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Flank Wear Monitoring in Coated Carbide Tool Using Ae Signal Analysis, Cutting Force, Motor Current and Acceleration Due to Tool Vibration

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Abstract: Wear of a cutting tool in a machining operation is highly undesirable because it severely degrades the quality of machined surfaces and causes undesirable and unpredictable changes in the work geometry. From a process automation point of view, it is therefore necessary that an intelligent sensing system be devised to detect the progress of tool wear during cutting operations so that worn tools can be identified and replaced in time. As a 'non-destructive' sensing methodology, Acoustic Emission (AE) based techniques offer some advantages over force or power based tool monitoring techniques because of the close relationship between the generation of the emission signal and the fracture or wear phenomenon in machining. The generation of the AE signals directly in the cutting zone makes them very sensitive to changes in the cutting process. Acoustic Emission Techniques (AET) is a relatively recent entry into the field of non-destructive evaluation (NDE) which has particularly shown very high potential for material characterization and damage assessment in conventional as well as nonconventional processes. This method has also been widely used in the field of metal cutting to detect process changes like tool wear etc. In this research work the results obtained from the analysis of Acoustic Emission sensor employs to predict flank wear in turning of C45 steel of 250 BHN hardness using Polycrystalline diamond (PCD) insert. Machining trails were conducted in 5 H.P all geared lathe to obtain the data. The observations noted during the experimental work are analyzed for correlations between the tool wear and the AE parameters.

Key words: Tool wear, acoustic emission, in-process monitoring, rise time, flank wear

INTRODUCTION

The present global industrial scenario is to produce quality products at competitive price. This is possible with the increased productivity aimed at zero error. To achieve this, industries are steering towards 'un manned factory' where human error is reduced to a great extent. An essential part of a machining system in the 'un manned factory' is the ability to change out tools automatically due to wear or damage. Hotton and Qinghuan (1999) has shown that the tool failure contributes on an average, up to 7% to the downtime of machining centers. They concluded that most of the tools fail either fracturing or gradual wear. Inasaki (1998) stated that even through more methods have been developed to monitor tool wear; none of them has achieved significant use in industry. A study by Jemielniak and Otman (1998) showed that the AE parameters did not exhibit a definite trend with tool wear but rather a general random behavior with sudden variations related in the process deterioration phenomena. Hence, the present work was carried out to study the suitability, applicability and relative sensitivity of AET in monitoring tool wear.

Acoustic emission technique: Acoustic Emission Technique (AET) is relatively recent entry in the field of NDE which has particularly shown a very high potential for material characterization and damage assessment in conventional as well as non-conventional materials. Due to its complementary non-destructive evaluation methods, it is utilized for a wide range of applications. Acoustic Emission (AE) is defined as the class of phenomenon where transient elastic waves are generated by the rapid release of energy from localized sources within a material, or the transient elastic waves so generated. In other words, AE refers to the stress waves generated by dynamic processes in materials. Emission occurs as a release of a series of short impulsive energy packets. The

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energy thus released travels as a spherical wave front and can be picked from the surface of a material using highly sensitive transducers, (usually electro mechanical type). Jemielniak (2000) showed that the picked energy is converted into electrical signal, which on suitable processing and analysis can reveal valuable information about the source causing the energy release.

In the analysis of AE signals generated during tool machining processes, two rather well distinct parts can be identified: a continuous emission and the burst emission exhibiting strong intermittence and relatively high amplitudes which is reported by Sundaram *et al.* (2007). These AE signal features are well shown in the time spike of Fig. 1.

The above discussion provides the possibilities of detecting the malfunctions in the cutting processes, such as chip tangling, chatter vibration and innovative breakage and identifying the tool wear state, which is essential for predicting the tool life by means of the AE sensor.

