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An Experimental Investigation on Surface Roughness of AA8176/Nano Graphene Metal-matrix Composite via Novel Encapsulate Stir Casting Technique by Drilling Process

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Abstract

The main goal of this research is to evaluate the surface roughness of AA8176 with reinforcement of nano graphene (10%) by using a novel encapsulation technique and to compare this composite with as-cast AA8176. Using the novel encapsulating stir casting method for fabricating the samples of both groups. Group 1 combines AA8176 with nano graphene reinforcement and group 2 has as-cast AA8176. As per the ASTM standards all the samples were prepared, and the surface roughness testing machine found surface roughness. We must prepare 20 samples for each group with 80% G-power and $\alpha = 0.05$. The AA8176 reinforced with nano graphene has a better surface roughness when compared with the as-cast 8176 material. The surface roughness in AA8176 with nano graphene reinforcement is 14% lesser than in as-cast AA8176. T-test's statistical analysis shows a significant $p = 0.00$ ($p < 0.05$) difference in the mean variance of surface roughness between group 1 and group 2. Within the limitations of our study, we can conclude that the surface roughness of aluminum alloy is increased by adding the nano graphene (10%) reinforcement.

Keywords

Surface roughness, Sustainability, Stir casting, Metal matrix composite, Energy, Novel encapsulate, AA8176, Graphene

Introduction

Aluminum alloys are used for their lightweight in most automobile industries. The industries which use aluminum alloys are electrical, aerospace, and architectural. Since it is suitable for stranding conductors, AA176 is used for building wires and service cables. The wires and cables are built in the electrical sector [1]. Copper wire is also used to build cable wire, but the AA8000 series has the same creep rate and performs the same thing as copper. AA8000 wire has the equal ampacity of copper wire and a good strength-to-weight ratio. Aluminum alloy is lighter, reducing the pulling tension [2]. Aluminum alloy AA8176 with the reinforcement of nano graphene gives high strength to the material. Material is toughened by the mechanical strain hardening method. This aluminum alloy is frequently used in structural components because of its high weldability [3]. Many industries employ aluminum alloy because of its enhanced performance. We can name some industries which include automotive, electrical and electronics. It is applied in various industries for manufacturing its products because the composite material will drastically increase its strength [4].

Google scholar and Science Direct have published several articles on the aluminum alloy AA8176 and its surface roughness properties. 285 papers were published in Google Scholar and 122 in Science Direct. In those papers we can clearly understand the surface roughness properties of aluminum alloy AA8176

[5]. The investigation was also done on the effects of particle sizes of nano graphene on the microstructural level and mechanical properties were also studied [6]. A novel and efficient technology of depositing Al_2O_3 film for OLEDs thin film encapsulation research paper is one of the best papers for novel encapsulation techniques and its surface roughness properties [7].

A limited amount of research conducted on the novel encapsulation method with composite materials. Developing a novel encapsulating stir-casting method fabrication of AA8176 with the reinforcement of nano graphene (10%) is the main aim of this study. As-cast material's surface roughness value and composite material's surface roughness value are compared in this study.

Materials and Method

The research was predominantly conducted at Saveetha Industries, Saveetha School of Engineering, and the Saveetha Institute of Medical and Technical Sciences, Chennai (Tamil Nadu, India). In this research, the primary focus was on examining the surface roughness of two distinct groups: as-cast and composite materials. The study used metals with a thickness of 10 mm for the testing. The research comprised 40 samples, with each group containing 20. The sample size, determined with a G-power of 80%, was methodically chosen to ensure comprehensive results.

The first group, group 1, was centered on as-cast samples. For its preparation, an aluminum alloy AA8176 with a diameter of 1.2 mm was utilized. Interestingly, AA8176 is a wire material unlike other aluminum alloys, thereby eliminating the need for machining [8]. A crucible with a 1 kg standing capacity was filled with this alloy, which was then subjected to high temperatures in a furnace, reaching up to 700 °C. As the alloy melted, the molten material was poured into molds. Once solidified, the cast material was carefully removed, eliminating any excess material [9].

The next set of samples, group 2, was dedicated to composite materials. Given the wired nature of AA8176, direct machining wasn't feasible. Instead, a small hole was drilled into the alloy to facilitate the introduction of nano graphene reinforcement, as depicted in figure 1. This reinforcement was done at a concentration of 10% [10]. The alloy-reinforcement mix was placed in a crucible and melted in a furnace (Figure 2). Crucially, before this molten mix was poured into molds, it underwent a thorough blending process via the stir-casting method, ensuring uniformity, as illustrated in figure 3.

