Measurement of Hydrogen Gas Concentration Using Ultrasound

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（超音波を用いた水素ガス濃度の測定に関する研究）

論 文 内 容 の 要 旨

The purpose of this dissertation is to measure of H_2 gas concentration in a pipe using ultrasound. The gas concentration was measured from the exterior of the pipe without making a hole in the pipe. Since gas is not extracted for the measurement, there is no risk of explosion, which is a unique and attractive advantage of this ultrasonic gas sensor. This research focuses measuring both the non-flowing and flowing gas. Different kinds of pipe material were used to observe the airborne signal from the exterior of the pipe. The concentration of gas is measured based on the speed of sound variation in various gasses, this method is simple comparing with other sensors. I have summarized the experimental results obtained during my PhD tenure as below:

CHAPTER 1 discusses the background and the research problem of this study in details. The detailed literature review on various topics related to the present work is also discussed. Moreover, research objectives and structure of the thesis are included in this chapter.

CHAPTER 2 describes the non-flowing H_2 gas concentration measurement from the exterior of the stainless (SUS) pipe. Since the noise signal was circling inside the SUS pipe surface itself, the airborne signal was difficult to observe from the exterior of the pipe. Two experiments were conducted to reduce the noise signal. One of them was pasting sound absorbing material (SAM) on the SUS pipe surface and the airborne signal was observed. As a result, the concentration of H_2 gas was successfully measured. Two transmitters condition was applied to cancel the noise signal. FDTD simulation method revealed that it is possible to cancel the noise signal circulating in the pipe by using two transmitters having exactly the same frequencies and amplitudes, however it was difficult in practical test.

CHAPTER 3 focuses on the flowing H_2 gas concentration measurement instantly from the exterior of the pipe, which was more challenging than measuring non-flowing gas concentration. The concentration of H_2 gas was measured based on speed variation of the ultrasound traveling inside the pipe. H_2 gas was flowing inside a polyvinyl chloride (PVC) pipe and the concentration of H_2 gas was measured accurately up to 39 m/s. Since the PVC pipe was used for this experiment, the airborne signal was clearly observed. The response time of measuring the gas concentration was fast as less than 0.1 s. Due to the fluctuation of waveform, the maximum error in the H_2 gas concentration at 39 m/s flow was calculated about 0.32%. Since longitudinal and transverse waves can propagate through the solid, the limit speeds of flow were calculated as 30 m/s and 60 m/s for longitudinal and transverse wave, respectively.

CHAPTER 4 reports the propagation of ultrasound trough two-layer mixed gas. In the above experiments, a large ultrasonic signal intensity degradation was observed while H_2 gas was mixed into the airflow. Hence, the ultrasonic signal propagation passing through the 'air-H_2-air' two-layer gas flowing model system was studied. The concentration of hydrogen gas was measured from the exterior of an acrylic pipe and it was found that the intensity of ultrasound does not depend on the average gas concentration. An acrylic pipe was chosen to visualize H_2 by using Schlieren photography from the exterior of the pipe. Two fluctuated interfaces in air-H_2-air system were observed. An air-H_2-air system was proposed, and the loss of signal intensity in this system was described. It was found that the intensity loss of ultrasonic signal propagation through two fluctuated interfaces of air-H_2 two-layer gas flow was due to the refraction at the interfaces.

CHAPTER 5 summarizes the whole research work and actual findings are briefly mentioned based on the objective of the thesis. The findings of this study showed that the ultrasonic gas sensor could be effectively applied for the measurement of H_2 gas concentration in a pipeline from exterior of a pipe. Ultrasonic gas sensor can also be applied to measure the concentration of other gases.