VELOCITY PROFILE INSIDE THE PIPELINE AN ANALYSIS FOR CORROSION DETECTION

by

BRYAN ANAK SIMON TITIK

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

UniversitiTeknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak DarulRidzuan

CERTIFICATION OF APPROVAL

VELOCITY PROFILE INSIDE THE PIPELINE AN ANALYSIS FOR CORROSION DETECTION

by

Bryan anak Simon Titik

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____
Assoc. Prof. Josefina Barnachea Janier
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2010

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 acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or person

____

BRYAN ANAK SIMON TITIK

ABSTRACT

This report presents the velocity profile of crude oil inside a pipeline as an analysis for corrosion detection. The scope of the project being tested is a straight pipeline that is used to transport crude oil and used constant temperature for simulation and calculation of the velocity profile. Other than that, pipeline diameter between corroded and non corroded pipeline and material being used will be held constant. Likewise, a pipe wall surface roughness between corroded and non corroded pipeline where the surface roughness has effect on the Reynolds number that is being used to determine the type of flow and the friction factor. In identifying the velocity profile on the pipeline, FLUENT software was use for simulation. For designing the pipe so that it can be simulated, GAMBIT software is used.

ACKNOWLEDGEMENT

From this project, I would like to express my fullest gratitude and appreciation to my supervisor, Assoc. Prof. Josefina Barnachea Janier for her guidance, suggestion and knowledge offered in completing the project.

My appreciation is also extended to the Department of Electrical and Electronic Engineering especially to all technicians, FYP committee and lectures for their support directly or indirectly during the period of my research. Last but not least, I would like to thank all my fellow friends who helped me towards the completion of my project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The velocity profile and characteristic of fluid flow inside pipeline can be useful to detect corrosion especially in the petroleum industry as it is hard and very crucial to determine the severity of corrosion inside the pipelines. In oil and gas industry it is very crucial that crude oil extracted from reservoir need to be transported from point of extraction to storage terminal for processing purposes. The medium that is being used for the crude oil transportation is the pipeline and it is exposed to the risk of corrosion due to the contact with the hydrocarbon itself as well as water.

1.2 Problem Statement

In oil and gas industry, the condition of pipeline is very important since it is functioning as a medium to transport crude oil from offshore to the crude oil terminal. Among major problem being faced by the pipeline are corrosion activity that is due to the exposure of the internal pipe wall to water and contaminant in the crude oil. The corrosion activity will weaken the structure of the pipe and might cause leakage. If the corrosion activity of the pipeline remains undetected and corrected, it will cause a major damage to the safety and environment or to its surrounding area, as well a loss in production.

1.3 Objectives and Scope of Study

1.3.1 Objectives

The objective of this project is to determine the velocity profile and characteristic of the liquid inside the pipeline due to the effect of corrosion. Also using the results obtained, the relationship between surface roughness and velocity profile will be analyzed. The software, GAMBIT and FLUENT are used to obtain the simulation results.

1.3.2 Scope of Study

For this project, it is limited for the following:

- Study the effect of corrosion to velocity profile
- Study the software to be used
- Simulations of velocity profile in different pipe conditions
- Analysis of the simulation results

1.3.3 Feasibility of the Project within the Scope and Time frame

The project begins by collecting related materials from journals, technical papers, books as well as from internet specifically on fluid velocity profile, pipeline corrosion. For this project, the focus is on the simulation of velocity profile in different pipe condition using GAMBIT and FLUENT software. The project was done in two semesters.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory

In general pipelines are composed of a few parts which are pipe, valves, compressor unit, pump stations, metering stations, regulator stations, delivery stations and equipment attached to the pipe itself.

The importance of pipeline is that it is used to transport products to the market. In modern world today, transportation of product or material by using pipeline is important as it is one of the most efficient and safe approach of delivery system for oil and gas.

In oil and gas industry, among the biggest challenge being faced by the industry is the monitoring process of the pipeline itself. Among the factors that need to be considered in monitoring the pipeline are geographical distance they cover, burial depth and the need to keep the crude oil to flow without much interruption [1]. One of the reasons in conducting pipeline monitoring is to determine the internal corrosion of the pipeline.

In transportation of crude oil from offshore to the terminal on the onshore, the pipeline is usually buried on the seabed and this exposed the pipeline to the sea water [2]. Other than that, crude oil extracted from reservoir is containing contaminant that might cause corrosion. Due to these two factors, it is seen that the pipeline has a greater risk of having corrosion.

2.2 Pipeline Corrosion

The degradation of pipeline structure is a result of corrosion activity. This corrosion activity usually attack pipeline materials which consist of coating, weld, pipe, etc. Corrosion activity weakens the structure of the pipeline and eventually will cause leakage or breakage. Generally corrosion can be divided into three forms which are [3]:

1. Uniform corrosion
    - It is having the same rate of the whole surface being corroded.
2. Localized corrosion
    - This form of location usually involves selective removal of metal from part of exposed metal surface
3. Stress corrosion cracking
    - Stress corrosion cracking did not involve losses of material. It only involves cracking of the metal and it occurs when certain metals are exposed under specific environment tensile stress.

2.3 Fluid Viscosity

Fluid viscosity is a representation on the resistance of the fluid to flow. In Newton's equation, it relates the liquid shear stress with the fluid's velocity gradient flow. Velocity of fluid in each level of pipeline cross section varies. Theoretically, velocity at pipeline wall is zero and as it move away from the pipe wall, the velocity will increase and it will be maximum the farthest it is from the pipe wall [4]. Determining the fluid viscosity is relevant with the project because it is part of the parameters that is required to get the Reynolds Number.

2.4 Fluid Density

Fluid density is the mass per unit volume of the fluid. It is generally a measure in kg/m^3. Another commonly used term is specific gravity [6]. It is simply defined as the ratio of the mass fluid to its volume and denoted as a symbol of ρ [7]. In SI system, unit measurement of fluid's mass is kg and volume of the fluid is in cubic meter (m^3) thus the unit of measurement of fluid density is kg / cubic meter (kg / m^3) [7].

2.5 Fluid Velocity Profile

Within a pipeline, not all fluid travel with the same velocity. Fluid velocity within a pipe is influenced by the shape, cross section, pressure and the viscosity of the fluid itself. There are two categories of fluid flow characteristic. Those two categories are known as [4]:

- Laminar
  - The characteristic of laminar flow is that velocity of distribution at cross sectional will be in a parabolic shape. The maximum velocity of the fluid flow at the centre is twice the average velocity in the pipe.

