A STUDY ON PIPELINE INSPECTION GAUGE (PIG) FLOW PARAMETERS IN SMALL SIZE PIPE

MOHAMAD NORZUHRI BIN BASIRUN

BACHELOR OF CHEMICAL ENGINEERING (GAS TECHNOLOGY)

UNIVERSITI MALAYSIA PAHANG

A STUDY ON PIPELINE INSPECTION GAUGE (PIG) FLOW PARAMETERS IN SMALL SIZE PIPE

MOHAMAD NORZUHRI BIN BASIRUN

A thesis submitted to the Faculty of Chemical and Natural Resources Engineering in
partial fulfillment of the requirements for the award of the Degree of
Bachelor in Chemical Engineering (Gas Technology)

Faculty of Chemical & Natural Resources Engineering
Universiti Malaysia Pahang

FEBRUARY 2013

SUPERVISOR'S DECLARATION

"I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering (Gas Technology)."

Signature : ……………………………………..

Name : PROF. Dr. ZULKEFLI BIN YAACOB

Date : JANUARY 25, 2013

STUDENT'S DECLARATION

"I declare that this thesis entitled "A Study on Pipeline Inspection Gauge (PIG) Flow Parameters in Small Size Pipe" is the result of my own research except as cited in references. The thesis has not concurrently submitted in candidature of any other degree."

Signature : ……………………………………..

Name : MOHAMAD NORZUHRI BIN BASIRUN

ID Number : KC09033

Date : JANUARY 25, 2013

Special Dedication to my family members that always love me,

my friends, my fellow colleagues

and all faculty members

For all your Care, Support and believe in me

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim,

First of all, I would like express my appreciation to my caring supervisor, Prof. Dr. Zulkefli Yaacob. I was honored to be his student. He gave encouragement and all support to my study until the end of the day. Besides, I am also very thankful to Mr. Abu Samah colleague of Prof. Dr. Zulkefli for his guidance. He is a nice person from the beginning to the last.

In particular, I wish to express my sincere appreciation to my lovely P.A., Dr. Hayder A. Abdul Bari for encouragement, guidance and critics. I am also very thankful to Assoc. Prof. Dr. Abdurahman Hamid Nour for his constructive criticism during research presentation evaluation, which helped me to make necessary improvements.

My sincere appreciation also extended to my colleagues who are helpful especially in giving ideas and valuable advice during the progress of completing this research proposal. Their views and tips are very useful indeed. Thank you very much.

I would like to dedicate my appreciation to all the lecturers that involve in this research/project for their invaluable time, guidance and advice. Without your cooperation and sacrifices this research will not able to complete and published. I would also like to thank my beloved siblings and friends for their encouragement and besides giving some idea to this project. Thank you.

A STUDY ON PIPELINE INSPECTION GAUGE (PIG) FLOW PARAMETERS IN SMALL SIZE PIPE

ABSTRACT

Pipeline inspection gauge or known from its acronym as PIG was basically a tool or a device that was inserted into a pipeline with the purpose of cleaning or pipeline inspection. There were different types of pigs for different use in pipeline. The most basic form and most frequently used of pig is for cleaning purpose of pipeline. There are other types of pig that was known as smart pig. Smart pig can do more than just cleaning. They can inspect the physical condition of the pipe. The main objectives of this research are to study the flow of natural gas through different types of pigs of different worn out percentage ranging from 20%, 15% and 10% from initial diameter and varied gas flow velocity from lowest to highest allowable to find the most effective types of pigs for cleaning purpose. Other than that the purpose of this research paper was to analyzed hydrates effect on natural gas flow in pipeline by studying the complex behavior of gas flow through pipeline (Velocity, Pressure, and Turbulent) using CFD modeling. In order to get the result, simulation was performed by using Computational Fluid Dynamic (CFD) software namely Fluent and Gambit. Volume meshing in GAMBIT is very important part before doing simulation in FLUENT as a solver. The model simulation helps further understanding of the variables change in form of type of PIG used and effect of hydrate to velocity, pressure and turbulent intensity in natural gas pipeline flow.

Keywords: PIG, hydrates, simulation, CFD, single phase

KAJIAN KE ATAS PARAMETER ALIRAN GAUGE PEMERIKSAAN PAIP (PIG) DALAM PAIP BERSAIZ KECIL

ABSTRAK

Gauge pemeriksaan paip atau dikenali dari singkatan sebagai (PIG) pada asasnya alat atau peranti yang dimasukkan ke dalam saluran paip dengan tujuan pemeriksaan atau pembersihan saluran paip. Terdapat beberapa jenis pig untuk kegunaan yang berbeza. Bentuk pig yang paling asas dan paling kerap digunakan adalah untuk membersihkan talian paip. Terdapat lain-lain jenis babi yang dikenali sebagai smart pig. Smart pig boleh melakukan lebih daripada sekadar pembersihan. Mereka boleh memeriksa keadaan fizikal paip. Objektif utama kajian ini adalah untuk mengkaji aliran gas asli melalui beberapa jenis pig yang berbeza yang mengalami pengecilan saiz disebabkan kehausan permukaan pig. Kehausan permukaan pig antara 20%, 15% dan 10% daripada diameter asal pig dan halaju aliran gas yang pelbagai dari terendah hingga tertinggi yang dibenarkan untuk mencari jenis pig yang efektif untuk tujuan pembersihan. Selain daripada itu tujuan kertas penyelidikan ini adalah untuk mengkaji kesan hidrat yang dianalisis pada aliran gas asli dengan mengkaji tingkah laku kompleks aliran gas melalui talian paip berdasarkan halaju, tekanan, dan gelora menggunakan model CFD. Dalam usaha untuk mendapatkan keputusan, simulasi telah dilakukan dengan menggunakan perisian Dinamik Bendalir Komputeran (CFD) iaitu Fluent dan Gambit. Meshing dalam Gambit adalah bahagian yang sangat penting sebelum melakukan simulasi dalam FLUENT sebagai penyelesai. Model simulasi membantu pemahaman lanjut perubahan pembolehubah dalam bentuk jenis pig yang digunakan dan kesan hidrat halaju, tekanan dan intensiti bergelora dalam aliran saluran paip gas asli.

