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# EXPERIMENTAL STUDY ON MANUFACTURING COMPLEX PARTS FROM COMPOSITE MATERIALS USING WATER JET CUTTING

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***Abstract:*** *The paper presents an experimental study on manufacturing complex parts from multi-layer composite materials consisting of carbon fiber reinforced plastics (CFRP) using abrasive water jet cutting (AWJC) process. AWJC have some advantages, such as: no thermal distortion, high machining versatility and high flexibility. It is difficult to manufacture composite materials using conventional machining technologies. The main problems of conventional manufacturing are: tool wear, material delamination, high cutting forces and more. The experimental research proves that CFRP materials could be processed using AWJC processes at a good surface quality, good dimensional accuracy and a competitive cost.*

***Key words:*** abrasive water jet cutting, composite materials, CFRP, CNC manufacturing

## 1. INTRODUCTION

Composite materials consisting of carbon fiber reinforced plastics (CFRP) are being used for many applications because of their advantages, as compared to other materials. The main characteristics of CFRPs are: high strength to weight ratio, high modulus, high fracture toughness, corrosion and thermal resistance [1].

CFRP are used often in different areas, such as: space industry, automotive industry, aerospace industry or marine industry [1, 2].

Composite materials are difficult to machine using conventional technologies. The main problems when these materials are processed are: tool wear, material delamination, high cutting forces and more [2, 3].

Abrasive water jet cutting (AWJC) process receives much attention from the industry because of the beneficial characteristics of material removal. The main advantages of this cutting technique are: good quality of the surfaces, good dimensional accuracy, competitive cost, could be cut “difficult-to-cut” materials without inducing thermal stresses [4].

However, cutting CFRP using this technique involves several challenges. The most important problem is material delamination due to the high velocity impact of the jet [4, 5].

## 2. AWJC TECHNIQUE

The Abrasive Water Jet Cutting is the generic name for the whole group of techniques which are using water jet as a cutting energy to remove material from the work piece. In all cases, the water jet cutting uses pressurized water, which acts either by itself at a very high pressure, or in connection with the erosion of the abrasive particles, added into the water jet [6, 7].

Figure 1 illustrates the main components of the AWJ head, including the mixing tube, where the pressurized water jet is mixed together with abrasive particles, which are necessary when cutting metals. The AWJ working principle is based on a very high pressure water jet, which takes the abrasive particles into the mixing chamber, in order to create a proper cutting device, a fluid cutting tool. When using abrasive grains, the water jet transfers its own kinetic energy to the abrasive particles. The impact of this water jet carrying the abrasive particles, onto the work piece, leads to the mechanical erosion and material removal from the work piece [6, 7].

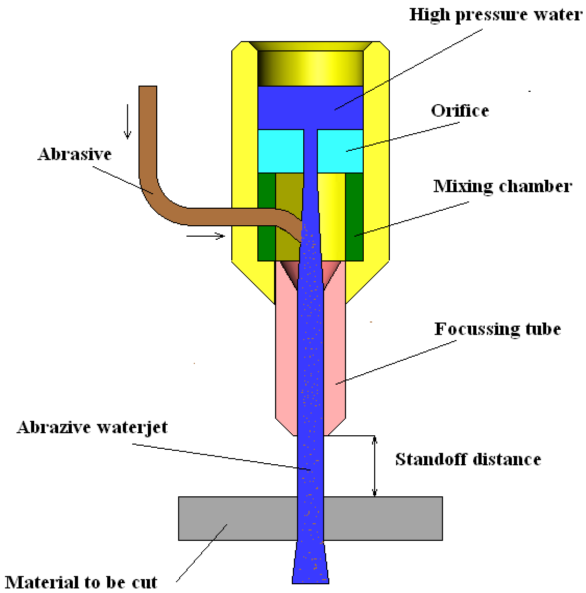


**Fig. 1.** AWJ head's working principles [6]

## 3. EXPERIMENTAL STUDY

Using CAD software the 3D model of the test part was designed. The test part has a 2D complex shape, it is looking like a gear but it doesn't have the involute gear profile.

Starting from this 3D model was generated the 2D cutting sketch. The 3D model and the 2D sketch are illustrated in next figure:

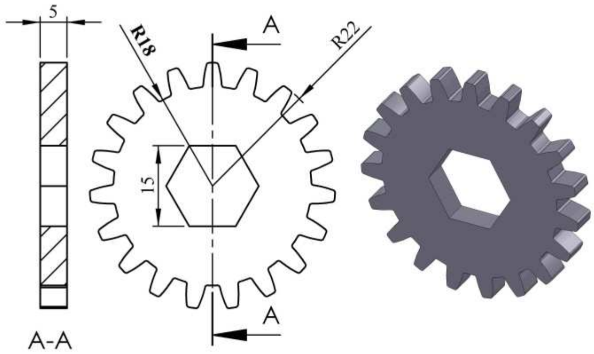


**Fig. 2**. The test part

The material used in this study is a multi-layer composite materials consisting of carbon fiber reinforced plastics: a biaxial balanced carbon fibber material, of 200 g/m$^2$, plain-weave 5 layers in epoxy resin, type Epiphen RE4020 for the matrix produced by Bostic Company. In the case of the material, 50% of filaments are orientated along the longitudinal direction, while the remaining of 50% is oriented along the transverse direction [7].

