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DEVELOPING REGRESSION MODEL TO PREDICT THE TENSILE STRENGTH, BENDING LOAD AND MICRO HARDNESS AND TO OPTIMIZE THE WT % OF SIC IN AL-SIC COMPOSITE

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ABSTRACT

Aluminium - silicon carbide (Al-SiC) metal matrix composite manufactured using stir casting method. Here different wt % of SiC reinforcement such as (4%, 8% & 12%) using stir casting method. Micro hardness, tensile test and bend test were performed to evaluate the mechanical behvaviour with respect to wt % of SiC on Al-SiC composite. Increase in wt % of SiC tends to increase in micro hardness and tensile strength but it reduces the bend strength and elongation (%) of the material. Using empirical model wt % of SiC in Al - SiC composite was optimized. Optimized result showed 7.66 wt % of SiC had desirable result between wt% (4% to 12%) of SiC reinforcement. Al - 8% SiC have good micro hardness and tensile properties without losing the elongation (%) and bending strength. The mechanical properties of Al - 7.66 % SiC composite were predicted was very close to Al - 8% SiC composite. So Al - 8% SiC was chosen as optimized wt % of SiC for Al - SiC composite without losing its ductility to gain increased tensile strength.

Keywords: Al-SiC composite, regression equation, tensile properties, bending load and micro hardness.

INTRODUCTION

Manufacturing of aluminium metal matrix composite uses various methods such as powder metallurgy, spray coating, electroplating and stir casting process [1]. Stir casting method is more economical [2] and it is also suitable for mass production. Stir casting process is mainly used for manufacturing of whiskers [3] and particulate [4] type reinforcement in metal matrix composite [5]. In composite material, matrix phase is major constituent and reinforcement is minor constituent [6-7]. Here reinforcement phase is added with matrix phase to form composite material. Aluminium is widely used matrix medium and it can combined with various reinforcements such as SiC [8], TiB_2, TiC, B_4C, Al_2O_3, MgO and fly ash [9-11]. SiC reinforcement is widely used as reinforcement for aluminium metal matrix composite due to lesser density difference and higher wetabilty between aluminium and SiC [12-14].

Al - SiC composite showed improved strength with respect to increase in wt % of SiC. Increase in SiCwt % on aluminium matrix showed decreased ductility [15] and formability [16] of the Al - SiC composite. This indicates that strength is directly proportional to the wt % SiC and inversely proportional to ductility of the composite [17]. Al-SiC composite should be reasonable strength and ductility otherwise it should be higher toughness [18]. So optimizing the wt % of SiC in aluminium composite is needed. Predicting the tensile strength with respect to the wt % of SiC, shows significant importance [19]. Mathematical model [20-21] developed to predict the tensile strength, micro hardness and bend strength. And also it can be used to optimize the wt % of SiC on Al - SiC composite [22]. Design Expert ® statistical software is used to predict mechanical behvaiour and optimize the wt % SiC on Al - SiC composite.

EXPERIMENTS

Using Stir casting machine aluminium with different wt (%) of SiC (4%, 8% and12%) was added after both get preheated as indicated in Table-1. To the molten aluminium, 2% of magnesium was added to increase the wettability. Then SiC was added slowly and molten aluminium was stirred until the all the SiC particles were poured into it. Coverall was added finally to remove the slag to get pure cast of Al-SiC composite. Permanent mould was also preheated as mentioned in Table-1 to get cold shunt free casted product.

Table-1. Process parameter for stir casting process.

Process parameter	Value
Stirrer speed	350 rpm
Stirring time	600 seconds
Preheating time	90 minutes
Stirring temperature preheating temperature of SiC	775 ^{o} C
Preheating temperature of SiC	900 ^{o} C
Preheating temperature of Aluminium	450 ^{o} C
Preheating temperature of permanent mould	300 ^{o} C
SiC, Mg and coverall - powder feed rate	2-3 g/s

Vickers micro hardness was measured according to the standard of ASTM E 384.Tensile test was tested according to the ASTM E8 standard. Specimen of sub sized sample with length of 100mm, width of 30mm, thickness 5mm and gauge length of 50mm were considered. Bend test was also performed using same machine with the standard of ASTM E190 on sub sized sample with dimensions of 100mm x 30mm x 5mm (L x W x T).

