euspen's 20th International Conference & Exhibition, Geneva, CH, June 2020
www.euspen.eu

Prediction of tool breakage in small diameter drilling with acoustic emission technique

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Abstract
In this study, a technique for predicting drill breakage in small-diameter drilling using acoustic emission (AE), which can detect small deformations and fractures of materials with high sensitivity, has been investigated. Small-diameter drilling of 1 mm under wet process was carried out until the drill broke. The number of AE events, which is the number of burst AE waves detected in a rotation period of a drill, was used as an index of abnormality. The number of AE events increased from 0 for a normal condition to 7 for a condition just before the drill breakage. When the sign of abnormality in the number of AE events was detected, severe adhesion and deposition of chips were observed on the flank and the rake face of the drill head. As the machining process continued with the drill in such condition, the accumulated chips peeled off together with the cutting edge of the drill, which led to the drill breakage. This phenomenon is the origin of the burst AE waves. Thus, prediction of drill breakage in small-diameter drilling is achieved by high-sensitivity monitoring of the number of AE events.

acoustic emission (AE), prediction, drill breakage, small diameter drilling, AE event

1. Introduction

In order to prevent sudden tool breakage during machining processes, it is essential to detect signs of abnormality. For low cutting force machining such as small-diameter drilling, it is difficult to detect the processing conditions with the conventional method of monitoring the spindle motor current because the abnormal signals observed in the spindle motor current are very small [1]. In this study, a high-sensitivity technique for predicting drill breakage in small-diameter drilling using acoustic emission (AE) [2, 3], which can detect small deformations and fractures of materials, has been investigated.

2. Experimental methods

Small-diameter drilling of 1 mm under wet process was carried out until the drill broke. The acoustic waves were measured with an AE sensor attached to the workpiece side, as shown in Fig. 1. The propagation path of AE waves and a block diagram of the measurement system are shown in Fig. 2. The cutting conditions and AE-signal measurement conditions are shown in Tables 1 and 2, respectively. In the drilling process, the burst AE waves are generated when an anomaly occurs in the drill head. In this experiment, the number of AE events, which is the number of burst AE waves detected in a rotation period of a drill, was used as an index of abnormality.

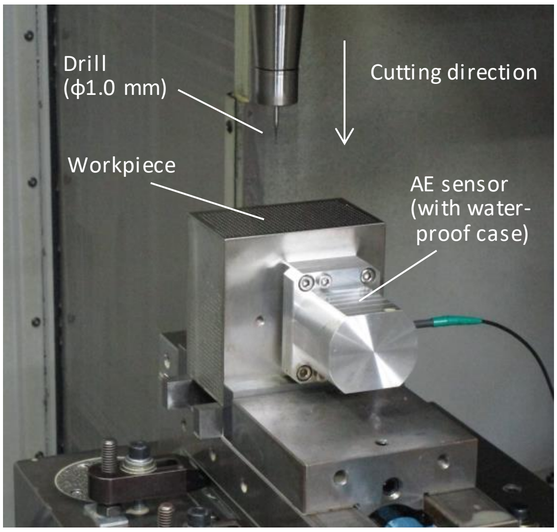

Figure 1. Setup of drill, workpiece, and AE sensor.

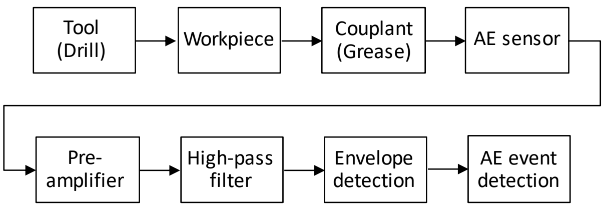

Figure 2. Block diagram of AE-signal acquisition.

3. Results and discussion

Time-series data of AE-signal waveforms and the number of AE events during drilling are shown in Fig. 3. The drill broke during processing of the 135th hole. All the holes were produced in the same workpiece and in a common geometric plane. As the maximum amplitude of the AE signal in Fig. 3(a) was almost constant in the states I and II, it would be difficult to