Kata Kunci: PIG, hidrat, simulasi, CFD, fasa tunggal

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS/ABBREVIATIONS

^{o}C	degree Celcius
%	percent
.msh	mesh file
2D	two dimensions
API	American Petroleum Institute
CFD	Computational Fluid Dynamic
CH_4	Methane
CO_2	Carbon dioxide
cm	centi meter
H_2S	Hydrogen Sulfide
H_2O	Water
HDPE	High-Density Polyethylene
h	hour
m/s	meter per second
MPH	miles per hour
NGL	Natural Gas Liquid
NH_3	Ammonia
O	Oxygen
OD	Outer diameter
Pa	Pascal
PGB	Petronas Gas Berhad
PGU	Peninsular Gas Utilisation
PIG	Pipeline Inspection Gauge

CHAPTER 1

INTRODUCTION

This chapter will give the ideas on the significant of this research. The first chapter will cover up the subtopic of background of study or information, problem statement, research objectives, scope of proposed research, expected outcomes and significance of the proposed research.

1.1 Background of Study

One of the biggest project involving oil and gas in Malaysia was the Peninsular Gas Utilisation (PGU) which was owned and operated by PETRONAS Gas Berhad (PGB). The Peninsular Gas Utilisation was basically networks of pipeline build for the purpose of distributing natural gas from gas processing plant in Kerteh, Terengganu to users all over Malaysia and Singapore.

In the oil and gas industry generally we can say that it was divided into two sectors that are the upstream and downstream. Upstream is where the exploration and production work were done. While downstream is where the product of crude oil and natural gas were transported and distributed to the consumer.

Focusing more on the downstream activities where the natural gas is transported and distributed to the consumer, the characteristics of pipe such as type and size used vary differently base on the purpose. Transportation of gas from gas processing plant to region that used up natural gas generally use big diameter pipe. “Mainline transmission pipes, the principle pipeline in a given system, are usually between 16 and 48 inches in diameter.”(The Transportation of Natural Gas, n.d.).

From the transportation line, natural gas will go through city gate where after that it will go into the distribution line. The distribution line is where the gas supply arrive to the user which can generally be divided to a few categories mainly, industrial, residential and commercial use. Pipeline used for distribution line is fairly small in diameter as the volume transported is small and the pressure is much smaller compared to that of in transmission line.

Pipeline inspection gauge or known from its acronym as PIG is basically a tool or a device that was inserted into a pipeline with a purpose such are cleaning and pipeline inspection. There are different types of PIG for different use in pipeline. The most basic of PIG is used for the sole purpose of cleaning only. There are other types of pig that was known as smart pig. Smart pig can do more than just cleaning. They can inspect the physical condition of the pipe.

“Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane. The composition of natural gas can vary widely. In its purest form, such as the natural gas that is delivered to your home, it is almost pure methane. Methane is a molecule made up of one carbon atom and four hydrogen atoms, and is referred to as CH4. The distinctive “rotten egg” smell that we often associate with natural gas is actually an odorant called mercaptan that is added to the gas before it is delivered to the end-user. Mercaptan aids in detecting any leaks. (Natural Gas Background)

Natural gas hydrates are solid crystalline compounds of snow appearance with densities smaller than that of ice. Natural gas hydrates are formed when natural gas components, for instance methane, ethane, propane, isobutene, hydrogen sulfide, carbon dioxide, and nitrogen, occupy empty lattice positions in the water structure. In this case, it seems like water solidifying at temperatures considerably higher than the freezing point of water. Gas hydrates constitute a solid solution-gas being the solute and water the solvent-where the two main constituents are not chemically bounded. (Adewumi M., 2012)

Computational Fluid Dynamics (CFD) is the science of predicting fluid flow, heat transfer, mass transfer, chemical reactions, and related phenomena by solving the mathematical equations which govern these processes using a numerical process. There are several CFD software in the market, but for this particular study, FLUENT by ANSYS was used as the solver and GAMBIT pre-processor for geometry and mesh generation.

1.2 Problem Statement

1. Differential pressure is required to move a pig or sphere through the pipeline. The force required depends on the elevation changes in the pipeline, friction between the pig and the pipe wall and the amount of lubrication available in the line (a dry gas pipeline provides less lubrication than a crude oil pipeline. Cups are design to seal against the wall by making them larger than the inside diameter of the pipe. As the cups become worn the amount of blow by fluid by passing the pig increase because the seal is not as effective.

The type of pig to be used and its optimum configuration for a particular task in a particular pipeline should be determined based upon several criteria, which include:

- The purpose
  - O Type, location, and volume of the substance to be removed or displaced in conventional pigging applications,
  - O Type of information to be gathered from an intelligent pig run,
  - O Objectives and goals for the pig run.
- The line contents
  - O The contents of the line while pigging,
  - O Available vs. required driving pressure,
  - O Velocity of the pig.
- Characteristics of the pipeline
  - O The minimum and maximum internal line sizes,
  - O Maximum distance pig must travel,

O Minimum bend radius, and bend angles,

O Additional features such as valve types, branch connections, and the elevation profile.

Problems arise when this pig move in the pipeline, the effect of friction cause the diameter of the pig to worn out and reduced in size. Thus at different worn out percentage of 20 %, 15 % and 10 % from initial size which pigs perform better in the pipeline. Pigs that were compared were between foam pig and solid cast pig. Both pigs were made from the same material which is polyurethanes.

Hydrates are solids resembling ice in appearance, which are consist of a gas molecule surrounded by a cage of water molecules. In particular, hydrate blockages becomes areal menace to flow assurance in inadequately protected flow lines. All available studies on hydrate formation however have focused mainly on its ability to plug the pipe-length without a consideration of its ability to initiate corrosion, Hydrate formation in natural gas pipelines increased flow pressure drop flow path blockage and sometimes explosive pipeline will flow every year and ultimately lead to injury very much for the cost of oil and gas industry

Existences of hydrates in pipeline affect the efficiency of gas flow across the pipeline. The hydrates cause a change in pipeline velocity and pressure. This change can cause harm to pipeline integrity and disturbed the flow of the natural gas. Study needed to find out what cause the hydrates to have such impact to pipeline.

1.3 Research Objectives

i. To choose the best PIG between foam pig and solid form pig to be used for cleaning purpose base on varied worn out percentage and gas flow velocity.

ii. To analyzed hydrates effect on natural gas flow in pipeline by studying the complex behavior of gas flow through pipeline (Velocity, Pressure, and Turbulent) using CFD modeling.

1.4 Scope of Research Proposed

i. Run CFD simulation using Gambit and Fluent.

ii. Model a natural gas flow in 2D pipeline with hydrates inside the pipeline.

iii. Model a natural gas flow in 2D pipeline with different types of pigs inside the pipeline.

