THE EFFECT OF FACTORS ON THE OCCURRENCE OF VIBRATION UNDER OPERATIONAL CONDITIONS

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When using the method of processing materials by a plasma beam it is necessary to know the specific requirements for quality and economy of cutting. Vibrations occur during this process, which can have a negative effect on lifespan of the machine. Therefore currently there is greater emphasis on exploring the effects causing these vibrations. The goal of this paper is to analyze and consider the effect of input technological factors on the occurrence and size of mechanical vibration under operational conditions. It analyzes the effect of change of the feed speed on the plasma machine under the use of four beams on the acceleration amplitude and vibration frequency. Graphic dependencies are created from measured values, which are used for comparison and evaluation of the technical condition of selected device.

KEYWORDS

monitoring, processing, factor, mechanical vibration, frequency spectrum

1 INTRODUCTION

The mechanism of cutting using a plasma beam consists in melting the material under very high temperatures created by the occurring plasma. These temperatures subsequently cause the melting of the material in desired spot [Herman 1988, Chraska 1992]. This process of material removal is mostly affected by the diameter of the nozzle (range from 0.79 mm to 6.35 mm), arc power source (depending on the thickness of the cut material), used plasma gasses, distance between the material and the torch, cutting speed (it increases linearly with higher performance and grows also with decreasing thickness of the material). During processing these effects create complex processes of mechanical vibration machine - tool - work piece. Vibration intensity is sometimes small and does not have any adverse effect [Zeeland 2006, Pandit 1980, Jiménez, 2005]. However there are cases when the vibration is very intense and causes adverse effect in several ways - tools wear rapidly and wear of the machine is increasing. One of the examined input technological factors is speed [Wang 2010]. It is know that speed has [Vogl 2009, Kumar 1997, Maščenik, 2015] a big effect on the character of creating splinter and creation of growth [Panda 2016, Salokyová 2014, Baron 2016].

The goal of this paper is to observe the effect of selected technological factors, namely the feed speed and beam on size of the vibration under operational conditions. After carrying out the experiments, original graphic dependencies are created and based on them comparison graphs of frequency range covers. In conclusion of the paper knowledge is proposed based on evaluation of the measurements, which will serve to improve the efficiency of the operation of the machine, reduce failure rate and refining products.

2 EXPERIMENTAL MEASUREMENT

All measurements have been carried out under operational conditions at a pre-selected company dealing with the production of rail freight wagons and chassis. Measurement of the size of mechanical vibration has been carried out in a contactless manner at the nozzle head (Figure 1) of the plasma machine, type HiFocus 280i, on which technological factors have been changing during the processing, specifically the feed speed and current. During the measurement, material of the type S355J2C was processed – it is construction steel, which is suitable for cold forming.

Nine successive measurements have been carried out split in 3 experiments. Input constant and changing parameters, under which measurements were carried out, are listed in Table 1.

Figure 1. Detail of measuring mechanical vibration at the nozzle head of the plasma machine

Table 1. Measuring conditions

Factors	**Experimental range**
currents	220, 240 and 260 A
cutting velocity	700, 1200 and 1700 mm/min
voltage	147 V
cutting performance	36 kW
Type of head	370.1
Cut material indication	S355J2C mechanical characteristics (Rm = 490 – 680 MPa, Re = 355 MPa, HB = 160) chemical characteristics (C 0,24 %, Mn 1,7 %, P 0,035 %, S 0,035 %, Si 0,6 %, Cu 0,6 %)
Thickness of material	15 mm

3 TECHNICAL SYSTEM USED FOR THE MEASUREMENT

As already mentioned at the beginning of the paper, assembly of the laser vibrometer Polytec PDV 100 has been used for monitoring the frequency analysis of the vibration. This assembly consists of the head of vibrometer placed on a positional stand. The data collector records acceleration of the vibration signal from the sensor and it is integrated onto the speed of the vibration signal. Vibration acceleration amplitudes in the processing axis recorded in this way are written into the memory of the measuring device CompactDAQ NI 9234 from the National Instruments Company and are evaluated in the frequency range using quick Fourier transformations. It allows determining the multitude of harmonic frequencies in the monitored signal. The evaluated signal then can be immediately observed on a portable computer using the SignalExpress software. The SignalExpress program contains several functions necessary for the correct evaluation, recording measurements and their analysis.

