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Design and Simulation of Disposable S Shape Coriolis Mass Flow Sensor using FEA Method

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Abstract: The aim of this paper is to design and evaluate natural frequency of disposable S shape coriolis mass flow sensor (CMFS). Three disposable materials used for performing modal analysis are PVDF (polyvinylidene fluoride), PP (polypropylene) and PEEK(polyether ether ketone). The design of coriolis mass flow sensor (CMFS) is done in CATIA V5 and simulation is performed in ANSYS 16.2. Simulation is performed by considering fluid inside the tube. Water is used as working fluid.

Keywords: CMFS, FEA, PEEK, PP, PVDF, FEA.

I. INTRODUCTION

Coriolis mass flow sensor is a device for flow measurement which depends on the fluid and solid interaction in order to sense the changes in the solid structure generated due to acceleration produced because of Coriolis force acting on the geometry. Coriolis flow meter consists of two parts, one the flow sensor also known as flow transducer and second is the flow converter also known as flow transmitter. The flow sensors comprises of vibrating tube, sensors, drive system to provide external vibration and structure to support the system. The flow converter gives input to the flow sensor, process the flow sensor signal and then gives the output.

II. LITERATURE REVIEW

Pradeep Gupta et al. [1] performed experiments on various shapes (U, S, and L) of mass flow sensor. The results show measured phase shift to be directly proportional to the mass flow rate. The slope ratio of U tube is witnessed to be constant for different parameters and maximum sensitivity is deduce for S and L tubes by varying the sensor position. Tao Wang et al. [2] did literature survey of development of CMFM in past years. S.C. Sharma et al. [3] carried out analysis of U type copper tube to check performance of coriolis mass flow meter. Pravin Patil et al. [4] used response surface method (ESM) for optimization of copper omega type coriolis mass flowmeter.

Bobovnik et al (2004) et al. [5] was the first to simulate straight beam mode coriolis mass flow meter using computational fluid dynamics(CFD). Sensitivity of coriolis mass flow meter was evaluated by measuring the moment created by the fluid flow at each step. Wang et al (2009) et al. [6] carried out analysis for cryogenic conditions and found that unlike elevated temperature the material property changes non linearly for cryogenic temperature.

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Coriolis mass flow sensors manufactured now are found not be affected by the viscosity and density of the working fluids. Advanced coriolis mass flow sensors are independent of viscosity and density of flowing fluids. Also the velocity profile and Reynolds number does not have any significant effect on the operation of coriolis flow sensors as compared to other sensors based on volume measurements.

III. RESEARCH METHODOLOGY

For the optimization of process parameter the study has been conducted as following.

Study of Coriolis Mass Flow Sensor

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Literature Review

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Geometry construction (Catia V5)

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Different Material Study on S-Shape Coriolis Mass Flow Tube for Frequency Variation

↓

Natural frequency identification using modal analysis (ANSYS)

IV. FEA ANALSIS OF TWIN S SHAPE TUBE

FEA is a method to check the designed product in the working stage. It helps in determining whether the product will work properly or it will break down. To carry out the analysis the product is divided into small finite number of parts known as elements. Each element is connected with the help of nodes.

The sensor tube for this study is considered to be a S shape tube. To obtain the S shape a hollow tube is bent in the shape of alphabet S. The profile's dimension is: the height (L) is 400 mm and the semi distance is 300 mm. The outer and inner diameter for all three configurations is kept the same. The outer diameter and inner diameter of tube is 12.7mm and 10.9 mm.

The solid model of S shape CMFS is prepared in CAD software CATIA V5. After completing the designing the *.stp file is imported to ANSYS 16.2 software for analysis. The profile of tube is shown in Fig. 1. Finite element analysis is carried out by firstly dividing the tube into small pieces. These small pieces are known as elements and the point that join these elements is called nodes. The meshed model created in ANSYS 16.2 of flow tube is shown in Fig. 2.

