Comprehensive Review on Recent Trend on Abrasive Water Jet Machining

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Abstract— In the area of machining technology, Abrasive water jet machining is considered as one of the most significant non-conventional machining process where by means of erosion effect of high velocity abrasive are entrained in water jet to remove material. AWJM processes is widely been used in the filed of industrial and automotive applications. Now a day, due to advancement in conventional AWJM, it is also used in machining stainless steel, alloyed material, as well as composite material also. This AWJM process have significant advantage over other conventional process such as low production time and cost, no coolant required, vibration free, etc. in this paper a comprehensive review has been presented which shows the noteworthy contribution of various researchers in improving the technology of AWJM.

Key words: AWJM, Experimental

I. Introduction

Manufacturing engineering has advanced in many fields and still continues in progress to meet the rapid transformations of the new techno-logical era. Manufacturing fields are continually developing upon existing designs and approaches to make the life easier and simple. One of the significant manufacturing technologies is abrasive waterjet (AWJ) machining, which is regarded as a non-conventional machining method. Abrasive water jet machining subjects on a high-pressure of water provided by a pump on the orifice (nozzle) inside the cutting head wherever it can be transformed to a high velocity jet. Simultaneously, the water makes a vacuum though it passes through the mixing chamber to draw abrasive particles to the focusing tube where the AWJ mixture is created (Anwar et al.,2013). The idea of AWJ started in the 70s when quarry companieswere looking for an efficient technique to cut stone over the tradi-tional diamond coated wet saws. It was discovered that directing avery high-velocity narrow stream of water can cut any object (Tiffany, n.d.[2]). The use of abrasive water jet for machining origi-nated almost 30 years ago with the abrasive water jet cutting themetals without heat (Dobbins, n.d. [3]). Since then, the AWJ technol-ogy has been rapidly improved to meet the necessity of modernindustries. Abrasive water jet has the ability to cut any materialranging from very soft flexible materials to very hard and brittlematerials. The main advantages of AWJ over other non-conventional machining processes, e.g. laser and electric dischargemachining are the high accuracy of components and features gen-erated, quick setup of the AWJ cutting and no/negligible heat gen-erated during the process Sreekesh and Govindan,[4].Furthermore, the AWJ process can generate complex 3D shapes.

In AWJM the mixture between the water jet (the water is the accelerating work agent) and abrasive particles performs the actual cutting. In figure 1 the technological work parameters are presented together with the abrasive water jet cutting head. From this image the water jet delay can be observed in the lower part of the work piece due to variations of the water pressure and cutting speed parameters which generate the cut surface quality depending on its roughness. This delay of the water jet is characterized by a distance obtained from the difference between the entrance and exit points of the water jet in the material being cut.

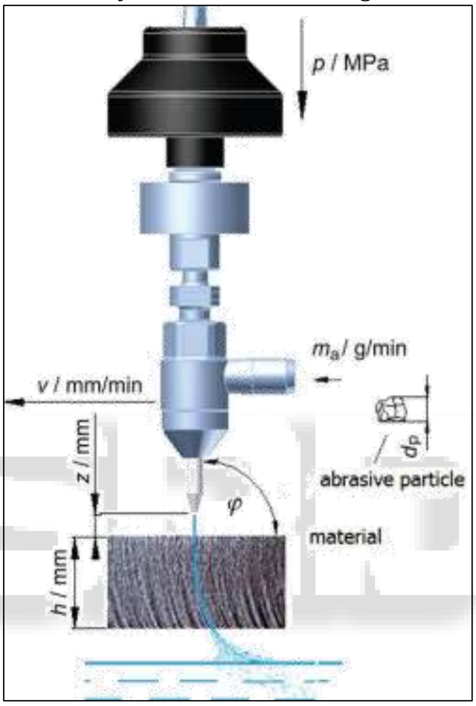

Fig. 1: Abrasive water jet cutting – water jet cutting head and process parameters

