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Investigation on Hardness of Al7075/Gr./SiC_p Hybrid Metal Matrix Composites

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***Abstract*: In this paper effort have been made to validate the hardness of Al7075 hybrid composite through Taguchi's Techniques. Hybrid composites were prepared by using Al7075 as matrix material and SiC. (0, 2, 4 and 6 wt.%) and graphite (1, 3, 5 and 7 wt.%) as reinforcement through stir casting technique. Hardness of hybrid composite increased with increase in wt.% of reinforcement in the Al7075 matrix material. In the present study, Taguchi's L16 Orthogonal array was used to know the percentage contribution of each factors on hardness by Analysis of Variance (ANOVA). Regression equation have been generated by using design of experiments through Minitab software.**

Keywords - Al7075; SiC_p; Graphite; Stir casting; Regression Equation.

I. INTRODUCTION

Hybrid composite material plays an important role in industrial application such as automobile sector, aerospace, marine field etc. The useage of these hybrid composites is due to their high strength, low density, high wear and corrosion resistance and good thermal conductivity. Composite material consists of base material know as matrix and secondary material know as reinforcements in order to improve the strength and stiffness of the matrix. The choice of composites in many occurrences will depend on factors which includes number of items to be produced, working lifetime requirements, complexity of the product and skills of the designer in tapping the optimum potential of composites [1]. Aluminum is the most popular matrix for the metal matrix composites. Aluminium alloys are quite attractive due to their capability to be strengthened by precipitation, low density, good corrosion resistance, and high electrical and thermal conductivity. Aluminum Matrix Composites (AMCs) are the class of light weight high performance materials [2,3]. Composite materials are striking since they offer the possibility of attaining property combinations which are not possible to obtain in monolithic materials and which can result in a number of vital service benefits. The key feature of composites is that they generally exhibit the optimum qualities of their constituents and often some attractive qualities that neither of the constituents possesses [4]. Reinforcing the aluminum alloys with ceramic particles can contribute to activate strengthening mechanisms due to morphological variations such as geometrically increased density of dislocations, grain refinement caused by thermal mismatches of the matrix and reinforcements and load transfer from Al onto reinforcements [6]. Al6061 was reinforced with different reinforcement ratios of SiC by stir casting method to evaluate and compare the results with Al6061 for better improvement in mechanical properties. The results were shown that there was significant improvement in tensile properties and compressive strength and hardness as the wt.% of reinforcement of particles increases as compared to the unreinforced matrix [9].

The literature survey reveals that presently very few research studies are carried out on the mechanical properties of aluminum alloy matrix reinforced with different reinforcing material such as boron carbide, Al_2O_3, TiB_2, fly ash, e-glass fiber, SiC, graphite etc. Therefore, in the present investigation Al6061/Gr./SiC_p hybrid composites were prepared by using stir casting process to evaluate the hardness properties. Further, Taguchi's Technique was been employed to validate the experimental hardness value.

II. EXPERIMENTAL DETAILS

In this chapter, selection of matrix and reinforcement material, formation of hybrid composites, preparation of hardness specimens and Taguchi's Technique have been discussed.

A. Material selection

In this work, Aluminum alloy 6061 is used as a matrix material. The reinforcements are graphite and silicon carbide. The chemical composition of Al7075 alloy is shown in Table 1.

Table 1: Chemical composition of Al7075 alloy

Element	Cu	Cr	Mn	Mg	Si	Ti	Zn	Fe	Al
Wt. %	1.8	0.2	0.4	1.9	0.5	0.15	3.25	0.5	91.3

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B. Formation and Machining

Calculated amount of Al6061matrix material were cut and placed in the pre-heated crucible for melting. The pre-heated reinforcements in wt.% were introduced into the molten metal for preparation of Al6061/Gr./SiC_p hybrid composite. Proper stirring was employed in order to ensure uniform distribution of reinforcements into the matrix to achieve better mechanical properties.

Vickers Hardness test specimens were prepared as per IS 1501-2011 standard size by using conventional machine tool to evaluate the experimental VHN.