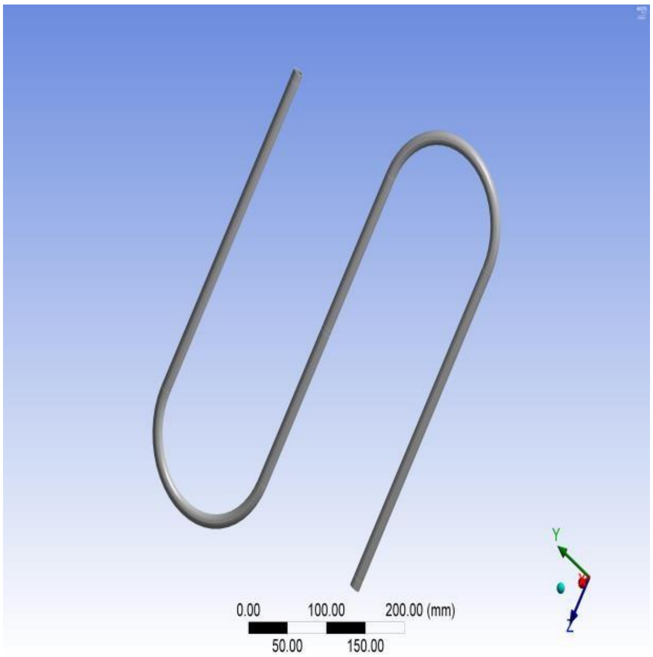


Fig.1. S Shape Tube

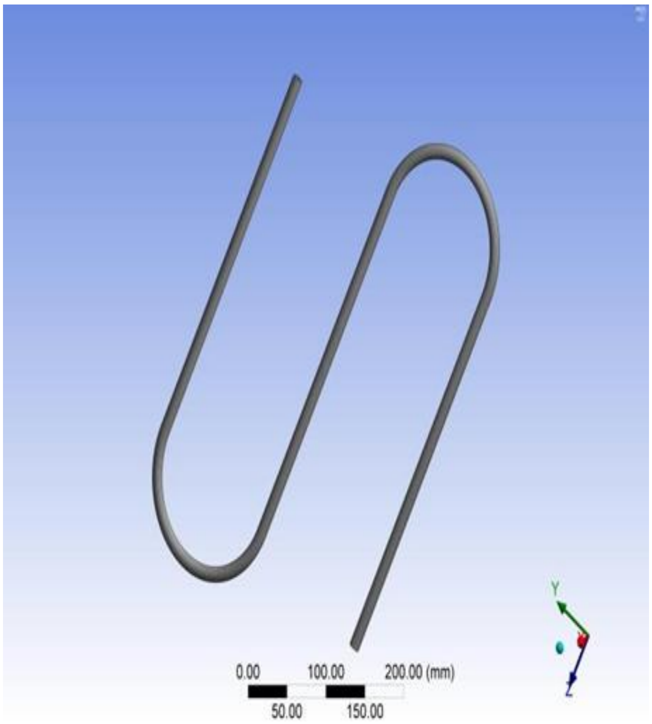


Fig.2. Mesh model of Shape tube.

The important parameters for performing the vibration analysis of the flow meter are the material's mechanical properties. The materials selected for the study of the flow sensor are PVDF (polyvinylidene fluoride), PP (polypropylene) and PEEK (polyether ether ketone). Properties of three materials are shown in Table I.

Table- I: Mechanical Properties of three materials used as a tube material for analysis of disposable CMFS.

