Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-080

Research Article

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Analysis of Tensile Properties for AA8176/Nano Graphene Metal-matrix Composite by Novel Encapsulate Stir Casting Technique

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Received: July 28, 2023
Accepted: October 13, 2023
Published: October 17, 2023

Citation: Babu S, Natrayan L, Richard T. 2023. Analysis of Tensile Properties for AA8176/Nano Graphene Metal-matrix Composite by Novel Encapsulate Stir Casting Technique. *NanoWorld J* 9(S3): S439-S443.

Published by United Scientific Group

Abstract

The main objective of this research is to understand the tensile strength of AA8176 reinforced with nano graphene (10%) by using novel encapsulation techniques and comparing it with as-cast AA8176. A novel encapsulation technique is used to make the test samples in two different groups with the help of a stir-casting method. For group 1, as-cast AA8176 is used and for group 2, composition of AA8176 and nano graphene (10%) is used. ASTM E08-8 standards are used for preparing the test samples and the machine used for evaluating the sample's tensile strength is a universal testing machine (UTM-Auto instrument). Each group consists of 20 samples. G-power of 80% is used to calculate the sample size, $\alpha = 0.05$ per set and a sum of 40 samples. The maximum tensile strength of AA8176 with nano graphene (10%) is 19% higher than the AA8176 as-cast material. Between group 1 and group 2's mean variance of tensile strength there is a significant $p = 0.00$ ($p < 0.05$) difference in t-test's statistical analysis. Within the limitations of this study, it is observed that the tensile strength of AA8176 has increased with nano graphene (10%) reinforcement. Within the limitations of this study, it is observed that the tensile strength of AA8176 has increased with nano graphene (10%) reinforcement.

Keywords

AA8176, Graphene, Energy, Novel encapsulate, Tensile strength, Stir casting, Metal matrix composite, Sustainability

Introduction

Aluminum alloys are used for their lightweight applications. They are used in various fields for their size, low density, and resistance to corrosion. AA8176 aluminum alloys used in this study are commonly used in building wires and service cables in the electrical sector. The aluminum alloy AA8176 is suitable for stranding into the conduction. The 8000 series aluminum alloy has a similar creep rate to the copper wire. So, instead of using copper wire we can use this AA8176. The AA8000 series has an equal ampacity of copper wire and a better strength-to-weight ratio when compared to copper wire. The aluminum alloy has a reduced pulling tension because the wire is lighter. AA8176 wire material will have high strength because of the nano graphene (10%) reinforcement. The material is toughened by mechanical strain hardening [1]. Aluminum alloys are used frequently in the combination of structural components because of their high weldability. Aluminum is used in automotive, electrical, and aerospace industries for its enhanced performance. The strength of these composite materials will be increased and applied to various industries for manufacturing products.

Many papers have been published about the AA8176 and its tensile strength in the past few years. Google Scholar has 197 papers and Science Direct has 76 papers based on AA8176's tensile strength. This study helps to estimate the tensile strength of friction stir welded aluminum alloy joints AA8176. Investigation of the effects of nano graphene particle sizes on the microstructural and mechanical properties of AA8176/graphene. A novel friction stirs welding deposition technique to refill the keyhole of friction stir spot weld [2]. Nano graphene encapsulation process: enhanced tensile properties of aluminum matrix composites reinforced with nano graphene encapsulated SiC nanoparticles paper can be considered one of the most relatable papers for the novel encapsulation method and it explains the novel encapsulation technique very well [3]. This study entirely focuses on aluminum's tensile strength properties [4].

It is observed that only a limited amount of research has been conducted on the novel encapsulation method with composites. The main objective of this study is to develop a novel encapsulating stir-casting method for fabricating the AA8176 with nano graphene (10%) reinforcement. Comparing the tensile strength characteristics of as-cast and composite materials is the main reason for conducting this study.

Materials and Method

The research location for this study is the Institute of Mechanical Engineering, Saveetha Industries, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai (Tamil Nadu, India). As-cast and composite materials were the two groups that contributed to the investigation of the tensile strength study. A little hole was drilled in the as-cast and composite samples to study tensile strength. Two groups are there and a total of 40 samples in which the G-power is 80% and each group has 20 samples.

This study consists of 2 groups, in which as-cast is group 1. It is used for preparing the first 20 samples. The AA8176 with a diameter of 1.2 mm is used; machining is not required for the material because it is a wire material [5]. The crucible with a capacity of 1 kg contains 1 kg of AA8176. Then, the crucible will be placed inside the furnace and the temperature of the furnace is increased up to 700 °C; when the temperature is increased then the aluminum alloy inside the crucible will start to melt [6]. After the melting process, the molten metal is poured into the mold and will be cooled. The casting material is removed from the mold, and the excess material is eliminated. The casting metal is divided into some cylindrical pieces for tensile strength.

