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Investigation on Hardness of AA8176 Reinforced Nano Graphene Using Novel Encapsulate Stir Casting Technique

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Abstract

The primary objective of this study was to gauge and subsequently analyze the hardness quotient of AA8176 when reinforced with 10% nano graphene. This amalgamation was achieved through an innovative encapsulation method, and the outcome was juxtaposed against the hardness of the as-cast AA8176. A distinctive encapsulation stir-casting technique was the methodology chosen for the fabrication of the samples in both groups. Group 1 was the product of an amalgamation between nano graphene (comprising 10% of the total) and AA8176. Conversely, group 2 exclusively utilized AA8176. Adherence to the ASTM E92 standards was paramount in the preparation of these samples. The hardness of these prepared samples was then discerned by employing a Vickers hardness apparatus. Each of the two groups had a set of 20 meticulously prepared samples. The computational procedure to determine the sample size was anchored in a G-power of 80%, with an α value set at 0.05, resulting in a total sample size of 40. The results revealed that the hardness apex was achieved with the material infused with 10% graphene, registering a hardness uptick of 25% in comparison to the as-cast AA8176. The t-test, a statistical analytical tool, confirmed a marked variance in the hardness mean between the two groups, registering a significant p-value of 0.00 ($p < 0.05$). Drawing from the evidence and data presented within the contours of this research, one can conclusively infer that the integration of 10% nano graphene into the AA8176 composite markedly elevates its hardness.

Keywords

Novel encapsulation, Sustainability, Hardness, Stir casting, Energy, Metal matrix composite, AA8176, Graphene

Introduction

Aluminum alloys are most commonly used in the architectural, lithographic, aerospace, electrical, and electronic industries. AA8176 is used in building wires and service cables in the electrical sector because it is suitable for stranding into conductors. Aluminum alloys from the 8000 series perform similarly because of their similar creep rates to those of copper building wire. Comparing 8000 to the copper wire of equal ampacity, the former has a better strength-to-weight ratio [1]. Pulling tension is reduced because it is lighter. AA8176 is reinforced with nano graphene which gives a high strength to the material. Mechanical strain hardening is used to toughen the material [2]. The high weldability of aluminum is the main reason for its frequent use in combination with structural components [3, 4]. Due to the enhanced performance of aluminum, it is employed in several industries like aerospace, automotive, electrical and space. This composite material will drastically increase its strength and can be applied to various industries to manufacture its products [5].

Numerous publications about aluminum 8176 metal's hardness characteristics have been published over the past few years. The AA8176 and its hardness characteristics were the subjects of 1870 research articles published in Google Scholar and 287 articles published in Science Direct. A novel feeding technique in squeeze casting to improve reinforcement mixing ratio is the best study of novel encapsulation methods, in which they explained the process very clearly about encapsulation technique and reinforcement method [6].

We observed limited research on developing composites using the novel encapsulation method [7]. To create AA8176/10% nano graphene composite, this work attempted to develop a unique encapsulating stir-casting technique [8]. This study mainly compares as-cast material and composite material's hardness characteristics.

Materials and Method

The study, anchored at Saveetha School of Engineering and Saveetha Institute of Medical and Technical Sciences, Chennai (Tamil Nadu, India), delves into material hardness evaluations. The research bifurcates the materials into two groups: Group 1 comprises as-cast material, while group 2 is centered on composite material [9]. Both groups employ samples with a thickness range of 8 - 10 mm, aiming to discern differences in hardness properties. Each group consists of 20 samples, and throughout the evaluation, the G-power remains consistent at 80%.

The first group, or group 1, is built around the as-cast material. The wire form of AA8176 with a 1.2 mm diameter negates the need for machining. Following the initial preparations, 1 kg of AA8176 is relegated to a 1 kg capacity crucible. When this crucible finds its way into a furnace, the temperature is calibrated to hover around 700 °C, facilitating the composite's meltdown within the crucible. Once the metal transitions to its molten state, it's systematically poured into a mold, leveraging gravity [10]. The cooling process follows, post which the cast material is extracted from the mold, unnecessary excess is pruned, and the resultant metal is sectioned into 8 - 10 mm segments, setting the stage for hardness testing.

