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MONITORING OF FOCUSING TUBE WEAR DURING ABRASIVE WATERJET (AWJ) CUTTING OF AISI 309

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The paper deals with the investigating the possibility of using vibrations as a potential source of information for the detection of the malfunctions during the abrasive supplying and focusing tube wear in the process of AWJ. The tested material was the stainless steel AISI 309. Variable factors in the experiment were the abrasive mass flow m_a and the focusing tube diameter d_f. The scanned vibration signal of the material was subjected to frequency analysis. With the increase of the abrasive mass flow, the shift of the amplitudes will follow the opposite direction and decrease. Frequency spectra of all assessed signals are similar by shape in the high-frequency area.

Key words: stainless steel, AWJ cutting, vibrations, Frequency analysis

INTRODUCTION

The technology of AWJ machining is currently one of the leaders in cutting technologies. Although this technology is continually the focus of research and development, the commercially used model of online management or process control is still missing. The major problem is the failure of abrasive delivery due to abrasives moisture, or obstruction in the inlet tube. There is no reliable automatic indicator of focusing tube wear, so this is inspected just visually by the operator. Both issues have a direct impact on the quality of the generated surface. Several authors addressed their research to the process modeling for the prediction of the cutting factors. Vundavilli et al. [1] dealt with the prediction of cut depth using an expert system based on fuzzy logic. Ma et al. [2] focused on predicting the cut profile. Nozzle wear was examined by Nanduri et al. [3] and wear of the focusing tube was studied by Jegaraj et al. [4]. Only few of the authors have researched the utilization of secondary emission of the AWJ cutting process. Their attention was mostly devoted to acoustic emission. Asraf et al. [5] designed a model for on-line monitoring of the cut depth in the AWJ cutting process by means of acoustic emission. The relationship between generated high pressure flow and acoustic emission was studied by Foldyna et al. [6]. Arulu et al. [7] used acoustic emission for quality control during drilling composite materials. Hreha et al. [8] used vibrations as a carrier of information for predicting the quality of the surface generated by AWJ cutting. He used vibrations to investigate the effect of abrasive mass flow in material perforation [9].

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MATERIALS AND METHODS

The material used for the experiment was stainless steel AISI 30 with thickness 15 mm. Technological factors of the cutting are described in the table (Table 1). Feed rate of a cutting head v was set to 150 mm·min^{-1}. The abrasive mass flow m_a was set to 250 and 400 g. min^{-1}. Diameter of the focusing tubes d_f was 0,8 and 1,4 mm (Figure 5). During the cutting of experimental samples the vibrations of the cut material were recorded. For the data acquisition the NI PXI - 1031, NI PXI - 6106 system was used for eight-channel simultaneous collection with the sampling frequency of 30 kHz. Vibrations were recorded by uniaxial accelerometers PCB IMI 607 A11.

Table 1 Technological conditions

Factors	Levels
Pressure *p* / MPa	350
Feed rate *v* / mm/min	150
Abrasive mass flow rate m_a/g/min	250, 400
Orifice diameter d_o / mm	0,33
Focusing tube diameter d_f / mm	0,8; 1,4
Standoff *z* / mm	3
The angle of the cutting	90°
Abrasive type Barton Garnet MESH 80	
Material thickness	15 mm

Recorded signals were then analyzed by a tool created in the object-oriented programming environment of LabVIEW 8.5. The procedure of data collection is shown in the figure (Figure 1). Parameters of the surface were recorded by means of non-contact method using an optical profilometer MicroProf FRT. Parameters were measured in nineteen in-depth lines, equidistant with 0,75 mm. The first measured line is in the distance 0,75 mm from the sample top edge.

RESULTS

The obtained signal was processed in a proper environment of LabVIEW 8.5. As for the research parameter of the vibration signal, the so-called effective value of vibrations RMS was chosen. The study aims at investigation the impact of the focusing tube wear by changing its diameter d_f and detecting changes in abrasive mass flow m_a. RMS parameter value on the frequency spectrum while changing the focusing tube diameter can be seen in the Figure 1.

Overall, higher RMS values were recorded at the focusing tube diameter $d_f = 0,8$ mm. The highest peak value of 0,183 g was recorded at a frequency of 11 800 Hz. Notable peaks of the spectra have been recorded also at low frequencies, i. e. 1 100 Hz, 2 100 Hz and 2 900 Hz. Other significant peaks with similar value can be observed at frequencies of 4 100 Hz and 5 800 Hz. Highest frequency at which the increase of RMS amplitude was recorded is 14 500 Hz. Amplitude value at the frequency spectrum that corresponds with the signal generated by using the focusing tube with a diameter $d_f = 1,4$ mm is generally lower. The individual increases of amplitudes are not as significant as in the previous case. The highest amplitude value 0,077 g was recorded at a frequency of 10 400 Hz. Significant increases of the amplitudes of the spectrum can be observed at frequencies 500 Hz, 1 000 Hz, 1 600 Hz, 5 300 Hz and 5 800 Hz. The highest frequency at which the increased amplitudes were recorded was 14 400 Hz. Assessed frequency spectra show signs of similarities. Comparative diagram (Figure 2) shows not only the RMS amplitude variations, but also their shift in the frequency spectrum.