4 EXPERIMENTAL RESULTS IN TIME DOMAIN

The analysis of the vibration-diagnostic signal measured on the diagnostic machine in time period consists of evaluation of measured time progressions of signals of the characteristic parameter of vibrations, thus acceleration. Based on progressions of the signal immediate, median and effective values of the signal can be easily determined. Time analysis is suitable and can be used especially when there is only one or at least dominating source of vibrations. If this is not the case, there can be loss of information in the noise of vibration signals from other sources and thus localization of the cause of excessive vibration is very difficult. There was no such problem in our case.

Time progression of vibration acceleration (Figure 2) for feed speed of 700 mm/min and current 220, 240 and 260 A is graphically depicted as an example. Graphic dependencies of vibration acceleration amplitude and frequency vibration for other examined speeds (1200 mm/min, 1700 mm/min) and currents 220, 240 and 260 A has been created analogously.

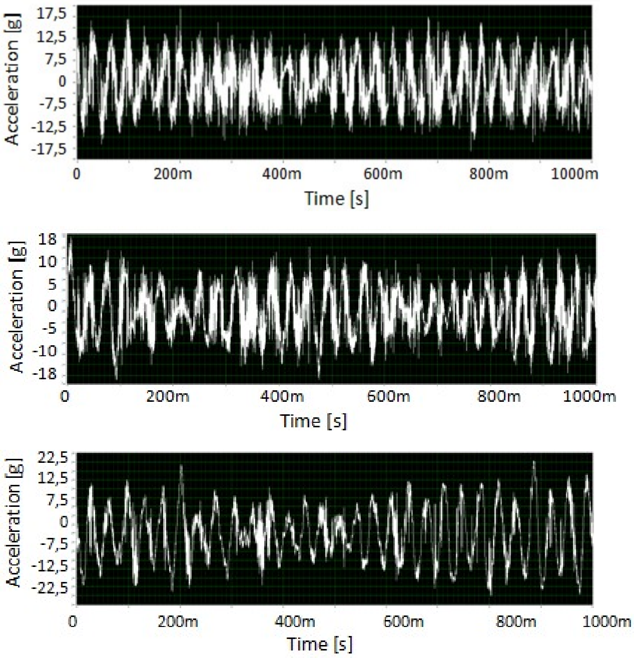

Figure 2. Time progression of vibration at velocity 700 mm/min and current 220, 240 and 260 A

Based on graphic dependencies (Figure 2) we can state that amplitudes with growing currents increase periodically. During processing amplitudes fluctuate usually non-periodically, but we consider them stable. Time recording of the progression under the current 220 and 240 A smaller amplitudes have been recorded when compared with the record under the current 260 A.

5 FREQUENCY ANALYSIS

Frequency analysis allows the exact identification of individual causes of vibration. It removes the disadvantages of the analysis in the time domain in other words it localizes the arising defect of individual parts of the diagnostic tool. Frequency analysis is given by the amplitude spectrum - amplitude spectral density and phase spectrum.

Since the time record shows a non-periodic progress, for the frequency analysis a part was selected with stabilized progression of 10 seconds and through FFT a frequency range of 0 - 10.0 kHz has been generated. Just like for time record a graphic example is depicted for frequency spectrums for feed speed 700 mm/min and current 220, 240 and 260 A (Figure 3). Similarly frequency ranges have been evaluated from other speeds and currents.

