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Research Article

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Assessing Novel AA5051/SiO_2 Nanocomposite with Monolithic AA5051 for Improving Flexural Strength

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Abstract

This paper investigated the performance of a recycled AA5051 alloy with nano silicon dioxide (SiO_2) ceramic strengthening particulates reinforced by stir casting method in terms of flexural strength. Aluminum alloy of series AA5051 alloys were used as matrix materials and novel nano SiO_2 ceramic particles of particle size < 50 nm was used as reinforcement particles. To achieve uniform reinforcement distribution in matrix materials, it was casted using a stir casting method at a melt temperature of 720 °C and a stirring speed of 500 rpm. The fabrication of the recycled AA5051 alloy nanocomposite utilized both an experiment group and a control group with a sample size 20 for each group. The results of the experiments were examined using t-test, and the significance level of the flexural strength of fabricated composites and as-cast recycled AA5051 alloy was analyzed. From the experimental observation it was found that the flexural strength of innovative nano SiO_2 reinforced recycled AA5051 alloy composites significantly improved 26% owing to higher surface areas between the mixtures.

Keywords

Metal matrix composites, Recycled AA5051 alloy, Novel silicon dioxide, Stir casting, Stirring speed, Flexural strength

Introduction

Aluminum matrix composites have proved to be the finest substitute for conventional materials like steel, brass, and aluminum. The primary objective of metal matrix composites is to produce a material with a suitable combination of durability and rigidity. Metal matrix composites are extensively used in the automotive, aerospace, and marine industries due to their low density, high strength-to-weight ratio, and enhanced rigidity; however, the distribution of ceramic particles has a significant impact on the formation of such characteristics [1]. When micron sized ceramic reinforcement is introduced to metal matrix composites, a particle damage process produces a loss in physical properties [2]. This can be solved by incorporating nanoceramic strengthening particles into the matrix alloy. The inclusion of nanoceramic particles in the matrix alloy enhances mechanical properties compared to micron-sized composites [3]. Poor wettability between the matrix and the ceramic strengthening particles is a key obstacle that must be overcome during the production of such nanocomposites [4]. To fix this, add a few nano ceramic strengthening particles and a process setting to mitigate these impacts. The researchers suggest using nano-metal matrix composites for vehicle, aircraft, and consumer products due to their low density and high performance [5].

On Google Scholar, there are about 90 research on aluminum alloys reinforced with new nano SiO_2 ceramic particulates, and on Science Direct, there are about 102. Using a stir casting process, the impact of SiO_2 reinforced aluminum alloy composites was tested, and their mechanical characteristics were measured in accordance with ASTM standards. It was observed that good interfacial reactions between the mixtures resulted in significantly improved mechanical properties compared to cast alloys [6]. The influence of SiO_2 reinforced aluminum alloy was manufactured utilizing the vacuum assorted stir casting process. It was concluded that only a low percentage of nanoparticles in aluminum alloys leads to uniform distribution of reinforcement in the matrix alloy and improved mechanical properties the drilling performance of aluminum alloy composites reinforced with nano SiO_2 particles was analyzed. Higher material removal rates have been observed compared to micron-sized ceramic reinforcing particles. The stir casting process was used to create micron-sized reinforcements for an aluminum alloy. An increase in the weight fraction of the ceramic reinforcement in the matrix alloy was found to be a damage mechanism, thus resulting in decreased mechanical properties. Incorporating a small quantity of nanoceramic reinforcement into the matrix alloy enhanced its properties, according to a review of the relevant literature, which was deemed the best study for the current investigation.

Only a few studies on synthesizing novel nano SiO_2 reinforced recycled AA5051 alloys utilizing the bottom pouring stir casting process have been identified from the literature investigations. The wettability of novel nano SiO_2 in AA5051 alloy has yet to be analyzed, so an attempt has been made to synthesize such composites and study their flexural strength and by viewing this as a major research gap.

Materials and Method

For the fabrication of recycled AA5051 alloys nanocomposites, the required quantities of aluminum alloy matrix material were combined with novel SiO_2 with a particle size of 50 nm. Table 1 displays the AA5051 alloys' chemical constitution, which may be identified in recycled condition.

