REVIEW ON ULTRASONIC SENSOR USED IN NON-CONTACT TYPE FUEL LEVEL MEASUREMENT

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ABSTRACT

The work explains the functional advantages of ultrasonic sensor in determination of distance over other non-contact type distance measuring devices particularly measuring the level of liquid in a fuel tank. The work also points out the estimation of free-surface turbulence of liquids, Liquefied Petroleum Gas Level Monitoring, Detecting Obstacles, and Operating in Millimetre Range, Measurement of Level and Flow were observed.

Keywords: Ultrasonic; sensor; turbulence;

1. INTRODUCTION

[1]Conventional Distance measuring devicesfollows a contact type sensor like linear variable differential transformer which influences the potential difference variation that gives a electrical signal. These electrical signals are then converted into calibrated digital or analogue display. This approach is irrelevant in the application of level measurement in fuel tank, so a suitable non-contact type distance measurement device is to be chosen. This study is to summarize the ability of the ultrasonic sensor to suite in this application.

1.1.ULTRASONIC SENSOR

[2]Ultrasonic methods are one class among the many methods of measuring level; the graduated dip-stick, the float, follower gauges, capacitive and resistive sensors, manometers, bubble systems, optical and radiation methods, to name only a few. The variety of devices proves that there is no universal method. In fact, each measurement has to be considered from a number of different view-points:

1. State of the medium whose level is to be gauged (viscosity, temperature, pressure). 2. Chemical composition.
3. Storage condition and access.
4. Accuracy and form of reading required. 5. Installation costs (investment, maintenance).

The purpose of this paper is to describe the contribution of ultrasonic, especially the methods known as ultrasonic relaxation methods.

1.2. BASIC PRINCIPLE OF ULTRASONIC SENSOR

[3]Most ultrasonic methods are based on the setting up of an echo. A transducer emits an acoustic pulse in the direction of the surface whose level is to be measured and the surface reflects the pulse back to its source. The time that elapses between emission and reception of the pulse is proportional to the distance between the transducer and the surface. If c is the speed of sound, the relationship can be written

$$t = 2L/c$$

[4]Transducer in the liquid phase when the transducer is immersed in the liquid.

It can be placed either inside or outside the container wall (Fig. 1). When the liquid is disturbed it is necessary to calm a small volume by means of a stabilizing tube. This tube can also act as a waveguide for the ultrasound pulse when the angle between the acoustic beam and the surface is such that the pulse cannot, in spite of its tendency to diverge, return to the transducer after reflection.

[5]When the transducer is in air, it must be placed inside the vessel, since transmission conditions do not permit the wave to penetrate from air through even athin wall. The substance to be measured need not necessarily be a liquid; it may be a pulverized solid or a granular material. The stabilizer tube is employed, as

when the transducer is immersed in the liquid phase, if the liquid surface is subject to disturbance. With solid materials the tube obviously cannot be used; it is, however, unnecessary as the coefficient of reflection is not reduced to zero outside the normal to the surface. The principles behind these modes of operation therefore reveal three significant facts:

1. In the liquid phase the transducer can be placed outside the container, which gives added flexibility
2. When the transducer is in the gaseous phase, it is possible to gauge solids
3. The apparatus is entirely static. Maintenance is therefore slight.

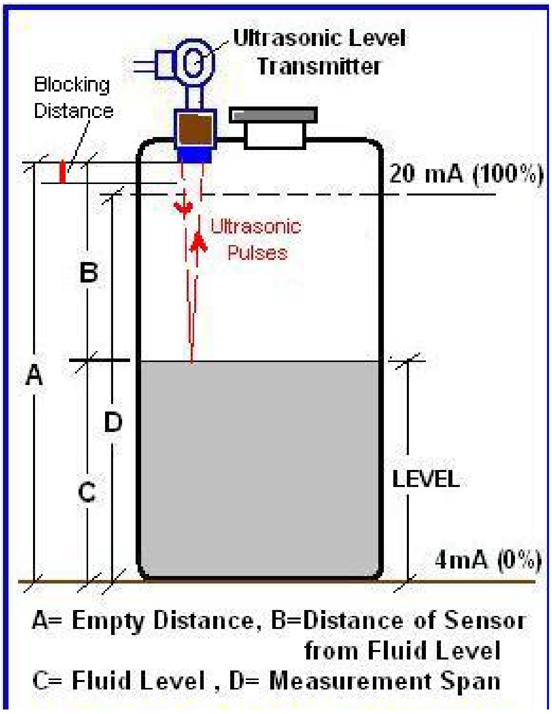

Fig 1-Ultrasonic level measurement

2. TECHNOLOGY

[6]The operating frequency is chosen so as to obtain the necessary directivity and accuracy.

