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768kHz / 32bit High-Resolution Acoustic Analysis-Based Method for Determining Empty Alkaline Dry Battery

768kHz/32bit 高解像音響計測を用いた打音検査による
アルカリ乾電池残量の判別方法

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1. Background, Motivation and Objective

Alkaline batteries are widely used around the world for various portable devices that require a continuous current. However, it is generally so difficult to visually check whether an alkaline dry battery has been used or not, as well as being impossible to visually check whether watermelon is ripe or not.

Finding a way to discriminate alkaline dry batteries in a simple way is important to save energy resources and avoid misuse of empty alkaline batteries. As a previous study to solve this problem, a method of dropping an alkaline dry battery and measuring the coefficient of restitution has been proposed[1]. However, it is difficult to visually measure the correct coefficient of restitution and keep good reproducibility.

On the other hand, many non-destructive inspection methods have been studied. Among them, the hammering method is one of analyzing the response (striking sound). As a well-known example, when a greengrocer sells watermelon, it may judge the degree of ripeness by acoustic response. This is a non-destructive inspection by a hammering method[2].

Therefore, we propose a method to check an empty or non-empty alkaline dry batteries by tone color when tapping alkaline dry batteries like hammering method. In this study, we employ 768kHz / 32bit super high-resolution acoustic measurement system, and we evaluate and discuss the discrimination method using the acoustic characteristics for detection of empty alkaline dry battery.

2. Methods

The hammering method is a method of discriminating whether the internal state is good or bad by analyzing the response sound when hitting the object[3]. In this study, similarly, we present a quick and easy acoustic method tapping an alkaline dry battery with another alkaline dry battery as shown in Fig.1.

Fig.1 Tapping method

Table. 1 Combination of dry batteries and timbre of hammering sound

state	Non-empty (F)	Empty (E)
Non-empty (F)	dull	dull
Empty (E)	dull	shrill

Table. 2 Details of alkaline batteries

Production company	Number (F/E)
DURACELL	40 (20/20)

Table 1 shows a tone color of hammering sound of alkaline dry batteries. The results suggest remarkable difference. Here, we assumed “F” as the non-empty of dry cell, and “E” as empty dry battery.

3. Measurement and Analysis

In this Measurement, tapping sounds of alkaline dry batteries. Tapped batteries are 3 kinds of combinations, i.e., F vs. F, F vs. E, E vs. E. Details are shown in Table 2.

We use an super-high resolution acoustic measurement system for sound collection[4], and the signal was standardized with energy as preprocessing. We analyzed attenuation time as information in time domain and band-limited power of frequency-amplitude characteristics as information in frequency domain, respectively.

The decay time τ was taken as the time required to attenuate 12 dB for the envelope curve obtained by moving-RMS restricted in the band from 4 kHz to 20 kHz. On the other hand, the band-limited power p is a value obtained by

integrating the power spectrum from 2 kHz to 10 kHz obtained by Fourier transforming

Fig. 2 shows the analysis results of the hammering method using Duracell's AA alkaline battery.

(a) shows the time signals of the striking sounds of E vs. E and F vs. F.

(b) shows the frequency-amplitude characteristics of hitting sounds between E vs. E and F vs. F. The blue dashed line represents the band from 2 kHz to 10 kHz.

(c) shows the time-power signal of the hitting sound of E vs. E and F vs. F, and their envelopes are also depicted. The blue line shows the decay time.

(d) shows histograms of attenuation time of each of E vs. E and F vs. F. The thick vertical line represents the average value, the thin vertical line represents n-times standard deviation.

(e) shows a histogram of the band-limited power of each of striking sounds of E vs. E and F vs. F.

4. Result / Discussion

Fig. 2 illustrate that acoustic characteristics between striking sounds of E vs. E and that of F vs. F have clear difference. Therefore, this result suggests that the possibility of acoustic analysis-based method for determining empty alkaline dry battery using the hammering-like method.

Fig. 2 (d) and (e) indicate that we can classify non-empty (F) and empty (E) dry battery using three times standard deviation method.

4. Conclusion

In this study, we developed an acoustic analysis-based method to check an empty or non-empty alkaline dry batteries by hammering-like method.

Employing 768kHz / 32bit super high-resolution acoustic measurement system, we evaluate the proposed method. From this analysis, it was found that we can acoustically check whether an alkaline dry battery has been used or not.

In the future, we investigate an automatic classification application tool using acoustic characteristics.

References

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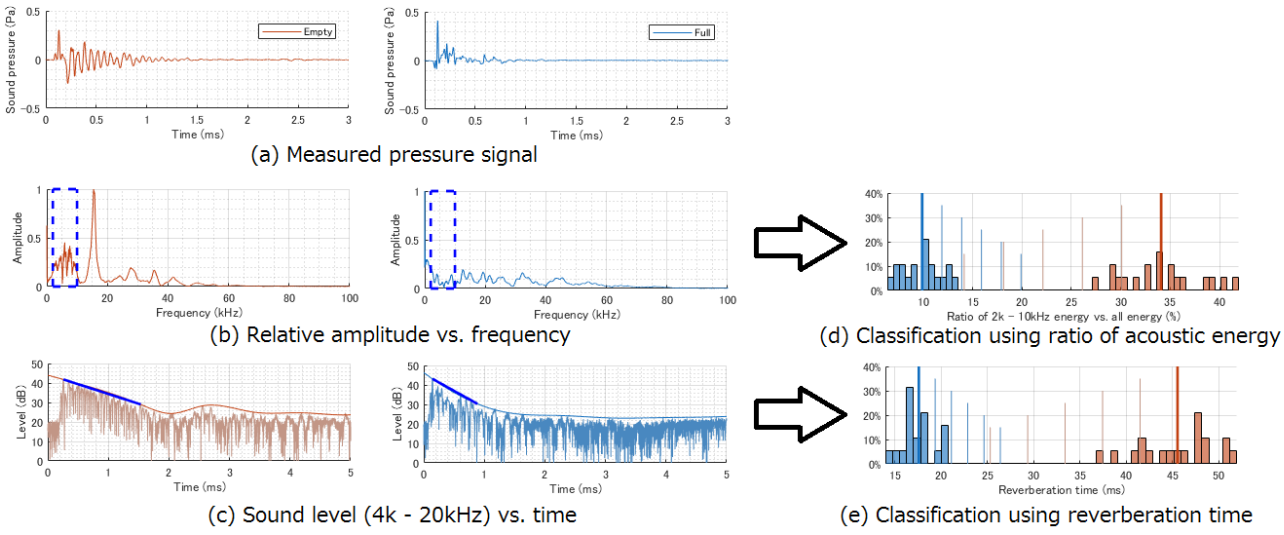

Fig. 2 Analysis result of hitting sound for determining empty alkaline dry battery