Materials	Density (Kg/m3)	Young's modulus (GPa)	Poisson's ratio	Coefficient of thermal expansion (1/K)
PVDF	1780	2.5	0.34	0.00012
PP	946	1.3	0.26	0.00023
PEEK	1320	3.6	0.37	0.00072
WATER	997	9	0.27	0.00207

V. RESULT AND DISCUSSION

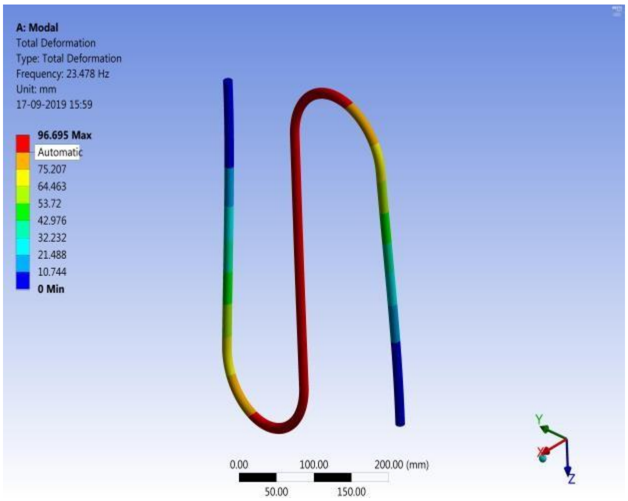
In this study FEA method was used to design and simulate S shape coriolis mass flow sensors to calculate the frequency for all three disposable materials used as tube materials. First natural frequency achieved in modal analysis is known as resonant frequency. It is the natural frequency for S Shape tube filled with the fluid (water). Resonance frequency for first mode for PEEK is 23.478 Hz, 19.359Hz for PP and for PVDF is 20.181 Hz.

Simulations are performed for different materials under fixed constraints. ANSYS 16.2 software was used to perform the modal analysis for six modes. Natural frequency for these disposable material for six mode is calculated. Mode shape result for the six modes are also generated. Table II gives the natural frequency obtained for PEEK, PP and PVDF.

Table- II: Mechanical Properties of three materials used as a tube material for analysis of disposable CMFS.

Modes	Frequency(PEEK)	Frequency(PP)	Frequency(PVDF)
1	23.478	19.359	20.181
2	25.122	20.408	21.451
3	39.314	28.464	32.432
4	53.493	46.132	46.61
5	65.539	55.603	56.737
6	89.18	74.047	77.001

Mode shape results of first six modes for PEEK is shown in figure 3. Figure 4 shows the mode shape result for PP. Mode shape result for PVDF is shown in figure 5. Graph for variation of frequency of all three disposable materials is shown in figure 6.



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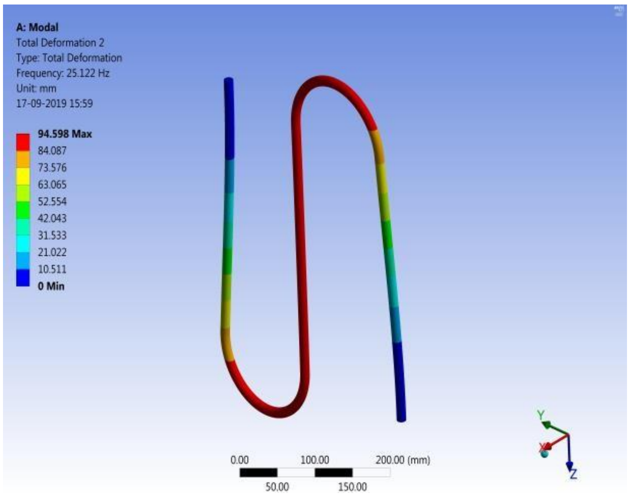

