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VARIATION OF DEPTH OF CUT ON AL7075-T6 AND FLY ASH METAL MATRIX COMPOSITE IN ABRASIVE WATERJET CUTTING

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ABSTRACT

Aluminium metal matrix composite is advances in manufacturing of new composite production. Present work carries an investigation of variation of depth of cut on Al7075-T6 and Fly ash metal matrix composites (AMMCs) in Abrasive water jet cutting (AWJC). The aluminum metal matrix was casted in stir casting process with variation of fly ash percentage (15%, 20% and 25%). The four samples namely pure aluminum sample and the three AMMCs are cut with AWJC by variation of different parameters to attain the optimization of the cutting condition in each sample. The cutting parameters are set based on Response Surface Methodology (RSM) using Historical data method. The results were analyzed using response graphs. From the analysis, it depicts that, high waterjet pressure; low standoff distance (SOD), low traverse speed (TS) and low abrasive flow rate (AFR) are resulted in higher depth of cut (DOC) in the unreinforced Al 7075-T6 as well as MMCs.

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INTRODUCTION

The Aluminium Metal Matrix Composite (AMMCs) consists of atleast two distinct constituent parts one is matrix and second is filler (reinforcement). In AMMC, the matrix is usually an alloy such as aluminium (Al), Zinc (Zn), etc., and the reinforcement is usually a hard material. Some of the materials are Fly ash, aluminium oxide (Al2O3), silicon carbide (SiC), boron carbide (B4C), etc. AMMCs have improved properties of material such as high hardness, low specific weight, high wear resistance, improved stiffness than that of conventional materials. AMMCs are widely used in various application such as in nuclear, high temperature thermo electricity, ballistic protections, space shuttle, aerospace, electronics, defense, automobiles, etc. (Chawla, 2013; Surppa, 2003). AMMCs are produced by liquid cast metal, powder metallurgy technology or by using special manufacturing method.

The powder metallurgy has a limitation in size of component and cost, so only the casting method is to be considered as the most optimum and economical method to produce aluminum composite materials (Muhammad Hayat Jokhio, 2011). In this experiment a stir costing is used to produce AMMCs with different reinforcement weight percentage (15%, 20% and 25%). AMMCs are produced with superior properties; non-traditional machining process is preferred by the manufacturer due to the dis advantage of conventional machining of AMMCs. Some of the reasons are high cutting forces, poor surface finish, poor dimensional accuracy, excessive tool wear, etc. One of the non-traditional, machining process is abrasive waterjet Machining (AWJM). In AWJM, a high velocity and high pressure waterjet mixed with garnet abrasive particle is introduced in the stream of flow. The momentum of the flow is gained by the abrasive particles and directed to the cutting target for cutting. (Member, 1998; John Rozario Jegaraj, 2005;

Pramanik, 2004). In AWJM there is no heat affected zone (HAZ) so no thermal distortion, low stress on the cutting material, ability to cut difficult-to-machine materials and even MMCs. In this experiment, the effects of AWJM process parameters on MMCs are studied. The four categories of AWJM namely (i) hydraulic parameter: pump pressure, orifice diameter, water flow rate, etc. (ii) mixing chamber and acceleration parameters: focus nozzle diameter and focus nozzle length, etc. (iii) cutting parameters: traverse speed, number of passes, standoff distance, impact angle, etc. (iv) abrasive parameters: abrasive flow rate, abrasive particles diameter, abrasive size distribution, abrasive particle shape, abrasive particle hardness, etc. (7-10). From different papers on machining aspects of MMCs using AWJM can be obtained from (11-13). From the literature survey, it is observed any small change in the AWJM process parameters will affect the DOC. It is also observed that there has been no attempt to machine AMMC consisting of Al 7075-T6 and Fly Ash using AWJM process. Hence, in this work an experiment is carried out to study the effect of AWJM process parameters such as waterjet pressure, SOD, abrasive flow rate and traverse speed on AMMCs consisting of Al 7075-T6 and Fly Ash in various proportion (15%, 20% and 25%) and to compare the results with that of unreinforced Al 7075-T6 in order to achieve higher depth of cut.

