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Synthesis, characterization, simulation and Analysis of Metal matrix Composite System.

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Abstract

In the present industrial scenario composite material are given the first preference due to its high strength and less weight ratio. Conventional materials like steel, brass, and aluminum etc. Will fail without any indication, crack initiation; propagation will take place within short span. To overcome this problem conventional materials are replace by aluminum alloy and its composites. In this project work Aluminum Alloy 6061 is selected as matrix material and Silicon Carbide as reinforcement material based on literature review. Fabrication of composite is done by Stir Casting method. Tensile specimens are prepared according to ASTM E08M standards and testing was done under tensometer at room temperature. Finite element method (FEM) is used to simulate the tensile test in ANSYS workbench to identify the occurrence of stress distribution, deformation and elongation etc., without investing much during the initial phase of the product development. Validation of mechanical results with analytical result is done to know the percentage of error associated. Statistical tools like correlation and regression is used to generate regression equation to predict the unknown properties (output) by varying the input variables.

Keywords: Aluminium Silicon Carbide (AlSiC), ANSYS Workbench, Finite Element Analysis (FEA), Metal Matrix Composites (MMC's), Stir Casting etc.

INTRODUCTION

Many of the engineering applications in today's world wants materials with extraordinary mechanical properties that cannot be fulfill by conventional materials like metals, polymers or ceramics. Mechanical properties of materials play a major role, especially in the field of Aerospace and Transport applications. New classes of materials called "composite materials" are capable of producing desired properties to meet the industrial needs. The final outcome of any composite material should be of light weight, longer life span and cost effective. The mechanical property of composites depends on fabrication technique and percentage of reinforcement added to matrix material. In present work Aluminium Alloy 6061 is reinforced with Silicon carbide in different wt. (5%, 10%, 15% and 20%) ratios to fabricate AMMCs through stir casting technique. Tensile test is carried out, to know the improvement in tensile properties of AMMCs. Improve in tensile strength is one of the key reason they are widely used in industrial prospectus.

OBJECTIVES

1) To fabricate AlSiC MMCs by stir casting technique.
2) Preparing tensile specimen according to ASTM standards by machining.
3) Simulation of tensile tests through ANSYS workbench (FEA).
4) Comparing the experimental results with analytical results to determine the percentage of error.
5) Implementation of statistical tool to experimental results, correlation and regression analysis to determine the formula that fits the relationship between the variables and strength of relationship between them.
6) Expressing results through tables and graphs.

3. MATERIALS AND METHOD OF FABRICATION

3.1 Matrix Material

AA 6061 is selected as matrix material. AA 6061 is one of the most widely used of the 6000 series Aluminum Alloy. AA 6061 series contain silicon and magnesium in order to form magnesium silicate. The chemical composition and Properties of AA 6061 is tabulated below.

Test Method: ASTM E 1251-2011.

Equipment Used: Optical Emission Spectrometer BAIRD DV6.

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Table 3.1: Chemical Composition of Aluminium Alloy 6061

Element	Cu	Si	Fe	Mn	Ti	Zn	Cr	Mg	Al
% Weight	0.282	0.728	0.183	0.027	0.171	0.053	0.235	0.999	97.322

3.2 Reinforcement Material

Silicon Carbide is selected as reinforcement material; ‘Carborundum’ is an alternative name of Silicon carbide with a chemical formula SiC. Present days is widely used as reinforment in Composites preparation and good abrasive. In Present work SiC partial size of 400 Mesh (37 micron) have been used.

Table 3.2: Mechanical Properties of SiC and Aluminium Alloy 6061

Properties	SiC	AA 6061
Elastic Modulus (GPa)	410	70-80
Density (g/cc)	3.1	2.7
Poisson's Ratio	0.14	0.33
Hardness (Kg/mm^2)	2800	95
Modulus of Rigidity (GPa)	140	26
Shear Strength (MPa)	-	83
Tensile Strength (MPa)	390	115

3.3 Stir Casting (Fabrication Process)

Stir casting is most commonly used method to produce MMCs because of its simple procedure and cost effectiveness. In this process Pre weighed AA 6061was fed in to electric furnace set-to 700^{0}C.The experimental setup show in figure. After melting of Al 606, magnesium powder as wetting agent and hexachloroethane (C_2Cl_6) as degassing agent added to remove entrapped gases. Pre heated reinforcement (SiC) up to 300^{0}C is slowly added to molten matrix with manual stirring and then by motor operated mechanical stirrer with speed of 300 rpm for a period 10 minutes. After uniform distribution of SiC in molten AA 6061, the mixture is slowly poured to pre-heat die to 300^{0}C and cooled to room temperature. Casting is separated form mould and finishing is done. The same procedure is repeated to produce AlSiC MMCs of different weight ratios-5%, 10%, 15% and 20%.