1.5 Significance of the Proposed Research

1. Simulation in virtual world can cut cost compare to practical testing using the real equipment.

2. Any improvement that can be made will be test in the simulation.

3. Simulation can be run repeatedly to get the best results.

4. We know what to expect when the experiment is executed practically.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Overview

There are five parts in this literature review. First, part was on natural gas. Second, part was about hydrates in pipeline. PIG was discussed in the third part while pipeline was elaborated in the fourth part and finally in the final part, computational fluid dynamic (CFD) are being explained.

2.2 Natural Gas

Natural gas start with a humble beginning, as it was once dub as unwanted by product of crude oil. But all that changed as “Since its discovery in the United States at Freedonia, New York, in 1821, natural gas has been used as fuel in areas immediately surrounding the gas fields.”(Chi, 1992, p. 21) “Natural gas is a mixture of hydrocarbon gases and impurities. The hydrocarbon gases normally found in natural gases are methane, ethane, propane, butanes, pentanes, and small amounts of hexanes, heptane, octanes, and the heavier gases. The impurities found in natural gas include carbon dioxide, hydrogen sulfide, nitrogen, water vapor, and heavier hydrocarbons. Usually the propane and heavier hydrocarbon fractions are removed for additional processing because of their high market value as gasoline-blending stock and chemical plant raw feedstock. What usually reaches the transmission line for sale as natural gas is mostly a mixture of methane and ethane with some small percentage of propane." (Chi, 1992, p. 38)

"Raw natural gas contains between 65% and 96% methane with impurities such as water (H20), carbon dioxide (C02), hydrogen sulfide (H2S), and oxygen (O) among others (Stress, 2003). These impurities, though, of little composition are capable of causing serious pipeline corrosion, hence, the need to monitor its transportation to the end users." (Obanijesu, 2009, p.2)

"Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas, to produce what is known as 'pipeline quality' dry natural gas which is entirely, or almost entirely methane. There are regulations in terms of quality of the gas that can be carried in a pipeline system. While the ethane, propane, butane, and pentane (NGLs) must be removed from natural gas, this does not mean that they are all 'waste products. In fact, these NGLs can be very valuable by products of natural gas processing; they are sold separately and have a variety of different uses, including enhancing oil recovery in oil wells, providing raw materials for oil refineries or petrochemical plants, and as sources of energy." (Resources Centre for Energy Economics and Regulation (RCEER), 2006)

"While describing natural gas pipeline design, it is necessary to distinguish between two cases: the design of pipelines for transportation of regular dry gases (no liquid, single-phase transportation) and the design of pipelines for transportation of wetter gases - where multiphase conditions due to condensate dropout may are possible." (Adewumi M., 2012)

2.3 Hydrates

"Particles deposition is a process that plays a key role in many fields ranging from atmospheric applications to material sciences. In oil and gas pipelines field, accumulation of hydrate is one of the most challenging aspects in the flow assurance modeling. Hydrate can pose a major risk in all high pressure natural gas transport lines including the connecting lines and manifold systems in all offshore production facilities. Marine transportation of compressed natural gas is one example where prediction of hydrate formation is a requirement for the safe transport of gas to and from ocean going ships. Production facility components such as chokes, velocity-controlled subsurface safety valves, and conventional valves and fittings can all act as restrictions to the flowing fluids resulting changes in flow conditions which could lead to the formation of hydrate particles accumulated eventually in the pipeline." Esam J., M. Abedinzadegan Abdi, Y. Muzychka (2010)

Adewumi M., (2012) also state the key circumstances that are essential for hydrate formation can be summarized as:

1. Presence of “free” water. No hydrate formation is possible if “free” water is not present. Here, we understand the importance of removal of water vapor from natural gas, so that in case of free water occurrence there is likelihood of hydrate formation.

2. Low temperatures, at or below the hydrate formation temperature for a given pressure and gas composition.
3. High operating pressures.
4. High velocities, or agitation, or pressure pulsations, in other words turbulence can serve as catalyst.
5. Presence of H_2S and CO_2 promotes hydrate formation because both these acid gases are more soluble in water than the hydrocarbons.

Tohidi B. (2012) stated those important properties of hydrates:-

1. Capture large amount of gas (up to 15 mole %).
2. Remove light component from oil and gas.
3. Form at temperature well above 0^oC.
4. Generally lighter than water.
5. Need relatively large latent heat to decompose.
6. Exclude salts and other impurities.
7. Result from physical combination of water and gas.
8. Hydrate composition is differing from the HC phase.
9. Large amounts of methane hydrates exist in nature.

The main problem of hydrate is it could lead to pipeline blockage.

2.4 Pipeline Inspection Gauge (PIG)

"Pigs have been used in the pipeline industry for about 80 years. The first pigs were made out of straw or wood and wrapped tightly with wire or barbed wire and propelled down the pipeline with the crude oil or product to do a cleaning job inside the pipe. This scraping tool made a squealing sound, like a pig, as it went by in the pipeline and that is where the name "pig" came about."Shashi Menon, E Ph.D., P.E., Bany G. Bubar, P.E., Glenn A. Wininger, Hal S. Ozanne, William E. Bauer (2011, p. 319).

2.4.1 Purpose of Pig

Pigs have many use and purpose "many procedures that are needed for increased pipeline longevity, improved pipeline efficiency, and risk reduction, such as reducing the effect of internal corrosion, cannot be done without having pigging capability. Operators need to run cleaning pigs to de-wax and descale the inside surface of the pipe and remove debris, which help improve pipeline performance, and they can do all this without significantly interrupting product flow to the customer." (E. Shashi et al. 2011, p. 320).

"A large variety of pigs has now evolved to perform operations such as cleaning out deposits and debris, locating obstructions, liquid and gas removal, and internal inspection for damage corrosion spots in pipelines. Pigging helps keep the pipeline free of liquid, reducing the overall pressure drop, and thereby increasing the pipeline flow efficiency.” (Hosseinalipour, S.M., ZarifKhalil, A., Salimi, A., 2007)

“The PIG is a device which is inserted into a pipeline and travels throughout the pipeline to be inspected. It plays a major role in pipeline operation such as maintaining continuous operation and maximum efficiency by removing any debris and deposit restricting the flow. Furthermore, it plays a role in monitoring the physical conditions of the pipeline.”(Nguyen, T.T., Kim, S.B., Yoo, R.H., Rho, ¥.W., 2001)

2.4.2 Types of PIG

Since the introduction of pigs until today there have been many changes and evolution on the pig design and purpose. Today we can classify that pig into several types such are, utility pigs, inspection pigs, specialty pigs and gel pigs. Under the type of utility pigs there was a much broader selection of pigs. Utility pigs can be divided to 2 groups, first is cleaning pigs and second is sealing pigs. “Cleaning pigs, which are used to remove solid or semi-solid deposits or debris from the pipeline. Sealing pigs, which are used to provide a good seal in order to either sweep liquids from the line, or provide an interface between two dissimilar products within the pipeline.”(Pigging What, Why, and How, 2011)

Under the two groups mention above there are more types of pigs for more specific job. Other forms of pigs are such:-

- “Mandrel pigs, which have a central body tube, or mandrel, and various components which can be assembled onto the mandrel to configure a pig for a specific duty.
- Foam pigs, which are molded from polyurethane strips and/or abrasive materials permanently bonded to them.
- Solid cast pigs, which are molded in one piece, usually from polyurethane.
- Spherical pigs or spheres, which are of either a solid composition or inflated to their optimum diameter with glycol and Or water.” (Pigging- What, Why, and How, 2011)

Other types of pigs other than utility pigs are specialty pigs, inspection pigs and gel pigs.

