Change of Acoustic Emission Signals in Damaged Wind Turbine Blades

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Abstract- A failure diagnosis method using Acoustic Emission (AE) sensors is proposed in this study. AE signals could be observed and became larger in accordance with increasing the blade damages. The signals obtained were analyzed by using the Wavelet Transform Analysis. The result of the Discrete Wavelet Transform (DWT) analysis showed that the difference in each spectrum was expressed as the statistical variances. The statistical variance became larger in accordance with increasing the blade damages. From Continuous Wavelet Transform (CWT) analysis, the early failure in the wind turbines could be easily detected with the large information quantities by AE sensors..

Keywords – Failure Forecast Diagnosis, Wind Turbine, AE Sensor, Wavelet Function

I. INTORODUCTION

After the accident of the nuclear power plant in Fukushima, the renewable energy such as a wind power generation has been reconsidered. As the reason, it is important for the renewable energy to not discharge greenhouse gas emission such as carbon dioxide, and not affect the environmental disruption [1, 2]. The numbers of the wind power generation increased greatly in the past several years, and the further increase of the wind power generation will be expected. However, there are many reports on the faults such as blade damages of the wind turbine. The failure diagnostic technology for the wind turbines has not been established enough. Therefore, one possibility on a technical hint of failure diagnosis method for small wind turbines is proposed in this study. Authors have studied failure diagnosis method till now. The object observed and analyzed in here is Acoustic Emission (AE) signals which occur from the positions of breakdown such as blade damages. The AE signals were analyzed using the wavelet transform. The wavelet transform is one of the analysis methods which are well used for analyzing time and frequency simultaneously in some scientific fields.

II. EXPERIMENTAL PROCEDURE

The schematic illustration of the small wind turbine generator (MWG-50W) used in this experiment is shown in Fig.1. This small wind turbine has the following features.

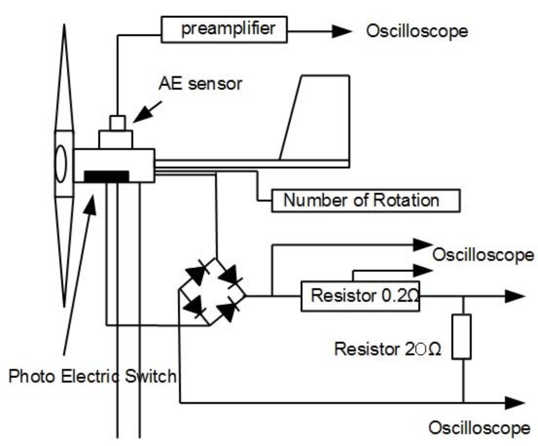

Figure1. Measurement equipment setup for a small wind turbine used in this study.

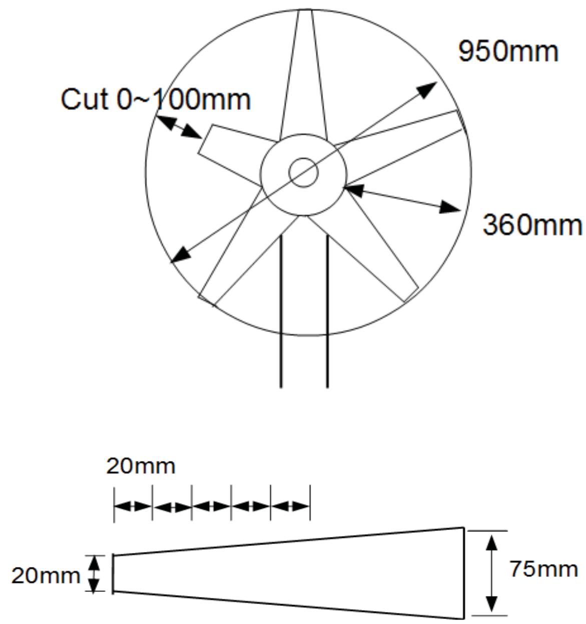

Figure2. Distribution of the 5 blades. One blade was partly cut off.

