STUDY OF FLANK WEAR IN SINGLE POINT CUTTING TOOL USING ACOUSTIC EMISSION SENSOR TECHNIQUES

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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 non-conventional 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. The correlation between the tool wear and AE parameters is analyzed using the experimental study conducted in 5 H.P all geared lathe.

Keywords: tool wear, acoustic emission, process, monitoring, rise time, flank wear.

1. 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 *et al.* (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 *et al*. (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.

1.1. 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 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 *et al.* (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 Figure-1.

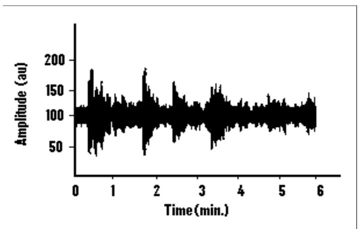

Figure-1. Time Series illustrating both continuous AE components and burst AE events.

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.

1.2. 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.

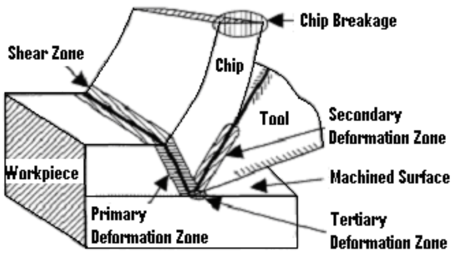

Figure-2. Sources of acoustic emission signals.

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 [Yang chang-Fei *et al.*, (2001)].

2. EXPERIMENTAL DETAILS

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 following specifications are selected for this study:

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
Feed	0.05-0.5 mm/rev.
Depth of cut	1.5 mm/cut
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

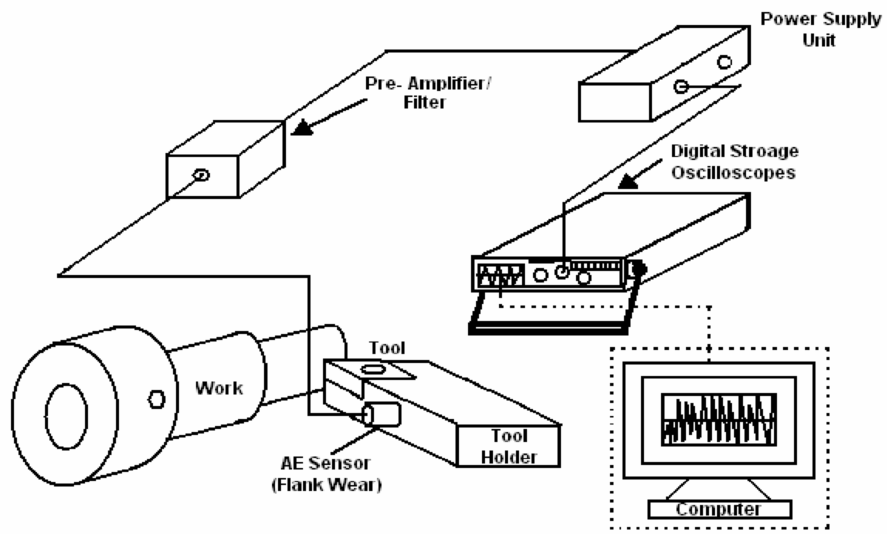

Figure-3. Schematic diagram of the experimental setup for flank wear.

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Figure-4. Shows the Pictorial View of the Experimental Setup.

The schematic and pictorial view of the experimental setup is shown in Figure-3 and Figure-4, respectively. 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, amplified and stored in the digital storage oscilloscope for further analysis through computer using 'AUTO DASP" software. The experimental procedure is given below:

1. The work piece is turned to clean the surface from rust and to get roundness before starting the experiment.
2. The cutting conditions were set as given in section 3.3
3. The machine was operated for one minute and at the same time to obtain the AE signal through oscilloscope.
4. The AE waves stored in the oscilloscope were transferred to a computer through the RS 423 serial interface for off-line analysis.
5. 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.
6. Again the tool was fitted to the tool holder and the experiment was repeated for required number of observations.

3. RESULTS AND DISCUSSIONS

3.1 Flank wear vs. AE signals

Figure-5 shows the three stages of wear such as Stage-I indicate slow wear, Stage-II is indicate moderate wear and Stage-III is indicate faster wear.

