EVALUATION OF MECHANICAL BEHAVIOR OF Al/SiC METAL MATRIX COMPOSITES WITH RESPECT TO THEIR CONSTITUENTS BY TAGUCHI'S TECHNIQUES

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ABSTRACT

The matrix alloy Al 6061 contributes very large values of yield strength, ultimate tensile strength, ductility and bending force to the Al-alloy/SiC metal matrix composites. The matrix alloy 7072 exhibits lower ductility to the Al-alloy/SiC metal matrix composites than the matrix alloy Al 6063. Mg improves the wettability between Al and SIC particles by reducing the SiO_2 layer on the surface of the SiC. The SiC particles are distributed unevenly in the as-cast composite with no distinct evidence of clustering but very little agglomeration. MgO and $MgAl_2O_3$ are formed along the grain boundaries. The phases Al2Cu, Mg_2Si, $Al_5Mg_8Cu_2Si_5Al_3Fe$ and Al_3FeSi are also observed in the microstructures of Al-alloy/SiC composites. With increasing volume fraction, more load is transferred to the reinforcement which results in a higher yield strength, ultimate tensile strength and bending force to the Al-alloy/SiC composites. The decrease in ductility can be attributed to the earlier onset of void nucleation with increasing amount of reinforcement in Al-alloy/SiC metal matrix composites. The decrease in the particle size increases the yield strength, ultimate tensile strength, bending force and ductility (tensile elongation).

Keywords: Al-Alloys, SIC, Mechanical Properties, Taguchi Technique.

INTRODUCTION

Silicon Carbide (SiC) particulate form has been available for a long time. It is quite cheap and commonly used for abrasive, refractory and ceramic purpose. SiC particle reinforcements are two types round and angular morphology (Chawla, 1998).

Jayalakshmi et al (2004) have explained in their paper that the modulus of elasticity of the metal matrix is twice that of unreinforced counterpart alloys. The density of reinforced metal matrix is higher than that of unreinforced; and density increases with volume fraction of the reinforcing phase. Hyo et al (2001) have studied the mechanical properties of SiC/Al metal matrix composites and they reported that the tensile strength of SIC/Al-MMCs increased from 71 to 430 MPa and the hardness increase from 29 to 103 HV due to decrease of grain size for the specimens prepared by the extrusion and forging processes. Geni et al (1998) have explained that the SIC particle volume fraction and aspect ratio largely affect the stress-strain relationships and their effect increase by increasing the particle volume fraction. The tensile strength increases by increasing the particle aspect ratio. The effect of particle size on tensile behavior has been documented by Chawla et al (2001). With the increase in volume of the particle, the probability of a strength-limiting flaw existing in the volume of the material also increases.

Mcanels (1985) has evaluated the mechanical properties and stress-strain behavior for several types of discontinuous SIC/Al composites, containing SiC-whiskers, nodules and particulate reinforcement, matrix alloy, and reinforcement content by analyzing the stress-strain curves. The elastic modulus of the composites was found to be isotropic and independent of type of reinforcement and matrix alloy. Arsenault et al (1991) have studied the 0.5µm20 vol% SiC spherical particles reinforced Al-1100 and they have observed that as the proof stress increases with increase in reinforcement content.

The present work was focused on the effects of matrix alloy composition and reinforcement (in terms of % volume fraction and particle size) on the properties of Al-alloy composites. This paper is to analyze and interpret the experimental results obtained from the design of experiment (according to Taguchi techniques) to improve the performance characteristics of the Al-alloy/SiC matrix composites.

1. Materials Selection and experimental Procedure

The material selection criteria involves the requirement of high strength and good corrosion resistance aluminum alloys for the matrix materials, and the inexpensive reinforcement particles which can result in increased yield strength and elastic modulus at little expense of ductility. The matrix materials used in the present work are Al 6061, Al 6063 and Al 7072. The reinforcement material is SIC at 12%, 16% and 20% volume fraction of the composites with average size 10µm, 20µmand 30µm. the chemical composition of alloys is given in Table 1. The properties of the matrix materials are given in table-2. The matrix alloys and composites were prepared by stir casting process.

1.1 Stir Casting Process

Stir casting is a liquid state method for composite materials fabrication, in which a dispersed phase (ceramic particles) short fibers) is mixed with a molten matrix metal by means of mechanical stirring (Figure 1). The liquid composite material is then cast by conventional die casting method.

1.2 Selection the Quality Characteristics

The selection of quality characteristics to measure as experimental output greatly influences the number of tests that will have to be done to be statistically meaningful. The quality characters, which were selected to influence the mechanical properties of the metal matrix composites, are: yield strength, ultimate tensile strength and tensile ductility (%elongation), hardness and bending force.

Alloy	Composition determined spectrographically, %								
	Al	Si	Fe	Cu	Ti	Mg	Mn	Zn	Cr
6061	97.6	0.68	0.61	0.021	0.053	0.92	0.044	0.072	0.0051
6063	98.8	0.271	0.325	0.0047	0.0376	0.52	0.0076	0.076	0.0005
7072	97.8	0.387	0.464	0.013	0.0053	0.396	0.0082	0.85	0.012

Table 1. Chemical composition of matrix alloys

Matrix alloy	Density, g/cc	Modulus of Elasticity, GPa	UTS, MPa	Elongation %
Al 6061	2.70	68.9	241	22
Al 6063	2.70	68.9	172	22
Al7072	2.72	68.0	168	15

