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STUDY OF ACOUSTIC EMISSION SIGNAL DURING TURNING

SUMMARY: In this paper acoustic emission (AE) generated during turning was detected and analyzed in order to study tool wear development during metal cutting. Turning tests were carried out on several types of steel, cast irons and aluminum , nickel and titanium alloys. The comparison between the AE responses from different work materials allowed to verify the applicability of AE for determination of work material machinability.

1. INTRODUCTION

Traditional methods of cutting process conditions control do not seem to be sufficient and that is the reason why in recent years an attention has been given to the use of acoustic diagnosis in metal cutting process.

The primary source of acoustic emission (AE) signals is the area where chips undergo plastic deformation during detachment from the machined material (primary deformation zone). Among the secondary sources of AE signals are the plastic deformation and friction at the chip-tool interface (secondary deformation zone) and the plastic deformation and friction at the work material-cutting tool flank interface (tertiary deformation zone). AE pulses are spread from their sources as the primary longitudinal or transverse ultrasonic wave which is after incidence on the interface of two mediums reflected and transformed. The frequency spectrum of the AE signals has components with amplitudes from 0,1 to 1 MHz.

AE signal evaluation was derived from the characteristic signal pattern. If AE analysis techniques based on the monitoring of the counts are used, energy and power of signals are refered to the total number of counts Nc and to the number of counts in time period (as the standard within 1s) Nc.

2.EXPERIMENTAL EQUIPMENT

For sensing, processing and storage of AE signals we use a measurement chain consisting of the piezoelectric transducer, threshold pulse counter DAKEL, power supply unit and IBM PC AT computer.

Work materials: steels 12 050, 11 700, 15 128.1, 16 125.3, 11 373 (the marking of steels is according to the czechoslovak standards ČSN), cast irons, aluminum, nickel and titanium alloys.

Tool :material P20

rake angle -8°,relief angle 8°,cutting edge angle 45°.

The feed rate f = 0,18 mm/rev, depth of cut d = 1 mm.

The piezoelectric AE transducer was applied on the side of the tool shank. The detected signals were amplified, filtered and sent to a counter. On computer PC was evaluated N_C - count rate and N_C total event counts.

3.TOOL WEAR MONITORING THROUGH ACOUSTIC EMISSION

The first group of experiments was performed by cutting with pre-worn tools.The AE signal detected during turning of the steel bars by using of worn tools was compared with the level of signal during cutting with sharp tool (Fig.1).

From Fig. 1, it can be seen that the $\dot{N}_C$ - wear dependence are not monotonic for all cutting speeds during turning of steel.

AE total counts N_C increase rather smoothly with increasing flank wear, for all combinations of cutting speed and feed rate.

In Fig. 2 are shown typical $\dot{N}_C$ - time and N_C - time curves for the nickel alloy, cutting speed v = 18 m/min.

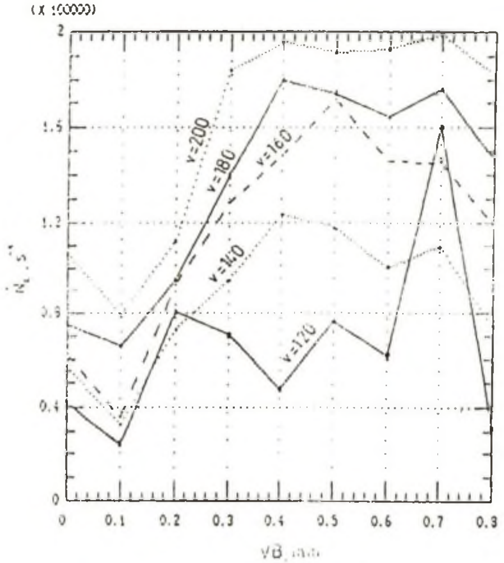

Fig.1. Count rate $\dot{N}_C$ vs. flank wear VB.
Work material steel

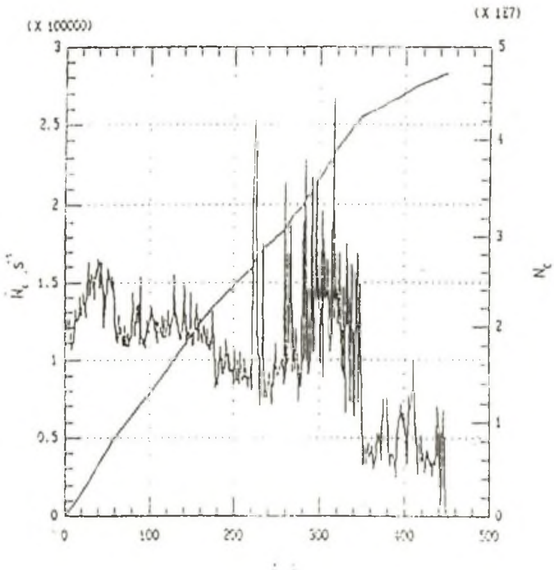

Fig.2. Count rate $\dot{N}_C$ and total counts N_C vs. time.
Work material nickel alloy

The comparison between conventional wear-time curves and AE N_C-wear plots shows how both curve types are characterized by tree typical zones that seem to be related. The transition from the second to the third zone in the wear-time curve is known to signal the initiation of tool rapid breakdown and need for tool change. The correspondent transition in the AE curve, therefore, could be used to identify, during the process, the moment for tool change. But to do so, we need an AE curve which is not plotted versus wear : in fact, if we already possess direct information on wear, the information obtained from the AE curve would be utterly redundant. Although the three typical zones in the AE curve are not as clearly identified as in the wear curve,there still is a good agreement between transitions in the two curves; this time, though an AE plot not depending on direct wear measurement is used which may be actually helpful for tool wear control in unattended manufacturing systems.

