ANSYS Modelling and Vibration Stability Analysis of Pipelines Conveying Fluid

IVAN GABAN

MECHANICAL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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by

Ivan Gaban
18222

Dissertation submitted in partial fulfilment of

as a Requirement for the

Bachelor of Engineering (Hons)

(Mechanical)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
32610 Seri Iskandar
Perak Darul Ridzuan
Malaysia

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Universiti Teknologi PETRONAS
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(MECHANICAL)

Approved by,

____

(Dr Setyamartana Parman)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
January 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

IVAN GABAN

ABSTRACT

Material engineering has develop considerably over the year to the extent it has allow cost reduction in testing, therefore making studies relevant to the vibrational stability of pipelines conveying fluid to become more important than ever. The research for this field has grown considerably over the year, but there are still some gaps which have yet to be covered. One of said gap is the hypothesis that a natural frequency of pipeline is subjected to the presence and absence of fluid flow within it. Thus, to prove the hypothesis and expand the understanding of fluid-structure interaction uncertainty, this project aims to present the ANSYS model of pipelines conveying fluid where the presence and absence of fluid flow are varied. The proposed model geometry will be a straight, tight and horizontal pipe with fluid passing through it. The model will then be simulated using the ANSYS CFX Solver and the resultant data tabulated and analysed. Additionally, comparisons were also made with previous research paper as to verify the results. In the end, the results show that fluid flow within the pipeline has little to no effect on its natural frequency.

ACKNOWLEDGEMENT

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TABLE OF CONTENT

CERTIFICATION OF APPROVAL i

CERTIFICATION OF ORIGINALITY ii

ABSTRACT iii

ACKNOWLEDGEMENT iv

TABLE OF CONTENT v

LIST OF FIGURES vii

LIST OF TABLES viii

CHAPTER 1 : INTRODUCTION 9

1.1 Background 9

1.2 Problem Statement 10

1.3 Objectives 10

1.4 Scope of Study 11

CHAPTER 2 : LITERATURE REVIEW 12

2.1 Significance of Pipelines Conveying Fluid 12

2.2 Eigenvalues 13

2.3 The Effect of Fluid Flow on a Pipeline Natural Frequency 14

2.4 Significance of Literature Review 15

CHAPTER 3 : METHODOLOGY/PROJECT WORK 17

3.1 Project Flowchart 17

3.2 Methodology 18

3.2.1 Mathematical Modelling of the dynamic behaviour of a pipe 18

3.2.2 Familiarisation with ANSYS... 20

3.2.3 ANSYS Modelling of pipeline conveying fluid.............. 20

3.2.4 Mesh Modal, Apply Constraint and Loading.................. 21

3.2.5 Run ANSYS CFX Solver 22

3.2.6 Compare Vibrational Stability of different conditions.... 23

CHAPTER 4 : RESULTS AND DISCUSSION 28

4.1 Results.. 28

4.1.1 Absence of Fluid Flow 28

4.1.2 Presence of Fluid Flow.. 33

4.1.3 Comparison of Results... 38

4.2 Discussion 39

CHAPTER 5 : CONCLUSION AND RECOMMENDATION 41

5.1 Conclusion... 41

5.2 Recommendation... 41

REFERENCES.. 42

LIST OF FIGURES

Figure 3.1 Flowchart of Project Methodology.. 17

Figure 3.2 Single Span Prestressed Pipeline... 18

Figure 3.3 Solid Model of Pipe.. 20

Figure 3.4 Mesh Model of Pipe with applied constraints 21

Figure 3.5 Fluid Body Boundary 22

LIST OF TABLES

Table 2.1 List of related past research 15

Table 3.1 List of Software Required 18

Table 3.2 Project Milestone for FYP I 24

Table 3.3 Project Milestone for FYP II 25

Table 3.4 Gantt Chart for FYP I 26

Table 3.5 Gantt Chart for FYP II 27

Table 4.1 Absence of Fluid Flow – For Carbon Steel 28

Table 4.2 Absence of Fluid Flow – For PVC 31

Table 4.3 Presence of Fluid Flow – For Carbon Steel 33

Table 4.4 Presence of Fluid Flow – For PVC 36

Table 4.5 Data Comparison for Carbon Steel 38

Table 4.6 Data Comparison for PVC 38

Table 4.7 Comparison of result with previous research paper 39

CHAPTER 1

INTRODUCTION

1.1 Background

Since the beginning of the 21^{st} Century, the major advances done regarding both Material and Software Engineering has led to the development of better manufacturing process, Engineering Simulation Software (such as ANSYS, CATIA, FLUENT) and such. For that reason, research relating to a complex problem such as dynamic flow and behaviour of fluid has become a common topic for many. One such popular topic is the various analysis conducted for a fluid conveying pipeline. Pipeline conveying fluid forms a critical component of any infrastructure around the world as it is essential in moving tonnes of goods and material to and fro. Recent data shows that a near total of 3,500,000 km of the pipeline has already been laid out for 120 countries around the world, which is nearly two-third of the total number of countries in the world [1]. However, pipelines themselves are not immune to the effects of natural environment and such which make them both volatile and dangerous. This concern primarily comes from the induced vibration which causes permanent damage to a pipeline in the long run which leads to various effects, most which are fatal and dangerous to the public.

So it should come to no surprise that extensive research has already been carried out by various individual and institutions around the world that have analysed the pipe stability through different means. This research ranges from using dynamic modelling and simulation of pipeline under different effects to conducting an experimental study of the pipeline with various materials. One common factor that majority of these research share is that they use the concept of vibration as the basis of the analysis, which indicates that the stability of a pipe is affected by the amount of vibration induced on it, whether it comes internally or externally. For that reason, this paper aims expand further by studying the effects of varying the condition of fluid flow in a pipeline conveying fluid while simultaneously varying the base material of the pipeline.

1.2 Problem Statement

The study of vibrational stability analysis for a pipeline is very broad. However, the effect of induced vibration on a pipeline stability due to fluid flow within a pipeline is a research gap which needs further exploration.

One such research gap is to see whether the act of varying the condition of fluid flow will affect the natural frequency of pipelines conveying fluid

Therefore, the aim of this project is to use ANSYS to model and simulate the pipeline and analyse the difference in stability by varying the condition of the fluid within the pipeline.

1.3 Objectives

The objectives of this proposal are as followed:

(i) To investigate the relationship between fluid flow within the pipeline and the vibrational stability on the pipeline

(ii) To compare the effect of the presence of fluid flow on a pipeline vibrational stability

1.4 Scope of Study

The system under consideration would be to a fixed, finite length and straight pipes, passing through it fluid. In addition, the analysis of the system will have the following assumptions.

