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AWJM Factors Categorization and Identification

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BIOGRAPHICAL NOTES

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Dr.h.c. prof. Ing. Miroslav Badida, PhD. He is a graduate of Mechanical Faculty of Technical University of Košice. His scientific and research work focuses on the field of environmental engineering. An accent is put on the issue of environmental management systems, ecologization of products and their production and life cycle analysis of products. Lately his attention is paid on research in the field of physical factors of working and living environment.

doc. Ing. Lýdia Sobotová, PhD. is a docent on Technical University in Košice, Faculty of Mechanical Engineering. She graduated at the Faculty of Mechanical Engineering, VŠT Košice in 1983. She received her PhD. Degree from Technical University in Košice in 1992. Her scientific focus is oriented to metal forming, material testing, thermal drilling and progressive mechanical technologies. Today Mrs. Sobotová is an associated professor at the Faculty of Mechanical Engineering and is a member of the Department of Technologies and Materials. She is a co-author of academic textbooks. She has published more than 140 publications in home and foreign journals and conference proceedings. She was also incorporated in various grant research projects and industrial projects.

Ing. Miroslav Gombár, PhD. graduated from the Technical University of Košice in 2002 where he studied at the Faculty of Manufacturing Technologies. Nowadays he is a director of the private company dealing with the coating services of metals, aluminium and its alloys. From 2004 to present time he was educated at the University of Prešov in Prešov and at the Technical University of Košice, i.e. at the Faculty of Manufacturing Technologies with a seat in Prešov. On the present time he has been educated at the Faculty of Management. In parallel he has been interested in practical engineering, especially in the chemical and electrochemical surface treatment. In the field of scientific research he is primarily focused on the issue of research and optimization of factors affecting during the individual technologies of electrochemical processes for surface treatment, mostly in anodic oxidation of aluminium and its alloys. In addition he deals with applications of mathematical-statistical methods and methodology of Design of Experiments (DoE) in the field of mechanical engineering technologies and surface treatment of materials. The results of his scientific-research activities have been published in 6 monographs, in some university textbooks and scientific publications. He has published over 100 scientific articles in domestic and international journals, in scientific conference proceedings and has participated in several grant projects and engineering works as author and co-author.

KEY WORDS
Water jet technology, categorisation, surface quality

ABSTRACT
Water jet cutting technology (hydro-erosion) presents as unique, for future-oriented technology, with the high possibility of the introduction of automation for high-power cutting for actually all types of materials.The aim of the way was to find the definition of cutting parameters of water jet, which will guarantee technological and economical aspects. This process is associated with extensive utilisation of mathematical methods, using of computational procedures for specific tasks and at the utilisation of methodology of mathematics for methods of formulating solutions.

1. Introduction
Power of water in a form of erosion has acted in nature for millions of years. High pressured water jet cutting – known also as Jet-Cutting – has been developed continually for several decades. An important motion for water jet use in manufacturing technology as a tool has come from aircrafts and space industry. Water jet cutting technology represents high performance and shape cutting suitable for all materials. The best advantage of this technology in comparison to other cutting methods is a cold cutting process. It is used when chip-less, chip and thermic production techniques provide due to mechanical and/or physical reasons unsatisfying results or they fail.

From general point of view, the water jet technology can be classified according to a graphic model (Fig 1) called as Kmec´s Water Jet Cutting Model 1 (KWJCM1).

The given classification created in a firm WATING in Prešov in cooperation with Department of Technologies and Materials of Faculty of Machinery (Technical University in Košice), was formed on the base of practical knowledge from 1985 till today. Water jet as a new, inventional and progressive technology was introduced and developed in Slovakia, at that time in Czechoslovakia, 25 years ago within a scientific and manufacturing association MVVZ ROBOT Prešov.

The given classification for water jet technology in Fig 1 can be characterized also as jet technological water methods or as water jet technology, as normally used by internationally reputable research and technical community as well as by development and technology experts.

