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Effect of Dispersoid Size and Content (SiO_2) for Improved Mechanical Properties and Microstructure of LM-13

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ABSTRACT

Metal Matrix Composites (MMC's) have been developed to meet the demand for lighter materials with high specific strength, stiffness and wear resistance. Among Metal matrix composites particulate reinforced Aluminum matrix composites are attractive due to significant improvements in mechanical and physical properties like such as superior strength to weight ratio, good ductility, high strength and high modulus, low thermal expansion coefficient, excellent wear resistance, excellent corrosion resistance, high temperature creep resistance and better fatigue strength. Aluminum based MMC's find wide applications in aerospace, automobiles and marine sectors, etc. The mechanical properties of Aluminum matrix composites are strongly dependent on microstructural parameters like shape, size, volume fraction and distribution of reinforcement particles which have to be carefully chosen. Therefore, judicious selection of the variables is important to optimize the properties of the composites. The present investigation is aimed at studying the effect on microstructure and mechanical properties of Aluminum alloy (LM-13) a hybrid metal matrix composites by varying dispersoid size and content Silica (Sio2). The size of the Silica (Sio_2) particles varies from 1, 3 and 5mm and amount of addition varies from 4.25 to 11.76wt% in steps of 4.25wt%. Stir casting process was used to produce cast Aluminum alloy - silica particulate composites in moulds. The microstructure and hardness of the fabricated composite were analyzed and reported. Above prepared composites are subjected to the mechanical testing as per the ASTM standards. The investigation reveals that there is a significant improvement in the mechanical properties of the composite. The tensile strength and hardness were found to increase with the increase in the wt% of SiO2 reinforcement.

Keywords *- Aluminum alloy (Lm-13), chill casting, Silica (SiO2), hardness, microstructure, stir casting.*

1. INTRODUCTION

Industrial technology is growing at a very rapid rate and consequently there is an increasing demand and need for new materials. Particulate reinforced composites constitute a large portion of these new advanced materials. The choice of the processing method depends on the property requirements, cost factor consideration and future applications prospects (Hamouda et al., 2007).

Incorporation of hard second phase particles in the alloy matrices to produce MMCs has also been reported to be more beneficial and economical due to its high specific strength and corrosion resistance properties (Thoguluva, 2009).

Aluminum Alloy Composites (AACs) are becoming potential engineering materials offering excellent combination of properties such as high specific strength, high specific stiffness, electrical and thermal conductivities, low coefficient of thermal expansion and wear resistance (Das, 2004). A good combination of high strength and ductility of the Aluminum based metal matrix composites (MMCs) have introduced the material to a wide area of possible advanced applications (Wahab et al., 2009). For instances, reinforcing aluminum metal with silica particulate yields a material that displays combination of physical and mechanical properties of both the metal matrix and the silica. The demand for structural materials to be cost effective and also to provide high performance has resulted in continuous attempts to develop composites as serious competitors to the traditional engineering alloys (Zuhailawati et al., 2007). Accordingly, the objective of the present study was to investigate the mechanical properties of aluminum matrix composites reinforced with low-cost silica sand, which is attained from mines. Particular emphasis was placed to study the effect of presence of silica reinforcing particulates on the microstructural variation in the metallic material and to correlate the particulate's associated microstructural variation in the metallic material with the hardness and modulus of fracture of the metallic matrix.

Al based MMCs refer to the class of light weight high performance Al centric material systems. The reinforcement in Al MMCs could be in the form of continuous/discontinuous fibers, whiskers or particulates in volume or weight fraction ranging from 15% up to 70%. Properties of Al based MMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route (Joel, 2009). Strength and hardness increase with increase in dispersoid content and this may be possibly because of the occurrence of a more uniform distribution of SiO_2 particles within the matrix (Babu et al., 2010).

