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Abrasive Water Jet Machining Of Composite Materials– A Review

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Abstract-Composite materials are being increasingly used in various applications like space, aircraft, marine, architectural and automobile sector because of their superior physical and mechanical properties even though they are a little bit costly. Machining of composite materials is of great interest because of variety of reinforcement from high strength fibers to natural fibers. Due to this, the machine manufacturers do not provide good database for machining the composite materials. Abrasive water jet machining provides some advantages over conventional and non-conventional machining process for cutting the composite materials like no thermal effect, high machining versatility and small cutting forces. This paper reviews the various experimentations carried out by number of authors in this field.

Keywords*:* Composite materials, abrasive water jet machining, machinability, transvers speed, standoff distance.

I.INTRODUCTION

The use of composite materials in various sectors like space, marine and automobile is high because of their properties like light in weight but of enough strength. Also they withstand in some difficult environments in which normal materials cannot withstand. Composite materials are made up of highly strong fibers interwoven into softer matrix. Due to the anisotropy and heterogeneous nature they are difficult to cut using conventional machining processes. Conventional machining process like band saw cutting results into poor cutting quality along with low productivity. The non-conventional process like laser cutting results in generation of large burr and it is hazardous for heat sensitive materials. On the other hand the abrasive waterjet cutting process offers some advantages like no thermal distortion, high machining versatility, high flexibility, narrow kerf width so reduced material wastage and small cutting forces while cutting the composite materials.

II. LITERATURE REVIEW

Mahesh Haldankar [1] studied the solid particle erosion of polymer matrix composites like vinylester/glass using Taguchi approach. He selected parameters like impingement velocity, impact angle, abrasive particle size and standoff distance. S/N ratio analysis is carried out to find most significant factor. He concluded that erosion rates are lower at lower values of S/N ratio. Jet impingement angle shows more erosion rate with high value of S/N ratio. Theabrasive particle size do not play significant role in erosion rates.

A. Alberdi [2] commented that the machine manufacturers do not provide good database for processing the composite materials like FRP and CFRP so he performed experimentation to find out the machinability model for cutting FRP and CFRP material with varying thickness. Along with this, effect of process parameters on quality of cut was also studied. Based on results obtained he reported that the machinability index for different material is different. To increase the

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productivity, proper tool should be selected. Also he concluded that transvers speed should be selected such that material will be cut without delamination.

Roxana Nedelcu [3] analyzed conventional and non-conventional machining processes of composite cutting and stated the requirements of each process along with their advantages and disadvantages. She considered conventional processes like turning, drilling, milling and grinding and nonconventional processes like abrasive water jet machining, laser machining technique, electric discharge machining and ultra-machining. She did not recommend particular processes for composite cutting but concluded that every composite material possesses unique machining characteristics and machining processes should be selected according to material characteristics.

R. V. Shah [4] conducted experimental investigations to study the effect of abrasive water jet machining process parameters on material removal rate of granite material. Analysis of variance (ANOVA) is carried out to optimize the AWJM process parameters for effective machining. He considered the process parameters like abrasive water pressure, transvers speed and standoff distance for his studies. Based on experimental investigations he formulated a mathematical model to predict the material removal rate. Based on the results obtained he concluded that transvers speed is most significant factor in deciding the MRR. MRR increases with increase in hydraulic pressure and SOD up to a certain limit.

Izzet Karaurt [5] conducted experiments to study the effect of AWJM process parameters and material properties of granite on kerf angle. The design philosophy like Taguchi was used to conduct experiments and the analysis of variance (ANOVA) was used to decide most significant factor or parameter affecting the kerf angle of granite. After conducting various experiments he concluded that the transvers speed, abrasive water pressure and standoff distance are the significant factors in deciding the kerf angle of granite material. Increase in these parameters results in increase in the kerf angle. Further he commented regarding the process parameters that the abrasive flow rate did not play important role in deciding the kerf angle in granite. About the material properties he commented that the grains and their boundaries as well as material composition especially feldspar and quartz play important role in deciding kerf angle.

