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APPLICATION OF ACOUSTIC EMISSION FOR EVALUATION OF TOOL WEAR IN HARD TURNING

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ABSTRACT: This paper deals with monitoring of tool wear through the acoustic emission. There is presented analysis of correlation between tool wear and some parameters of acoustic emission signals (applied low-frequency sensor and high-frequency sensor). There is also shown influence of flank tool wear on formation of white layers formation on the machined surface.
KEYWORDS: hard turning, acoustic emission, tool wear

❖ INTRODUCTION

Real-time monitoring systems for manufacturing processes are necessary in connection with improving quality of products in combination with production intensification. Process of monitoring and control is important for finishing processes such as hard turning and grinding.

Hard turning is finishing process which has in many cases significant benefits. However, this process can damage surface quality in the form of white layer and some other aspects of precision of produced parts. And so, it is important to monitor the cutting edge and related aspects of surface integrity in the real process. Acoustic emission (AE) is possible tool for on – line monitoring of process and it is applied in this study. [1]

There is formation of segmented chip when hard turning process. Intensive plastic deformation is localized into narrow area and generate border of segment. It forms chip with heterogeneous distribution of plastic deformation (figure 1.). Segment border area is characteristic by intensive plastic deformation, whiles alone chip segment is plastically nearly non deformed. Chip segmentation frequency is, in dependence on feed and cutting speed, up to 80kHz, and so it is not possible to detect this process through the accelerometers and application of AE signals is required. [3]

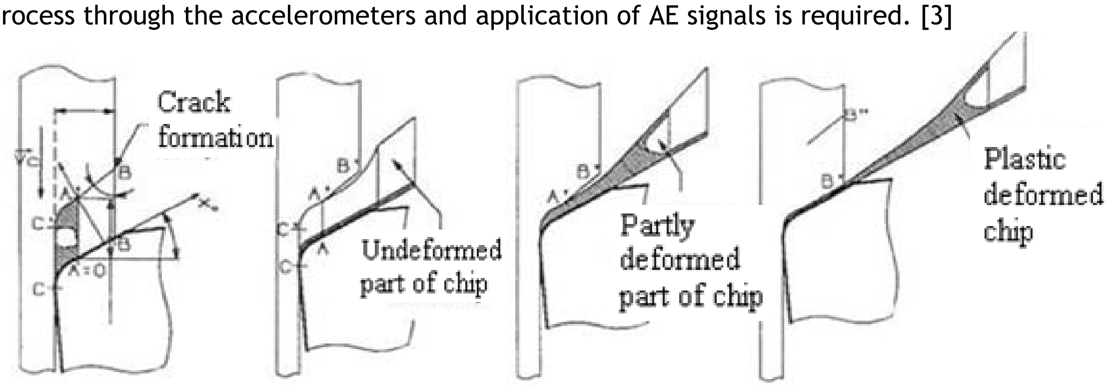


Figure 1. Stages of chip segment formation [3]

Acoustic emission (AE) is physical phenomenon, where in certain localities of material rise to release of energy, due to dynamic processes induced by external or internal forces [7].

Rising energy is transformed into a mechanical pressure impulse, which expands through material as elastic pressure wave. When achieve surface of material, expand as surface wave. Through the detection of elastic stress waves on workpiece surface, using wideband piezoelectric AE sensor, it is possible to obtain an electric signal of AE. This signal passes through the preamplifier to the measuring apparatus for processing (figure 2.).

❖ METHODOLOGY

Machined material: hardened bearing steel 100Cr6 (62HRC)
Cutting tool: ceramic cutting insert Al2O3+TiC with TiN coating
Machine: lathe SUI 40
Sensors for measuring acoustic emission signals (Europhysical Acoustic):
- low frequency sensor D9241A (signal range 0,02 - 0,16 MHz)
- high frequency sensor WD (signal range 0,1 - 1 MHz)

Measuring settings:
- Threshold: 45dB, PreAmp: 40dB
- Software filter for D9241A: 1 – 200 kHz
- Software filter for WD: 100 kHz - 1MHz
- Sample rate: 2MSPS

