ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

Analysis of Coriolis Mass Flow Meter Tube using ANSYS

Kishore.S[1], Milan Patel.R[2], Mohamed Ashik.A[3], Venubalan. T[4], M.Shanmugavalli[5]

Professor, Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Tamil Nadu, India[5].

Final year Student, Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Tamil Nadu, India.[1,2,3,4]

ABSTRACT: Coriolis mass flowmeter (CMF) measures the mass flow of the fluid, such as water, acid, chemicals and gas/vapor. This paper covers various analysis such as Pressure, Velocity and Frequency for the CMF model which is based on Single U-tube design done in ANSYS. Frequency analysis is mainly focused and the various ways by which it can be determined is also discussed.

KEYWORDS: Frequency analysis, ANSYS, Coriolis Mass Flow Meter.

I.INTRODUCTION

A mass flow meter, also known as an inertial flow meter is a device that measures mass flow rate of a fluid traveling through a tube. There are two types of mass flowmeters one is Coriolis mass flowmeter (CMF) and other is Thermal mass flowmeter. The Coriolis mass flowmeter works on the principle of Coriolis effect. An effect whereby a mass moving in a rotating system experiences a force (the *Coriolis force*) acting perpendicular to the direction of motion and to the axis of rotation. The CMF can take measurement of high viscosity fluids, such as crude oil, heavy oil, residual oil and other liquids with higher viscosity. Previously, volumetric flowmeters, target flowmeters, etc. were used to measure flow. Now, Coriolis mass flowmeters are used, with good reliability and accurate measurement result.

The mass flow rate is the mass of the fluid traveling past a fixed point per unit time. The mass flow meter does not measure the volume per unit time (e.g., cubic meters per second) passing through the device rather it measures the mass per unit time (e.g., kilograms per second) flowing through the device. Volumetric flow rate is the mass flow rate divided by the fluid density. If the density is constant, then the relationship is Linear. If the fluid has varying density, then the relationship is nonlinear. Application of CMF is in food processing industry, Oil refinery, Petrochemical industry and Natural Gas industry.

The latest trends in CMF technology and the latest research using Modbus and Profibus alongside various tubedesigncanbestudiedin[1]andhowithasimprovedwhencomparedtothepreviousrecordsareseenin[2]. A three-phase metering of the CMF can be seen in [3] and the results demonstrate the potential for using Coriolis mass flow metering combined with water cut metering for three-phase (oil/water/gas) measurement. Unsatisfactory performance due to precision of flow signal because of presence of large damping and hysteresis is one notable constrain in CMF and the delay it causes in response time is given in [4]. Theoretical and experimental studies on CMF which shows method for predicting the optimum detection positions in relation to signal-to-noise ratio is discussed in [5]. The CMF model which is used for simulation in this paper is briefly explained in [6]. [7] and [8] tells about the Finite Element Analysis (FEA) study done on CMF using ANSYS for the U-Tube model. How vital the tube design can be and how it can influence the sensitivity of the CMF is experimentally analyzed in [9]. Method to determine the natural frequency of the tube is explained in [10]. The FEA on determining the resonant frequency and the sensitivity of the CMF is verified using ANSYS in [11]. [12] briefs about the unsteady flow behavior of various CMF models and the reduction

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

techniques to overcome the damping effect. Design of CFM to determine it is resonant frequency with help of COMSOL is given in [13].

ANSYS is a Computer Aided Design (CAD for short) software for modeling and testing Engineering designs in a virtual instance. It is also a Mechanical finite element analysis software which is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Various online tutorials and support is provided from Ansys.com to get familiarize with the ANSYS -Workbench environment [14]. The simulation of CMF tube excited by a fluid flow and exterior harmonic force using ANSYS is discussed in [15]. This paper provides simulation results for the CMF model using ANSYS -Workbench for Pressure, Velocity and Frequency analysis.

The Single tube design of the Coriolis mass flow meter is discussed in section 2. The tube modelling in ANSYS is explained in section 3. Section 4 discusses about Pressure and Velocity simulation done on the tube model designed using ANSYS. Frequency analysis for the tube is given in section 5.

