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The application of ultrasonic waves and envelope energies in a closed chamber based on an air/methane mixture

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ABSTRACT

This work proposes the experimental method of using a new matching layer (chemical wood) which can measure the methane gas of the main component in natural gas from a PZT (MS-21) of the most widely using $BaTiO_3$. The experiment includes a differentiated analysis of envelope voltage, standard Gaussian distribution, acoustic pattern, and energy attenuation in a closed chamber according to an air/methane gas mixture. Experimental devices and methods were used to examine the characteristics of envelope energies via control models and transmission devices using a designed circuit, which could be fitted at resonance points of electrical signal change, frequency change, and pulse change to high sensitive ultrasonic sensors, for energy measurement regarding envelope, pattern, and attenuation. Signal analysis was used to verify the characteristics of transmission signal, voltage, shape, and frequency of the envelope which was measured factually by oscilloscope equipment. The experimental results were verified by a characteristic of acoustic energy whereby an ultrasonic sensor was diffused at minimal side energy from an λ_2 sensor, while maintaining a value of θ at a minimum of 0.3 m, 18° and maximum of 1.5 m, 15° from the envelope energy pattern characteristics. Consequently, the matching layer material of general ultrasonic sensors has a significant weakness in not transferring a receiving signal that includes strength, permeability, and directivity of acoustic energy in a gaseous medium.

1. Introduction

Ultrasonic wave sensors are a promising form of technology that have been applied to many measurement gauges such as level [1,2], concentration, and thickness [3], and a range of processes and devices including cleaning [4], welding [5], motors [6], humidifiers [7], and medical appliances across a variety of environmental and industrial fields [8,9]. Ultrasonic sensors are used with techniques which can measure variation in characteristics from acoustic energy among frequencies over 20 kHz [10]. In particular, ultrasonic technology is advantageous for its ability to miniaturize fuel measurement in automobile fields and it is still being developed as a valuable measuring instrument for examining fuel levels in gasoline as well as diesel [11] and natural gas [12]. General ultrasonic sensors have the advantage of being able to easily measure the receiving energy in a high-density medium in the order of air < liquid < solid [13]. However, it is difficult to accurately measure acoustic energy in ultrasonic waves in a diffused medium such as natural gas (CH_4) or ideal gas [14].

These problems can be solved when the composition of matching layers is examined regarding characteristics from designed PZT in ultrasonic sensors [15]. The matching layer of ultrasonic sensors is used to design a method of material use calculated by theoretical equations [16]. The acoustic energy present in ultrasonic waves is characterized by a mixture of longitudinal waves [17] and transverse waves [18], and transverse waves in a gaseous medium have a weakness in the way they extinguish the partial energies that attenuate about 1/2 of the energy from actual energies. Therefore, the matching layer, which can create longitudinal waves, has an advantage in that it can improve energy increase, noise reduction, and the transmission coefficient in a gaseous medium such as natural gas [19,20].

The ceramic material used in general ultrasonic wave sensors is a form of polycrystalline material [21]. This polycrystalline material uses the PZT, PT, PZT-complex perovskite, and $BaTiO_3$, and the PZT ceramic [22] has the widest range of applications such as vibration and acting as a filter [23], resonator [24], ignition element [25], and sensor at a reasonable price. Also, the matching layer for the acoustic performance of ultrasonic waves, uses the numerous materials according to the medium of measuring objective, and ultrasonic energy is very

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important for controlling technology in methods used to amplify envelope energy [26]. The first method of amplifying acoustic energy [27] uses consolidated materials for density increase or decrease, and the second method involves input voltage being amplified compulsively in control systems, circuits [28], and algorithms [29]. In particular, the use of acoustic energy analyzes the energy's performance with trigger technology in accordance with voltage height [30], shape, phase, width and the location's envelope energy change from the receiving signal.

This work proposes the experimental method of using a new matching layer (chemical wood) which can measure the methane gas of the main component in natural gas from a PZT (MS-21) of the most widely using $BaTiO_3$. Where definition of "Chemical wood" is the epoxy which includes the chemical raw materials mixed as acetic acid, alcohol, synthetic resins, artificial wood, acetone by carbonization. Particularly, this chemical wood is a promising matching layer (material) for developing ultrasonic sensor which can measure the longitudinal wave in gas fuel area. The experiment includes a differentiated analysis of envelope voltage, standard Gaussian distribution, acoustic pattern, and energy attenuation in a closed chamber according to an air/methane gas mixture.

2. Experimental devices and methods

Fig. 1 depicts a structural diagram of the conventional and high sensitive ultrasonic sensors designed by the authors for this experiment. The conventionally designed ultrasonic sensor was bonded on the lower section base of a PZT ceramic center, and the structure was designed on a PZT face with absorbent materials used to reduce the acoustic energy transferred towards the backing section. Also, the conventional ultrasonic sensor was designed by a method of inserting an epoxy which is flexible in empty space to minimize changing properties according to residual noise, impact, and temperature change. On the structural diagram the authors outline in detail the high sensitivity ultrasonic sensor used to measure a gaseous medium. The structure of the high sensitivity ultrasonic sensor was designed to maintain balance by resonance phenomena on a sidepiece comprising a PZT ceramic and cork material. Also, the matching layer was designed to increase transmission energy by its use of a chemical wood material so that acoustic energy could only be transmitted in a gaseous medium.

