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MACHINING CHARACTERISTICS OF Al5052 HYBRID COMPOSITES FABRICATED BY STIR CASTING PROCESS

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Abstract: Aluminium hybrid metal matrix composites are gaining their usage in aerospace, automotive industries because of their inherent properties like high strength to weight ratio, low wear rate, etc. Aluminium 5052 metal matrix composites reinforced with Aluminium oxide (Al_2O_3) and Graphite (Gr) were fabricated by using stir casting process. Stir casting is selected because of its simplicity, flexibility, applicability to large quantity production and cost economic. The samples were fabricated by keeping the matrix and reinforcement percentages constant as Al5052 (94%), Al_2O_3 (4%) and Gr (2%). The samples were then tested for its machining characteristics. Drilling was carried out on the fabricated samples by varying the Spindle speed, feed rate and Drill bit material. Three process parameters and three levels were considered and Taguchi L9 orthogonal array design of experiment was taken. The output parameters such as Material Removal Rate (MRR) and Surface Roughness (SR) were measured for the drilled samples. The optimal process parameter of Spindle speed 1000 rpm, feed rate 150 m/min and Drill bit material HSS – TiAlN coated was obtained for maximum material removal rate of value 0.466 g/sec. The optimal process parameter of speed 3000 rpm, feed rate 150 m/min and Drill bit material HSS – TiN Coated was obtained for minimum surface roughness of value 1.182 microns.

Keywords: Stir casting, matrix, reinforcement, Material Removal Rate and Surface Roughness.

I. INTRODUCTION

Particulate reinforced aluminium metal matrix composites (PRAMMCs) are extensively used in automobile, aircraft, marine, transportation, aerospace and defence sectors because of their outstanding strength to weight ratio, good thermal conductivity and better wear resistance. It is most predominantly used in the manufacture of automotive components like connecting rods, drive shafts and cylinder liners. Aluminum reveals outstanding and incomparable exclusive properties like high strength, non-toxic, non-magnetic, non-sparking, low density, light weight and resistance to wear and corrosion. Different processing methods such as stir casting, powder metallurgy, liquid infiltration and squeeze casting, etc., have been attempted and discussed to synthesize dual particles reinforced aluminum matrix composites AMCs. Among those techniques, stir casting method have shown some incomparable advantages. It is simple, flexible, economical and suitable for near net shape component and is applicable for mass production. Liquid state stir casting has been relatively inexpensive and offers better matrix-particle bonding, due to stirring action of particles, into the melts. The stir casting method is universally used liquid state processing technique for the preparation of particulate reinforced MMC. In the recent decades, most of the researchers have focused mainly on the study of machining characteristics of dual particles reinforced hybrid composites. In this present work, an investigation has been made to investigate the machining characteristics of Al_2O_3 and graphite particles reinforcement in Al5052 alloy based MMCs fabricated by stir casting route. The machining characteristics such as drilling, the drilling operations performed on a drilling machine, which rotates and feed the drill to the work piece and creates the hole. Productivity is concerned with the material removal rate (MRR) during machining operation and quality refers to the product characteristics. So, the quality and productivity can be improved through parameters optimization. There are number of research works related to various drilling parameters optimization for achieving the performance responses. Among them surface roughness, material removal rate (MRR) and thrust forces on drill bit are the major performance responses.

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II. MATERIAL SELECTION

Aluminium is selected as the metal matrix for the composite due to its abundance, low cost and already proven track record for the similar purpose. It is relatively soft, durable, light weight, ductile, malleable metal and has high corrosion resistance, excellent heat conductivity. The selected aluminium alloy Al 5052 bears excellent characteristics for marine applications. The composition of Al 5052 is shown in the table 1.

TABLE 1 AL 5052 CHEMICAL COMPOSITION

Mg	Cr	Cu	Fe	Mn	Si	Zn	Others	Aluminium(Al)
2.20 to 2.80 %	0.14 to 0.36 %	0.05 %to 0.10	0.01 % 0.40	0.05 % to 0.10	0.1 % to 0.25	0.05 % to 0.10	0.06 % max	Balance

Aluminium oxide is taken as the reinforcement phase due to the fact that Al2O3 it has good wettability with Al, high hardness, and high temperature stability. Aluminium oxide Al2O3 in its various levels of purity is used more often than any other ceramic material.

