Research Progress in Mechanical and Manufacturing Engineering Vol. 3 No. 1 (2022) 298-305

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Flow Induced Vibration of Simply Supported Cantilever Beam Based On One-Way Fluid Structure Interaction

Nazren Al Nazirul Mohamad Faizal[1], Izzuddin Zaman[1]*

[1]Department of Engineering Mechanics, Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2022.03.01.031
Received 15 Nov. 2021; Accepted 15 April 2022; Available online 30 July 2022

Abstract: Vibration problems occur in many structural buildings and piping systems as a result of fluid flow. This is because fluid flow is an energy source that capable of generating structural and mechanical oscillations. The most accurate description to describe this interaction between the fluid's dynamic forces and elastic forces of a structure is flow-induced vibration. In these study, a flow-induced vibration of simply supported cantilever beam was investigated based on one-way fluid structure interaction (FSI). Ansys Workbench was used to simulate the dynamic behaviour of the beam when subjected to air flow. There are two beam angle positions analysed at 60° and 90° vertically, where each beam was exposed to two different fluid flow rates of 10 and 15 m/s. Transient structural, modal analysis, harmonic analysis and fluid fluent were among the analyses used in the study. Simulation results show that the overall value of a 90° beam orientation in fluid pressure, velocity, total deformation, von-mises stress, and frequency response is higher than a 60° beam orientation. This shows that beam orientation significantly affects vibration level. Higher vibration levels also affect fluid flow speed and type. As the surface area of the beam struck by the fluid flow increases, so will the overall value of the beam's fluid pressure, velocity, total deformation, Von-Mises stress, and frequency response. In this case, the 90° beam orientation has more surface area where the fluid flow strikes than the 60° beam orientation.

Keywords: Fluid Structure Interaction, Flow Induced Vibration, Beam, Vibrations

1. Introduction

Flow-induced vibrations, abbreviated as FIV, are the dynamic behavior of structures immersed in or conveying fluid flow. Fluid flow is a source of energy that can cause structural and mechanical oscillations. Flow-induced vibrations are the most accurate depiction of the interaction of a fluid's dynamic forces with a structure's inertial, damping, and elastic forces. It can happen in a structural

**Corresponding author: izzuddin@uthm.edu.my*

building or in high-speed turbulent fluid pipe configurations. Flow-induced vibration occurs and affects a wide range of engineering applications, including bridge decks and skyscrapers.

A cantilever beam is a rigid structural element that is supported at one end and has free ends. The cantilever beam can be made of either concrete or steel, with one end attached to a vertical support. A variety of engineering applications use this basic mechanical structure. The cantilever beam deflects because it is supported on just one end. The primary focus of this research is on the simulation analysis of one-way fluid-structure interaction and the effect of different fluid flow velocities on the angle placement of a simply supported cantilever beam.

2. Materials and Methods

Methodology is a section that describes the stages of work that must be completed or used to complete a project or research in order to collect the necessary data.

2.1 Materials

Aluminum Alloy was chosen as the beam material for this study. The materials' specifications and properties are depicted in the table below.

Table 1: Properties material of aluminum alloy

Specification	SI/Metric Unit
Density	2770 kg/m^3
Young’s Modulus	7.1×10^7 Pa
Poisson ratio	0.33
Bulk Modulus	6.9608×10^{10} Pa
Shear Modulus	2.6692×10^{10} Pa

2.2 Models Preparation

Procedures can be described using flowcharts and algorithms. Include the appropriate references to standards. Authors can also explain the scope and limitations of the methods.

