Taguchi Method Analysis of Machining Properties of Al-Slag/Flyash Hybrid Composite

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Abstract--- Metal Matrix Particulate Composites (MMPCs) have emerged as a promising material for automotive and aerospace applications. Metal Matrix Composites (MMCs) AA2024 have a wide range of applications in aerospace and automotive engineering. An attempt is made in this research work to investigate the machining qualities of the AA2024 MMCs. Slag and Fly-Ash elements were used as reinforcement during a two-stage stir casting method. The dry drilling test with the twit drill tool was investigated experimentally. The drill's optimal parameters have been determined. The thrust applied to the work piece when it was drilled was measured using a dynamometer.

Keywords--- Metal Matrix Particulate Composites, Twist Drilling, Burr Formation, Surface Roughness, Thrust

I. INTRODUCTION

Metal Matrix Composites consist of metal alloys reinforced with continuous fibers, and whiskers or particulates. The basic attributes of metals reinforced with hard ceramic particles or fibers are improved strength and stiffness, high temperature resistance, improved creep and fatigue resistance and increased hardness, wear and abrasion resistance. The aforesaid properties make the MMCs to be found wide application in many areas. Metal Matrix Composites exhibit good mechanical properties. MMCs consist of two chemically and physically distinct phases, which are distributed to provide properties not obtainable with either of the individual phases. Reinforcing material in the form of fibres, particles or flakes are used in MMCs and the constituents are combined at microscopic level, which are not soluble in each other. The matrix phase's materials are generally continuous. The matrix holds the reinforcement to form the desired shape, while the reinforcement improves the overall mechanical properties of the matrix. The new combined material exhibits better strength than each individual material. There are various types of MMCs viz. Aluminium Matrix Composites (AMCs), Magnesium Matrix Composite, Titanium Matrix Composite and Copper Matrix Composite. Aluminium Matrix Composites have fascinated more care due to their collective properties such as high specific strength, high stiffness, low thermal expansion coefficient and grander dimensional stability at higher temperatures. Burr formation is a key feature in drilling of aluminium metal matrix composites.

The effects of burr formation during the drilling process of materials are of severe apprehension, both in the performance and economic viewpoint. Burrs could lead countless glitches during accumulating and examination of precision parts. It depreciates the surface quality and the enactment of the components. Burrs would source blockage of serious channels in pneumatic, hydraulic and electronic circuits and cause serious problems during service. It can be explained that when a drill nearly touches the exit surface of the work piece, a thin layer is formed between the exit surface and the drill's cutting edge. Since this layer does not have enough rigidity to be cut by the drill, plastic deformation occurs instead of cutting operation. During the drilling of every hole, entrance and exit burrs are produced. The entrance burr can be removed easily by chamfering the hole. In contrast, the exit burr is of the foremost apprehension due to the difficulty in eliminating it if the burr is formed inside the hole. Special tools could be hired for deburring which upsurges the total production cost and time. Hence, burr minimization requires more attention.

II. RELATED WORKS

Innumerable investigators have evaluated the drilling parameters such as twist drill's geometry, feed and cutting speed on the formation of exit burrs and have planned burr formation mechanisms. Tosun Gul and Muratoglu Mehtap [1] stated that drilling of MMCs sources many difficulties to the manufacturing industry such as high drilling force, tool wear and burr. Pande and Relekar [2] examined burr formation in terms of burr height and thickness by changing the cutting speed and feed rate. Sung-Lim Ko and Jing-Koo Lee [3] have inspected the impacts of cutting constraints such as cutting velocity, feed rate and the drill's geometries on the accurateness of hole and burr formation. Gaitonde et al [4] deliberate the effect of drill's geometries and cutting parameters on burr height and burr thickness using Taguchi method. Nihat Tosun [5] engaged grey relational analysis to enhance the drilling process parameters for diminishing the surface roughness and burr height. During drilling of MMCs, the cutting tool experiences severe abrasive wear due to the occurrence of rigid earthenware particles. Coelho [6] testified that the quantity of cutting force components is extremely indispensible to investigate the machinability aspects of the composites. Literature study publicized that the burr formation can be curtailed by selecting optimal drill's geometries and cutting parameters conferring to the work piece material.

In this study, a twist drill has been engaged to diminish the burr size. Ramulu and co researchers [7] conducted drilling experimentations on Al-Al203 reinforced composites exhausting different drill materials and the unwarranted edge wear found in HSS tools [8]. Therefore, the current effort intentions to examine the outcome of process parameters such as feed, spindle speed and twist drills (HSS, carbide, coated carbide) on the exit burr formation and surface roughness in drilling of Al-Slag -Fly ash hybrid composites. To study the consequence of thrust forces on burr height, force signals from dynamometer were also investigated through the data acquisition system.