II. Literature review

M. Chithirai Pon Selvan et al. [5] carried out the work on the influence of process parameters on depth of cut which is an important cutting performance measure in abrasive water jet cutting of stainless steel. The process variables considered here include traverse speed, abrasive flow rate, standoff distance and water pressure. Experiments were conducted in varying these parameters for cutting stainless steel using abrasive water jet cutting process. In order to correctly select the process parameters, an empirical model for the prediction of depth of cut in abrasive water jet cutting of stainless steel is developed using regression analysis. This developed model has been verified with the experimental results that reveal a high applicability of the model within the experimental range used. In this full factorial experiments were not considered in this study [5].

$$D_c = 678 \times \frac{m_a}{\rho_w d_j u} \times \left(\frac{p}{E}\right)^{0.324} \times \left(\frac{s}{d_p}\right)^{0.884} \times \left(\frac{s\, m_a}{d_p^3 \rho_p u}\right)^{-0.893} \times \left(\frac{\rho_p u^2}{p}\right)^{-0.015}$$

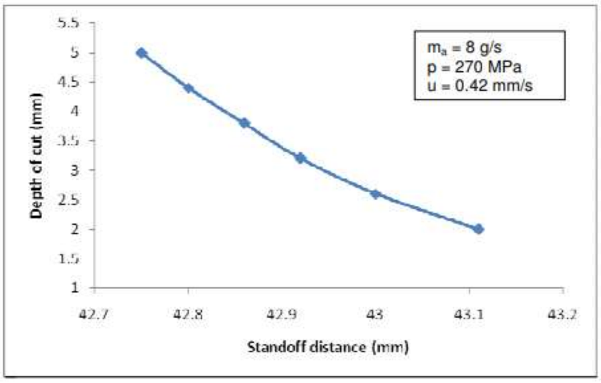

Fig. 2: Effect of standoff distance on depth of cut [5]

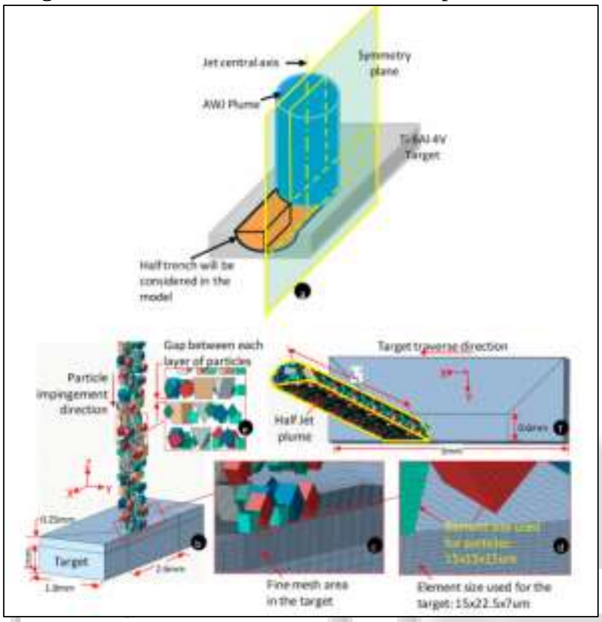

Fig. 3: (a) Symmetry of the AWJ milling process at 90◦ incidence angle. (b) 3D view of the model. (c) Meshing of the target and the particles. (d) Zoomed-in view of the elements used in the fine mesh area. (e) Gaps among the layers of the particles; in between these gaps the target will be traversed by some percentage of total distance to be covered across the jet. (f) Tilted top view of the model showing the length of the particles column.

Murugabalaji et al.[6] worked on experimental investigation on AWJM of Stainless steel 304 of thickness 40mm is supported using Response Surface Methodology (RSM) with Box-Behnken method. The stainless steel work piece is shown in figure 3 below. The input process parameters measured are pressure (P), traverse rate (TR) and mesh size (MS). Effects were investigated using a method named as Analysis of Variance (ANOVA) and response surfaces independently on depth of cut (DOC) and surface roughness (Ra).

