CERTIFICATION OF APPROVAL

EFFECT OF THE INTERNAL FLUID FLOW IN THE GLASS FIBRE REINFORCED PLASTIC (GFRP) DYNAMIC

By

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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.

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ABSTRACT

The petroleum produced by the offshore platforms is transported to processing plant through carbon steel pipelines. Usually, expectancy of maximum production capacity of pipelines is never meeting the prediction made in the early stage. Among the main reason for the declining of production capacity of pipelines over time is corrosion. This project aims to prove the dynamic of glass fibre reinforced plastic (GFRP) pipe dynamic is better than steel pipes dynamic in oil pipelines. Whilst it is more common to see in Oil and Gas industry to utilize steel pipes in their pipelines, GFRP pipes show a promising future to reduce corrosion problems. When it comes to pipeline, corrosion had caused severe to production capacity of a line to replace the corroded pipelines will cost a lot of money. The industries are desperate to alternative for the steel pipes. With that in mind, this Final Year Project will be focused more on study of the dynamic behavior of glass fibre reinforced plastic (GFRP) pipe fluid flow properties. A pipe modeling will be created to study the effect of the internal fluid flow in the GFRP pipe and compare it with the steel pipes dynamic. The model will be constructed using the ANSYS Workbench software and it will be analyzed using ANSYS FLUENT. The fluid flow model will be created using the k-epsilon model and all the calculation and iteration will be calculated using second order upwind. This project may lead to explore a better option than steel pipes to use in the oil and gas industry.

ACKNOWLEDGEMENT

This Final Year Project involves many parties in order for the student to complete it successfully. First of all, highest appreciation to Ir Idris Bin Ibrahim, my Final Year Project supervisor for the entire lesson learnt in assisting me, tireless and continuous support given to me to complete this research project.

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Apart from that, I would like to give credits to my colleagues who give excellent cooperation in completing this Final Year Research Project. Not to be forgotten, to my family for their boundless support from the beginning till the end of this project. Lastly, thank you to all parties who participate directly or indirectly in completing this project. Your contributions are highly appreciated.

Last but not least, I would like to thank Universiti Teknologi Petronas, UTP for providing this lifetime opportunity by providing me the facilities, laboratories and assistant in all aspect. I hope this experience and knowledge I gained while completing my Final Year Project will be a valuable stepping stone in my future career development

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In the last quarter of 20^{th} century, the global demand for crude oil has been stable with an annual growth averaging 1%. Experts foresee that for the next 20 years, 80% of the world's energy requirements will come from petroleum, natural gas and coal (IEA, 2008). This statistic tells that the oil will still remain the dominant source of energy for the next half century. [1]

Usually, the petroleum produced by the offshore platforms is transported to processing plant through carbon steel pipes. However, steel lines will rapidly corroded in overtime by the combination of salt water and sour sulfur crude, no matter how well the operating companies look after their pipeline such as regular pigging, cathodic protection, injecting corrosion inhibitor and many more. Replacing the current pipeline with new pipes would take up production time and also cost a lot.

The need of the oil companies to continuously seek more cost-effective and safer materials for the installations and of the suppliers to find new markets were the driving force to find a new replacement for carbon steel pipes.

Glass fibre reinforced plastic (GFRP) is material which, mainly due to low weight and corrosion resistance is attractive alternative to many metals. Several studies have been carried out by different companies to compare the cost of GFRP pipe with various metal alternatives. The following general trend in cost comparison seems to apply: [2]

- GFRP usually comparable in cost to carbon steel
- Low installation cost compared to other metal alternatives
- Low maintenance cost and long lifetime

1.2 Problem Statement

1.2.1 Problem identification

The petroleum produced by the offshore platforms is transported to processing plant through carbon steel pipelines. Usually, expectancy of maximum production capacity of pipelines is never meeting the prediction made in the early stage. Among the main reason for the declining of production capacity of pipelines over time is corrosion. Corrosion will decrease the wall thickness in pipelines. The characteristic of the fluid flow will change with the change of pressure and temperature. The change in characteristic of the fluid influences the design of the pipe and its reliability and integrity.

When higher flow rate are needed, fluid deformation is higher and shear stresses increase, so more pressure must be applied to maintain the flow at the same average velocity. However, specification of pipeline design may limit the amount of pressure that can be employed or rise substantially the investment cost. [1]

Both reductions lower the operating pressure and flow rate of the oil transfer which eventually reduces the main production. In order to rise and maintain the production performance, the corroded pipelines could be replaced with new ones. This make the GFRP pipes is better option than the carbon steel pipes.

1.2.2 Significant of the project

By referring to the problem identification, through this project, observation of the detail the effect of internal fluid flow in the GFRP pipe dynamic will be conducted. GFRP is not new material in the offshore oil industry. In fact, it represents a proven technology. Thus, this experiment will explore and examine the change in the characteristic of internal fluid flow to ensure GFRP pipe dynamic is better than the steel one. As a conclusion, three objectives are being set for this project. [2]

1.3 Objective

The objective of the project is:

1. Study of the dynamic behavior of the glass fibre reinforced plastic (GFRP) fluid flow properties

1.4 Scope of study

The scope of study is mainly focusing on the effects of the internal fluid flow in GFRP pipe dynamics. Through this project, the dynamic of the GFRP pipe structure will be observe more thoroughly especially on the friction between GFRP pipe and fluid.

This project will be divided into two stages; the first stage will involve on researching and study thoroughly about GFRP pipe properties, fluid structure interaction and hydrodynamic in pipe.

The second stage will focus on simulation work in the lab, where computer software likes ANSYS: FLUENT and a simulation will be conducted so the effect of internal fluid flow in GFRP pipe will be monitored closely. Result collected from experiments will be analyzed and discussed.

1.5 The relevancy of the project

Corrosion is the biggest threat for pipelines all over the world. As it is too costly to replace the corroded pipe, new material has been researched to replace the steel pipes. The GFRP pipe has good environmental and corrosion resistance and less expensive metal. [2]

By carry out this project, the GFRP pipe can be studied closely and see effectiveness of the material. The parametric study will be done to analyze the dynamic pipeline structure. This to ensure the GFRP pipe dynamics is better than steel one thus replacing the steel pipe in the future uses

1.6 Feasibility of the project

This project will need a simulation in order to complete it. In the time given, the project could be done within time given provided that everything goes according to the plan. The objective can be achieved if the procedures are closely followed.

CHAPTER 2

LITERATURE REVIEW

2.2 Fluid Structure Interaction (FSI)

The fluid structure interaction is use to find the relation between the pipe surface and the effect of the pipe surface to the fluid flow. In the majority of analyses reviewed, the pipes are slender, thin walled, straight, prismatic and circular of cross section. The liquid and the pipe wall material are assumed linear elastic and cavitations is assumed not to occur. Important dimensionless parameter in FSI analyses are:

- Poisson ratio
- Ratio of pipe radius to pipe wall thickness
- Ratio of liquid mass density to pipe wall mass density
- Ratio of liquid bulk modulus to pipe wall young modulus

The dynamic of behavior of liquid and pipe system should be treated simultaneously. Two liquid pipe interaction mechanisms can be distinguished:

- Friction coupling represents the mutual fiction between liquid and pipe
- Poisson coupling relates the pressure in the liquid to the axial (longitudinal) stresses in the pipe through radial contraction or expansion of the pipe wall.

Governing Equation

- The moving reference frame

$$\frac{D\boldsymbol{u}}{Dt} = \nabla_{\hat{x}}\boldsymbol{u}(\boldsymbol{u} - \hat{\boldsymbol{v}}) + \dot{\boldsymbol{u}},$$

^v ¼ o^x=ot is the velocity of the reference point

- Momentum

$$\rho(\dot{\boldsymbol{u}} + (\nabla_{\hat{x}}\boldsymbol{u})(\boldsymbol{u} - \hat{\boldsymbol{v}}) - \boldsymbol{f}) - \nabla_{\hat{x}} \cdot \boldsymbol{\sigma} = \boldsymbol{0} \quad \forall(\hat{\boldsymbol{x}}, t) \in \Omega \times I,$$
$$\nabla_{\hat{x}} \cdot \boldsymbol{u} = 0 \quad \forall(\hat{\boldsymbol{x}}, t) \in \Omega \times I,$$

Where q, f and r represent, respectively, the fluid density, the volume force vector and the Cauchy stress tensor.

- Structural dynamic

$$\rho(\ddot{\boldsymbol{d}} - \boldsymbol{f}) - \nabla \cdot \boldsymbol{\sigma} = \boldsymbol{0},$$

Where q is the current density of the deformed solid and the vector d represents the displacement field, whereas the body forces are given by the vector f.