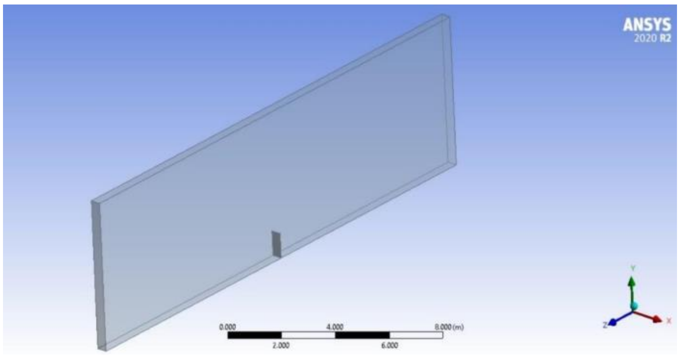

Figure 2: Overall configuration for 90° beam orientation in an enclosure

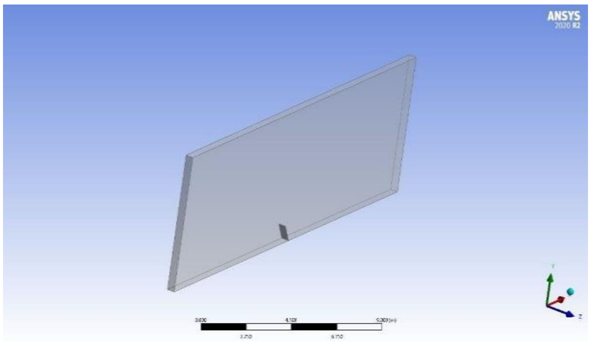

Figure 3: Overall configuration for 60° beam orientation in an enclosure

2.3 Ansys Simulation

Four tools were used to conduct the analysis in Ansys simulation: Transient Structural Analysis, Fluent Analysis, System Coupling Analysis, and Modal Analysis. All of these analyses were carried out in order to meet the study's objectives. The four major types of measurement systems used to achieve results are depicted in Figure 4.

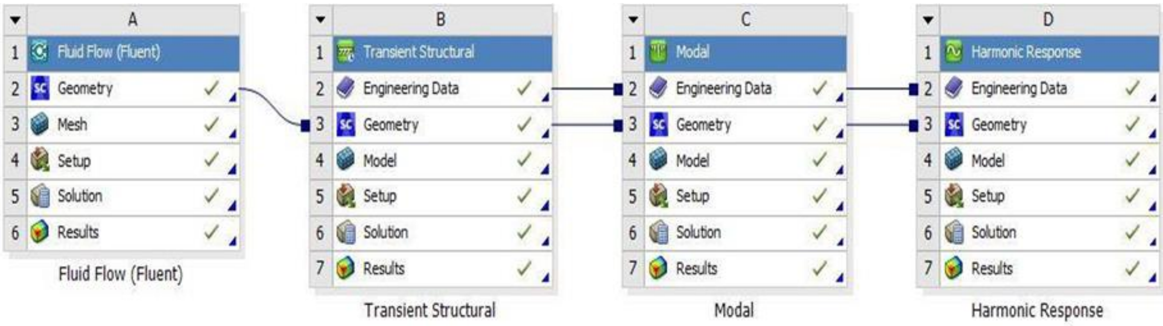

Figure 4: Four major types of measurement systems

3. Results and Discussion

3.1 Results

The table below summarizes the fluid pressure, velocity, total deformation, and Von-Mises stress for both beam orientations and speeds. The frequency response for both beam orientations at both speeds is depicted in the figure 4 and 5.

Table 1: Fluid pressure comparison for both beam orientation and speed

Beam Orientation	Maximum pressure of fluid (Pa)		Minimum pressure of fluid (Pa)	
	10 m/s	15 m/s	10 m/s	15 m/s
90°	7.409e+01	1.456e+02	-4.002e+02	-8.757e+02
60°	7.277e+01	1.607e+02	-3.562e+02	-7.642e+02

Table 2: Velocity Comparison both beam orientation and speed

Beam Orientation	Maximum velocity of fluid (m/s)		Minimum velocity of fluid (m/s)	
	10 m/s	15 m/s	10 m/s	15 m/s
90°	2.118e+01	3.095e+01	0.000e+00	0.000e+00
60°	2.006e+01	2.953e+01	0.000e+00	0.000e+00

Table 3: Total deformation comparison for both beam and orientation

Beam Orientation	Maximum deformation (m)	
	10 m/s	15 m/s
90°	6.8674	15.451
60°	6.7449	14.888

