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Correlating the Compressive Strength of Novel AA7075/TiO_2 Nanocomposite with Monolithic Recycled AA7075 Alloy

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Abstract

This project aims to compare the compression strength of the recycled AA7075 alloy metal matrix composite with and without reinforcing novel titanium dioxide (TiO_2). Recycled AA7075 alloys constituted the matrix, whereas novel TiO_2 with particle sizes less than 50 nm was used as reinforcement. It was squeeze cast at 720 °C and 500 rpm to provide homogeneous reinforcement distribution in matrix materials. There are two types of recycled AA7075 alloy nanocomposite (Experiment 1 and control group 1). With the aid of the SPSS (Statistical Package for the Social Sciences) v26 statistical analysis program, the compressive strength of the innovative silicon dioxide reinforced recycled AA7075 alloy was examined and contrasted with the material used in the control group. It was noted that $p = 0.000$ (2-tailed) was observed, which is less than ($p < 0.05$) exemplifying that there was statistically noteworthy variance between the investigational and controller group. When compared to the base alloy, the impact strength of innovative TiO_2-reinforced recycled AA7075 alloy composites was found to be 69.89% higher than that of the base alloy.

Keywords

Metal matrix composite, Recycled AA7075 alloy, Novel TiO_2, Squeeze casting, Stirring speed, Compression strength

Introduction

Metal matrix composites are modern engineering materials that have stronger strength, wear and high toughness, improved damping, and lower thermal expansion, making them perfect for applications such as transportation, cutting tools, consumer electronics, defense, space, and aircraft [1]. The distribution of ceramic particles has a significant impact on the form of these characteristics. When micro-sized ceramic reinforcement is introduced to metallic materials, a particle damage process occurs, resulting in a loss of physical attributes [2]. These composites have a higher temperature capacity, superior hardness and strength, and stronger electrical and thermal conductivities. Novel TiO_2, which is mixed up with recycled AA7075 Alloys and is used as a consumption resistance material, is used in a variety of applications, including in-vehicle enterprises and manufacturing enterprises [3]. This difficulty can be solved by incorporating nanoceramic strengthening particles into the matrix alloy. When compared to micron-sized composites, the introduction of nano-ceramic particles in the matrix alloy improves mechanical properties [4]. These nano metal matrix composites may be utilized for a variety of applications, including components for automobiles and aerospace vehicles as well as consumer goods due to their low density and improved performance. However, one of the primary challenges that must be overcome in the production of nanocomposites is the limited wettability that exists

between the immixture [5]. A limited number of micro ceramics strengthening particles, as well as a process parameter capable of reducing these effects, were employed to overcome this problem.

Over the course of the last five years, a significant amount of investigation into recycled AA7075 alloy reinforced with other components has been carried out, and this data has been analyzed. There were around 1,080 publications that were published on Google Scholar, and there were approximately 160 journals that were published on Science Direct. As a consequence of this, metal matrix composites that are based on aluminum are used in a range of industries, including the aerospace and automotive industries [6]. When contrasted with pure Al6063, metal matrix composites based on Al6063 and reinforced with Al_2O_3, SiC (Silicon carbide), and TiO_2 have been shown to have superior values for hardness, tensile strength, and yield strength. [7]. This research found that SiC particle concentration increases hardness, tensile strength, and yield strength. Microstructure and surface morphological investigations determined particle and surface distribution [8]. The SiC and TiO_2 nanoparticles were added to the final composite by a method known as squeeze casting. The weight percentages of each nanoparticle were carefully calculated. Each specimen went through both the cold mechanical treatment and the heat treatment processes. According to the findings of this research, an increase in the concentration of SiC particles leads to a rise in the hardness, tensile strength, and yield strength of the SiC particles. Examinations of the microstructure and surface morphology were carried out in order to identify the distribution of their surface and particles [9]. This study investigated the mechanical properties of hybrid aluminum-based metal matrix composites produced using the liquid metallurgy stir-casting method, including tensile strength, yield strength, percentage elongation, impact strength, and hardness [10].

