IJCTA, 9(40), 2017, pp. 383-387 ISSN: 0974-5572

Design and FEA Simulation of Omega Type Coriolis Mass Flow Sensor

Pravin Patil*, Ashwani Kumar*, Sourabh Kumar* and Faraz Ahmad*

ABSTRACT

The main objective of this research article is to investigate omegatype, Coriolis Mass Flow Sensor (CMFS) for evaluatingresonant frequency. Modelling of CMFS can be split into two domains- structural and fluid. The omega shaped tube, forming the structural part and the fluid flowing through it, being modeled as a string and composing the fluid domain.Omega tube is clamped at both ends and vibrates in the x–z plane on its fundamental natural frequency. The measuring characteristic of the mass flow rate is phase shift, which is experienced in the motion of sensing points that are located symmetrically at the two limbs of the tube.Frequency response of omega type CMFS resonant frequency with water was investigated. Simulation of CMFS has been done using Ansys 14.5.Copper is selected as omega tube material and water as working fluid.

Keywords: Coriolis Effect, Sensor,Natural Frequency, Excitation, FEA.

1. INTRODUCTION

Artificial Neural Network (ANN) is new field of engineering analysis. Now days it has been applied for different engineering problems[1-3]. In this research article, 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]. Advanced coriolis mass flow sensors are independent of viscosity and density of flowing fluids. During flow inside tube generated velocity profile and obtained Reynolds number of the flow does not affect the flow meter as compared to others conventional flow meters based on volume measurements [5]. Coriolis flowmeter is also used for measuring fluid density by measuring change in natural frequency [6].Many Authors have numerically investigated working method of Coriolis flow meters. In coriolis flow meters there are no moving parts only fluid carrying flow tube vibrates with small amplitude [7-11].

Artificial Neural Network (ANN) based model was developed for copper type CMFS [14]. The developed model has been found in agreement with experimental setup model. Modelling of CMFS using Adaptive neuro-fuzzy inference system (ANFIS)has been studied [15] to check the influence of material. The input parameters are tube material, drive frequency, sensor location and height of tube. Using various parameters performance of mass flow sensor has been predicted. Material influence is an important criterion to check the structural rigidity and performance. Material based free vibration analysis was performed for transmission system using FEA [16]. [21, 24 & 25] Author has used Fuzzy interference system tools for comparison of texture and CMFS study. Coriolis effect and new straight coriolis flow meter has been investigated by researcher [22 & 23] for further development.

2. EXPERIMENTAL ARRANGEMENTS

Using theory of Coriolis phenomenon an experimental setup was prepared. Simulation and experimental investigation of coriolis mass flow sensor (CMFS) is required for direct mass

* Department of Mechanical Engineering, Graphic Era University, Dehradun-248002 India, *Emails: Pravinppatil2004@gmail.com, kumarashwani.geu@gmail.com*

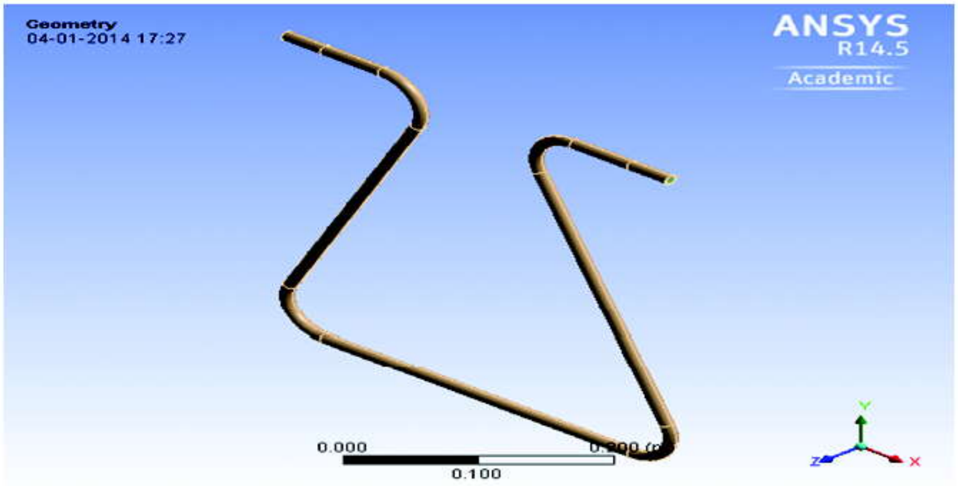


Figure1: Copper Omega tube model.

