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TAGUCHI METHOD PARAMETRIC OPTIMIZATION OF SURFACE ROUGHNESS AND MRR ON HPMMC IN CNC TURNING PHASE

S.N. Baba, Akbar. B.S.*
Department of Mechanical Engineering, Madanapalle Institute of Technology and Science, India
*Email: AkbarBS21@hotmail.com

Abstract

In the machining phase, graphite in ceramic reinforced aluminum metal matrix composites improves machining efficiency. As a result of the forming of the tribological sheet, standard machining performance may increase. They need the most precise machining operations in the manufacturing fields, which result in the production of high-quality goods under ideal conditions. Composites' uses in engineering are increasingly expanding due to their unique properties, and these composites need the most detailed machining operations due to their manufacturing costs and applications. The fabrication of the hybrid particulate aluminum metal matrix composite (HPMC) in the sand casting method, as well as the findings of an experimental analysis on the Machinability properties of hybrid particulate aluminum metal matrix composite (HPMC), are presented in this article (Al-SiCp-Gr). The impact of strengthened silicon carbide and graphite particle ratios of 10 and 15 weight percentages was investigated. On the resulting surface roughness and material removal rate of workpieces, control factors of the turning process such as speed, feed rate, and depth of cut were investigated. Using the Taguchi, ANOVA, and S/N ratio techniques, the performance values were evaluated and optimized. It was discovered that increasing graphite strengthening and adding SCP to the mix improved the MRR while maintaining a strong surface finish. The pace and feed speeds of the cutting method are primarily responsible for surface roughness. The pace and DOC of the cutting operation have a significant impact on the MRR.

Keywords: Fabrication, optimization, sand casting process, turning, surface roughness

1 Introduction

Aluminum Metal Matrix Composites (AMCs) are becoming increasingly popular due to their excellent machinability and strength-to-weight ratio, especially in automotive and aerospace applications (Koli, Agnihotri, & Purohit, 2015; Suryanarayanan, Praveen, & Raghuraman, 2013). As ceramic reinforcements (B_4C, Al_2O_3, or SiCp) are added to AMCs, both wear resistance and mechanical strength increase. Particulate Metal Matrix Composites are the name for this kind of AMC (PMCs). However, owing to the nature of ceramic elements, they have low machinability characteristics. For the machining of PMCs, high-strength cutting tools such as High Carbon Steels (HCS tools) or Polycrystalline Diamond Coated tools (PCD tools) were needed, as well as specific machining requirements. Jinfeng Leng et al. proposed in 2008 that the machinability of PMCs containing Graphite and a mixture of hard ceramic particles be investigated.

Since graphite is used as a strong lubricant during machining processes due to its tribological properties, the inclusion of soft materials like graphite in the compound of PMMCs decreases cutting powers. It avoids further power usage and high tool wear rates during Al-Gr composites machining by discontinuing chips. Graphite acts like a chip cutter in this situation. Omrani, Moghadam, Menezes, and Rohatgi (2016) stated that Al-Gr Composites have features like low wear rate, low friction, and also prevents seizing for the period of inadequate liquid lubrication condition by this lifetime is increased, and reduces. The weight or volume percentage of reinforcements such as Graphite and Ceramics such as SiCp, Al_2O_3, or B4C in AMCs is restricted to a certain range above which introducing Graphite or Ceramics to AMCs is not useful.

Selvakumar and Narayanasamy (2016) researched hybrid composites and their tribological properties in 2010, comparing single element reinforced composites to composites with several reinforcements in their compound. Basavarajappa determined in 2007 that the Al-2219/15SiC composites subsurface were deformed up to a height of 150m underneath the machined base, but not in the case of 15SiC&3Gr/Al-2219 fusion complexes due to low friction between instrument and workpiece due to the existence of Graphite Particles. Stefano, Iuliano, and Marcelli (2001) discovered that the majority of composites are shaped, manufactured, or assembled with specific measurements, and that machining for tolerance and surface integrity control of the final shape is also needed.

