

Omega Design and FEA Based Coriolis Mass Flow Sensor (CMFS) Analysis Using Titanium Material

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Abstract. The main highlight of this research work is evaluation of resonant frequency for titanium omega type coriolis mass flow sensor. Coriolis mass flow sensor is used for measuring direct mass flow in pipe useful for various industrial applications. It works on the principle of Coriolis effect. Finite Element Analysis (FEA) simulation of omega flow sensor was performed using Ansys 14.5 and Solid Edge, Pro-E was used for modelling of omega tube. Titanium was selected as omega tube material. Experimental setup was prepared for omega tube coriolis flow sensor for performing different test. Experimental setup was used for investigation of different parameters effect on CMFS and validation of simulation results.

Keywords: Omega Tube, CMFS, FEA, Titanium, Coriolis Effect.

1. Introduction

These In practice, Coriolis type sensors are used in continuous process and parallel pipes in plant pipe systems. Coriolis mass flow sensor (CMFS) has various applications in engineering field [1-3]. S.C. Sharma [1] has performed analysis on U type copper tube and checked performance of CMFS. Pravin Patil [2] has performed optimisation of copper omega type CMFS. For optimisation they have used response surface method (RSM). ANFIS advanced tools were also used for performance evaluation of omega tube [3]. Fluid carrying tube with omega shape has been analysed. Tube vibrates at its fundamental frequency. Flowing fluid inside tube apply forces on tube walls due to this mode shape changes [4]. Anklin has performed literature survey of past studies in field of CMFS [5 & 8]. Coupled fluid structure model was studied [6, 7 & 10] for advanced development in CMFS. Advanced coriolis mass flow sensors are independent of viscosity and density of flowing fluids.



For performing FEA simulation of omega tube fixed constraint based boundary conditions were developed in Ansys. Ashwani kumar [9 & 11] has performed the constraint based analysis on transmission gearbox using FEA. Many Authors have numerically investigated working method of Coriolis flow sensors. In coriolis flow sensors there are no moving parts only fluid carrying flow tube vibrates with small amplitude [14].

Pravin Patil [15] has investigated material properties effect on Electromechanical Mass flow sensor (EMMFS) using ANFS modelling tool. To determine resonant frequency of coriolis flow tube in meso and micro level FEA simulation was performed [18]. Fixed constraint based studies using FEA simulation is currently used for heavy vehicle dynamics analysis [16, 17 & 19]. Finite Element Analysis (FEA) is an advanced technique used for complex geometry analysis. Artificial Neural Network (ANN) based model was developed for copper type CMFS.

2. FEA and Experimental Setup

Performing modal analysis of the measuring tube subjected to the physical boundary constraints is the first step of the simulation scheme. The only purpose being to ascertain the natural frequency of the tube, as in the Coriolis sensor the tube is to be vibrated in its first mode of vibration. Also, it provides estimation for the experimentation phase to expect Coriolis action generation around the evaluated frequency. Therefore, modal analysis is performed using finite element code ANSYS [12] for all tube configurations and results are tabled. The foundation of test rig was prepared using rubbers pad to provide the passive isolation.



(a) Model of Omega Configuration (40x40)

(b) Mesh model of omega tube

Figure 1 Omega tube configuration and FEA meshed model.

The actual photograph of the experimental test rig is shown in figure 2. It consists of the functional elements like, Hydraulic bench, excitation system. An excitation system consists of shaker, CU (control units), Accelerometer and Vibration Sensor. Working fluid (Water) mechanical properties are Density 1000 Kg/m³, Young's Modulus 1.32e7 Pa, Poisson's Ratio 0.499, Bulk Modulus 2.2e9 Pa and Shear Modulus 4.4029 e6. Omega titanium tube Properties are Density 4620 Kg/m³, Young's Modulus 9.6 e10 Pa, Poisson's Ratio 0.36, Bulk Modulus 1.1429 e11 Pa and Shear Modulus 3.5294 e10.

