VIBRATIONS MEASUREMENTS IN THE EVALUATION OF THE IMPACT OF FOCUSING TUBE WEAR AT ABRASIVE WATERJET MACHINING

ВИБРАЦИЯ ИЗМЕРЕНИЙ В ОЦЕНКЕ ВОЗДЕЙСТВИЯ НА ТРУБУ УПОРОМ НА АБРАЗИВНОГО ИЗНОСА ГИДРОАБРАЗИВНАЯ ОБРАБОТКУ

Sergej Hloch, Jan Valíček, Jana Mullerova
Faculty of Manufacturing Technologies of Technical University of Košice with a seat in Prešov

Abstract: *Abrasive waterjet cutting monitoring of materials has become an important area of research in the recent years. The article deals with potential applications of vibration analysis at technological process of material cutting. In order to provide the vibration analysis at abrasive waterjet cutting, the experiments have been carried out to measure the vibration and ultrasonic emissions in order to ascertain the context of the parameters measured the vibrations at the aluminium cutting technology. The main challenge is to find the existence of the link between the focusing tube wear and vibrations.*
***KEYWORDS**: ABRASIVE WATERJET CUTTING, VIBRATION ANALYSIS, FOCUSING TUBE WEAR*

1. Introduction

For on-line automation of abrasive waterjet technology technology, it is also an effective way to measure the surface quality and find the appropriate feedback [8]. The ambition is to create a continuous measurement and control of immediate state of the surface in the process of abrasive waterjet cutting of materials with the reassurance of feedback [7]. Therefore, we studied the process of abrasive waterjet cutting starting to examine ways of using mechanical vibrations. Abrasive waterjet cutting of materials causes the mechanical oscillations and vibrations. In addition to the adverse effects of vibration in the cutting material they bear important information to study the cutting mechanism, where the immediate state of the technological process can be monitored. Taking into account that the material is subjected to high-speed erosion power, the use of vibration analysis for the application and monitoring abrasive waterjet cutting is accurate. It should be noted that the vibrations record the waves that are generated by local deformation of the stress on materials [6]. Several efforts vibration analysis applications, or acoustic emissions have been processed in the works [2], [3] for on-line management and monitoring of the immediate stat of surface morphology created by the AWJ in the works [1], [4], [5].

2. Experimental set up

The experiment had been carried out within the framework of academic cooperation between the Department of Production Management, Faculty of Manufacturing Technologies Technical University of Kosice, with a seat in Presov, and the Institute of Physics, HGF, VSB - TU Ostrava in cooperation with Slovak firms DRC, Ltd., Presov (Mr. Mikita), and the company Technical Diagnostics, Ltd., Presov (Dr. Adamčík, Ing. Baroš), supported by the Scientific Grant Agency in the framework of the project VEGA 1/4157/07 where the main goal is to develop on-line technology of the management of materials cutting by abrasive waterjet. The diagnostic measurements of vibrations in the evaluation of the impact of focusing tube wear during abrasive waterjet cutting of aluminum has been used to the precise cutting table from PTV company, designed for surface application of the AWJ technology. The water pressure was generated by the pump FLOW 9xD55 with V = 4.7 l.min^{-1} with a power p = 60 HP. An Ingersoll Rand cutting head has been used at the experiment. All samples have been produced with a constant setting of input factors (Table 1).
Vibration measurement (data collection) was provided during abrasive waterjet cutting of aluminum. Vibration sensors were mounted on the workpiece and the focusing tube (Fig. 1). To fix their position, the sensors had been attached to the adapter by a threaded screw M6. The absolute vibration had been recorded - the surface vibration sensors had been installed on site. The analysis was transferred from the time (TIME) records and FFT spectra.