In order to avoid the setting up of parasitic resonances, it is necessary to confine the ultrasonicradiation to a narrowly divergent beam. The divergence of the beam (u) can be calculated from its diameter D at the origin and the wavelength. In water, for example, Q = 6° when D = 30 mm and the frequency is 1MHz. The accuracy of measurement is dependent on the exact determination of the instant at which the wave returns. The accuracy of this determination increases the shorter the rise time of the signal, i.e. as the frequency increases. If detection is considered to take place on the front of the wave before the first cycle in the time measurement corresponds to a quarter of a cycle, for example it would be 0'4mm in water at 1MHz. Once the conditions of directivity and accuracy are satisfied, there is no advantage to be gained from increasing the frequency. Indeed there are good reasons for keeping to low frequencies. If directivity is increased over much, a serious problem of beam verticality arises if the echo is not to be lost: also, surface irregularities and inhomogeneity due to impurities and bubbles become a significant fraction of the wavelength as frequency is increased and are likely to cause diffusion of the beam and even parasitic reflections that cause reception to degenerate. Finally, absorption, which increases rapidly with frequency, can cause serious attenuation. The frequencies currently employed range from 0'1-2 MHz for liquids to 20-100 kHz for gases.

3. TRANSDUCER

[7]A transducer has several resonant frequencies and it must be designed so that the working frequency corresponds to that which is most suitable for radiation. The transducer is excited at its resonant frequency by either a wave train or a short pulse. With a wave train, efficient transfer of energy is obtained (e.g. 30’70) and some amplification may be possible over a narrow band: in the second case, the pulse needs to be calibrated in order to suppress vibration at the other resonant frequencies. The efficiency is then less good, but the possibility of measuring over short distances is added. There is a relationship between the duration of the pulse excitation and the energy stored in the transducer in each of its modes. Good results are generally obtained with a pulse the duration of which equals half a period of the principal frequency. The transducers most generally employed are made of piezoelectric ceramiCS, basically either barium titanate or lead zirconatetitanate. The high frequencies used in liquids are obtained by resonance across the thickness of the specimen in a piston-like mode of oscillation. The low frequencies used in gases are best obtained by a flexural vibration, which has the additional advantage of giving better coupling to the gas. In order to excite

such a mode of vibration, a bimorph element has to be used. The use of ceramics poses no particular problems at low temperatures.

[8]At high temperatures lead zirconatetitanate ceramics can be used up to 300°C, although their piezoelectric properties gradually fall off. In liquid phase measurements a well cooledintermediate medium can be used in order to reach higher temperatures.

4. RESOLVING POWER

[9]As the speed of sound is relatively low and as time intervals can be measured with great precision, the resolving power of the measurement is very high. Table 1 gives some values for several types of medium expressed in millimetres for an absolute accuracy of time measurement of Ws. The very low values recorded prove that the accuracy of measurement is not limited by resolution but by the accuracy with which the speed of sound is known

5. CALLIBRATION

[10]To allow for variations in the speed of sound, systematic calibration is necessary, unless the properties of the medium and its temperature are sufficiently accurately known. The calibration is carried out by means of an additional acoustic path of known length in the same medium as that which will be used in the level measurement. Calibration can be either manual or automatic.

6. LITREATURE SURVEY

6.1.On the estimation of free-surface turbulence using ultrasonic sensors

[11]The free-surface dynamics in several turbulent flows commonly found in nature were investigated using a synchronised setup consisting of an ultrasonic sensor and a high-speed video camera. General sensor capabilities were tested in dry conditions to allow for a better characterisation of the present sensor model. The ultrasonic sensor was found to frequently reproducing free-surface dynamics up to the second order, especially in two-dimensional scenarios with the most energetic modes in the low frequency range. The sensor frequency response was acceptable in the 20 Hz band, and its signal quality might be further improved by low-pass filtering prior to digitisation.

6.2.Ultrasonic Instrumentation System for Liquefied Petroleum Gas Level Monitoring

[12]An approach has been constructed to facilitate the process of LPG level measurement inside a cylinder tank. In this research, a novel method is developed by using a non-invasive ultrasonic instrumentation system for surviving LPG level in a 14 kilogram cylinder. The ultrasonic system was integrated with the designed experimental rig. Module ultrasonic sensors Trauma.LC-V1.15 were attached vertically on the surface of cylinder wall on a sensor holder of the experimental rig. The ultrasonic sensors emit the ultrasonic signals and the signals will then propagate through the cylinder wall. The reflected signal was captured back by the ultrasonic sensors. The reflection of the ultrasonic signal depends on the type of the medium's impedance. The generated signals from the transceiver type of sensors were sent to the Pico Scope Data Acquisition System (DAQ) for data reading.