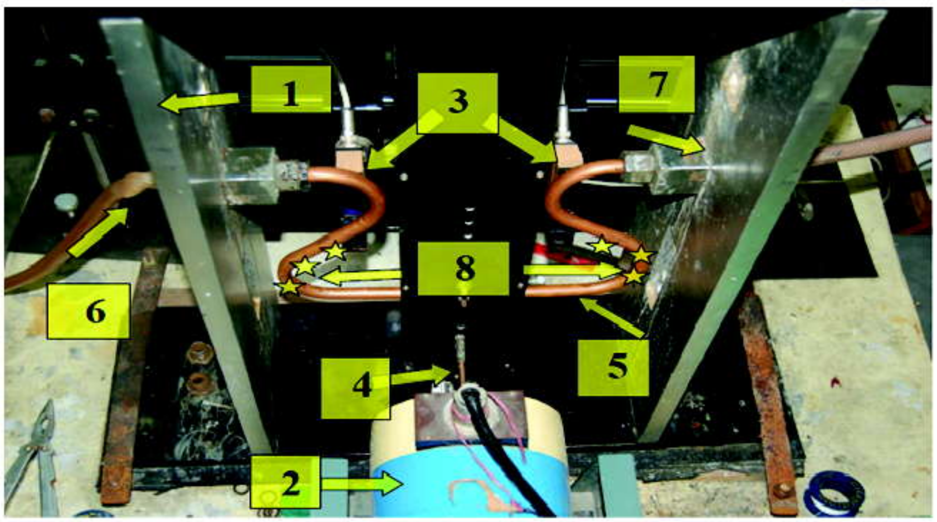


Figure 2: Experimental test rig of Copper omega tube.

measurement.The operating test conditions are finalized and listed along with the identification of natural mode shapes for various tube configurations and materials using finite element code ANSYS [12]. Figure 1 shows the geometry model of omega tube. Geometry of omega tube is prepared using hollow tubes with specific dimensions. FEA meshed model of Cu tube consists of 6497 nodes and 1080 elements.

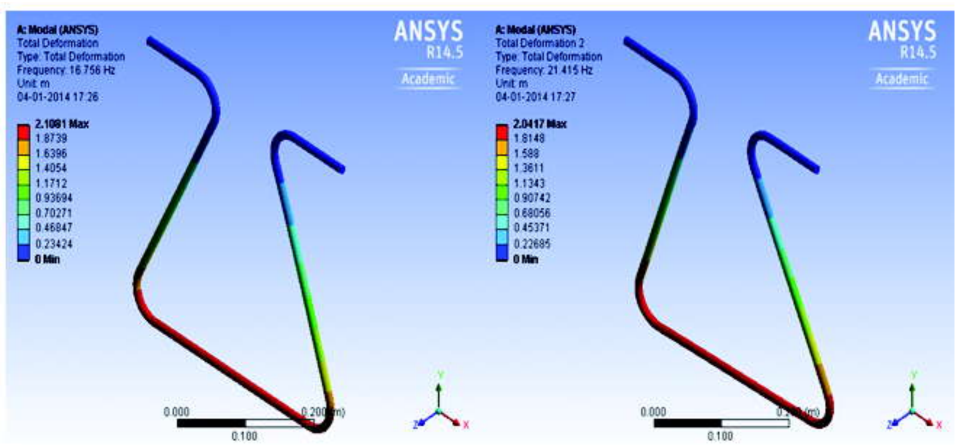
Figure 2 shows experimental set up which was designed using Pro-E [13].The actual photographs of the experimental test rig are shown in figure 2. It consist of the functional elements like, Hydraulic bench (It provides continues water supply to flow meter), test bench(supporting element-used for tubes support). Mechanical excitation was provided to the flow meter using excitation system. An excitation system consists of shaker, CU (control units), Accelerometer and Vibration Meter. Optical Sensors were used for motion sensing. It eliminates the surroundings disturbance and humidity, oil. Working fluid (Water) mechanical properties are Density 1000 Kg/m^{3},Young's Modulus 1.32e7 Pa, Poisson's Ratio 0.499, Bulk Modulus 2.2e9 Pa and Shear Modulus 4.4029 e6. Omega copper tube Properties are Density 8950 Kg/m^{3}, Young's Modulus 1.1e11 Pa, Poisson's Ratio 0.34, Bulk Modulus 1.145 e11 Pa and Shear Modulus 4.1045 e10. Omega tube of Coriolis mass flow sensors has dual functions that impose conflicting requirements.

