The 8th TSME International Conference on Mechanical Engineering
12-15 December 2017
Bangkok, Thailand

AMM0011

Development of the evaluation method for the surface condition of spur gears using AE method

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Abstract. A vibration method is a standard non-destructive inspection method used to identify defects in rotary machines, however, the use of this method to detect defects at an early stage is difficult. Therefore, an alternative effective monitoring technique for detecting defects at an early stage is necessary. The acoustic emission (AE) method can be used to find small defects in a material by detecting elastic waves that occur when cracks or deformations start to form. In this study, we developed a method to monitor wear, and the relationship between the surface condition of gear teeth and the released AE wave was studied. We first measured the AE waves produced by gears with different surface roughness. Teeth with indentations and contamination generate AE waves with larger amplitudes. Additionally, the amplitude of the AE signals was correlated to the wear depth after the test. We next studied the relationship between surface geometry and the AE parameter; the maximum amplitude and RMS voltage tend to increase with increasing protuberance height.

1. Introduction

The excessive wear of gears due to excessive load, foreign matter contamination, and lubrication problems can cause serious mechanical component failure [1]. Evaluating the lifespan of gears is difficult in order to prevent accidents. Therefore, inspecting gears regularly is essential to prevent accidents due to gear failure. The acoustic emission (AE) method is a monitoring method used for identifying mechanical component failure by detecting elastic waves inside a material produced by dynamic deformation, transformation, dislocation, micro-fracture and breakage [2]. Various researches about gear monitoring was proposed by using AE method [3][4]. However, sensitivity of defect detection was almost same as well as conventional inspection method such as vibration method. Detecting defects in gears at an early stage can be possible to utilize some AE parameter.

In this study, we determined the feasibility of using the AE method to monitor the gear reducer to detect some gear failure, as well as to estimate the surface condition of gears.

2. Experimental setup for monitoring the AE waves caused by gears

Figure 1 shows the experimental setup used to monitor AE signals produced when gears are damaged. A gear reducer, angle sensor, AE sensor, pre-amp, and oscilloscope were used in this study to measure AE waves. AE signals from gears were classified according to which tooth of the gear they came from using the angle sensor. Table 1 shows the specification of the gear. Teeth of the small gear were numbered 1 to 16, and over the course of the experiment, some of these teeth were adapted to several types of damage. Table 2 shows the surface condition of the damaged gear teeth.

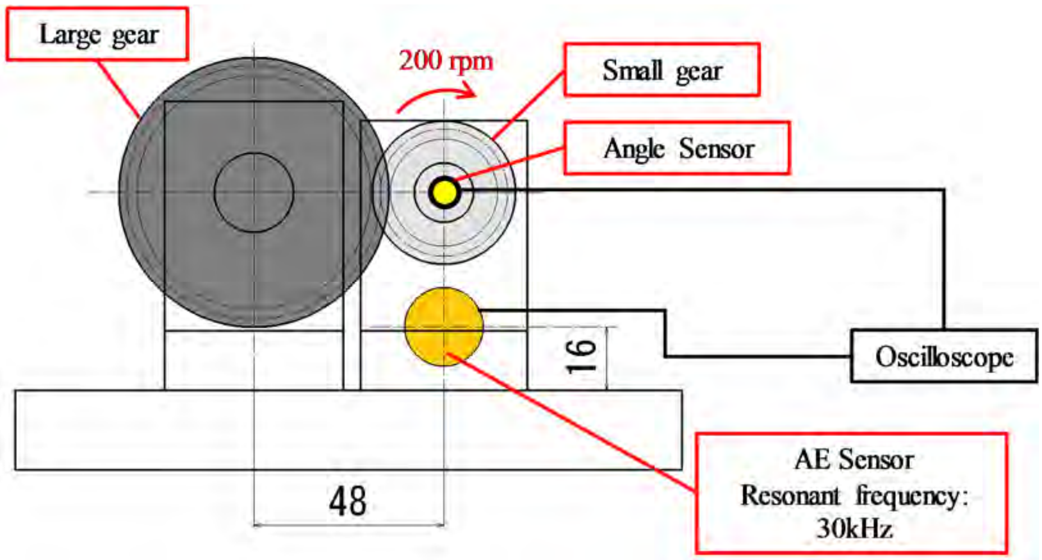

Figure 1. Experimental setup for monitoring AE signals from wearing of gear

Table 1. Specification of gears

	Small gear	Large gear
Material	C3604	A2017
Number of teeth	16	32
Module [mm]	2.0	
Reference circle diameter[mm]	32	64
Pressure angle [deg]	20	
Teeth width[mm]	30	

