NanoWorld Journal

https://doi.org/10.17756/nwj.2023-s3-001

Research Article

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Fabrication of AA8176/Graphene Composite by Novel Encapsulate Stir Casting Technique and Investigation on Wear Properties

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Received: July 26, 2023
Accepted: September 25, 2023
Published: September 28, 2023

Citation: Babu S, Natrayan L, Vickram AS. 2023. Fabrication of AA8176/Graphene Composite by Novel Encapsulate Stir Casting Technique and Investigation on Wear Properties. *NanoWorld J* 9(S3): S01-S05.

Published by United Scientific Group

Abstract

This research aims to evaluate the wear of AA8176 with graphene (10%) reinforcement by novel encapsulation technique and as-cast AA8176 is compared with the composite. A novel encapsulating stir casting method is used for fabricating the samples in both groups. In group 1, AA8176 with the reinforcement of graphene 10% is used and in group 2, as-cast AA8176 is used. The samples were prepared by ASTM E92 standards, and their wear is tested on pin-on-disc equipment. Each group has 20 samples with a G-power of 80%, and $\alpha = 0.05$ is set for calculating the sample size and the total sample size is 40. The maximum wear is 79% higher in the AA8176 with 10% graphene reinforcement compared with the as-cast AA8176. The t-test statistical analysis shows a significant $p = 0.00$ ($p < 0.05$) difference in the mean-variance of wear between group 1 and group 2. Within the limitations of this study, it is observed that AA8176 alloy with graphene 10% reinforcement improves the wear of the material.

Keywords

Graphene, Sustainability, AA8176, Wear, stir casting, Metal matrix composite, Energy, Novel encapsulate

Introduction

Due to their on-magnetic, recyclable, and ductile properties aluminum alloys which they have are commonly used in industries. Also, aluminum alloys are light weighted [1]. It is also used in the electrical, electronic, aerospace, and architectural industries. AA8176 aluminum alloy is a wire type material. It is used in building wires and service cables. Most commonly used in the electrical sector for the wiring purpose because it is suitable for stranding into the conductors. The aluminum alloy AA8000 series has a similar creep rate to copper wires [2]. It has an equal ampacity of copper wire. But at the same time, it has a better strength-to-weight ratio. When AA8176 is reinforced with graphene, it will give the material high strength. Since it is a light material the pulling tension is also reduced. For toughening the material mechanical strain hardening is used. Aluminum alloys are most frequently used with structural components because of their high weldability. Aluminum is employed in several industrial applications because of its enhanced performance. The strength will be drastically increased in the composite materials and can also be used in various industries for manufacturing its products.

In the past few years, many papers were published in Google Scholar and Science Direct about the wear of AA8176 aluminum alloy. In google scholar 224 papers were published and In Science Direct 94 papers were published. This study focuses on the wear characteristics of the aluminum alloy AA8176 fabricated by friction stir welding [3]. Graphene encapsulation process: A road map for manufacturing aluminum with superior mechanical properties is considered the best paper for novel encapsulation techniques, which explains the method very well. This study mainly focuses on the nanoparticles and encapsulation technique [4]. Moreover, the aluminum-based composites were addressed with different reinforcements.

Only a limited amount of research was conducted on the novel encapsulation technique with composite materials. This study mainly focused on developing novel encapsulating stir casting methods to fabricate AA8176 with graphene reinforcement (10%). This study compares the wear of the as-cast material and the composite material.

Materials and Method

The Institute of Mechanical Engineering, Saveetha Industries, Saveetha School of Engineering, and Saveetha Institute of Medical and Technical Sciences, Chennai (Tamil Nadu, India) is the research location for this study. Two groups of materials are used in the investigation of wear's study, in which as-cast and composite materials are considered the two groups. The 8 mm diameter and 30 mm height samples are used as an as-cast and composite materials to compare the wear behavior. Twenty samples are in each group, and two groups in which the G-power is 80% [5].

This study has two different types of groups, which we can take as cast as group 1. As-cast is used in the prepared 20 samples in group 1. AA8176 aluminum alloy is used with a diameter of 1.2 mm. Since it is a wire material, machining is not required. 1 kg of AA8176 is placed inside the crucible with a capacity of 1 kg. Later, the crucible is placed inside the furnace and up to 700 °C the temperature of the furnace increases in temperature the aluminum alloy AA8176 will start to melt inside the crucible. Then, the molten metal will be poured into the mold after the melting process [6]. When the molten metal is cooled, it returns to the mold and removes excess material.

In group 1, as-cast is considered as the sample material and in group 2, composite material is considered as sample material in which the remaining 20 samples will be obtained. AA8176 is a wire type of material, so instead of machining, a small hole has to be drilled inside the wire to fill the reinforcement. After drilling the hole inside the wire, graphene (10%) is filled for reinforcement as shown in figure 1. Again, the crucible with composite material has to be placed inside the furnace as shown in figure 2 and the temperature is also increased for the melting process [7-10]. After the melting process, the molten AA8176 alloy with reinforced graphene (10%) has to be blended with the help of a stir-casting method as shown in figure 3. It should be done before pouring the metal into the mold. After the cooling process the composite is pulled from the mold and material is removed.

For conducting the wear resistance test for both as-cast and composite materials a specified equipment is used which is known as pin-on-disc equipment. By using the ASTM

Figure 1: Graphene (10% reinforcement).

Figure 2: AA8176 aluminum alloy.