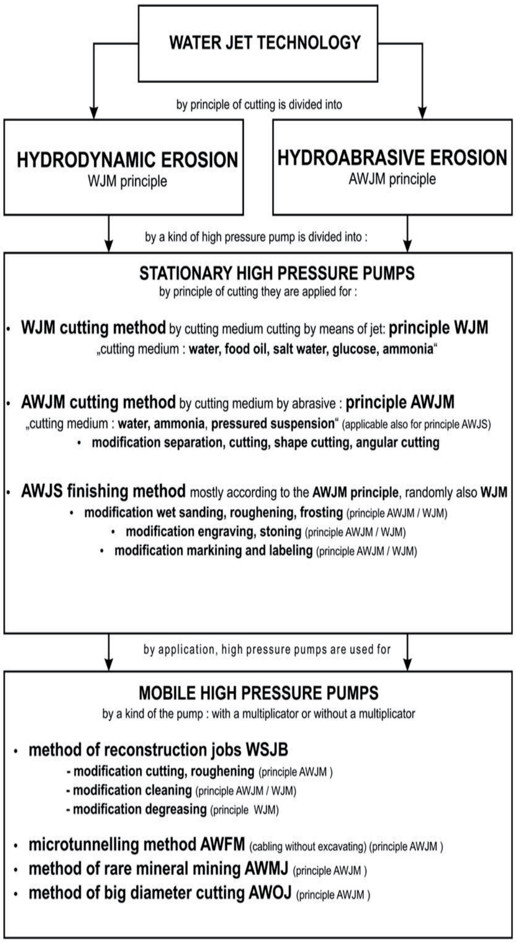


Fig. 1: *Water Jet Technology Classification – Graphic model of KWJCM1*

Nowadays, a perpendicular cutting area of very high quality, dimensional accuracy of a cutting shape and relatively high cutting speed can be obtained by water jet technology using values of pressure 350 MPa – 620 MPa for stationary high pressure pumps and 0,5 MPa – 320 MPa for mobile pumps.

Other technological methods, cutting abrasives and technological modifications, which definitely substantially extend application potentiality of this technology, are being developed.

Firstly, optimal complexes of physical, technical and technological factors in relation to quality and productivity of hydroabrasive erosion were identified and formuled within three categories. Thus a complex model of factors describing cutting area surface formed by hydroabrasive erosion was made. Factors directly and indirectly affecting erosion surface can be formulated into three categories as follows:

1. Category of basic physical properties and hydrodynamic relations of liquids

2. Category of technical factors affecting the hydroabrasive production process

3. Category of technological factors affecting the hydroabrasive cutting surface

Based on the stated complex specification, a graphic model of the factors complex was suggested, defined at the Department of Technologies and Materials, Faculty of Mechanical Engineering, Technická univerzita v Košiciach, called KMF1 (the Kmec´s model of factors, the first), shown in Fig 2.

In the Fig. 3 are shown the Water/Hydroerosive water jet cutting principles, The water pressure is transported by high press pipes into cutting head according to Fig. 3 and following with dividing of high pressed water, it means cutting operation with two cutting heads simultaneously.

The centre of the high pressure cutting system is a high pressure pump, a pump with a pressure converter and intensifier with an oil and hydraulic drive and a pressure accumulator.

The pressured water is fed along the high pressure pipe to the cutting head which is controlled by an electro-pneumatic valve. The principle of water jet cutting is in the Fig 3.

In the Fig 4 two models with high pressured water distribution into two cutting heads, i. e. two heads simultaneous cutting are shown. The following models can be set:

a) Model KMWJ-WW – uses principle of WJM + WJM

b) Model KMWJ-WA – uses principle of WJM + AWJM

c) Model KMWJ-AA – uses principle of AWJM + AWJM

Based on the above given approach to the hydroerosive jet cutting, several variants of flow rate combinations for simultaneous two heads cutting were formed.