- Turbulent
    - Characteristic of turbulent flow is that velocity of the fluid is fairly distributed across the pipe section.

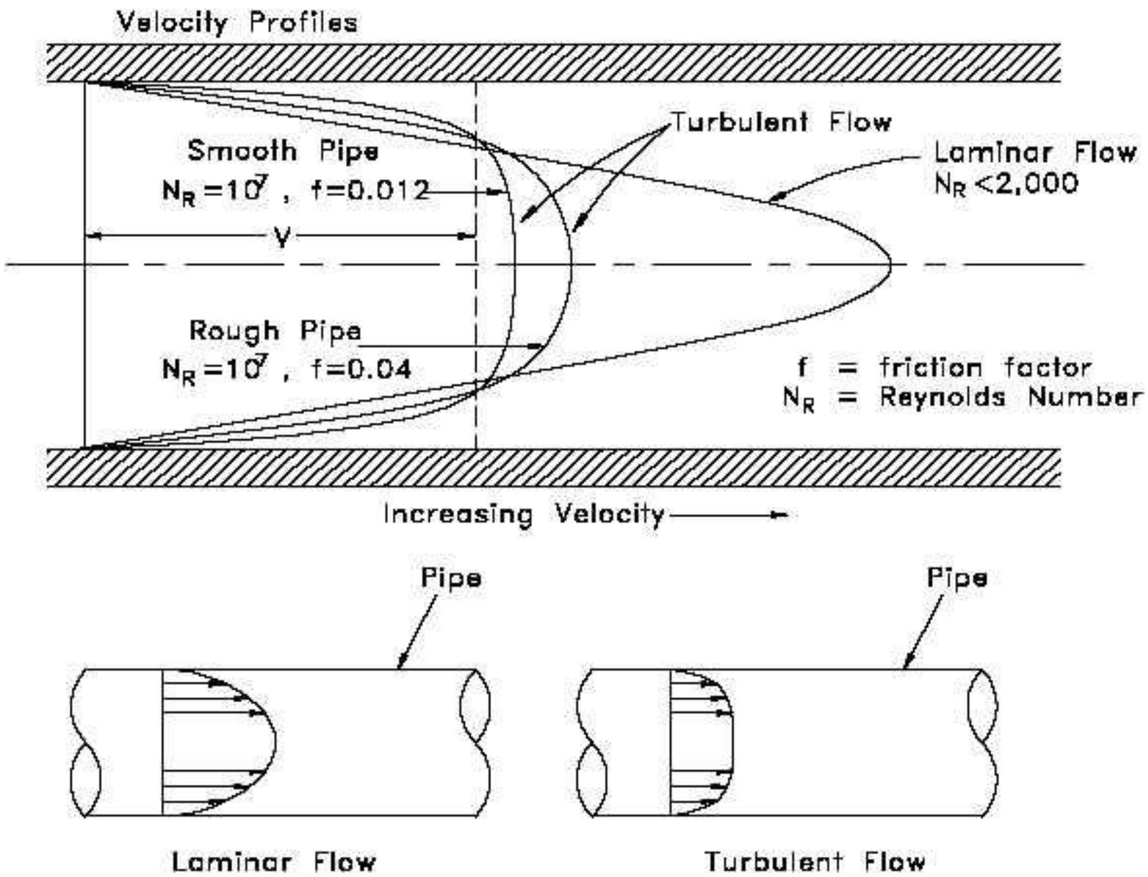


Figure 1: Fluid Velocity Profile

Laminar and turbulent flow are determined by evaluating the Reynolds number of the flow. As studied by Osborn Reynolds, Reynolds number is a dimensionless number that comprises the physical characteristic of the flow. Below is the equation used to calculate the Reynolds number of the fluid flow [5]:

$$N_R = \rho v D / \mu g_c \qquad (1)$$

Where,

N_R = Reynolds number

V = average velocity

D = pipe diameter

μ = absolute fluid viscosity of fluid

ρ = fluid mass density

g_c = gravitational constant

It is relevant to study the Reynolds Number because from it we can determine the type of flow inside the pipeline depending on the Reynolds number value.

2.6 Moody Diagram

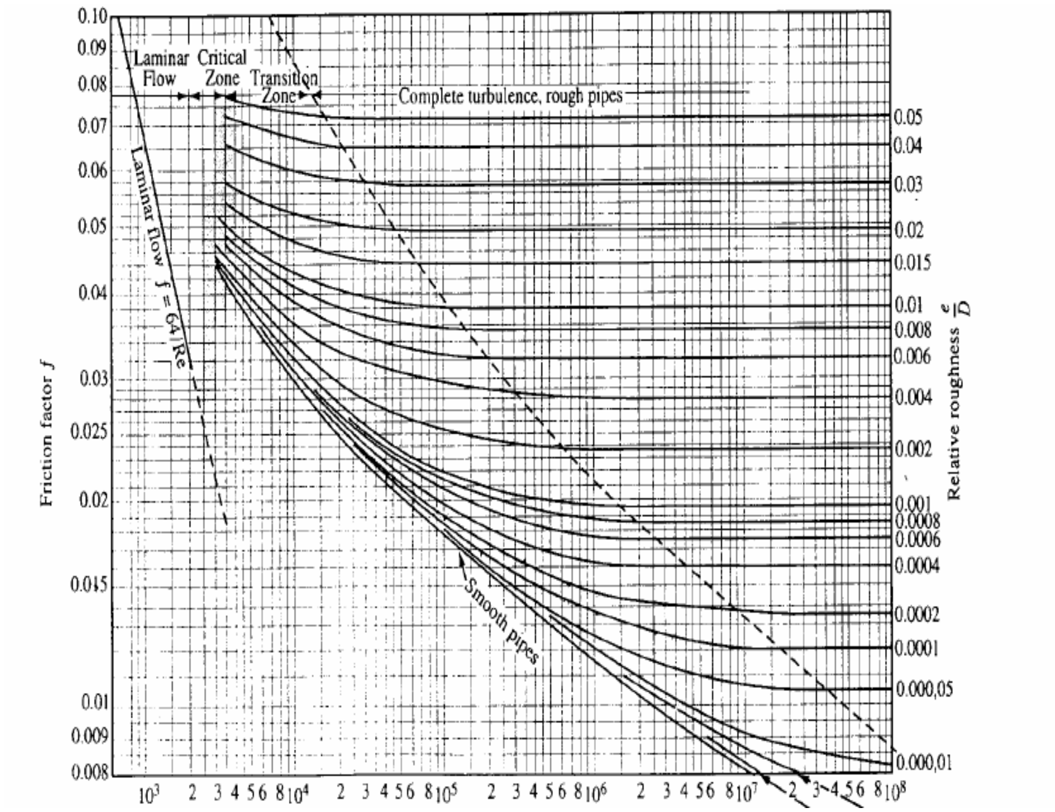


Figure 2: Moody Diagram

Value of friction factor in turbulent flow can be determined by using Moody diagram. It can be read from the Reynolds number plotted on the horizontal axis and the relative roughness plotted on vertical axis to the right. Moody chart is relevant because it is a quick way to get the friction factor without performs trial and error approach by using Colebrook – White equation [5]. Colebrook – White equation is a formula that is being used to calculate turbulent flow. Below is the Colebrook – White equation:

$$1/\sqrt{f} = -2\ \text{Log10}\ [(e/3.7D) + 2.51/(R\sqrt{f})]\ (2.15) \qquad (2)$$

Where, f is the Darcy friction factor

D is the inside pipeline diameter

e is the absolute pipe roughness

R is the Reynolds number

f is the friction factor

Generally, friction factor, f depends on the Reynolds Number of the pipe wall and relative roughness, *e*/*D* of the pipe wall [8].

Absolute pipe roughness, e is defined as the average size of the bump compared to the size of the bumps on the pipe wall [8]. Therefore, relative roughness, *e*/D is the size of the bumps compared to the pipe diameter and for commercial pipe, the value is usually small [8]. It also noted that for a perfectly smooth pipe, it would have a roughness of zero [8].

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

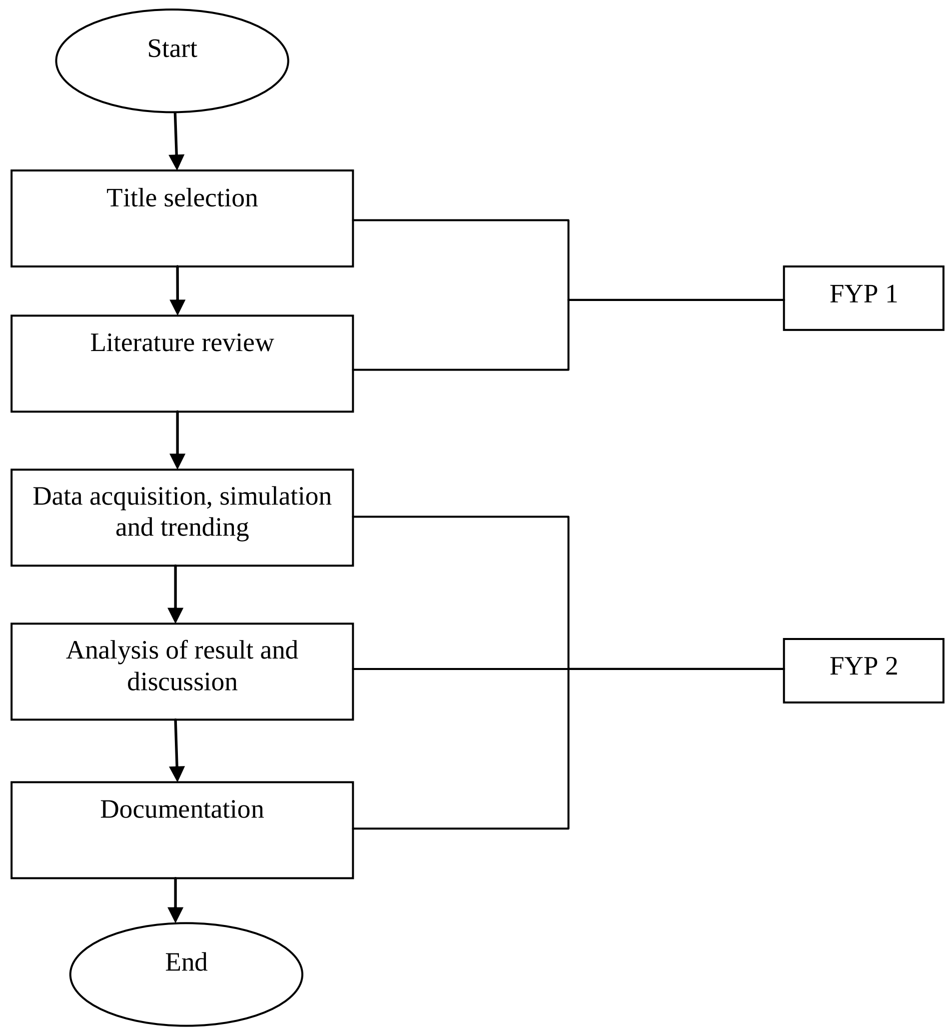


Figure 3: Project Flow

3.2 Research

To achieve the project's objective, the researcher read and studied all the sources regarding the project. This was acquired from technical journal, academic paper as well as from the internet. Related equation and theory regarding the velocity profile was also acquired.

3.3 Project Flow

In order to achieve the objectives of this project, it was divided into two parts, these are FYP 1 where during FYP 1, the focus is more on the literature review to get the basic idea of the project, and during FYP 2 the focus and effort is on simulation of the project. First thing to do is to get all the information that is related with corrosion, pipeline, velocity profile and the fluid properties where for this project, pentane liquid (C_5H_{12}) will be tested along with galvanized iron pipeline

3.4 Project Method

To get the velocity profile, before any calculation and simulation can be done, data on feature of pipeline need to be acquired. Among the features that need to be considered are:

- Type material
- Diameter
- Length

In this project, galvanized iron pipeline was chosen since it is widely used in the industry with a diameter of 20 inch and with a length of 20 meters. The fluid properties also need to be acquired. Among features of the fluid that need to be considered are:

- Liquid types
- Viscosity
- Density

Below is the liquid that is being used in the project:

- Liquid type is pentane liquid (C_5H_{12})
- Viscosity = 0.000229 kg/ms
- Density = 626 kg/m^3

For this project, corroded and non corroded pipeline will be compared in terms of velocity profile. For the testing, pipeline that will be used is a single straight pipeline for both corroded and non corroded condition with few parameters such as diameter, pipe material and pipe length remain constant. Figure 4 is the simple diagram for the pipe:

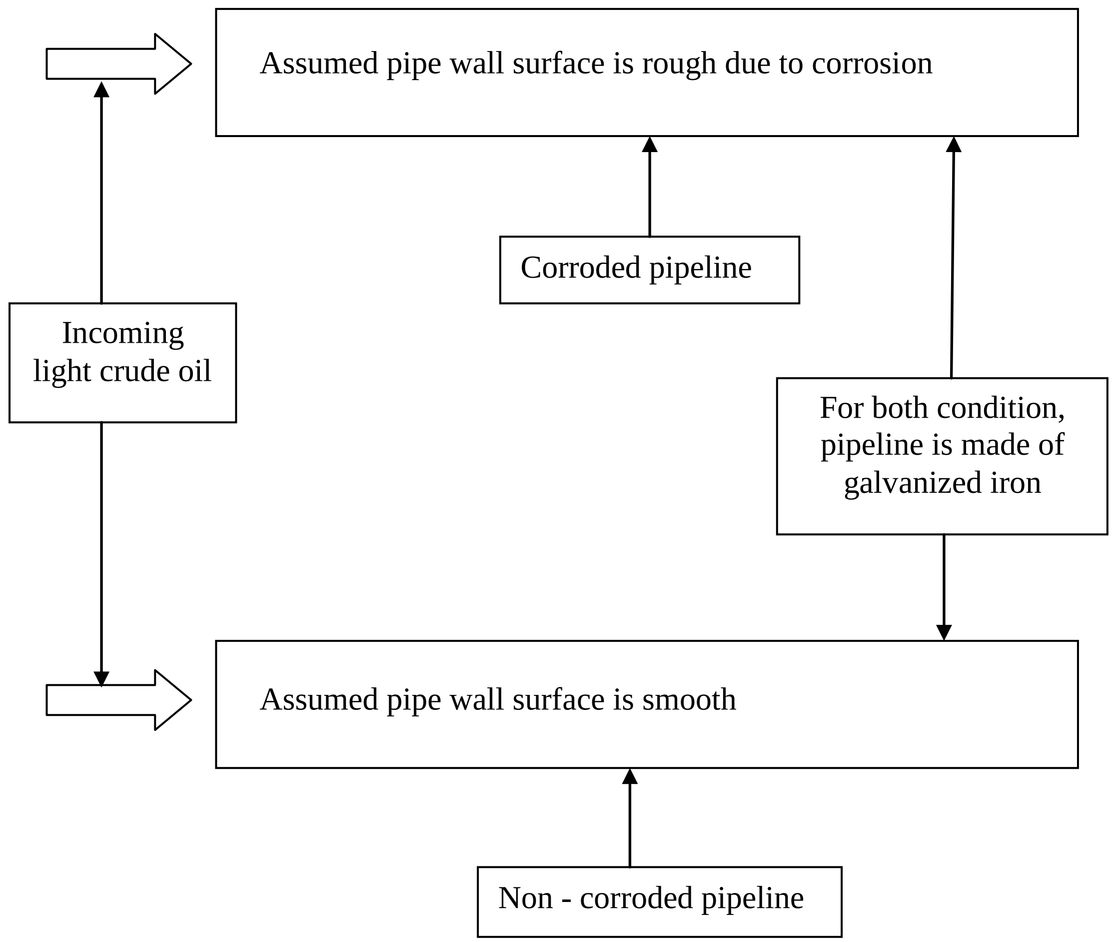


Figure 4: Model of Pipe Testing Diagram

First step of determining the velocity profile is to get the Reynolds Number of the flow. Equation for Reynolds number is as below:

$$\mathrm{Re} = \frac{\rho V D}{\mu} = \frac{V D}{\nu} = \frac{Q D}{\nu A} \tag{3}$$

Where, V is the mean fluid velocity

D is the pipeline diameter

V = average velocity

D = pipe diameter

μ = absolute fluid viscosity of fluid

ρ = fluid mass density

From the Reynolds number calculated, we can determine the flow type inside the pipeline. There are 3 types of flow based on the value of the Reynolds number. The 3 types of flow are:

Table 1: Flow Type Based on Reynolds Number

Flow Type	**Reynolds Number Range**
Laminar	Less than 2000
Critical	Existed between 2000 and 4000
Turbulent	More than 4000

From the Reynolds number obtained, value of friction factor can be calculated. There are 2 types of equation to compute for the friction and each equation is depending on the types of fluid flow. Below are the equation used to compute for the friction factor:

- For laminar flow, the equation is:
  - $f = 64 / R_e$ [5] (4)

Where, f is the friction factor

R_e is the Reynolds Number

- For turbulent flow, the equation is :
  - $1/ \sqrt{f} = -2 \text{ Log10}[(e/3.7D) + 2.51/(R \sqrt{f})]$ [5] (5)

Where, R is the Reynolds Number

D is the pipeline diameter

e is the absolute surface roughness

f is the Darcy friction factor

3.5 Tools and Equipment

Among the tools and equipment that were used in the project are:

- Microsoft Office Excel
- Microsoft Office Word
- GAMBIT software. It is used to design the pipeline before it being simulated in the FLUENT software
- FLUENT software. It is used to run the simulation of the pipeline after the pipe model being built by GAMBIT software

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Calculation of Reynolds Number

In the simulation of the pipe with a diameter of 0.4953 m and carrying pentane liquid ($C5H12$) with a flow of 50 m^3 / h at a distance of 100 meter the calculation to find the velocity of the flow is as following:

Velocity (m /s) = Flow (m^3 /h) ÷ [3600 × pipe cross section area (m^2)]

= 50 ÷ [3600 × (3.14 × $(495.3 / 1000)^2$ /19.5]

= 0.35 m/s

For the simulation, pentane liquid ($C5H12$) is used as the fluid. Table 2 shows the properties of the pentane liquid ($C5H12$):

Table 2: Pentane Liquid Properties

Properties	**Value**
Density (kg / m^3)	626
Thermal conductivity (w / mk)	0.136
Viscosity (kg / ms)	0.000229
Mean velocity	0.35 m / s

To get the Reynolds number, the calculation is shown below:

Re = [(626) × (0.35) × (495.3 / 1000)] ÷ 0.000229

= 473887.5

Since the value of the Reynolds number is more than 4000, type of the flow is turbulent. [Refer to Table 1]

