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THE EFFECT OF MACHINING CONDITION ON SURFACE ROUGHNESS OF METAL MATRIX COMPOSITE (MMC) AL-SI/10% ALN IN TWIST DRILL

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ABSTRACT

The Metal Matrix composite (MMC) are widely used in various industrial sectors such as transportation, domestic equipment, aerospace, military, construction, etc. The purpose of this experiment was to demonstrate the surface roughness by drilling the aluminum silicon alloy (Al-Si) matrix composite reinforcement with 10% of aluminum nitride (AIN) with three types of twist drill cutting tools. This experiment was conducted at various tools type, spindle speed and feed rate according to Taguchi Method. This method is using a Standard Orthogonal Array L_9. The effects of tools type, spindle speed and feed rate on the surface roughness in drilling operation were evaluated using the Taguchi optimization methodology by utilizing the signal to noise (*S/N*) ratio. The parameters used in machining are the spindle speed, 1000 rpm, 1500 rpm and 2000 rpm, while for the types of tools used uncoated carbide, TiN and TiCN coated and the feed rate of this research made it 50 mm/tooth, 100 mm/tooth and 150 mm/tooth. The experiment data is collected and analyzed using Taguchi Method from MINITAB 16 software. The result is show the optimum parameters are (uncoated, 1500 rpm, 50 mm/tooth). The optimum parameter gained will help the automotive, military, aerospace industry has the competitive machining process from an economic perspective and manufacturing.

Keywords: Al-Si/10% AlN MMC; Twists Drill; Surface Roughnes; Taguchi Method

INTRODUCTION

Metal Matrix Composites (MMC) is a composite material widely used in the aerospace, automotive, electronics and medical industries. It has the outstanding properties like high strength, low weight, high modules, low ductility, high wear resistance, high thermal conductivity and low thermal expansion. These desired properties are mainly manipulated by the matrix, the reinforcement element and the interface[1].

A good surface finish is required to improve the materials properties, fatigue strength, corrosion resistance and aesthetic appeal of the product. Meanwhile, the surface roughness is affected by several factors including cutting tool geometry, cutting speed, feed rate, the microstructure of the workpiece and the rigidity of the machine tool [2]. This study has utilized the Taguchi Method in determine the optimum condition for surface roughness based on the smaller the better characteristic in machining Al-Si/10%AlN MMC.

Machining is a process that creates a part or shape with specified dimensions and its tolerance. Studies have found that surface roughness is related to the quality of products, as it allows the proper function of the product in its usage. Surface quality significantly improves fatigue strength, corrosion resistance, or creep life. Furthermore, the need for this parameter is increasing in the automotive, aerospace, die and mold manufacturing application. Surface roughness is expressed in surface roughness value. The higher the value, the poorer the surface finish and the shorter fatigue life is [3]. Therefore, the surface roughness need to be clearly stated in a design to ensure the machining process is adjusted to achieve it.

METHODOLOGY

In the AI-Si MMC, the composition of the matrix of the MMC is experimentally found to contain 11.1% Si, and 0.02% Zn apart from other traces elements. The chemical composition of this AISi alloy is shown in Table 1. The reinforcement is a particulate Aluminum Nitride with grain size ranging <10 µm and purity of <98%, which is fabricated using stir casting method. To increase the mechanical properties of this AI-SiC MMC, heat treatment was conducted. Table 2 shows the mechanical properties of the materials AISi/AIN 10wt% MMC[4].

Table 1: Chemical Composition of the Material

Elements	Fe	Si	Zn	Mg	Cu
wt %	0.42	11.1	0.02	0.01	0.02

Sn	Co	Ti	Cr	Al
0.016	0.004	0.0085	0.008	Balance

Table 2: Mechanical Properties

AlN(%)	Hardness (HB)	Tensile Stress(Mpa)	Ductility (%)
10%	56	146±8	6.2

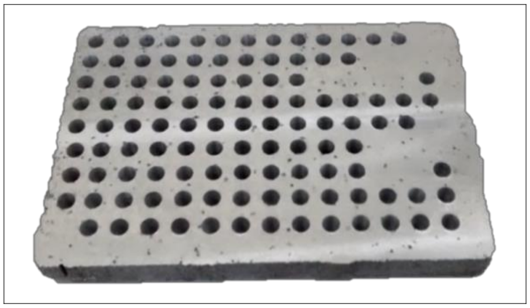

Figure: 1 Metal Matrix Composite (MMC)

This study was carried out in a CNC Milling Lagun GVC 600. The drill bits Ø6 attached with the drill holder. The machining was conducted using three different revolution per minutes (1000, 1500 and 2000 rpm) and the feed rate (50, 100, 150 mm/tooth) with the depth of cut made by through hole, and the dimension of the material Al-Si/10%AlN MMC that is 147 mm x 99 mm x 12 mm. The operation was done under dry cutting condition. The surface roughness of the machined surface was observed using the Roughness Tester Mpi Mahr Perthometer as shown in Figure 2.

