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A Comparative Study of MRR Properties by HSS and Carbide Tool on Aluminum Alloy (AA6063) with SiC and TiO_2 Novel Reinforcement Using End Milling Operation

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Abstract

Aim: The objective of the investigation is to scrutinize the efficacy of high-speed steel (HSS) and carbide tools on the material removal rate (MRR) of aluminum alloy (AA6063) that has been reinforced with hybrid metal matrix composites (HMMCs) containing both silicon carbide (SiC) and titanium dioxide (TiO_2).

Methodology: The stir-casting process produced the SiC and TiO_2-reinforced metal matrix composites. Two groups were involved in the experiment (total sample size n = 40), and both experimental and control groups were carried out for 20 samples (samples were made with HSS and carbide tool, respectively).

Results: The carbide tool has attained the maximum MRR value of 1654.21 mm^3/min compared to the HSS tool. This occurred at a spindle speed of 2800 rpm, a feed of 0.02 mm/rev, and a 10% weight of SiC. Based on statistical analysis, a 2-tailed value of 0.000 satisfied ($p < 0.05$) the condition. Additionally, a statistically significant difference between the two groups was observed.

Conclusion: The mean value of the MRR from the drilled hole increased for carbide tools and decreased for HSS tools as the particle content increased. Carbide drill bits were the most effective tools tested regarding MRR.

Keywords

End milling, AA6063, Titanium dioxide, Metal matrix composites, Sustainable production, Surface roughness

Introduction

End milling is a widespread machining technique with diverse applications in major industrial sectors such as automobiles and aircraft [1]. It is a conventional approach to execute a series of time-consuming and financially demanding trial runs to ascertain the characteristics of the ultimate grinding process. An evaluation approach that can accommodate multiple responses is necessary to anticipate a workpiece's physical and mechanical characteristics. These characteristics include tool geometry, cutting rate and depth, surface finish, and MRR. Using GRA, machining variables such as cutting speed, rotation speed, tool nose radius, and percentage of coating material can be optimized for turning to reduce chip size and improve the roughness of machined surfaces [2]. The spinning activity was optimized for multiple responses using grey correlation analysis [3]. Emel conducted a study on the sustainable production of aluminum 7075, focusing on sections and sub-basis. The study involved identification and correction of surface roughness and tool wear, and force. Additionally, the analysis included investigation of tool rotation speed, and depth of cut.

Composites are superior to matrix composites, owing to their distinctive properties, including exceptional strength and remarkable abrasion resistance, toughness, resistance to corrosion, commendable thermal behavior, and a remarkable tolerance to high temperatures and creep resistance [3, 4]. Among the various composite materials accessible, aluminum and its variants are frequently used in the production of metal matrix composites and have achieved rapid industrialization. The primary objective entails the advancement of pragmatic aluminum-based metal matrix composites incorporating diverse hard and soft reinforcements, namely aluminum oxide, graphite, SiC, and mica, in the interest of realizing sustainable production. These alloys hold tremendous potential for generating exceedingly desirable composites [5]. Skolianos [6] investigated the distinct impacts of particulate SiC reinforcement in aluminum matrix, 4.5% copper, and 1.5% magnesium on the structural properties of the materials. Examined the impact of operating parameters, including feed rate, cutting speed, and depth of cut. In addition, the effect of coolant application on the MRR during spinning is investigated. The findings evince that there is a direct correlation between the augmentation of the feed rate and the escalation of the MRR. It has been found that milling the workpiece when coolant is supplied produces higher material rates than machining without coolant. The investigation of surface roughness and MRR in the context of machining operations that employ a computer numerical control (CNC) lathe was conducted [7]. The investigation utilised rotation speed, feed rate, and cut depth process variables.

The end milling technique was used in several experiments by choosing the right weighting factors to create combinations of performance-measured data for different components. The present study examines the influence of different manufacturing parameters on the mechanical properties of AA6063-SiC-TiO_2 composites. These factors included the depth of cut, rotational speed, transverse speed, and weight percentage of reinforcement. This study focuses on a statistical approach to transforming balances using the SPSS correlation matrix to achieve the appropriate result of decreased surface roughness, reduced workpiece material, lower cutting conditions, and increased MRR.

