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Measurement of elastic waves propagating from processed area during ultrasonic welding

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1. Introduction

Ultrasonic welding of thermoplastic resins is widely used in various fields. For quality control of samples and improvement of manufacturing efficiency, it is necessary to understand the welding conditions of specimens during ultrasonic welding. Vibrations during ultrasonic welding propagate as elastic waves to the base on which the specimen is placed and fixed. These elastic waves may contain information about the welding state of the specimen [1)]. Therefore, in this study, we measure the elastic waves propagating from the weld during ultrasonic welding using an accelerometer and report the results of the analysis.

2. Measurement system

2.1 FFT analysis system and welding conditions

Fig. 1 shows the measurement system. The welding machine and the oscillator (JP80S, J3610s, SEIDENSHA ELECTRONICS CO., LTD) were used in this system. An acceleration sensor was attached to the bottom of the base on which two 0.2 mm-thick PP sheets were placed as a welded sample to measure the acceleration propagated in the base during welding. The signal waveforms obtained from the acceleration sensors were frequency analyzed by FFT analysis using an FFT analyzer (DS-3200, Onosokki). Tracking analysis, one of the functions of the measurement device, was simultaneously performed to track the peak values of the fundamental and harmonic waves, and their time variation was recorded on a PC. The frequencies to be tracked are the resonance frequency of the horn, 19.2 kHz, and its second to fifth harmonics.

The welding conditions of the oscillator are shown in **Table 1**. The subduction amount is the translational distance from the point where the horn contacts the PP sheets to the end of welding. The welding time was varied every 100 ms, and three welds were performed for each welding time condition. The pressure and contact speed of the welding machine were set at 0.16 MPa and 30 mm/s, respectively.

Table 1 Setting conditions.

Welding conditons		Holding condition	Trigger setting
Welding time [s]	Subduction [mm]	Holding time [s]	Load [N]
0.1-2.2	-	1.0	100

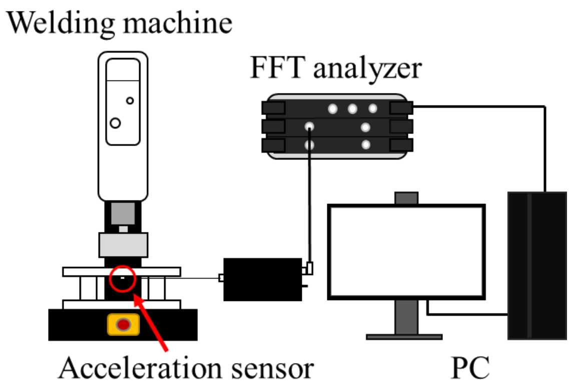

Fig. 1 Measurement system

2.2 Tool horn for welding machine

Fig. 2 shows the tool horn used in the welding machine (JP80S, SEIDENSHA ELECTRONICS CO., LTD). The resonance frequency is about 19.2 kHz. In this study, the resonance frequency of this horn was used as the fundamental wave, which was used as an index for measurement. The second to fifth harmonics of the fundamental wave was also measured.

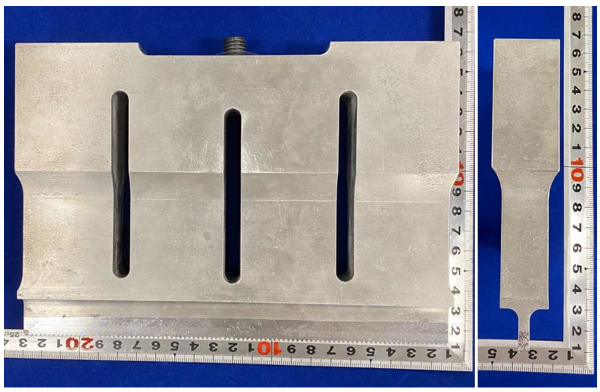

Fig. 2 Welding horn (Reso. freq.:19.2 kHz)

3. Tension test

To ascertain the welding condition of the specimens, tensile tests were conducted and weld strength was measured. The weld formed by one

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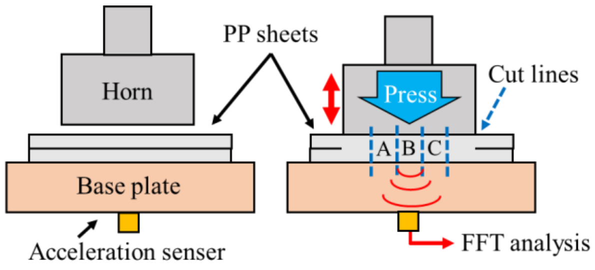
weld was divided into three parts as shown in **Fig. 3(b),** A, B and C., and the test specimens were prepared as shown in **Fig. 4**. The average welding strength(AWS) was then compared with the time-frequency waveform acquired by the tracking function and discussed.