Izzet Karakurt and Gokhan Aydin [6] studied the effect of various AWJM process parameters on depth of cut and kerf width. The experimentation is carried out by using the design philosophy of Taguchi and results were evaluated using analysis of variance. In this study they concentrated on process parameters like transvers speed, abrasive flow rate, standoff distance, water pressure and abrasive particle size. Considering these parameters they developed a L16 orthogonal array to carry out the experimentation. Based on experimental results obtained they concluded that increase in transvers speed decreases the depth of cut and kerf width but both the parameters increase with increase in abrasive flow rate. Increase in standoff distance decreases the depth of cut but increases the kerf width. Again for water pressure the increase in water pressure increased both depth of cut and kerf width up to a certain limit, then on further increase in water pressure shows a decreasing trend. Based on the analysis of variance the most significant factor in deciding the depth of cut is transvers speed, abrasive flow rate and abrasive size. The kerf width in granite is decided by standoff distance, abrasive flow rate, transvers speed, water pressure and abrasive particle size.

D. Baburao [7] conducted experimentation on CFRP, ceramics and various composite materials used in space applications and studied the importance of the water jet cutter for composite tooling, space structure fabrication and ceramic test coupon generation. In this study he focused on the process of water jet cutting and commented that the abrasive water jet technique is normally used to cut hard materials like titanium, ceramics, Kevlar fiber composites and the advantage of using water jet cutter with abrasives. After conducting the experiments he concluded that the cutting parameters arriving after many trials were used for all the cutting activities and higher accuracy/high cut edge quality was achieved. Suitable maintenance and good housekeeping procedures also played important role in improving the cutting quality.

E. Leema [8] carried out experimentation on cutting of fiber reinforced composites using abrasive water jet machining with cutting head oscillating. In this investigation, comparative study between oscillating head and without oscillating head cutting of GFRP composite is carried out. After taking the trials he concluded that with oscillating head surface quality improves as compared to normal AWJM. The improvement in surface quality up to 20 percent was found. Further he commented that surface quality improves more with increase in angle of oscillation than frequency of oscillation.

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H Ho Cheng [9] focuses on delamination at the hole bottom occurs in composite laminates like graphite epoxy laminates during the waterjet drilling process. For analysis of delamination he considered fracture mechanism with plate theory. Based on experimentation carried out, he developed a model to decide the optimum water pressure for no delamination.

Fig.1Waterjet induced delamination at exit

He explained the mechanism of lamination by commenting that during water jet drilling the thrust jet force acting perpendicular to lamellae showed a bend in response. As the jet moves to the end portion of the hole the uncut thickness reduces resulting in decrease in resistance to deformation. At particular point the deformation occurs that interlinear bond strength breaks and delamination occurs and this happens before the laminate is completely pierced.Futher he commented that water pressure and jet diameter plays important role in deciding the delamination in composite laminates. In the end he concluded that the water jet force is a significant factor in deciding the delamination.

P. S. Jain and A. A. Shaikh [10] studied the various processes for cutting the polymer matrix composites like cotton fiber polyester composites. In this study they compared the processes like CO2 Laser, water jet cutting and diamond saw cutting with their process parameters. Based on experimentation carried out they concluded that laser cutting is better over water jet and diamond saw cutting because of fiber pull out in diamond saw and fiber curling and pulling out in multiple directions which is observed in water jet cutting. Regarding water jet cutting they commented that fibers may be affected by water moisture.

III.CONCLUSION

Abrasive Waterjet Machining is most suitable method for machining the composite materials because of some advantages like lack of thermal damage, low tool wear, small cutting forces and high productivity as compare to other conventional and non-conventional process. Also problem of burr formation and delamination is almost negligible in abrasive waterjet machining. The most significant process parameters are transvers speed, standoff distance, abrasive water pressure and mass flow rate.

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