Machinability Investigation of Aluminium Based Hybrid Metal Matrix Composite

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ABSTRACT*:* Metal matrix composites are used mostly in aerospace, space ships, automotive, nuclear, biotechnology, electronic and sporting goods industries. Due to their high cost, experiments are usually done to reduce the cost of the composites and in expensive materials are utilized for metal matrix composites. Aluminum alloys are alloys in which aluminum is predominant metal. During stir casting, 1 Kg of Al (6351) has been taken with 50gm by wt. % of Sic and 50gm by wt. % of B_4C as Sample. Then the sample is made in the form of cylindrical rod of 10mm diameter and 30mm length. This study describes multi-factor based experiments that are applied to optimization on machinability of stir-cast aluminum alloy 6351 with Silicon Carbide and Boron Carbide reinforced metal matrix composites (MMC'S). The effects of parameters such as Cutting Speed, Feed Rate, and Depth of cut on the Power, Surface Roughness, and Material Removal Rate are analyzed using Grey relational analysis on a CNC turning machine. Analysis of variance (ANOVA) is also performed to identify which design parameters significantly affect the machinability of the composite.

KEYWORDS: Surface Roughness, Material Removal Rate, Power.

I. INTRODUCTION

A composite material is a material composed of two or more constituents. Generally a composite material is composed of reinforcements (fibers, particles/ particulates,flakes) embedded in a matrix (metals, polymers). MMC manufacturing can be in two ways: Solid,Liquid. Powder blending and consolidation: Powder metal and discontinuous reinforcements are mixed and then bonded through a process of compaction, degassing and thermo-mechanical treatment (extrusion). Liquid phase fabrication methods are moreefficient than the solid-phase fabrication methods because solid-phase processing requires a longer time. Aluminum alloys are alloys in which Al is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely cast alloys and wrought alloys. The physical properties of Aluminum alloy: Melting point, Modulus of elasticity, Poisson's ratio. The role of the reinforcement material in a composite material increases the mechanical properties of the base metal respectively. All of the different particulates or fibers used in composites have different properties and so affect the properties of the composite in different ways: High strength, Ease of fabrication and low cost. Silicon carbide (SiC), also known as carborudum, is a compound of silicon and carbon with the chemical formula SiC. The properties of silicon carbide: Melting point: 2200-2700, Hardness (Kg/mm²): 2800. Boron carbide (B_4C) is an extremely hard boron-carbon ceramic material used in tank armor, bulletproof vests and numerous industrial applications robust material having high hardness, high cross section. The following are the properties of boron carbide: Melting point: 2763˚c, Boiling point: 3500˚c, Density: 2.52 g/cm³, Poisson's ratio: 0.207

II. Problem definition

Aluminium alloys have aluminum as the predominant metal in it. The typical alloying elements are Copper, Magnesium, Silicon and Zinc. Though there are aluminum alloys with some higher tensile strength than the commonly

used type of steels, simply replacing a steel part with an aluminum alloy might lead to problems. An important structural limitation of aluminum alloys is their lower fatigue strength.

III. Methodology proposed

Metal Matrix composites have been chosen in the present study. From the series of wrought alloys, Aluminum 6351 series have been chosen in which magnesium and silicon are alloyed. The above composite material is fabricated by the stir casting technique. Then the casted material is machined as per ASTM standard. The aim of the experiment is to study about the mechanical properties of the hybrid composite and also to study the machining parameters and to plot the response graphs for the obtained values. To study the mechanical properties of the materials tests were carried down such as Micro, Tensile, Impact, and Hardness. The above mentioned tests were carried out using tensile testing machine; De-Wintor inverted Trinocular Metallurgical Microscope, Charpy test and

Brinel hardness machine. The basic concept of the work is the fabrication of hybrid metal matrix composite of Aluminium which is added with Silicon Carbide and Boron Carbide in a composition of 5% of weight of the Aluminium

N1000 G00 T0X0Z0 G90 G95 G71 M05*

N1010 T0404 M06*

N1020 S2000 M03*

N1030 G00 X32.5 Z02*

N1040 G00 X27.5*

N1050 G01 Z-35 F0.1*

N1060 G01 X 32.5*

N1070 G00 Z02*

N1080 T0X0Z0 M05*

N1090 M30

According to the result of the experiments which were carried out for the output parameters such as Material Removal Rate, Power, and Surface Roughness according to the input parameters, the response graphs were drawn. These response graphs give the relation between the input and the output parameters which were taken accordingly.

