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Experimental Study on Tensile Strength of AA5059 Reinforced Nano Kaolinite Composite Subjected to Novel Encapsulate Technique

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Abstract

This investigation compares 10% kaolinite-reinforced composites manufactured with a novel encapsulation technique to as-cast AA5059 to assess the tensile strength of the others. The test samples in both groups were made utilizing a novel encapsulation technique in addition to the stir-casting method. As-cast AA5059 was utilized for group 1, and a composite made of nano kaolinite (10%) and AA5059 was used for group 2. The samples were produced following ASTM E08-8 standards, and a universal testing machine (UTM-Auto instrument) was used to evaluate the sample's tensile strength. The number of samples in every group was 20. The sample size was calculated with a G-power of 80%, $\alpha = 0.05$ per set, and 40 samples. Maximum tensile strength, 48% higher than the AA5059 as-cast, was found in the material containing 10% kaolinite. The t-test's statistical analysis indicates a substantial difference with a p-value of 0.00 ($p < 0.05$) between group 1 and group 2's mean-variance of tensile strength. Within the limitations of this study, it is notable that the 10% nano kaolinite reinforcement considerably improves the AA5059 composite's tensile strength.

Keywords

AA5059, Kaolinite, Energy, Stir casting, Composite, Novel encapsulation, tensile strength, Substantiality

Introduction

Globally, all states focus on reducing emissions, pollution control, and quality enhancement due to acute energy consumption and environmental degradation [1]. The vehicle's weight may be significantly reduced by selecting and developing lightweight materials like aluminum [2]. As a result, lightweight materials are particularly crucial for sustainably expanding the sustainable industry [3]. An aluminum alloy with excellent corrosion resistance, exceptional formability, and substantial hardness is known as AA5059. It is a lightweight structural alloy [4]. Compared to the more common AA5083 aluminum alloy, the complex AA5059 aluminum alloy provides notable strength gains [5]. To refine the grain, aluminum alloy (AA5059) possess more significant at magnesium (Mg) quantities when compared to AA5083 and also contains increased amounts of zirconium and zinc, made in Koblenz, Germany, by Aleris International, Inc., it is a Mg alloy that cannot be heated [6-8] $Al_2Si_2O_5(OH)_4$ is the molecular equation for kaolinite, which consists of layers of silicate (Si_2O_5) sheets bonded to layers of aluminum oxide/hydroxide ($Al_2(OH)_4$) layers. In AA5059, nano kaolinite is utilized as reinforcement to increase its tensile strength. Mechanical strain hardening more challenging it harder [9]. Due to its exceptional weldability, aluminum alloy is commonly utilized to join structural components. This research used the stir casting method for producing the aluminum alloy mixed with nano kaolinite [10].

Stir casting helps to mix the reinforcement with the AA5059 better. Stir casting is done after melting the metal using a stirrer connected to electricity. Several industries, including marine, aviation, automotive, and defense, employ aluminum alloy because of its enhanced performance [11]. It is extensively used in the shipbuilding business, the aviation sector, and other electronic-related sectors. As a result, this composite material will become substantially stronger and be suitable for producing items across various industries [12].

Eventually, several papers regarding the AA5059 and its tensile strength were released. Based on the AA5059 and tensile strength, Science Direct published 41 research papers and nearly 171 published in Google Scholar. A study to estimate the tensile strength of friction stir welded AA5059 aluminum alloy joints [13]. Investigating the effects of SiC particle sizes on microstructural and mechanical properties of AA5059/SiC surface composites during multi-pass FSP [14]. Microstructure-property characterization of a friction-stir welded joint between AA5059 aluminum alloy and high-density polyethylene [15]. Influence of nano graphite on dry sliding wear behaviour of novel encapsulated squeeze cast Al-Cu-Mg metal matrix composite using artificial neural network [16]. The study on metal matrix composite by novel encapsulated squeeze cast is regarded as the finest one that described the novel encapsulation technique in depth [17]. This study demonstrates the collaboration of the mechanical and computer science areas by enhancing the alloy well, not only did they employ the artificial neural network technique with a new encapsulation feeding process for casting, but they also used multiple reinforcements [18].

This research caught that comparatively few works on producing composites employing novel encapsulation techniques. This study aimed to create a novel encapsulation stir-casting technique to create the AA5059/10% nano kaolinite composite. The research intended to assess the as-cast and composite materials' tensile strength characteristics.

Materials and Method

This research was conducted at the Institute of Mechanical Engineering, Saveetha Industries, Saveetha School of Engineering, and Saveetha Institute of Medical and Technical Sciences, Chennai (Tamil Nadu, India). The total number of sizes is 40, distributed across two categories. As-cast and composite samples were machined to be cylindrical shapes used in the study to compare the tensile strength [19]. There are two classifications and a total of 40 sizes. G-power was found to be 80% and each classification has 20 sizes [20].

