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Mechanical Properties of Aluminium Matrix Nanocomposite Reinforced with Silicon Carbide

RafiullahAnsari[1], AkhtarHussain Ansari[2]

[1]PG scholar, Department of Mechanical Engineering, Aligarh Muslim University, UP, India

2Professor, Department of Mechanical Engineering, Aligarh Muslim University, UP, India

Abstract: ***The present study deals with the nano composite of aluminium matrix reinforced with silicon carbide particles of 50 nm size. Tensile strength and toughness of the composite is determined by tensile test. Specimens were prepared through stir casting route as per the ASTM b577 standard. Also the effect of pouring temperature and filler material content is studied on mechanical properties of aluminium composite and the results were analyzed by ANOVA. The results showed a negligible effect of pouring temperature on mechanical properties while composition has significant effect. An increase of 65% in tensile strength and 101.5% improvement in toughness is observed with filler content of 0.8 % and 0.6 % by weight consecutively.***

Keywords: aluminium, composite, tensile strength, toughness, ANOVA

1. Introduction

With the advancement of technology the demand of material with specific properties has increased. This increasing demand of materialwith specific properties leads to the development of composite materials. Composite materials can fulfill a wide range of demand. A composite is generally composed of two or more components which are chemically distinct and insoluble phases [1]. These individual components of composites do not dissolve or merge into each other rather they act as a single unit. The properties of composite material are superior to any of the individual material from which it was produced. generally the material in bulk is known as matrix material and is soft, having good ductility, formability and thermal conductivity while the material in less quantity is called as reinforcement and is generally hard and having high stiffness. There are varieties of methods through which composites can be produced like powder metallurgy[2] [7], ball milling [3], friction stir process, diffusion bonding [6], vapour deposition method [6], stir casting [1] [4] method etc. According to S. Naher the cost of preparing composite materials using a casting method is about one third to one half that of competing methods, and for high volume production, it is projected that costs will fall to one tenth [5]. In this stir casting method first of all the matrix metal is heated so that it gets melted and then reinforcement is added into this melt which may be preheated to improve wettability [1]. Subsequently the mixture is stirred to make a homogeneous mixture of metal matrix and reinforcement [1]. Finally the homogeneous mixture is solidified to get the composite. In this manner reinforcement does not get dissolved rather it gets embedded into the metal. Addition of magnesium also improves wettability [1].Properties of composites depend on many factors like shape and size of reinforcement, matrix material, composition of reinforcement etc. [8] [9] [10] [11].A.A. Hussain and S. Haqueet. al. studied the effect of stirring speed and pouring temperature on metal matrix composite reinforced with silicon carbide micro composites and concluded that by increasing speed impact strength and hardness increases up to a certain value then it get decreased with further increase in speed [13].

2. Experimental Procedure

The material used in our case is 97% pure aluminium and silicon carbide of 50 nm size. To produce the specimen for tensile test, stir casting method is adopted. 250 g of aluminium is taken into a graphite crucible and up to 700 ^{o}C to melt an an electric resistance furnace. Preheated silicon carbide particles are added into the melt and stirred with a mechanical stirrer at a speed of 600 rpm for 10 minutes. Subsequently temperature of molten metal is raised up to the pouring temperature which is 800 ^{o}C and 900 ^{o}C. this molten metal is then poured into a die fabricated to produce specimen for tensile test. Tensile test specimen is as per ASTM b577 standard in rectangular shape. In our case independent parameters are temperature and composition while dependent parameters are tensile test and toughness.

2.1 Tensile Test

By tension test one can determine various parameters like strength, ductility and toughness elastic limit, elongation, proportional limit etc. The two ends of specimen are gripped into the universal testing machine then uniaxial tension force is applied to the specimen. Elongation and applied load is noted down at various levels.

Figure 1: Specimen for tensile test

Test is conducted three times at each temperature and composition level and mean of the observations is taken as final value.