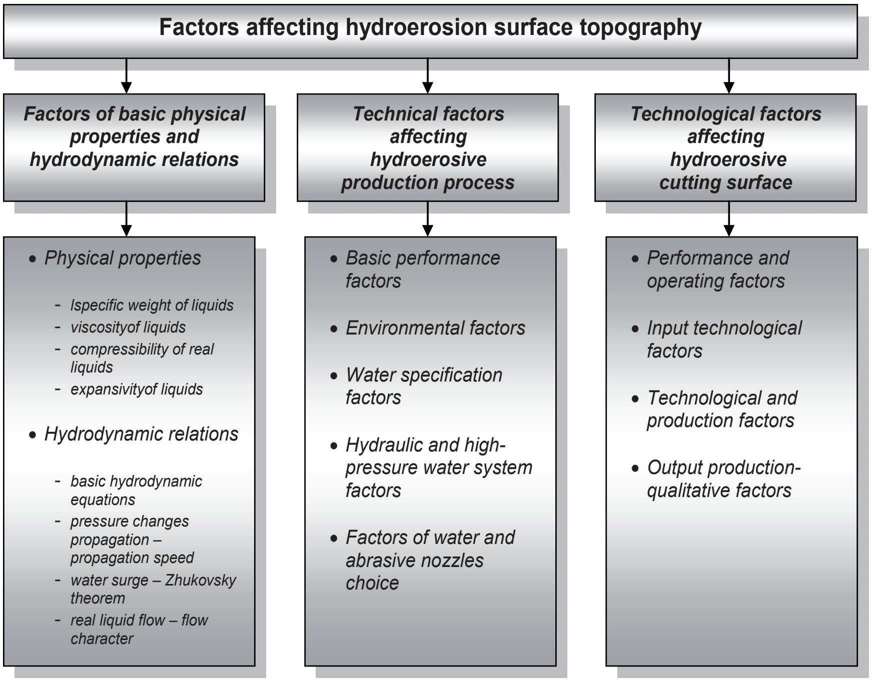
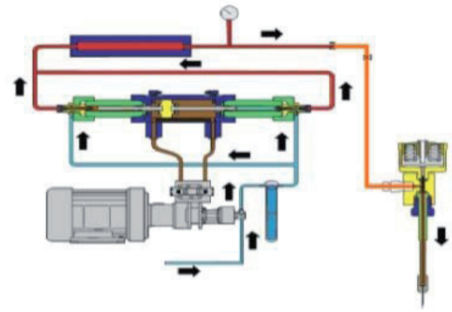
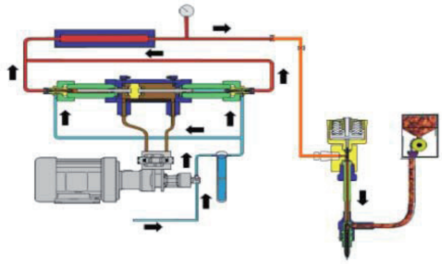


Fig. 2: *Graphic model of hydro erosion factors complex – Model KMF1*

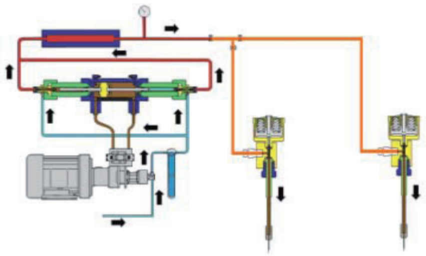


a) WJM principle

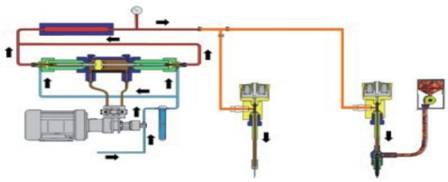


b) AWJM principle

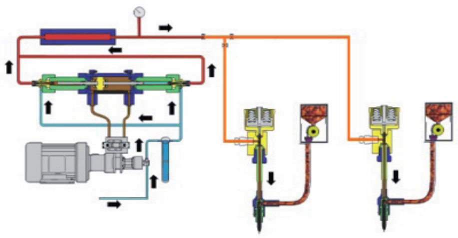
Fig. 3: *Water/Hydroerosive water jet cutting principles.*