IV. Experimental procedure

Aluminum 6351 is taken as the base material. The base material is then kept in the furnace and is heated till liquidators state. Then it is melted at 750˚C temperature in the furnace. Preheating of reinforcement (Silicon Carbide and Boron Carbide) materials was done for one hour to remove moisture and gases from the surface of the particulates. The reinforcement particles were sieved by sieve shaker. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible. The stirrer consists of three blades at an angle of 120˚ apart. The speed of the stirrer is then raised gradually at a particular rpm and the preheated reinforced particles were added simultaneously. The speed controller maintained a constant speed of the stirrer, as the stirrer speed got reduced due to the increase in viscosity of the melt when the particulates were added into the melt. After the addition of reinforcement, stirring was continued for 8 to 12 minutes for proper mixing of prepared particles in the matrix. The melt was kept in the crucible for approximate half minute in static condition and then it was poured into the cylindrical mould of 30mm diameter and 180mm length. Figure 5.1 shows the aluminum metal matrix composite. The machined composite material is then used for testing the mechanical properties as follows: Microstructure, Tensile. The microstructure property is studied and analyzed by viewing the composite material through the microscope named; De-Wintor inverted Trinocular Metallurgical Microscope. The properties were analyzed and studied by viewing from this microscope. The optical scheme of metallurgical microscope is shown in the picture. The image quality and its resolving power are mainly determined by the quality of the objective. The total magnification of the microscope may be calculated by the formula: M = (L*E)/ F

Tensile testing is done practically in this machine by applying varying loads to the work piece i.e. the composite material. During tensile testing, pressure is given to pull the material on both side or ends simultaneously. The pressure generated in the material tends to elongate it, till it loses its elasticity. It can vary the load range of maximum 5 ton. At a particular range, the material loses its elasticity and yield point occurs. This test gives the strength of the composite material and also the elongation of the casted material. Once all the tests for the mechanical properties were done, the matrix is taken to study about the machinability. For this machining a L_{27} has been with the input parameters as Cutting Speed, Feed Rate and Depth of Cut and the Output parameters as Material Removal Rate, Power and Surface Roughness. The constructed L_{27} array with the consideration of the input parameters is given below. By the use of this array the turning operation has been done with the above stated Viking Program and the process is done in the EC 410 KIRLOSKAR CNC lathe. The Output parameters have been noted during the experiments. The considerations and the descriptions about the PCD insert and the power clamp that is used to analyze the power consumption during the turning process is given below.

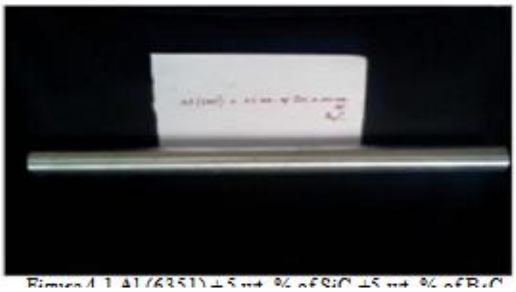

Figure 4.1 Al (6351) + 5 wt. % of SiC + 5 wt. % of B_4C

Figure 4.2 Tensile testing Machine

S. No	Parameters	Level 1	Level 2	Level 3
1	Cutting speed (rpm)	2000	2250	2500
2	Feed Rate (mm/rev)	0.1	0.2	0.3
3	Depth of Cut (mm)	0.50	0.75	1.00

Experimental Parameters	Specification
Machine	CNC turning machine (Kirloskar EC410)
Tool	Brazed PCD tool, Nose radius = 0.5mm, rake angle = 6°, front rake angle = 12°

Coolant	Dry Machining
Machining Parameters	Cutting Speed 2000,2250,2500rpm Feed Rate 0.1,0.2,0.3 mm/rev Depth of cut 0.5,0.75,1 mm
Surface Texture Equipment	Surftest 301,Make:Mitutoyo
Power Harmonic Analyzer	AC Voltage 600; AC current, 2000amps; 3ϕ/1ϕ True RMS Power Clamp

Figure 4.3 Tool Holder

Figure 4.4 Brazed PCD Figure

4.5 CNC Machine

For the tool inserted to merge with the axis of the work piece when fixed to the chuck, a tool holder was designed. During the turning process, the Power Harmonic Analyzer with the given specifications, the power and the power

factor are noted. The Power Factor is noted to check whether the Power value is correct or not. Because when the value of the Power Factor is less than 1 then the value that is noted is approximately similar to the correct value. The value for Surface Roughness is observed from the Mitutoyo Surf test 301 equipment. From this equipment the values for the Arithmetic mean roughness (R_a) and Maximum peak-to-valley height roughness (R_t). This device specializes in testing the output performance of the power cell as well as the rotational speed of the brushless motor. It can perform real time monitoring, sampling, recording and analyzing. Specifications: Working voltage: 6~60V, Testing current: 0~150A, Electric current sampling A/D dissolution: 10bit. Statistical analysis of one parameter is possible. Displays and prints frequency histograms as well as statistical calculation results (average, standard deviation, maximum value, minimum value, pass ratio).

