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Comparative Study on Tensile Strength of Novel Metal Matrix Composite of Aluminum Alloy AA5083 with 0% and 2% SiC Powder Reinforcement

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Abstract

To compare the tensile strength (TS) of the aluminum alloy AA5083 reinforced with silicon carbide (SiC) nanoparticles by 2% of volume and the as cast AA5083. The metal matrix composite (MMC) of aluminum alloy AA5083 with SiC nanoparticles was prepared using stir-casting method. A G-power calculation of 80% was used to determine 20 samples per group. Twenty sample specimens of as cast aluminum alloy AA5083 made up the control group, whereas twenty sample specimens of aluminum alloy reinforced with 2% nano SiC made up the experimental group. The ASTM-D2583 standard was followed in the TS testing. The mean TS of as cast AA5083 was 233.15 MPa and the mean TS for AA5083 + 2% SiC novel MMC was 243.45 MPa. Using the independent sample t-test a value of significance of $p = 0.001$ ($p < 0.05$) was obtained. Within the limitations of this study, the MMC with 2% weight percent of nano SiC microparticles as filler materials had a 12% relative increase in TS compared.

Keywords

Novel metal matrix composite, Nanoparticle, Silicon carbide, Aluminum AA5083, Sustainable production, Tensile strength, Universal testing machine, CNC machining

Introduction

Aluminum novel MMC with SiC are widely employed in the automotive and aerospace sectors due to its desired micro-structure and superior mechanical properties over pure aluminum material at a cheaper expense [1]. Aluminum metal is notable for its reduced density and resistance to corrosive damage [2]. The current study aims to investigate the mechanical properties and micro-structural characteristics of aluminum reinforced with nanoparticulate SiC (average particle size 50 - 100 nm) in varied weight percentages (wt.%) ranging from 0 - 15 wt.% in 5% steps [3]. The micro hardness, ultimate TS, and density of the manufactured MMC were studied as a behavior of nano SiC weight percentage [4]. Micrographs show that reinforcement is distributed fairly.

According to google scholar, 506 articles were published, and 61 articles have been published on science direct over the last 5 years. Due to their advantageous microstructure and superior mechanical properties compared to pure aluminum material at a cheaper cost, aluminum strengthened with SiC composites are extensively employed in the automotive and aerospace sectors. Aluminum is exceptional due to its low density and capacity to withstand corrosion [5]. Materials having metals as the basic matrix and often organic or ceramic compounds added as reinforcements to improve the characteristics are known as MMC. There will be fibers, whiskers, and particles as reinforcements [6]. By adjusting the component nature and volume fractions, MMC may be customized, and it supports sustainable production. In terms of creep resistance, enhanced strength, wear resistance, stiffness, conductivity, dimensional stability, and other qualities, MMC is superior to base metal [7]. Graphite particles, boron carbide (B4C) particles, SiC particles, aluminum oxide (Al_2O_3) particles, zirconium silicate ($ZrSiO_4$) particles, and titanium di-boride particles are among the reinforcing materials that are often employed (TiB_2) by their novel MMC.

According to the literature research, the key challenge was achieving uniform reinforcement dispersion [6]. The material has commercial applications such as heat sinks, electronics, heaters, electronic chips, and the automotive industry. Effects of SiC particle volume fraction on Al/SiC composite characteristics were investigated the parameters of the composites, including TS, and surface hardness. Novel MMC were examined [8, 3].

Materials and Methods

The preparation and testing of specimen were done in the premises of Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. Because this experiment is related to MMC ethical approval was not required. Experimental group and control group are the two groups into which they are divided. A total of 20 specimens are created for both groups, for 40 samples from both groups. The sample size is determined using ClinCalc software using an 80% G-power, a threshold of 5%, and a 95% confidence interval. The aluminum AA5083 sheets and SiC nanoparticle are being used for the reinforcement or the casting process supporting sustainable production as shown in figure 1 and figure 2. AA5083 aluminum alloy and nano SiC are the materials utilized in the fabrication. The matrix material was AA5083, which was purchased from PMC Corporation Ltd. For the fabrication process, the aluminum is being cast in the base form as shown in figure 3 which was employed as reinforcing material. The novel MMC content are made in the liquid state by the combination of a distributed ceramic state into a molten aluminum metal and subsequent crystallization. In all liquid state manufacturing techniques, stir-casting is the most economical procedure. The stir-casting process for the sustainable production of the MMC is shown schematically.