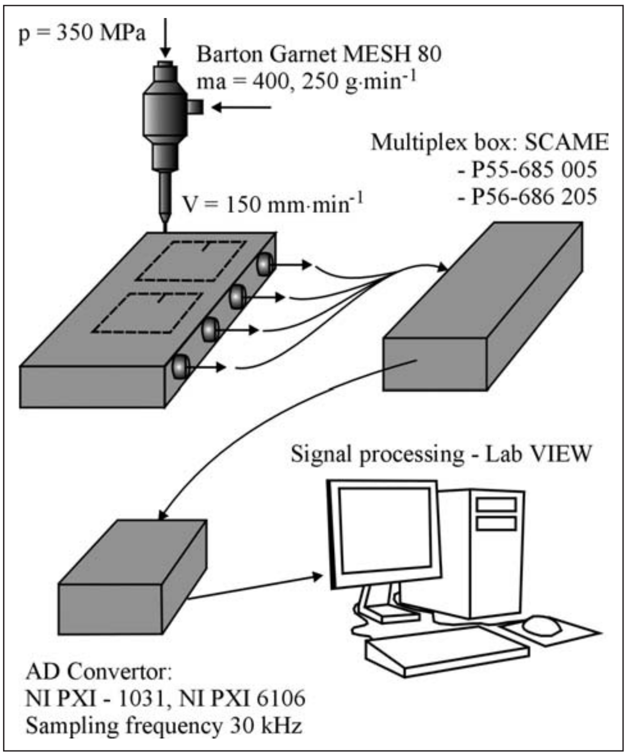

Figure 1 Experimental procedure

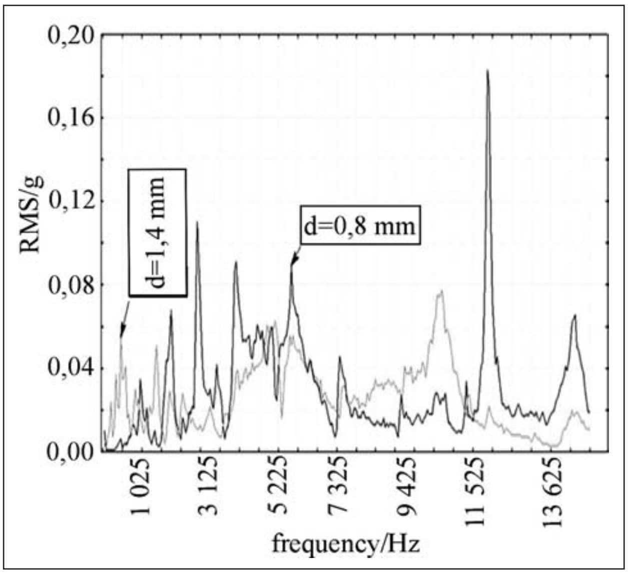

Figure 2 RMS value at the frequency spectrum, constant factors: $v = 150$ mm/min, $m_a = 250$ g/min, variable factors: $d_f = 0,8$ mm, $d_f = 1,4$ mm

With an increase of the focusing tube diameter d_f to 1,4 mm a shift to higher frequencies occurred. This phenomenon is clearly visible in the spectrum 4 000 Hz to 7 000 Hz and 10 500 Hz to 15 000 Hz. Amplitudes in lower frequencies are shifted by 200 Hz. In the higher frequency range the shift was recorded at 100 Hz. As it was already mentioned, the next examined factor was the change of abrasive mass flow m_a. Comparative diagram describing the change is in the figure (Figure 3).

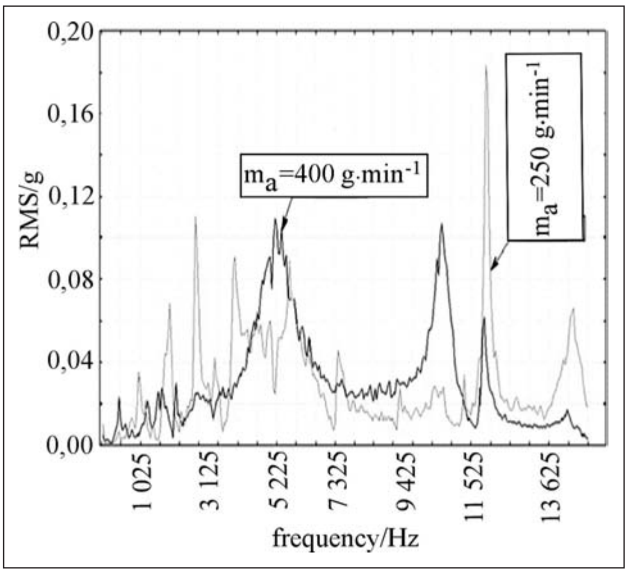

Figure 3 RMS value at the frequency spectrum, constant factors: $v = 150$ mm/min, $d_f = 0,8$ mm, variable factors: $m_a = 250$ g/min, $m_a = 400$ g/min