Only a few studies using the bottom pouring squeeze casting process to create recycled AA7075 alloys with unique TiO_2 reinforcement have been found. There was not much comparison made between a plain aluminum alloy combination of 2 wt.% novel TiO_2 reinforced recycled AA7075 alloy using metal matrix nanocomposites. The novel TiO_2 reinforced recycled AA7075 alloy was revealed to have received less research. This investigation will look at the changes in impact in plain aluminum AA7075 composite and TiO_2 supported aluminum AA7075 alloys with a 2 wt.% TiO_2 content [11]. This research was made to be expertise in fabricating metal matrix nanocomposites, and it was characterized for functional applications.

Materials and Method

Squeeze casting created recycled AA7075 alloy nanocomposites. The matrix was sufficient aluminum alloy, and the reinforcing was a unique 50 nm TiO_2 particle size. Table 1 lists recycled AA7075 alloy chemical components.

A resistance heating furnace was preheated to 4500 °C, the required amount of AA7075 alloy was added, and the furnace was subsequently heated to 785 °C, at which point the appropriate amount of alloy was added. The stirrer was allowed to revolve at 450 rpm in order to make sure the melt was complete. Additionally, an external sprue delivered 2% nano-TiO_2 particles with 50 nm particle size into the molten metal. The stirring speed was increased to 500 rpm, and the stirring duration was maintained at 10 min, with the goal of achieving homogeneous reinforcement dispersion in the matrix alloy [12]. Before being poured into the mold, the molten slurry was brought to a temperature of 8000 °C to make the viscosity superior. To reduce the amount of porosity in the matrix material, the die was heated to 250 °C. Additionally, an external sprue delivered 2% nano-TiO_2 particles with 50 nm particle size into the molten metal.

ASTM-E9 standards were used to perform compression strength. The specimen is shaped like a cylindrical rod. By adjusting the initial setup knob, the load point was set to neutral. The dimensions of the test specimen were determined with the help of vernier calipers. The specimen was held between the crushers during testing. The load on the specimen was gradually raised until it was compressed to obtain ultimate breaking strength. Figure 1 depicts the compression strength of nano-TiO_2 reinforced aluminum alloy.

Statistical analysis

The investigation was carried out using the statistical software SPSS v26, using novel TiO_2 reinforced recycled AA7075 metal matrix composite as independent factors and compression strength as dependent factors, as well as different correlation tables and G-graphs were obtained the statistical significance between the groups was determined using an independent samples test [13].

Result and Discussion

The current study utilizes the novel TiO_2 as reinforcement and recycled AA7075 alloys as matrix materials to create aluminum composites using the squeeze casting method. Figure 1 shows the compressive strength of TiO_2 reinforced recycled

Figure 1: Aluminum nanocomposites subjected to compression strength.

AA7075 alloys nano composites. Figure 2 shows the SPSS tool comparing recycled AA7075 alloy and 2 wt.% TiO_2 enhanced aluminum nanocomposites.

The chemical configuration of recycled AA7075 alloy is inferred in table 1. The comparison of compression strength of recycled AA7075 alloy and 2 wt.% of TiO_2 reinforced aluminum nanocomposites is listed in table 2. Table 3 shows the average of the values. The mean and standard deviation are shown in table 4, and table 5 shows the results of the independent sample test.

Nano-TiO_2 strengthening particles were found throughout the matrix alloy without residual pores. The intermixture's matrix-reinforcement load distribution increases impact strength [14]. Nano-TiO_2 lowers dislocation motion in aluminum matrix alloys due to grain refining. The Orowan mechanism inhibits dislocation mobility in nano-TiO_2 containing aluminum matrix alloys due to grain refining. Compression casting was used to make aluminum composites, which lowers porosity and refines grain [15, 16].

