Composite Materials -Abrasive Water Jet Machining

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ABSTRACT

The research work and development of composites and advanced ceramics has a variety of manufacturing challenges. Also it is well-known that many of these materials cannot be effectively machined by conventional machining methods. Apart from huge investments and economy concern, the process selection is based on the machined surface integrity. The high pressure waterjet with abrasive additives known as abrasive water jet (AWJ) can be used as an alternative to conventional processing and has been suggested for use in post mold shaping of composites and other hand to cut materials very effectively. The research works on abrasive water jet cutting is discussed in this paper. Omni directional cutting potential as well as minimal thermal and mechanical loading are few advantages. Composite materials are widely used in various applications like space, aircraft, marine, architectural and automobile sector because of their superior physical, chemical and mechanical properties even though they are a little bit expensive.

Keywords:
Composites, Water jet, Omni-directional, Abrasives, Applications of Composites.

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 nonconventional 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. The abrasive 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 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

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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.

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. 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. METHODOLOGY

Design of Experiments (DOE) techniques accommodates the designers to determine simultaneously the individual and interactive effects of many factors that could affect the output results in any design. DOE also provides a full insight of interaction between design elements; therefore, it helps turn any standard design into a robust one. Simply put, DOE helps to pin point the sensitive parts and sensitive areas in designs that cause problems in Yield. Designers are then able to fix these problems and produce robust and higher yield designs prior going into production. The Response Surface Methodology (RSM) emerged in the 1950s within the context of Chemical Engineering in construction of empirical models which enables to find useful statistical relationships between all the variables making up a system. This methodology is based on experimental design with the final goal of evaluating optimal functioning of industrial facilities, using minimum experimental effort. These methods are used to examine the relationship between one or more response variables and a set of quantitative experimental variables or factors. Here, the inputs are called factors or variables and the outputs represent the response that generates the system under the causal action of the factors. Analysis of Variance (ANOVA): Analysis of Variance (ANOVA) is a powerful analyzing tool to identify which are the most significant factors and it's (%)

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percentage contribution among all control factors for each of machining response. It calculates variations about mean ANOVA results for the each response. Based on F-value (Significance factor value) important parameters can be identified. Table 5 and Table 6 are ANOVA Table obtained by Minitab 16 software. ANOVA Table contain Degree of freedom (DF), Sum of Squares (SS), Mean squares (MS), Significant Factor ratio (F Ratio), Probability (P) and calculated percentage contribution.

IV. TECHNIQUES USED FOR CUTTING COMPOSITES MATERIALS

IV.I. Water jet

In water jet machining, materials are removed by the impingement of a continuous stream of high-energy water beads. The machined chips are flushed away by the water. As in conventional machining tools, the water jet exerts machining force on the workpiece during the cutting process. This force is transmitted by the water beads causing the cut. The direction of the force is given predominantly by the attack angle of the water jet and is insignificantly affected by the tail flow beyond the cut.

IV.II. Abrasive water jet

Abrasive water jet cutting technology uses a jet of high pressure and velocity water and abrasive slurry to cut the target material by means of erosion. The impact of single solid particles is the basic event in the material removal by abrasive water jets.
In previous investigations, it has been found that three cutting zones exist in the processing of ductile and brittle materials under abrasive water jets, that is the primary cutting zone at shallow angles of attack, the primary cutting zone at large angles of attack, and the jet upward deflection zone. The attack angle is defined as the angle between the initial jet direction and the particle cutting direction at the point of attack.

IV.III. Laser cutting

The three essential components of a laser-cutting machine are laser medium, excitation source and the optical resonator. The excitation source drives the atom, ions or molecules of the laser medium to a situation where there is an excess of those at high energy level over those at a low level. This inversion of the normal thermodynamic population distribution leads to laser action: an excited member of the medium undergoing a transition from high to low energy will emit a photon, which in turn stimulates further emission, perfectly in phase, and at the same wavelength, from the other ex-cited members of the medium. The radiation is thus rapidly amplified; the role of the optical resonator is to direct and control the radiation by allowing an appro-priate fraction to be bled off as a near-parallel beam while the remainder is circulated within the cavity to maintain laser action. The output is monochromatic, usually with high spatial and temporal coherence. CO_2 laser was used for cutting composites, the laser action results from electric discharge excitation of a low-pres-sure gas mixture containing carbon dioxide. The beam is invisible, having a wavelength k lying in a far infrared at k ¼ 10:6 lm. the cutting process is based on location of beam focus at the surface of the (moving) workpiece, and provision of a jet of gas coaxial with the laser beam cuts the composite.