II.SINGLE TUBE DESIGN

Theflowmeter design is referred from [6] for which the various analysis is to be done in ANSYS. The material of construction is Poly Vinyl Chloride (PVC) pipe of dimensions as shown in Figure: 1 is used for the simulation. The U-Tube setup is mounted on a wooden table 28.5 cm out of the entire length and rest is suspended freely. From a user point of view single tube designs are often preferred since they offer the best cleanability and the most careful fluid handling. However, it is challenging to find a balancing mechanism for such flowmeters.

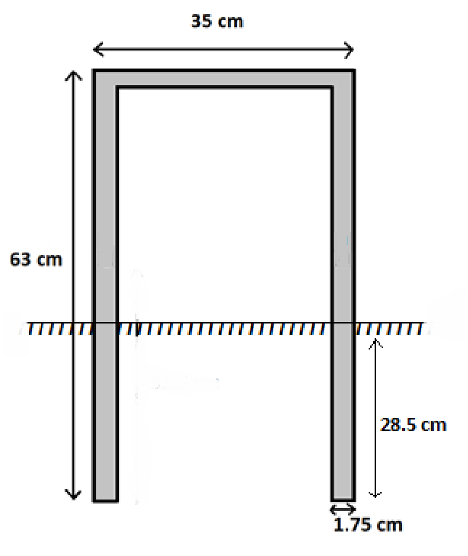


Figure: 1 Single U-Tube design of the Coriolis mass flow meter.

III.THE CORIOLIS MASS FLOWMETER TUBE MODELLING IN ANSYS

The Figure: 2 shows the Static Structural analysis for the CMF Single U-Tube design done using ANSYS-Workbench. The Elastic module 2.82 GPa, Poisson Ratio 0.38, Density 998.2 Kg/m^3 are the following parameters which are fed into the model.To create the flow tube, the Geometry is modelled as below. The globalaxis set in XY plane and the unit for dimension is set as centimeter (cm). Using Draw options in the menu, a circle is drawn and extruded for 63 cm. A mirror image of the same structure is done in the same XY plane at the distance of 35 cm. Two circles of inner diameter

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

1.2 cm and outer diameter is 1.75 cm is drawn at YZ plane and is extruded for 35 cm. To bring the curves at the edges Fillet function available in draw menu is used.The structure created is meshed using Auto mesh. The edges of U-Tube is fixed to run the analysis.

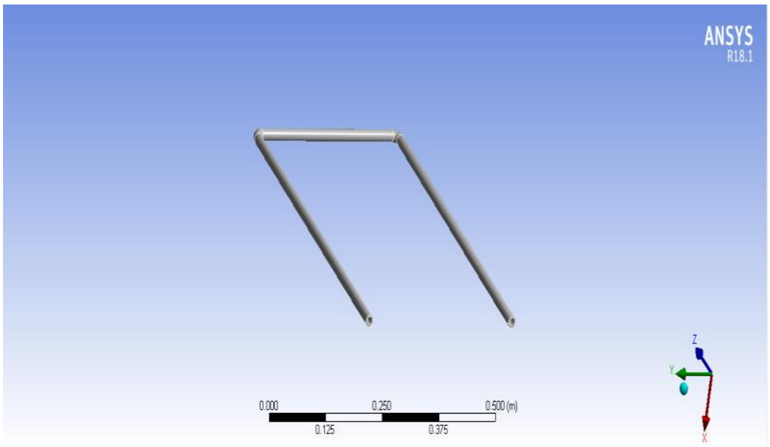


Figure: 2 Modelling of the Single U-Tube Coriolis mass flow meter in ANSYS.

