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Automatic detection of a damaged cutting tool during machining II: method to detect gullet crack in a bandsaw during sawing

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Abstract This paper presents a method for detecting gullet cracks in a bandsaw during sawing by monitoring burst-type acoustic emission (AE) signals with large amplitude. The amplitudes of the AE signal and profile height amplitude distributions based on roughness profiles of the sawn surface were compared for the bandsaw with and without gullet cracks. The amplitudes of the AE signal increased and the sawn surface quality became worse with the increased number of gullet cracks in the bandsaw.

Key words Acoustic emission · Bandsaw · Gullet crack

Introduction

The monitoring technique of the wood-cutting process is important for the automation of wood-machining operations. Some researchers[1–6] have found that acoustic emission (AE) monitors the machining process more precisely and easily than the cutting forces. This means that measurement of AE is a better technique than that using the cutting force for monitoring the machining process.

In a previous paper[7] we reported an on-line method for detecting damaged bandsaw teeth during sawing by using the AE energy. During the sawing operation, gullet cracks in the bandsaw often are caused by sawing hard knots, pieces of metal, or small stones in the timber sometimes owing to the varying sawing loads[8] and fatigue loading of the bandsaw.[9] A bandsaw with gullet cracks is said to affect the sawn surface quality, sawing efficiency, and accuracy. This study investigates the possibility of detecting gullet cracks in a bandsaw during sawing by using AE signal measurement technology.

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Experimental procedures

Cutting condition

The sawing was conducted using a woodworking bandsaw machine with 700mm wheel diameter and with a distance between the wheel axles of 1250mm. The saw blades had a length of 4700mm, width 45mm, thickness 0.65mm, gullet depth 5mm, tooth pitch 20mm, and number of teeth 235. Three saw blades were used in this experiment. One of them had no gullet crack (bandsaw A), and the others had one (bandsaw B) and two (bandsaw C) successive gullet cracks in the gullet, as shown in Fig. 1. The crack length, which was manufactured by a shearing machine, was approximately 6mm. The sawing velocity and feed speed were kept at 13.3m/s and 5m/min for the experiment. The workpiece for the experiment was yellow poplar (*Liriodendron tulipifera* Linn.) with a moisture content of 12%–14%, specific gravity 0.51, thickness 20mm, length 800mm, and width 80mm.

The kerf widths of all teeth for the three bandsaws were measured with a micrometer. The average kerf widths of bandsaws A, B, and C were 1.55, 1.54, and 1.55mm, respectively, with standard deviations of 0.012, 0.009, and 0.014, respectively. We considered from these measurements that the kerf widths of those bandsaws used in this study were almost the same.

AE signal measurement method

The AE signal was measured at two cases for sawing by successive teeth including the gullets without a crack (normal position) and with a crack (crack position). The method and apparatus for measuring the AE signal were the same as those used in the previous report.[7] The AE sensor (microphone) was positioned 50mm away from the bottom of the workpiece and 100mm away in the front of the sawteeth. The microphone responded up to 100kHz with uniform sensitivity. The AE signal was measured on the frequency range of 50–100kHz through the pass filter. The

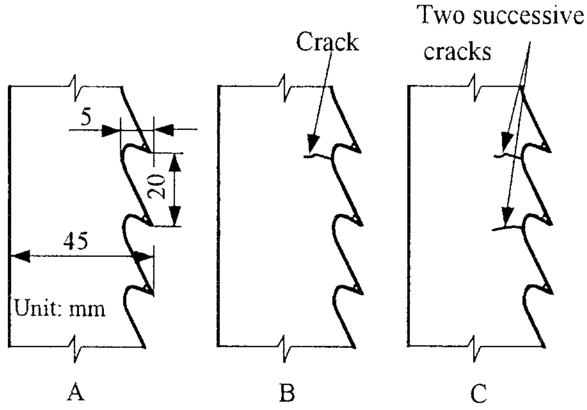

Fig. 1. Three bandsaws used in the experiment. **A** Normal bandsaw. **B** Bandsaw with one gullet. **C** Bandsaw with two successive gullet cracks

fast Fourier transform (FFT) analyzer recorded data at a rate of 256 sample points per millisecond. The AE signal data recorded in the FFT analyzer were transmitted to a personal computer.

Surface roughness measurement

The primary profile was measured using a stylus-type surface measuring instrument with a diamond tracer point having a tip radius of 0.8mm. The trace was moved perpendicular to the tooth marks on the surface at 100mm length. The sampling was recorded at a rate of 256 points per 10mm. The roughness profile was derived from the primary profile using a 2RC filter,[10] and the cutoff wavelength was 2.5mm. The distance from each sampling point to the mean line of roughness profile was defined as the profile height, and the profile height amplitude distribution[11] was calculated at each 20μm interval.