Materials and Method

The execution of end milling procedures with the aid of CNC technology was undertaken at the SIMATS School of Engineering (Chennai, Tamil Nadu, India). Stir-casting techniques were employed to fabricate the HMMCs. AA6083 was selected as the base material for the test, and SiC and TiO_2 were used as reinforcement materials. Two groups were taken with 20 samples for each group with a G-power of 80% and coincidence interval (CI) of 95% and statistical significance. The SiC particles are 63 µm in size, while aluminum particles are typically 45 µm. The addition of TiO_2 nanoparticles is thicker than SiC particles. Whereas the weight fraction of SiC changes between 5%, 10%, and 15%, the fraction of TiO_2 is fixed at 5%. The reinforcements were spread evenly by using stir casting to create multiple analyzed and evaluated with dimensions of 130 mm, 100 mm, and 50 mm. The nanocomposite was melted via an electric arc furnace and later transferred to a crucible furnace. A composite consisting of SiC and aluminum was subjected to a temperature of 900 °C, and thereafter introduced to the molten aluminum alloy at a temperature of 750 °C. A 600-rpm mixer was used to mix the base and reinforcement materials for five minutes. The stir-casting machine setup is shown in figure 1. A small amount of magnesium (1%) was added to the mixture to increase moisture content for sustainable production. It is poured into a solid metal mould to give the product the appropriate size and shape. G-power was set to 80% before testing.

The utilization of HSS drilling within as-cast HMMCs comprised of the aluminum alloy (AA6063) supplemented with SiC and TiO_2 yielded a superior outcome compared to the control group within group 1. Our present investigation was centred upon the hybrid composite plate, measuring for the dimension of 150 x 150 x 10 mm.

Group 2 is an improved experimental group made of SiC, TiO_2, and aluminaum (AA6063) strengthened HMMCs that were stir-cast using an end milling operation with a carbide tool. A rectangular die was used to create the hybrid composite plate with dimensions of 150 x 150 x 10 mm.

Machine characteristics were applied to specimens (Al6063 and 5% TiO_2 + 5% SiC, 5% TiO_2 + 10% SiC, and 5% TiO_2 + 15% SiC) with different machining parameters. The process of end milling machining operation was executed on AA6063/SiC/TiO_2 utilizing both HSS and carbide tooling for each of the 20 individual specimens. The tool inserts were located on a workpiece with the TE90AX 220-09-L code. The tooling fixture was measured to a length of 170 mm and in diameter of 20 mm. The location where the final grinding process was carried out was determined by the width of the specimen (100 mm). An increasing MRR of both tool effects was observed from the final grinding process. The mean roughness value was calculated through the computation of the arithmetic average of three distinct measurements undertaken at three pre-determined locations on the surface that had undergone end-milling. This process was repeated three to four times to ensure accuracy and reliability of the results.

Statistical analysis

The average MRR was computed by adhering to the test run. The application of SPSS statistical software facilitated the calculation of the mean value, standard deviation, and standard error. The attainment of statistical significance is deemed achievable when the p-value is less than 0.05. The dependent

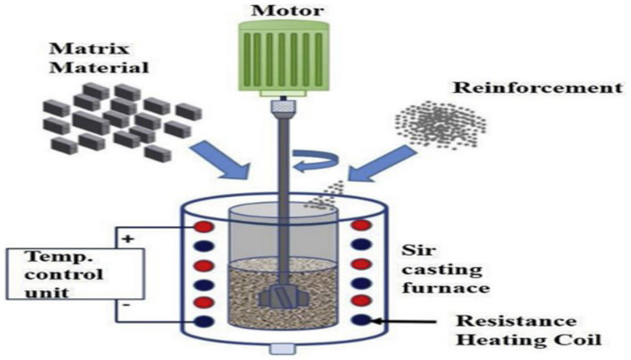

Figure 1: Schematic representation of stir casting setup used to fabricate HMMCs for plate dimensions 150 x 150 x 10 mm.

variables under scrutiny were surface roughness and MRR, while the three independent variables considered were feed, speed, and tool nose radius. In determining the significance of machining parameters on surface roughness, an independent t-test was administered to analyze the outcomes and establish statistically significant results [8].

Results

The properties of the reinforcing materials, namely AA6083, SiC, and TiO_2, are presented in table 1 and table 2. Table 3 provides a comprehensive list of the thermal and mechanical properties of SiC. Additionally, table 4 illustrates the influence of the parameters during the end milling process on the MRR of the composites. Figure 1 shows an analytical graph for the MRR during CNC end-milling of an aluminum alloy. The simulation is fixed to the piezoelectric-based KISTLER multi-component testing machine, as shown in figure 2.

