The use of acoustic emission phenomenon to detect defects in the workpiece during machining process.

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Abstract

The on-line process monitoring is well developed but there is not too many studies carried out on workpiece condition on-line monitoring. Preliminary research were carried out to determine the possibility of AE signal use to identify signal changes during entrance/exit of the tool. The article presents an idea of workpiece condition monitoring during machining process with the use of acoustic emission. Main aspects of acoustic emission phenomena are presented and main characteristics of acoustic emission apparatus are given.

Keywords

Acoustic emission (AE), AE parameters; AE sensors

1. Introduction

During machining process, in the subsurface layer some changes occur through which new zones with new properties are generated. The most realistic model of subsurface layer consists of eight zones as shown in Fig 1.

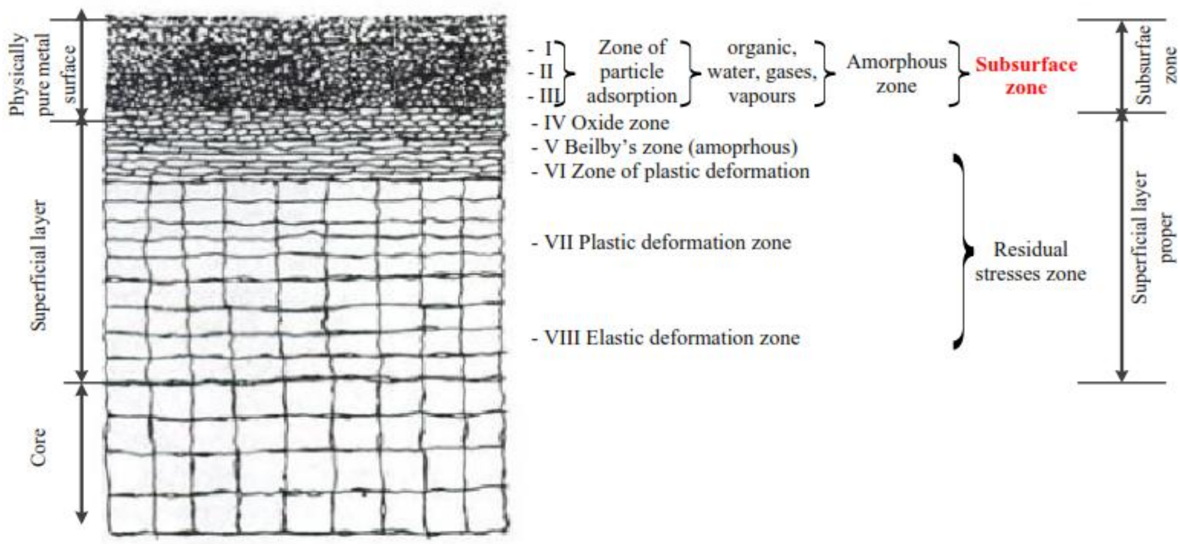


Fig.1 *The 8- zone model of the subsurface layer [1]*

First three zones are generated as a result of adsorption of water particles and gases. The thickness of these three zones is in the range of (2÷ 3) 10^{-4} µm. Zone number four constitutes a layer of oxides of the core metal, created as a result of a chemical reaction between oxygen and the core material.

Zone number five is formed as a result of damage inflicted on the grains of the core metal by the machining tool. It's thickness ranges from 0, 1÷1 μm. This zone is also know as a Beilby's layer or amorphous layer. Zone number VI consists of permanently deformed material as a result of unidirectional forces. Zone VII consists of the material which is only permanently deformed (as a result of twinning process or slip). Its thickness is bigger than the thickness of zone VI and usually do not exceed several tenths of a millimeter. Zone number VIII comprises the zone of elastic deformation and tensile stresses [1].

Shaping methods and cutting operations are affected by the development of new technologies and by new workpiece' requirements. The main attention is focused on the subsurface layer' quality of the workpiece. For the technologist, planning the machining operation , it is important to define factors influencing the subsurface layer' quality correctly. The factors are shown in Fig.2.