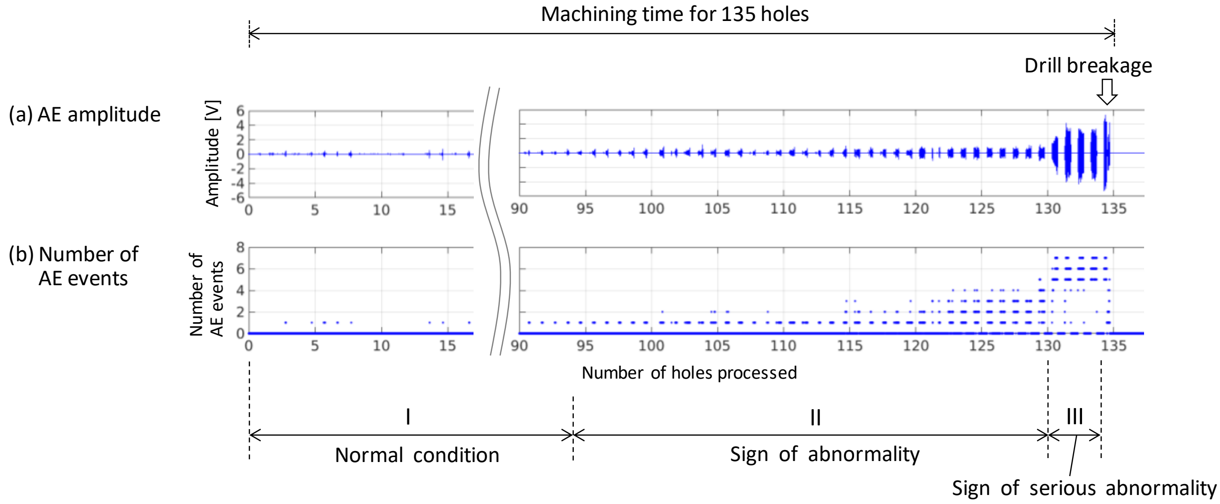

Figure 3. Time-series data of AE-signal waveforms: (a) AE amplitude, (b) number of AE events.

Table 1. Cutting conditions.

Workpiece material	Austenitic stainless steel (EN: 1.4301(X5CrNi18-10), JIS: SUS304)
Tool	High-speed steel drill
Drill diameter	1.0 mm
Drilling depth	2.5 mm
Rotation speed	4,800 min^{-1}
Feed rate	0.03 mm/rev

Table 2. AE-signal measurement conditions.

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

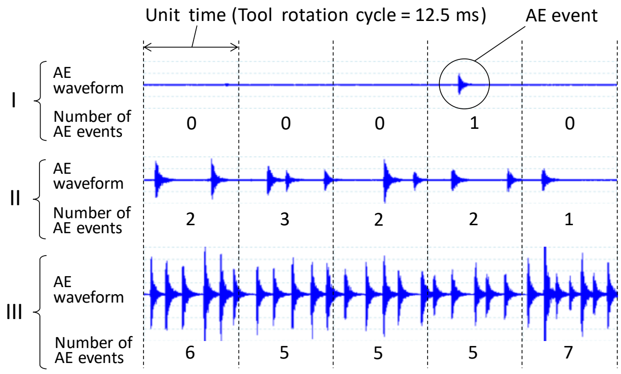

Figure 4. Change in AE waveform and the number of AE events: Typical examples of state I, II, and III in Figure 3.

detect signs of abnormality using a threshold for the AE-signal amplitude before reaching the state III, which is a condition just before the drill breakage. On the other hand, the change in the number of AE events in Fig. 3(b) were observed earlier than that in the maximum amplitude in Fig. 3(a). In Fig. 4, the number of AE events in the states I, II, and III are compared. In state I, the number of AE events was 0 in most rotation cycles for a normal condition. As the machining process continued, the number of AE events increased to 1–3 and appeared repeatedly (state II). This repetition of the AE events was considered as a sign of abnormality. The drill broke after the number of AE events reached 5–7 (state III). In the repeated test using the same type of drill, the drill broke after the number of AE events reached 5 or more. Therefore, abnormality could be detected earlier than

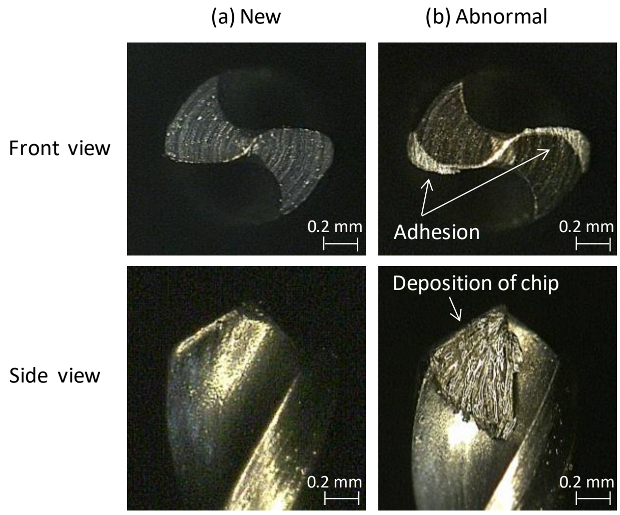

Figure 5. Tool conditions: (a) new drill, (b) abnormal drill.

the amplitude of the AE signal by monitoring the change in the number of AE events.

When the sign of abnormality in the number of AE events (state II in Fig. 4) was detected, severe adhesion and deposition of chips were observed on the flank and the rake face of the drill head, as shown in Fig. 5. When continuing the machining process with the drill in such condition, the accumulated chips peeled off together with the cutting edge of the drill, which lead to the drill breakage. This phenomenon is the origin of the burst AE waves. Thus, prediction of drill breakage in small-diameter drilling is achieved by monitoring the number of AE events with high sensitivity.

4. Conclusions

The prediction of drill breakage in small diameter drilling can be achieved by high-sensitivity monitoring of the number of AE events, which is the number of burst AE waves detected in a rotation period of a drill. Such AE waveforms are generated by the strong adhesion and deposition of chips observed on the tip of the drill.

References

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