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Original Research Article

ANALYSIS THE MACHINING EFFECT ON CFRP MATERIAL USING AJM

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Abstract - An effort evaluates the advantages offered by non-conventional machining for the development of composite fiber reinforced polymer material (CFRP). Although, abrasive jet Machining (AJM) is highly efficient in the machining of advanced composite materials due to their unique characteristics, efficient machining of sandwich structures by AJM needs many challenges to be addressed. This work presents various issues observed in AJM on CFRP composite materials, and the effects of AJM are analyzed in processing these composite materials. In the AJM process used drilling experiment was done on glass as the work piece and aluminum oxide (Al_2O_3) as abrasive powder. The effect of Overcut (OC) and Material removal rate (MRR) of glass material was finding by using L_9 orthogonal array based on Taguchi design and considering the, pressure of air and stand-off-distance are control parameter.

Key Words:-CFRP, Abrasive jetmachining, Taguchi Method, ANOVA analysis.

Introduction: CFRP (Carbon Fiber Reinforced Polymer) is the super hero of the materials world. It is one of the strongest and most lightweight materials available on the market today. Carbon fiber is a synthetic material that offers a unique combination of qualities, high strength, high stiffness and low weight. Carbon fiber composites are about 3 times stronger and 5 times lighter than steel, and about 1.5 times lighter than aluminum. Together with the right binding systems, carbon fiber composites are also known for being extremely corrosion resistant and able to withstand high wear. Carbon fiber has been described as a fiber containing at least 90% carbon obtained by the controlled pyrolysis of appropriate fibers.

Carbon fibers are used in composites with a lightweight matrix. Carbon fiber composites are ideally suited to applications where strength, stiffness, lower weight, and outstanding fatigue characteristics are critical requirements. They

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also can be used in the occasion where chemical inertness and high damping characteristics are required. With increase in temperature, strength of carbon fiber decreases therefore new technologies are being developed to sustain the properties of carbon fiber at elevated temperatures, in result to which, CFRP could be used where machine components are prone to high thermal environment such as piston, cams, piston rings, bearings, bushes. In general, it is seen that the higher the tensile strength of the organic compound the higher is the tenacity of the carbon fiber. Tensile strength and modulus are significantly improved by carbonization under strain when moderate stabilization is used. Overall, the strength of a carbon fiber depends on the type of organic compound, the processing conditions, heat treatment temperature and the presence of flaws and defects. Carbon fibers are very brittle. The layers in the fibers are formed by strong covalent bonds. The sheet-like aggregations allow easy crack propagation. On bending, the fiber fails at very low strain.

Problem Description: Composites are combinations of two materials in which one of the materials, called the reinforcing phase, are in the form of fibers, sheets, or particles, and are embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile, or tough, material. If the composite is machined correctly, it combines the strength of the reinforcement with the toughness of desirable properties not available in any conventional machining. To avoid this problem use the non-conventional machine and analysis the effect on CFRP material.

Not only developing of innovative shape design of product and its component but also new exotic alloy material creates lots of pressure on conventional machining. AJM was not available in our production laboratory. So there was much difficulty to machining of glass, ceramic and brittle material, and composites material. So the composite material can be machine by AJM process.

Fatigue is weakening of the material due to cyclic loading and is difficult to predict and to validate because of the inhomogeneous structure of composite materials, and because failure often is sudden and without prior notice. If fatigue is critical is very much dependent on the type of loading and the design of the structure. It is therefore important to have fatigue in mind when designing in composite materials, to minimize its impact and the risk it occurs.

Fabrication of CFRP

The term carbon fiber is used to describe one of the following three products, material composed of fine carbon fibers, carbon-reinforced plastic, or the trademarked carbon fiber insulation. But, while carbon fiber fabricators are involved in the creation of all three products, basic carbon fiber fabrication refers to the manufacture of the ultra-thin carbon fibers. Reinforcement is combining or joining two layers of similar or dissimilar material with the help of reinforcingagent. Epoxy resin is used as matrix for fabrication of CFRP. There are different materials required for the fabrication of CFRP.

Materials required for CFRP

1. Carbon Fiber Cloth
2. Epoxy Resin
3. Hardener
4. Accelerator

In general, the top surface of the glass fiber skin layer will be covered by a layer to protect from the damage caused by the red hot chips spill onto the top surface in the conventional machining operations. Laying the protective layer before machining, peeling it after machining and cleaning the top skin increases the manufacturing cost drastically, and also increases the down time. However, abrasive jet has generated damage free surface on the top skin of the glass fiber material after machining -

both in the cutting and radial drilling operations. This encouraging result contributes towards reduction of the manufacturing cost of unit component and down time.

