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[1.] Luba BICEJOVA, [2.] Martina NOVAKOVA, [3.] Juliana LITECKA

MODIFICATIONS OF THE WATER JET SPLITTING

[1-3.] TECHNICAL UNIVERSITY OF KOSICE, FACULTY OF MANUFACTURING TECHNOLOGIES WITH A SEAT IN PRESOV, STUROVA 31, 080 01 PRESOV, SLOVAKIA

ABSTRACT: Water jet cutting technology represents a high-performance cutting and shape dividing of all materials. The factors that influence the properties of machined surface can be summarized as factors of liquid hydrodynamic properties, technical factors influencing hydro-erosive process and technological factors influencing hydro-erosive surface of the cutting. Technology of the water jet cutting present progressive approach with unique possibilities that enables shape cutting and dividing of various hard-to-process materials without producing the heat-affected zone of cutting edge within the workpiece. The paper is focused on practical aspects of the AWJ technology setup alternatives; particularly on those which are connected with splitting of the high pressure jet.
KEYWORDS: water jet technology, cold cutting, multi-head cutting

INTRODUCTION

A water power in its erosive form exists in nature for millions of years. High-pressure water jet cutting known as Jet-Cutting has been continually developed for several decades. An important impulse for water jet using in production technology as a tool has come from aircrafts construction and space technologies areas [1,2].

Water jet cutting technology represents a high-performance cutting and shape dividing of all materials. The best advantage of this technology comparing to the other dividing methods is a process of cold cutting. It is used in conditions where splinter-less, splinter and thermic production technologies provide due to mechanical or physical reasons unsatisfying results or where they totally fail [3]. The factors that influence the properties of machined surface can be summarized as factors of liquid hydrodynamic properties, technical factors influencing hydro-erosive process and technological factors influencing hydro-erosive surface of the cutting [4-6].

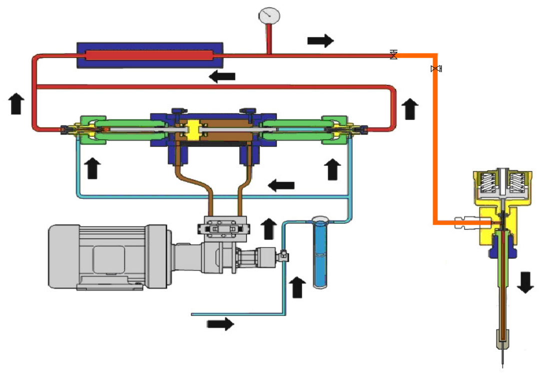
The paper is discussing some of the newest trends in the area of the AWJ utilization in the field of production engineering and has been created within cooperation with WATTING firm in Presov.

METHODOLOGY

According to common setups, hydroabrasive cutting is performed on one cutting desk with one technological head (water nozzle 0.35, abrasive nozzle 1.1 and abrasive flow 650 g/min).

The core parts of high-pressure cutting device are high-pressure pump, pump with pressure converter, multiplicator with oil-hydraulic drive and pressure accumulator.

Water pressure is being fed along a high-pressure pipe into the cutting head which is controlled by an electro-pneumatic valve. The water jet cutting principle (Fig. 1) and subsequent cutting with high-pressure water splitting, i.e. cutting with two heads simultaneously (Fig. 2) are possible models of water jet splitting [7,8].


(a)