a) Model KMWJ-WW



b) Model KMWJ-WA



c) Model KMWJ-AA

Fig. 4: *Models of water jet distribution into two heads.*

2. Description of experimental methods and used material

In the Tab. 1 is shown the final collecting table, [P/R/A = variables]. The cutting parameters of the mentioned specimens were entered in the records and their evaluation is decisive for final conclusion important for practice.

The collecting reports of verified specimens are similar as n Tab. 1. Consequently, Evaluation of 9 specimens (thickness 8 mm) and 4 specimens (thickness 30 mm) was performed. Material for verification was AISI 304 which secured continuity not only of material thickness but also of material itself. The cutting parameters of verified specimens were entered in reports and graphically demonstrated. The relations represent abrasive weight effect on cutting surface quality. From the graphs it is clear that the cutting surface quality is largely depended on abrasive quantity used during cutting.

3. Results and discussion of achieved results

Similarly, an interesting result was obtained – shown in Fig. 5 for material AISI 304 with demonstrated relation of cutting surface roughness to flow rate and cutting head distance from material called as KMGRa1.

As an interesting finding can be abrasive mass weight consumption regarded. It was - during cutting either with one head or with heads - reduced by one third.

The most significant advantage of this technology in comparison to other cutting methods is cold cutting process. It is used in situations when chipless, chip and thermic production technologies provide - due to mechanical or physical reasons - unsatisfactory results or when they totally fail.

In the Fig. 6 is shown relation of roughness to cutting speed for AISI 304 at material thickness 8 mm. In the Fig. 7 is shown relation of roughness to cutting speed for AISI 304,at material thickness 30 mm.

Similar effect on cutting surface quality is caused also by quantity of high-pressured water used during cutting. It means that water nozzle size, which determines high-pressured water flow-rate, rather interestingly affects the cutting surface quality and mainly in a combination with cutting head shift during various high-pressured water flow-rates. Next figures represent area relations of roughness to various high-pressured water flow-rates.

For contemporary practice, in terms of economical effect of hydroerosive jet cutting, the survey of flow change or its distribution into two heads represents rather extensive encroachment into water jet technological parameters to find out a way how to define cutting parameters which would guarantee the output qualitative technological aspect and simultaneously the economical aspect of water jet cutting process at optimal hydroerosion factors.

The Fig. 5 to Fig. 8 illustrate selected area relations of above mentioned and other various technological factors which were evaluated within the survey and which – according to authors – point at other possibilities of survey within water jet technology.

Table 1: *Final collecting table [P/R/A = variables]*

Specimen number	Dist. of nozzle from mat. [mm]	Water nozzle [mm]	Abrasive nozzle [mm]	HP Water flow [l]	Abrasive weight flow [g/min.]	Cutting speed [mm/min.]	Roughness Ra [micron]
1-123-50	3	0.20	1.02	1.05	100	50	9.34
18-123-75	3	0.25	1.02	1.65	150	75	12.65
35-123-100	3	0.30	1.02	2.37	200	100	13.05
52-123-125	3	0.35	1.02	3.25	250	125	16.96
5-123-50	5	0.20	1.02	1.05	100	50	9.94
22-123-75	5	0.25	1.02	1.65	150	75	13.85
39-123-100	5	0.30	1.02	2.37	200	100	17.05
56-123-125	5	0.35	1.02	3.25	250	125	19.86
9-123-50	3	0.20	0.76	1.05	100	50	9.34
26-123-75	3	0.25	0.76	1.65	150	75	12.65
43-123-100	3	0.30	0.76	2.37	200	100	14.73
60-123-125	3	0.35	0.76	3.25	250	125	18.74
13-123-50	5	0.20	0.76	1.05	100	50	7.37
30-123-75	5	0.25	0.76	1.65	150	75	8.71
47-123-100	5	0.30	0.76	2.37	200	100	15.15
64-123-125	5	0.35	0.76	3.25	250	125	16.98

