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Experimental Investigation of Abrasive Water Jet Drilling Process on Al6063/5% SiC/5% Al_2O_3 Novel Hybrid Composites in Comparison with Al6063 Alloy on Circularity Error

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Abstract

This study compares the circularity error of aluminum alloy 6063 (Al6063) metal matrix composites (MMCs) that have new silicon carbide (SiC) and aluminum oxide (Al_2O_3) reinforcing materials. The SiC and Al_2O_3 reinforcement for the hybrid MMC was created by stir casting at 720 °C and 500 revolutions per min to achieve uniform reinforcement distribution in the Al6063 matrix materials. There are two groups (experimental 1 and control group 2). Each group had 20 typically consisting of reinforcement and matrix materials. Al6063 was employed as the matrix substance. In this investigation, reinforcement materials including SiC, Al_2O_3 using stir casting AWJD. The statistical analysis was carried out using the statistical software SPSS, employing experimental specimens. The sample size is determined using p = 0.025 per set, and the overall sample size is 40. The G - power for this approach is 80%. The Al6063 alloy has a higher circularity than the Al6063/5% SiC/5% Al_2O_3 composite, which also contains 5% volume-fractions of novel SiC and Al_2O_3.The difference between Al6063 alloy and Al6063/5% SiC/5% Al_2O_3 is statistically significant. With a p value of 0.000 ($p < 0.05$), these findings demonstrated a statistically significant difference between the two groups. Statistics show that the observations on Al6063/5% SiC/5% Al_2O_3 are substantial. Within the constraints of this investigation, Al6063/5% SiC/5% Al_2O_3 has a lower circularity and appears to be much higher than Al6063 alone.

Keywords

Circularity, AWJD, Al6063, Aluminum oxide, Novel silicon carbide, Aluminum alloy, Hybrid composites, Sustainable production

Introduction

In this scenario, Al6063, SiC, and Al_2O_3 components are mixed to make a composite material using the stir casting process [1, 2]. The current study focuses on the testing and investigation of the behavior of composite materials. MMCs based on Al6063 use novel SiC and Al_2O_3 as reinforcement [3, 4]. Al_2O_3 is extensively used in a range of engineering sectors and industries due to their low density, outstanding specific mechanical properties, and low weight [5, 6]. We should try to improve aluminum's weak toughness and hardness by mixing it with another material, sustainable production, because these properties are weak in aluminum. This will offer innovative aluminum alloy with desirable properties to obtain a sustainable product [7, 8].

For that, we conducted an experiment blending Al_2O_3 as the base material and SiC as the reinforcement material [9]. SiC was chosen due to its high strength, good hardness, and high melting point. The right mixing of the materials is a crucial component because if the materials are not mixed properly, they won't have the desired qualities. Stir casting machining is used to help mix the materials properly to get the sustainable product [10-12]. Aluminum composites are made in a liquid state using the stir casting technique. By mechanical churning, the particle reinforcement is often distributed throughout the Al_2O_3melt [13, 14]. When Al_2O_3 is compared to conventional materials, the materials created via the stir casting technique have exceptional mechanical qualities [15]. A composite material differs from a traditional material in terms of hardness, thermal conductivity, melting temperature, and other traits to produce a sustainable product [16, 17]. Aside from their significance to the Al_2O_3 industry and their status as the "6000 series," Al_2O_3 and its alloys have recently had a high rate of consumption compared to iron-steel products and are being used more in sectors like electrical, chemical, medicine, construction, automotive, and aviation, as well as their related subsectors. [18]. Al6063 material is utilized in the current work since it is well renowned for its excellent extrusion capabilities, strong corrosion resistance, and low processing cost [19, 20]. The hybrid substance was produced. In 2014 by Kumar and Mishra using Al_2O_3, MOS_2, and MMCs made of Al6063. The amount of MOS_2 in the material was shown to boost its hardness while lowering its ultimate tensile strength. A study on the creation of CMC material utilizing copper as a matrix form and titanium dioxide as a composite for casting reinforcement [21]. This is because one of the main components, Cu, develops a percolating network during the CMC's matrix phase [22]. The mechanical, corrosion, and wear performance of the materials was investigated in research of the various reinforcing material combinations employed in the creation of hybrid Al_2O_3 matrix composites [23].

The mechanical, corrosion, and wear performance of the materials was investigated in research of the various reinforcing material combinations employed in the creation of hybrid Al_2O_3 matrix composites [24]. The process of creating composite materials with Sic and graphite (Gr) as reinforcement components and using Al6063 as the building block [25]. As a result, the material's mechanical properties were enhanced [26]. The composite is created first, and then four distinct specimens are created. The A1 (Al6063), A2 (Al6063 + 2% SiC + 2% Gr), A3 (Al6063 + 4% SiC + 2% Gr), and A4 (Al6063 + 6% SiC + 2% Gr) are some examples of these composites. Positive outcomes from this experiment increased the material's strength in comparison to pure aluminum [27]. The stir casting process was used to produce hybrid material. Al6061/SiC/Gr hybrid materials were developed and tested, and it was found that the amount of Gr particles increased the tensile strength and compressive strength while lowering the hardness of the composite material that was generated in 2018 using the stir casting method. Aluminum and SiC are among the materials used. The experiment's findings indicate that SiC raises the aluminum alloy's hardness and ultimate tensile strength from 84 MPa to 130 MPa and 23 HV to 47 HV, respectively.

