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Detecting cutting tool fractures and changes in chip formation in finish turning with acoustic emission technique

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Abstract

In this research, the acoustic emission signal from a cutting tool was monitored with an AE (acoustic emission) sensor to investigate the feasibility of in-process detection of cutting tool fractures during the finish turning in metal cutting. The outer diameter of die steel was turned with cemented carbide tools at a cutting speed of 180 m/min, a feed rate of 0.1 mm/rev, and a cutting depth of 0.2 mm. The amplitude and frequency components of the AE wave were mostly constant before the tool fractured. However, when a small tool fractured, the AE frequency component shifted to the lower side and the AE amplitude began to decrease. The tool fractures were 250–275 μm deep. The observation results of the chips before and after the tool fracture showed that serrations formed on the side surfaces of the chips was larger after the fracture. The change in the serration pitch of the chips was found to correlate with the frequency change of the AE signal. Therefore, chip formation changes resulting from tool fractures could be detected as changes in the frequency component of the AE signal.

acoustic emission (AE), tool fracture, chip formation, finish turning

1. Introduction

Cutting tool fractures must be detected to maintain processing quality and improve processing efficiency. In high-load processing such as roughing or medium finishing, a cutting tool fracture can be detected by monitoring cutting forces or spindle motor current [1-3]. However, in low-load processing such as finishing, the processing conditions are difficult to recognize because the cutting phenomenon is microscopic [4]. In this research, the acoustic emission signal from cutting tool was monitored with an acoustic emission (AE) [5] sensor to investigate the feasibility of in-process detection of cutting tool fractures during the finish turning in metal cutting.

2. Experimental methods

In this experiment, the outer diameter turning of a die steel workpiece under the wet process was carried out as a finish turning as shown in Fig. 1. The cutting conditions are shown in Table 1. The acoustic wave generated by the damage of the cutting tool tip and the destruction of the workpiece was measured using an AE sensor attached to the tool holder. The

Table 1. Cutting conditions.

Cutting tool	Cemented carbide (nose radius: 0.8 mm)
Workpiece material	AISI H13 die steel (EN: 1.2344 | X40CrMoV5-1, JIS: SKD61) (hardness: HRC50)
Type of processing	Wet processing
Form of processing	Outer diameter turning
Cutting speed	180 m/min
Cutting feed rate	0.1 mm/rev
Cutting depth	0.2 mm

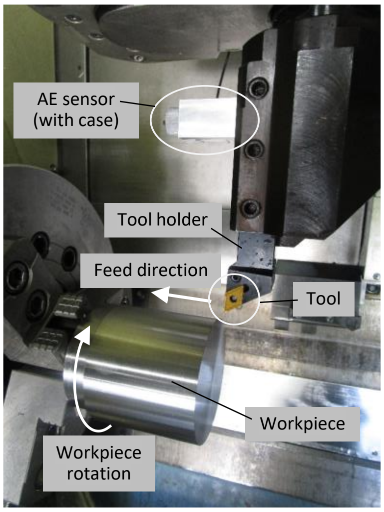


Figure 1. Setup of workpiece, cutting tool, tool holder, and AE sensor for outer diameter turning.

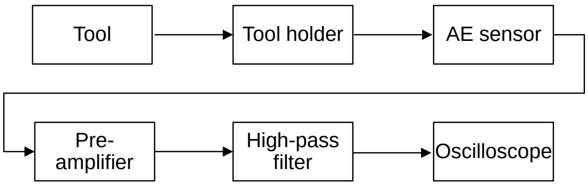


Figure 2. Block diagram of AE-signal acquisition.

Table 2. AE-signal measurement conditions.

Bandwidth of AE sensor	0.1–1.0 MHz (±10 dB)
Amplification factor	20 dB
Cut-off frequency of high-pass filter	20 kHz
Sampling frequency	2.0 MHz

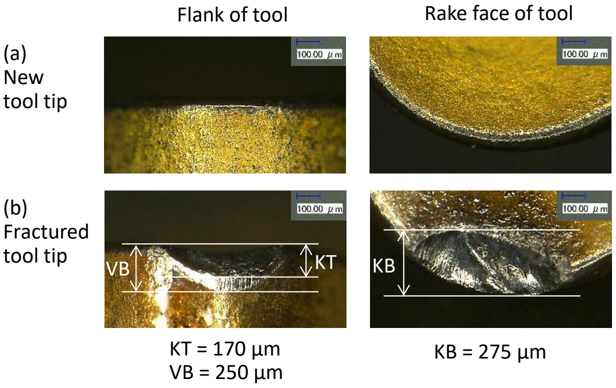
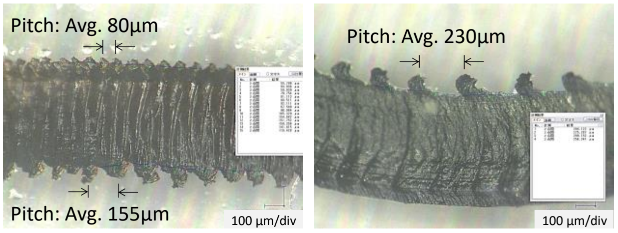


Figure 3. Flank and rake face of (a) new and (b) fractured tool tip.



