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PRELIMINARY STUDY FOR LOW VACUUM AND PRESSURE MEASUREMENT USING ULTRASONIC ACOUSTIC TRANSDUCERS

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Abstract: New pressure measurement technique using acoustic impedance ultrasonic transducers was studied. Air-coupled ultrasonic transducers of 500 kHz frequency were used in the pressure range 1.33×10^3 Pa–2.03×10^5 Pa. In the pressure range almost linearly proportional results were obtained for all five He, N_2, Dry air, Ar, and Kr gases. It is suggested that the ultrasonic transducers can be successfully used for pressure measurements as it has many advantages against other measurement methods.

Keywords: Vacuum, Pressure, Ultrasonic transducer, Gas sensitivity

1. INTRODUCTION

Ultrasonic testing using transducer is most popular technique for non-destructive testing of solid materials. In the most non-destructive evaluation tasks such as investigation of materials whose properties may be changed by liquid contact, this technique can not be used. Also, liquid couplants can not be used when materials under investigation are hot, or when water can fill defects and the detestability of the defects may be reduced. The air-coupled ultrasonic investigation methods are very attractive because they enable to avoid disadvantages caused by the liquid coupling materials such as water, oil and gel based materials [1, 2]. The primary difficulty with air-coupled transducers techniques is the high signal loss at solid-to-air and air-to-solid interfaces due to the gross acoustic impedance mismatch. Recent reports indicate that the impedance matching problem has been overcome to the extent that employing air-coupled ultrasound is in common practice [3]. Ultrasonic technology also provides good accuracy and reproducibility. A fast response time is also achieved as a new ultrasonic signal is generated for every measurement cycle. In the attractive features of ultrasonic sensors were in the process industry has been summarized [4, 5].

2. EXPERIMENTAL SET UP

The schematic diagram of the experimental system is shown in Figure 1. It consists of a gas chamber which is pumped by a high vacuum pumping unit. The high vacuum pumping unit is comprised of a turbomolecular pump (pumping speed: 230 L/s for N_2) backed by a rotary vane pump (pumping speed: 4.44 L/s for N_2). The vacuum chamber and the high vacuum pumping unit are separated by a gate valve (GV). The chamber is equipped with different types of vacuum gauges including two capacitance diaphragm gauges by with pressure ranges of 1.33×10^3 Pa and 1.33×10^5 Pa, respectively. To measure pressure above 1.33×10^5 Pa, a pressure gauge by Paroscientific, Inc. (Model 745) with measuring range of 6.89×10^5 Pa is installed while a convectron gauge is also attached to the chamber. Both the CDGs and pressure gauge were calibrated by national low vacuum standard systems [6] and piston gauge before install on the chamber. The base pressure of the system is measured with a full range gauge made by Pfeiffer Vacuum, which can read pressure from atmosphere to 1.33×10^5 Pa–10^{-7} Pa. The system is attached to five inlet gas manifold containing a gas regulator through which the test gas can be provided to the system one-by-one.

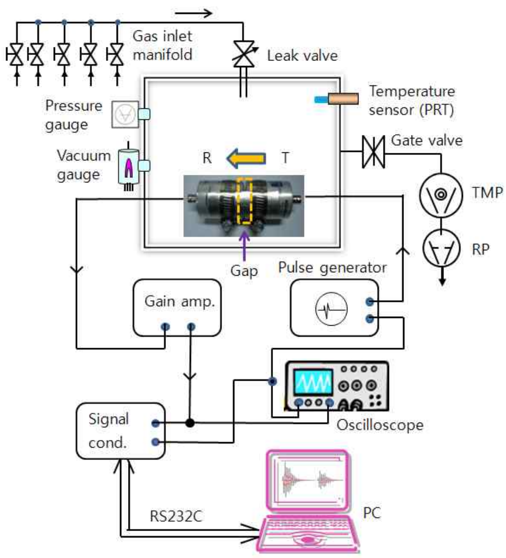

Figure 1. Schematic diagram of the experimental system.