The experimental research was made with the Abrasive Water Jet (AWJ) equipment, type *Omax 2626* (Figure 3). The equipment's main components are: the high pressure pump with an output pressure of 3.500 bar; an abrasive cutting head and abrasive delivery system; a numerical controller which controls the movements of the cutting head and the water tank [6, 7].


**Fig. 3.** AWJ equipment, Omax 2626

The 2D sketch was opened in the *Omax Layout* software. *Omax Layout* is drawing software developed for AWJC process. From the software the cutting quality Q5 was selected, in order to obtain a good surface quality and a high accuracy. (Figure 4)

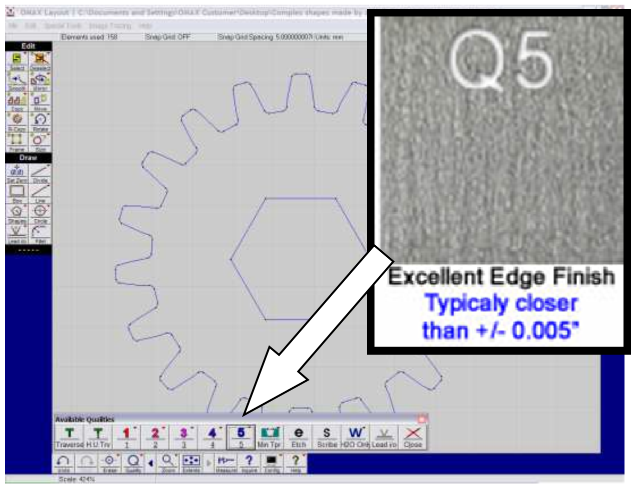


**Fig. 4.** The cutting quality Q5

The zero point was selected on the center of the part, because in this way it is easy to setup the machine.

Another step on process setup was choosing the lead In/Out. The lead In/Out was choose automatically within this application and was selected just the length of lead In of 15 mm, to avoid the material delamination on drilling point.

The *Omax Layout* software offers the possibility to simulate the cutting process. In figure 5 it is represented the jet path and the jet offset.

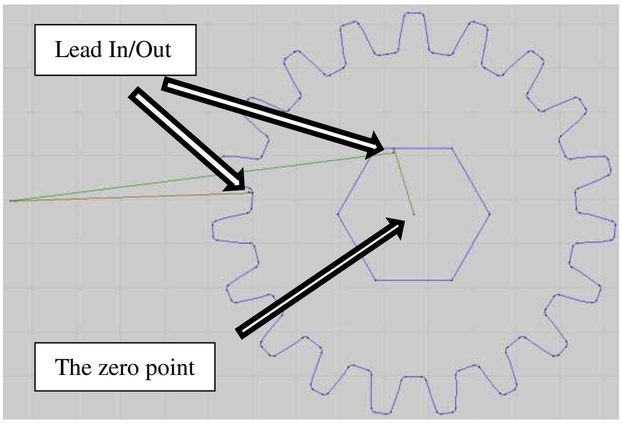


**Fig. 5.** Setting the zero point and Lead In/Out

The *Tool Path* made by using *Omax Layout* was imported onto Omax Make software, from where was selected also the material type (Carbon Fibre laminated with 550 Machinability), material thickness (5 mm) and were calculated al the process parameters.

For cutting the part were selected the following process parameters: cutting speed V= 300 mm/min; water pressure: P= 3500 bar; abrasive flow rate: $M_a$=0.45 Kg/min; abrasive size: 80 Mesh and standoff distance: $S_{od}$= 2 mm.

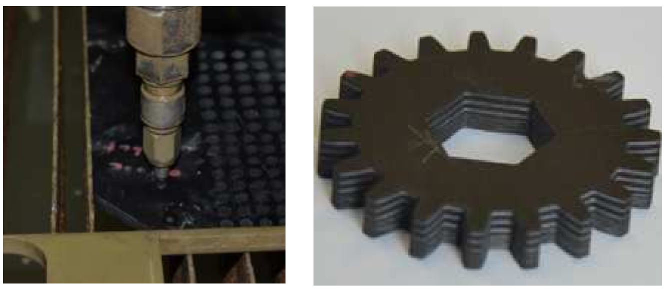

**Fig. 6.** The camping system and the test part

## 4. RESULTS AND DISCUTIOM

A Mitutoyo Surftest SJ-210 was used for measuring the surface roughness.

