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COMPETITIVE 2D MACHINING USING THE WJC PROCESS

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Abstract: The paper presents results of the experimental research undertaken at the Technical University of Cluj-Napoca, in the field of Water Jet Cutting (AWJ). Complex 2D profiles in different materials could be cut using the AWJ process, with lowest costs, as compare to the traditional cutting methods. Both, metallic and non-metallic raw materials were cut. Besides cutting, the AWJ process was used for etching or scribing parts. Modern procedure of programming the optimal cutting speed is presented.

1. INTRODUCTION

Abrasive waterjet cutting (AWJ) has various distinct advantages over the other cutting technologies, such as no thermal distortion, high machining versatility, high flexibility and small cutting forces, and has been proven to be an effective technology for processing various engineering materials (1).

There are strong requirements within the manufacturing industry, to decrease the costs of the consumables and labor, but to provide efficient techniques to produce accurate parts in short time.

The range of materials used with new designed products is wide and more complex shapes are required from the customer's point of view. That is why non traditional machining technologies are having an increasing importance, in order to provide efficient methods to manufacture complex shapes in hard materials and sometimes in small volume production.

AWJ is the only solution for cutting complex profiles of the 2D decorative stone. For obtaining some better cutting surfaces, for elimination the cutting lines created through classical dislocation. Nowadays AWJ has developed more and more in comparison with the classical methods through perforation – shooting or with diamond cables, the decorative stones cut through water jets method have a recoverable percent of 70% (3).

AWJ technology proves to be in a continuous development, using an abrasive jet can engrave and scribe different parts (6).

That is why we took into consideration the Abrasive Water Jet (AWJ) machining, mainly to be used for cutting complex 2D profiles.

2. TECHNOLOGICAL PARAMETERS OF AWJ

The Water Jet Cutting (AWJ) is the generic name for the whole group of techniques which use the water jet as the cutting energy to remove material from the work piece. It is mechanical energy and mechanical erosion, the process itself which removes small particles from the part to be machined.

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.

Figure 1 illustrates the main components of the AWJ head, including the mixing tube, where the pressurized water jet is mixed together with the abrasive particles, which are necessary when cutting metals.

The AWJ working principle is based on the very high pressure water jet, which takes the abrasive particles in the mixing chamber, in order to create a proper cutting device, a fluid cutting tool.

When using abrasive grains, the water jet transfers its 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.

The most important process parameters are:

- Input parameters :
  - do orifice diameter (mm);
  - df focus tube diameter (mm);
  - Ma abrasive mass flow rate (Kg/min);
  - P water-jet pressure (Bar);
  - Sd stand-off distance (mm);
  - V traverse feed rate (mm/min);
  - φ impact angle (º);
- Output parameters:
  - H processing depth (mm);
  - Ta kerf taper angle (deg);
  - Ra surface roughness (μm);
  - t machining time (s).

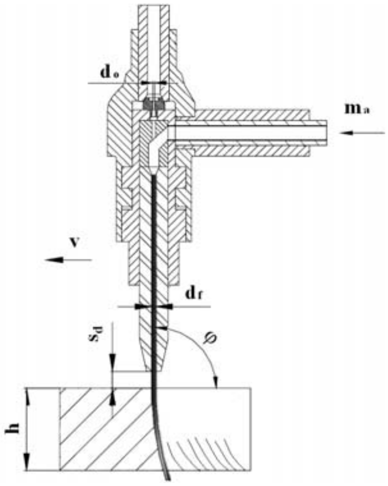

Fig. 1 Cutting head

AWJ process is strongly influenced by the water-jet pressure and traverse feed rate, the rest of the parameters have a small influence (1).

Depth of processing is strongly influenced by the water-jet pressure and traverse feed rate. By increasing the water-jet pressure, the processing depth increases and by increasing the traverse feed rate the processing depth decreases (2).

Surface roughness is another important output parameter. By increasing water-jet pressure, the surface roughness increases and by increasing the traverse feed rate the surface roughness decreases (2).

