Acoustic Emission During Air Blowing on the Surface of Aluminum Plate

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Abstract. This study aims to find the development for the non-contact evaluation method of the surface roughness by the acoustic emission (AE) with air blowing. We paid attention to the AE wave due to air blowing on the specimens, three aluminium plates, that they have different surface roughness. The relationship between the AE wave and surface roughness of specimen plates was investigated. Furthermore, the audible sound level on the surface of the specimens during air blowing was also measured. As the result, there is larger tendency in the root mean square (RMS) value of their AE waveform than the audible sound level by different surface roughness of the specimens. The RMS value decreases by increasing of the surface roughness of specimen. It suggested that this characteristic has the possibility to establish a new non-destructive method of surface roughness testing.

1. Introduction

Acoustic emission (AE) is defined as the ultrasonic wave phenomenon due to rapid release of strain energy during the fracture, crack generation or growth, deformation and so on in some kinds of structures or solid materials. By the sensing of AE wave and collecting of AE parameters, we can analyse the specific phenomenon that worked as the AE source. The AE analysis has the possibility to determine the dynamic behaviour of materials such as martensitic transformation, micro cracking or some kinds of phenomenon. Furthermore, the AE occurs during gas leakage from artificial defects, the pinholes with several sectional planes, on the steel pipe [1, 2]. It means the AE was also generated due to the interaction between airflow and solid materials. In this research study we paid attention to the latter phenomenon, the AE due to airflow on the solid material, for developing a new method of the surface roughness testing.

We investigated a tendency of the relationship between the AE waves due to air blowing on the specimen plates and theirs surface roughness in this research study. Three aluminium specimen plates with different surface roughness were prepared and constant airflow was blown to them in the experiment. During the experiment, the AE waves can be observed from the specimens. We compere the Root Mean Square (RMS) value of the AE waves due to three types of specimen. And more, we measured the audible sound level during same experiments. From the results, it was suggested that this relationship investigated has the possibility of a new development for the evaluation of the surface roughness by the AE method with air blowing.

2. Methodology

2.1 Specimen Preparation

Three aluminium plates (size: length = 100 mm, width = 40 mm, thickness = 1.5 mm) were prepared with different surface roughness. The first specimen plate has untreated surface. The second one has filed surface that it was finished using the smooth-cut file. The third one also has filed surface that it was finished using the rough-cut file. The standard piece of surface roughness for sandpaper and file finish (SRSS, Nihon Kinzoku Denchu) was referred to make two-filed surface.

The surface roughness of the three specimen plates was measured utilizing the stylus type surface roughness tester (SURFCOM 130A, Tokyo Seimitsu). The roughness curves were evaluated in range of 20 mm from specimen center. However, overall surface of one specimen plate has almost same roughness. The value of calculated average roughness, *Ra* [μm], is determined from the following expression.

$$Ra = \frac{1}{l}\int_0^l |f(x)|\,dx$$

where, $f(x)$ is the roughness curve and l is the measurement length. The calculated average roughness of untreated, filed by smooth- and rough-cut file specimen plates were Ra = 0.231, 0.812 and 1.72 μm. Figure 1 (a), (b) and (c) shows the roughness curve of three specimen plates and Figure 2 (a), (b) and (c) shows the microphotographs of each surface. The back surface of all specimen plates have same untreated surface.

