EXPERIMENTAL STUDY OF DRILLING PROCESSPARAMETERS ON ALUMINUMMETAL MATRIX COMPOSITES

J. Laxman[1], K. Eswaraiah[2], P.Prabhakar Rao[3]
[1,2,3]Department of mechanical Engineering, Kakatiya Institute of Technology & Science, Warangal

ABSTRACT-The growing demand for metal matrix composite material and the production of components with high dimensional accuracy lead the researchers to investigate on the metal matrix composites. In this work experimental investigation was done on Aluminum 6065 Metal Matrix Composite with 10 mm thickness using twisted carbide drill bits by conventional drilling. The Taguchi's experimental design and Analysis of Variance (ANOVA) techniques had been implemented to understand the effects, contribution, and significance of process parameters, namely, spindle speed, composition and drill diameter. The outcome can reveal that which parameter have the most significant impact on the the thrust force and torque. The objective of this workis to investigate the effect of various process parameters on machining performance. The Taguchi method is used to formulate the experimental layout, analyze the effect of input process parameters on the machining characteristics.

Key words:**Aluminum metal matrix composite,Sic,Composition, stir casting, drilling.**

1. INTROCUCTION

Aluminum alloy materials or simply composites are combinations of materials. They are made up of combining two or more materials in such a way that the resulting materials haveCertain design properties on improved properties .The Aluminum alloy composite materialsConsist of high specific strength, high specific stiffness, more thermal stability, morecorrosion and wear resistance, high fatigue life.Al-SiC, pronounced 'alsick' is a metal matrix composite consisting of aluminum matrix withsilicon carbide particles. The mechanical properties ofaluminum alloys reinforced with ceramic particulates are known to be influenced by theparticle size and the volume fraction. Arsenault, 1984 has concluded from the series ofexperiments that 0.2% proof stress and ultimate tensile strength tend to increase, andtoughness and ductility decrease with increasing volume fraction of particulate or decreasingparticle size.B.Venkatesh, B.Harish had done experiments to fabricate Al-SiC metal matrix composites by using powder metallurgy as it homogenously distributes the reinforcement in the matrix with no interfacial chemical reaction and high localized residual porosity. SiC particles containing different weight fractions (10 and 15 wt. %) and mesh size (300 and 400) is used as reinforcement. The paper presents the processing of Al/SiC by powder metallurgy method to achieve desired properties and also the results of an experimental investigation on the mechanical properties of Al/SiC are determined[1].

Hashim et al., have made the type of processing in commercial use for particulate Al basedcomposites. Casting is a probably one of the most ancient processes of manufacturingmetallic components. First melting the Aluminum metal with 0%, 10%, and 20% on mass fraction basis. Pouring it into a previously mademould or cavity which conforms to theshape of the desired component. Allowing the molten metal to cool and solidify in the mould.Removing the solidified component from the mould. The solidified piece of metal, which is taken out the mould and casted object turned by lathe machine for required shape and size[2].K Karvanis, D Fasnakis, A Maropoulos and S Papanikolaouhad conducted experiments on properties of Al-SiC metal matrix composites. Al-SiC composites of various carbide compositions were produced using a centrifugal casting machine. The mechanical properties, tensile and compression strength, hardness and drop-weight impact strength were studied in order to determine the optimum carbide % in the metal matrix composites. Scanning electron microscope was used to study the microstructure-property correlation. It was observed that the tensile and the compressive strength of the composites increased as the proportion of silicon carbide became higher in the composites. Also with increasing proportion of silicon carbide in the composite, the material became harder and appeared to have smaller values for total displacement and total energy during impact testing[3].