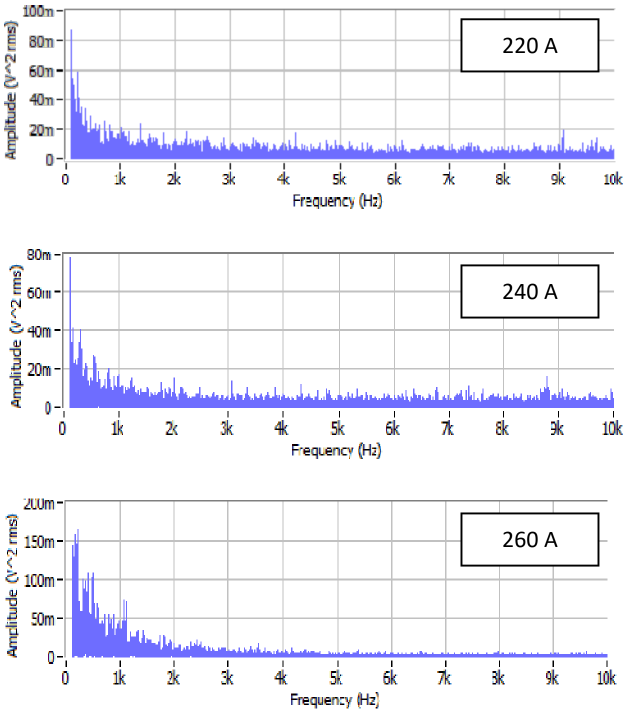

Figure 3. Frequency spectrum for speed of 700 mm/min and current 220, 240 and 260 A

The frequency range progression shows that for all processes the maximum frequencies were frequencies in the range 100 Hz – 700 Hz. Frequencies in the range 1.0 kHz – 10.0 kHz overall did not show significant dependency on the examined input factors of the experiment.

6 THE FREQUENCY ANALYSIS OF RMS PARAMETER

Since the FFT spectrum of absolute acceleration amplitudes is very dense, overlay of individual spectrums for the purpose of comparing does not provide the information value. The cover method is not suitable, since these are not periodic occurrences. The Peak to Peak parameter describes the maximum amplitude deviations and neglects lower value. The amplitude absolute values mean smoothens the extreme value. Because of these reasons to better compare FFT spectrums the attention was focused on the value of RMS in the whole frequency range.

Graphs (Figure 4 through 6) depict RMS values based on frequencies measured under setting variable factors of feed speed 700, 1200 and 1700 mm/min individually for examined currents 220, 240 and 260 A.

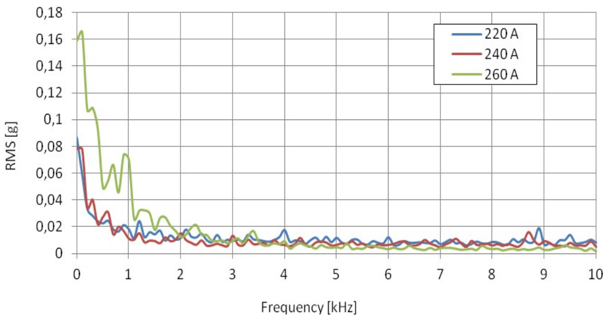

Figure 4. RMS value based on frequency under feed speed 700 mm/min

Dependencies when processing at 700 mm/min show that the curve corresponding to current of 260 A shows significantly higher value in low frequencies. First major increase of amplitudes can be observed at the frequency of 100 Hz. The highest value of amplitude has been recorded at this frequency with the value of 0.165 g. In the 200 Hz range there are significant peaks of the curve corresponding to the current of 220 and 240 A, where short increases of amplitude have been recorded with the value of 0.0862 g. Most similar in shape are curves for all examined currents in the frequency range from 2.0 kHz to 10.0 kHz, where the highest value was approx. 0.02 g at frequency of 8.8 kHz under the processing current of 220 A.

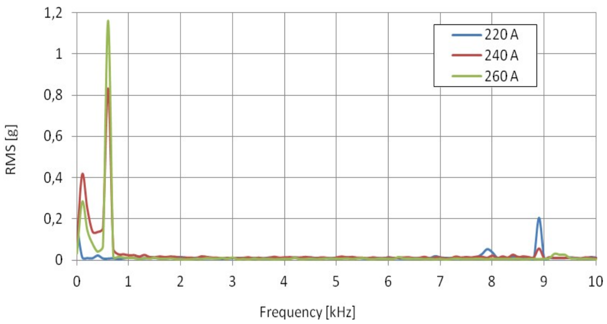

Figure 5. RMS value depending on the frequency under feed speed 1200 mm/min

Graph in Figure 5 depicts RMS values under the same setting of factors as in the previous case. First major increases of amplitudes in the spectrum of the data measured under feed speed of 1200 mm/min were recorded at the frequency of 200 Hz. Another increase of amplitudes occurred at the frequency of 1.0 kHz with two major peaks when using current of 240 A and 260 A. This was followed by a range of lower amplitudes. Just like in the previous case the highest amplitude value correspond to the curve with the current of 260 A. The highest amplitude was recorded at the frequency of 600 Hz with a value of 1.158 g. The RMS value corresponding to the current of 240 A when compared to the previous case differs by the value measured in the low frequency range. At frequency of 600 Hz it reached the highest value of 0.831 g. Further the spectrum behaves in a standard way and displays a peak with increased amplitude around the frequency of 8.8 kHz with a value up to 0.18 g under processing current of 220 A.

