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

Fabrication of Coriolis Flow Meter Using 3D Printing

M.Divya Prabha[1], J.Jayashree Priyadharshini[2], R.Saranya Devi[3], M.Shanmugavalli[4]

UG Scholar, Department of ICE, Saranathan College of Engineering, Tamil Nadu, India[1, 2, 3]

Professor, Department of ICE, Saranathan College of Engineering, Tamil Nadu, India[4]

ABSTRACT: This paper reports the design and various analysis of Micro Coriolis flow meter (CFM) in INTELLISUITE software. The flow meter is designed in 3D BUILDER and simulation part is done using Thermo Electro Mechanical (TEM) module in INTELLISUITE. The transient behaviour and the resonant frequency are analysed in TEM module. The three modes of frequency of the structure are obtained. The CFM is designed using AUTODESK INVENTOR. The design is then fabricated using CREATBOT with the dimensions provided in analysis part.

KEYWORDS: Transient behaviour, Modes of frequency, micro Coriolis flow meter, TEM analysis, fabrication.

I. INTRODUCTION

Coriolis flow meter measures multiple parameters like direct mass flow rate, density, velocity and even viscosity of the fluid. It is widely used in the measurement of liquids, gas and slurries. The largest Coriolis flow meter that is currently available has a maximum flow rating of 25,000 lb/min (11,340 kg/min), and is equipped with 6 in. (15 cm) flanges. Coriolis Meter is designed according to the principle of Coriolis force. Whenever mass (either liquid or air) flows through the measuring tubes, Coriolis force is generated, causing a “bending” or “deflection” in the top of the tubes. This deflection is sensed as a phase shift by piezo electric displacement sensor mounted on each sides of the tube. The degree of phase shift is directly proportional to the mass flow within the tubes. The mass flow rate can be calculated by detecting the phase shift of the tubes.

The prototype of micro coriolis flow meter is designed using **Autodesk Inventor**. The design is then fabricated using CREATBOT. Autodesk Inventor is 3D mechanical solid modelling design software developed by Autodesk to create 3D digital prototypes. It is used for 3D mechanical design, design communication, tooling creation and product simulation. This software enables users to produce accurate 3D models to aid in designing, visualizing and simulating products before they are built. The **CreatBot DE** Plus is a large volume dual extruder 3D printer.

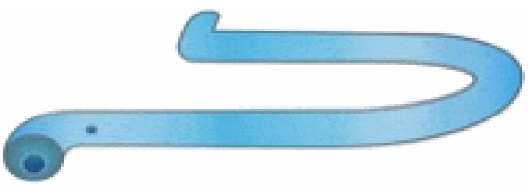


Fig.1. “Swinging” is generated by vibrating the tube(s) in which the fluid flows

Process of designing the CFM in nano size which is developed in INTELLISUITE software is given in [1] the thermal expansion of the measuring tube is increased by using bent tubes is given in [2] Through wafer-to-wafer bonding with

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

getters, that the average Q of the resonators did not vary in a statistically significant manner whether the parts were at room temperature or elevated temperature is given in [3] A new guttering method was developed to accomplish high-vacuum packaging is given in [4] The amplitude of the induced angular motion is linearly proportional to the mass flow and, thus, a measure thereof. The sensor can be used for measurement of fluid density since the resonance frequency of the sensor is a function of the fluid density is given in [5] .The expansion of flow range into either ultra low or high flow rates and the enhanced capability to deal with gas entrainment is given in [6] A resonating micro tube can be used to measure both the density and viscosity of a fluid is given in [7] The packaging of a micro Coriolis mass flow sensor into a stainless steel housing is demonstrated in [8] Reducing the size decreases the effect of gas and bubbles in the flow and maintain the gain, Q and frequency of the resonator is given in [9] Change in fluid density results in a change in the resonance frequency is given in [10]

In this paper we have designed micro Coriolis flow meter using intellisuite software. The transient behaviour and natural frequency of Coriolis flow meter is done using the TEM module. The modes of frequency are obtained from the frequency analysis. In section 2, the design of CFM in 3D builder is described. In section 3, Fabrication methods are discussed. In section 4, the transient behaviour of the CFM is analysed. In section 5 the resonant frequency of the CFM is discussed. In section 6 the conclusion of this paper is given.