The limitation of present research constraint is that it is difficult to achieve homogeneity with squeeze casting method

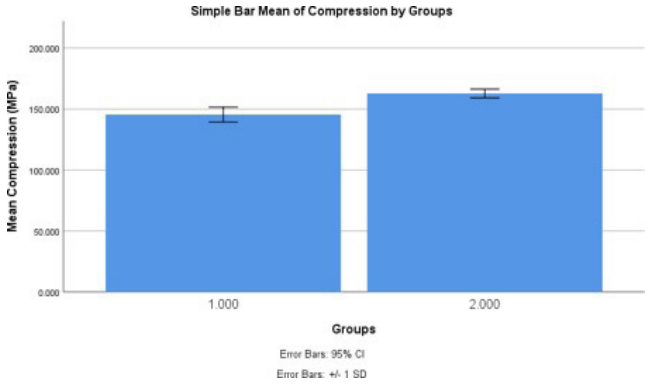

Figure 2: The graph was formed with the help of the SPSS tool for the comparison of recycled AA7075 alloy and 2 wt.% TiO_2 enhanced aluminum nanocomposites.

Table 1: Chemical composition of recycled AA7075 alloy [1].

Element	Concentration (Wt.%)
Al	Remaining
Mg	0.72 - 1.32
Si	0.34 - 0.24
Fe	0.03 - 0.07
Cu	0.023 - 0.34
Cr	0.03 - 0.31
Zn	0.01 - 0.21
Ti	0.0 - 0.12
Mn	0.0 - 0.12

Table 2: Compression strength (MPa) of recycled AA7075 and AA7075 + 2 wt.% TiO_2.

Specimens	Recycled AA7075 alloy	Recycled AA7075 + 2 wt.% TiO_2 composite
1	138.628	158.387
2	141.965	159.532
3	143.159	160.381
4	139.739	162.822
5	144.227	158.715
6	146.209	165.925
7	138.723	159.559
8	142.479	164.203
9	148.734	167.476
10	145.073	161.844
11	139.916	158.299
12	145.864	165.687
13	140.621	168.876
14	138.827	159.472
15	147.27	163.836
16	148.396	167.837
17	142.938	161.017
18	143.527	159.739
19	141.474	162.638
20	143.051	168.66

Table 3: Average compressive strength of recycled AA7075 alloy and 2 wt.% of TiO_2 reinforced aluminum nanocomposites.

S. No.	Combinations	Average compressive strength (MPa)
1	Recycled AA7075 alloy	4.53
2	Recycled AA7075 alloy + 2 wt.% of TiO_2	5.98

Table 4: Group statistics for compressive strength of recycled AA7075 alloy and 2 wt.% of TiO_2 reinforced aluminum nanocomposites.

	Groups	N	Mean	Std. deviation	Std. error mean
Compression strength	1	20	145.4410	6.068575	1.356975
	2	20	162.7452	3.609907	0.807200

Table 5: Independent sample test for compressive strength of recycled AA7075 alloy and 3 wt.% of TiO_2 reinforced aluminum nanocomposites.

		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
Compressive strength	Equal variance assumed	7.581	0.001	-10.9	38	0.00	-17.304	1.578	-20.50	-14.10
	Equal variance not assumed			-10.960	30.95	0.00	-17.304	1.578	-20.524	-14.083

of novel TiO_2 reinforced aluminum 6061 alloy. Additionally, wetting characteristics of such intermixture needs to be analyzed at high temperature by varying different weight proportions and its physical properties needs to be analyzed is considered to be future scope of present investigations.

Conclusion

This experiment evaluated the compression strength behavior of a recycled AA7075 mix that had been treated with TiO_2 to that of the basic alloy material. Compression strength was found to be 68.89% higher in the innovative TiO_2 reinforced recycled AA7075 composite compared to the unreinforced recycled AA7075 alloy. This idea has considerable promise for the development of cutting-edge improvements in automotive bodywork and other aluminum-based materials.

Acknowledgements

None.

Conflict of Interest

None.

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