Results and discussion

Figure 2 shows the AE signal due to sawing by bandsaws A, B, and C. The AE signal was measured in normal position. It was observed that the amplitudes of the AE signals for sawing by three types of bandsaw were different. That is, the AE signal was the smallest for bandsaw A and largest for bandsaw C. The AE signal for bandsaw B was intermediate. The behavior can be explained as follows: The gullet crack upset the even reaction of tension throughout the bandsaw because the tension stresses became uneven, and the sawing rapidly deteriorated owing to the bandsaw commencing to oscillate.[8] As a result, it is thought that the deteriorated sawing generated a larger AE signal than that occurring under stable conditions.[12]

Figure 3 shows the AE signal due to sawing by teeth with gullet cracks in bandsaws B and C. A workpiece of 20mm thickness, which was equal to the tooth pitch of the bandsaw, was used to identify the AE signal generation per tooth. An abrupt increase in the amplitude of the AE signal

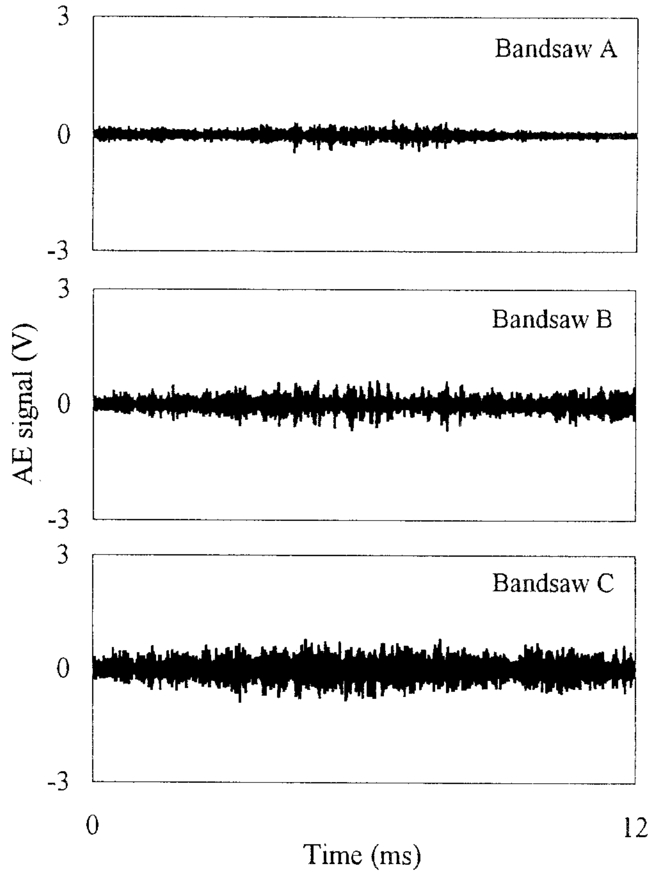

Fig. 2. Acoustic emission (AE) signal due to sawing by a normal bandsaw A, bandsaw B with one gullet crack, and bandsaw C with two successive gullet cracks. The AE signal was measured in normal position

was observed when the two teeth of bandsaw B or the three teeth of bandsaw C that included the gullet crack sawed the workpiece. The continuous time of the burst of the AE signal with large amplitude corresponded to the time that the two teeth of bandsaw B were sawing and three teeth of bandsaw C were sawing. It is thought that the teeth that included the gullet crack were unstable (owing to the influence of the gullet crack) and that the deformation or fracture process of the workpiece changed, producing the burst-type AE signal with large amplitude when the unstable teeth sawed the workpiece.[2,13]

Moreover, compared with normal teeth, when unstable teeth saw the workpiece, it is thought that the deformation zone spreads to a wide area of the workpiece material, and much AE is generated. Therefore, as described above, by monitoring the large-amplitude burst-type AE signal caused by sawing with teeth that have a gullet crack, it is possibly to detect such gullet cracks.

At the same time, sawing with bandsaws with gullet cracks is thought to damage the sawn surface quality because unstable teeth saw the workpiece and the bandsaw oscillates unstably. This was investigated by comparing the profile height amplitude distributions of sawn workpiece surfaces after sawing with three types of bandsaw.