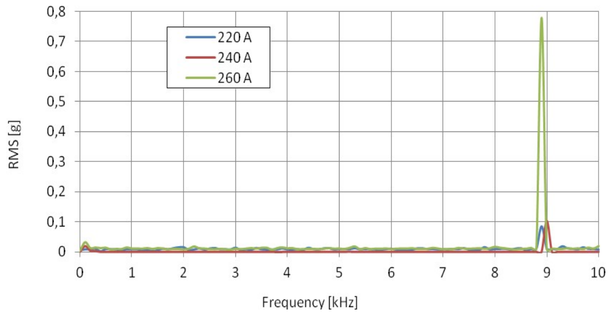

Figure 6. RMS value depending on the frequency under feed speed of 1700 mm/min

As opposed to the previous cases the peaks of the curves for the examined currents are shifted into the high frequency range of the frequency spectrum. The dominant curve in the high frequency range is the curve of the current 260 A. The RMS value of this curve reached the highest value of 0.778 g. Increase values can be observed also for curves for currents of 220 and 240 A around the frequency of 9.0 kHz, which have the size around 0.1 g.

7 COMPARISON OF RMS PARAMETER MAXIMUM VALUES

The RMS parameter was used for the analysis of comparing the vibration signal for three examined feed speeds and three changing currents during processing. Highest RMS values of the vibration amplitude are listed in Table 2.

Figure 7 graphically depicts the maximum RMS values selected from a stabilized progression of 10 seconds. The highest RMS value equals 1.15 g and it was recorded at 1200 mm/min and for input current of 260 A. A little lower RMS value of 0.77 g was recorded at feed speed of 1700 mm/min also at 260 A. The longest progression was achieved by the curve under processing at 700 mm/min. Generally it can be said that with growing currents used for processing an increasing trend of vibration amplitude values is recorded.

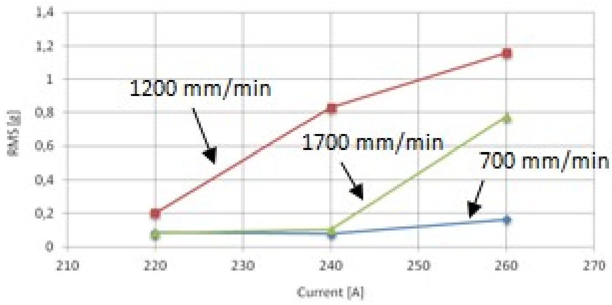

Figure 7. Dependency of RMS values on the value of current under three feed speeds

Table 2. Values RMS

		currents [A]		
		220	240	260
700 mm/min	frequency [Hz]	200	400	100
	RMS value [g]	0.086273	0.078237	0.165121
1200 mm/min	frequency [Hz]	8900	600	600
	RMS value [g]	0.203284	0.31194	1.158542
1700 mm/min	frequency [Hz]	8900	9100	8900
	RMS value [g]	0.08384	0.102763	0.778047

8 SIGNIFICANCE OF FACTORS

The DOE method was used to determine the effect of individual factors on the measured RMS parameter of vibrations. Standard design of the experiment was implemented with 2 examined factors and three levels. Feed speed of the spindle head were used as examined factors, wit levels of 700, 1200 and 1700 mm/min and current at levels of 220, 240 and 260 A. Tab 3 contains measured values from the measurements carried out. The highest average output value of Ȳ was achieved at E5 (0.0329 g).