As-cast is considered the group 1 material, and composite material is the group 2 material in which another 20 samples will be fabricated. Nano graphene is used as reinforcement, as shown in figure 1. A tiny hole has been drilled inside the wire material. The hole is filled with nano graphene (10%), as shown in figure 2. Afterwards, the crucible is placed inside the furnace and the temperature is increased gently for the melting process. The molten AA8176 alloy with nano graphene (10%) is blended by the stir-casting method before pouring the molten metal inside the mold as shown in figure 3. When it is cooled the composite is pulled out of the mold then the excess material is removed from the composite. Then the composite material will be cut into cylindrical sections for the testing of tensile strength as shown in figure 4.

Figure 1: Nano graphene (10% reinforcement).

Figure 2: AA8176 aluminum alloy.

Figure 3: Stir casting.

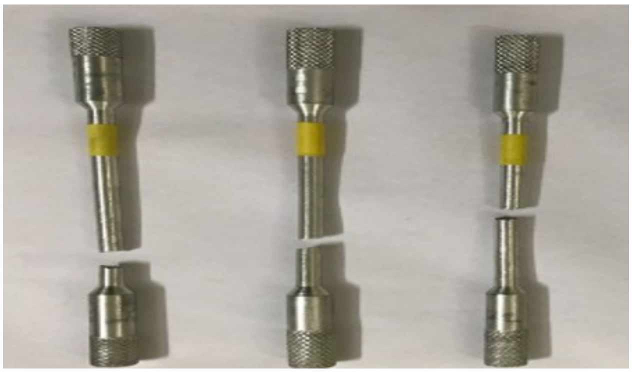

Figure 4: Fabricated materials for tensile strength.

A UTM is used for taking the tensile strength for both as-cast and composite materials as shown in figure 5. The tensile strength of the cylindrical rod of cast composites was ac-

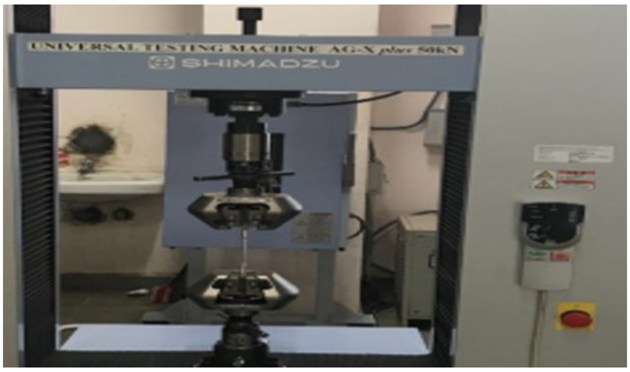

Figure 5: Tensile strength test.

cessed according to the ASTM E08-8 standard [7]. To reduce the machining scratches and the effects of surface flaws on the sample, the test specimens were polished with 1200-grit grinding paper. For taking the tensile test in the UTM with a load of 10 kN load cell. The tensile strength test used a 2.5 mm/min crosshead speed [8]. To carry out the tensile test by the UTM machine the sample must be held tightly between the two jaws of the testing machine [9]. The main reason for drawing the jaws is to provide tension on the sample. Continuous tension is applied to the sample till the fracture point. When the subjected force applied to the specimen reaches the fracture point the tensile strength of the specimen is noted [10].

Each group has 20 samples, and all the 20 samples will have the same procedure. As-cast material's tensile values for all 20 samples are shown in table 1 and the tensile value for all 20 samples of composite materials are shown in table 2.

Statistical analysis

A particular software application called SPSS (Statistical Package for the Social Sciences) has been developed by IBM for data processing, data administration, mathematical analysis, etc., The SPSS statistical software is used for taking the t-test for the tensile strength of the experimental specimens [11]. By using the SPSS statistical program, descriptive tables and the Bonferroni analysis are also conducted [12]. Stir speed and the percentage of reinforcement are independent variables, and tensile strength is considered the dependent variable [13]. Meanwhile, the research gives information about the mean data, standard deviation, and significance [14]. The mean tensile strength is shown in figure 6.

Results

In the conducted research, the tensile strength of two distinct materials is tabulated and elaborated upon. Table 1 showcases the tensile strength (measured in MPa) of the as-cast AA8176 alloy without any reinforcement and the AA8176 alloy enhanced with nano graphene reinforcement. Diving deeper into the data, table 2 presents the group statistics concerning the tensile strength of both these materials. Table 2 provides a detailed analytical breakdown, providing insights into the mean, standard deviation, and standard error values. It's worthy of note that, with the inclusion of the nano graphene, there's an observable increase in tensile strength, reaching up to 19%.

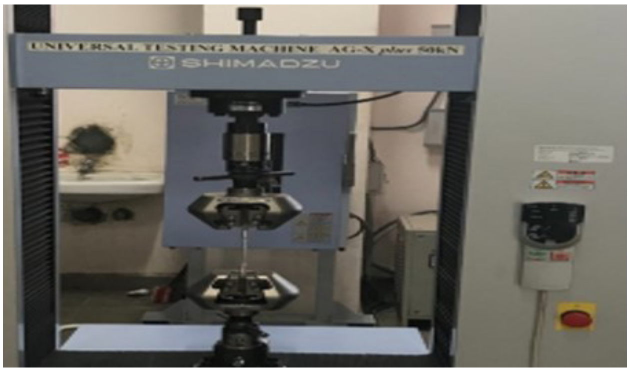

Figure 6: Comparing the mean tensile strength with and without reinforcement. The mean value table clearly shows that the composite metal with reinforcement has a 19% higher value than the as-cast material's tensile strength.

