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Flow Induced Vibration in Fuel Transportation Pipes

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

وَتَرَى الْأَرْضَ هَامِدَةً فَإِذَا أَنْزَلْنَا عَلَيْهَا الْمَاءَ اهْتَزَّتْ

وَرَبَتْ وَأَنْبَتَتْ مِنْ كُلِّ زَوْجٍ بَهِيجٍ

(سورة الحج :5)

صدق الله العلي العظيم

Certification

I certify that this research entitled **"Flow Induced Vibration in Fuel Transportation Pipes"** has been prepared by "***Noora Mansourar Hadi*** " under my supervision at the department of Mechanical Engineering, College of Engineering, University of Babylon as a partial fulfillment of the requirements for the Degree of Higher Diploma of Science in Mechanical Engineering / Fuel and Power.

I recommend that this research be forwarded for examination in accordance with the regulation of the University of Babylon.

Signature

Prof. Dr. Alaa Abbas Mahdi

Department of Mechanical Engineering

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Data: / / 2022

Dedication

To

My mother may God prolong her life

My dear husband, may God prolong his life

My dear brother and the flowers of my life my sisters

My children

I dedicate my humble effort.

Noora Mansour Hadi

Acknowledgments

(In The Name of Allah, The Gracious, The Merciful)

(Thanks to Allah for his guidance and help)

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Abstract

Flow- induced vibration causes serious problems in oil and gas systems, most of these problems are high displacement due to resonance, fatigue failure due to cyclic stress, and structural wear due to relative movement of the pipe, the main objective of this research is to analyze flow-induced vibration.

In this research, four types of metals were used (aluminum, steel, concrete, and chlorinated polyvinyl chloride (CPVC)). Each metal of the tubes has four different ends: (simple - simple, clamped, clamped, clamped - simply, clamp-free) to study the normal frequency and permissible speed before failure by using three types of working fuels (gasoline, kerosene and diesel), also the present work studied the effect of the Length (3.048 m and 12 m).

(Matlab2014) program used to study the effect of pipe vibration. The transport matrix where used to describe the dynamic behavior of the fluid flowing inside the tube

From the results, it was concluded that the best metal that can withstand a wide range of speeds is steel. The results show that (c-c) pipe is the best case study and the weakest case (c-f) pipe.

From the applied case of Karbala refinery, it was found that the best types of pipes are simple - simple. They work on a safety factor equal (2) as the ratio is (ω / ω_n) is far from the induced vibration.

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Table of Contents

Nomenclature:

Symbol	Description	Units
A	Pipe cross sectional area	m^2
D	Pipe diameter	m
D_i	Inner diameter for the pipe	m
D_o	Outer diameter for the pipe	m
E	Modulus of elasticity for pipe	N/m^2
I	Inertial moment of cross-section area	m^4
L	length of pipe	m
m_f	mass per unit length of fluid	kg/m
m_p	mass per unit length of pipe	kg/m
m_t	mass per unit length of the pipe and fluid	kg/m
p	Pressure	Pa
Q	Transverse shear force in the pipe	N
S	Perimeter of the pipe	m
T	Longitudinal tension in the pipe	N
th	Thickness	m
v	velocity	m/s

Greek Symbols

ω_n	Natural frequency	rad/s
ω	Excitation frequency	rad/s
β	Dimensionless parameters	
τ	Shear stress on the internal surface of the pipe	N/m^2
μ	Dynamic viscosity of the fluid	kg/m s
ρ	Density	kg/m^3
ρ_f	Liquid density	kg/m^3
ρ_p	pipe density	kg/m^3
Ω	characteristics matrix	

Sub-Scripts

C	constant
f	Fluid
Ni	Shape function
p	Pipe
Re	Reynolds number

Abbreviations

AX	Axial motions
BP	British Petroleum
CCS	Carbon dioxide Capture and Storage
CF	Cross-flow
CFD	Computational Fluid Dynamics
DM	Direct method
DNS	Direct numerical simulation
DQM	Differential Quadrature Method
DTM	Different Transform Method
ETM	Energy Transaction Measure
FDM	Finite difference method
FE	finite element
FEA	Finite Element Analysis
FFT	Fast Fourier Transform
FIV	Flow-Induced Vibration
FSI	Fluid-Structure Interaction

GITT	Generalized Integral Transform Technique
GTM	Galerkin truncation method
IDE	Integro-differential equations
IFE	Internal Flow Effect
LDA	Laser Doppler Anemometer
MOC	Coupling Method of Characteristics
MOF-DAS	Microstructure Optical Fiber Distributed Acoustic Sensor
NES	Nonlinear Energy Sink
ODS	Operating Deflection Shape
OMA	Operational Modal Analysis
PIM	precise integration method
ROV	Operating vibration Data is measured
SD	standard deviation
TET	Target Energy Transfer
TMM	Transfer Matrix Method
VIM	Vibrational Iteration Method

VIV	vortex-induced vibration
WIV	wake-up induced vibration

Chapter One

Introduction

Chapter One: Introduction

1.1 General

The flow of fluid inside the pipe causes the fluid to press against the pipe walls, causing the pipe to vibrate and deflect. Valve chatter is associated with the opening and closing of valves in response to these pressures. Pipeline damage this is the dynamic response of the pipeline to an instantaneous rupture. Constant flows cause the pipes to deflect, and the high-velocity flows inside the pipe, causing the pipes to bend (vibrate) at a remarkable speed. Instabilities and instability caused by leakage and external axial flow are study in this chapter, [1].

Flow induced vibration, occurs as a result of actual and practical disturbances in the fluid, where vibration is caused by discontinuities such as valves and bends, kinetic energy at high levels is concentrated at low frequencies less than (100HZ), vibrations mainly depend on the design of the pipes, the type of metal used and the hardness, [2].

The issue of fluid flow pipes has been seriously studied since about 1950 to analyze the vibrations of oil pipelines. Although this system is structurally simple, it is very complex in terms of dynamic behavior. Various nonlinear phenomena are more pronounced in the dynamic behavior of these systems, especially in tubes with free ends. Modeling of such systems is used in heat exchangers, nuclear reactors, micro and nano tools, robots and underwater equipment, etc. One of the main features of these systems is that if the velocity of the material being transferred is high enough, the structure may suffer from deflection or oscillation instability in bending modes. For these structures, the rate of acceleration that leads to the onset of instability is called the critical mass transfer rate. In analyzing such systems, it is usually to determine two cases. The first is the critical velocity of the mass being transferred and the second is the relation between the characteristic frequencies (specific values) and the velocity of the transfer mass. The first is the main goal of sustainability analysis, and the second is important if the characteristics of the free frequency and the response to a set of specific excitation are considered. Extensive research has been done on various types of tubes containing fluid flow, [2].

Pipeline vibration is a hazard to pipe structures and their integrity, and this vibration is due to flow-induced vibration [FIV] and sound-induced vibration, other possibilities for pipe vibration are mechanical vibration, pump vibration, valves and pressure pulsations due to flow and cavitation, [2].

The failure of components or parts occurred by the reversal cyclic stress which is well below the yield stress of the material. This type of failure is called a fatigue. The vibration of structure or components is subjected to cyclic stress and that will lead to Fatigue failure. The vibration caused by a fluid flowing in or around a body is known as Flow Induced Vibration (FIV). FIV best describe the interaction that occurs between the fluid's dynamic forces and a structure's inertial, damping and elastic forces. Various researchers have considerably contributed by doing lot of researches to study the characteristics behavior of pipe conveying fluid flow.. The kinetic equation was developed through the structure of the tube and the internal pressure of the fluid on the tube walls to calculate the Coriolis force. And experimental studies of the wall pressure due to vibration in the pipeline were conducted where it was found that the natural frequency of the fluid is affected by the fluid flow velocity inside the pipe, pipe length, density, stiffness, and modulus of elasticity. Where researchers analyze one dimension, very few of them analyze the 3-Dimensional, [4].

Pipe and fluid flow structures are dynamic systems, due to the fluid flow within a pipe. This flow generates a force that causes pipe deformation and deflection and this deflection affects the fluid flow characteristics. Several experimental and analytical studies have been conducted on the vibration of pipes conveying fluids, in which fluid flow and its effect on pipes have been studied. Vibration is based on dynamic movement. Especially in oil and gas pipelines, Flexible pipe vibration during flow is turbulent. Pipes are affected by vibration, and this vibration causes pipe damage and noise, so the problem of vibration is solved by placing pipe supports. This is evident in oil pipelines. The purpose of the structures is to reduce vibration and expansion of the heat pipe, show the fig, (1-1), [5].

Different types of pipe lines are used in many sections, especially large pipe lines used in oil and gas pipe lines. Where oil and gas are transported to long distances, and these pipes are placed above or in the ground as in the Figs. (1-2), (1-3) these pipes must be non-corrosive, strong and low-vibration pipes.

Pipeline vibration is one of the biggest and most serious problems, especially in offshore and onshore pipelines, petrochemical plants, and oil and gas refineries. In the case of the oil and gas industry, the vibration is very dangerous because of the risks to human life and the environment if the pipes rupture due to vibration, but in onshore pipelines, where environmental conditions are harsh or due to the high flow rate of pipeline fluid. This is an important factor that makes pipelines does not working properly. Flow-induced vibration (FIV) is an important factor causing piping stress which occurs when the interaction between the piping structure and the fluid leads to. Associated with repetition, the variety of pipes, sizes, and supports have caused many problems in tube vibration control, especially the phenomenon of resonance, and with the development of dampers to absorb vibrations, [6].

In oil and gas extraction processes flowing together, many substances such as sand and water come out with them. This causes flow problems, Corrosion of pipes and the resulting vibration, and this vibration causes major problems, especially when extraction oil in offshore systems, [2].

Piping fatigue failure due to excessive piping vibration is a major cause of machinery downtime, leaks, excessive noise, explosions and fires in refineries and petrochemical plants. Due to the potential dangers associated with this type of failure, it is a major concern to engineers. Excessive vibration levels typically occur when the natural mechanical frequency of the piping system is excited by a pulsation or mechanical source. If fracture occurs, the sudden release of a hazardous or flammable pressurized fluid can be extremely hazardous to health as well as having environmental consequences. The financial costs involved in the loss of, show the fig, (1-5),[7]

most of the excitation is concentrated at low frequency (typically below 100 Hz); the lower the frequency, the higher the level of excitation from turbulence. This leads to excitation of the low frequency vibration modes of the pipe work, in many cases causing visible motion of the pipe and, in some cases, the pipe supports, and this phenomenon is called Flow induced vibration (FIV),[7].

If the piping system is not properly designed, this excitation would lead to piping component fatigue failure. It has been reported that more than 20% of the piping failures in the United Kingdom UK sector of the North Sea were due to piping vibration and fatigue failures. In 1974, an error in the piping system in a petrochemical plant resulted in an explosion which caused more than USD 114 million in damages. In nuclear reactors, over 80 cases of ruptures or leaks were identified in the pressurized water system to the pump load over a two-year period.

Piping vibration is a serious risk since a single pipe-work failure can shut down a facility for hours or even weeks, resulting in lost production at the very least. Consequently, it is essential for the oil and gas industry that vibration issues are considered at the design stage,[7]

Previous studies mainly focused on pipes that convey high pressure and fluid flow at high speed. These pipes have different types such as reduced pipe, Tee type, and ball valve. If the pipe fails due to (FIV), necessary action must be taken, as the pipe diameter, thickness or metal type must be changed, [7].

The study considers the operation modes of the Novo portovskoye oil and gas gathering pipeline were show in (Fig. 1-4). The aim of this work is to build a model of the study influence of hydraulic modes of pipeline operation on its mechanical stability. The pipeline is designed for multiphase transportation of well products from well clusters. Now adays, the pipeline transports up to (26000 m^3/day) of liquid, (13400) thousand sc.m3/day of gas. The pipeline is built with the following sizes: diameter – 820 mm, wall thickness – 10 mm, length – 10182 m, steel grade – 13ΦA. The pipeline's above-ground design is arranged on piled bases, with (90°) U-shaped compensators intended for smoothing longitudinal displacements from the thermal expansion of the pipeline. In order to prevent transverse displacements, the sliding supports are provided with guide angles located before and after the compensators .to prevent liquid freezing, [8].

1.2 Motivation and Justification for Flow Induced Vibration (FIV) Studies

Problems caused by (FIV) have uncontrolled risk ratios and these problems are classified in to fatigue problems in the pipes that carry the flowing fluid and associated structures pipes, corrosion problems and resonance. These problems when measured at the sea floor are costly more than if they were on the surface of the earth. Fatigue failure occurs at stresses below the yield stress of the material and can cause pipe fractures and rupture of walls and structures. The figure shows fatigue failure Fig. (1-5), when the natural frequency of the flow line pipe, matches the frequency at which FIV, resonance occurs, and when occurs it leads to pipe failure and rupture,[3].

The oil and gas fields of the United Kingdom are located in the North Sea. Studies on piping have confirmed that failure of piping structures occurs at high rates due to vibration, and in extractions(oil and gas) there is an increase in FIV due to the long distance, increased flow rate and piping, all this leads to an increase in FIV,[2].

In dynamic systems, the dynamic properties of spacing, viscosity single and double mode, instability and flutter in fluid transmission pipes must be studied. The hydrodynamic force generated by pipes and associated structures such as vibrations and sound problems in industrial machinery is dangerous . This vibration is known as flow-induced vibration and leads to unwanted damage. This study focused on reducing (FIV) in turbulent gas and liquid flow, [9].

Fig.(1-7) shows, the classifications of (FIV), a broad and old classification that describes random perturbation and resonance,[1].

(FSI) includes hydrodynamic forces and dynamic structural forces. Structural dynamic forces from fluid motion affect structures. This results in structural stress and deformations which may in turn increase the turbulence of the flow as shown in Fig. (1-7).

1.3 Dynamic response of structures

The dynamic behaviors of vibratory structures determine the normative information of the structures during the vibration of the structure, when the structures respond to a specific frequency so that the individual vibration frequencies are extracted, the damping and the natural frequency and the shape of the structure are set. This information constitutes the typical analysis of the structure.

With the development of computer programming, the (FEA) method is the better way the model is analyzed and the kinematic equation is solved. The (FEA) method is able to model pipe structures designed to increase reliability and data validation. (FEA) is an economical method for analyzing large models of structures where the risk of failure may be very clear and dangerous rather than costly practical experiments.[2]

The resonance main danger to structures when vibrating the pipe is during fluid flow, If the vibration of the structures matches the natural frequency of the structures, resonance occurs, [2].

1.4 Objectives of the Present Work

One of the most important objectives of this research is a theoretical and numerical study of the vibrations that occur in the fuel transport pipelines. The main equation governing the motion of fluids has been applied according to the energy equation. The study included the selection of three types of fuel (gasoline, diesel, kerosene). Four types of metals, namely steel, aluminum and concrete, were selected for the four types of tubes (simply - simply - riveted, riveted - riveted -

riveted - simple - riveted-free). Various lengths of tubes were also selected in order to determine the natural frequency, critical velocity and regions of resonance.

Fig.(1-1) supports pipe (pipe oil), [6]

Fig.(1-2) pipe under the ground, [6].

Fig. (1-3) the above-ground pipeline is loaded with strong supports, [6]

Fig. (1-4) pipeline system, [8]

Fig. (1-5) pipe fatigue failure due to FIV, [2]

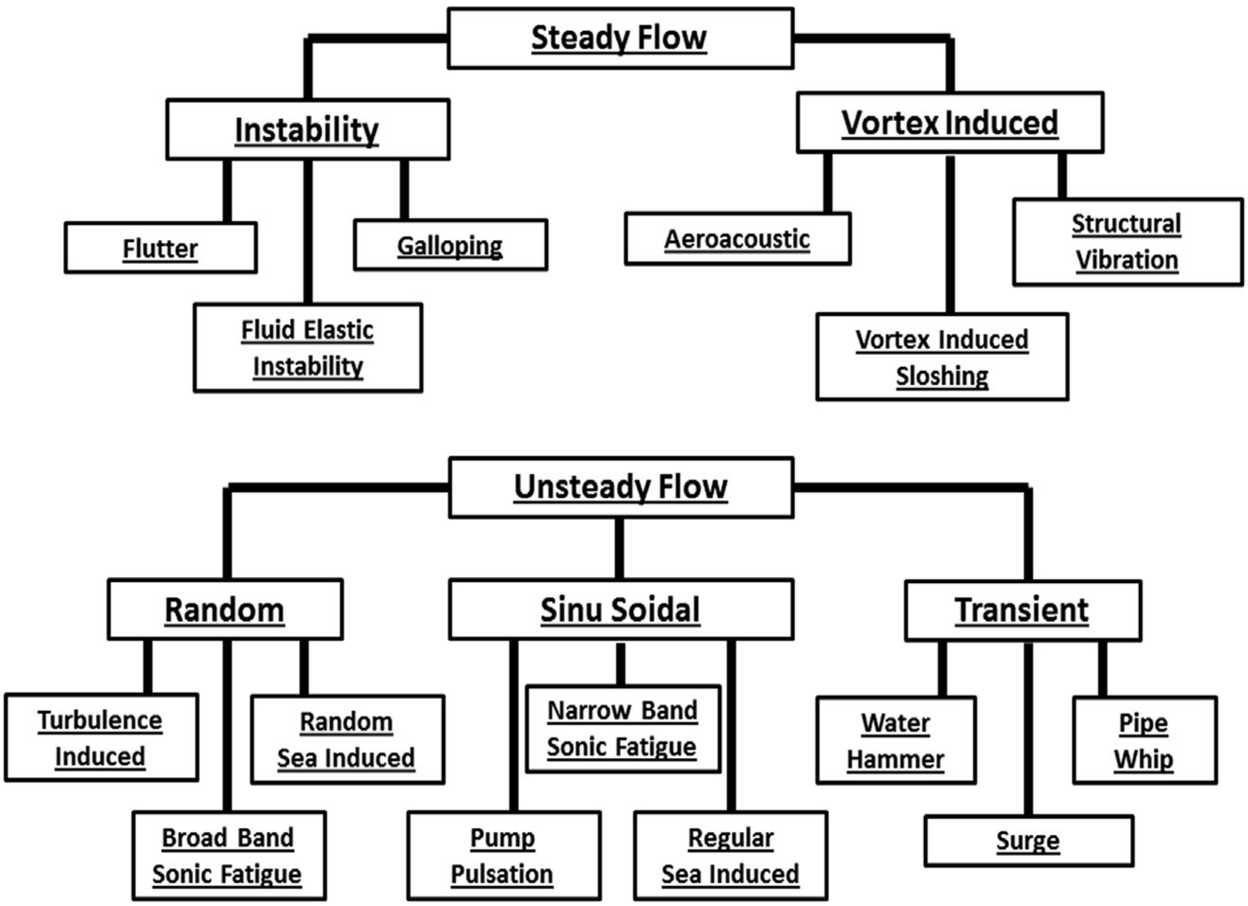


Fig. (1-6) classifications of FIV, [1]

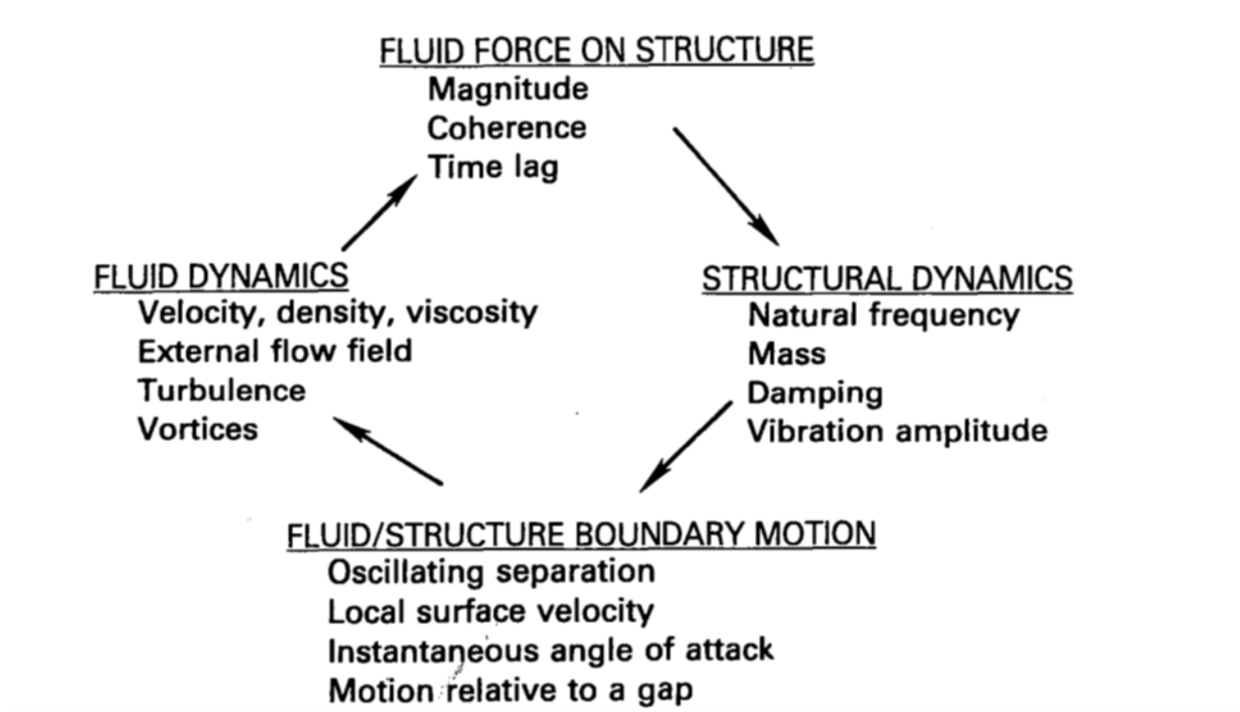


Fig. (1-7) the relationship between dynamics and fluids in FIV, [1]

Chapter Two

Literature Review

Chapter Two: Literature Review

The main purpose of this part of this study is to summarize all works and studies at the present time as well as previous studies directly related to studies. In this chapter, the latest developments, result and research related to this study are mentioned and reviewed, as this chapter has been divided in to three main sections: experimental Studies, numerical studies as well as experimental and numerical studies together.

At the present time, there is increasing in interest in studying flow induced vibration in Fuel transportation pipes .There is also great importance in controlling the pipes Vibration, and it was noted that general criteria such as the number of time the pipe fatigue, the many experimental and numerical work have been performed to verify the flow pattern flow induced vibration (FIV) in pipe, Piping fatigue failure due to extravagant piping vibration is a major cause of machinery down time.

2.1 Experimental Studies

Przemysław, (2011), [10], presented the customary limits for the vibration and natural frequency of pipes are determined, where these values are taken as the permissible limit for pipe vibration and stress caused by deformation.

One of the causes of pipe failure is their vibration and the control of the pipe vibration. In this paper, the vibration limits are determined depending on the length and diameter of the pipe. The parameters adopted are based on the permissible length deformation of the pipe caused by vibration and pressure.

Nathera, (2012), [11], investigated the free vibration of plates when changing the length, location and inclination of a plate crack. The free vibration analysis of these plates was carried out using a program ANSYS11. The results of this research were compared with the latest numerical results showing that the length, location and inclination of the crack have effects on the natural frequency.

The most important conclusions in this research was that when the slit length increases, the frequency decreases .While the direction of the slit has less effect on the frequency. The direction of the slit at an angle of [ϴ=45 °] is more dangerous because it contains the highest decreasing in frequency.

Yang, et.al, (2012), [12], studied the oscillating force resulting from the internal flow was studied, and the test was conducted on the diameter of (52.5mm and 90^0) elbow where he found the maximum flow reached in the annular flow system.

The investigation was conducted on a (52.5 mm I.D), (76.2 mm radius),and (90°) because of the experimental flow and the oscillatory force where the resulting flow can be separated from each the other, the dynamic force was measured without the influence of vibration, as the case study included the mechanisms and characteristics of the resulting flow.

Dai, et.al, (2012), [13], studied the application of the (TMM) matrix to the vibration analysis of three-dimensional pipes, where the natural frequency of pipes with straight or curved shapes was calculated.

It was used to analyze the critical frequency and velocity, if it neglects the static combined force and fluid flow, where the results obtained are incorrect when applying both (FEM) ,(TMM) to vibration analysis of flat pipes or three-dimensional pipes.