Table 2. The type of defects

No. 1	Indentation (small)
No. 4	Contamination (glue)
No. 15	Indentation (large)

3. Relationship between the AE waves caused by the failure of gears

First, the AE signals from damaged teeth were studied. AE signals for the damaged gear teeth were monitored. Figure 2 shows the change in the surface conditions of gear teeth No. 1 and No. 15 and figure 3 shows the change of the AE signal amplitude of the gear tooth No.1 and No.15. The amplitude of the AE signals from tooth No. 1 rapidly decreased immediately after the start of rotation because the uplift near the boundary of the indentation was chipped. On the other hand, the amplitude of the AE signals from the tooth No. 15 gradually decreased because the uplift near the boundary of the indentation was shaved off slowly.

Figure 4 shows the change in the AE amplitude caused from tooth No. 4. The amplitude of AE signals from tooth No. 4 increased after the start of the test owing to the introduction of foreign matter contamination. After 20 days, the AE signal amplitude decreased because the thickness of the contamination layer decreased.

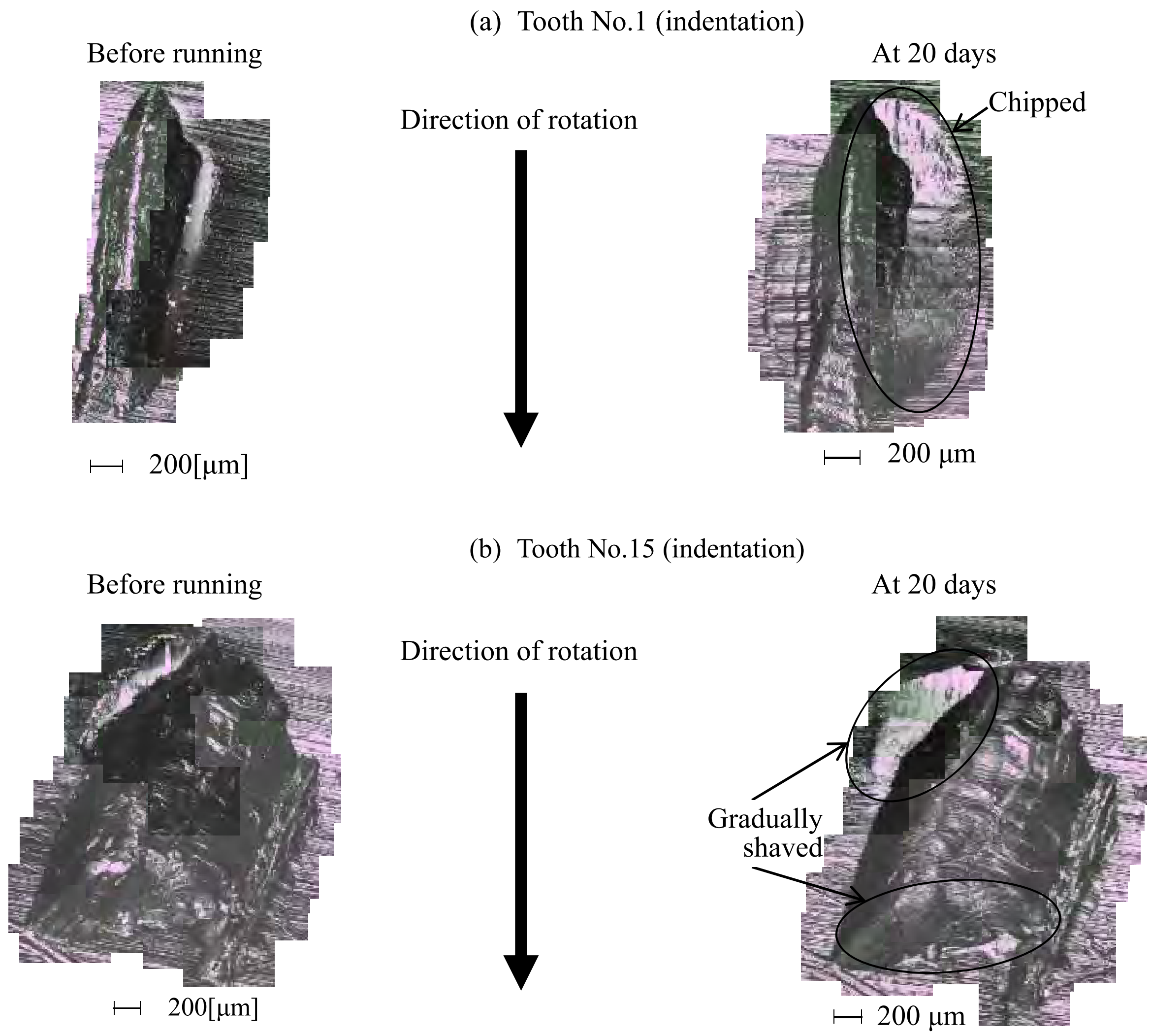

Figure 2. Condition of the damaged teeth

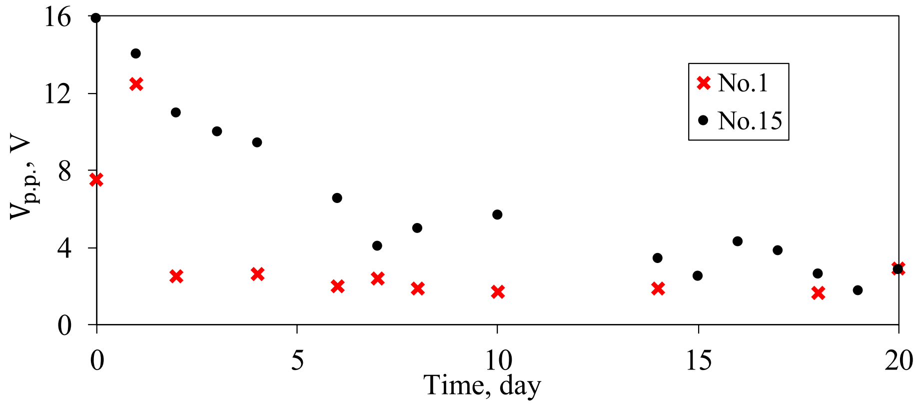

Figure 3. Change in the $V_{p.p.}$ of the AE wave in the case of indentation (No. 1, 15)

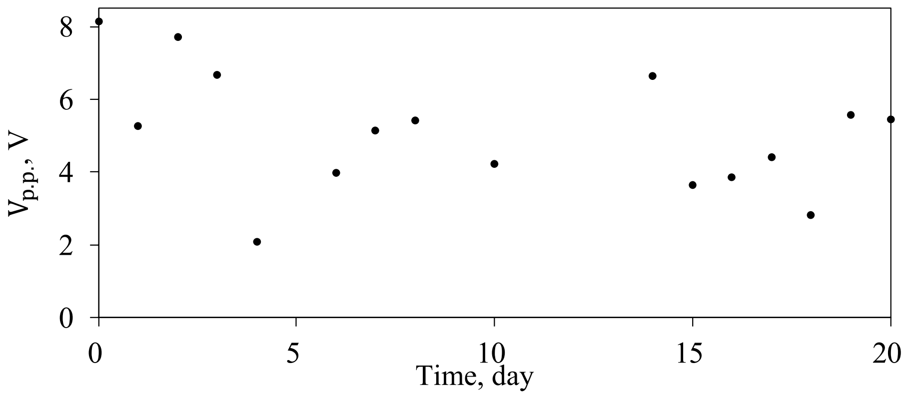

Figure 4. Change in the $V_{p.p.}$ of the AE wave in the case of contamination (No. 4)

