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Research Article

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Comparative Study on Hardness Strength of Novel Metal Matrix Composite of Aluminum Alloy 5083 with 0% and 2% SiC Powder Reinforcement

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Abstract

This experimental study aims to relate the hardness strength of the as cast aluminum alloy 5083 (AA5083) and the metal matrix composite AA5083 reinforced with 2% volume of silicon carbide (SiC) nanoparticle. Composites were produced in two groups using the stir-casting method. The aluminum alloy strengthened with SiC nanoparticle composite without filler of 20 sample specimens were used as the control group and the aluminum alloy reinforced with SiC composite of 20 sample specimens were used as the novel composite the experimental group. The ASTM-D2583 standard was followed for the tensile testing specimen. The G-Power used for determining sample size is 80%. The as cast AA5083 shows a mean surface hardness of 57.06 BHN whereas the metal matrix composite of AA5083 + 2% nano SiC gives mean surface hardness of 71.46 BHN. The independent sample t-test gives a significance of $p = 0.001$ ($p < 0.05$). Within the limits of the study and the results obtained from the t-test, the hardness of the AA5083 material increases by 25% relatively for samples containing 2 wt.% novel SiC microparticles as filler materials.

Keywords

Novel composite, Silicon carbide, Nanoparticle, Aluminum alloy, AA5083, Sustainable production, Surface hardness, CNC machining

Introduction

Corrosion resistance, strength, and material weight are just a few of the considerations that must be made while producing parts for the any machine. Aluminum is one of the materials that is used the most frequently to make parts because of its strength and lightweight [1]. AA5083, which has low density, good corrosion resistance, and good formability, is one of the materials that meet the requirements. It is the strongest non-heat-treatable alloy utilized in annealed circumstances [2]. The temperatures below the melting point are used in a common naval welding technique for building ships. Taguchi approach to analyze the surface hardness properties of two different AA5083, sustainable production in order to determine the ideal process parameters.

AA5083 is a lightweight substance with numerous industrial uses [3]. Al-SiC alloys (5083-0 series) up to around 5% magnesium can be dissolved in aluminum to offer a significant amount of solid solution strengthening because of their low "weight/mechanical resistance" ratio, strong corrosion resistance, and ability to have varied surface finishes. SiC nanoparticle inclusion also supports sustainable production of the alloys. For slightly hardened 5083-0, there is a small increase in hardness across the weld nugget compared to HAZ [4]. The surface hardness indirectly influences the weld strength. Al-4.5Mg-0.26Sc alloy TIG and friction stir joints were compared [5].

As per the research survey, there are limited studies done on the hardness of the novel composite AA5083 + 2% SiC [5]. Thus, the hardness of this composite material was examined and compared to that of the base material AA5083 without reinforcement in this study.

Materials and Methods

There was no need for ethical approval for this experiment because it involved the fabrication of metal matrix composite [6]. They are split into two categories: Experimental group and Control group. The samples which are fabricated for each group 20 total number of samples required from both groups are n = 40 [7]. Using ClinCalc software, a G-power of 80%, threshold of 5%, and 95% confidence interval the sample size is calculated [8]. For this research aluminum AA-5083 sheets were combined with 2 wt.% of SiC nanoparticles for sustainable production to produce metal matrix composite.

The AA5083 was melted and cast into the mold. This as-cast sample comprise the control group of the study. Then with the measured weight of AA5083, shown in figure 1, the 2 wt.% of SiC nanoparticles were measured and taken, shown in figure 2, and mixed to form the metal matrix novel composite using the stir casting method. The metal matrix composite was poured into the mold and the specimen was produced as shown in figure 3. This was the experimental group of the study.

The as cast AA5083 and the metal matrix novel composite AA5083 + 2% nano SiC are machined, cut and finished as per ASTM specifications using CNC machining for the hardness testing. Standard specimens of hardness test samples done as per ASTM-D2583 standard by CNC machining as shown in figure 4. The hardness test was performed on the hardness tester IT-30 as shown in figure 5 for all 20 samples of both the groups. The hardness test for the samples was performed and the experimental results were recorded as shown in table 1.

Statistical analysis

The value of the results was statistically assessed using software SPSS-V26 using independent t-test. The comparison between the dependent (hardness) and independent variables is established by the same analysis. The bar graph was plotted against the hardness results and trial numbers for each sample.

Results and Discussion

The results from the experiment were tabulated as in table 1. When compared to the composite without nanoparticle filler particles, the composite containing novel Aluminum nanoparticles has a higher hardness. Using SPSS software, this data was subjected to an independent t-test analysis. The average and standard deviation of test results obtained with SPSS software are as shown in table 2. For both sample classes, demonstrates the importance of the findings (hardness strength) obtained using independent t-test as shown in table 3.

The mean hardness for the as cast AA5083 is found to be 57.06 BHN and the mean hardness of the aluminum alloy re-

Figure 1: AA5083 metal used for casting.

Figure 2: SiC particulate used for casting process.

Figure 3: Casting sample of AA5083 reinforced with 2% SiC.

Figure 4: Brinell hardness testing of aluminium sample.

