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Study of surface roughness by acoustic signal obtained from piezoelectric electret sensors in milling machine with CNC

Introduction. Nowadays, quality requirements in industry is an important issue. Study of surfaces machined with milling machine tools with computer numerical control by acoustic signal is informative method of monitoring of machining in industry. Also, studying of machining parameters and surface quality can be applied in different methods of machining metals, for example in abrasive waterjet cutting [1]. Quality of surfaces is important for machines and details.

Roughness is main parameter of machining quality. Such parameters as chatter [2], which also refer to surface quality, also can be researched by acoustic methods. Study of surface roughness had been represented in [13]. Advanced methods of monitoring see [14]. Combination of acoustic and force signal are represented in [15]. Research of tool conditions recognizing using complicate sensor system was made in [8]. Usage of fuzzy logic to identify acoustic emission in cutting is effective method of analyzing of data obtained from monitoring system [10]. Usage of neural network in hard turning monitoring of surface roughness is researched in [11].

Main part. In this research acoustic signal was measured by two piezoelectric sensors with thin electret plate to find out how surface roughness correlate with it. Electret material have dielectric properties and have high resistance to cutting fluids and coolants. It is important, because cutting of metals in experiment have been done in condition of machining with coolants. Electret microphone circuit shown on fig. 1. Acoustic signal obtained from electret microphone is characterized by frequency (Hz) and decibels relative to full scale (dBFS). Studying of this parameters compared with g-code and operation on machine tool allows to correlate acoustic signal with characteristics of finished surfaces.

In process of machining we need to analyze data obtained from sensors, highlight the useful component of the data, noises of environment and of self-noise of microphone conducted to another microphone. Different methods of integration of two and more different sensors are represent in [3, 4, 5]. It is important to optimize position and mounting of sensors in the machine-workpiece-tool system, eliminating of noise, proper signal characterization in order to obtain correct results. Proposed formula for interference of two signals from two electret microphones:

$$\begin{cases} f_1 = k_1 P_{u1} + k_2 P_{n0} + k_3 P_{n2} \cdot \sin\alpha \\ f_2 = k_4 P_{u2} + k_5 P_{n0} + k_6 P_{n1} \end{cases}$$

where k_i is coefficients, P_{ui} is useful signals from sensors, P_{n0} is noise signal, P_{ui} is signal from one sensor, which is displayed in another sensor, α is phase shift during interference of two signals.

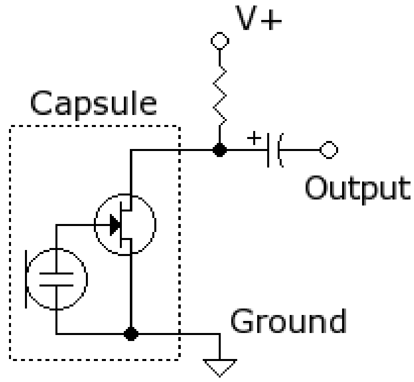

Fig. 1. Electret microphone circuit

Comparison of two signals:

$$F = f_1 - f_2 = k_1 P_{u1} + k_2 P_{n0} + k_3 P_{n2} \cdot \sin\alpha - (k_4 P_{u2} + k_5 P_{n0} + k_6 P_{n1})$$

where F is compare signal.

Method of processing signals needs to be automatic. For example, we can use neural network technology to solve this task [11]. Usage of such technology is effective in solving the tasks of machining [9].

Table 1. Cutting parameters

Tool position	Cutting conditions used on operation	Type of cutting tool
T01	F: 500…800 mm/min S: 4500…6000 r/min	Mill Ø10
T02	F: 50…60 mm/min S: 700…900 r/min	Spiral drill Ø12

Formulation of the experiment settings. The experiment was done on HAAS VF-2 machining center with support of ISO 6983 G-code. Two main operations were milling of planar and cylindrical surfaces and drilling of holes. Total of 5 parts with same drawings were machined. Each part was machined with one fixture outfit. Finished detail is shown in fig. 2. Material of workpiece was Duralumin D16 GOST 4784-97. Dimensions of the workpiece was L×H×B = 130×80×25mm. Cutting tools used in research was mill Ø10 with length of cutting part 20mm and spiral drill Ø12 with length of cutting part 70mm. Table 1 demonstrate the cutting parameters of the experiment.

Measurement of roughness is performed using profilometer. And compared to signal in specialized fast Fourier transform (FFT).

