

# Analysis of Two Phase Flow Induced Vibration in Piping Systems

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**Abstract** — Flow induced vibration with internal fluid flow for long slender cylindrical pipe conveying fluid is studied in this thesis. The fourth order partial differential equation of motion for lateral vibration is employed to develop the stiffness and inertia matrix corresponding to two of the terms of the equations of motion. The Equation of motion further includes a mixed-derivative term that was treated as a source for a dissipative function. Four type of boundary condition namely pinned-pinned, clamped-pinned, clamped-clamped and clamped-free were considered for the pipe. Analytical approach is used which are based on Galerkin's method to finding the natural frequency at different boundary conditions and velocities. Further, ANSYS 15.0 is used as a tool for computational analysis for different boundary conditions and velocities. A comparison are made between these two methods and evaluate the percentage error to check the accuracy of the solutions. Pipe buckling or divergence is observed by increasing the flow velocity of fluid for different boundary conditions. The velocity at which the buckling starts is called critical velocity and natural frequency is diminishes at the onset of divergence for pinned-pinned, clamped-pinned, clamped-clamped boundary conditions. But very little effect was observed for the velocity ranges used. The instability of pipe is planed-pinned, clamped-pinned, clamped-clamped boundary conditions are due to centrifugal forces in the pipe is observed. But, for clamped-free pipe the Coriolis component of force causes instability in pipe.

**Keywords**- cascade induced vibration; Mechanics of fluid; Momentum transfer; Slender cylindrical pipe; clamped free pipe.

## I. INTRODUCTION

**1.1 Overview of Internal Flow Induced Vibrations in Pipes** The vibration brought on by a liquid flowing in or around a body is known as Flow Induced Vibration (FIV). FIV best portray the cooperation that happens between the liquid's dynamic strengths and a structure's inertial, damping and flexible forces. The flow of a liquid through a pipe can force pressure on the walls of the pipe making it deflect under certain conditions. This deflection of the pipe may cause structural instability of the pipe. The fundamental natural frequency of a pipe for the most part reduces with increasing speed of liquid flow. There are sure situations where reduction in the natural frequency can be critical, for example, those utilized as a part of sustain lines to rocket engines and water turbines. The pipe ends up noticeably to resonance or fatigue failure if its natural frequency decreases up to certain limits. With expansive liquid speeds the pipe may become unstable. The most common type of this instability is the whipping of an unlimited garden hose. The investigation of dynamic reaction of a liquid passing on pipe in conjunction with the transient vibration of cracked pipes uncovers that if a pipe breaks through its cross area, then an adaptable length of unsupported pipe is left spewing out fluid and is allowed to whip about and affect different structures. In power plant plumbing pipe whip is one of probable condition for a failure of pipe. An investigation of the impact of the subsequent high speed liquid on the static and dynamic qualities of the pipe is accordingly vital.

**1.2 Classification Of Flow Induced Vibration** The classification of flow induced vibration is shown in the figure 1. The classification is categorize according to the type of flow:

1. Steady
2. Unsteady

In steady flow the vibration in pipes is due to two phenomenon. The first is instability and other is vortex induced. The instability in pipes occurs due to flutter, galloping and fluid elastic instability. Flutter basically occurs in pinned-pinned and pinned-clamped pipes. When fluid velocity reaches a critical velocity the buckling (divergence) phenomenon occurs due to centrifugal forces and pipe will become unstable. This phenomenon is called flutter. The fundamental frequency is zero due to flutter and instability in pipes occurs.