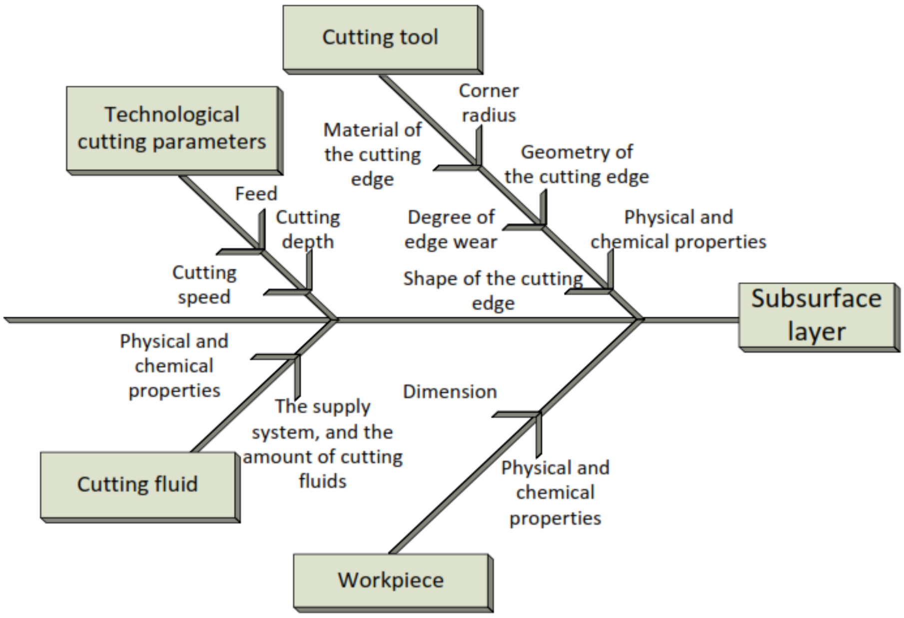


Fig.2 *Factors that affect the shape of the subsurface layer*

During machining process three zones can be distinguished. Fig.3 presents characteristic phenomena that take place during machining process.

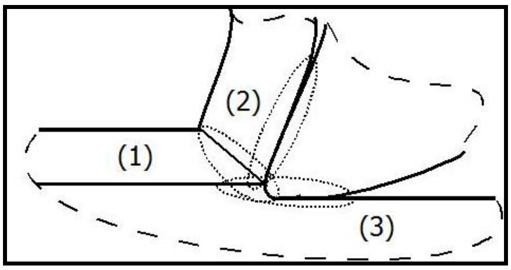


Fig.3 *Plastic deformation zones in the cutting area [2]*

Elastic deformations also known as a reversible strain, do not cause any significant changes in the atom arrangement of the lattice structure. Deformations are generated as a result of atomic movements in the area that usually do not exceed the size of the lattice distance. In the I-st zone plastic deformation of irreversible character occur. In this zone chip is formed. Plastic deformation in metal occur by slip mechanism and by a process of twinning. In the first zone maximum amount of heat is exuded which is caused by plastic deformation. The second zone is in the contact area between rake face and cutting edge [2].

2. Acoustic emission phenomenon

During changes that occur in the subsurface layer (including: elastic deformation, plastic deformation, twinning or slip process) noises are generated which lead to the acoustic emission phenomenon that is possible to record by AE equipment.

Acoustic emission refers to the generation of transient elastic waves produced by a sudden distribution of stress in the material. The acoustic emission phenomenon is shown in Fig.4.

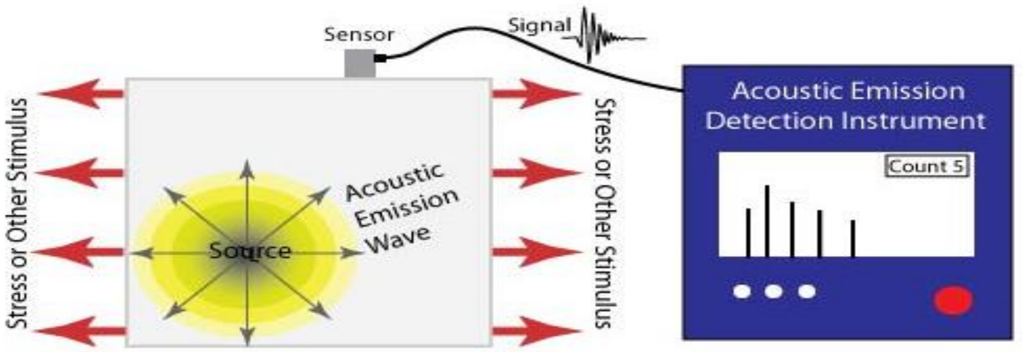


Fig.4 *Acoustic emission phenomenon*

Fig 5. presents sources of the AE which are as followed [3]:

- Plastic deformation in the shear zone;
- Plastic deformation and friction between chip and rake face of the tool;
- Friction between workpiece and flank face of the tool;
- Formation, tangling and breakage of the chip.

Because of the dynamic character of milling process additional two sources of AE can be given:

- Wave that occurs in the entrance of the cutting tool into the workpiece;
- Sudden chip breakage on the exit of the cutting tool from the workpiece[3].

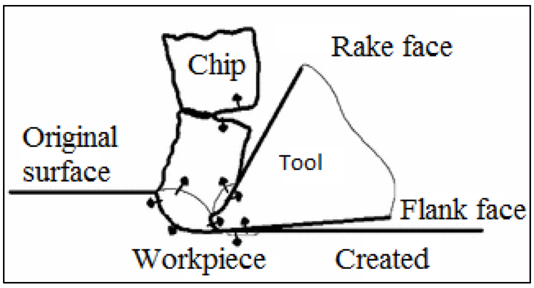


Fig.5 *Sources of AE[4]*

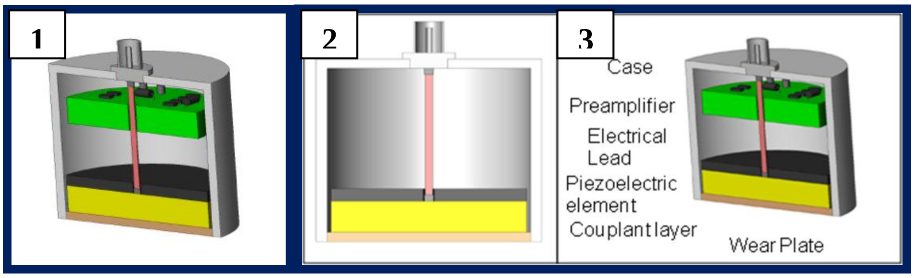
Milling process plays a significant part in the machining technology. Therefore, monitoring of the machining process is very important. During machining process complex phenomena take place which may cause surface damage or damage of the cutting tools [5]. Additionally, the surface of the workpiece should be monitor and in case of a damage or unwanted phenomenon, machining process should be stopped. It is possible to monitor machining process in a real time with the use of AE. Regular AE apparatus consist of the following elementary elements:

- AE sensors;
- preamplifier;
- cables;
- data base acquisition.

AE sensor (Fig.6) converts the surface movement caused by elastic wave into an electrical signal which can be processed by the measurement equipment. AE frequency ranges from 20kHz to 1MHz. Two AE sensors can be distinguish: resonant and broadband which are usually used according to the specific requirements of e.g. low/high fidelity. The resonant sensors can record AE signal in one of three frequency ranges:

- low: 20-100kHz;
- intermediate: 100-450kHz;
- high: 200-100kHz.

The construction of broadband sensors is more complicated than construction of resonant sensors and they are usually used for composites or ceramic elements. Theses sensors are typically used in research applications or other applications where a high fidelity AE response is required.



Rys.6 *1 - Integral AE sensor; 2- an example of AE sensor; 3 -the cross-section of AE sensor and its element [6]*

The preamplifier is used to boost the signal strength. An exemplary preamplifier is shown in Fig.7. Majority of the information about the processes occurring inside of the workpiece are in the range of 100kHz. Therefore, high-pass filters are used to eliminate unwanted date of low frequency.

Fig.7*Preamplifier of 60dB [6]*

When a useful AE signal is correctly obtained, basic parameters shown in Fig.8 can be generated.