6.3.Effects of Environment on Accuracy of Ultrasonic Sensor Operates in Millimetre Range

[13]The objective of this paper is to discuss on the various parameters on the environment that influences the accuracy of the ultrasonic sensor and to formulate a simplified mathematical formula to calculate the instantaneous speed of sound by considering the various

This paper conclude that the accuracy of the ultrasonic sensor influences the instantaneous speed, which further depends on the temperature and the relative humidity of the atmosphere.

6.4.Design of an ultrasonic sensor for measuring distance and detecting obstacles

[14]This paper introduces a novel method for designing the transducer of a highly directional ultrasonic range sensor for detecting obstacles in mobile robot applications.

The transducer consists of wave generation, amplification, and radiation sections, and a counter mass. The principle of operation of this design is based on the parametric array method where the frequency difference between two ultrasonic waves is used to generate a highly directional low-frequency wave with a small aperture. The aim was to design an optimal transducer to generate the two concurrently longitudinal modes efficiently.

[15]Amodel combining the continuum model and the compatibility condition was appropriate for designing the ultrasonic range sensor based on the difference frequency wave resulting from the nonlinear effect between two high-frequency components. This model can be applied to various types of Langevin transducers consisting of a horn and piezoelectric disk actuators. The analytical model provided an approximate solution for the optimal length and decreased the computation time of the finite element model by trial and error.

6.5. Fluid level measurement in dynamic environments using a single ultrasonic sensor and Support Vector Machine

[17]A fluid level measurement system to accurately determine fluid levels in dynamic environments has been described. The measurement system rely on a single ultrasonic sensor and Support Vector Machine (SVM)based signal processing and classification scheme. For exemplification of the measurement system in changing environments, the new measurement system is experimented and verified on a fuel tank of a running vehicle.The effects of slosh and temperature difference on the acoustic sensor based measurement system are reduced using the novel approach. The novel approach is based on SVM classification method with the Radial Basis Function (RBF) to compensate for the measurement error induced by the sloshing effects in the tank because of the motion of the moving vehicle. In this novel approach, raw sensor signal is differentiated after smoothing with some selected pre-processing filters, namely, Moving Mean, Moving Median, and Wavelet filter. The derivative signal is then transformed into Frequency Domain to decrease the size of input features before performing the signal classification with SVM. Field trials were performed on original vehicle under normal driving conditions at various fuel volume ranging from 5L to 50L to acquire example data from the ultrasonic sensor for the training of SVM model.A comparison of the accuracy of the forecasted fluid level obtained using SVM and the pre-processing filters is provided.

7. CONCLUSION

The Conclusion and discussions of the study can be summarized as follows:

From the practical measurements of the ultrasonic sensors the measuring distance with high accuracy is upto 3 metres, with accuracy percentage 0.5% to 0.7% over 6 metres and the percentage decreases to 0.4%. All the measurements were realized approximately under the same conditions (23 Centigrade).

[18]A highly directional ultrasonic range sensor with HPBW of 1.3 was generated using a parametric acoustic array with this transducer having more than 120 dB that of the difference frequency wave was 83 dB, which is better than conventional ultrasonic range sensor. To have an ultrasonic sensor with high accuracy in millimetre range we need the instantaneous speed of sound which requires two major parameter that are temperature and relative humidity of the medium. The percentage error while working at a temperature range of 0 to 50Celsius was 60% to 43%. A developed ultrasonic instrumentation system is capable to measure the level of liquid inside a closed container. The change of voltage value represent liquid level inside the container. By calibrating the values of voltage difference the level of the liquid inside the container is calculated. The ability of an ultrasonic sensor to detect the level of liquid was 10% error. The error is due to sensor’s constraint in detecting a small area because of its size.

An ultrasonic sensor measures either impedance of a fluid or liquid level utilizes moderately directional, bulk SV mode sound waves generated by a transducer and propagated in a homogeneous, flaw-free solid member. The SV wave intrudes in the solid medium along a ZigZag path that reflects at a solid-fluid interface in at least two areas and at an angle of incidence that exceeds the first critical angle by at least five degrees and is less than the second critical angle by at least ten degrees.The attenuated amplitude of the wave due to acoustic coupling between the solid and the fluid measures the impedance or an impedance related parameter of the fluid.

[19]A device that determines liquid level or volume by means of charging a plurality of capacitors in sequence. Each capacitor is charged for a fixed time interval. The voltage level obtained is a function of the liquid level and is compared with a known voltage to obtain an output signal that can be used to represent liquid depth. The capacitors are formed by two concentric tubes. The tubes U.S. PATENT DOCUMENTS reduce the effect of sloshing in the tank, resulting in a To measure volume or level in an irregular shaped tank, the capacitors can be arranged in a non-linear manner.

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