Graphite is well known as a solid lubricant and its presence in aluminium alloy matrices makes the alloy, self-lubricating. Graphite being a solid lubricant can improve the machinability of the composites. Furthermore, graphite possesses excellent thermal and electrical conductivity thereby, can improve the conducting capability of aluminium composites.

III. EXPERIMENTAL WORK

A. Fabrication of composites

The experimental setup of stir casting essentially consists of an electric furnace and a mechanical stirrer. The stir casting machine set up at GCT, Coimbatore is shown in Figure 1.

Fig. 1 Stir casting setup

In this process, the aluminium alloy is melted using a furnace and the reinforcements are added when the melt is stirred at high speed. Subsequently, the aluminium melt is poured into a fixed die to produce the components of desirable shape and size.

B. Experimental plan

The matrix material is aluminium alloy Al 5052. Sample is to be prepared using Al 5052 reinforced with Aluminium oxide Al2O3 (4%) and Graphite (2%) by volume at melting temperature of 800°C and reinforcement pre-heat temperature as 300°C.

C. Material requirement

Diameter of die (D) = 30 mm
Length of die (L) = 250 mm

TABLE 2 MASS CALCULATION OF AL 5052, AL2O3 AND GRAPHITE

Al 5052 (gm)	444.95 (94%)
Al2O3 (gm)	27.906 (4%)
Graphite (gm)	8.004 (2%)

The Table 2 shows the mass of matrix and reinforcement required for the sample.

D. Stir casting

The aluminium alloy Al 5052 ingots were cut in power hacksaw machine to the small rods of 50 mm thickness and 25

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mm diameter to feed the materials in to the crucible. The required proportion of the rods as per experimental plan is fed into crucible and melted by heating in the induction furnace at the temperature of 800 °C for 1 to 2 hours and melt the rod above its liquidus temperature to make it in the form of semi liquid state (around 600°C).

The Al_2O_3 and graphite particles in the right proportion as per the experimental plan are preheated to a temperature of 300°C to make their surface oxidized. Preheated die is heated to a temperature of 200°C for proper solidification. During the reheat process of aluminium alloy at 850°C stirring is done by means of a mechanical stirrer as shown in figure 1 which rotates at a speed of 600 rpm. Then the reinforcement powders are added to semi liquid aluminium alloy in the furnace. Argon gas is passed in to the molten metal to remove the soluble gases present in the liquid state metal. Stirring of molten metal is carried for 3 minutes duration. The aluminium composite material reaches completely liquid state at the temperature of about 850°C and the completely melted aluminium hybrid composite is poured in to the permanent metal die and subjected to solidification to produce the required specimen. Figure 2 shows the Reinforcement preheater.

Fig. 2 Reinforcement preheater

E. Drilling process

For the drilling tests of the produced MMCs, a computer numerically controlled (CNC) vertical machining center (BMV 40 T20) with SIEMENS 802D control system having the capacity of 10 kW and 60-6000 rpm was used. The machining conditions and geometrical properties of the drills are given in table 3 and the fig. 3 shows the VMC machine.

TABLE 3 DRILLING PARAMETERS

Machine Tool	CNC Vertical Machining Center (BMV 40 T20)
Work Piece Material	Mass Fraction: 94% Al5052, 4% Al_2O_3, 2% Graphite
Cutting Parameters	Spindle Speed(n): 1000 rpm, 2000 rpm and 3000 rpm Feed Rate(*f*): 50 mm/min, 100 mm/min and 150 mm/min Drill Bit Material: HSS, HSS – TiN Coated and HSS – TiAlN coated

Fig. 3 CNC Drilling machine

Where, the figure 4(a) is the casting sample and figure 4(b) is the after drilling sample with 3 levels and 3 process parameters.