Two ultrasonic sensors (Type: NCG500-D25 by Ultran Group) of 500 kHz frequency are placed inside the vacuum. These ultrasonic sensors are coupled together with 2 mm distance between. The medium of contact between them is only gas and air with variable pressure. Such arrangement where there is no liquid or solid as medium of contact between the sensors is known as non-contact ultrasounds (NCU). The active element of the transducer in the air-coupled or NCU technique is usually piezo or ferroelectric material that converts electrical energy such as an excitation pulse into an ultrasonic energy. Piezoelectric effect is a phenomenon in which piezoelectric crystals expand and contract when they are subject to a changing radio frequency field or socked by a high voltage electrical pulse. Their thickness changes are a function of the applied voltage, typically 100 volts to 2000 volts. In our experiment, a negative spike pulse is sent by the pulse generator (DPR 300, JSR Ultrasonics) to one transmitter which converts this signal into ultrasound. The ultrasound, after passing through the medium, is received by the receiver which converts the transmitted signal into electrical pulse. The transmitted pulse is amplified by 5307 Differential Amplifier (NF Corporation) and the final signal is fed to the LeCroy Wave Surfer 424 oscilloscope.

The pressure chamber was evacuated to base pressure less than 3.0×10^{-4} Pa and then the chamber was isolated from the pumping system by closing the GV. Test gas was delivered to the chamber through needle valve (NV) installed on the top of the chamber. The data was recorded for a total of nine points in the entire pressure range of 1.33×10^{3} Pa–2.03×10^{5} Pa. Five different gases He, N_2, dry air, Ar, and Kr of 99.99 % purity were used in this work. The experiment was repeated four times, for each gas, under same conditions of operation and the average value was considered in plotting the data. The room temperature was kept constant at (23 ± 0.5) ^{o}C.

3. RESULTS AND DISCUSSIONS

During experiment, no signal was detected by the receiving sensor at pressures less than 1.33×10^{3} Pa for all He, N_2, Dry air, Ar, and. However, at 1.33×10^{3} Pa and above, amplitudes of the transmitted signal appeared which were different for different gases. It was observed that this amplitude was dependent on gas pressure inside the vacuum chamber pressure range from 1.33×10^{3} Pa to 2.03×10^{5} Pa.

In Figure 2, the graphs for all five gases, in the time domain, have been plotted at pressures of 2.03×10^{5} Pa. The waveforms of the received ultrasonic signals show that He gas, being the lightest, has quick response to the ultrasonic signal of the emitter. While the heaviest gas, Kr, gas has delayed response to the same type of signal. This reveals the behaviour of gases to same type of ultrasonic pulse. It is important to note that the appearance of transmitted ultrasonic signal and its amplitude, as received by the receiver, could be different for different frequency sensors as well as pressure ranges.

4. CONCLUSIONS

Air-coupled ultrasonic transducers of 500 kHz frequency were used in the pressure range 1.33×10^{3} Pa–2.03×10^{5} Pa to investigate the pressure measurement technique in a gas chamber. During this study, it was observed that propagation of ultrasonic waves, frequency 500 kHz, is closely related to gas pressure. In the pressure range 1.33×10^{3} Pa to 2.03×10^{5} Pa, almost linearly proportional graphs were obtained for all five He, N_2, Dry air, Ar, and Kr

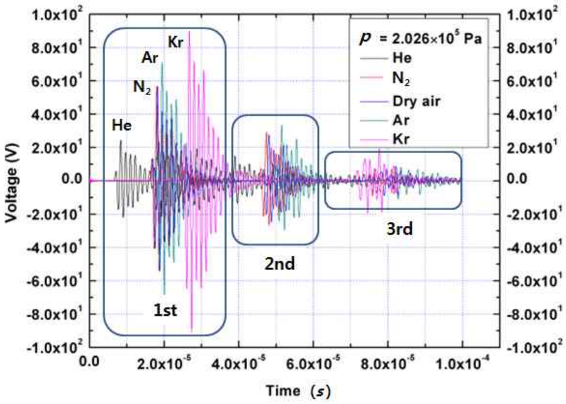

Figure 2. Amplitude of transmitted waves for different gases at 2.03×10^{5} Pa.

gases. Besides, the data obtained for all gases were reproducible which has great importance in pressure metrology. On the basis of this work, it is suggested that ultrasonic transducers can be successfully used for pressure measurements as it has many advantages over other measurement methods. If the proposed method is developed in the near future, high resolution in a broad range of pressure measurement is expected.

5. REFERENCES

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