III. EXPERIMENTATION

A. Specimen Preparation

In this learning, stir casting technique has been engaged to formulate the composites. AA 2024 was cast-off as the matrix material. Slag and fly ash particles have been used as reinforcements.

B. Micro Structural Study

Optical microscopy has been employed to study the dissemination of Slag and fly ash particles in the Al matrix

Fig.1.Microstructure of AA 2024- 5wt% Slag- 5wt. % Fly ash

C. Dry Drilling Test

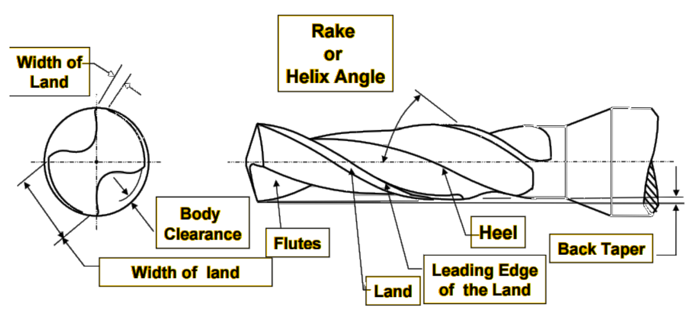


Fig.2 Schematic of twist drill

Fig. 3: Experimental Setup

Fig. 4: Twist Drill Tool

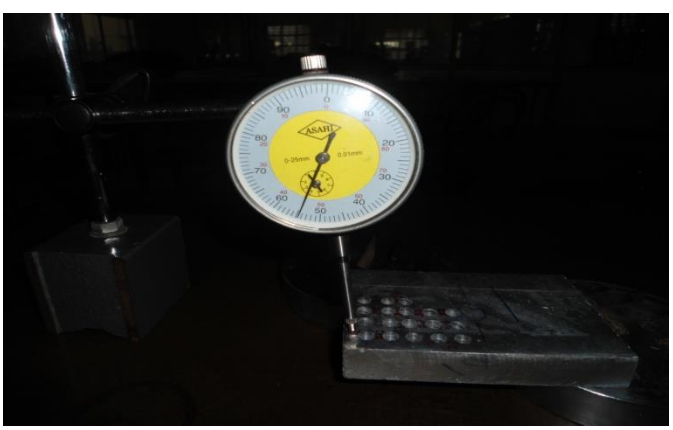


Fig . 5: Burr Height Measurement Setup

Fig. 6: Surface Roughness Tester

Drilling test has been carried out without using any lubricants on a vertical machining center which is shown in the experimental setup depicted in Fig.1. AA – Slag -fly ash composites were designated as work materials having size of 50 × 40 × 15 mm. 5.5 mm diameter twist drill (as shown in schematic Fig.2) stood engaged in the drilling process. The drilling experimentations have been done conferring to the investigational settings (Table.1). The exit burr height of each drilled hole has been measured by using a dial indicator (resolution of 0.001mm) attached to an indirect measuring height gauge and a surface plate as shown in Fig.5. The stylus was swept slowly towards the periphery of the drilled hole by moving the base of the dial indicator gauge on the surface plate. Burr height readings were taken at four positions spaced at 90° intervals around the circumference of the hole and mean value has been considered. Thrust forces have been measured with a multi-component dynamometer and force signals were processed through computerized data acquisition system. The mean surface roughness (Ra) was measured in the surface using a transverse tracing drive unit type surface roughness tester, Mitutoyo SJ -201 which is shown in Fig.6. The specifications of the instrument have been tabulated in Table 2.

Table 1: Summary of Experimental Conditions

Drill	Dia 5 mm
Drill types	HSS, carbide, coated carbide (TiN)
Twist drill's geometry parameters	Point angle 90°, 118°, 140°
Cutting parameters	Spindle speed: 600, 800, 1000 rpm Feed: 0.05, 0.075, 0.1 mm/rev

Table 2: Specifications of Surface Roughness:

Tester Nomenclature	surface roughness tester
Make	MITUTOYO
Identification No :	SF01
Serial No :	900
Model	SJ201
Measuring Range	12.5mm
Detector Range	350µm (-200µm + 150µm)

Level	Spindle speed(rpm) (A)	Feed(mm/ rev)(B)	Tool (C)
I	500	0.05	A (Coated carbide)
II	750	0.075	B (Carbide)
III	1000	0.10	C (HSS)