Materials and Methods

In this study, aluminum was chosen as the matrix material while SiC was used as reinforcement to create composite materials. The chemical composition of aluminum is detailed in table 1. Aluminum was used in the casting process, and the SiC mesh size was 120 m [1]. The furnace temperature was first elevated above the liquidus temperature of aluminum, which is approximately 805 ˚C, and then it was decreased to a temperature just below the liquid required to maintain the slurry in a semi-solid form in order to completely melt the aluminum alloy. Al_2O_3 was heated to 805 ˚C in a furnace during the melting process [28].

Table 1: Circularity during AWJD of Al6063/5% SiC/5% Al_2O_3 hybrid composites and Al6063 alloy.

Exp no	Al6063 alloy	Al6063/5% SiC/5% Al_2O_3 hybrid composites
1	0.335	0.335
2	0.353	0.353
3	0.336	0.336
4	0.334	0.334
5	0.322	0.322
6	0.345	0.345
7	0.317	0.317
8	0.316	0.316
9	0.336	0.336
10	0.322	0.322
11	0.314	0.314
12	0.355	0.355
13	0.304	0.304
14	0.336	0.336
15	0.317	0.317
16	0.338	0.338
17	0.367	0.367
18	0.359	0.359
19	0.363	0.363
20	0.331	0.331

Heat-treated SiC particles were added to the molten metal through a funnel at 805 ˚C after preheating for about three hours at 50 ˚C. A Gr impeller was used to create an electric resistance furnace, and it served as the stirrer. After adding SiC, the liquid metal reinforcement mixture was stirred for 10 min at 100 RPM. Automatic stirring was carried out at a 100 RPM rate using a stir casting machine [29, 30]. The material is examined for mechanical qualities after production.

In order to assess the manufactured composites' performance in terms of their microstructures, rockwell hardness, tensile strength, and impact (Izod) test results, numerous experiments were carried out. A sample that was utilized to assess the tensile qualities of composite material using UTM M/C in the workshop lab at Suresh Gyan Vihar University in Jaipur, India (Figure 1). Aluminum and SiC are heated to 805 ˚C in a furnace, thread treated, and then poured into a mold to produce the desired specimen shape. After melting the combination of Al6063 + SiC mold at 805 ˚C in Jaipur, India; a sample was taken from the workshop lab of the Uni-

Figure 1: Fabrication setup for the stir casting process.

Figure 2: Abrasive water jet drilling machining.

versity (Figure 2). In a furnace at the University's workshop lab, AA6063 melted up to 799 °C [31].

Hardness is the measure of a material's resistance to surface recognition. According to the findings of the hardness test for the fabricated composite made of Al6063 and SiC reinforcement, the hardness of AMCs is higher than that of Al6063 without reinforcement. SiC reinforced mixing improved hardness as a result of applied load transmission to the securely bonded SiC reinforcement in Al6063 matrix [5]. After conducting a Brinell hardness test, we discovered that adding SiC reinforcement enhanced the material's hardness from 25 HB to 38 HB because of the load imparted to the SiC reinforcement's tightly bonded Al6063 matrix.

The results of the tensile test of Al6063 with reinforcing material SiC of produced composite show that the tensile strength of AMCs is greater than that of unreinforced Al6063. Tensile strength is increased with SiC reinforced due to applied load transmission to the securely bonded SiC reinforcement in Al6063 matrix. We found that adding SiC reinforcement increased strength from 130 MPa to 142 MPa after performing the tensile strength test due to applied load transfer to the closely bonded SiC reinforcement in Al6063 matrix. According to the results of the impact test for the manufactured composite made of Al6063 with SiC reinforcement.

The impact strength of AMCs is greater than that of Al6063 without reinforcement. The strength with SiC reinforced mixing was improved as a result of applied load transfer to the tightly bonded SiC reinforcement in Al6063 matrix. We found that adding SiC reinforcement increased strength from 130 MPa to 138 MPa after performing an impact strength test because load transfer was delivered to the securely bonded SiC reinforcement in Al6063 matrix [32].

Statistical analysis

Software called SPSS was used for statistical analysis. Independent sample tests are computed and assessed using descriptive statistics, means plots, and group statistics in the SPSS software [33, 34]. To store graphical data, mean plots and bar graphs are examined. The independent variable in this case is Al6063 alloys are the dependent variable for the circularity for AWJD of Al6063 hybrid MMCs [16].