V.BACKGROUND

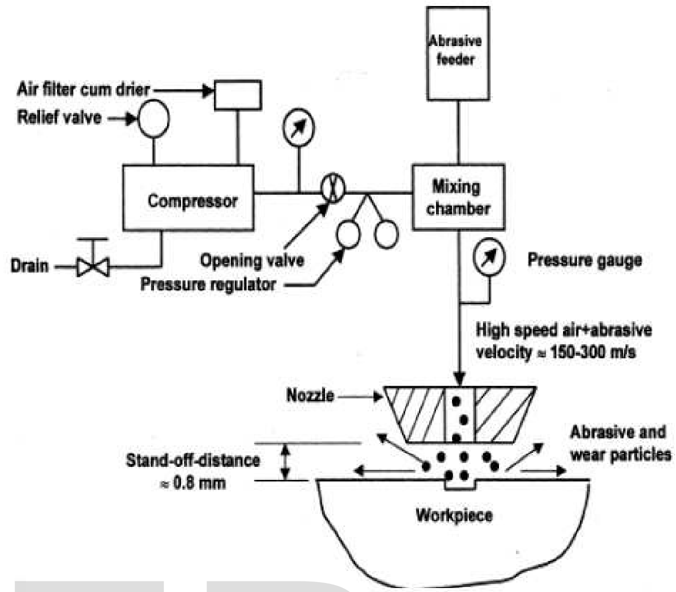

Fig 1: Schematic Diagram of AJM

This novel technology was first initiated by Franz to cut laminated paper tubes in 1968 and was first introduced as a commercial system in 1983... In the 1980s garnet abrasive was added to the water stream and the abrasive jet was born. In the early 1990s, water jet pioneer Dr. John Olsen began to explore the concept of abrasive jet cutting as a practical alternative for traditional machine shops. His end goal was to develop a system that could eliminate the noise, dust and expertise demanded by abrasive jets at that time. In the last two decades, an extensive deal of research and development in AJM is conducted. Based on the extensive literature review of AJM Process the works on this can be classified based on the performance measure considered in to Four different categories, namely Experimental Modeling, Analytical modeling, Optimization modeling, Hybrid modeling.

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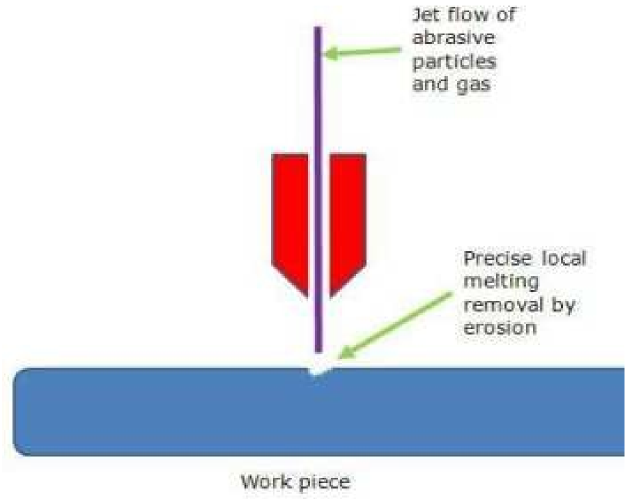

Fig 2: Metal Removal by Erosion

VI.CONCLUSION

An extensive review of the research and development in the AJM has been conducted in this paper. It was shown that AJM process is receiving more and more attention in the machining areas, particularly for the processing of difficult-to-cut materials. Its unique advantages over other conventional and un-conventional methods make it a new choice in the machining industry. A brief review of the Experimental modelling was conducted in the fourth section of this paper. It was followed by the Analysis of various parameters on MRR, analytical modelling are reviewed in detail. The Optimization modelling, Hydride modelling are discussed later. While these investigations show a good understanding of the cutting performance and the associated science, most of the results are for particular Cutting conditions and materials. The new technologies for modelling like Simulation, Taguchi approach, etc. are discussed. To enhance the cutting performance, number of new techniques have been explored. These models were developed using an AJM erosion mechanism, fracture mechanics and energy conversation approach. Most of these models are limited to particular cutting conditions and target materials. Also, they have a complex mathematical expression which is difficult for practical use. Some of them include unknown factors needed to be determined by other research. It is concluded that more experimental work is required to fully understand the relationship between important AJM parameters, namely Air pressure, nozzle size and shape, abrasive mass flow rates and process output in greater detail for aluminum, brass, cast iron, ceramics, copper, composites, granite, mild steel, stainless steel and titanium as the right choice of process parameters is very important for good cutting performance. As the Analyzing and modelling of effect of process parameters are not projected completely with complete optimization by advanced optimization techniques. Extended research works are required to study, experimentation and modelling of various parameters by advanced Analysis and Modelling techniques, the effect of parameters on AJM, Kerf characteristics. In order to correctly select the process parameters, reliable predictive mathematical models can be developed for the depth of cut in the AJM process of Various Metals. There is much scope of research in the AJM which can be performed by changing the nozzle design, nozzle pressure, SOD, etc. and Comparing the effect of various parameters on MRR on various metals like composites, ceramics, by improving the Kerf Characteristics, Integration of AJM with CNC, Model comparison, etc. The Optimized models can be developed by using various optimization techniques, and also the surface characteristic measurements are yet to be performed.

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 andmass flow rate.

VII.ACKNOWLEDGMENT

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VIII.REFERENCES

[1] Mahesh Haldankar "Experimental and FEA of particle impact erosion for polymer composites" International Journal of Mechanical and Production Engineering, ISSN: 2320-2092 vol.1, issue-5, Nov.2013

[2] A Alberdi "Composite cutting with abrasive water jet" Proceedings of 5th Manufacturing Engineering Society International Conference, Zaragoza, June 2013

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

[4] 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

[5] Izzet Karakurt "Analysis of kerf angle of the granite machined by abrasive waterjet" Indian Journal of Engineering and Materials Science vol.18,12/2011,pp.435-442

[6] Izzet Karakurt and Gokhan Aydin "A Machinability Study of Granite Using abrasive Waterjet Cutting Technology" Gazi Unversity Journal of Science GU J Sci 24(1):143-151(2011).

[7] D Babu Rao "Water Jet Cutter: An Efficient Tool for Composite Product Development" National Conference on Scientific Achievements of SC & ST
Scientists & Technologists 14–16 April 2009, National Aerospace Laboratories, Bangalore-17.

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[8] E Leema "Study of Cutting Fiber-Reinforced Composites by Using Abrasive Waterjet with Cutting head Oscillation" Composite Structures, vol.55/1-4(2002), pp297-303.

[9] H Ho-Cheng "A Failure Analysis of Water Jet Drilling in Composite Laminate" Int.J.March Tools Manufact. Vol.30, no.3, pp 423-429, 1990.

[10] 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

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