The purpose of this chapter is to investigate the effect of control variables such as spindle speed, feed rate, depth of cut, and equal weight fraction of SiCp-Gr particulates on the performance characteristics of surface roughness and material removal rate (MRR) during turning of Al-SiCp-Gr hybrid particulate metal matrix composites.

2 Methodology

2.1 Material

Aluminum alloy 6061 was used as a matrix element in a variety of aerospace and automotive applications. Al-6061 alloy was used to fabricate Al-SiCp-Gr hybrid composites with a mixed reinforcement of SiCp and Graphite in the shape of particulates at 10% and 15% (Tabel 1). SiCp and graphite reinforcements had an estimated particle size of 35m and 5m, respectively.

Table 1. Al-6061's chemical composition (Christy, Murugan, & Kumar, 2010)

Element	Contribution	Units
Silicon (Si)	0.40 – 0.80	%
Ferrous (Fe)	0.70	%
Copper (Cu)	0.15 – 0.40	%
Manganese (Mn)	0.15	%
Magnesium (Mg)	0.8-1.2	%
Chromium (Cr)	0.04-0.35	%
Zinc (Zn)	0.25	%
Titanium (Ti)	0.15	%
Other (each element)	0.05 each	%
Other total	0.15 overall	%
Leftovers aluminium	95.85 – 98.56	%

2.2 Hybrid Particulate Metal Matrix Composites Fabrication

Graphite and Silicon Carbide particles were held separate and pre-heated to 900 °C for 90 minutes each. Silicon Carbide reacted with ambient oxygen during the preheating phase. It developed an oxidation coating around it, preventing the development of Al_4C_3 when mixed with Al, however the graphite can withstand temperatures up to 2350 °C. The Al-6061 was held in a graphite crucible and heated to a semisolid condition before mixing with the preheated reinforcements. The mixture was then manually mixed to create a homogeneous mixture, and the temperature of the mixture was increased to 850 °C for 30 minutes. The melt was then degassed and washed. The liquid slurry was then poured into the cavity of the sand mold and permitted to solidify.

2.3 Setup of the experiment

As measuring specimens, Al-SiCp-Gr composite rods with a diameter of 30 mm and a length of 50 mm are used, along with the Polycrystalline Diamond coated (PCD) equipment CCMT040808 cutting tool insert. Spindle speed in revolutions per minute (rpm) (A), feed rate in millimeters per revolution (mm/rev) (B), and depth of cut in millimeters (mm) (C) are considered control variables, while surface roughness and MRR are considered output responses for the turning operation. Table 2 summarizes the selected variables and their magnitudes. The surface roughness (Ra) was determined using an MITUTOYO surf tester (SJ-210 type) equipped with a 0.8 mm cutoff length and a 5 mm transverse length. The roughness of the surface Ra is the arithmetic sum of the absolute values of the roughness abnormalities' heights relative to the mean value calculated. The answers were retained in Table 3 as control variables for the turning mechanism of each specimen (‘X,' ‘Y'). MRR was determined by comparing the volume of workpieces prior to and after the test Equations 1.

$$MRR = \frac{Iv - Fv}{Mt} \tag{1}$$

Where: MRR- Material removal rate (mm^3/min); Iv-initial volume (mm^3); Fv-final volume (mm^3); Mt-machining time (min).

Table 2. Machining Parameters: Levels and Factors

No levels	Factors		
	Speed (rpm)-A	**Feed (mm/rev)-B**	**DOC (mm)-C**
1	1000	0.025	0.50
2	1500	0.050	0.75
3	2000	0.075	1.00

Table 3. Experiments with surface roughness and material removal rate (MRR) response factors and their related turning action control factors

Sample Code	Work piece X		Work piece Y	
	MRR (mm^3/min)	Surface roughness (Microns)	MRR (mm^3/min)	Surface roughness (Microns)
A1-B1-C1	874.08	0.341	640.56	0.426
A1-B2-C2	1714.92	0.425	2008.44	0.470
A1-B3-C3	1734.36	0.453	3637.2	0.438
A2-B1-C1	2707.32	0.634	1791.72	0.490
A2-B2-C2	3588.18	0.560	2395.8	0.530
A2-B3-C3	2649.18	0.512	2324.82	0.570
A3-B1-C1	2256.48	0.765	4379.16	0.20
A3-B2-C2	1762.2	0.609	2501.22	0.603
A3-B3-C3	4481.34	0.592	3411.72	0.670