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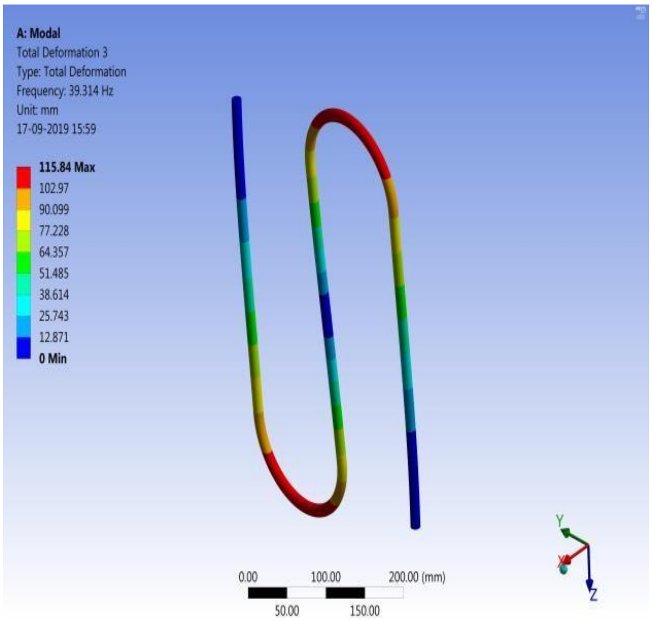

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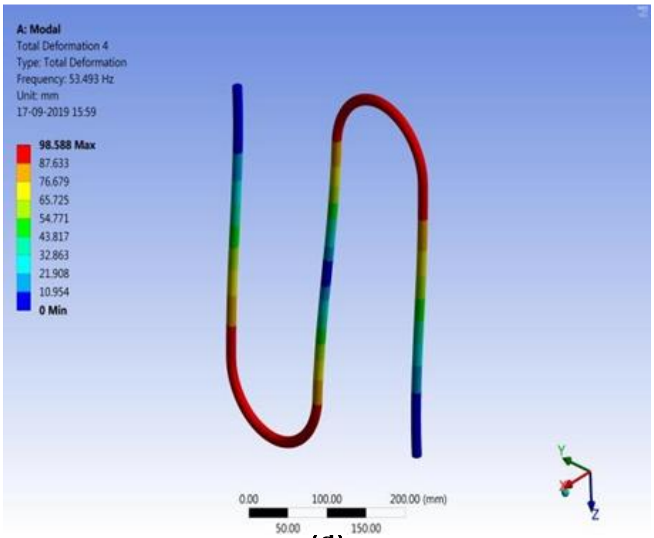

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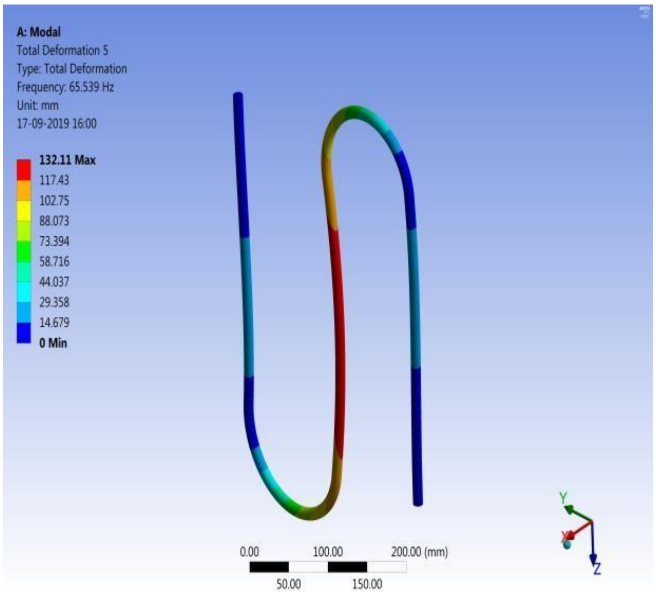