Cutting conditions:
vc=100m.min-1, ap=0,25mm, f=0,09mm

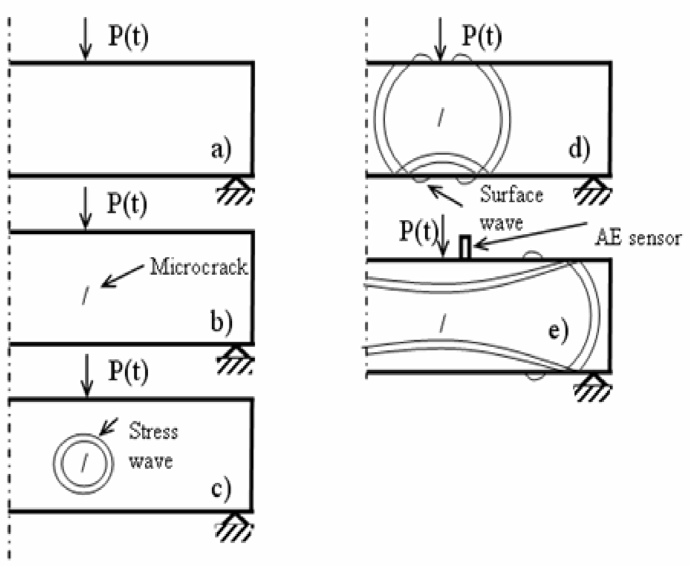


Figure 2. Scheme for generation, propagation and detection of AE signals [7]

❖ FINAL RESULTS

Tool wear significantly affect the surface quality. Tool wear was measured (through the VB value) in the regular time periods. Experiment was stopped when tool wear (VB) overcomes the critical value 0,25 mm. Characteristic flank tool wear curve for hardened steel 100Cr6 can be seen in figure 3. There is the initial stage of tool wear, which is relatively short, (high intensity of tool wear because of high partial pressures between tool and workpiece). The intensity of tool wear fall down after the initial phase of cutting becomes stable up to cutting time 30min. Phase of critical tool wear leads to significant increasing of tool wear and high risk of its breakage. There is formation micro breakage and the following macro breakage of cutting edge up to VB = 0,37 mm.