Kong, et.al, (2013), [14], presented vibration caused by flow (FIV) for pipelines is the most common risk exposed to the transmission pipeline, especially oil and gas. A new proposal has been made to analyze the failure of (DNS) pipes due to (FIV) and this depends on Operational Modal Analysis (OMA) ,Operating Deflection Shape (ODS). Finite Element Analysis (FEA). This information from (OMA) was used to correlate with the FE model, the operating conditions were checked and it was found that (360 mm) and (400 mm) CFD control valves are in a state if they are fully open or partially open, respectively, at this point the piping system fails.

A new method has been proposed to determine the causes of failure in (DSS) pipes during work by analyzing (OMA) and the materials carried out by ozone and (FEA). The highest flow rate can occur as far as failure is (360) and (400mm) (CFD).

Veerapandi, et.al, (2014), [4], presented the mathematical, This paper deals with the mathematical model and Computational analysis of flow induced vibration of Rocket Engine Test Facility. In this set up, the main components of piping elements which causes vibration is angle type valve. Experimental study and analysis of flow induced vibration is to be carried out by study the effect of turbulence of gas flow in the piping system during the course of sub cooling of flight static fire test or flow trial. Mathematical Model of pinned pipe carrying fluid has been developed. Governing Equation of motion for pipe conveying fluid of real system has been derived. The critical fluid velocity has been calculated by analytical approach.

This paper deals with the Analytical study and Computational analysis of flow induced vibration in pipeline. Modal Analysis in the pipe flow configuration is studied. The dynamic fluid behaviors in the valve annular region are studied and obtained results in CFD and Fluid Flow analysis to be extended full pipe configuration. Flow Induced Vibration of Coupled analysis to be done by ANSYS CFX. Experimental Study and Analytical Study to be extended to solve the real physical problem are planned.

Igor, et.al, (2015), [15], presented a method for measuring the frequencies and amplitudes of sound vibrations, writing the input as a function of (Strouhal number) and the energy absorbed, the frequency was calculated for (the Zaporozhye nuclear power plant with WWER-1000)generated by turbulent vortices in closed toroidal sections.

The difficult problem at present is the mechanical vibrations of the pipes where he proposed a method they were tested with closed branch pipes, according to the difference between the experimental and calculated frequency, in this method the forced vibration of steam pipes was analyzed.

Shankarachar, et.al, (2016), [16], presented the effect of the final conditions of the tube on the natural frequency of the pipe was studied, then Euler-Bernoulli equation and Hamilton energy equation were used, through which the motion equation was obtained and the natural frequency was calculated. A FORTRAN program was used to calculate the natural frequency and ABAQUS software is used to analyze the fluid velocity.

The kinematic equation is derived from Hamilton's equation for the transport of pipes, using the method of separation of variables to in this paper, the FORTRAN program was used to analyze the natural frequency of the tube

Siba, et.al (2016), [17], studied The Flow-induced vibration has recently the topic of experimental, numerical, and theoretical studies. It was intended to implement better applications for controlling the flow using orifice technique. Having the flow under control, the orifice becomes an instrument for measuring the flow. The flow of all fluid such as water, oil, gas and vapours through an orifice was tested and mathematical models were developed adequately.

Investigating the flow emerging from or within the orifice has become increasingly important due to many industrial and experimental applications. The main purpose of these investigations is to create very accurate measurement procedure for the discharge of the flow in pipes for economic and safety reasons. The current review shows the chronical historical developments for orifice techniques which include the geometry and the shape of the orifice plate.

Ahmad, et.al,(2019),[7], studied Piping systems in crude oil production facilities tend to handle high pressure and high velocity flowing fluid at certain flow rate limit resulted in generation of turbulence flow. This turbulence can generate high levels of broad band kinetic energy which can propagate through the system. Even though the energy is distributed across a wide frequency range, most of the excitation is concentrated at low frequency (typically below 100 Hz); the lower the frequency, the higher the level of excitation from turbulence. This leads to excitation of the low frequency vibration modes of the pipe work, in many cases causing visible motion of the pipe and, in some cases, the pipe supports, and this phenomenon is called Flow induced vibration (FIV).

This study deals with computational analysis of flow-induced vibration in the piping system, focusing more on oil and gas industry. The modal analysis in the pipe flow configuration was studied to verify the accuracy the changes physical properties of the pipe in term of the outer diameter size and wall thickness to wards the formation of excessive vibration in the piping system.

Manoj and Subodh (2019), [18], investigated flow induced vibration in pipes conveying fluid with different end conditions and different materials is studied in this paper. Four types of end conditions (s-s, c-c, c-s and c-f and four materials: aluminum, steel, chlorinated poly-vinyl chloride (CPVC) and concrete are used for the study, Hamilton's energy principle. Use the (FEA) method to analyze the properties of tubes that convey fluids. Results of the simply-simply supported aluminum pipe are compared with the experimental results for the purpose of validation of finite element model. Natural frequency of vibration and critical flow velocity are determined and vibration characteristics of pipes of different ends conditions and materials are analyzed. Natural frequencies and critical flow velocities from (FE) method are compared with the values form (DM).

Natural frequency of vibration and critical flow velocity were found to be very high for clamped-clamped steel pipe as (87.47 rad/sec and 141.43 m/sec) respectively and very low for clamped-free CPVC pipe as (2.2114 rad/sec and 3.36 m/sec) respectively.. The order of the stability with respect to end conditions was found to be (c-c, c-s, s-s and c-f) from higher stability to lower stability. By comparing the results for the pipes having same size and dimensions with respect to the material, steel pipes were found to be stable for large range of flow velocity and (CPVC) pipes were found to be stable for small range of flow velocities against (FIV). The order of the stability with respect to the material was found to be steel, aluminum, concrete and (CPVC) from higher stability to lower stability.

Richard and Jacqueline, (2021), [19], presented fatigue life was studied, so he used numerical simulations of the natural gas flow line at different speeds and also investigated the pressure of the wall. Engineers depend on the guidelines of the Institute of Energy to avoid failure caused by vibration in the pipes.

In oil and gas stations, the vibration of the pipes should be checked periodically to ensure the structural integrity of the pipes. The guidelines recommended by the EI for the main pipes are careful and discreet, as they recommend if the fatigue life is less than (40) years is removed or re-supported. Two important things SBC changed its direction and put clamps between the SBC and the lines the mains for pipes, where this research focused on single-phase flow.

2.2 Numerical Studies

Long and Fuzhen, (2010), [20], Studied the method of micro-integration of vibrating reinforced tubes, and they were analyzed dynamically .Where they deduced an equation for tubes .Various forms of support with respect to displacement and momentum. To achieve this approach, several tubes with different ends at different speeds and different frequencies are used.

(PIM) is faster than the Runge-Kutta method which can remain stable for a period of time, in this paper discusses the nonlinear dynamic behavior of tubes with different ends and different velocities of the flowing fluid. This method is approximate ratios, as it is supposed to study more accurate and effective methods for the Hamiltonian system.

Fall and Derakhan, (2011), [21], studied the self-vibration of a pipe due to internal flow .The Euler-Bernoulli model is considered to analyses the vibration of pipe. The equation of motion is derived which is a differential equation that derives the transverse displacement of the pipe with respect to time and distance to obtain the natural frequencies of the pipes and study their effects. The natural frequencies of the system, The effects of the hardness, velocity, density of the inlet fluid, the inner diameter of the pipe of a given thickness, the modulus of pipe elasticity and the pipe length have been studied.

The main conclusions of this work wae the system's natural frequencies are increased by increasing the stiffness also by decreasing the internal fluid density, internal velocity, pipe diameter (with constant thickness) and length

Yetzirah, et.al, (2011), [22], studied internal flow vibrations in subsea tubes, where the vibrations are measured by the (ROV) associated with the tubes in which the fluid flows, and the data obtained from the (ROV) is analyzed for the purpose of validating the model used, where the data is present in pairs between the (ROV) and (FE), to display an improvement The model to make the frequencies operate within the required range

In this paper, the (FEA) method was used to analyze and measure pipe vibrations. (FEA) has been used in the marine industry due to increased production and stress on pipes and what causes vibration problems that lead to failure.

Khudayarov and Turaev, (2015), [23], presented the vibrations in pipes for transporting liquids and gases. A tube model with a cylindrical cap and a rubber base was used. Boltzmann-Volterra's special theory of viscoelasticity, in which he studied the effect of vibration on the Pasternak, was used for the structure with viscoelastic properties.

It was concluded that the most interesting method for calculating the viscoelastic properties of tube structures is according to the algorithm, which is important for vibratory tubes with fluid flow inside the tubes, and it was concluded that when γ is increased, it leads to an increase in the radius, a decrease in the length of the tube and a dimensionless increase in velocity. The results of the research showed that the study of the viscoelastic properties leads to a reduction of vibration by 20-40%, so it was found that the process of damping the vibrations in the pipes is due to the calculation of the viscosity properties.

Chen An and Jian, (2015), [24], studied the dynamic behavior of tubes that transport liquid and gas together in an analytical and numerical way, and this depends on the basis of the Generalized Integration Transfer Technique (GITT).

(GITT) is used to analyze the vibration equation and convert it into a second-order differential equation with time-varying. The properties of liquid and gases are calculated through the slip ratio .A study of the volumetric gas analysis of the flow of gas and liquid.

The analysis of the dynamic behavior of liquid and gas by (GITT) method showed that it is a very good method for two-stage flow analysis. This is good for natural frequency analysis. Infer that the fundamental frequency decreases with the volumetric gas. It was found that the fluid flow inside the tubes loses its stability when the fluid flow rate reaches the critical value. Vibrations increase with increased flow.

Li Yun and Yang, (2016), [25], developed a new analytical method, in which he developed a method for repeating variables, to be applied to the vibration of free tubes that transport fluids. The experimental results were compared with the experimental results of this research. It was found that (DTM) and (VIM) are identical in results and use tubes with different ends.

The free oscillations of tubes with different ends were analyzed by the (VIM) method. The two methods (VIM) and (DTM) have the same accuracy in the results of the velocity and frequency of the fluid-carrying tubes, and the critical velocity and frequency of fluid-carrying tubes can be resolved from the flexible tubes installed by the (VIM) method, and calculated by the conditions below (DTM). Types of pipes with different ends by (VIM), (VIM) is more accurate than (DTM).

Shuai, et.al, (2017), [26], suggested that it captures (carbon dioxide) and these tubes can dissipate or gain strength. In this paper, focus on the effect of internal flow on CF (transverse flow) and (VIV) (vortex induced vibration) on the carbolic tubes, a model is proposed in this paper for the skeletal fluid interaction use the linear equation to study the transverse vibrations. Comparison of (VIV) and (IFE) experiments in simulations, where (IFE) and (VIV) were examined by time-tuning during discharge time to show the response of riser, vibration and prevailing frequencies, it was found that at a few small flow velocities, (VIV) decreases significantly. The importance of the tube becomes unstable and increases (VIV).

In this paper, focus on the simulation of tubes that transmit internal flow. Therefore, the elastic lever was considered in the form of Euler radiation and relied on the Euler-Bernoulli equation, where it was measured (VIV) by an oscillator. The tube discharges energy into the inflow. This vortex-induced vibration can be reduced by (IFE). The critical velocity increases as the empty flow increases.

Mustafa, (2017),[27], investigated the fundamental natural frame frequency and critical inlet flow velocity of the simply supported stepped pipe conveying fluid. The influence of some outline parameters, similar pipe diameter ratio with different cross-sectional areas (sudden enlargement or sudden contraction),

conclude the inlet fluid flow velocity of the stepped pipe increases as the outer diameter ratios (Od2/Od1) increase until they reach 1 (straight pipe), then drop smoothly. For each inlet fluid flow velocity, length ratios, and diameter ratios, there is an optimum pipe thickness that gives the best dynamic characteristics

Etim (2018), [28], presented the Fluid flow inside tubes causes vibration, so vibration (FIV) was calculated and an equation was derived to study the effect of fluid flow inside tubes and the effect of natural frequency on tube displacement. In this paper, a certain mechanical method was used to derive the (FIV) equation. (FIV) was developed for tubes that are double-sided and easy to support.

In this research, he concerned with the method of vibration analysis, the method of calculating the natural frequency, the critical speed, the method of tube deflection, and how to avoid and control tube failure on the state of resonance.

Where the research was compared with the previous research, which showed good agreement.

Xia Tan, et.al, (2018), [29], studied Timoshenko beam theory was used for the first time to examine the vibrational properties of fluid-transporting tubes, as Hamiltonian principles were used to derive the governing equation. Length, thickness, critical velocity and shear modulus. In this paper the Timoshenko beam method is very important in the work and in the vibrational properties of the tubes that transport fluids at high speeds.

He focused in this research on finding the equilibrium and stability of the tubes that transmit fluids, as well as the natural frequencies according to the Timoshenko ray theory. The governing equation in this research is according to the generalized Hamiltonian principle. It was found that when changing the length, the deformation of these lines showed the Timoshenko beam in a non-linear manner. As for Euler-Bernoulli, the deformation was found to be linear. From the numerical results it was found that the critical natural frequency and above are very sensitive to the physical properties .The higher the speed, the more sensitive the physical properties. From the results it was found that the theoretical Timoshenko beam is more suitable for the dynamic perception of vibration of tubes transporting fluids.

Haider, (2018), [30], evaluated the corrosion rate of (API 5L X60) and (API 5L X80) steel pipes that transport crude oil was studied. It was deduced from the experimental results that were conducted to measure corrosion, which showed that the vibrations help in the dissolution of crude oil into water and solvent gases.

The properties of the oil affect the vibrations. The vibration separates the components of the crude oil, and the high temperature increases the vibration of the metal and the oil, which leads to increased wear. Vibration reduces the process of molecular bonding of a steel metal, and, accordingly, the resistance of the metal to oxidation processes decreases . An increase in the oxidation process. It was concluded that the vibrations increase the oxidation process of (H_2S) and (CO_2) gases, and thus the etching process on the surface increases.

Qianli and Zhili, (2018), [31], presented a new method for vibration analysis was proposed, as he proposed a new matrix method based on the Laplace transform. He proposed three types of curved, flexible and fixed carburetor tubes. To achieve the accuracy of the proposed matrix .Where critical velocity and natural frequency are calculated as a function of velocity to show wide applications. Study it in other languages.

This research is concerned with (FIV) by the Laplace transform method, so three curved tubes were used to achieve this. The critical velocity was calculated using the proposed method for a curved tube with flexible supports. If flexibility increases enough, instability is the only flutter. This Laplace transform method is important in solving engineering problems. In this way, he concluded that he had studied the most complex problems.

Sergio, et.al, (2018), [32], studied a pipelines transporting liquid and gas, a model has been proposed to measure the vibrations that occur due to the flow. This proposal is implemented in three dimensions of the pipeline, where the forces occur due to the bending of the pipe, where this model allows the analysis of many geometric shapes. In the areas of oil extraction also studied Slug frequency.

The proposed model of liquid and gas tubes, as it assumes a dynamic simulation of these lines, wrote a three-dimensional algorithm due to curvature and variability, and the internal flow strength was tested.

Khudayarov and Komilova, (2019) [33], concerned the vibration and dynamic stability of tubes. According to Winkler's rule, the rubber wife model is used to study the vibrations of tubes in which the gas flows, according to the Boltzmann-Volterra theory, which is concerned with viscoelasticity, which is done by knowing the properties of the tubes. The Winkler rule studies the viscosity properties of pipelines. It was concluded that the reason is the decrease in oscillations and the decrease in the pipeline frequency due to the increase in the length of the gas zone.

Developed a mathematical dynamic model of viscoelastic pipelines in which it flows in two stages, to solve the dynamic problems of viscoelastic pipes, an algorithm was developed, and based on this, a relevant application program was created with the realization of the oscillation of viscoelastic pipes in which gas flows, critical flow decreases due to the properties of the viscosity of the pipes, which is found when the mass of the earth increases, and this leads to an increase in the critical flow rate of the gas.

Kirill, et.al, (2019), [8], investigated the oil field in Russia is an oil production field, the length of which is pipes about 8 km above the ground with a span of (1-5 m) meters above surface on a concrete support. A model based on the dynamic flow of different phases was used to complete the piping work. Vibration measurement equipment was used to check the model.

Density of multistage tubes improved. Hydrodynamic work, analysis and modeling were carried out. One of the factors that affect the operation of pipes is the terrain. With a higher gas flow rate, the speed of the slug increases. At the critical gas velocity, the gas flow becomes stratified, and this presents more vibration and less dynamic impact of the tubes. Pressure has an effect. It is very clear that the velocity of the gas, due to the compressibility of the gas, if the pressure increases, the velocity decreases. The tubes have weight, as an increase in the weight of the tubes can reduce movement. It can lead to the failure of the stent and its damage can damage the tubes and this causes losses. The complex terrain of the pipeline. The presence of the pipeline elevation sections extends the slug regime zone (up to 30% in gas flow rate) in comparison with a flat pipeline and increases the mechanical influence up to (3-5) times. These estimations are based on modeling data. Gas flow rate, with higher gas flow rates, the slug velocity increases (velocities of up to 25 m/s fixed), which strengthens the mechanical influence of slugs on the compensators. Al though the weight of slugs decreases with higher gas flow rates, velocity is influenced by more. When the critical gas flow rate is reached, slugs are destroyed. The flow becomes stratified, which is characterized by greater vibration but much less mechanical influence (no pipeline movements).

Wenwu, et.al, (2019), [34], studied the vibration caused by a two-phase flux vortex, which was used by (Van der Poel) to describe the oscillating force. He used the finite element method in the solution and concluded that the geometric linear analyzes have an influential effect on the natural frequency as well as the critical velocity. From the results it was found that the increase in gas leads to an increase in the natural frequency and this increase in the fluid flow rate.

Model (VIV), which is built with (CF), (AX), and solved by finite elements, is found to increase the gas flow to increase the natural frequency. Dynamic analyzes were performed to determine the stability of the effect of gas volume and fluid flow rate on pressure and displacement, for different velocities(c-f)clamped -free. It was found that an increase in the fluid flow rate R causes an increase in resonance.

Qian , et.al,(2020),[35], studied a mathematical model was created for this research, the Galerkin differential equation, which is solved by the fourth-order Runge-Kutta algorithm in which wave bifurcation occurs in tubes when the flow velocity increases. In this paper, he studied the dynamic properties of incomplete tubes. There are cases of low and high field echo-conveying pipe has been one central issue of concerns in nonlinear dynamics.

In this paper, the novel nonlinear model of fluid-conveying pipe with geometric imperfection has been proposed for the first time. The dynamic equation of the imperfect pipe conveying fluid was derived through the generalized Hamilton's principle. The resonance response of the imperfect pipe can be suppressed by increasing the viscoelastic damping coefficient. The vibration state is transformed from high energy resonance to low energre sonance especially in the multi-mode vibration frequency range.

Peter and Leonid, (2021), [36], presented a mathematical model is developed as well as a computer to calculate the acoustic oscillation if the medium is water or gas. The acoustic effects can be caused by bending or branches due to an external source connected to the tube. Non-linear damping by hydraulic friction both take the output model obtained from computer code NETPULS are developed for evaluation of an acoustic oscillation in a liquid or gaseous medium. Use the input data to calculate mechanical vibration and evaluate mechanical vibration.

Vibration caused by flow is examined with high efficiency. The labor penalty in this paper determines the cost. To avoid the shortcomings of NETPULS, it is necessary to integrate the NETPULS code with the specialized piping program to analyze the complex piping vibration. Experimental model will help to verify developed software against experiment.

Fig, (2-2) installation of GERB Viscous Damper (Run B)

Gian, et.al, (2021), [37], examined tubes that transport fluids have many practical applications, such as hydraulic control lines and aviation fuel lines. The high velocity flowing inside the pipe leads to vibrations not due to centrifugation, because of the Coriolis force, in this paper a numerical technique was used to solve the dynamic problems of annular fluid transporting pipes by (FEM) this method solves in particular the equations of pipelines transporting fluids.

In this paper, a steel tube with water was studied. The results show the congruence between FEM) and the Hermitian method, especially the first one-dimensional frequency of the items used. The effect of the Coriolis force on tube vibrations cannot be compared in any other way because it is not available in the previous literature.

Noora, (2020),[38], studied four types of metals were used (aluminum, steel, concrete, and chlorinated polyvinyl chloride (CPVC)). Each metal of the tubes has four different ends: (simple - simple, clamped, clamped, clamped - simply, clamp-free) to study the normal frequency and permissible speed before failure by using three types of working fuels (gasoline, kerosene and diesel), also the present work studied the effect of the Length (3.048 m and 12 m). (Matlab2014) program used to study the effect of pipe vibration.

From the results, it was concluded that the best metal that can withstand a wide range of speeds is steel. The results show that (c-c) pipe is the best case study and the weakest case (c-f) pipe. From the applied case of Karbala refinery, it was found that the best types of pipes are simple - simple. They work on a safety factor equal (2) as the ratio is (ω / ωn) is far from the induced vibration

2.3 Experimental and Numerical Studies

Ni, et.al, (2011), [39], studied the problem of vibration of free tubes that transport fluids with several different ends. Therefore, he used a new method called Differential Transformation Method (DTM). The method (DTM) was used to calculate the natural frequency and critical velocity and the results were compared with the differential Quadrature method (DQM) and the results previous.(DTM) which features high accuracy in vibration analysis and critical velocity calculation.

Free-tube vibration analysis using a differential analysis method with exemplary limits . The results obtained using the (DQM) method are compared. In this paper, the accuracy and efficiency of (DTM) in the analysis of tubes that transport fluids are demonstrated.

Shuichiro,et.al,(2014),[40], presented the hydrodynamic force generates destructive vibrations to structures and pipes, and this may lead to acoustic problems in industrial machinery This phenomenon is known as flow-induced vibration. This vibration causes malfunctions in pipes and engineering equipment. Vibration problems are important in the engineering industry because of the damage it causes to industry, whether it's one-stage or two-stage for different flows, external or internal flow. In this paper, focus on the previous literature and what has been addressed in (FIV), and (FIV) classification in the academic industry. Internal interest at (FIV) has focused on the two phases generated in flow systems in industrial piping.

In previous literature where (FIV) was presented in two stages, And in the previous studies of flow-induced vibration where it was performed in two stages in a wide field, from previous studies it was found that the two-stage inflow-induced vibration (FIV) requires a high concentration. Fluid flows should be checked in two stages for the causes of problems. Researchers agree that slow streams have fluctuations in forces, compared to other streams. To reduce the internal FIV, attention should be paid to the engineering and operational conditions. Therefore, the natural frequency of the tube structures should be higher than the characteristic frequency. Two-stage (50Hz) to prevent resonance, so pay attention to the natural frequency of the pipe and increase it, so it takes care of installing the pipe solid support, choose the appropriate metal for the pipe and reduce the occurrence of liquid slug. In the case of two phases, the flow of fluid mass on the wall of the pipes is very large. Therefore, sharp elbows should be avoided.

Jan and Andrzej, (2014), [41], studied in this paper discusses the model of transverse vibrations of a pipe induced by flow velocity pulsation. The motion is described by a system of two non-linear partial differential equations with periodically variable coefficients. The analysis uses the Galerkin method with orthogonal polynomials. The instability regions are determined by Floquet's method. The influence of selected parameters on natural frequencies and on the character and level of vibrations is studied

Discuss in this paper the vibrations caused by the tube due to transverse velocity. Two nonlinear differential equations with coefficients were used for this purpose, so the Galerkin method was used to study the areas of instability in the tube by the Floquet’s method, where the effect of velocity on the natural frequency as well as vibration levels was studied.

Andrzej and Jan, (2017), [42], summarized the experimental studies and numerical simulations of the vibrations of unplanned tubes. The theoretical analysis was carried out on a three-dimensional dynamic model of the curved tube. Experiments were carried out in the case of complex simple standard resonance.

The theoretical and empirical analysis of the parametric vibration of tubes due to the flowing liquid was studied. A three-episode model of a tube was used. In such vibrations occur inside and outside the aircraft there are different types of resonance. Occurs when the natural frequency is equal to a group of two modes and this is equal to the pulse frequency, the simple resonant frequencies are the type of vibration that takes the form of free vibration. The results showed that the Corolis force is related to the fluid flow in the hydraulic system.

Khudayarov, et.al, (2019), [43], studied the problems of vibration of pipelines .Where they developed a mathematical model according to Winkler's rule paying attention to the viscosity properties of the pipe material axial strength and internal pressure according to the Boltzmann-Volterra model. Viscosity leads to a fracture at the critical velocity. As the viscosity modulus increases and the internal pressure increases, this leads to a decrease in the critical flow rate. It was found that the vibration increases when the mass is reduced.

