for SEM Analysis.



Graph 3.1 Surface roughness v/s Cutting speed graph

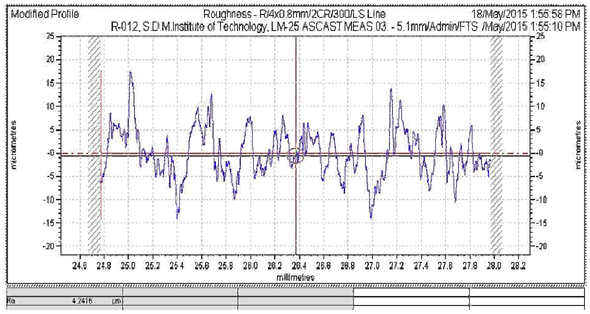


Figure 3.1.2 Surface Roughness profile of LM25 As Cast at 1800 rpm

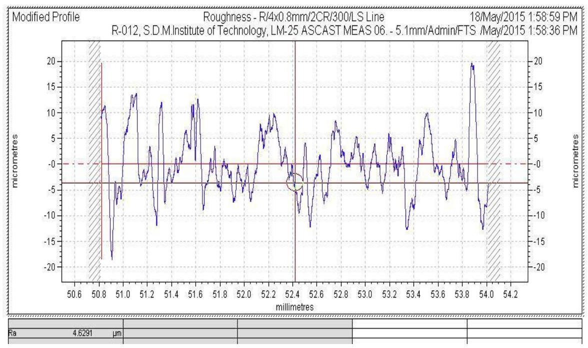


Figure 3.1.3 Surface Roughness profile of LM25 As Cast at 1400 rpm

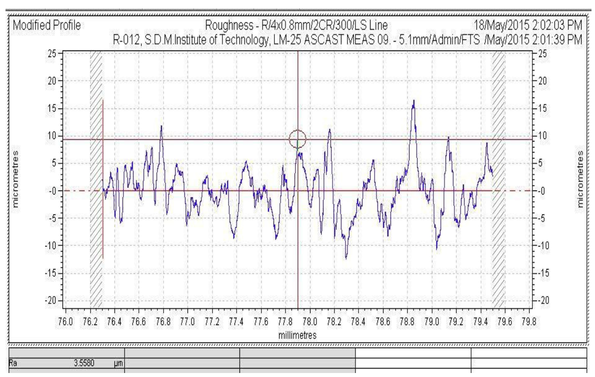


Figure 3.1.4 Surface Roughness profile of LM25 As Cast at 1000 rpm

SL NO.	speed (rpm)	Feed rate (mm/rev)	Depth of Cut (mm)	Roughness of sample, Ra (µm)				
				LM-6 As cast	LM-6 5th group	LM-6 7th group	LM-6 10th group	LM-25 As cast
1	1800	0.06	0.4	3.8020	2.5245	2.8604	3.1902	3.5580
2	1800	0.04	0.3	2.1345	2.0777	2.4317	3.0257	3.6176
3	1800	0.02	0.2	5.4313	1.1278	1.2595	2.0042	1.4265
4	1400	0.06	0.4	3.7316	3.5004	3.1268	4.4261	4.6291
5	1400	0.04	0.3	1.5010	3.2979	3.7283	3.8798	3.0430
6	1400	0.02	0.2	4.5817	1.8008	1.5979	2.4420	1.0607
7	1000	0.06	0.4	6.0447	4.7508	3.9798	5.1640	4.2416
8	1000	0.04	0.3	2.1495	3.2296	2.4404	4.2046	3.1966
9	1000	0.02	0.2	4.2129	2.0609	2.0751	1.7745	1.3363

Table 3.1.1 Results of Surface roughness

SL NO.	speed (rpm)	Feed rate (mm/rev)	Depth of Cut (mm)	Roughness of sample, Ra (µm)				
				LM-25 14th group	LM-25 15th group	LM-25 18th group	LM-30 As cast	LM-30 17th group
1	1800	0.06	0.4	3.2650	3.6428	5.9988	1.5778	2.7409
2	1800	0.04	0.3	1.7640	3.9076	3.0185	1.8337	2.4808
3	1800	0.02	0.2	4.4315	3.6680	2.0935	1.5806	3.1378
4	1400	0.06	0.4	2.9253	3.1862	5.2738	1.0434	3.5880
5	1400	0.04	0.3	1.9376	2.1034	3.0796	0.9711	2.0722
6	1400	0.02	0.2	3.2804	1.6733	1.4474	0.9711	1.2534
7	1000	0.06	0.4	3.5559	4.5497	4.3898	0.6793	3.1668
8	1000	0.04	0.3	8.9249	1.6377	3.2820	0.6793	2.0480
9	1000	0.02	0.2	8.2413	1.8604	1.8604	0.7963	2.1820

Table 3.1.2 Results of Surface roughness

3.2 Chemical composition:
Results of chemical composition experimented using Optical Emission Spectrometer is given below:

RESULT :