(a) Before fracture (b) After fracture

Figure 4. Microscopic images of chip details.

propagation path of AE waves and a block diagram of the measurement system are shown in Fig. 2. The AE-signal measurement conditions are shown in Table 2.

The size of the tool fractures and the shape of the chips before and after tool fracture were observed. Changes in the amplitude and frequency domain of the AE waves before and after tool fracture were also monitored.

3. Results and discussion

3.1. Changes in tool tip and chip formation

Fig. 3 shows the microscopic images of the cutting tool tips of new and fractured tools. The shape of the tool tip and the amount of wear were measured using a microscope at a magnification of 150 times. The observation results of the tool tip showed that the sizes of the fracture were 250 µm for the principal flank wear width VB, 170 µm for the crater depth KT, and 275 µm for the crater width KB.

Fig. 4 shows the microscopic images of chip details formed during turning process. Chips generated before and after the tool fracture were cut out by 5 samples each, and the shape of the chips was observed with a microscope. The observation results of the chips showed that the serrations were formed on both sides of the chips before fracture, whereas the serrations were formed only on one side after fracture. It was also observed that the pitch of serrations was larger after the tool fracture. Before the tool fracture, the average pitch of the serrations was 80 µm for the thin part and 155 µm for the thick part, whereas after the tool fracture, the average pitch was 230 µm for the thin part and did not appear in the thick part. Since the above-mentioned changes of the serration pitch were observed in the chips, they were expected to appear as a frequency change in the AE signal.

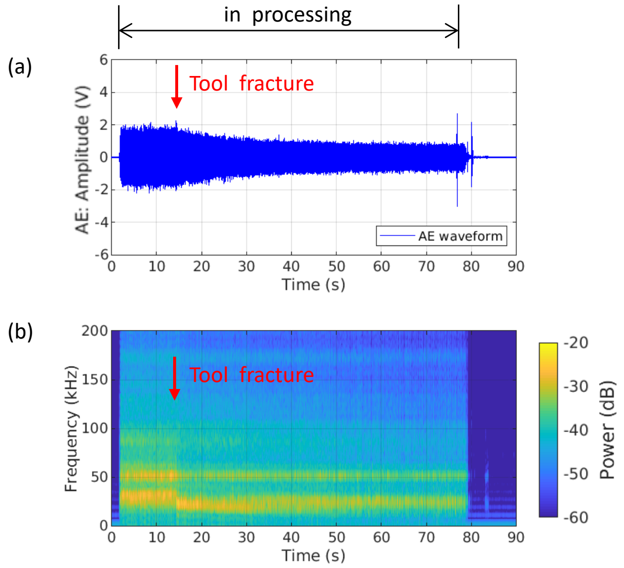


Figure 5. AE-signal waveforms: (a) AE amplitude and (b) spectrogram.

3.2. Change in AE signal

Fig. 5 shows the time-series data of the amplitude and spectrogram of AE signal. The amplitude and frequency components of the AE wave were almost constant before the tool fractured. However, when a small tool fracture occurred, the AE amplitude began to decrease and the AE frequency component shifted to the lower frequency side. Since a remarkable change appeared in the frequency domain before and after the tool fracture, a small tool fracture that occurs during finishing could be detected by the change in the frequency component of the AE waves.

The frequency components of the AE waves shifted to the low frequency side after the tool was fractured. This change correlates with an increase in the pitch of the serrations of the chips.

4. Conclusions

To detect cutting tool fractures during finish turning, the signal from a cutting tool was monitored with an acoustic emission (AE) sensor attached to the tool holder. Tool fractures that occurred during finish turning could be detected as changes in the frequency component of the AE signal.

The shape of the chips was observed to change before and after the tool fracture, and the change in the serration pitch of the chips was found to correlate with the frequency change of the AE signal. Therefore, it was suggested that by monitoring the frequency change of the AE signal using an AE sensor, it would be possible to detect the characteristics of chip formation as a change in the quality of the finished surface.

References

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