S. Tzamtziset. al. conducted experiments on particle distribution in the metal matrix compsites. The current processing methods often produce uneven distribution of particles in the ductile matrix and as a result these composites exhibit extremely low ductility. The key idea to solve the current problem is to adopt a novel Rheo-process allowing the application of sufficient shear stress (s) on particulate clusters embedded in liquid metal to overcome the average cohesive force or the tensile strength of the cluster. In this study, cast A356/SiCp composites were produced using a conventional stir casting technique and a novel Rheo-process. The microstructure and properties were evaluated. The adopted Rheo-process significantly improved the distribution of the reinforcement in the matrix. A good combination of improved ultimate tensile strength (UTS) and tensile elongation (e) is obtained[4].

D. P. Myriounis, S. T. Hasan and T. E. Mtikas conducted experiments on micro structure of Al-Sic metal matrix composites. They found how the various factors like heat treatment and nature of cooling effects the particle distribution. At the micro-level, the development of local concentration gradients around the reinforcement can be very different according to the nominal conditions. These concentration gradients are due to the metal matrix attempting to deform during processing. This plays a crucial role in the micro-structural events of segregation and precipitation at the matrix-reinforcement interface. The amount and width of segregation depend very much on the heat treatment temperature and the cooling rate, the concentration of solute atoms and the binding energy between solute atoms and vacancies[5]. Md. HabiburRahmana, H. M. Mamun Al Rashedb worked on Characterization of silicon carbide reinforced aluminum matrix composites. They investigated how the properties would change with increase in percentage of Sic. The results showed that introducing SiC reinforcements in Aluminum matrix increased hardness and tensile strength and 20 wt. % SiC reinforced AMC showed maximum hardness and tensile strength. Microstructural observation revealed clustering and non-homogeneous distribution of SiC particles in the Al matrix. Porosities were observed in microstructures and increased with increasing wt. % of SiC reinforcements in AMCs. Pin-on-disc wear test indicated that reinforcing Al matrix with SiC particles increased wear resistance[6].

Neelimadevi.v, Mahesh.v, Selvaraj.Nhad conducted experiments to find how the properties would change with the change in wt% of SiC. Tensile strength experiments have been conducted by varying mass fraction of SiC (5%, 10%, 15%, and 20%) with Aluminium. The maximum tensile strength has been obtained at 15% SiC ratio. Mechanical and Corrosion behavior of Aluminum Silicon Carbide alloys are also studied[7]. From the literature it is clear that cutting conditions and drill geometry have much influence on quality of hole drilled. In this investigation Al-SiC metal matrix composites are chosen by considering the most important parameters influencing the torque and thrust force are speed, drill bit size and composition of SiC. In order to reduce the number of experiments taguchi's design of experimental technique has been implemented. Results obtained were analyzed by ANOVA technique to identify the factors that are most significant in affecting the thrust force and torque.

2. METAL MATRIX COMPOSITES

Metal matrix composites (MMCs) usually consist of a low-density metal, such as aluminum or magnesium, reinforced with particulate or fibers of a ceramic material, such as silicon carbide or graphite. Compared with unreinforced metals, MMCs offer higher specific strength and stiffness, higher operating temperature, and greater wear resistance, as well as the opportunity to tailor these properties for a particular application. However, MMCs also have some disadvantages compared with metals. Chief among these are the higher cost of fabrication for high-performance MMCs, and lower ductility and toughness. Presently, MMCs tend to cluster around two extreme types. One consists of very high performance composites reinforced with expensive continuous fibers and requiring expensive processing methods. The other consists of relatively low-cost and low-performance composites reinforced with relatively inexpensive particulate or fibers.

Aluminum-matrix composites are not a single material but a family of materials whose stiffness, strength, density, and thermal and electrical properties can be tailored. The matrix alloy, the reinforcement material, the volume and shape of the reinforcement, the location of the reinforcement, and the fabrication method can all be varied to achieve required properties. Regardless of the variations, aluminum composites offer the advantage of low cost over most other MMCs. In addition, they offer excellent thermal conductivity, high shear strength, excellent abrasion resistance, high-temperature operation, nonflammability, minimal attack by fuels and solvents, and the ability to be formed and treated on conventional equipment.