2. EXPERIMENT

The materials used in this work are aluminum LM13 alloy for the matrix and SiO_2 as dispersiod. The size of dispersoid added varies both in size and wt%. The size of dispersoid added varies in the range of 1, 3, 5mm and percentage of addition varies from 4.25 to 11.76wt% in steps of 4.25wt % based on the variation in size. The tensile test specimens of SiO_2 particulate reinforced LM13 alloy composites used here is prepared according to ASTM E8M standards. The toughness and formability of Aluminum –12% silicon alloy can be combined with the strength of quartz particles. Cast iron permanent mould is used for processing composite castings. The details of the LM13 alloy composition is shown in Table 1. Quartz is a hard mineral and provides excellent hardness on incorporation into the soft lead-alloy, thereby making it better suited for applications where hardness is desirable. The mechanical, thermal and electrical properties of LM13 are shown in the Table 2. LM13 alloy is actually a eutectic alloy having the lowest melting point that can be seen from the Al-Si phase diagram. The main composition of LM13 is about 85.95% of Aluminum, 12% to 13% of silicon. The properties of pure SiO2 are in the Table 3.

Elements	**Cu**	**Zn**	**Mg**	**Si**	**Fe**	**Mn**	**Ni**	**Pb**	**Sn**	**Ti**	**Al**
% by wt	0.7	0.5	1.4	12.0	1.0	0.5	1.5	0.1	0.1	0.2	Balance

Table 1: Chemical Composition of Matrix Material (LM 13).

Physical Properties	**Values**
Density (g/cm3)	2.7
Mechanical Properties	**Values**
Tensile strength (MPa)	170-200 0.2%
Proof stress (MPa)	160-190
Elongation %	0.5
Hardness (VHN)	130
Thermal Properties	**Values**
Coefficient of thermal expansion (/^{0}C at 20-100^{0}C)	0.000019
Coefficient of thermal expansion (/^{0}C at 20-300^{0}C)	0.000021
Thermal conductivity (cal/cm2/cm/^{0}C at 25^{0}C)	0.28
Melting point (^{0}C)	695
Electrical Properties	**Values**
Electrical conductivity (% copper standard at 25^{0}C)	29

Table 2: Mechanical, Thermal and Electrical Properties of LM13.

Elements	**Si**	**O_2**
% by wt	0.46	0.53

Table 3: Chemical Composition of Silica (Sio2).

Properties	Values
Tensile strength	25 N/mm^2
Melting point	1830^0C
Boiling point	2230^0C
Density	2.65 gm/cm^3
Thermal conductivity	1.3 W/m-k
Compressive strength	2070 N/mm^2
Poisson’s ratio	0.17
Modulus of elasticity	70 GPa
Thermal shock resistance	Excellent

Table 4: Properties of Reinforcement Silica.

3. TEST PROCEDURE

Microscopic examination of the MMCs was executed by means of optical microscopy. Various etchant were tried but dilute Kellers etchant proved to be the best and was therefore used. Hardness tests were performed with a Vickers micro Hardness (Zwick/Roell ZHV, German make) testing machine on the polished specimens used for microstructural analysis. The specifications dimension, and shape of the specimen used are shown in the Fig 1 and a clear explanation in given below. SiO_2-particulate reinforced LM13 alloy composite cast test specimens are processed by stir casting process. Different wt% percentage of SiO_2 particulates is added to produce the cast test samples. The photograph of the tensile test specimens before and after testing is shown in the Fig 2 and 3. A 150 KN servo hydraulic UTM is used to conduct the tensile tests. The test samples are subjected to a tensile load and the mechanical properties are determined. Hence, the tensile strength, and young’s modulus values are calculated.

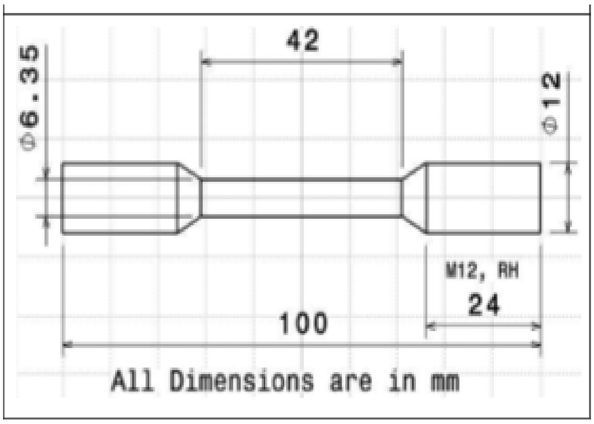

Fig 1: Tensile Specimen.