Figure 3: Stir casting.

standard E92 a total number of 40 samples are cut into slices with a diameter of 8 mm and height of 30 mm for wear resistance as shown in figure 4. An oil hardened nickel steel with a steel disc diameter of 55 mm and hardness of 60 HRc. The pin-on-disc machine is shown in figure 5. For conducting the test various loads were used; they are 20 N, 40 N, and 60 N. The sliding speed will be 0.6, 0.8, and 1.0 m/s for a sliding distance of 2000 m. A room temperature of 30 °C and relative humidity of 60 - 65% were used in this test.

Figure 4: Material for the wear test.

Figure 5: Pin-on-disc machine.

There are 20 samples in each group and the same procedure will be carried out for all 20 samples [11-13]. The wear value for the as-cast material is shown in table 1 and the wear value for the composite material is shown in table 2.

Statistical analysis

SPSS (Statistical Package for the Social Sciences) is a statistical tool used for data management, data analysis and mathematical modeling, etc. This statistical tool package was developed by IBM. T-tests are conducted to measure the wear of the research samples. The t-test is conducted using the SPSS statistical software. Using the SPSS software, we can also perform the descriptive table and Bonferroni studies. Independent variables are stirred speed and reinforcement weight percentage, whereas dependent variable is wear. This study also gives the standard deviation, significance, and mean data. The mean wear rate output shows that the AA8176 with graphene reinforcement has 79% less wear than the as-cast material without reinforcement [14-16].

Table 1: The wear rate of as-cast AA8176 without reinforcement and AA8176 with reinforcement graphene.

Sample number	As-cast AA8176	AA8176/graphene
1	1.445	0.379
2	1.407	0.341
3	1.420	0.354
4	1.386	0.320
5	1.397	0.331
6	1.411	0.345
7	1.388	0.322
8	1.382	0.316
9	1.379	0.313
10	1.336	0.270
11	1.346	0.280
12	1.308	0.242
13	1.321	0.255
14	1.287	0.221
15	1.298	0.232
16	1.312	0.246
17	1.289	0.223
18	1.283	0.217
19	1.280	0.214
20	1.237	0.171

Table 2: Group statistics of wear rate in as-cast AA8176 without reinforcement and AA8176 with reinforcement graphene.

Groups		N	Mean	Std. deviation	Std. error mean
Wear rate	As-cast AA8176	20	1.3456	0.05810	0.01299
	AA8176/ graphene	20	0.2796	0.05810	0.01299

Results

Table 1 has the wear property values of as-cast AA8176 without reinforcement and AA8176 with graphene reinforcement. Table 2 shows the wear properties of as-cast AA8176 without reinforcement and AA8176 with graphene (10%) reinforcement. It shows the table's mean, standard deviation, and standard error mean. The wear rate is reduced up to 79%. Table 3 has the independent samples test of the wear property in which we can get the Levene's test for equality of variances values and t-test values. Table 4 has the descriptive of the wear property of as-cast AA8176 without reinforcement and AA8176 with graphene reinforcement. It shows the confidence interval of the mean. The result of the wear property data may be noted in the two group's tables [17-18].

Table 3: Independent samples test of the wear rate in as-cast AA8176 without reinforcement and AA8176 with reinforcement graphene.

		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
Wear rate	Equal variances assumed	0.000	1.000	58.021	38	0.000	1.06600	0.01837	1.02881	1.10319
	Equal variances not assumed			58.021	38.000	0.000	1.06600	0.01837	1.02881	1.10319

Table 4: Descriptive of the wear rate in as-cast AA8176 without reinforcement and AA8176 with reinforcement graphene.

	N	Mean	Std. deviation	Std. error	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
As-cast AA8176	20	1.3456	0.05810	0.01299	1.3184	1.3728	1.24	1.45
AA8176/graphene	20	0.2796	0.05810	0.01299	0.2524	0.3068	0.17	0.38
Total	40	0.8126	0.54283	0.08583	0.6390	0.9862	0.17	1.45

Discussion

The study we conducted with AA8176 alloy with graphene (10%) reinforcement has a good enhancement in the wear rate compared with the as-cast 8176 without reinforcement. The descriptive table will give the standard deviation values, standard mean error values and the mean error. With the help of this we can determine the wear rate for both as-cast and composite material. Previously, some studies have been conducted on this method and they have a 56% lower wear rate than the base metal. Another work on composite material has been used to reduce the wear rate. But, in our study we achieved nearly 79% less wear rate than the as-cast AA8176 material than AA8176/graphene. This can be achieved by employing the novel encapsulation technique which helps spread the reinforcement to the aluminum alloy at the time of stir casting. We have achieved a lower wear strength using the novel encapsulation and stir casting technique. The affecting factors of the study were the stirrer and pouring technique. At the time of our research, we found some casting defects [19]. Blow holes, pinholes and shrinkage cavities were the casting defects of our study. These defects happened because we poured the molten metal into the die under the influence of gravity. These casting defects were the limitations of our study. By employing the squeeze casting method, we can avoid casting defects such as the generation of air bubbles. This is the future aim of our project.

Conclusion

Within the limitations of this study, the novel encapsulation technique employed in our research reduces the composite materials (AA8176 with 10% graphene) wear rate, which is the conclusion of our study. The wear rate of AA8176 alloy was reduced up to 79% when 10% of graphene was reinforced. The technique used in this study was a novel encapsulation method with a stir casting method and it has a significant role in the wear resistance of AA8176 with graphene 10% reinforcement. Under the consideration of wear resistance tests, it is possible to make electrical wires and service cables that can withstand good wear.

Acknowledgements

The authors thank Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Conflict of Interest

There is no conflict of interest in this manuscript.

Funding

We thank the following organizations for providing financial support that enabled us to complete the study: Surya Engineering Industries (Chennai), Saveetha University, Saveetha Institute of Medical and Technical Sciences, and Saveetha School of Engineering.

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