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Experimentation of Coriolis flow meter using self sensing electronics

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Abstract

In Coriolis mass flow meter, the fluid is allowed to flow through the pipe. When the fluid flows through the pipe, it actuates through a piezo actuating sensor using self sensing electronics and its vibration is sensed by a piezo electric sensor and the output is given to the Digital Storage Oscilloscope (DSO).The input from the Audio Frequency Oscillator (AFO) is given to the piezo actuation system. The output of the piezo actuating system is given to the piezo actuating sensor to provide vibration and it is sensed by piezo electric sensor which is then given to the piezo sensing unit. Then it is filtered by using a band pass filter. The output is viewed using DSO.

Keywords: Coriolis flow meter, self sensing electronics, mass flow rate, PVC pipe, piezo electric sensor, piezo electric actuator

Subject classification: MEMS

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1. Introduction

Coriolis mass flow meter has much industrial and commercial significance. In recent years, Coriolis flow meter has gained a greater interest in many applications like chemical, medical industries etc. The two flow meters which measure the mass flow rate are Coriolis flow meter and thermal flow meter. An important problem of thermal flow sensor is that the measurement is highly dependent on temperature and fluid properties like density and specific heat. The main advantage of the Coriolis flow meter is that it directly measures the mass flow rate of the fluid travelling through a tube and independent on temperature, pressure, flow profile and fluid properties whereas the other flow meters measure the volumetric flow. The mass flow rate is the mass of the fluid travelling through a fixed point per unit time. It is the multiplication of volumetric flow rate and density of the fluid. The principle of Coriolis flow meter is that the fluid inertia twist the tube in proportionate to the mass flow rate. A Coriolis flow meter consists of a tube which is energized by a fixed vibration. When a fluid flow through this tube, the mass flow momentum will cause a change in the tube vibration; the tube will twist resulting in a phase shift. This phase shift can be measured and a linear output is derived proportional to the flow. Mass is not affected by changing temperature and pressure and also recalibration is also not required for Coriolis flow meter. The high accuracy, rangeability and repeatability of Coriolis mass flow meter are further reasons for their fast growth and acceptance in industries. There are various types of sensors and actuators used for measuring mass flow rate such as electromagnetic, capacitive, accelerometer, laser vibrometer etc as sensing units and electromagnetic, electrostatic etc as actuating units. The piezo electric is used as the sensing and actuating unit because they are strong, chemically inert and inexpensive. In this paper, U shape pipe Coriolis flow meter using sensing and actuation is designed. The experimentation of Coriolis flow meter using self sensing electronics to replace function generator is attempted and for varying mass flow rate of Coriolis flow meter, phase difference or time difference is used.

In [1] the presence of mass is detected in a metallic resonant sensor consisting of a cantilever beam structure with closed loop electronics. A self-actuating biosensor based on the piezoelectric cantilever optimized by Taguchi method for the label-free detection of specific bimolecular is presented in [2]. In [3] the vibration characteristics of Coriolis mass flow sensor by experiment, using commercial meters (U-shape tubes) are investigated. An updated review of Coriolis flow measurement technology is provided in [4]. In [5] the requirement for flexible, self-validating instrumentation to support the goals of Industrial Cyber-Physical Systems is described. The importance of measuring the mass flow rate in industrial & irrigation applications is provided in [6]. In [7] the fluid flowing through a flexible tube structure which comprises a parallel tube which forms loop in a Coriolis mass flow meter is measured.

A mass flow rate of a fluid flowing in a measuring pipe fixed to housing, utilizing Coriolis' force generated in proportion to mass flow rate of the fluid is measured in [8]. In [9] the structural Integrity meter is verified. The analog and digital closed-loop control system by experiment study is investigated in [10].

In section II, smart Coriolis flow meter is discussed. Section III says about the vibration of Coriolis flow meter using measurement system. Section IV gives the experimentation of Coriolis flow meter using self sensing electronics. The resonant frequency is identified in section V. The experimentation is concluded in section VI. The acknowledgement is given in section VII.