4. Relationship between the AE waves caused by the wear of gears

The tooth No. 6 was observed for large-scale wear, therefore we researched the AE wave caused by the wear of gears. Figure 5 shows the change in the AE signal amplitude caused from tooth No. 6. The AE signal amplitude from tooth No. 6 increased because of friction after the start of driving, but by day 20, the amplitude of the AE wave decreased. Figure 6 shows the surface condition of the worn part. Before running, the surface existed the horizontal direction of the stripe. At 7 days, the stripe was disappeared because of the rotational direction of wear. At 14 days, the vertical direction of the stripe was appeared because of also the rotational direction of wear, and at 20 days the surface was smoothed because of the progressing wear. Next, the relationship between the roughness (R_a) of the surface of tooth No. 6 and the AE parameter was studied. Figure 7 shows the change of the roughness of the worn surface. By and large, the worn surfaces were smoothed with time, but at 14 days the worn surfaces were roughed because of the vertical direction of the stripe. Figure 8 shows the relationship between the AE parameter and the roughness (R_a). It turns out that there is a weak correlation between the AE parameter and the roughness (R_a). However, although the maximum amplitude and value of RMS voltage decreased with time, the roughness (R_a) increased 14 days after the start of driving. This is because the contact between pair of teeth is unstable because a shaft which is the side of a large gear is not installed on the flywheel.

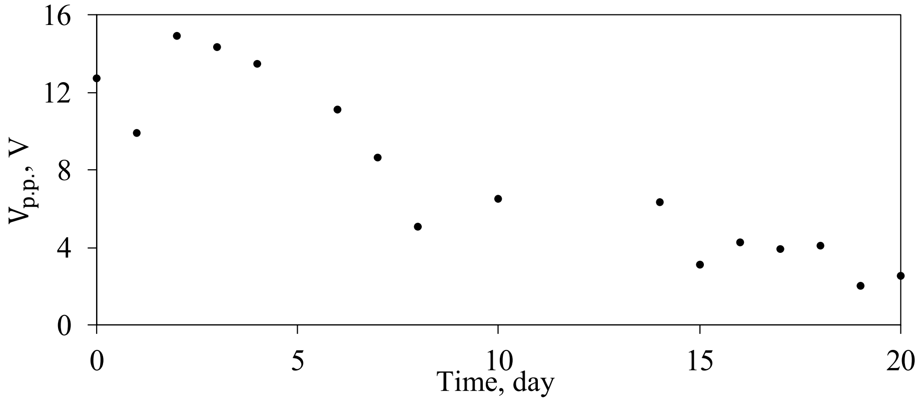

Figure 5. Change in the $V_{p.p.}$ of the AE wave in the case of friction (No.6)