(i) The pipeline is horizontal

(ii) The pipe is inextensible

(iii) The shear strain, the rotational inertia, the effect of gravity and coefficient of the damping material are negligible

(iv) The theory Euler-Bernoulli is applicable to describe the vibration bending of the pipe y assuming the lateral movement of $y(x, t)$ is small and with large length wave compared with the diameter of the pipe.

(v) The velocity distribution in the cross-section of the pipe is negligible.

CHAPTER 2

LITERATURE REVIEW

The following chapter will be explaining the significance of a pipe conveying fluid, the use of eigenvalues on stability analysis as well as the effect of fluid flow on the natural frequency of a pipeline.

2.1 Significance of Pipelines Conveying Fluid

For many years, pipelines conveying fluids have become an essential component in many factory complex sites due to its critical application which makes its a considerable interest in various industrial branches. According to Dr. Muhsin J. Jweeg and Thaier J. Ntayeesh [2], the role of pipes in transporting fluids from one point to another are of significant value as they form the basic structural component in Energy-Generating Plants, Hydraulics Systems, Rocket-Piping, Refrigerators and such.

Nevertheless, the exposure of pipes to various environmental conditions can easily trigger vibrations that cause both finite and irreversible extension to the pipe over a period. That is to say "excessive pipe vibration will eventually lead to machine downtime, leaks, fatigue failure, high noise, fires and explosions in refineries and petrochemical plants" [3]

Because of this, the dynamics and stability of pipeline conveying fluid are a subject of interest to many, leading to research in the various form of techniques, each considering different parameters and conditions for the fluid-conveying pipelines. For example, Ritto, et al. [4] introduces the probabilistic model that takes into account of uncertainties in their computational model which they would analyse by varying the fluid flow speed inside the pipe. Likewise, Elfelsoufi and Azrar [5] introduce integral equation formulation for the mathematical modelling of the dynamic stability of the pipeline. Moreover, there were researchers like Alizadeh, et al. [6] who instead studied and analysed the reliability of a pipe conveying fluid with stochastic structural and fluid parameters. Others such as Veerapandi, et al. [7] took a step further by conducting a 3-Dimensional Fluid Flow Analysis. Additionally, Sinha, et al. [8] came up with a non-linear optimisation method to predict the excitation forces in pipe conveying fluid while Zhu, et al. [9] investigate the vortex-induced vibration of a curved flexible pipe. Special mention also goes to Soo Kim, et al. [10] who made an analytical study of flow-induced vibration with cooling effects and Yi-min, et al. [11] that highlighted the influence of boundary condition on a pipeline natural frequency.

2.2 Eigenvalues

Eigenvalues' are necessary components to investigate the vibrational stability of a pipeline conveying fluid. Eigenvalues, better known as original roots, latent roots, proper values or spectral values [12, 13] are a particular set of scalars associated with a linear system of equation.

An example of such conditions is in the equation shown below [13];

$$T(v) = \lambda v \tag{2.1}$$

whereas λ is a scalar in the field, known as the eigenvalue while the v is the eigenvector associated with mentioned scalar.

According to Weisstein [14], the determination of the eigenvalues and eigenvectors of a system is paramount in physics and engineering. Similar to matrix diagonalization, they find many usages in common applications as stability analysis, the physics of rotating bodies, and small oscillations of vibrating systems, to name only a few".

Generally speaking, eigenvalues represent the natural frequency of vibration while eigenvectors represent the shapes of these vibrational modes. A study conducted by Mediano and Garcia-Planas [15] regarding the stability properties of linear dynamics system representing the pipelines shows that a system is considered safe in Lyapunov's sense if and only if the eigenvalues are located on the imaginary axis and are either simple or semi-simple.

The above statement is proven by highlighting eigenvalues found on an imaginary axis of a given stable Hamiltonian system. In their case, the distinctive equation of the matrix is as followed;

$$\lambda^4 + (2a^2 - b - c)\lambda^2 + (a^2 + c)(a^2 + b) = 0 \tag{2.2}$$

Moreover, the eigenvalues

$$\lambda = \pm \frac{\sqrt{2a^2 + b + c \pm \sqrt{-8a^2b - 8a^2c - 2bc + b^2 + c^2}}}{2} \tag{2.3}$$

Eigenvalues in terms of β, λ

$$\lambda = \pm \sqrt{\frac{\lambda_1 \pm \beta\sqrt{\lambda}_2}{2}} \tag{2.4}$$

Consequently, this also means that the roots obtained in the equation shown above are to be real and adverse.

2.3 The Effect of Fluid Flow on a Pipeline Natural Frequency

Contemporary speaking, there have been studies conducted by academician around the world on the effect fluid flow on pipe stability. A good example would be from Zou, et al. [16] whose paper covered the influence of fluid's Poisson Ratio, the ratio of pipe radius to pipe-wall thickness, the ratio of liquid mass density to pipe-wall mass density, laminate layup, the fluid velocity, fluid pressure and initial tension.

Additionally, a study done by Mediano and Garcia-Planas [17] whose studies shows that not only are the dynamics and stability of pipes conveying fluid dependent on the material of the pipe and the pressure produced by the liquid, there are also influence by the pipes boundary conditions. Within the same year, Zahid I. Al-Hashimy, et al. [18] conducted as a study which highlighted the effect of fluid density in altering the natural frequency of a pipeline with sudden enlargement and contraction.

Lastly, a research article by Jung, et al. [19] and Elabbasi [20] shows that the natural frequency of an object when enclosed in a liquid body or vice versa undergo changes due to the liquid itself.

2.4 Significance of Literature Review

The following table below sums up the list of related research conducted on vibrational stability analysis of a pipeline conveying fluid.

Table 2.1 List of related past research

No.	Researchers	Year	Remarks
1	Sinha, et al. [8], Prediction of flow-induced excitation in a pipe conveying fluid	2005	Develop method in predicting flow-induced vibrations
2	Soo Kim, et al. [10], Analysis of Fluid Induced Vibration of Cryogenic pipes in consideration of cooling effect	2008	Develop method in predicting flow-induced vibrations while accounting for thermodynamics
3	Yi-min, et al. [21], Natural frequency analysis of fluid conveying pipeline with different boundary conditions	2010	Effect of boundary condition on a pipeline natural frequency
4	Ritto, et al. [4], Dynamic stability of a pipe conveying fluid with an uncertain computational model	2014	Develop method for predicting fluid flow for a pipe using probabilistic approach
5	Mediano and Garcia-Planas [15], Stability Analysis of a Clamped-Pinned Pipeline Conveying Fluid	2014	Effect of pipe constraint on pipeline stability when fluid flow through it
6	Zahid I. Al-Hashimy, et al. [18], Effect of Various Fluid Densities on Vibration Characteristics in Variable Cross-section Pipes	2014	Effect of fluid density on natural frequency for a variable cross-sectional pipe
7	Zhu, et al. [9], An experimental investigation of vortex-induced vibration of a curved flexible pipe in shear flows	2016	Effect of vortex on stability for a curved pipeline

We can see that there are still many research gaps which are still left unsolved. Not only has there never been any known research to see if and only if the natural frequency of a pipeline is affected by the presence or absence of fluid flow within it, most of the research conducted so far is mostly focus generating a more accurate method using linear or non-linear optimization in predicting their flow with only few considering the effect of liquid parameters on a pipeline stability. Thus, this research aim at filling one part of the hole which in turn improves the understanding of fluid-structure interaction and bridge the gap between simulation and real-world applications.