Fig 2: Tensile Specimen before Test.

Fig 3: Tensile Specimen after Test.

4. RESULTS AND DISCUSSION

The microstructure of Al-Si (LM13) alloy, in as cast condition, shows the dendrites of aluminum and eutectic silicon in the interdendritic regions and around the dendrites. The micrograph of LM13 with 3 to 12 wt% Silica composite, in as cast condition, shows uniform distribution of Silica particles in Aluminum matrix. Below Fig shows the microstructural observation of prepared composites.

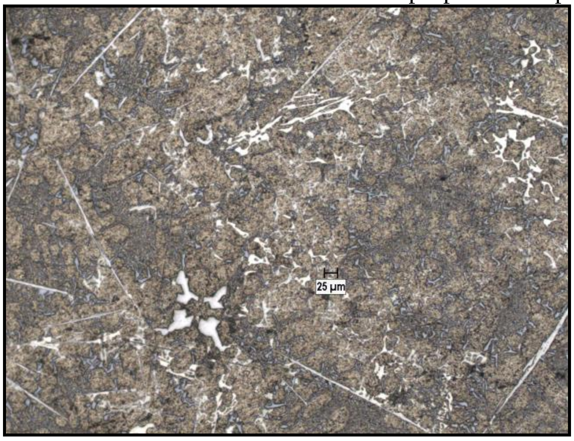

Fig 5: 1mm & 60 Gm Sio2 (Unetched-100X).

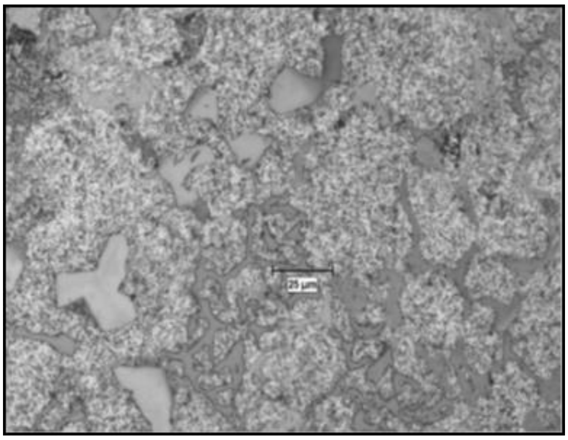

Fig 6: 1mm & 60 Gm Sio2 (Killer's Etched 500X).

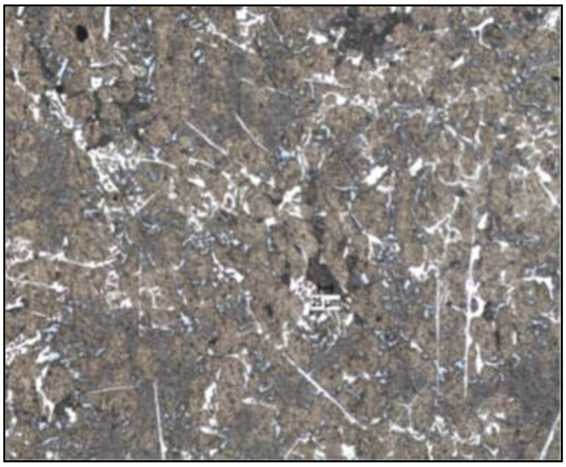

Fig 7: 5mm & 60 gm SiO_2 (Unetched-100X).