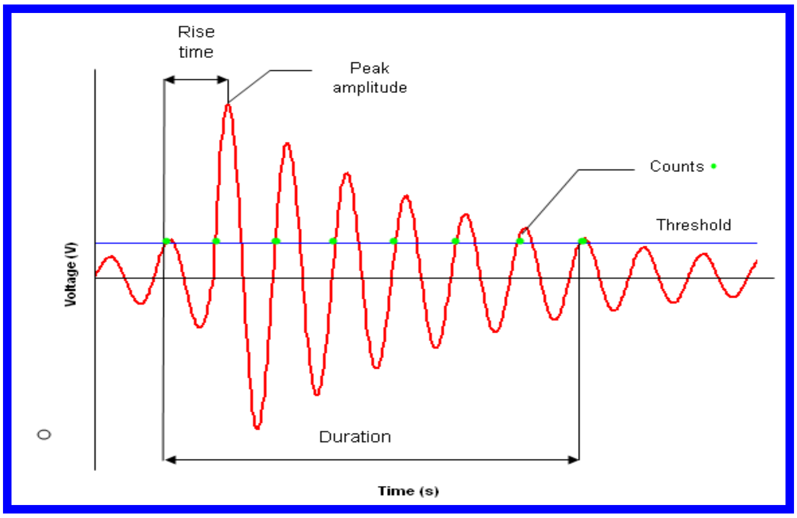


Fig.8 *AE signal features*

The following AE features are described below:

- **Peak amplitude** - it is a maximal value of AE signal. This is an important parameter in acoustic emission inspection because it determines the detectability of the signal. Signals with amplitudes below the operator-defined, minimum threshold will not be recorded;
- **Duration** - is the time difference between the first and last threshold crossing;
- **Rise time** - is the time interval between the first threshold crossing and the signal peak. This parameter is related to the propagation of the wave between the source of the acoustic emission event and the sensor. Therefore, rise time is used for qualification of signals and as a criterion for noise filter;
- **Counts** - number of pulses emitted by the measurement circuitry if the signal amplitude is greater than the threshold;
- **Threshold** - certain value [7].

3. Carried out studies

Preliminary research were carried out in cooperation with dr Ślusarczyk Ł. (Institute under the direction of Prof. Zębala W.) and mgr Nowak M. (Applied research laboratory). Preliminary registration and AE signal analysis were performed on a cone-shape shaft during process of turning. Registered AE signal and AE energy are shown in Fig.9 and Fig.10.