Sources of acoustic emission signals: It is well known that there are different cutting states during the turning operation. In the case of the most desirable cutting state, the chip is broken in the proper length without generating chatter vibration and without forming a built up edge. Other cases, which are rather undesirable in practice, or cutting states with continuous chip, chatter vibration or built up edge. These undesirable cutting stages must be monitored and controlled to obtain the desirable one.

The method to detect continuous chip formation and chatter vibration as the representative malfunctions in the turning operation and to monitor the source of AE signals is presented. Figure 2 shows the plastic deformation zones in the metal cutting process (primary, secondary and Tertiary deformation zone) and indicates the main location of the fracture mechanism (breakage of chips and the cutting edges) were burst type AE signals are generated (Chang-Fei and Houghton, 2001).

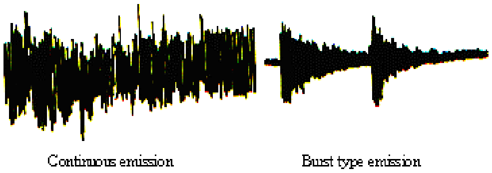

Fig. 1: Time series illustrating both continuous AE components and burst AE events

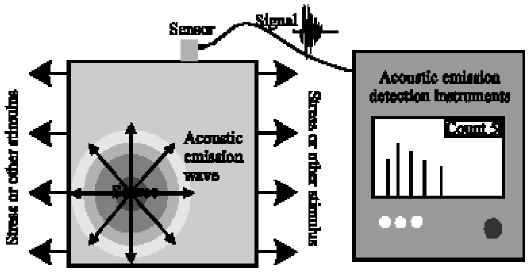

Fig. 2: Sources of acoustic emission signals

MATERIALS AND METHODS

Experimental set up includes 5 HP all geared lathe along with Pre-Amplifier, AE Sensor, Digital Storage Oscilloscopes and Computer. To approach these points C45 steel of 270 BHN is used to study the flank wear. The specifications are selected for this study shown in Table 1.

Experimental procedure: The schematic and pictorial view of the experimental setup is shown in Fig. 3. The AE sensor was positioned on the side surface of the tool holder to sense AE signal due to flank wear. These AE signals were captured for the same cutting condition for 100 kHz to 2 MHz of AE signal. The signal is filtered,

Table 1: Specifications

Work piece	
Diameter of the work piece	50 mm
Length of the work piece	100 mm
Cutting Tool	Rough turning grade of TK35
Cutting condition	
Cutting speed	110-300 m min^{-1}
Feed	0.05-0.5 mm rev^{-1}
Depth of cut	1.5 mm cut^{-1}
AE Sensor	
Make	FAC 500
S.No	151618
Sensor Element	Piezoelectric Transducer
Operating Frequency Range	100 kHz – 2 MHz
Pre-Amplifier with filters	
Make	Physical Acoustic Corporation
Model	140 B; Gain – 40 dB
Operating Voltage	+15V
Filter	125 kHz - High Pass

Fig. 3: Shows the pictorial view of the experimental setup

amplified and stored in the digital storage oscilloscope for further analysis through computer using 'AUTO DASP software. The experimental procedure is:

- The work piece is turned to clean the surface from rust and to get roundness before starting the experiment.
- The cutting conditions were set as given in Table 1.
- The machine was operated for one minute and at the same time to obtain the AE signal through oscilloscope.
- The AE waves stored in the oscilloscope were transferred to a computer through the RS 423 serial interface for off-line analysis.
- The AE signal was stored in 15 frames at the interval of 4 seconds. Tool was removed from the tool holder and cleaned with carbon tetrachloride in order to ensure that no work piece material or other foreign materials are adhering to the tool.
- Again the tool was fitted to the tool holder and the experiment was repeated for required number of observations.
- The experiment conducted other techniques also, i.e. Tool dynamometer, vibration and motor current.
- All the results are compared.

The results and findings on tool condition monitoring through AET, were verified for their repeatability by carrying out the same experimental work with same conditions for 10 min. During this repeated experiment 300 AE waveforms of each 2 seconds duration were captured separately for flank wear.