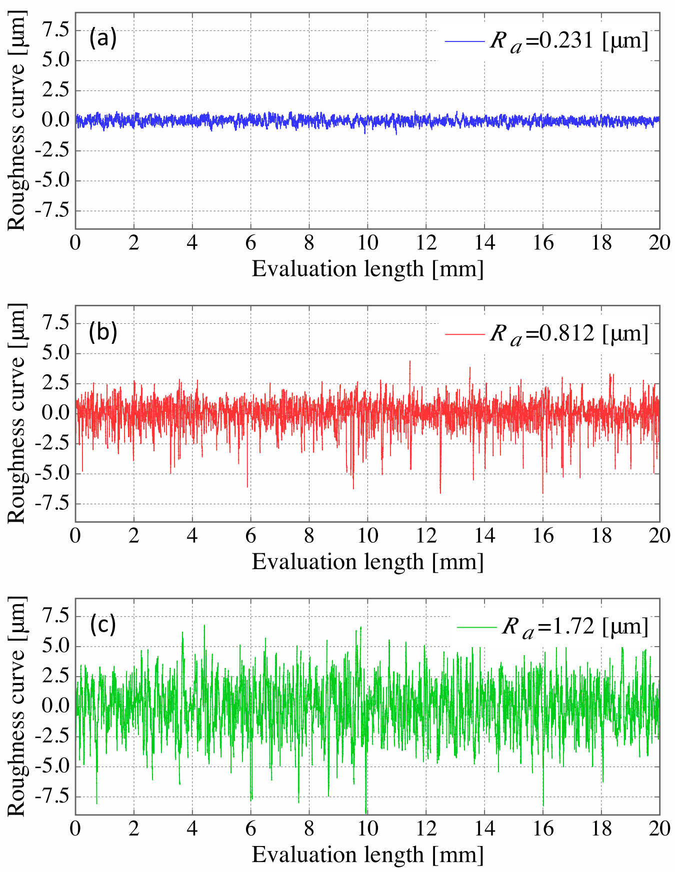

Fig. 1. Roughness curve of three specimen plates

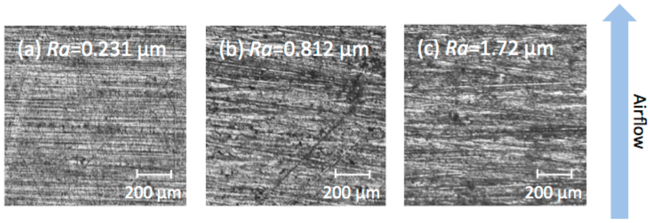

Fig. 2. Surface microphotographs of three specimen plates

2.2 Experimental Setup

Figure 3 (a) and (b) shows the schematic diagram of experimental setup. We blew the compressed air (0.7 MPa, Bebicon, Hitachi) to the specimen plate in 8 seconds. The front surface of the specimen plate was set at an angle of 45 degree to the direction of air nozzle. At the same time, the AE or the audible sound level was monitored. The experiments with same condition and three specimen plates were repeated five times.

In the case of AE monitoring as shown in Figure 3 (a), the AE sensor (PICO, Physical Acoustics) was attached on the back surface of the specimen plate. The position of the AE sensor was the specimen edge of the air nozzle side, the upstream side of airflow, and the center of specimen width. The detected AE waves were amplified by the pre-amplifier (NF9913, 40 dB) and sent to the RMS voltage meter (3400A, Hewlett Packard). The signal of RMS voltage meter was saved in the digital oscilloscope recorder (GDS-1072A-U, GW Instek). Before measurement of RMS value, we checked AE waveform itself. On the other hand, we used the audible sound level meter (LA-210, Ono Sokki) in the case of audible sound monitoring as shown in Figure 3 (b). The microphone of sound level meter was set and fixed at 30 mm distance from the specimen edge of upstream side. The angle setup was 30 degree to the direction of air nozzle and 0 degree to the specimen plate direction.

In fact about the experimental setup, the air nozzle and the specimen plate were fixed strongly by fixing tools. During the experiment, blowing air to the specimen plate, the flapping motion of specimen plate was not observed. We utilized the pencil lead break testing for proofing the noise detection. The pencil lead break testing is one of the methods to simulate the burst AE wave by the fracture of the brittle graphite lead in a suitable setting. It is often used as the method for excitation of the artificial AE source [3]. In this study, the setting and the graphite lead in Figure 4 was prepared. Breaking a diameter = 0.3 mm and length = 3 mm pencil lead on the surface at several spots of the fixing tools. We checked no AE wave detection from the fixing tools. When the pencil lead was broken only on the specimen plate, the AE wave was detected.