Another equation used

- If pipe diameter at X, location of fluid element is D(x) the cross sectional area is; $A(x) = \frac{\pi Dx^2}{4}$
- And the mass flow rate; $Q_{up}(x) = \rho_{up(x)}A(x)v_{up}(x)$
- Total volume of fluid element at x is; V(x) = A(x)dx
- Mass contained within it is just that volume multiplied by average density ρ(x); mass (x) = A(x)dxρ (x)
- Net force from pressure; Fup (x) – Fdn (x) = -dx A (x) $\frac{dp}{dx}$

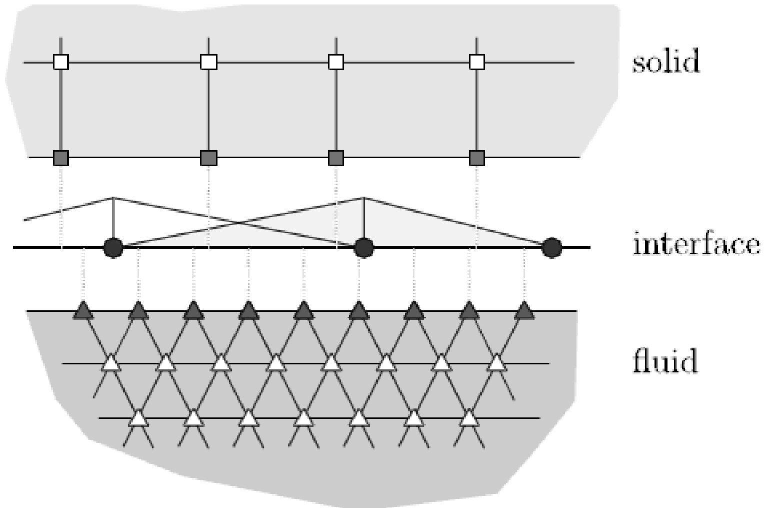

Figure 2.2: example general interface modeling transfer based on finite element type interpolation of interface domain.

2.3 Finite Volume Method

Finite Volume Method is one of several numerical methods that can be used to solve complex problems and is the dominant method used today. As the name implies, it takes a complex problem and breaks it down into a finite number of simple problems. A continuous structure theoretically has an infinite number of simple problems, but finite volume analysis approximates the behavior of a continuous structure by analyzing a finite number of simple problems. "Finite volume" refers to the small volume surrounding each node point on a mesh. In the finite volume method, volume integrals in a partial differential equation that contain a divergence term are converted to surface integrals, using the divergence theorem. These terms are then evaluated as fluxes at the surfaces of each finite volume. Because the flux entering a given volume is identical to that leaving the adjacent volume, these methods are conservative. Another advantage of the finite volume method is that it is easily formulated to allow for unstructured meshes. An accurate assessment of all boundary conditions also must be made because the accuracy of this method will be dependent on this assumption. Finite volume methods also are widely used and highly successful in computing solutions to conservation laws, such as those occurring in fluid dynamics. The most compelling feature of the finite volume method is that the resulting solution satisfies the conservation of quantities such as mass, momentum, energy, and species. This is exactly satisfied for any control volume as well as for the whole computational domain and for any number of control volumes. Even a coarse grid solution exhibits exact integral balances. Basically there are three steps in finite volume analysis:

1. Preprocessing

   Preprocessing involves the preparations of data, such as nodal coordinates, connectivity, boundary conditions and loading and material information. The preparation of data require considerable effort if all data are to be handled manually. If the model is small, the user can often just write a text file and feed it into the processor, but as the complexity of the model grows and the number of elements increase, writing the data manually can be very time consuming and error-prone. Therefore it is necessary with a computer preprocessor which help with mesh plotting and boundary conditions plotting.

2. Analysis

   This stage involves stiffness generation, stiffness modification, and solution of equations, resulting in the evaluation of nodal variables. This is a typical "black box" operation, where the user will see little of what is going on. The data is fed from the preprocessor to get the data out.

3. Post processing

   Typically, the deformed configuration, mode shapes, temperature, and stress distribution are computed and displayed at this stage as the result. Graphical displays are used in modern codes to assist in visualizing the results

2.3.2 Theory

Dynamic analysis using computer software is often used nowadays because of its efficiency besides saving cost and time. For instance finite element analysis can be used to determine the fluid flow dynamic in the pipe. The result of this simulation is very important for the pipe manufacturers especially to run test later to predict the fluid flow dynamic in the pipe. Some of the past work done related on this topic has been included in this literature study section. Besides, some theories as well as the main function of finite element method will be presented.

P.Salizonni, Van Liefferinge and L. Soulhac and has done a study in relationship between surface roughness and the fluid flow dynamic. In the numerical simulations, the role of the wall roughness was taken into account only by varying the friction velocity. They suggest that there is increased in turbulent intensity with pipe roughness. In his experiment, he used using a pseudo-temporal finite volume method, iterating until the solution converged to a stationary state. The advection term was integrated with an explicit forward-in-time scheme, and the diffusion term was computed by the semi-implicit Crank−Nicholson scheme (solved by the Thomas algorithm). [11]

G.F.K Tay had conducted an experiment of measurements in rough-wall turbulent flows subjected to adverse pressure gradients. The levels of the relative turbulent intensities and Reynolds shear stress increased with both adverse pressure gradient (APG) and surface roughness. The experiments were performed in a two-dimensional channel. Profiles of the mean velocity, turbulent intensities, Reynolds stress ratios, mixing length, eddy viscosity and the production terms were then obtained to document the effects of adverse pressure gradient (APG) on low Reynolds number rough-wall turbulent boundary layers. A particle image velocimetry technique was used to conduct the velocity measurements [12]

Study done by E.S. Zanoun presented and interesting theory about the relation between the wall skin frictions, mean velocity profile and the wall roughness. E.S. Zanoun predicted the profile of the wall skin friction coefficient and the mean velocity profile from the surface roughness. The investigations were carried out at LSTM-Erlangen using the pipe test facility. The pipe flow measurement was done using both pitot tube and hot-wire anemometry. A precise pressure transducer was employed for pressure measurements at each downstream location having an accuracy of ±0.25% of the actual readings. [13]

2.3.3 K-Epsilon model

The K-epsilon model is one of the most common turbulence models, although it just doesn't perform well in cases of large adverse pressure gradients. It is a two equation model that means it includes two extra transport equations to represent the turbulent properties of the flow. This allows a two equation model to account for history effects like convection and diffusion of turbulent energy.

The first transported variable is turbulent kinetic energy, □. The second transported variable in this case is the turbulent dissipation, έ. It is the variable that determines the scale of the turbulence, whereas the first variable, □, determines the energy in the turbulence. K-epsilon model has been shown to be useful for free-shear layer flows with relatively small pressure gradients. Similarly, for wall-bounded and internal flows, the model gives good results only in cases where mean pressure gradients are small; accuracy has been shown experimentally to be reduced for flows containing large adverse pressure gradients.

For turbulent kinetic energy, □

$$\frac{\delta}{\delta t}(pk) + \frac{\delta}{\delta x_i}(pku_i) = \frac{\delta}{\delta x_j}\left[\left(\mu + \frac{\mu_t}{\sigma k}\right)\frac{\delta k}{\delta x_j}\right] + P_k + P_b - p\epsilon - Y_M + S_k$$

For dissipation ϵ

$$\frac{\delta}{\delta t}(p\varepsilon) + \frac{\delta}{\delta x_i}(p\varepsilon u_i) = \frac{\delta}{\delta x_j}\left[\left(\mu + \frac{\mu_t}{\sigma\varepsilon}\right)\frac{\delta\varepsilon}{\delta x_j}\right] + \frac{C_{1\varepsilon}\varepsilon}{k}(P_k + C_{3\varepsilon}P_b) - C_{2\varepsilon}p\ \frac{\varepsilon^2}{k} + S_\varepsilon$$

2.3.4 Fluid flow

The fluid flow mainly concern about the study of motion. In fluid dynamic, fluid kinematics is the study of how fluid flows and how to describe fluid motion. There are two distinct way to describe fluid motions: [3]

- Lagrangian description ; analysis is analogous to the system analysis
- Eulerian description; a finite volume called a flow domain or control volume is defined, through which flow in or flow out

Fluid flowing in pipes has two primary flow patterns. It can be either:

- laminar when all of the fluid particles flow in parallel lines at even velocities
- turbulent when the fluid particles have a random motion interposed on an average flow in the general direction of flow

There is also a critical zone when the flow can be either laminar or turbulent or a mixture. It has been proved experimentally by Osborne Reynolds that the nature of flow depends on the mean flow velocity (v), the pipe diameter (D), the density (ρ) and the fluid viscosity Fluid Viscosity (μ). A dimensionless variable for the called the Reynolds number which is simply a ratio of the fluid dynamic forces and the fluid viscous forces, is used to determine what flow pattern will occur. The equation for the Reynolds Number is

$$Re = \frac{vDp}{\mu}$$

For normal engineering calculations, the flow in pipes is considered laminar if the relevant Reynolds number is less than 2000, and it is turbulent if the Reynolds number is greater than 4000. Between these two values there is the critical zone in which the flow can be either laminar or turbulent or the flow can change between the patterns.