IV.PRESSURE AND VELOCITY EFFECT ON THE CMF TUBE

The pressure analysis of the structure is carried out by setting the inlet pressure as 2Pa. Figure: 3 shows the simulated result of CFD (Fluent) pressure analysis done on the CMF model. It can be seen from the simulated model that the pressure at INLET side is initially more and it gradually decreases and almost becomes 1.45 Pa at OUTLET. The Figure: 4 shows the Velocity analysis done on the model by keeping the velocity as 0.01 m/s. This particular Single U-Tube design model shows the constant velocity of the fluid Water is chosen as the fluid.

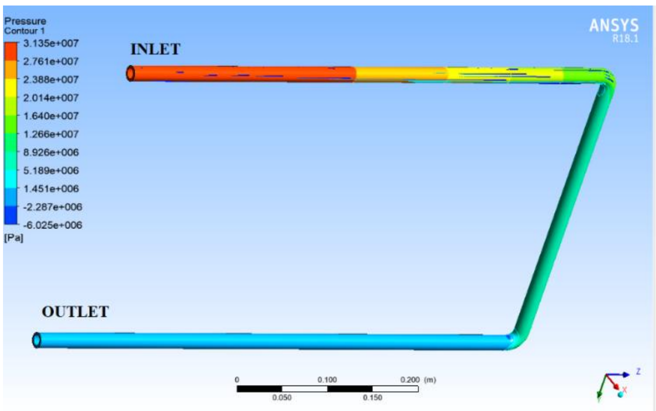


Figure: 3 Simulated Pressure analysis results of the CMF Model.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

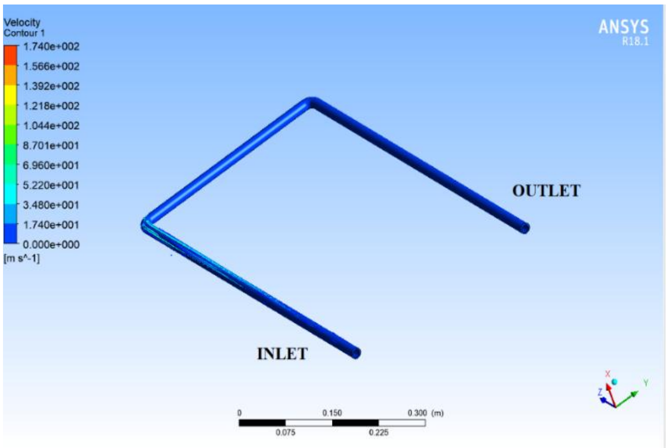


Figure: 4 Simulated Velocity analysis results of the CMF Model.

V. FREQUENCY ANALYSIS OF THE CMF MODEL

Most common configuration includes one or two U-shaped flow tube with inlet on one side and outlet on the other enclosed in a sensor housing connected to an electronics unit. The flow is guided into the U-shaped tube. When an oscillating excitation force is applied to the tube causing it to vibrate, the fluid flowing through the tube will induce a rotation or twist to the tube because of the Coriolis force acting in opposite directions on either side of the applied force. Vibration of Coriolis flowmeters has very small amplitude, usually less than 2.5 mm (0.1 in), and the frequency is near the natural frequency of the device, usually around 80 Hz. Finally, the vibration is commonly introduced by electric coils and measured by magnetic sensors. This twist results in a phase difference (time lag) between the inlet side and the outlet side and this phase difference is directly affected by the mass passing through the tube.

The likelihood of the occurrence of unwanted vibrations is higher in an industrial environment. Coriolis flow meter manufacturers do their utmost to reduce the influence of vibrations on the measured value by use of common technical solutions, such as using higher driving frequencies, dual sensor tubes, different sensor shapes, mass inertia (e.g. mass blocks), passive and active vibration compensation, pigtails. Vibrations can influence the measuring accuracy of Coriolis flow meter, but only if the vibrations have a frequency close to the resonance frequency. So, it becomes a crucial factor to determine the optimal resonant frequency for the CMF model in order to yield the better result.

