Evaluation of the Surface Roughness using AE method with Air Blowing

T Yasuda[1], S Takata[1], T Hino[1] and K Yoshida[2]

[1] Department of Mechanical Engineering, Anan National College of Technology, Anan-city Tokushima 774-0017, Japan
[2] Department of Mechanical Engineering, Faculty of Science and Engineering, Tokushima Bunri University, Sanuki-city Kagawa 769-2193, Japan

E-mail: yasuda@anan-nct.ac.jp

Abstract. This study aims to find the development for the evaluation of the surface roughness by the Acoustic Emission (AE) method with air blowing. We paid attention to the AE wave due to air blowing on the specimen plate with different surface roughness. The relationship between the AE wave and surface roughness of specimen plates was investigated. As the result, there is large and continuous difference in the Root Mean Square (*RMS*) value of their AE waveform. The *RMS* value decreases by increasing of the surface roughness of specimen plates. It suggested that this characteristic has the possibility to establish a new method of non-destructive 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 analyze the specific phenomenon that worked as the AE source. The AE analysis has the possibility to determine the behavior 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 air blowing. In this research study we paid attention to the latter phenomenon, the AE due to air blowing, for developing a new method of the surface roughness testing.

Krogstad P. A. and Antonia R. A. were summarizing some researches and introducing them about the normal stresses in boundary layer due to flows along the wall; the normal stress is decreased by increase of the ordinate in boundary layer [3]. Considering their research, we thought that the AE source during air blowing is the interaction between normal stresses and wall in boundary layer of the flow.

In this research we investigated a tendency of the relationship between the AE waves due to air blowing on the specimen plates and theirs surface roughness. Four aluminum 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 four types of specimen. 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. Experimental setup

Figure 1 shows the schematic diagram of experimental setup. We blew the compressed air (from Hitachi Bebicon, 0.7 MPa) to the specimen plate. At the same time, the AE monitoring was conducted. The front surface of the specimen plate was set at an angle of 45 degree to the direction of air nozzle. The AE sensor (Fuji ceramics M5W) was attached on the back surface of the specimen plate. The detected AE waves were amplified by the pre-amplifier (NF9913, 40 dB) and sent to the digital oscilloscope (GW Instek GDS-1072A-U). After the experiment, detected AE waves were investigated on the personal computer.

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. Furthermore, 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 from 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 [4]. In this study, the setting and the graphite lead in Figure 2 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.
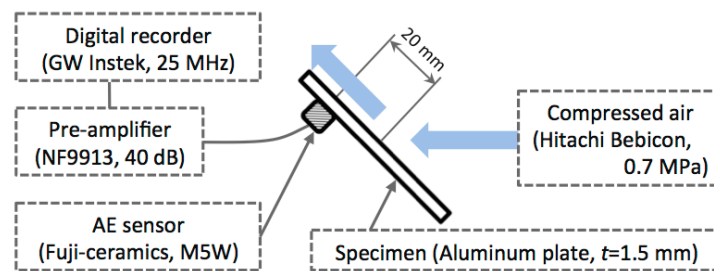

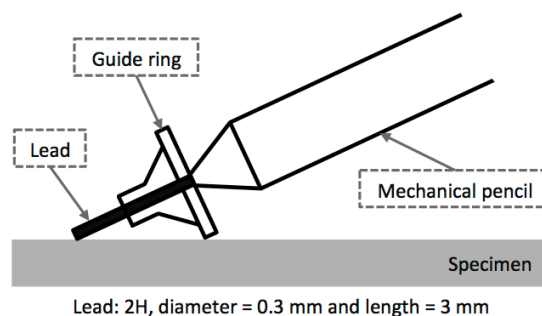**Figure 1.** Schematic diagram of experimental setup

Lead: 2H, diameter = 0.3 mm and length = 3 mm

Figure 2. Pencil lead break testing

2.2. Specimen

Four types of specimen plates (Aluminum plate, thickness = 1.5 mm) were prepared with different surface roughness. The first specimen plate has untreated surface. The second one is sanded using #800 sanding paper. The third and fourth one are filed using smooth- and rough-cut files. Each back surface of the specimen plates have untreated surface.

The surface roughnesses of the four specimen plates were measured utilizing the stylus type surface roughness tester (SURFCOM 130A). Each calculated average roughnesses were Ra = 0.223, 1.50, 1.91 and 3.04 μm. The same experiment of air blowing and AE monitoring above-mentioned were conducted to these four specimens.