It is important to know the type of flow in the pipe when assessing friction losses when determining the relevant friction factors. In this project, the fluid selected to be used is water. The water properties are:

- Density : 1000kg/m^3
- Viscosity : 0.001 Pas at 20°C

In any real moving fluid, energy is dissipated due to friction. In turbulence flow, the energy dissipated is even higher. Head loss can be categorized as two, the major losses and the minor losses. The major losses usually associated with loss per length of pipe and the minor loss associated with bends, fitting and valves. In this project, the Hazen-Williams equation will be used to calculate the theoretical head loss per length pipe. The Hazen-Williams equation is used because it is more empirical and suitable for the project because in the project, the pipe design was relatively short pipe.

$$V = kCR^{0.63}\,S^{0.54}$$

Where, V is velocity of the fluid, K is the conversion factor (in SI unit K is 0.849), C is the roughness coefficient, R is the hydraulic radius and S is the head loss per length pipe. The figure 2.5 below show the example of the fluid flow in the circular pipes. From the figure, we can classify the fluid flow into two sections, the hydrodynamic entrance region and the fully developed region Close to the entrance region (on the inside of the pipe), significant viscous effects will be concentrated to a thin boundary layer attached to the pipe wall. The fluid in the middle is basically inviscid. As the flow progress further into the pipe, these boundary layers will increase in thickness until you reach a point where they merge, so that the whole fluid is significantly affected by viscosity. That is when "fully developed flow" has its onset.

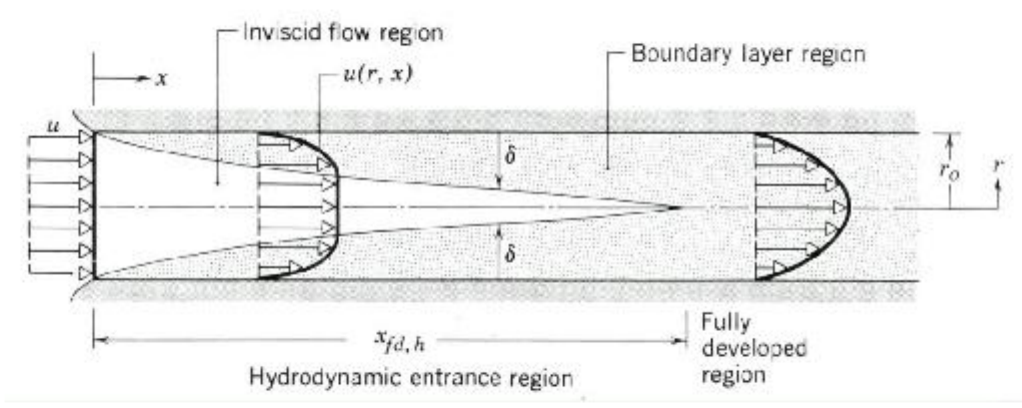

Figure 2.5: hydrodynamic entrance region

2.3.5 GFRP

Fibre-reinforced plastic (FRP) (also fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually fibreglass, carbon and aramid, while the polymeris usually an epoxy, vinylester or polyester thermosetting plastic. A reinforced plastic material composed of glass fibers embedded in a resin matrix. The GFRP was chosen as the material in the project because mainly because of it high corrosion resistance and long term of properties. The good environmental and corrosion resistance is one of the main reasons for choosing this material.

GFRP is designed for weather exposure and normally fabricated with resin rich surface layer which protect the underlying material by screening out the ultraviolet rays and minimizing water absorption along fibre interfaces. Since GFRP are almost perfect elastic to failure the addition of glass fibre reinforcement increases the creep resistance of the thermosetting resins. GFRP also can offer many benefit compare to the ordinary steel pipe such as weight reduction offered. The potential for weight savings by substitution of steel pipes with GFRP is a major impetus for increasing concern in the oil companies for applying GFRP pipes.

It can be concluded that use of GFRP pipes generally lead to weight reduction in range of 50% - 60%. A comparison has been made on how the weight reduction depends on the pipe dimension for similar working conditions between GFRP pipe and the molybdenum alloyed stainless steel. The cost comparison between these two materials also has caught the oil companies. GFRP usually comparable in cost to carbon steel but it is less expensive than stainless steel.

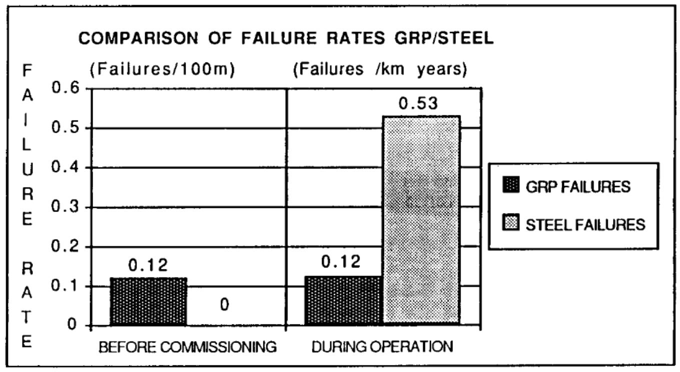

Figure 2.6: The performance of GFRP piping system in sea water conditions compared to the steel [2]

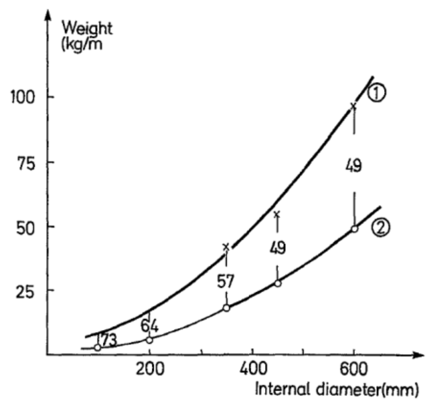

Figure 2.6.1: Dimension vs. Weight for the GFRP (2) and the steel pipe (1) [3]

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The objective is to study the dynamic behavior of the glass fibre reinforced plastic (GFRP) pipe fluid flow properties. The K-epsilon turbulent model is used to describe the system and simulation.

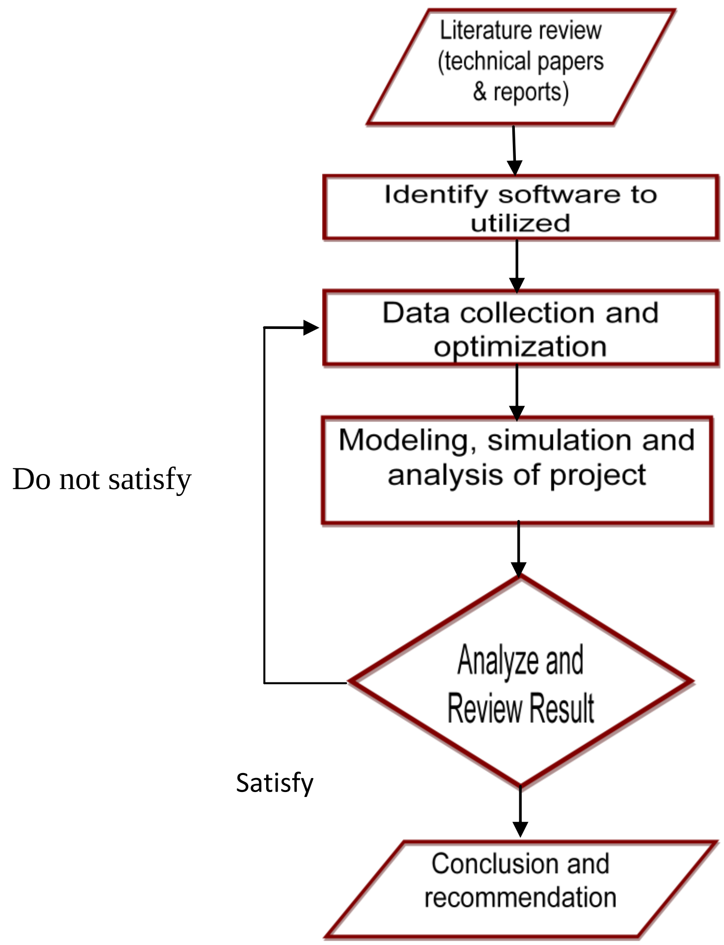

Figure 3.1: Flowchart

3.2 Project activities

Title Selection:

After discussing with the supervisor, a title for the project is proposed depending on the availability of data and possibility to obtain results. The author decided to go glass fibre reinforced plastic (GFRP) because of it potential to replace common carbon steel pipe in the oil and gas industries.

Preliminary Research:

This phase would be reading related research journal papers and almost similar project about glass fibre reinforced plastic (GFRP) mechanical properties. For gfrp, all the characteristics of a hydraulic mechanism is being studied and reviewed. For fluid flow models, all the means of fluid flow is being considered and studied on to justify which one should be further used in this project.

Study on Software:

A thorough research is done to investigate the computer software suitable to design and simulate on fluid flow in pipe. The software's chosen is the ANSYS Workbench and the ANSYS FLUENT.

Data Collection:

Information data fact sheet regarding the fluid flow in GFRP pipe obtained by searching through journals and the web. The data expected to be obtained are type of flow, speed of flow, type of analysis done, and model of the flow

Project Design and Simulation:

Design and simulation of the fluid flow mechanism will be done to obtain certain information and results. After research, to design the pipe, the ANSYS Workbench software will be considered. For simulation and results, ANSYS FLUENT software will be used.

Analysis of Results:

A detailed study will be done on the expected results which are the flow properties in both of pipes. This is in line with the objective of this project which is analyzing the flow properties in the GFRP pipe.

Conclusion:

The expected analysis from the experiment would be to display the flow properties of the GFRP pipe and the steel pipe. This is done by comparing both simulations. The simulation result also will be compared with the theoretical value.