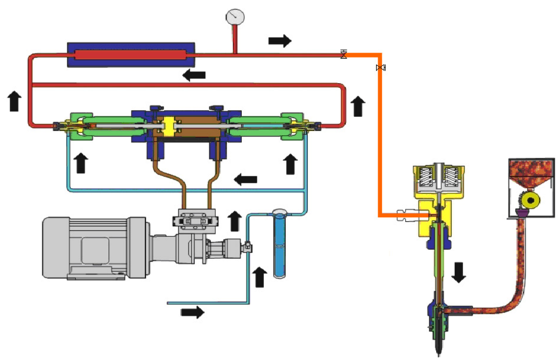
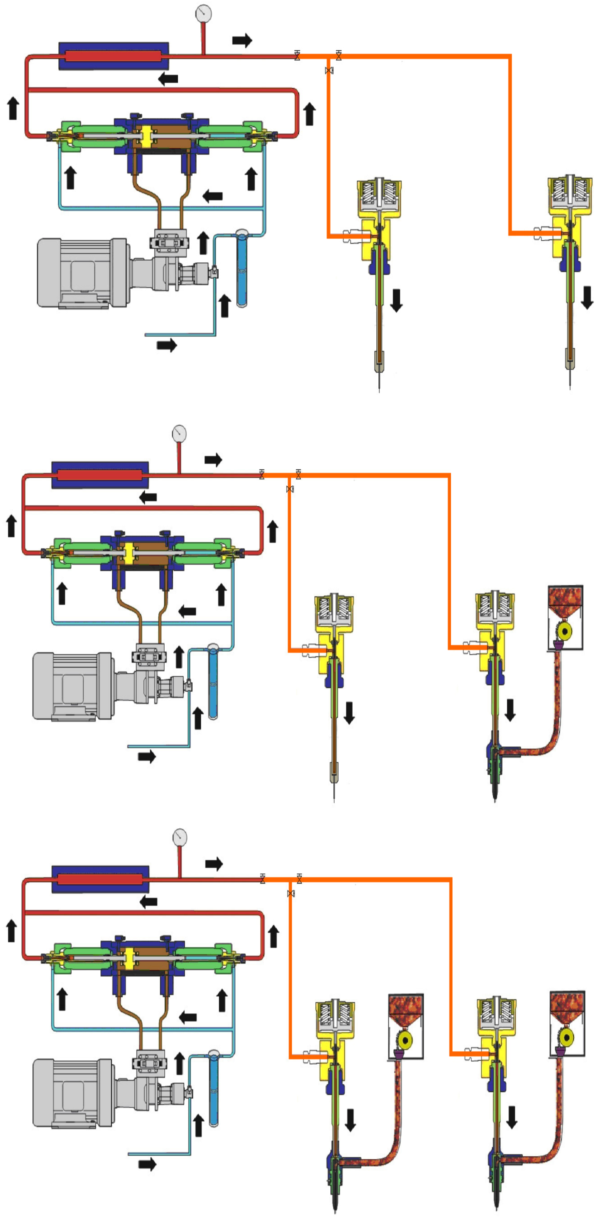

(b)

Figure 1: Schematic representation of the principles of water jet cutting and hydroerosion cutting: (a) WJM (hydrodynamic water jet) and (b) AWJM (hydroabrasive water jet)



a)

b)

c)

Figure 2: Models of water jet splitting into two heads:
a) Model of KMWJ-WW based on principles WJM + WJM;
b) Model of KMWJ-WA based on principles WJM + AWJM;
c) Model of KMWJ-AA based on principles AWJM + AWJM

In the case of two cutting desks, one head for one desk is commonly used. Cutting performance of each of them is designed according to the high-pressure pump performance. Such a way was carried out at the working place of WATING Presov where cutting heads were designed according to a variant I, where head markings are Dw/Da/Pw and where Dw represents inner nozzle diameter, Da represents inner abrasive nozzle diameter and Pw represents water flow rate per minute.

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Variant I: 1st desk - head 0.35/1.02/3.25
and 2nd desk - head 0.35/1.02/3.25

In accordance with requirements for cutting and to increase competitiveness in the market, new possibilities to increase performance without shifting demands were being looked for. One of them is water jet splitting. In the case of water jet splitting into two cutting heads simultaneously on one cutting desk or on two cutting desks, it is possible to combine the cutting heads in variants according to technology producer recommendation.

In this case, the water jet splitting has been performed contrarily to recommendation of the technology producer for two cutting heads on both desks simultaneously. Combinations of different water nozzles to abrasive nozzle with inner diameter of 0.76 mm were used, accordingly to the variants 1 - 3 with corresponding Dw/Da/Pw:

Variant 1: 1st desk - head 0.20/0.76/1.05
2nd desk - head 0.25/0.76/1.65
Variant 2: 1st desk - head 0.20/0.76/1.05
2nd desk - head 0.30/0.76/2.37
Variant 3: 1st desk - head 0.25/0.76/1.65
2nd desk - head 0.25/0.76/1.65