2. SMART FLOW CORIOLIS MASS METER

Smart Coriolis flow meter uses piezo for sensing and actuating. We used the PVC (Poly Vinyl Chloride) pipe because it is light in weight, it has high flexibility, water tight joints, reduced co-efficient of friction, flame resistance and has high degree of versatility. The dimensions and material property of U shape pipe Coriolis mass flow meter is given in Table I.

Table I: Dimensions of U shape pipe

Parameters	**Symbol**	**Measurements**
Length (mm)	L	300
Distance of separation (mm)	W	300
Thickness (mm)	T	1.0
Inner diameter (mm)	d	13
Outer diameter (mm)	D	15
Young's modulus (N/m^2)	E	2.4
Density ($g/m^{3)}$	ρ	1380000

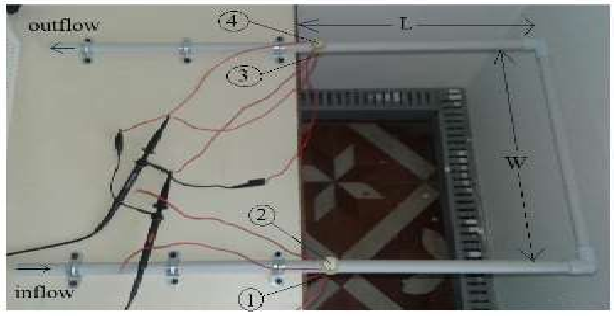

Figure 1 a: U shape pipe setup

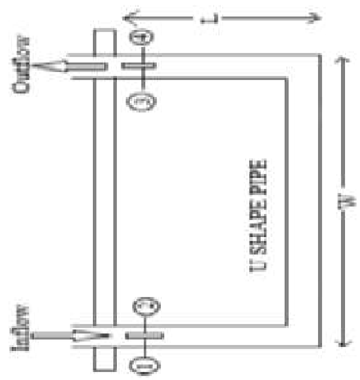

Figure 1 b: U shape pipe schematic

1. Piezo actuator 1
2. Piezo sensor 1
3. Piezo actuator 2
4. Piezo sensor 2

The pipe is attached with the base at 300mm. The piezo electric sensor is placed at 400mm away from the fixed end. The piezo electric patches pasted in collocated manner at the inlet and outlet of the pipe acts as sensor and actuator which is shown in Figure 1.

3. Measurement System

A .Piezo Actuation Unit:

The AFO provides input to the circuit. The input voltage given from an AFO is 20V and the resonant frequency is 41.2 Hz. The output terminal of AFO is connected to the piezo actuation unit which vibrates when voltage is applied.

B.Piezo Sensing Unit:

It contains power ON button and two channels and each channel contains sensing voltage display, sensing input, sensing output, gain selector switch for input sensing.

The piezo crystal sensing terminal is connected to the input of piezo sensing unit. By using the gain selector switch, the gain selector switches for input sensing.

The piezo crystal sensing terminal is connected to the input of piezo sensing unit. By using the gain selector switch, the gain value is adjusted to 2. (The signal from the piezo crystal is multiplied by 2). The output of the piezo sensing unit is connected to the input of the band pass filter.

C.Band Pass Filter:

It contains power ON button and two channels. Each channel has an input terminal, output terminal, frequency range selection switch and multiplier switch for adjusting low pass filter and high pass filter.

The output of the band pass filter is connected to the DSO. The output of the piezo sensing unit has some noises which are filtered by adjusting the gain of low pass and high pass filter to generate a sine wave which is viewed in the DSO. Figure 4 shows the output waveform of piezo sensors.

The block diagram of Coriolis flow meter using measurement system is given in Figure 2.

The photograph of Coriolis flow meter design and experimentation is given in Figure 3.