Results and Discussion

In this research, the investigation on the circularity of Al6063/5% SiC/5% Al_2O_3 hybrid composites and Al6063 alloy. Which provides improved performance than the base metal, for each group considered. So, our goal in research is to find the greatest circularity of drilled, which has been measured using the coordinate measuring machine and to record every reading. Additionally, using the SPSS application, discovering increases in circularity These results showed a statistically significant difference between the two groups with a p value of 0.000 ($p < 0.05$) [35]. The average, standard deviation, and 95% confidence interval for the hybrid composites constructed of Al6063, 5% SiC, and 5% Al_2O_3 are shown in table 2 and table 3. Al6063 alloy has an average material removal rate of 0.3355500.

Whereas hybrid composites made of Al6063/5% SiC/5% Al_2O_3 have a mean material removal rate of 0.15410. Standard deviations of circularity for Al6063 alloy and hybrid composites made of Al6063/5% SiC/5% Al_2O_3 are 0.017750 and 0.026606, respectively. Al6063 alloy has a minimum standard error mean of 0.003969, and Al6063/5% SiC/5% Al_2O_3 hybrid composites have a minimum standard error mean of 0.005949. Values from 20 samples are displayed in table 1.

The graph on the average circularity during AWJD of Al6063/5% SiC/5% Al_2O_3 hybrid composites and Al6063 alloy is shown in figure 3. Table 3 gives significance ($p < 0.05$) and the findings of an independent test. 20 samples of the Al6063 alloy and Al6063/5% SiC/5% Al_2O_3 hybrid composites are collected for each phase. When the circularity of

Table 2: Group statistics of the circularity during AWJD of Al6063/5% SiC/5% Al_2O_3 hybrid composites and Al6063 alloy.

Circularity	N	Mean	Std. deviation	Std. error mean
Experimental group	20	0.335	0.01775	0.00397
Control group	20	0.1541	0.02661	0.00595

Table 3: Independent samples test of the circularity during AWJD of Al6063/5% SiC/5% Al_2O_3 hybrid composites and Al6063 alloy these results showed that there was a statistically significant difference between the two groups with the p value is 0.000 ($p < 0.05$).

Circularity	F	Sig.	t	df	Significance (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
								Lower	Upper
Equal variances assumed	5.459	0.025	25.295	38	0.000	0.180900	0.007152	0.166422	0.195378
Equal variances not assumed	-	-	25.295	33.116	0.000	0.180900	0.007152	0.166352	0.195448

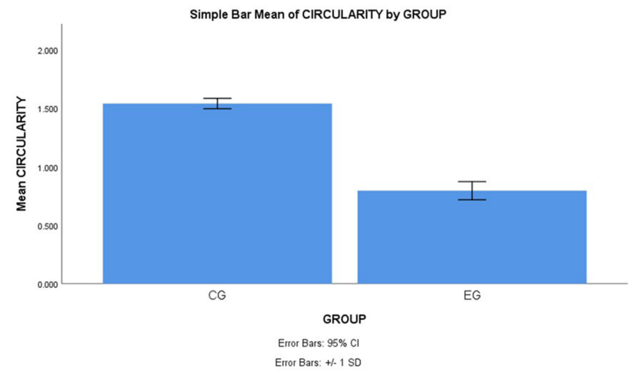

Figure 3: Graph on mean value of circularity during AWJD of Al6063/5% SiC/5% Al_2O_3 hybrid composites and Al6063 alloy.

the equal variances is taken into account, the 95% confidence interval of the difference at the lower value is 0.166422 and the upper value is 0.195378. If the equal vacancies are not assumed, the difference in the bottom and upper values in the circularity has a 95% confidence range of 0.166352 and 0.195448, respectively [36].

The optical microstructures of AMC reinforced with 5% SiC, as revealed by microstructure research, have an impact on the properties of composite materials [3]. The microstructural test revealed clustering and non-homogeneous dispersion of SiC particles in the Al matrix. The difference in contact time between the SiC particles and the molten was the cause of this [32]. Because SiC particles were added, porosities were seen in all microstructures [9]. Figure 3 illustrates the Energy Dispersive X-Ray Analysis (EDX) of point Al with (27.5) and SiC with the EDX spectrum of a SiC particle over Al particles. Figure 3 depicts the SEM test for properly mixing Al6063 with SiC. The heterogeneous microstructure of SiC is shown here. The composite material's hardness value can be seen in the microstructure of the mixed SiC. Figure 3 shows the composite material's tensile values.

Conclusion

Using the bottom stir casting technique, the Al6063 alloy and Al6063 hybrid MMCs were created. Comparing the AWJD of Al6063, 5% SiC, and 5% Al_2O_3 to the Al6063 alloy obtained the more modest circularity result. Because of the 54% increase in mechanical characteristics among hybrid MMCs.

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None.

Conflict of Interest

None.

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