COMPARISON BETWEEN THE ACCURACY AND EFFICIENCY OF EDMWC AND WJC

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Abstract: *The paper presents a comparison between two different cutting technologies, Water Jet Cutting (WJC) and EDM Wire Cutting (EDMWC). Water jet cutting technology is a unique process that is able to cut almost all materials. Within this experimental study the authors have made a comparison between WJC and EDMWC concerning the cutting surface accuracy. To determine the advantages and disadvantages of these technologies an experimental investigation has been made. In this study were analyzed some aspects of the parts, such as: dimensional accuracy, surface roughness and surface characteristics. EDMWC and WJC are two technologies that provide solutions for manufacturing parts and developing new products at lower cost. We cannot say which of the two technologies is better, but each one is suitable for a diversified manufacturing environment.*
Key words: *EDM wire cutting, water jet cutting, accuracy.*

1. INTRODUCTION

Cutting technologies are one of the most used technologies in industry. These technologies are used both for preparing the material for manufacture and also for manufacture parts that do not require further processing.
Current trends in the manufacturing industry requirements are that the parts are processed in a short time and at a high dimensional accuracy.
The key to produce high quality parts is to choose wisely which of the cutting technologies suites to your applications. Water Jet Cutting (WJC) technology is seen as being in competition with other cutting methods, such as laser cutting, plasma cutting, EDM wire cutting (Electrical Discharge Machining) or another technology. Also many manufacturers use more than one of these processes and view them as complementary to each other.

2. MATERIALS AND METHODS

2.1 WJC capabilities

Water jet cutting technology is used in rapid manufacturing of prototypes and also in series production. Using this technology it is possible to produce finished parts, without the need for further processing.
Materials most often cut with water jet are aluminium, stainless steel, titanium, cooper, composites material reinforced with fibre, glass, rubber, stone, ceramics, food, paper, etc. There is no bacterial transfer from tool to food and no downtime for sharpening, as there with knives. The water jet cutting technology is ideal for cutting hardened materials, which can be a challenge for conventional machining processes. All these materials can be cut easily at a high accuracy, without any thermal distortion and without affecting the surface of the part.
Hard materials are cut using water jet cutting technology with abrasive agent, while soft materials, such as rubber, are cut using water jet cutting without abrasive. Titanium is an expensive material and using WJC technology considerable cost savings can be obtained in order to reduce waste material.

a) b)

c)

d)

e)

Fig.1. Parts made by AWJ cutting technology; a) Aluminum; b) Cooper; c) Composites material reinforced with fibre; d) Glass; e) Marble pattern, made at TUCN, (Omax)

Abrasive water jet cutting is the only technology suitable for marble pattern. The jet does not split very small particles from the marble and the cutting surface remains intact. In this way it can be cutted very easy using this technology.

There are a lot of 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 Water Jet Cutting (WJC) is the generic name for the whole group of techniques which are using 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.

In figure 2 is presented the working principle of WJC cutting. The main components of the water jet cutting head, including the mixing chamber, where the pressurized water jet is mixed together with the abrasive particles, which are necessary when we are cutting metal parts.

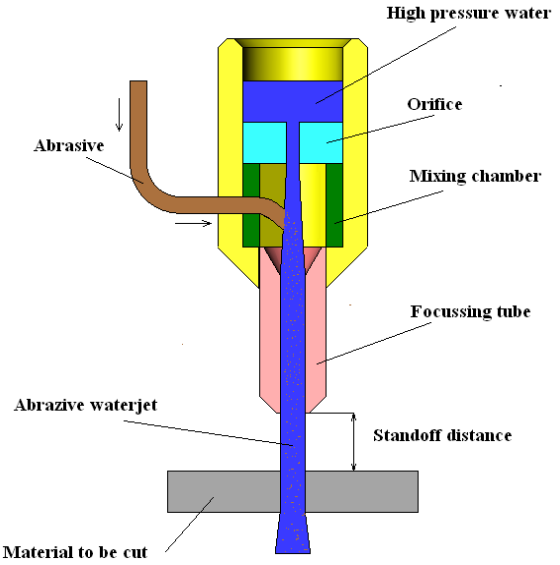


Fig.2. Working principle of WJC process

The water jet pressure and the feed rate influence the WJC process. The rest of the parameters (orifice diameter, abrasive mass flow rate, standoff distance, etc) are almost neglectable.

2.2 EDM wire cutting capabilities

Wire Electrical Discharge Machining (EDM) uses spark erosion to remove material from electrically conductive materials.