2.4.3 PIG Speed

“The general rule-of-thumb - velocity for any size diameter pipeline is greater than four feet/sec but less than 15 feet/sec. It is not that velocities greater than 15-feet/sec cannot be used, but experience and studies by pig manufacturers have shown that, at that elevated speed, hydroplaning of the pigs will occur in the presence of liquids, which causes greater blow-by, leaving greater volumes of liquid and entrained solids in the pipeline. This frustrates the objective, which is to remove the solids and minimize free liquids in the pipeline. Special procedures must be designed with your cleaning service company to counteract this concern.” (Randy L. Roberts , 2009). “On stream gas pigging speed is in the region of 2Mph to 8 Mph, though the following are considered to be typical speeds for utility pigging and are given as reference only." (Wint D., 2012)

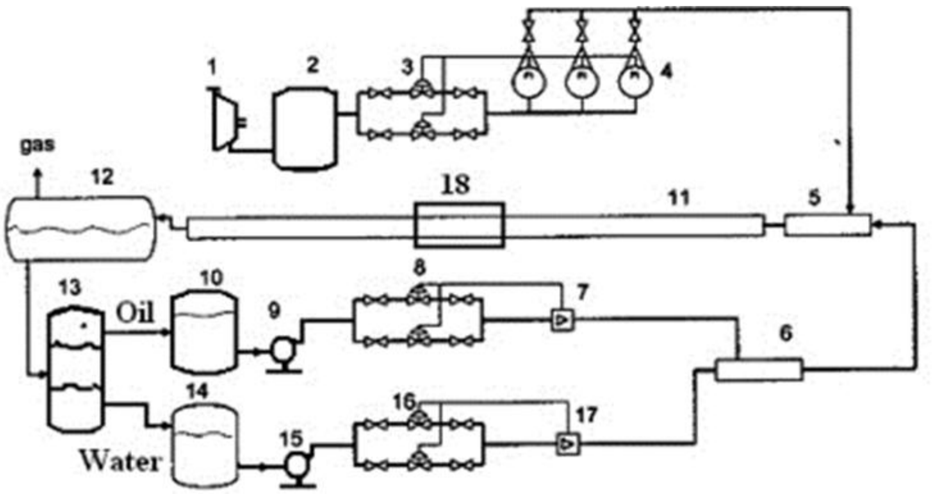
2.5 Pipeline

"An important decision to be made when planning the installation of a new pipe-line or modifications to an existing pipeline is to determine the materials to be used in the design and construction of the line. Factors to be taken into consideration when making this determination include the following: product and daily volume to be transported, operating pressure, location where the line is to be installed, and types of construction to be employed. American Petroleum Institute (API) codes and recommended practices are used in the pipeline industry in the selection of materials for pipelines and components. These codes are incorporated by reference in regulations regulating the industry."

"Steel pipe is normally used for pipelines operating at a pressure of 100 psig or more. Steel pipe withstands high pressures, is durable, and has a long operating life cycle. Fiberglass, PVC, or high-density polyethylene (HDPE) pipe is used in certain instances for low-pressure gas gathering pipelines. Components of the pipeline include the following: pipes, valves, fittings, and equipment such as metering, pumps, and compressors."

2.5.1 Example of Test Pipeline Loop

Example of Three-phase flow test loop in China University of Petroleum.



1—compressor, 2/10/14—surge tanks, 3/8/16—regulator, 4/7/17—single-phase flowmeter, 5/6—mixter, 12/13—separator, 9—oil pump, 15—water pump, 11—straight pipes, 18 —test section

Figure 2.1: Phase flow loop (Source: Geng Y. et al., 2011)

2.6 Computational Fluid Dynamics (CFD)

"Traditional restrictions in flow analysis and design limit the accuracy in solving and visualization fluid-flow problems. This applies to both single-and multi-phase flows, and is particularly true of problems that are three dimensional in nature and involve turbulence, chemical reactions, and/or heat and mass transfer. All these can be considered together in the application of Computational Fluid Dynamics, a powerful technique that can help to overcome many of the restrictions influencing traditional analysis."

“CFD modeling provides a good description of flow field variables, velocities, temperatures, or a mass concentration anywhere in the region with details not usually available through physical modeling. It is especially useful for determining the parametric effects of a certain process variable. Once the basic model is established, parametric runs can usually be accomplished with reduced effort. In addition, CFD can be used to simulate some of the hard to duplicate experimental conditions or to investigate some of the hard to measure variables.” Mr. Thomas L. Lumley, Mr. Marc D. Voisine P. Dr. Henry V. Krigmont (n.d.)

CHAPTER 3

MATERIALS & METHODS

3.1 Chapter Overview

This chapter will discuss about the software used to run the flow of natural gas simulation in the small size pipeline. The overview of step by step approach from the geometry building in Gambit to iteration in Fluent and the parameters involved to get the required result.