**1.3 Slender structures in axial flow** practically, the dynamics of the problems are often too difficult to fully describe starting purely from the fundamentals of Mechanics such as Newton's Laws or Hamilton's principle. Rather, a multi-faceted investigation involving empiricisms, experience, numerical simulation, experiments and analogy to simpler problems is necessary; unfortunately, by being so specific, rarely can the results be generally applicable. Luckily, there exist more than a few cases for which general theory can be established under a set of reasonable assumptions, and from

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**Thomas P. Shurtz**



## **Analytical Study Of Piping Flow Induced Vibration Cvs Spb:**

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Eng Yew Goh, 1990      *Numerical Analysis on Flow-induced Vibration of Pipe System* Jiann-Chang Lo, 1986      **Analysis of Induced Vibrations in Fully-developed Turbulent Pipe Flow Using a Coupled LES and FEA Approach** Thomas P. Shurtz, 2009

Turbulent flow induced pipe vibration is a phenomenon that has been observed but not fully characterized. This thesis presents research involving numerical simulations that have been used to characterize pipe vibration resulting from fully developed turbulent flow. The vibration levels as indicated by pipe surface displacement velocity and acceleration are characterized in terms of the parameters that exert influence. The influences of geometric and material properties of the pipe are investigated for pipe thickness in the range 1 to 8 mm at a diameter of 0.1015 m. The effects of pipe elastic modulus are explored from 3 to 200 GPa. The range of pipe densities investigated is 3 000 to 12 000 kg m<sup>3</sup>. All pipe parameters are varied for both a short pipe length to diameter ratio 3 and a long pipe length to diameter ratio 24. Further the effects of varying flow velocity, fluid density and fluid viscosity are also explored for Reynolds numbers ranging from  $9.1 \times 10^4$  to  $1.14 \times 10^6$ . A large eddy simulation fluid model has been coupled with a finite element structural model to simulate the fluid structure interaction using both one way and two way coupled techniques. The results indicate a strong nearly quadratic dependence of pipe wall acceleration on average fluid velocity. This relationship has also been verified in experimental investigations of pipe vibration. The results also indicate the pipe wall acceleration is inversely dependant on wall thickness and has a power law type dependence on several other variables. The short pipe and long pipe models exhibit fundamentally different behavior. The short pipe is not sensitive to dynamic effects and responds primarily through shell modes of vibration. The long pipe is influenced by dynamic effects and responds through bending modes. Dependencies on the investigated variables have been non dimensionalized and assembled to develop a functional relationship that characterizes turbulence induced pipe vibration in terms of the relevant parameters. The functional relationships are presented for both the long and short pipe models. The functional relationships can be used in applications including non intrusive flow measurement techniques. These findings also have applications in developing design tools in pipe systems where vibration is a problem.

Bruce Ngs A Flow-induced Vibration of Main Steam Piping : Summary of Research Program, Findings and Recommendation R.T. Hartland,      Flow Induced Vibrations in Pipes Ivan Grant, 2010

Flow induced vibrations of pipes with internal fluid flow is studied in this work. Finite Element Analysis methodology is used to determine the critical fluid velocity that induces the threshold of pipe instability. The partial differential equation of motion governing the lateral vibrations of the pipe is employed to develop the stiffness and inertia matrices corresponding to two of the terms of the equations of motion. The equation of motion further includes a mixed derivative term that was treated as a source for a dissipative function. The corresponding matrix with this dissipative function was developed and recognized as the potentially destabilizing factor for the lateral vibrations of the fluid.

carrying pipe Two types of boundary conditions namely simply supported and cantilevered were considered for the pipe The appropriate mass stiffness and dissipative matrices were developed at an elemental level for the fluid carrying pipe These matrices were then assembled to form the overall mass stiffness and dissipative matrices of the entire system Employing the finite element model developed in this work two series of parametric studies were conducted First a pipe with a constant wall thickness of 1 mm was analyzed Then the parametric studies were extended to a pipe with variable wall thickness In this case the wall thickness of the pipe was modeled to taper down from 2.54 mm to 0.01 mm This study shows that the critical velocity of a pipe carrying fluid can be increased by a factor of six as the result of tapering the wall thickness