V. RESULT AND DISCUSSIONS

The Response values that were obtained by the turning process are used to draw the Response graphs with all the considerations kept as it is.

MATERIAL REMOVAL RATE

Influence of Cutting Speed

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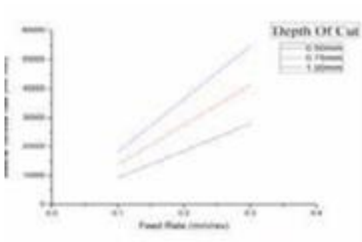


gure 5.1 Cutting Speed as 2000 rpm

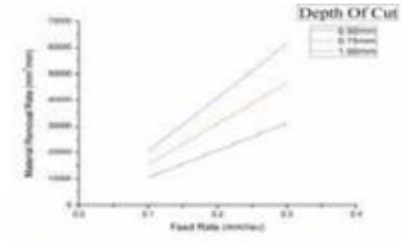


Figure 5.2 Cutting Speed as 2250 rpm

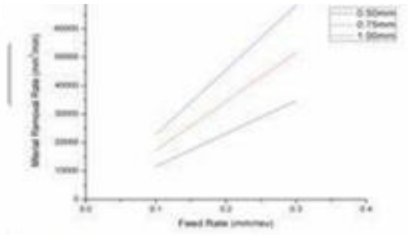


Figure 5.3 Cutting Speed as 2500 rpm

From the graphs, it is justified that when the Cutting Speed increases with increasing Feed Rate and Depth of Cut the Material Removal Tends to increase accordingly. This may be due to increased contact of the Tool insert with the Work piece.

Influence of Feed Rate

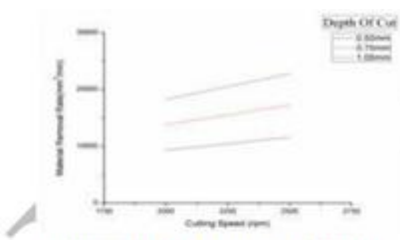


Figure 5.4 Feed Rate as 0.1mm/rev

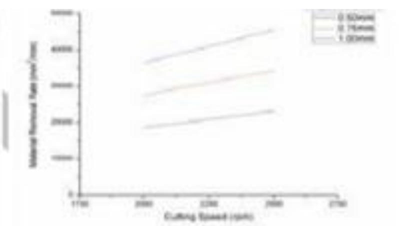


Figure 5.5 Feed Rate as 0.2 mm/rev

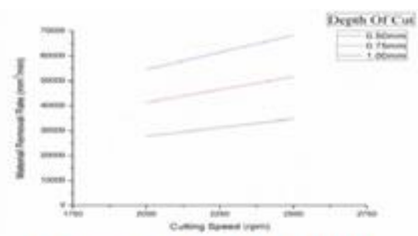
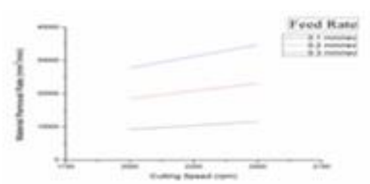
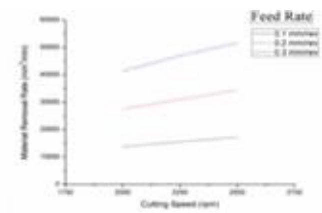
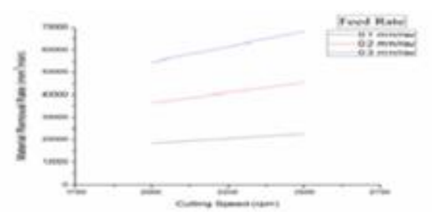


Figure 5.6 Feed Rate as 0.3 mm/rev

The increase in the Material Removal Rate in these graphs may be due to which when the Cutting Speed increases with the Feed Rate, the movement of the Tool Insert will be higher than at the normal cases.