CHAPTER 3

METHODOLOGY/PROJECT WORK

The following section is dedicated to highlighting the task planning as well as the various activities that will be executed to achieve the objectives of the project.

3.1 Project Flowchart

The overview of the project methodology is shown in Fig. 3.1.

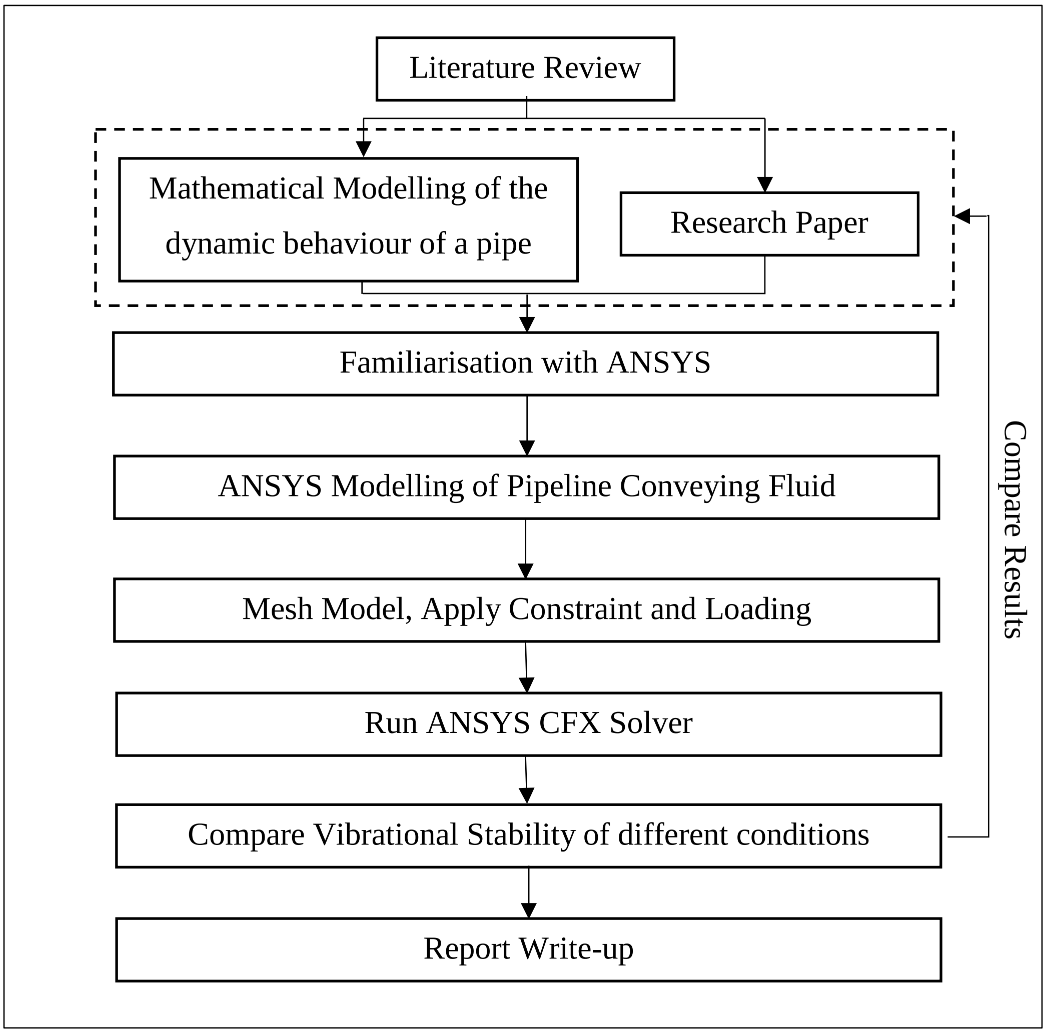


Figure 3.1 Flowchart of Project Methodology

Firstly, the dynamic behaviour of a pipe will be model mathematically to provide an analytical solution of the pipe when under various support conditions. Followed by one being familiar with the ANSYS Software and continuing with the ANSYS Modelling of the pipeline conveying fluid. Once that is finished, it will then proceed with the simulation of the pipe under different conditions which are followed by conducting a vibration stability analysis. Lastly, the project concludes with the report writing as well as the required project demonstration at the end.

The following table highlight the software required to conduct the project.

Table 3.1 List of Software Required

Software	**Purpose**
ANSYS Ver 17.2 (CFX)	For the modelling and simulation of the pipes under various scenarios

3.2 Methodology

3.2.1 Mathematical Modelling of the dynamic behaviour of a pipe

The following section details the mathematical model to be used.

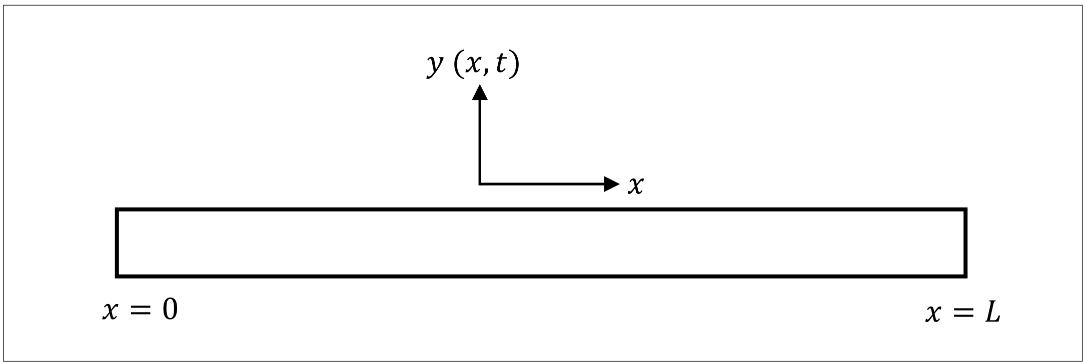


Figure 3.2 Single Span Prestressed Pipeline

For a single span pipeline (assume to be prestressed), where the movement of fluid is a function of distance x and time t. Using the Beam Theory [22, 23], we then get the following characteristic equation which best describe the pipeline;

$$\frac{d^2}{dx^2}\left(EI\frac{d^2\omega}{x}\right) = -\mu\frac{d^2\omega}{dx^2} + q(x) \tag{3.1}$$

Whereas the EI represent the bending stiffness of the pipe (Nm^2), u is the pipe mass per unit length $(\frac{kg}{m})$ and the q(x) represents the inside forces acting on the pipe.