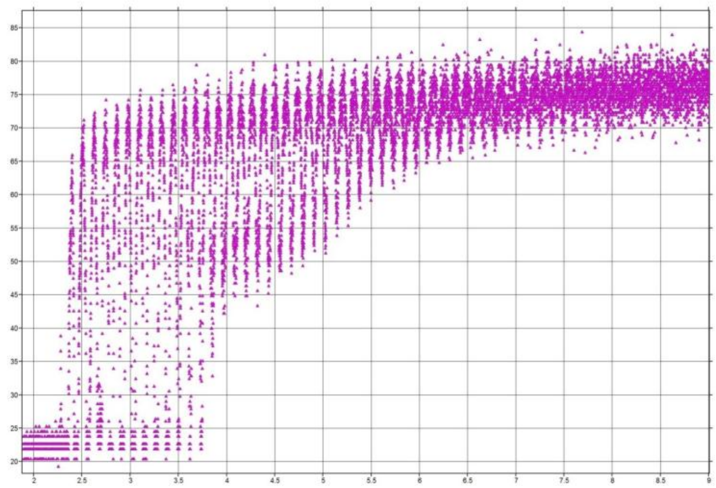


Fig.9 *Registered AE signal (Ti6Al4V f=0,105mm/rev; rε= 0,8mm)*

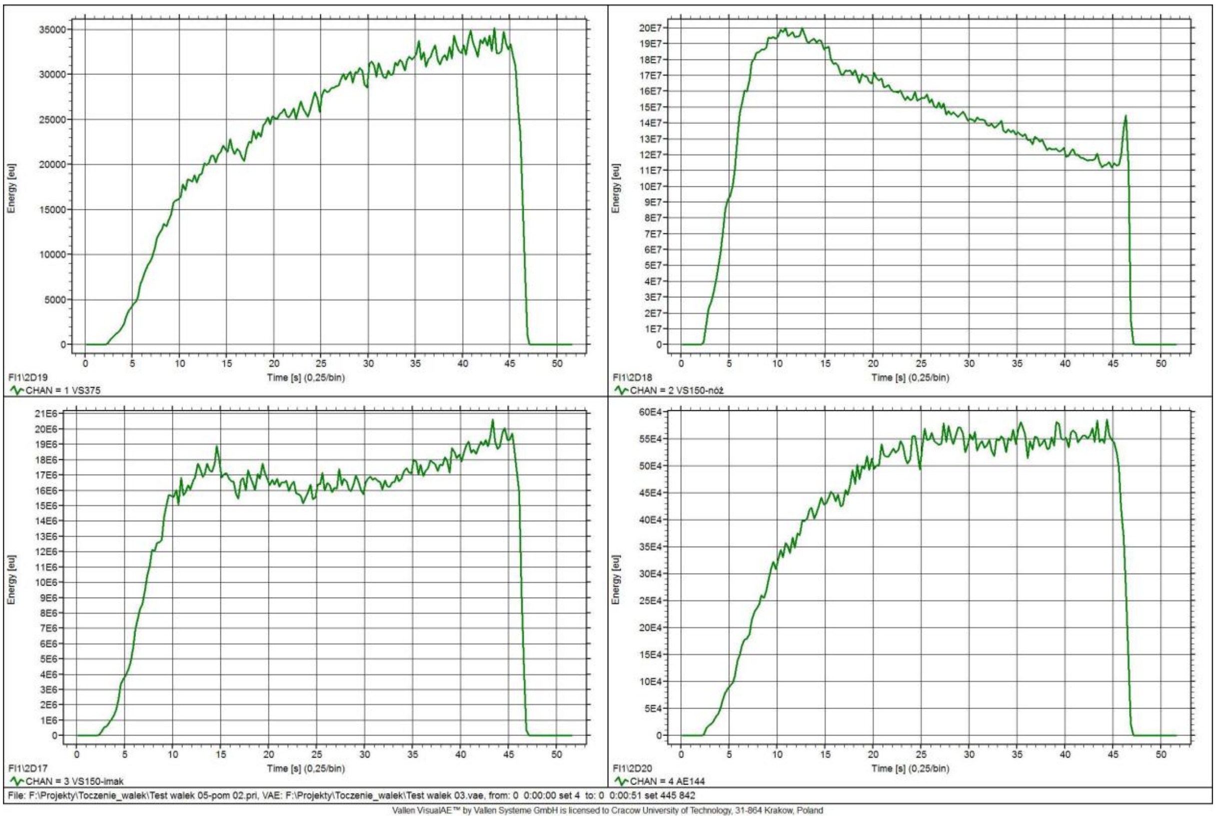


Fig.10 *AE energy (Ti6Al4V; f = 0, 105 mm/rev; rε= 0,8mm)*

During preliminary research, four AE sensors were used. A different arrangement of AE sensors was done in order to asses if the signal is recorded; and to asses if the analysis of the signal is possible. Sensors were localized as close to the source of AE as possible (on the side wall of cutting tool's surface; on the side wall of the vice; on the bottom of the vice and on the vice's surface). Carried out studies show the possibility of using AE to detect decohesion process and to determine changes in the materials.

4. Conclusion

The phenomenon of acoustic emission is well known and well developed in process condition monitoring (PCM) and in tool condition monitoring (TCM). The preliminary research that were carried out in the Institute of Technology and Automation Equipment, show the possibility of using AE as a predictable tool for changes in the workpiece during machining process. Although, it is possible to use AE for workpiece condition monitoring the following aspects need to be taken into account: sensors localization; reference signal; signal processing; Curie temperature; signal demodulation; signal registration,. Two main advantages of this method need to be pointed out: this is a non-destructive method and AE signal is recorded in a real time of machining process. Due to these advantages and many others it is reasonable to develop this method.

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