3. FEA SIMULATION RESULTS

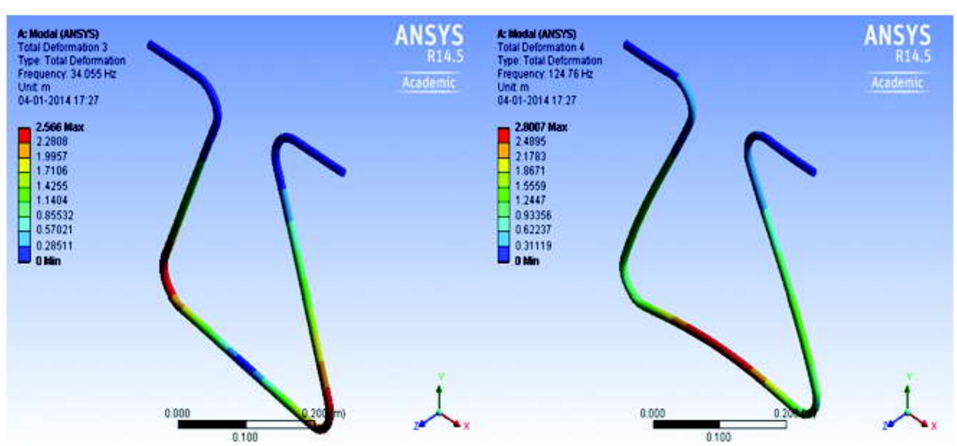
In this research article Modal analysis serve as starting point for detailed dynamic analysis of CMFS. In dynamic harmonic or transient analysis can be performed on omega type CMFS. The output of Modal analysis is modal frequency (natural frequency) and mode shapes. These two parameters serve as important criteria in design of structure subjected to dynamic loading conditions.Varieties of tube designs are currently available like U tube flow meters. In this research article omega tube typeCMFS was designed and analysed. Table 1 shows the frequency variation for omega tube Coriolis mass flow sensor.

Table 1
Natural Frequencies for Omega Tube Configurations

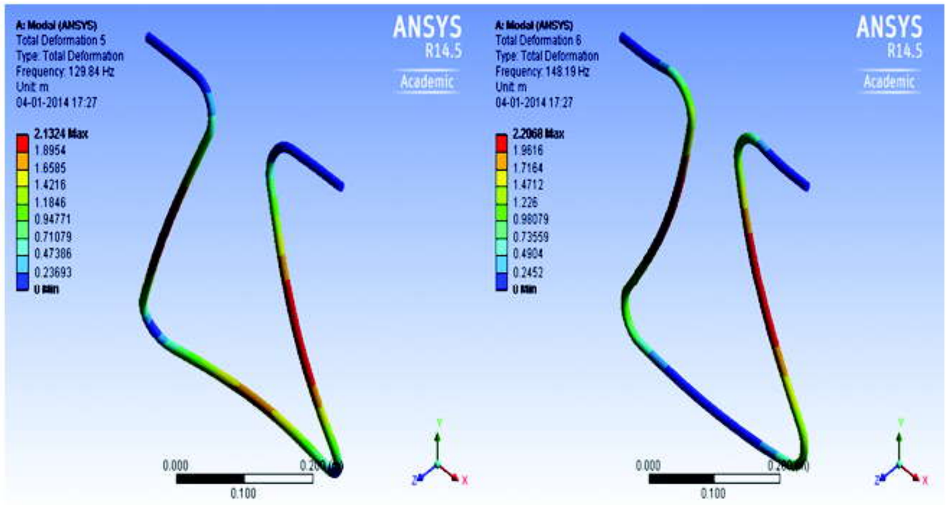
	Cu Omega Tube Frequency Variation (Hz)
Mode	*Frequency*
1	16.756
2	21.415
3	34.055
4	124.76
5	129.84
6	148.19



Mode 1 f1=16.756 Hz Mode 2 f2=21.415 Hz



Mode 3 f3=34.055Hz Mode 4 f4 =124.76 Hz



Mode 5 f5=129.84 Hz Mode 6 f6=148.19 Hz

Figure 3: Frequency and mode shape variation for omega type CMFS with fluid

Table 1 shows the frequency variation for omega tube CMFS with fluid condition. Figure 3 shows frequency and mode shape representation. Using mode shapes in different condition, deformations level can be predicted. The fundamental frequency is 16.756 Hz.

4. CONCLUSIONS

FEA based modal analysis of omega type CMFS was performed for fluid and without fluid condition. The aim of the research work has been achieved by measuring resonant frequency. The resonant frequency is 16.756 Hz. Other natural frequencies are 21.415 Hz, 34.055 Hz, 124.76 Hz, 129.84 Hz and 148.19 Hz. Obtained fundamental frequency will be used for excitation of CMFS. In future this research work can be extended for experimental analysis of vibration pattern for omega type Coriolis mass flow sensor under resonant frequency.

ACKNOWLEDGEMENT

Authors are thankful to Department of Science and Technology (DST, New Delhi) for necessary funding of this project.

REFERENCES

[1] Sharma Satish C. , Pravin P. Patil , Major Ashish Vasudev, S. C. Jain, Performance Evaluation of an Indigenously Designed Copper (U)tube Coriolis Mass flow sensors, Measurement, 43(9) (2010) pp. 1165-1172.