From there, we then approximate the internal fluid flow as a plug point thus rendering all other points of the liquid to have similar velocity, U in relation to the pipeline. By doing so, the inside forces acting on the pipe can also be written as followed;

$$q(x) = -m_f \frac{d^2y}{dt^2} \tag{3.2}$$

The equation shown above is a reasonable approximation for a turbulent flow profile. Also, the m_f is the fluid mass per units length $(\frac{kg}{m})$ and U is the fluid velocity $(\frac{m}{s})$. The equation for local acceleration, Coriolis and centrifugal was then obtained by breaking down the total acceleration which is simplify as followed;

$$m_f \frac{d^2y}{dt^2} = m_f[\frac{\partial^2 y}{\partial t^2} + 2U \frac{\partial^2 y}{\partial x \partial t} + U^2 \frac{\partial^2 y}{\partial x^2}] \tag{3.3}$$

For the internal fluid which will cause hydrostatic pressure on the pipe wall, it is mathematically modelled using the following equation;

$$T = -A_i P_i \tag{3.4}$$

whereas the internal cross-sectional area of the pipe (m^2) is represented by A_i , while the hydrostatic pressure inside the pipe (Pa) is represented by P_i. Last and not least, the resulting equation describing the pipe oscillation is obtained once we equate the total acceleration as being equal to the configuration of local, Coriolis and centrifugal acceleration.

$$EI \frac{\partial^4 y}{\partial x^4} + \left(m_f U^2 - T\right) \frac{\partial^2 y}{\partial x^2} + 2 m_f U \frac{\partial^2 y}{\partial x \partial t} + \left(m_p + m_f\right) \frac{\partial^2 y}{\partial t^2} = 0 \tag{3.5}$$

3.2.2 Familiarisation with ANSYS

Given that there are many individual component systems in ANSYS Workbench which can be used for the simulation of fluid within the pipeline, this section is dedicated to identifying the ideal component system to be used within the ANSYS Workbench as the project mirrors closely to a Two-Way Fluid Structure Interaction.

In general, the ANSYS Workbench set-up began with setting up a Transient Structural Analysis System whose output will be used by the ANSYS CFX Solver through the coupling. The resultant data will then be outputted to both a Static Structural Analysis System and a Harmonic Structure Analysis which will then provide the mode and natural frequency of the pipeline conveying fluid.

3.2.3 ANSYS Modelling of pipeline conveying fluid

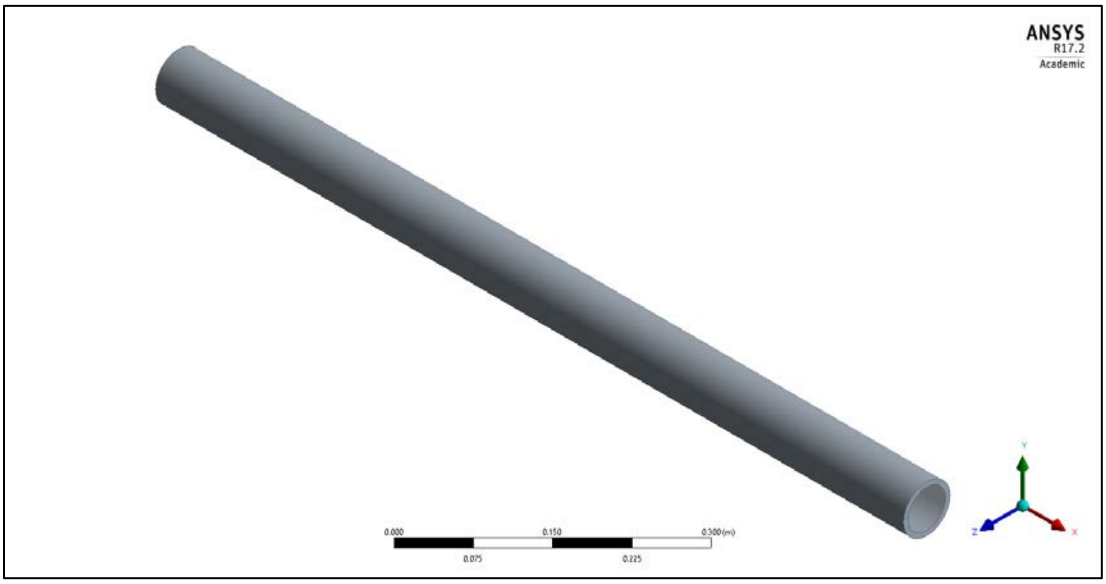


Figure 3.3 Solid Model of Pipe

The Solid Model of the pipe as shown in Fig 3.3 above was produced using the ANSYS Design Modeler (Geometry Editor) with the following specifications.

(i) Length of Pipeline, L = 1000mm
(ii) Pipeline Inner Diameter, ∅ = 50mm
(iii) Pipeline Thickness, T = 6mm
(iv) Material Type is Carbon Steel

Given that the fluid passing through the pipeline will be interacting with the walls of the pipe, the fluid bounding box was modelled to the exact same size of the pipe with its material type designated as “Water” at standard temperature and pressure.