For decreased kerf taper angle it is recommended processing with a high water-jet pressure and a low traverse feed rate.

3. HOW TO USE AWJ FOR ETCING

With the almost limitless applications for use in cutting, the water-jet also is useful for etching or scribing part numbers and logos in parts (Fig.2). The operating principle of the engraving is moving the abrasive jet at a high speed so abrasive jet does not pierce the full material thickness. This allows us to save time and not to have another operation for stamping part numbers into parts.

Fig.2 Etched parts from marble and steel (6)

4. OPTIMAL CUTTING SPEED FOR AWJ

Software plays a key role in abrasive jet machining. In fact, it is only through software that precision abrasive jet machining truly is possible.

The abrasive jet is not a rigid tool that simply must be guided along a particular path to make a part. The jet bends and wobbles from side to side, and its shape is highly dependent upon the speed at which it is moved along the path.

Moving too slowly, the jet cuts a wider kerf at the bottom of the part than the top and also wastes precious machine time (Fig.3). Moving too quickly results in a wider kerf at the top of the part than the bottom, a poor surface finish, and the possibility that the jet may not cut through the material (Fig.4). Accelerating too hard at a corner causes the jet to kick back and damage the part.

Compensation for this behavior is essential to economic production of precise parts. This compensation requires that the software include a mathematical model of the cutting process.

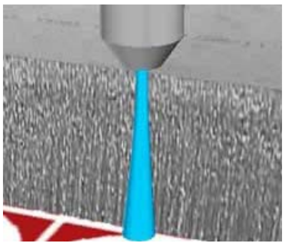

Fig.3 Low feed rate

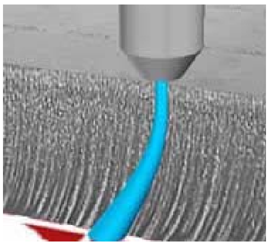

Fig. 4 High feed rate

Software used in AWJ process, containing a mathematic model that provides an ideal cutting feed rate, considering the machine parameters, surface quality, thickness and type of material. Researcher Zeng proposes a mathematic model for calculating this cutting feed rate. This formula is one of the best publicly available models of the cutting process.

$$V = \left(\frac{f_a \cdot M \cdot P^{1.594} \cdot d^{1.374} \cdot M_a^{0.343}}{163 \cdot Q \cdot H \cdot D_m^{0,618}} \right)^{1,15} \qquad (3);$$

Fig.5 Complex velocity profile (6)

Where: P is pressure of the waterjet; d is orifice diameter, Ma is abrasive flow rate, fa is abrasive factor, Q is quality, H is material thickness, dm is mixing tube diameter, V is traverse speed and M is machinability of material.

The cutting model besides providing ideal cutting speed, it anticipates the effects of the jet speed and adjusts the jet motion to make the part to a far greater accuracy in a given time.

In figure 5 is plotted the complex velocity profile generated by a cutting model in the cutting process. The blue and red indicate the areas where the speed is reduced, and the white areas where uses are given a higher speed.

Today, the human part programmer need not consider all these factors by hand to choose an optimum speed to move at every point along the path. He simply defines the part geometry and the quality of part that he requires.

Software then generates the tool-path including the proper speeds at every point along the path required to achieve the specified part quality in the minimum time.

Programming and operation of AWJ machine Omax 2626 is made with a CAD/CAM software package (Fig.6).

The *Omax Layout* software represents the CAD component, which is used to do the sketch 2D drawing, or to import the drawing from another CAD system, within a *.DXF file format.