・The wind turbine had five blades. ・A rated power output is 50W, and the full length of a blade is 960 mm.
・Rotor form is horizontal-axis propeller type, and has a self-starting system.

The exact details about the feature and specification are shown in a reference [3]. In this study, An AE sensor was attached to the upper part of the generator MWG-50W. AE wave is the ultrasonic waves which are produced when the material undergoes stress and/or external forces. This phenomenon is applied to some troubles, such as breakage of a small wind turbine, which can be detected by AE sensors. As an advantage that uses AE sensor, possibilities of an early detection, diagnosis of the equipment under operation, and detection capability is high. The acquisition method of AE signal used for analysis in this study is explained. Experiments were carried out under the condition of natural wind. The failure of the wind turbine was manufactured by destroying one of braid part of a small wind turbine. Fig.2 shows the situation of the blade distribution. The small wind turbine had five blades, and each one was with length of 360mm. We made intentionally the failure of the wind turbine by cutting off one of blades from 20 to 100mm length.

III. RESALTS AND DISCUSSIONS

3.1. AE signal detection –

AE signals obtained are shown in Fig.3 in accordance with the cut-length (cut 0~100mm). The AE signals until cut 20mm length do not change , but remarkable change appears in the AE signals cut over 20mm length. It is understood that the damage levels of the blades can be expressed by the AE signal. For example, when the blades of a small wind turbine are at a normal condition, the large AE signal is not observed at all. When a blade had breakage, AE signals showed that a certain amount of failure diagnosis was possible.

3.2. Discrete Wavelet Transform (DWT) analysis of AE signals –

Here we briefly explain about the DWT analysis which divides a signal with various frequencies into a low(A) spectrum function and a high(D) frequency spectrum function. The low frequency function (cA1) obtained through DWT analysis is furthermore processed in the next process. The low frequency spectrum is again processed in the next step. The obtained low frequency spectrum function is written as cA1, and high frequency spectrum function is written as cD1. This is illustrated in Fig.4.

We have processed the AE signals until Level5 in this study. The above Level means the number of times in DWT analysis on the AE signal. Thus, the cA2 low frequency function is allotted to Leve2. However, as total data are so much, we show only data of “normal” and “cut-80mm” in Figs. 5-1, 5-2, 5-3 and 5-4, respectively.

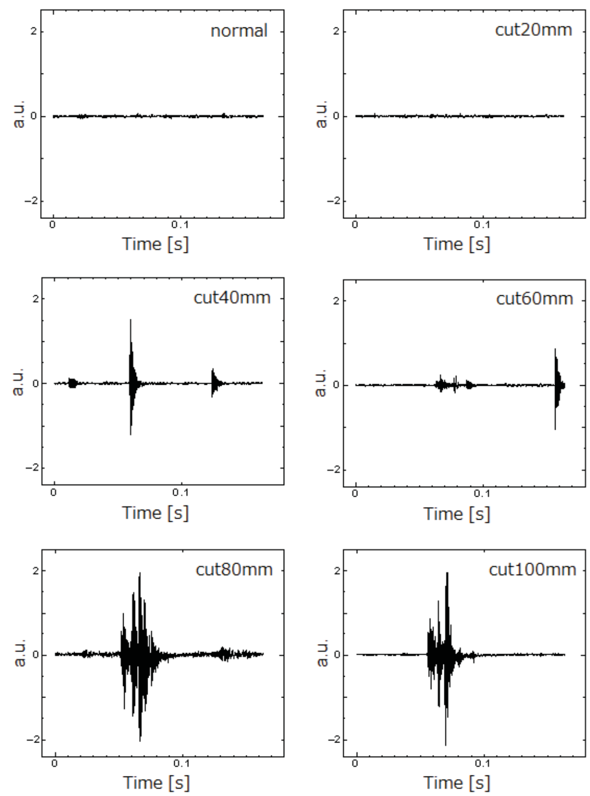

Figure3 AE signals can be observed and become larger in accordance with increasing the blade damages.