Table 4: Von-Mises comparison for both beam orientation and speed

Beam Orientation	Maximum stress (Pa)		Minimum stress (Pa)	
	10 m/s	15 m/s	10 m/s	15 m/s
90°	6.2858	14.165	0.00036595	0.00093544
60°	6.1582	13.612	0.00040347	0.0010649

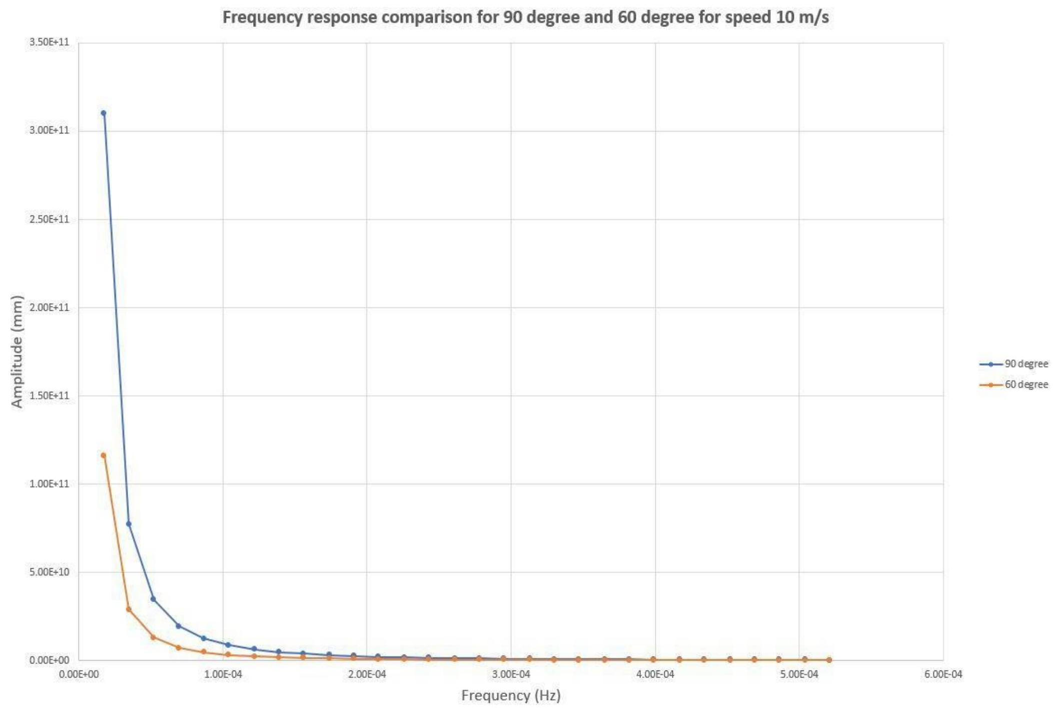

Figure 4: Frequency Response comparison for 60° and 90° for speed 10 m/s

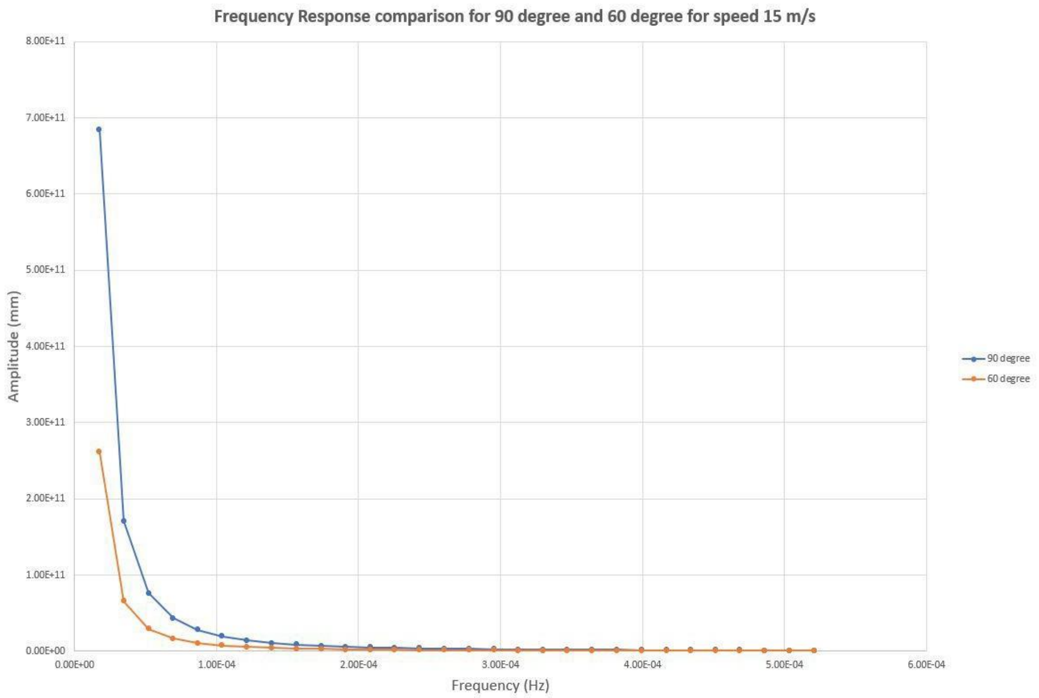

Figure 5: Frequency Response comparison for 60° and 90° for speed 15 m/s

3.2 Discussions

According to the table and figure above, 90° beam orientation has higher values for fluid pressure, velocity, total deformation, Von-Mises stress, and frequency response than 60° beam orientation for both fluid flow speed. This demonstrates that the value of surface area in contact with fluid flow is more likely to result in a higher vibration value.

4. Conclusion

According to result of the research, the 90° beam orientation has a higher rate of pressure dispersion than the 60° beam orientation. Furthermore, the total deformation under 90° beam orientation is greater than under 60° beam orientation due to orientation differences. This study's frequency response of the vibration level on the beam surface is in the frequency domain. The vibration level is significantly higher in the 90° beam orientation condition than in the 60° beam orientation condition, as can be seen. In a nutshell, these studies show that the fluid structure interaction of the beam is affected by its 90° and 60° orientations.

Acknowledgement

The authors wish to thank to the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia that has supported on the accomplishment of research activity.