Report Writing:

The final stage of the study will be the compilation of all research findings, literature reviews, design and simulation works, calculations available and outcomes into the final report.

3.3 Gantt Chart for Final Year Project

Table 3.3: Gantt chart

No	Detail Month	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12
1	Title Selection	■								
2	Background Study and Literature Review Research	■	■	■	■	■	■	■	■	■
3	Extended Proposal		■							
4	Submission Extended Proposal		▲							
5	Data Gathering		■							
6	Proposal Defence		■	▲						
7	Interim Report Preparation		■	■						
8	Interim Report Draft Submission			▲						
9	Interim Report Submission				▲					
10	Data Analysis			■	■	■	■			
11	Progress Report Preparation						■	■		
12	Progress Report Submission							▲		
13	Poster Preparation							■		
14	Pre-SEDEX								▲	
15	Report Preparation							■	■	
16	Draft Report Submission								▲	
17	Dissertation Submission (softbound)								▲	
18	Technical Paper Preparation								■	
19	Technical Paper Submission								▲	
20	Oral Presentation Preparation								■	
21	Oral Presentation Preparation									▲
22	Project Dissertation Submission									▲

■	Progress
▲	Key Milestone

This Gantt chart shows the summarization of the activity that will be done by the author in FYP I and FYP II. Basically, FYP I is just more on doing research, familiarization on the topic and getting as many information available. All the technical work such as modeling, analyzing and simulation will be done in FYP II. During the whole project, the author also needs to submit a few reports, doing some presentation for the project to be evaluated.

3.4 Tools, Equipment and Materials

Stated below are the list of tools, equipment, and materials needed to conduct this project:

Materials:

- This project I mainly based on simulation, so there is no specific requirement in the material usage.

Equipment:

- ANSYS Workbench
- ANSYS FLUENT

There software's that are to be used in this project are ANSYS Workbench and ANSYS FLUENT. The designing stage of the pipe will be done using ANSYS Workbench. ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. After designing stage is finished, the model will be imported to ANSYS FLUENT to be analyzed. One of the ANSYS FLUENT ability is to analyze fluid flow dynamic. In this project, the author will do analysis on fluid flow in pipe.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Theoretical Calculation

There are several loads conditions that need to be calculated which the Reynolds number (Re), head loss, and flow rate. The fluid dynamic analysis will be done at according to below table condition.

Table 4.1: Parameter in the project

Temperature	20ºC
Pressure	1 atm
Density	1000 kg/m^3
Length	8m
Diameter	0.2m
Conversion Factor, K	0.859
Hazen Williams Roughness Coefficient (GFRP)	150
Hazen Williams Roughness Coefficient (steel)	100
Roughness (GFRP)	$5 x 10^{-6}$ m
Roughness (Steel)	$45 x 10^{-6}$ m
Viscosity	0.001 Pa

4.2 Reynolds Number

$$Re = \frac{\rho v l}{\mu}$$

$$Re = \frac{1000 \times 1 \times 0.2}{0.001}$$

$Re = 200\ 000$ (It is more then 4000, so it is fully turbulent)

4.3 Flow Rate

$$V = \frac{1}{4} \times \pi \times d^2 \times v$$

$$V = \frac{1}{4} \times \pi \times 0.2^2 \times 1$$

$$V = 0.03142\ m^3/s$$

4.4 Hazen Williams Coefficient

$$V = kCR^{0.63}\, S^{0.54}$$

GFRP pipe

$$1 = 0.859 \times 150 \times 0.1^{0.63} \times S^{0.54}$$

$$S = 4.2 \frac{kPa}{100} m$$

$$h_f = 0.042\ kPa$$

Steel Pipe

$$1 = 0.859 \times 100 \times 0.1^{0.63} \times S^{0.54}$$

$$S = 8.8\ \frac{kPa}{100} m$$

$$h_f = 0.088\ kPa$$

4.5 Head loss converts to Pressure Loss

$$p = \frac{h_f}{100} \times L \times SG$$

GFRP pipe

$$p = \frac{0.042}{100} \times 8 \times 1$$

$p = 3.36 \times 10^{-3} tone/m^2$ (1 tone/m^2 = 9.81kPa)

Steel pipe

$$p = \frac{0.088}{100} \times 8 \times 1$$

$p = 7.04 \times 10^{-3} tone/m^2$ (1 tone/m^2 = 9.81kPa)

4.6 Modeling

For this part, the author needs to design a pipe for the use in the simulation. The Design is in 2-Dimension. The pipe measurement is:

- Length, D = 8m
- Diameter, d = 0.2m
- $V_{inlet,}$ V =1 ms
- Roughness = $45x10^{-6}$m (steel)
  = $5x10^{-6}$m (GFRP)

There is few assumption and constant variables are decided to be used in the model:

- Pipe is horizontal
- Gravity is neglected
- The pipe is fully wetted flow
- The pipe is thin walled
- The liquid and the pipe material are linear elastic
- Cavitations not to occur
- No backflow