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Table 1: Tensile strength at different temperature and composition

Temperature(°C)	Composition (% wt. SiC)	Mean tensile strength (Mpa)
800	0	139.3004
	0.1	148.1438
	0.2	159.7611
	0.4	175.9643
	0.6	214.7228
	0.8	230.559
900	0.1	144.9429
	0.2	169.7683
	0.4	185.7417
	0.6	212.3883
	0.8	216.5183

It is clear from the table that tensile strength is increasing with increase in silicon carbide content. Also it can be seen that at each corresponding temperature level tensile strength is generally more at temperature of 800 °C in comparison to 900 °C.

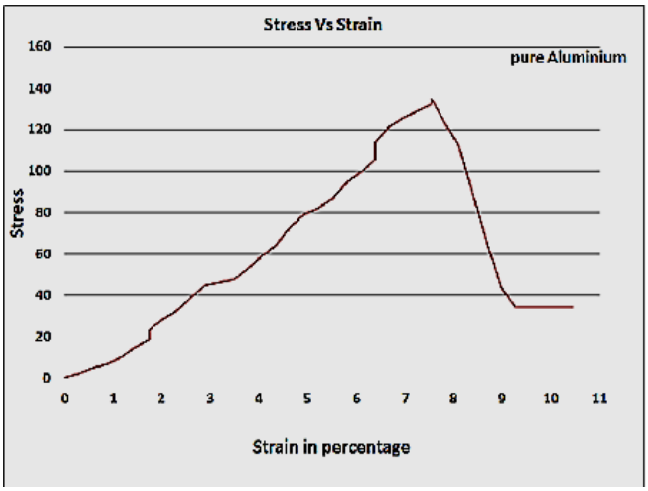

Figure 2: Stress- strain diagram for pure Aluminium

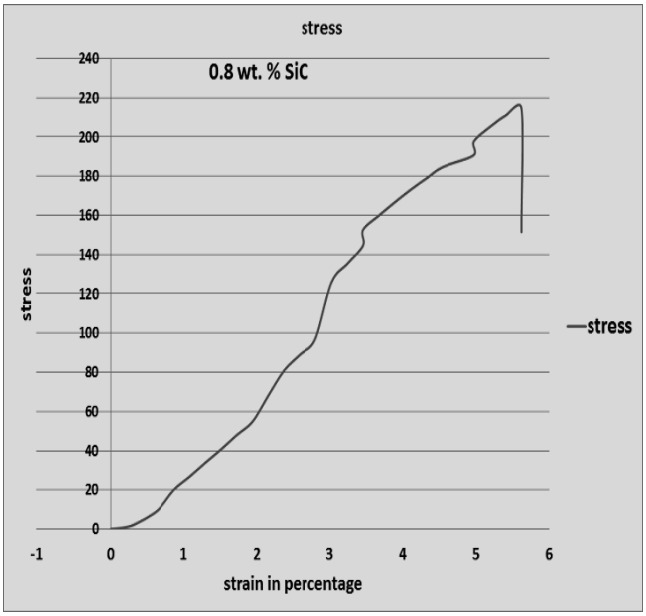

Figure 3: Stress-strain diagram for Al+ 0.8 % by wtSiC

It is evident from the diagrams given above that percentage elongation of aluminium has decreased with increasing SiC content in the composition. This is because hard particles of silicon carbide produce hindrances in the movement of dislocations by which plastic deformation takes place.

2.2 Toughness

Toughness is a mechanical property which is a measure of the ability of a material to absorb energy up to fracture. The amount of energy absorbed up to fracture per unit volume of material is constant for every material which is called as toughness. For dynamic loading condition ie.high strain rate two standardized tests are there namely **Charpy and Izod** test for the determination of toughness. But for static loading condition (low strain rate)toughness can be approximated as the area under tensile stress-strain curve upto the point of fracture. In this study same method is applied for the calculation of toughness.

Table 2: Toughness at different temperature and composition

temperature (°C)	*Composition wt % SiC*	*mean toughness*
800	0	403.1899033
800	0.1	479.0021765
800	0.2	499.3542536
800	0.4	764.6741139
800	0.6	788.6002793
800	0.8	709.2590518
900	0.1	445.8138149
900	0.2	493.5433463
900	0.4	691.6934142
900	0.6	812.703604
900	0.8	602.2960149

It is clear from the table that toughness first increases with SiC content up to 0.6 % and then decreases. Increase in toughness can be attributed to increase in strength of composite. But after the addition of 0.6% silicon carbide toughness decreases which is due to decrease in ductility.

