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Simple Sound Velocity Measurement System with Ultrasonic Distance Sensor

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Abstract: In this study it was aimed to detect the certain type of gasses such as LPG according to the changes of sound velocity. The velocity of sound waves was measured by using a very simple ultrasound distance sensor and Arduino Uno microprocessor while monitoring the temperature of medium. The sound velocity of air and LPG measured and compared with calculated results at temperatures between 268 K to 298K . The observed results showed that this very simple setup can easily developed to determine gas leaks.
Keywords: Ultrasonic distance sensor, gas measurement, Arduino, temperature sensor

1. Introduction

Sensing gas leaks before explosive mixtures occur and taking precautions are vital in conditions such as emerging, storing and transporting of flammable and explosive gasses in a production process. Gasses such as natural gas and liquid petroleum gas (LPG) used in daily life and besides these, detectors, sensitive tomany explosive gasses, may occur in various industrial environments are produced according to gas sensing properties. Although gasses such as carbon monoxide, carbon dioxide, hexane, ammonia are not explosive, being poisonous and stifling, detectors that are sensitive to such gasses are used in industry, indoor garages, and boiler rooms and even in houses. Preventing the fire and explosion derived from the effects of such gasses is very important. Gas sensing systems are used to avoid such events and minimize loss of property and life.

LPG is one of the most used gasses in industry and living spaces. To mention briefly, LPG is primarily composed of propane, butane, isobutene and mixtures of these gases. LPG exists as liquid or gas (vapor), depending on pressure and temperature. LPG, liquefied through pressurization, comes from natural gas processing and oil refining. There are a few studies about measuring the sound velocity for LPG with different mixtures of gases. [2-4]

Ultrasonic sensors widely used to determine sound velocity of gases. [1]This study aims to develop a simple and inexpensive sound velocity measurement system which can be used to determine gas leaks. For this reason, an ultrasonic distance sensor based system was designed to measure sound velocity at different temperature by using anArduino microprocessor.

2. Methodology

The velocity of sound for ideal gasses depends on specific heat capacity rate,molar mass and temperature.The velocity of sound for LPG was calculated by using the ideal gas formula. For any measurement the pressure and humidity is also important factors. Furthermore, the velocity of sound in air was calculated with the given formula: [5]

$$v \approx 331.4 + 0.6 * (T - 273.15) \qquad (1)$$

Considering the formulas it is clearly seen that generally the sound velocity increases as the temperature (T) of air increases. Since the movements of molecules arise as the temperature increases indoor environment, the velocity of sound increases as well.

The designed system schematic was shown in Fig.1. The components of the system were cylindrical gas container, Arduino Uno, ultrasonic distance sensor (HC-SR04), temperature sensor (BMP085) and 2x16 LCD. The sensor outputs were measured from analog inputs of Arduino Uno. The time difference Δt, between send ultrasonic signal and received one was measured. Basically, the velocity equation can be calculated from: $2L/\Delta t$.

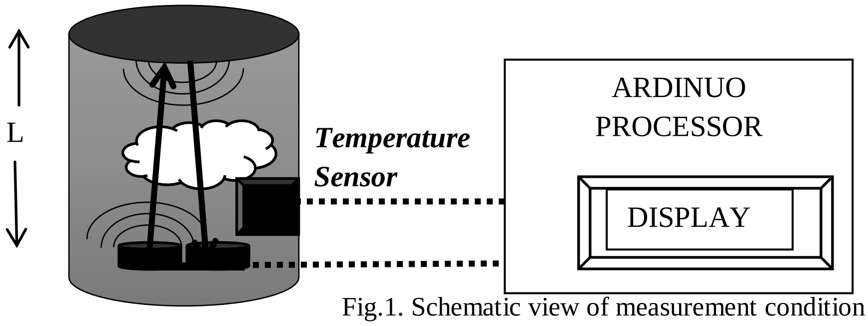

Fig.1. Schematic view of measurement condition

The composition of LPG is important parameter for velocity of sound. The LPG used for measurement and calculation hasthe main composition of %30 Propane and %70 Butane.

3. Results and Discussion

The performance of the system was first observed in air medium. Just the temperature increased from 268 K to 298 K by 5 K steps and velocity of sound measured. As can be seen in Fig.2, the results were very close to theoretical results. The maximum error of 1.17 m/s was observed. The error sources can be identified as the thermal expansion of gas container, humidity and pressure differences form ideal case.