In this paper, vibration problems were studied in pipelines made of composite materials, so a mathematical model was developed for it, taking into account the properties, axial force and vacuum pressure according to Winkler's rule, so he developed the algorithm according to the differential equation. The flow where the increase in the viscosity coefficient and the internal pressure as well as the mass leads to a decrease in the critical flow rate, so it was found that the critical flow increases with the increase of Reynolds number, as well as the increase of the coefficient of singularity and the Winkler base coefficient. Note that more mass is left on the pipeline.

Qian, et.al, (2019), [44], presented the barometric vibrations of tubes that transport fluids connected at both ends. Under pulsed flow excitation, the equation is derived by Hamiltonian principle. And the viscosity of Kevin-Voigt, and the intrinsic frequencies are determined according to the conditions of the elastic limit. According to Galerkin, normal frequencies and transmission fluid modalities are obtained for pipes of different flow capacities. The results show that sub-harmonic resonance and complex resonance can appear in the supported tubes. Sub-harmonic resonance occurs at(1/5, 1/8 and 1/13) at a given time.

In this paper, he mainly focused on the barometric resonance of flexible tubes supported under the influence of flux. A dynamic, non-linear model of vibration of flexible tubes at both ends was generated by Kevin – Voigt for viscous damping. The effect of spring stiffness coefficients and pulsating flow equations on flow characteristics was also studied. When analyzing the effects of different response stiffness, it was concluded that the free vibration of the tubes corresponds to the boundary conditions (null, clamped, clamped and clamped) if the stiffness is zero. To achieve the correctness of the dynamic model, the flow velocity is increased. The natural frequency is reduced.

Khudayarov, et.al, (2019), [45], studied the problems of vibration and vibration of pipes made of composite materials for transporting gases and liquids were studied. A dynamic model of the motion of pipes that convey fluid flow is generated by the Hetenyi rule, as well as the calculation of axial force and viscosity, pipe structural materials, pressure, internal pressure, and the Winkler rule of elastic viscosity, which were used in this integrated model of Boltz-Mann-Multera research with Weak single core genes. By Bubnov-Galerkin, an (IDE) is being studied for a system of ordinary differential equations. He developed a computational algorithm to solve the problem of single cores in the IDE using the quadratic formula. Pipeline information and rate velocity were analyzed flow. Basic Vibration Information Viscosity of the pipe material and the base of the pipeline we observe a large change in the critical flow rate.

This paper is concerned with the vibration of composite pipelines. A mathematical model was developed using the Hetenyi rule. Attention is paid to the characteristics of tube viscosity and axial strength. t the viscosity parameter of the material and the pipeline base leads to a decrease in the critical flow rate. In this research, vibration problems were studied in pipes made of composite materials. Therefore, a mathematical model was developed for it, taking into account the properties of the pipe, axial force, and vacuum .Compression according to Winkler's rule, so he developed the algorithm according to the differential equation. The flow where the increase in the viscosity coefficient and the internal pressure as well as the mass leads to a decrease in the critical flow rate, so it was found that the critical flow increases with the increase of Reynolds number, as well as the increase of the coefficient of singularity and the Winkler base coefficient. Note that more mass is left on the pipeline.

Kadhum and Mohamed (2020),[46], presented the vibrations caused by the vortex were studied using an obstacle. This obstacle is used to generate the vortex. The obstruction is placed in a square tube used to transport the fluid. Flow rate is related to the Reynolds number where it is (2100-860) in laminar flow and when it is (6200-3500) turbulent flow. Use the ANSYSFLUENT program to solve the Navier-Stokes equation in the case of turbulent flow. Experimental results showed that the obstruction increases the frequency of the tubes. Reynolds number has a strong effect on vibration. Vibration is caused by the intense friction of the fluid against the walls of the tube. It was found through the results that the height of the obstacle has an effect on the pressure and leads to a decrease in pressure.

Check for vibration if there is an obstruction within the pipe being supported simply if the flow is turbulent or laminar. Through the results, it was found that Reynolds has an effect on vibration, which leads to an increase in the wall displacement and also the frequency of the tube in the absence of an obstacle, but in the case of an obstacle, when Reynolds increases, the wall displacement increases.

Enbin, et.al, (2020), [47], focused on abnormal vibrations of pipelines, especially natural gas pipelines, which pose a pipeline safety hazard. In the event of a pipeline failure, this leads to huge economic losses and damage to the environment. Yongchang gas station has been set up in China's East-West gas pipeline system. Abnormal vibrations in the western outer pipelines of Yongchang Station , and this vibration varies according to the volume of gas transported. Analyzes are performed for these lines and a digital model of these tubes is generated. To reduce pipeline vibration, Note that fluid pressure fluctuation is the main cause of vibration. The greater the volume of gas, the greater the intensity of pipeline vibration, the right thing is to enlarge the diameter and put strong restraints and supports for pipelines.

The law of vibration was obtained in this paper by numerical simulation. To transmit vibration, it was concluded in this paper that the main cause of abnormal vibration is the fluctuation of fluid pressure in pipes. This fluctuation generates a fluid excitation force. This force acts in the elbow and changes the diameter, which leads to abnormal vibration of the tube by analyzing the fluid pressure fluctuation model in the tubes. The pressure frequency close to the low natural frequency of the tubes causes resonance and this makes the vibration more complex.

Gia, et.al, (2020), [48], examined the vortex-induced vibration is a research center for the FSI. The vortex vibrations are of pure interest to engineers, especially mariners, with the development of research. Because of the flux-induced vibration (FIV), many of the vibrations are caused by the wake-up vibration (WIV) and (VIV).

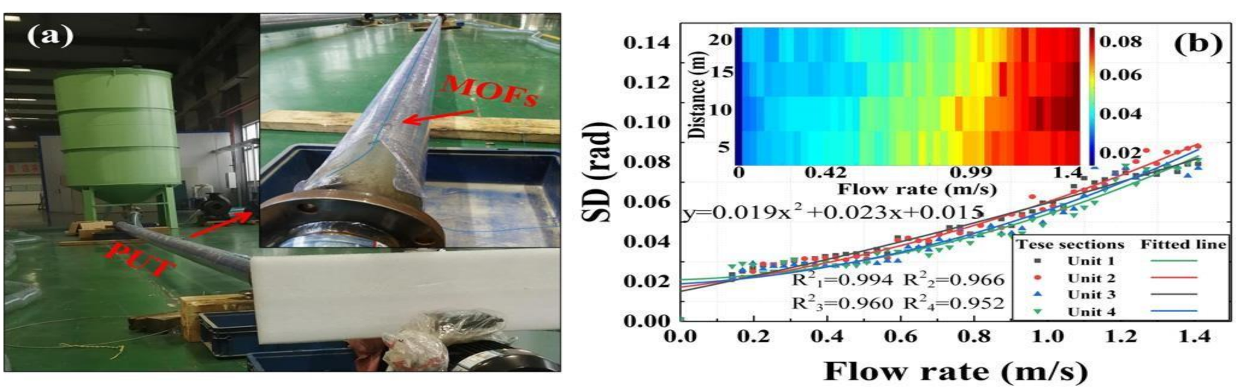
To study the problems of FIV by CFD of great importance and accuracy in the results of WIV arthrography, different models were used to show the effect of Reynolds number. Where it was found that the (DNS) method is characterized by high accuracy in calculating the results of (FIV).

Feng, et.al, (2021), [49], examined the excited model for the nonlinear parameters of the tube, such as the periodic velocity and flow velocity, the tube stability and vibration are studied analytically and numerically. Through numerical simulation, it is revealed that no motion except for complex parametric resonance can occur in periodic relativistic motion. Flow velocity, viscosity and damping affect the parametric vibration.

Where this paper suggested a non-linear dynamic model of the insulation tube conveying fluids by means of rotational speed and turbulent speed due to the tube axis that can be extended and viscous damping axis as well as geometric lines .Parametric vibrations can be caused by a periodically turbulent liquid, where the parametric motion has the opposite effect of the rotational motion, and the parametric vibrations affect the rotational motion, where the parametric fire is affected by the static rotational motion.

Tongda, et.al, (2021), [50], studied Non-invasive pipeline monitoring is a key business for pipeline sustainability, in this paper a pipeline distributed (MOF-DAS)-based pipeline flow rate is proposed. This proposed system explores (FIV) to measure flow rate. Euler radiation theory was used. - Bernoulli to create the Sensor Model (FIV). The pressure on the tube wall was analyzed at different flow rates. From the results, it was found that the pressure is proportional to the squared flow, and this was experimentally examined using a 25-meter tube using (MOF-DAS), which is the first time that (MOF-DAS) was used for exploration. Gas flow rate, the results showed that the experimental and numerical simulations are in good agreement.

In this paper, a sensitive system for measuring output flow by (MOF-DAS) was developed to measure (FIV). From the results, it was found that the pressure SD simulation is related to the increase of the squared flow rate in the case of (MOF-DAS) performed in the laboratory and the use of monohydric water was found in this. Flow rate (0.8 to 3.6 m/s) from the results found that high flow has high sensing and accuracy.



Fig, (2-3) (a) , prepare an experiment for testing. (b) flow results for carbon steel tubes.

2.4 Summary of Literature Review

The tables (2-1, 2-2, and 2-3) shows a summary of the research mentioned previously.

Table (2-1) summary of experimental studies

Ref. No.	Authors	Year of the study	Main conclusion and results
10	**Przemyslaw**	2011	This paper presents a procedure that allows the determination of vibration limit values depending on the length and diameter of pipeline spans and allows one to calculate the frequency of free vibrations of pipeline spans.
11	**Nathera**	2012	It is shown from the computed results that the crack orientation has less effect on frequencies for the internal crack plate than the edge crack and corner crack in the first mode.
12	**Yang, et.al**	2012	In summary the experimental investigation, Because of the fluctuation of the force leads to the flow in two stages a52.5mmI.D.76.2mm radius,901elbow is presented in his paper.
13	**Dai, et.al**	2012	studied the application of the (TMM) matrix to the vibration analysis of three-dimensional pipes, where the natural frequency of pipes with straight or curved shapes was calculated.

14	**Kong, et.al**	2013	The FE model is valid and hence suitable to be used for stress analysis. The highest operating flow rate for the piping system are360mmscfd and 400mmscfd for fully-opened and partially-opened FCVs respectively. Beyond this limit, the piping
4	**Veerapandi, et.al**	2014	The maximum deformation occurs at the top pipe Configuration is0.074019mm and the corresponding natural frequency is 27.407Hz Analytical result of Natural Frequency at Mode Shape2is27.912.Accuracy:1.8%, hence the computational results are validated.
15	**Igor, et.al**	2015	A cous to mechanical vibrations of pipelines, induced by the formation of turbulent vortices in a liquid or gas flow, are a currently central
16	**Shankarachar , et.al**	2016	The results of the guided end conditions show interesting facts, which was not dealt before. As the fluid velocity increases, both analytical and FEA results presents the variation in frequencies.
17	**SIBA, et.al**	2016	The main purpose of these paper is to create very accurate measurement procedure for the discharge of the flow in pipes for economic and safety reasons
7	**Ahmed, et.al**	2019	This study deals with the screening analysis and computational analysis of flow-induced vibration in the piping system, focusing more on oil and gas industry

18	**Manoj and Subodh**	2019	Natural frequency of vibration and critical flow velocity were found to be very high for clamped-clamped steel pipe as 87.47 rad=sec and 141.43 m=sec respectively and very low for clamped-free CPVC pipe as 2.2114 rad=sec and 3.36 m=sec respectively.
19	**Richard and Jacqueline**	2021	The importance and complexity of the piping manifold in oil and gas industries are discussed. Specifically, the lack of research into the role that wall pressure fluctuations play in generating flow induced turbulence in a piping manifold

Table (2-2) summary of numerical studies

Ref. No.	**Authors**	**Year of the study**	**Main conclusion and results**
20	**Long and Fuzhen**	2010	It was studied according to the method of micro-integration of the vibration of the reinforced tubes, and it was analyzed dynamically.
21	**FAAL and DERAKHAN**	2011	The non-dimensional natural frequencies of the tubes are increased by increasing the stiffness of the tubes. In the stability analysis of the pipe vibration the parameter β plays an important rule.

22	**Yetzirah, et.al**	2011	Higher production rates and resulting piping vibration problems are frequently encountered in on-shore facilities as existing infrastructure is pushed well beyond design capacity.
23	**Khudayarov and Turaev**	2015	The results of the research showed that the study of the viscoelastic properties leads to a reduction of vibration by 20-40%, so it was found that the process of damping the vibrations in the pipes
24	**Chen Ana and Jian**	2015	The analysis of the dynamic behavior of liquid and gas by (GITT) method showed that it is a very good method for two-stage flow analysis.
25	**Li Yun and Yang**	2016	The free oscillations of tubes with different ends were analyzed by the VIM method. The two methods VIM and DTM have the same accuracy results in the velocity and frequency of the tubes carrying fluids.
26	**Shuai, et.al**	2017	A model is proposed in this paper with an equation structure project. Comparison of VIV and IFE experiments in simulations, where IFE and VIV were examined by time-tuning during discharge time to show riser, vibration and prevailing frequencies
27	**Mastaf**	2017	Studied fundamental natural frame frequency and critical inlet flow velocity of the simply supported stepped pipe conveying fluid

28	**Etim**	2018	Favor ably to experimental results FIV model has been developed for the case of clamped ends of a free pipe section and the case of simply supported ends of a free pipe section.
29	**Xia Tan, et.al**	2018	They focused in this research on finding the balance and stability of the tubes that transmit fluids, as well as the natural frequencies according to the Timoshenko beam theory.
30	**Haider**	2018	The properties of the oil affect the vibrations. The vibration separates the components of the crude oil, and the high temperature increases the vibration of the metal and the oil, which leads to increased wear.
31	**Qianli and Zhili**	2018	In this paper, a new method for vibration analysis was proposed, as he proposed a new matrix method based on the Laplace transform. They proposed three types of curved, flexible and fixed carburetor tubes. To achieve the accuracy of the proposed matrix.
32	**Sergio, et.al**	2018	In pipelines that transport liquid and gas, a model has been proposed to measure the vibration that occurs due to flow.
33	**Khudayarov and Komilova**	2019	They developed a mathematical dynamic model of the two-stage flowing viscoelastic pipelines, to solve the dynamic problems of viscoelastic pipelines, an algorithm was developed..

8	**Kirill, et.al**	2019	Modern computational algorithms of dynamic multiphase flow are able to describe with sufficient accuracy (25-30% quantitative error), the processes of slug formation and movement.
34	**Wenwu, et.al**	2019	In this paper they studied the vibration caused by a two-phase flux vortex, which was used by Van der Poel to describe the oscillating force.
36	**Komilova**	2019	In this paper, he focuses on the elastic properties of the material and the vibration of tubes that transport fluid in viscous vibrating tubes. Vibration is measured in a mathematical program as the fluid flows through the tube.
35	**Qian , et.al**	2020	A mathematical model was created for this research, the Galerkin differential equation, which is solved by the fourth-order Runge-Kutta algorithm.
36	**Peter and Leonid**	2021	Results of performed analyses clearly show that severe vibration in considered case is induced by superposition of two resonances: steam acoustic resonance and piping structural resonance
37	**Gian, et.al**	2021	In this paper, a steel tube with water was studied. The results show the congruence between FEM) and the Hermitian method, especially the first one-dimensional frequency of the items used.
38	**Noora**	2021	From the applied case of Karbala refinery, it was found that the best types of pipes are simple -

			simple. They work on a safety factor equal (2) as the ratio is (ω / ωn) is far from the induced vibration

Table (2-3) summary of experimental and numerical studies

Ref. No.	Authors	Year of the study	Main conclusion and results
39	**Ni, et.al**	2011	In this paper, they studied the problem of vibration of free tubes that transport fluids with several different ends. Therefore, they used a new method called Differential Transformation Method (DTM).
40	**Shuichiro ,et.al**	2014	The phenomenon of vibration caused by the flow has been studied This vibration causes failure in pipes and engineering equipment. Vibration problems are important in the engineering industry because of the damage it causes to industry.
41	**Jan and Andrzej**	2014	Discuss in this paper the vibrations caused by the tube due to transverse velocity. Two nonlinear differential equations with coefficients were used for this purpose, so Galerkin's method was used.
42	**Andrzej and Jan**	2017	The theoretical and empirical analysis of the parametric vibration of the tubes due to the flowing liquid was studied. A three-eternal model

			of the tube was used, in such vibrations that occur inside and outside the aircraft there are different types of resonance.
43	**Khudayarov, et.al**	2019	it was revealed that the viscosity parameter of the material and the pipeline base leads to a decrease in the critical flow rate.
44	**Qian ,et.al**	2019	, they mainly focused on the barometric resonance of flexible tubes supported under the influence of flow. A dynamic, nonlinear model of vibration of flexible tubes at both ends was created by Kevin – Voigt for viscous damping.
45	**Khudayarov, et.al**	2020	studied the problems of vibration and vibration of pipes made of composite materials for transporting gases and liquids. A dynamic model of the motion of pipes that convey fluid flow is generated by the Hetenyi rule,
46	**Kadhum and Mohamed**	2020	the results concluded that the insertion an obstacle in the square pipe lead to increase the pressure drop and the friction factor with high percent
47	**Enbin, et.al**	2020	This research studied the abnormal vibrations of pipelines, especially natural gas pipelines, which pose a pipeline integrity hazard. In the event of a pipeline failure, this leads to huge economic losses and environmental dangers.

48	**Gia, et.al**	2020	As vortices must be the key analysis contents in the modeling of FIV of offshore structure, we think this vortex identification method may be applied to reveal the vortex structures in future numerical simulation analysis
49	**Feng, et.al**	2021	Create an excited model of the non-linear parameters of the tube, such as the periodic velocity and flow velocity, in which the tube stability and vibration are studied analytically and numerically.
50	**Tongda, et.al**	2021	In this paper a pipeline microstructure-based flow rate sensing system (MOF-DAS) is proposed. This proposed system explores flow-induced vibration to measure flow rate. Euler radiation theory was used. - Bernoulli to create the Sensor Model (FIV).

Chapter Three Mathematical Model and Numerical Analysis

Chapter Three: Mathematical Model and Numerical Analysis

In this chapter, the theoretical analysis of a flow induced vibration for four types of the end conditions: (simply-simply, clamped-clamped, clamped-simply and clamped-free) and four kind of pipe materials: aluminum, steel, chlorinated poly-vinyl chloride (CPVC) and a concrete are used for this study. MATLAB2014 program used to analyze the flow induced vibration of the pipe.

3-1 Vibration Analysis

Fig. (3-1) shows a straight pipe that conveys a flowing fluid, where the straight pipe is simply supported on both sides, has dimensions of diameter (D), thickness (th), and length (L) where the pipe is thinner with a degree (D/L < 0.1) where this ratio is considered beam, and the fluid flowing inside the pipe must be incompressible (the fluid whose volume or density does not change with pressure),[5].

The study of vibrations of pipelines carrying fluids, with the flow-induced vibrations in the pipe line need to find the derivation of the equation of motion and the instability of the pipe depends on the type of end conditions on the pipe, where the pipe supported by both ends is bent outward, as shown in Fig (3-1), [1].

The equation of motion for a straight pipe was developed and solved according to

Fig. (3-2), which shows the transverse deflection Y(x, t) of the pipe.

$$F - P.A\frac{\partial^2 y}{\partial^2 x} = \rho A\left(\frac{\partial}{\partial t} + v\frac{\partial}{\partial x}\right)^2 y \qquad \dots (3\text{-}1)$$

As a result of generating shear stress due to fluid friction with the pipe walls, it generates opposite pressure, for a constant flow velocity, summing the forces parallel to the pipe axis in figure (3-2a) gives, [1].

$$A\frac{\partial P}{\partial x}+\tau.S=0 \qquad \text{… (3-2)}$$

Where, (S) is the inner perimeter of the pipe, (τ) is the shear stress on the inner surface of the pipe, the equations of motion of the pipe are derived from Figure (3-2b), Summing forces parallel to the pipe axis gives

$$\frac{\partial T}{\partial x}+\tau.S-Q\frac{\partial^2 y}{\partial x^2}=0 \qquad \text{… (3-3)}$$

Where,

(T): is the tension longitududinal that occurs in the pipe due to the fluid flow

(Q): is the transverse shear load to which the pipe is subjected

The forces on the element of the pipe that act normal to the pipe axis accelerate the pipe element in the (y) direction for simple deformation:

$$\frac{\partial Q}{\partial x}+T\frac{\partial^2 y}{\partial x^2}-F=m_p\frac{\partial^2 y}{\partial t^2} \qquad \text{… (3-4)}$$

(m_p) is the mass per unit length of the pipe without flow

The transverse shear force (Q) in the pipe is related to the bending moment (M) and the pipe deformation by

$$Q=-\frac{\partial M_b}{\partial x}=-EI\frac{\partial^3 y}{\partial x^3}=0 \qquad \text{… (3-5)}$$

Where I: is the moment of inertia of the pipe and it's given b

$$I = \frac{\pi}{64}\left(D^4{}_o - D^4{}_i\right) \qquad \text{… (3-6)}$$

(Q): is proportional to ($\frac{\partial^3 y}{\partial x^3}$) of Eq. (3-3), where (y^2) can be neglected due to slight deformation. By combining Eqns. (3-1), (3-4), (3-5) to eliminate (Q) and (F):

$$EI\frac{\partial^4 y}{\partial x^4} + (PA - T)\frac{\partial^2 y}{\partial x^2} + \rho.A_f\left(\frac{\partial y}{\partial t} + v\frac{\partial}{\partial x}\right)^2 Y + m_p\frac{\partial^2 y}{\partial\ t^2} = 0 \qquad \text{... (3-7)}$$

Shear stress (τ) is excluded from Eqns. (3-2) and (3-3) to give.

$$\frac{\partial(PA - T)}{\partial x} = 0 \qquad \text{… (3-8)}$$

The term ($PA - T$) is separate of location along the pipe, as it assumes that at the end of the tube the tension is zero. Where the pressure generated by the fluid is equivalent to the external pressure (P = T=0 at x=L), so ($PA - T = 0$ for each x). The momentum is given by the equation $PA - T = \rho Av(v_j - v)$ where ($v\ j$) is the throat velocity.

Substituting $PA - T = 0$ into Eq. (3-7) gives the equation of motion for free transverse vibration of a straight, tension-free fluid-conveying pipe.

$$EI\frac{\partial^4 y}{\partial x^4} + m_f v^2\frac{\partial^2 y}{\partial x^2} + 2m_f v\frac{\partial^2 y}{\partial x\partial t} + m_t\frac{\partial^2 y}{\partial t^2} = 0 \qquad \text{… (3-9)}$$

The equation of motion for forced vibration of pipe conveying fluid may be written as, [1]

$$EI\frac{\partial^4 y}{\partial x^4} + m_f v^2\frac{\partial^2 y}{\partial x^2} + 2m_f v\frac{\partial^2 y}{\partial x\partial t} + m_t\frac{\partial^2 y}{\partial t^2} = F(x,t) \qquad \text{… (3-10)}$$

Where F(x, t): is the external harmonic force being applied normally on the pipe axis in the y- direction

3.2 The Governing Equations

Consider a fluid conveying pipeline based on the Euler-Bernoulli Beam theory. The pipe shall be supported at both ends by simple support, fixed support or free at one end. The fluid inside the pipe is assumed non-viscous and in-compressible. The mathematical model of the transverse vibration equation of the pipeline conveying fluid is derived by using Hamilton's energy principle. The structure of the pipe is assumed to be small deformation, internal damping and pressurization effects are either absents or neglected.