Where: P – flow, A – abrasive, R - speed

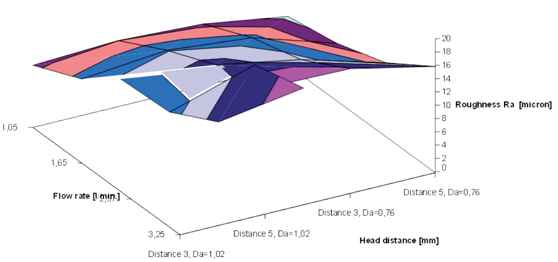


Fig. 5: *Relation of roughness to flow rate and distance of the cutting head above material – model KMGRa1.*

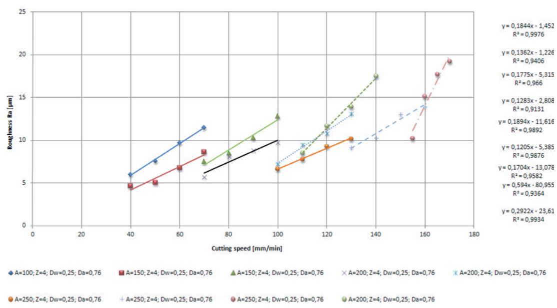


Fig. 6: *Relation of roughness to cutting speed for AISI 304, thickness 8 mm.*

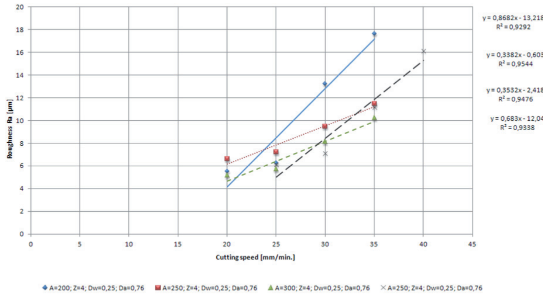


Fig. 7: *Relation of roughness to cutting speed for AISI 304, thickness 30 mm.*

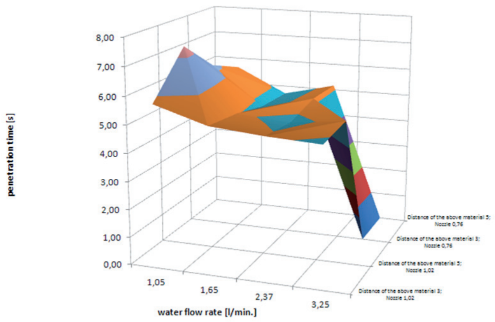


Fig. 9: *Relation of material penetration time to flow-rate at various distances of the head above material.*

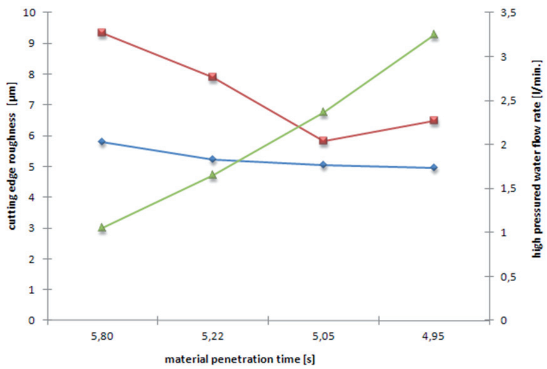


Fig. 8: *Relation of flow rate to material penetration time and cutting roughness.*