SL. NO	Sample I.D	CONTENT %							
		Cu	Mg	Si	Fe	Mn	Ni	Zn	Ti
1	LM-6 (As cast)	0.17	0.079	11.62	0.43	0.028	0.011	0.020	0.039
2	Lm6(5_group)	0.10	0.11	7.14	0.75	0.31	0.084	<0.001	0.036
3	LM6(7_group)	0.12	0.14	7.72	0.73	0.32	0.066	0.003	0.047
4	LM6(10_group)	0.049	0.079	12.22	0.36	0.028	0.006	0.003	0.041
5	LM-25(As cast)	0.13	0.10	7.24	0.76	0.33	0.083	<0.001	0.036
6	LM25(14_group)	0.12	0.10	7.64	0.71	0.33	0.081	<0.001	0.035
7	LM25(15_group)	0.13	0.15	7.54	0.70	0.31	0.078	<0.001	0.041
8	LM25(18_grooup)	0.11	0.10	7.12	0.69	0.29	0.076	0.006	0.047
9	LM-30(As cast)	4.55	7.03	15.76	1.59	0.41	0.034	0.21	0.13
10	LM30 (Al-Cu)(17_group)	3.15	7.01	17.51	1.97	0.37	0.17	0.22	0.16

Table 3.2 Chemical composition of LM 6 , LM 25 & LM 30 group

SEM Results: The Microstructures of the Samples were taken in Scanning Electron Microscopy with magnification of 2.5KX.

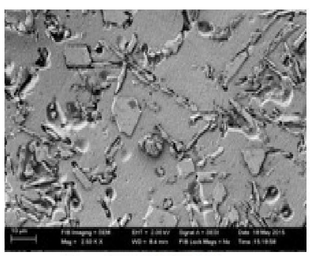


Figure 3.3.1 LM 6 As Cast

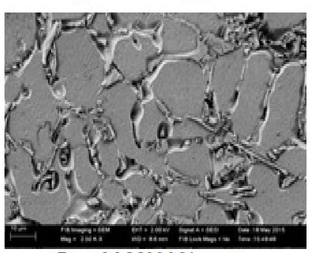


Figure 3.3.2 LM 6 5th group

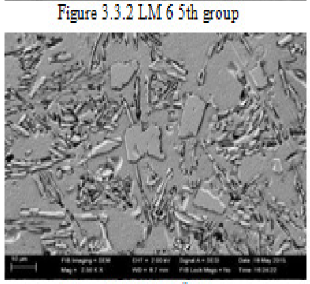


Figure: 3.3.3 LM 7th Group

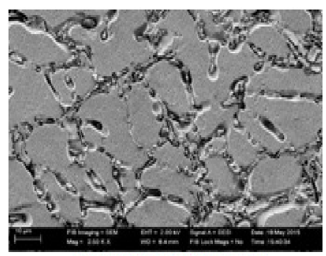


Figure 3.3.5 LM 25 As cast

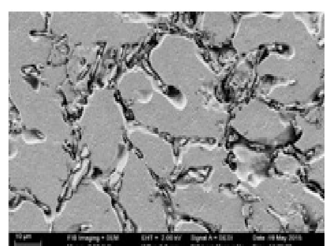


Figure 3.3.6 LM 25 14th group

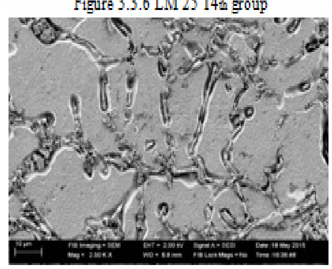


Figure 3.3.7 LM 25 15th group

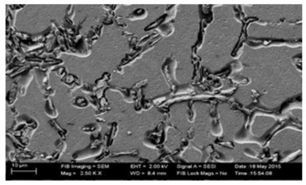


Figure: 3.3.4 LM6 10th Group

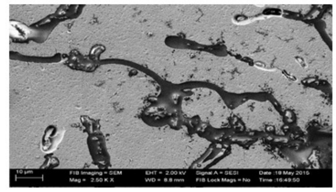


Figure 3.3.8 LM 25 18th group

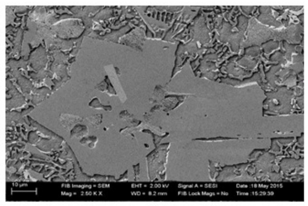


Figure 3.3.9 LM 30 As cast

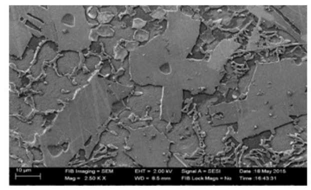


Figure 3.3.10 LM 30 17th group

IV. CONCLUSION

The prepared aluminium-silicon alloys have homogenous distribution of silicon throughout the cast. The microstructure of stir-cast alloys revealed spherical and/or rosette shape of αparticles and broken (small) needle-like eutectic silicon and the modification of the alloys by AI-10 Sr master alloy resulted in fine and spheroidal eutectic silicon.

Successfully grain refined and modified of Al-Si alloys using B-rich Al-B master alloys and Al-Sr modifier. The surface roughness is significantly influenced by the depth of cut and cutting speed. The surface roughness increases with increase in depth of cut. The surface roughness slightly decreases with the increase cutting speed.

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