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Design and Simulation of Micro Coriolis Flow Meter using IntelliSuite

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Abstract: This paper reports the design and various analysis of Micro Coriolis flow meter 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 values of three modes of frequency of the structure are obtained.

Keywords: Transient behaviour, Modes of frequency, Micro Coriolis flow meter, TEM analysis

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.

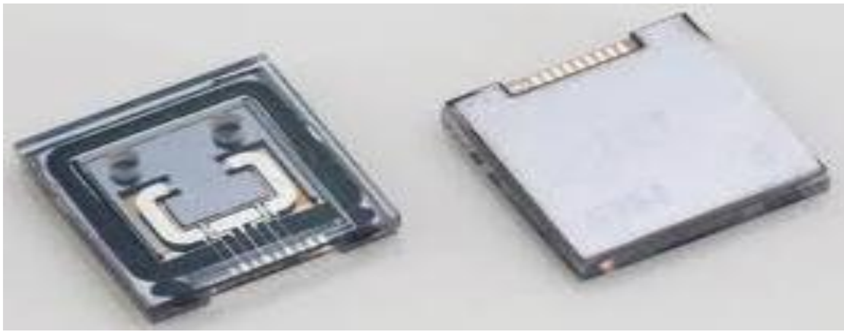

Fig.1. E+H MEMS Coriolis sensor chip. Left: bottom view with fluidic connection holes, sensing and excitation pads.

Right: top view on the sensor cap and the bond pads for electrical connections.

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.

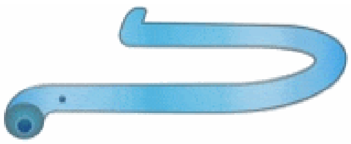

Fig.2. "swinging" is generated by vibrating the tube(s) in which the fluid flows

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 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

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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 TEM module. The modes of frequency is obtained from the frequency analysis.

In section 2, the design of CFM in 3D builder is described. In section 3, the transient behaviour of the CFM is analysed. In section 4 the resonant frequency of the CFM is discussed. In section 5 the conclusion of this paper is given

II. CORIOLIS FLOW METER MODELLING

In the 3D BUILDER a hollow u-tube structure is built. Initially the distance between the grids are changed according to our convenience. **Auto meshing** helps you to easily create Manhattan, isotropic or adaptive meshes. 3D Builder allows you to manually generates **meshes** or automatically convert a mask set into a parametric mesh. 3D Builder allows you to build fidelity **hexahedral** meshes. Use mesh refinement techniques such as subdivision, zippering, spider-webbing and corner frames to intelligently refine mesh.. Works great for optimal meshes the two square shapes for the inlet and outlet flow is drawn at level 0. 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 is 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. The material of the structure is modified to silicon. The inlet and outlet face are fixed in the boundary conditions. The code is then analysed by the software and the results are seen.

Design of CFM in Intellisuite:

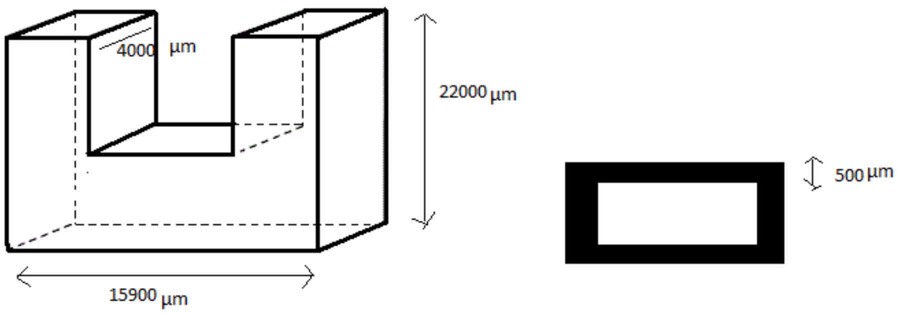

Fig.4. dimensions of the u-tube is shown

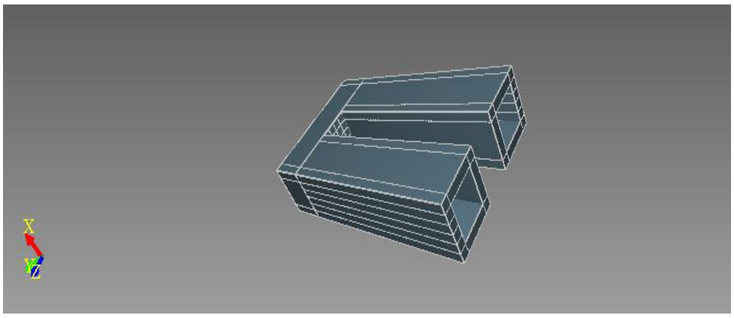

Fig.3. Modelling of u-tube in INTELLISUITE 3D builder

Table.1. Dimensions of u-tube

Length	22000 µm
Wall Thickness	500 µm
Inner Diameter	4000 µm
width	15900 µm

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III. TRANSIENT FREQUENCY

The 3D BUILDER file is imported to TEM module. In the simulation the setting is changed to dynamic. The material of different entity in the structure is checked and modified to silicon. The inner is defined as fluid entity and the outer is defined as 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