Every reinforcement has a typical profile, which is significant for the effect within the composite material and the resulting profile. The group of discontinuousreinforced metals offers the best conditions for reaching developmenttargets. In the present work the Al alloy is the matrix and SiC is the reinforced material, The Al metal matrix composite was prepared using stir casting method varying percentage of SiC.

3. DESIGN OF EXPERIMENTS USING TAGUCHI METHOD

Taguchi method is a statistical method developed Initially it was developed for improving the quality of goods manufactured, later its application was expanded to many other fields in Engineering. Success in achieving the desired results involves a careful selection of process parameters and bifurcating them into control and noise factors. Selection of control factors must be made such that it nullifies the effect of noise factors. Taguchi Method involves identification of proper control factors to obtain the optimum results of the process. Orthogonal Arrays (OA) are used to conduct a set of experiments. The Full Factorial Design requires a large number of experiments to be carried out as stated above. It becomes laborious and complex, if the number of factors increase. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. The factors and their levels were decided for conducting the experiment, based on orthogonal array, experiments are conducted with their factors and their levels as mentioned in OA table. The experimental layout with the selected values of the factors is shown in Table 2 and 27 experiments were conducted to account for the variations that may occur due to the noise factors[8]. The Torque and thrust force are measured using Drill dynamometer. The table shows the measured values obtained from different experiments.

4. Properties of Aluminum (6065) alloy

The 6065 aluminum is an alloy of aluminum, further classified within the AA 6000 series (aluminum-magnesium-silicon wrought alloy). 6065 is the Aluminum Association (AA) designation for this material. The Material Properties and composition are given in below.

4.1. Properties

Density	2.8 g/cm^3 (170 lb/ft^3)
Elastic (Young's, Tensile) Modulus	71 GPa (10 x 10^6 psi)
Elongation at Break	4.6 to 12 %
Modulus of Resilience (Unit Resilience)	550 to 1020 kJ/m^3
Poisson's Ratio	0.33
Specific Heat Capacity	890 J/kg-K
Strength to Weight Ratio	110 to 150 kN-m/kg

Tensile Strength: Ultimate (UTS)	320 to 410 MPa (46 to 59 x 10^3 psi)
Tensile Strength: Yield (Proof)	280 to 380 MPa (41 to 55 x 10^3 psi)
Thermal Expansion	22 µm/m-K
Unit Rupture Work (Ultimate Resilience)	14 to 16 MJ/m^3

4.2. Composition

Aluminum (Al)	94.4 to 98.2 %
Bismuth (Bi)	0.5 to 1.5 %
Magnesium (Mg)	0.8 to 1.2 %
Silicon (Si)	0.4 to 0.8 %
Iron (Fe)	0 to 0.7 %
Copper (Cu)	0.15 to 0.4 %
Zinc (Zn)	0 to 0.25 %
Chromium (Cr)	0 to 0.15 %
Manganese (Mn)	0 to 0.15 %
Residuals0 to	0.15 %
Zirconium (Zr)	0 to 0.15 %
Titanium (Ti)	0 to 0.1 %
Lead (Pb)	0 to 0.050

5. Aluminum metal matrix composites preparation method

Aluminum metal matrix composites with SiC as reinforcement was prepared by stir casting, it is an economical process for the fabrication of aluminum matrix composites. The method used for the production of the composites was a combination of melt-stirring and compo-stirring. This combination method was used in order to obtain a better dispersion of the particles and to avoid particle agglomeration and sedimentation in the melt. The silicon carbide particles were heated to 1076^0 C for one hour and 30 minutes in order to remove the absorbed hydroxide and other gases. In addition, the moulds and the stainless steel stirrer were preheated and the aluminum matrix was melted in an electric furnace at 720^0 C. 0.8% copper was added as a wetting agent.When the slurry being in a semi-solid condition, the furnace temperature was adjusted below the melting point of the aluminum and it was stirred at 50 rpm, when the reinforcement particles were added the matrix. After the addition of the SiC particles, the mixture was completely melted (above 720^0 C). The stirring process was carried out at 150 rev/min by the stainless steel stirrer for 20 min. Then the slurry was poured in the moulds, which were on the centrifugal machine and centrifugal casting took place. The rpm of the centrifugal machine was adjusted to 280 rpm, since segregation of the particles either at the inner or the outer periphery of the casting was noticed at higher rpm. The following figures shows the stir casted materials and the process that takes place, the preparation of the Aluminum silicon carbide alloy by using mass basis ratio of 100:0, 100:10, and 100:20 are prepared.