References

[1] Audaa Jehhef, Kadhum & Abed Al Abas Siba, Mohamed. (2020). Experimental and Numerical Investigation of Vortex-Induced Vibrations and Pressure Drop in Square Pipe with Obstacle. Journal of Mechanical Engineering Research and Developments, 43(4), pp. 68 - 81

[2] Seyed-Aghazadeh, B, Samandari H, & Dulac S. (2020). Flow-induced vibration of inherently nonlinear structures with applications in energy harvesting. AIP Advances Fluids and Plasmas Collection, 32(20), pp. 1-7

[3] Tabatabei M, Eren T, Luo J, Mi S, & Temir G. (2020). Three-Dimensional Fluid– Structure Interaction Case Study on Elastic Beam. Marine Science and Engineering, pp. 1-21

[4] Bano T, Hegner F, Heinrich M, & Schwarze R. (2020). Investigation of Fluid-Structure Interaction Induced Bending for Elastic Flaps in a Cross Flow. Applied Science, pp. 1-19

[5] Dahmane M, Boutchicha D, & Adjlout L. (2016). One-way fluid structure interaction of pipe underflow with different boundary conditions. MECHANIKA, 22(6), pp. 495 - 503

[6] Eslami, Ghiyam, Vahed A, & Mousa R. (2016). Effect of Open Crack on Vibration Behavior of a Fluid-Conveying Pipe Embedded in a Visco-Elastic Medium. Latin American Journal of Solids and Structures, pp. 136 - 155

[7] Meng S, Kajiwara H, & Zhang W. (2017). Internal flow effect on the cross-flow vortex- induced vibration of a cantilevered pipe discharging fluid. Ocean Engineering, 137(17), pp. 120 - 128

[8] Yang W, Ai Z, Zhang X, Chang X, & Gou R. (2018). Nonlinear dynamics of three-dimensional vortex-induced vibration prediction model for a flexible fluid-conveying pipe. International Journal of Mechanical Sciences, 39(18), pp. 99 - 109