Group 2 pivots its attention to composite material. The initial steps involve creating a diminutive hole in the wire material, into which 10% nanographene is instilled, as depicted in figure 1. This composite-laden crucible is then placed within the furnace (refer to figure 2), where the temperature is progressively escalated to liquefy the aluminum wire. Leveraging the stir-casting methodology, the molten alloy undergoes amalgamation with 10% nano graphene (Figure 3). This blend is then cast into molds, cooled, and excess material is excised post-extraction. The composite is subsequently dissected into 8 - 10 mm segments, primed for hardness evaluation [11].

The hardness assessments for both as-cast and composite materials employ a Vickers hardness tester. Adhering to the ASTM E92 benchmark, each 10 x 10 mm sample from the two 20-sample groups undergoes evaluation. The process involves placing a sample on a worktable, activating the machine, and using a diamond indenter to apply force. The force exerted is calibrated at 0.5 kgf, with a dwell time spanning 10 s. A microscope aids in gauging the indentation depth, extracting readings from three distinct points on each sample. Once a sample's hardness metric is ascertained, the result is exhibited on a monitor (as illustrated in figure 4) and duly recorded.

Figure 1: Nano graphene (10% reinforcement).

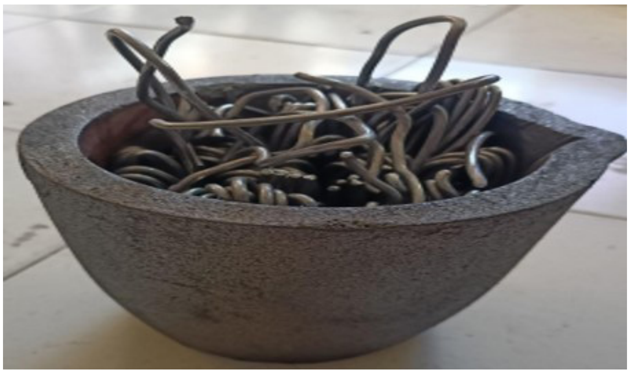

Figure 2: AA8176 aluminum alloy.

Figure 3: Stir casting.

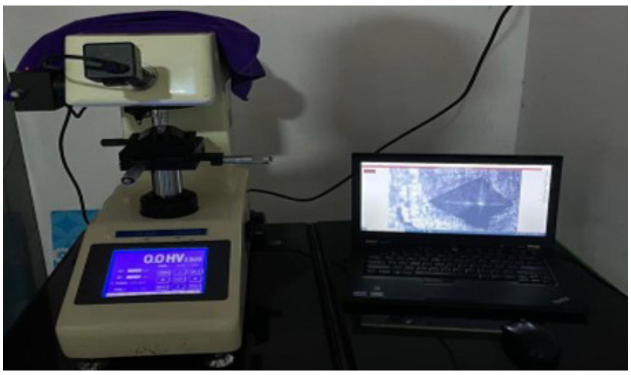

Figure 4: Hardness test.

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

Sample number	As-cast AA8176	AA8176/Nano graphene
1	40.63	53.21
2	40.48	53.06
3	39.57	52.15
4	40.54	53.12
5	38.34	50.92
6	37.54	50.12
7	38.20	50.78
8	36.42	49.00
9	37.77	50.35
10	38.87	51.45
11	37.43	50.01
12	36.78	49.36
13	35.46	48.04
14	35.08	47.66
15	33.32	45.90
16	34.68	47.26
17	36.48	49.06
18	37.48	50.06
19	39.08	51.66
20	39.47	52.05

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

Group statistics		N	Mean	Std. deviation	Std. error mean
Hardness	As-cast AA8176	20	37.6810	2.04227	0.45666
	AA8176/nano graphene	20	50.2610	2.04227	0.45666

This meticulous methodology is replicated across every sample in both groups for comprehensive documentation. Table 1 consolidates the hardness values for all two decades of as-cast samples, while table 2 does the same for the composite material samples.

Statistical analysis

IBM has developed a statistical software package known as SPSS (Statistical Package for the Social Sciences) for data analysis, data management, mathematical modeling, etc. Using the SPSS statistical software, the t-test will be conducted to the hardness measurements generated for the research samples. SPSS statistical software performs the descriptive tables and the Bonferroni studies [11]. Stir speed and reinforcement weight percentage are the independent variables, and hardness is the dependent variable in this research. In addition, the study provides the mean data, significance, and standard deviation [11]. The mean hardness graph is shown in figure 5.