By using the energy equation depend on Hamilton's energy principle, [17, 26, 50,59, and, 1]

$$EI\frac{\partial^4 y}{\partial x^4}+m_f v^2\frac{\partial^2 y}{\partial x^2}+2m_f v\frac{\partial^2 y}{\partial x \partial t}+m_t\frac{\partial^2 y}{\partial t^2}=0 \qquad \ldots (3\text{-}11)$$

Where, $m_t = [m_p + m_f]$,

L, is length of the pipe.

m_p, is the mass per unit length of the pipe.

$$mp=\frac{\pi}{4}(D_O{}^2-D_i{}^2)\times\rho_{pipe} \qquad \frac{kg}{m} \qquad \ldots (3\text{-}12)$$

The product of the density times the area gives:

$m_f = \rho . A$ ….. is the mass of the fluid per unit length.

$$m_f = \frac{\pi}{4} D_i^{\,2} \times \rho_{fluid} \qquad \frac{kg}{m} \qquad \ldots (3\text{-}13)$$

v : is the flow velocity of the fluid (m/s)

E : is the modulus of elasticity of the pipe material

I : moment of inertia of the cross section of the pipe, [50, 59]

1- Stiffness term : $EI \frac{\partial^4 y}{\partial x^4}$

In the equation (3-11), first term ($EI \frac{\partial^4 y}{\partial x^4}$) is the describe a component of influencing force component acting on the pipe as a result of pipe bending

2-Curvature term: $m_f v^2 \frac{\partial^2 y}{\partial x^2}$

The term ($m_f v^2 \frac{\partial^2 y}{\partial x^2}$) exemplifies a component of the force performing on the pipe resulted from flow in the region of a deflected pipe (curvature in pipe). This term greatly affects the pipe stability which makes a pipe unstable

3-Coriolis force term: $2m_f v \frac{\partial^2 y}{\partial x \partial t}$

The third term ($2m_f v \frac{\partial^2 y}{\partial x \partial t}$) is the force required to rotate the fluid element. This force is called Coriolis force.

The coriolis is a result from the rotation of the fluid element due to the system lateral motion since each point in the span rotates with angular velocity

4-Inertia force term: $M \frac{\partial^2 y}{\partial t^2}$

The last term ($M \frac{\partial^2 y}{\partial t^2}$) is referred the effecting force on the pipe, because of the pipe inertia and the fluid flowing through it. Finally, it is observed that the dynamic behavior of the system greatly relies on a pipe stiffness, velocity of flow, and lateral displacement (boundary conditions). Thus, varying elastic structure flexibility should alter the dynamic behavior,[50,59]

3.3 Natural Frequency and critical velocity

The natural frequency equation The beam mass is replaced by the pipe mass. Therefore, the natural frequency of the pipe is taken.

[5, 50, 59]

$$w_n = (\beta \quad L)^2 \sqrt{\frac{EI}{ML^4}} \qquad \ldots (3\text{-}14)$$

The value of constant (βL)

Table (3.1) constant (βL)

Clamped- clamped	Simply-simply	Clamped-simply	Clamped-free
4.73	3.142	3.937	1.875

According to [Rao , 2004],the critical velocity of the fluid flowing into the pipe inside as:

$$V_{cr} = \frac{c}{L}\sqrt{\frac{EI}{\rho A}} \quad \text{… (3-15)}$$

The value of constant (c):

Table (3.2) constant (c)

Clamped- clamped	Simply-simply	Clamped-simply	Clamped-free
6.285	3.142	4.5	1.571

3.4 Finite Element Discretization of the Governing Equations

The equation of element deflection for straight two dimensional beam element could have the form, [5, 50, 59].

$$Y = \sum_{i=1}^{n} N_i a_i \quad \text{… (3-16)}$$

The above shape functions, Ni, represent the conventional customary two-dimensional beam elements which have two degrees of freedom at each node: one lateral displacement and the other rotational. And (a_i) is the generalized coordinates (displacement and rotation),(Y) is the deformation polynomial cubic function which defines the displacements and rotations at the nodes.

$$N_1 = \frac{1}{L^3}\left(2x^3 - 3Lx^2 + L^3\right) \quad \text{… (3-17a)}$$

$$N_2 = \frac{1}{L^2}\left(x^3 - 2Lx^2 + L^2 x\right) \quad \text{… (3-17b)}$$

$$N_3 = \frac{1}{L^3}\left(3Lx^2 - 2x^3\right) \quad \text{… (3-15c)}$$

$$N_4 = \frac{1}{L^2}\left(x^3 - Lx^2\right) \quad \text{… (3-17d)}$$

Where, L is the length of the pipe element. The kinetic and potential energies of a pipe element is give by:

$$PE = \frac{1}{2}\int_a^b EI\left(\frac{\partial^2 y}{\partial x^2}\right)^2 dx = \frac{1}{2}\int_a^b EI\left(y''\right)^T\left(y''\right)dx \quad \text{… (3-18)}$$

$$KE = m_t \frac{\partial^2 y}{\partial^2 t} dx = \frac{1}{2}\int_a^b m_t \left(\frac{\partial y}{\partial t}\right)dx \quad \text{… (3-19)}$$

The element stiffness matrix for pipe as beam element is obtained as,

$$K_1 = \frac{2EI}{L^3}\begin{pmatrix} 12 & 6L & -12 & 6L \\ 6L & 4L^2 & -6L & 2L^2 \\ -12 & -6L & 12 & -6L \\ 6L & 2L^2 & -6L & 4L^2 \end{pmatrix} \quad \text{… (3-20)}$$

The force acting on the pipe due to the fluid flow is given by,

$$\pi = \int_a^b m_f v^2 \left(\frac{\partial^2 y}{\partial x^2}\right)dx = \int_a^b \rho A v^2 \left(y'\right)^T\left(y'\right)dx \quad \text{… (3-21)}$$

Where, ρ is the density of fluid and A is the cross sectional area of pipe.

Where it was found that the stiffness matrix occurs due to the fluid flow inside the deviated pipe.

$$K_2 = \frac{m_t v^2}{30L}\begin{pmatrix} 36 & 3L & -36 & 3L \\ 3L & 4L^2 & -3L & -L^2 \\ -36 & -3L & 36 & -3L \\ 3L & -L^2 & -3L & 4L^2 \end{pmatrix} \quad \dots (3\text{-}22)$$

The stiffness matrix [K2] tends to weaken the overall stiffness of the pipe system. The force that tends to create instability of the fluid flowing inside the pipe is the Coriolis force, where it is called a dissipation matrix, which is given by, [50].

$$D = \int_a^b 2m_f v\left(\frac{\partial^2 y}{\partial x \partial t}\right)dx = \int_a^b \rho A v^2 (y')^T (\dot{y}) dx \quad \dots (3\text{-}23)$$

$$D = \frac{\rho A v}{30}\begin{pmatrix} -30 & -6L & -30 & 6L \\ 6L & 0 & -6L & L^2 \\ 30 & 6L & 30 & -6L \\ -6L & -L^2 & 6L & 0 \end{pmatrix} \quad \dots (3\text{-}24)$$

Mass matrix,

$$m = \frac{(m_p + m_t)L}{420}\begin{pmatrix} 156 & 22L & -54 & -13L \\ 22L & 4L^2 & -13L & -3L^2 \\ 54 & 13L & -156 & -22L \\ -13L & -3L^2 & -22L & -4L^2 \end{pmatrix} \quad \dots (3\text{-}25)$$

3-5 Dynamic Analysis

The standard equation of motion in the finite element form is given by

$$(M_g)(\ddot{y}) + (D_g)(\dot{y}) + (K_g)(y) = 0 \quad \dots (3\text{-}26)$$

the global mass matrix: Mg

the global dissipation matrix: Dg

the global stiffness matrix: Kg=K1-K2

the solution of eigenvalues problem shall be executed with the characteristics matrix, which is equal to

$$\Omega = \begin{pmatrix} -(M_g)^{-1}(K_g) & -(M_g)^{-1}(D_g) \\ I & 0 \end{pmatrix} \quad \dots (3\text{-}27)$$

The damping term for the equation of motion, in which the matrix of eigen values is solved. This eigen value has two roots, one to measure the natural frequency, which is the imaginary part, and the second root is to measure the free frequency vanishing, which is the real part. This was solved using [MATLAB 2014] [50,59]

3-6 Cases Studied

The resulting vibration was studied due to the flow in the pipes that transport the liquid, where various materials (aluminum, steel, concrete and chlorinated poly-vinyl chloride (CPVC)) were used with different final conditions, namely (simply-simply, clamped-clamped, clamped-simply and clamped-free).The Hamilton equation was used because it was based on the Euler-Bernoulli beam theory. The equations were solved using (MATLAB R2014) program. The values shown in Tables (3-3) to (3-6):

Table (3-3) Aluminum properties, [50]

SN	parameter	Value
1	Length of pipe	3.048m
2	Outside diameter of pipe	0.0254m
3	Thickness of pipe	0.00165m
5	Density of aluminum	2699kg/m^3
6	Young`s of modulus of elasticity	68.9GPa

Table (3-4) Steel properties, [50]

SN	parameter	Value
1	Length of pipe	3.048m
2	Outside diameter of pipe	0.0254m
3	Thickness of pipe	0.00165m
5	Density of aluminum	8000kg/m^3
6	Young`s of modulus of elasticity	207GPa

Table (3-5) chlorinated poly–vinyl chloride properties, [50]

SN	parameter	Value
1	Length of pipe	3.048m
2	Outside diameter of pipe	0.0254m
3	Thickness of pipe	0.00165m
5	Density of (cpvc)	1550kg/m^3
6	Young`s of modulus of elasticity	2.9GPa

Table (3-6) concrete properties, [50]

SN	parameter	Value
1	Length of pipe	3.048m
2	Outside diameter of pipe	0.0254m
3	Thickness of pipe	0.00165m
5	Density of concrete	2400kg/m^3
6	Young`s of modulus of elasticity	17GPa

3. 7 Boundary Conditions for Pipes

Boundary conditions for pipes in matrices give a description of the state information at the supported ends of pipes with different boundary conditions, and the following describes the pipe ends as shown in the Figs. (3-7) to (3-9),[50]

3.1.1Simply-simply support:

At x=0

$$EI\,\frac{\partial^2 y}{\partial x^2}=0,\delta y=0$$

At x=L

$$EI\,\frac{\partial^2 y}{\partial x^2}=0,\delta y=0$$

3.1.2 Clamped- clamped support:

At x=0

$$\frac{\partial}{\partial x}\delta y=0,\delta y=0$$

At x=L

$$\frac{\partial}{\partial x}\delta y=0,\delta y=0$$

3.1.3 Clamped-simply support:

At x=0

$$\frac{\partial}{\partial x}\delta y=0,\delta y=0$$

At x=L

$$EI\,\frac{\partial^2 y}{\partial x^2}=0,\delta y=0$$

3.1.4Clamped-free support:

At x=0

$$\frac{\partial}{\partial x}\delta y = 0, \delta y = 0$$

At x=L

$$EI\frac{\partial^2 y}{\partial x^2} = 0, EI\frac{\partial^3 y}{\partial^3 x} = 0$$

3.8 Description and Application of the Pipe Program

MATLAB R 2014 software was developed, pipes with flowing liquid were used, it contains four types of pipes for four different materials with different supports, and dimensions for a given pipe (length, diameter and thickness). Different speeds are used to find out their effect on the pipe in terms of frequency, pipe deformation and when the distortion occurs .These effects are shown in the Figs. (3-10) to (3-13)

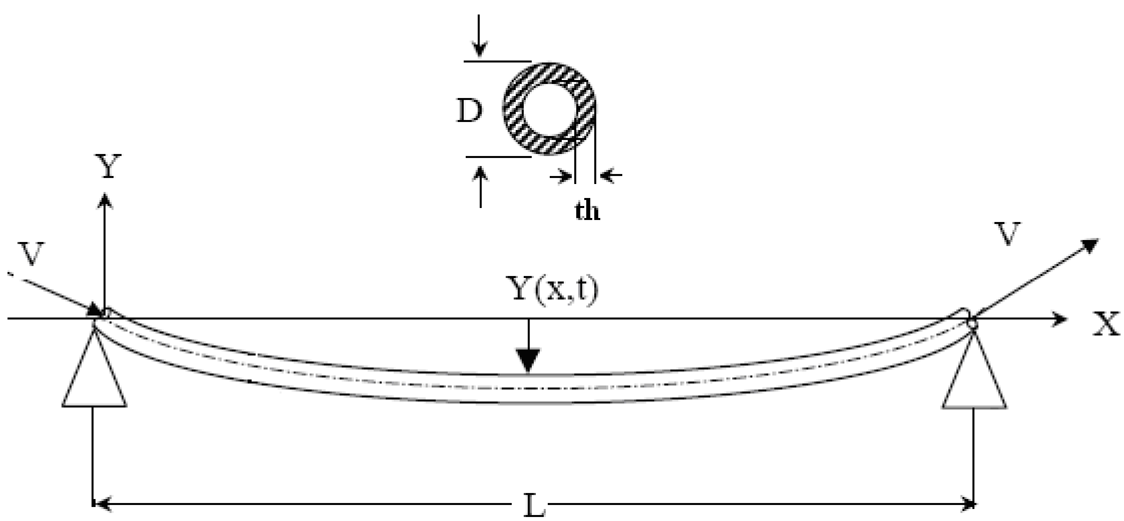


Fig. (3-1) fluid conveying Pipe ,[1]

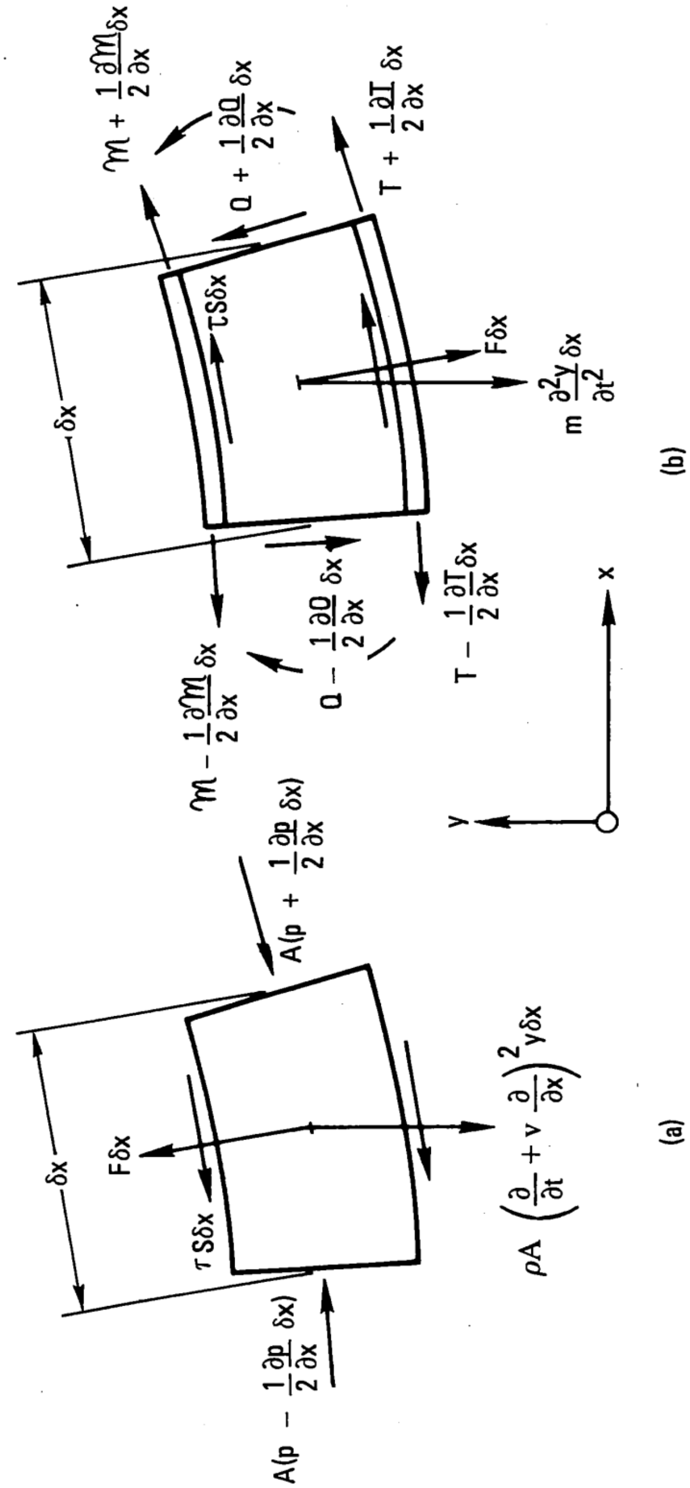


Fig (3-2) force and moments action (a)fluid(b)pipe element,[1]