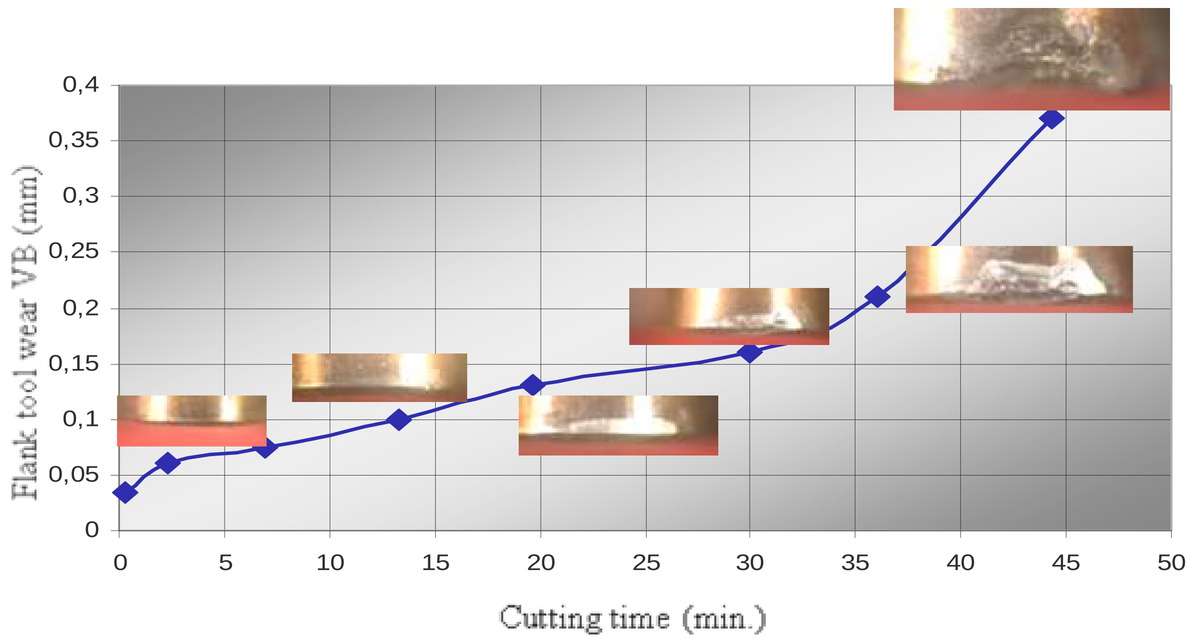


Figure 3. Flank tool wear curve when turning hardened steel 100Cr6, vc=100m.min-1, ap=0,25mm, f=0,09mm

Figures 4 and 5 illustrate the relaxation character of AE signal. First of all it is visible when application of frequency sensor D9241A (figure 4), because the segmentation frequency fall into the frequency range of this sensor. On the other hand, the cyclic character of this signal can be seen on high frequency sensor WD, but character of the signal is different. Figure 4 illustrates the accumulation of energy in the front of cutting edge and fast relaxation of this energy during the segment border formation.

Analysis of AE signals were carried out not only through the signal itself but through the some related parameters analyzed in the software AEwin. There were realized analysis of some parameters of AE signals and tool were respectively formation of white layers on the surface (figures 6, 7, 8, 9). This analysis was done especially for low frequency sensor.

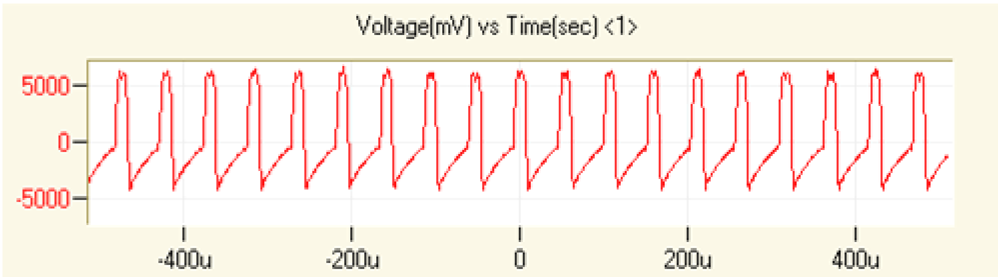


Figure 4. Characteristic signal of AE recorded by low frequency sensor D9241A

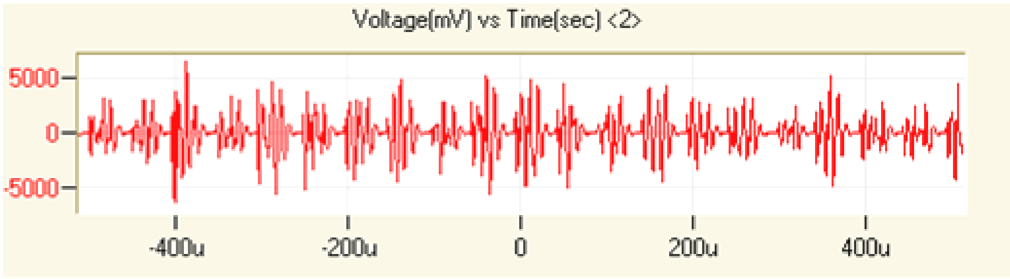


Figure 5. Characteristic signal of AE recorded by high frequency sensor WD

Figure 6 illustrates the high values of AE signals in the initial stage of cutting process and its fall in the normal phase. Decreasing of RMS values is related to damping effect of contact between cutting edge and workpiece. RMS AE increases again in the third phase, until tool breakage. This dependency can be seen by low frequency and high frequency sensor, too.