Taking a further investigative step, table 3 delves into the independent samples test, focusing on the materials' tensile strength (MPa). Table 3 offers a comprehensive understanding of Levene's test results, primarily centered around the equality of variance values. Additionally, the t-test values, crucial in statistical analysis, are highlighted [15].

Lastly, table 4, titled "Descriptive of the tensile strength (MPa)", provides a comprehensive overview of the tensile strength of the as-cast AA8176 without reinforcement juxtaposed against the tensile strength of the AA8176 alloy bol-

Table 1: Tensile strength (MPa) of as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

Sample number	As-cast AA8176	AA8176/nano graphene
1	117.01	145.10
2	116.58	144.56
3	113.96	141.31
4	116.76	144.78
5	110.42	136.92
6	108.12	134.06
7	110.02	136.42
8	104.89	130.06
9	108.78	134.88
10	111.95	138.81
11	107.80	133.67
12	105.93	131.35
13	102.12	126.63
14	101.03	125.28
15	95.96	118.99
16	99.88	123.85
17	105.06	130.28
18	107.94	133.85
19	112.55	139.56
20	113.67	140.96

Table 2: Group statistics of tensile strength (MPa) in as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

Group statistics		N	Mean	Std. deviation	Std. error mean
Tensile strength (MPa)	As-cast AA8176	20	108.5215	5.88184	1.31522
	AA8176/nano graphene	20	134.5660	7.29386	1.63096

Table 3: Independent samples test of tensile strength (MPa) in as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

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 of the difference	
								Lower	Upper
Equal variances assumed	0.827	0.369	-12.431	38	0.000	-26.044	2.09519	-30.285	-21.803
Equal variances not assumed			-12.431	36.367	0.000	-26.044	2.09519	-30.292	-21.796

Table 4: Descriptive of the hardness of as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

	N	Mean	Std. deviation	Std. error	95% CI for mean		Minimum	s
					Lower bound	Upper bound		
As-cast AA8176	20	108.5215	5.88184	1.31522	105.7687	111.2743	95.96	117.01
AA8176/nano graphene	20	134.5660	7.29386	1.63096	131.1524	137.9796	118.99	145.10
Total	40	121.5438	14.72073	2.32755	116.8358	126.2517	95.96	145.10

stered with nano graphene reinforcement. An essential feature of this table is the "confidence interval (CI) of the mean", which offers a range within which the true population mean is expected to lie with a certain confidence level [16]. From the data presented across these tables, one can infer the significant enhancements in tensile strength between the two examined groups.

Discussion

The final data of the tensile strength (MPa) test shows that the AA8176 alloy reinforced with nano graphene has an improved tensile strength than the as-cast AA8176 without the reinforcement. The results we get from the descriptive table will provide the standard deviation values, standard mean error values, mean values to help make it more convenient [17]. By using this the tensile strength for both as-cast and composite will be determined [18]. Previously, some work was done on this AA8176 alloy which gives 10% higher tensile strength than the base metal [19]. But our work gives 19% more tensile strength than the as-cast AA8176 metal and we also introduced a novel encapsulation method for casting aluminum alloy [20]. It improves tensile strength more than the other AA8176 alloy used in the previous research [21]. This is achieved because of the equal distribution of the reinforcement to all the metals during the process of casting and the process of stir-casting. Therefore, we have produced a higher tensile strength composite using the novel encapsulation method and reinforcing the nano graphene.

The stirrer and pouring method were the affecting factors of our research work. During our research, some casting defects were found shrinkage cavities, pinholes, and blow holes. These casting defects were caused due to pouring of the molten metal under the influence of gravity. It is considered that the casting defect is the only limitation of our research work. So, by using the squeeze casting method we can avoid the formation of air bubbles, which would be our study's future scope.

Conclusion

Within the parameters defined by this research, notable observations have been made regarding the tensile strength of the composite material AA8176 when reinforced with 10% nano graphene. A significant enhancement in tensile strength was achieved by harnessing the innovative encapsulation technique. Specifically, there was a 19% uptick in the tensile strength of the AA8176 alloy post its reinforcement with nano graphene. This increase is particularly noteworthy when set against the tensile strength of the as-cast AA8176, which served as the reference point for this comparison. The crucial catalyst in this achievement appears to be the novel encapsulation method and the stir casting process, which has effectively optimized the tensile properties of the AA8176 when merged with nano graphene reinforcement. The implications of this development are quite profound. Given the enhanced tensile strength of this nano graphene reinforced AA8176 alloy, it becomes an ideal candidate for manufacturing robust service cables and electrical wires. Such cables and wires would be particularly resilient and capable of enduring significant applied loads primarily due to their elevated tensile strength.

Acknowledgements

None.

Conflict of Interest

None.

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