Table 3.3: Process Parameters of Stir Casting

Parameters	Specifications
Pre-heating of SiC and Die	300^{0}C
Stirring Time	10 minutes
Stirring Temperature	700^{0}C
Pre-heating time of SiC and Die	60 minutes
Furnace Temperature	700^{0}C
Stirring speed	300 rpm

EXPERIMENTAL DETAILS

Tensile test is the most commonly used mechanical test on the material because of its simple, relative inexpensive and fully standardized. Where pulling load is applied at the terminals of the specimen to find its strength along with how much it will be elongated.

The loading is continued until the material breaks to get tensile complete profile. Curve shows how the material goes on elongation on loading, the point at which the material fails called "Ultimate Strength"/ultimate tensile strength (UTS) on the curve. The slope of Stress-Strain curve gives the young's Modulus "E".

Figure 4.1: Tensometer

Figure 4.2: Tensile Specimens After Test

Tensile Specimens Before Test

5. RESULTS AND DISCUSSIONS

5.1 Tensile Strength

Table 5.1: Tensile Strength of AMMCs Tensile Specimens

% of SiC in AA 6061	0%	5%	10%	15%	20%
Tensile Strength (N/mm^2)	102.56	120.23	84.1	121.56	124

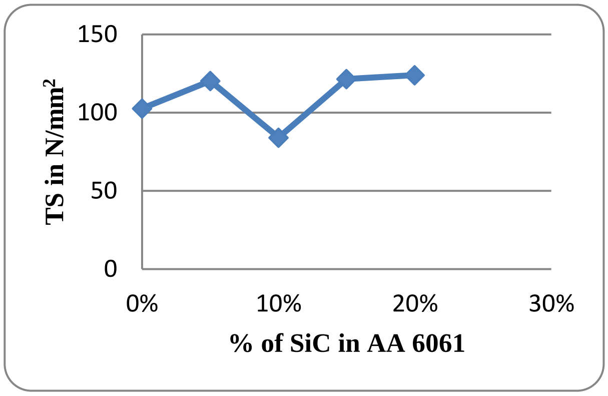

Figure 5.1: Ultimate Tensile Strength of AlSiC MMCs

Figure 5.1 shows the variation of Ultimate Tensile strength as a function of % SiC in AA 6061. As seen from the graph, at 0% SiC, UTS is found to be 102.56 which drastically increase to 120.23 at 5% SiC, due to addition of reinforcement. There is a drastic reduction in UTS at 10% SiC which may be due to segregation of SiC in tensile test specimen. Thereafter it again increases at 15% and 20% SiC, due to increase in percentage of SiC in AA 6061 matrix.

5.2 Displacement

Table 5.2: Displacements of AMMCs Tensile Specimens

% of SiC in AA 6061	0%	5%	10%	15%	20%
Displacement (mm)	1.48	1.36	1.95	1.37	1.3

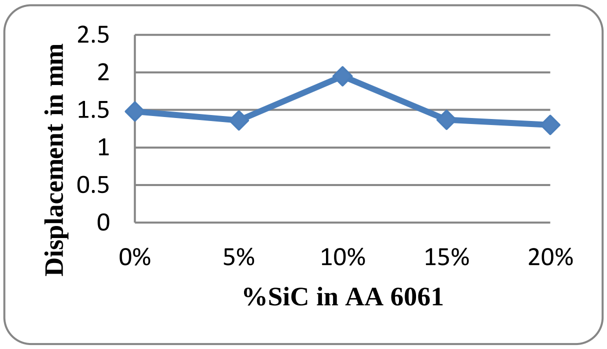

Figure 5.2: Displacements of AMMCs Tensile Specimens

Figure 5.2 shows the variation of displacement as a function of % SiC in AA 6061. The displacement at 5% SiC is less than that at 0% SiC. But the displacement is found to be maximum at 10% SiC, which may be attributed to segregation of SiC in AA 6061 matrix. While on contrary, the values have dipped at 15% and 20% SiC. The decrease in displacement may be due to increase in percentage of SiC or decrease in elasticity.