[2] Pravin PPatil, Satish C. Sharma, S.C. Jain, Response surface modelling of vibrating omega tube (Copper) Electromechanical Coriolis mass flow sensor, Expert Systems With Applications , 39 (4) (2012) pp. 4418 – 4426.

[3] Pravin PPatil, Satish C. Sharma, S.C. Jain, Performance evaluation of a Copper omega type Coriolis Mass Flow Sensor with an aid of ANFIS tool, Expert Systems with Applications, 39 (5) (2012), pp. 5019-5024.

[4] R. Cheesewright, A. Belhadj and C. Clark, "Effect of mechanical vibrations on Coriolis mass flow meters", Journal of Dynamic Systems, Measurement, and Control, 125 (2003), pp. 103–113.

[5] Anklin M, Drahm W, Rieder A., Coriolis mass flow meters: Overview of the current state of the art and latest research, Flow Measurementand Instrumentation, 17 (6) (2006), pp. 317-23.

[6] G. Bobovnik,N. Mole, J. Kutina, B. Stok, I. Bajsic, Coupled finite-volume/finite-element modellingof the straight-tube Coriolis flowmeter, Journal of Fluids and Structures 20 (2005), pp. 785–800.

[7] N. Mole , G. Bobovnik,J. Kutina, B. Stok, I. Bajsic, An improved three-dimensional coupled fluid–structure model for Coriolis flowmeters, Journal of Fluids and Structures 24 (2008), pp. 559–575.

[8] Tao Wang, Roger Baker, Coriolis flowmwters: A review of developments over the past 20 years and an assessment of the state of the art and likely future directions, Flow Measurement and Instrumentation 40 (2014),pp. 99-123.

[9] 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, Middle-East Journal of Scientific Research 23 (Sensing, Signal Processing and Security): 23 (2015) pp. 239-242,ISSN 1990-9233. DOI: 10.5829/idosi.mejsr.2015.23.ssps.101.

[10] LuoRongmo, Wu Jian, Fluid-structure coupling analysis and simulation of viscosity effecton Coriolis mass flowmeter, APCOM & ISCM11-14th December, 2013, Singapore.

[11] SiavashHooshmandzadeh, Simulation a disposable mass flow meter by an advanced FSI modeling and finite element analysis, Master's Degree Thesis, ISRN: BTH-AMT-EX—2015/D02—SE, Department of Mechanical EngineeringBlekinge Institute of TechnologyKarlskrona, Sweden2015.

[12] Ansys R 14.5, Structural Analysis guide 2015.

[13] Pro-E 5.0, Designing manual, 2013.

[14] Pravin PPatil, Satish C. Sharma, Vipul Paliwal, Ashwani Kumar,ANN Modelling of Cu Type Omega Vibration Based Mass Flow Sensor, Procedia Technology, 14 (2014), pp. 260-265.

[15] Pravin PPatil, Satish C. Sharma, Himanshu Jaiswal, Ashwani Kumar,Modeling Influence of Tube material on vibration Based EMMFS using ANFIS, Procedia Material Science, 6 (2014), pp. 1097-1103.

[16] Ashwani kumar, Arpit Dwivedi, Himanshu Jaiswal, Pravin P Patil, Material based Vibration Characteristic Analysis of Heavy Vehicle Transmission Gearbox Casing using Finite Element Analysis, Advances in Intelligent Systems and Computing, 308 (2015), pp. 527–533. Doi:10.1007/978-81-322-2012-1_56.

[17] Chester M. Neural networks—a tutorial. Englewood Cliffs, NJ: Prentice Hall, 1993.

[18] Rumelhart D, Hinton G, Williams R. Parallel distributed processing. Cambridge, MA: MIT Press, 1986.

[19] Richard W. Miller, "Flow Measurement Engineering Handbook", third ed., McGraw-Hill International Edition, 1996.

[20] Neural Network Toolbox User's Guide of MATLAB 8.0, The Math Works Company, Natick, MA, 2010.

[21] E. Avci,. Comparison of wavelet families for texture classification by using wavelet packet entropy adaptive network based fuzzy inferencesystem. Applied Soft Computing, 8 (2008), pp. 225–231.

[22] F. Cascetta, SD Valle, AR Guido, S. Pagano, P. Vigo. A new straight-pipe Coriolis mass flow meter: The mathematical model.Measurement 9 (1991), 115-23.

[23] H. Raszillier, F. Durst. Coriolis effect in mass flow metering. Archive of Applied Mechanics 61 (1991), pp. 192-214.

[24] L.C. Ying, M.C. Pan. Using adaptive network based fuzzy inference system to forecast regional electricity loads. Energy Conversationand Management 49 (2008), pp. 205–211.

[25] J.S.R Jang. ANFIS: Adaptive Network-Based Fuzzy Inference System. IEEE Trans. Syst. Man Cybern 23 (1993), pp. 665–685.