II. CORIOLIS FLOW METER MODELLING

The design and simulation of CFM is done using Finite Element Analysis (FEA) Computer Aided Design (CAD) tool Intellisuite. In the 3D BUILDER a hollow u-tube structure is built. Initially the distance between the grids is changed. Auto meshing helps you to easily create Manhattan, isotropic or adaptive meshes. 3D Builder allows manually generating meshes or automatically converting a mask set into a parametric mesh. 3D Builder allows building fidelity **hexahedral** meshes. The mesh refinement techniques such as subdivision, zippering, spider-webbing and corner frames are used to intelligently refine mesh. At level 0, the two square shapes for the inlet and outlet flow is drawn. The height of the squares is modified to create the pipe like structure. In level 1, 2 and 3 rectangle shape is placed covering both the squares. The areas covering the holes of the square pipe are etched so that the fluid can flow through it. This file is saved and exported to TEM module. In the simulation, the settings are changed to either dynamic or frequency according to the required analysis. Silicon is chosen as the material of the structure. The inlet and outlet face are fixed in the boundary conditions. The code is then analysed by the software and the results are analysed.

DESIGN OF CFM IN INTELLISUITE:

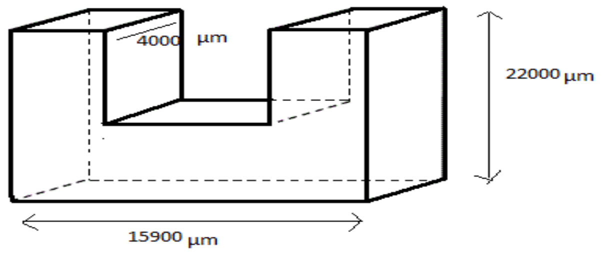


Fig.2. Dimensions of the u-tube is shown

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

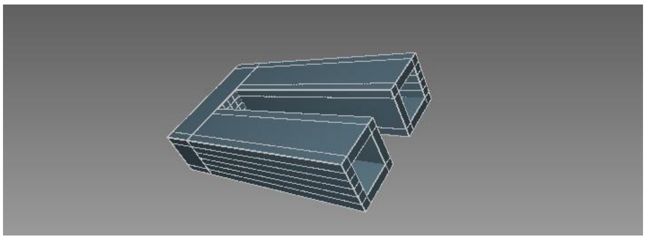


Fig.3. Modelling of u-tube in INTELLISUITE 3D builder

Table.1. Dimensions of u-tube

Length	22000 µm
Wall thickness	500 µm
Inner diameter	4000 µm
Width	15900 µm

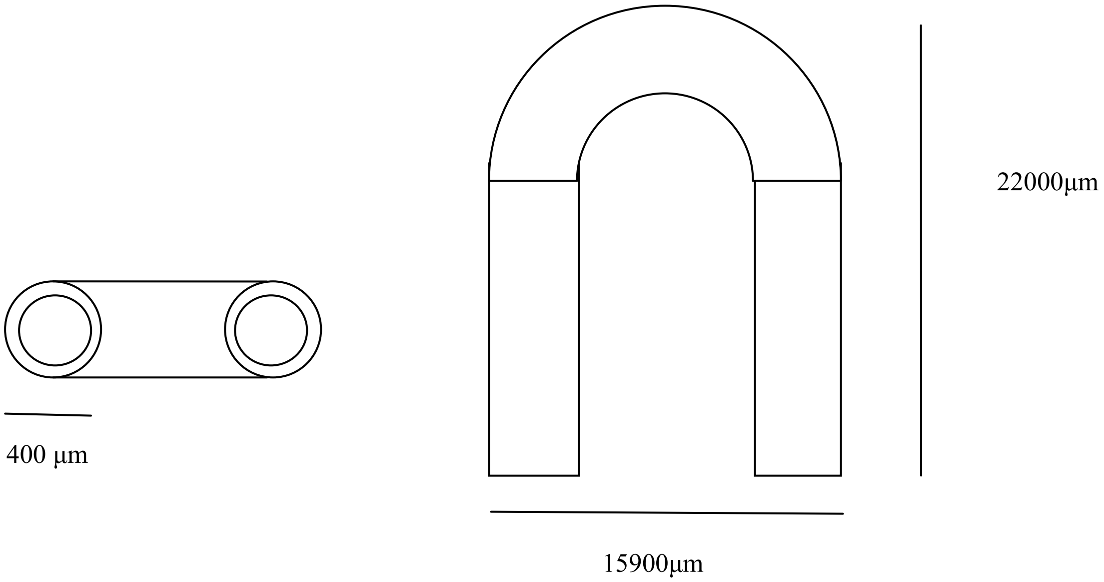


Fig.4. Dimensions of the above prototype

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

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

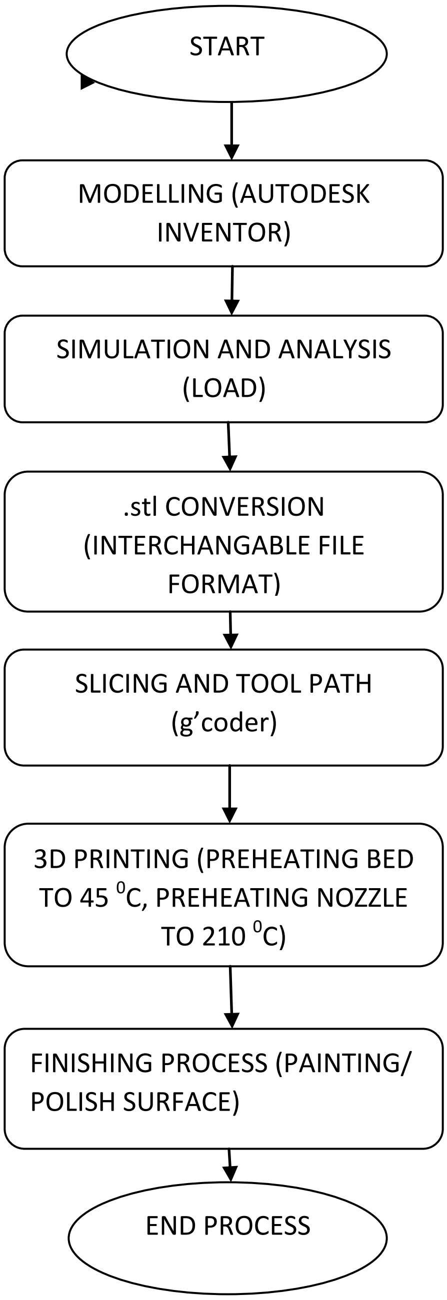
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 9, Issue 2, February 2020

III. FABRICATION METHODS INVOLVED IN CREATBOT

FLOW CHART



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)

