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Study on the defect detection algorithm by the non-contact acoustic inspection method using spectrum entropy

スペクトルエントロピーを用いた非接触音響探査法による欠陥検出アルゴリズムの検討

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1. Introduction

In recent years, some concrete bridge or tunnel fall and the degradation of the concrete structures has become with the serious social problem.The importance of an inspection, repair, and updating is recognized as the measure against degradation. We have so far studied the non-contact acoustic inspection method using airborne sound and the laser Doppler vibrometer [1-2]. In this method, depending on the surface states (reflectance, dirt, etc.), the quantity of light of the returning laser decreases and the optical noise resulting from the leak of the light reception arises. As the factor, there are the stability of the output of a laser Doppler vibrometer, the low reflective characteristic of the measurement surface, the diffused reflection characteristic, measurement distance, a laser irradiation angle, etc. If it depends for defect detection only on the vibration energy ratio since the frequency characteristic of the optical noise resembles white noise, it may detect the optical noise resulting from the leak of the light reception as a defective part. Therefore, in this paper, by using together a vibrational energy ratio and spectrum entropy, the judgement of a healthy part and defective part and a measurement poor point is performed, and the algorithm which detects a defective part more vividly is proposed.

2. Principle of the defect detection algorithm

The optical noise resulting from the leak of the light reception of the vibration velocity waveform is detected as big oscillating amplitude by external noise. Spectrum entropy is what considered that the spectra of a signal were probability distributions and calculated the information entropy, and is the amount of the features showing the white nature of a signal.

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By a signal with a uniform spectrum like white noise, spectrum entropy shows a high value and serves as a low value in a signal with an uneven spectrum. Spectrum entropy H is expressed by

$$H = -\sum_f P_f \cdot \log_2 P_f$$
$$P_f = \frac{S_f}{\sum_f S_f} \qquad (1).$$

Here, S_f is an amplitude spectrum and H becomes a high value by a white signal with a uniform spectrum. That is, both the measurement poor point of having received the influence of the leak of the light reception and healthy parts show a high value. On the other hand, in the case of a vibration energy ratio, a defective part and a measurement poor point show a high value. If these two features are combined, it will become discriminable from a defective part, a healthy part, and a measurement poor point as shown in **Fig.1**.

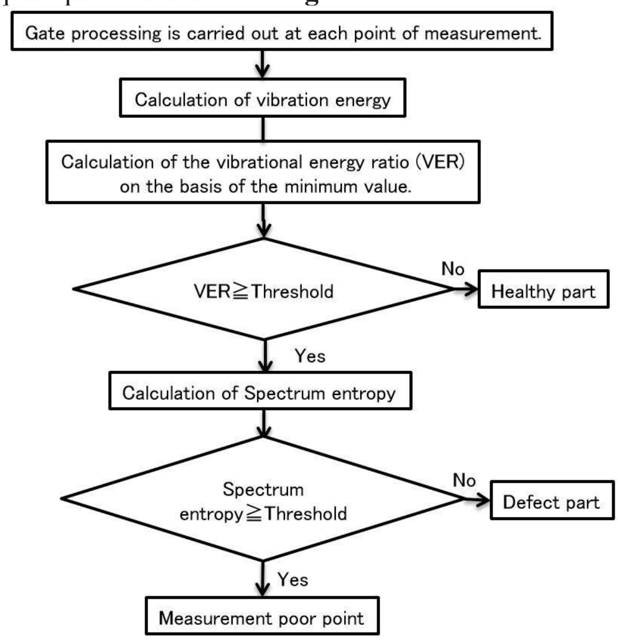

Fig.1. Defect detection algorithm using spectrum entropy and vibration energy ratio.

3. Applied example to the measurement result

Calculation was actually performed using the measurement result (number of scan point is 9x7) of a steel plate beam bridge with the float in an N^2U bridge (Nagoya Univ.). **Fig.2** shows the vibration energy ratio and spectrum entropy in each point of measurement, respectively. The measurement point 32 has low energy ratio and high spectrum entropy, and shows the feature of a healthy part. The measurement point 53 has high energy ratio and high spectrum entropy, and shows the feature of a measurement poor point. The measuring points 35 and 43 have high energy ratio and low spectrum entropy, and show the feature of a defect part.

