UTILIZATION OF ACOUSTIC EMISSIONS 
IN THE EVALUATION OF MACHINING PROCESS

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Abstract: The thesis deals with the use of non-destructive testing methods (acoustic emission) for the description and identification of stages during the machining process. For this measurement, advanced machining was selected. Selected cutting speeds -0.0028 m/min, 0.004 m/min and 0.008 m/min, and the rotor speed was 56 rpm with a chip size of 1mm. At each cutting speed, the resulting graphs were recorded. The test material was chosen as the structural steel 12050-structural plain steel for tilth and hardening ISO C60E4 ISO 683-1-87 (Ferona). In the experimental part the methodology of continuous emission signal recording, continuous processing and evaluation of the measured data and monitoring of the response of the stressed material (during the machining process) was designed in real time. The detected values were then inserted into this methodology, subsequently evaluated, it was the detection of emission signals using the acoustic emission apparatus. Acoustic emission is a fast, short release of energy in the form of elastic waves. The acoustic emission curve has several parameters that can be used to characterize the source defect. Through an appropriately designed methodology for detecting, processing, and evaluating AE signals, it is possible to track the progress of the machining process, the measured data allow you to obtain new information about the processes that accompany the machining. Thus, the emission signals can be used to indicate microcracks in the internal structure of the stressed materials.

Key Words: machining, cutting material, acoustic emission, machining monitoring

INTRODUCTION

Nowadays, most engineering companies are engaged in increasing the productivity of machining processes and also reducing operator demands. Therefore, it is very important to choose a suitable monitoring system to prevent the production of faulty pieces. Machining is defined as the stage at which the machining operation can be performed in the highest productivity with the lowest cost (Seco). The principle of monitoring the machining process is based on the monitoring or measurement of selected quantities or their combination. In the future, sound analysis could be used, for example, in adaptive machine control. Auditory analysis can identify excessive tool wear or vibrations that are undesirable in the machining process.

The aim of the measurement is to monitor the course of the machining process by means of a non-destructive method using the acoustic emission monitoring system AE, which enables us to identify defects such as cracks, corrosion, etc. Delamination creates transient elastic waves resulting from sudden change in stress in the material. These elastic waves are called acoustic emission (AE) phenomena. Acoustic emission measurement allows you to "listen" to the resulting defects in the material using piezoelectric sensors. (Mistras) The machining process is realized in a machining system, which is generally subdivided into subsystems of machine tools, cutting tools, handling devices and machining environment. The machining system consists of a machine tool, a cutting tool, a workpiece, and a tool (Humar 2008). For this measurement, a high-speed milling was chosen. The machining process is a complicated process due to many ambient influences that can affect the machining result. Therefore, it is necessary to identify these influences and identify such influences that positively affect and remove unwanted effects.
MATERIAL AND METHODS

The material for the test specimens was chosen to be 12 050 steel (ISO C60E4 ISO 683-1-87), carbon steel. This steel is suitable, for example, for surface hardening. The cutter speed setting was 56 rpm at a single chip size of 1 mm. For these measurements, these feed rates were 28 mm/min, 40 mm/min and 80 mm/min. The cutting angles of cutting plates were $\gamma=20^\circ$, $\alpha=8^\circ$ (Tumlikovo). The tested samples were of the same shape with dimensions: height-4 cm, width-10 cm, length-20 cm. The following table shows the chemical composition of the test steel.

**Table 1 Chemical composition of steel, mechanical properties of steel 12 050**

<table>
<thead>
<tr>
<th>C$_{\text{max}}$</th>
<th>Mn$_{\text{max}}$</th>
<th>Si$_{\text{max}}$</th>
<th>P$_{\text{max}}$</th>
<th>S$_{\text{max}}$</th>
<th>Cr$_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.51</td>
<td>0.69</td>
<td>0.25</td>
<td>0.023</td>
<td>0.017</td>
<td>0.15</td>
</tr>
</tbody>
</table>

**Mechanical properties**

<table>
<thead>
<tr>
<th>Tensile strength $R_m$</th>
<th>min. 370 MPa</th>
<th>Hardness</th>
<th>225 HB</th>
<th>Yield strength $R_e$</th>
<th>min. 250 MPa</th>
</tr>
</thead>
</table>

TOS FNK 25 milling brackets with six indexable inserts from Pramet were used for machining. The plates were made of sintered carbides coated with a TiD-based PVD method (Figure 1).

