International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 3, March 2016 | ISSN: 2394-4404

Analysing The Factors Affecting Surface Roughness In Abrasive Jet Machining

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Abstract: Nowadays increase in the need of light and high strength materials in the automobile and aerospace sectors leads to the development of composite materials. It is difficult to machine the composite materials using conventional machining process because of the heterogeneous property of the composite material structure. Moreover the cutting tool used for the machining process may also get affected because of the nature of the composite materials. The above problems lead to the invention of unconventional machining process to machine composite materials. Abrasive Jet Machining (AJM) and Abrasive Water Jet Machining (AWJM) are such processes employed for machining composite materials. Though AJM and AWJM have many advantages the main problem in this machining process is surface roughness of the machined surface. This paper studies about the process parameters which involves in determining the surface roughness of the machined surface.

I. INTRODUCTION

Machining of composite materials by traditional machining process is a tedious method. Because of the heterogeneous combination of matrix resin and fibre, the cutting tool encounters varying resistance due to inter layered hard abrasive fibres and softer resin which puts stress on tool. Overheating of the cutting or drilling site can heat the resin above glass transition temperature and damage locally. Hence this makes the machining of composite materials difficult.

Challenges during conventional machining of composites:

- ✓ Machining of composite materials creates discontinuity in the fibre and it affects the performance of the machining part.
- ✓ Machining exposes fibres to chemicals and moisture.
- ✓ It is difficult to attain dimensional accuracy during the cutting of composites because of differences in the coefficient of thermal expansion ratio between fibre and matrix resin.
- ✓ Tool life is usually shorter because of the abrasive nature of the composite.
- ✓ Obtaining a smooth cut edge is difficult with composites, especially with aramid composites.
- ✓ Machining of composites causes delamination at the cut edges of continuous composites.

NEED OF ABRASIVE JET MACHINING

In order to overcome the above mentioned difficulties, Water jet machining (WJM) or abrasive water jet machining (AWJM) process is carried out. Since water jet method is low temperature, controlled erosion that do not introduce any heat or heat reheated stress to material and is unaffected by heterogeneity of composite materials. To withstand erosive effect of high velocity, orifice is made from low wear diamond or sapphire. To withstand high wear rate by the movement of abrasive particles the Focusing tube is made up of tungsten carbide. Moreover abrasive jet machining processes are free from Heat Affected Zone (HAZ). Commonly occurring

International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 3, March 2016
ISSN: 2394-4404

problems such as crystallization, Hardening, edge defects, reduction in weldability and machinability. *Merits of WJM & AWJM*

- ✓ No thermal distortion
- ✓ High machining performance
- ✓ High flexibility
- ✓ Small cutting forces.

II. PROCESS PARAMETERS

Some common process parameters affects the quality and nature of the machined surface based upon its application. Surface roughness is one such parameter which determines the nature and quality of the machined surface. Usually Surface roughness values are determined according to the application of the machined surface. Surface roughness of the machined surface is normally affected by the following factors,

- ✓ Kerf characteristics
- ✓ Mass flow rate
- ✓ Size of reinforced particle
- ✓ Time and cutting speed
- ✓ Traverse speed
- ✓ Feed rate

A. KERF CHARACTERISTICS

This paper investigates on the kerf taper angle, an important cutting performance generated by abrasive water jet machining. Layered composites are difficult to machine as it is heterogeneous due to matrix properties and fiber orientation. The experiment is conducted on two types of laminated composites such as glass epoxy and graphite epoxy. The process parameters that are considered this process are

- ✓ Water pressure
- ✓ Standoff distance
- ✓ Abrasive mass flow rate
- ✓ Traverse speed

Increase of water pressure, decreases the taper angle;