SIMULATION OF TENSILE TEST

Steps involved in simulating tensile test in FEA Software,

1. Create or import 3D CAD Model
2. Define the material properties
3. Mesh the CAD Model
4. Apply the boundary conditions
5. Define the type of load
6. Solve

Figure6.1:CAD Model

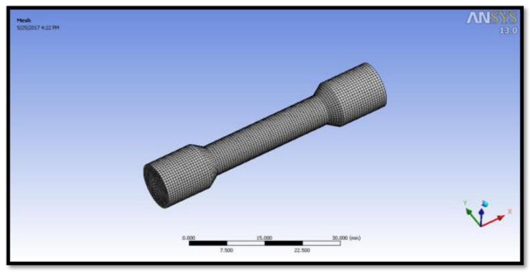

Figure 6.2: Meshed Model

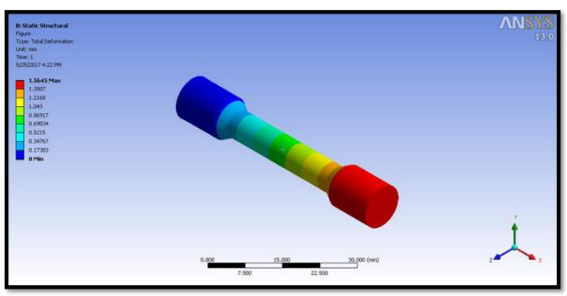

Figure6.3: Displacement in tensile Specimen

CAD Model Specifications,

1) Length of Tensile Specimen = 51 mm
2) Diameter of Tensile Specimen = 9.5 mm
3) Number of Nodes = 135199
4) Number of Elements = 31400

Table 6.1: Displacement in Tensile Specimens

Composite Material	Total Deformation in mm	
Aluminium Silicon Carbide	Minimum	Maximum
AlSiC (0%)	0	1.7401
AlSiC (5%)	0	1.4645
AlSiC (10%)	0	2.105
AlSiC (15%)	0	1.4792
AlSiC (20%)	0	1.5645

CORRELATIN AND REGRESSION ANALYSIS

Regression Analysis is done to know how an independent variable(X) is numerically related to the dependent variable (Y).

Correlation is a measure of the strength of the relationship between the dependent and the independent variables. Correlation coefficient 'r' varies from -1 to +1, if r=1 indicates strong relationship between the variables. When value of r near to zero implies that there is a little or no linear relation between variables.

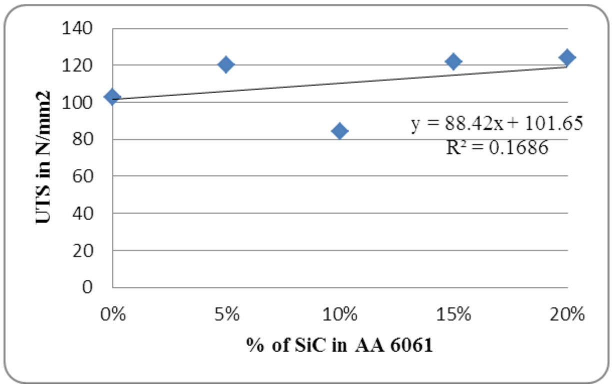

Figure 7.1: Curve fit for tensile strength

$$y = 88.42x + 101.65 \qquad (1)$$

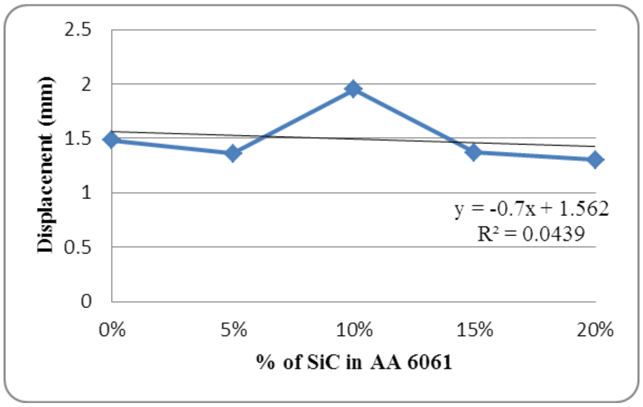

Figure 7.2: Curve fit for displacement

$$y = 88.42x + 101.65 \quad (2)$$

Unknown Tensile Strength and Displacement can be predicted by using regression equation (a) and (b) respectively.

CONCLUSIONS

Stir casting is a simple method of fabricate of AlSiC MMCs because of its good castability and cost effectiveness. Tensile strength improved by increasing reinforcement concentration but at 10% SiC there is a drastic fall in tensile strength due to segregation of SiC and casting defect. Experimental results are good agreement with analytical results. Unknown values can be predicted using regression equation by varying the input parameters.

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