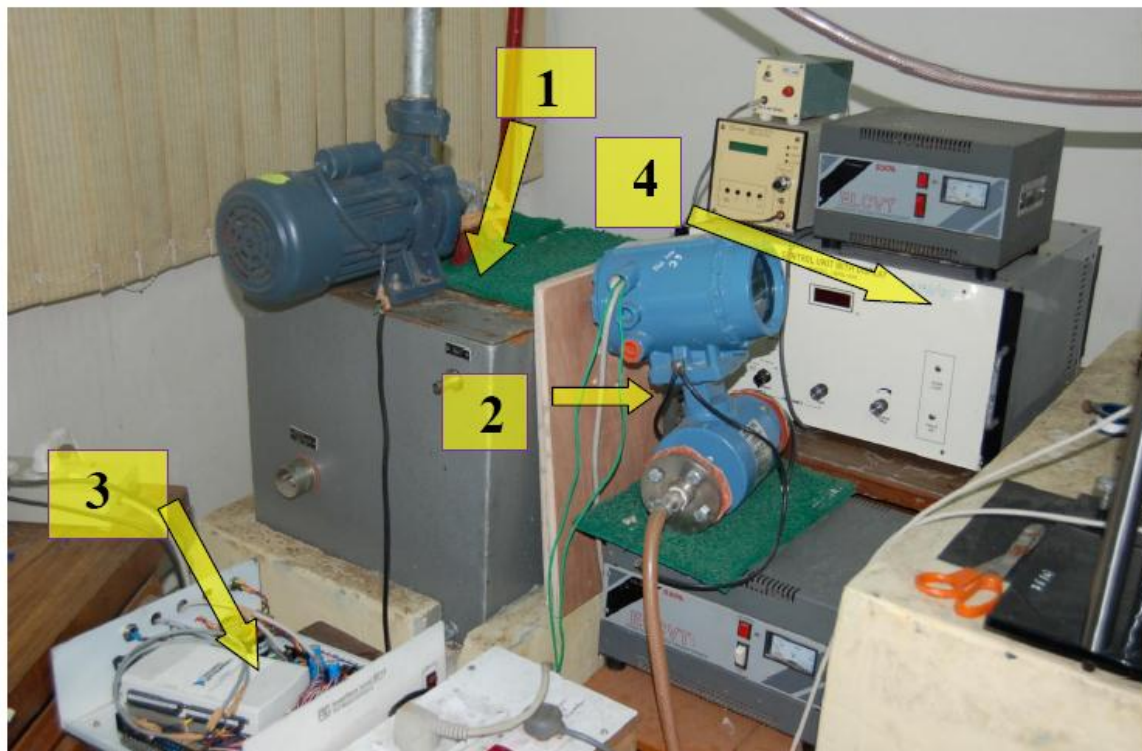


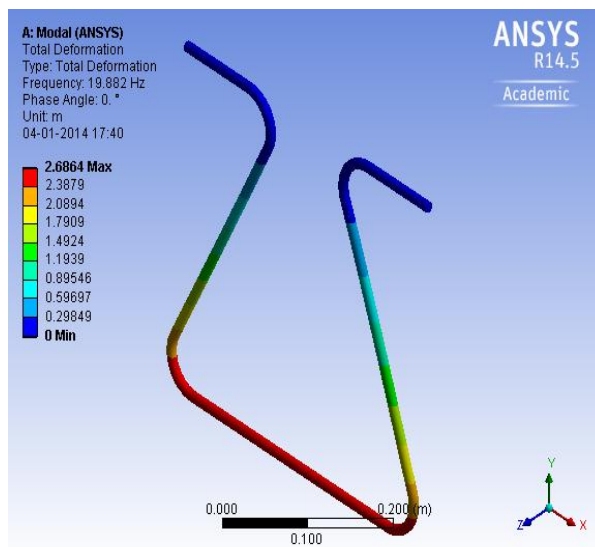
Figure 2 Experimental arrangements for CMFS.

3. FEA Results

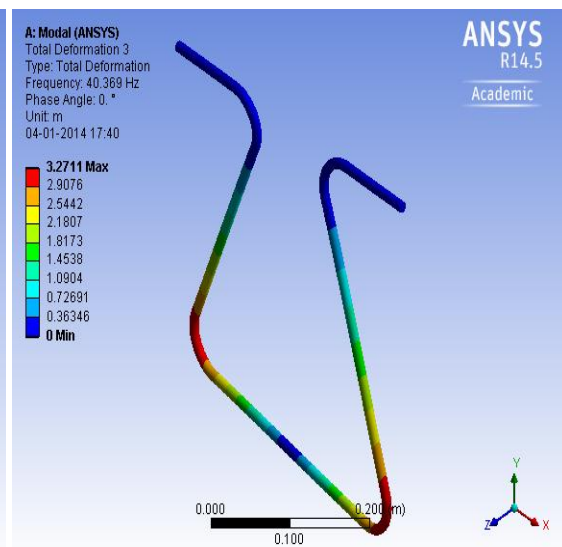
In this study titanium omega tube type flow sensors was designed and analysed using FEA simulation method. Table 1 shows natural frequency variation for Coriolis flow sensor. In modal analysis, first natural frequency is known as fundamental frequency. It is resonance frequency for empty omega tube. The first six-mode shape of vibration under empty condition with fluid is shown in figure 3. Fundamental frequency is 19.882 Hz and highest frequency is 330.56 Hz. Table 1 shows the frequency variation for omega tube Coriolis flow sensor with fluid condition. In comparison, it was found that increased height and width of tube causes higher fundamental frequency. Fundamental frequency increases by 2.5 times in comparison to earlier titanium tube flow sensor (40x40) cm. Figure 4 shows the frequency variation for omega tube with vibration mode.