Wire EDM equipment is a discharge machine that uses CNC movement to produce the desired contour or shape. It does not require a special shaped electrode; instead it uses a continuous-traveling vertical wire under tension as the electrode. The electrode in wire-cut EDM is about as thick as a small diameter needle whose path is controlled by the machine computer to produce the required shape.

The wire does not touch the part, so there is no physical pressure on the part. The accuracy, surface finish and time required to complete the process is extremely predictable. The EDM process leaves no residual burrs on the work piece, which reduces or eliminates the need for subsequent finishing operations.

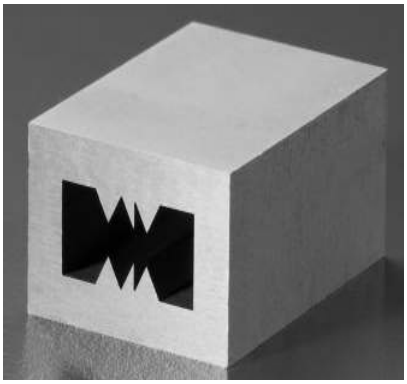
EDM wire cutting process could be considered complementary to conventional machining methods, because it is possible to produce accurate parts with complex shapes, which are more difficult to be made by conventional methods. (Agarwal, 2010)

Wire EDM has the ability to cut parts with complex shapes from any conductive material,

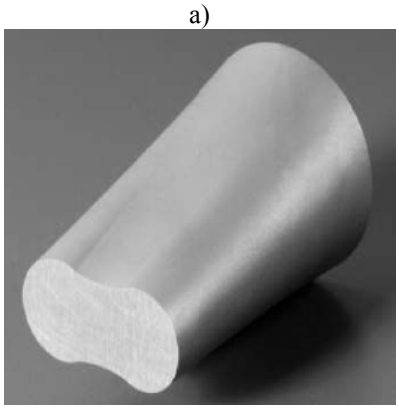
including hard materials, titanium, zirconium, carbide, graphite, aluminum, copper, etc.
Wire material varies depending on the application. For example, zinc-coated brass wires cut quickly, while stronger wire, such as molybdenum wires cut, resulting a better surface quality.

Fig.3. EDM Wire Cutting Equipment, SP-640P, TUCN

In figure 3 is presented the wire EDM equipment from TUCN (Department of Manufacturing Engineering).
For obtaining a better surface quality, it is important to set suitable machining parameters, such as: electrical parameters, dielectric fluid, work piece material, etc. (Agarwal, 2010)
Typically, the processing is done in two passes (roughing and finishing) the accuracy obtained is 0.01 - 0.02 mm and surface roughness 0.8μm.
In the next figures are presented some representatives case studies, using wire EDM technology.
In figure 4.a) is a steel part with various corner cuttings, made by three passes. The material thickness is 32 mm and the cutting length is 460.847 mm. For cutting the part, a wire with the 0.2 mm diameter was used. The machining time is 2 hours and 32 minutes, obtaining a surface roughness of 0.65 μm.
In figure 4.b) a taper shape is presented. The part is made from steel, by three passes, using 4 axes simultaneous interpolation. The material thickness is 50 mm and the cutting length is 97.933 mm. For cutting the part, a wire with the 0.2 mm diameter was used. The machining time is 48 minutes, obtaining a surface roughness of 0.68 μm.



a)



b)

c)

Fig 4. Parts made using wire EDM technology (Accutex)

The part from the last figure (figure 4.c) is made from a special material, PCD (Polycrystalline diamond), used for manufacture inserts for high precision machining (applicable for non-ferrous metal, non metal turning, milling and other various type of cutting).
The part is made by 1 pass. The material thickness is 3 mm and the cutting length is 63.121 mm. For cutting the part, a wire with the 0.25 mm diameter was used. The machining time is 43 minutes. (Accutex)

3. EXPERIMENTAL RESEARCH

The purpose of this paper is to compare the experimental results regarding the quality of the parts made by using two important technologies: WJC and EDM wire cutting.

- *Water Jet Cutting – case study*

In water jet cutting process, the high pressure developed by the pump is converted to high velocity at the cutting head by the orifice. The resulting high velocity stream does the cutting, not the pressure.
The experimental study was done using the OMAX 2626 equipment from TUCN (Department of Manufacturing Engineering). The equipment's main components are: the high pressure pump with output pressure of 3.500 bars; an abrasive cutting head and abrasive supply container; a numerical controller which controls the movements of the cutting head and the water tank.
The first step in manufacture the part is to develop the 3D model and the 2D drawings using CAD software (Solid Works) or using OmaxLayout software.
The cutting profile has the following dimensions: length 30 mm and width 20 mm.
The sketch is opened with OmaxLayout / OmaxMake programs where the cutting parameters are set up.