3.2.4 Mesh Modal, Apply Constraint and Loading

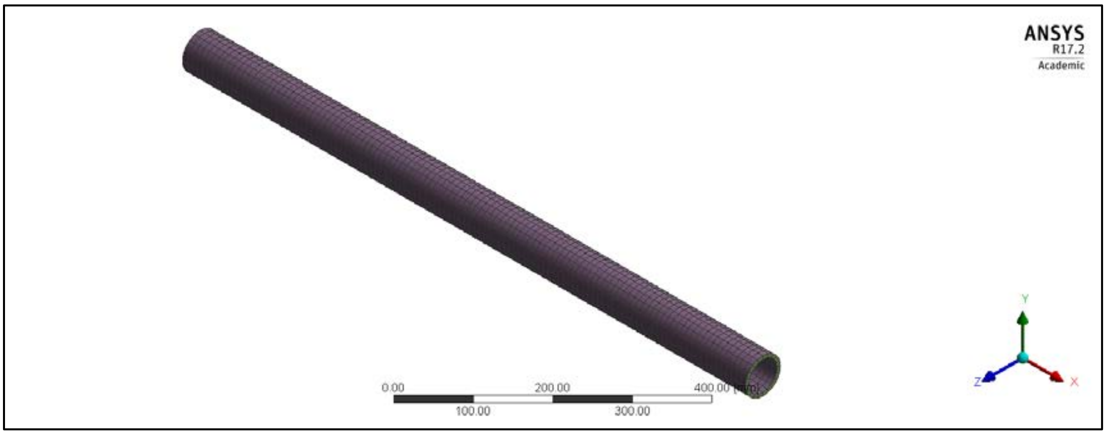


Figure 3.4 Mesh Model of Pipe with applied constraints

Importing the Solid Model geometry into the ANSYS APDL Mechanical Software, the pipe was then meshed accordingly with a fineness preferring more towards high speed for simplicity. Additionally, the mesh was further fine-tuned using face meshing on the pipe inner and outer walls to generate a more uniform mesh for the simulation.

As for the set parameters, the purple-shaded surface shown in Fig. 3.4 above highlights the region set for Fluid Structure Interaction. In addition, the light-green shade found at both ends of the pipeline is configured as fixed loading respectively. These boundary conditions are set as to create and simulate a pipe whose both ends are fixed.

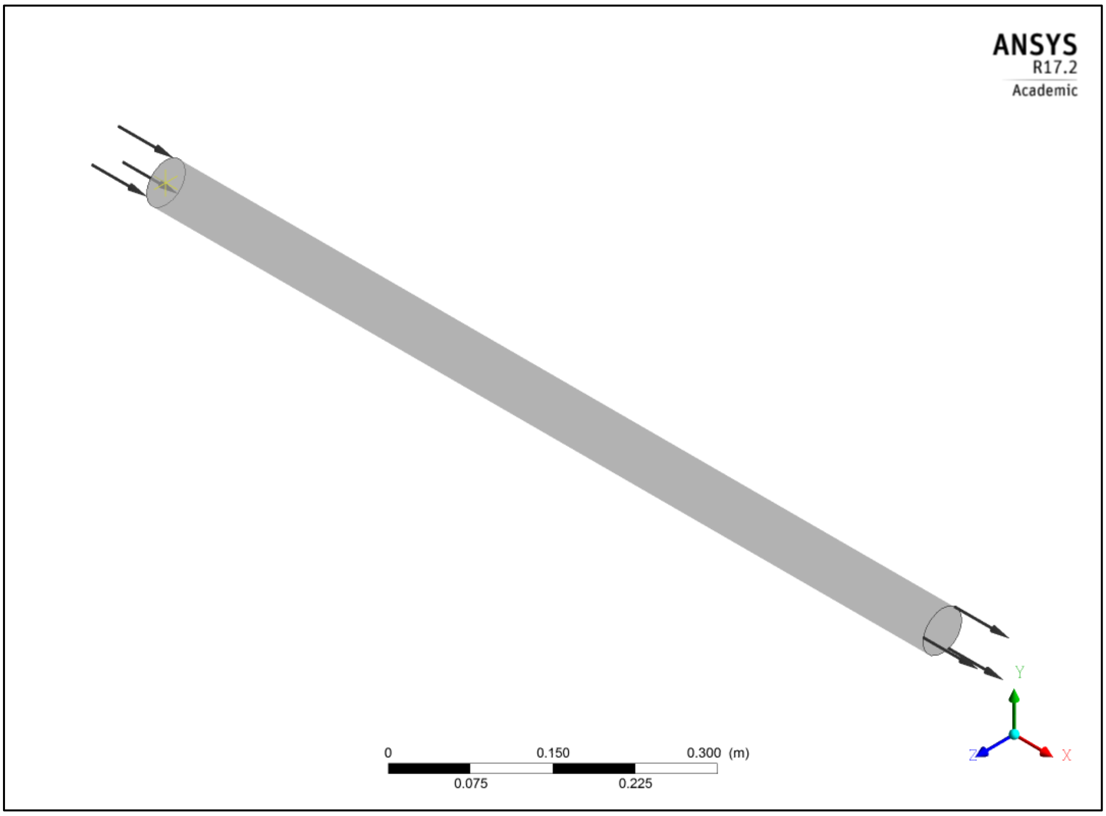


Figure 3.5 Fluid Body Boundary

On the other hand, the above Fig. 3.5 shows the Fluid body with both its inlet and outlet domain set at both ends of the pipe. Using CFX-Pre, the fluid flow is assumed to be turbulent with the inlet mass flow rate designated for 2 $\frac{kg}{s}$ while its outlet mass flow rate is 2 $\frac{kg}{s}$. The fluid material is water while the pressure exerted on the walls of the pipe is 400 kPa (4 bars).

3.2.5 Run ANSYS CFX Solver

Since this simulation will involve a two-way Fluid Structure Interaction, both the structural and fluid equations will be assembled and solved separately through the ANSYS Software. The discrete physics are then coupled simultaneously until an equilibrium is reached. The simulation is set to find and solve for 6 different mode shape. The process is repeated by going through the following steps above albeit with the material type set to PVC instead. In addition, both set of simulation will include a static pipeline that will have no fluid flow within it since it will be used constant for comparison.

3.2.6 Compare Vibrational Stability of different conditions

From the data obtain from the ANSYS Simulation, the pipe displacement and eigenvalues will then be tabulated and compared to analyse the effect of whether the fluid flow conditions will alter the natural frequency of a pipeline conveying fluid.