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RESULT

Bending load, micro hardness, tensile tested result such as ultimate strength, yield strength and % of elongation data were processed using Design Expert ® to develop mathematical model such as regression equation, % error Table and error graph. This mathematical model was also used to optimize the wt% of SiC on Al-SiC composite.

Regression equation

Table-2 showed the regression equation (R) to predict the micro hardness, ultimate strength, yield strength, elongation (%) and bending load. Correlation coefficient for all the regression equation had 0.99. This showed higher level of consistence in the mathematical model.

Table-2. Regression equation and correlation coefficient.

Response	**Regression equation** (R)	**Correlation coefficient** (r^2)
Micro hardness	R_{MH} = (25.92+(5.0675*wt% of SiC)-(0.2031*wt% of SiC*wt% of SiC))	0.99
Ultimate tensile strength	R_{US} = (58.27+(4.2285*wt% of SiC)-(0.0181*wt% of SiC *wt% of SiC))	0.99
Yield strength	R_{YS} = (42.05+(1.5276*wt% of SiC)-(0.2617*wt% of SiC *wt% of SiC))	0.99
Elongation (%)	R_{El} = (28.3-(1.4971*wt% of SiC)+(0.0077*wt% of SiC *wt% of SiC))	0.99
Bending load	R_{Bl} = (3.05-(0.1496*wt% of SiC)+(0.0001*wt% of SiC *wt% of SiC))	0.99

Percentage of error table

Table-3 showed the error percentage between actual value (experimental value) and predicted value (developed using regression equation). Ultimate strength has error % between actual value and predicted value is less 1%. Yield strength and elongation % showed error % upto 2%. Table-4 showed error % for micro hardness and bending load for different wt% (4, 8 and 12) of SiC in Al-SiC composite between the actual value and predicted value. Bending load has error % upto 1.5% but micro hardness shows maximum error of 0.2%. This showed micro hardness had very consistent result through regression equation than other mechanical properties.

Table-3. Error percentage for tensile properties - ultimate tensile strength, yield strength and percentage of elongation.

Condition	**Ultimate tensile strength** (MPa)			**Yield strength** (MPa)			**Elongation** (%)		
	Actual value	**Predicted value**	**Percentage of error** (%)	**Actual value**	**Predicted value**	**Percentage of error** (%)	**Actual value**	**Predicted value**	**Percentage of error** (%)
Pure Al	58.05	58.27	-0.39	41.69	42.05	-0.85	28.41	28.30	0.38
Al-4%SiC	76.15	75.48	0.88	53.41	52.34	2.00	22.11	22.44	-1.47
Al-8%SiC	92.59	93.26	-0.73	69.95	71.02	-1.52	17.14	16.81	1.90
Al-12%SiC	111.85	111.63	0.20	98.42	98.06	0.36	11.33	11.44	-0.96

Table-4. Error percentage for micro hardness and bending load.

Condition	**Micro hardness** (HV)			**Bending load** (KN)		
	Actual value	**Predicted value**	**Percentage of error** (%)	**Actual value**	**Predicted value**	**Percentage of error** (%)
Pure Al	25.9	25.92	-0.08	3.06	3.05	0.28
Al- 4 %SiC	43	42.94	0.14	2.43	2.46	-1.05
Al- 8 %SiC	53.4	53.46	-0.11	1.89	1.86	1.35
Al- 12 %SiC	57.5	57.48	0.03	1.27	1.28	-0.67

Error graph

Error graphs were drawn using Table-5 and Table-6 values. The line drawn in all the error graphs showed predicted value developed using regression equations. Figure-1.a showed error graph for ultimate strength, error graph for yield strength was observed in Figure-1.b. Figure-1.c showed error graph for elongation (%) and error graph for bending load was observed in

Figure-1.d. Figures 1.a to 1.d showed all predicted value and actual value were coinciding with each other. Very small amount of positive and negative deviation were also observed in Al-8% SiC and Al-12% SiC between actual and predicted values. Figure-1e showed very consistent result without having any significant deviation in error graph of micro hardness.