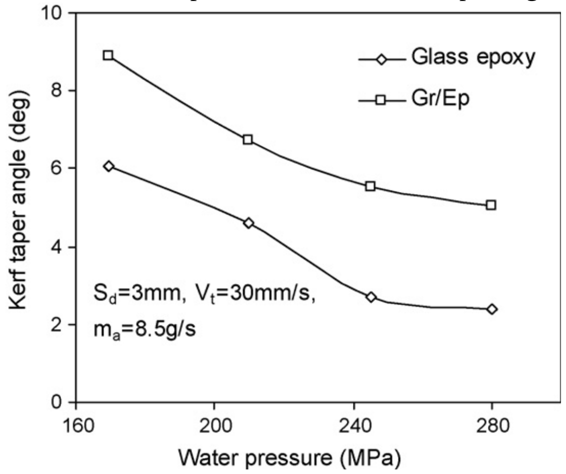

Figure 1: Effect of water pressure on kerf taper angle

When water pressure is increased, jet kinetic energy increases that leads to a high momentum transfer of abrasive particles, generating a wider bottom kerf. Hence, difference in top and bottom kerf width is reduced. Increase of traverse speed, increases kerf taper angle;

Increase of kerf taper angle is direct measure of exposure time, at higher speed, less overlapping of jet on the target material occurs which leads to increased taper angle.

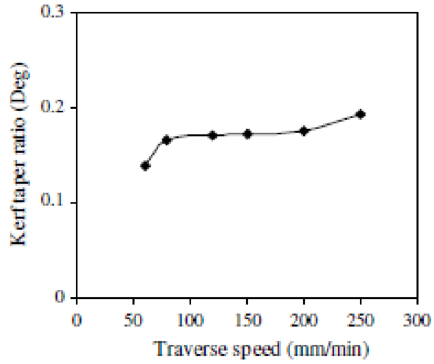

Figure 2: Effect of traverse speed on kerf ratio

Increase in standoff distance, increases the kerf taper angle within the range of 2-5 mm.

With the increased standoff distance, the jet starts to diverge losing its coherence therby reducing effective cutting area that directly affects kerf taper angle.

B. THERMALLY ENHANCED ABRASIVE JET MACHINING

This work explains thermally enhanced abrasive water jet machining process to improve the machining capabilities of conventional abrasive water machining process. It is done by heating the work by an external heat source. It is carried out by adding an oxy-acetylene gas welding setup as external heat source to machine setup which heats the work locally.

The usage of the thermally enhanced machining (TEM) reduces yield strength, hardness and strain hardening of work piece. Deformation behavior of hard to machine materials changes to allow plastic deformation. Thus enables the difficult to machine materials to be machined easily along with low energy requirement, which increases.

C. EFFECT OF MASS FLOW RATE

With an increase in abrasive mass flow rate, the kerf taper angle seems to decrease insignificantly.

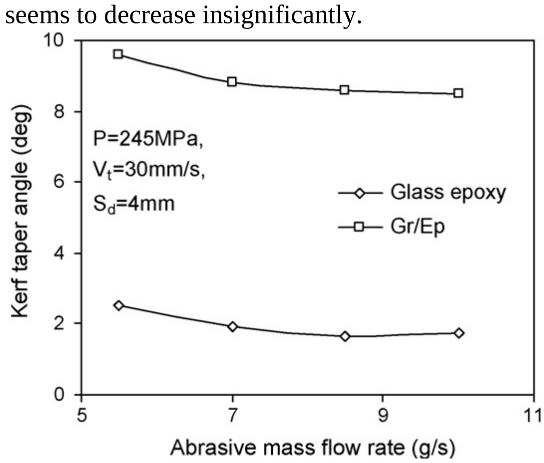

Figure 3: Effect of abrasive mass flow rate on kerf taper angle

The optimum condition to be operated in order to achieve maximum surface finish is to have high water pressure, low traverse speed and short standoff distance

D. EFFECT OF REINFORCED PARTICLES SIZE

Reinforced particles in Metal Matrix Composites (MMC) are much smaller than abrasive particle size.

Effect of reinforced particles on surface finish is negligible compared to effect of abrasive particles. Reinforced particles in Metal Matrix Composites (MMC) size equal the abrasive particle size.

It is difficult to remove reinforcement particle and It causes indentation while removing.

Reinforced particles in Metal Matrix Composites (MMC) are much greater than the abrasive particle size.

In this case, material removal is slow but smoother surface can be achieved.

E. EFFECT OF TIME & CUTTING SPEED

Time take to remove the material per unit area decreases with increase in cutting speed.

At higher speed, lower depth of cut is achieved but surface roughness and striations increases at higher cutting speed.