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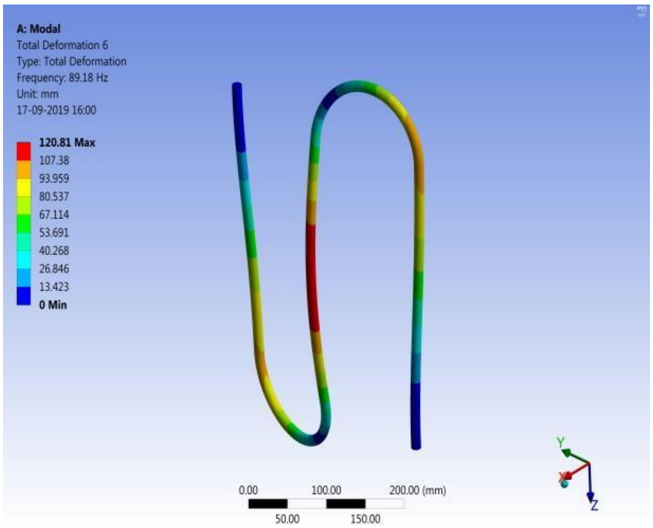

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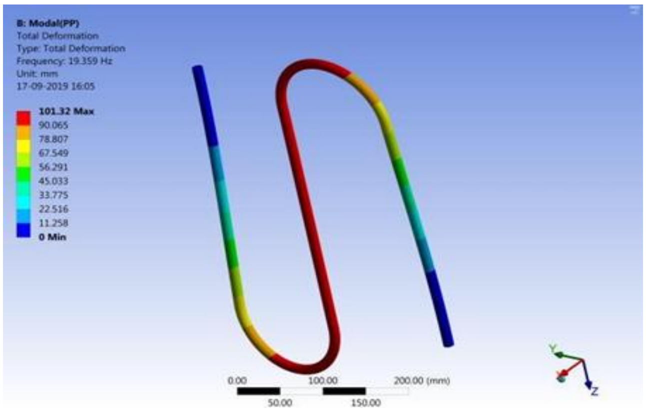
Fig.3. Six mode shapes for PEEK



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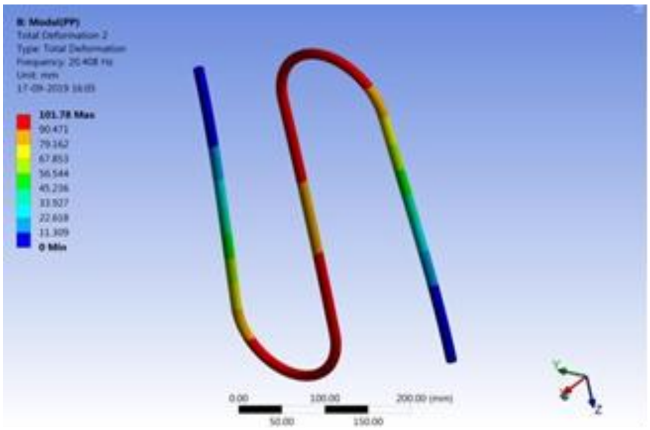

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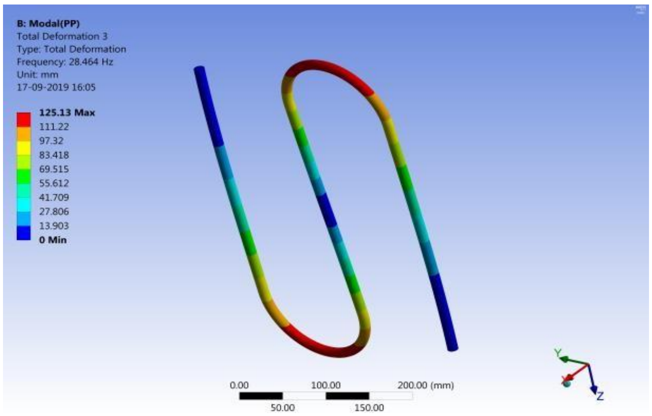