Table 3.2 Project Milestone for FYP I

No.	Key Milestone	Start Date	End Date
1	Selection Of Project	12 September 2016	18 September 2016
2	Completion of Research & Data Gathering	19 September 2016	16 October 2016
3	Submission of Extended Proposal	03 October 2016	09 October 2016
4	Proposal Defence	10 October 2016	23 October 2016
5	Completion of Mathematical Modelling of the Dynamic Behaviour of a pipe	24 October 2016	20 November 2016
6	Completion of Analytical Solution of the pipe under various support conditions	31 October 2016	27 November 2016
7	Submission of Pre-Interim Report	28 November 2016	04 December 2016
8	Submission of Interim Draft Repot	05 December 2016	11 December 2016
9	Submission of Interim Report	12 December 2016	18 December 2016

Table 3.3 Project Milestone for FYP II

No.	**Key Milestone**	**Start Date**	**End Date**
1	Completion of Familiarisation with ANSYS	16 January 2017	12 February 2017
2	Completion of ANSYS Modelling of pipelines conveying fluids	30 January 2017	26 February 2017
3	Completion of ANSYS simulation of the pipe under various material types and fluid constant	13 February 2017	12 March 2017
4	Submission of Progress Report	06 March 2017	12 March 2017
5	Completion of Vibration Stability Analysis	06 March 2017	16 April 2017
6	Completion of Pre-SEDEX (Project Demonstration)	27 March 2017	02 April 2017
7	Submission of Draft Final Report	03 April 2017	09 April 2017
8	Submission of Dissertation (Softbound)	10 April 2017	16 April 2017
9	Submission of Technical Paper	10 April 2017	16 April 2017
10	Completion of Viva	17 April 2017	23 April 2017
11	Submission of Project Dissertation (Hard Bound)	01 May 2017	07 May 2017

Table 3.4 Gantt Chart for FYP I

No.	**Detail/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of Project Topic	■													
2	Project Start	■													
3	Research & Data Gathering		■	■	■	■									
4	Submission of Extended Proposal				■										
5	Proposal Defence					■	■								
6	Mathematical Modelling of the Dynamic Behaviour of a pipe							■	■	■	■				
7	Analytical Solution of the pipe under various support conditions								■	■	■	■			
8	Submission of Pre-Interim Report												■		
9	Submission of Interim Draft Repot													■	
10	Submission of Interim Report														■

Table 3.5 Gantt Chart for FYP II

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Familiarisation with ANSYS															
2	ANSYS Modelling of pipelines conveying fluids															
3	ANSYS simulation of the pipe under various material types and fluid constant															
4	Submission of Progress Report															
5	Vibration Stability Analysis															
6	Pre-SEDEX (Project Demonstration)															
7	Submission of Draft Final Report															
8	Submission of Dissertation (Softbound)															
9	Submission of Technical Paper															
10	Viva															
11	Submission of Project Dissertation (Hard Bound)															

CHAPTER 4

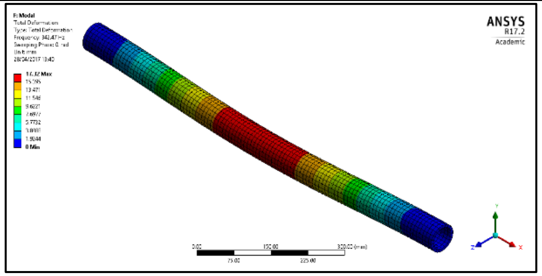
RESULTS AND DISCUSSION

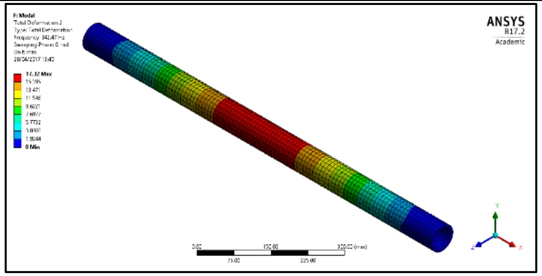
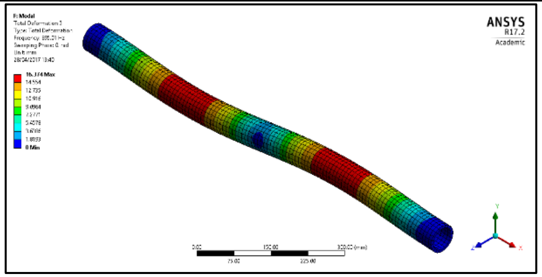
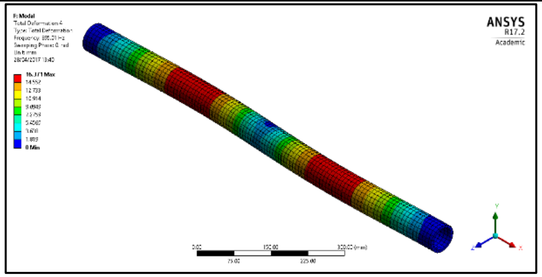
4.1 Results

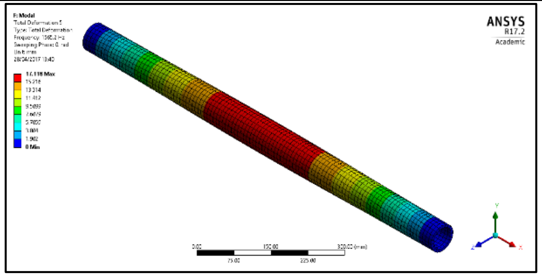
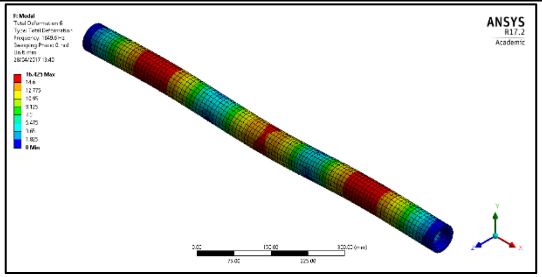
4.1.1 Absence of Fluid Flow

The results obtained from the ANSYS simulation are as shown in the table below. The material type of the pipeline set for this simulation is Carbon Steel.

Table 4.1 Absence of Fluid Flow – For Carbon Steel

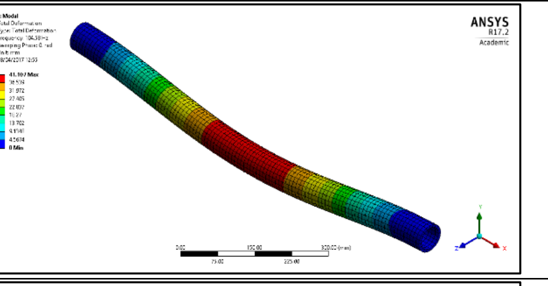
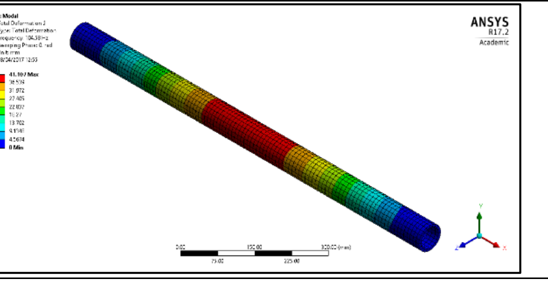
Mode Shape	Natural Frequency (Hz)	Displacement (mm)	Figure
1	342.47	17.32	