RESULTS AND DISCUSSION

The EIGHT observations presented in Table 2 are compared in Fig. 4 to study the relative sensivities of tool wear monitoring techniques.

A close observation of Fig. 4 on the trend and the rate with which the various parameters vary with respect to flank wear reveals that the sensitivities of the various techniques decrease in the order given below:

- AET
- Cutting force and acceleration due to tool vibration.
- Motor current.

It also reveals that the sensitivities of AE parameters decrease in the order given below which further confirms the findings:

- Cumulative mean area (mV.s).
- Cumulative mean RMS value (mV).
- Cumulative mean average value (mV).

This study proves the supremacy of AET in monitoring tool condition.

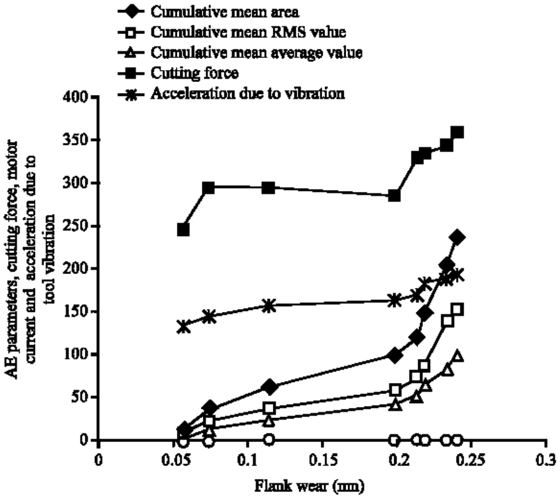

Fig. 4: Flank wear vs. AE parameters, cutting force, motor current and acceleration due to tool vibration

Table 2: Flank wear Vs AE parameters, cutting force, motor current and acceleration due to tool vibration

			AE Parameters								
S.No	Time (Min)	Flank wear (mm)	Mean Area Value (mV)	Cumulative mean area Value (mV)	Mean RMS Value (mV)	Cumulative Mean Value (mV)	Mean RMS Value (mV.s)	Cumulative average Value (mV.s)	Cutting Force ('N')	Acceleration to tool due Vibration (m s^{-2})	Motor current ('A')
1	0.5	0.058	13.410	13.410	9.250	9.250	3.704	3.704	245	133	0.8
2	1.0	0.075	22.880	36.290	13.842	23.092	10.170	13.874	294	145	0.8
3	1.5	0.115	25.565	61.855	14.960	38.052	11.650	25.524	294	157	0.8
4	2.0	0.200	36.685	98.540	20.423	58.475	17.964	43.488	285	164	0.8
5	2.5	0.215	21.781	120.321	13.434	71.909	9.500	52.988	329	169	0.8
6	3.0	0.220	27.968	148.289	16.028	87.937	14.166	67.154	334	183	0.8
7	3.5	0.235	57.216	205.505	50.202	138.139	16.015	83.169	344	189	0.8
8	4.0	0.242	31.149	236.654	15.384	153.523	15.120	98.289	358	194	0.8

CONCLUSION

The discrimination of flank wear on AE and also enhancing the individual effects can be achieved by positioning the sensor for flank wear on the side surface of the tool holder, adjacent to flank face. This has been proved experimentally. Tool condition monitoring through AET has significant effect above 200 kHz. Flank wear stages can be monitored by:

- Observing cumulative mean values of AE parameters like area, RMS value and average value.
- Noting the transitions in the time vs. cumulative AE parameters plot.
- Monitoring the signal type (or) co efficient of variation of RMS value.
- The sensitivities of AE parameters in monitoring tool wear decrease in the order given below:
    - Cumulative mean area.
    - Cumulative mean RMS value.
    - Cumulative mean average value.
- The results of the repeated experiment confirm the repeatability of the research conclusions on tool condition monitoring through AET.
- AET stands supreme in monitoring of tool condition.

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