It is the main part of fabrication system which is made in the production laboratory. Before goes to fabrication, different component were designed in the catia software, which is shown in the figure 1.

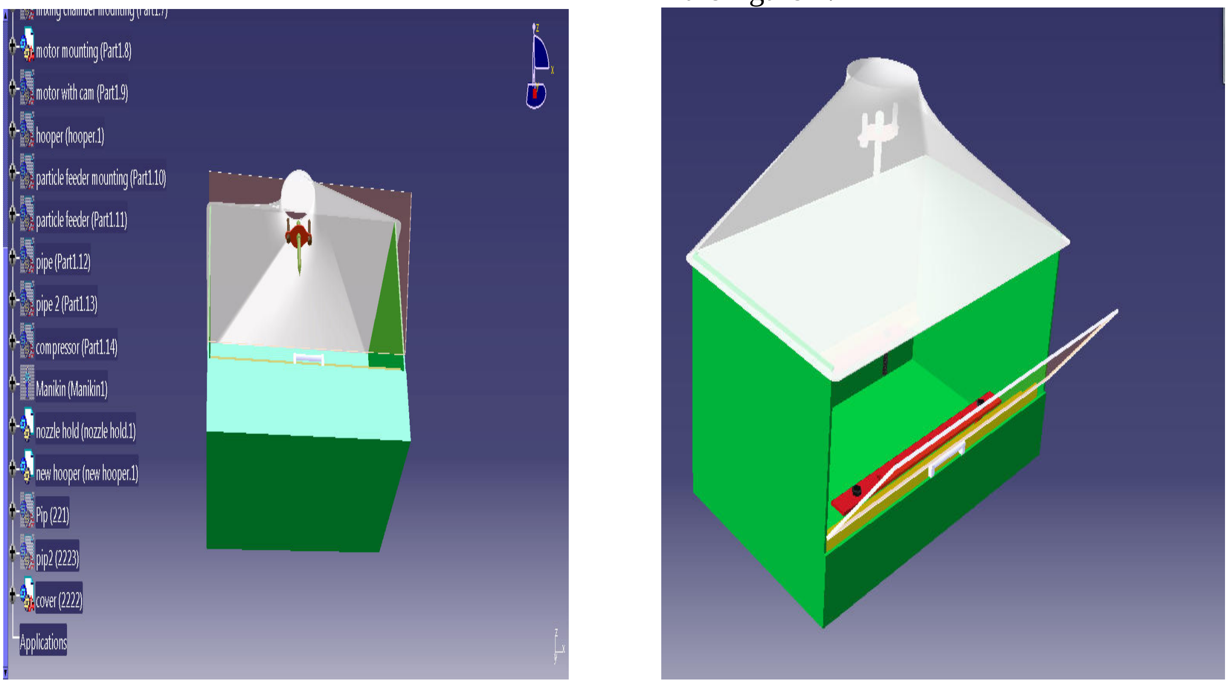

Fig.1. Modeled view of working chamber

Taguchi design: Taguchi design is a statistical method, was discovered by Dr. Genichi Taguchi of japan. It is a robust parameter design, used for designing experiments to calculate how different parameters affect the mean and variance of a process performance characteristic [3]. It is mainly focusing on minimizing variation and sensitivity to noise. It provides an efficient method for designing products and process that operates smoothly, consistently and optimally over a variety of conditions. These methods consist of two, three, four, five, and mixed-level fractional factorial designs. To determine which factors most affect product quality, it allows only the collection of the necessary data thus saving time and resources. Taguchi gives orthogonal array design which reduces the experiment run.

The experimental data are analyzed in the Taguchi method and finding the best response under optimum condition. It is used for estimating the individual factor contribution and also their interaction in the process response. It generates and analysis the main effect plot and interaction plot for signal to noise ratio, means, and standard deviations. It also produces residual plot on histogram, normal plot, and residual versus fits, residual versus order.

By applying the Taguchi Parameter Design techniques, improve the performances of product and process designs in the following ways:

- Improve consistency of performance and save cost
- Build insensitivity (Robustness) towards the uncontrollable factors

In this experiment, a two factor and three levels setup (Table1) is chosen with a total of nine numbers of experiments to be conducted and hence L_9 Orthogonal Array (OA) was chosen.

