Condition Monitoring of Turning Tools using Acoustic Emission

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The Challenge

Machining is the process of removing material using tooling to form a shape. Many mechanical structures such as gas turbine engines and axles in cars are made up of machined parts.

In industry, precision machining is used to create the final shape of the part and to ensure a good surface finish. The wear state of the tool at this point is crucial to the process as damaged tools produce undesired surface quality leading to early part failure.

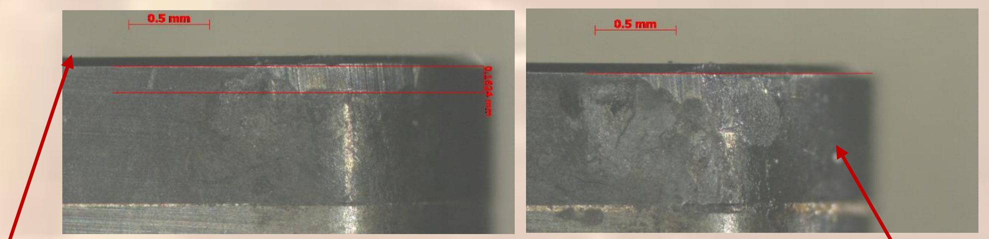
Polycrystalline cubic Boron Nitride (PCBN) tools are used for precision machining as they are the hardest material capable of machining steel. During the manufacturing stage of the tools, they are rigorously tested to find their length of tool life. This is called tool wear testing.

Tool wear testing is time consuming, as it requires the operator to intermittently halt the machining process, in order to visually inspect the state of the tool life, with the use of optical microscopy.

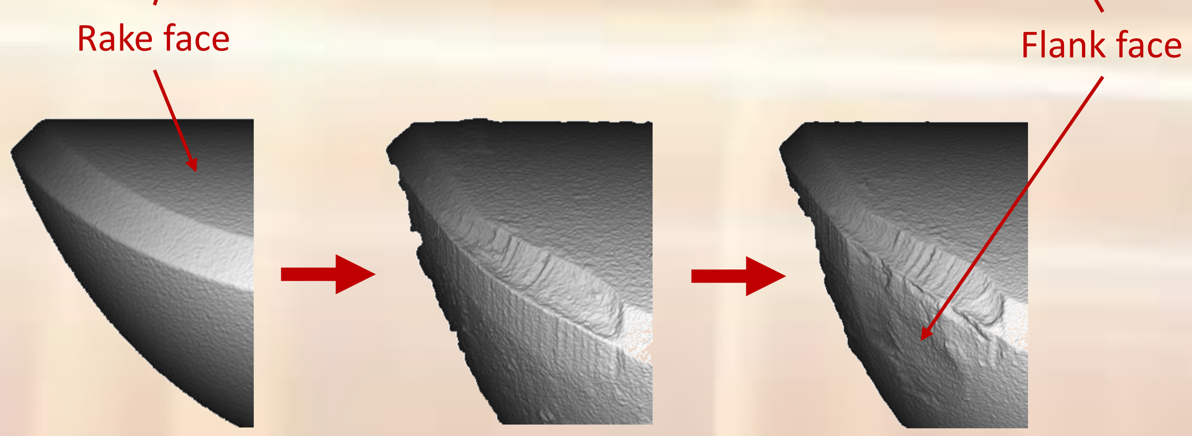
Tool Condition Monitoring (TCM) can be used to automate the process of tool wear measurement and consequently eliminate the use for optical microscopy and reduce testing time. TCM models use the indirect measurements such as Acoustic Emissions (AE) data obtained from the machining process for training.

What is Tool Wear?

There are two types of wear scars of interest for the tool manufacturer. Flank wear is one of them as is caused by abrasion on the flank face of the tool. The second type is crater wear on the rake face of the tool often caused by diffusion, adhesion and abrasion. These wear mechanisms are directly correlated with cutting force, AE, cutting temperature and other indirect measurements of the machining process.