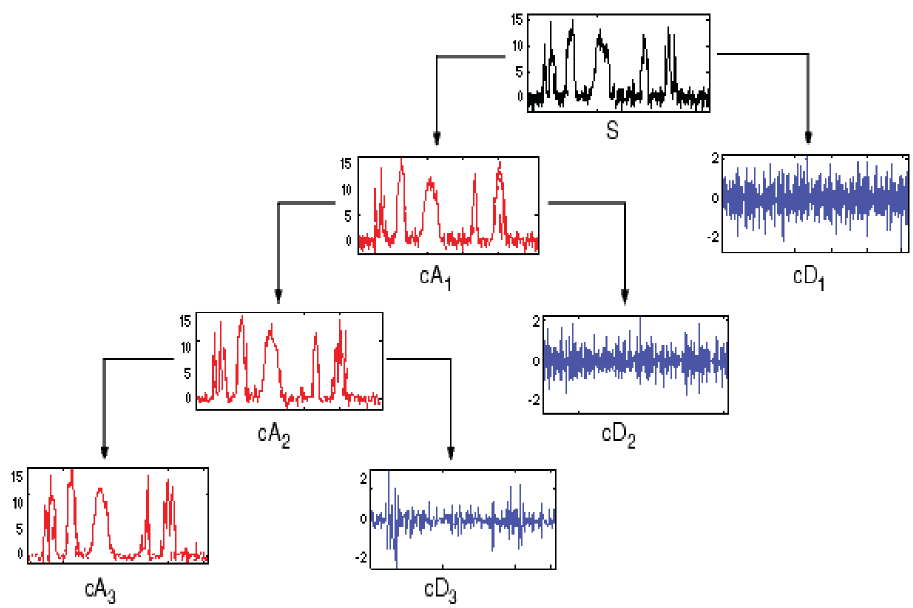

Figure4 When one signal is processed by DWT, the signal is divided into high and low frequency spectrum functions.

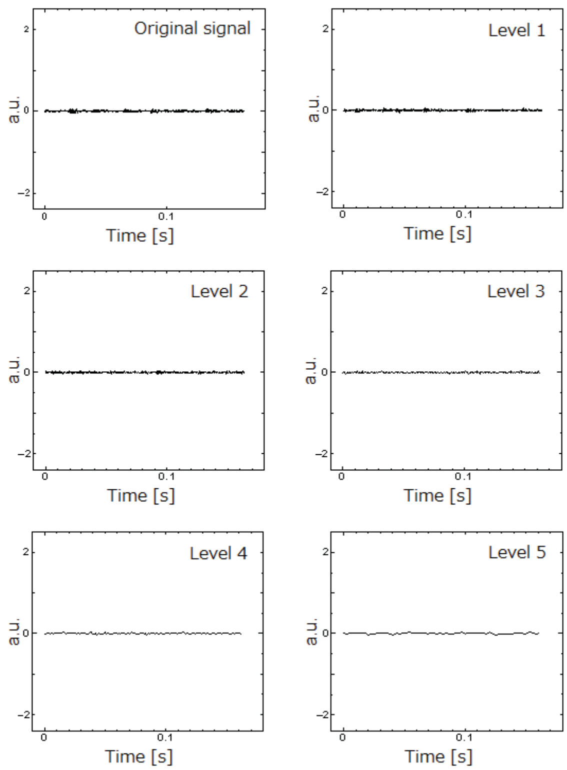

Figure5-1 DWT analysis for an AE signal of “normal” in low frequency spectrum functions.