Table 2. Properties of matrix materials

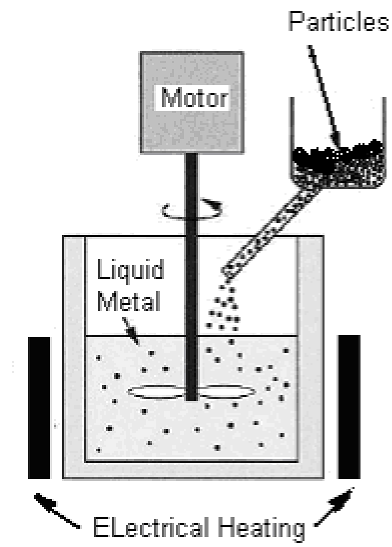

Figure 1. Charge preparation in the stir casting process

1.3 Selection of Process Parameters

This is the important phase of investigation. If important parameters unknowingly left out of the experiment, then the information gained from the experiment will not be in a positive sense. The parameters which influence the performance of the metal matrix composites properties are:

- Aluminum alloy type: Al 6061, Al 6063 and Al 7072
- Volume fraction of reinforcement: 12%, 16% and 20%
- Particle size of reinforcement: 10µm, 15µm and 20µm

The objectives of the end were developing good metal matrix composite properties. The factors to include in the investigation should be the ones thought relevant to the objective of producing good metal matrix composite. The important parameters were optimized by Taguchi's method (Taguchi, 1986, Chennakesava et al 1998). Taguchi techniques offer potential saving in time and cost.

1.4 *Selection of Levels for Control Parameters*

Control parameters are those parameters that a manufacturer can control the design of the product, and the design of process. The levels chosen for the control parameters were in the operational range of the metal matrix composites process. Each of the four control parameters was studied at three levels. The chosen control parameters are summarized in table 3.

1.5 Assignment of Parameters in Orthogonal Array (OA)

The orthogonal array, L_9 was selected for the present work. The parameters were assigned to the various columns of OA. The assignment of parameters along with the OA matrix is given in Table 4. One interaction among matrix alloy and volume fraction of reinforcement (AxV) was also considered.

Factor	Symbol	Level – 1	Level – 2	Level - 3
Aluminum alloy	A	Al 6061	Al 6063	Al 7072
Volume fraction	V	12%	16%	20%
Particle size	P	10µm	20µm	30µm

Table 3. Parameters and Levels for SiC reinforced composites

1.6 Preparation of Al-Alloys and Composites

Al alloys were melted in an oil-fired furnace. The melting losses of alloy constituents were taken into account while preparing the charge. The charge was fluxed with coverall to prevent dressing. The molten alloy was degasified by tetrachlorethane (in solid form). The crucibles were made of graphite. The preheated reinforcement particles were added to the liquid melt. The molten alloy and reinforcement particles are thoroughly stirred using a mixer to make the melt homogenous. The temperature of the melt was measured using a dip type thermocouple. The dross removed melt was finally gravity poured into the preheated mould.

1.7 Conduction of Tests

The following tests were conducted on the metal matrix composites:

- Tensile test for yield strength, ultimate tensile strength and % elongation
- Bending test
- Hardness test
- Microstructure analysis
- Scanning electron microscopy

Treat No.	A	V	P	AXV
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 4. Orthogonal Array (L_9) and control parameters

The samples were machined to get dog-bone specimen for tensile test. The shape and dimensions of the tensile specimen are shown in Figure 2. The computer-interfaced UTM (Universal Testing Machine) was used for the tensile test. The loads at which the specimen has reached the yield point and broken were noted down. The extensometer was used to measure the elongation. The load v/s deflection graph was attached to the machine. Two specimens were used for each trail.

Th shape and dimensions of the bending specimens are shown in Figure 3. Three-point bending tests were conducted on the metal matrix composite samples by using the universal testing machine. Two specimens were used for each trial. The specimens were loaded hydraulically. The digital acquisition system was used to record the load applied on the specimens. Figure 4 shows the three-point bending for testing of metal matrix composite samples.

Microscopic analysis of the cast composite materials was performed by optical microscopy. An image analyzer was used to examine the distribution of the reinforcement particles within the aluminum matrix. The specimen to be observed under the microscope is placed in a plastic capsule and allowed to set for some time. The mold is then polished on various grits of sand paper and finally with alumina solution according to standard procedures. The polished specimens were ringed with distilled water and etched with 5% HF solution. The specimen were then viewed under on optical microscope.