CNC machining was used to prepare the tensile specimen in accordance with ASTM E-8 specifications. The experimental test was performed using a shimadzu AG-X plus TM, universal testing machine (UTM) and tensile behavior such as ultimate TS, percentage of elongation, and fracture behavior were also analyzed. After the sample's preparation of the aluminum composite metal with and without reinforcement, the tensile test values are being taken as shown in table 1. Then tensile groups are classified in the form of group statistics shown below table 2. The metal is being measured with ASTM E-8 as in figure 4. The dimensions of the tensile specimens were made as per ASTM standards using CNC machining.

The sample was mounted to the machine and the tensile testing done [9, 10] as shown in Figure 5. The mechanical properties of the sample [11, 12] manufactured end route stir casting were examined in accordance with ASTM standards. Tensile test specimens were manufactured in accordance with ASTM E8-95 requirements and evaluated on a universal testing equipment (UTM). The specimens used for tensile testing

Figure 1: Aluminum AA5083 metal used for casting of base metal.

Figure 2: SiC particulate material used for casting process.

Figure 3: Casting of aluminum metal composite without SiC reinforcement.

Table 1: TS of group 1 and group 2.

S. No.	AA5083 TS without reinforcement	AA5083 TS with reinforcement of SiC with volume of 2%
1	242	255
2	239	248
3	241	252
4	236	245
5	238	247
6	240	253
7	237	245
8	234	248
9	233	241
10	235	243
11	232	240
12	230	239
13	237	242
14	229	241
15	226	239
16	228	240
17	227	238
18	225	236
19	226	237
20	228	240

Table 2: Group statistics.

	group	N	Mean	Std. deviation	Std. error mean
TS (MPa)	1	20	243.45	5.4913808	1.2279101
	2	20	233.15	5.499043	1.2296234

had a gauge diameter of 12.5 mm and a gauge length of 62.5 mm (Figure 5) [11-13].

Statistical analysis

The statistical significance of the findings was evaluated using the independent t-test in the SPSS-V26 program. The tensile test results from the research samples are subjected to a t-test using SPSS statistical software. Statistical tests were also conducted using Levene's test and descriptive statistics tests. To display the data graphically, G graphs are employed.

Figure 4: Tensile sample specimen as per ASTM standard machined by CNC machining.

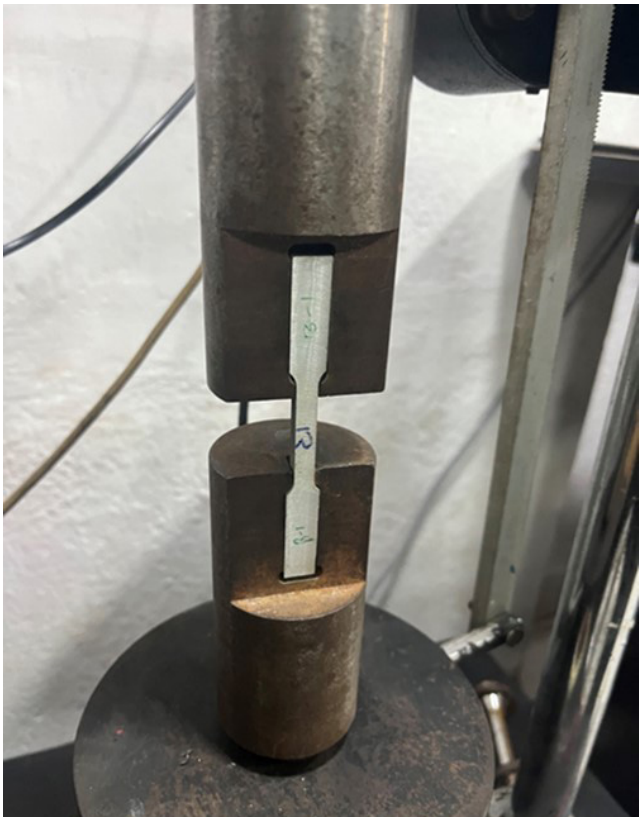

Figure 5: Tensile testing of the aluminum alloy AA5083 base material.