Fig. 2 Al metal matrix composite casting

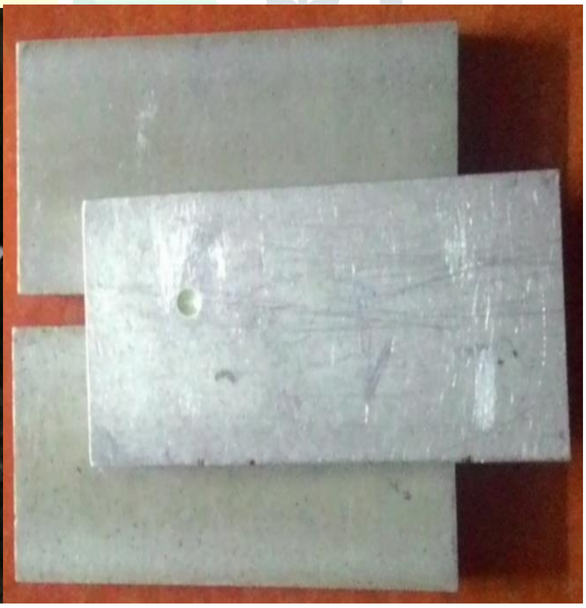

Fig. 3 Al MMC specimens

6. Experimental work

6.1. Experimental set up

Physical construction of a strain gauge type 2 – D drilling dynamometer for measuring torque and thrust force is typically shown schematically in Figure 6. Four strain gauges are mounted on the upper and lower surfaces of the two opposite ribs for PX – channel and four on the side surfaces of the other two ribs for the torque channel. Before use, the dynamometer must be calibrated to enable determination of the actual values of T and PX from the voltage values or reading taken control panel which is shown in figure 5. The drilling machine used for the experimentation is Radial drilling Machine shown in figure 4.

Fig. 4 Radial drilling Machine

Fig. 5 control panel

Fig. 6 Strain gauge type drilling dynamometer .

6.2. Machining conditions

The main machining condition are dry and cutting tool used is HSS for machining of Al-SiC metal matrix composite material work pieceswhich were stir casted. Parameters used for drilling holes are shown in table 7.

Table 7 Machining parameters and their levels

Process Parameter	Symbol	Units	Range of Parameter	Levels		
				1	2	3
Speed	N	rpm	290-890	290	580	890
Drill Diameter	D	mm	4-12	4	8	12
Composition	C	%	0-20	0	10	20

Drill dynamometer was attached to the radial drilling machine with proper care. Trail experiments were performed with a dummy work piece for checking the proper working of the machine. After testing with a dummy work piece, machining of the actual piece was done.

The experiments are conducted based on the taguchi design of experiments that is L27 orthogonal array and the experimental design is shown in table 2. During drilling process thrust force and torque readings were noted, these reading are noted when the drill bit is in the middle of the work piece using drill tool dynamometer shown in figure 6. Repeat the same procedure for all conditions.

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Fig.7Drill bits used for machining

Fig.8 Work pieces with drilled holes

Figure 7 shows the drill bits with 12mm, 8mm and 4mm diameters which were used to drill the holes on the work pieces with different conditions and the drilled work pieces are shown in figure 8, all the machining operations are carried out on the radial drilling machine.

7. Results and discussions

The experiments were conducted based on design of experiments shown in table 2. In the present study torque and trust forces were measured using Drill tool dynamometer and results are shown in table 2. The following observations are done based on the results.