C. Taguchi's Techniques

A Taguchi design or an orthogonal array, is a method of designing experiments that usually requires only a fraction of the full factorial combinations. It is an efficient approach to optimize the process parameter for reducing production cost and improved quality. The three major tools in this process are orthogonal array (OA), Signal to Noise ratio and Analysis of Variance (ANOVA) [17].

D. Process parameter and its levels

In the current research work, two parameters (SiC_p and Gr.) have been selected with 4 levels each. These two factors and their level were tabulated in Table 2 (a). Design of L16 (4^5) Orthogonal array have been consider and shown in Table 2 (b).

Table 2 (a): Process parameter and its level

Sl. No.	Parameter	Level
1	Silicon Carbide (SiC)	0, 2, 4 and 6 (wt.%)
2	Graphite (Gr.)	1, 3, 5 and 7 (wt.%)

Table 2 (b): Taguchi L16 orthogonal array

RUN	Silicon carbide (wt.%)	Graphite (wt.%)
1	0	1
2	0	3
3	0	5
4	0	7
5	2	1
6	2	3
7	2	5
8	2	7
9	4	1
10	4	3
11	4	5
12	4	7
13	6	1
14	6	3
15	6	5
16	6	7

III. RESULTS AND DISCUSSION

Vicker's hardness number were evaluated for the formed hybrid composite material. The load of 100gm for a period of 10 seconds is applied on specimens. The average of five readings for all 16 specimens was calculated. Table 3 shows the variation of hardness number with respect to different wt.% of reinforcements in Al7075 alloy. As the wt.% of graphite and SiC particle increased the hardness number has increased [17].

A. Signal to Noise ratio and Optimum process parameter for hardness.

The response of hardness for each parameter i.e., graphite (wt.%) and SiC (wt.%) at each level was found and its output is plotted in Figure 1. It represents the main effect graph for hardness and its characteristics is based on "Larger is better"

Table 3: L16 Orthogonal array with response

RUN	Silicon carbide (wt.%)	Graphite (wt.%)	Vicker's Hardness (VHN)	S/N ratio
1	0	1	124.3	41.89
2	0	3	150	43.52
3	0	5	172.2	44.72
4	0	7	170.8	44.65
5	2	1	131	42.35
6	2	3	160.8	44.13
7	2	5	168.8	44.55
8	2	7	186.4	45.41
9	4	1	139	42.86
10	4	3	163.4	44.27
11	4	5	178.2	45.02
12	4	7	189.2	45.54
13	6	1	136	42.67
14	6	3	164	44.30
15	6	5	182.8	45.24
16	6	7	191	45.62

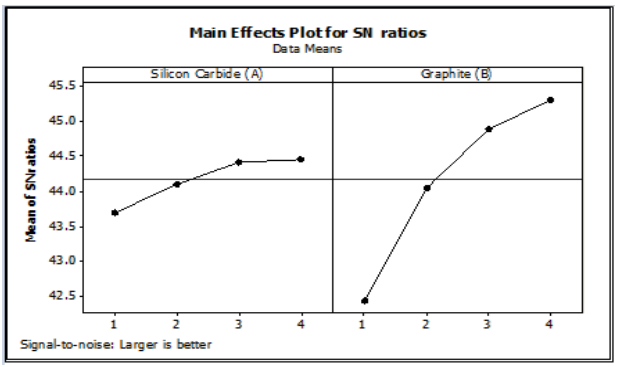

Figure 1: Main effect plot for SN ratio

Based on the main effect of SN ratio as shown in Figure 1 the optimum process parameter and their levels for obtaining maximum hardness is Graphite at level 4 (7 wt.%) and SiC. at level 4 (6 wt.%). The S/N ratio for each run is tabulated in Table 3. Response table for Signal to Noise ratio is shown in Table 4 which signifies that graphite is the most effective factor for hardness and is designated at rank 1 followed by silicon carbide.

Table 4: Response Table for S/N ratio

Level	Silicon Carbide (A)	Graphite (B)
1	43.7	42.44
2	44.11	44.05

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3	44.42	44.88
4	44.46	45.3
Delta	0.76	2.86
Rank	2	1
Optimum level	4 (6 wt.%)	4 (7 wt.%)

B. Analysis of Variance (ANOVA)

ANOVA is used to investigate the percentage contribution of each factor on hardness of Al6061/Gr./SiC hybrid composite. It defines the optimum combination of the factors that show the more accurate by observing their comparative significant among them. Table 5 represent the ANOVA for hardness, using Adjusted SS for test. It is observed that wt.% of graphite has highest percentage contribution (90.86%) on hardness followed by wt.% of silicon carbide having (7.4%) and collectively error obtained is 1.72%.