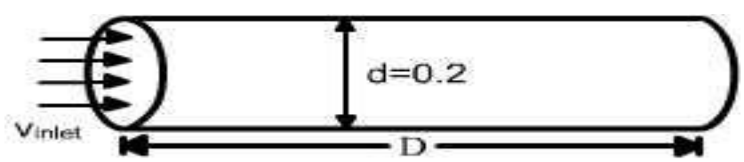

Figure 4.6.0: Draft of the pipe model

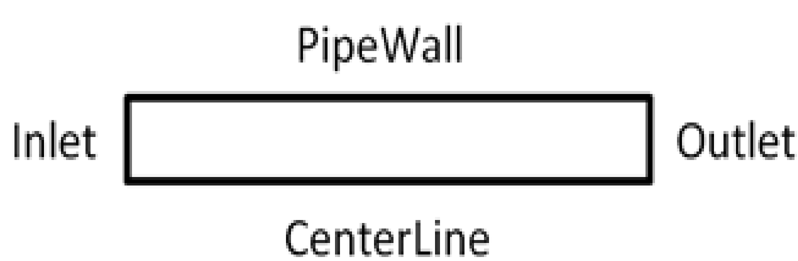

Figure 4.6.1: Draft of the pipe model

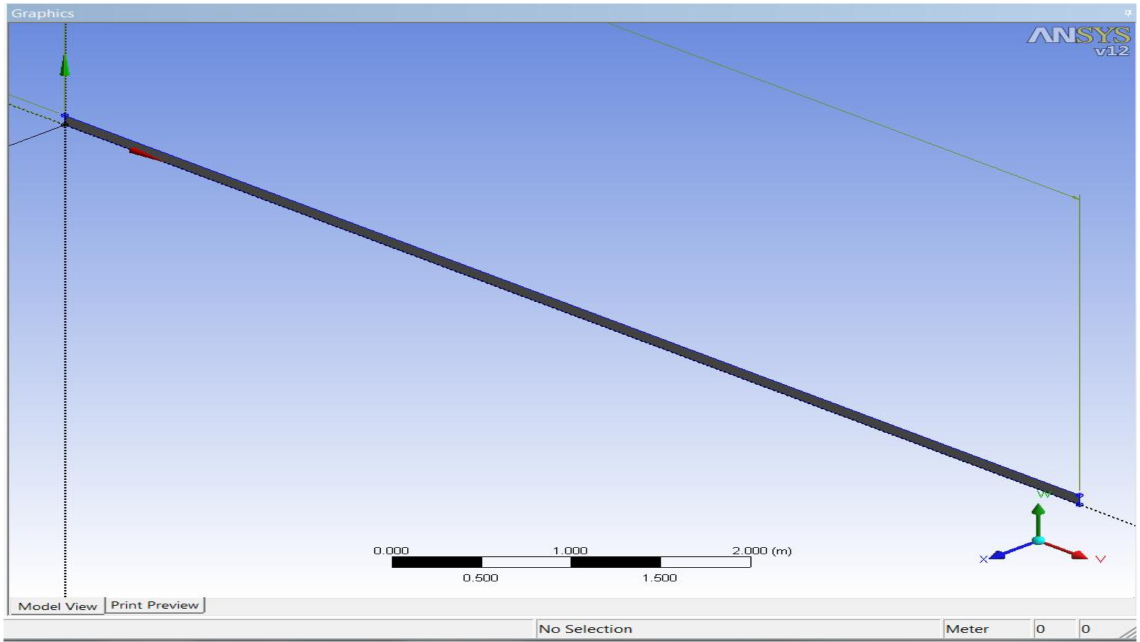

Figure 4.6.2: Initial drawing

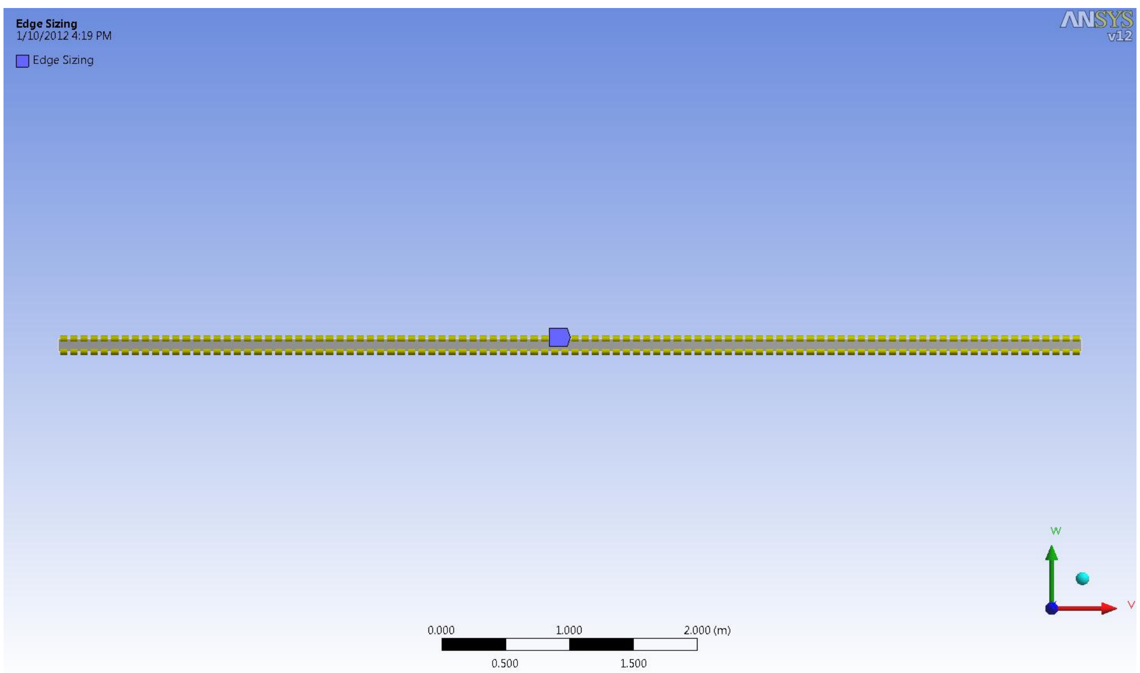

Figure 4.6.3: Edge sizing of the pipe

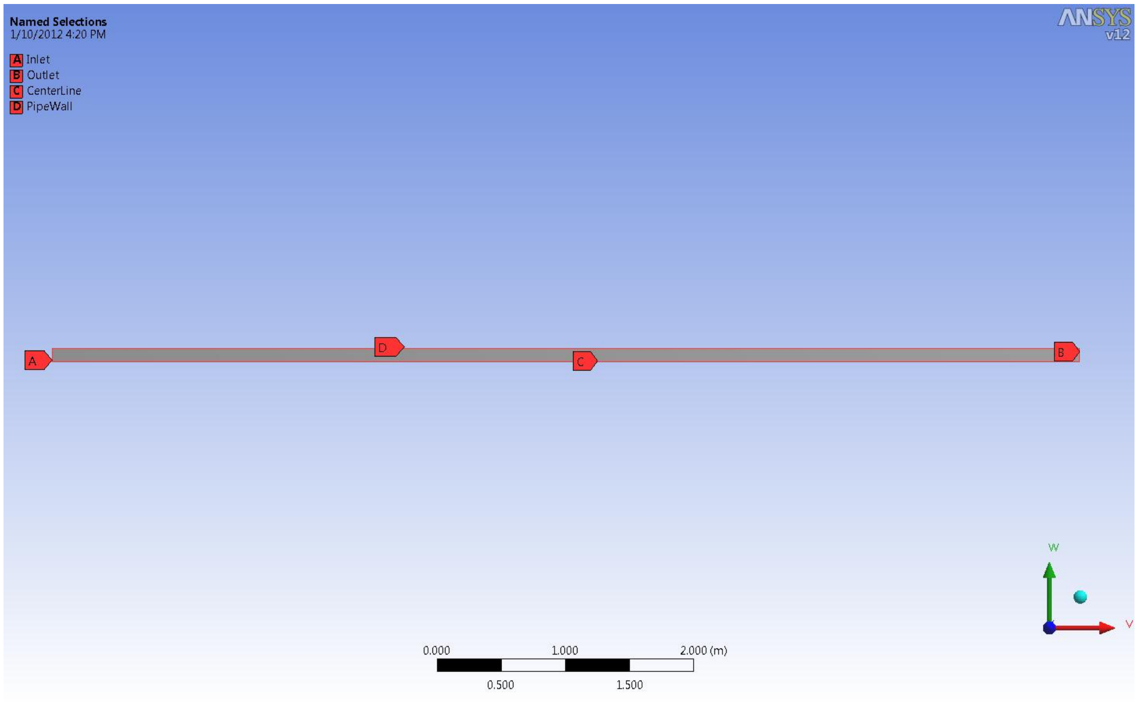

Figure 4.6.4: Named selection

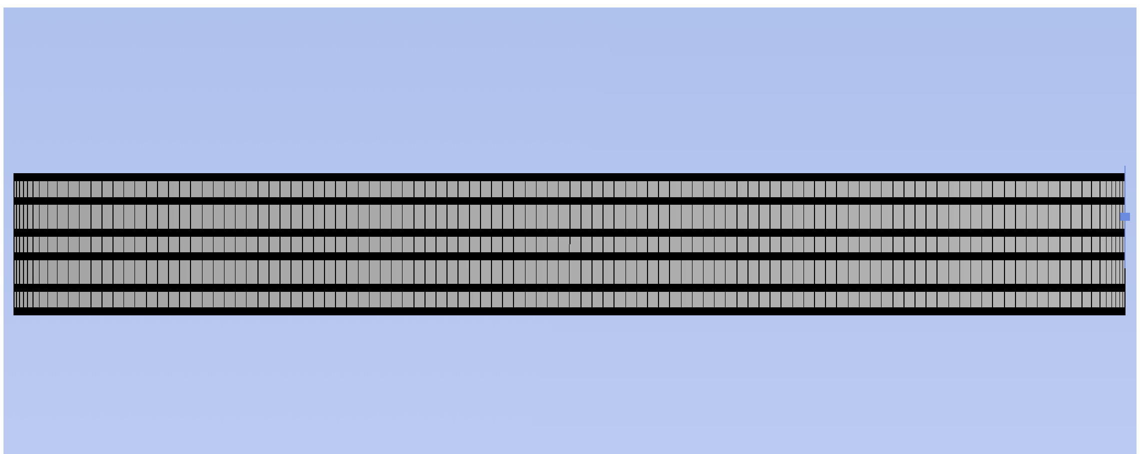

Figure 4.6.5: Pipe after the meshing done

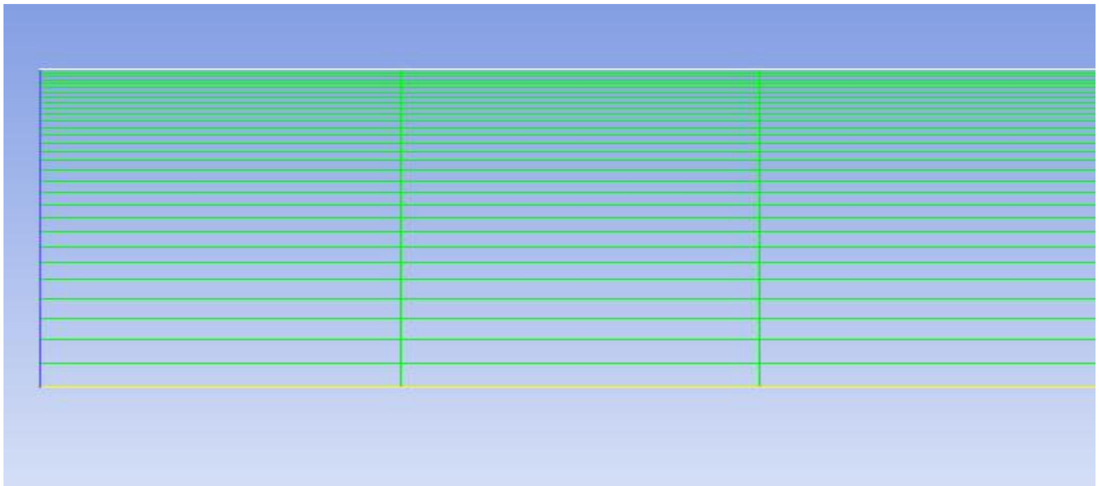

Figure 4.6.6: Meshing from the center of the pipe to the pipe wall

4.7Analysis

The simulation in this project was run on the k-epsilon model and was calculated using the second order upwind.

4.7.1 Turbulence intensity at the center line of the pipe

From the GFRP pipe graph (figure 4.7.0), the turbulent intensity is quite stable. The turbulent start with discontinuous and when it reaches 2m, then it becomes continuous. This probably happen because the fluid flow has been fully developed. Then the turbulent intensity decreasing slowly until it reaches 4m. After 5m, the turbulence start increasing back until it reaches the pipe outlet. From the steel pipe graph (figure 4.7.1), the turbulent intensity is not stable. The turbulent start with discontinuous and when it reaches 2m, then it becomes continuous. The slope for the turbulent intensity in the steel pipe is quite steep. Then after 4m, the turbulent start increasing until it reaches the pipe outlet. The lowest point of turbulent intensity achieved by the GFRP pipe is 3.00e+00 which is lower than the steel pipe, 4.00e+00. This can show that the pipe roughness in steel pipe has become the factor in increased of turbulence. The steel pipe turbulent intensity also is not stable compared to the GFRP pipe. The graph plot in steel pipe is much steeper than GFRP pipe. The fluctuation in the steel pipe flow happen become flow in the steel pipe cannot settle. This is contrast in the GFRP pipe flow where turbulent intensity level becomes almost constant. From the result, role of wall roughness had influences on the turbulent intensity of the fluid flow in pipe. The result is satisfying the predicted theory from the experiment of P.Salizonni, Van Liefferinge and L. Soulhac in the turbulent intensity relation with pipe roughness.