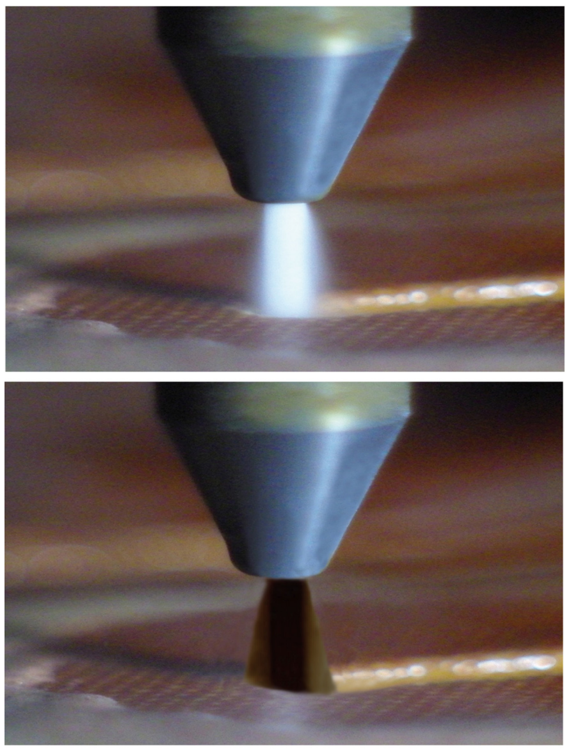

Figure 3: Hydroerosive jet surrounded by water mist
(a) AWJM - water mist (b) AWJM - dispersion
of abrasive material into the water mist

Figure 3 shows the hydroerosive jet with clear water mist surrounding water-abrasive suspension flowing out the abrasive nozzle. Inside the mist, a very tiny amount of abrasive particles can be found. This phenomenon of hydroerosive jet structure confirms that the lift of the nozzle over the material influences upper erosive edge of cut material.

RESULTS AND DISCUSSION. One head cutting costs formula - model KMN1

On the base of long-term practical experience, costs for one head cutting can be calculated with help of *cost function which should include both direct and indirect expenses.*

Suggested cost function used in WATING Prešov for one head cutting took into account all suggested cost items:

$$C_{KMN1} = (CA + CW + CE + CU + CM + CH + CP) \times 1 / PV$$

[EUR per mm of cut]

where: CA – abrasive material costs; CW – water processing and consumption costs; CE – energy costs (high-pressure pump, XY-desk, cooling, air); CU – consumables costs, water and abrasive, focusing nozzles; CM – handling and storage costs (fork-lift truck, crane, pallets etc.); CH – other indirect variable costs (salary, planned maintenance, amortization etc.); CP – other all operating costs (overhead, testing cuttings, preparations etc.); PV – number of products made at one-layer cutting (depends on the number of cut layers)

Subsequently, it is possible to create also a cost function of two heads hydroerosive jet parallel cutting which is considered a contribution for future users in practice.

For parallel two heads cutting, suggested costs function takes into account all principal costs items which are related to it.

Two heads cutting costs formula – model KMN2

Based on the previous statements, it is possible to formulate a cost function for two heads simultaneous hydroerosive jet splitting which is considered to be a positive contribution for next users in the field:

$$C_{KMN2} = (CA + CW + CH + CP + 2x\,(CE + CU + CM)) \times 1/\,PV \text{ [EUR per mm of cut]}$$

where the parameters are the same as for model KMN1.

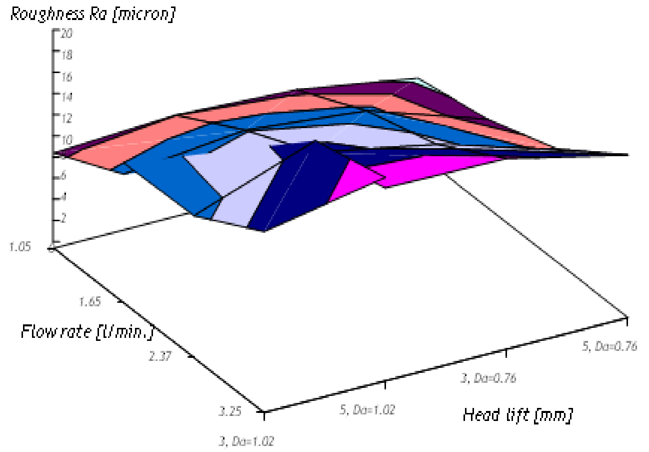

Figure 4: Dependence of roughness, flow rate and head lift

On the base of submitted approaches to hydroerosive jet dividing, in the framework of extended survey of WATTING with material AISI 304, thickness 15 mm, high-pressure water jet was split according to various flow rates. Complex identification of technical, technological, measured and interpreted factors presents sum of 25 factors which can be mutually compared in various interpreting relations.