Results and Discussion

The TS testing was done in the UTM machine and the results for both the groups of samples were tabulated as shown in table 1. The statistical data - average, standard deviation, and standard deviation error, for the experimental results are as shown in table 2. The control group specimen of as cast AA5083 samples had a mean TS of 233.15 MPa with a standard deviation of 5.499 and a standard mean error of 1.229. The experimental group of the novel MMC AA5083 + 2% SiC, had a mean TS of 243.45 MPa and a standard deviation

Table 3: Independent samples test.

TS (MPa)	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	5.927	38	< 0.001	< 0.001	10.3	1.737739	6.7821313	13.8178687
Equal variances not assumed	-	-	5.927	38	< 0.001	< 0.001	10.3	1.737739	6.7821311	13.8178689

of 5.491 and a standard mean error of 1.228. According to the independent t-test results shown in table 3, the experimental study has a significance of $p = 0.001$ ($p < 0.05$). This is the resulting data from the statistical analysis of the experimental results from the 20 samples of each group. The statistical comparison of TS of the two groups is represented as a bar graph as shown in figure 6.

The UTM was utilized to measure the TS. The mean TS of the as cast AA5083 and the MMC AA5083 + 2% SiC were found to be 233.15 MPa and 243.45 MPa respectively. The respective standard deviations are 5.499 and 5.491 as per the statistical analysis. As per the t-test statistical analysis, the mean variance of the TS between the two groups is significantly different with a two tailed value of significance of $p = 0.001$ ($p < 0.05$).

This increase in TS is due to the inclusion of SiC filler material which improves the material properties of the aluminum alloy 5083. The stir casting process for inclusion of the filler material was done properly for the uniform distribution of the material. But still there could be minor discrepancies in the filler material distribution and imperfections like clumping, voids, and micro-cracks, which could influence the experimental results.

The limitation of this work is the stir casting process done without any mold preheating, no heat treatment of cast material and lack of processing of the filler materials. This could be considered and included in future studies. Also, novel sustainable production methods for MMC production other than stir-casting can be employed to study the effectiveness of the composites produced in the upcoming works.

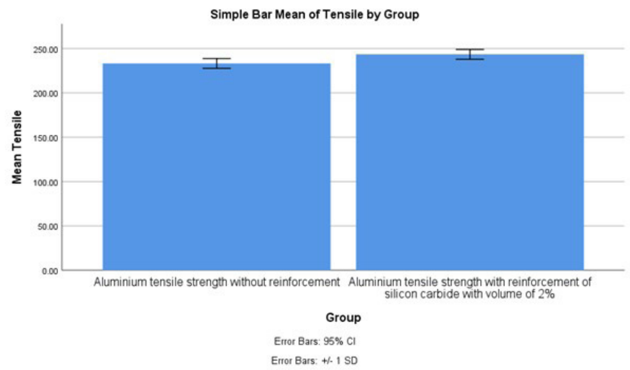

Figure 6: Graphical representation of TS (MPa) for group-1 AA5083 aluminum alloy reinforced with 2-wt.% of SiC and group-2 AA5083 aluminum alloy with no reinforcement; X axis: Material groups; Y axis: TS (MPa) with mean accuracy of detection 95% CI.

Conclusion

Within the limitations of this study, the novel MMC of AA5083 + 2% SiC material exhibits greater mean TS when related to the as cast AA5083 aluminum alloy. The difference in mean TSs between the two groups is 10.3 MPa.

Acknowledgements

None.

Conflict of Interest

None.

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