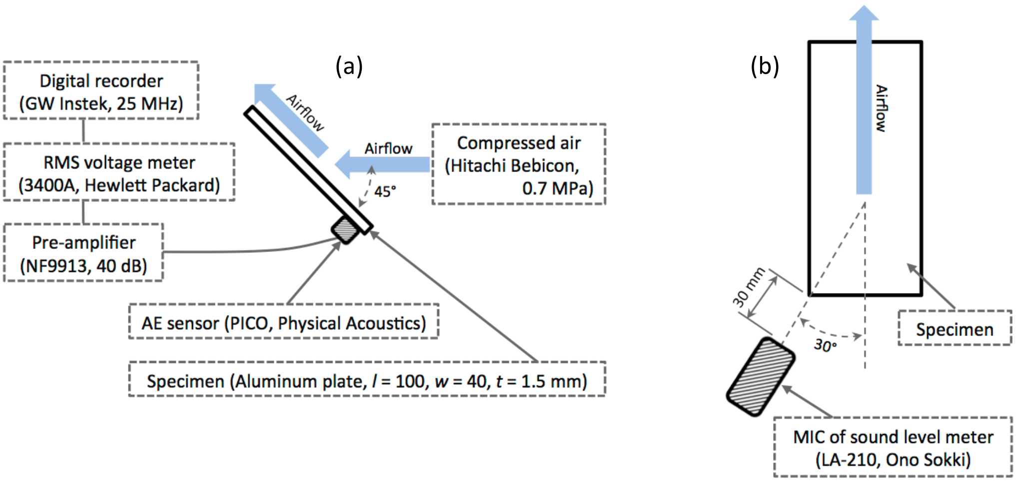

Fig. 3. Schematic diagram of experimental setup

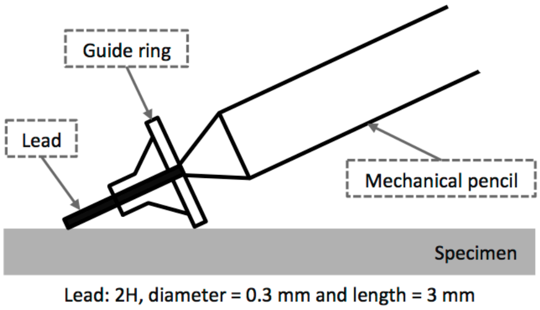

Fig. 4. Pencil lead break testing

3. Experimental Results

3.1 Continuous AE Waveform Monitored

Figure 5 shows the typical AE waveform that it was monitored during air blowing experiment using specimen plate with untreated surface. As shown like this, the continuous AE wave was observed on the back surface of the specimen plate. From the other two specimen plates, the same style continuous AE waveforms were observed. Therefore, we convinced to utilize RMS value as the AE parameter for comparison of result from three specimen plates in this research study.

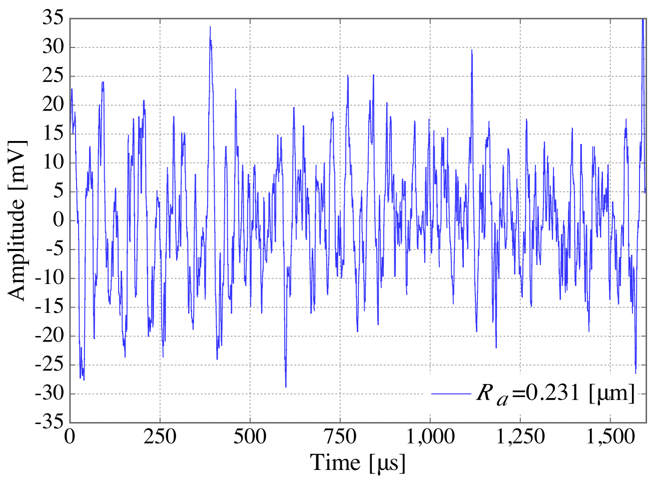

Fig. 5. Typical AE waveform during air blowing experiment (specimen plate: untreated surface)

3.2 RMS Values of AE Waves from Three Specimen Plates

Figure 6 shows the sampled signals from RMS voltage meter during experiments using three specimen plates. The signals in Figure 6 were observed from the fifth experiment, Experiment 5. At the starting point of experiment, Time = 0 [s] in Figure 6, the RMS value increases immediately to the maximum value due to the "valve open" of air ccompressor. After increasing, the signals of RMS value show a little decreasing. 8 seconds later from the starting point of experiment, we stopped the recording of RMS value to the digital oscilloscope recorder. Moreover, the three signals of RMS value were different by the surface roughness of three specimen plates. In order of surface roughness, the RMS values show the changes from large to small.

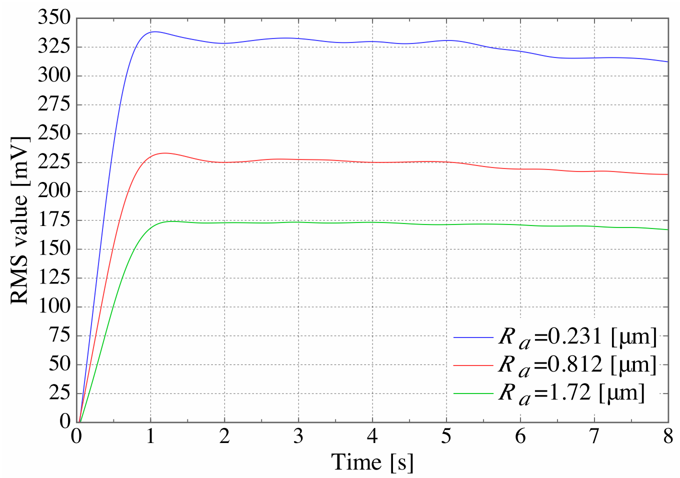

Fig. 6. Signal of RMS voltage meter during the air blowing experiment (Experiment 5)

Table 1 is the summary of maximum RMS values that they were observed from the first to fifth experiment, Experiment 1 to 5. The RMS value decreases by increasing of the surface roughness of specimen plates in every experiment. Using the results in Table 1, Figure 7 shows the relationship between the surface roughness and the average RMS value. There is the behaviour of continuously decreasing in RMS value of AE wave between smooth and rough surface roughness. We supposed that this characteristic possess the ability to grow as the new method for non-destructive surface roughness testing.