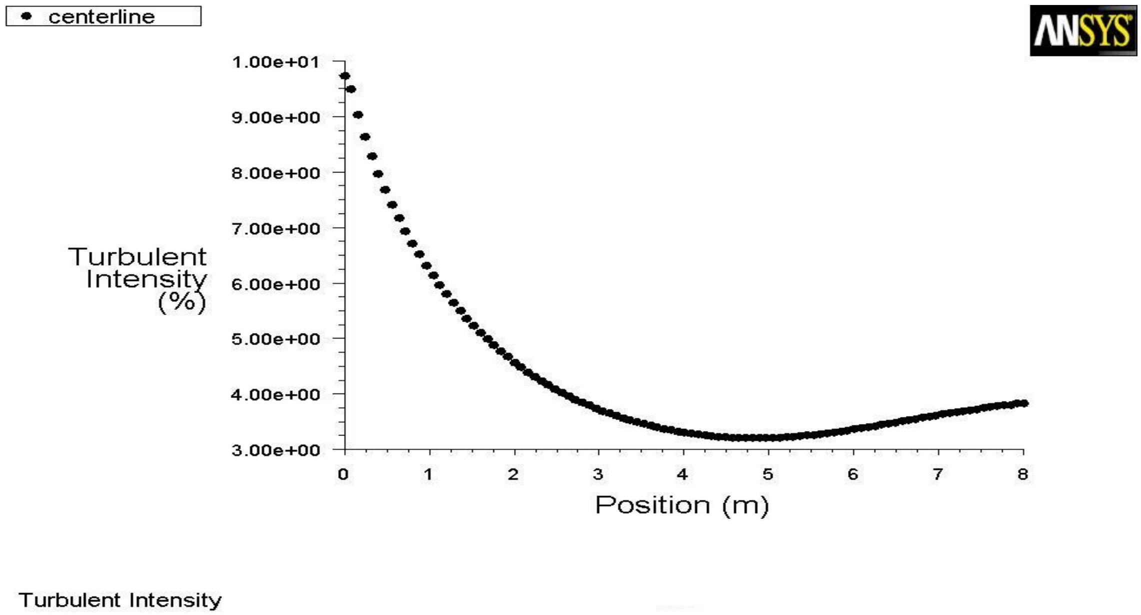

Figure 4.7.0: GFRP pipe, turbulent intensity vs. pipe length

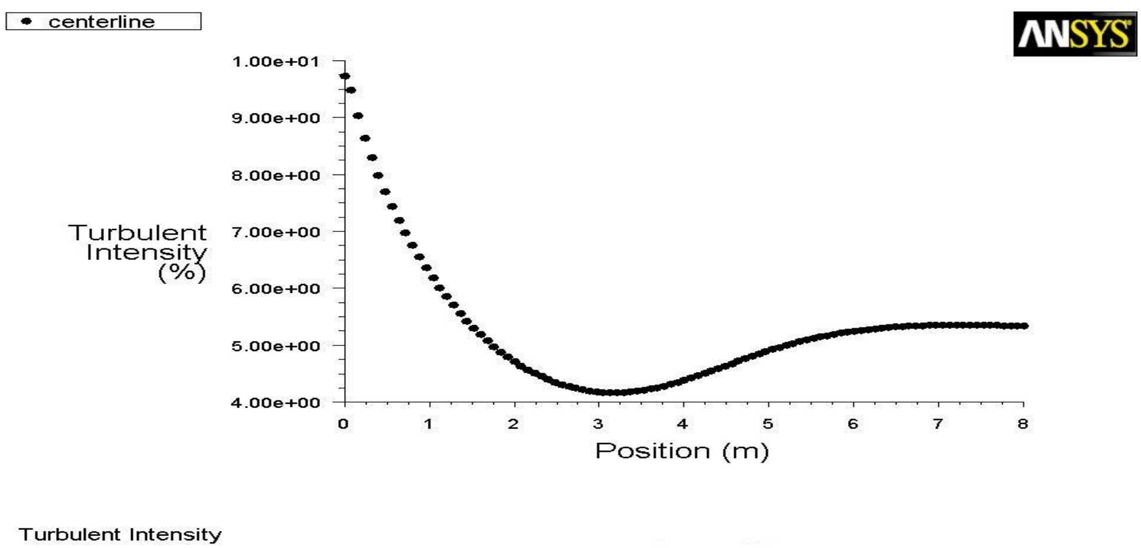

Figure 4.7.1: Steel pipe, turbulent intensity vs. pipe length

4.7.2 Dynamic pressure at the pipe wall

From GFRP pipe graph (figure 4.7.2), the dynamic pressure is stable. The dynamic pressure start with discontinuous curve and when it reaches 2m, then it becomes continuous. This probably happen because the fluid flows almost becomes fully developed. Then the dynamic pressure decreasing slowly until it reaches 4m. After that, it becomes almost constant until it reaches the pipe outlet. From the steel pipe graph (figure 4.7.3), the dynamic pressure is stable. The dynamic pressure start with discontinuous curve and when it reaches 1m, then it becomes continuous. The slope for the turbulent intensity in the steel pipe is quite steep. Then the dynamic pressure decreasing slowly until it reaches 2m. After that, it becomes almost constant until it reaches the pipe outlet. Form both graph, we can identify that the pressure drop at the pipe wall at the steel pipe is higher than the GFRP pipe. At GFRP pipe, the pressure drop 4.80e+02 to 3.10e+02 while in the steel pipe the pressure drop from 4.60e+02 to 2.50e+02. The roughness has effect on the pressure drop along the pipe wall where the higher the roughness of the pipe, the higher the pressure drop. Pressure drop in pipe flow is not desirable because it will decrease the pipe flow rate. Measurements in rough-wall turbulent flows subjected to adverse pressure gradients have been reported. The results indicate that surface roughness and adverse pressure gradient significantly modify the mean flow field. This result can be related with the experiment conducted by G.F.K Tay and his colleagues, that pipe wall roughness has an effect in the fluid flow dynamic