4.2 Pipeline Design using GAMBIT software

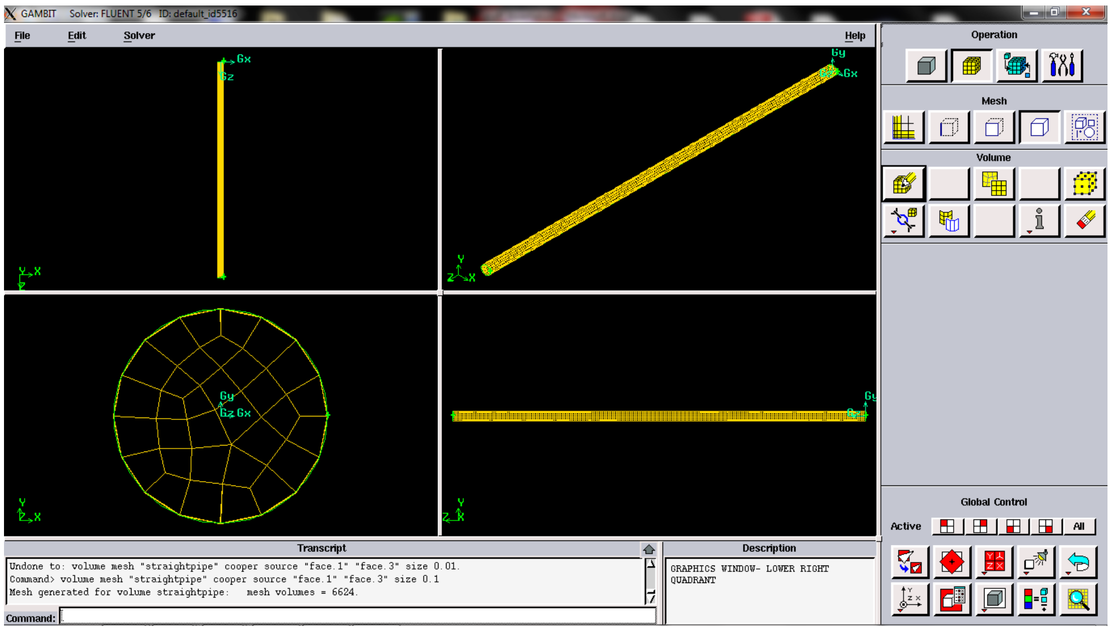


Figure 5: Pipeline Design Using GAMBIT software

Using the GAMBIT software, few parameters of the pipe are being set as below:

- For z-axis, the length of the pipe is 20 meter
- For x-axis, the radius of the pipe is 0.24765 meter
- For y-axis, the radius of the pipe is 0.24765 meter

The mesh generated for the pipe volume is 6624

4.3 Simulation Result Using FLUENT Software

For non corroded pipe with surface roughness of 0.00026 m, the simulation result is shown below using the FLUENT software:

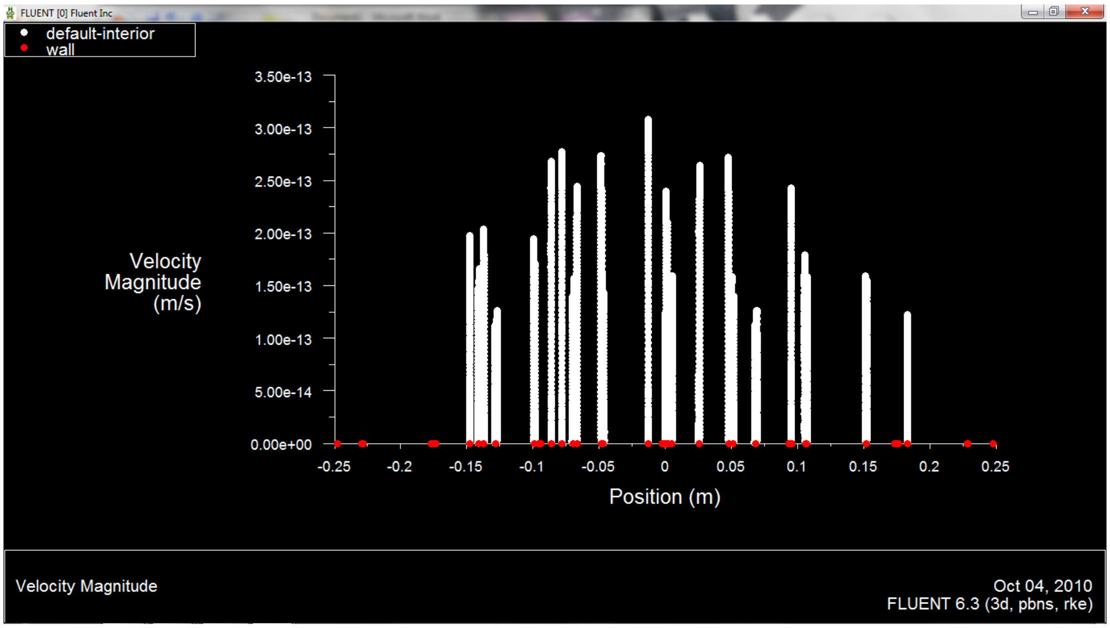


Figure 6: Plot of Velocity Magnitude vs Direction Vector at x-axis plot direction

From the simulation result, for x-axis plot direction, the velocity magnitude is the highest at position of near zero (m). Position of zero (m) is the centreline of the pipe and is located far from the pipe wall. Thus, less friction is experienced at the centreline compared with the position near the wall.