Table 1. Summary of maximum RMS values of all experiments

Surface roughness of specimen plate *Ra* [µm]	**Maximum RMS value [mV]**					
	Experiment 1	**Experiment 2**	**Experiment 3**	**Experiment 4**	**Experiment 5**	**Average**
0.231	272	336	340	376	332	331
0.812	212	280	248	264	228	246
1.72	208	216	200	188	176	198

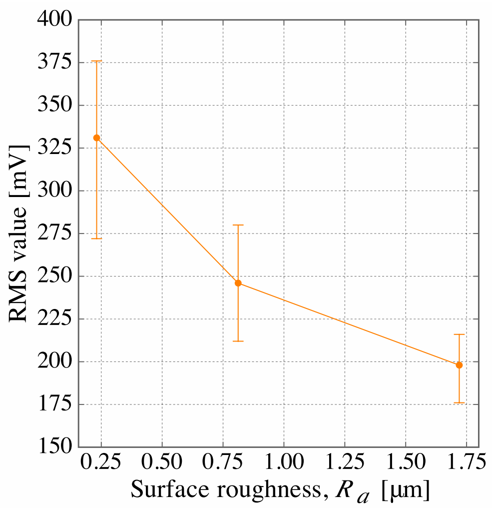

Fig. 7. Relationship between the surface roughness and the average RMS value

The pencil lead break testing was conducted on three specimen plates using same suitable setting above-mentioned Figure 4. The maximum amplitude of AE waves due to the pencil lead break testing was almost same, the average of five results were 1.69, 1.85 and 1.86 mV on the specimen with *Ra* = 0.231, 0.812 and 1.72 µs.

3.3 Audible Sound Levels from Three Specimen Plates

As the next, we conducted audible sound monitoring as shown in Figure 3 (b) using the audible sound level meter. The experimental condition of air blowing was same as the experiment of AE monitoring. Table 2 shows the summary of maximum audible sound levels of five times experiments and Figure 8 shows the relationship between the surface roughness and the average audible sound level. There are not large changes and tendencies in the relationship that was shown in Figure 8. And also, we paid attention to the result values in Table 2. The changes of result values are not following the order of surface roughness of specimen plates like the result of RMS value in AE monitoring above mentioned. The tendency of the results show opposite behavior, the increasing of surface roughness increases the result value in Experiment 3 and 4. Therefore, it is thought that the audible sounds during air blowing to the specimen plates have not reliable information of surface roughness. It is needed to examine and confirm more phenomena, but we thought that the audible sound has the many kinds of large noise expect the noise due to surface roughness.

Table 2. Summary of maximum audible sound levels of all experiments

Surface roughness of specimen plate *Ra* [μm]	Maximum audible sound level [dB]					
	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Average
0.231	121	118	120	118	119	119
0.812	119	117	121	118	118	119
1.72	119	115	118	120	118	118

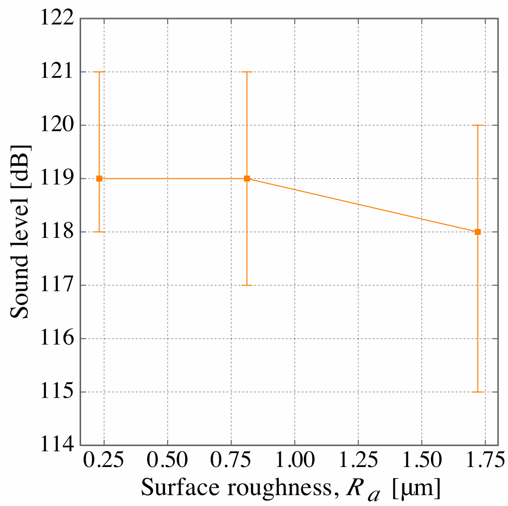

Fig. 8. Relationship between the surface roughness and the average audible sound level

4. Discussion

From the results above mentioned, the RMS value of AE wave during air blowing to specimen plates has the relation with the surface roughness of the specimen plates used. The increasing of the surface roughness of specimen plates decreased the RMS value. On the other hand, the level of audible sound due to air blowing to the specimen plates shows not large and continuous differences. Thus, the characteristic of AE could show the ability.