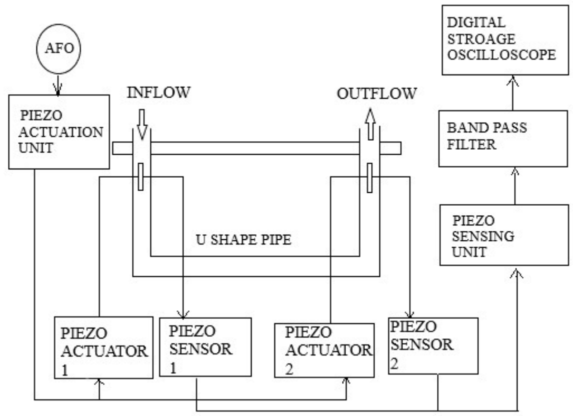

Figure 2: Block Diagram of Coriolis mass flow meter

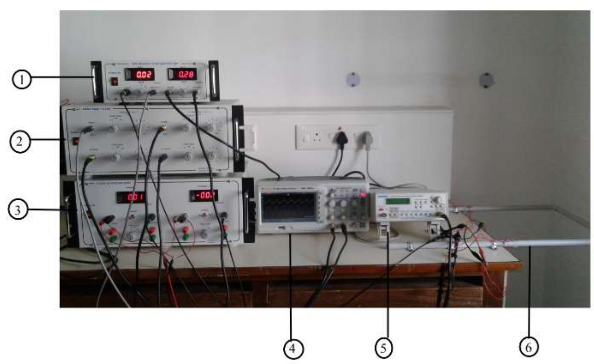

Figure 3: Vibration of Coriolis Flow Meter using measurement system

1. Piezo sensing unit
2. Band pass filter
3. Piezo actuation unit
4. Digital Storage Oscilloscope
5. Audio Frequency Oscillator
6. U shape pipe

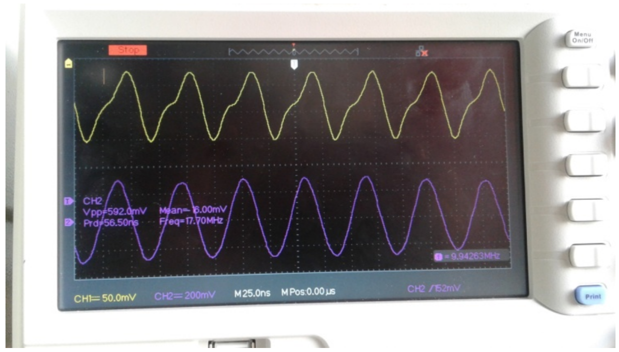

Figure 4: Output waveform of Coriolis Flow Meter using measurement system

4. Self Sensing Electronics For Coriolis Mass Flow Meter:

Two oscillator circuits are employed for vibration on both the sides of the arm which is shown in Figure 5. The oscillator consists of an IC741 in which the inverting terminal is connected with a 0.1µF and a non-inverting input is connected to a 10 kΩ resistor. The purpose of a capacitor is that it acts as the energy storage element and amplifies the input voltage to higher voltage. A feedback resistor of 220kΩ is connected across the inverting input and the output terminal. A 2.2kΩ resistor is connected at the output terminal of IC. The piezo sensing is connected to the non-inverting input terminal and the piezo actuator is connected to the output terminal of an IC. A power supply of +15V is given to the 7th pin and -15V is given to the 4th pin of an IC. The output of an oscillator circuit is connected to the DSO from which the time difference or phase difference is measured which is shown in Figure 6.

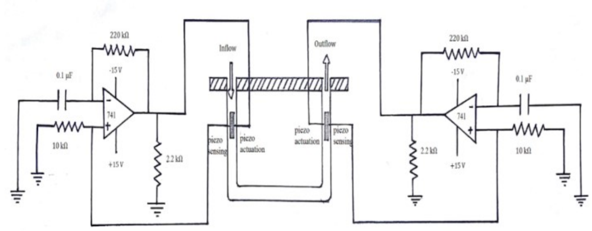

Figure 5: Self sensing electronics for Coriolis Mass Flow meter

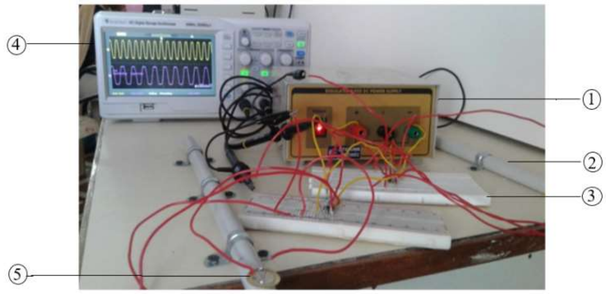

Figure 6: Output waveform of self sensing electronics

1. Regulated power supply
2. U shape pipe
3. Electronics circuit connection
4. Digital Storage Oscilloscope
5. Piezo electric sensor

5. Identifying Resonant Frequency

The input frequency is varied using AFO until the vibration of the pipe is achieved. The amplitude is high only at the first harmonics of the vibration and the corresponding frequency is the resonant frequency which is 41.6 Hz.