In order to make these results easy to understand, the example which expressed spectrum entropy and a vibrational energy ratio as an axis is shown in a **Fig.3**. In this figure, the healthy part, measurement poor point and a defective part can be seen the left, the upper right, and at the lower right of this figure, respectively. It can check that the healthy part, measurement poor point and the defective part are divided into the left, the upper right, and the lower right of this figure to three zones, respectively

Fig. 4 shows vibrational energy ratio distribution, and the example which applied our proposed algorithm to the left figure is the right figure. It turns out that the measurement poor points are removed using our proposed algorithm, and the image of a defective part is clearer.

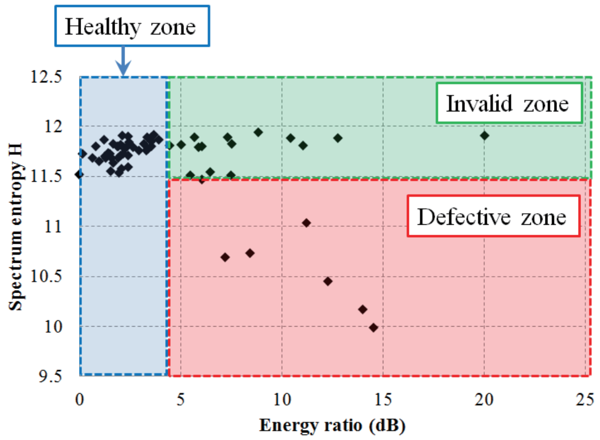

Fig.3. Spectrum entropy vs. energy ratio.

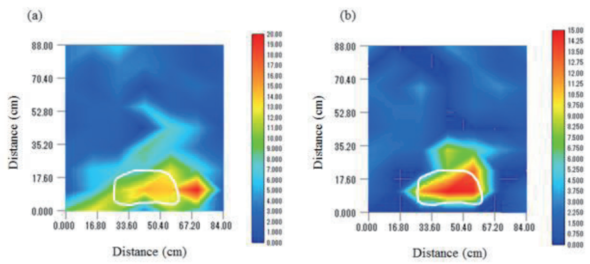

Fig.4. Vibration energy ratio distribution. (a)Old algorithm, (b)Proposed algorithm.

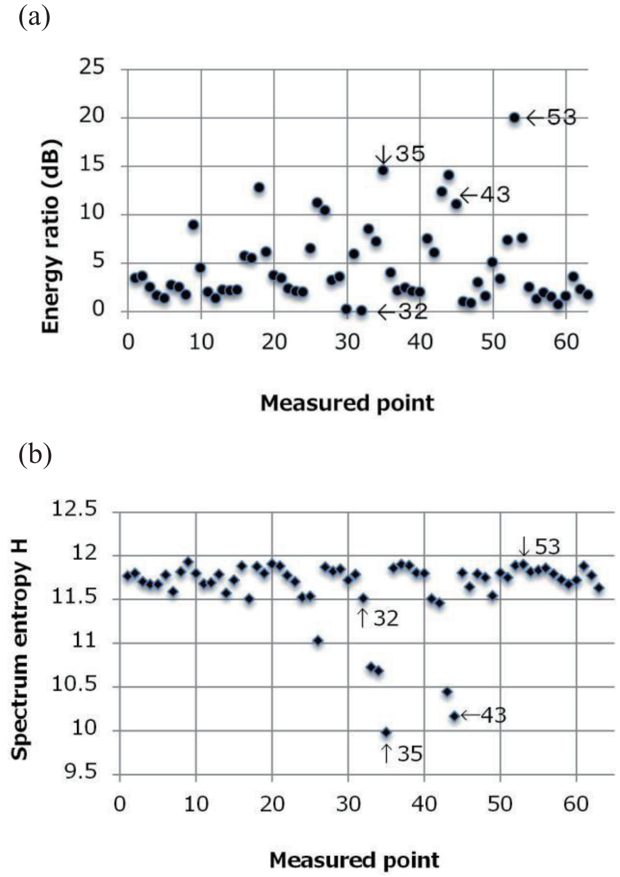

Fig.2. Calculation results. (a)Vibration energy ratio, (b) Spectrum entropy.

4. Conclusions

The defective detection algorithm which combined spectrum entropy with the vibrational energy ratio was devised for the non-contact acoustic inspection method. When applied to the experimental result of real concrete structures, the defective part could be extracted more vividly and the validity of our proposed algorithm was able to be checked.

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