For the critical task of evaluating the surface roughness (Figure 4) of both as-cast and composite materials, a specialized instrument, the Mitutoyo surface roughness tester (SJ-410), was employed [11]. The device, showcased in figure 5, was operated by ASTM standards for surface roughness. The materials, each with 20 drilled holes, were carefully positioned so the tester's needle could gauge the surface's roughness [12]. The tester operated at different speeds, ranging from 0.002 to 0.04, to provide accurate measurements.

The process was consistently replicated for all 40 samples. The results, segregated by group, were meticulously tabulated [13]. Table 1 detailed the surface roughness values for the as-cast materials, while table 2 presented the equivalent data for the composite materials.

Figure 1: Nano graphene (10% reinforcement).

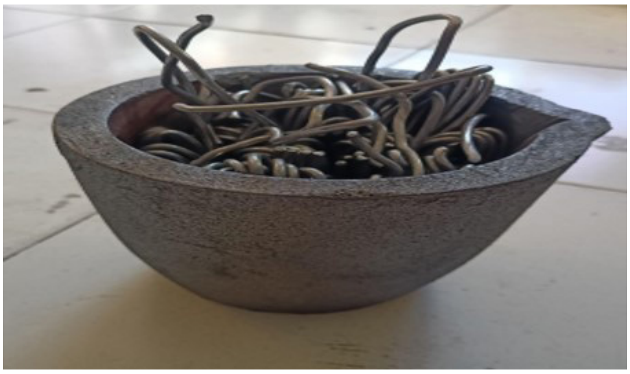

Figure 2: AA8176 aluminum alloy.

Figure 3: Stir casting.

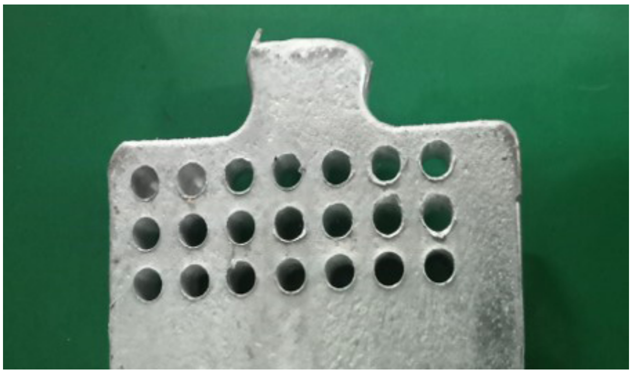

Figure 4: Material for surface roughness.

Figure 5: Surface roughness testing machine.

Statistical analysis

SPSS (Statistical Package for the Social Sciences) software is mainly developed for analyzing and managing data and for mathematical modeling. This SPSS is a statistical software package developed by IBM [14]. It is used for conducting the t-test to generate the surface roughness for the sample specimens. The important work of this SPSS software is to perform the descriptive table; it is used for Bonferroni studies also. Two types of variables are there in this test, in which we can consider stirring speed and reinforcement weight as the independent variables and surface roughness as the dependent variable. In this study we can also get the mean data, standard deviation, and significance [15]. The mean surface is shown in figure 6. The mean surface roughness value shows that the AA8176 with nano graphene reinforced has a 14% lower surface roughness than the as-cast AA8176 metal.

Figure 6: Comparing the mean surface roughness value with and without nano graphene reinforcement.

Table 1: Surface roughness of as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

Sample number	As-cast AA8176	AA8176/nano graphene
1	6.284	5.447
2	5.873	5.036
3	5.624	4.787
4	5.382	4.545
5	5.050	4.213
6	4.964	4.127
7	5.050	4.213
8	5.415	4.578
9	6.283	5.446
10	7.509	6.672
11	8.560	7.723
12	5.958	5.121
13	5.547	4.710
14	5.298	4.461
15	5.056	4.219
16	4.724	3.887
17	4.638	3.801
18	4.724	3.887
19	5.089	4.252
20	5.957	5.120

Table 2: Group statistics of surface roughness in as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

Group statistics		N	Mean	Std. deviation	Std. error mean
Surface roughness (Microns)	As-cast AA8176	20	5.6493	0.96858	0.21658
	AA8176/nano graphene	20	4.8123	0.96858	0.21658

Results

The research meticulously examined the surface roughness of AA8176 aluminum alloy in its as-cast form and when reinforced with nano graphene. Table 1 provides a comprehensive overview of the surface roughness values of two distinct sets of materials: as-cast AA8176 devoid of any reinforcement and its counterpart that integrates nano graphene reinforcement. The clear differentiation allows for a comparative understanding of how reinforcement impacts the inherent properties of the alloy [16].