The phase shift (Φ) relation with mass flow rate (m) can be determined by (1),

$$\Phi = \frac{360}{\pi}\left[\frac{4LW^2 m\omega}{GJ}\right] \quad (1)$$

Where, L - Length of the pipe

W – Distance of separation

m – Mass flow rate

$\omega = 2\,\pi f$

f – Resonant frequency

G – Modulus of rigidity

J – Torsion constant

The input –output characteristics Obtained Using (1) is given in Figure 7. As mass varies, phase angle varies.

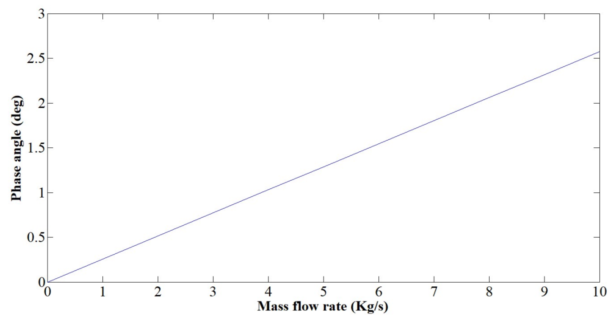

Figure 7: Input Output characteristics

6. Conclusion

The vibration is produced using measurement system and the resonant frequency of the pipe is obtained. The piezo electric sensor and actuator is used to produce vibration with the help of self sensing electronics uses RC circuit paired with IC. As mass varies, phase angle varies.

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References

[1] G. Uma, K. Suresh, M. Umapathy and M. Shanmugavalli “Closed Loop Electronics for Resonant Sensors “International Conference on Smart Materials Structures and Systems July 24-26, 2008.
[2] Il-Han Hwang and Jong-Hyun Lee "Self-actuating biosensor using a piezoelectric cantilever and its optimization” Journal of Physics: Conference Series 34 (2006) 362–367, International MEMS Conference 2006.
[3] Shuai Wang ,Dezhi Zheng and Shangchun Fan "Analysis on Vibration Characteristics of Coriolis Mass Flow Sensor "The Ninth International Conference on Electronic Measurement & Instruments ICEMI’2009.
[4] Tao Wanga and Roger Baker "Coriolis flow meters: a review of developments over the past 20 years, and an assessment of the state of the art and likely future directions " Flow Measurement and Instrumentation 40 (2014) 99–12.
[5] Olga Ibryaevaa, Pavel Taranenkoa, Michael Tombsb, Feibiao Zhoub and Manus Henrya "Matrix Pencil Method for Coriolis Metering with Liquid/Gas Flow II: Experimental Results"978-1-5386-6531-2/18/$31.00 © 2018 IEEE.
[6] Vikram A. Kolhe and Ravindra L. Edlabadkar "An overview of Coriolis Mass Flow meter as a Direct Mass Flow Measurement Device” International Journal on Emerging Trends in Technology (IJETT).
[7] Yousif A. Hussain "Coriolis Mass Flow meter”.
[8] Hironobu Yao, Iwao Matsumoto and Masami Kishiro "Coriolis Mass Flow meter".
[9] Timothy J. Cunningham "An In-Situ Verification Technology for Coriolis Flow Meters” August 2009.
[10] Wang Shuai, Zheng Dezhi, Fan Shangchun,Wang Ping and Wang Weiwei "Experimental Study on the Closed-loop Control System of Coriolis Mass Flow meter for Oil-water Two-phase Flow Measurement" 978-1-4244-7647-3/10/$26.00 ©IEEE.
[11] Mohammed N. Al-Khamis, Ali A. Al-Nojaim and Muhammad A. Al-Marhoun "Performance Evaluation Of Coriolis Mass Flow meters" Journal of Energy Resources Technology June 2002.