Performance Analysis of Abrasive Water Jet Cutting Process in Carbon Fiber Epoxy Polymer Composite

Performance Analysis of Abrasive Water Jet Cutting Process in Carbon Fiber Epoxy Polymer Composite

Binduk Potom[1], S. Madhu[2 *],S.Kannan[3], P. Prathap[4]

[1,2] Department of Automobile Engineering, Saveetha School of Engineering, Thandalam, Chennai, Tamilnadu, India
[3]Department of Mechanical Engineering, Hindustan College of Engineering and Technology, Coimbatore, Tamilnadu, India
[4] Department of Mechanical Engineering, Sri Krishna College of Technology, Coimbatore, Tamilnadu, India

Corresponding Author: mathumarine@gmail.com

Abstract. Abrasive water jet machining is unconventional material removal process used to dissolve openings and cavities by the force of rough particles of the slurry on hard and materials. It is a non traditional machining process able to machine wide scope of hard to cut materials such as alloys, composite materials. This work explores the impact of different process parameters on kerf angle and amount of materials removed which are imperative execution measures in abrasive waterjet machining. The variable abrasive water jet parameters considered here include water pressure, nozzle diameter stand-off distance and abrasive flow rate. Experiments were conducted on carbon fibre reinforced polymer composites by varying these parameters.This work concluded that maximum abrasive jet pressure increase the material removal rate and minimum stand off distance (SOD) will decrease the kerf angle in carbon fibre composites.

1. Introduction

Abrasive water jet(AWJ) cutting is a unconventionsalcutting procedure that utilizes high pressure water for delivering high speed stream, entrained with grating particles for a wide assortment of materials extending from delicate to hard materials. It is an adaptable procedure that can be utilized in numerous producing applications, for example, cutting, processing, cleaning, and surface treatment [1]. It has kind advantages like negligible heat affected zone in cutting procedure, high degree of accesability, and less machining time. In Abrasive water jet process, materials get removed by because of effect of high speed stream (blend of water and rough abrasive particles) on the surface to be machined [2]. The abrasive water jetmachining is fundamentally influenced by the different process parameters such as (i) Water jet pressure (ii) Abrasive flow rate (iii) Stand-off distance (iv) Abrasive jet traverse rate and (v) Diameter of nozzle[3]. In which kerf angle is a unwanted in abrasive water jet. The increased pressure and minimum stand-off distance decrease the kerf angle [4]. Material removal rate in directly influence by waterjet pressure. Also minimum stand-off distance (SOD) increases the mateiral removal rate [5].The quality of the machine surface depends upon the abrasive waterjet parameters. For improve the quality of the surfacedetailed knowledge of the effect

of process parameters is required. In this way, to explore the impact of procedure factors on performance of AWJM, following parameters are considered in this paper [6]. In this work CFRP composite material is machined by abrasive water jet machining. Abrasive water jet pressure, nozzle diameter, flow rate and SOD were selected [7] as input process parmeters in this investigation. The mateiral removal rate (MRR) and Kerf angle were invetigated.

2. Materials and Method

2.1 CFRP Composite

In this work CFRP composites with 5 mm thickness were fabricated by hand layup process [8,9]. Epoxy rein was used as matrix material[10]. Hardner LY565 is used for mixing epoxy resin and carbon fibre. Unidirectional carbon fibre was used for this investigation.

2.2 Abrasive waterjet machining

Abrasive water jet is used for macgining CFRP samples. Holes were made on CFRP samples using the following waterjet parameters. The water jet pressure (2500 to 4000 bar) is used for machining the composite samples.The flow rate of the water along with abrasive particles is a major process parameter that affects the material removal rate in abrasive jet machining.It is the diameter of the tip of the nozzle [11,12]. It has a major impact on material removal rate of the composite.It is the distance between the nozzle tip and the workpiece. It influence of water jet parameters on material removal rate, diameter of hole and kerf angle were investigated. Kerf angle is a quantity which is often used to reflect the inclination of the kerf wall from the top surface kerf to the bottom of the kerf. The distance between the two kerfs determines the kerf angle of the material.

3. EXPERIMENTATION

Abrasive water jet investigations were done on CFRP composie as shown in Figure 1. Carbon fiber reinforced polymer was used as workpice material. CFRPare lightweight, solid materials utilized in the manufacturing of various items utilized in our day by day life. It is utilized in the modern, structural, and transportation fields [13, 14]. Abrasive water jet machining, which does not make a significantheat influenced zone, is more usable for machining of CFRP for present day applications[15].

Abrasive water jet parameters significanly affect the quality of the machined surface are considered in this work are pressure, flow rate, nozzle diameter and stand-off distance. The experiments were conducted on CFRP samples as shown in the Table 1.