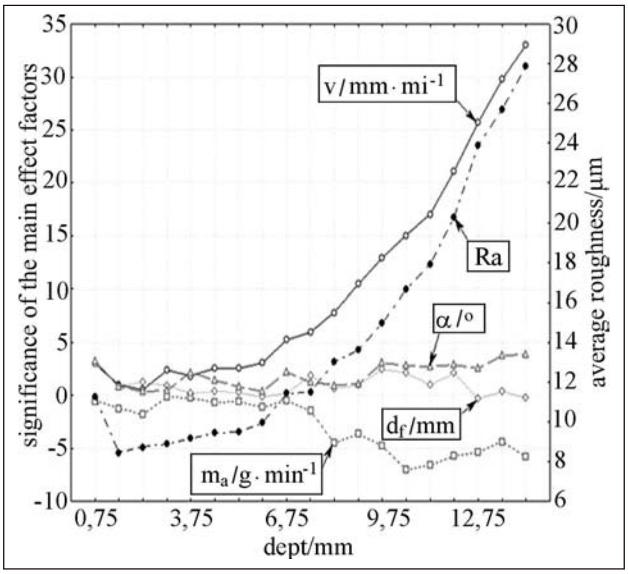

Figure 4 The development of factors effect on the *Ra* parameter in dependence of depth

Spectrum describing the RMS value at the mass flow m_a = 250 g/min corresponds to the spectrum of the previous case and to a focusing tube diameter d_f = 0,8 mm. Amplitudes at each frequency are described above. Spectrum corresponding with abrasive mass flow m_a = 400 g/min is significantly higher in two areas of the spectrum.

The highest RMS value, 0,109 g was recorded at a frequency of 5 300 Hz. Other significant increases in amplitudes can be observed at frequencies 10 500 Hz, 11 800 Hz and lower peak at a frequency of 14 300 Hz. In the low frequency area up to 3 000 Hz low amplitude peaks not exceeding 0,03 g can be observed. Assessed curves are similar in the high frequency range from 11 000 Hz. Increasing the abrasive mass flow m_a results in the shift of the peaks in the frequency range to the lower areas. This phenomenon is clearly visible in the high-frequency field. The amplitudes of the single peaks are shifted by 200 Hz. Examined technological factors – abrasivemass flow m_a and focusing tube diameter d_f have a direct impact on the resulting surface topography of the cut surface. The influence of these parameters was demonstrated by the research works of several authors [10]. The development of factors effecting the Ra parameter in dependance on the depth shows a graph (Figure 4). It describes the effects of individual factors on the resulting surface roughness parameter. Increasing the depth,the effect of feed rate of the cutting head vincreases significantly. Focusing tube diameter has an increased effect in the lower area. Its increase causes the increase of roughness parameters.

CONCLUSIONS

The article deals with the investigation of the possibility of detecting the focusing tube wear and failures of abrasive supply by means of material vibration. As the

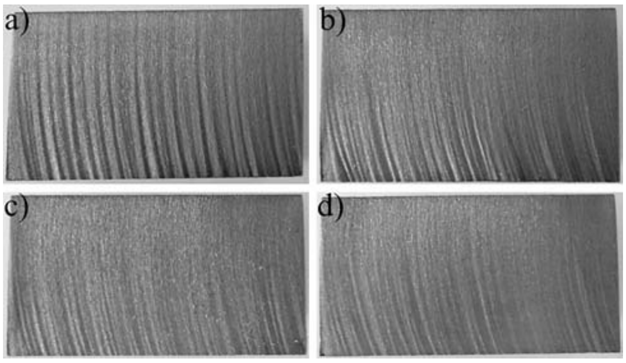

Figure 5 a) d_f = 0,8 mm, m_a = 400 g/min, b) d_f = 0,8 mm, m_a = 250 g/min, c) d_f = 1,4 mm, m_a = 400 g/min, d) d_f = 1,4 mm, m_a = 250 g/min

experimental material AISI 309 stainless steel 15 mm thick was used (Figure 5).

Abrasive mass flow m_a and focusing tube diameter d_f were examined. Material vibration signals captured during AWJ cutting were subjected to spectral analysis. Attention was paid to the RMS value of the frequency spectrum. Based on the experiments, it can be concluded: 1. curves of all investigated spectra show a similar shape, especially in the high frequency region, 2 - increasing the focusing tube diameter d_f has shifted the amplitude peaks in a frequency spectrum upwards in the range 100 to 200 Hz, 3 - increasing the abrasive mass flow m_a has shifted the amplitude peaks the frequency spectrum downwards in the range of 200 Hz, 4 -significant and stable amplitude peaks were observed around the frequencies of 10 500 Hz and 14 400 Hz ,5 - the influence of the focusing tube diameter d_f and abrasive mass flow m_a on surface roughness parameters were confirmed by the experiment. Further research on material vibration as a potential source of information for fault detection and quality control in the process of AWJ will focus on identification of the frequency ranges that serve as a source of information on a given plot during cutting.

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Note: The responsible person for english language is prof. Martin Šuto, University of Osijek