ANOVA and response surface analyses showed that combinations of process parameters such as high pressure (300 MPa), medium mesh size (# 100) and low traverse rate (30 mm/min) caused in higher DOC whereas lower Ra is obtained with combinations of pressure around (300 MPa), small mesh size (# 80) and less traverse rate (30 mm/min). Orthogonal array of experiments were conducted further full factorial experiments were not conducted to investigate the influence of pressure, mass flow rate, and traverse speed on depth of cut .[6].

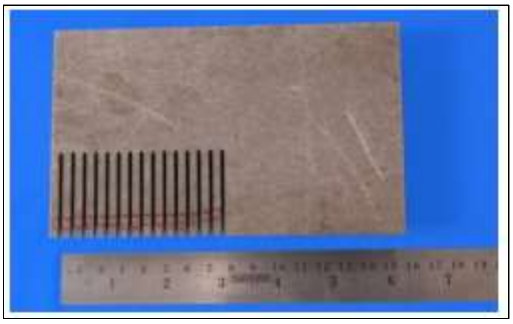

Fig. 4: Photograph of the Stainless Steel work piece (Top surface) [6]

Chirag M Parmar et al. [7] presented work on AWJM using Taguchi method to optimize process parameters for commercially three different materials AL-6351, Fiber Reinforced Plastic and SS-316. Experimental investigations conducted to assess the influences of penetration on standoff distance, work feed rate and jet pressure. The output parameters to be studied were surface unevenness and MRR [10].

P. P Badgujar et al. [8] experimented the influence of process parameters pressure, abrasive material, grain size, standoff distance, nozzle speed and abrasive mass flow rate on surface roughness which is an important cutting performance measure in abrasive water jet cutting of stainless steel (SS304). The objective of this paper was to select the level of parameter one variable at a time analysis (OVAT). The input parameters were pressure, abrasive material grain size, standoff distance, nozzle speed and abrasive mass flow. Also the effect of input parameter on surface roughness was analyzed for machining Stainless steel (SS 304). It was observed that, higher levels of the process parameters excluding the abrasive size resulted in higher surface roughness in the work piece. The lower surface roughness was obtained when higher mesh size was used, while the higher roughness was achieved with an abrasive of smaller mesh size. As water jet nozzle speed was increased, surface roughness also increased. It was concluded that the higher standoff distance resulted in a constant increase in the surface roughness same result was observed for higher water jet pressure. The number of experiments conducted was six trials and however full factorial experiments were not conducted to investigate the influence of pressure, mass flow rate, and traverse speed on depth of cut. [8].

Ion Aurel perianu et al. [9] carried out research in the field of abrasive water jet cutting of materials which are hard to process by machining such as austenitic stainless steels, in this presented work, austenitic steel EN 1.4306 with a thickness of 20 mm and only three altered water pressure values with a range 3400 – 3800 bars was considered.

Fig. 5: Cut sample of austenitic steel EN 1.4306 [9]

AWJ cutting of composite laminates possesses several challenges. There are a few studies that analyse the effect of input parameters on the quality of the cutting edge, e.g. Kalla et al. [10], Shanmugan and Massod [11] and Wang [12], or investigations that optimise process parameters for trimming CFRP materials with good quality, e.g. Etxeberria et al. [13]. Nevertheless, industrial end users still need to develop process knowledge, since machine manufacturers do not provide good databases for composite cutting. It is necessary to develop a methodology to adapt the process parameters for each type of FRP & CFRP material which will allow AWJ trimming operations to be easily carried out on composite materials.