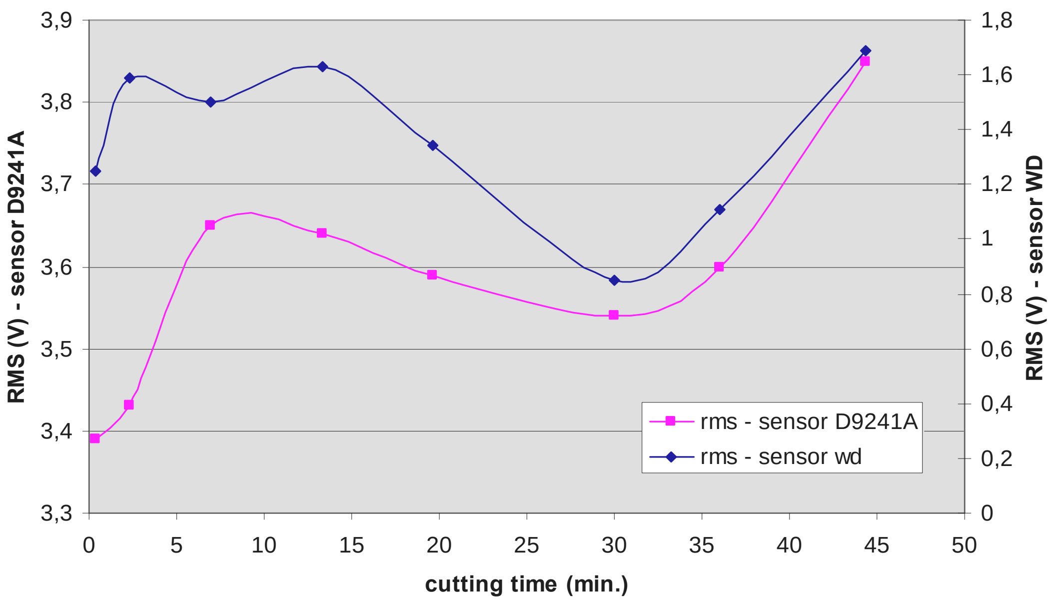


Figure 6. RMS of AE signal in dependency of cutting time

The similar character of some parameters as energy, signal strength, absolute energy, average frequency, rise time and counts can be seen for low sensor. Application of high frequency sensor does not provide correlation with the tool wear or parameters of surface integrity as formation white layers (its thickness).

Very similar to energy of AE signal (figure 7) is signal strength. Signal strength is calculated through whole dynamic range of AE signal and is independent of gain. There is seen similar relation as by other AE parameters from sensor D9241A.

Absolute energy is real energetic measurement of AE count. Rise time is defined as the time between start of AE hit after crossing threshold and peak of AE amplitude. It is illustrated in figure 8. Count is also called hit crossed threshold. This function simply rates overshoot of AE signal through the threshold. It is illustrated in figure 9.