Figure 1 Abrasive water jet machine

Table 1: Experimental parameters

S.No	**Parameter**	**Unit**	**Levels**		
			1	**2**	**3**
1	Pressure	bar	1500	2000	2500
2	Flow rate	gm/min	200	400	600
3	Nozzle diameter	mm	1.1	1.5	1.9
4	Stand-off distance	mm	3	5	7

The weight of the CFRP samples was measured using digital weighing machine before and after hole. The the top and bottom holes diameter was measured by using optical microscope. By using the material Plus software bottom and top diameter of the hole were eveluatedas shown in the Figure 3 and Figure 4.By using the equation 1 kerf angles were calculated and recorded. Totally 9 experiments were carried out for different abrasive waterjet parameters as ashown in Table 1. For each experuimets MRR and kerf angle were recorded as shown in Table 2

Table 2: Abrasive water Experimental results

Exp No	**Input Parameters**				**Output Responses**		
	P (Bar)	**FR (g/min)**	**SOD (mm)**	**ND (mm)**	**MRR (g/min)**	**TK (mm)**	**BK (mm)**
1	1500	200	3	1.1	5.8	2.202	2.067
2	1500	400	5	1.5	5.1	2.109	2.012

3	1500	600	7	1.9	6.0	2.538	2.228
4	2000	200	3	1.9	5.6	2.445	2.207
5	2000	400	5	1.1	6.2	2.674	2.319
6	2000	600	7	1.5	6.3	2.051	1.883
7	2500	200	3	1.5	6.4	2.656	2.193
8	2500	400	5	1.9	6.7	2.034	2.000
9	2500	600	7	1.1	6.5	2.496	2.252

4. Result and discussion

After conducting the waterjet experiments, the values of output parameters such as material removal rate (MRR), top kerf (TK) and bottom kerf (BK) were recorded in the Table 2.To investigate the quality of machined surface of CFRP composites the effect of abrasive water jet parameters on MRR, TK and BK were studied in this investigation. From this investigation it was seen that abrasive water pressure and SOD is the significant parameters [15, 8].

4.1 Effect of abrasive water jet parameters on MRR

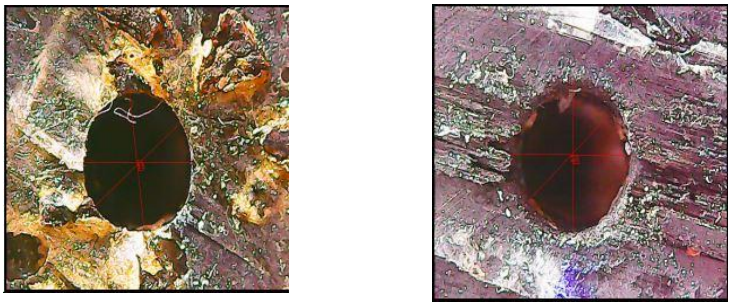
From the figure it was seen that maximum water jet pressure increase the material removal rate in CFRP composite. When the pressure increases the kinetic energy of the abrasive particle increases which in turn erode the material surface rapidly. In this investigation maximum of 6.7 g/min MRR obtained.

From the experimental results it was seen that minimum stand-off distance (SOD) increase the material removal rate [8, 17]. When the distance between the work surface and the nozzle is minimum the high pressure abrasive particle coming out from the nozzle remove the material drastically.

4.2 Effect of abrasive water jet parametrs on Top and bottom kerf

In this current investigation top hole diameter depend upon the water jet pressure. When the pressure increases the kerf also increased as shown in Figure 2a. When the distance between the nozzle and the work surface is minimum [18], more amounts of abrasive particles impinging the work surface. Hence the top kerf increased.

When the pressure decreased, the abrasive particls reach the bottom surface with low kinetic energy.Hence the bottom kerf is smaller than the top kerf as shown in Figure 2b. When the stand-off distance (SOD) is minimum, the abrasive particles reach the bottom surface with more energy which in turn removes the material in CFRP composite material.



Top hole diameter **Bottom hole diameter**

Figure 2 Microscopic images of top and bottom kerf of CFRP samples

5. CONCLUSION

From this investigation, it was obseved that abrasive water jet pressure and SOD are the significant parameters which affect the material removal rate and kerf charecterisitcs of the CFRP samples. The effect of water pressure and stand-off distance on kerf charecterisitics and MRR were studied. In this experimental research the following conclusion were drawn.When the water jet pressure is maximum, the MRR in the CFRP samples increased up to 6.7 g/min.The outcome of the research demonstrated that the top and bottom kerf varies according to the variable parameters provided, stand-off distance and abrasive flow rate.