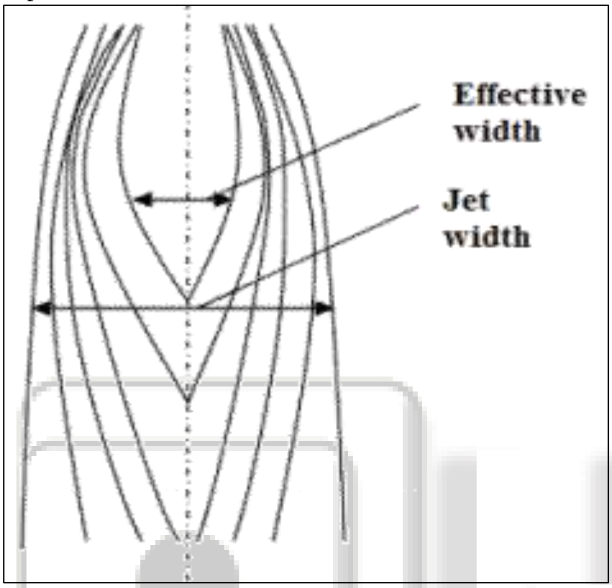

Fig. 6: Radial velocity distribution across the width of the nozzle [10]

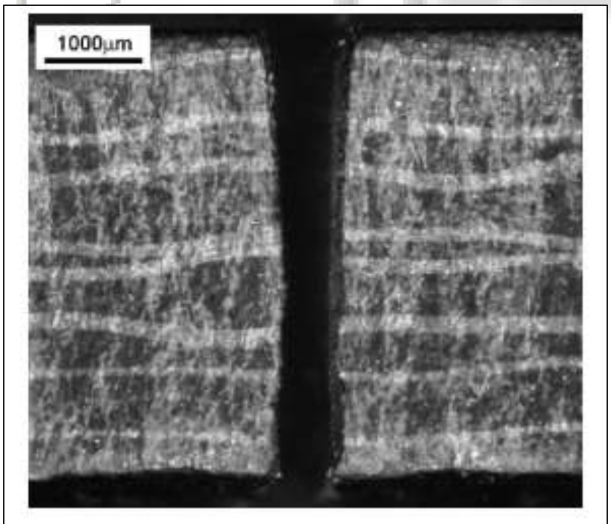

Fig. 7: Cross-section of Gr/Ep composites cut with abrasive waterjet: water pressure = 210 MPa, traverse speed = 30mm/s, standoff distance = 3mm, abrasive mass flow rate = 8.5 g/s. [11]

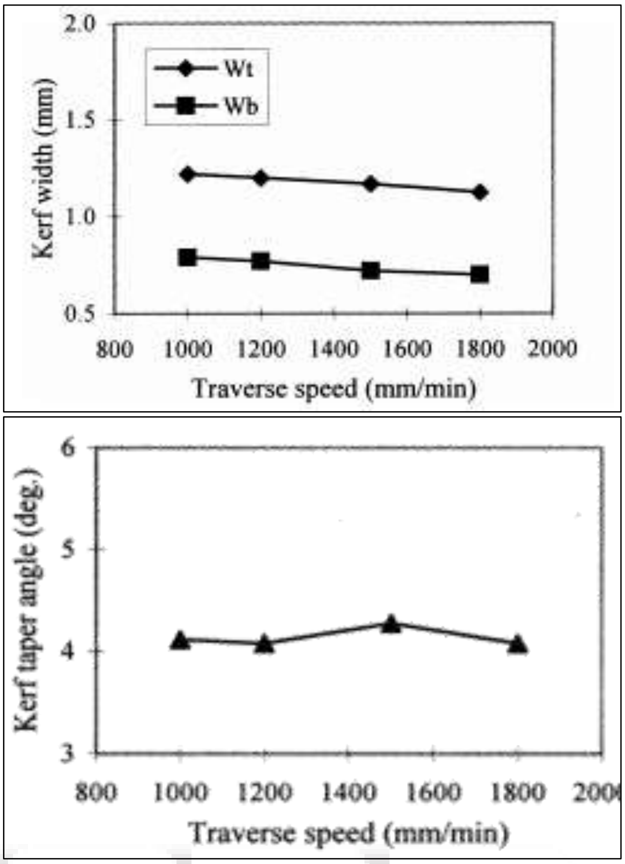

Fig. 8: The effect of traverse speed on the kerf geometry (water pressure=35 000 psi, stand-off distance=4 mm). Wang [12]