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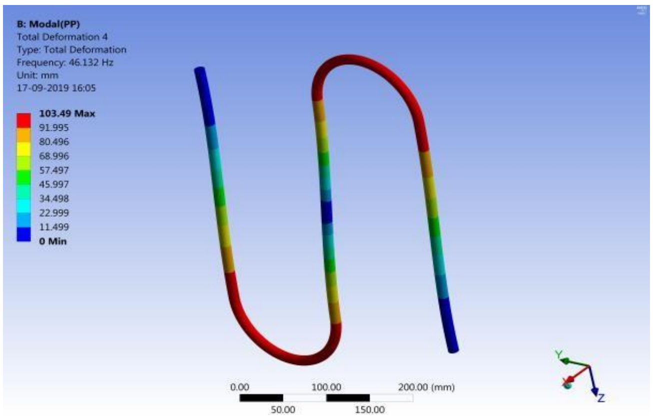

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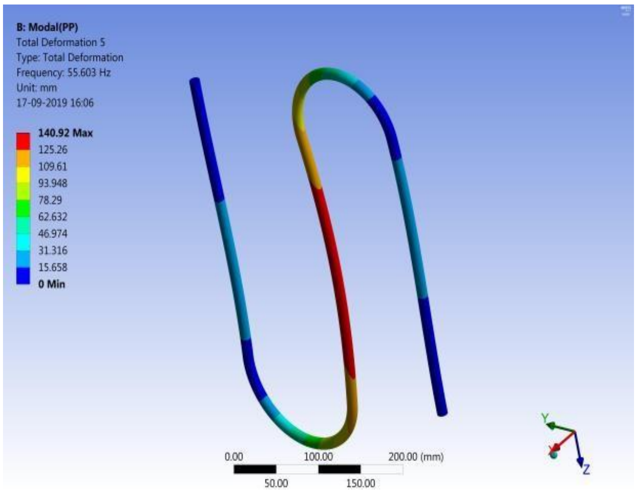

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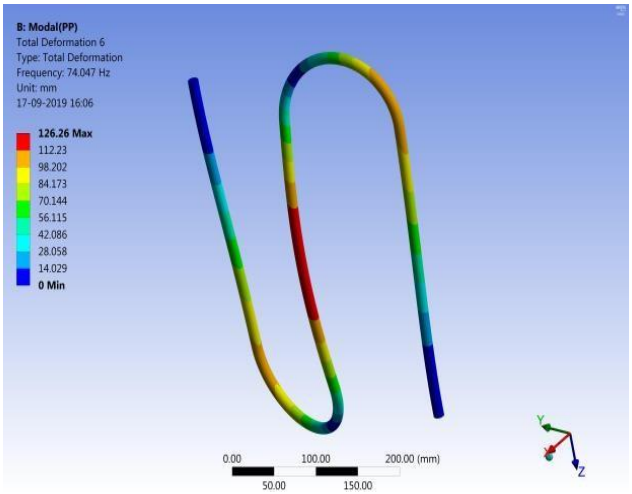

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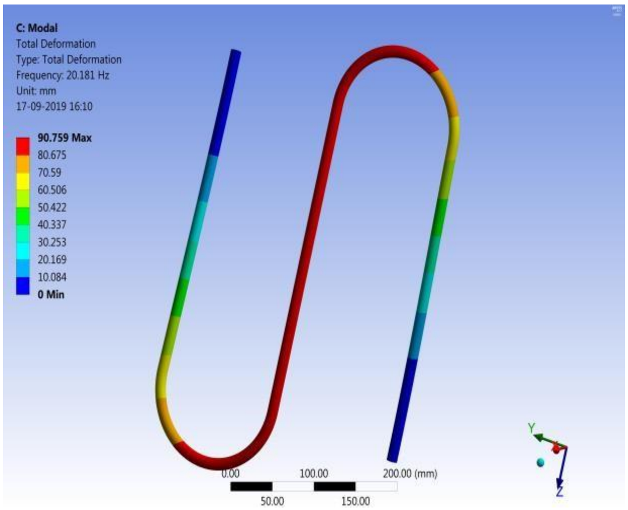
Fig.4. Six mode shapes for PP