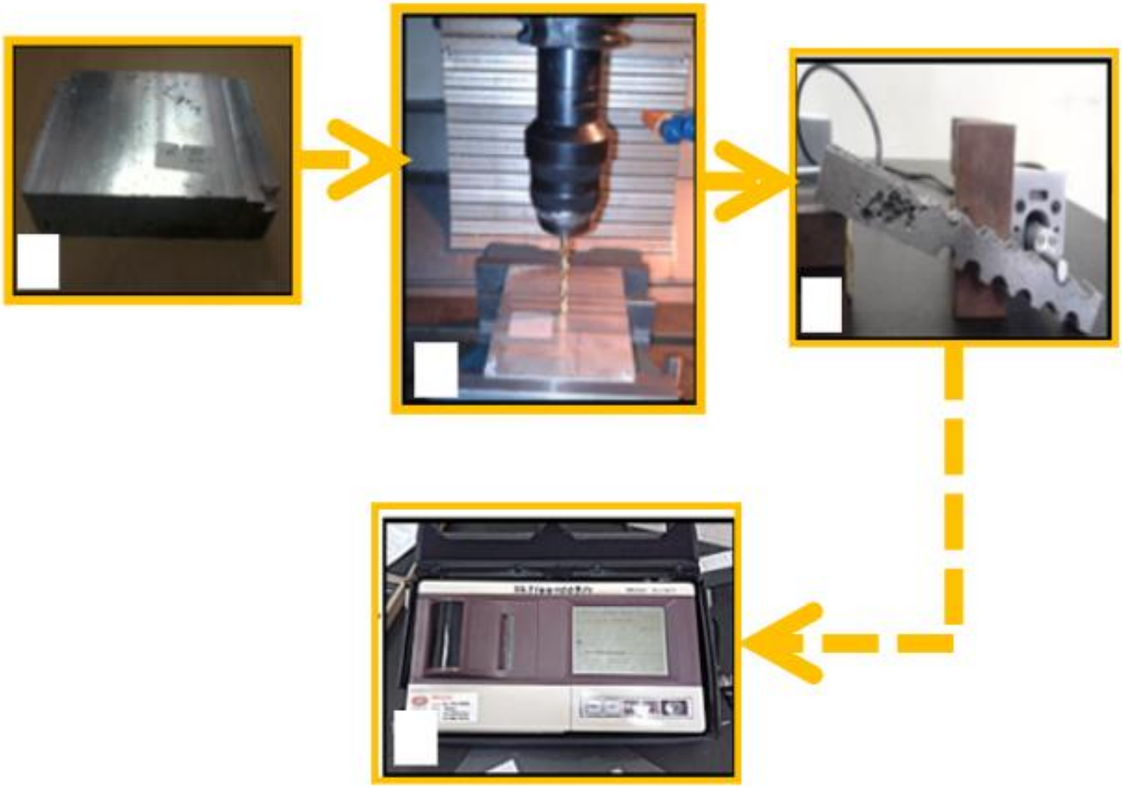

Figure 2: The Process Flow

Design of Experiment (DOE)

This experiment was handled using Taguchi Methods analysis. All parameter were collected depending on the factor, range and level. The L_9 method was used as the method in this study, thus, this experiment will be repeated nine times using the different factor, level and range. Table 3 below show the three levels of cutting speeds, feed rates and types of tool tested, whereas Table 4 below display the orthogonal array L_9 that was used for the experiments. The nine sets of settings were made to analyze the response, which is the surface roughness of the metal matrix composite (MMC).

Table 3: Factor and Level Used In the Experiment

Factor / Level	0	1	2
A – speed (rpm)	1000	1500	2000
B – feed (mm/tooth)	50	100	150
C – depth of cut (mm)	thru hole	thru hole	thru hole
D- types of tool	Uncoated	TiN	TiCN

Table 4: Orthogonal array L_9 Taguchi analysis

Experiment Number	Type of tools	Spindle speed *(rpm)*	Feed rate *(mm/tooth)*
1	uncoated	1000	50
2	uncoated	1500	100
3	uncoated	2000	150
4	TiN	1000	100
5	TiN	1500	150
6	TiN	2000	50
7	TiCN	1000	150
8	TiCN	1500	50
9	TiCN	2000	100

RESULT AND DISCUSSION

Table 5 demonstrate the result for surface roughness of drilling machining for the uncoated, TiN and TiCN coated drill bit with the difference spindle speed and feed rate. The coated tool normally produces better surface roughness (*Ra*), because the coating material used will act as a dry lubrication. Similar result was also found by previous research [3].