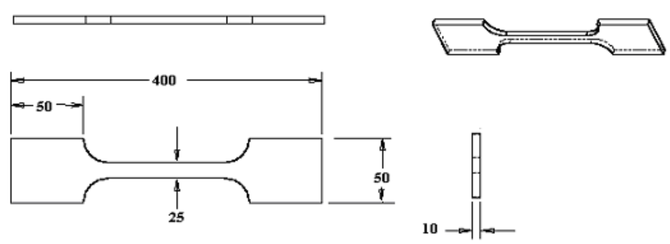

Figure 2. Tensile specimen, all dimensions are in mm

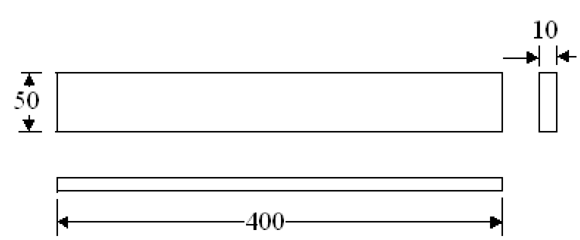

Figure 3. Bending specimen, all dimensions are in mm

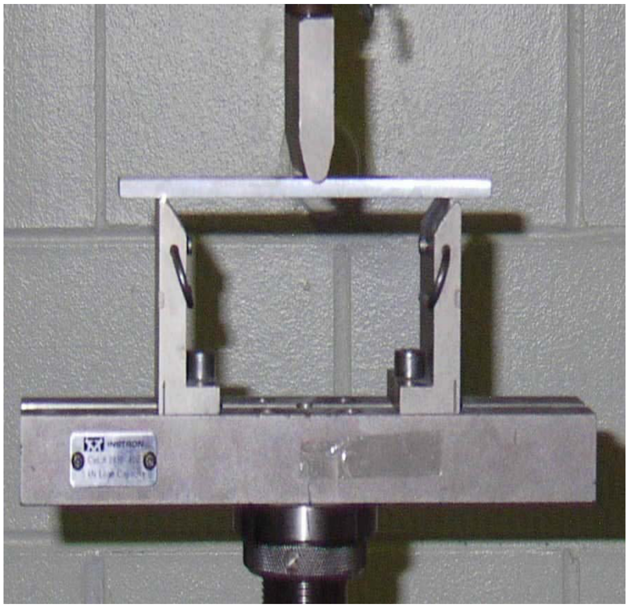

Figure 4. Three-point bend testing

Figure 5.Tested tensile specimens

Treat No.	Yield strength, MPa		UTS, MPa		Elongation ‘		Bending force	
	Trial-1	Trial-2	Trial-1	Trial-2	Trial-1	Trial-2	Trial-1	Trial-2
1	349.6	345.7	365.5	367.6	5.9	6.0	3689	3706
2	355.7	353.6	366.7	366.2	5.8	5.6	3726	3703
3	353.1	356.2	366.6	371.1	5.7	5.7	3732	3701
4	321.2	331.1	362.7	354.2	5.3	5.4	3380	3446
5	322.6	339.3	348.4	352.2	5.5	5.7	3285	3312
6	366.7	359.3	387.2	377.3	6.2	6.4	3832	3772
7	320.3	312.7	335.2	328.6	5.1	5.4	3295	3285
8	356.5	351.0	368.2	373.7	6.0	6.1	3632	3887
9	356.2	361.3	376.5	366.3	5.8	5.7	3760	3687

Table 5. Experimental results of Taguchi's design matrix

Scanning electron microscope (SEM) is carried out of characterize the fine-scale topography and establish the microscopic mechanisms governing fracture. Samples for SEM observation were obtained from the failed specimens by sectioning parallel to the fracture surface and the scanning was carried on S-3000N Toshiba scanning electron microscope.

2. RESULTS

The experiments were scheduled on random basis to accommodate the manufacturing impacts (like change in pouring temperature of liquid melt, dressing, stirring, etc). The Al-SiC metal matrix composites were cast in the cast iron metal moulds by stir casting process. The tested tensile specimens are shown in Figure 5. The experimental values of Al-SiC metal matrix composites are given in Table 5.

2.1 Effect of MMC parameters on the yield strength

Table 6 gives the ANOVA (analysis of variation) summary of raw data. The Fisher's test column confirms only three parameters (A, V, and P) accepted at 90% confidence level. The percent contribution indicates that the metal matrix composite (MMC) parameter, A (matrix alloy composition) contributes 9.95% of variation, parameter, V (% volume fraction of SiC) aids 50.44% of variation, parameter, and P (particle size of SiC) influences 28.08% of variation in the yield strength. The interaction between variables A and V does not influence the yield strength.

Column No	Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	F-Test*	P
1	A	2116.9	2040.2	2058.0	537.16	2	268.58	6.71	Accepted	9.95
2	V	1983.6	2078.7	2152.8	2397.97	2	1198.98	29.95	Accepted	50.44
3	P	2131.8	2079.1	2004.2	1370.50	2	685.25	17.12	Accepted	28.08
4	AXV	2077.7	2068.3	2069.1	9.05	4	2.26	0.06	Rejected	-3.29
5	Error	----	----	---	280.25	7	40.03	1.00	------	14.82
6	T	----	----	----	4594.95	17	-------	------	------	100.00

* F-Test belongs 90% confidence level.

Table 6. ANOVA summary of the yield strength of al-alloy/SiC composites

2.2 Effect of MMC parameters on the ultimate tensile strength

The summary of ANOVA (analysis of variance) for the ultimate tensile strength (UTS) is given in Table 7. The Fisher's test column establishes only three parameters (A, V, and P) accepted at 90% confidence level influencing the variation in ultimate tensile strength. According to the analysis of variance, there are two strong parameters, which influence UTS. Looking at the ANOVA table, parameter, P (particle size of SiC) has the largest effect (43.36%), parameter, V (% volume fraction of SiC) the second largest effect (38.26%). Parameter, A (matrix alloy composition) has the least effect (5.37%). The interaction between A and V is negligible.

2.3 Effect of MMC parameters on the ductility (tensile elongation)

The ANOVA summary of ductility measure in terms of tensile elongation is given in Table 8. The Fisher's test column ascertains only three parameters (A, V, and P) accepted at 90% confidence level influencing the variation in the ductility (tensile elongation). The parameter, A (matrix alloy composition) all by itself contributes the variation of 77.30 % on the ductility of composites, and the least effect by the parameters, V (% volume fraction of SiC), P (particle size of SiC). The influence of the interaction (AXV) between matrix alloy composition and % volume fraction of SiC is ignorable.

The ANOVA summary of bending force is given in Table 9. The Fisher's test column ascertains only three parameters (A, V, and P) accepted at 90% confidence level influencing the variation in the bending force. According to the analysis of variance, the first strongest parameter is P (particle size of SiC), the second largest parameter V (% volume fraction of SiC) and the third strongest parameter A (matrix alloy composition). The interaction (AXV) between matrix alloy composition and % volume fraction of SiC is pitiable.