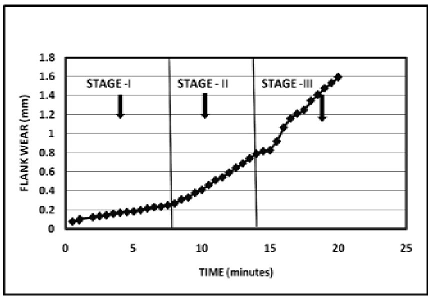

Figure-5. Time vs. Flank Wear.

3.2 Flank wear vs. Cumulative mean AE parameters

Figure-6 shows the flank wear and mean AE parameters using mean average value; mean RMS value and mean area. This reveals that the random variations of mean AE parameters with respect to the flank wear. This can be accredited to the measurement of the flank wear. The flank wear measured was cumulative one and not the instantaneous one, where as the AE parameters measured were due to the release of AE at the particular instant.

The correlation between flank wear and the cumulative mean AE parameters is shown in Figure-7. Comparison of Figure-5 and Figure-7 reveals that the cumulative mean AE parameters, when plotted against flank wear, shows transitions similar to the one in the curve in Figure-5. Hence, the values of cumulative mean AE parameters at the transitions are suggested as limiting values to monitor the stages of flank wear. This is presented in Table-1. From this, it is concluded that the cutting condition selected for this experimental work, the flank wear will be in Stage-I if the cumulative mean average value, mean RMS value and mean area of AE signal are between 0 to 450 mV, 0 to 690 mV and 0to1100 mV.s, it will be in Stage-II if the respective cumulative mean AE parameters are above 450 to 750 mV, above 690 to1150 mV and above 1100 to 1880 mV.s and it will be in

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Stage-III if the respective cumulative mean AE parameters are above 750 mV, above 1150 mV and above 1880 mV.s.

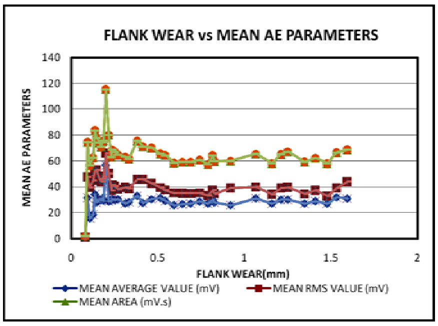

Figure-6. Flank Wear vs. mean AE parameters.

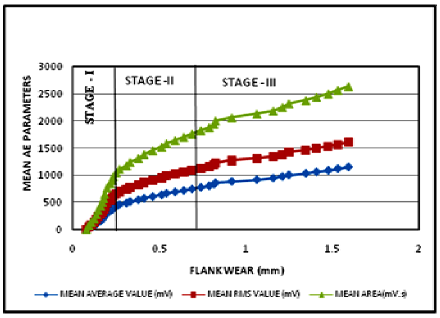

Figure-7. Flank Wear vs. Cumulative mean AE parameters.

Table-1. Trend of Flank wear vs. Cumulative mean AE parameters.

Stages of Flank wear	Stage I	Stage II	Stage III
Flank wear (μm)	0 – 0.250	Above 0.250– 0.8	Above 0.8
Time (minutes)	0 – 7.5	Above 7.5 – 14	Above 14
Cumulative Mean Average value (mV)	0 – 450	Above 450 – 750	Above 750
Cumulative Mean RMS value (mV)	0 – 690	Above 690 – 1150	Above 1150
Cumulative Mean Area (mV.s)	0 – 1100	Above 1100 – 1880	Above 1880

Figure-8 shows the trend of cumulative mean AE parameters with respect to cutting time. The characteristics of the curve changes at Sixth minute, where as the second change point coincided with the wear curve (Figure-5). These change points clearly shows that measure to monitor the different stages of flank wear.

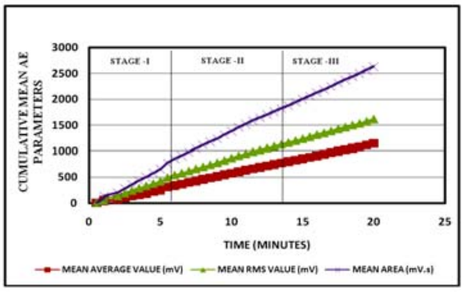

Figure-8. Time vs. Cumulative Mean AE parameters due to Flank Wear.