Results

The hardness of as-cast AA8176 without reinforcement and AA8176 with nano graphene reinforcement is shown in table 1. The group statistics of hardness in As-cast AA8176 without reinforcement and AA8176 with 10% nano graphene reinforcement are shown in table 2. This table shows the mean, standard deviation, and standard deviation values. The hardness increased up to 25%. The independent samples test of the hardness is shown in table 3 in which the values of Levene's test for equality of variances and t-test values were obtained. The description of the hardness of as-cast AA8176 without reinforcement and AA8176 with nano graphene reinforcement is shown in table 4 where the confidence interval (CI) of the mean is obtained. In this result, the hardness data can be noted in the two group's tables.

Discussion

The recent data presents a clear distinction in the hardness

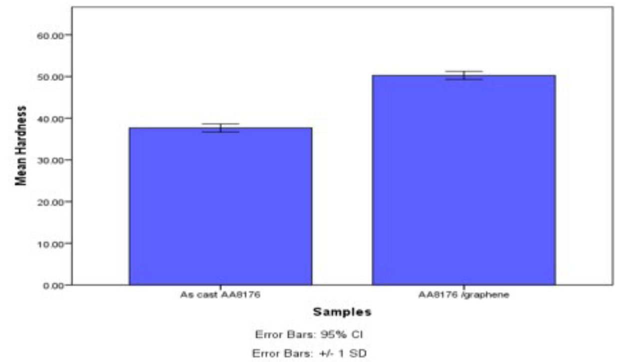

Figure 5: Comparison of mean hardness value with and without reinforcement. The mean value of the table shows that the composite material with reinforcement has a maximum value of 25% more than the as-cast metal's hardness value.

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

Hardness	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	-19.479	38	0.000	-12.58000	0.64582	-13.88740	-11.27260
Equal variances not assumed			-19.479	38.000	0.000	-12.58000	0.64582	-13.88740	-11.27260

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

Hardness	N	Mean	Std. deviation	Std. error	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
As-cast AA8176	20	37.6810	2.04227	0.45666	36.7252	38.6368	33.32	40.63
AA8176/nano graphene	20	50.2610	2.04227	0.45666	49.3052	51.2168	45.90	53.21

values between two variants of the AA8176 alloy. The as-cast AA8176 alloy, when reinforced with 10% nanographene, demonstrates superior hardness compared to its counterpart without the nano graphene reinforcement. Utilizing the detailed descriptive table, we can extract vital statistics such as mean, standard mean error, and standard deviation, which are instrumental in deciphering the hardness characteristics of the material. It is noteworthy to mention previous research on nano graphene reinforcement [12]. In contrast to that earlier study, our research findings indicate a significant 25% elevation in hardness. The novel encapsulation developed specifically for casting this type of aluminum alloy seems to be at the heart of this enhancement, bestowing the AA8176 with 10% nano graphene reinforcement with greater hardness than the as-cast AA8176 examined in prior studies. This augmentation in hardness is attributed to the integration of stir casting and the innovative encapsulation technique [13], which ensures a uniform distribution of the reinforcement throughout the metal during the casting process [14]. Subsequent findings from various studies also validate the efficacy of this encapsulation method in boosting hardness when used alongside 10% nano graphene reinforcement [15, 16].

However, it's crucial to highlight that the hardness observed in our study is influenced by specific factors, particularly the stirrer and pouring methods employed. Despite the gravitational pull directing the molten metal into the die, challenges such as pinholes, blow holes, and shrinkage cavities persist. We aim to integrate the squeeze casting method as we chart our future research direction. This method is anticipated to counteract the formation of air bubbles, which are often culprits behind casting defects.

Conclusion

Based on the findings from this research, it has been observed that the innovative encapsulation technique enhances the hardness of the composite material made of AA8176 alloy and 10% graphene. Specifically, when the AA8176 alloy is fortified with 10% nano graphene, the resulting material's hardness increases by a notable 25% in comparison to the unmodified, as-cast AA8176 material. A significant factor contributing to this heightened hardness in the AA8176, and 10% nano graphene composite is the use of stir casting in conjunction with the groundbreaking encapsulation method. Given this substantial improvement in hardness, the reinforced AA8176 with 10% nano graphene offers promising potential for crafting cable wires capable of enduring increased wear and stress.

Acknowledgements

None.

Conflict of Interest

None.

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