Table 3. Measured values of measurement

		cutting velocity	current	amplitude vibration
order	experiment	A	B	Ȳ
1	E1	700	220	0.012623
2	E2	700	240	0.010594644
3	E3	700	260	0.016859436
4	E4	1200	220	0.015372158
5	E5	1200	240	0.032987347
6	E6	1200	260	0.026373604
7	E7	1700	220	0.009203673
8	E8	1700	240	0.002095446
9	E9	1700	260	0.018513003

Analysis of the main effect of individual factors is listed in Tab. 4. Individual values A1, A2, A3, B1, B2, B3 are average values of the resulting value Ȳ, where given parameter was found. Thus for:

- A1 these are experiment values where parameter A had value 700 thus E1, E2, E3
- A2 these are experiment values where parameter A had value 1200 thus E4, E5, E6
- A3 these are experiment values where parameter A had value 1700 thus E7, E8, E9
- B1 these are experiment values where parameter B had value 700 thus E1, E4, E7
- B2 these are experiment values where parameter B had value 1200 thus E2, E5, E8
- B3 these are experiment values where parameter B had value 1700 thus E3, E6, E9

Table 4. The main effects of outputfactors Ȳ

		A	B	Ȳ
A1	A=700	0.013359		0.016069146
A2	A=1200	0.024911		
A3	A=1700	0.009937		
B1	B=220		0.0124	
B2	B=240		0.015226	
B3	B=260		0.020582	0.016069146

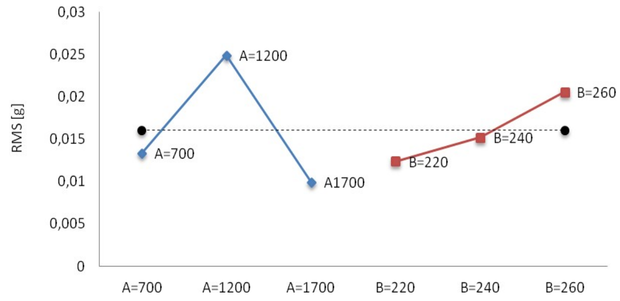

Figure 8. Main effect of individual factors and their levels on the Y output

Size of the vibrations amplitude (RMS) when processing material using plasma is mostly affected by the factor – speed of spindle head. As is shown in fig. 8 the greatest effect on the RMS vibrations value has the medium level of factor A, thus feed speed of spindle head of 1200 mm/min. The upper level of factor A, thus feed speed of spindle head of 1700 mm/min has the same effect. Lower effect on the size of RMS vibrations has the second observed factor, namely current, in all three B levels.

9 EVALUATION OF MEASUREMENT

The paper analyses the effect of individual input technological factors on the level of vibration parameters. Based on the results of the measurement it is suitable to recommend the elimination of vibrations of the machine itself. The first possibility how to eliminate the values of amplitudes of the machine itself is the adjustment of the operational use of the machine and its settings by choosing the suitable current under specific feed speeds. The second possibility of eliminating amplitudes is suitable maintenance, especially of moving parts and parts transmitting vibrations. It is recommended to check the will of the moving axes of the machine, check of the lateral track against the longitudinal and check of the condition of the coarse and fine grids and pollution. It is also recommended to eliminate vibrations around the machine, specifically the transfer of vibrations by placing the machines on a mat. Because of these reasons several aspects need to be considered; some of these changes could negatively affect the economy and planning of the production.

10 CONCLUSION

The technology of processing by plasma is currently broadly used. Despite its benefits, just like any other technology, it has its shortcomings. The development of new devices and innovations to remove or eliminate these shortcomings is always the subject of several researchers not only in Slovakia, but abroad as well. This paper contributes to the clarification of questions surrounding relations between the input technological factors - current and feed speed and the resulting parameters, in our case the size of the vibration amplitudes on the nozzle head. The analysis of vibration signals pointed to the effect of the size of the current and feed speed. Significant growth of amplitude values have been observed in the frequency analysis during processing at speeds of 700 mm/min and 1200 mm/min in the low frequency range of the spectrum. On the other hand when using the speed 1700 mm/min growth of amplitude values were recorded in the high frequency range of the spectrum. This creates a basis for a more detailed solution of the issue, where it is necessary to expand research of input technological factors with suitable range of setting values. Further it is recommended to asset the complete technology using the vibration analysis, assign those corresponding frequencies and subsequently identify the transfer of vibration to the processed material.

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