III. Conclusion

– AWJ cutting is a significant technology used for cutting any intricate profile and drill holes in extensive range. It can be also be used for detailed machining. The efficient performance of abrasive water jet process depends on process parameters such as traverse speed, mass flow rate of abrasives, standoff distance, water jet pressure, abrasive mesh size etc. and material parameters like thickness, type of the material.
– It was concluded from literature that hydraulic pressure and type of abrasive materials were considered as the most significant control factor in influencing surface roughness and depth of penetration. High traverse speed results in lower material removal rates in material.
– Decrease in standoff distance and traverse speed leads to improve machining performance.
– Proper selection of nozzle and orifice can improve quality of kerf.
– There is a scope to investigate machinability studies on stainless steel by conducting full factorial experiments.

References

[1] (N. Ramachandran and N. Ramakrishnan, A review of abrasive jet machining, Journal of Materials Processing Technology, 39 (1993) 21-31
[2] P S Jain and A A Shaikh "Experimental study of various technologies for cutting polymer matrix composites"

International Journal of Advance Engineering Technology E-ISSN0976-3945, vol.II/issue I/Jan-Mar/81-88

[3] Dirk Biermann, Robert Aßmuth, Sebastian Schumann, Michael Rieger, Bernd Kuhlenkötter Wet Abrasive Jet Machining to Prepare and Design the Cutting Edge Micro Shape, Procedia CIRP, Volume 45, 2016, Pages 195-198

[4] N.S. Pawar, R.R. Lakhe, R.L. Shrivastava, Validation of Experimental Work by Using Cubic Polynomial Models For Sea Sand as an Abrasive Material in Silicon Nozzle in Abrasive Jet Machining Process, Materials Today: Proceedings, Volume 2, Issues 4–5, 2015, Pages 1927-1933

[5] D.V. Srikanth, M. Sreenivasa Rao, Application of Taguchi & Response Surface methodology in Optimization for Machining of Ceramics with Abrasive Jet Machining, Materials Today: Proceedings, Volume 2, Issues 4–5, 2015, Pages 3308-3317

[6] Roxana Nedelcu “A concise analysis on composite machining technologies” International Conference of Scientific paper AFASES 2013Brasov, May 2013

[7] R V Shah “A study of Abrasive water jet Machining process On Granite Material” International journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, vol.2, issue 4, 08/2012

[8] Alberdi, A. Suárez, T. Artaza, G.A. Escobar-Palafox, K. Ridgway, Composite Cutting with Abrasive Water Jet, Procedia Engineering, Volume 63, 2013, Pages 421-429

[9] Kalla, D. K., Dhanasekaran, P. S., Zhang, B., Asmatulu, R, 2012. Abrasive Waterjet Machining of Fiber Reinforced Composites: A Review. AIP Conf. Proc. 1431, 535-542.

[10] Shanmugan, D. K., Massod, S. H., 2008. An investigation on kerf characteristics in abrasive waterjet cutting of layered composites. Journal of Materials Processing Technology 209, 3887-3893

[11] Wang, J, 1999. A machinability study of polymer matrix composites using abrasive waterjet cutting technology. Journal of materials processing technology 94, 30-35

[12] Etxeberria, I., Suárez, A., Orbanic, H., Lebar, A., 2010. Abrasive water jet trimming and piercing and surface evaluation of carbon fibre reinforced polymers. 20th International Conference on Water Jetting, Graz, Austria

[13] GuihuaHu, Wenhua Zhu, Tao Yu and Jin Yuan, “Numerical Simulation and Experimental Study of Liquid-solid Two-phase Flow in Nozzle of DIA Jet”, IEEE international conference korea (2008)

[14] Guihua Hu, Wenhua Zhu, Tao Yu, and Jin Yuan, “Numerical Simulation and Experimental Study of Liquid-Solid Two-Phase Flow in Nozzle of DIA Jet”, ICIC 2008, CCIS 15, pp. 92–100, 2008. © Springer-Verlag Berlin Heidelberg 2008