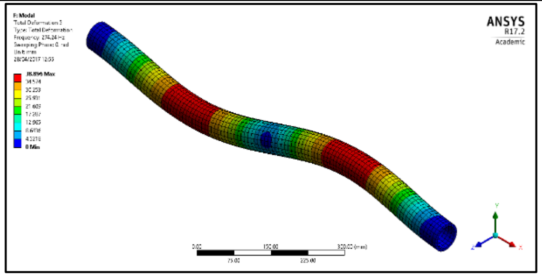
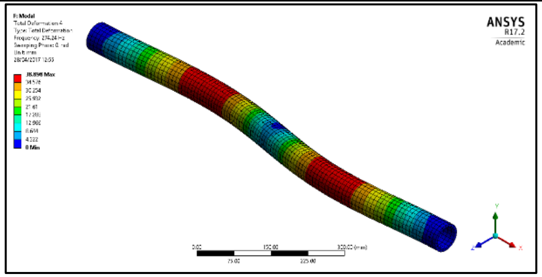
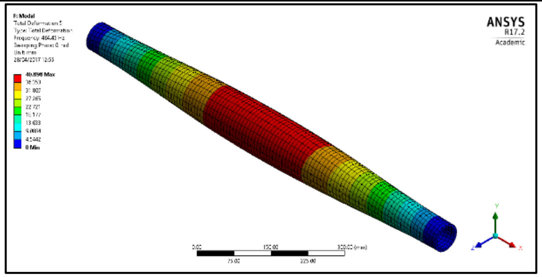
2	342.47	17.32	
3	895.01	16.374	
4	895.01	16.371	

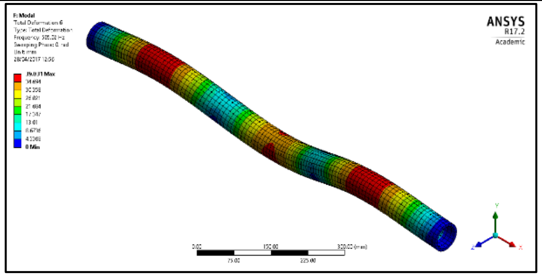
5	1565.2	17.118	
6	1649.6	16.425	

The next set of results was also obtained from the ANSYS simulation as shown in the following table. However, the material type of this pipeline set for this simulation is PVC.

Table 4.2 Absence of Fluid Flow – For PVC

Mode Shape	Natural Frequency (Hz)	Displacement (mm)	Figure
1	104.58	41.107	
2	104.58	41.107	

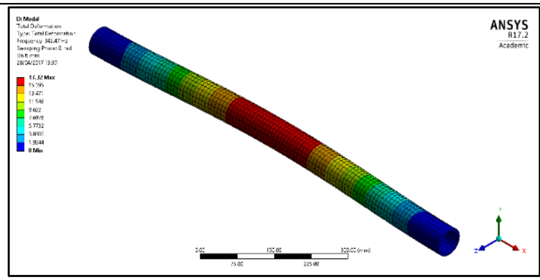
3	274.24	38.896	
4	274.24	38.898	
5	464.45	40.898	

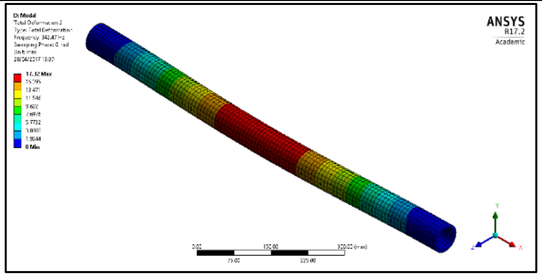
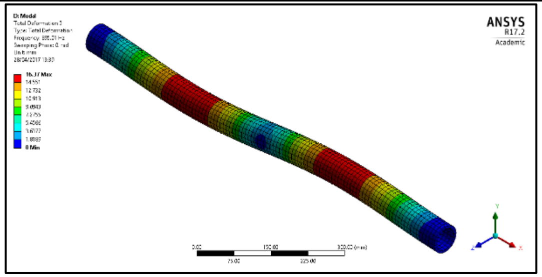
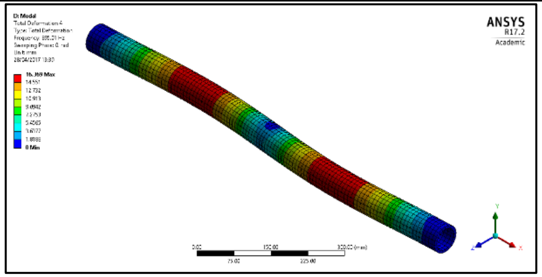
6	505.02	39.031	

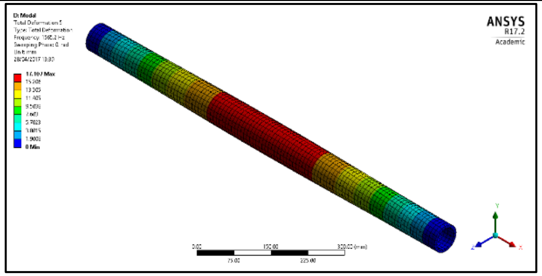
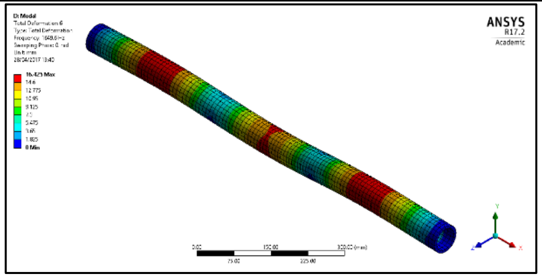
4.1.2 Presence of Fluid Flow

The following set of data is obtained from the ANSYS Simulation with fluid flow within the pipeline. For the following table below, the material type of the pipeline is Carbon Steel.