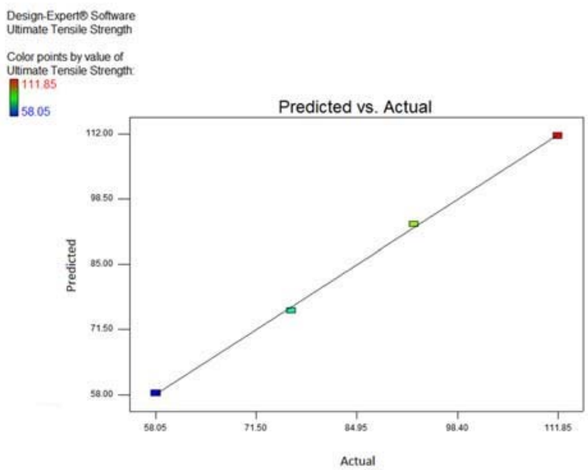

Figure-1a. Experimental value vs. predicated value for ultimate tensile strength.

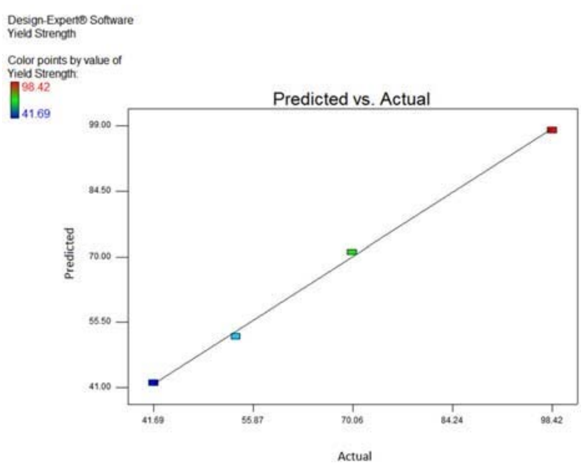

Figure-1b. Experimental value vs. predicated value for yield strength.

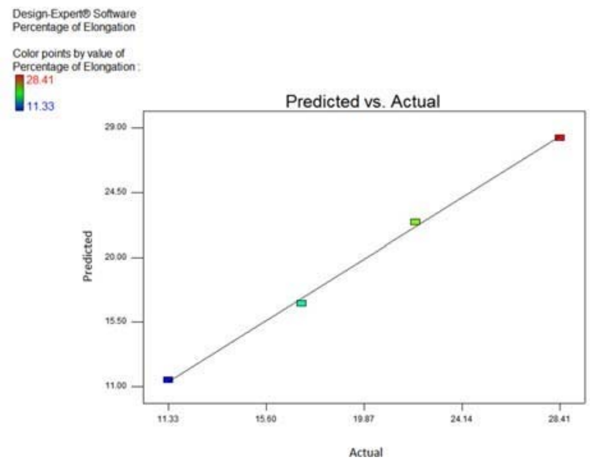

Figure-1c. Experimental value vs. predicated value for elongation (%).

was less than 9%. Error % in yield strength and elongation (%) is less than 6%. Micro hardness and bending load have less 5%. This error is due to making the wt % of 7.66 into 8 of SiC in Al - SiC composite.

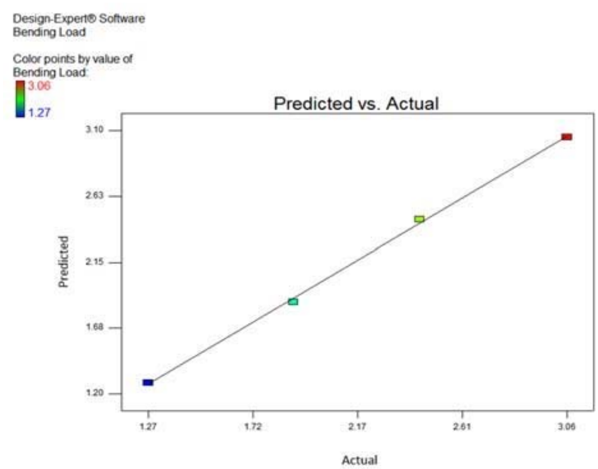

Figure-1d. Experimental value vs. predicated value for bending load.

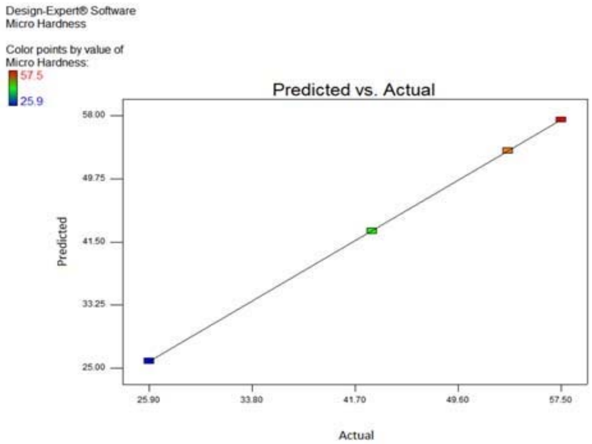

Figure-1e. Experimental value vs. predicated value for micro hardness.