Preparation of specimen and Methodology

The AL 7075-T6 is purchased from Bharat Aero Space Metal, Mumbai in the form of a flat plate. The chemical composition of unreinforced metal is obtained using optical emission spectrometry (Composition: 0.35%Si, 0.164%Fe, 2.02% Cu, 0,02%Mn, 2.06% Mg, 0.15%Cr, 5.99% Zn, 0.01%Ni, 0.05% Ti,0.01%Pb and Al balance).This metal is reinforced with Fly Ash in the form of particulate average size of (1-53µm) is added in weight fraction such as 15%, 20% and 25%). The specimens are produced by stir casting process as a rectangular plate of 250*100*15 mm thick. The die for rectangular plate is prepare and shown in Fig 1.

Fig 1. Die

The AMMCs are prepared with varying the weight percentage of Fly Ash by stir casting process (Fig 2). During the preparation of specimen, the Al7075-T6 is heated in the electric induction furnace at a temperature of 800°C and the reinforcement material (Fly Ash) is preheated upto 600°C in other furnace to remove the gases and improve the wettability.

Fig 2. Cast specimens (15%,20% and 25% Fly Ash)

While melting of matrix metal is degreased by adding hexa chloro ethane at 750°C in order to remove the slag. The stirrer starts rotation at the speed of 350 rpm about 10 minutes in the molten metal, than the Fly ash particles were added to the melt to mix thoroughly and distribute uniformly in the molten metal. The die is preheated to remove the dirt and gases formation while pouring the molten metal matrix composite. Before pouring the molten metal in to the die the stirrer is raised and slows down the formation of vortex and poured in the die and then it is allowed to solidify in the die itself for about 2 hours. The presence of the fly ash is identified by SEM images and identifies that the distribution of the reinforcement particles of Fly Ash in the matrix (Fig. 3).

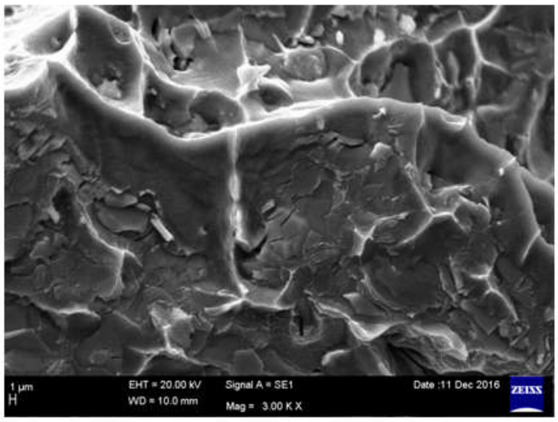


Fig 3. SEM images of the composite (Al7075-T6 + 20%)

The Brinell harness test is carried to measure the hardness of the four samples. The specimens are machined on AWJM system. AWJM is manufactured by M/s OMAX corporation (Model 2626) used in this work. The input process parameters such as waterjet pressure, SOD, traverse speed (TS) and abrasive flow rate (AFR) are varied at three levels. The machining is carried out using garnet abrasives of mesh size 80#, orifice diameter of 0.3 mm, focusing nozzle diameter of 0.76 mm and jet impacting angle at 90°. Experiment are conducted using based on Taguchi L27 and analyzed data in Response Surface Methodology (RSM) using design exports10 software and the output response is considered as DOC (Table 1). During each machining, the high pressure waterjet is allowed to cut until the jet splashing occurs. Thereafter, the depth of cut in each run is calculated by measuring depth by digital vernier at three different places and average the value is obtained. The significant AWJM process parameters and their levels are identified using response graphs for achieving higher DOC in all the fabricated workpieces using Design of Expert software.