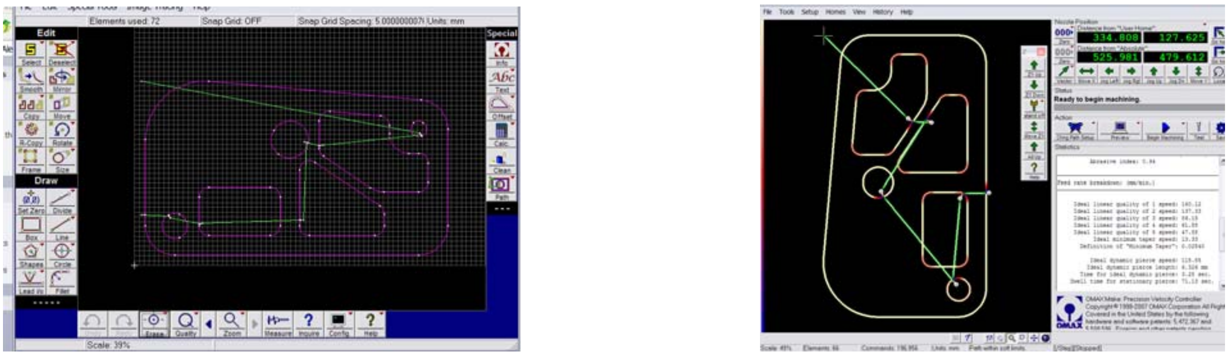

Fig.6 The Omax software: Omax Layout and Omax Make

The cutting head's movements could be automatically controlled by the *Omax Make* – CAM software, or they could be acted manually. There is an important feature of the software, which could generate an adaptive speed of the cutting head, along the contour, by taking into account the water jet pressure and the material thickness.

5. CASE STUDIES

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

Fig.7 The AWJ equipment, Omax 2626, Technical University of Cluj-Napoca, TUCN

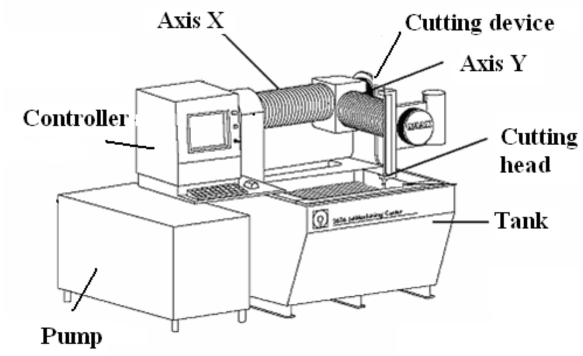

Fig.8 The AWJ equipment's components

For the first cutting test was used the linear cutting speed 86.15 m/min the other parameters of the cutting process were: the water pressure 3500 bar; the maximum traverse speed 5000 mm/min; the nozzle diameter 0.35 mm; the jet impact angle 90˚; the abrasive flow rate 0.45 Kg/min; the abrasive size 80 Mesh; the standoff distance was 2 mm. The part is from steel OL52 with thickness 20mm and it has a 2D complex shape.

Fig.9 The part made from Steel OL52 with 20mm thickness

The part was made in 25 minutes resulting surface quality and precision desired (roughness 3.2µm) .For processing this part was used 11,4 Kg abrasive and the part cost 50 Euros (Fig.9). Initially the part was made using conventional technology in 121 minutes, by milling at a cost of 65 Euros.

For the second cutting test was used the linear cutting speed 500 m/min the other parameters were from the first test. The parts are made out of white and black marble, with a 15mm thickness.

Fig.10 The part made from marble whit 15mm thickness

The parts were processed in 10 minutes resulting a good surface quality and precision. For the processing of this parts were used 5.6 Kg abrasive and the parts cost 26 Euros (Fig.10).

4. CONCLUSIONS

In the first case study was a piece of steel processed with a complex shape in 25 minutes at a cost of 50 Euros. This shows that we can work with AWJ complex parts with contours meet short and at a competitive price. AWJ proves to be a viable alternative to conventional technology.

In the second case study were cut two pieces of marble with a highly complex shape in 10 minutes with a price of 26 euros. AWJ is the only solution for the parts of decorative stone with complex contours.

Software plays a key role in abrasive jet machining. Software must predict and compensate the complex behavior of the jet, to enable producing accurate parts in short time.

AWJ technology proves to be continually development, using an abrasive jet can engrave and scribe different parts.

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