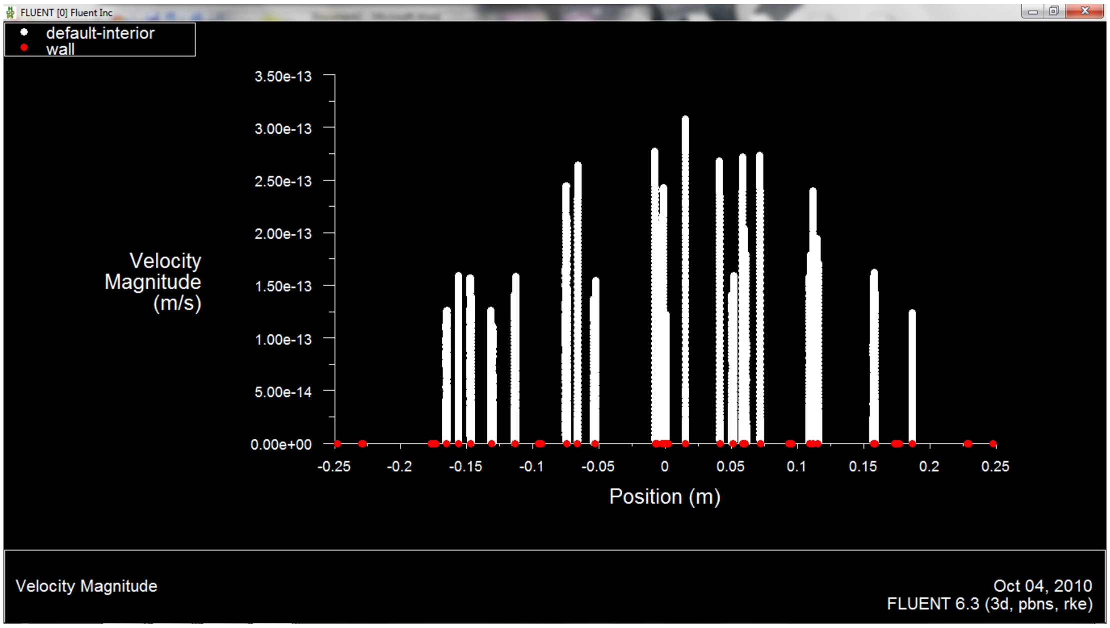


Figure 7: Plot of Velocity Magnitude vs Direction Vector at y-axis plot direction

For y-axis plot direction, the velocity magnitude is the highest at the position of zero (m). Since the highest velocity magnitude is at position of zero (m), the location is the furthest from the pipe wall, it experienced less friction compared with when the position is near to at the pipe wall.

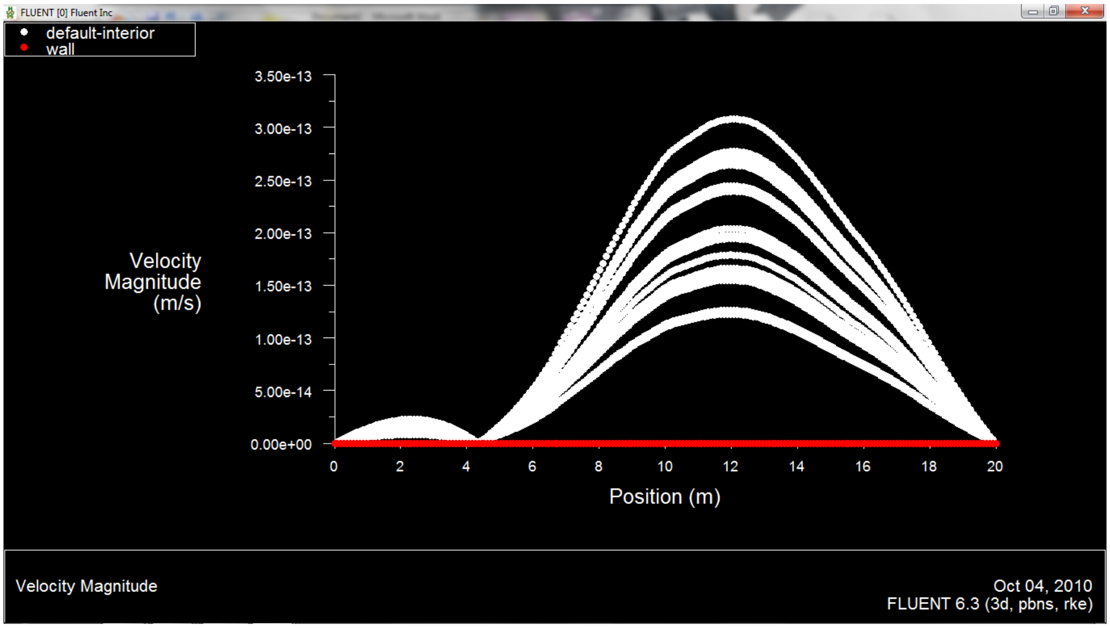


Figure 8: Plot of Velocity Magnitude vs Direction Vector at z-axis plot direction

For z-axis plot direction, from position of 0 to 4 meter, the velocity magnitude is decreased. This was due to the turbulence experience at the velocity inlet. However, from position of 4 to 12 meters, the velocity magnitude of the fluid increased. This happen since at that position, the flow is already developed thus the velocity is increased. From position of 12 to 20 meters, the velocity magnitude begins to reduce. This situation occurs since at that position, the fluid begins to flow out from the pipe thus the velocity magnitude is also reducing.

For corroded pipe with surface roughness of 0.002 m, the simulation result is shown below using the FLUENT software:

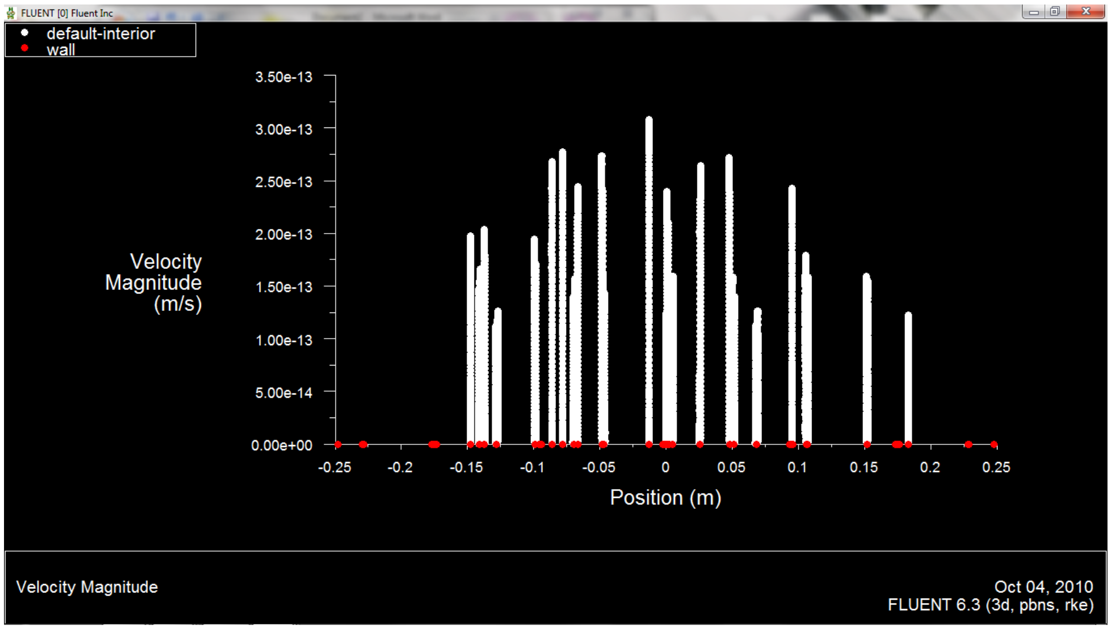


Figure 9: Plot of Velocity Magnitude vs Direction Vector at x-axis plot direction

For x-axis plot direction, the velocity magnitude is varying from the pipe wall to the center line of the pipe. The highest velocity is recorded at position of near zero (m). At that position, the velocity magnitude is approximately 3.025e-13 m/s. This was due to the less friction experienced by the fluid during the flow.