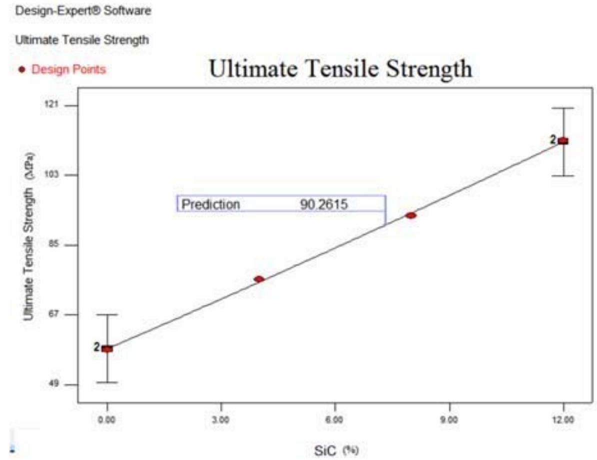

Figure-2b. Predication of optimized Al-SiC composite - ultimate tensile strength.

OPTIMIZED RESULT

Using Design Expert ® statistical software, empirical model is developed and it used to optimize the wt % of SiC reinforcement in Al - SiC composite. Figure-2.a showed desirability of 0.99 at 7.66 wt % of SiC. This indicates that optimized wt % of SiC reinforcement is 7.66% of SiC. For this optimized condition, ultimate tensile strength of 90.26MPa was shown in Figure-2.b. Yield strength of 67.32MPa was observed in Figure-2.c. Elongation of 17.75 was observed for optimized wt % condition from Figure-2.d. Figure-2.e showed bending load of 1.96KN and figure 2.f depicted the micro hardness value of 52.2HV. These values were tabulated in Table-5 and compared with actual experimental condition. Deviation between actual experimental values and predicted optimized value of ultimate tensile strength was less than 9%. Error % in yield strength and elongation (%) is less than 6%. Micro hardness and bending load have less 5%. This error is due to making the wt % of 7.66 into 8 of SiC in Al - SiC composite.

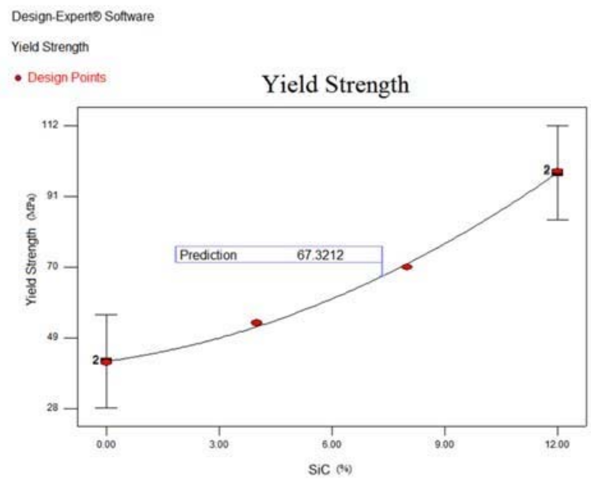

Figure-2c. Predication of optimized Al-SiC composite - yield strength.

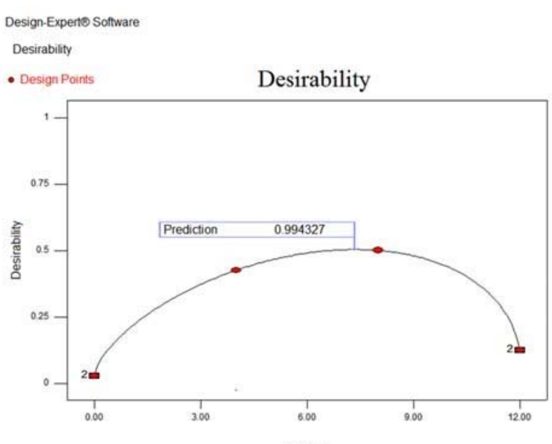

Figure-2a. Predication of optimized Al-SiC composite - Desirability.