Fig.5. 3D model of CFM in CREATBOT

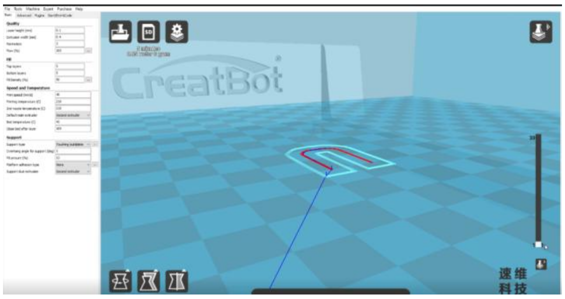


Fig.5.a

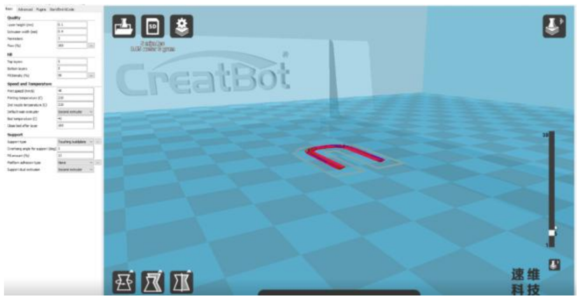


Fig.5.b

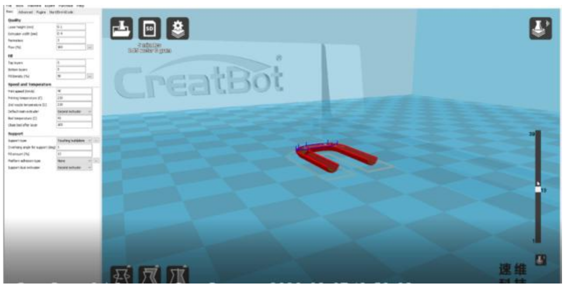


Fig.5.c

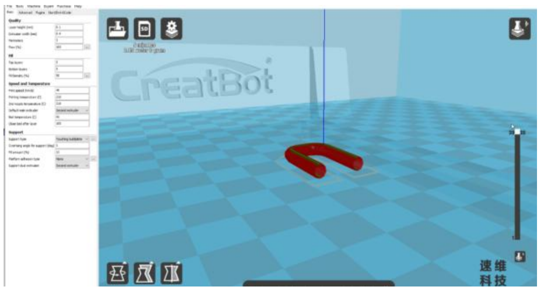


Fig.5.d

The 3D model of the CFM is created using AUTODESK INVENTOR. The 3D model file format must be either in .stl or .iges format. After completing the design in AUTODESK INVENTOR, the file is exported to CREATBOT. The preheat temperature for the CREATBOT bed must be in 45 ^{0}C and the nozzle should be in 210 ^{0}C. The printing is made layer by layer as shown in fig.5.

Material used- **Polylactic Acid** is a bio plastic made from lactic acid and is used in the food industry to package sensitive food products. However, **PLA** is too fragile and is not compatible with many packaging manufacturing processes. Therefore it should be strengthen with additives.

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

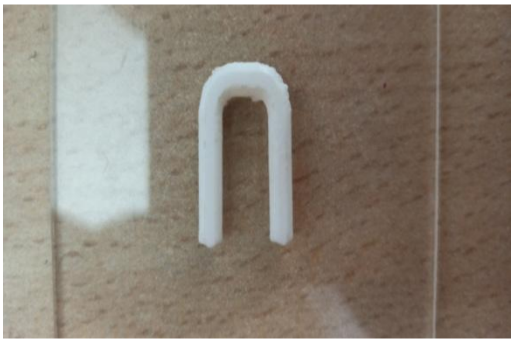


Fig.6. Fabricated u-tube

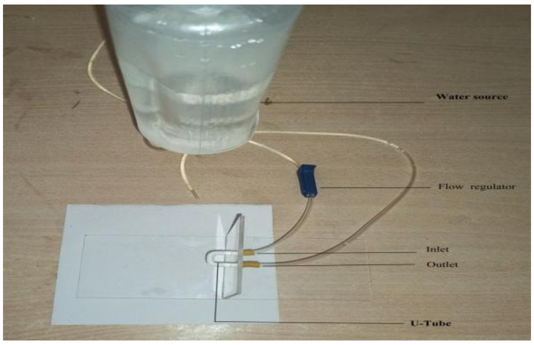


Fig.7. CFM experimental setup

In figure 6, the fabricated u-tube is shown. The fabrication is done using CREATBOT 3d printer. The material used for this u-tube is polyacitic acid. The dimension of the u-tube is mentioned in figure 4. The CFM experimental setup is made for flow measurement which is shown in figure.7. The fluid flows from the reservoir through the u-tube which consists of inlet and outlet. The u-tube will experience the Coriolis force when the fluid flows through it. The displacement produced during the flow will be measured using displacement sensor.

IV. TRANSIENT ANALYSIS

The 3D BUILDER file is imported to the TEM module. In the simulation the setting is changed to dynamic. The material of different entities in the structure is checked and modified to silicon. The inner is defined as a fluid entity and the outer is defined as a solid entity. The Coriolis force is applied to the CFM. The inlet and outlet face are fixed in the boundary conditions. Once we start the analysis the command prompt pops up. The result which is the dynamic mechanical response is obtained

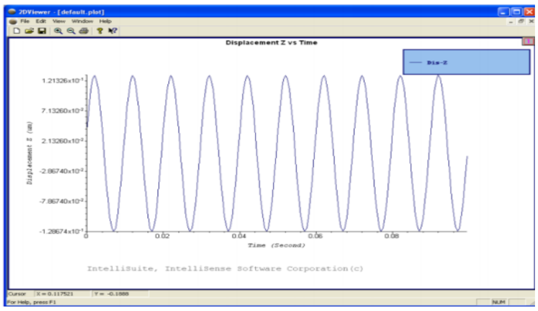


Fig.8.Dynamic mechanical response

V. RESONANT FREQUENCY ANALYSIS

Resonant frequency is the oscillation of a system at its natural or unforced resonance. Three modes of resonant frequency are obtained from this analysis. Initially the natural resonant frequency of the CFM is obtained by providing no load condition to the model. The density is set to 1000 units and all the other parameters are changed to negligible value. The frequency is obtained after the simulation part is completed.