The aluminum nanocomposites were cast using a stir casting process with bottom pouring at a temperature of 4500 degrees Celsius, achieved in a resistance heating furnace. After that, the required alloy elements were included. The melting point of the alloy was reached after being heated to 750 degrees Celsius. To liquefy the liquid metal, the stirrer turned at 400 rpm. After the aluminum alloy melted at 785 degrees Celsius, the outside sprue was filled with 50 nm nano SiO_2.

Table 1: Chemical constitution of recycled AA5051 alloys.

Concentration of wt.%	
Cr	0.28
Cu	0.1
Fe	0.4
Mg	2.6
Mn	0.1
Si	0.25
Cr	0.35
Zn	0.1
Al	Balance

The matrix alloy was agitated at 500 rpm for 10 min to achieve consistent reinforcement distribution. Before flowing into the mould, the molten fluid was heated to 8000 degrees Celsius to thicken it. The molten slurry was put into the mold and let to settle at room temperature. Synthetic composite materials were machined using the ASTM standard to determine performance. In figure 1, ASTM D790 was used to determine the flexural strength of recycled AA5051 alloy nanocomposites.

Statistical analysis

In the current investigation, the SPSS V26 software was used to determine whether or not there was a significant difference between the as cast and the synthesized nanocomposites for that t-test was carried out. The mean value, standard deviation, and standard error of the descriptive tabular column of flexural strength for recycled AA5051 alloy nanocomposites were determined to be 17.119, 0.014, and 0.0031, respectively. These values were discovered in the descriptive tabular column.

Results and Discussion

In this study, a novel nano SiO_2 reinforcement was employed as the reinforcement, and recycled AA5051 alloys were used as the basis material in order to generate aluminum nanocomposites by means of the stirring casting process. The developed aluminum nanocomposites bar graph was shown in figure 2.

Table 2 and table 3 show the chemical composition as well as the flexural strength and percentage elongation values that

Figure 1: Flexural strength of recycled AA5051/SiO_2 composites.

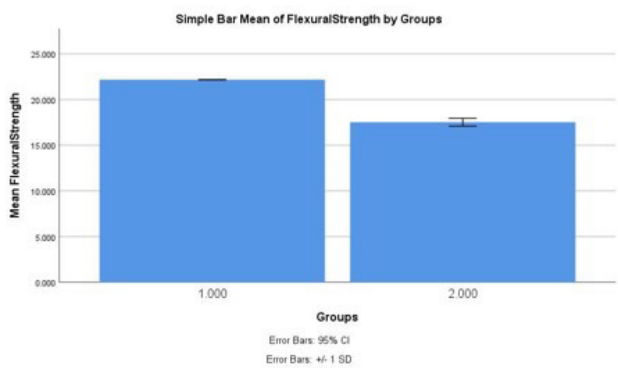

Figure 2: Flexural strength of recycled AA5051 alloys with 2 wt.% of nano SiO_2.

Table 2: Flexural strength of recycled AA5051 alloys with + 2 wt.% of nano SiO_2 reinforced recycled AA5051 alloy composites.

Exp. No.	Recycled AA5051 alloy	Recycled AA5051 alloy + 2 wt.% of nano SiO_2
1	17.119	22.185
2	17.116	22.182
3	17.112	22.181
4	17.109	22.179
5	17.107	22.176
6	17.105	22.174
7	17.106	22.171
8	17.102	22.169
9	17.101	22.167
10	17.1	22.164
11	17.99	22.161
12	17.97	22.158
13	17.94	22.156
14	17.96	22.154
15	17.95	22.153
16	17.93	22.151
17	17.92	22.149
18	17.91	22.146
19	17.9	22.142
20	17.89	22.137

were determined using composites that had been developed. The average, mean, and standard deviation all are words used to describe the average, mean, and standard as shown in table 4. Independent sample test for flexural strength represents the significance values p = 0.007 was illustrated in table 5.