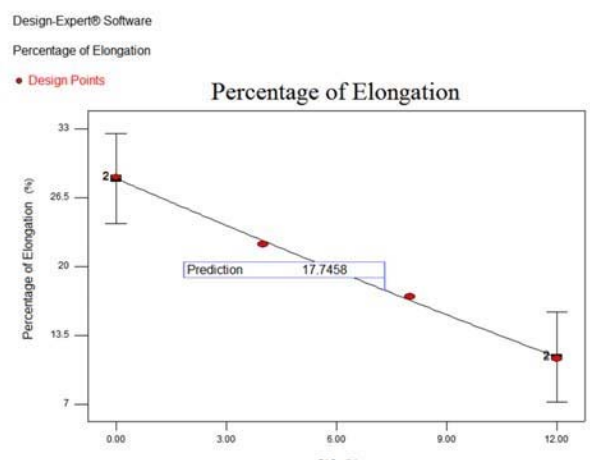

Figure-2d. Predication of optimized Al-SiC composite- elongation (%).

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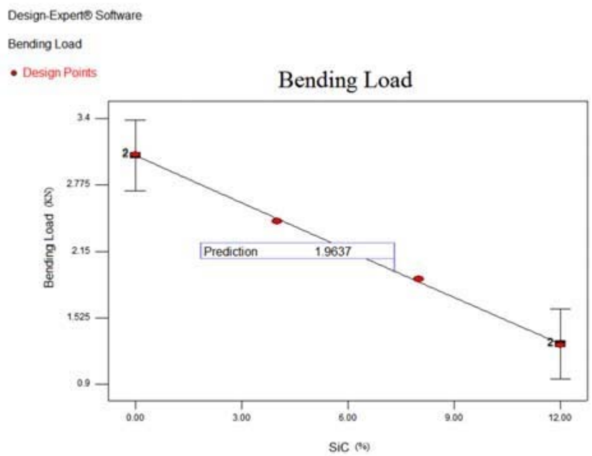

Figure-2e. Predication of optimized Al-SiC composite - bending load.

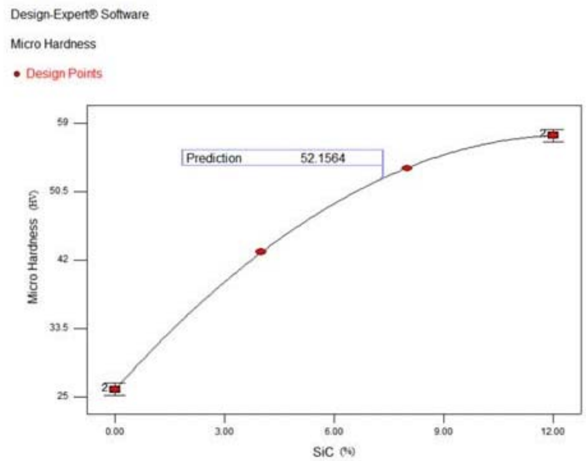

Figure-2f. Predication of optimized Al-SiC composite- micro hardness.

Table-5. Optimized predicted value vs. experimental actual value.

Parameters	Optimized predicted values	Experimental actual values		
Aluminium (wt%)	92.33	92		
SiC (wt%)	7.66	8		
Desirability	0.99	Trail 1	Trail 2	Trail 3
Ultimate strength (MPa)	90.26	90.25	88.58	98.94
Yield strength (MPa)	67.32	70.22	68.29	71.34
Elongation (%)	17.75	16.33	17.21	17.88
Bending load (KN)	1.96	1.89	1.84	1.91
Micro hardness (HV)	52.2	50.9	51.2	50.4

CONCLUSIONS

Micro hardness, tensile test and bend test were performed to evaluate the mechanical behaviour with respect to wt % of SiC on Al-SiCcomposite. Increase inwt % of SiC tends to increase in micro hardness and tensile strength but it reduces the bend strength and elongation (%) of the Al - SiC composite material. Regression equations were developed to predict the tensile strength, micro hardness and bend strength for various wt % of SiC reinforcement in Al -SiC composite. All the regression equation showed correlation co-efficient of 0.99. This showed that all the regression equations developed were more consistent. Using empirical model wt % of SiC in Al - SiC composite was optimized. Optimized result showed that the 7.66wt % of SiC have maximum desirable result between wt% (4% to 12%) of SiC reinforcement. Experimental value Al- 8% SiC have showed equally near value to optimized predicted value. This showed good micro hardness and tensile properties without losing the elongation (%) and bending strength.

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