3. Discussion And Validation

The influence of control parameter (viz. matrix alloy, volume fraction and particle size of SiC) on the mechanical properties is discussed. The validation is confirmed through the behavior of constituent elements in the matrix alloy, mechanism of microstructural phenomena and arguments made by the other researchers.

3.1 Effect of matrix alloy composition on the mechanical properties

Alloy -1 is Al 6061. Alloy -2 is Al 6063. Alloy – 3 is Al 7072. The mechanical properties of matrix alloys are given in Table 2. Figure 6 shows the influence of matrix alloy composition on the yield strength (YS) of Al-SiC composites.

Column No	Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	F-Test*	P
1	A	2116.9	2040.2	2058.0	537.16	2	268.58	6.71	Accepted	9.95
2	V	1983.6	2078.7	2152.8	2397.97	2	1198.98	29.95	Accepted	50.44
3	P	2131.8	2079.1	2004.2	1370.50	2	685.25	17.12	Accepted	28.08
4	AXV	2077.7	2068.3	2069.1	9.05	4	2.26	0.06	Rejected	-3.29
5	Error	----	----	---	280.25	7	40.03	1.00	------	14.82
6	T	----	----	----	4594.95	17	-------	------	------	100.00

* F-Test belongs 90% confidence level.

Table 7. ANOVA summary of the ultimate tensile strength of Al-alloy/Sic composite

2.4 Effect of MMC parameters on the bending force

Column No	Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	F-Test*	P
1	A	2202.7	2182.0	2148.5	249.35	2	124.68	4.51	Accepted	5.37
2	V	2113.8	2174.4	2245.0	1437.23	2	718.62	25.97	Accepted	38.26
3	P	2239.5	2191.6	2102.1	1621.30	2	810.65	29.29	Accepted	43.36
4	AXV	2176.5	2160.2	2196.5	110.19	4	27.55	0.99	Rejected	-0.01
5	Error	----	----	---	193.73	7	27.68	1.0		13.02
6	T	----	----	----	3611.80	17	------	-----		100.00

* F-Test belongs 90% confidence level.

table 8. ANOVA summary of the ductility of Al-alloy/SiC composites

Column No	Source	Sum 1	Sum 2	Sum 3	SS	v	V	F	F-Test*	P
1	A	2202.7	2182.0	2148.5	249.35	2	124.68	4.51	Accepted	5.37
2	V	2113.8	2174.4	2245.0	1437.23	2	718.62	25.97	Accepted	38.26
3	P	2239.5	2191.6	2102.1	1621.30	2	810.65	29.29	Accepted	43.36
4	AXV	2176.5	2160.2	2196.5	110.19	4	27.55	0.99	Rejected	-0.01
5	Error	----	----	---	193.73	7	27.68	1.0		13.02
6	T	----	----	----	3611.80	17	-------	------		100.00

* F-Test belongs 90% confidence level.

Table 9. ANOVA summary of the bending strength of Al-alloy/SiC composites

It can be seen that the Al 6061 exhibits very large YS; Al 6063 very low YS; and Al 7072 intermediate strength. The influence of matrix alloy composition on the ultimate tensile strength (UTS) of composite is shown in Figure 4.4. It is observed that the Al 6061 contributes very large UTS; Al 7072 very low UTS; and Al 6063 intermediate strength.

Figure 7 shows the effect of matrix alloy composition on the ductility (measured in terms of % elongation) of metal matrix composites. The variation in the ductility of composites is largely effected by the change in matrix alloy composition. The ductility of Al-SiC composites is much lower than that of un-reinforced Al-alloy. It can be seen that the Al 6061 attributes very large variation in the ductility; Al 7072 very low ductility; and Al 6063 intermediate ductility of the composites.

Figure 8 shows the influence of matrix alloy on the three-point bending force of Al-SiC composites. It can be seen that the Al 6061 exhibits very large bending force; Al 6063 very low bending force; and Al 7072 intermediate bending force of composites.

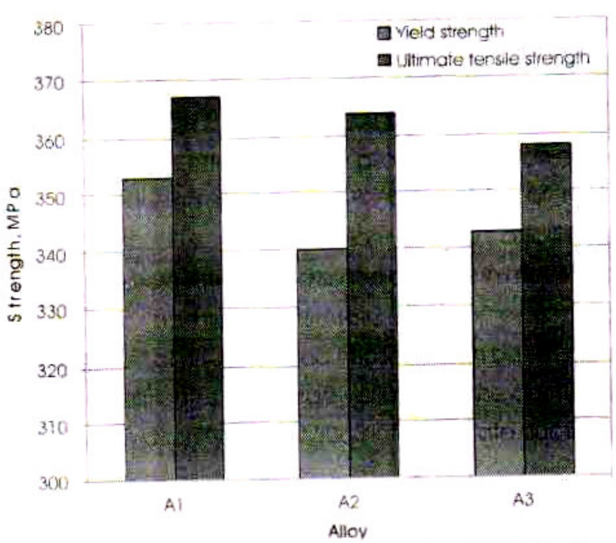

Figure 6. Influence of matrix alloy on the yield and ultimate tensile strengths of Al-alloy/SiC composite

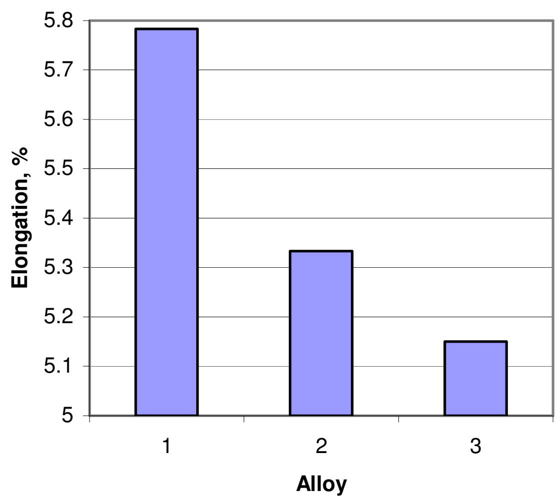

Figure 7. Influence of matrix alloy on the ductility of Al/SiC composite

The elements of Si, Fe, Cu, Mn and Mg in Al-alloys are known to increase tensile properties by forming precipitates such as Al_2Cu and Mg_2Si during the fabrication process