Table 1 Natural frequency for Omega Tube configuration

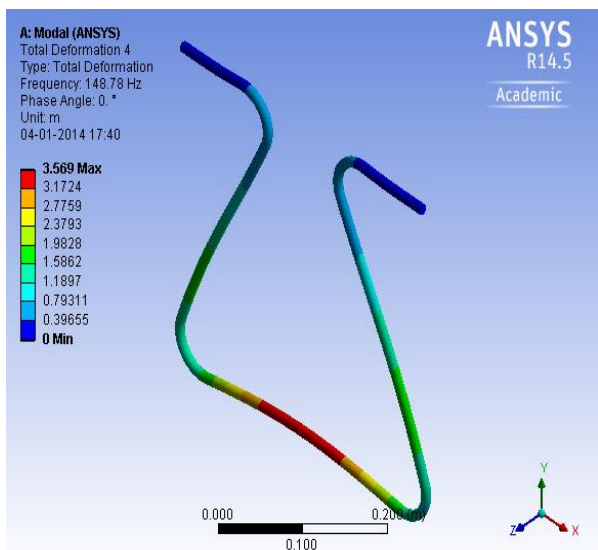
Frequency Variation (Hz)	
Mode	Frequency (Hz) Titanium Omega Tube (With Fluid: 40x40)
1.	19.882
2.	25.443
3.	40.369
4.	148.78
5.	154.74
6.	176.78