Table 4.3 Presence of Fluid Flow – For Carbon Steel

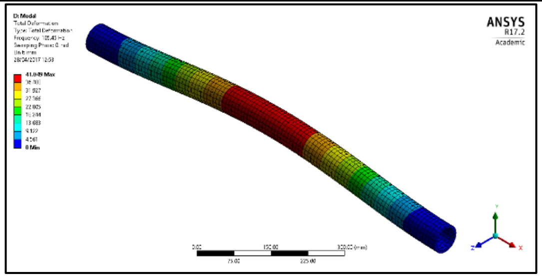
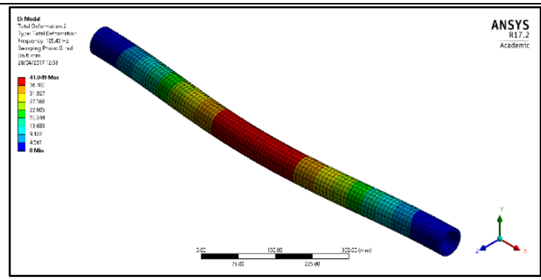
Mode Shape	Natural Frequency (Hz)	Displacement (mm)	Figure
1	342.47	17.32	

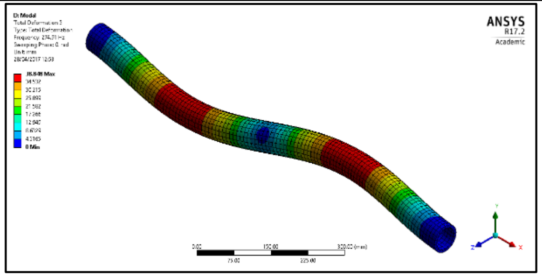
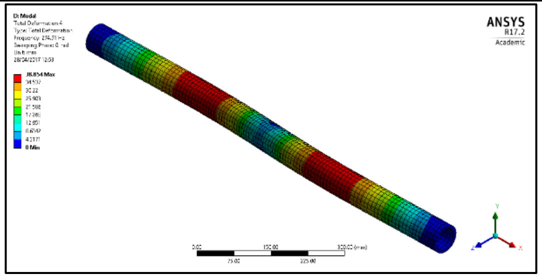
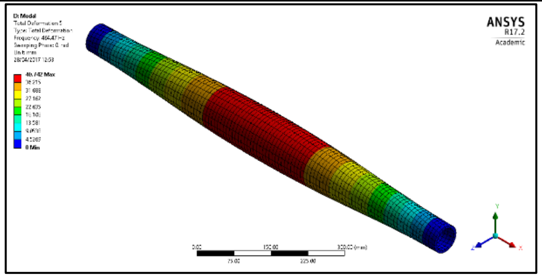
2	342.47	17.32	
3	895.01	16.37	
4	895.01	16.3769	

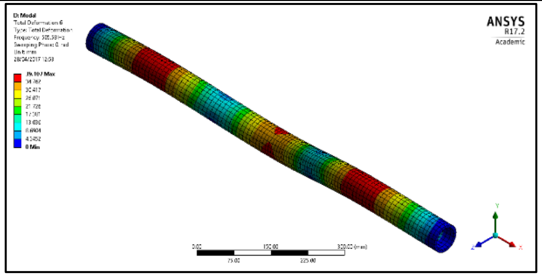
5	1565.2	17.107	
6	1649.6	16.425	

The following results obtained from the ANSYS simulation with fluid flowing is as shown in the following table. The material type of this pipeline set for this simulation is PVC.

Table 4.4 Presence of Fluid Flow – For PVC

Mode Shape	Natural Frequency (Hz)	Displacement (mm)	Figure
1	105.45	41.049	
2	105.45	41.049	

3	274.91	38.848	
4	274.91	38.854	
5	464.47	40.742	

6	505.58	39.107	

4.1.3 Comparison of Results

The following tables displays the comparison of results for the absence and presence of fluid flow within the pipeline.

Table 4.5 Data Comparison for Carbon Steel

Mode Shape	1		2		3		4		5		6	
	Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence
Natural Frequency (Hz)	342.47	342.47	342.47	342.47	895.01	895.01	895.01	895.01	1565.2	1565.2	1649.6	1649.6
Displacement (mm)	17.32	17.32	17.32	17.32	16.374	16.37	16.371	16.377	17.118	17.107	16.425	16.425

Table 4.6 Data Comparison for PVC

Mode Shape	1		2		3		4		5		6	
	Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence
Natural Frequency (Hz)	104.58	105.45	104.58	105.45	274.24	274.91	274.24	274.91	464.45	464.47	505.02	505.58
Displacement (mm)	41.107	41.049	41.107	41.049	38.896	38.848	38.898	38.854	40.898	40.742	39.01	39.107

4.2 Discussion

In the above Table 4.5, we can see that there is no change in natural frequency for both conditions in all six-different mode shapes. However, there is a change in displacement although the change in value is minuscule. Given that change in mass of an object will change its natural frequency, it is possible that the change of mass within the pipeline due to fluid flow is too short within a period therefore negating any effect it has on the pipelines natural frequency.

Another possible explanation is that the young modulus of material also the magnitude of change in a natural frequency for both conditions. This can be seen in Table 4.6 where the pipeline is made of PVC. For both conditions, the natural frequency and displacement varies by a significant amount for all six-different mode shape. To justify the previous statement, the young modulus for carbon steel is 180-200 GPA as opposed to PVC which is 2.4 - 4.1 GPA. Therefore, it can be said that the lower the young modulus, the higher the variation in natural frequency and displacement.

Last and not least, another plausible explanation is that the parameters set for the fluid flow for the simulation is too low to induce any actual change on the pipelines natural frequency. The evidence supporting the above statement is by comparing the values obtained with a previous research paper conducted by Mediano and Garcia-Planas [15] who conducted a similar simulation in their work. The compared value shares the same characteristics such as the pipelines is made of carbon steel and there is fluid flow that induces a constant pressure of 4 bar on the walls of the pipe.

Table 4.7 Comparison of result with previous research paper

Model	Mode 1		Mode 2	
	Natural Frequency (f)	Displacement (dx)	Natural Frequency (f)	Displacement (dx)
Mediano and Garcia-Planas [15]	424.28 Hz	8.767 mm	424.256 Hz	8.767 mm
ANSYS CFX	342.47 Hz	17.320 mm	342.47 Hz	17.320 mm

Despite so, neither research paper has yet to conduct an actual lab experiment to verify the data obtained from their respective simulation other than doing comparison with existing data. According to Mediano and Garcia-Planas [15], the data obtained has so far been verified by comparing the data with pipes used in public works.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this paper, an ANSYS modelling and vibration stability analysis of a pipeline conveying fluid has been presented. Furthermore, it covers research gap which investigates the relationship of whether the presence and absence of fluid flow will affect the natural frequency of a pipeline conveying fluid.

From the results obtained at the end of the simulation, the presence of fluid flow has little to no effect on the natural frequency a pipeline other than displacement. The reason being that period of change in mass within the pipeline is too short which negates any possible changes to a pipeline natural frequency.

Thus, this shows that the dynamic vibrational stability of a pipeline is not dependent on the fluid flow but on other factors instead.

5.2 Recommendation

Given that results obtain from the simulation-based project are extremely subjective due to the input data which comes from the user themselves, it must be verified through actual lab experiment before it can be applied in the real-world.

Thus, for those who will continue this work, it is recommended to conduct a lab experiment and compare the obtained results with this research. From there, a further refinement can then be done on the simulation parameter itself and increase its relative reliability for future applications in industry.

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