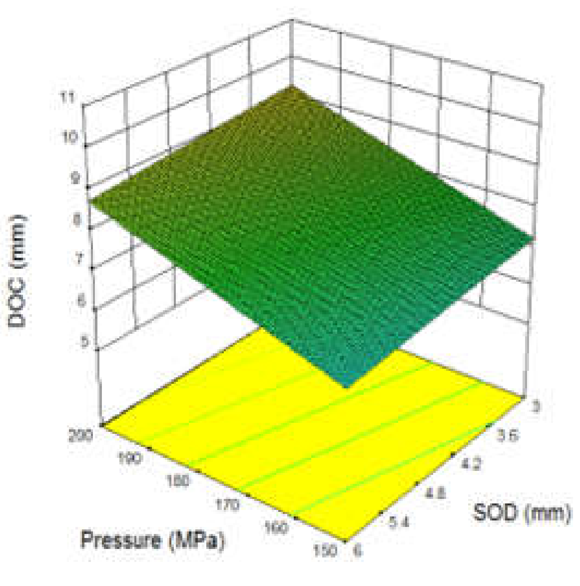
RESULTS AND DISCUSSION

From the experimental data obtained by regression model for the depth of cut are generated in 3D surface graph to analyze the effect of various combinations of input variables on the output DOC in all samples. Fig. 4 shows DOC graphs obtained with different combination of AWJM input process variables for unreinforced AL7075-T6. Fig 4a, depicts that the DOC is high at varying the TS (200mm/min-300 mm/min) and abrasive flow rate (0.24kg/min – 0.44kg/min), while jet pressure and SOD are maintained at different levels. By varying the pressure and SOD shows the higher depth of cut at high pressure (200 MPa) and low SOD (3mm).

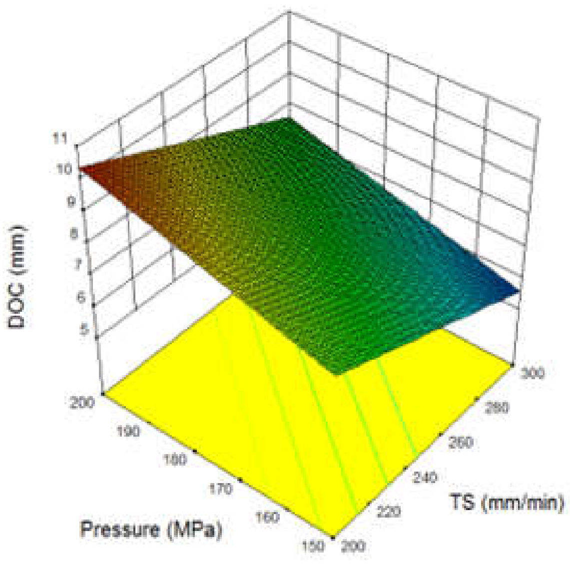
The depth of cut (DOC) obtained from the combination is nearly 9.5mm. Fig 4b shows that the DOC is high at varying SOD (3mm- 6mm) and AFR (0.24kg/min – 0.44 kg/min), while jet pressure and TS are varying at three levels it is observed that at high pressure and low traverse speed the DOC is high. Similarly from the above surface response graphs it is observed that the higher depth of cut (DOC) can be achieved by varying the jet pressure (150MPa – 200MPa) and abrasive flow rate (0.24kg/min – 0.44 kg/min) along with low SOD and low TS. Fig 4c. illustrate that at high pressure and low abrasive flow rate leads to higher depth of cut. Similarly, higher depth of cut can also be achieved by varying AFR (0.24kg/min – 0.44 kg/min) and TS (200mm/min-300 mm/min) with high pressure (200MPa) and low SOD (3mm).