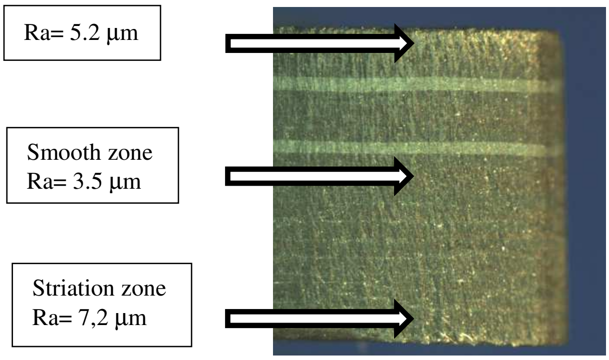


**Fig. 7.** The surface roughness

*Fig. 7. Process simulation*

Analyzing figure 7, the surface roughness of the initial damaged zone is Ra= 5.2 µm. For smooth zone was measured Ra= 3.5 µm and the biggest value for surface roughness was obtained on striation zone Ra= 7,2 µm.

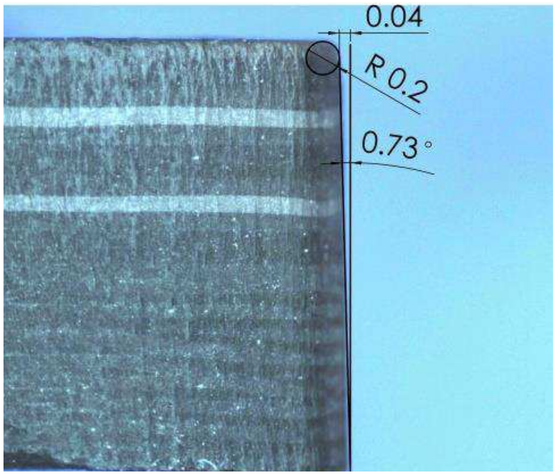


**Fig. 8.** The kerf geometry

After analyzing the test part a good dimensional accuracy of ±0.05 mm was obtained. Analyzing the kerf geometry (figure 8) was obtained: a cutting angle error of 0.04 mm, taper angle 0.73° and the top edge radius of 0.2 mm.

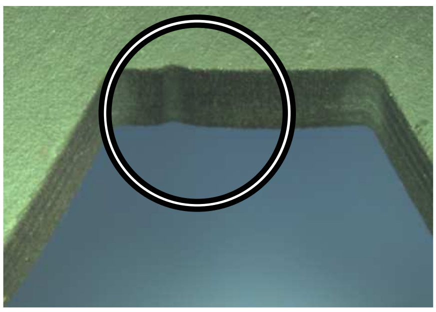

**Fig. 9.** The cutting start and end error

On the cutting "start" and "end" points was measured an over cut of 0.3x1.3 mm (figure 9). This error can be reduced by using proper starting and ending strategies.

## 5. CONCLUSION

A composite material was machined by AWJC processes. The experimental results show that, after cutting the complex part with this technique a good surface quality and good dimensional accuracy, was obtained.

After analyzing the test part was obtained a dimensional accuracy of ±0.05 (mm) a roughness Ra= 7,243 (µm).

The cutting surface was analyzed using a microscope and the conclusion is that the part doesn't have delamination and abrasive inclusions in the material mass. On the cutting "start" and "end" points was observed an over cut.

The paper points out that the AWJC is a viable solution for machining composite materials.

## 6. ACKNOWLEDGEMENT

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**Studiu experimental privind prelucarea pieselor cu formă complexă din material compozit prin tăiere cu jet de apă**

**Rezumat:** Lucrarea prezintă un studiu experimental privind prelucrarea prin tăiere cu jet de apă şi agent abraziv (AWJC) a pieselor complexe din materiale compozite armate cu fibră de carbon. AWJC se remarcă prin cateva avantaje, cum ar fi: flexibilitate crescută, actioneaza fară a incalzi materialul prelucrat şi fortele de prelucrare sunt scăzute. Prelucrarea materialelor compozite se dovedeşte a fi destul de dificilă prin utilizarea procedeelor de prelucrare clasice. Principalele probleme apărute in timpul prelucrarii sunt: uzura prematură a sculelor aşchietoare, delaminarea si incălzirea materialului prelucrat. Acest studiu experimental prezintă metodologia de lucru la prelucrarea materialelor compozite prin AWJC si caracteristicile de calitate ale pieselor prelucrate.

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