TABLE 3. PARAMETERS AND LEVELS

IV RESULTS AND DISCUSSION

It can be seen from the micrograph (Fig 1) that the both Slag and fly ash particles are distributed uniformly and well bonded with the aluminum matrix. The interface between the Al matrix and reinforcement particles is clean and ensures a strong interfacial bonding. No agglomeration of the reinforcement particles was observed in the composite. Taguchi's parameter design can be employed to determine the optimum parameters. which have an effect on the process and performance. It eliminates the need for repeated experiments and thus saves time, material and cost. By studying the effect of individual factors on the results, the combination of optimum parameters can be determined. In the Taguchi method, the term 'signal' expresses the desirable value (mean) and the term 'noise' expresses the undesirable value (standard deviation) for the output quality characteristics. In the present work, "Smaller is better" S/N ratio is used to predict the optimum parameters because the lower burr height and surface roughness were desirable. In the present investigation, drilling tests were conducted in the composite material as per the L27 orthogonal array. Accordingly, 27 experiment

TABLE 4 MEASURED EXIT BURR HEIGHT AND SURFACE ROUGHNESS VALUES OF AL-SLAG- FLY ASH COMPOSITES AND S/N RATIOS

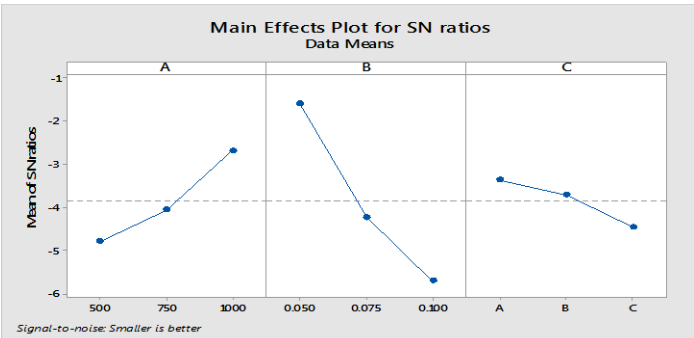
Exp. No	Factors			Signal / Noise Ratio	
	Spindle speed (m/min) (A)	**Feed (mm/rev) (B)**	**Tool (C)**	**Exit burr height**	**Surface roughness**
1	500	0.05	A	-2.00741	-9.00498
2	500	0.05	B	-2.21179	-9.48433
3	500	0.05	C	-3.86249	-10.0758
4	500	0.075	A	-4.60898	-10.1571
5	500	0.075	B	-4.86076	-10.2377
6	500	0.075	C	-5.15357	-10.3703
7	500	0.10	A	-6.14992	-10.6805
8	500	0.10	B	-6.92706	-11.1261
9	500	0.10	C	-7.30976	-11.5038
10	750	0.05	A	-1.51094	-7.99347
11	750	0.05	B	-1.86843	-8.49763
12	750	0.05	C	-2.34543	-8.94316
13	750	0.075	A	-4.95947	-9.42583
14	750	0.075	B	-4.60898	-9.74277
15	750	0.075	C	-4.65992	-9.99374
16	750	0.10	A	-5.20143	-10.1841
17	750	0.10	B	-5.43683	-10.5268
18	750	0.10	C	-5.88932	-10.8565
19	1000	0.05	A	0.00000	-8.1308
20	1000	0.05	B	-0.17200	-8.49763
21	1000	0.05	C	-0.34067	-8.78665
22	1000	0.075	A	-1.51094	-9.03573
23	1000	0.075	B	-2.34543	-9.24796
24	1000	0.075	C	-5.34343	-9.54243
25	1000	0.10	A	-4.29688	-9.686
26	1000	0.10	B	-4.91025	-10.0485
27	1000	0.10	C	-5.20143	-9.93859

Table 5. Response table for Signal to Noise Ratios (Burr height)

Level	A- Spindle Speed (m/min)	B-Feed (mm/rev)	C- Tool
1	-4.788	-1.591	-3.361
2	-4.053	-4.228	-3.705
3	-2.680	-5.703	-4.456
Delta	2.108	4.112	1.096
Rank	2	1	3

Table 6. Response table for Signal to Noise Ratios (surface roughness)

Main effects plot for SN ratios (Burr height)



Level	A- Spindle Speed (m/min)	B-Feed (mm/rev)	C- Tool
1	-10.293	-8.824	-9.367
2	-9.574	-9.750	-9.712
3	-9.213	-10.506	-10.001
Delta	1.081	1.682	0.635
Rank	2	1	3

Main effects plot for SN ratios (surface roughness)