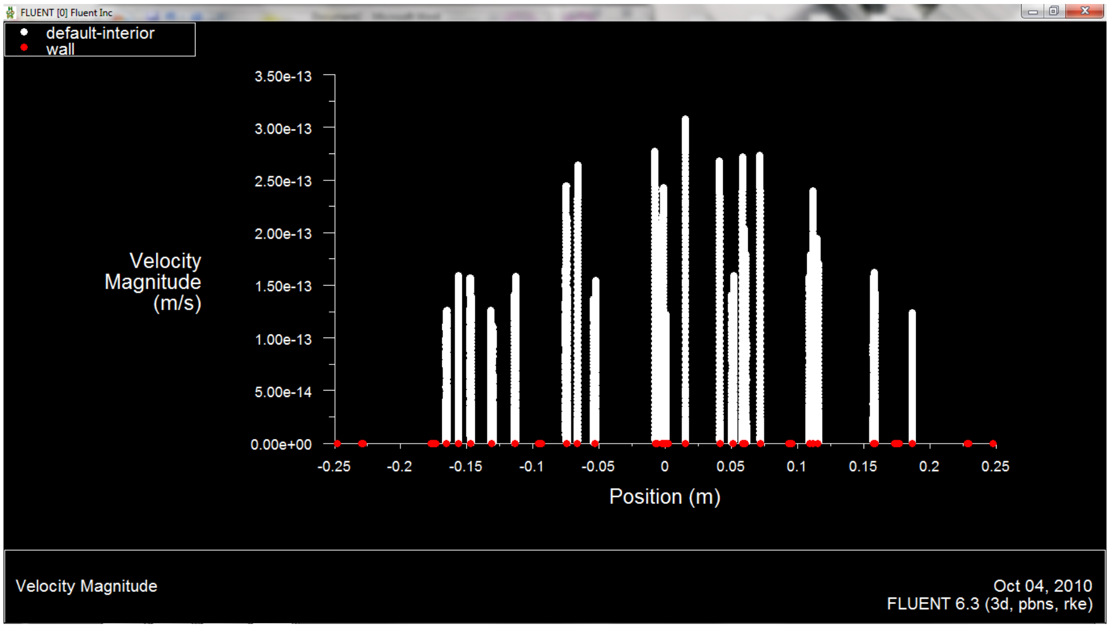


Figure 10: Plot of Velocity Magnitude vs Direction Vector at y-axis plot direction

For y-axis plot direction, the velocity magnitude at position of range 0.15 m to 0.2 m and – 0.1 to – 0.15 have almost the same velocity magnitude. The characteristic of the fluid velocity at those two locations are low compared with the velocity magnitude at the position that is near the center line. Among the factor that affects the velocity magnitude at those two regions are because it is located near the pipe wall compared with region near the pipe center. Since located near the pipe wall, the fluid flow across those two regions will experience more friction with the pipe wall.

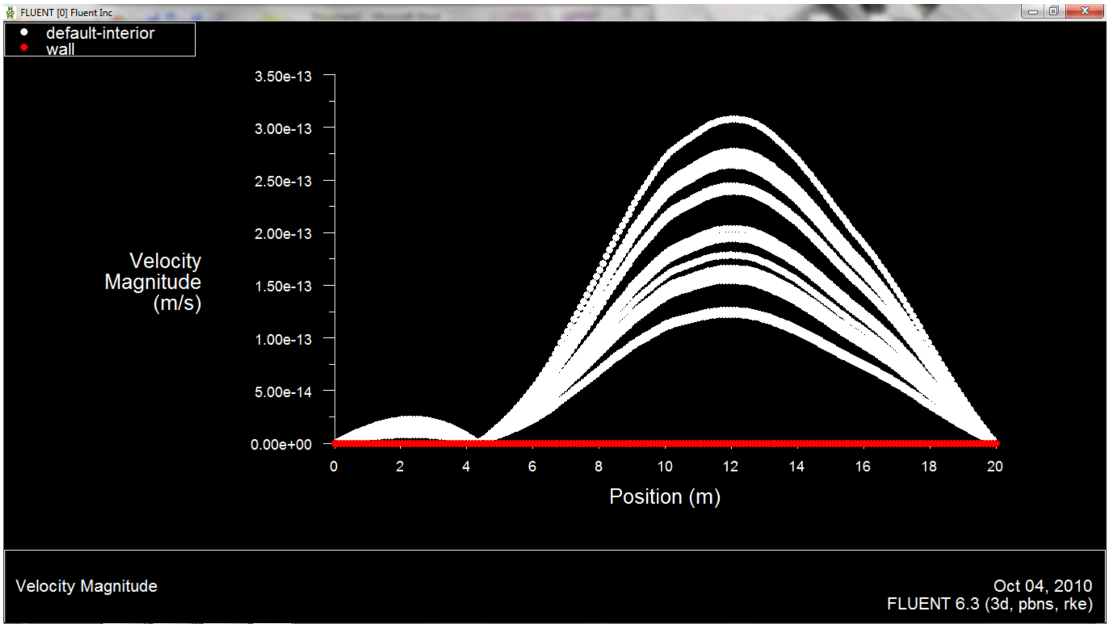


Figure 11: Plot of Velocity Magnitude vs Direction Vector at z-axis plot direction

For z-axis plot direction, the characteristic of the velocity magnitude is that it is high at the position in the middle of the pipe length. This characteristic occurs due to the developed fluid flow at the middle of the pipe length.

CHAPTER 5
CONCLUSION

5.1 Conclusion

The objective for this project is to analyze the velocity profile inside the pipeline for corrosion detection.

From the Reynolds number calculation, it was found that the type of flow inside the pipeline was turbulent because the value of the Reynolds number was 473887.5 which is more than 4000.

As a result of the simulation made using FLUENT software, the surface roughness is critical in determining the velocity profile between non-corroded and corroded pipe. For a corroded pipe, the value of the surface roughness is higher compared with the non corroded pipe.

From the simulation result, it was found that at the center of the pipe, the magnitude of velocity is higher compared with the velocity near the pipe wall which shows that the farther the fluid from the pipe wall, the higher is the velocity magnitude of the fluid.