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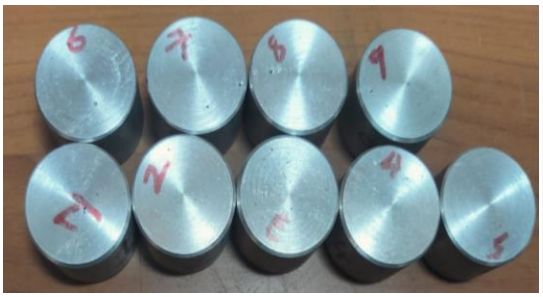

Fig. 4(a) Samples – Before Drilling

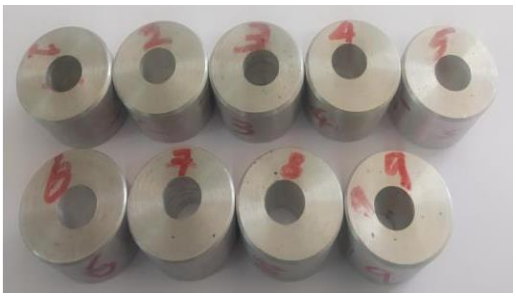

Fig. 4(b) Samples – After Drilling

IV. RESULT AND DISCUSSION

In this study drilling experiments were carried out to study the effects of the machining parameters on the Surface roughness and Material removal rate. Moreover, the optimum drilling parameters were obtained for the performance characteristics using the Taguchi analysis.

A. Calculation of Material removal rate

TABLE 4 OUTPUT PARAMETERS OBTAINESD FROM DRILLING MACHINE - MRR

S.No	Spindle Speed (RPM)	Feed Rate (m/min)	Drill Bit Material	Before Machining (g)	After Machining (g)	Time (Sec)	MRR (g/sec)
1	1000	50	HSS (-1)	32.3	26.77	29	0.191
2	1000	100	HSS - TiN Coated (0)	31.8	26.325	16	0.342
3	1000	150	HSS - TiAlN Coated (1)	32.7	27.109	12	0.466
4	2000	50	HSS - TiN Coated (0)	32.1	26.4	35	0.163
5	2000	100	HSS - TiAlN Coated (1)	32.1	26.598	18	0.306
6	2000	150	HSS (-1)	32	26.539	12.19	0.448
7	3000	50	HSS - TiAlN Coated (1)	32.3	26.718	32	0.174
8	3000	100	HSS (-1)	31.7	26.282	17	0.319
9	3000	150	HSS - TiN Coated (0)	31.9	26.6	12	0.442

The table 4 is the result of material removal rate. The Maximum material removal rate can be obtained from speed=1000rpm and Feed rate= 100 m/min. The minimum material removal rate can be obtained from speed= 2000rpm and Feed rate= 50m/min.

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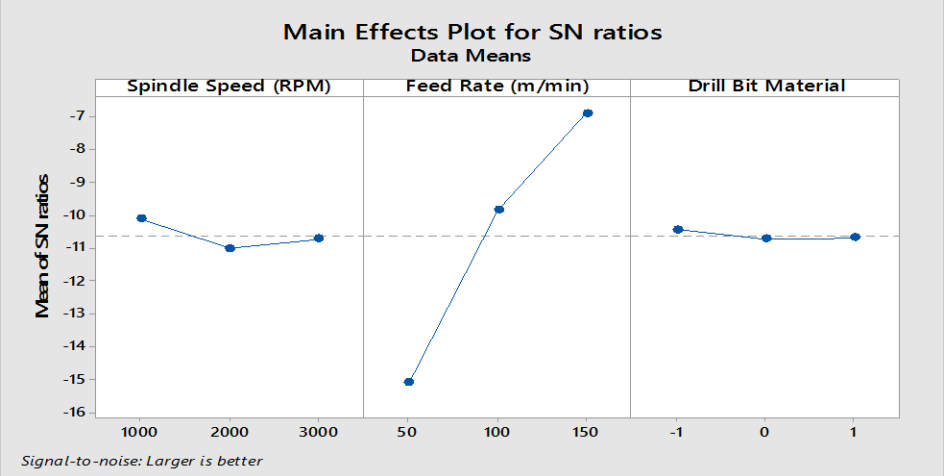

Fig. 5 Main effect plot for S/N ratios in Material removal rate

Figure 5 shows the obtained values, the comparison graphs for S/N ratios are done with the help of the MINITAB software.