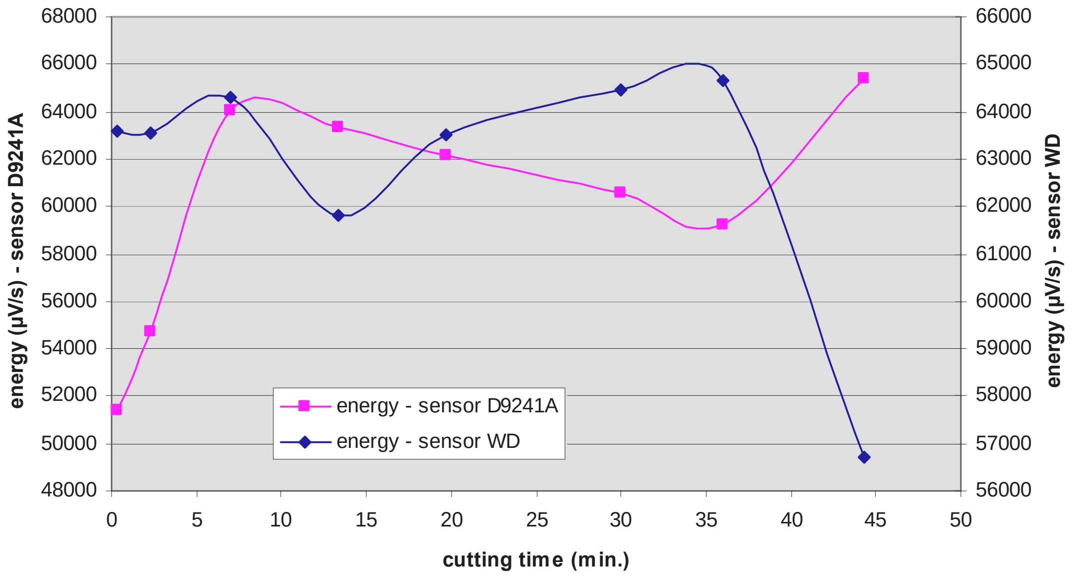


Figure 7. Relation between energy of AE signal and cutting time

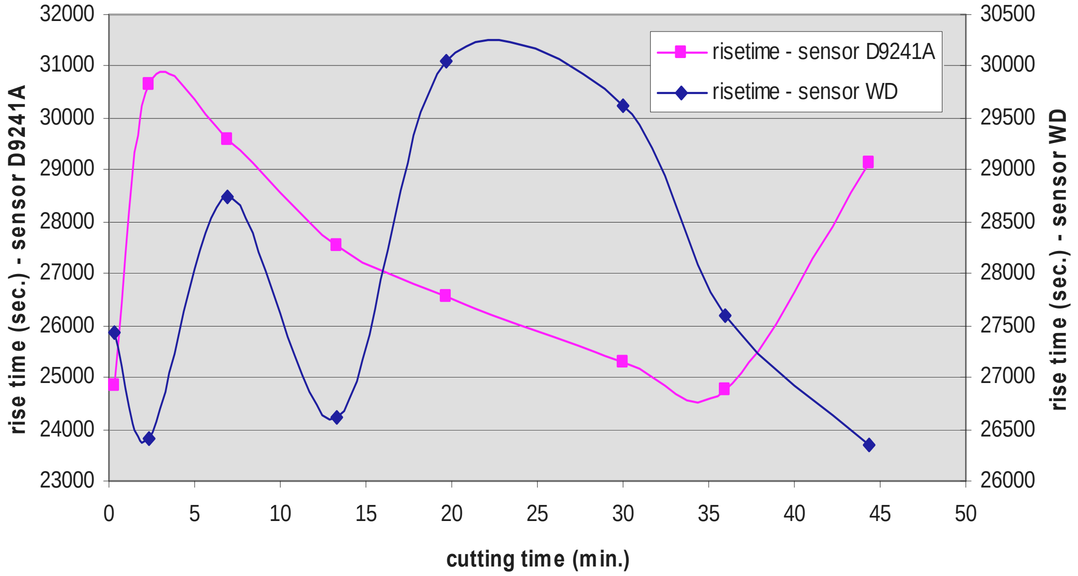


Figure 8. Rise time dependency on cutting time

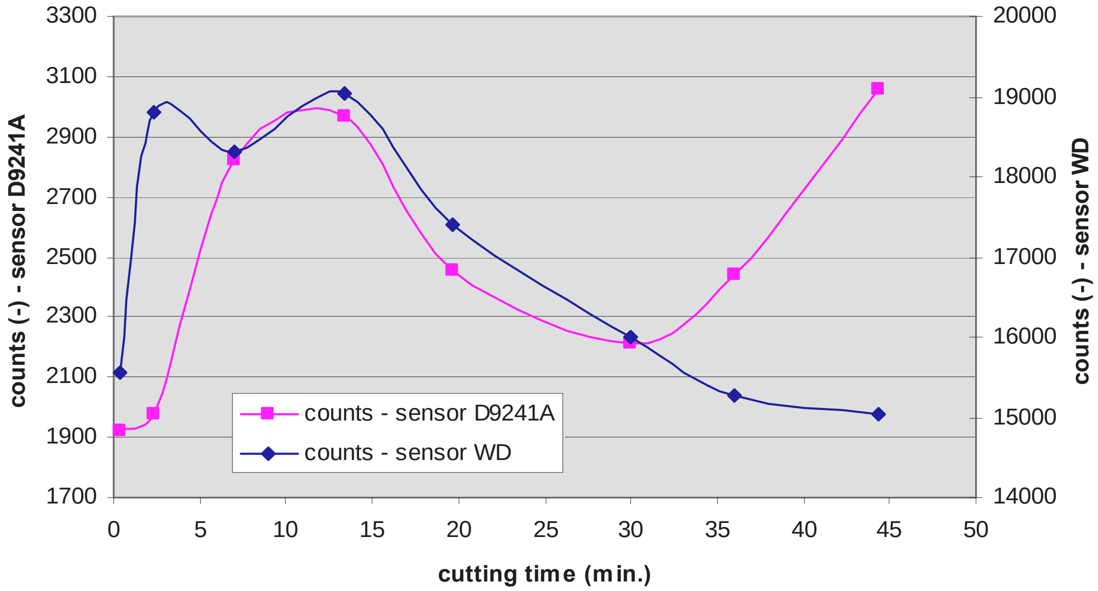


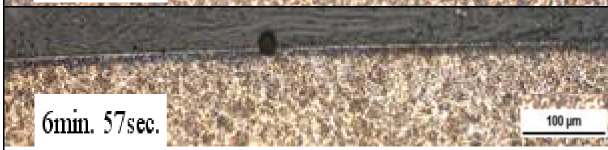
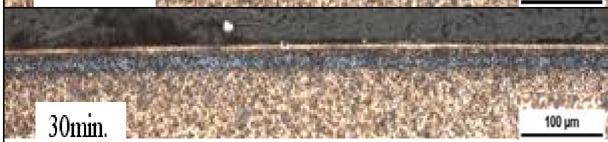
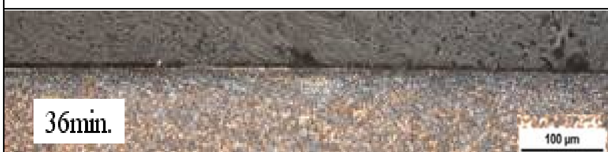
Figure 9. Counts dependency of cutting time

Characteristic change of parameters recorded by high-frequency sensor does not provide correlation with characteristic flank tool wear curve. There is the significant aspect related sensor frequency which does not fall into the segmentation frequency of the signal. This frequency in the real process is up to 80 kHz, while high frequency sensor DW frequency range starts at 100 kHz and ends by 1MHz.

Due to flank tool wear formation there is flow of machined material under the cutting edge. Because of high temperatures and mechanical pressure in this contact (intensive thermo plastic deformation) there is formation of white layers on machined surface. There is no formation of white layers on the machined surface during the initial phase of cutting process, but increasing tool wear leads to more intensive thermoplastic deformation of machined surface and formation of white layers on the surface. This is illustrated by table 1. Formation of white layers starts very soon, when the tool wear (VB) overcomes 0,075 mm.