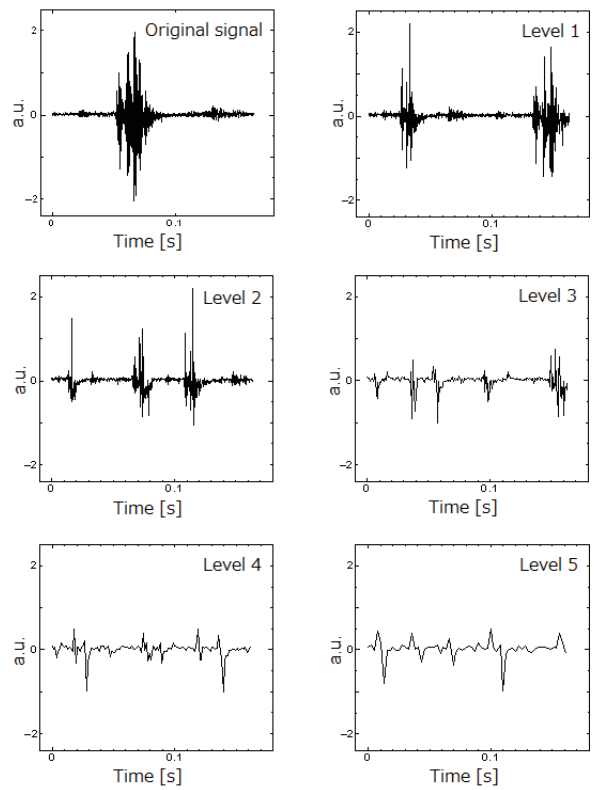

Figure5-2 DWT analysis for an AE signal of “cut-80mm” in low frequency spectrum functions.

We can observe the difference to the four Figures. However, there are no large differences on the Level in low and high frequency spectrums of the DWT analysis results of the “normal”. On the other hand, as for the results of cut-80mm in low and high frequency spectrum functions, there are complex changes at each Level. It is important to clarify quantitative differences for all data and Levels. The calculated statistical variance values from the frequency spectrum functions are shown in Table 1.

Here, the statistical variance values are classified under the four failure levels by using criterions shown in Table 2. The statistical variance values are painted in accordance with the criterions in Table 2. A change of failure levels depending on size of the cutting blades was almost observed. By processing DWT analysis to AE signals, a change of the failure level to the time can be obtained. It will be able to predict wind turbine troubles by using a suitable system which analyzes the statistical variance values. For the further development, many data collection of other type wind turbines will be necessary for future.

Table1 Statistical variance calculated from DWT spectrum functions.

		Lv1	Lv2	Lv3	Lv4	Lv5
normal	s	0.0001905	0.0001996	0.0001449	0.0001318	0.000181
	w	0.000149	0.0001749	0.0001897	0.0001639	0.000171
20mmcut	s	0.000204	0.0002611	0.0002141	0.0001869	0.000152
	w	0.0001476	0.0001982	0.0002293	0.000218	0.000153
40mmcut	s	0.0056367	0.0062621	0.0063749	0.0022496	0.003122
	w	0.0042731	0.0085261	0.0043854	0.0022645	0.003904
60mmcut	s	0.0014474	0.001232	0.0011119	0.0012459	0.001262
	w	0.0014891	0.0009296	0.0012175	0.0010833	0.000825
80mmcut	s	0.0559256	0.0443537	0.0334813	0.0313298	0.046087
	w	0.0381008	0.0558943	0.0352041	0.0267654	0.032036
100mmcut	s	0.0299982	0.0217559	0.0232411	0.0146624	0.013287
	w	0.0205856	0.0273038	0.0222653	0.0167714	0.011333

Table2 The criterions assumed in this study.