The increase in the Material Removal Rate may also be due to the Cutting Length. Because when the Cutting Length is more the contact of the Tool insert with the Work piece increases this may increase the Material Removal Rate of the matrix. The major fact for increase in the Material Removal Rate of the matrix is due to the contact between the tool insert and the work piece.

SURFACE ROUGHNESS

Influence of Cutting Speed

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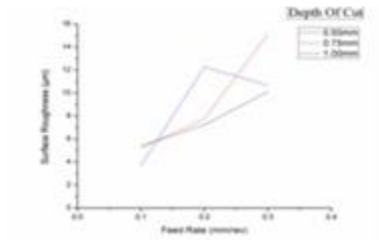
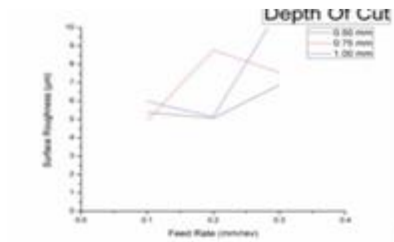
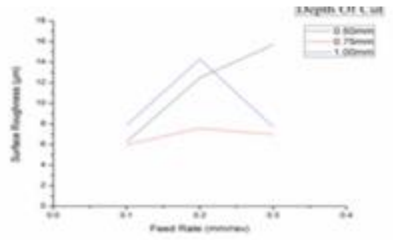





Surface Roughness may be affected largely due to the effect of Feed Rate and Depth of Cut. At the lower level of Cutting Speed, the contact between the tool and the work piece gets increases. By which the Surface Roughness may be affected. If the Depth of Cut is high with lower Cutting Speed, the Surface Roughness will decrease but when the Cutting Speed is high whatever the Feed Rate or Depth of Cut, it may not make any variation in the surface of the matrix regarding the Surface Roughness. This is why because, at higher Cutting Speed, the contact with the Tool insert to the Work piece will decrease. And also, in these criteria, the Temperature gets increased in the Shear Zone which may make the tip of the insert to blunt which may slide over the surface of the matrix with making any visible difference in the value of the Surface Roughness.

Influence of Feed Rate

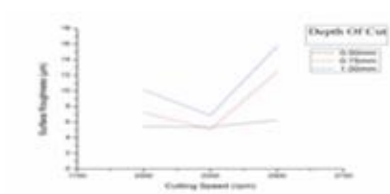
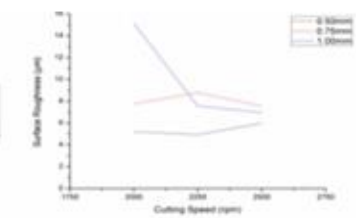
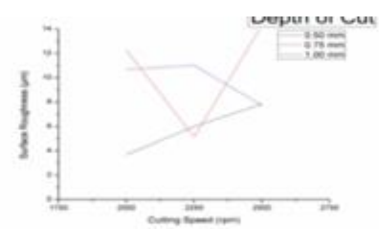
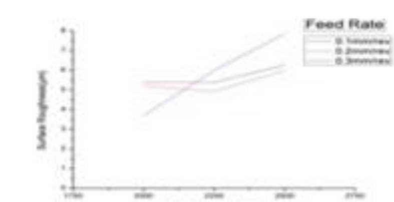
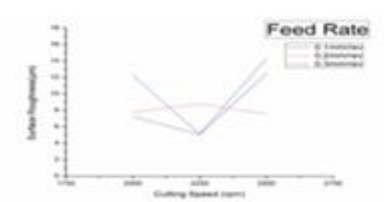




Figure 5.13 Feed Rate as 0.1 mm/rev Figure 5.14 Feed Rate as 0.2 mm/rev Figure 5.16 Feed Rate as 0.3 mm/rev

When the Depth of Cut and Cutting Speed is low, we could obtain better Surface Roughness. This is because, at these criteria, the contact between the tool and the work piece will be very good and the stress to the insert will also be less. When the Depth of Cut increases, the impression of the tip of the insert over the matrix surface will be higher.