Table 1 illustrates the increasing thickness of white layer on the machined surface. The thickness of white layer is increasing during the normal stage of cutting process. Macro breakage of cutting edge leads to decreasing of contact area between tool and workpiece and so low intensity of thermoplastic deformation of machined material. The thickness of white layer on the machined surface is decreasing at begin of the catastrophic stage of cutting tool wear. There is formation of the massive crater on cutting tool and related decreasing of white layer thickness. The next cutting leads to increasing of white layers on the surface.

Table 1. Photos of white layers formed on the surface

Machined surface	Tool wear VB(mm)	Thickness of white layer (μm)
	0,035	0
	0,06	0
	0,075	1,72
	0,1	1,63
	0,16	3,75
	0,21	1,86
	0,37	3,24

❖ CONCLUSION

The correlation between acoustic emission signals and cutting tool wear were found especially for low frequency sensor D9241A. This is related to segmentation frequency that fall into sensor frequency. The measuring range of the high frequency sensor does not fall into the segmentation frequency and to parameters of AE signal recorded by high frequency sensor does not match process of tool wear or formation of white layers on the machined surface.

The future research should be related to the location of processes realized between machined surfaces of flank area of the tool. These processes are crucial for on – line monitoring of such aspects as formation of white layers or process of micro breakage of cutting edge. Some problems of this location are related to very strong AE signal formed during the segment formation. Process of segment formation creates the strong AE noise and it will be necessary to filter this signal and find the suitable way of signal processing.

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