F. EFFECT OF FLOW RATE

Increasing the flow rate increases the removal rate because high quantity of abrasive particles are available for cutting. However as the powder flow rate is increasing, the mass fraction of abrasives used in the jet is also increasing. As the mass fraction increases, the abrasive velocity decreases, thus reduces the removal rate. Hence, surface roughness increases with increase in cutting speed and decrease in abrasive material flow rate.

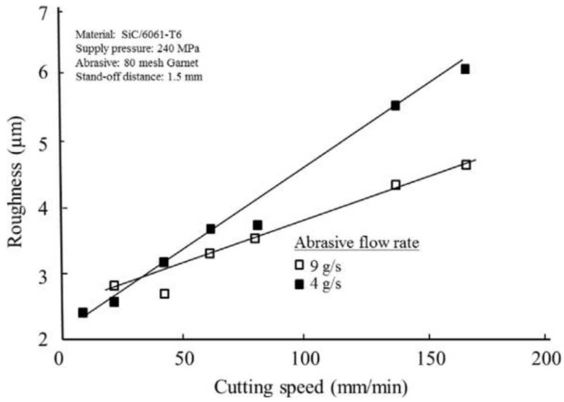

Figure 4: Effect of cutting speed on the average surface roughness for different flow rates of abrasive

G. EFFECT OF TRAVERSE SPEED

Experimental results indicate that the traverse speed of jet is an important parameter on surface roughness. It is observed that traverse speed increases results in the increase of kerf taper ratio and surface roughness. Low jet traverse speed not only results in high material removal rate but also in high surface waviness. From the experimental results, increase in traverse speed causes a constant increase in the surface roughness. This may be anticipated as increasing traverse speed permits less overlap machining action and fewer abrasive particles to impinge on the surface, increasing the roughness of the surface.

As the traverse speed increases, the Abrasive Jet Machining cuts narrower kerf width with a greater kerf taper ratio. This is because of traverse speed of abrasive water jet permits fewer abrasives to strike on the jet target and hence generate narrower slot.

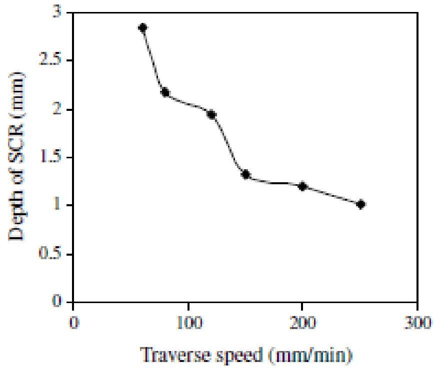

Figure 5: Depth of SCR for different traverse speed

With increase in cutting speed, smooth cutting region depth of sample decreases. At higher traverse speed, SCR decreases to about 25% of total cutting surface area while this ratio is about 60% at low traverse speed.

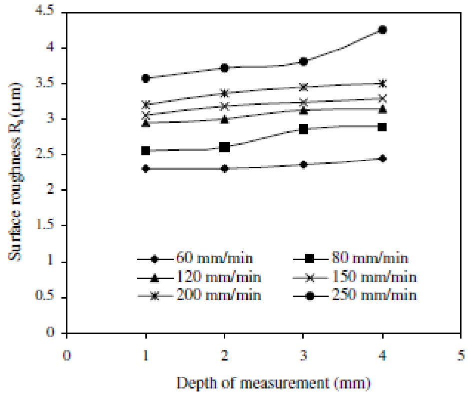

Figure 6: Surface roughness Vs depth of measurement for different speed

H. EFFECT OF FEED RATE

It is found that surface quality deteriorates as the depth of cut gets deeper. Surface roughness gradually reaches its maximum value when the cut surface depth reached to the thickness of material. As the depth of cut increases, the jet loses its energy due to the jet material interaction, mutual particles, etc. This results in rougher surface characteristics at lower parts of cut surface. Higher reduction in feed rate results in limited improvement in surface quality.

III. CONCLUSION

Thus the major process parameters that affect the surface roughness of the machined composite layer by abrasive jet

ISSN: 2394-4404

machining process are discussed. The effect of various parameters on the surface roughness of the material is studied and optimum conditions to achieve maximum surface finish is analysed.

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