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

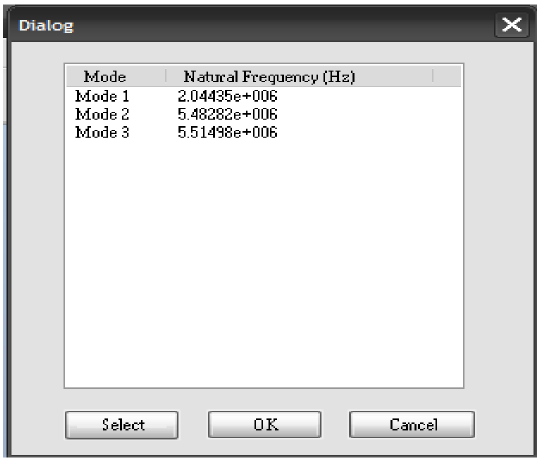


Fig.9 Values of three modes of natural frequency

VI. CONCLUSION

The Coriolis mass flow meter, a typical fluid structure interaction case is analysed using thermo electro mechanical analysis module of intellisuite. The structure is made of silicon bulk material with one inflow and one outflow. The three modes of frequency of the structure is obtained. The design of Coriolis mass flow meter at micro level is done. By this, the performance of the actual device could be updated with fast response time. Also the three modes of natural frequency is done using intellisuite software. The CFM is designed using AUTODESK INVENTOR. The design is then fabricated using CREATBOT with the dimensions provided in analysis part.

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] Enoksson P, Stemme G, Stemme E, “A silicon resonant sensor structure for Coriolis mass-flow measurements”. Journal of Micro electro mechanical System 1997; vol 6:119–25.
[2] Mehendale . A ” Coriolis mass flow rate meters for low flows.” (PhD thesis) journal of . University of Twente; 2008.
[3] Zhang Y, Tadigadapa S, Najafi N., Schneider R, Najafi N. “A micromachined Coriolis-force-based mass flowmeter for direct mass flow and fluid density measurement.” In: 11th international conference on solid-state sensors and actuators. Munich, Germany; 2001.
[4] Sparks D, Smith R, Cripe J, Schneider R, Najafi N. “A portable MEMS Coriolis mass flow sensor”. IEEE Sens Conf 2003.
[5] Sparks D, Smith R, Massoud-Ansari S, Najafi N. “Coriolis mass flowdensityand temperature sensing with a single vaccum sealed MEMS chip 2004”.
[6] Sparks D, Cruz V, Najafi N." The resonant behavior of silicon tubes under twophase microfluidic conditions with both microbeads and gas bubbles. Sensor Actuators”, A 2007;135:827–32
[7] Clark C, Wang S, Cheesewright R. “The performance characteristics of a micromachined Coriolis flow meter: an evaluation by simulation. Flow Meas Instrum” 2006;17:325–33.
[8] Sparreboom W, van de Geest J, Katerberg M, Postma F, Haneveld J, Groenesteijn J, et al. “Compact mass flow meter based on a micro Coriolis flow sensor. Micromachines “2013;4:22–33.
[9] Lötters JC, Lammerink TSJ, Groenesteijn J, Haneveld J, Wiegerink RJ.” Integrated thermal and micro-Coriolis flow sensing system with a dynamic flow range of more than five decades”. Micro machines 2012;3:194–203
[10] Sparks D, Smith R, Cruz V, Tran N, Cimbayo A, Riley D, et al. “Dynamic and kinematic viscosity measurements with a resonating micro tube Sensor Actuators”, A 2009;149:38–41.

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

[11] Smith R, Sparks D, Riley D, Najafi N.” A mems-based Coriolis mass flow sensor for industrial applications”. IEEE Trans Ind Electron 2009;56:1066–71.
[12] Wiegerink RJ, Lammerink TSJ, Groenesteijn J, Dijkstra M, Lotters JC. “Micro Coriolis mass flow sensor for chemical micropropulsion systems”. In: First international conference on microfluidic handling systems (MFHS-2012). Enschede, The Netherlands; 2012.
[13] Enoksson P, Stemme G, Stemme E. “Vibration modes of a resonant silicon tube density sensor”. J Microelectromech Syst 1996;5:39–44.
[14] Standiford DM, Lee M.” Inter-laboratory comparison results for Coriolis mass flow meter calibration facilities”. In: Proceedings of the 15th flow measurement conference (FLOMEKO 2010). Taipei, Taiwan; 2010.
[15] Griffin CR, Moore M, Pankratz AW. “Vibrating flow device and method for fabricating a vibrating flow device”. US2010263456; 2010.