Table 1 Machining parameters and their level

Factor	Symbol	Unit	Level		
			Level 1	Level 2	Level 3
Stand of distance	(SOD)	mm	0.6	0.8	1.0
Pressure	(P)	bar	2	4	6

Table 2 Design of observation table

Run no	SOD (mm)	P (bar)	Weight of work piece (gm)		Cavity dia (mm)	MRR (mm^3/min)
			Initial weight	Final weight		
1	0.6	2	65.679	65.675	2.265	1.667
2	0.6	4	65.674	65.665	2.365	3.750
3	0.6	6	65.665	65.648	2.875	7.083
4	0.8	2	65.729	65.723	2.290	2.500
5	0.8	4	65.723	65.709	2.613	5.833
6	0.8	6	65.709	65.684	3.015	10.417
7	1.0	2	65.764	65.759	2.320	2.083
8	1.0	4	65.759	65.748	2.413	4.583
9	1.0	6	65.748	65.729	2.915	7.917

Influences of MRR: The observed values of MRR are shown in Table. During the process of AJM, the influence of machining parameter like SOD and pressure has significant effect on MRR as shown in main effect plot for MRR in fig 2. The pressure (p) is directly proportional to MRR in the range of 2 to 6 bar.

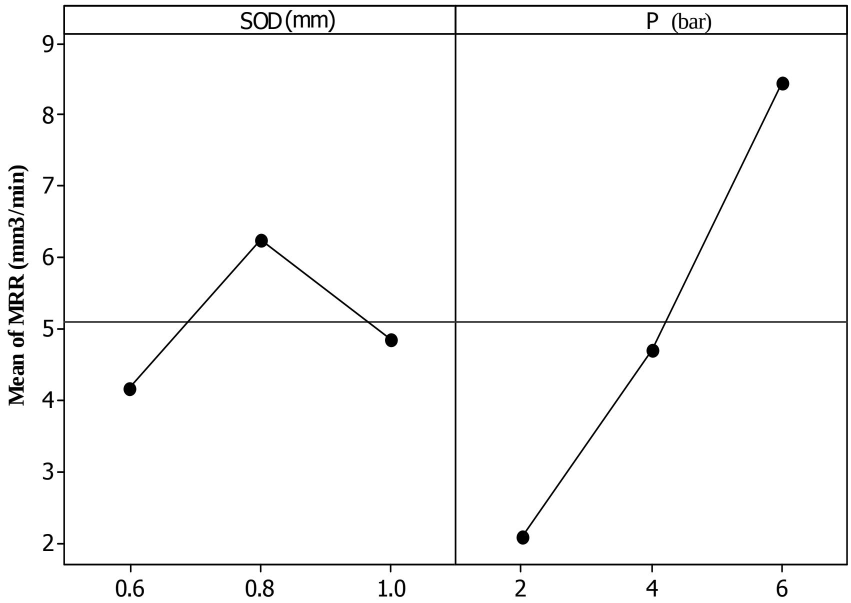

Fig 2 Main effect plot for mean of MRR

This is expected because an increase pressure produces strong kinetic energy which produces the higher temperature, causing more material to erode from the work piece. The other factor SOD does not influence much as compared to pressure. It is clearly indicated from the above fig.5.1 at SOD 0.8mm the MRR was maximum. It decreases with increase in SOD and also decreases with decrease in SOD. It suggests that the effect of one factor is dependent upon another factor.

Conclusions: By addition of long chain polymers to the water, the divergence of the jet can be reduced significantly by that, uniform bottom skin surface can be expected. By effective design of the CFRP, the efficiency can be improved, and divergence of the jet can be reduced, which helps in achieving uniform bottom skin surface that is near to the quality of the Abrasive jet cut top skin. Abrasive jet machining can be made to eliminate the no uniform surface issue on the skin of the CFRP structure.

The AJM is can be used for drilling and milling of glass plates or other brittle materials. By feeding different type of programming on controller, various complicated shapes are machined. Experimental work was done by considering SOD and Pressure are machining parameter to study MRR and OC. For MRR both SOD and pressure are significant factor and for OC only pressure is significant. MRR is increases with increase in pressure. For increase in SOD firstly MRR increases then it is remain constant after that it is decreases.

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