3.2 Methodology Flow Chart

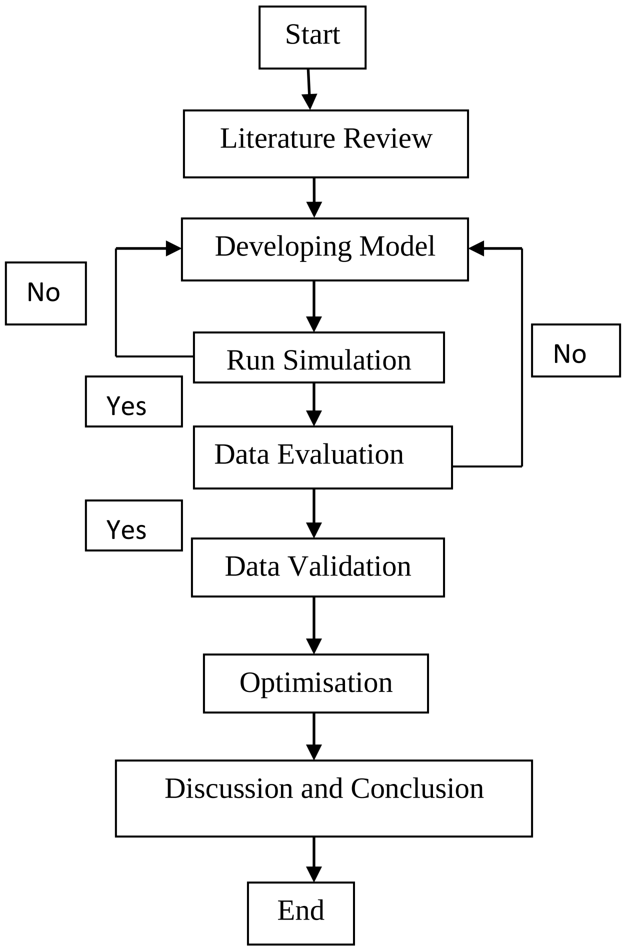


Figure 3.1: Process Work Flow

3.3 CFD Methodology

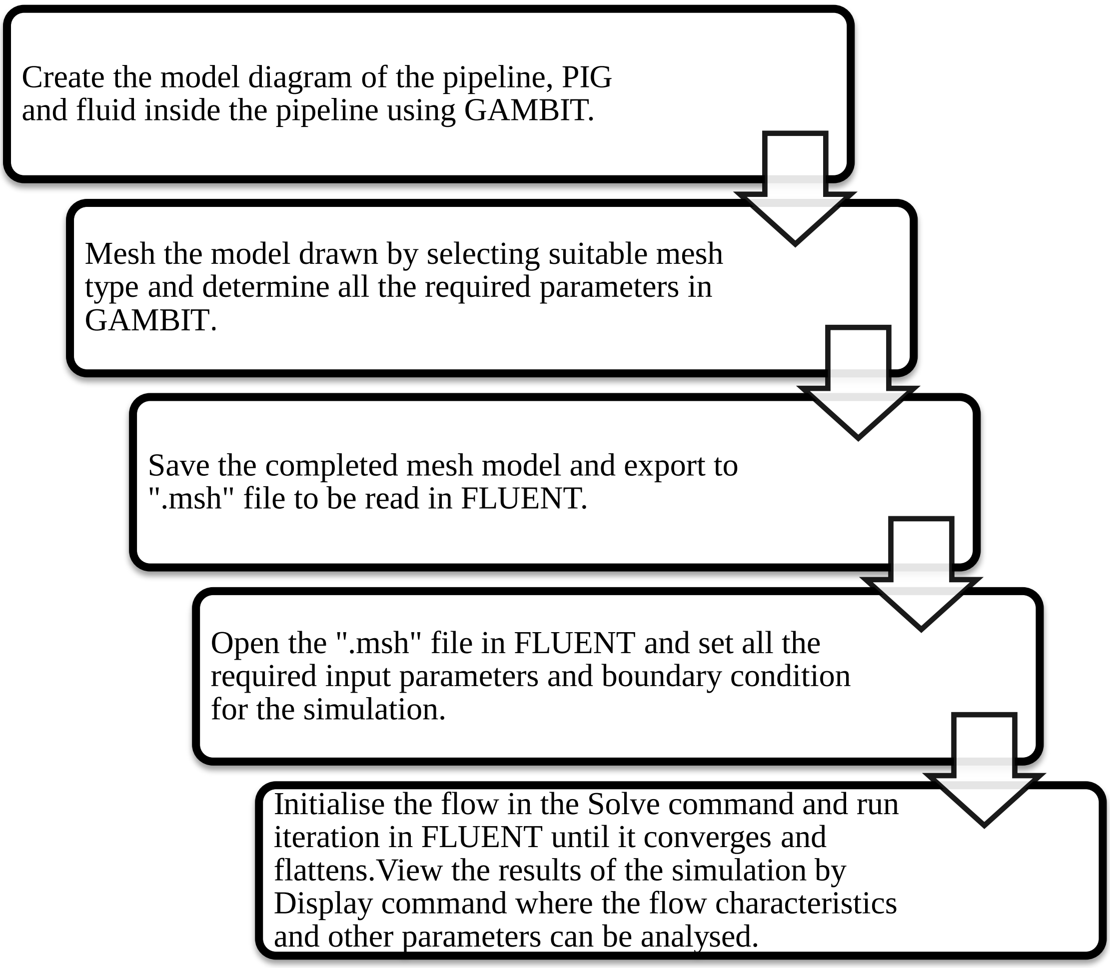


Figure 3.2: CFD Work Flow

3.3.1 CFD Methodology Used

1. Create face of pipe and pig on the interface as shown in Figure 3.3.1.

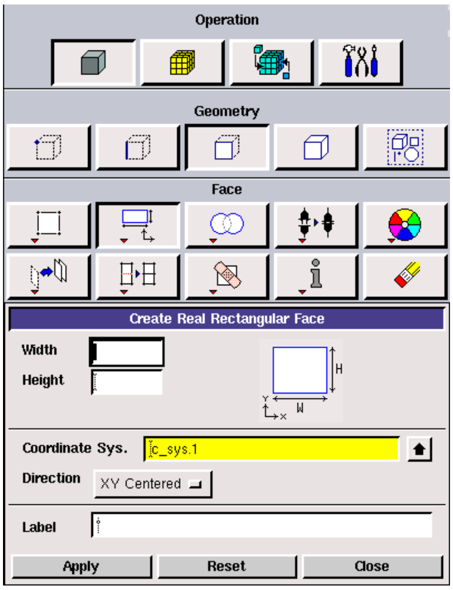


Figure 3.3.1: Face Creation Interface

2. Mesh the face of the model drawn using the interface as shown in Figure 3.3.2.

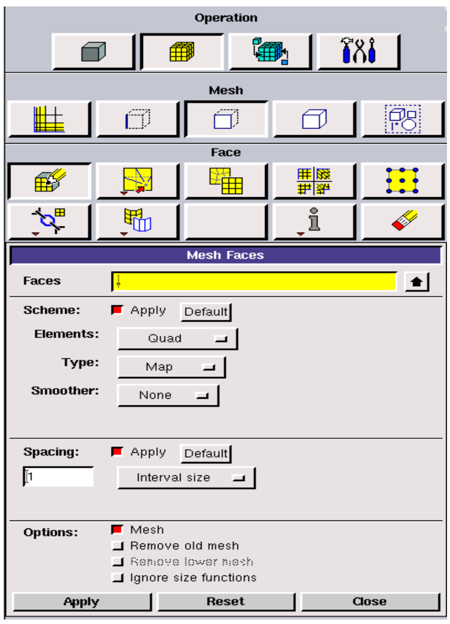


Figure 3.3.2: Mesh Drawing Interface

3. Specify the boundary and continuum types on the interface shown in Figure 3.3.3.