Flank wear – Worn tool (left), failed tool (right)

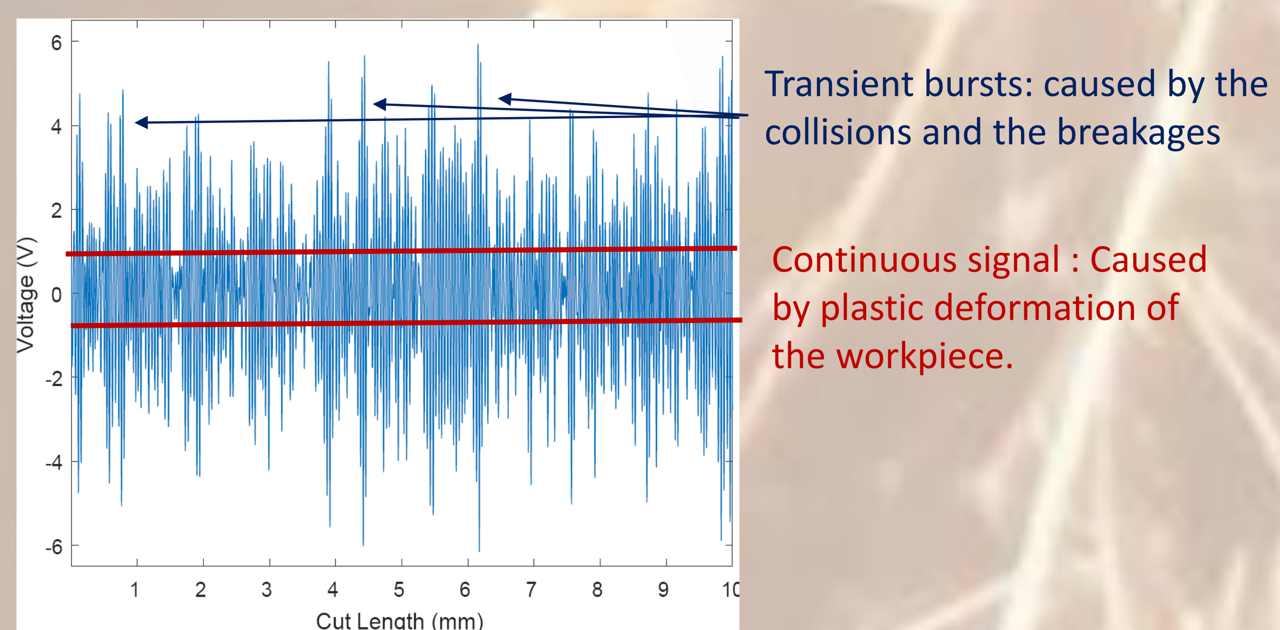


The crater wear progression – New tool to worn tool to failed tool

What is Acoustic Emission?

AE is the release of elastic energy during the deformation of a material. AE is captured by piezoelectric transducers. It is possible to use AE signals to predict tool wear in metal cutting.