Further, table 2 delves into the statistical intricacies of the surface roughness, showcasing data for both material types. This table is particularly insightful, presenting key statistical metrics such as each sample group's mean, standard deviation, and standard error. An interesting observation from the research data indicates a notable reduction in surface tension by as much as 14%, suggesting that incorporating nano graphene might play a pivotal role in this change.

Table 3 transitions into a more detailed statistical evaluation. It presents the independent samples test for surface roughness. This table becomes indispensable for those looking to understand the nuanced differences between the two material types. It offers valuable insights into the t-test values, which is critical for determining the statistical significance of the observed differences [17]. Additionally, Levene's test for equality of variance values is presented, further adding depth to the analytical rigor of the study.

Concluding the series of tables, table 4 focuses explicitly on the surface roughness data for both the as-cast AA8176 and its nano graphene-reinforced version. Notably, this table sheds light on the confidence interval of the mean, a metric that provides a range within which the true population mean is likely to fall. This confidence interval is pivotal for drawing reliable conclusions from sample data. Such comprehensive data representation allows for an informed understanding of how nano graphene reinforcement influences the surface properties of the AA8176 alloy.

Table 3: Independent samples test of the surface roughness in as-cast AA8176 without reinforcement and AA8176 with reinforcement nano graphene.

Surface roughness	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	0.000	1.000	2.733	38	0.009	0.83700	0.30629	0.21694	1.45706
Equal variances not assumed			2.733	38.000	0.009	0.83700	0.30629	0.21694	1.45706

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

Surface roughness (Microns)	N	Mean	Std. deviation	Std. error	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
As-cast AA8176	20	5.6493	0.96858	0.21658	5.1959	6.1026	4.64	8.56
AA8176/nano graphene	20	4.8123	0.96858	0.21658	4.3589	5.2656	3.80	7.72
Total	40	5.2308	1.04582	0.16536	4.8963	5.5652	3.80	8.56

Discussion

As a result of our study, the surface roughness value of AA8176 alloy with nano graphene reinforcement is reduced when compared with the as-cast AA8176 alloy without reinforcement [18]. To simplify our study, we can use the values of mean error, standard deviation, and standard error from the descriptive table. Previously, some research work has been done on this surface roughness. In this research work, friction stir welding is used to improve the properties of AA8176 metal. In our research, the surface roughness has a good enhancement, and we got a 14% lesser surface finish value on AA8176 alloy with nano graphene reinforcement when compared with as-cast metal. A novel encapsulation method has been introduced in our study to spread the metal equally during the casting process which helps in a better surface roughness. The previous study has shown a different kind of result and improved our work.

There are certain factors that affect our research work. The stirrer and pouring factors affected the factors. Our research work has certain limitations and casting defects such as pin holes, blow holes, and shrinkage cavities. These casting defects occurred because of pouring the molten metal into the mold under the influence of gravity [19]. When we searched for a better improvement in our study, we learned about the squeeze casting method. Therefore, the future goal of our study is to employ a squeeze casting method to stop the generation of air bubbles.

Conclusion

In this study explored the effects of a pioneering encapsulation technique on the surface roughness of the AA8176 composite material, specifically when reinforced with a 10% nano graphene addition. Although certain limitations confined the research, the results were compelling. A comparative assessment between the as-cast AA8176 metal and its counterpart reinforced with 10% nano graphene revealed a noteworthy observation: the reinforced version exhibited a 14% improvement in surface finish. This improvement is significant, underscoring the efficacy of the novel encapsulation process, particularly when used in conjunction with the stir-casting method. The synergy between these two techniques appears to be instrumental in mitigating the surface roughness of the AA8176 alloy when augmented with nano graphene. Given this enhanced smoothness, the potential applications of the reinforced AA8176 alloy extend considerably. The reduction in surface roughness is not merely a cosmetic enhancement but can have practical implications. For instance, this material's improved properties make it exceptionally suitable for manufacturing electrical wires and service cables. The smoother finish ensures better conductivity and less resistance, which is vital for such applications. In essence, through the strategic integration of nano graphene and the utilization of advanced fabrication techniques, we've unlocked new potential uses for the AA8176 alloy.

Acknowledgements

None.

Conflict of Interest

None.

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