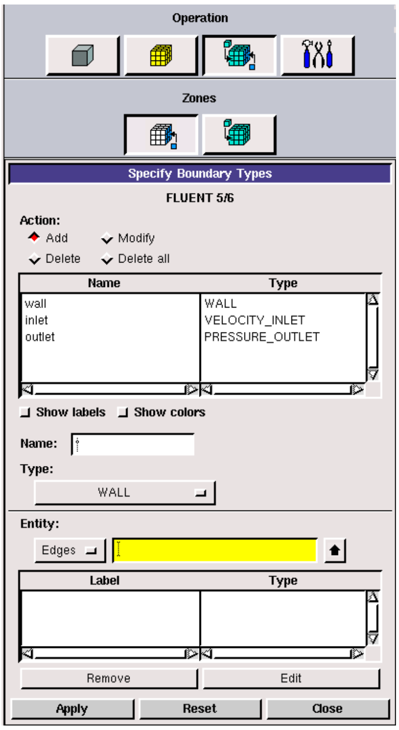


Figure 3.3.3: Boundary and Continuum Setting Interface

4. Export to ".msh" file like as shown in Figure 3.3.4

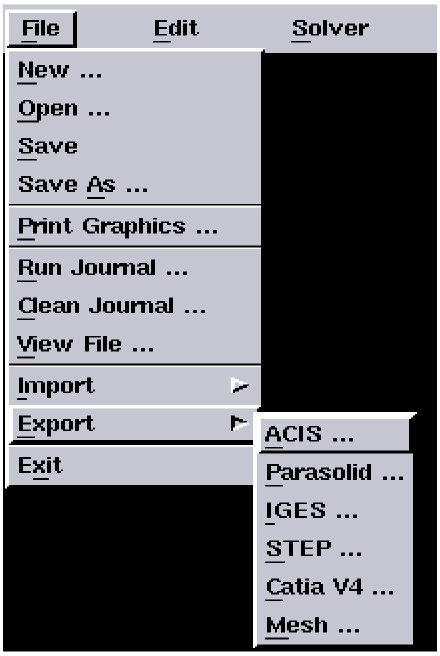


Figure 3.3.4: Exporting .msh file

5. Run FLUENT and Read Case (".msh") file exported from GAMBIT following step shown in Figure 3.3.5 and Figure 3.3.6.

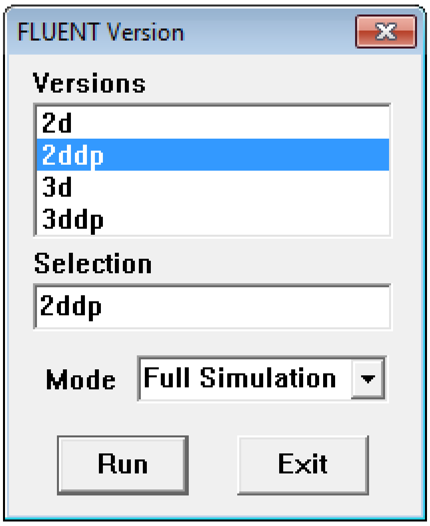


Figure 3.3.5: Fluent Starting Interface

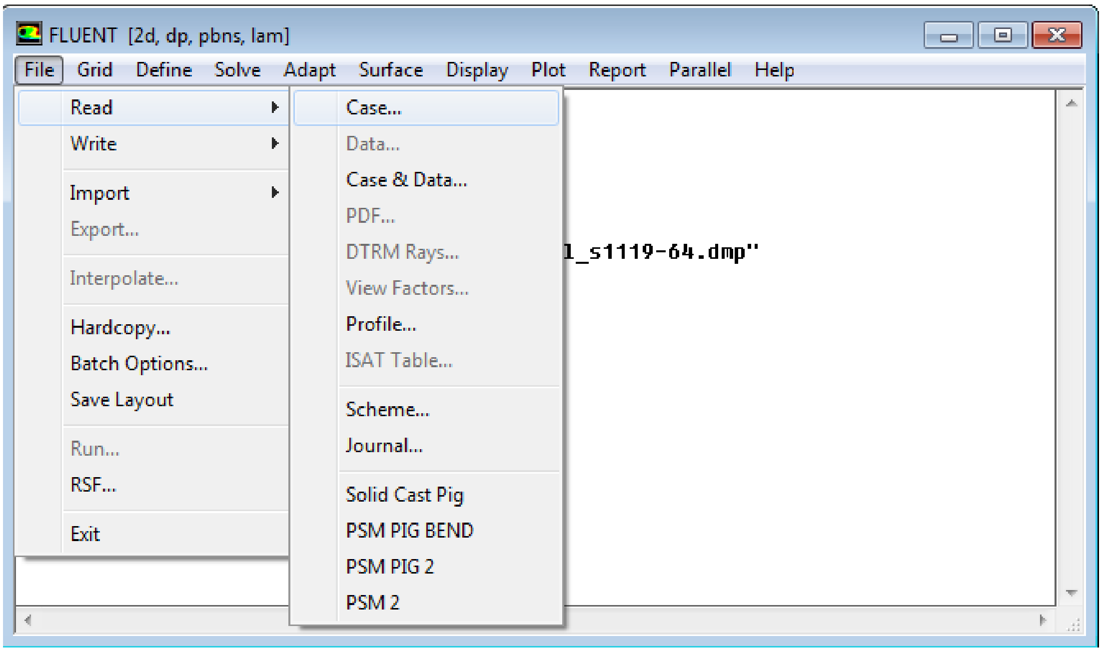


Figure 3.3.6: Reading .msh Case File

6. Specify Solver, Viscous Model, Material, Operating Condition, and Boundary Condition following each step as shown from Figure 3.3.7 to Figure 3.3.10