For considerate the cause of phenomenon that it was shown in AE monitoring, we expect about the effect of the flow separation. Generally, the primary factor of flow separation is the rapid increases of pressure due to shape of object that it is catching the airflow. Therefore usually for preventing the flow separation, the shape of objects is streamlined smoothly [4] as shown in Figure 9. In the case of this research study, the rougher surface makes easy to separate the airflow from the specimen plate. And next to considering about the essence of AE source in this research study, the “wall jet flow” was mentioned. As shown in Figure 10, the boundary layer and the shear layer are formed on the wall surface in the case of the wall jet flow, and the friction stress on wall surface τ is gained [5] at the outer layer of the wall. We estimate the interaction of the friction stress on specimen plate due to airflow of the boundary layer and the elasticity of specimen plate itself is the continuous AE source in this research study. Because of the blowing airflow was separated from the rougher surface of specimen plate, it thought that the AE source was lost. Therefore the increases of surface roughness of specimen plates decreased the RMS value of AE wave.

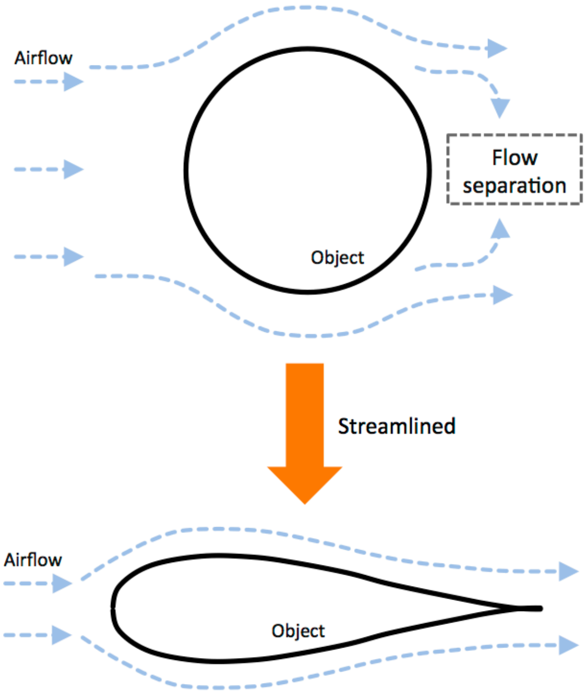

Fig. 9. Shape of objects and the flow separation

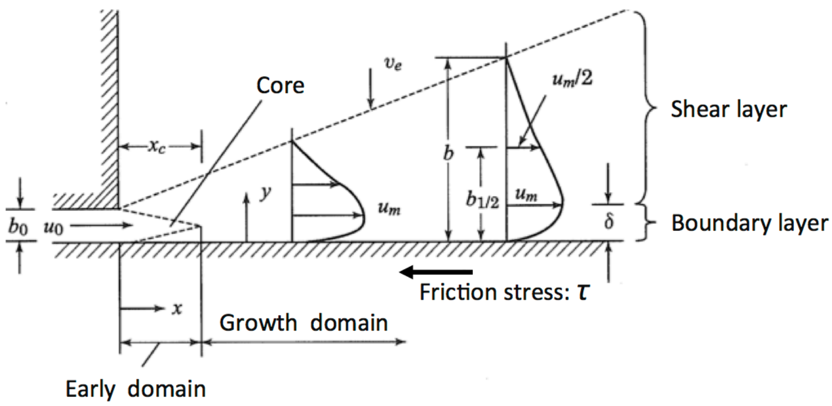

Fig. 10. 2D-model of the “wall jet flow” [5]

5. Conclusion

In this research study, we conducted the AE and the sound level monitoring during the air blowing to the three aluminium specimen plates with different surface roughness. And the possibility was found for a new non-destructive method of surface roughness testing using AE method. The conclusions of this research study are as follows:

1. The continuous AE wave was monitored during air blowing on the aluminium specimen plate.
2. In order of the surface roughness of specimen plates in the range of Ra = 0.231 to 1.72 μm, the RMS values of AE wave due to air blowing were decreased. However, the audible sound level has no changes.
3. The AE source in the case of this research study was estimated that it is caused the interaction of the friction stress on specimen plate due to airflow and the elasticity of specimen plate itself. And it was thought that the effect of the flow separation on rough or smooth surface was made the AE behaviour.

References

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