Level	VAR
1.safety(Blue)	0≦VAR0.0002
2.attention(Green)	0.0002≦VAR0.001
3.caution(Orange)	0.001≦VAR0.01
4.danger(Red)	0.01≦VAR

3.3. Continuous Wavelet Transform (CWT) analysis of AE signals

Here, we consider another analysis by using the continuous wavelet transform (CWT). The continuous wavelet transform is used to divide a continuous-time function into wavelets. The continuous wavelet transform possesses has the ability to construct a time-frequency representation of a signal that offers very good time and frequency localization. In this study, the program of the CWT analysis was produced by using C^{++} language. In other word, the CWT analysis expresses a dependence on time of the frequency for the signals. A state frequency for the time is calculated for the signal. Fig.6 shows results of the calculated and is drawn as the figures of three data. Each pattern has different distribution of colour. This means the frequency. If the frequency becomes higher, the distribution of this colour is bluer. When the frequency lowers, it almost becomes the red colour. The difference from the “normal” signal level means the increase of the signal. It is shown in Fig.7 to have calculated the increase from “normal”. These are similar to those of the Fig.6. That is, the early failures in the wind turbines can be easily detected with the large information quantities by AE sensors. Classification of the troubles will be possible by introducing a technique of the image recognition. Even if we will use DWT analysis or CWT analysis for failure diagnosis method, more data accumulations on the small wind turbines are necessary.

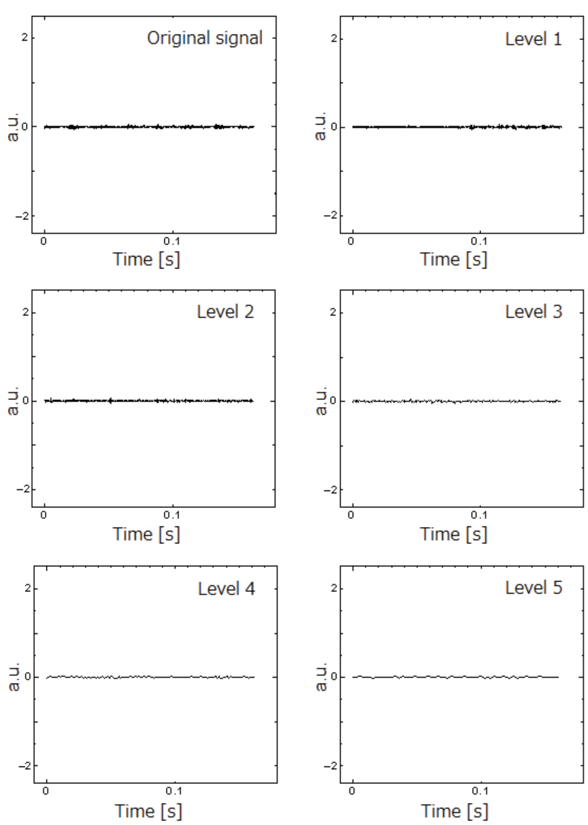

Figure5-3 DWT analysis for an AE signal of “normal” in high frequency spectrum functions.

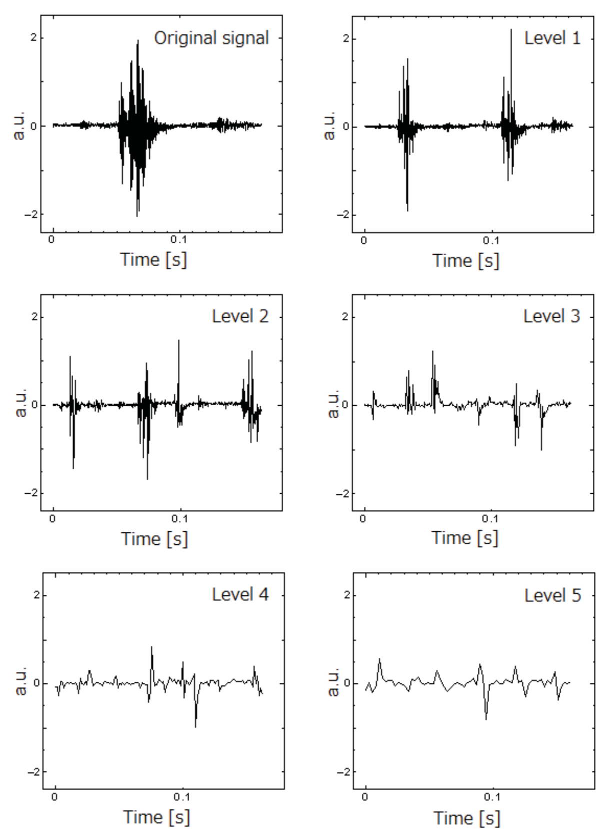

Figure5-4 DWT analysis for an AE signal of “cut-80mm” in high frequency spectrum functions.