*Figure 1 Cutter with indexable inserts – Place the piezoelectric sensor on the sample*

For each measurement, the piezoelectric sensor IDK-09 was placed on the sample. The acoustic emission signals were scanned and analyzed by the Dakel XEDO measuring system with one piezoelectric sensor. This sensor was fixed at the bottom of the samples with a second adhesive. The contact surface of the sensor was equipped with an ultrasonic gel. Figure 2. The 2 to 8 MHz sample signal processing with 12-bit resolution was fully digitized. The gain is programmable in the range of 0 to 80 dB. The counts 1 and 2, RMS and emission event parameters (time of arrival, maximum, length, count 1 and 2 and the whole event) are evaluated (Dakel). Configuration of the measuring instrument has been set: Amplifier values 10 dB, set levels (count 1) to 302%, (count 2) 600% range, 4 MHz sampling and 1000 ms period.

**Table 2 Technical data of piezoelectric sensor (Dakel)**

<table>
<thead>
<tr>
<th>PZT material</th>
<th>Dakel Class 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size PZT element</td>
<td>4 x 3 mm</td>
</tr>
<tr>
<td>Capacity</td>
<td>60 pF</td>
</tr>
<tr>
<td>Output</td>
<td>cabel with conector</td>
</tr>
<tr>
<td>Cover</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Touch screen</td>
<td>Corundum, 6 mm</td>
</tr>
</tbody>
</table>
When measuring acoustic emission, the RMS signal of acoustic emission with the number of exceedances of C1 (Counts 1) and C2 (Counts 2) was monitored. This parameter indicates the so-called effective signal value. For alternating voltage, the RMS is equal to the DC voltage which, when applied to the resistive load, would give the same average power. The RMS unit is mV. This value corresponds to the quantitative characteristic of the measured acoustic emission events (amount of energy). The overshoots of the set signal levels C1 and C2 characterize the behaviour of the signal with respect to its time course.

RESULTS AND DISCUSSION

When measured, the acoustic emission sensor was placed directly on the material. The material here serves as a waveguide for an acoustic signal. From which it follows that the composition of the machined material can affect the signal characteristics. From Figure 2 to 4 are apparent when comparing them that increasing the cutting speed increases the number of overshoots in hard steel 12 050, as well as the RMS values and the regularity of the individual acoustic signals. Individual overshoots across the set threshold are relatively accurate, and for this reason we can assume that they are shots of each cutting tool's blades. During the measurement, it is possible to record and identify individual shots of the tool's teeth, according to the total energy of the RMS signal. From the forecast, we found that vibratory machines did not affect our measurement. The acoustic emission depicts the dependence of the RMS signal size on the speed of the feed. Therefore, we can assume that individual acoustic events characterize the cutting of material by the individual blades of the cutter.

*Figure 2 Record AE steel 12 050 at cutting speeds 0.0028 m/min*

On Figure 2 we can observe a 4 second record, in terms of the appropriate machining process characteristics. As mentioned above, the feed rate affects the size and frequency of the RMS signal. We can see that during the measurement, the signal did not exceed 800 mV. The RMS signal overlaps here with the blades.

From Figure 3 we can see an increase in the frequency of signal overruns, this phenomenon will be even more noticeable at Figure 4.
There are sudden RMS anomalies in all records, but at the moment it is not known why this is happening, it would be necessary to subject the sample to a larger number of measurements to produce statistics. It can be assumed that acoustic emission statistics could be used here, but this is a matter of more extensive research.

The acoustic emission system AE is usable as a monitoring process, but we can not directly evaluate the machining conditions, Cutting speed, removal, etc.

Part of her record we can evaluate the hardness of the material. The hardness or toughness of the machined material is one of the factors that influences the machining process, and the acoustic emission is noticeable.

CONCLUSIONS

The work deals with the use of acoustic emission during machining. For the machining method, the steep milling of the steel 12 050 was chosen, with a shift of 0.0028 m/min, 0.004 m/min and 0.008 m/min. Chip removal of 1 mm for all feeds remained the same. The main tool used to describe the internal characteristics during the measurement was the non-destructive acoustic emission method. The paper demonstrates the real-time visualization capability of AE.
The machining process is constantly influenced by a number of defect variables, such as workpiece shape, material machining, cutting depth, cutting tool etc. The wear of the cutting edge increases the number of pulses of acoustic emission when the cutting edge is worn. As a result, the wear and tear of the cutting edge can also be observed. In this work, turning is monitored, turning in comparison with milling is a major difference in the location of the acoustic emission sensor. (Novotný 2013) After evaluating the measured data, it can be seen that the acoustic emission system appears to be a suitable monitoring system for machining, the acoustic signal is very dependent on the material to be machined and the feed rate. It can be assumed that in the emission records, acoustic events represent shots of the individual blade of the milling cutter. The acoustic emission sensor thus provides inputs corresponding to the reality of the machining. For this reason, AE can be used for continuous monitoring, especially for serial production, where thousands of dimensionally identical workpieces are produced. In this way it would be possible to react in a timely and correct manner to changes in the machining process, thus preventing the production of a non-conforming workpiece from the point of view of dimensional or surface tolerances.

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REFERENCES