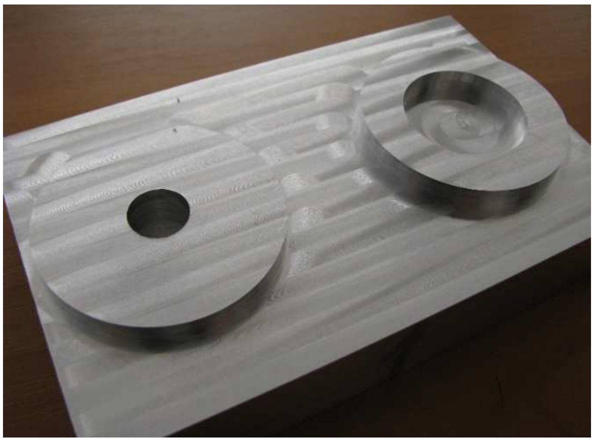

Fig. 2. Example of machined detail on vertical milling center

The goal of milling was to obtain surface roughness Ra 1,25. Drawing of part shown in fig. 3.

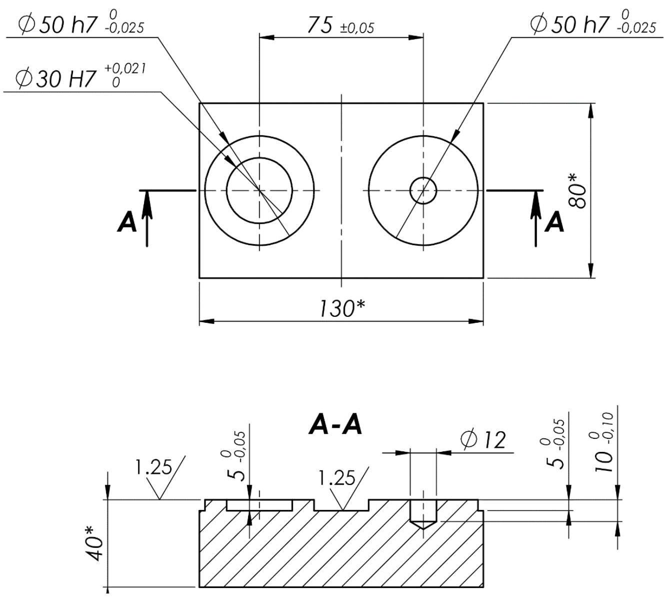

Fig.3. Drawing of part

As chip formation was not influenced on signal as sensors was isolated.

Acoustic signal of milling of planar surface is shown in fig.4. As we can see from chart, increase in frequency response relative amplitude scale also increases. The peak amplitude was for -83,22 dB. 3-D plot for this signal shown on fig.5. Analyzing of harmonic spectrum series and frequency, we can characterize the technological process. To do this, we need to compare G-code with signal.