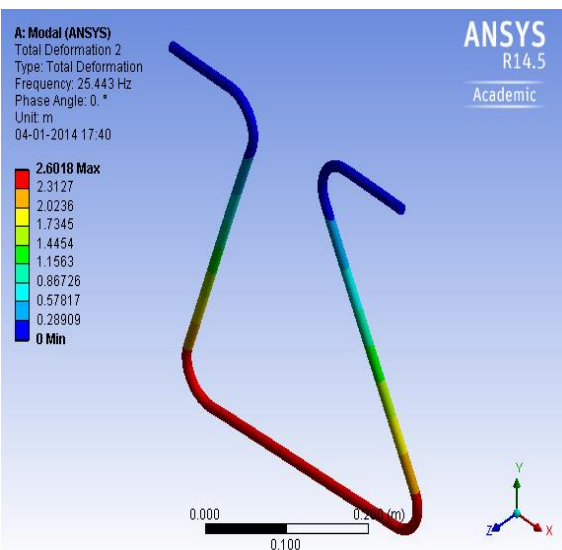
Mode 1 $f_1=19.882$ Hz



Mode 2 $f_2=25.443$ Hz



Mode 3 $f_3=40.369$ Hz



Mode 4 $f_4=148.78$ Hz

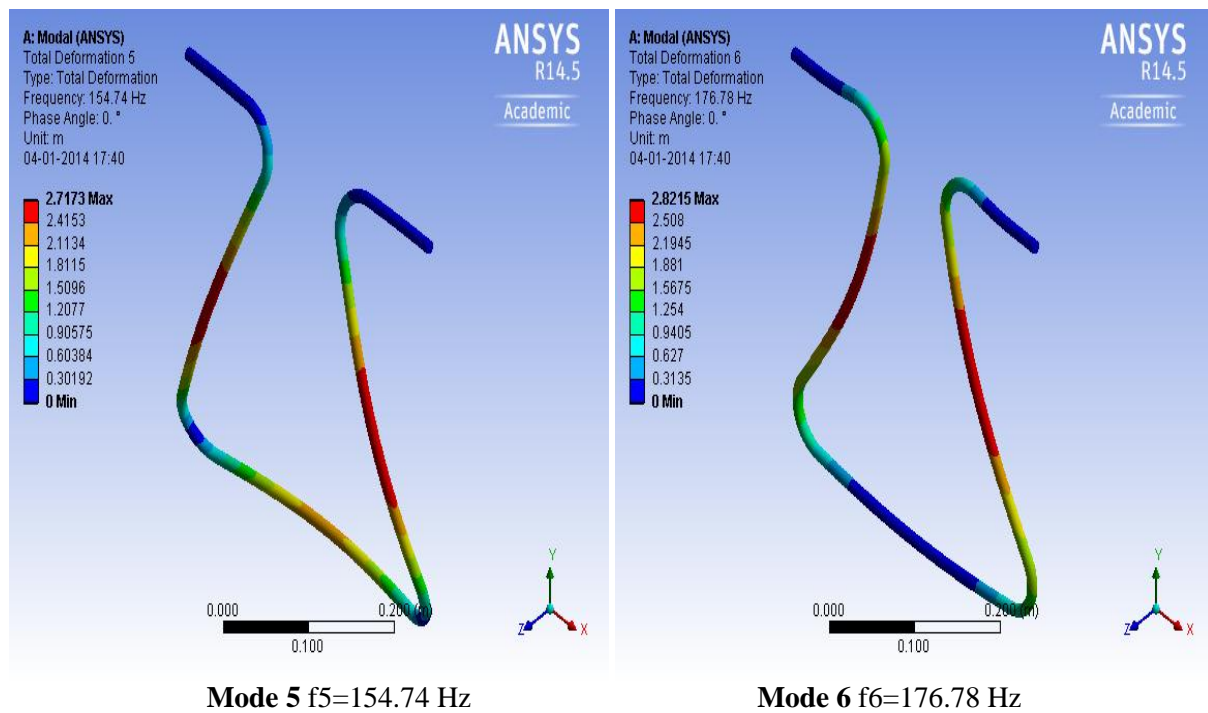


Figure 3 Frequency and mode shape variation.

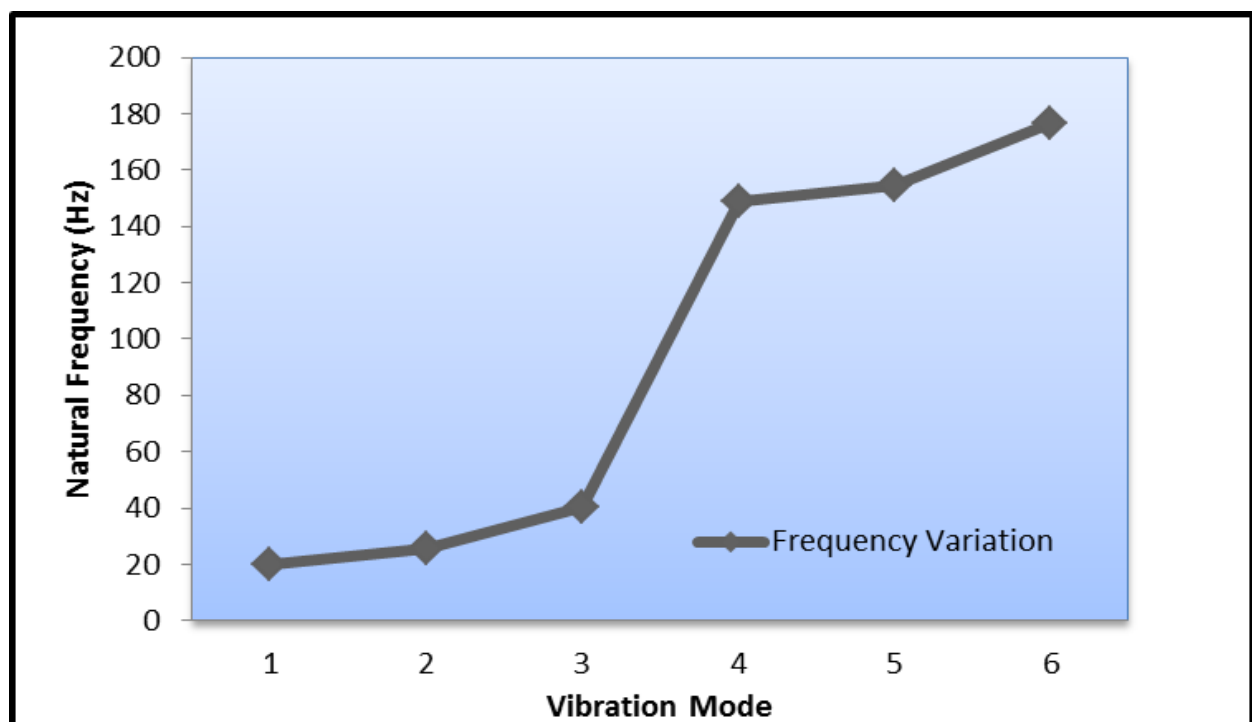


Figure 4 Frequency variation graph.

4. Conclusion

Solid Edge and Pro-E has been used for modelling of omega tube. Ansys has been used for FEA analysis. FEA based modal analysis of titanium omega tube was performed for omega tube to evaluate vibrating frequencies and mode shapes. The resonant frequency was measured in Hz. For titanium omega tube dimension (40x40) c.m. was selected. For this resonant frequency is 19.882 Hz. Others 5 natural frequencies are 25.443 Hz, 40.369 Hz, 148.78 Hz, 154.74 Hz and 176.78 Hz. By evaluating fundamental frequency the first step of this research work has been completed. Next step is to perform experimental simulation corresponding fundamental frequency at 19.882 Hz. In future this research work can be extended for experimental analysis of Coriolis flow sensor under sensor location variation and mass flow rate variation.

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