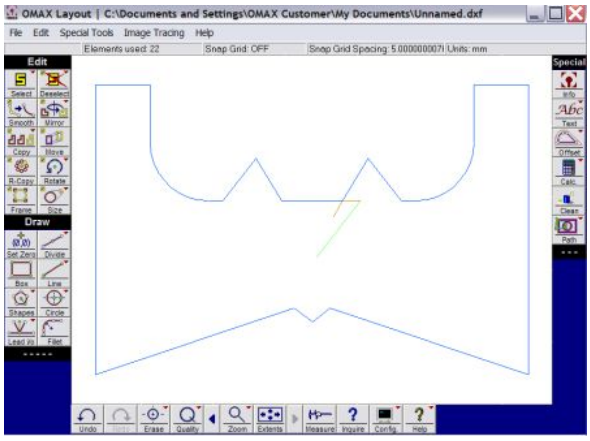


Fig.5. OmaxLayout software

In figure 5 the starting point, the cutting quality (5 surface qualities are available) and also the processing strategy is selected. In this case the best quality is selected.
The next step is to select the cutting parameters (Fig. 6).

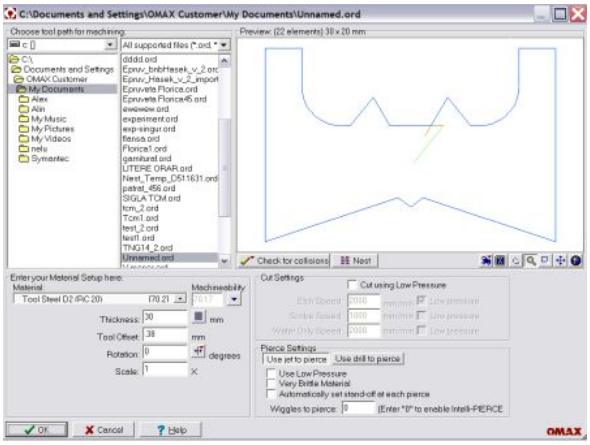


Fig.6. OmaxMake software

The material type is also selected here (tool steel), the material thickness (30 mm) and tool offset (0.38).
A simulation is necessary to know some aspects regarding the manufacturing time (27 minutes), the abrasive quantity (12.5 kg of abrasive) and the manufacturing costs (30 Euro).
The cutting speed is adjusted; it anticipates the effects of the jet speed and adjust the jet to obtain parts at high accuracy (Fig. 7). The blue line indicates the areas where the speed is reduced. With red line are marked the areas with a higher speed.

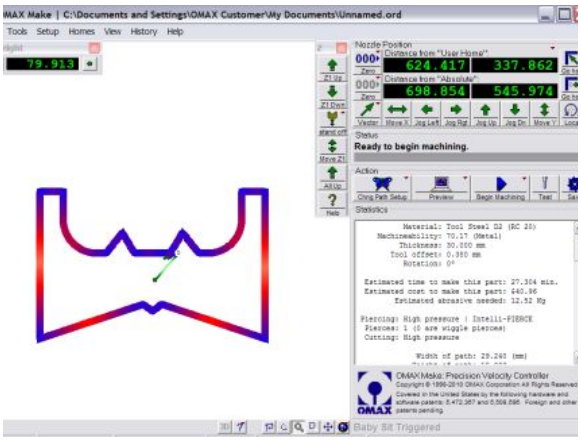


Fig.7. WJC simulation

The surface roughness is influenced by the water jet pressure. Increasing the water jet pressure, the surface roughness also increases.
When the feed rate increases then the surface roughness decreases. (Akkurt, 2004)
The part was made in 27 minutes resulting the required surface quality and accuracy (surface roughness 1.02 μm and dimensional acurracy ±0.13 mm).

Fig.8. Surface roughness obtained by WJC

The software has a key role in abrasive water jet cutting technology. Using the software the operator must predict and compensate the water jet errors, to be able to produce parts at high accuracy, in a short time.