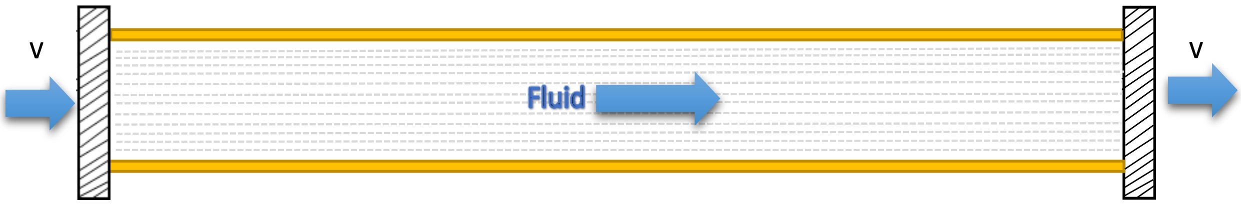


Fig.(3-3) pipe drawing Clamped- clamped

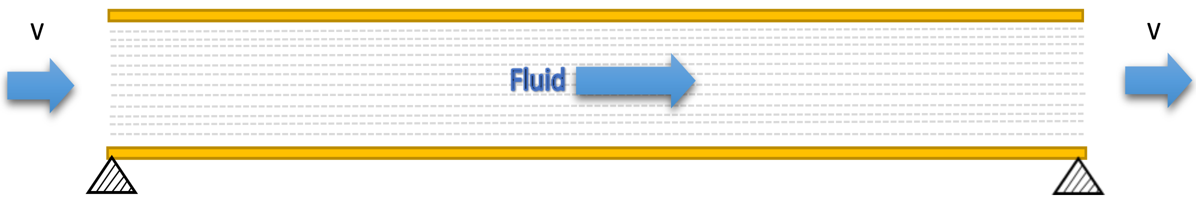


Fig.(3-4) pipe drawing simply –simply

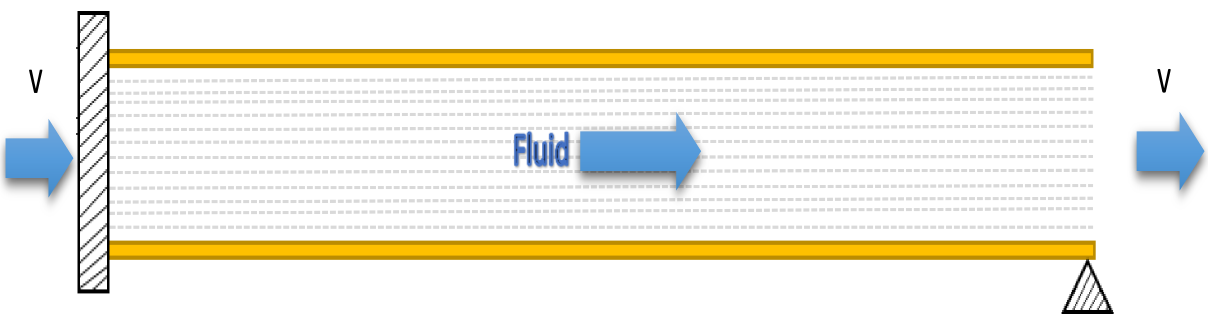


Fig.(3-5) pipe Clamped-simply

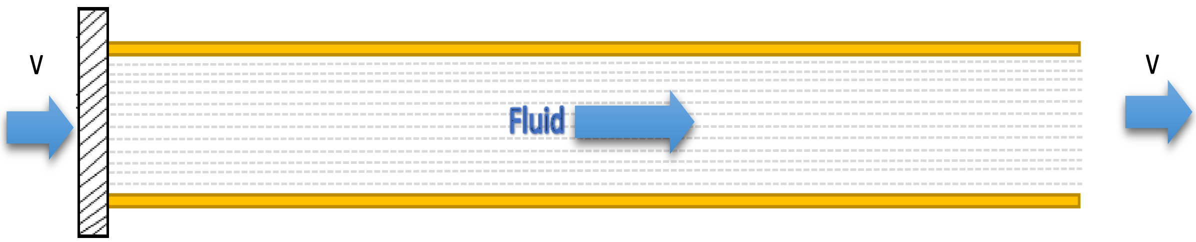


Fig. (3-6) pipe drawing Clamped- free

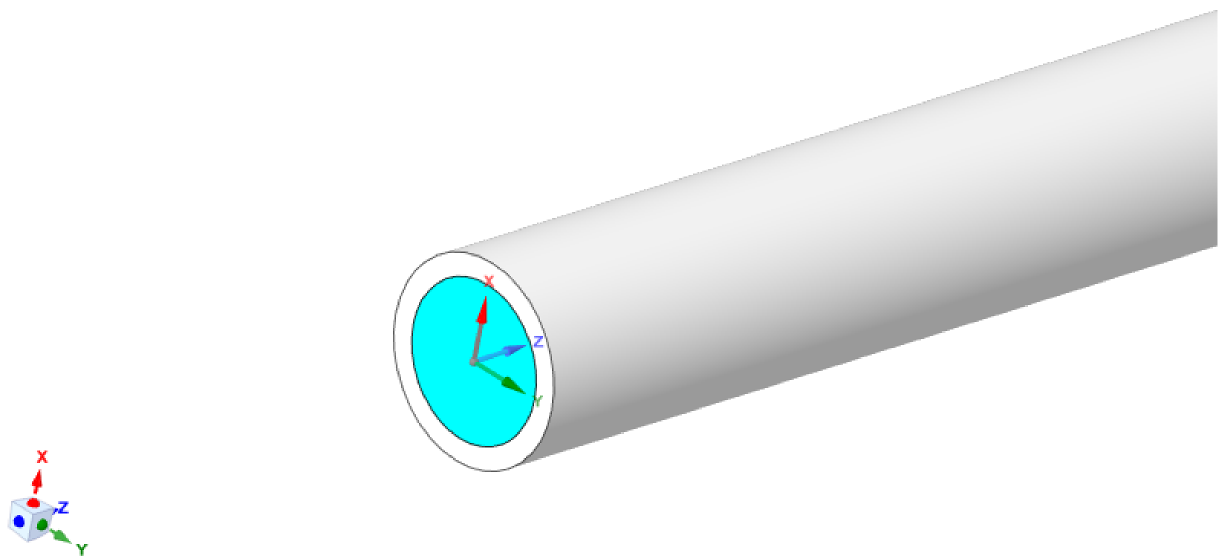


Fig. (3-8) 3-D pipe

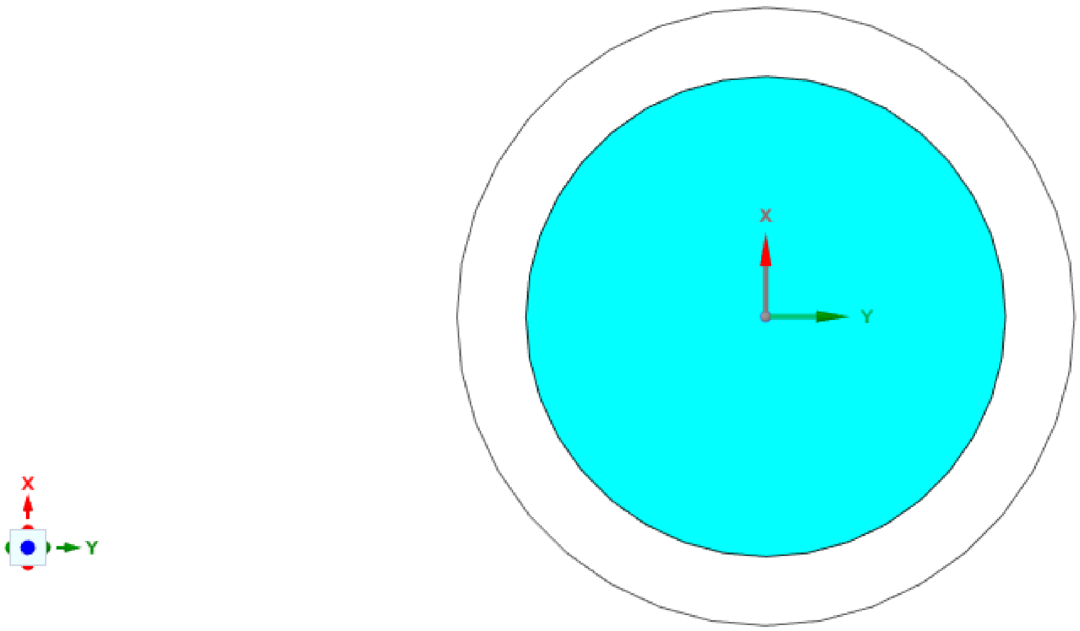


Fig. (3-9) cross-section of pipe

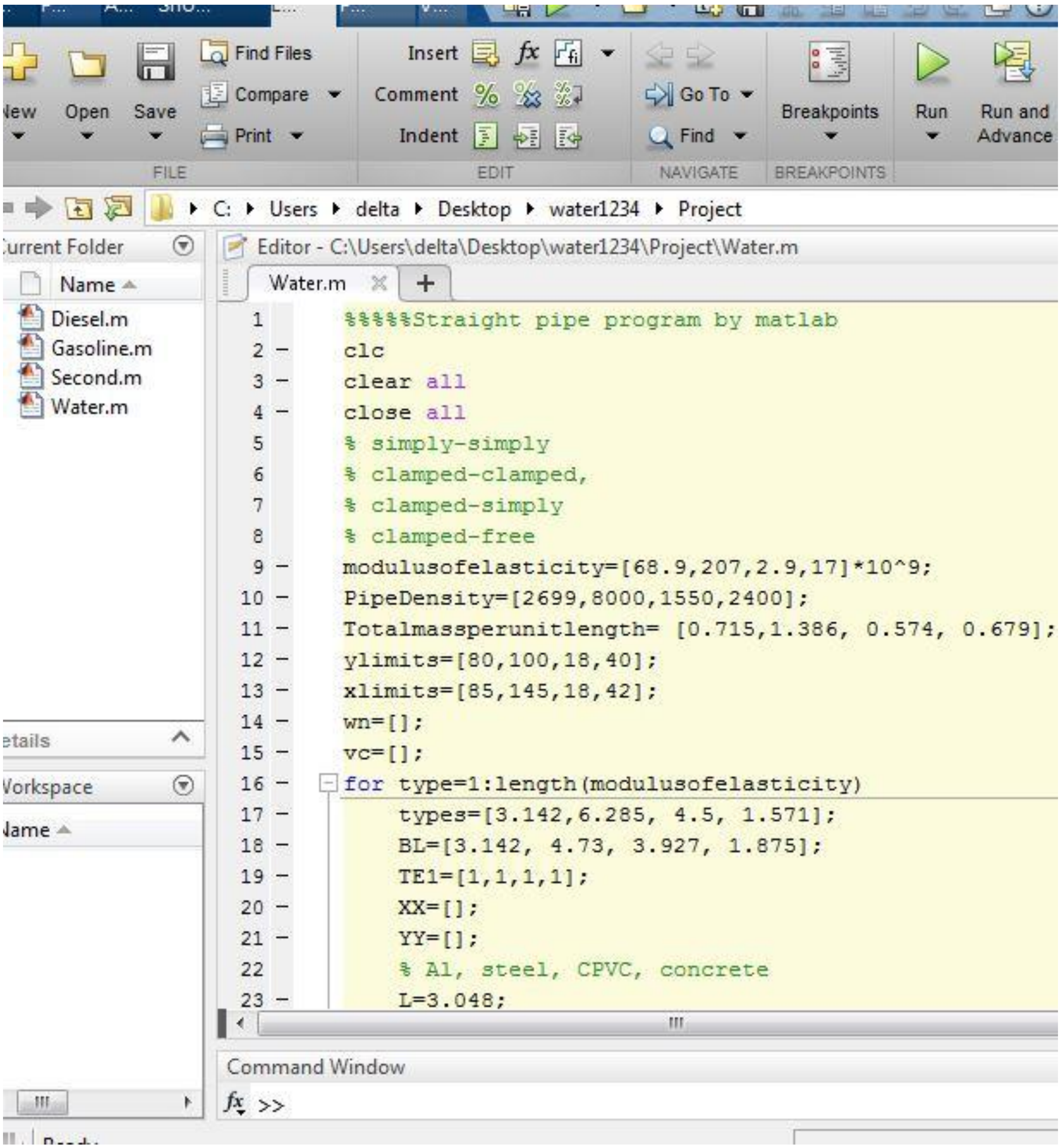


Fig. (3-10) flowing water

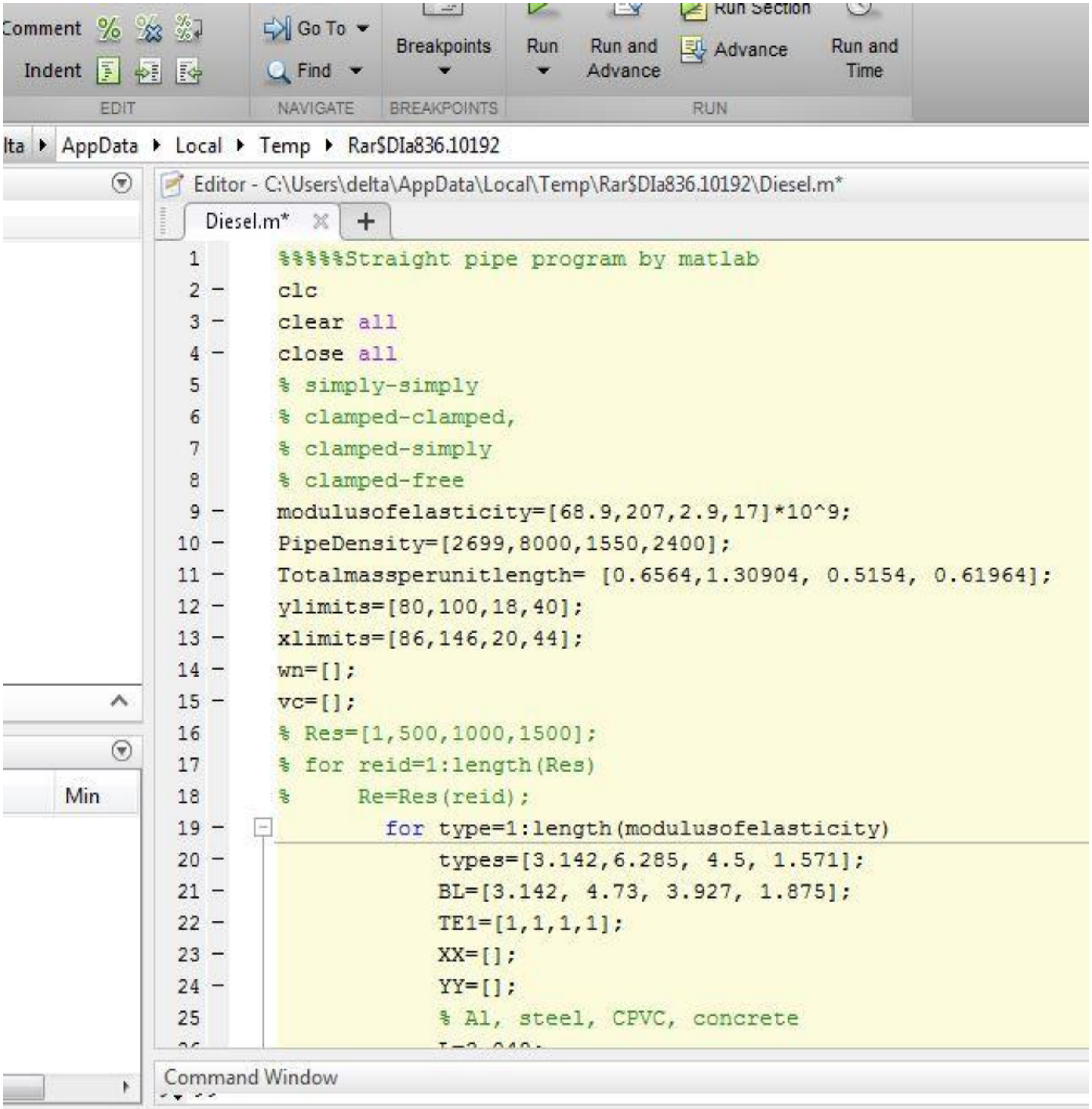


Fig. (3-11) Flowing fuel diesel

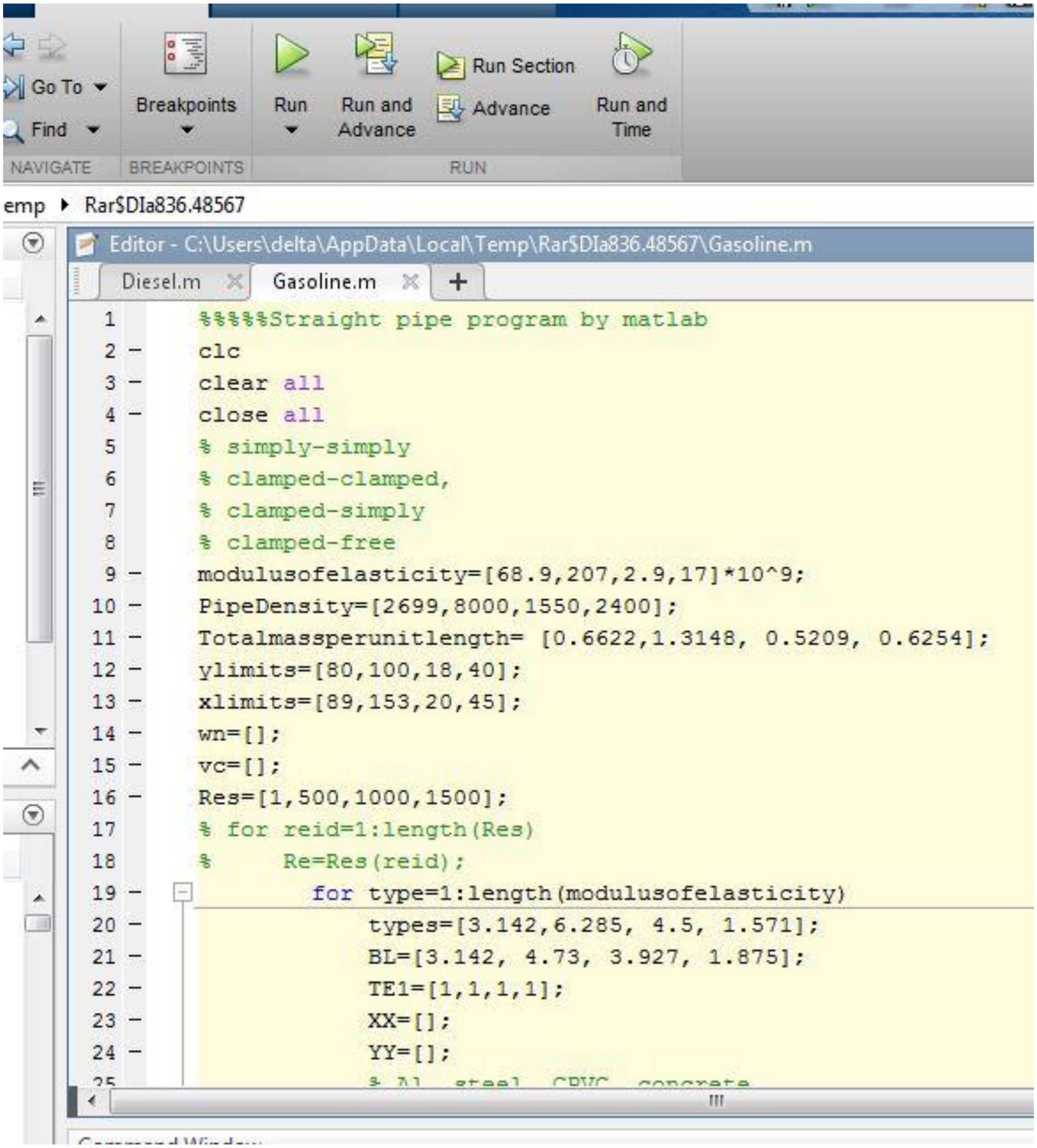


Fig. (3-12) Flowing fuel Gasoline

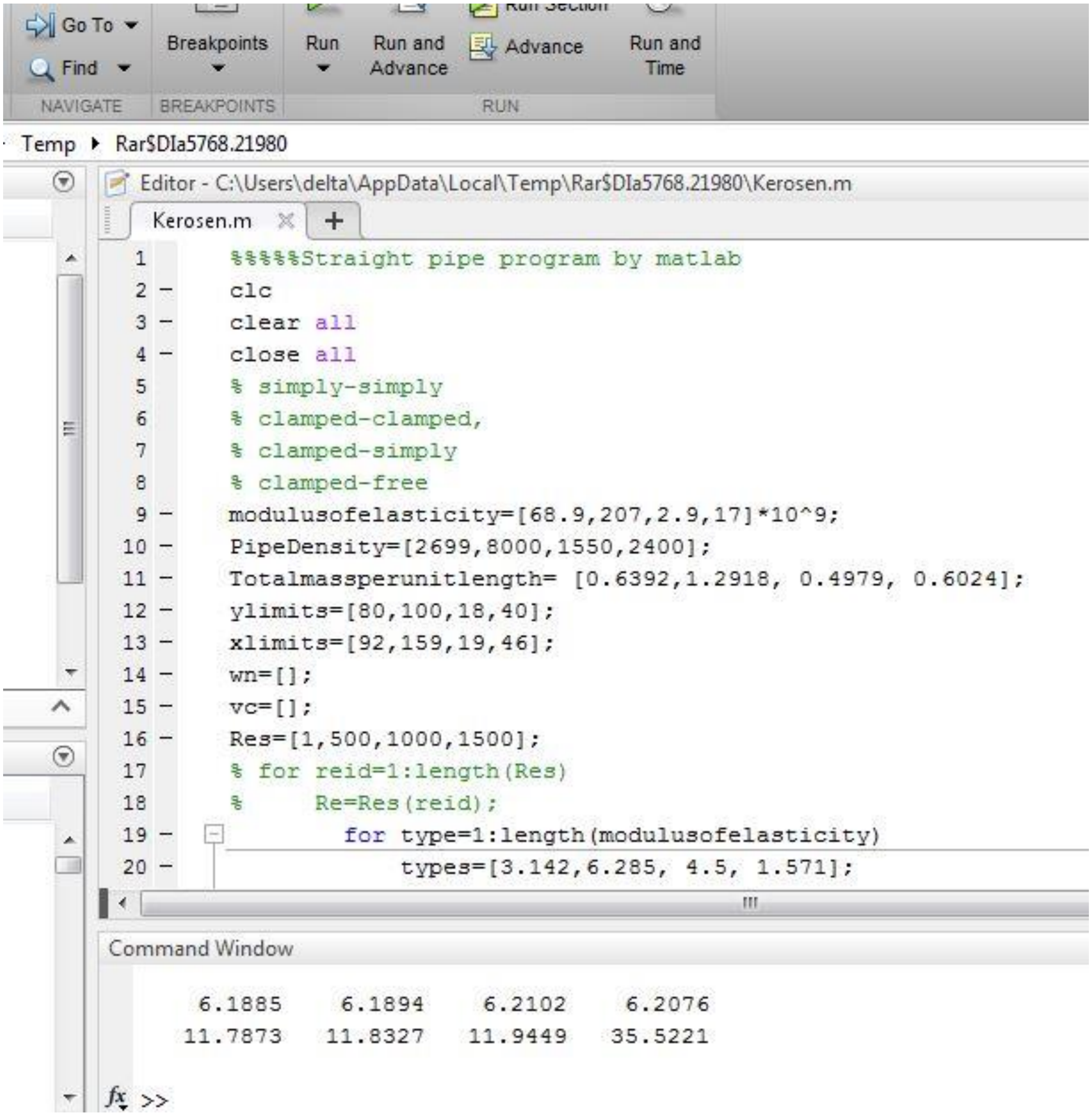


Fig.(3-13) kerosene fuel

Chapter Four

Results and Discussion

Chapter Four: Results and Discussion

In this chapter, the numerical results of pipe vibration during fluid flow are presented, Four types of supports are used (simply-simply, clamped-clamped, clamped-simply and clamped-free) for four materials (aluminum, steel, chlorinated poly-vinyl chloride (CPVC) and concrete) The effect of the types of supports on the natural frequency as well as the effect of the velocity of fluid flow was studied.

Where the MatlabR2014 program was used to study the problem of this work this program was developed to be used to determine the critical speed and frequency, different speeds are entered to know the change that occurs on the tube and when it causes failure and resonance.

4-1 Validation of Finite Element Model

For the validation of the finite element model, the results obtained for pipes were compared with the experimental results of [Manoj and Subodh][50]. Same parameters as used in experimental analysis were used in finite element analysis too.

$$m_t = m_f + m_p \quad \dots (4\text{-}1)$$

$$m_f = \frac{\pi}{4} D_i^2 \times \rho_{fluid} \qquad \frac{kg}{m} \quad \dots (4\text{-}2)$$

$$m_f = \frac{\pi}{4}(0.0221)^2 \times 1000 = 0.3836 \qquad \frac{kg}{m}$$

$$mp = \frac{\pi}{4}(D_O{}^2 - D_i{}^2) \times \rho_{pipe} \qquad \frac{kg}{m} \qquad \text{… (4-3)}$$

$$mp = \frac{\pi}{4}(0.0254^{\ 2} - 0.0221^{\ 2}) \times 2699 = 0.3323 \qquad \frac{kg}{m}$$

$$mp = \frac{\pi}{4}(0.0254^2 - 0.0221^2) \times 8000 = 0.9849 \qquad \frac{kg}{m}$$

$$mp = \frac{\pi}{4}(0.0254^2 - 0.0221^2) \times 1550 = 0.191 \qquad \frac{kg}{m}$$

$$mp = \frac{\pi}{4}(0.0254^2 - 0.0221^2) \times 2400 = 0.2955 \qquad \frac{kg}{m}$$

Table (4-1) properties of water

water	m_p(kg/m)	m_f (kg/m)	m_t(kg/m)
Aluminum	0.3323	0.3836	0.7159
Steel	0.9849	0.3836	1.3685
CPCV	0.191	0.3836	0.5746
Concrete	0.2955	0.3836	0.6791

4-1-1 mistake percentage (Error %)

$$Error = \frac{w_n - w_{n(ref)}}{w_{n(ref)}} \quad \ldots (4\text{-}4)$$

$$Error = \frac{v_c - v_{c(ref)}}{v_{c(ref)}} \quad \ldots (4\text{-}5)$$

4-1-1-1 For Aluminum pipe case study:

1-Simply-simply

Error (Freq.) = (30.80718-30.78)/ 30.78(100%) =0.088304%

Error (vc.) = (40.80154-41) / 41(100%) = - 0.484049%

2- Clamped-clamped

Error (Freq.) = (69.81711- 69.77) / 69.77(100%) = 0.0675218%

Error (vc.) = (81.61606- 81.6) / 81.6(100%) = 0.019681%

3- Clamped-simply

Error (Freq.) = (48.12396- 48.08) / 48.08(100%) = 0.091431%

Error (vc.) = (58.43632-58.36) /58.36(100%) = 0.130774%

4- Clamped-free

Error (Freq.) = (10.9709- 10.96) /10.96 (100%) = 0.099452%

Error (vc.) = (20.40077- 16.96) /16.96 (100%) = 20.28756%

Table (4-2) Aluminum error

Case Aluminum	Flow Velocity m/s	The frequency obtained from Experience, FE model, rad/s		Critical Velocity m/s	
Simply-simply	50	W result	W ref	Vc result	Vc ref
		30.80718	30.78	40.80154	41
		Error =0.088304%		Error=- 0.484049%	
Clamped-clamped	90	69.81711	69.77	81.61606	81.6
		Error = 0.0675218%		Error =0.019681%	
Clamped-simply	60	48.12396	48.08	58.43632	58.36
		Error = 0.091431%		Error = 0.130774%	
Clamped-free	25	10.9709	10.96	20.40077	16.96
		Error = 0.099452%		Error =20.28756%	

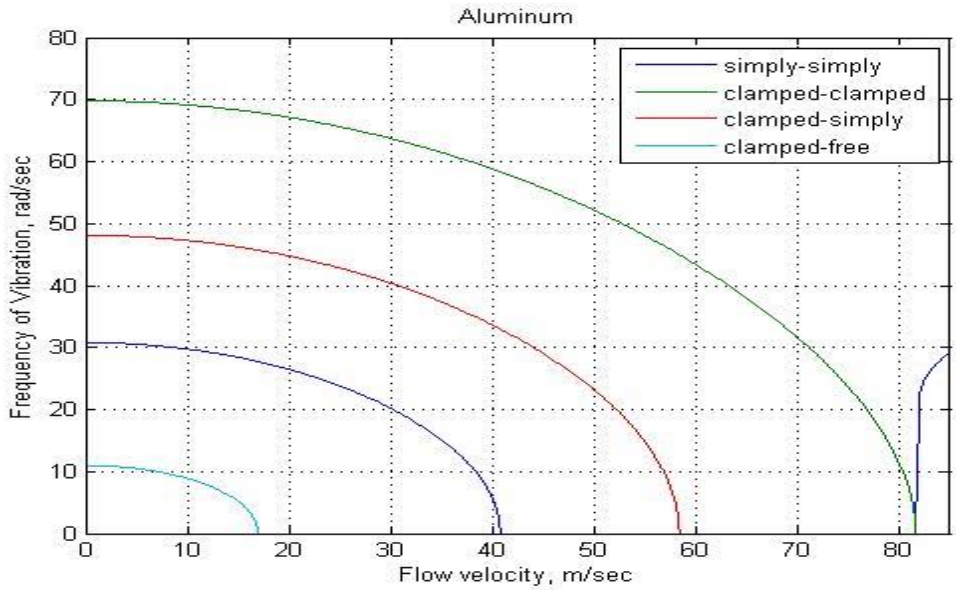


Fig.(4-1) (a) Aluminum Pipe

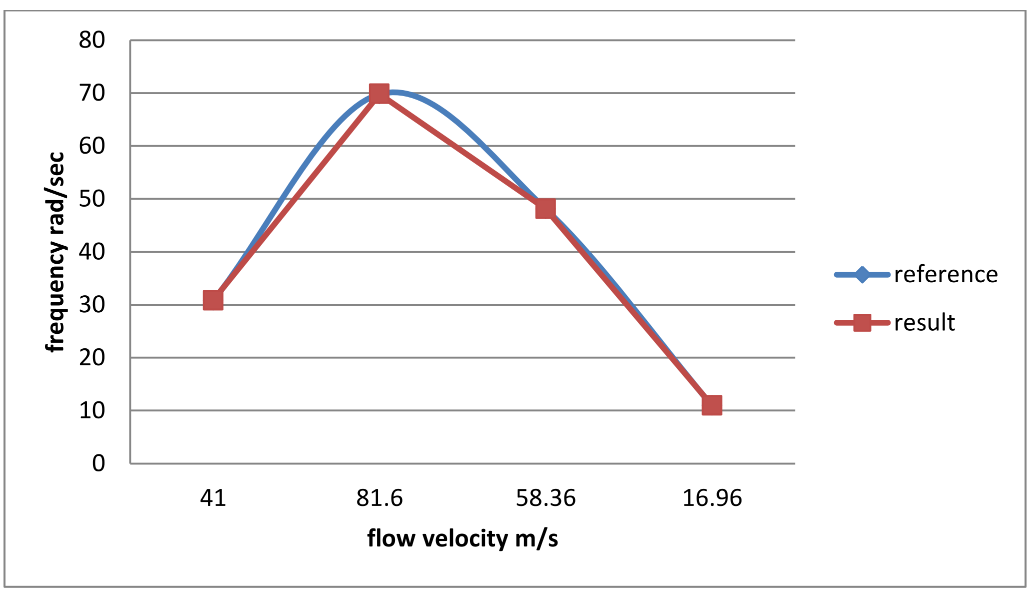


Fig.(4-1) (b) Aluminum Pipe [Validation]

4-1-1-2 For Steel pipe case study

1-Simply-simply

Error (Freq.) = (38.35296- 38.59) / 38.59(100%) = -0.614252%

Error (vc) = (70.7216-70.72) / 70.72(100%) =0.002262%

2- Clamped-clamped

Error (Freq) = (86.91782-87.47) / 87.47(100%) = -0.63128%

Error (vc) = (141.4657-141.43) /141.43(100%) = 0.025242%

3- Clamped-simply

Error (Freq.) = (59.91124-60.28) / 60.28(100%) = -0.61174%

Error (vc) = (101.2881-101.21) / 101.21(100%) = 0.077166%

4- Clamped-free

Error (Freq) = (13.65806-13.74) /13.47(100%) = -0.596361%

Error (vc) = (35.3608-31.76) /31.76 (100%) =11.33753%

Table (4-3) Steel Error

Case steel	Flow velocity m/s	The frequency obtained from Experience, FE model, rad/s		Critical Velocity m/s	
Simply-simply	75	W result	W ref	Vc result	Vc ref
		38.35296	38.59	70.7216	70.72
		Error =-0.614252%		Error=0.002262%	
Clamped-clamped	150	86.91782	87.47	141.4657	141.43
		Error = -0.63128%		Error =0.025242%	
Clamped-simply	105	59.91124	60.28	101.2881	101.21
		Error = -0.61174%		Error = 0.077166%	
Clamped-free	35	13.65806	13.47	35.3608	31.76
		Error = -0.596361%		Error =11.33753%	