3.3 Flank wear vs. AE signal types

Figure-9 shows the coefficient of variations of RMS value against Flank wear. On observation of this plot, it has been noted that coefficient of variations of RMS values are high when the flank wear is in Stage-I, Where as it is low value when the Flank wear is in Stage-II and the lowest Flank wear in Stage-III. This reveals that the AE Signals are burst type in Stage-I, and II and they are continuous emission type in Stage-III. Those findings are confirmed by plotting the AE wave forms of Stage I, II and III in Figures 10, 11 and 12 respectively for 3 minutes and 50 seconds after cutting process starts. From the Figures 10, 11 and 12 clearly shows that the signals contain much variation in amplitude level in the first two Stages of wear, where as the variation in amplitude level is less in the third stage of wear. The reasons for this change in the type of signals can be recognized to the rate of wear. Monitoring the changes in signal type is suggested as a method for on line tool condition monitoring, which can be achieved by measuring the coefficient of variation of RMS values. In this case, the flank wear would be in Stage-I, Stage-II and Stage-III, when the coefficient of Variation of RMS value is above and up to 0.065, below 0.065 and up to 0.051 and below 0.051, respectively.

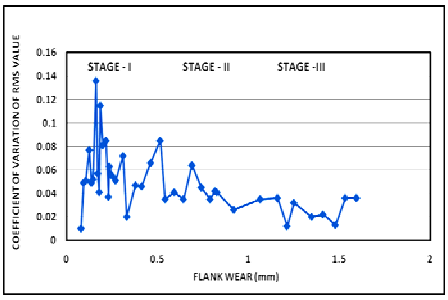

Figure-9. Flank wear vs. coefficient of variation of RMS value.

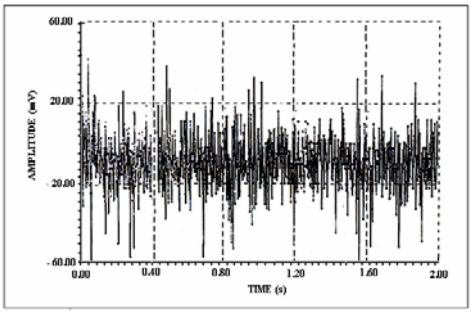

Figure-10. AE Wave Form Captured Flank Wear at Stage-I

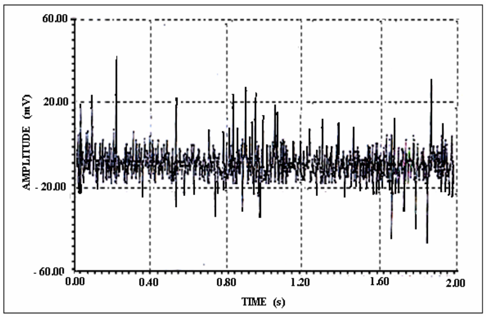

Figure -11. AE Wave Form Captured Flank Wear at Stage-II

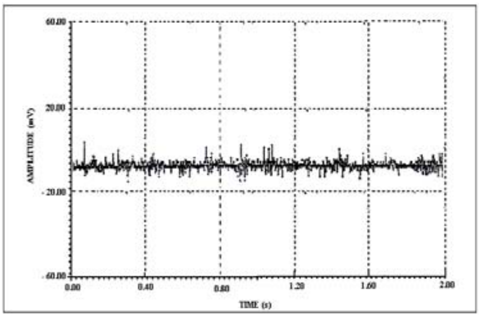

Figure-12. AE Wave Form Captured Flank Wear at Stage-III

3.4 Relative sensitivities of AE parameters in monitoring flank wear

A close study of the slopes of the curves in Figure-7 which shows the trend of cumulative mean AE parameters with respect to flank wear. By monitoring the Flank wear, this study shows that the sensivities of the AE parameters decrease in the following order:

1. Cumulative mean Area (mV.s)
2. Cumulative RMS value (mV)
3. Cumulative average value (mV)

4. CONCLUSIONS

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. This is adjacent to flank face. This has been proved experimentally. The significant effect of tool condition monitoring through AET is identified above 200 kHz in the present study, The Flank wear stages are monitored by

a. Observing cumulative mean values of AE parameters such as area, RMS value and average value.
b. Noting the transitions in time vs. cumulative AE parameters plot and monitoring the signal type (or) coefficient of variation of RMS value.
c. While monitoring tool wear, the sensitivities of AE parameters in monitoring tool wear decrease in the following order:

   I. Cumulative mean area;
   II. Cumulative mean RMS value; and
   III. Cumulative mean average value.

d. The limiting values of AE parameters obtained to monitor tool condition for a given cutting conditions is found to be within ± 10% by keeping all other cutting conditions constant.
e. Peak to peak amplitude is found to be the suitable AE parameter in sensing the tool breakage.
f. From the study, it is found that AET is supreme method to monitor the Flank wear.

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