5.2 Recommendation

For recommendation, hopefully in the future this project will be continued for different sizes or shapes of pipe since for my project, the focus was only limited to a straight pipeline.

REFERENCES

[1] Narasi Sridhar & Garth Tormoen Southwest Research Institute 6220 Culebra Road San Antonio, TX 78228. Ashok Sabatu Aginara, Inc.3 Chambry Court Freehold, NJ 07728

[2] Corrosion Protection of Oil and Gas Subsea Pipelines, WillieS <http://www.brighthub.com/engineering/marine/articles/69274.aspx>

[3] Ginzel, R.K & Kanters, W.A. Eclipse Scientific Products Inc. Williamsford, Ontario, Canada

[4] Flow Velocity Profiles – Fluid Flow <http://www.engineersedge.com/fluid_flow/flow_velocity_profiles.htm>

[5] Liquid Pipeline Hydraulics, E. Shashi Menon, P.E., PDHengineer.com Online Course

[6] Best Practice Manual, Fluid Piping Systems by Devkl Energy Consultancy Pvt. Ltd., 405, Ivory Terrace, R.C. Dutt Road, Valodara -39007, India

[7] Properties of the Fluid: Part 1 by Haresh Khemani

[8] Pipe Friction Calculation < http://www.efunda.com/formulae/fluids/calc_pipe_friction.cfm>

[9] Effect of Channel Roughness on Heat Transfer and Fluid Flow Characteristic at low Reynolds Numbers in Small Diameter Tubes by Satish G. Kandlikar, Shailesh Joshi and Shurong Tian , Mechnical Engineering Department, Rochester Institute of Technology, NY 14623

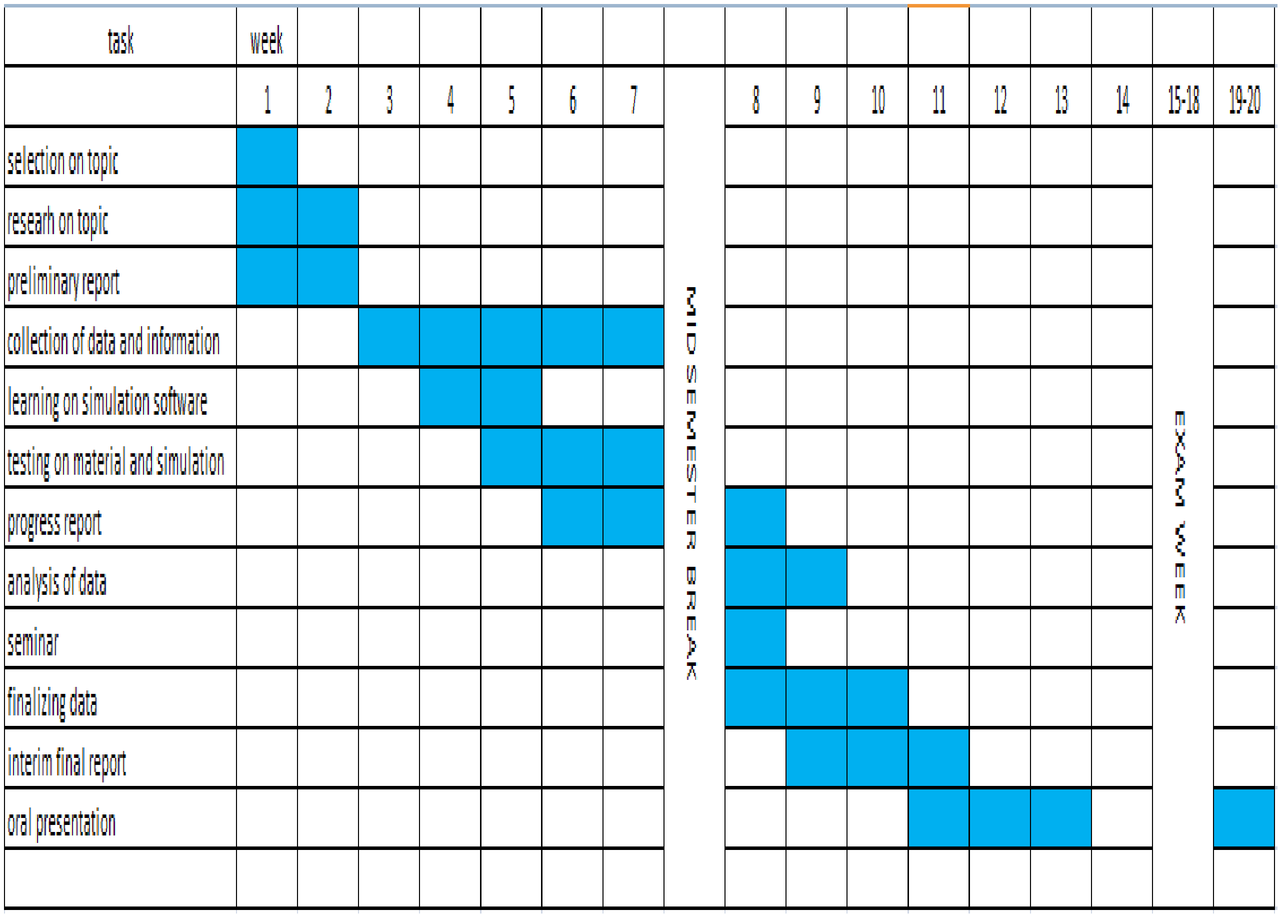
[10] GAMBIT 2.2 Tutorial Guide

[11] FLUENT 6.3 Tutorial Guide

APPENDICES

APPENDIX A

GANTT CHART FOR FYP I


task
week
1
2
3
4
5
6
7
MID SEMESTER BREAK
8
9
10
11
12
13
14
15-18
19-20
EXAM WEEK
selection on topic
researh on topic
preliminary report
collection of data and information
learning on simulation software
testing on material and simulation
progress report
analysis of data
seminar
finalizing data
interim final report
oral presentation

APPENDIX B

GANTT CHART FOR FYP II

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	21
Project continue																	
Briefing																	
Install Pipe Flow Advisor																	
Familiarization with software																	
Progress Report 1																	
Simulation on velocity profile using MATLAB																	
Analysis																	
System simulation to detect corrosion																	
Pre EDX																	
Submission of Draft Report																	
Submission of Final Report																	
Submission of Technical Report																	
Oral Presentation																	
Complete Final Report																	