The matching layer sidepiece was designed to toughen the acoustic energy transmission coefficient by bonding a cork material so that the

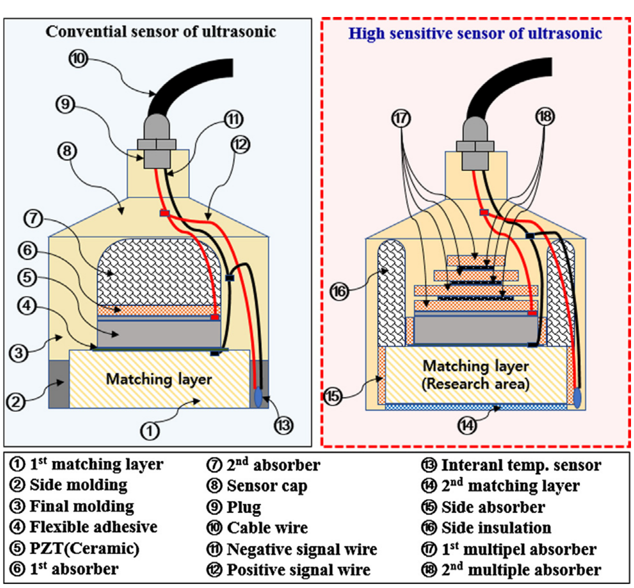

Fig. 1. Structural diagram of conventional and high sensitivity ultrasonic sensors.

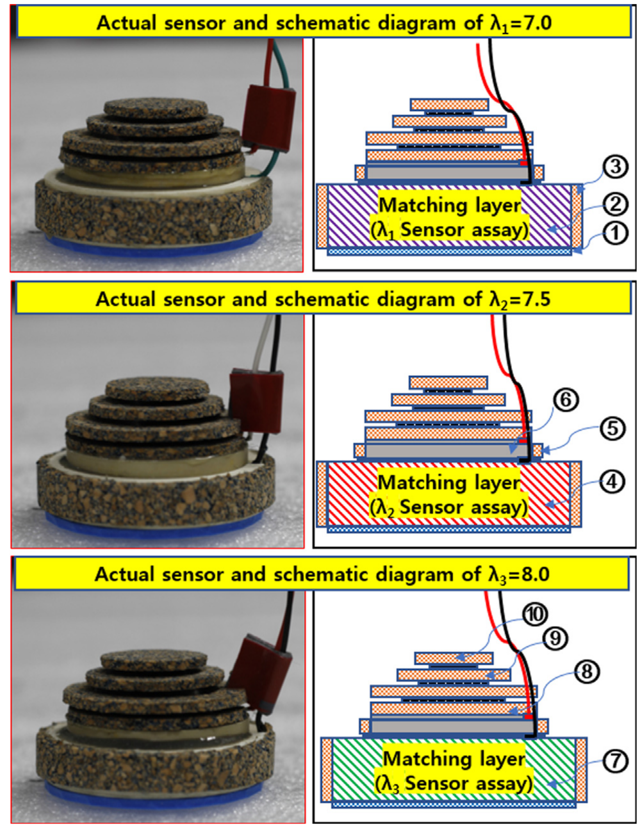

Fig. 2. Actual models of high sensitivity ultrasonic sensors for gas measurement.

ringing signal, created by self-vibrations, could be absorbed, and the face of the ultrasonic wave sensor was designed to greatly amplify the acoustic energy in a gaseous medium via its EVA (ethylene vinyl acetate) material. Additionally, the absorbent structure was designed to gradually extinguish energy towards the backing section of the conical shaped structure through its use of cork and rubber materials.

Fig. 2 depicts actual models of the high sensitivity ultrasonic sensors developed to measure the envelope energy of an air/methane gas mixture. These models can be referred to as sensor assays due to their capability of determining ultrasonic sensor performance, and may be divided into PZT ceramic, matching layer and backing layer components. Where PZT ceramic performs the role of converting electronic energy to acoustic energy, the matching layer performs a supporting role so that acoustic energy, created on the PZT ceramic face, is fitted with a methane gaseous medium and acoustic rate. The backing layer acts to absorb acoustic energy that is created on the backing face of the PZT ceramic. The authors calculated the λ (wavelength) rate of the matching layer to create the greatest envelope energy using the theoretical equation [31]:

$$\lambda = \frac{\boldsymbol{V}}{\boldsymbol{f_r}} \tag{2-1}$$

where V is sound velocity (430 m/s) of CH_4 fuel, and $\boldsymbol{f_r}$ is resonance frequency for the PZT ceramic. Additionally, fundamental resonance frequency of PZT ceramic is divided into 2 methodologies (minimizing and maximizing impedance frequencies) measured by impedance analyzer (4294A of Agilent Technology). MS-21 PZT ceramic used in this work has a fundamental resonance frequency encompassed minimum (46.6 kHz) and maximum (51.3 kHz). Table 1 shows the materials and specifications of the ultrasonic sensors for CH_4 gas, and Table 2 shows the acoustic properties of material inside the ultrasonic sensors for CH_4 gas.