The methods by which the resonant frequency can be determined for the CMF model is done in two ways. One is convectional frequency analysis using Lead ZirconateTitatnate (PZT) Piezoelectric patches (Figure: 5) as external source of vibration by applying a sinusoidal input to it and observing the amplitude change in Digital Storage Oscilloscope (DSO). This method was experimentally carried out and the observed results are plotted on the Graph (Figure: 6) The PZT patches are placed on the top as shown in the Figure: and the input to the sensors are given using Audio Frequency Oscilloscope.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

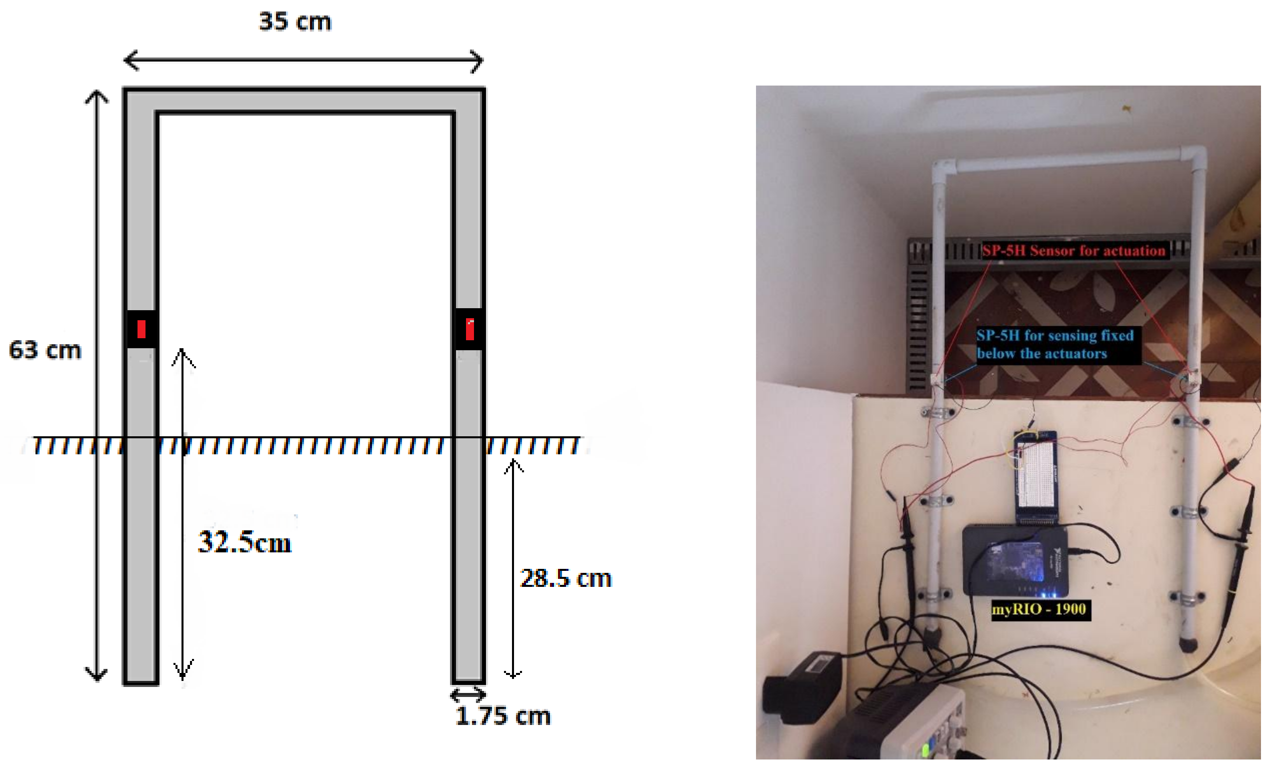


Figure: 5 PZT patchesplacement on the CMF model for frequency analysis.