2.3 ANOVA Analysis

Analysis of variance is used a method to test the hypothesis that there is no any difference between two or more process means. It is often used to test the hypothesis that there is no difference between different treatments. In our case the purpose of ANOVA was to check which parameter affects the properties most [12]. The software used for ANOVA analysis is MINITAB 15. In this study, the value of alpha "α" i.e. level of significance was taken as 0.05 that is 95% confidence interval to analyze the problems by ANOVA.

ANOVA: Tensile strength versus composition(% wtSiC), temperature(°C)

Table3. ANOVA table for tensile strength

Source	DF	SS	MS	F	P	% contribution
composition	4	16807.6	4201.90	254.66	0.00	96.67930215
temperature	1	0.0	0.03	0.00	0.968	0
Interaction	4	412.2	103.06	6.25	0.009	2.371023129
Error	10	165.0	16.50			0.949099506
Total	19	17384.9				

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The P value for composition is zero which means composition is highly significant factor in affecting the composite tensile strength which is also evident with its percentage contribution of 96.7%. percentage contribution of other factor including error is 3.3% which is very less in comparison to that of composition.

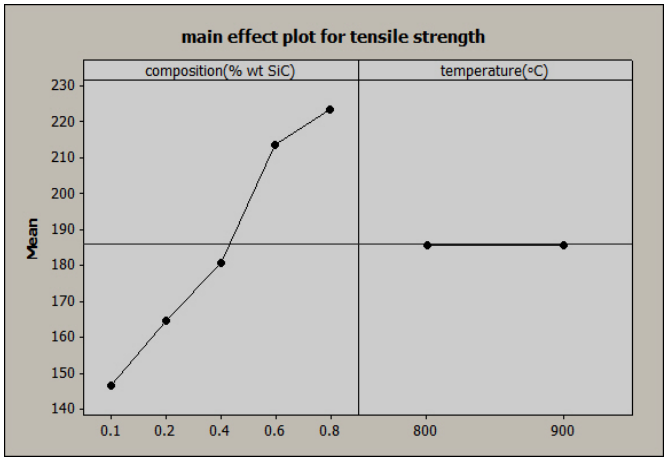

Figure 4: Main effect plot for tensile strength

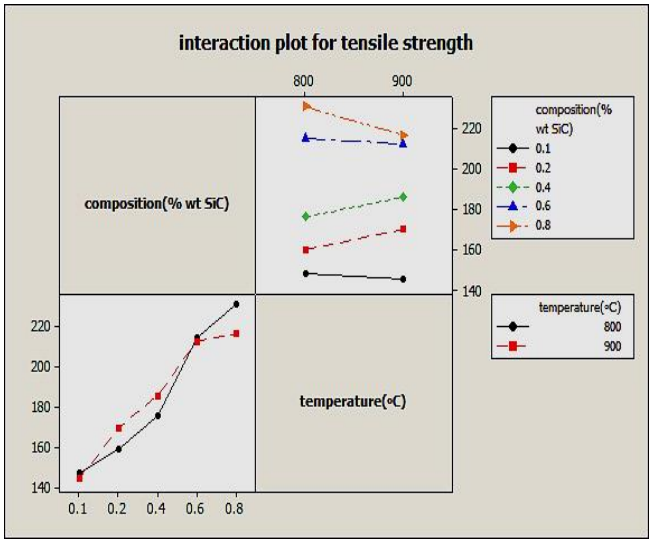

Figure 5: Interaction plot for tensile strength

ANOVA: Toughness versus composition (% wtSiC), temperature (°C)

Table 4: ANOVA for Toughness

Source	DF	SS	MS	F	P	% contribution
composition	4	5428	1357	31	0	71.64207864
temp	1	686	686	16	0	9.052166729
Interaction	4	597	149	3	0	7.875425968
Error	20	866	43.3			11.43046064
Total	29	7577				

It is clear from the ANOVA analysis that major contribution is of composition and rest contributes very less in comparison to it.