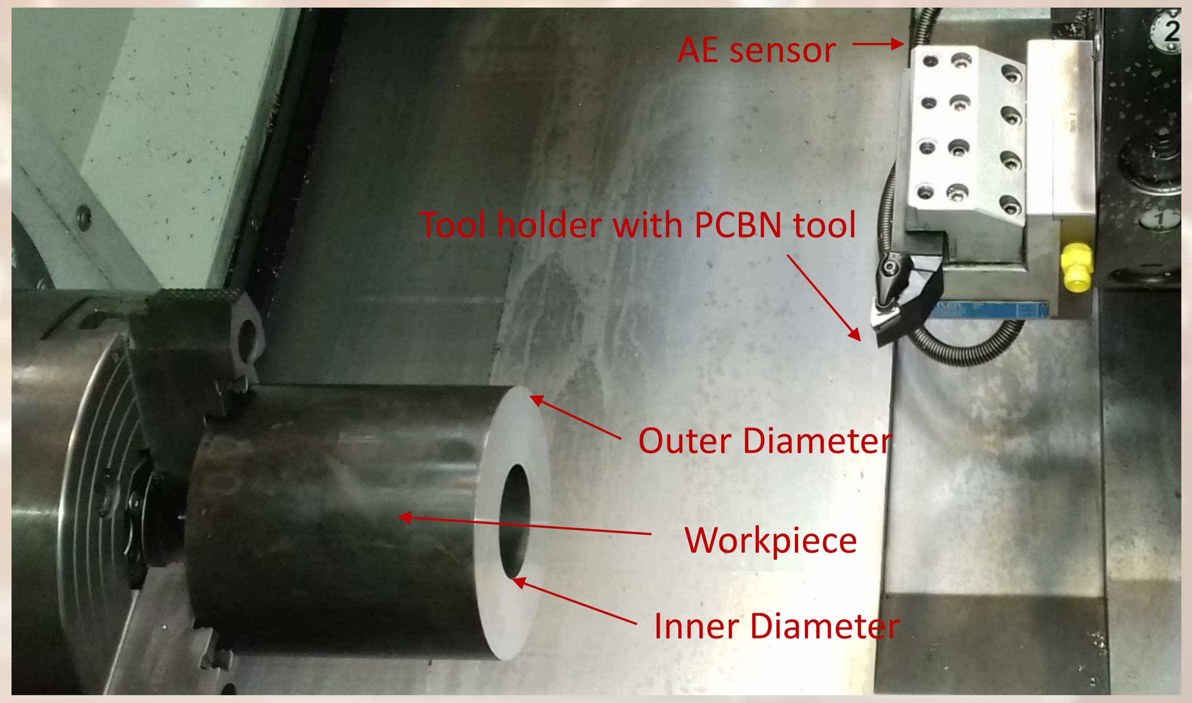
AE signals obtained during machining have both continuous and transient components. Wear of a tool can correlate with AE features



This is a signal captured by an AE sensor

The Experiment

A machining trial was conducted on a computer numerical control (CNC) lathe using a PCBN tool and a steel workpiece with a hardness of 55 – 57 Rockwell C (HRC). AE was collected using an AE sensor that was connected to a pre-amplifier and data acquisitioning hardware. The tool travelled between the outer diameter to the inner diameter of the workpiece 110 times before failing.