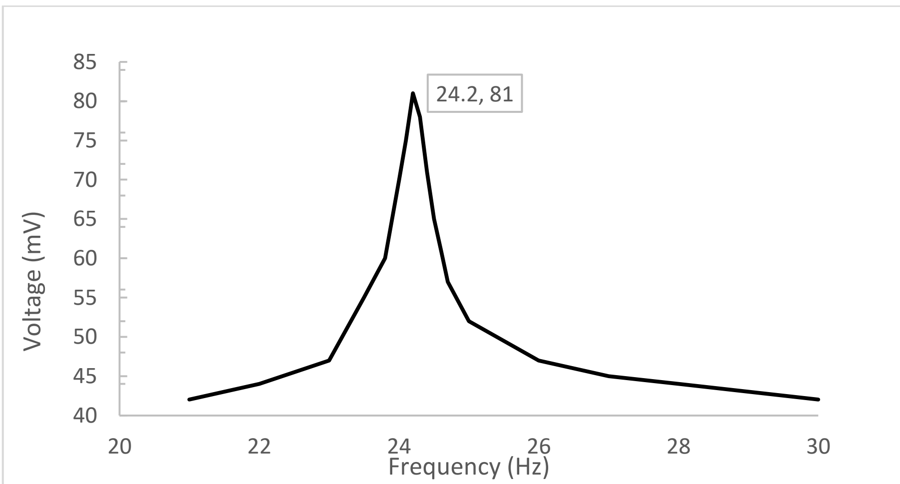


Figure: 6 Frequency analysis of the CMF model using PZT patches as external source of vibration.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

The CMF model is simulated using ANSYS- Workbench for obtaining the resonant frequency and it shows almost nearer results to the experimentation method using DSO and PZT Patches. The minor difference in both the results can be because of the PZT sensors ageing. Table: 1 shows the different resonant frequency of the simulated Coriolis flow meter. Figure: 8 shows the different modes of resonance of the simulated CMF Model.

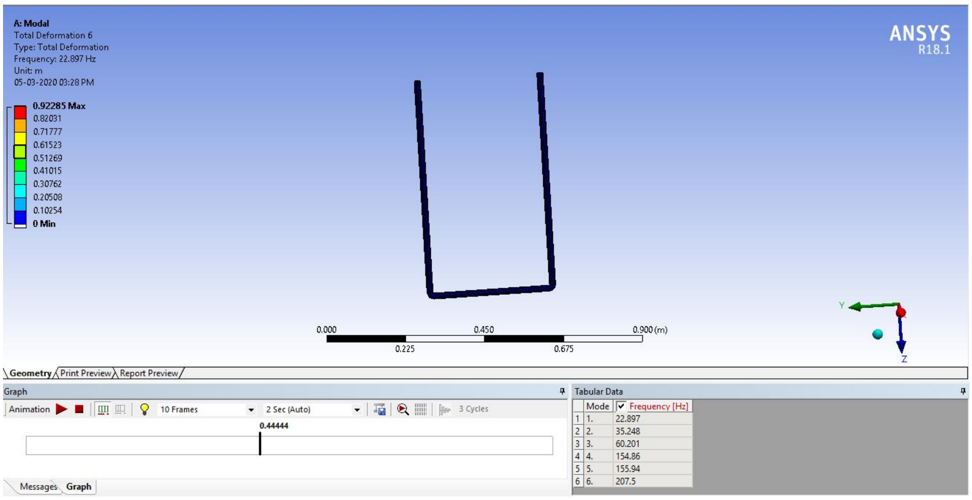
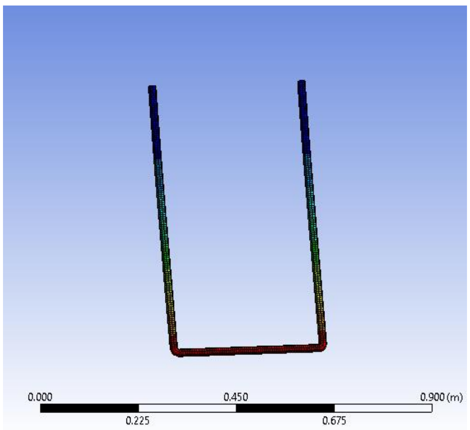


Figure: 7 Frequency analysis of the CMF model in ANSYS.

Table: 1 Six modes of resonance obtained from simulated CMF model using ANSYS.