Table 5: Result of Surface Roughness

No	Spindle Speed *(RPM)*	Feed Rate *fr (mm/tooth)*	Tool Type	Surface Roughness *Ra*, *(μm)*	*S/N*
1	1000	50	Uncoated	0.67	3.60912
2	1500	100	Uncoated	0.89	1.0122
3	2000	150	Uncoated	1.74	-4.91025
4	1000	100	TiN	1.912	-5.6343
5	1500	150	TiN	1.628	-4.22775
6	2000	50	TiN	1.875	-5.46929
7	1000	150	TiCN	1.823	-5.23477
8	1500	50	TiCN	1.043	-0.36569
9	2000	100	TiCN	1.292	-3.88763

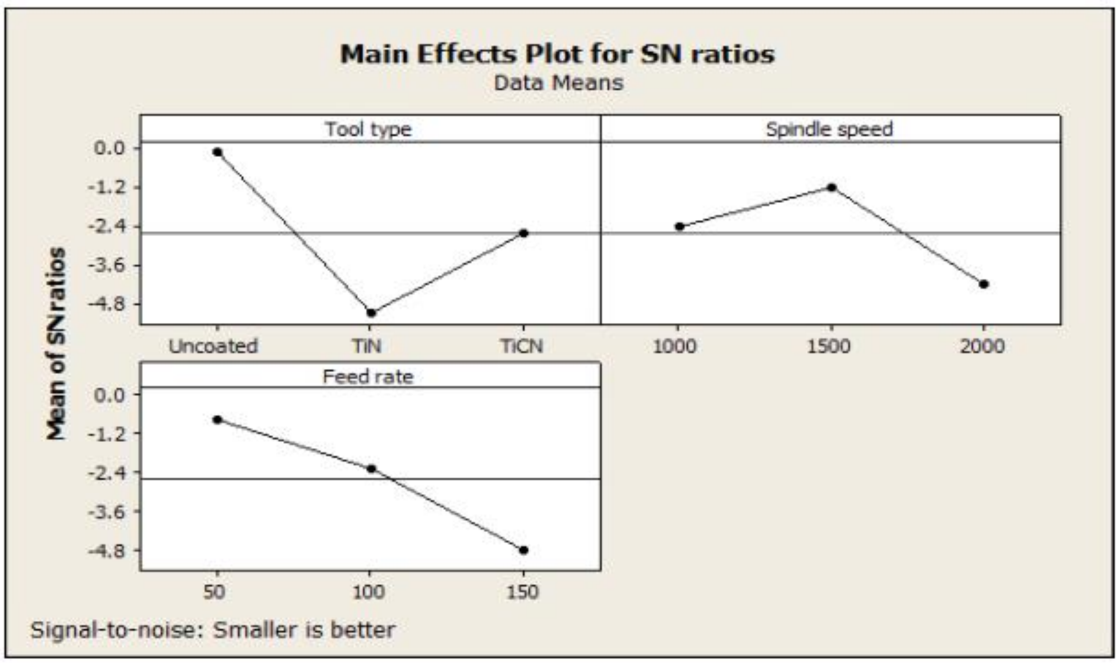

Figure 3: The Graph Shown the Main Effect Plot for S/N Ratio

The optimization process in this study uses the *S/N* ratio for the smaller the better value of surface roughness that was obtained using Minitab 16. From the slope of the graph, it can be observed that the type of tool is the most significant factor, followed by the feed rate and spindle speed. Taguchi method of experimental design has been applied in the optimization of multi response process parameter for machining Al-Si/10% AlN MMC using optimized L_9 orthogonal array. The results of this experiment were drawn based on the experiments conducted, which found that the best parameters for surface roughness are tool type: uncoated, spindle speed: 1500 rpm, feed rate: 50 mm/tooth. Uncoated carbide is the best drill bit to be used in drilling Al-Si/10%AlN MMC to get a good surface roughness as illustrated in Figure 3.

Table 7 indicates the response for S/N ratios by using the smaller is better and their ranks accordingly for the best optimization and process parameters as mentioned earlier.

Table 7: Response Table for Signal to Noise Ratios (Smaller is Better)

Level	Tool type	Spindle speed	Feed rate
1	-0.09631	-2.41998	-0.74195
2	-5.11045	-1.19375	-2.28469
3	-2.61081	-4.20384	-4.79093
Delta	5.01413	3.01009	4.04898
Rank	1	3	2

CONCLUSION

Taguchi method of experimental design has been applied in the optimization of multi response process parameter for machining Al-Si/10% AlN MMC using optimized L_9 orthogonal array. The result of this experiment were drawn based on the experiments conducted, which found that the best parameter for surface roughness are tool type: uncoated, spindle speed: 1500 rpm, feed rate: 50 mm/min. Uncoated carbide is the best drill bit to be used in drilling on Al-Si/10%AlN MMC to obtained a good surface roughness.

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