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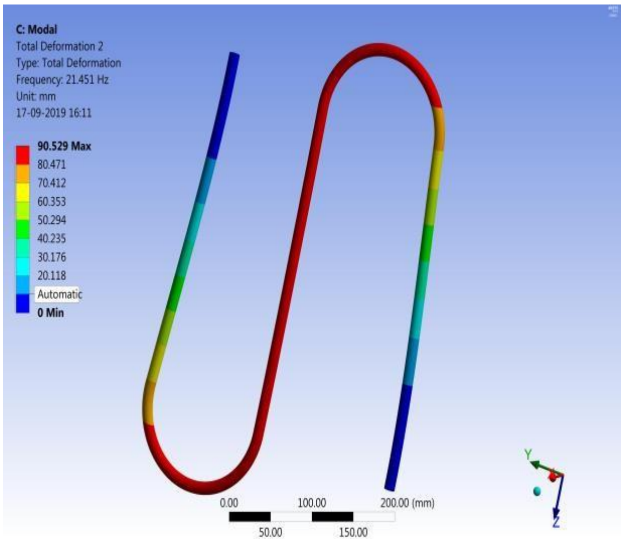

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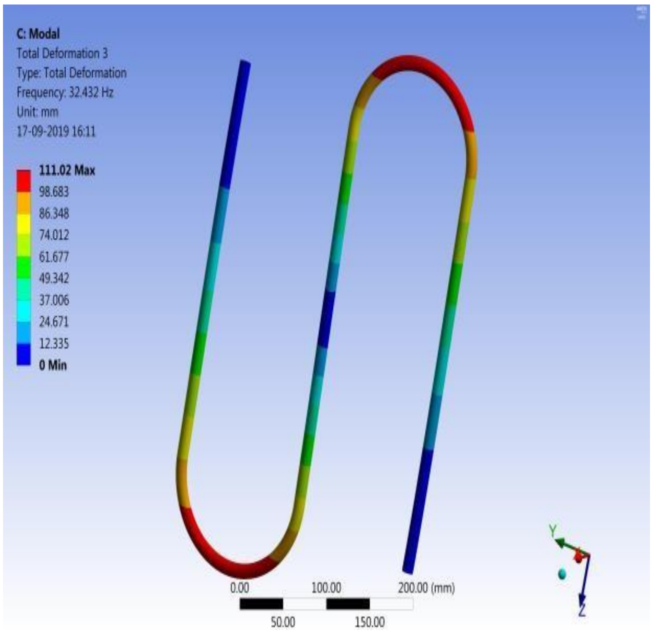

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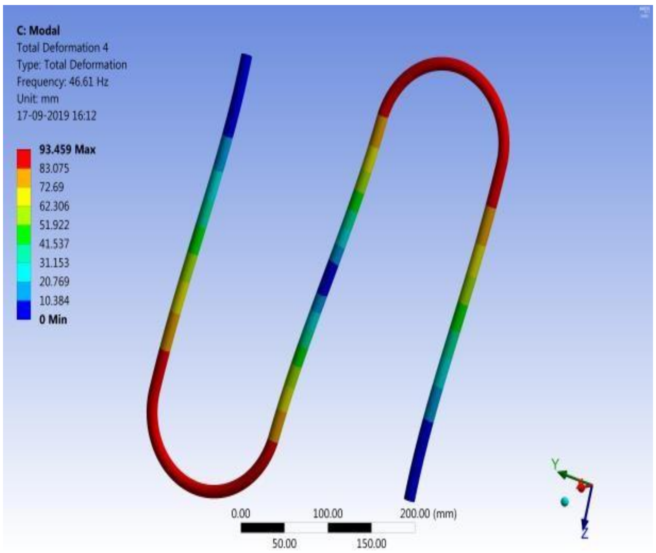