Similarly, an important result was obtained (see Fig. 4) showing relation between surface cutting topography roughness and flow rate as well as head lift.

That was interesting to find that the abrasive flow was in such condition for cutting with both one head and two heads lower by one third. An influence of abrasive weight was tested at values of 100, 150, 200 and 250 g/min. Final evaluation showed optimal weight values in the range of 180 - 250 g/min.

Finally, verification on the samples (thickness 8 mm and 30 mm, respectively) was carried out. The reason was to work out a methodology of identification of technology and cutting factors for various thicknesses of material AISI 304 and for other kinds of materials being cut by hydroabrasive erosion.

Verification of formulated factors was finally carried out on samples made of material AISI 304, thickness 8 mm. Figure 5 shows pieces of verified samples.

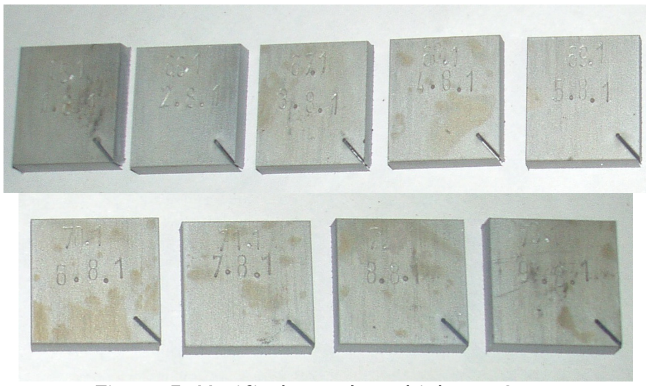

Figure 5: Verified samples, thickness 8 mm

Cutting parameters of verified samples mentioned above were recorded and graphically representation of the evaluation is given in Figure 6.

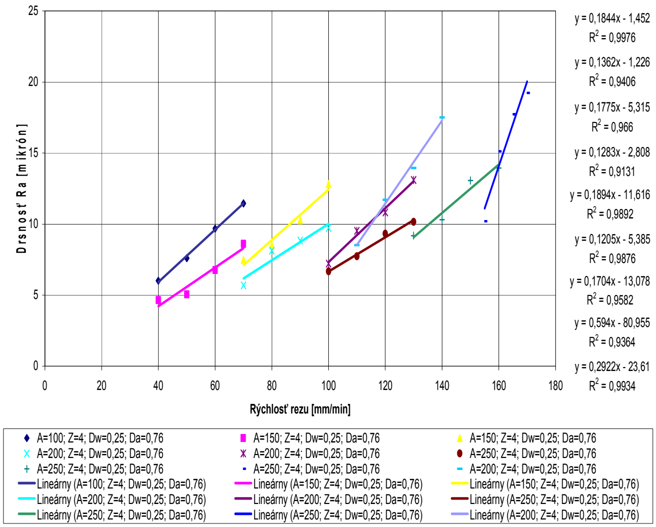

Figure 6: Relation between roughness (y-axis) and cutting speed (x-axis) for various abrasive flow rates for AISI 304 material verification, thickness of 8 mm

CONCLUSIONS

Water jet cutting technology and high-pressured water split into two jets represent progressive approach to the shape cutting and dividing of various kinds of materials without producing of the heat-affected zone at cutting edge of the workpiece. Various designs with respect to the jet splitting are experimentally verified and discussed.

Results are important for contemporary practice and from hydroabrasive cutting economy point of view.

Presented work provides an important extension of water jet cutting technology itself with an ambition *to test possible ways to definition of cutting parameters which would guarantee both technology and economy aspects of water jet cutting process at high-pressure water split into two smaller water flow rates or at one smaller water flow rate.*

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