3. Result and Discussion

Figure 3 shows the typical AE waveforms. During the experiment, the continuous AE wave was observed on the back surface of the specimen plates. The third line of Table 1 shows the Root Mean Square (*RMS*) value of their AE waveforms. The *RMS* value means the average power of the AE waveform. It is given by next formula:

$$RMS = \sqrt{\frac{1}{\tau} \int_t^{t+\tau} V^2(t)dt}$$

where $V(t)$ is the voltage from pre-amplifier and τ is the time range of the AE waveform.
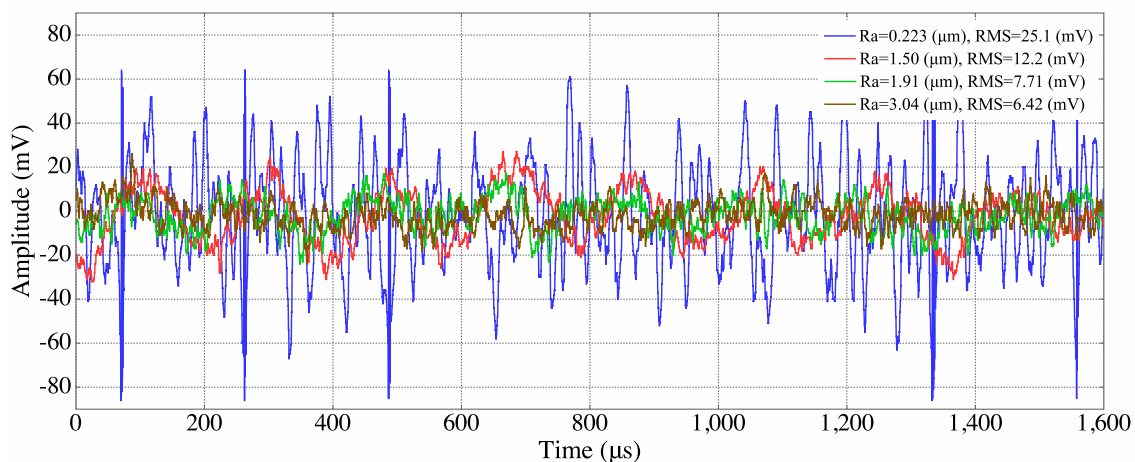

Figure 3. Typical AE waveforms during air blowing experiment

Table 1. Surface of the specimen

Specimen number	No. 1	No. 2	No. 3	No. 4
Ra of specimen (μm)	0.223	1.50	1.91	3.04
RMS of experiment (mV)	25.1	12.1	7.71	6.42
RMS of Pencil lead break (mV)	18.3	17.0	19.2	20.3

In Table 1, the *RMS* value decreases by increasing of the surface roughness of specimen plates. And there is the behavior of continuously decreasing in *RMS* value between smooth and rough surface specimen plates. On the other hand, the fourth line of Table 1 shows the *RMS* value of the AE waveforms due to the pencil lead break testing on each specimen plates. The pencil lead break testing was conducted using same suitable setting above-mentioned section 2.1. The AE waves and the *RMS* value of the pencil lead break testing were almost same. Therefore from these results, it is thought that the difference of *RMS* values due to air blowing has remarkable behavior in comparison with the result of the pencil lead break testing. We supposed that this characteristic possess the ability to grow as the new method of non-destructive surface roughness testing.

Figure 4 is the AE waveforms in frequency domain of four AE waveforms shown in Figure 3. It seems that only untreated surface specimen, the smoothest surface in four specimen plates, has stronger high frequency characteristic especially range of over 400 kHz. It suggested to some different phenomenon is included as the AE source. We expect about the effect of the flow separation. The rougher surface makes easy to separate the airflow from the object. Therefore usually for preventing the flow separation, the shape of objects is streamlined smoothly [5]. Suppose that the normal stress in