The experimental design values of all proposed machining effects on MRR values are shown in table 4. The statistical data of the independent variables and the outcomes of the independent t-test are presented in table 5 and table 6, correspondingly. As result enhance the sustainable production of AA6063 reinforced with different composites for optimized machining parameters. The adequacy of the mathematical model difference between both control and experimental groups is shown in figure 3.

Table 1: Chemical composition of AA6063 alloy.

Element	%
Si	0.3 - 0.69
Fe	0.35
Cu	0.1
Mn	0.15
Mg	0.6 - 0.9
Zn	0.15
Ti	0.14
Cr	0.05
Al	Balance

Table 2: Mechanical properties of AA6063 alloy.

Mechanical properties	Value
Tensile strength	220 MPa
Elongation	5%
Proof stress	190 MPa

Table 3: Mechanical and thermal properties of SiC.

Properties	Value
Melting point	2730 °C
Thermal conductivity	120 W/m-K
Poisson's ratio	0.35
Density	3.22 g/cm^3
Modulus of elasticity	90 GPa
Yield strength	21 GPa
Tensile strength	0.1379 GPa

Discussion

According to the SPSS analysis, the influence of cutting force was considerably compared to the influence of process parameters, which was insignificant. According to the statistics, cutting speed substantially impacted the MRR compared to the feed rate's minimal impact [9]. The SPSS statistical software analysis was carried out for end milling machining operations to determine the improved properties of both HSS and carbide cutting tools. Through the implementation of statistical analysis on the outcomes of both mathematical and empirical experiments, a mathematical growth model has been formulated for the purpose of approximating the MRR.

The machining process under the spindle speed of 2800 rpm and feed rate of 0.002 'mm/rev' at 5% of TiO_2 and 10% of SiC resulted in a higher MRR value of 986.75 mm^3/min for the HSS tool. However, the carbide tool demonstrated an enhanced MRR of 1654.21 mm^3/min. While keeping the val-

Table 4: Results of MRR (mm^3/cm) for HSS (Group 1) and carbide (Group 2) tool on (AA6063/SiC/TiO_2) hybrid composites.

S. No.	HSS	Carbide
1	695.21	854.62
2	765.48	925.46
3	735.62	912.53
4	745.29	886.34
5	768.69	934.25
6	765.34	945.68
7	776.32	953.28
8	785.42	965.38
9	762.74	986.28
10	776.36	1025.32
11	835.21	1088.23
12	782.46	1023.54
13	776.52	1066.58
14	766.75	1165.28
15	749.24	1178.31
16	758.65	1154.28
17	986.75	1654.21
18	938.62	1324.85
19	954.23	1452.76
20	945.72	1356.38

Figure 2: Vertical Milling Machine for machining a slot in the aluminum composites (AA6063/SiC/TiO_2) HMMCs using HSS and carbide tool.

Table 5: Group statistics obtained for the MRR of HSS (Group 1) and carbide tool (Group 2).

	Group	N	Mean	Std. deviation	Std. error mean
MRR	HSS CG	20	803.510	82.89697	18.53633
	Carbide tool EG	20	1092.6780	211.28226	47.24415

ue of spindle speed increases at 2800 rpm, an increase in the feed rate value for the range of 0.002 mm/rev - 0.006 mm/rev increases the value of the MRR. The utmost score for MRR stands at 1654.21 mm^3/min, which is attained by utilizing a feed rate of 0.06 mm/rev. A vector parameter called the feed rate is perpendicular to the vector representing the cutting speed. A significant p-value of 0.000 ($p < 0.05$) has been obtained for the developed mathematical model of optimized machining parameters [1]. There is statistical significance between the two groups.

It indicates the relative speed at which the cutting tool moves across the workpiece. Metal removal rate increases with feed rate because of how quickly the cutting tool reaches the workpiece to remove material, and vice versa. In contrast, the longitudinal depth of the cut calculates the length where the centreline of the cutting tool meets the workpiece [10, 11]. The impact of machining operations on the rate of MRR and the surface area of machined aluminum alloy was examined [11].

Conclusion

The outcomes of the independent t-test also demonstrate that the process variables exert a statistically significant influence on the MRR of AA6063 aluminum alloys. The spindle speed of 2800 rpm, feed rate of 0.004 mm/rev, depth of cut of 2 mm, in addition to 5% of TiO_2 and 10% of SiC reinforcement, produced the highest MRR of 1654.21 mm^3/min. By improving the importance of the experimental groups, the mathematical model attained a p-value of 0.000 ($p < 0.05$), rendering both groups significant.