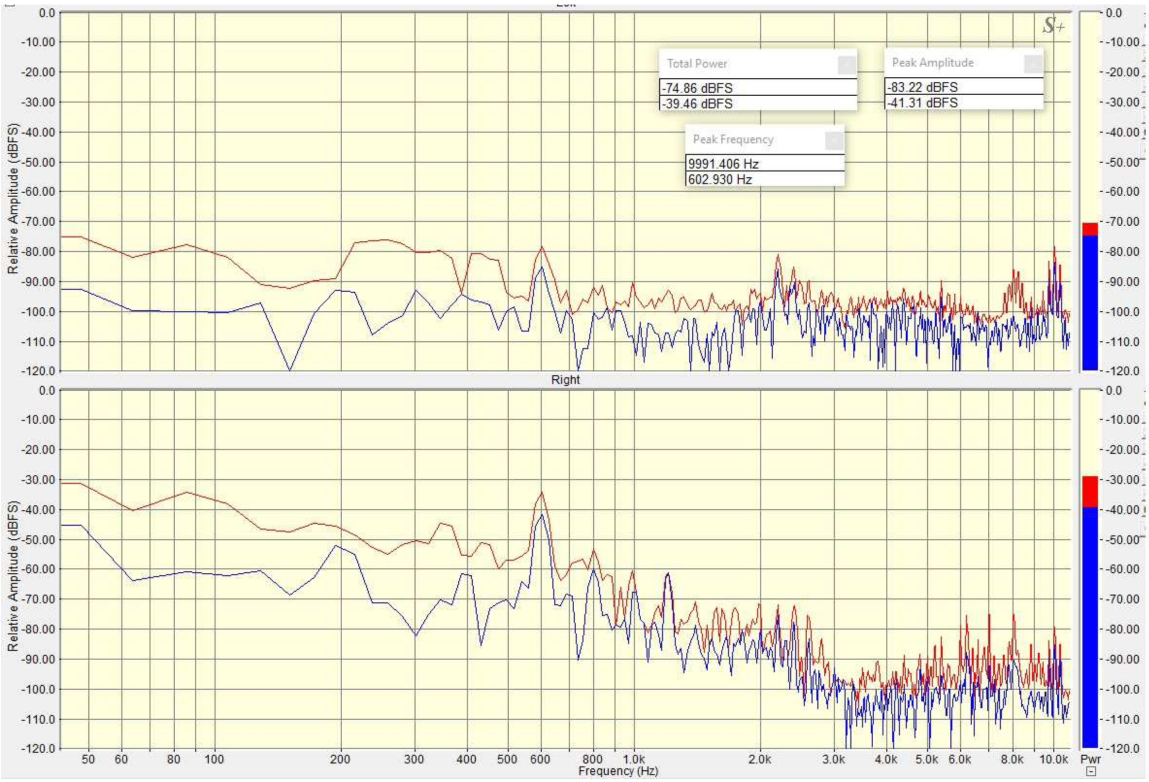

Fig. 4. Example view of acoustic signal of milling of parts

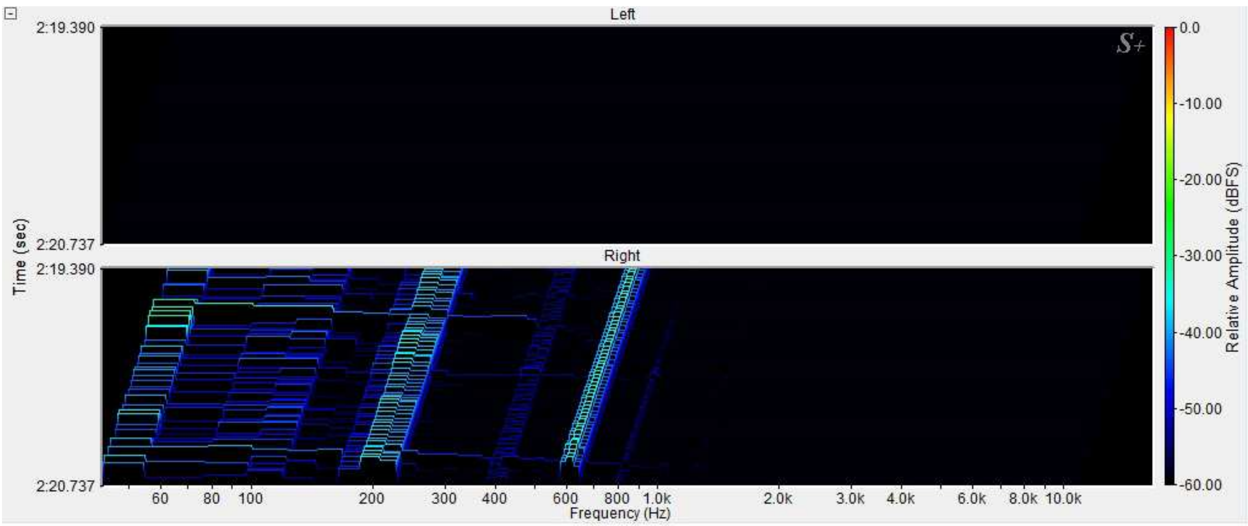

Fig.5. Example of 3-D plot of acoustic signal obtained on operation of milling planar surface

Results and discussion. Experiment of correlation between acoustic signal and surface roughness had been done. 3-D plot of acoustic signals was prepared for analyzing.

