ABSTRACT

Hard turning, as a manufacturing process is slowly gaining industrial acceptance. Over the last four decades, the process has been stabilized and appropriate machine tools, cutting conditions, tool materials and tool geometry have evolved. High wear rates of the cutting tool, deterioration in the surface finish due to excessive tool wear and white layer formation are some of the major problems hindering wider industrial acceptance. Most of these issues can be satisfactorily addressed by having a reliable and robust monitoring system in place.

Many attempts have been made to monitor the tool condition in hard turning. Most of the methods use either the three component cutting force dynamometer or an Acoustic Emission (AE) sensor for monitoring the process.

AE monitoring using the statistical parameters of the root mean square of AE (AE_{RMS}) distribution have gained prominence in monitoring conventional metal cutting processes. This study attempts to evolve a reliable monitoring method for hard turning. Cubic Boron Nitride (CBN) cutting tool with low CBN content was taken as the typical tool material and experiments were carried out on hardened high carbon - high chromium steel having the hardness of about 60 HRC. Since hard turning is a finishing process, typical
feed rate of 0.05 mm/rev and 0.1 mm depth of cut are used in the study. Experiments were carried out at three cutting speeds of 70, 100, 130 m/min.

Initially, attempts were made to monitor the process using the vibration signal in the cutting speed and feed direction. The relatively robust nature of the vibration sensor and its low cost were the primary reasons for undertaking this exercise. In spite of various signal processing techniques like Fast Fourier Transform and Wavelet Transform being employed, the suitable metrics for monitoring the process status could not be arrived at. This could be probably because of high rigidity of the tool holder system and very low signal to noise ratio.

Subsequent experiments were carried out using an AE sensor. At various tool wear states, the machining time, tool wear, the surface roughness of the workpiece in terms of Ra, Rt & Rz and AE signal were measured. The AE signal was obtained as a set of 2000 $AE_{RMS}$ values calculated with time constant of 0.12 ms. The images of the flank and rake face of the cutting tool were taken using an optical microscope.

The flank wear Vs cutting time curves were plotted. The traditional three phases of tool wear, (ie), initial run-in wear, the steady state wear and rapid wear phases are not clearly distinguishable. This appears to be unique to tool wear taking place for hard turning. The plots of surface roughness plotted for various values of tool wear reveal the surface roughness value Ra to be well within 1µm making hard turning a suitable process for finish machining.
The $\text{AE}_{\text{RMS}}$ signal captured for each condition of the tool status was transferred to computer using GPIB interface. Using the 2,000 $\text{AE}_{\text{RMS}}$ values, the statistical parameters of $\text{AE}_{\text{RMS}}$ distribution were computed. The skew and kurtosis of $\text{AE}_{\text{RMS}}$ distribution were found to correlate well with the tool wear status. The skew was found to decrease as the tool wear increased. This is due to increased rubbing at the tool - workpiece interface, shifting the mass of $\text{AE}_{\text{RMS}}$ distribution to right leading to decrease in the value of skew.

As tool wear increased more of AE bursts due to rubbing between tool and workpiece occurred and this led to more acoustic emission close to the central value of the $\text{AE}_{\text{RMS}}$ distribution. This led to increased skew value.

The flank view of all worn tools revealed a severe abrasive flank wear that had taken place at the tool - workpiece interface. The rake face of the tool revealed small but well defined crater formation, very close to the cutting edge. The formation of crater very close to the cutting edge is due to the small value of uncut chip thickness (feed) used in hard turning. This makes catastrophic fracture of crater wall at the flank side to prematurely end the tool life in hard turning.

This study had demonstrated the possibility of using the distribution parameters like skew and kurtosis of the $\text{AE}_{\text{RMS}}$ distribution for effective monitoring of hard turning.