B. Measurement of surface roughness

TABLE 5 MEASUREMENT OF SURFACE ROUGHNESS

S.No	Spindle Speed (RPM)	Feed Rate (m/min)	Drill Bit Material	Ra (Microns)
1	1000	50	HSS (-1)	3.272
2	1000	100	HSS - TiN Coated (0)	3.828
3	1000	150	HSS - TiAlN Coated (1)	3.148
4	2000	50	HSS - TiN Coated (0)	4.907
5	2000	100	HSS - TiAlN Coated (1)	4.309
6	2000	150	HSS (-1)	5.38
7	3000	50	HSS - TiAlN Coated (1)	4.726
8	3000	100	HSS (-1)	3.246
9	3000	150	HSS - TiN Coated (0)	1.182

The table 5 is the result of Surface Roughness. The Maximum Surface roughness can be obtained from speed=2000rpm and Feed rate= 50 m/min. The minimum Surface roughness can be obtained from speed= 1000rpm and Feed rate= 50m/min.

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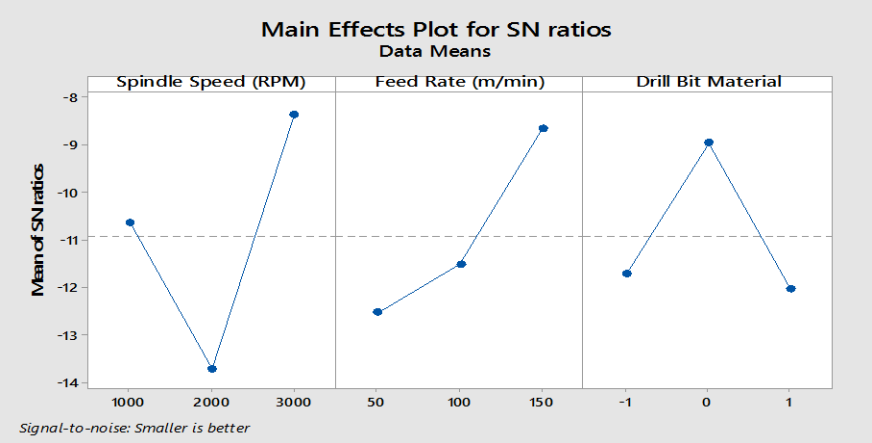

Fig. 6 Main effect plot for S/N ratios in Surface roughness

Figure 6 shows the obtained values, the comparison graphs for SN ratios is done with the help of the MINITAB software

V. CONCLUSION

The aluminium hybrid metal matrix composites were sucessfully fabricated by stir casting process and drilling of the composites were carried out and the following results were obtained:

- Maximum material removal rate of 0.466 g/sec was obtained at speed 1000 rpm, feed rate 150 m/min and HSS - TiAlN Coated (1).
- Minimum material removal rate of 0.163 g/sec was obtained at speed 2000 rpm, feed rate 50 m/min and HSS - TiN Coated (0).
- Minimum surface roughness of 1.182 microns was obtained at speed 3000 rpm, feed rate 150 m/min and HSS - TiN Coated (0).
- Maximum surface roughness of value 5.38 microns was obtained at speed 2000 rpm, feed rate 150 m/min and HSS (-1).
- The R^2 value for Material removal rate and surface roughness indicates the model is significant.
- The rank indicates feed rate is the major influencing factor in material removal rate followed by speed.
- The rank indicates speed is the major influencing factor in surface roughness followed by feed rate.
- The optimal process parameter of speed 3000 rpm, feed rate 150 m/min and Drill bit material HSS – TiN Coated (0) was obtained for minimum surface roughness of value 1.182 microns.
- The optimal process parameter of Spindle speed 1000 rpm, feed rate 150 m/min and Drill bit material HSS – TiAlN coated (+1) was obtained for maximum material removal rate of value 0.466 g/sec.
- The optimal process parameter of speed 3000 rpm, feed rate 150 m/min and Drill bit material HSS – TiN Coated (0) was obtained for minimum surface roughness of value 1.182 microns.
- The optimal process parameter of Spindle speed 1000 rpm, feed rate 150 m/min and Drill bit material HSS – TiAlN coated (+1) was obtained for maximum material removal rate of value 0.466 g/sec.

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