Tab. 1 Experimental set up

Factors	Unit and dimension	Value
Pressure	p [MPa]	350
Orifice diameter	d_0 [mm]	0,14 (inch)
Focusing tube diameter (Roctec)	d_f [mm]	0,8
Stand off	z [mm]	2
Abrasive (Barton Garnet)	*MESH*	80
Material thickness (aluminum)	b [mm]	40
Abrasive mass flow rate	m_a [g.min^{-1}]	400
Feed rate	v [mm.min^{-1}]	20, 40, 60, 80, 100, 120, 140, 160, 180, 200

Fig. 1 Diagnostic measurement of vibrations in the evaluation of the impact of focusing tube wear during abrasive waterjet cutting of aluminum

Measurements of vibration had been repeatedly recorded during the abrasive waterjet cutting. The vibrations at abrasive water jet cutting running with a new focusing tube (Roctec 100) and worn focusing tube (after 60 hours of operation) were compared. Data collection was carried by NI PXI by measurement system (a type of measurement card PXI 4472B, 8-channel simultaneous collection, 24 bit A / D converter, sampling frequency of 102 kHz, the dynamic range of 110 dB) and frequency analyzer microlog GX-S. Data analysis was transferred by Lab View Professional Development System, including Sound and Vibration Toolset and Order Analysis Toolset, and Aptitude Analyst SKF Condition Monitoring. As sensors, accelerometers were used PCB IMI type 607A11 with integrated cable (sensitivity of 100 mV / g, frequency range up to 10 kHz). Control - calibration - measurements have been transferred through the spectrum analyzer (data collectors) SKF microlog GX-S, the analysis of measured data was transferred via software SKF Aptitude Analyst.

3. *Results and discussion*

The following Figures 2 and 3 are graphically interpreting measured the total amount of vibration measured for each technology division of the material conditions of Table 1 and selected measuring methods which examined the dependence of vibration and displacement speed with using the new focusing tube (Fig. 2) and worn focusing tube (Fig. 3), the vibration velocity [mm.s^{-1}] survey in the frequency range from 0.5 Hz to 500 Hz with Fast Fourier Transform (FFT) and Time analysis. Fig. 2 graphically illustrates the comparison of the vibration velocity by using of new and worn focusing tubes to change the speed of displacement where the signal was obtained from the sensor located on the workpiece.

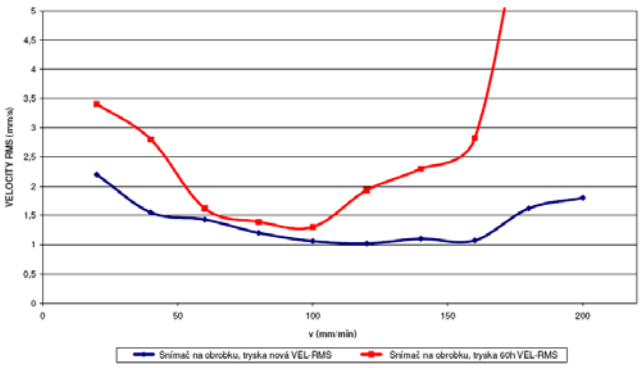

Fig. 2 Comparison of velocity RMS using the new and worn focusing tubes at different traverse rate of cutting head (sensor placed on workpiece)

The graphic behavior the RMS (Fig. 2) shows that the value of RMS reaches low levels, using the worn focusing tube in the range of speed shift from 50 to 100 traverse speed mm.min^{-1}. Furthermore, the Fig. 2 shows the existence of dependence between the vibration and displacement at which the speed of displacement over 100 traverse speed mm.min^{-1}, using the worn focusing tube (Roctec 100), the RMS value, detected by the sensor PCB IMI type 607A11 placed on the workpiece, is increasing. Using the new focusing tube (Roctec 100) the RMS values were significantly lower. The increased RMS values were measured at traverse speed of 20 traverse speed mm.min^{-1} and at a traverse speed 180 and 200 traverse speed mm.min^{-1}. Fig. 3 graphically illustrates the comparison of the speed of vibration with using new and used focusing tubes at change the rate of speed where the signal was obtained from the sensor placed on focusing tube. Experimental data show that the oscillations speed is increasing with the increase of traverse speed in the use of new and worn focusing tube. Based on the experimental findings further experiments will be realized to establish the connection between vibration and the surface quality and relationship between vibrations and technological conditions of cutting materials as well as the material properties.