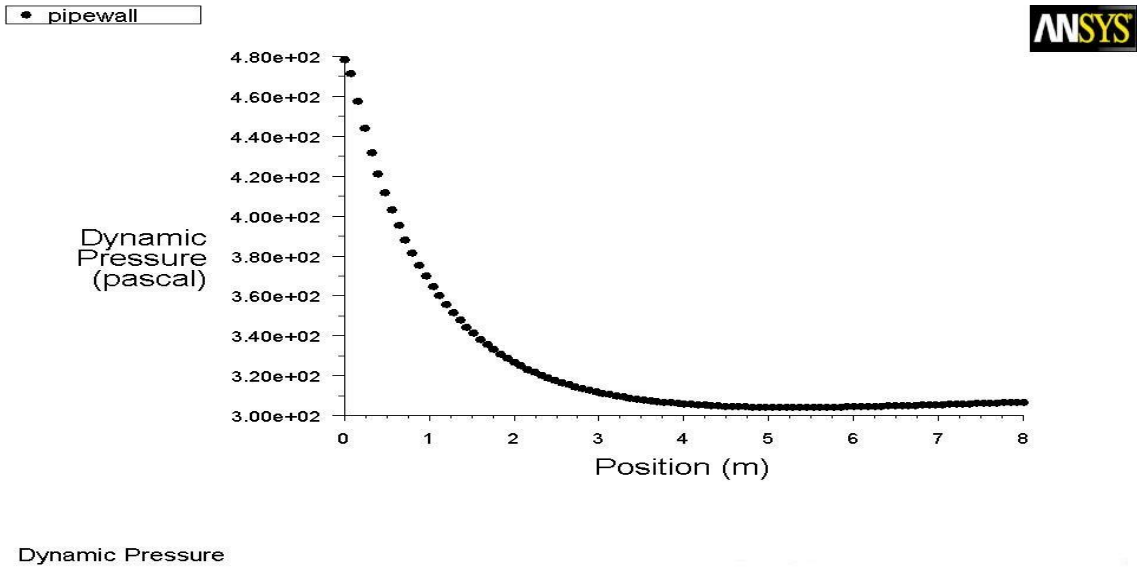

Figure 4.7.2: GFRP pipe, dynamic pressure vs. pipe length

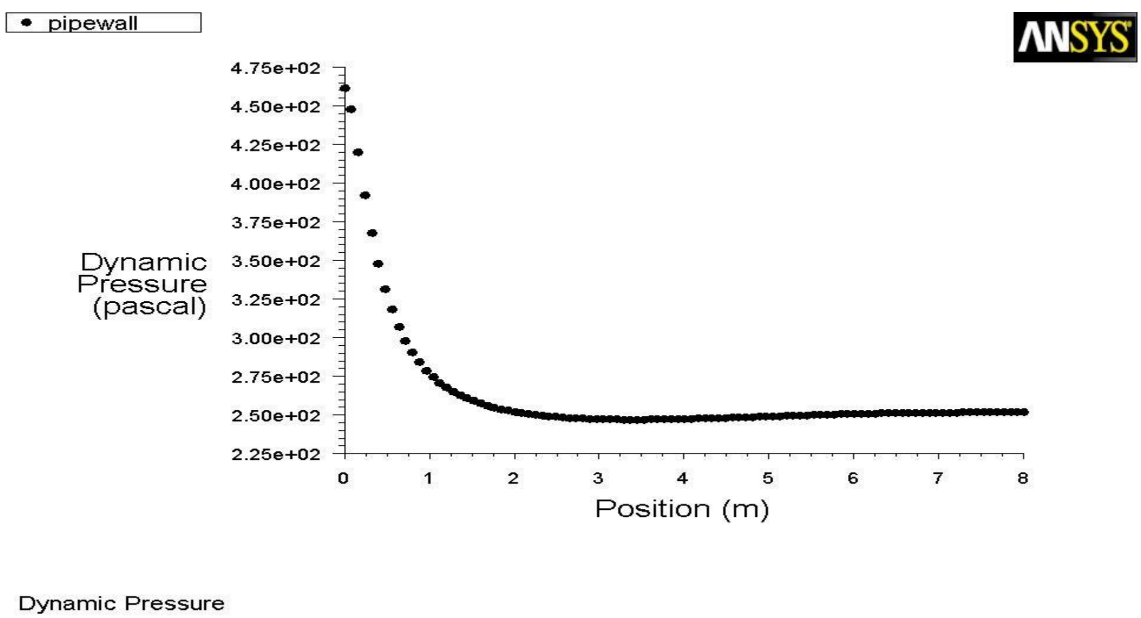

Figure 4.7.3: Steel pipe, dynamic pressure vs. pipe length

4.7.3 Velocity Profile at Center Line

From the GFRP pipe graph (figure 4.7.4), the velocity magnitude is quite stable. The velocity magnitude starts with discontinuous and when it reaches 2.5m, then it becomes continuous. This probably happen because the fluid flows almost becomes fully developed. Then the velocity magnitude increase at the constant rate until it reaches 7m. After that the velocity drop a little bit until it reaches outlet. From steel pipe the graph (figure 4.7.5), the velocity magnitude is not stable. The velocity magnitude starts with discontinuous and when it reaches 3m, then it becomes continuous. The slope for the turbulent intensity in the steel pipe is quite steep. Then after 5m, the velocity magnitude start decreasing until it reaches the pipe outlet. The GFRP pipe flow is slower then steel pipe but in the GFRP pipe, the pipe flow is more stable. There is no sudden change in velocity in GFRP pipe. The stable pipe flow is more desirable than the non-constant high-speed flow. The velocity profile, in our transitional wall roughness variable are valid for all types of standard wall roughness, in contrast to traditional wall the friction cause by increase of wall roughness predicts the results explicitly independent of wall roughness.

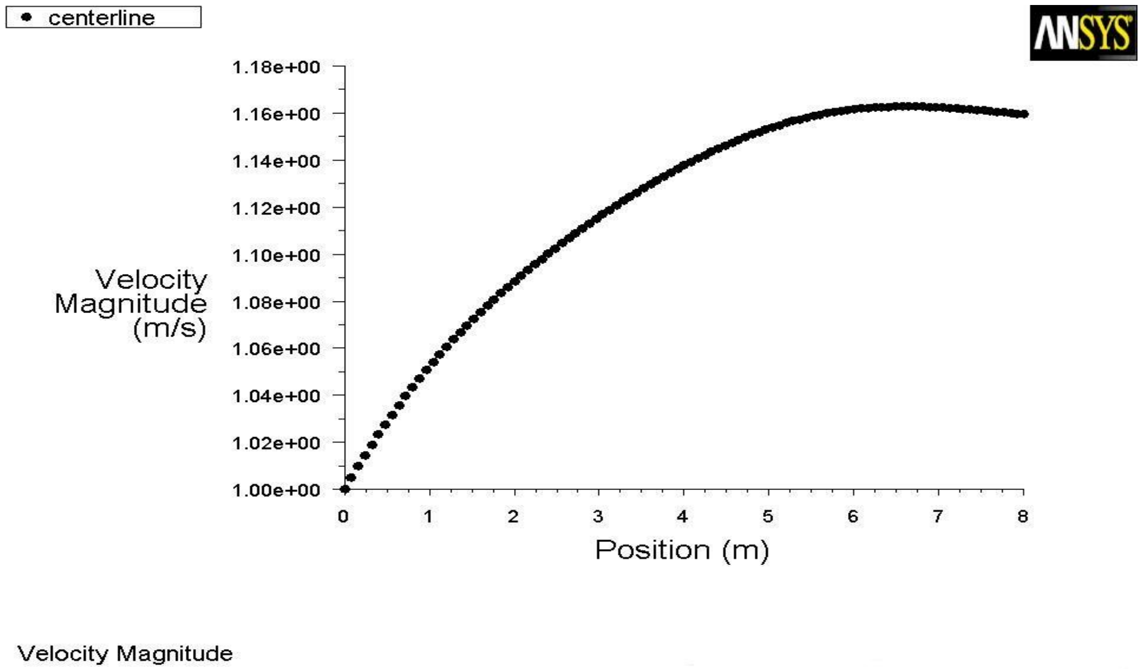

Figure 4.7.4: GFRP pipe, velocity magnitude vs. pipe length

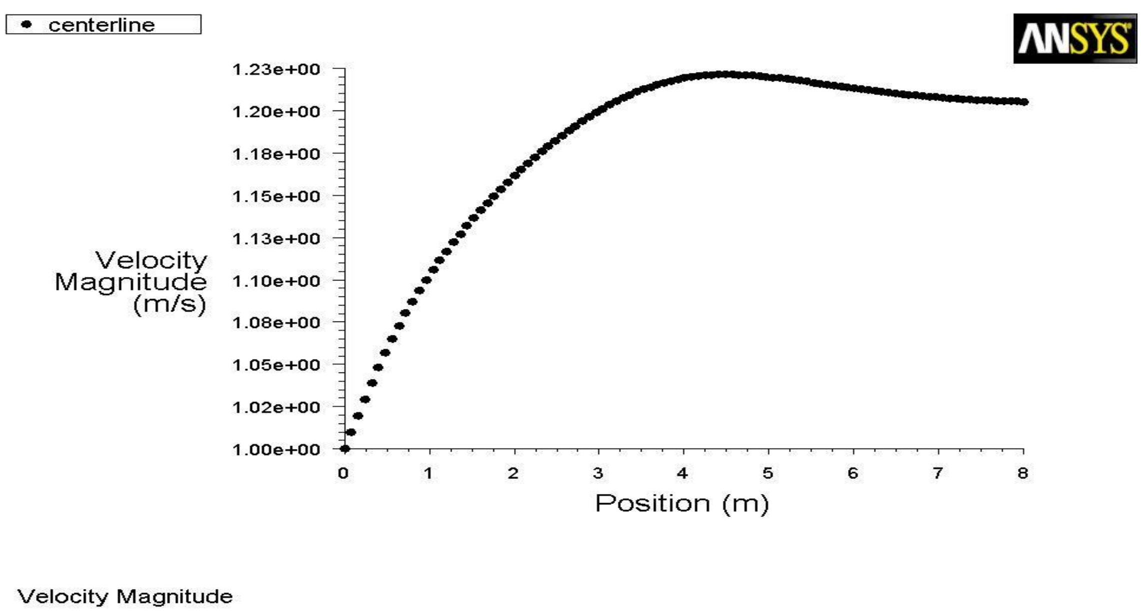

Figure 4.7.5: Steel pipe, velocity magnitude vs. pipe length

4.7.4 Skin Friction Coefficient at the pipe wall

From the GFRP pipe graph (figure 4.7.6), the skin friction coefficient stable. Like all other graph, the skin friction coefficient starts with discontinuous and when it reaches 1m, then it becomes continuous. This probably happen because the fluid flows almost becomes fully developed. Then the turbulent intensity decreasing slowly until it reaches 4m. After 5m, the skin friction coefficient become constant until it reaches the pipe outlet. From the steel pipe graph (figure 4.7.7), the skin friction coefficient intensity is not stable compare to GFRP pipe graph slope. The skin friction coefficient starts with discontinuous and when it reaches 1m, then it becomes continuous. The slope for the turbulent intensity in the steel pipe is quite steep. Then after 4m, the turbulent start increasing and fluctuates until it reaches the pipe outlet. The lowest point of skin friction coefficient achieved by the GFRP pipe is 3.15e+00 which is lower than the steel pipe, 5.50+00. This can show that the pipe roughness in steel pipe has an effect on the skin friction coefficient. This indicates that the GFRP pipe has lower parasitic drag at the pipe wall than the steel pipe. Lower parasitic drag mean that the GFRP pipe has better flow properties than steel pipe. The present work was carried out to re-examine the extensive experimental data of fully developed turbulent pipe flows obtained by E.S. Zanoun. In order to gain insight of the result produced, the author compare the simulation result. The velocity profile of the simulation agrees well with both result of the simulation.