- *Wire EDM – case study*

The studies were made using SP-640P EDM wire cutting equipment, produced by Seoul Precision Machine**,** South Korea.
The sketch of the part can be made in any CAD program. In figure 9 is presented the CAD model, which was inserted in the machine program.

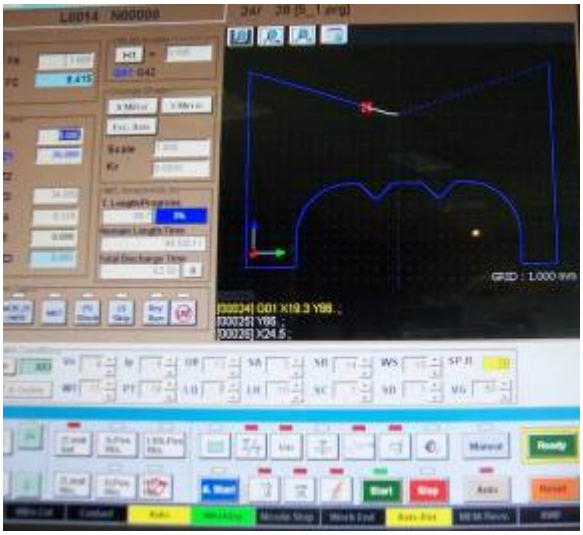


Fig.9. Wire EDM Software

The machine uses the SPM EzCut Ver 5.021 software. For all the operations we used pre-established working conditions, depending on the material type, material thickness and the wire cutting diameter.
For experimental research was used a material with 30 mm thickness (tool steel). The cutting profile has the following dimensions: length 30 mm and width 20 mm. At the beginning is necessary to choose the starting point for every contour. For fixing the wire, before to start the machining, some holes were made with a drill.
The wire used for this case study was a hard brass wire electrode, uncovered with paraffin with the diameter of 0.25 mm and 900 N/ mm^2 breaking strength. To obtain a high dimensional accuracy a tool offset was set up (0.185 for roughing and 0.135 for finishing).
The cutting speed variation during the process was between 2.9 mm/min and 3.3 mm/min.

Fig.10. Part made by wire EDM technology

The total discharge time, necessary to manufacture the part from figure 10, was 62 min. Within this case study the dimensional accuracy is about 0.016 mm and the surface roughness 0.72 μm. The manufacturing cost for this profile is about 43 Euro.
After processing the part, using water jet cutting technologies and wire EDM the measurements was undertaken in order to compare the quality of the part, the accuracy, the roughness, etc.

4. RESULTS AND DISCUSSIONS

After comparing the presented technologies, Water Jet Cutting and wire EDM (Electrical Discharge Machining) we can say that the accuracy and manufacturing time are the major differences between EDM wire-cutting and water jet cutting. EDM is suitable for applications that require tight tolerances, because EDM is an accurate process and is the best technology for this type of parts.
In the next paragraph are presented some advantages and disadvantages of the WJC and wire EDM:
- Using Wire EDM technology, extremely precise parts are possible (±0.016), while WJC is not a very precise technology (±0.13), comparing with EDM. Using wire EDM in the presented case study the surface roughness is 0.72 μm and for WJC only 1.02 μm
- WJC is up to five times faster than wire EDM, depending on part thickness and material type. In our case we obtained 27 min for WJC and 62 min for wire EDM.
- All type of materials can be cut using WJC, but with wire EDM only parts from conductive materials can be processed.

- The cutting surface is not affected by thermal distortion using WJC, so is not necessary a secondary operation.
- Using wire EDM a pre-drilled starter hole is needed, but using WJC the part is machined directly, without any other operation.
- WJC is simple, rapid programming and set up with minimal fixturing, while EDM wire cutting needs different wire types for different applications.
- WJC can produce large parts at reasonable costs.
- WJC leaves no contamination on the cut surface. Some medical and aerospace applications prohibit even minute amounts of copper or zinc deposits left by wire EDM.
- The garnet used in abrasive water jet as well as the water are recyclable.
- Using wire EDM is possible to process complex shapes from hard materials without any further operation.

5. CONCLUSIONS

In this article, theoretical and experimental researches were made to determine the benefits of WJC technology as compared with wire EDM cutting technology. The most important factors considered in this study were the surface quality obtained by varying the process parameters, the accuracy, manufacturing time and the price.
EDMWC and WJC are two technologies that provide solutions for manufacturing parts and developing new products at lower cost. We cannot say which of the two technologies is better, but each one is suitable for a diversified manufacturing environment.

6. ACKNOWLEDGMENTS

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