論　文　要　旨
Thesis Abstract

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主論文題名　（Title）

System for Monitoring Progress in a Mixing and Grinding Machine Using Sound Signal Processing

内容の要旨　（Abstract）

Pestle and mortar have been used to mix and grind materials, e.g. rice powder, peanut, pottery, etc. In order to achieve high quality and high quantity of grinding material, a machine is selected for the mixing and grinding process. Particularly, in the industrial manufacturing process, the Ishikawa mixing and grinding machine is well known in manufacturing. Additionally, the machine can be used to mix and grind various types of materials such as electronic parts, chemical products, art craftworks, and some kinds of special material such as solar batteries, fluorescent paint, and so on.

This research presents the development in the design and implementation of mixing and grinding machine using the signal processing of sound emitted from the machine. For the improvement to automatic machine or industrial internet of things (IoT), we present a concept of low cost and low maintenance device. The Raspberry Pi and Pumpkin Pi boards are two examples of such low-cost hardware devices selected for sound recording via microphone and analyzing sound signal. Each obtained sound data in regular intervals and converted to small size data. To estimate state changes while mixing and grinding material using the process machine, we used power spectral density (PSD) estimation values processed by measuring sound signals to estimate progress remotely.

In the experiment, we used peanut butter, Japanese rice, and Japanese green tea. The conditions were as follows: the motor speed of the mixing and grinding machine was set at 20 rpm; the sound signal was recorded via a microphone for 5 seconds every 2 minutes; the wave file bit rate was 16 bit/seconds with a sampling frequency of 48 kHz and the average PSD value was calculated for the recorded data every 5 second.

For the peanuts process, the PSD value decreases to until the grinded peanuts gather and become a ball shape. After that the PSD value increases to maximum value a ball shape binds and becomes large sticky lump. Finally, the average PSD value decreases slowly until approaching to straight line in which the lump peanut becomes creamy. The Japanese rice, PSD values a little has change in the beginning until the grain rice transforms to a smaller

size and some of them become powder. The PSD value increases until maximum values. At the time, grain rice mostly becomes rice powder. Finally, the PSD value decreases until the PSD graph does not change. After that, all grain rice transforms to powder. The Japanese green tea leaf change to a smaller particle size and the PSD value decrease and some green tea leaves become powder. When the Japanese green tea all changes to green tea powder, the PSD value observed as a low swing graph of the trend line.

Moreover, we measured the particle size distribution for Japanese rice and green tea and calculated the correlation between the particle distribution and the processed sound signal. The average PSD values depended directly on the particle size for Japanese green tea. Except for Japanese rice, the average PSD values increased to maximum, and then decreased as the particles size decreased until it became a powder. The sound signal could indicate the progress in the mixing and grinding machine and we demonstrated that the results were repeatable.

The proposed method can estimate the progress successfully in the mixing and grinding machine.

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