Influence of Depth of Cut





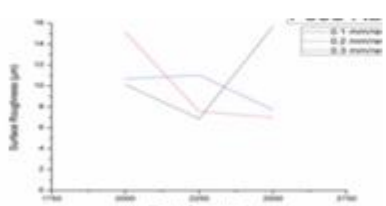


Figure 5.17 Depth of Cut as 0.5 mm Figure 5.18 Depth of Cut as 0.75mm Figure 5.19 Depth of Cut as 1 mm

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For the lowest Cutting Speed and Feed Rate better Surface Finish could be achieved. This is because, with the lower Cutting Speed, the Cutting Force will be less and the Shear angle of the tool will also be less. But when the Feed Ratevaries with the same Cutting Speed the Surface Roughness tends to decrease. This will stick to the tip of the insert. On the further travel of the insert, this may affect the Surface Finish. According to the conditions for the machining operations, when the Cutting Speed is increased by 50% the life of the tool decreases by 90% which may highly affect the Surface Roughness of the Matrix

Power

Influence of Cutting Speed

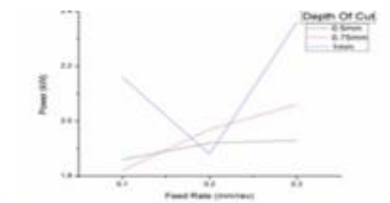


Figure 5.15 Cutting Speed as 2000 rpm

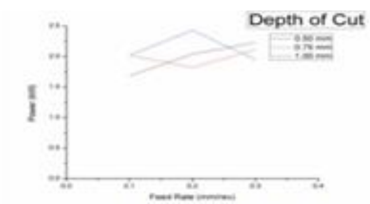


Figure 5.16 Cutting Speed as 2250 rpm

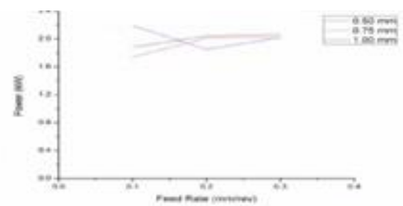


Figure 5.17 Cutting Speed as 2500 rpm

Influence of Feed Rate

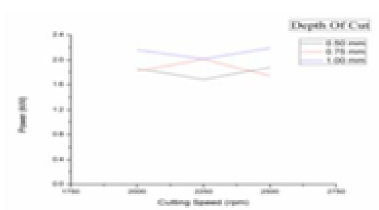


Figure 5.18 Feed Rate as 0.1 mm/rev

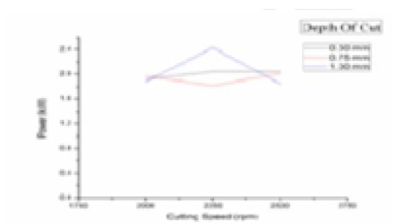


Figure 5.19 Feed Rate as 0.2 mm/rev

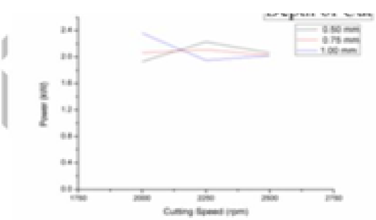
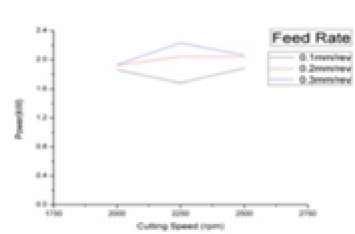


Figure 5.20 Feed Rate as 0.3 mm/rev

Influence of Depth of Cut



gure 5.21 Depth of Cut as 0.50 mm

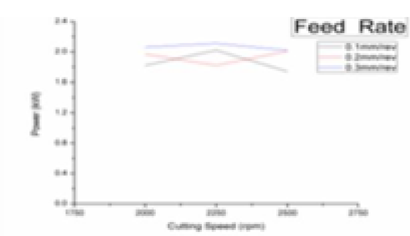


Figure 5.22 Depth of Cut as 0.75 mm

When the depth of cut is at maximum, the friction between the tool tip and the matrix surface will be higher. Because of this effect, the power will be highly consumed and also the material removal rate will also increase thus providing good quality of the matrix surface.

VI. Conclusion

Aluminum based hybrid metal matrix composite have been successfully fabricated by stir casting technique with fairly uniform distribution of Silicon Carbide and Boron Carbide. It is found that strength and hardness of the composite increases with the addition of reinforcements. The Microstructure test clearly reveals the dispersion of Silicon carbide and Boron Carbide Based on the concept of Degrees of Freedom, a L_{27} array was designed for the experiments that were conducted as turning operation in the EC 410 Kirloskar CNC lathe. The turning operation with the formed hybrid metal matrix composite gives the response values for the output parameters which could be used for plotting the response graphs. The response graphs which were plotted for Material Removal Rate, Surface Roughness and Power consumption gives the fluctuation in these parameters depending upon the change in the input parameters.

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