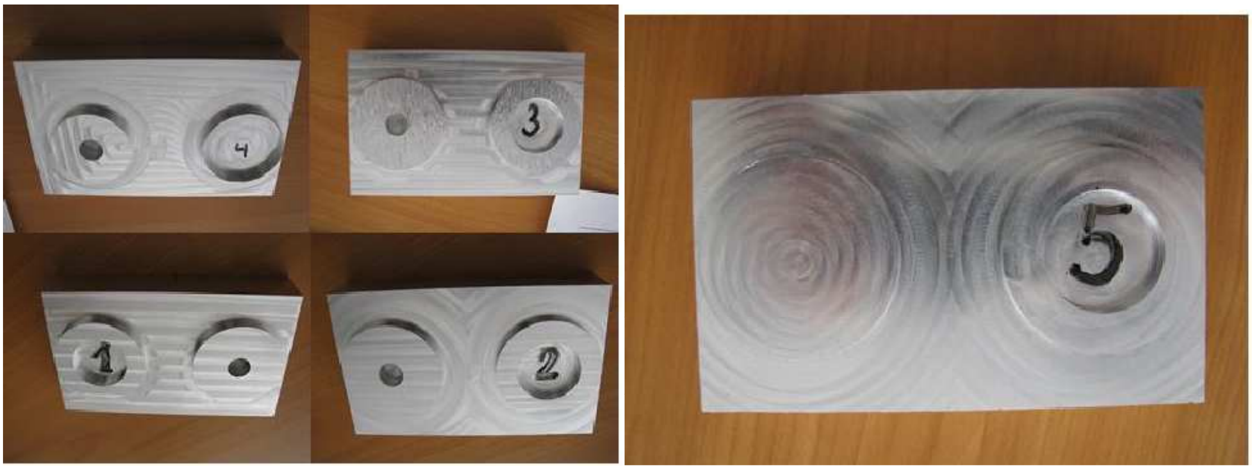

Fig. 6. Samples of machined parts

As shown in fig. 6, 5 samples of surfaces were machined. Each of samples have full recorded acoustic signals and collected by file in .wav format. Analysis of this data were done to correlate surface roughness via spectrogram data (see fig. 7).

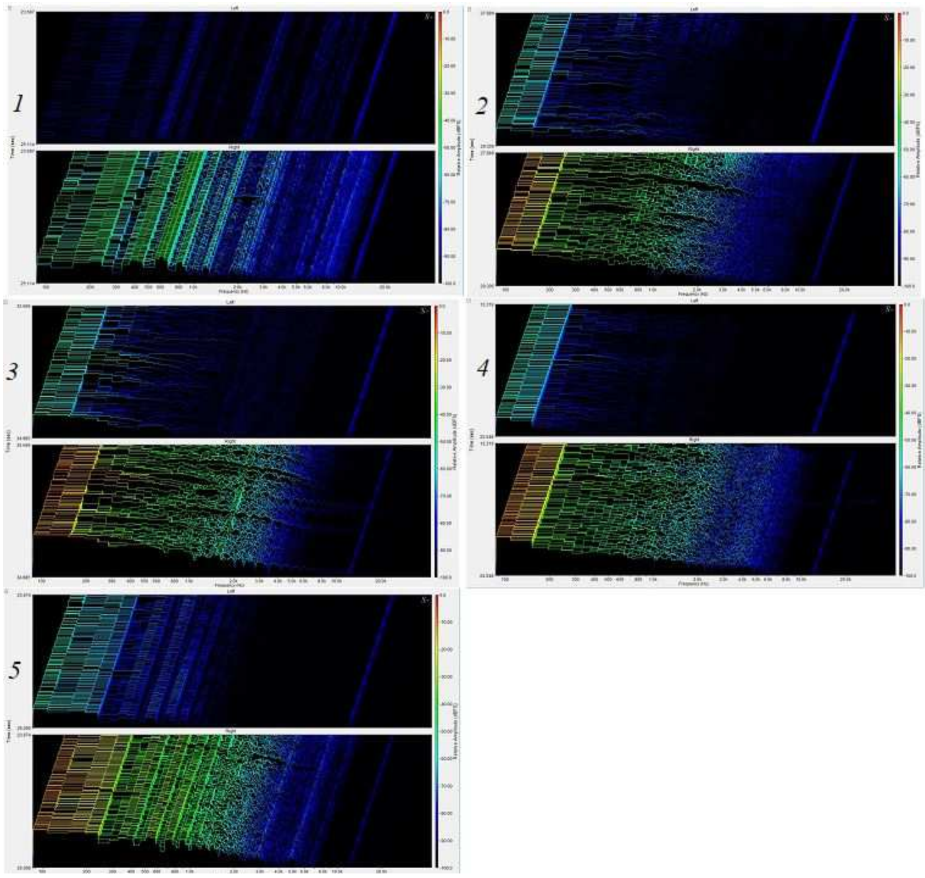

Fig. 7. Spectrogram examples for machined parts

Conclusion

As result of research study of correlation between acoustic signal and surface roughness was done. Acoustic spectrogram with fast furrier transform of machining was obtained and analyzed.

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