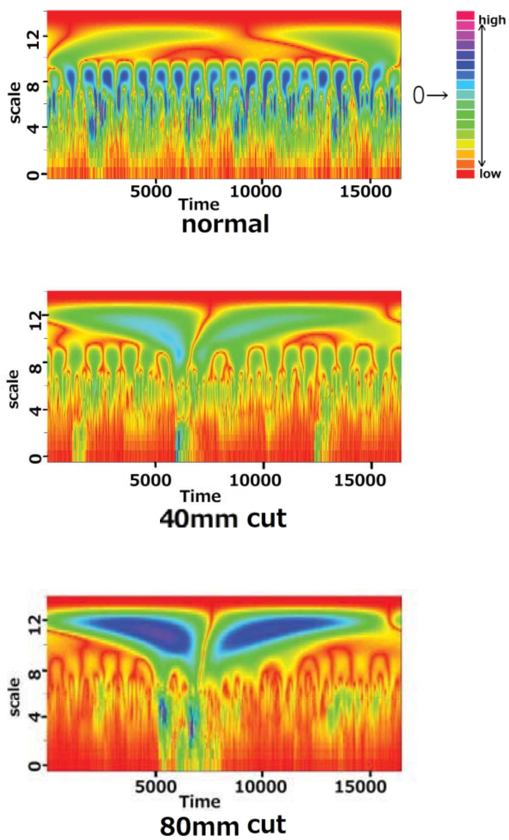

Figure 6 The CWT analysis for the three AE signals. When Blade damages become larger, high frequency is superior.

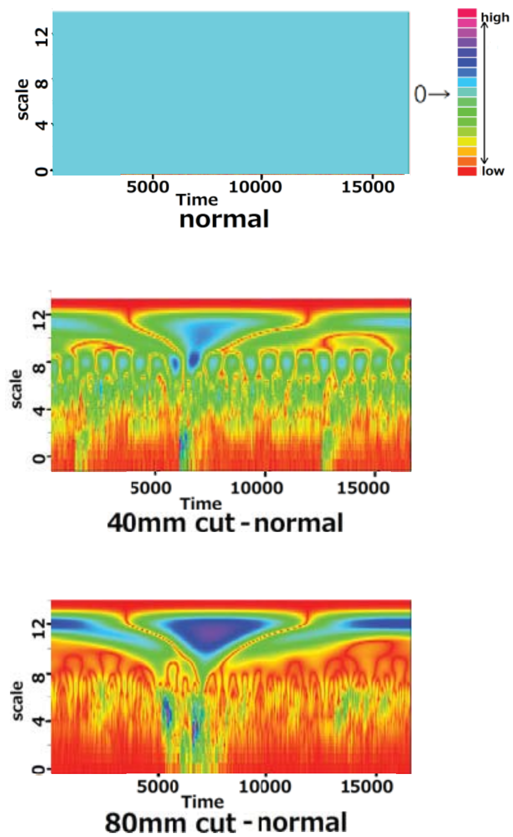

Figure 7 The CWT analysis on the subtraction between blade-cut and "normal" models.

IV.CONCLUSION

We made proposal for a failure diagnosis method of a small wind turbine by using the Wavelet Transform Analysis. The obtained results are as follows:

(1). AE signals could be observed and became larger in accordance with increasing the blade damages. This means that the AE signals surely occurred at the blade damages.

(2). AE signals processed in DWT also showed larger frequency spectrums with increasing blade damages. The difference to each spectrum was expressed as the statistical variances.

(3). Early failures in the wind turbines could be easily detected with the large information quantities from the subtraction between blade-cut and normal models.

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