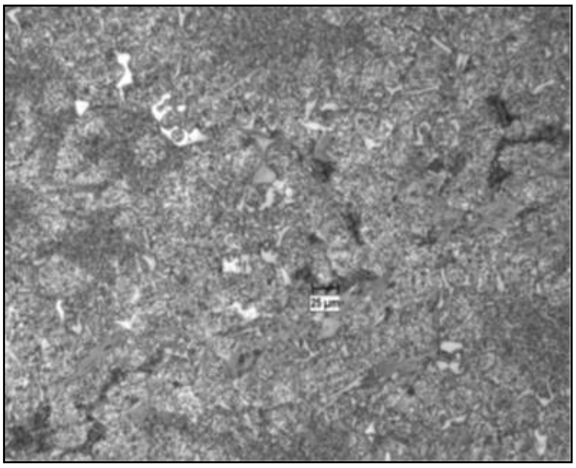

Fig 8: 5mm & 60 gm SiO_2 (Killer's Etched 500X).

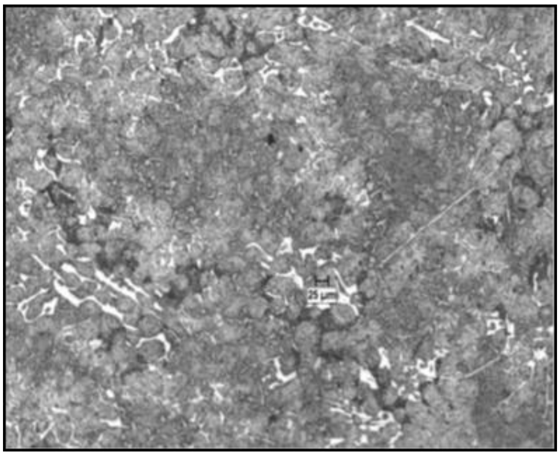

Fig 9: 3mm & 60 gm SiO_2 (Unetched-100X).

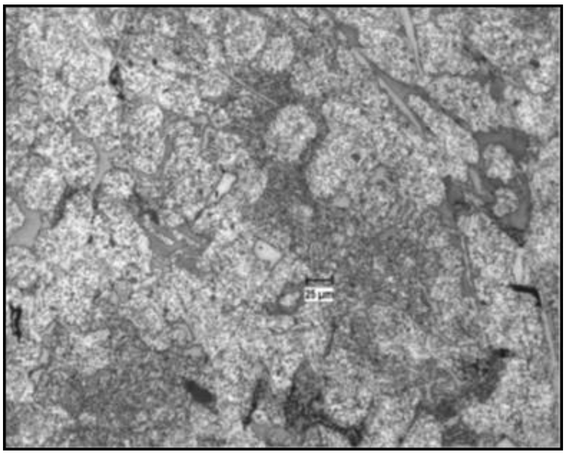

Fig 10: 3mm & 60 gm SiO_2 (Killer's Etched 500X).

5. TENSILE STRENGTH

The value of tensile strength and % of SiO2 is shown in the Table 5. The Fig 11 shows variation in tensile strength of Al-SiO_2 particulate composites for 1, 3, 5mm particle size. The tensile strength increased with increased weight percentage of SiO_2 up to 8.16 and decreased for 11.76 weight percentage. Because the increase in the percent of closed pores with increasing SiO_2 particulate content would create more sites for crack initiation and hence lower down the load bearing capacity of the composite. Besides if the number of contacts between SiO_2 particulate increases, then the particles is no longer isolated by the ductile aluminum alloy matrix.

Weight percentage of silica	Tensile strength, (Mpa)
4.25	74.71
8.16	75.31
11.76	72.95

Table 5: Tabulated Tensile Strength.