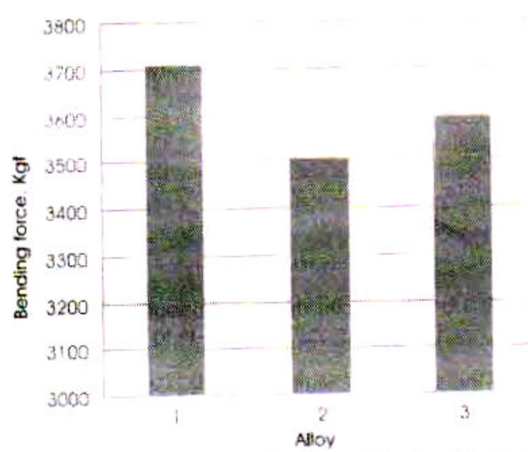

Figure 8. Influence of matrix alloy on the bending force of Al-alloy/SiC composite

[Maxim et al, 1998 & Dobrzanski et al, 2007]. The contents of alloying elements such as Si, Fe, Mg, and Cu in Al 6061 are higher than those in Al 6063 and Al 7072. Secondly, contents of alloying elements such as Si, Fe, and Cu in Al 7072 are greater than those in Al 6063 except Mg content. Therefore, it is expected that the yield strength of Al 6061 is higher than those of Al 6063 and Al 7072 and the yield strength of Al 7072 is greater than that of Al 6063.

The results of ultimate tensile strength and tensile elongation pertaining to Al 6063 and Al 7072 are quite interesting as compared to their behavior with respect to yield strength. This is because of the fact that the ultimate tensile strength and tensile elongation include both elastic and plastic range of the composite. During the plastic deformation of the composite, the nature of the chemical bond is very vital and it depends on the alloying elements. For instance, addition of Mg to composite matrix lead to the formation of MgO and $MgAl_2O_3$ at the interface and this enhances the wettability, which is otherwise poor. Mg has also improved the wettability between Al and SiC particles, by reducing the SiO_2 layer on the surface of the SiC [Zlaticanin et al, 2004]. The Mg content in Al 6063 is 0.520% and it is 0.396% in Al 7072. Hence, the UTS and tensile elongation of Al 6063 matrix alloy composite has considerably greater strength than those of Al 7072 matrix alloy composite.

Rohatgi et al (1990) have stated that the grain sizes of the Al-alloy matrix are sensitively dependent on the fabrication process and the composition. Qu et al (2007) found that the reinforcing particles are more or less non-uniformly dispersed in the metal matrix composites. In the as-cast conditions, the matrix is multiphase. Zhou and Xu (1997) have mentioned that the brittle phases can form at various stages of composite processing by reaction between the matrix and the reinforcement, during solidification.

The various intermetallics can be revealed in the microstructures shown in Figures 9-11. Figures also show the distribution of the SiC particles in the composites. It is clear that the SiC particles are distributed unevenly in the as-cast composite. There is no distinct evidence of clustering, but little agglomeration in Al 6061/SiC composite. There is clear indication of clustering and agglomeration in Al 6063/SiC and Al 7072/SiC composites.

In the as-cast condition, Al is present both in solid solution with the matrix and precipitated as $Al_{12}Mg_{17}$ phase that is present at and along the grain boundaries. MgO and $MgAl_2O_3$ are also seen along the grain boundaries. The phases Al_2Cu, Mg_2Si,