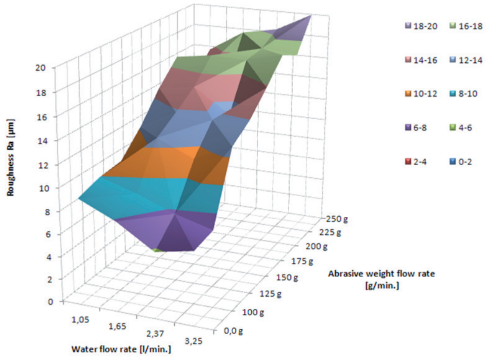


Fig. 10: *The area showing relation of roughness to abrasive weight flow-rate and water flow-rate.*

4. Conclusion

The water jet technology development formally started in the second half of the eighties by the international scientific and manufacturing association MVVZ ROBOT in Prešov. The first three years can be described as MVVZ ROBOT´s basic research mighty development in a cooperation with Faculty of Engineering, TU Košice and VUZ Bratislava. The participants from the Czech Republic were the Czech Academy of Sciences, Prague, ČUT Prague and VUT Brno.

Also, in period from 1986 to 1993 in former Czechoslovakia, preparations and founding of MVVZ ROBOT first water jet cutting machine-controlled technological workplaces and lines started. The MVVZ ROBOT association, during water jet technology implementation, became a main guarantor of water jet cutting automation process.

The first high-pressure pump with equipment and a handling robot were purchased by ČAV Prague and supplied by a firm Phoenix Prague. They were installed as a complex workplace in MENET, state enterprise, Průhonice in 1986.

In Slovakia, the founding of first workplaces started in the end of the eighties. Till 2000, 15 water jet cutting technological workplaces were installed. Only 7 of them were in operation in the end of the period. In the course of last ten years, much more extended development of the water jet technology has arisen. Now, approximately 30 workplaces are in actual operation. Except that, 12 high pressure mobile pumps are in operation used for various reconstruction and cleaning jobs as well as one water pump for cabling without excavation.

In terms of Slovak regions, in East Slovakia 5 water jet cutting technological workplaces and 1 device for cabling without excavation are installed. In Central Slovakia there are 4 technological workplaces and in the west part of the country 21 water jet technological workplaces and 12 mobile high pressure pumps for reconstruction and cleaning jobs are installed.

The water jet technology progress, especially focused on the hydroabrasive erosion method, was carried out in a form of the basic research at Faculty of Engineering of TU of Košice, Faculty of Engineering of STU of Bratislava, Faculty of Special Technology of TnUAD of Trenčín and later at Faculty of Manufacturing Technologies of TU of Košice with seat in Prešov, in a cooperation with local firms in the regions.

The leader of Slovak basic research and development within the discussed area is a firm MICROSTEM Bratislava. It regularly introduces results of its research and development into practice within complex delivery for water jet cutting technology workplaces. Recent possibility to perform 2D and 3D cutting and especially to gain perpendicular cutting area as well as ultra high pressures above 400 MPa offers significantly much wider water jet application than ever.

Due to cutting and competitiveness demands increase, new possibilities how to improve the performance have been sought. The solution is in high pressured water distribution into two cutting heads for cutting on two desks simultaneously. The high pressure distribution into several heads is performed commonly, according to recommendations of producers. Others than recommended combinations of water and abrasive nozzle ratios were tested and certified by research and implementation into practice. Although some limitations arose, the supposed efficiency was reached. The cutting edge quality was not worse and even time needed for one piece cutting and the price of the product were reduced. The cutting efficiency was improved and total operation costs were reduced, too.

The most significant advantage of this technology in comparison to other cutting methods is cold cutting process. It is used in situations when chipless, chip and thermic production technologies provide - due to mechanical or physical reasons - unsatisfactory results or when they totally fail.

Referring to practical results and experience gained in the international firm MVVZ ROBOT Prešov and mainly in firms WATING s.r.o. and WATING Prešov s.r.o., the authors of this work point at continuity of knowledge and results obtained from basic and applied research, realised projects, also from their own research as well as from almost twenty years practical experience in running their own workplace specialized on hydroabrasive and shape cutting.

5. Acknowledge

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