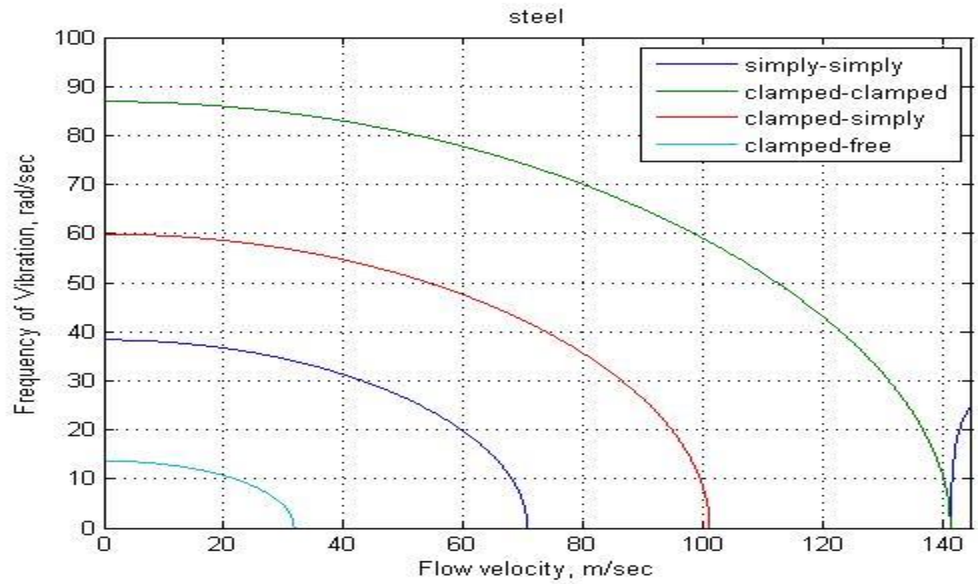


Fig.(4-2) (a) steel Pipe

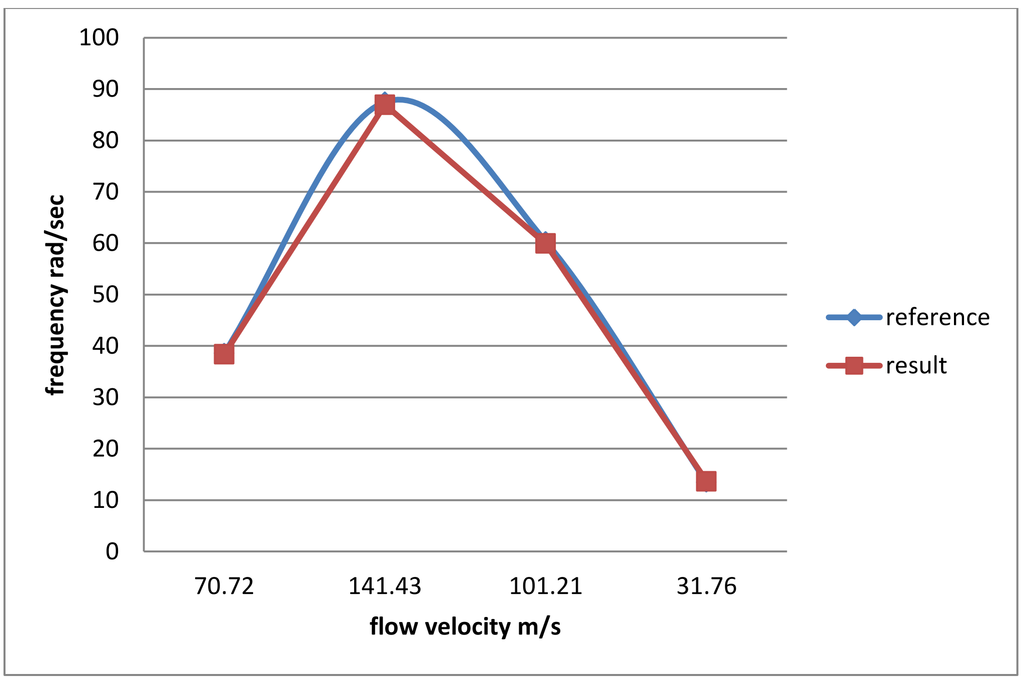


Fig.(4-2) (b) steel Pipe [Validation]

4-1-1-3 Chlorinated Poly-Vinyl Chloride (CPVC) Pipe case study

1-Simply-simply

Error (Freq.) = (7.054048- 7.05) /7.05(100%) = 0.057418%

Error (vc) = (8.370779-8.4) /8.4(100%) =- 0.347869%

2- Clamped-clamped

Error (Freq.) = (15.98631-15.98)/ 15.98(100%) =0.039487%

Error (vc) = (16.74422-16.74) / 16.74(100%) =0.025209%

3- Clamped-simply

Error (Freq.) = (11.01914-11.01) / 11.01(100%) =0.083015%

Error (vc) = (11.9887-12) / 12(100%) =-0.094166%

4- Clamped-free

Error (Freq) = (2.512052-2.2114) /2.2114(100%) =0.135955%

Error (vc) = (4.18539-3.36) /3.36(100%) =24.56517%

Table (4-4) (CPVC) **e**rror

Case CPVC	Flow velocity m/s	The frequency obtained from Experience, FE model, rad/s		Critical Velocity m/s	
Simply-simply	18	W result	W ref	Vc result	Vc ref
		7.054048	7.05	8.370779	8.4
		Error =0.057418%		Error=-0.347869%	
Clamped-clamped	8	15.98631	15.98	16.74422	16.74
		Error = 0.039487%		Error =0.025209%	
Clamped-simply	12	11.01914	11.01	11.9887	12
		Error = 0.083015%		Error = -0.094166%	
Clamped-free	5	2.512052	2.2114	4.18539	3.36
		Error = 13.5955%		Error =24.56517%	

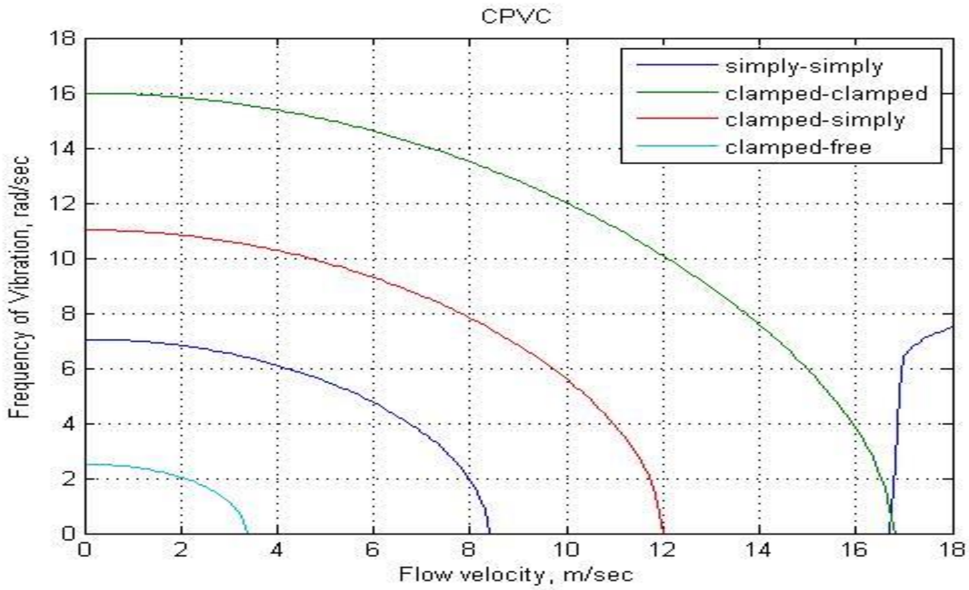


Fig.(4-3) (a) (CPCV) Pipe

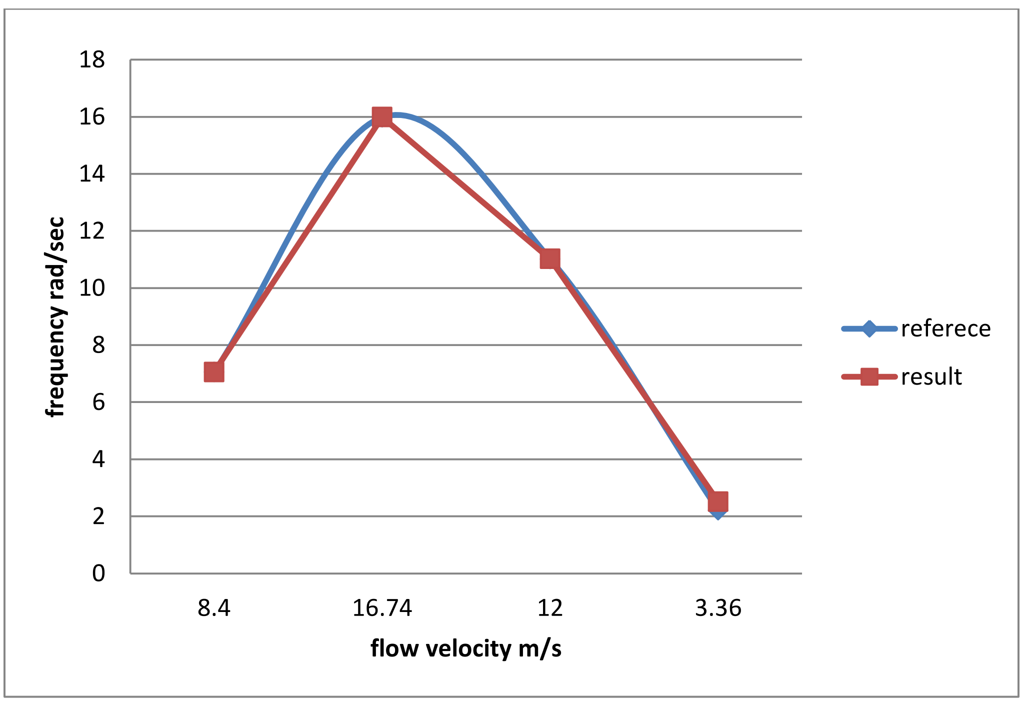


Fig.(4-3) (b) Case CPVC Pipe [Validation]

4-1-1-4 For Concrete pipe case study

1-Simply-simply

Error (Freq) = (15.70308- 15.7) /15.7(100%) = 0.019617%

Error (vc) = (20.26709-20.27) /20.27(100%) =- 0.014356%

2- Clamped-clamped

Error (Freq.) = (35.58728-35.58)/ 35.58(100%) =0.0204679%

Error (vc) = (40.54063-40.53) / 40.53(100%) =0.026227%

3- Clamped-simply

Error (Freq.) = (24.52982-24.52) / 24.52 (100%) =0.040048%

Error (vc) = (29.02670-28.99) / 28.99(100%) =0.12659%

4- Clamped-free

Error (Freq.) = (5.59210-2.5.59) /5.59(100%) =0.03757%

Error (vc) = (10.1335-8.36) /8.36(100%) =21.2146%

Table (4-5) Concrete error

Case Concrete	Flow velocity m/s	The frequency obtained from Experience, FE model, rad/s		Critical Velocity m/s	
Simply-simply	25	W result	W ref	Vc result	Vc ref
		15.70308	15.7	20.26709	20.27
		Error =0.019617%		Error=- 0.014356%	
Clamped-clamped	45	35.58728	35.58	40.54063	40.53
		Error = 0.0204679%		Error =0.026227%	
Clamped-simply	35	24.52982	24.52	29.02670	28.99
		Error = 0.040048%		Error = 0.12659%	
Clamped-free	10	5.59210	5.59	10.1335	8.36
		Error = 0.03757%		Error =21.2146%	

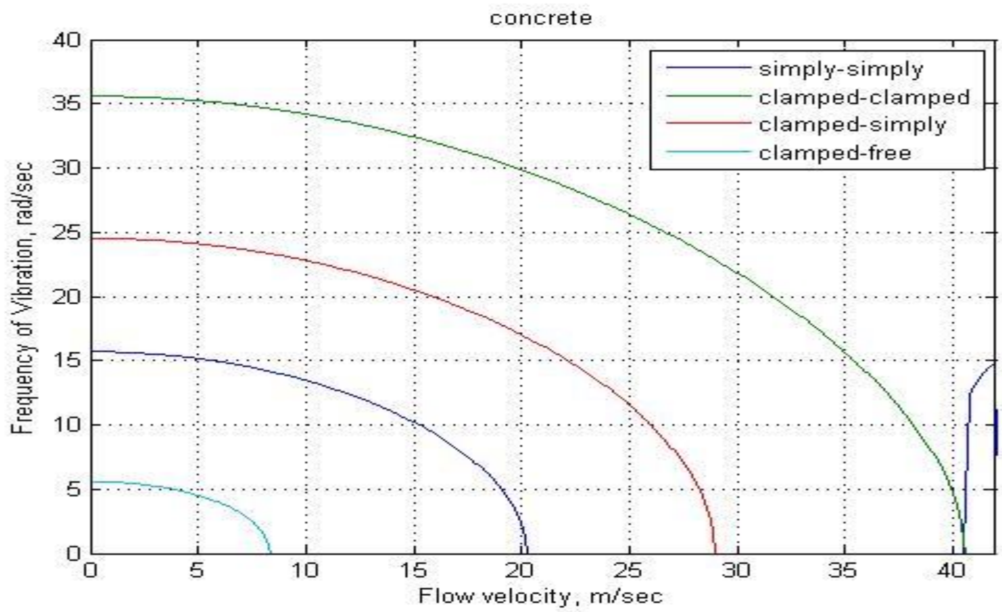


Fig.(4-4) (a) concrete Pipe

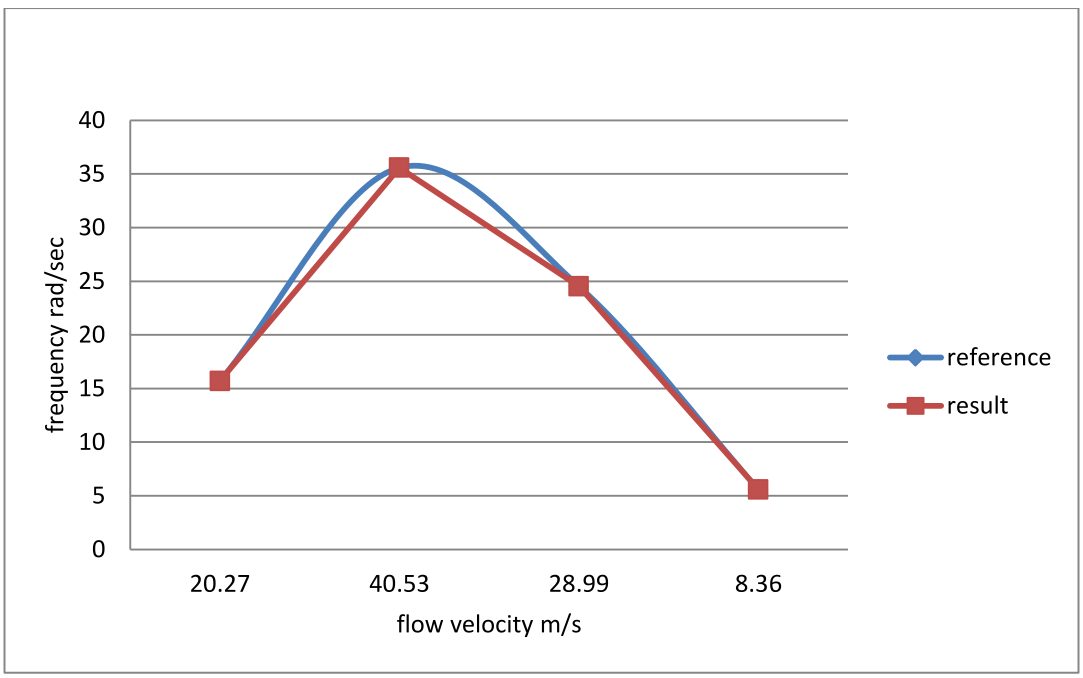


Fig.(4-4) (b) concrete Pipe [Validation]

4-2 Experimental Executed Cases

In this research, three types of fuel were used, namely gasoline, kerosene and diesel shown in Table (4-6) for four types of metals shown in Table (4-7).

$$R_e = \frac{\rho_f \times v \times D_i}{\mu} \quad \dots (4\text{-}6)$$

$$R_e = Cv \quad \dots (4\text{-}7)$$

(Re) is a function only of the velocity with the other variables held constant. As (Re) is considered an equation, if one of the constants changes, the natural frequency changes, so what depends on the flowing velocity becomes dependent on another parameter variable. If Re changes, the w changes and this is not a design.

Table (4-6) properties of working fluid

Working fluid	[ρ] Density (kg/m^3)	[μ] Dynamic viscosity (kg/m s)
Gasoline	860	7.00×10*-4
Diesel	845	3.8025×10*-3
Kerosene	800	2.00×10*-3

Table (4-7) properties of metal

Metal	(E) Modulus of elasticity for pipe (N/m^2)	(ρ) Density (kg/m^3)
steel	207Gpa	8000 kg/m^3
Aluminum	68.9Gpa	2699 kg/m^3
CPVC	2.9Gpa	1550 kg/m^3
concrete	17Gpa	2400 kg/m^3

$$m_f = \frac{\pi}{4}(0.0221)^2 \times 800 = 0.3069 \quad \frac{kg}{m}$$

$$m_f = \frac{\pi}{4}(0.0221)^2 \times 845 = 0.32414 \quad \frac{kg}{m}$$

$$m_f = \frac{\pi}{4}(0.0221)^2 \times 860 = 0.3299 \quad \frac{kg}{m}$$

Table (4-8) Diesel fuel properties

Diesel	m_p(kg/m)	mf (kg/m)	Mt (kg/m)
Aluminum	0.3323	0.32414	0.6564
Steel	0.9849	0.32414	1.30904
CPCV	0.191	0.32414	0.5154
Concrete	0.2955	0.32414	0.61964

Table (4-9) Gasoline fuel properties

Gasoline	m_p(kg/m)	m_f (kg/m)	m_t(kg/m)
Aluminum	0.3323	0.3299	0.6622
Steel	0.9849	0.3299	1.3148
CPCV	0.191	0.3299	0.5209
Concrete	0.2955	0.3299	0.6254

Table (4-10) (Kerosene) fuel properties

kerosene	m_p(kg/m)	m_f (kg/m)	m_t(kg/m)
Aluminum	0.3323	0.3069	0.6392
Steel	0.9849	0.3069	1.2918
CPCV	0.191	0.3069	0.4979
Concrete	0.2955	0.3069	0.6024

4-3 Aluminum pipes with four different supports and three types of working fuel (diesel, gasoline, kerosene).

Aluminum pipe having the identical size and dimensions was analyzed for four types of boundary conditions using different flowing fuels (gasoline, kerosene and diesel). The results showed the effect of the flowing fluid is to reduce the stiffness and to increase the damping as the flow velocity increases, as the vibration decreases when the speed increases until it becomes zero when it becomes zero. Here the velocity is known as the critical speed at which the tube becomes unstable. From the results, as show in fig.(4-5,4-6and 4-7), it is found that in the (c-c) state it is stable for a large range of flow velocity against flow induced vibration FIV, but in the (c-f) state the velocity range is very little so its stability is very little, the aluminum tube with stands a large range of speed, in the following table, the critical velocity and the normal frequency.

$$\omega_n - \omega = \omega_r \qquad \text{… (4-8)}$$

$$\omega_n = 2\pi \quad f_n \qquad\qquad \omega = 2\pi \quad f \qquad \text{… (4-9)}$$

When the v = 0, the excitation frequency (ω=0), the natural frequency is (ω_n=ω_r). When the velocity increases, the carollis force grows, at v=max is(f) generated. At the highest value, the natural frequency equals the excitation frequency due to the flux (ω_n=ω). This represents the highest value allowed. In the case of the simple - the simple, the range of speed is greater of the c-f.

Table (4-11) Aluminum (Diesel)

Aluminum	Natural frequency rad/sec	Critical velocity m/sec
s-s	30.8071783	44.38621946
c-c	69.81710589	88.78656566
c-s	48.12396068	63.57033341
C-f	10.97089617	22.19310973

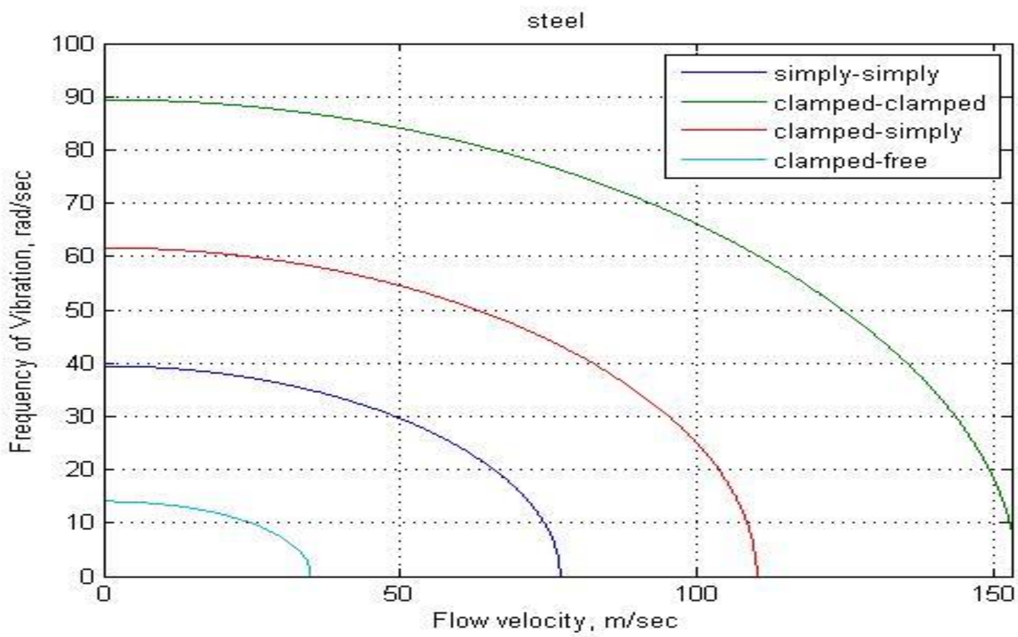


Fig.(4-5) Case Aluminum pipe (Diesel)

Table (4-12) Aluminum (Gasoline)

Aluminum	Natural frequency rad/sec	Critical velocity m/sec
s-s	30.8071783	43.99742757
c-c	69.81710589	88.00885814
c-s	48.12396068	63.01350224
C-f	10.97089617	21.99871378

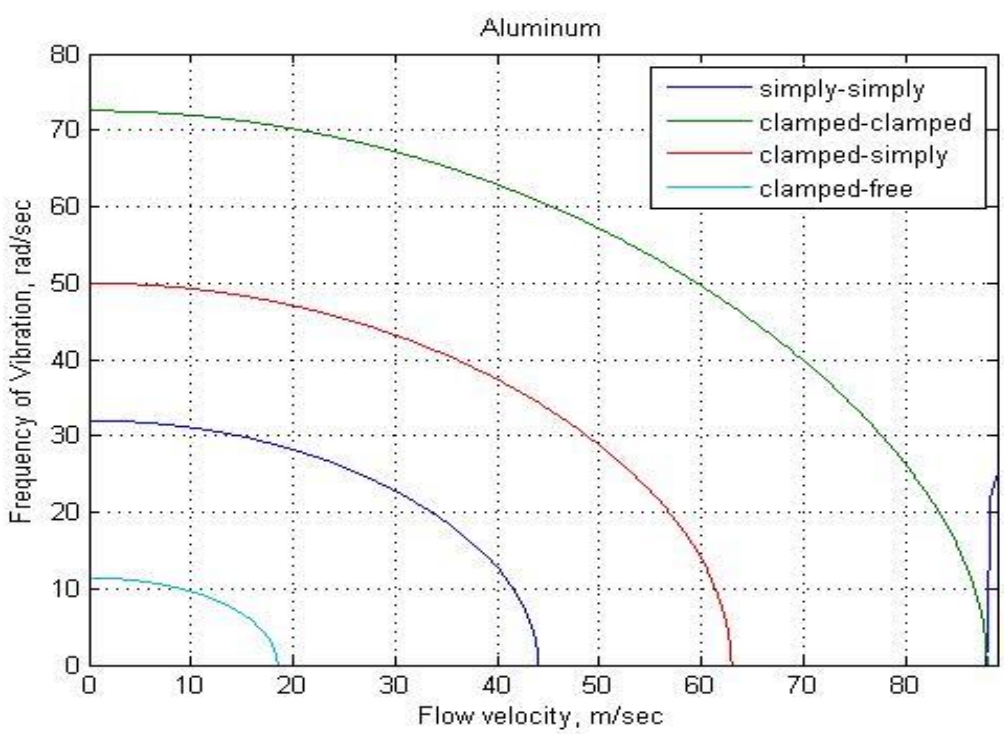


Fig.(4-6) Aluminum Pipe (Gasoline)