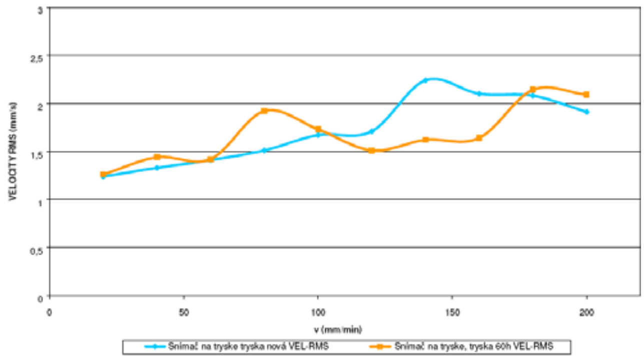

Fig. 3 Comparison of velocity RMS using a new and worn focusing tube at different speed rates of the cutting head (sensor placed on focusing tube)

4. *Conclusions*

On-line control of abrasive waterjet technology is currently one of the options to optimize the technology regarding the increase of the productivity and production quality management. On-line control, however, requires an effective way to measure the quality of the surface and find the appropriate feedbacks. Since the abrasive waterjet cutting of materials raises the mechanical oscillations and vibrations that can be bearers of important information for monitoring of the immediate state of the technological process, we started to investigate the possibility of a connection between the focusing tube wear and vibrations. On the basis of experimental measurements carried out by vibration and ultrasonic emissions at the cutting process of 40 mm thick aluminum, it can be concluded the following conclusions:

- It should be noted that measured vibrating signal doesn´t show significant periodicity. The level of the signal changes during the cutting process. This fact has to be taken into account in further measurements and analysis.
- The dependence between vibrations and focusing tubes wear has been observed; in the experimental conditions the cutting with the new focusing tube has induced less vibration.
- The existence of dependence between the vibration and displacement was confirmed at the traverse speed of over 100 mm.min-1, using worn focusing tube the value of the RMS, detected by the sensor PCB IMI type 607A11 placed on the workpiece, is increasing. Using the new focusing tube (Roctec 100) RMS values were found lower.
- Based on the above mentioned conclusions, further experiments will be carried out to determine the connection between vibration and the surface quality and further measurements will be provided to find the dependence between vibration and technological conditions at materials cutting as well as the material properties.

Acknowledgment
The authors would like to acknowledge the support of Scientific Grant Agency of the Ministry of Education of Slovak Republic, Commission of mechanical engineering, metallurgy and material engineering, for their contribution to project 1/4157/07.

5. *References*

[1] ANNONI, M.; CRISTALDI, L.; LAZZARONI, M., "Measurement and Analysis of the Signals of a

[2] BEŇO, J., MAŇKOVÁ, I. Technologické a materiálové činitele obrábania, 2004 Vienala Košice, s. 418

[3] FOLDYNA J., SITEK L., HABÁN V. Acoustic wave propagation in high-pressure system, Ultrasonics Volume 44, Supplement 1 , 22 December 2006, Pages e1457-e1460,

available through science direct http://www.lsbu.ac.uk/water/strange.html

[4] HLOCH, Sergej et al. : Vibračná analýza delenia hliníka. In: Strojárstvo : Strojárstvo extra. roč. 12, č. 6 (2008), s. 94/8-95/9.

[5] KOVACEVIC, R., MOHAN, R., ZHANG, Y. M. Cutting Force Dynamics as a Tool for Surface Profile Monitoring. In: AWJ. ASME J. of Engineering for Industry, 1995, vol. 117, p. 340-350

[6] LEBAR, A., JUNKAR, M. Simulation of abrasive waterjet machining based on unit event features. Journal of Engineering Manufacture (Part B) 217, 2003, s. 699-703.

[7] OHLÍDAL, M., PÁLENÍKOVÁ, K. Možnosti optického profilometru MicroProf FRT při 3D hodnocení kvality povrchu. Jemná mechanika a optika, 2004, roč. 49, č. 9, s. 251-259. ISSN 0447-6441.

[8] VALÍČEK, J., HLOCH, S. Dělení materiálu vodním paprskem (1) : Nové možnosti riadenia technológie delenia vysokorýchlostným hydroabrazívnym prúdom v reálnom čase. In: Svařování, dělení, spojování materiálů. vol. 5 (9), no. 2 (2007), p. 41-43. ISSN 1212-4044.