(a) Before welding (b) Under welding
Fig. 3 Welding process and cutting method.

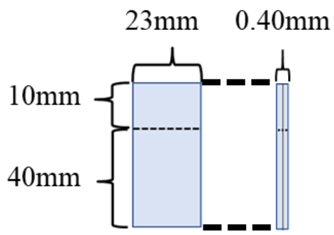


Fig. 4 Test piece size.

4. Experimental results

Fig. 5 shows the time variation of the power spectrum of the fundamental wave and second to fifth harmonics and the time variation of the subduction amount. The subduction amount is based on the data output from the oscillator. The frequency component showed a characteristic attenuation around 0.9 s. In particular, it can be seen that the third to fifth harmonics had relatively larger attenuation than the fundamental and second harmonics. Furthermore, it can be seen that chattering, which was included in the subduction amount from the beginning of processing, becomes smaller from around 0.9 s, and the subduction amount increased significantly. From these results, it can be said that the attenuation of the frequency component observed around 0.9 s is a phenomenon that occurs when the test specimen began to melt.

It can also be confirmed that the third to fifth harmonics around 1.4 to 1.5 s take a minimum and increase after 0.15 s. When this is considered in terms of the subduction amount, it can be seen that the subduction amount line begins to thicken at around 0.15 s. This is due to the subduction amount limit of the weld specimen. This phenomenon occurs when the subduction amount of the PP sheets reaches the limit value, and the base is struck through the thinner PP sheets. This is thought to have caused the elastic waves propagating to the base to increase and the frequency component to increase.

Next, compare the frequency components with the graph of weld strength in **Fig. 6**. The weld strength begins to increase from 0.9 s in **Fig. 6**, consistent with the above-mentioned factor of the frequency component attenuation. In addition, it is confirmed that the weld strength is not saturated at 1.5 s in **Fig. 6**. In the above-mentioned, we explained that this is the timing when the frequency component in **Fig. 5** begins to increase and is the limit value of the subduction amount. However, the weld strength in **Fig. 6** shows that the weld strength begins to saturate around 1.7 s. Based on this, it can be confirmed that the frequency component increases around 1.7 s. This suggests that the increase in power spectrum seen at 1.7 s, rather than the increase in the power spectrum at 1.5 s, is required to determine that sufficient weld strength is achieved.

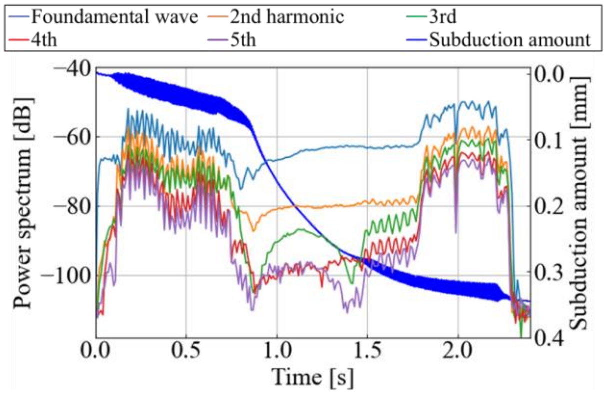


Fig. 5 Time variation of power spectrum and subduction amount.

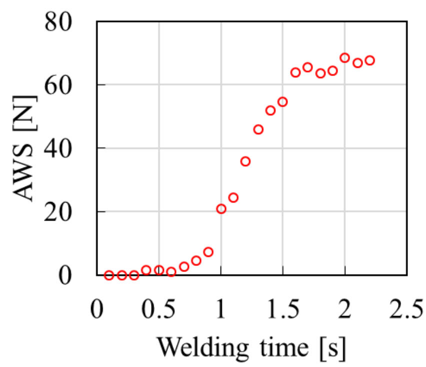


Fig. 6 AWS vs Welding time

5. Conclusion

The elastic waves propagating on the base during welding were measured and frequency analysis was carried out. The results showed that the waves contained various information indicating welding conditions and could be used as an indicator to determine welding conditions. In the future, we will investigate the trend when welding conditions and horns are changed.

References

1. N. Masuzawa and E.Ohdaira: Ultrasonics 38, pp.609–613, 2000.