Synthesized aluminum alloy nanocomposites outperformed recycled AA5051 alloy in flexural strength. Because the matrix alloy has no gaps, and nano SiO_2 ceramic reinforcing particles are evenly distributed. Additionally, since the stress distribution between the matrix and the reinforcement is considerable inside the intermixture, flexural strength is improved. The research's limitation is the development of innovative stir-cast nano SiO_2 reinforced aluminum alloy composites, whose flexural strength was measured for practical applications. It was inferred that by adding few percentages of nano reinforcement particle agglomeration is minimized and hence its properties also significantly increased.

Table 3: Flexural strength of as cast recycled AA5051/SiO_2 reinforced aluminum in mixture.

S. No.	Types of material	Flexural strength (MPa)
1	Recycled AA5051 intermixture	94.3295
2	Recycled AA5051 alloy + 2 wt.% of nano SiO_2	242.65445

The content of the SiO_2 nanoparticles in the nanocomposite can have a significant effect on its flexural strength. Increasing the nanoparticle content can enhance the strength of the material, up to a certain point, beyond which further additions may result in a decrease in strength. The size and morphology of the SiO_2 nanoparticles can also affect the flexural strength of the nanocomposite [7]. Smaller particles with a more uniform shape and distribution tend to provide better reinforcement and improve the mechanical properties of the material. The processing method used to fabricate the nanocomposite can affect the dispersion of the nanoparticles and, consequently, its flexural strength [8]. Techniques such as mechanical alloying, powder metallurgy, and extrusion can provide better nanoparticle dispersion and improve the strength of the nanocomposite. The effect of heat treatment on the flexural strength of the nanocomposite should also be considered. The temperature, duration, and cooling rate of heat treatment can influence the microstructure of the material, which in turn affects its mechanical properties. The testing method used to assess the flexural strength of the nanocomposite should be standardized and appropriate for the material. Common methods include three-point and four-point bending tests. The synergy between the SiO_2 nanoparticles and the AA5051 matrix can also play a role in improving the flexural strength of the nanocomposite. The nanoparticles should be well-bonded to the matrix and provide effective reinforcement. The chemical composition of the AA5051 alloy can also influence the

Table 4: Flexural strength (Mean value, standard deviation, and standard error) of Al-Mg-Cr alloy nanocomposite laminates.

	N	Sig	Mean	Std. deviation	Std. error	95% CI for mean		Minimum	Maximum
						Lower bound	Upper bound		
Recycled AA5051 alloy	20	0.001	17.119	0.014209	0.00317	4.44818	4.83361	17.89	17.119
Recycled AA5051 alloy + 2 wt.% of nano SiO_2	20		22.185	0.425503	0.09514	4.44167	4.84012	22.137	22.185
Total	40	0.001	19.652	0.219856	0.04915	4.44492	4.83686	20.013	19.652

Table 5: Independent sample test for flexural strength represents the significance values p = 0.007.

Flexural strength (MPa)	Levene's test for equality of variances		T-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference	
								Lower	Upper
Equal variance assumed	8.083	0.007	-19.63	38	0.000	-83.246	3.291	-91.934	-74.459
Equal variance not assumed	8.121	-	-19.52	33.3	0.000	-82.246	3.192	-91.326	-75.324

flexural strength of the nanocomposite. The alloy should be carefully selected to provide a suitable matrix for the nanoparticles.

In the present investigation only a few only a few percent of nanoparticles were added into recycled AA5051 alloy, and its wettability was analyzed. But still there was a void obtained while increasing the percentage of reinforcement in matrix alloy due to cause and effect of particle agglomeration. This can be resolved in future. Further different types of nanoparticles, such as carbon nanotubes or graphene, and investigate their potential for improving the mechanical properties of AA5051 and other materials.

Conclusion

As part of this research, innovative nano SiO_2 reinforced recycled AA5051 alloys were synthesized using the stir casting process. The flexural strength of these alloys was evaluated and compared to that of monolithic recycled AA5051 alloys. Due to their homogenous distribution of ceramic strengthening particles, decreased porosity, and higher grain refinement, nano aluminum composites outperformed recycled AA5051 alloys in functional applications. It was also decided to boost the proportion as high as feasible, and its attributes will need to be analysed to determine which ones are best for the functional applications that are the future focus of this study.

Acknowledgements

None.

Conflict of Interest

None.

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