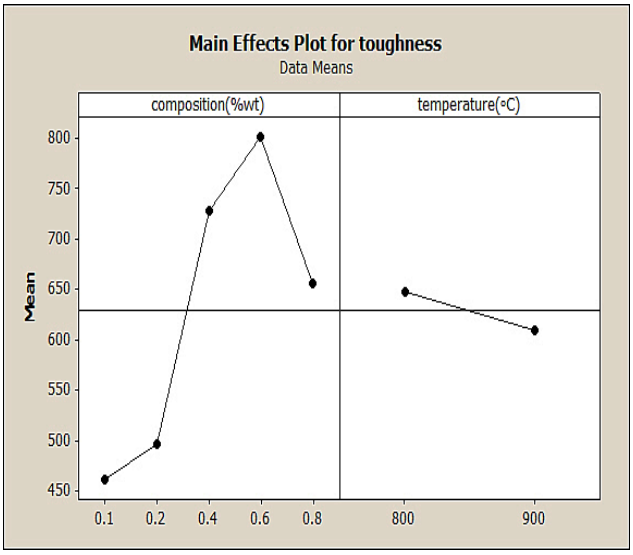

Figure 6: Main effect plot for wear rate

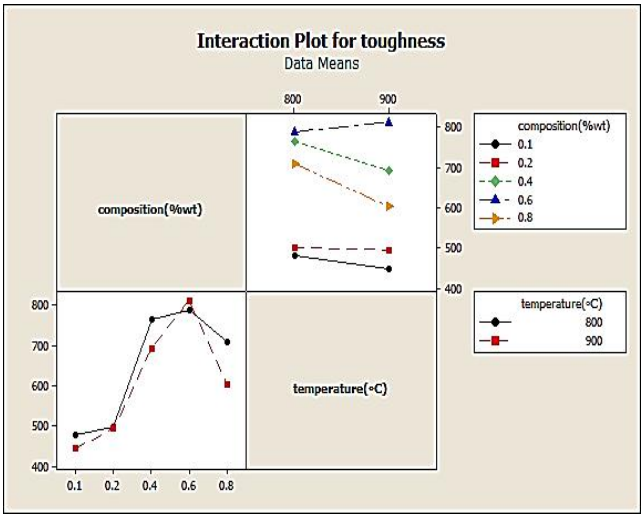

Figure 7: Interaction plot for wear rate

3. Conclusion

The effect of increase in silicon carbide content is more significant as compared to increasing pouring temperature. Tensile strength increases continuously by increasing silicon carbide content at both pouring temperatures. The maximum increase (65.5%) in tensile strength is observed when silicon carbide content is 0.8% and pouring temperature is 800 °C. Ductility of the composite decreases as filler content is increased. The value of toughness increases up to 0.6 % of SiC and onfurther addition it decreases. Maximum increase in toughness is 101.5% which is observed for 0.6 wt % of silicon carbide at a pouring temperature of 900 °C.

4. Scope for Future Work

1. This work can be investigated further by changing the various input parameters.
2. As tensile strength is still improving so percentage content of filler material can be increased further to see that the maximum SiC content beyond which there is a decrease.
3. Stirring speed and mixing time can be further studied for improved homogeneous mixing.

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4. Other filler materials or a combination of filler materials can be studied for better mechanical properties.

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Author Profile

Rafiullah Ansari received bachelor of technology in mechanical engineering from Aligarh Muslim University, Aligarh (India) in 2012. Currently he is pursuing M. Tech (Industrial and Production Engineering) in Aligarh Muslim University.

Akhtar Hussain Ansari completed his B.Sc. Engg (Mech.) M.Sc. (Ind. And Prod.) from Zakirhussain college of Engineering and Technology. Aligarh Muslim University. He received hid Ph.D in 2004. Currently he is a professor in the department of mechanical engineering (AMU). He has published 15 research papers in journals of national and international repute. He has 7 patents in his name

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