1) On Thrust Force, drill diameter has more influence followed by speed and composition. For minimum thrust force to be generated and better quality of holes can be generated with the conditions of high speed(890), drill diameter of 4mm, composition of 10%.

2) On Torque, drill diameter has more influence followed by speed and composition. For minimum Torque to be generated and better quality of holes can be generated with the conditions of high speed(890), drill diameter of 8mm, composition of 10%.

Analysis of Variance (ANOVA) is a method of apportioning variability of an output to various inputs.The purpose of the analysis of variance is to investigate which machining parameters significantly affect the performance characteristics. The following tables were obtained after performing ANOVA for thrust and Torque, As shown in table N and D has significant influence on thrust and torque.

Table 2orthogonal array with levels and response results

Sl. No.	Levels of factors			Selected parameters			Response Parameters	
	N	D	C	N (rpm)	D (mm)	C (%)	Trust Kgf	Torque Kg-m
1	1	1	1	290	4	0	34.1	0.03
2	1	1	2	290	4	10	39.2	0.02
3	1	1	3	290	4	20	44.6	0.02
4	1	2	1	290	8	0	71.4	0.02
5	1	2	2	290	8	10	71.6	0.03
6	1	2	3	290	8	20	67.6	0.01
7	1	3	1	290	12	0	80.0	0.03
8	1	3	2	290	12	10	64.2	0.1
9	1	3	3	290	12	20	81.3	0.15
10	2	1	1	580	4	0	31.4	0.05
11	2	1	2	580	4	10	34.3	0.04
12	2	1	3	580	4	20	27.3	0.06
13	2	2	1	580	8	0	52.4	0.02
14	2	2	2	580	8	10	41.2	0.02
15	2	2	3	580	8	20	50.5	0.03
16	2	3	1	580	12	0	71.3	0.03
17	2	3	2	580	12	10	45.2	0.02
18	2	3	3	580	12	20	61.4	0.02
19	3	1	1	890	4	0	37.4	0.01
20	3	1	2	890	4	10	37.5	0.06
21	3	1	3	890	4	20	34.2	0.02
22	3	2	1	890	8	0	35.2	0.02
23	3	2	2	890	8	10	39.2	0.01
24	3	2	3	890	8	20	38.9	0.01
25	3	3	1	890	12	0	43.4	0.03
26	3	3	2	890	12	10	46.4	0.02
27	3	3	3	890	12	20	51.2	0.02

Table 3 Analysis of Variance For thrust

Source	DF	SS	Contribution(%)	MS	F-Value	P- Value
N	2	2159.7	32.81	1079.85	15.18	0.000
D	2	2892.5	43.94	1446.23	20.33	0.000
Comp	2	107.0	1.63	53.49	0.75	0.484
Error	20	1423.0	21.62	71.15		
Total	26	6582.1	100.00			

DF= Degrees of freedom, SS= Sum of squares, MS= Mean square

Table 4 Analysis of Variance For Torque

Source	DF	SS	Contribution(%)	MS	F-Value	P- Value
N	2	0.002467	10.28	0.001233	1.42	0.266
D	2	0.003489	10.54	0.001744	2.00	0.161
Comp	2	0.000622	2.59	0.000311	0.36	0.704
Error	20	0.017422	72.59	0.000871		
Total	26	0.024000	100.00			

DF= Degrees of freedom, SS= Sum of squares, MS= Mean square

CONCLUSIONS

In this study the metal matrix composites are prepared by stir casting of Al-6065 Aluminium alloy and SiC as reinforcement by considering the most important three parameters speed, drill diameter and SiC percentagethat affecton the performances of torque and thrust force, to conduct the number of experiments Taguchi L_{27} Orthogonal array employed for setting up the different combination of the control factors, each at three different levels and observed that the drill diameter has higher influence on these responses than the speed and SiCpercentage. Using ANOVA analysis technique the factors that are the most significant in affecting the thrust force and torque identified.

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