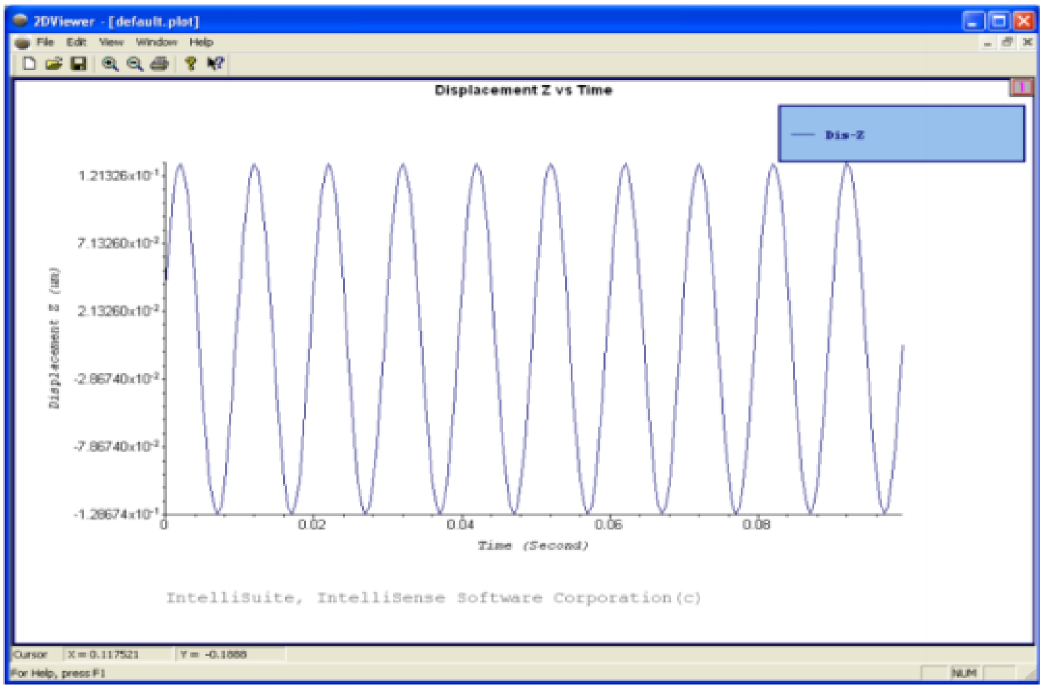

Fig.5.Dynamic mechanical response

IV. 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.

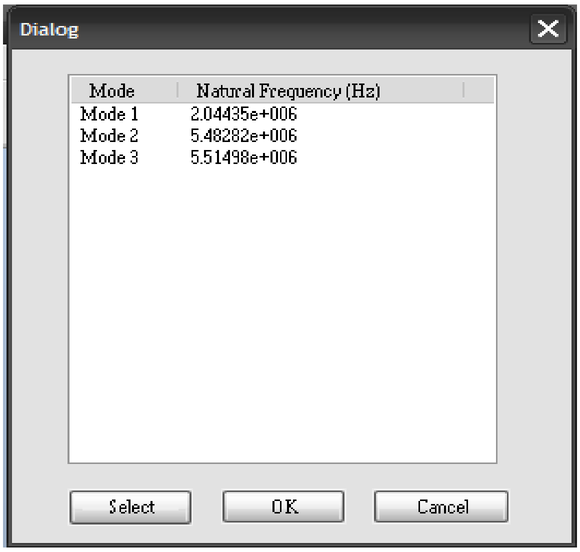

Fig.6 Values of three modes of natural frequency

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Mode1:

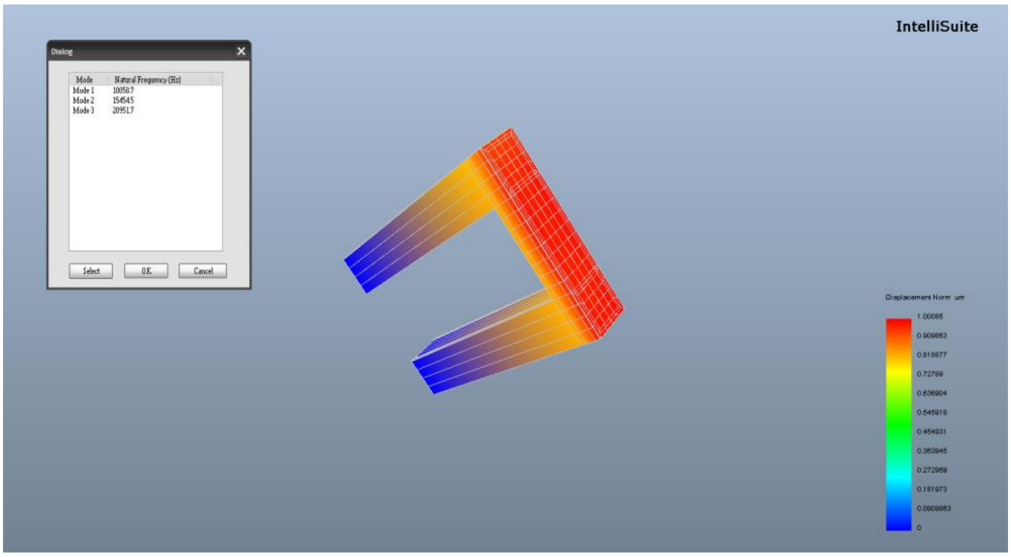

Fig.6 (a) In this mode the pipe oscillates up and down

Mode2:

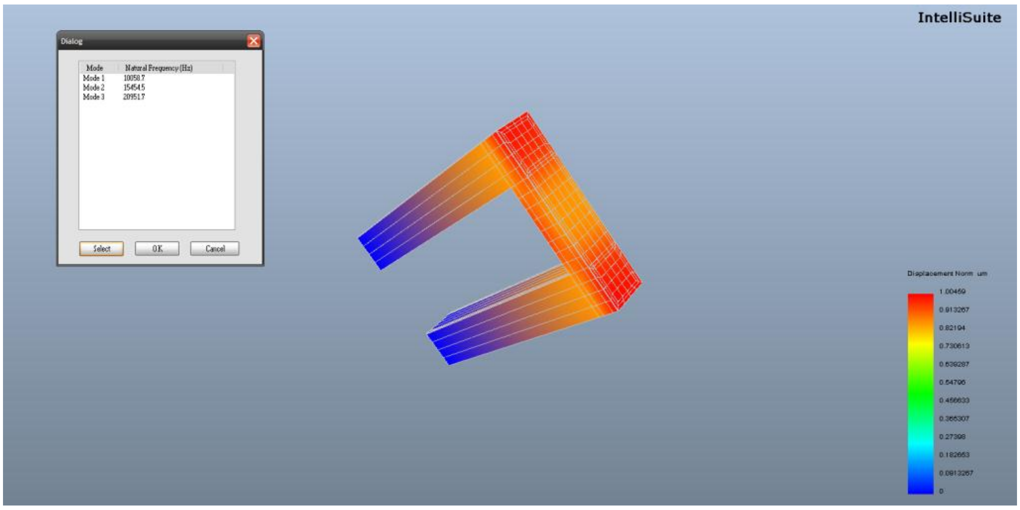

Fig.6. (b) In this mode the pipe oscillates sideways (left and right)

Mode 3:

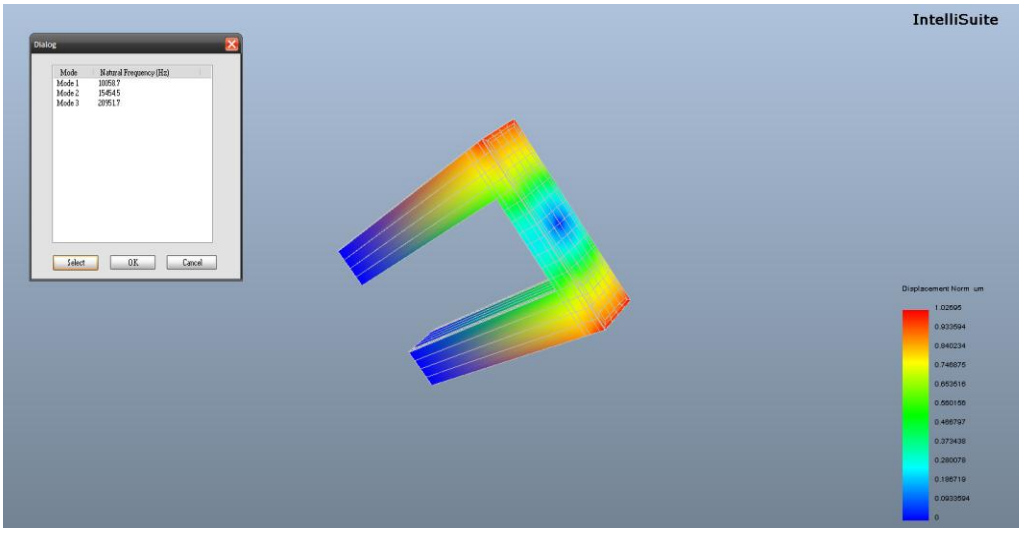

Fig.6. (C) In this mode the pipe oscillates in a twisted way

V. 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 frequency obtained for mode1 is 2.04435e+006. The frequency obtained for mode 2 is 5.48282e+006. The frequency obtained for mode 3 is 5.51498e+006.

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