Mode of Resonance	1	2	3	4	5	6
Frequency(Hz)	22.9	35.2	60.2	154.8	155.9	207.5



First mode of resonance

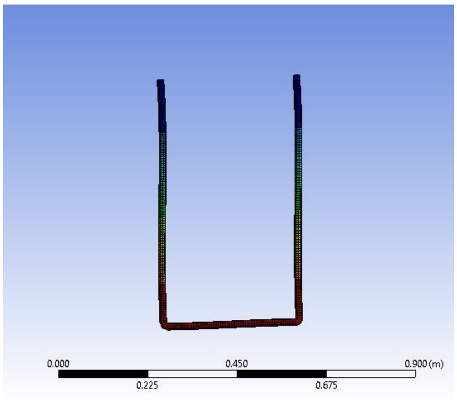
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

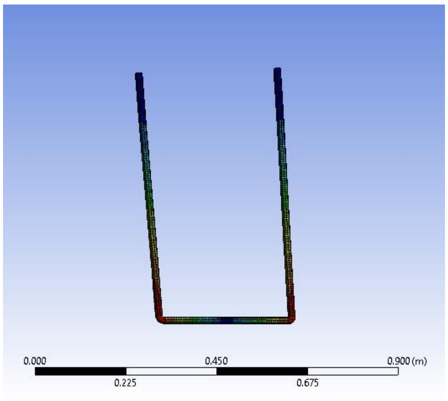
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

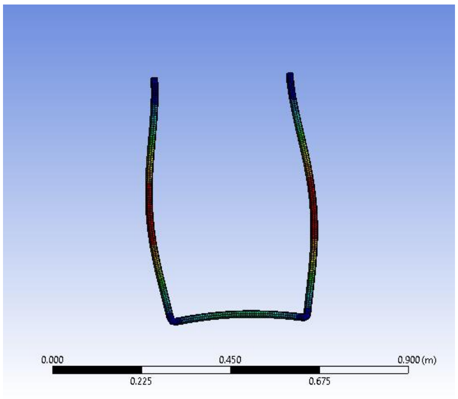
Vol. 9, Issue 2, February 2020



2^{nd} mode of resonance.



3^{rd} mode of resonance



4^{th} mode of resonance

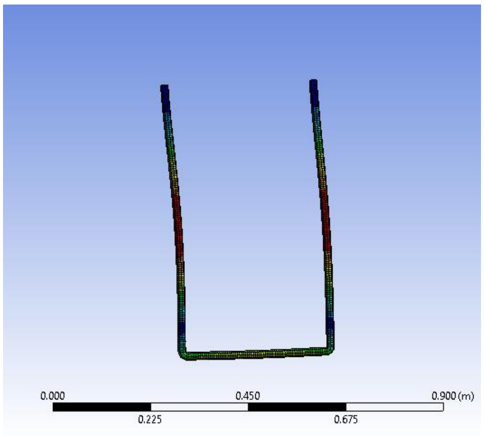
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

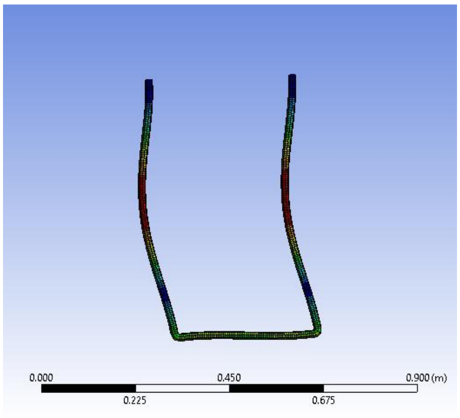
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020



5^{th} mode of resonance



6^{th} mode of resonance

Figure: 8 Frequency analysis of the CMF model in ANSYS.