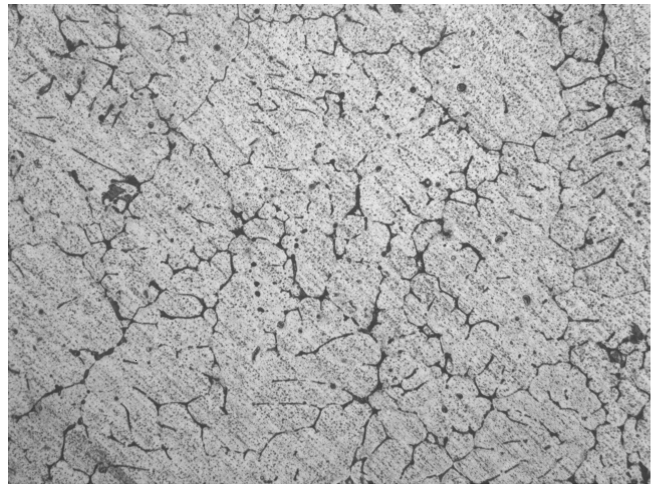

Figure 9. Microstructure of Al 6061/ SiC composite, 100X

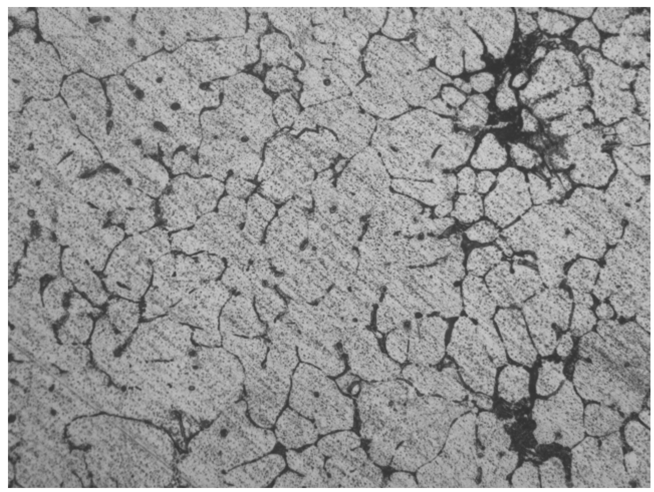

Figure 10. Microstructure of Al 6063/ SiC composite, 100X

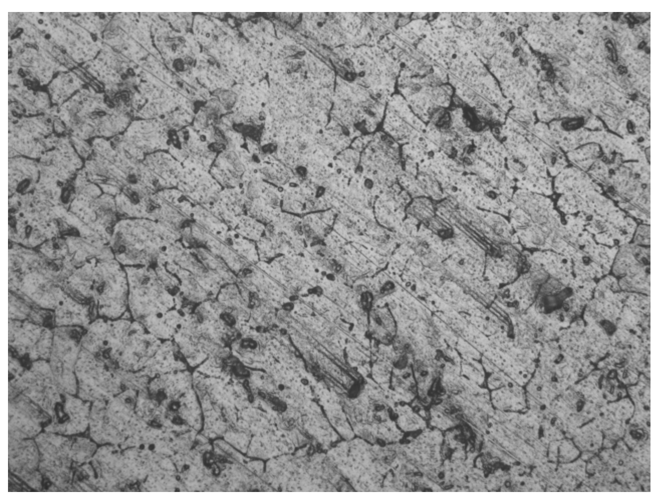

Figure 11. Microstructure of Al 7072/ SiC composite, 100X

$Al_5Mg_8Cu_2Si_6$ Al_3Fe, and Al_3FeSi are also observed in the microstructures. In the microstructure of composites, Si phase can also be seen apparently in the eutectic regions, and intermetallic compounds such as Mg_2Si, iron-containing phases or spinels may also exist due to the secondary alloying elements and impurities present in the matrix alloy scraps.

3.2 Effect of % volume fraction on the mechanical properties

Figure 12-13 illustrate the influence of % volume fraction of SiC (reinforcement) on the on the yield strength, and ultimate tensile strength of Al-SiC Metal matrix composite. The graphs indicate that the yield strength, and ultimate tensile strength increase with increase in % volume fraction of SiC in the composite. With increasing volume fraction, more load is transferred to the reinforcement which is also results in a higher yield strength, and ultimate tensile strength. This behavior is in agreement with the work carried by Ryu et al (2004). They have reported that the mechanical properties of Al/SiC (ultimate strength and yield strength) increase with increase the volume fraction because the load transferred to reinforcement. A similar kind of study on the properties of discontinuous reinforced aluminum composite was reported by Nardone and Prewo (1986) that an increase in volume fraction of SiC particles form 15 to 25 % produces increase in yield strength, and ultimate tensile strength.

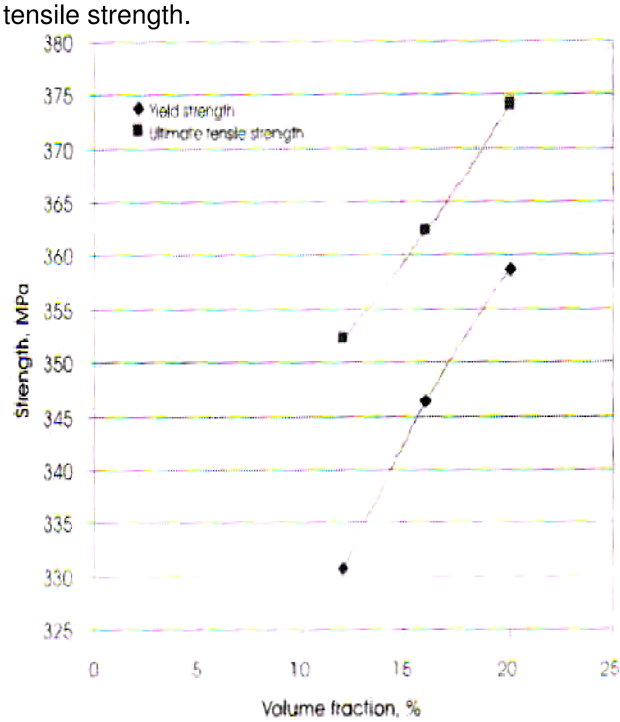

Figure 12. Influence of volume fraction on the ultimate tensile strength Al/SiC composite

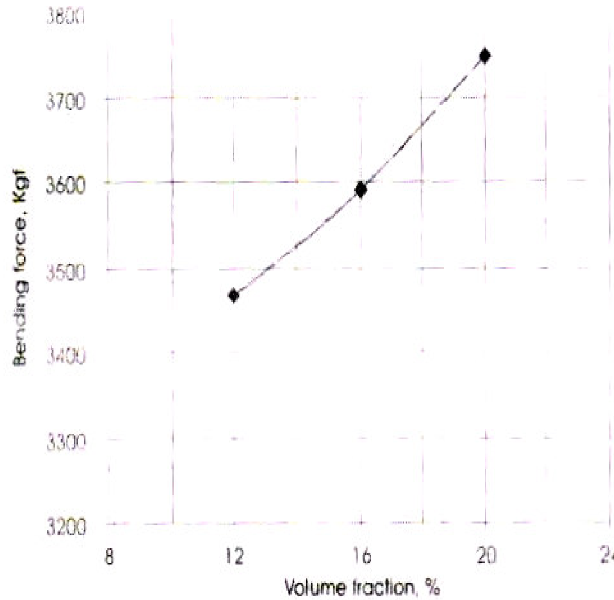

Figure 13. Influence of volume fraction on the bending force of Al/SiC composite

In metal matrix composites, the reinforcing phase typically is much stiffer than the matrix. The ultimate tensile of Al-SiC composite is only marginally higher than yield strength indicating that the work hardening rate past yielding is low. The yield strength, and ultimate tensile strength increase with the work hardening rate. The work hardening rate increases with increasing volume fraction of reinforcement (and decreased matrix volume). Microplasticity takes place in metal matrix composites due to stress concentrations in the matrix at the poles of the reinforcement and/or at sharp corners of the reinforcing particles.