Table 5: ANOVA for hardness.

Source	Silicon Carbide (A)	Graphite (B)	Error	Total
DF	3	3	9	15
Seq SS	505.3	6198.6	118	6821.9
Adj SS	505.3	6198.6	118	
Adj MS	168.4	2066.2	157.62	
F-Value	12.85	157.62		
P-Value	0.001	0		
% of contribution	7.4	90.86	1.72	
Rank	2	1		

C. Regression Equation

Regression equation is used to validate the experimental hardness number of Al6061/Gr./SiC_p hybrid composite by using general linear model through Minitab software. Table 6 shows the validation of experimental hardness value of formed hybrid composites. The general regression equation for hardness is shown in equation (1)

VHN = 121.528 + 2.40375 Silicon Carbide + 8.56375 Graphite (1)

Table 6: Comparison of experimental result and regression equation values for hardness.

RUN	Silicon carbide (wt.%)	Graphite (wt.%)	Vicker's Hardness (Exp.)	Vicker's Hardness from Regression (1)	% Error
1	0	1	124.3	130.09	4.65
2	0	3	150	147.22	1.85
3	0	5	172.2	164.35	4.56
4	0	7	170.8	181.47	6.24
5	2	1	131	134.90	2.97
6	2	3	160.8	152.03	5.45
7	2	5	168.8	169.15	0.20
8	2	7	186.4	186.28	0.06
9	4	1	139	139.71	0.50
10	4	3	163.4	156.83	4.01
11	4	5	178.2	173.96	2.37
12	4	7	189.2	191.09	0.99
13	6	1	136	144.51	6.26
14	6	3	164	161.64	1.43
15	6	5	182.8	178.77	2.20
16	6	7	191	195.90	2.56

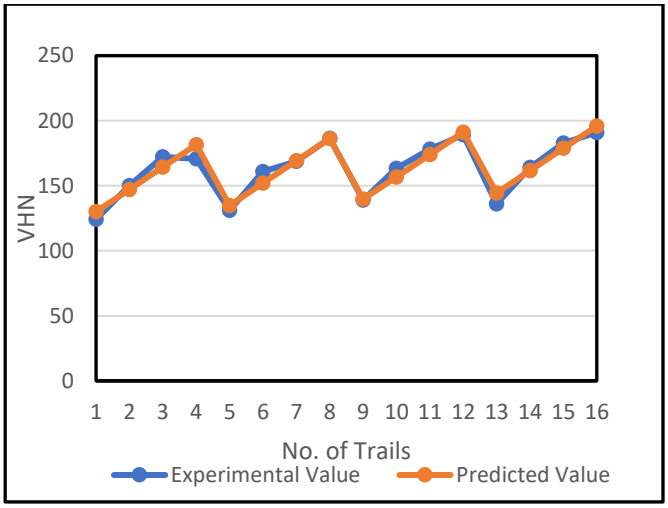

Figure 2: Comparison plot of experimental values v/s predicted values for VHN.

Figure 2 shows the plot of experimental values v/s predicted values for two factors at four levels each for hardness. It is clear that the experimental values are very close to the predicted values and hence experimental values of Vicker's Hardness Number (VHN) of the formed composites are validated.

III. CONCLUSION

This paper deals with study on Al6061/Gr./SiC_p hybrid composite fabricated through stir casting technique. Taguchi technique were employed to know the effect of each factor on hardness behaviour of hybrid composites. It is observed that the method is efficient and economical, to get enough information in a small period of interval with a smaller number of experiments. The results reveal that wt.% graphite is the most dominant factor for hardness followed by wt.% of SiC. particles. The optimum value for hardness is Gr.: 7 wt.% and SiC: 6 wt.% with 90.86% and 7.4% of contribution respectively. Regression analysis shows a good agreement with the experimental results for hardness.

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