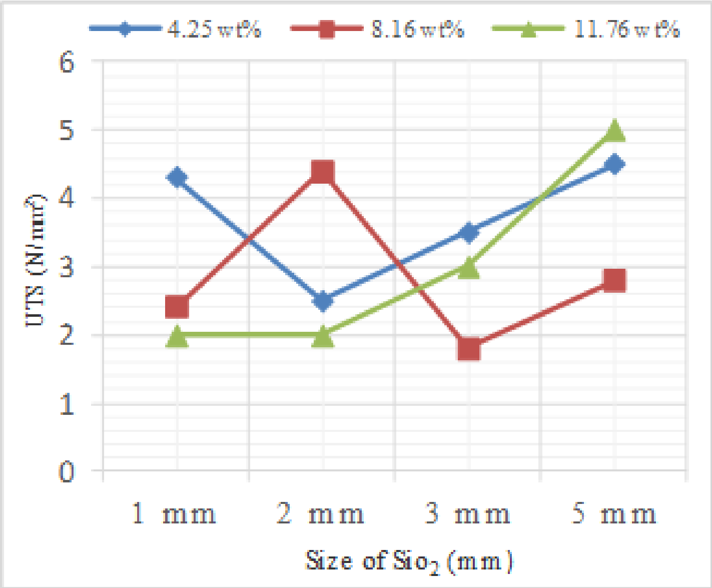

Fig 11: Plot of UTS v/s Size of Silica.

6. HARDNESS

Hardness tests were performed on composites to know the effect of silica in matrix material. The polished specimens were tested using Vickers micro hardness testing system. A load of 50 grams for a period of 10 seconds was applied on specimens. The hardness was determined by recording the diagonal lengths of indentation produced. The test was carried out at six different locations and the average value was taken as the hardness of the composite specimens. Table 6 shows the results of micro hardness test on composite containing different wt% of silica in it. From the Fig 12 it is evident that the hardness of the composite material is much higher than that of its parent metal. It is also shown that the hardness of the composite material increases with wt% of silica content. This may be because of addition of silica makes the ductile Al alloy into more brittle in nature with increase in the silica content. And also the dispersion of silica particles enhances the hardness, as particles are harder than Al alloy, and render their inherent property of hardness to soft matrix.

Weight Percentage of Silica	Hardness (VHN)
1mm	93.2
3mm	83.3
5mm	68.4

Table 6: Tabulated Hardness Number.

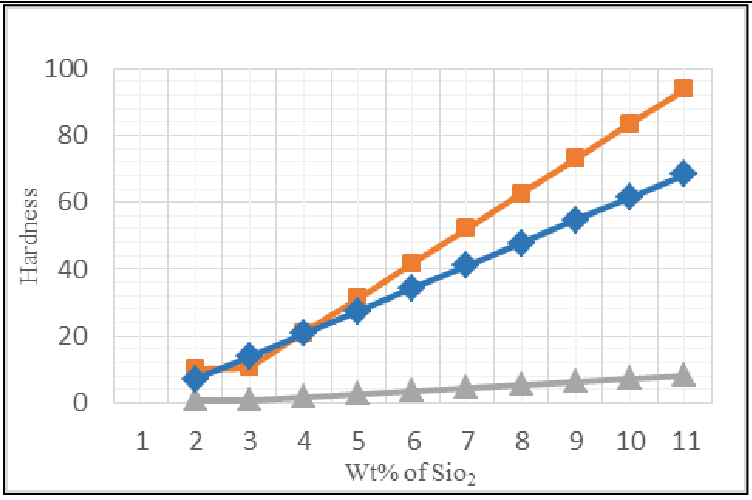

Fig 12: Hardness v/s wt. % of Silica.

7. CONCLUSION

- Aluminum matrix-silica reinforced composites were successfully cast by stir casting route. From the analysis of the cast specimens the following conclusions can be drawn.
- Fine grain structure, uniform distribution of dispersoid and good bonding between the matrix and the dispersoid is obtained with 1mm size and 4.25wt% of sio2, whereas, the grain size successively increases with the increase in size of sio2.
- A dispersoid content 8.16% silica + 3mm in size was found to increase the mechanical properties, and therefore, it is considered as the optimum limit.
- Liquid metallurgy techniques were successfully adopted in the preparation of Al alloy LM13-Silica composites containing the reinforcement up to 11.76 wt%.
- The microstructural studies revealed the uniform distribution of the particles in the matrix system.
- Strength is increases up to weight percentage of 8.16 of silica for micron size of 106 µm, after that decreases.
- From the studies it can be concluded that Al alloy LM13-Silica exhibits superior mechanical properties.

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