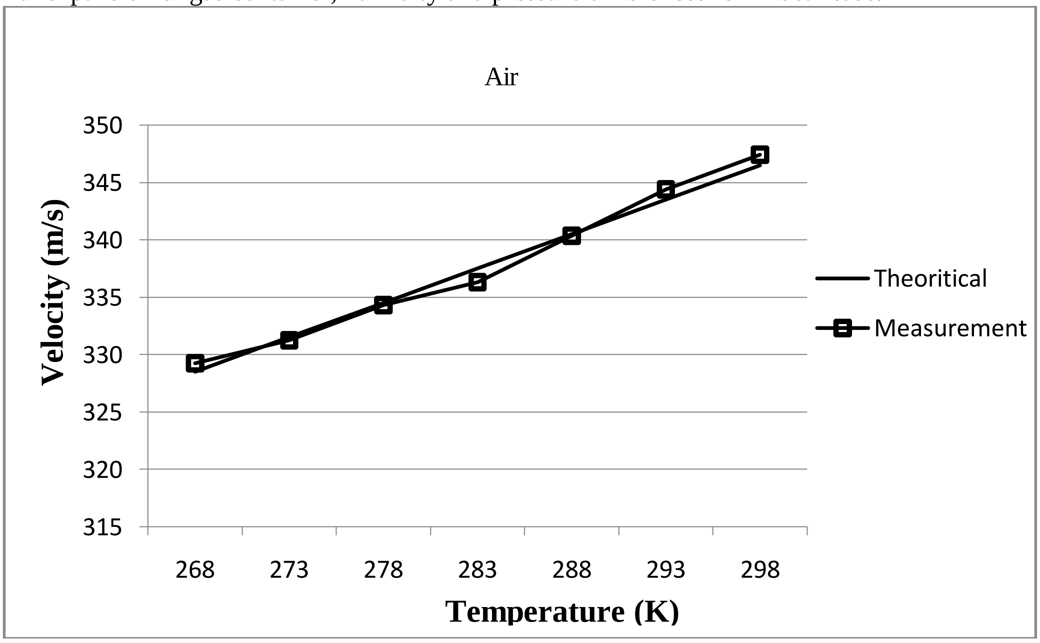

Fig.2 Comparison of theoretical and measurement result in air

After the test of the system with air the second measurement with LPG was conducted. As expected, sound waves can move faster in air than in LPG. The measured velocities were close to theoretical one as can be seen in Fig. 3. But error of measurement increased for LPG if we compare with air. The measurement results show that maximum 8.6 m/s difference observed at 268 K. Since the velocity difference is comparatively high for air and LPG, it is very easy to set a limit velocity and determine the LPG leakage. The LPG is heavier than the air so the sensor should be placed at ground below the place where LPG gas leakage can occur.

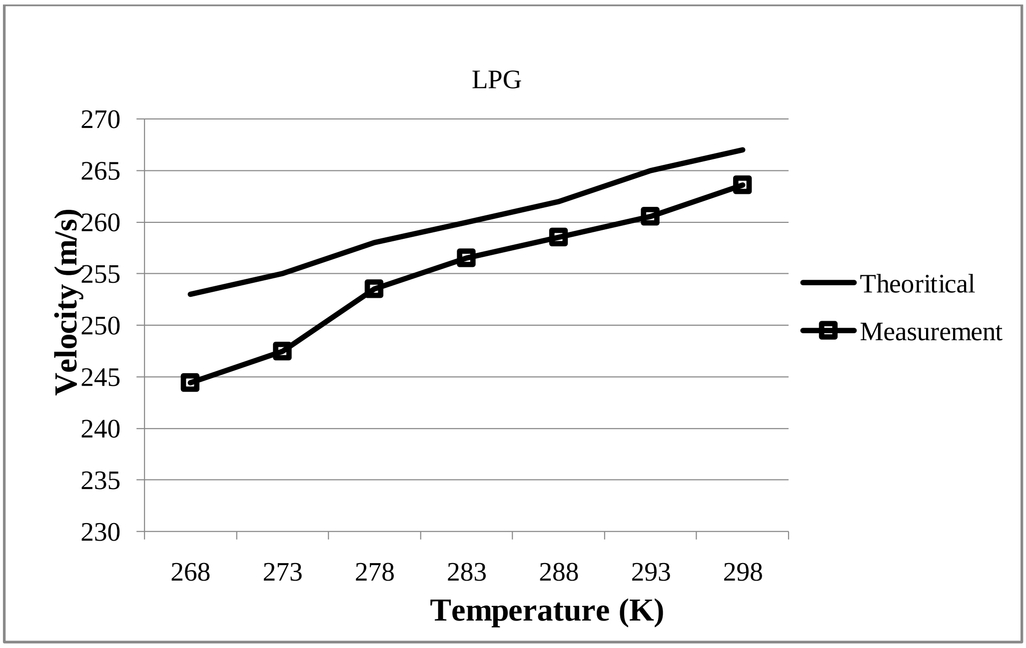

Fig.3 Comparison of theoretical and measurement result in LPG

4. Conclusion

In this study velocity of sound in air and LPG measured at temperature range of 268 to 298 K with very simple system. The results show that maximum 8.6 m/s velocity error was observed for LPG at 268 K. The error was smaller for air. This system can be used for educational purpose to show velocity change for different gases also can be developed to use as a gas leak sensor.

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