3 Results and Discussions

The tests were performed using a predesigned orthogonal array (L9 Array) to determine the effect of feed, rpm, and DOC on the machining responses material removal rate (MRR) and surface roughness (Ra). The following table contains the test results for MRR and Surface Roughness. Workpiece "X" is a composite of

Al6061 and 10% (SiCp + Gr), whereas Workpiece "Y" is a composite of Al6061 and 15% (SiCp + Gr).

The Taguchi technique is a highly efficient technique that industrial engineers often use to achieve high-quality efficiency at the lowest possible cost and time (Unal & Dean, 1991). The Lattice Square model is used to organize the variables influencing the answer. This is referred to as an Orthogonal Array. The Taguchi Process's primary parameters are the formation and selection of the Orthogonal Array and Factors for performing experiments. Signal to Noise Ratio (S/N Ratio) is the statistical mechanism used in the Taguchi system for predicting the optimal factors for the valued responses. The lower the S/N Ratio, the better; the higher the S/N Ratio, the better; and the nominal the S/N Ratio, the better (Ross, 1996) are three types of S/N Ratios for evaluating the Factor's enactment.

In this work, we assume that the smaller the surface roughness, the better the sort, and that the larger the surface roughness, the better the sort for MRR answer values in the S/N Ratio procedure. The surface roughness (SR) and material removal rate (MRR) of machined products have a significant impact on the rate and expense of industrial development. The primary objective of machining operations is to optimize MRR and reduce surface roughness in order to increase efficiency and machinability by the regulation of machining variables. Low surface roughness contributes to the longevity and beauty of machined items (Motorcu, 2010). A high MRR results in increased factory efficiency over time. However, the ANOVA is used to determine the effect of the Factors on their Responses.

Similarly, the optimum degree of control factors for the maximum MRR (4481.34 mm^3/min) generated by turning on Al-6061/10 SiCp& Gr workpiece-"X" is A3B3C2 (2000 rpm, 0.075 mm/rev, 0.75 mm), and for the maximum MRR (4379.16mm^3/min) produced by turning on Al-6061/15 SiCp& Gr workpiece-"Y" is A3B1C3 (2000rpm, According to Table 3, Work piece-X has a lower Surface roughness value (0.341 microns) but a higher MRR value (4481.34 mm^3/min). The solution factor values for work piece X are greater than those for work piece Y. Finally, we determined that Al-6061/10SiCP&Gr exhibits superior machinability characteristics to Al-6061/15 SiCP&Gr. Low feed rate, depth of cut, and high speed values of the machining phase both contribute to the final object's excellent surface finish; equally, high depth of cut and speed values of machining both contribute to fast material removal rates. This research demonstrates that Industrial Engineers may use Taguchi's plan of experiments to achieve optimum shape at the lowest possible expense for the fewest possible trail runs.

4 Conclusion

We effectively prepared 10, 15% SiCp& Gr/Al-6061 Hybrid Particulate Metal Matrix Composite specimens using the sand casting method by adjusting the SiCp and Gr weight fractions evenly. Via the S/N ratio ANOVA study, Minitab17 was used to determine the effect of control factors such as rpm, feed, and depth of cut on the turning process's reaction factors such as surface roughness and material removal rate. When machining the work piece-X and work piece-Y (10, 15% SiCp& Gr/Al-6061), Speed and Feed had a greater effect on the roughness of the surface. Similarly, Depth of Cut and Speed had a greater influence on the Material Removal Rate. A1B1C1 (1000 rpm, 0.025 mm/rev, 0.50 mm) is the optimum standard of control factors for the lowest valued outcome factor surface roughness of turning on all 10% SiCp and Gr/Al-6061 workpieces.

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