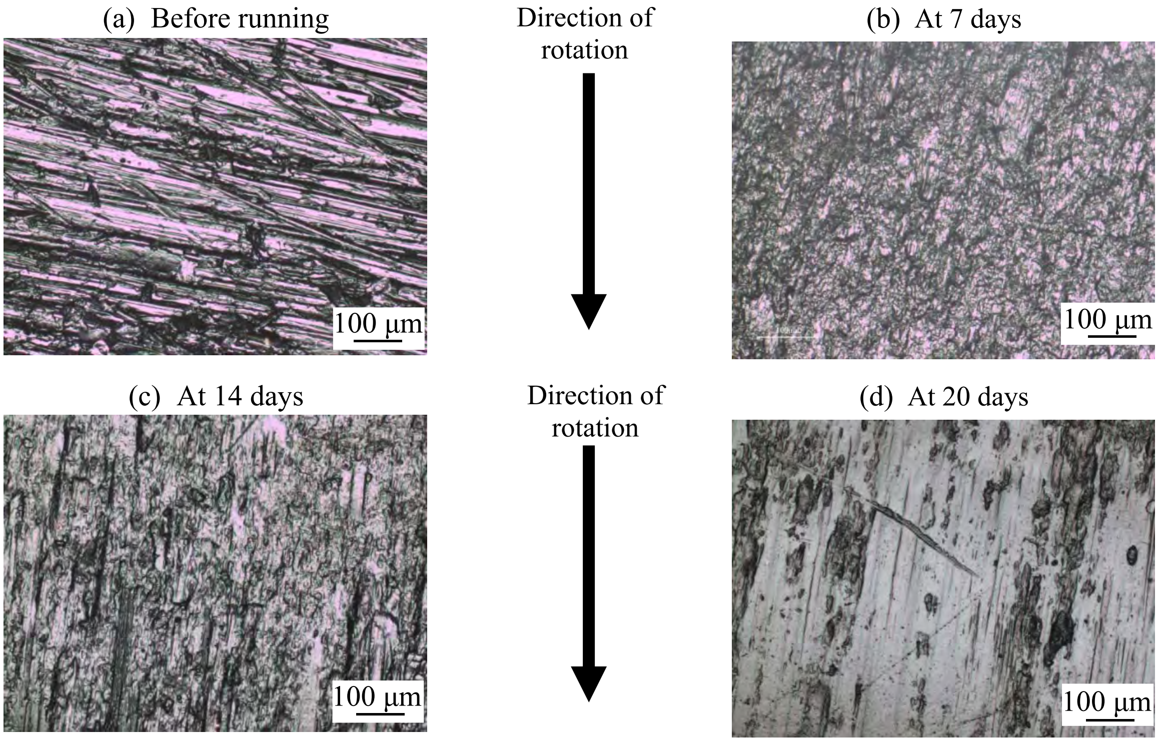

Figure 6. Condition of the worn surface (No.6)

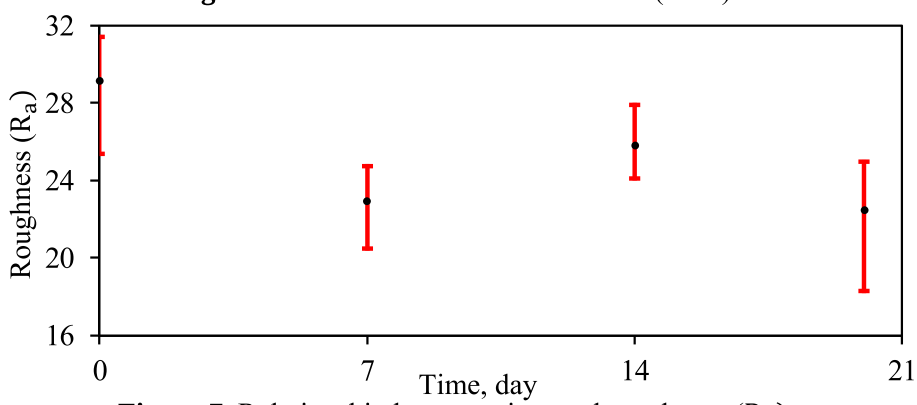

Figure 7. Relationship between time and roughness (R_a)

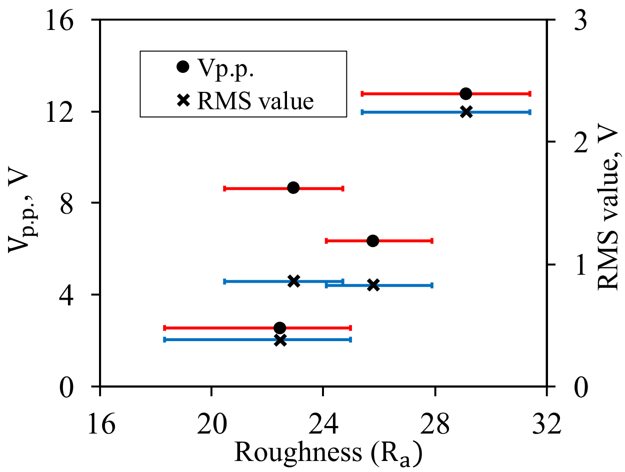

Figure 8. Relationship between roughness and AE parameter

4. Conclusion

In this study, we measured the AE wave caused by the gear reducer. We measured the amplitude of the AE wave produced by teeth with indentation, contamination, and friction damage. The AE wave produced by the various types of damage is larger than the AE wave produced by undamaged teeth. Further, the amplitude of the AE wave produced by teeth with indentations and contaminations decreases with driving time. From these results, the height of the uplift from the AE wave can be estimated. Additionally, there is a weak correlation between tooth surface roughness and the AE parameter. This is due to unstable contact between pair of teeth.

References

[1] The Japan Society of Mechanical Engineers 2006 *Gear Failure –A Pictorial Guide–* pp 1, 129, 211,

[2] The Japanese Society for Non-destructive Inspection, 2008 *Acoustic Emission Testing* pp 4, 42-43

[3] Tim Toutountzakis, Chee Keong Tan, David Mba 2004 *NDT&E international* **38** pp 27-36

[4] T.H. Loutas, G. Sotiriades, I. Kalaitzoglou, V. Kostopoulos 2009 *Applied Acoustics* **70** pp 1148-1159