Table (4-13) Aluminum (kerosene)

Aluminum	Natural frequency rad/sec	Critical velocity m/sec
s-s	30.8071783	45.61750382
c-c	69.81710589	91.24952626
c-s	48.12396068	65.33378969
c-f	10.97089617	22.80875191

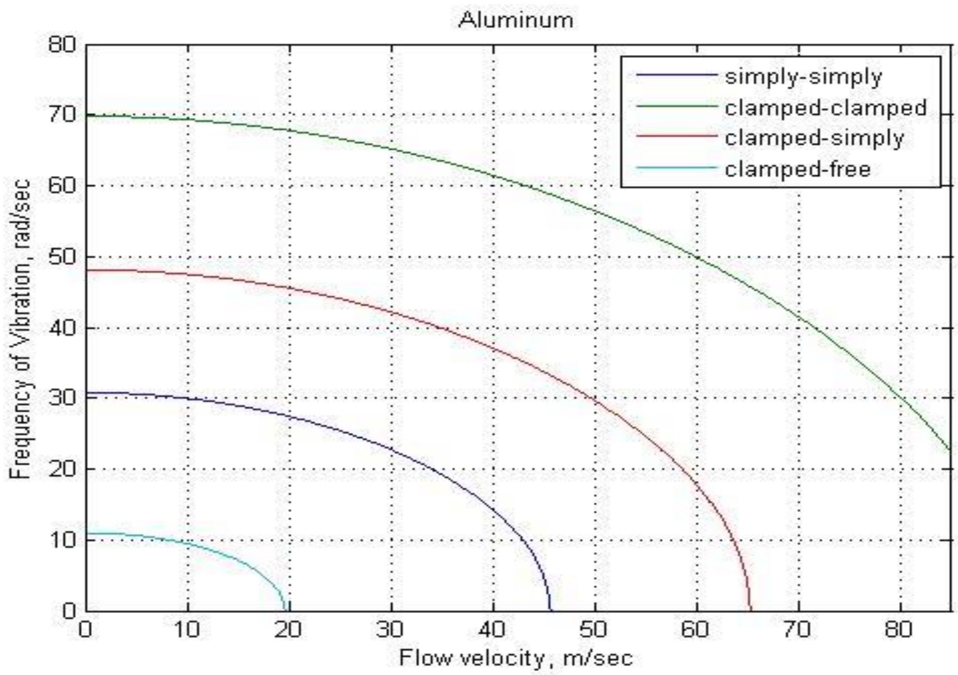


Fig.(4-7) Aluminum Pipe (kerosene)

4-4 Steel pipe with four different supports and three types of working fuel (diesel gasoline, kerosene)

The steel Pipes used in this research have equal dimensions and sizes for different ends. In fig(4-8,4-9 and 4-9), it is found that the natural frequency varies in contrast to the flow velocity, as clamped-clamped steel tube is stable over a very wide range of flow velocity compared to aluminum, concrete and carbon tubes. It has little stability in the case of clamped-free pipes. From the results as in Tables(4-11), (4-12),(4-13) the natural frequency of all supports is greater than that of the rest of the metals used, due to the high hardness of steel. As the flow velocity increases, the natural frequency decreases and this is due to the addition of fluid mass to the mass of the system. Where from the results it was found that the clamped-clamped is the best case, but in practical applications that the Simply-simply is the best case as it gives a wide range of speed.

Table (4-14) steel pipe (diesel)

steel	Natural frequency rad/sec	Critical velocity m/sec
s-s	38.35296019	76.93495745
c-c	86.91781691	153.8944009
c-s	59.91124309	110.1869219
C-f	13.65806177	38.46747872

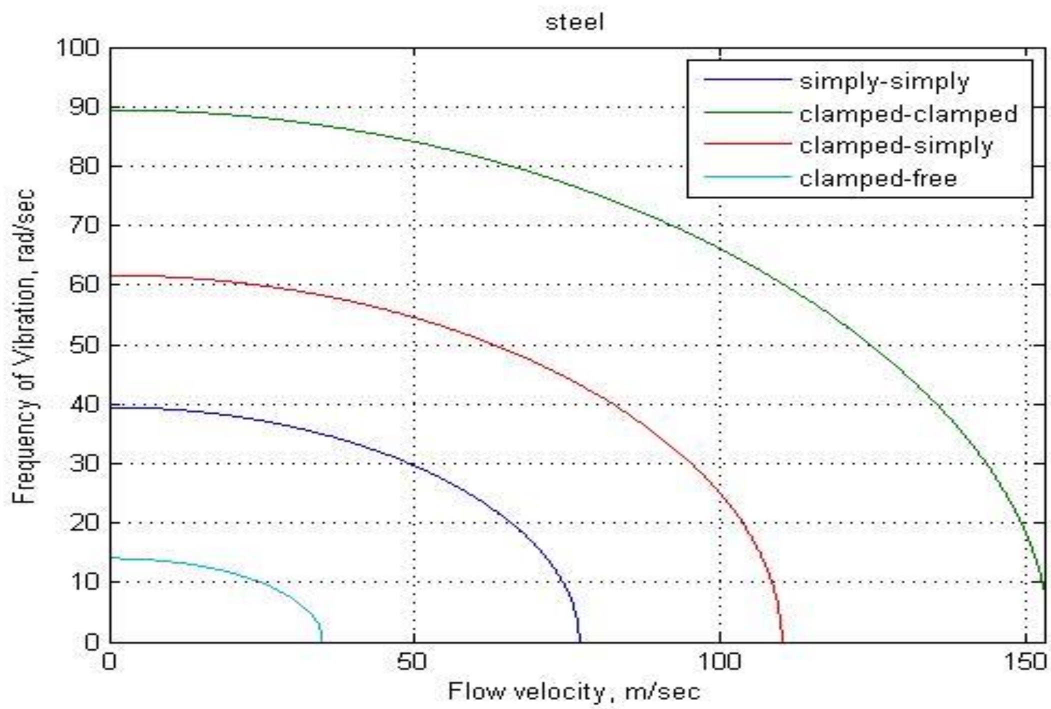


Fig.(4-8) steel Pipe(diesel)

Table (4-15) steel pipe (Gasoline)

steel	Natural frequency rad/sec	Critical velocity m/sec
s-s	38.35296019	76.26106162
c-c	86.91781691	152.5463948
c-s	59.91124309	109.2217624
C-f	13.65806177	38.13053081

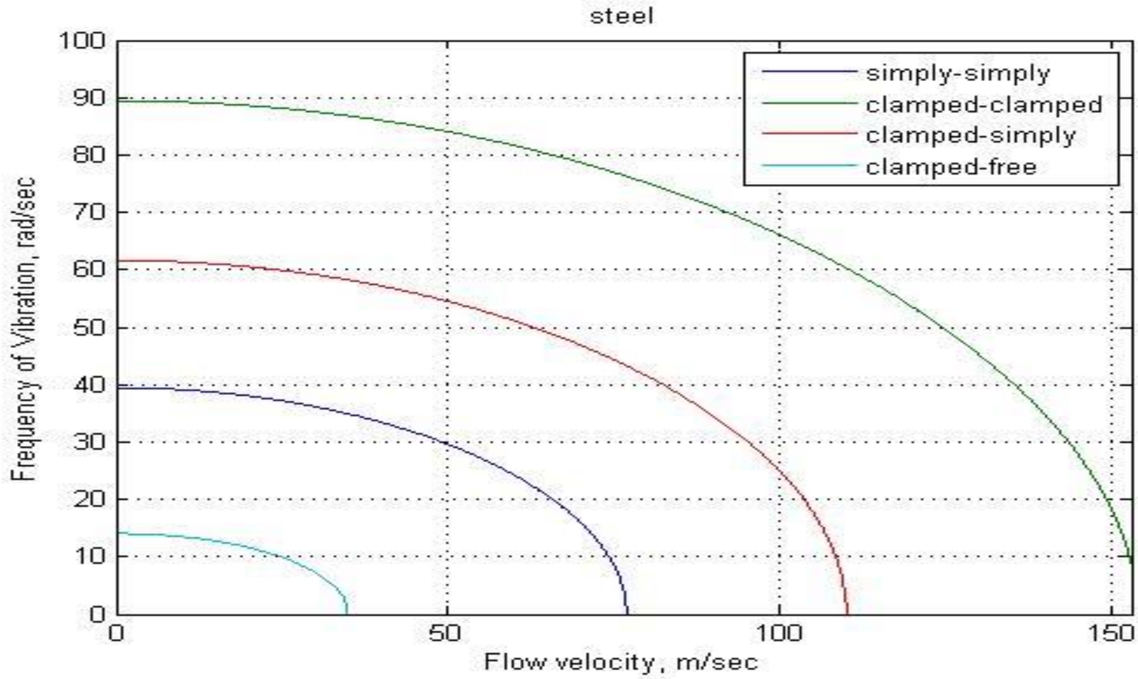


Fig.(4-9) Pipe steel (Gasoline)

Table (4-16) steel pipe (kerosene)

steel	Natural frequency rad/sec	Critical velocity m/sec
s-s	38.35296019	79.0691516
c-c	86.91781691	158.1634684
c-s	59.91124309	113.2435335
C-f	13.65806177	39.5345758

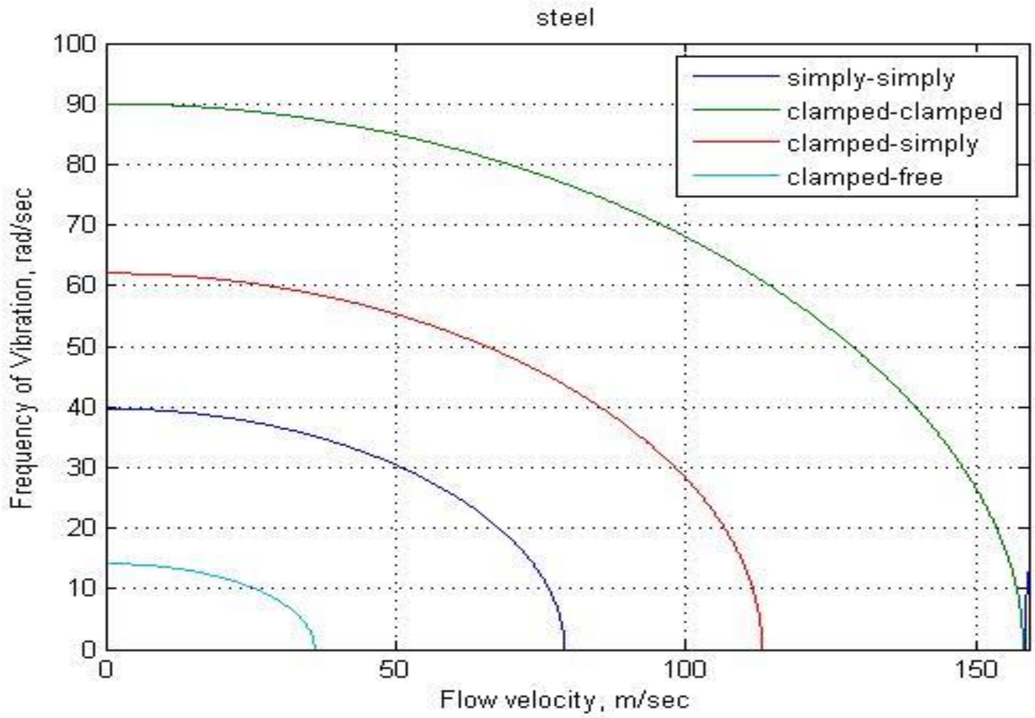


Fig.(4-10) steel Pipe (kerosene)

4-5 CPVC pipe with four different supports and three types of fuel (diesel gasoline, kerosene)

In Figs.(4-11,4-12 and 4-13), there is a relationship between natural frequency and flow velocity. Through the graph, it is found that CPVC pipe shall be stable for large range of flow velocity in the clamped-clamped condition and shall be stable for small range of flow velocity in the clamped-free condition against flow induced vibration. They are less stable tubes compared to other materials. Natural frequency of vibration and the critical flow velocity in four types of boundary conditions for CPVC pipe are as shown below, table (4-17,4-18,4-19)

Table (4-17) CPVC (diesel)

CPVC	Natural frequency rad/sec	Critical velocity m/sec
s-s	7.054047582	9.10620754
c-c	15.98631274	18.2153133
c-s	11.01914317	13.04199043
C-f	2.512051667	3.84021007

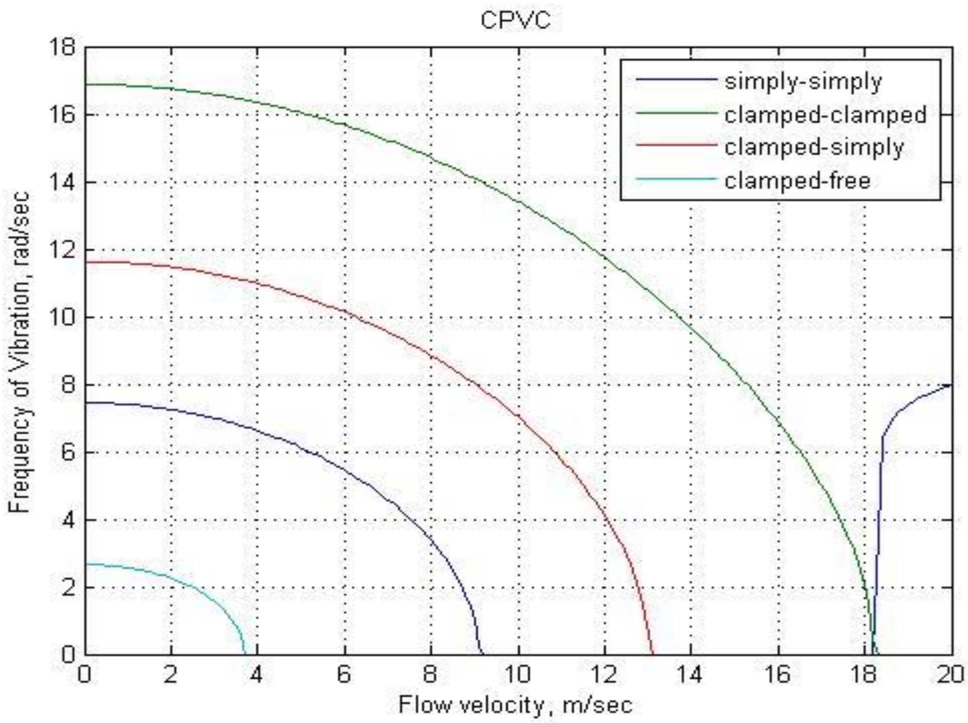


Fig.(4-11) CPVC Pipe (diesel)

Table (4-18) CPVC (Gasoline)

CPVC	Natural frequency rad/sec	Critical velocity m/sec
s-s	7.054047582	9.026443602
c-c	15.98631274	18.05576004
c-s	11.01914317	12.92775182
C-f	2.512051667	3.753221801

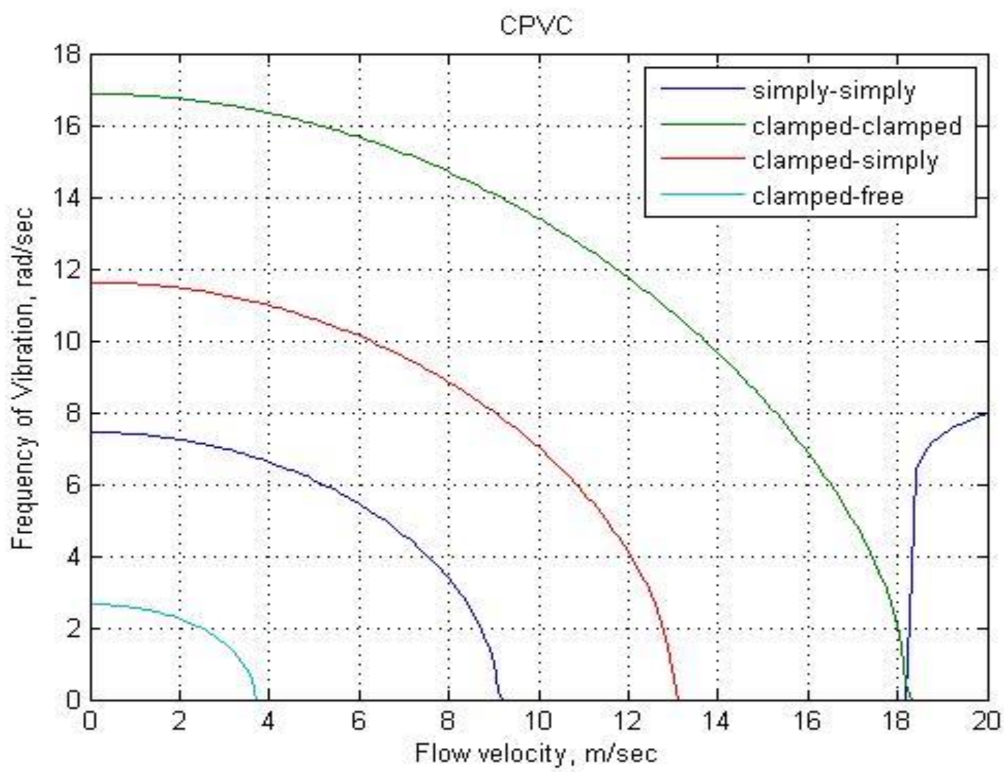


Fig.(4-12) Case Pipe CPVC (Gasoline)

Table (4-19) CPVC (kerosene)

CPVC	Natural frequency rad/sec	Critical velocity m/sec
s-s	30.8071783	9.61750382
c-c	69.81710589	18.24952626
c-s	48.12396068	13.78969335
C-f	10.97089617	3.80875191

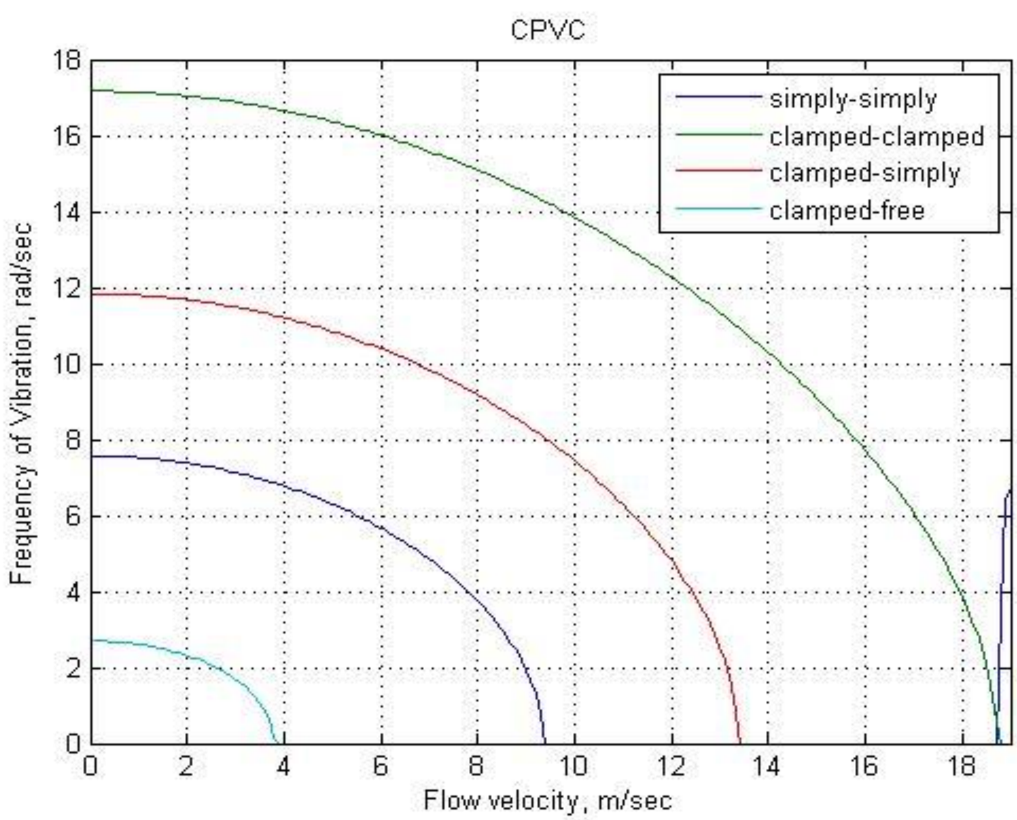


Fig.(4-13) pipe CPVC (kerosene)

4-6 Concrete pipe with four different supports and three types of working fuel (diesel gasoline, kerosene)

In concrete pipes, as in aluminum, steel and CPVC pipes, equal dimensions and sizes are used for four different ends. As in the previous materials, concrete is stable within a certain speed in the case of fixed pipes(c-c), but in the free (c-f) state, its stability is very little compared to aluminum and steel and greater than CPVC. Show in fig.(4-14,4-15 and 4-16)

Table (4-20) Concrete pipe (Diesel)

Concrete	Natural frequency rad/sec	Critical velocity m/sec
s-s	15.70308226	22.04768553
c-c	35.58728248	44.10238815
c-s	24.52981917	31.57688889
c-f	5.592102051	9.802384277

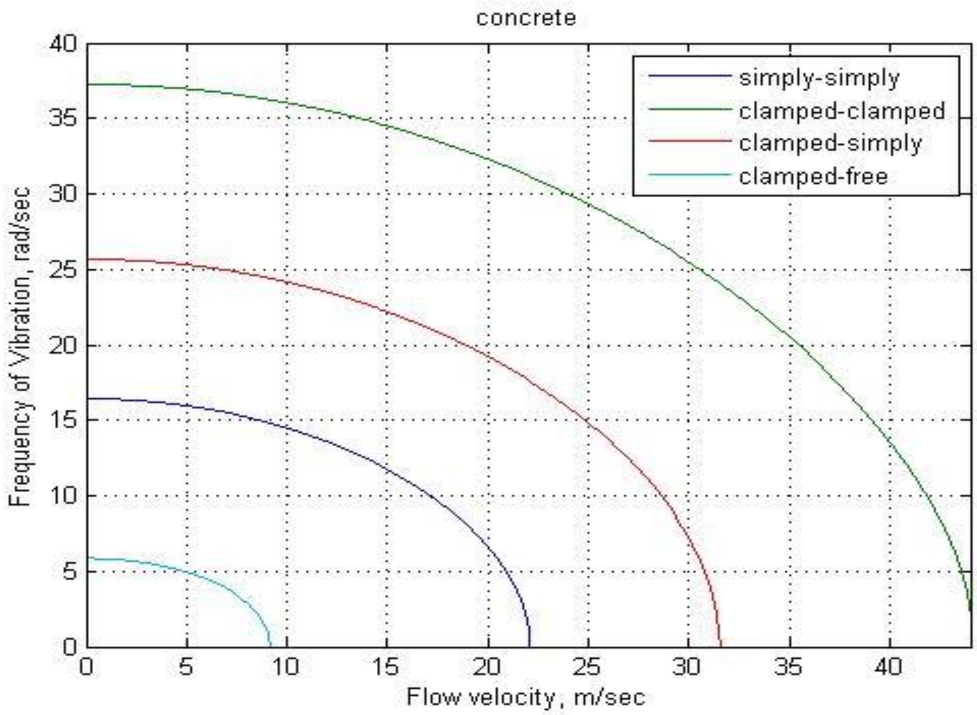


Fig.(4-14) Pipe Concrete (Diesel)

Table (4-21) Concrete (Gasoline)

Concrete	Natural frequency rad/sec	Critical velocity m/sec
s-s	15.70308226	21.8545634
c-c	35.58728248	43.71608242
c-s	24.52981917	31.30029767
C-f	5.592102051	9.9272817