Acknowledgements

None.

Conflict of Interest

None.

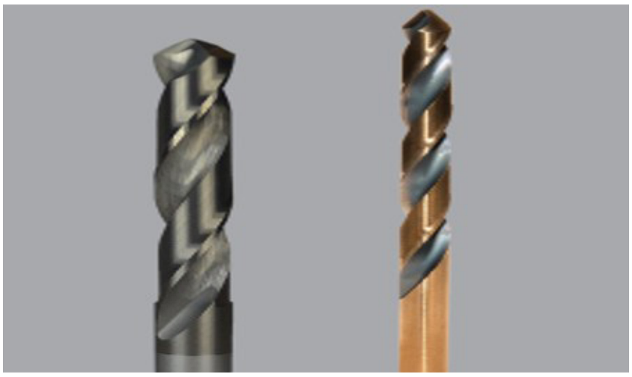

Figure 3: Schematic representation of HSS and carbide tool for evaluating MRR.

References

1. Abdulridha HH. 2020. Prediction of surface roughness of mild steel alloy in CNC milling process using ANN and GA technique. *Eng Technol J* 38: 1842-1851. https://doi.org/10.30684/etj.v38i12A.1579
2. Abhang LB, Hameedullah M. 2012. Determination of optimum parameters for multi-performance characteristics in turning by using grey relational analysis. *Int J Adv Manuf Technol* 63: 13-24. https://doi.org/10.1007/s00170-011-3857-6
3. Kibria G, Doloi B, Bhattacharyya B. 2013. Experimental investigation and multi-objective optimization of Nd:YAG laser micro-turning process of alumina ceramic using orthogonal array and grey relational analysis. *Opt Laser Technol* 48: 16-27. https://doi.org/10.1016/j.optlastec.2012.09.036
4. Rotariu T, Pulpea BG, Dîrloman FM, Diacon A, Rusen E, et al. 2022. The influence of potassium salts phase stabilizers and binder matrix on the properties of novel composite rocket propellants based on ammonium nitrate. *Materials* 15(24): 8960. https://doi.org/10.3390/ma15248960
5. Sasimurugan T, Palanikumar K. 2011. Experimental studies on machining characteristics of hybrid aluminium metal matrix composite and carbon nano tubes added hybrid aluminium metal matrix composite. In International Conference on Nanoscience, Engineering and Technology, Chennai, Tamil Nadu, India.
6. Skolianos S. 1996. Mechanical behavior of cast SiC_p-reinforced Al-4.5% Cu-1.5% Mg alloy. *Mater Sci Eng A* 210(1-2): 76-82. https://doi.org/10.1016/0921-5093(95)10043-1
7. Ravi P, Ankit K, Jitendra KV. 2016. Analysis and optimization of surface roughness in turning operation of mild steel using Taguchi method. *Int J Eng Trends Technol* 34(7): 337-341. https://doi.org/10.14445/22315381/IJETT-V34P267
8. Seçgin Ö, Sogut MZ. 2021. Surface roughness optimization in milling operation for aluminum alloy (Al 6061-T6) in aviation manufacturing elements. *Aircraft Eng Aerospace Technol* 93(8): 1367-1374. https://doi.org/10.1108/AEAT-05-2021-0146

Table 6: Levene's test for equality of variance and independent sample test statistics obtained for the MRR of HSS (Group 1) and carbide (Group 2).

MRR	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 variance assumed	10.441	0.003	-5.697	38	0.000	-289.417	50.750	-391.8858	-186.40
Equal variance not assumed	-	-	-5.697	24.714	0.000	-289.417	50.750	-393.73075	-184.56

9. Urbicain G. 2019. Machining—Recent Advances, Applications and Challenges. MDPI Publishing.

10. Singari RM, Mathiyazhagan K, Kumar H. 2021. Advances in Manufacturing and Industrial Engineering: Select Proceedings of ICAPIE 2019. Springer.

11. Krishnan BR, Ramesh M. 2020. Optimization of machining process parameters in CNC turning process of IS2062 E250 steel using coated carbide cutting tool. *Mater Today Proc* 21: 346-350. https://doi.org/10.1016/j.matpr.2019.05.460