To create the 20 samples, this research treats the material as-cast as group 1. To accomplish the machining on the alloy's surface, a rod of AA5059 measuring 20 mm in diameter is first brought for the operations under the lathe machine. To achieve a smooth surface and remove any extra material or burs on the metal's surface, results in getting a superior surface finish on the material. The crucible, which has a 1 kg capacity, still contains 1 kg of AA5059 after the machining. After that, the crucible is put inside the furnace, and the temperature is progressively raised to somewhere about 700 ˚C to start melting the alloy inside the crucible. After melting, the molten metal can pour into the mould against gravity and decrease the temperature. Finally, the surplus material must be eliminated after removing the casting metal from the mould. The casting metal is subsequently divided into several cylindrical pieces for tensile strength.

The composite material is classified as group 2 for 20 samples. The first step in creating a smooth, bur-free product is to spin an AA5059 rod with a 20 mm diameter on a lathe. Using a 2 mm drill bit, a hole is made in the middle of one end of the rod. A hole is created in the center of one end of the rod using a 2 mm drill bit. In figure 1, 10 g of nano kaolinite is taken. In figure 2, after filling the drilled rod's depth with 10% kaolinite, a 15 mm thick cup made on a lathe is used to cover it. The crucible is allied with the rod, then inserted in the crucible is to the furnace after being y elevates the temperature to melt the metal. In figure 3, the stir-casting method is used to blend the molten AA5059 alloy with 10% nano kaolinite before pouring

Figure 1: Nano kaolinite (10% reinforcement).

Figure 2: Feeding nano kaolinite to novel encapsulated AA5059.

Figure 3: Stir casting.

the mixture into the mould. After cooling, the composite is removed from the mold and the excess material removed. In figure 4, the alloy is cut into cylindrical sections for tensile strength testing.

Both as-cast and composite materials are subjected to a tensile strength test using a UTM. According to ASTM E08-8, the tensile strength of the cylindrical rod of cast composites was assessed. In figure 5, the test specimens were polished with 1200-grit SiC grinding paper to reduce machining scratches and the effects of surface flaws on the sample. The tensile test was carried out using the UTM loaded by a 10 kN load cell. WA crosshead speed of 2.5 mm/min was used. When testing the tensile strength. The sample is held lightly between the two jaws during the UTM test to carry out a tension test. The jaws are drawn further to increase tension on the sample when it is hastily placed. The sample is subjected to tension right up until the moment of the fracture point. The force subjected to the specimen reaches the fracture point and then is noted for the tensile strength of the specimen.

Every 20 samples in a group are subject to the same procedure. The tensile values of all 20 samples of as-cast material are noted in the 2nd column of table 1, and all 20 samples of composite material's tensile values are noted in the 3rd column of table 1.

Statistical analysis

For data administration, data processing, mathematical analysis, etc., IBM developed the statistical software application SPSS (Statistical Package for the Social Sciences). The t-test uses SPSS statistical software to generate the tensile strength value generated for the experimental specimens. Utilizing the statistical program SPSS, the descriptive and independent sample test tables and the Bonferroni analysis are conducted. While tensile strength is the dependent variable, stir speed and the reinforcement weight percentage are independent variables. The research furthermore gives the mean data, significance, and standard deviation.

Figure 4: Materials for tensile strength.

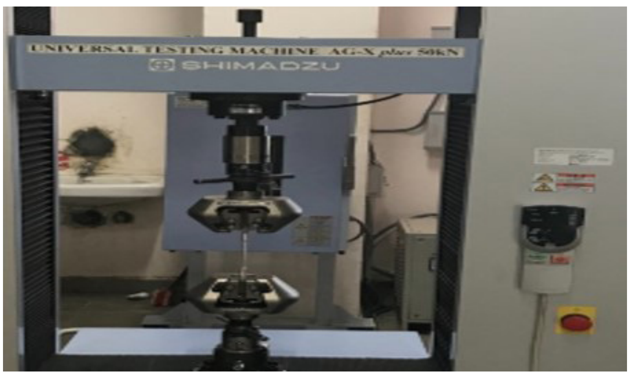

Figure 5: Tensile strength test.

Results

AA5059 with reinforcement kaolinite. Table 2 shows the group statistics of tensile strength in as-cast AA5059 without reinforcement and AA5059 with reinforcement kaolinite. Table 3 illustrates the independent samples test of the tensile strength (MPa). Table 4 shows the descriptives of the tensile strength (MPa) of as-cast AA5059 without reinforcement and AA5059 with reinforcement kaolinite. Thus, the tensile strength data are entered in the table format of the two groups.

Discussion

The results indicate that the tensile strength (MPa) of AA5059 with reinforcement nano kaolinite is improved more than the as-cast AA5059 without reinforcement. To make it

Table 1: Tensile strength of as-cast AA5059 and AA5059 with reinforcement kaolinite.