REFERENCES

[1]Chen L, Siores E, Wong WCK. Optimising Abrasive Waterjet Cutting of Ceramic Materials. J Mater Process Technol. 1998; 74: 251–4p.

[2]Shimizu Z, Shinoda Y, Peng G. Flow Characteristics of Water Jet Issuing from a Fan Jet Nozzle. In Proceedings of 19th International Conference on Water Jetting; 2008 Oct 15–17; Nottingham, UK: 2008; 55–66p.

[3]Srinivasu DS, Axinte DA, Shipway PH, et al. Influence of Kinematic Operating Parameters on Kerf Geometry in Abrasive Waterjet Machining of Silicon Carbide Ceramics. Int J Mach Tools Manuf. 2009; 49: 1077–88p.

[4]M. A. Azmir, A.K. Ahsan, A. Rahmah, M.M. Noor, and A.A. Aziz, “Optimization of Abrasive Waterjet Machining Process Parameters Using Orthogonal Array With Grey Relational Analysis”,

Regional Conference on Engineering Mathematics, Mechanics, Manufacturing & Architecture (EM3ARC) (2007), pp 21~30.

[5] M. A. Azmir1, A.K. Ahsan, A. Rahmah, "Investigation on Abrasive Waterjet Machining of Kevlar Reinforced Phenolic Composite Using Taguchi Approach", Proceedings of the International Conference on Mechanical Engineering 2007 (ICME2007) (2007), pp 29-31.

[6] Conner I., Hashish M., Ramulu M. "Abrasive water jet machining of aerospace structural sheet and thin plate materials", in Proceedings of the 12th American Water jet Conference, Houston, USA, 2003.

[7] S Madhu, M Balasubramanian (2017), "Effect of abrasive jet process parameters on machining glass fibre reinforced polymer composite" Materials Science & Engineering Technology, 48 (11), pp 1146-1157.

[8] S.Madhu, M. Balasubramanian (2018) "Effect of swirling abrasives induced by a novel threaded nozzle in machining of CFRP composites", The International Journal of Advanced Manufacturing Technology Volume 95, 9-12, pp 4175-4189.

[9] Jeyaprakash P, Prabakaran V and Devaraju A**.** "Experimental and Numerical Analysis of Carbon Epoxy Fibre Composite under Buckling Load", *Materials Today: Proceedings, Vol. 5 (*2018), pp.14526-14530.

[10] Devaraju, A**,** Babu, K and Gnanavel babu, A . "Investigation on the Mechanical properties of Coconut Bunch fiber Reinforced Epoxy with Al_2O_3 Nano particles Composites for Structural Application", *Materials Today: Proceedings, Vol. 5 (*2018), pp.14252-14257.

[11] Khan A.A. and Haque M.M. "Performance of different abrasive materials during abrasive water jet machining of glass", Journal of Materials Processing Technology, Vol. 191, 2007.

[12] Jain N.K., Jain V.K. and Deb K. "Optimization of process parameters of mechanical type advanced machining processes using genetic algorithms", International Journal of Machine Tools & Manufacture, 47, 2007.

[13] M. Joseph Davidson, K. Balasubramanian, G. R. N. Tagore "Surface roughness prediction of flow formed AA6061 alloy by design of experiments" journal of Material processing Technology, vol 202,NIT Warangal,2008.

[14] Siddiqui T.U. and Shukla M. "Robust Parameter Design for Multi-characteristic Optimization of Abrasive Waterjet Cutting of Aramid Composite", Journal of Modern Manufacturing Technology, Vol. 1, 2008.

[15] Deaconescu A, Deaconescu T. Performance of Machining by Waterjet Erosion. Proceedings of the 1st International Conference on Manufacturing Engineering, Quality and Production Systems (Volume II). 2009; 2(1): 313–6p.

[16] John RozarioJegaraj J., Ramesh Babu N. A Soft Computing Approach for Controlling the Quality of Cut with Abrasive Waterjet Cutting System Experiencing Orifice and Focusing Tube Wear. J Mater Process Technol. 2007; 185(1–3): 217–27p.

[17] Shanmugam DK, Wang J, Liu H. Minimization of Kerf Tapers in Abrasive Waterjet Machining of Alumina Ceramics Using a Compensation Technique. Int J Mach Tools Manuf. 2008; 48: 1527–34p.

[18] Jankovic P, Igic T, Nikodijevic D. Process Parameters Effect on Material Removal Mechanism and Cut Quality of Abrasive Water Jet Machining. TheoretAppl Mech. 2013; 40(2): 277–91p.