4. WORK MATERIAL IDENTIFICATION THROUGH ACOUSTIC EMISSION METHODS

The study was implemented during turning of several types of steel, cast irons , nickel , aluminum and titanium alloys. For experiments we chose five kinds of steel: material standard 12 050.1 and steels where we expected (according to the standards) better or worse machinability (the classes of machinability 11-14). With steels were also performed tests of metallography, the hardness was measured.

The data on the strength, durability, the values of the cutting resistance and fracture characteristics were gained from the experiments implemented in our Department of Machining and Automation.

The N_C - cuttig speed curves are in the examined interval increasing what complies with the theoretical expectation. It can be also seen an interesting mutual position of the particular curves - the order of the levels of AE signal for particular materials do not practically change -the curve for the steel with the worst machinability (11 700) is situated above the curve for material standard. The curves for steels with better machinability (15 128.1 and 16 125.3) are in the area of lower level of AE signals and the material with the best kinematic and dynamic machinability (11 373) gives the lowest level of AE (Fig.3).

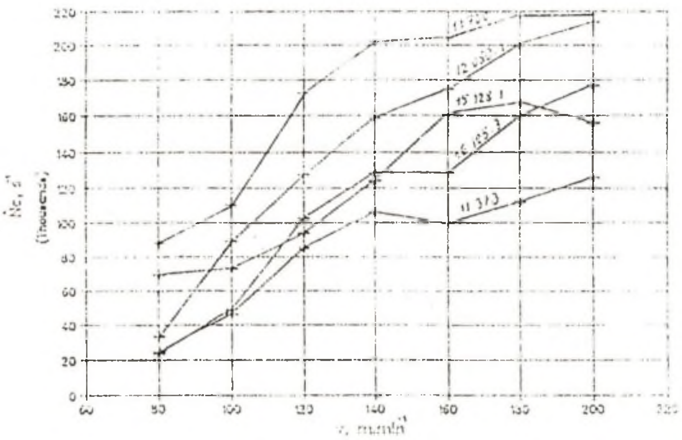

Fig.3. Count rate N_C vs. cutting speed. Work material steel.

The dependence on the depth of cut and the feed rate were not monotonic. The level of AE signal was expected to increase evidently with growing volume of the removed metal but in fact the level of AE signal was almost constant. We suppose that the results were mainly influenced by the chip form as the chips were in most experiments continuous and in many cases they were wound on the workpiece. But there is one interesting thing - the positions of the measured curves are the same and they correspond with the properties of the steels.

As for as cast irons machining we came to the following conclusions:

- The AE signals had in comparison with other machined materials the highest intensity. This fact means that the signal is mainly influenced by the chip breaking. The formation and propagation of the cracks is accompanied with the most intensive emission events
- The signal differs during cutting of different kinds of cast irons. This difference corresponds with the standard machinability tests and properties of the cast irons but, most of all, metallographical structure .

- As for as cutting conditions, the dominant influence on AE signal has the cutting speed. The intensity of the signal increases with the increasing cutting speed evidently. Depth of cut and the feed rate also increase the AE signal but with less intensity.

The experiments with aluminum alloy were implemented under the same cutting conditions. The AE signal had by degree lower intensity in comparison with the cast irons despite the fact that the chip was also separated. The low level of AE signals reflects the favourable conditions of cutting, low degree of deformation, low process energy consumption. The influence of cutting conditions on AE signal was similar to that for cast irons.

It was not possible to study the group of "hard" machinable Ni and Ti alloys under the same conditions because it was necessary to decrease the cutting speed from 100 to 18 m/min .The AE signal had relatively low intensity as only the small volume of the material was cut off and during the chip formation and flow did not occur the fracture mechanism.

5. CONCLUSIONS

The obtained results indicate that by using of our measurement chain and method it would be possible to control the cutting tool wear in certain technological system.

The idea of the application of AE method for identification of the properties of cutting and cut materials is very attractive as it would belong to the short-termed tests in relation to its character. This method would enable very quickly and operatively characterized the relation between cutting and cut materials under certain cutting conditions. The realization led to more sophisticated consideration of apparently known technological characteristics ,as machinability and cutting property.

As imply from the analysis of the present knowing in metal cutting theory, there is a need to follow in cutting process analysis separately two different but mutually connected processes:

a. separation of removed layer of the material
b. removing of the chips from the place of cutting, friction between the cutting tool and workpiece.

An essential influence on the realization and character of this processes has the way of the loading of the cutting zone, which is given by the value and direction of the loading force, its components for particular areas of the cutting tool and in deformation zones. The loading is influenced by the cutting tool geometry and the cutting conditions state.

It can be said that the processes in the area of chip formation depend exclusively on machined material and the way of loading (geometry and cutting conditions).

The processes accompanying the chip removal and the tool movement depend on the conditions of friction, e.g. they are influenced by both machined and cutting materials, cutting conditions ,contact areas, etc.

Theoretical analysis shows that in cutting process it is necessary to follow the process of the chip formation and friction in the interfaces of cutting zone. The machined material cannot be evaluated separately but only in interaction with the cutting material and under kinematic and dynamic conditions corresponding with the cutting process .

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