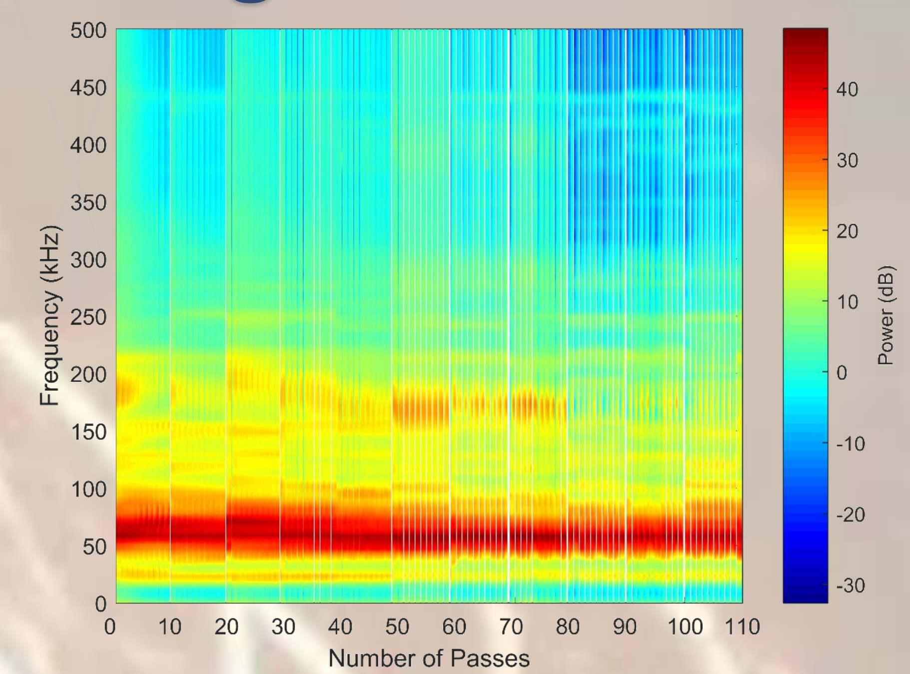


The set up of the machine. All standard cutting parameters were used

Main Findings

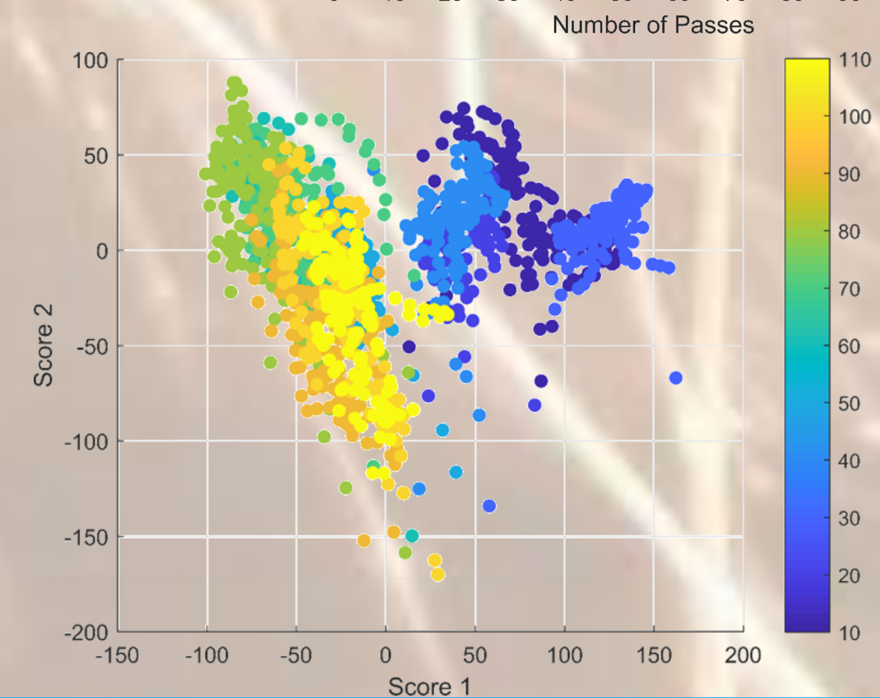
The frequency component of the AE signal was studied in detail. The following were the main findings:

- The frequency with the highest power (58.59kHz) seen in the spectrogram is assumed to correspond to the frequency at which the adiabatic shear band grows and breaks in the primary shear zone.
- The power of the signal at this frequency increases with tool wear.
- There are two peaks of high power at the start of tool life. This could be due to the progression of crater wear.
- At three times the frequency with the highest power (at 175.77kHz) another peak with high power can be seen. This could be a non-linear effect.
- Initial findings show that the tool states can be separated with Principle Component Analysis (PCA).



This is a spectrogram showing the frequency component of the signal collected by the AE sensor.

It is made up of over 1600 vertical lines. Each line represents the frequency of around 1.8 seconds of measured data.



This is a graph showing the results from the principle component analysis. Each data point represent a line of the spectrogram seen above.

The clustering of the data points is an indication that the wear states of the tool can be separated by using a PCA.

Conclusions & Future Work

This work is a very clear indication that AE can be used with tool condition monitoring algorithms. By using principle component analysis on the frequency of the signal, the wear states of the tool can be separated.

Next steps will be to concentrate on selecting suitable features from the raw AE signal for analysis. Moreover, wavelet analysis will be undertaken on the dataset, in order to eliminate the frequencies produced by the workpiece, therefore focusing solely on the frequencies generated by the tool.

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