VI. CONCLUSION

The research carried out shows that single tube Coriolis Mass Flowmeter model is effective enough to be used for the experimentation purposes. The first mode of resonance using ANSYS simulation is 22.8 Hz. The experimental mode of resonance is found to be 24.2 Hz. It is advisable to use the first mode of resonance for the CMF tubes as it yields higher amplitude. The Coriolis mass flow meter may need to be made out of exotic materials because of corrosion considerations or to prevent pitting. Carbon or stainless steel can often be used in process piping, because a small amount of pitting can be tolerated. In case of the Coriolis meter, even a small amount of pitting cannot be tolerated because the walls are thin, and pitting induces stress concentrations within the tube structure. Therefore, standard corrosion tables (based on weight loss criteria) are not suitable for selecting Coriolis tube materials, and the stricter guidelines of the manufacturers must be used.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

ACKNOWLEDGEMENT

The authors would like to acknowledge the financial support provided by the Department of Science and Technology (SEED division), Ministry of Science and Technology, Government of India, New Delhi, India to carry out research work under the project No. SP/YO/040/2017 dated 13.03.2018.

REFERENCES

[1]. Martin Anklina, Wolfgang Drahmb, Alfred Riederb “Coriolis mass flowmeters: Overview of the current state of the art and latest research” V.17 pp 317–323 (2006).
[2]. TaoWang, Roger Baker “Coriolis flowmeters: are view of developments over the past 20 years, and an assessment of the state of the art and likely future directions” V 40, pp 99–123,2014.
[3]. Manus Henry, Michael Tombs, Mayela Zamora, Feibiao Zhou "Coriolis mass flow metering for the three-phase flow: A Case study" V 30, pp 112-122, 2013.
[4]. Dezhi Zheng, Qiong Nan, Jiying Shi &Shangchun Fan "Experimental study on dynamic performance of Coriolis mass flow meter and compensation technology "ISSN 00204412, Instruments and Experimental Techniques, 2012, Vol. 55, pp. 503–507,2012.
[5]. Sultan G "Theoretical and experimental studies of the Coriolis mass flowmeter" V 03, pp 956, 1990.
[6]. Kishore S, Milan Patel R, Mohamed Ashik A, Venubalan T, M. Shanmugavalli "IoT based Coriolis mass flowmeter using LabVIEW”, V 8, PP 43-49, 2020
[7]. Pravin P Patil, Ashwani Kumar, Faraz Ahmad "Omega Design and FEA Based Coriolis Mass Flow Sensor (CMFS) Analysis Using Titanium material" V 310, pp 17-19, 2017.
[8]. Juan Zhao, Zhongxiang Li, Dezhi Zheng, Shangchun Fan "Modal simulation and experiment analysis of coriolis mass flowmeter" V 2019 Issue:23, PP 9013-9016, 2019.
[9]. Dezhi Zheng, Shuai Wang, Bei Liu, Shangchun Fan "Theoretical analysis and Experimental study of Coriolis mass flow sensor sensitivity" V 65, PP 295-312, 2016.
[10]. A S Khoruzhiy, P A Taranenko "Analysis of Effect of Internal Pressure on Natural Frequencies of Bending Vibrations of Straight pipe with Fluid" V ICIE 2018, pp 375-383, 2018.
[11]. Yao Kai, Zhao Jianhui "Finite Element Analysis of the Influence of Vibration Disturbance on Coriolis Mass Flow Meters" V 2013, PP 379-384, 2013
[12]. J Ruoff, M Hodapp, H KÜck "Finite element modelling of Coriolis mass flowmeters with arbitrary pipe and geometry and unsteady flow conditions" V 37, PP 119-126, 2014.
[13]. R M Saravanan, Christ W Raj and M Shanmugavalli "Design and Simulation of Coriolis Flow Tube in Meso and Micro Level to Determine its Resonant Frequency" V 23, pp 239-242, 2015.
[14]. Jiaping Zhang "Pipe Simulation using Ansys a Quick Introduction" Ansys.com 2017
[15]. V.A Romanov and V.P. Beskachko "The Simulation of Coriolis flowmeter tube movements excited by fluid flow and exterior harmonic force" V 2018, pp 294-306, 2018.