*Flow-induced Vibration*, 2001 **Flow-induced vibrations** American Society of Mechanical Engineers. Pressure Vessels and Piping Division. Operations, Applications, and Components Committee, *Flow-induced Vibration of Power and Process Plant Components* M. K. Au-Yang, 2001 Information on the most common flow induced vibration problems in power and process plant components Based on the author's own experience that most errors in engineering analysis come from confusions in the units the author begins with a short chapter on units and dimensions He then provides step by step examples in dual US and SI units leading to the final objective of design analysis problem solving diagnosis and trouble shooting **Flow-induced Vibrations**, 1986 *Experimental Study of Flow-induced Vibrations at a Cavity Opening* R. E. Bland, Eugen J. Skudrzyk, 1961 **Flow Induced Vibration Analysis of the Guide Tubes Of reactivity Mechanisms of 500 MWe PHWR**. A. Kakodkar, H. S. Kushwaha, S. C. Mahajan, B. Murali, K. K. Vaze, 1992 Flow Induced Vibration of a Cylinder Pair Carlos A. Bonilla, 2002 **Flow-induced Vibration of Circular Cylindrical Structures** American Society of Mechanical Engineers. Pressure Vessels and Piping Division, *Common Mistakes and Misconceptions in Flow Induced Vibration and Coupled Fluid Structural Dynamics Analysis* M. K. Au-Yang, 1999 **Flow Induced Vibration Analysis of the Guide Tubes of Reactivity Mechanisms of 500 MWe PHWR**, 1992 **Flow Induced Vibrations in a PWR Piping System** D. Seligmann, J. Guillou, 1995 *Flow-induced Vibration, 2001: Axial flow, piping systems, other topics*, 2001

**Flow-induced vibration of process system components : vibration analysis of steam generators and liquid heat exchangers : an overview** M. J. Pettigrew, 1996 Large Eddy Simulation Based Turbulent Flow-induced Vibration of Fully Developed Pipe Flow Matthew Thurlow Pittard, 2003 Flow induced vibration caused by fully developed pipe flow has been recognized but not fully investigated under turbulent conditions This thesis focuses on the development of a numerical Fluid Structure Interaction FSI model that will help define the relationship between pipe wall vibration and the physical characteristics of turbulent flow Commercial FSI software packages are based on Reynolds Averaged Navier Stokes RANS fluid models which do not compute the instantaneous fluctuations in turbulent flow This thesis presents an FSI approach based on Large Eddy Simulation LES flow models which do compute the instantaneous fluctuations in turbulent flow The results based on the LES models indicate that these fluctuations contribute to the pipe vibration It is shown that there is a

near quadratic relationship between the standard deviation of the pressure field on the pipe wall and the flow rate It is also shown that a strong relationship between pipe vibration and flow rate exists This research has a direct impact on the geothermal nuclear and other fluid transport industries

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## **Table of Contents Analytical Study Of Piping Flow Induced Vibration Cvs Spb**

1. Understanding the eBook Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - The Rise of Digital Reading Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Advantages of eBooks Over Traditional Books
2. Identifying Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - User-Friendly Interface
4. Exploring eBook Recommendations from Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Personalized Recommendations
  - Analytical Study Of Piping Flow Induced Vibration Cvs Spb User Reviews and Ratings
  - Analytical Study Of Piping Flow Induced Vibration Cvs Spb and Bestseller Lists

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  - Analytical Study Of Piping Flow Induced Vibration Cvs Spb Compatibility with Devices
  - Analytical Study Of Piping Flow Induced Vibration Cvs Spb Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Highlighting and Note-Taking Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Interactive Elements Analytical Study Of Piping Flow Induced Vibration Cvs Spb
8. Staying Engaged with Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Analytical Study Of Piping Flow Induced Vibration Cvs Spb
9. Balancing eBooks and Physical Books Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Analytical Study Of Piping Flow Induced Vibration Cvs Spb
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Setting Reading Goals Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Fact-Checking eBook Content of Analytical Study Of Piping Flow Induced Vibration Cvs Spb
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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