[9] Lyle E & Breaus P. (2020). Flow-Induced Vibration Problems in Process and Power Plants. Tech Brief, pp. 1-4

[10] Emmanuel M.B, Chang J, & Huang C. (2020). Flexible Plate in the Wake of a Square Cylinder for Piezoelectric Energy Harvesting Parametric Study Using Fluid–Structure Interaction Modeling. Energies, 13(20). Pp 1-29

[11] Micheal Yong P, Seung Eun J, Jae Young B, June Hoan B & Ga Eul J. (2012). Effect of Beam-Flow Angle on Velocity Measurement in Modern Doppler Ultrasound Systems. American Journal of Roentgenology, 8(11). Pp 1139-1143

[12] Zhao J, Sheridan J, Hourigan K, & Thompson M.C. (2019). Flow-induced vibration of a cube orientated at different incidence angles. Journal of Fluids and Structures, 91(19), pp.1-19

[13] Zhang X, Guowei H, & Zhang X. (2019). Fluid–structure interactions of single and dual wall-mounted 2D flexible filaments in a laminar boundary layer. Journal of Fluids and Structures, 92(20), pp 1-19

[14] Jang G, Chang M, & Gim H. (2013). Fluid–structure interaction of quasi-one- dimensional potential flow along channel bounded by symmetric cantilever beams. Journal of Fluids and Structures, 40(13), pp. 127-147

[15] Ni Q, Li M, Tang M, & Wang L. (2014). Free vibration and stability of a cantilever beam attached to an axially moving base immersed in fluid. Journal of Sound and Vibration, 333(14), pp 2543-2555

[16] Vaze M et al. (2016). Methodology Development for Wind Driven Cantilever Vibration Using ANSYS Fluent-Structural Interaction.

[17] Amir Hossein R. (2020). Two-degree-of-freedom flow-induced vibration suppression of a circular cylinder via externally forced rotational oscillations: comparison of active open-loop and closed-loop control systems. Journal of Brazilian Society of Mechanical Sciences and Engineering, 42(470), pp 1-15

[18] Sandeep P & M D Deshpande. (2004). The No-Slip Boundary Condition in Fluid Mechanics. Resonance, pp. 1 - 11

[19] Saeid S & Shams S. (2019). Vibration analysis of cantilever pipe conveying fluid under distributed random excitation. Journal of Fluids and Structures, 87(19), pp 84-101

[20] Anita A, Yahya M, & Rothstein J.P, (2020). Viscoelastic flow-induced oscillations of a cantilevered beam in the crossflow of a wormlike micelle solution. Journal of Non-Newtonian Fluid Mechanics, 286(20), pp 104-117

[21] Subekti, Kobayashi Y, Hoshino Y, & Emaru T. (2009). Identification of Nonlinearity of Flow-Induced Vibration for Structures Having Nonlinear Property by Using Wavelet Transform.

[22] Hossein Z & Narakorn S. (2016). Three-dimensional VIV prediction model for a long flexible cylinder with axial dynamics and mean drag magnification. Journal of Fluids and Structures, 66(16), pp. 127 - 146

[23] Yang W, Chang X, & Gou R. (2019). Nonlinear vortex-induced vibration dynamics of a flexible pipe conveying two-phase flow. Numerical Simulation and Novel Construction Methods in Oil and Gas Engineering, 11(10), pp. 1 - 9

[24] Zhou S, Zou Y, Hua X, & Liu Z. (2020). Comparison of Two-Dimensional and Three-Dimensional Responses for Vortex-Induced Vibrations of a Rectangular Prism. Applied Science, pp. 1-11

[25] Shifrin E & Lebedev L. (2020). Identification of multiple cracks in a beam by natural frequencies. European Journal of Mechanics/ A Solids

[26] Cen H. (2015). Flow-Induced Vibration of a flexible circular cylinder. University of Windsor: Master's Thesis

[27] Ramji K & Shyy W. (2005). Fluid-structure interaction for aeroelastic applications. Progress in Aerospace Sciences