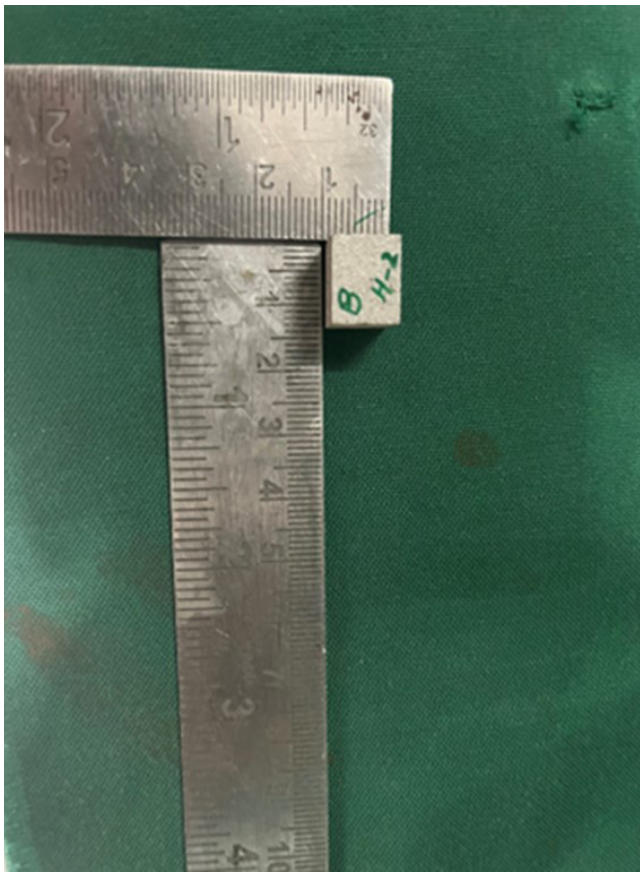

Figure 5: Hardness sample of aluminum casting as per ASTM specification.

Table 1: Hardness testing for group 1 and group 2.

S No.	AA5083 surface hardness without reinforcement	AA5083 surface hardness with reinforcement of SiC with volume of 2%
1	59.9	77.9
2	59.9	75.6
3	57.6	76.4
4	58.7	74
5	58.6	75.6
6	55.3	76.8
7	57.7	75.4
8	56.6	72.5
9	58.1	75.8
10	59.3	68.8
11	55.8	69.5
12	58.5	67.8
13	59.8	68.7
14	58.9	69.4
15	57	68.3
16	55.4	65.4
17	54.3	67.8
18	55.1	66.3
19	54.2	68.2
20	50.5	69

Table 3: Independent samples test.

Hardness BHN	Levene's test for equality of variances		t-test for equality of means							
	F	Sig.	t	df	Significance		Mean difference	Std. error difference	95% confidence interval of the difference	
					One-sided p	Two-sided p			Lower	Upper
Equal variances assumed	0.059	0.0109	13.674	38	< 0.001	< 0.001	10.4000000	1.0531107	12.2680889	13.8178687
Equal variances not assumed	-	-	13.674	31.0810	< 0.001	< 0.001	14.4000000	1.0531107	12.2523904	13.8178689

Table 2: Group statistics.

Hardness BHN	group	N	Mean	Std. deviation	Std. error mean
	1	20	57.06	2.4201783	0.5411683
	2	20	71.46	4.0402449	0.9034262

inforced with 2% SiC is found to be 71.46 BHN. The standard deviation for the hardness of the as-cast AA5083 sample and AA5083 + 2% nano SiC sample is 2.42 and 4.04 respectively. The samples fabricated with novel aluminum are experimentally tested and the hardness (dependent variable) evaluated for both the samples using statistical analysis are plotted in the given bar graph as shown in figure 6 [9].

The results revealed that filled hybrid composites have a higher hardness than those without filler. The mean hardness of the filler group is 71.46 BHN. The highest and lowest values evaluated for the filler group are 77.9 BHN and 65.4 BHN. The average value of the surface hardness for the without filler group is 57.46 BHN. The highest and smallest values measured for the without nanoparticle filler group are 59.9 BHN and 50.5 BHN. The results show that the presence of filler has a significant impact on the hardness of metal matrix novel composites. The t-test significance value is p = 0.001 (p < 0.05) of Levene's test for equality of variances.

This research does have some limitations. The stir-casting method of composite manufacturing may produce air inclusions, voids, and clumping of reinforcement particulates in the resulting cast. The efficacy of the composites created in the next works can also be studied using unique metal matrix composite sustainable production techniques other than stir-casting [10-12].

Conclusions

Within the limitations of this study, the novel metal matrix composite of AA5083 + 2% nano SiC material in comparison to the as cast AA5083, shows 25% greater hardness. The difference in mean hardness between the two groups is found to be 14.4 BHN.

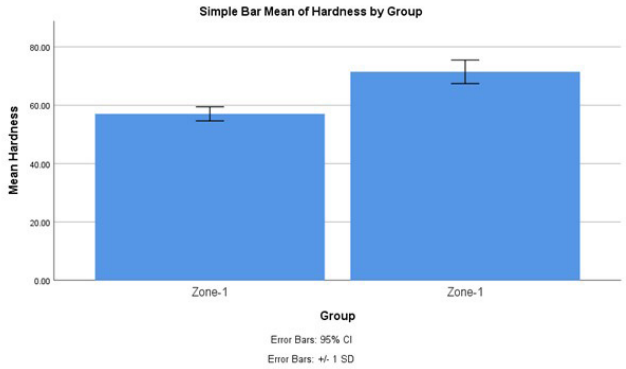

Figure 6: Graphical representation of hardness strength (MPa) for group-1 AA5083 with no reinforcement and group-2 AA5083 reinforced with 2-wt% of SiC, with ± 1 SD - X axis: material groups, Y axis: hardness strength (MPa) with mean accuracy of detection 95% CI.

Acknowledgements

None.

Conflict of Interest

None.

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