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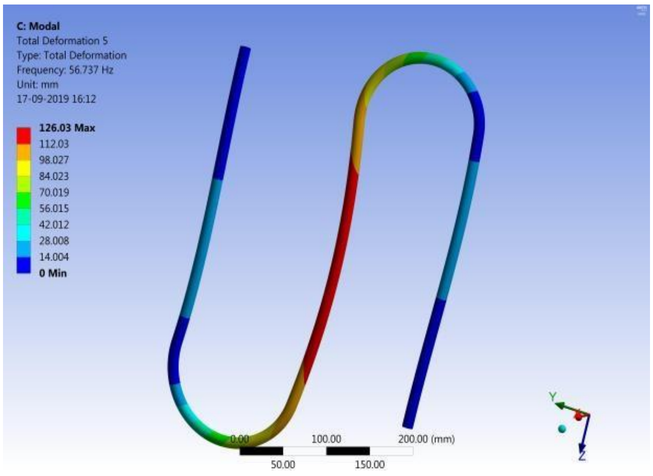

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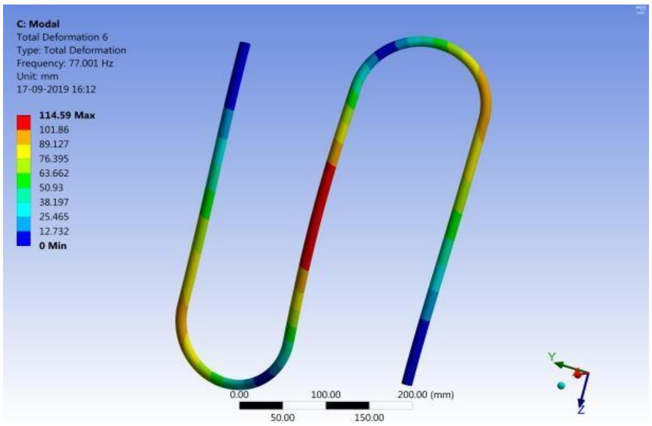

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Fig. 5. Six mode shapes for PVDF.

The modal analysis results completes the initial step of determining the natural frequency of the tube. The frequency of tube determined helps in calculating the displacement that is to be given to the tube for further analysis. The mode shape results obtained are useful in assuming the optimized position for sensors.

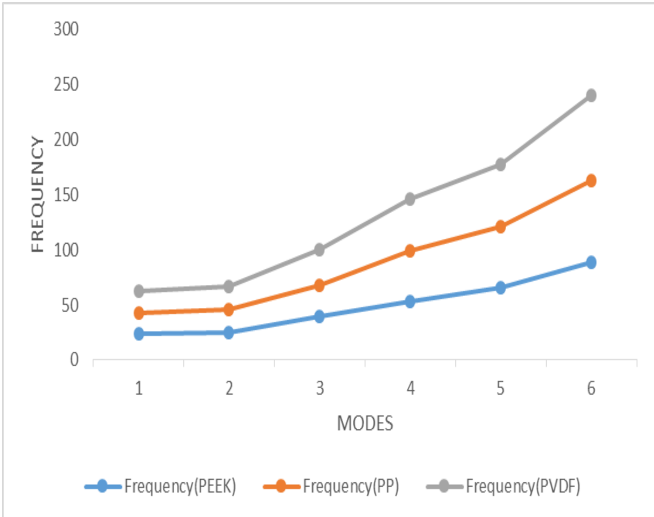

Fig. 6. Frequency variation for three disposable tube materials.

VI. CONCLUSION

Modelling of S configuration tubes is done in Catia v5 and Finite Element Analysis for two twin S profile is performed in Ansys to assay the fundamental frequency and mode shape results for each tube. The frequency is measured in Hz. Resonant frequency is 23.47 Hz for PEEK, 19.35 Hz for PP and 20.18 Hz for PVDF. By calculating the resonant frequency of the tubes, the initial step for this research has been completed. In future the results achieved in this analysis can be used for simulation as well as for experimental process to be carried out for Coriolis mass flow sensor under varying sensor positions and mass flow rate.

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