Sample number	As-cast AA5059	AA5059 with reinforced kaolinite
1	89.54	165.34
2	89.11	164.91
3	86.49	162.29
4	89.28	165.08
5	82.94	158.75
6	80.64	156.44
7	82.54	158.34
8	77.41	153.22
9	81.30	157.10
10	84.47	160.27
11	80.32	156.12
12	78.45	154.25
13	74.65	150.45
14	73.56	149.36
15	68.49	144.29
16	72.40	148.20
17	77.59	153.39
18	80.47	156.27
19	85.08	160.88
20	86.20	162.00

Table 2: Group statistics of tensile strength in as-cast AA5059 without reinforcement and AA5059 with reinforcement kaolinite.

Group statistics		N	Mean	Std. deviation	Std. error mean
Tensile strength (MPa)	As-cast AA5059 without reinforcement	20	81.0465	5.88190	1.31523
	AA5059 without reinforcement kaolinite	20	156.8475	5.88175	1.31520

Table 3: Independent samples test of the tensile strength (MPa) in as-cast AA5059 without reinforcement and AA5059 with reinforcement kaolinite.

Tensile 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	
								Lower	Upper
Equal variances assumed	0.000	1.000	-40.753	38	0.000	-75.801	1.8600	-79.56637	-72.03563
Equal variances not assumed			-40.753	38	0.000	-75.801	1.8600	-79.56637	-72.03563

Table 4: Descriptive of the tensile strength (MPa) of as-cast AA5059 without reinforcement and AA5059 with reinforcement kaolinite.

	N	Mean	Std. deviation	Std. error	95% CI		Minimum	Maximum
					Lower bound	Upper bound		
As-cast AA5059 without reinforcement	20	81.0465	5.88190	1.31523	78.2937	83.7993	68.49	89.54
AA5059 without reinforcement kaolinite	20	156.8475	5.88175	1.31520	154.0948	159.6002	144.29	165.34
Total	40	118.9470	38.8199	6.13797	106.5318	131.3622	68.49	165.34

more convenient, the results from descriptive and independent sample test tables also provide us with the values of mere deviation, standard means error, etc. It has quickly to easily determine the tensile strength of both materials for evaluation.

Previously, work on the AA5059 with SiC provided 5% greater tensile strength than the base metal. Another work on twin-roll casting high Mg AA5059 to alloy sheets provides us with 4.6% and 7.6% more tensile strength than the base metal. The work on welded joints of AA5059 aluminum alloy and high-density polyethylene provides 36% more tensile than the base material. But in our work, in figure 6, composite gives nearly 48% greater tensile strength than the as-cast metal. In addition to that, this research introduced a novel encapsulation technique to cast the aluminum alloy and it leads to a higher tensile strength than the other AA5059 alloy in previously worked research. It is achieved by equally distributing the reinforcement to overall metals during casting as wand stir-casting method. Therefore, this research produced a relatively more tensile-strength composite using a novel encapsulation technique and reinforcement kaolinite.

The factors which are affecting our research include the stirrer and pouring method. This research found some defects such as pinholes, blow holes, and rarely shrinkage cavities due to pouring molten metal under gravity to the intone. This research considered this casting defect to be the limitation of our research. Hence, the future scope of this study is to avoid such casting defects by using the squeeze casting method to avoid the forming of bubbles.

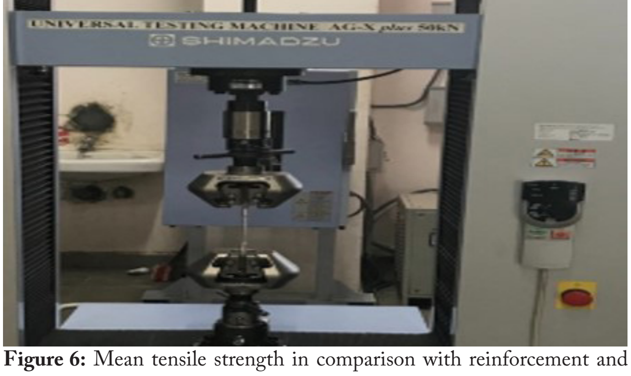

Figure 6: Mean tensile strength in comparison with reinforcement and without reinforcement. The mean value says that the composite metal with reinforcement obtained amore excellent value of 48% higher than the as-cast metal in tensile strength.

Conclusion

Within the limitations of this study, this research concluded that the composite material (AA5059 with 10 % kaolinite) is increased using a novel encapsulation technique in tensile strength. AA5059 alloy with reinforcement of 10% nano kaolinite provided nearly 48% more tensile strength than the as-cast AA5059 material without reinforcement. Novel encapsulation technique with stir casting method plays a major role in the tensile strength of AA5059 with 10 % kaolinite. Due to the more tensile strength in AA5059 with 10% nano kaolinite can be used in forming vehicle armor to hold enough tensile strength application. It is also applicable to cryogenic propellant tanks and several ship development purposes.

Acknowledgements

None.

Conflict of Interest

None.

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