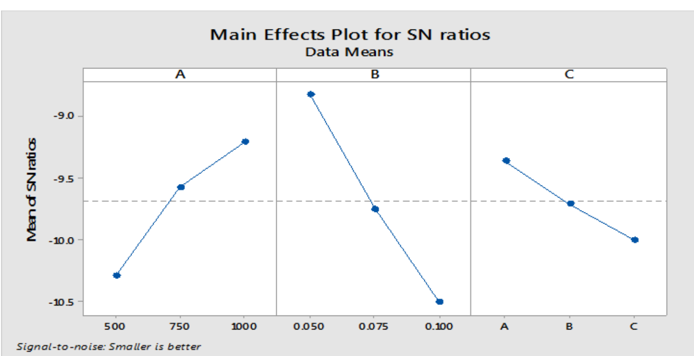


Table 4 elucidates the numerical effects of exit burr height and surface roughness by varying the drill parameters. In general, when spindle speed increases, heat generation at the cutting edge of the drill increases. It has an effect on the rate of tool wear, predominantly at the turning which is hypothetical to obligate consequence on burr formation. Coated carbide tool yields less burr height compared to HSS and carbide tools. It may be due to the reason of higher thermal stability of coated carbide tool than the HSS and carbide tools. The exit burr height enlarged considerably with increasing the feed. It was pragmatic that the flank wear improved when the feed was increased for all the tool materials. It can be accredited to the fact that the increase in temperature of the cutting zone. The minimum surface roughness can be achieved when the specimen is drilled at spindle speed of 1000 rpm, feed of 0.1 mm/rev with coated carbide tool. The upsurge in spindle speed diminishes the surface roughness in the drilling of AA 2024-Slag-fly ash hybrid composites. It can be resolved that feed and drill's material have arithmetical and physical consequence on the surface roughness of the composite materials. The effects of the drill tool material and feed are as explained below.

A. Drill's Tool Material

At all cutting conditions, coated carbide drills were thought to produce a better surface finish than carbide and HSS drills. The hardness of drills has a significant impact on composite surface roughness. This could be due to the drill's rubbing action on the surface when drilling. Coated carbide tools are stiffer and more wear resistant than carbide and HSS tools, making them ideal for drilling composite materials and cutting circumstances requiring greater feeds and speeds to reduce burr height and improve surface quality. It has been established that the cutting tool material has a significant impact on the surface roughness. Surface roughness, on the other hand, improved as the temperature increased.

B. Feed

A dynamometer (Kistler 9272 type) was used to measure the thrust force applied to the work piece during drilling. A data acquisition system was used to process the dynamometer readings. When the drill appears on the work piece's exit side, the work material beneath the drill's cutting edge becomes too weak to withstand the thrust force. As a result, slightly produced chips twist and become a burr due to plastic deformation at the work piece's bottommost surface. The thrust force signals obtained by front and step cutting edges during the drilling operation are coarsely steady before the front edge of the drill emerges the exit surface of the work piece, as shown in Fig.6.

The study found that low feed is the best parameter for minimizing exit burr height and surface roughness during composite drilling. As the feed rates increase, the thrust force rises, increasing the exit burr height and surface finish. As can be seen in the figure, increasing the feed increases the thrust force in composite drilling.

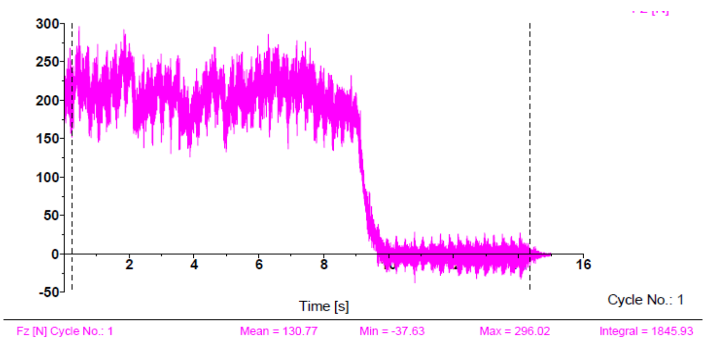


Fig. 6: Thrust– time Characteristics for Al-Slag -fly Ash Composites when Drilled at the Process Parameters (0.1mm/rev, 1000 rpm, Coated Carbide Tool)

The mean thrust force increases from 91.48 N to 130.71 N when the feed rate increases from 0.05 mm/rev to 0.1 mm/rev. When the feed rate is increased to 0.1 mm/rev, the burr height in Al – Slag – Fly Ash composite drilling increases from 2.55 mm to 3.05 mm. It may be stated that at lower feeds, the material is exposed to less thrust force, resulting in less plastic deformation and reduced burr height and surface roughness in composite material drilling. Because the interfacial bond between Al and Slag-fly ash particles is reduced, thrust force is transmitted via the drill's cutting edge, and the Al matrix tends to yield. The thrust force experienced at decreased feed was determined to be lower.

V. CONCLUSION

The two-stage stir casting method was used to cast AA2024-Slag-Fly Ash based composites. The uniform distribution of reinforcement materials in the composite was indicated by the microscopic structure. A dry drilling test was used to determine the machining properties of the fabricated MMC. Various experimental analyses have confirmed the combination of the optimum parameters. The optimum twist drill parameters were found to be 0.10mm/rev feed rate and 1000 rpm spindle speed with a coated carbide tool. As a result, it is concluded that the twist drill will minimise burr forming and surface roughness at these optimum drill parameters.

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