boundary layer of the flow was the AE source during air blowing in this research, it thought that the AE source was lost when the blowing airflow was separated from the rougher specimen plate and the ordinate of boundary layer was increased. Thus it thought that the increases of surface roughness of specimen plates decreased the *RMS* value of AE wave.
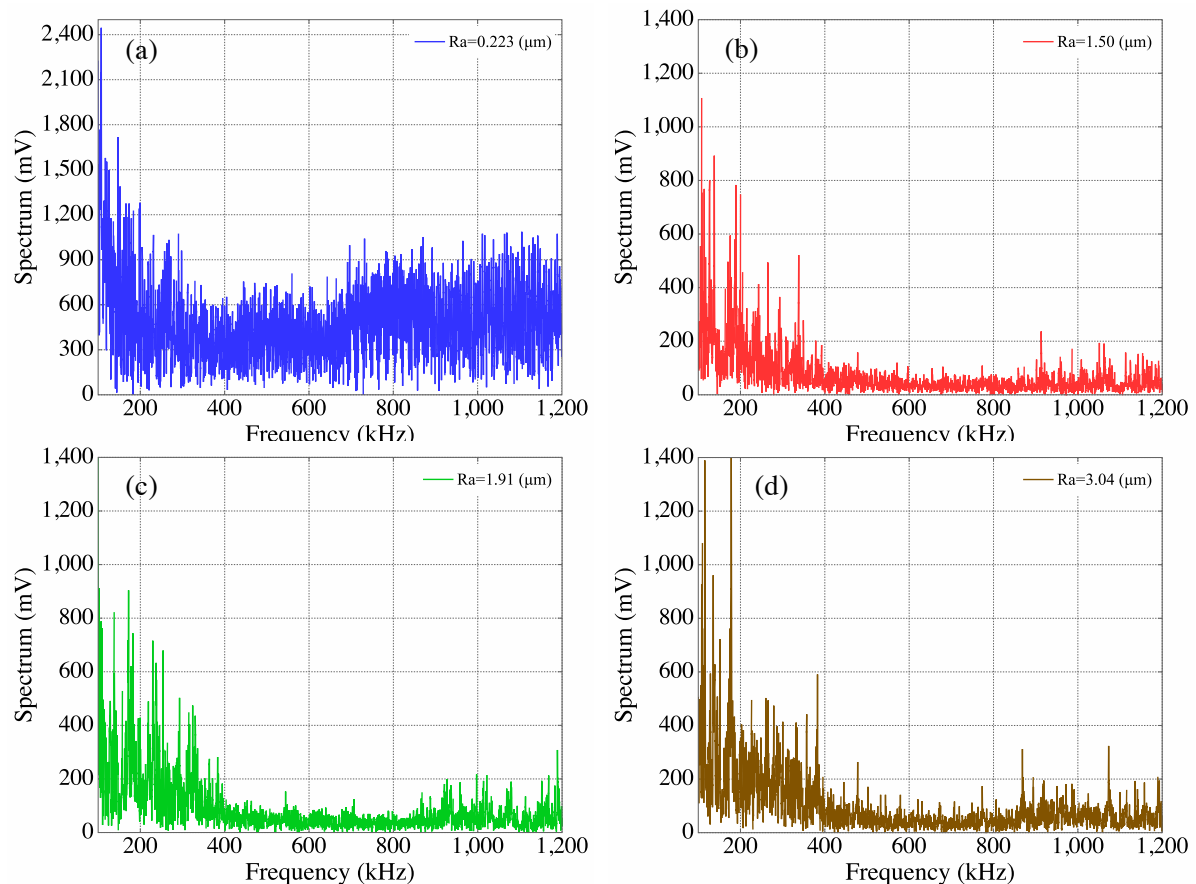

Figure 4. AE waveforms in frequency domain during air blowing experiment
(a) *Ra* = 0.223 μm, (b) *Ra* = 1.50 μm, (c) *Ra* = 1.91 μm and (d) *Ra* = 3.04 μm

4. Conclusion

In this study, we conducted the AE monitoring during the air blowing to the four kinds of specimen plate with different surface roughness and investigated the *RMS* value of AE waveforms observed. There are large changes in *RMS* value between smooth and rough surface specimen plates. The *RMS* value decreases by increasing of the surface roughness. Furthermore in the case of the pencil lead break testing on each specimen plate, the difference of the *RMS* values of artificial AE wave was small.

References

[1]   Laodeno R N, Nishino H, Yoshida K 2008 *Materials Transactions* **49**-10 2341-2346
[2]   Laodeno R N, Yoshida K 2013 Non-destructive Testing (NDT) Technique, Acoustic Emission
         Analysis of Gas Leak on Pipe *Lambert Academic Publishing*
[3]   Krogstad P A, Antonia R A 1999 *Experiments in Fluids* **27** 450-460
[4]   e.g. Shiotani T, Takada Y, Watanabe T and Ohtsu H 2012 *Progress in Acoustic Emission* **XVI**
         1-6
[5]   Nakamura K et al. 1997 Hydrodynamics (in Japanese) *Power Company*