Table 1.Experimental Data

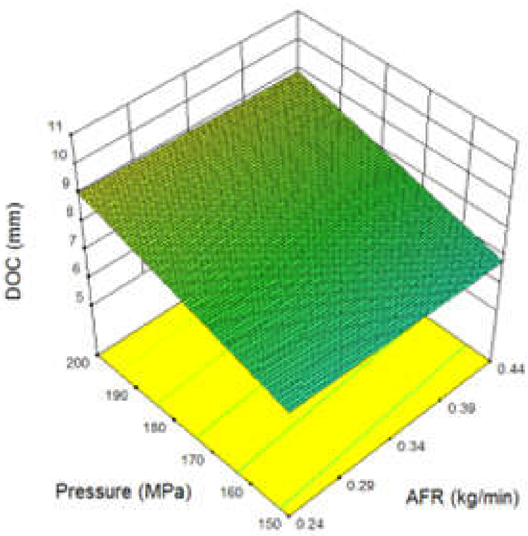
	Input process parameters				Depth of cut(mm)			
Sl No	Pressure Mpa	SOD mm	TS mm/min	AFR kg/min	Al (unreinforced)	Al+ 15% Fly ash	Al+ 20% Fly ash	Al+ 25% Fly ash
1	150	3	200	0.24	8.67	8.46	8.28	7.75
2	150	3	200	0.24	8.69	8.48	8.39	7.79
3	150	3	200	0.24	8.74	8.50	8.38	7.60
4	150	4.5	250	0.34	6.88	6.22	6.76	6.02
5	150	4.5	250	0.34	6.94	6.09	6.66	5.80
6	150	4.5	250	0.34	6.87	6.07	6.76	5.82
7	150	6	300	0.44	5.39	4.48	4.99	4.32
8	150	6	300	0.44	5.11	4.68	5.03	4.46
9	150	6	300	0.44	5.37	4.32	4.97	4.46
10	175	3	250	0.44	8.13	7.31	7.79	6.77
11	175	3	250	0.44	7.63	7.18	7.74	6.82
12	175	3	250	0.44	7.95	7.08	7.52	6.80
13	175	4.5	300	0.24	6.59	6.88	6.83	5.99
14	175	4.5	300	0.24	6.64	6.69	6.21	5.39
15	175	4.5	300	0.24	6.84	6.56	6.50	5.73
16	175	6	200	0.34	8.99	8.62	8.53	8.24
17	175	6	200	0.34	9.43	8.99	8.81	8.51
18	175	6	200	0.34	9.58	9.02	8.86	8.50
19	200	3	300	0.34	8.16	8.14	8.07	6.74
20	200	3	300	0.34	8.78	8.10	8.21	6.83
21	200	3	300	0.34	7.55	7.90	8.09	6.11
22	200	4.5	200	0.44	10.11	11.02	10.90	9.16
23	200	4.5	200	0.44	10.28	11.09	11.22	9.25
24	200	4.5	200	0.44	10.54	11.12	10.22	9.39
25	200	6	250	0.24	9.03	9.51	9.15	6.45
26	200	6	250	0.24	8.61	9.22	8.84	7.40
27	200	6	250	0.24	8.06	8.43	8.13	7.35



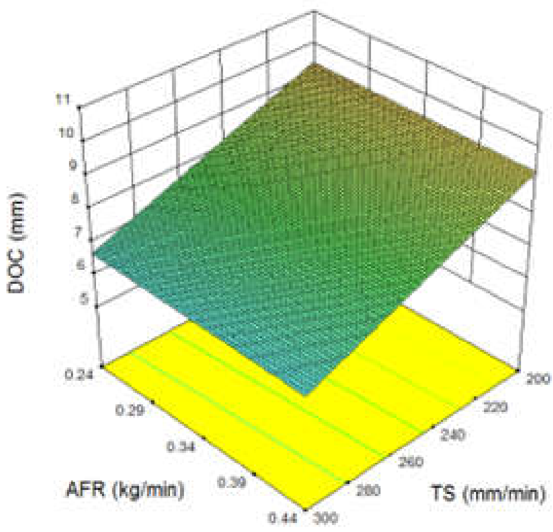
a) Pressure Vs SOD (at low TS and low AFR)



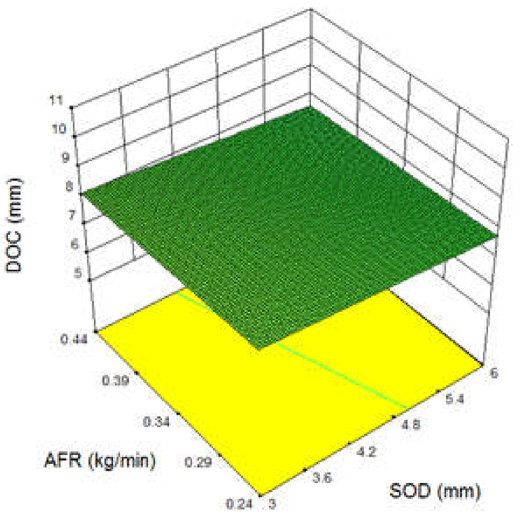
b) Pressure Vs TS (at low SOD and low AFR)