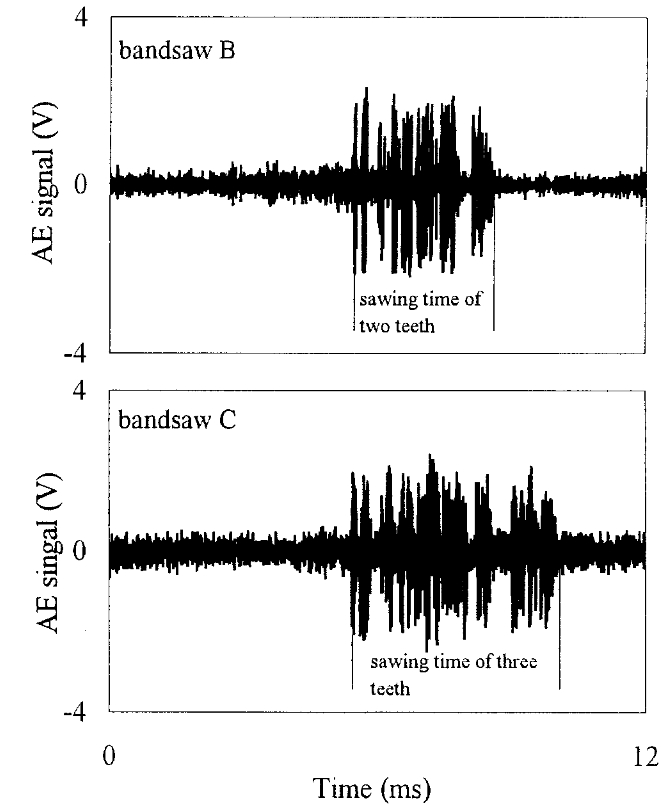

Fig. 3. AE signal due to sawing by teeth that include gullet cracks. Bandsaw B had one gullet crack, and bandsaw C had two successive gullet cracks

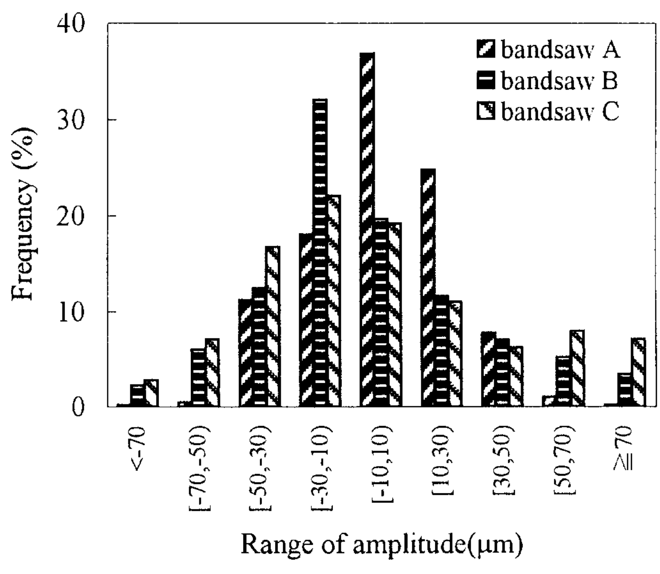

Fig. 4. Profile height amplitude distributions based on the roughness profiles

Figure 4 shows the profile height amplitude distributions based on the roughness profiles of the sawn surface after sawing by bandsaws A, B, and C. The profile height amplitude distribution was largest in the range of −10 to +10 μm for bandsaw A, and its frequency was approximately 37%. However, in the case of bandsaws B and C, the largest profile height amplitude distributions were −30 to −10 μm, respectively. Compared with the profile height amplitude distribution for bandsaw A, the distributions for bandsaws B and C were scattered widely over a range of −70 to +70 μm. This means that the sawn surface quality for bandsaw A was better than that for bandsaws B and C. Furthermore, in the range of −70 to −50 μm, 50 to 70 μm, less than −70 μm, and more than 70 μm, the profile height amplitude distributions for bandsaw C were larger than those for bandsaw B. That is, the sawn surface quality was more damaged by bandsaw C. Therefore, it is thought that sawing was unstable with bandsaw C, stable with bandsaw A, and intermediate with bandsaw B.

Conclusions

The amplitudes of the AE signal during sawing were compared for a normal bandsaw, a bandsaw with one gullet crack, and a bandsaw with two successive gullet cracks. The amplitude of the AE signal increased and the sawn surface quality became worse with an increased number of gullet cracks. The large-amplitude burst-type AE signal was generated during sawing by teeth that had a gullet crack. It is possible to detect gullet cracks in a bandsaw by monitoring large-amplitude burst-type AE signals.

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