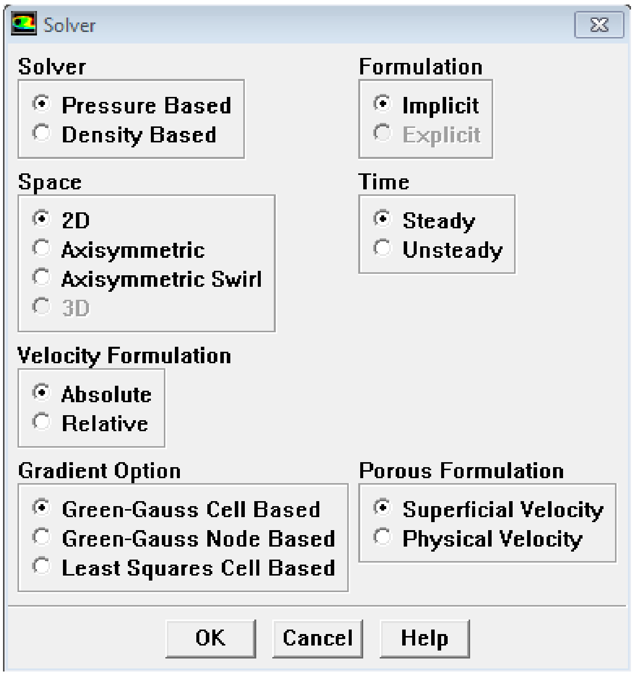


Figure 3.3.7: Solver Interface

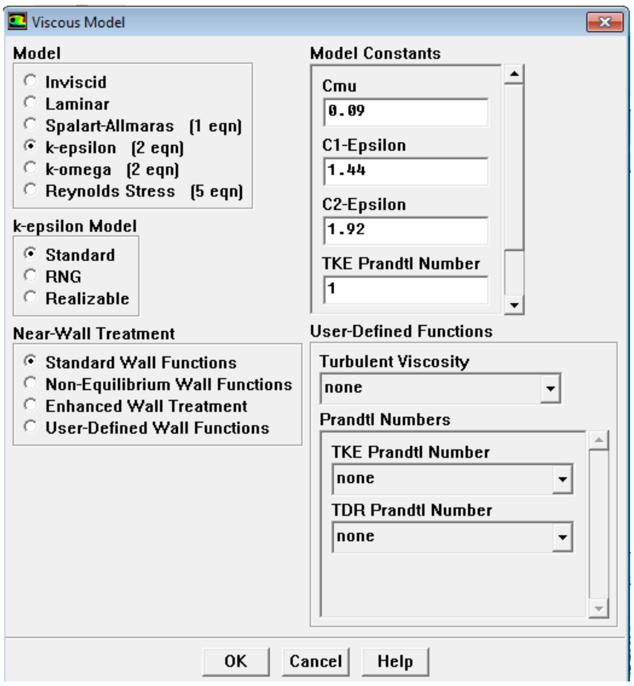


Figure 3.3.8: Fluid Viscous Model Interface

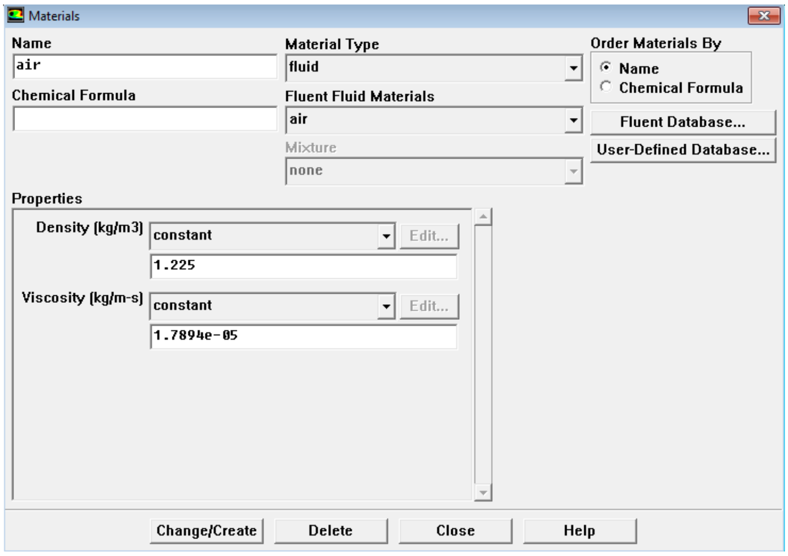


Figure 3.3.9: Material Selection Interface

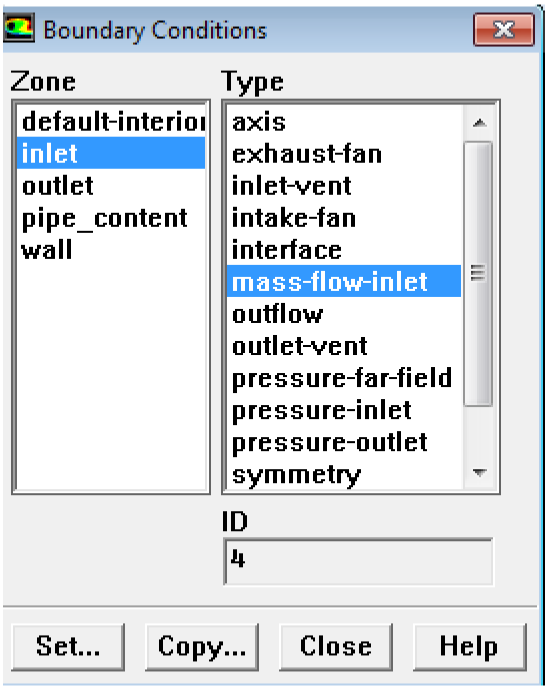


Figure 3.3.10: Boundary Condition Setting Interface

7. Initialise the problem as shown in Figure 3.3.11 and iterate like shown in Figure 3.3.12.

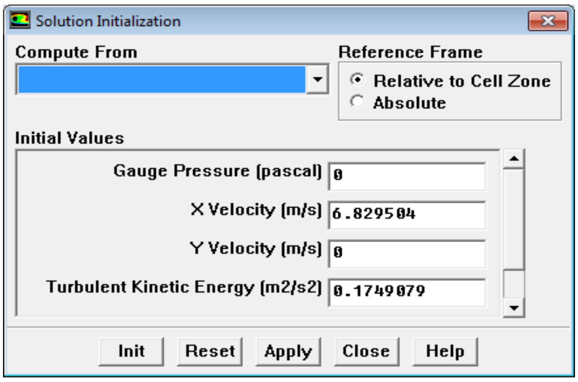


Figure 3.3.11: Solution Initialisation Interface

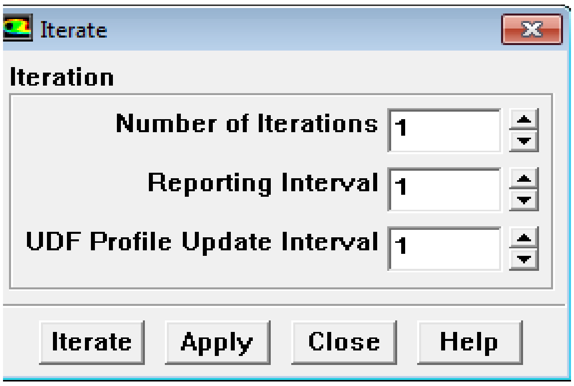


Figure 3.3.12: Iteration Setting Interface

8. Example of a converged iteration in Figure 3.3.13 and contour displayed in Figure 3.3.14

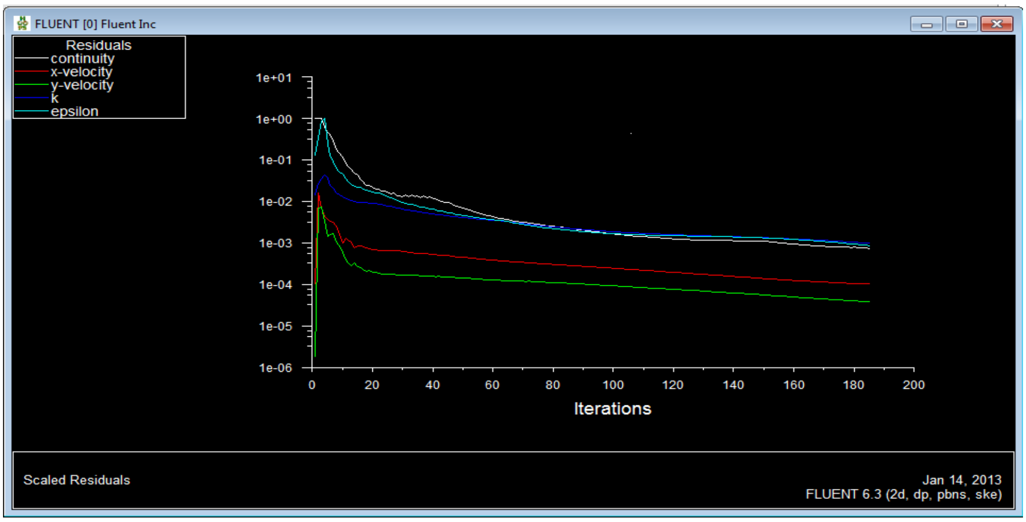


Figure 3.3.13: Example of Converge Iteration

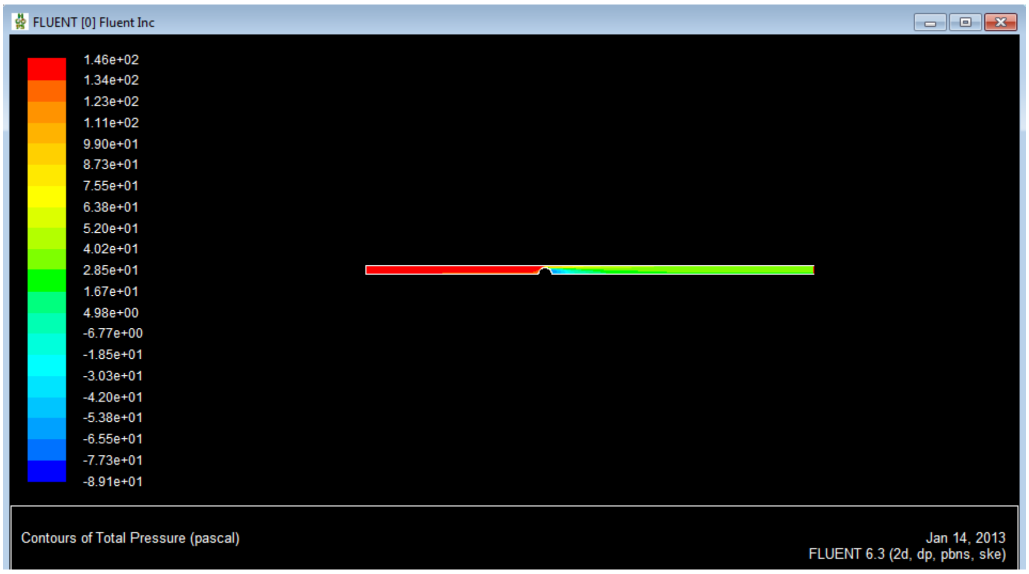


Figure 3.3.14: Example of Contour Result Display

3.4 Parameters

Assumptions made in the gas flow were:

- Natural gas flow was single phase.
- Flow was turbulent (K-Epsilon 2 Equation).
- The phase was single phase (Methane Only) dry gas.
- No energy loss due to friction with pipeline wall.
- Gas was in ideal gas condition
- Gas assume compressible
- Pipe has constant diameter

- As a rule, most pigs of any type are a standard design with a length-to diameter ratio of 1.5 times the OD of the pipe, i.e. a 24-inch pig is 36 inches in length. (Roberts R. L., 2012)

Table 3.1 Pig Variables

Fixed Variables	Manipulated Variables	Responding Variables