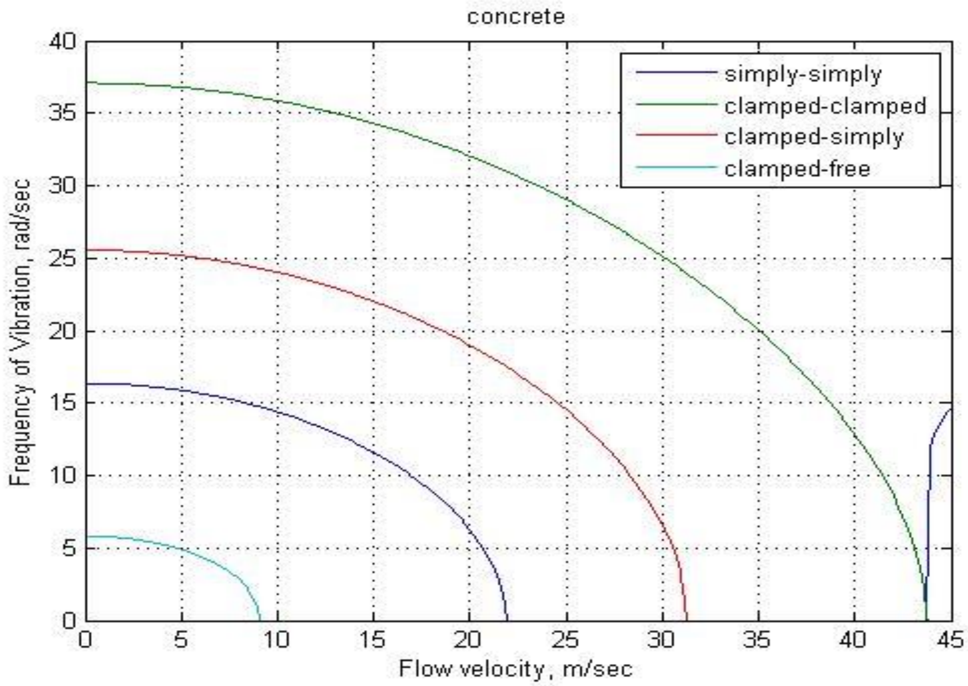


Fig.(4-15) Pipe concrete (Gasoline)

Table (4-22) Concrete Pipe (Kerosene)

Concrete	Natural frequency rad/sec	Critical velocity m/sec
s-s	15.7030822	22.65929361
c-c	35.58728248	45.32579896
c-s	24.52981917	32.45283935
C-f	5.592102051	9.93296468

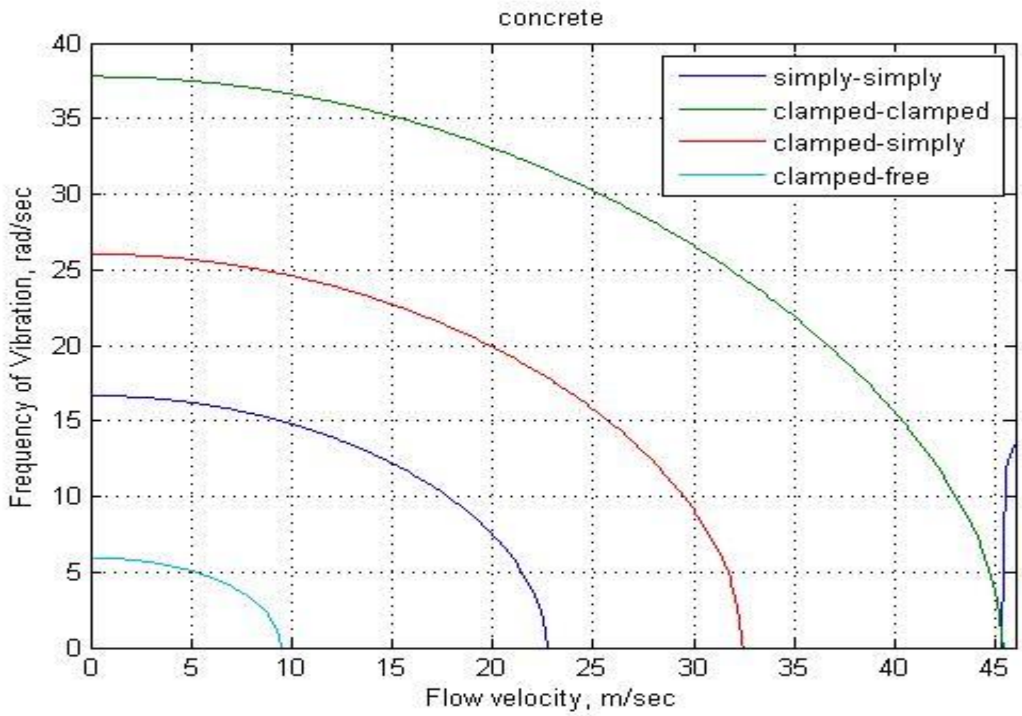


Fig.(4-16) Concrete Pipe (Kerosene)

4-7 Effect of Pipe Length

The results showed as in the fig.(4-17),(4-18) that when the distance between the installation points(12m) increases, the system weakens, as we reach (ω/ωn), it reaches the maximum speed in a short time. We note the effect of length is inversely proportional to the natural frequency (L$\infty \frac{1}{w_n}$). If the diameter is increased, it is positively proportional.

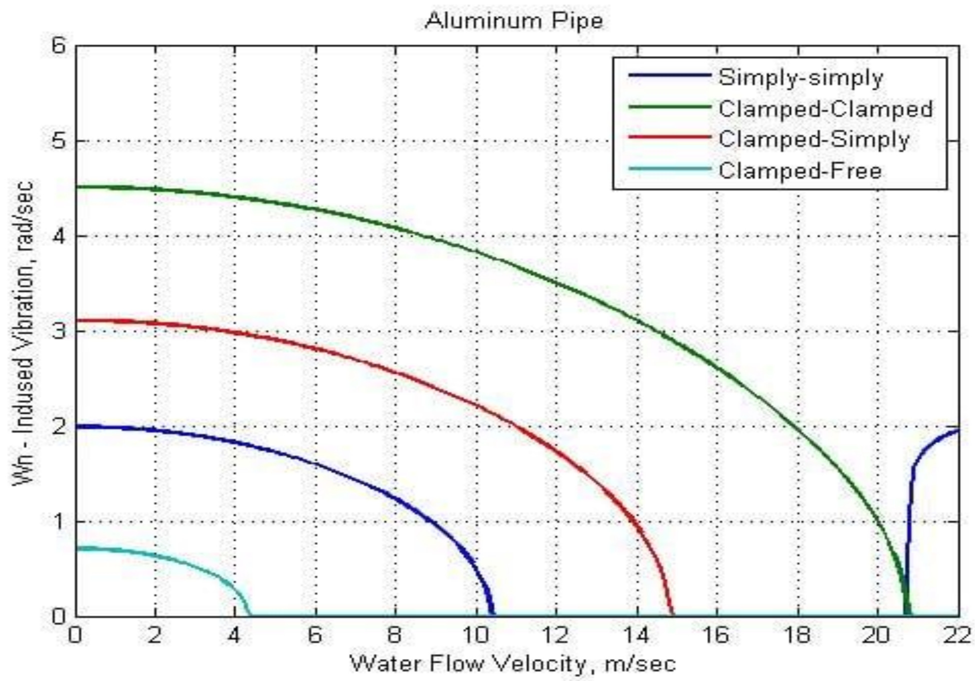


Fig.(4-17)The effect of increasing the length of the tube Aluminum

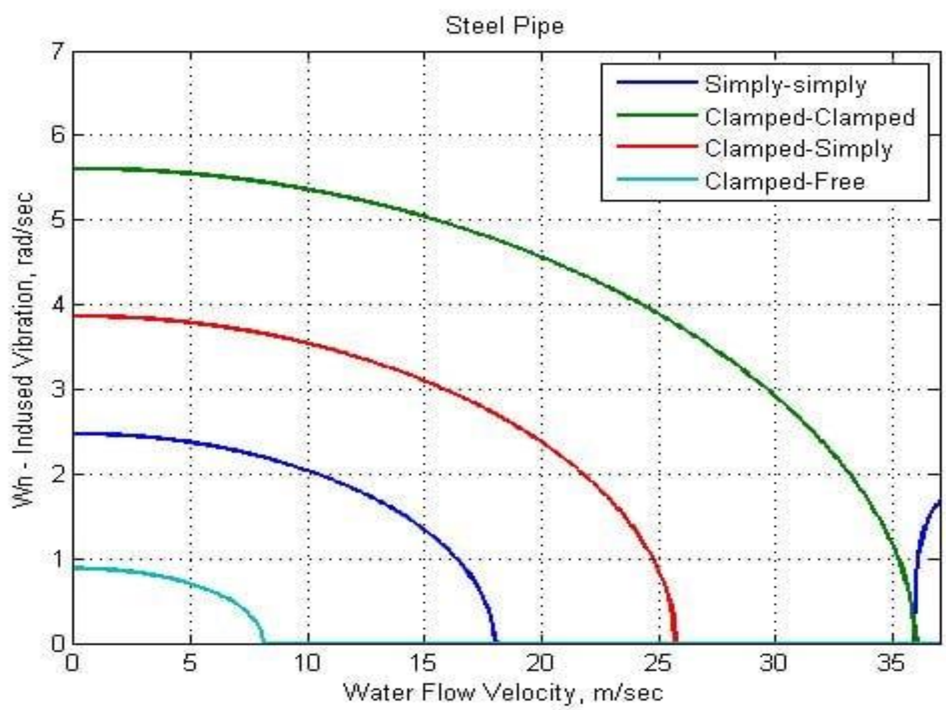


Fig.(4-18)The effect of increasing the length of the tube Steel

4-8 Pipe Resonance

pipe resonance occurs when the tube reaches a critical velocity and the tube becomes unstable, critical velocity is the maximum speed the tube can withstand before the tube fails (breaks).Here in this curve, ($\omega/\omega_n=0$), $\omega=0$, $v=0$, ($\omega/\omega_n=1$) we notice that when the ($\omega_n=\omega$) in the case of speed is the highest value, which is the greatest speed, I can reach it, then the system is destroyed.

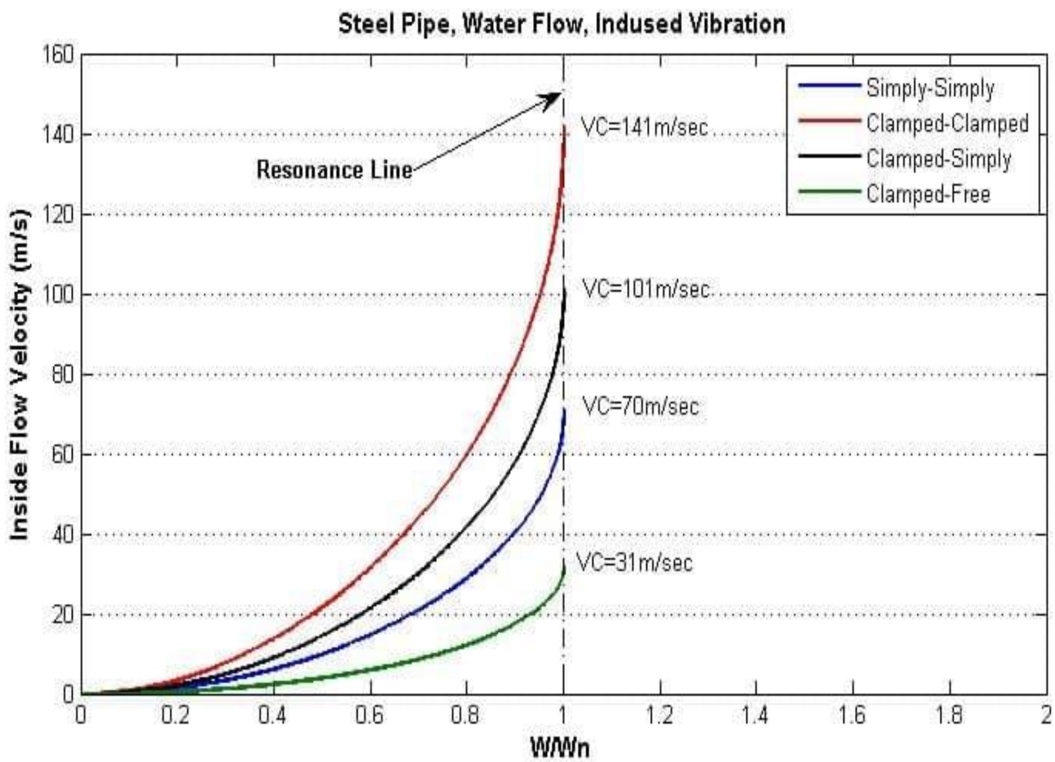


Fig.(4-19)water flow(steel)

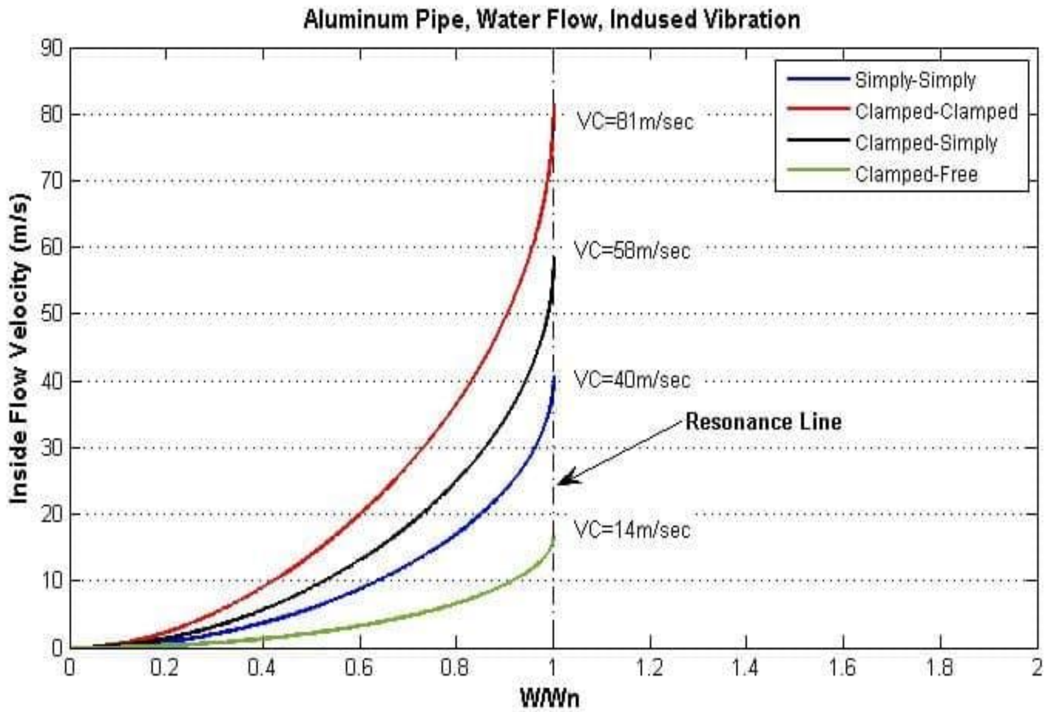


Fig.(4-20) water flow(Aluminum)

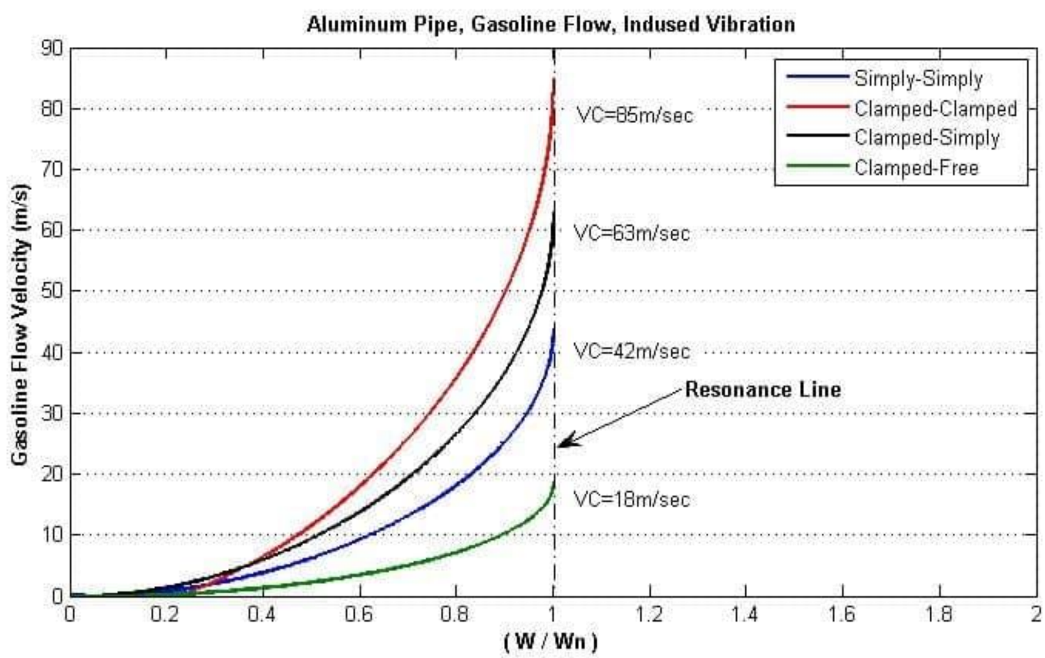


Fig.(4-21) Gasoline flow(Aluminum)

4-9 Actual Application Case Study

Table (4-23) properties of Actual Application Case Study

The pipe length	12m
the pipe diameter	0.1524m
pipe thickness	0.01588
flow rate	167.549 m^3 /h
Modulus of elasticity for pipe	205 N/m^2
pipe metal	carbon steel

$$Q = V \times A \quad \ldots (4\text{-}10)$$

Q=0.045659138 m^3 /s

A= $(\pi D^2/4)$ = 0.01824 m^2 … (4-11)

V=Q/A

V=0.04659138/0.01824=2.55m/s

From the applied case of Karbala refinery, it was found that the best types of pipes are simple - simple. They work on a safety factor = 2 as the (ω/ω_n) equal (0.5) is far from the induced vibration.

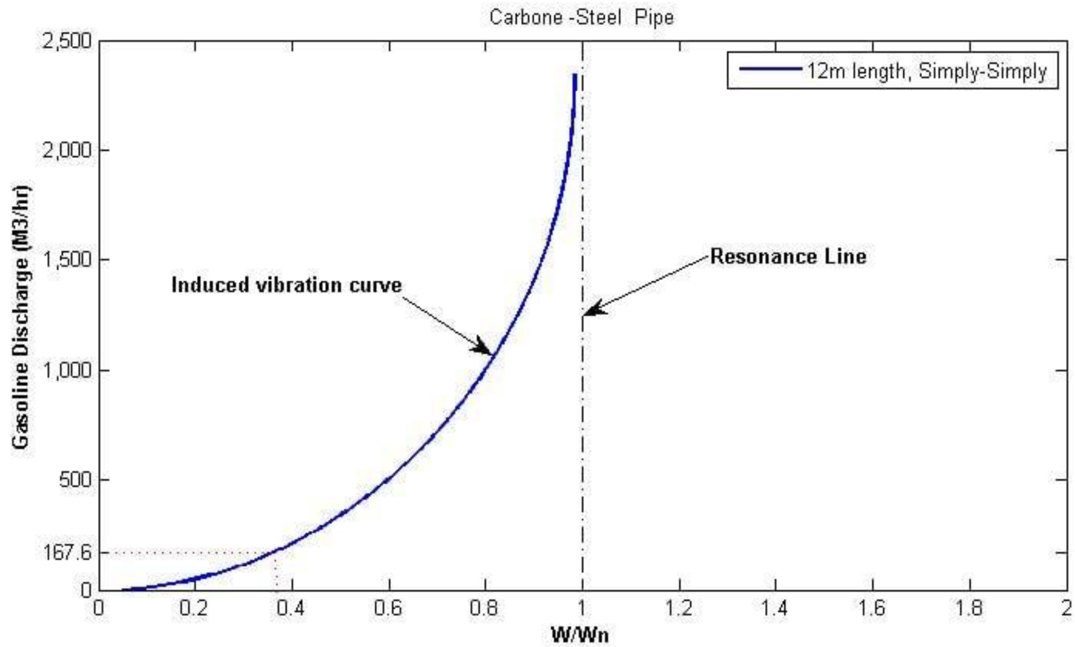


Fig.(4-22) Actual Application Case Study(Gasoline flow)

Chapter Five Conclusions and Suggestions for Future works

Chapter Five

Conclusions and Suggestions for Future works

5.1. Conclusions:

The present work studied flow-induced vibration in fuel transmission pipelines.

The results obtained from the theoretical study can be summarized as follows**:**

1. Steel pipes were found to be stable for large range of flow velocity and CPVC pipes were found to be stable for small range of flow velocities against flow induced vibration. The order of the stability with respect to the material was found to be steel, aluminum, concrete and CPVC from higher stability to lower stability.
2. The natural frequencies of fluids flowing inside the pipes are lower than the natural frequencies of pipes without fluid
3. The frequencies of the pipes that transport fluids decrease with increasing speed until it reaches zero. When the velocity limit is exceeded, the pipe ruptures, and this is called resonance.
4. The order of the stability with respect to end conditions was found to be clamped-clamped, clamped-simply, simply-simply and clamped-free from higher stability to lower stability. By comparing the results for the pipes having same size and dimensions. For all types of fuel
5. Natural frequency of vibration and critical flow velocity were found to be very high for clamped-clamped steel pipe as 86.91 rad/sec158.16m/sec respectively and very low for clamped-free CPVC pipe as 2.51 rad/sec 4.55m/sec respectively

6. The results show that the best fuel flow type is kerosene fuel, due to the dynamic viscosity of four types of final conditions: (simply-simple ,clamped- clamped, clamped-simple and clamp-free) and four type of pipe materials: aluminum, steel, chlorinated polyvinyl chloride (CPVC).
7. It was concluded from the applied case of Karbala oil refinery that the safety coefficient is (2) as the (ω/ω_n) does not exceed (0.5).

5-2 Suggestions for Future Works:

1. Presenting experimental researches for this type of applications.
2. Studying the effect of dampers on struts.
3. Applying advanced programs to solve the vibration equation and the effect of the flowing fluid on the pipes, and the use of new techniques to calculate the natural frequency

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الخلاصه

الاهتزاز الناجم عن التدفق يسبب مشاكل خطيرة في أنظمة النفط والغاز ، ومعظم هذه المشاكل هي إزاحة عالية بسبب الرنين ، وفشل التعب بسبب الإجهاد الدوري ، والتآكل الهيكلي بسبب الحركة النسبية للأنبوب ، والهدف الرئيسي من هذا البحث هو تحليل الاهتزاز الناجم عن التدفق.

في هذا البحث تم استخدام أربعة أنواع من المعادن (الألمنيوم , الحديد ,الخرسانة وكلوريد البولي فينيل المكلور) يحتوي كل معدن من الأنابيب على أربعة نهايات مختلفة: (بسيطة - بسيطة ، مثبتة-مثبتة ، مثبتة - بسطة ، وخالية من التثبيت) لدراسة التردد الطبيعي ومدى السرع المسموح بها قبل الفشل. وكذلك استخدم ثلاث أنواع من الوقود (بنزين والكاز والديزل). كما درس تأثير الطول (3.048 م و 12 م)

تم وصف السلوك الديناميكي لسائل نقل الأنبوب عن طريق نهج مصفوفة النقل. تم تطوير برنامج كمبيوتر في هذه الدراسة باستخدام لغة [Matlab R2014] للتنبؤ باستجابة الاهتزاز.

من النتائج ، استنتج أن أفضل معدن يمكنه تحمل مجموعة واسعة من السرعات هو (158m/s) الفولاذ . وتبين من النتائج أن (ثابت - ثابت) هو أفضل حالة وأضعف حالة (خالية من التثبيت)

من الحالة التطبيقية لمصفى كربلاء تبين ان افضل انواع الانابيب بسيطة - بسيطة. إنهم يعملون على عامل أمان = 2 حيث أن (ω / ωn) بعيد عن الاهتزاز المستحث

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
كلية الهندسة /جامعة بابل
قسم الهندسة الميكانيكية

الاهتزاز الناجم عن جريان الموائع في انابيب نقل الوقود

رسالة

مقدمة إلى كلية الهندسة – جامعة بابل وهي جزءا من متطلبات نيل درجة الدبلوم العالي علوم في الهندسة/ الهندسة الميكانيكية /وقود وطاقة

من قبل

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بأشراف
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2022