The effect of volume fraction of SiC on the ductility of the composites is shown in figure 4.19. The decrease in ductility can be attributed to the earlier onset of void nucleation with increasing amount of reinforcement. The high stress concentration at the tip of the cracked particles can also contribute to a decrease in the ductility (tensile elongation) in the composite.

3.3 Effect of particle size of reinforcement on the mechanical properties

Figures 15 - 17 illustrate the effect of particle size of SiC on the yield strength, ultimate tensile strength, and ductility (tensile elongation). The decrease in the particle size increases the yield strength, ultimate tensile strength, and ductility (tensile elongation). This is because, the small particle size means a lower inter-particle spacing so that nucleated voids in the

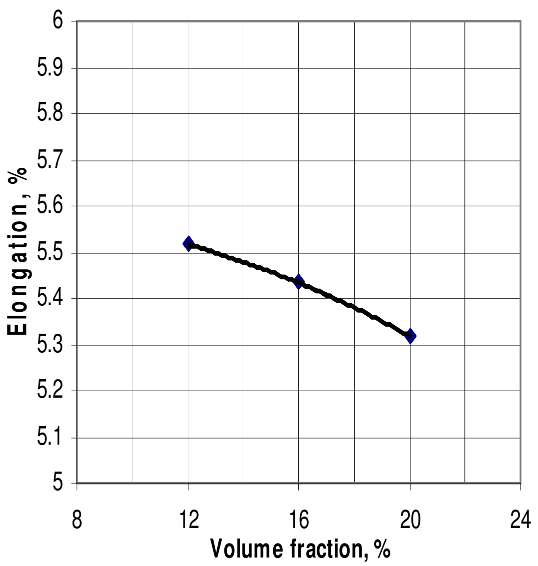

Figure 14. Influence of volume fraction on the ductility of Al/SiC composite.

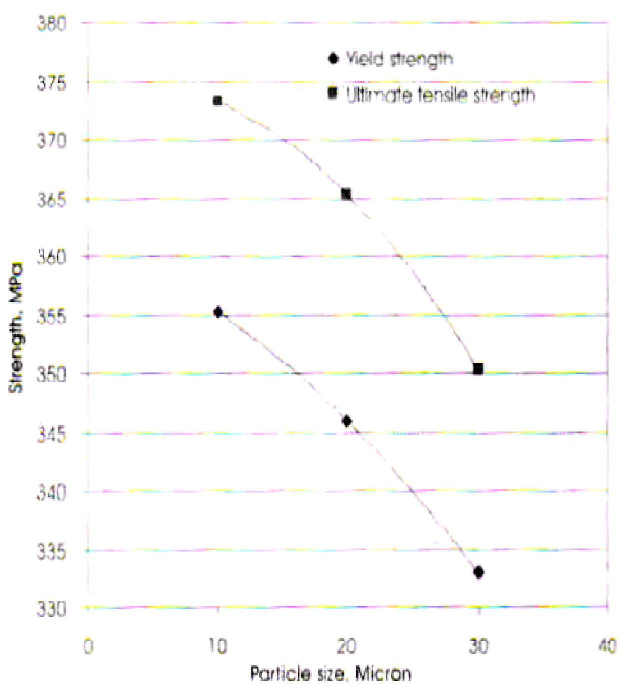

Figure 15. Influence of particle size on the yield and ultimate tensile strength of Al/SiC composite

matrix are unable to coalesce as easily. Also, the larger ceramic particle size is detrimental to composite strength. Therefore, yield strength, ultimate tensile strength, and bending force, increases with decreasing reinforcement particle size. It is also reported that the coarser particles are more likely to contain flaw, which severely reduce their strength than smaller particles (Maxim et al, 1998).

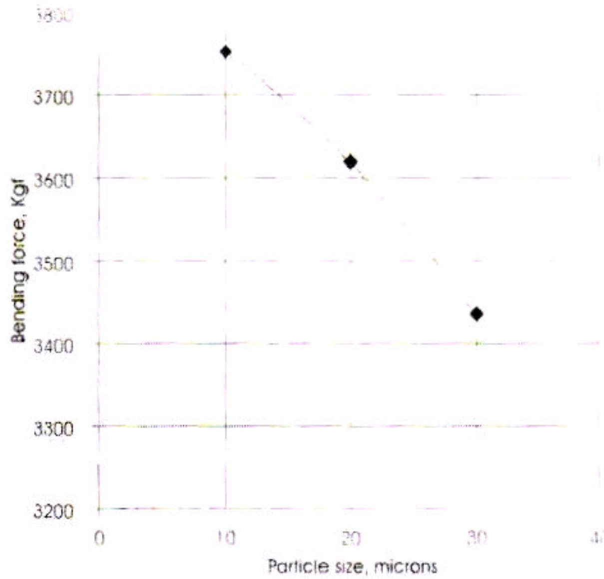

Figure 16. Influence of particle size on the bending force of Al/SiC composite.