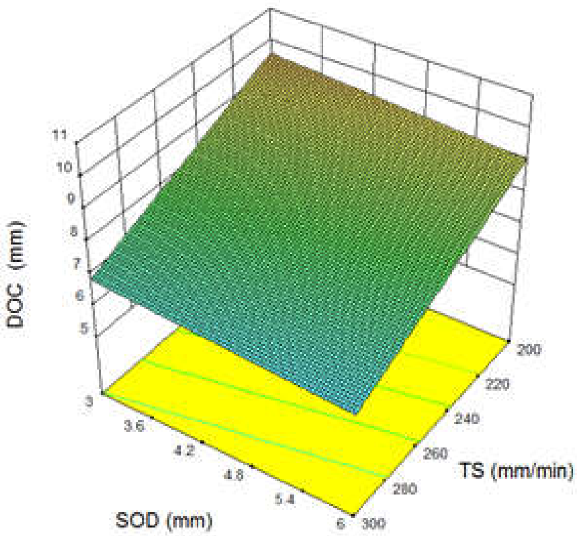
c) Pressure Vs AFR (at low TS and low SOD)



d) Abrasive flow rate Vs TS (at high Pressure and low SOD)



e) Abrasive flow rate Vs SOD (at high pressure and low TS)



f) Standoff distance Vs TS (at high pressure and low AFR)

Fig 4. DOC for different combinations (Unreinforcement Al 7075-T6)

The response surface for the above combination is shown in Fig 4 d. From this it is observed that at low AFR and low TS leads to higher depth of cut. Fig 4e, describes that the DOC varies with abrasive flow rate and standoff distance with three levels is observed at high pressure and low traverse speed. The depth of cut is increased at low SOD and low abrasive flow rate. Similarly Fig 4 f, depicts that the DOC is high at varying the SOD (3mm- 6mm) and traverse speed of nozzle (200mm/min-300 mm/min), while at high pressure and low abrasive flow rate leads to higher depth of cut. In this analysis it is observed that the combination of AWJM input process parameters and their levels such as high pressure, low standoff distance, low traverse speed and low abrasive flow result in higher depth of cut in unreinforced Al 7075-T6. The relationship between the input and response is expressed in the form of linear equation is given below.

DOC (unreinforced Al7075 –T6) = +8.68337+0.041022* Pressure – 0.017519*SOD – 0.02733*TS – 0.75556*AFR (1)

Analysis of AMMCs for the other samples also carried out considering higher DOC for Al7075-T6 +15% Fly ash, AL-7075-T6 +20% Fly ash and Al7075-T6 +25% Fly ash. The depth of cut for each sample reduces due to increase of percentage weight of Fly ash particles in the AMMCs. This is due to the fact of increased hardness and erosion rate during material removal. The response equation for the three samples is given below.

DOC (unreinforced Al7075 –T6) = +6.33426+0.060511*Pressure – 0.14370*SOD – 0.030611*TS – 2.47222*AFR (2)

DOC (unreinforced Al7075 –T6) = +6.83381+0.050244*Pressure – 0.19111*SOD – 0.027433*TS – 0.18333*AFR (3)

DOC (unreinforced Al7075 –T6) = +9.02452+0.032578*Pressure – 0.013937*SOD – 0.029067*TS – 0.0111111*AFR (4)

It is clear from the Fig 4; the depth of cut is higher in high pressure, low SOD, low TS and low AFR in all the materials. The depth of cut increase by using the abrasive particle size of 80mesh (0.177mm) will absorbed the pressure and covert it in to the kinetic energy and it impact from a high velocity to remove the material. Due to low TS the number of abrasive particles is targeted at point to give higher material removal. The low AFR will also help to observe and has a lead time to impact on the material to obtain higher DOC.

Conclusion

AMMCs at different weight percentage of Al 7075-T6 with 15%, 20% and 25% are prepared by hot die stir casting process successfully to study the DOC by unconventional machining process of AWJM. The following results are drawn. The SEM of prepared casting process it is found that homogeneous dispersion of fly ash particles in the MMCs. The hardness of the MMCs is increased due to increase in reinforcement. The effect of AWJM process parameters on depth of cut is studied in RSM. It is found that the three levels of AWJM parameters, high pressure, low SOD, low TS and low AFR are found to be the maximum depth of cut in Al7075-T6 and MMCs.

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