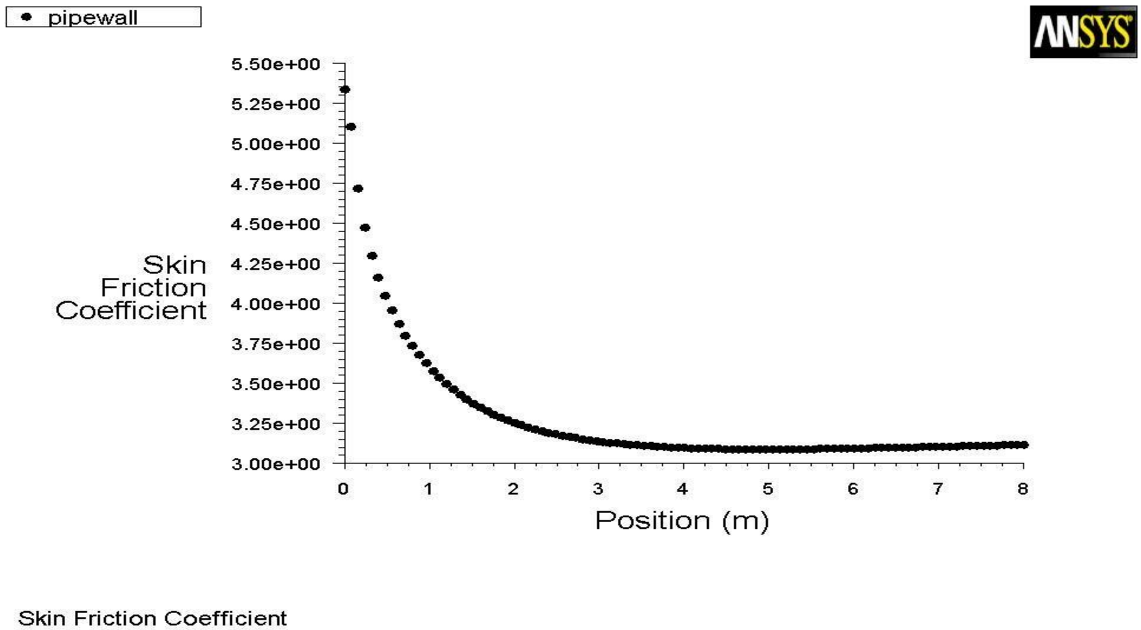

Figure 4.7.6: GFRP pipe, skin friction coefficient vs. pipe length

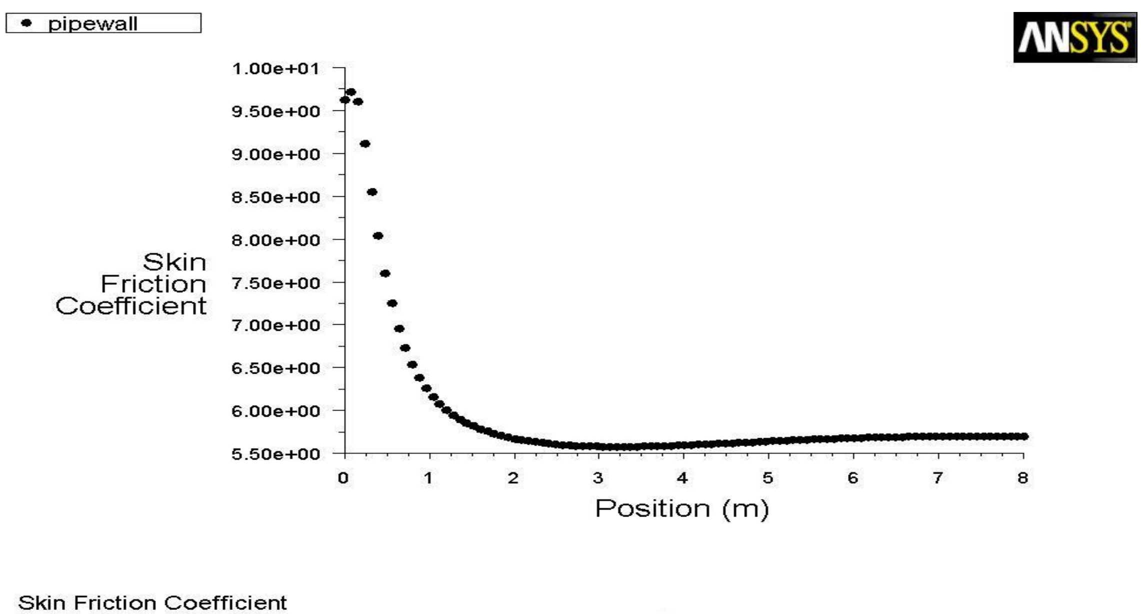

Figure 4.7.7: Steel pipe, skin friction coefficient vs. pipe length

4.8 Comparison between Theoretical and Simulation

Table 4.8: theoretical value

Material	GFRP	Steel
Head loss, h_f	0.042 kPa	0.088 kPa
Pressure loss, P	$3.36 \times 10^{-3} tone/m^2$	$7.04 \times 10^{-3} tone/m^2$

In theoretical section, the head loss and pressure loss for both of pipe have been calculated. The value is in the table 4.8 above. From table 4.8, the head loss and the pressure loss inside the GFRP pipe is lower than the steel pipe. If we compare it to the simulation result, the head loss and the pressure loss in GFRP pipe is also lower than the steel pipe. With this, the author can prove that the GFRP pipe have better flow properties than the steel pipe. From the simulation, a GFRP pipe flow property is superior to the steel pipe in almost every aspect.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The glass advantages of fibre reinforced plastic and it capabilities to replace the steel carbon pipe seems to be a promising approach to improve the heavy industries. By conducting researches, designing, and simulation, the result is expected to justify the flow properties of GFRP pipe. From the results, the GFRP pipe has tremendous advantages and can be applied to current heavy industry in the country.

Furthermore, GFRP pipe prove that the pressure drop in the pipe is lower than the steel pipe. This is important because the low pressure drop mean the pump pressure will be reduced. With lower pressure drop, GFRP pipe surely can reduce the cost in pipeline system.

Finally, from the simulation, GFRP pipe indicate it has better flow properties. From the parameter analyze, the GFRP pipe flow dynamic always edging the steel pipe flow dynamic. GFRP flow properties are superior in term of head loss, pressure loss, skin friction coefficient and turbulent intensity. It also has give significant flow properties compare to the steel pipe. So, the GFRP pipe should be introduced slowly to the heavy industries. Thus, objective have been achieved

5.2 Recommendation

A lot more of the flow properties of the GFRP pipe can be study. Simulation is just a tool to provide an initial study for designers to investigate and analyze the effect of the internal fluid flow in the GFRP pipe. Fabrication and actual testing should be performed in order to validate the result obtained from the simulation. The results from the actual testing must be compared to the simulation in order to come out with proper documentation. The GFRP thermal properties also should be analyzed. Thermal properties information is important if the GFRP pipe need to be applied in the sea water. Without proper preparation, pipe flow problems like waxing in oil pipeline could happen in the GFRP pipe.

REFERENCES

1. Rafael M. Palou et.al (2010): "*Transportation of heavy and extra crude oil by pipeline, A review",* Journal of Petroleum Science and Engineering 75(2011) 274-282.
2. R.Stokke, (1998): "*Use of glass fibre reinforced plastic (GFRP) in seawater pipe offshore*" ,Center for Industrial Research, OTC 5744
3. Yunus A. Cengel, John M. Cimbala,(2006): "*Fluid mechanics fundamental and application"*
4. C.A.M Van den Ende and J.C.m de Bruijin(1997): "Quality assurance of glass fibre reinforced piping systems", Corrosion 97, Paper 359
5. H.D. Pasinato(2009): *"Velocity and temperature dissimilarity in fully developed turbulent channelad plane coutte flows",* International Journal of Heat and Fluid Flow
6. S.Osisanya (2001): "*A simple empirical pipeline fluid flow equation based on actual oilfield data*", SPE, The University of Oklahoma
7. Libor Lobovsky, Jan Vimmr(2007): *" Smoothed particle hydrodynamic and finite volume modeling of incompressible flow*", University of West Bohemia
8. B. Sreejith, K. Jayaraj, N. Ganesan, C. Padmanabhan, P. Chellapandi, P. Selvaraj(2003): "*Finite element analysis of fluid structure interactionin pipeline systems"*
9. W. Dettmer, D.Peric(2006) "*A computational framework for fluid structure interaction: finite element and application",* University of Wales Swansea
10. Jason P. Modisette(2003) *"Physics of pipeline flow",* Pipeline Simulation Interest Group
11. P. Salizzoni, R. Van Liefferinge, L Soulhac(2008) " *Influence of wall roughness on the dispersion of a passive scalar in a turbulent boundary layer",* University of Claude Bernard, Lyon

12. G.F.K Tay, D.C.S Kuhn, M.F. Tachie(2009) " *influence of adverse pressuregradient on rough-wall turbulent flows"* University of Manitoba
13. E.S.Zanoun, F.Durst, O. Bayoumy, Al-Salaymeh(2007)" *Wall skin friction and mean velocity profile of fully developed turbulent pipe flows"*, University of Jordan