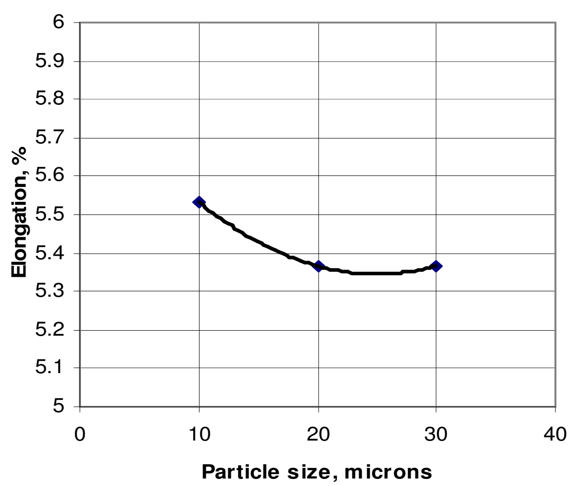

Figure 17. Influence of particle size on the ductility of Al/SiC composite

There is an increase in the ductility with a decrease in the particle size of the reinforcement. At relatively large particle sizes of SiC, a significant amount of particle cracking takes place during tensile testing of the composites. Cracked particles do not carry any load effectively and can be effectively thought of as voids, so the ductility is decreased. A higher working rates has also been observed with decreasing particle size (Nardone ans Prewo, 1986)..

Conclusion

The matrix alloy Al 6061 contributes very large values of yield strength, ultimate tensile strength, ductility and bending force to the Al-alloy/SiC metal matrix composites. The matrix alloy 7072 exhibits lower ductility than the matrix alloy 6063. Mg improves the wettability between Al and SiC particles by reducing the SiO_2 layer on the surface of the SiC. The SiC particles are distributed unevenly in the as-cast composite with no distinct evidence of clustering but very little agglomeration. In the as-cast condition, Al is present both in solid solution with the matrix and precipitated as $Al_{12}Mg_{17}$ phase along the grain boundaries. MgO and $MgAl_2O_3$ are also formed along the grain boundaries. The phases Al_2Cu Mg_2Si, Al_3Fe and Al_3Fesi are also observed in the microstructures of Al-alloy/SiC composites. With increasing volume fraction, more load is transferred to the reinforcement which results in a higher yield strength, ultimate tensile strength, and bending force to the Al-alloy/SiC composites. The decrease in the particle size increases the yield strength, ultimate tensile strength, bending force, and ductility (tensile elongation). The large ceramic particle size is detrimental to composite strength.

References

[1]. Chawla, K.K (1998). Composite materials: Science and Engineering, Springer-Verlog, N.Y.

[2]. Jayalakshmi, S., Seshan,S., Kailas, S. V., Kumar, K.,& Srivatsan, S. (2004). Influence of Processing and reinforcement on microstructure and impact behavior of magnesium alloy AM100, Sadhana, 29(5), 509-523.

[3]. Hyo S. L., Jae, S.Y., Soon H. H., Duk J. Y., Kyung H. N. (2001). The fabrication process and mechanical properties of SiC/Al-Si Metal Matrix Composites for automobile air-conditioner compressor piston, Journal of Metal processing Technology, 113, 202-208.

[4]. Geni, M & Kikuchi, M. (1998). Damage Analysis of Aluminum Matrix Composite Considering Non-uniform Distribution of SiC Particles, Acta Metallurgica, 46 (9), 3125-3133.

[5]. Chawla, N., & Shen,Y.L. (2001). Mechanical Behavior of Reinforced Metal Matrix Composites, Advanced Engineering Materials, 3(6), 357-370.

[6]. McDaneals, D.L. (1985). Analysis of Stress, Strain, Fracture and Ductility Behavior of Al Matrix Composite Containing Discontinuous SiC Reinforcement, Metallurgical Transactions A, 16A, 1105-1115.

[7]. Arsenault, R.J., Wang, L., & Feng, C.R. (1991).Strengthening of composites due to microstructural changes in the matrix, Acta Metallurgia, 39, 47-57.

[8]. Taguchi, G. 91986). Introduction to Quality Engineering, Asian Productivity Organization.

[9]. Chennakesava Reddy, A., & Shamraj, V.M., Reduction of Cracks in the Cylinder Liners Choosing Right Process Variables by Taguchi Method, Foundry, 10(4), 47-50.

[10]. Maxim. L. S., Seleznev, I. L., Cornie, J. A., Argon, A. S., & Mason, R. P. (1998). Effect of Composition, Particle Size, and Heat Treatment on the Mechanical Properties of Al-4.5 wt. % Cu based Alumina Particulate Reinforced Composites, SAE International Congress and Exposition, Detroit, MI, February 23-26, Paper No. 980700.

[11]. Dobrzanski, L. A., Maniara, R., Krupinski, M,. Sokolowski, J. H. (2007). Microstructure and mechanica properties of ALSi9Cu alloys, JAMME of achievement in Materials and Manufacturing Engineering, 24 (2).

[12]. Zlaticanin, B., Filipovic, M., Valcic, A., Aleksic, R., Nikolic, S., Radonjic, B., & Bosnjak, B. (2004). The effect of magnesium and titanium addition on the microstructure and properties of As-cast Al-5%Cu alloys, Materiali in Tehnologije, 38(1-2).

[13]. Rohatgi, P., Asthana, R., & Yarandi, E.(1990). In solidification of metal matrix composites, The Minerals, Metals and Materials society, 51-75.

[14]. Zhou, W., & Xu, Z.M. (1997). Casting of SiC Reinforced Metal Matrix Composites, Journal of Materials Processing Technology, 63, 358-363.

[15]. Qu, S, Geng, L., & Han, J.(2007). SiC/Al Composites Fabricated by Modified Squeeze Casting Technique, Journal of Materials Science and Technology, 23(5), 641-644.