1. Steel Pipe **2.** 3 inches diameter **3.** Isothermal **4.** 10 meter test length **5.** Single Phase flow **6.** Turbulent flow	1. Types of pig (foam pig and solid cast pig) 2. Pig worn out percentage (15% and 10%) 3. Mass flow rate (0.0835 kg/s, 0.2388 kg/s and 0.4124kg/s)	1. Velocity flow 2. Pressure 3. Turbulence Intensity

Table 3.2 Hydrates Variables

Fixed Variables	Manipulated Variables	Responding Variables
1. Steel Pipe 2. 3 inches diameter 3. Isothermal 4. 10 meter test length 5. Single Phase flow 6. Turbulent flow 7. Mass flow rate	1. Size of Hydrates (1/4 and ¾ of pipe diameter)	1. Velocity flow 2. Pressure 3. Turbulence Intensity

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Results

In this chapter, all the results obtained from the simulation using ANSYS Fluent software was presented and discussed accordingly. In the first part, the effect of hydrates to the flow of natural gas in small size diameter distribution pipeline and in the second part the analysis of criteria needed to choose the best type of PIG for pipeline cleaning purpose.

4.2 Hydrates

Hydrates was modeled to be a solid that plagued the below region of the pipe since it has higher density and mass compare to natural gas. The position of the hydrate was fixed and high velocity natural gas flow will not affect the position of the hydrate. The flow pattern of natural gas around the hydrate was studied, based on velocity, pressure and turbulence flow.

4.2.1 Velocity

Contours of Velocity Magnitude (m/s)

Fluent 6.3 (2d, dp, pbns, ske)

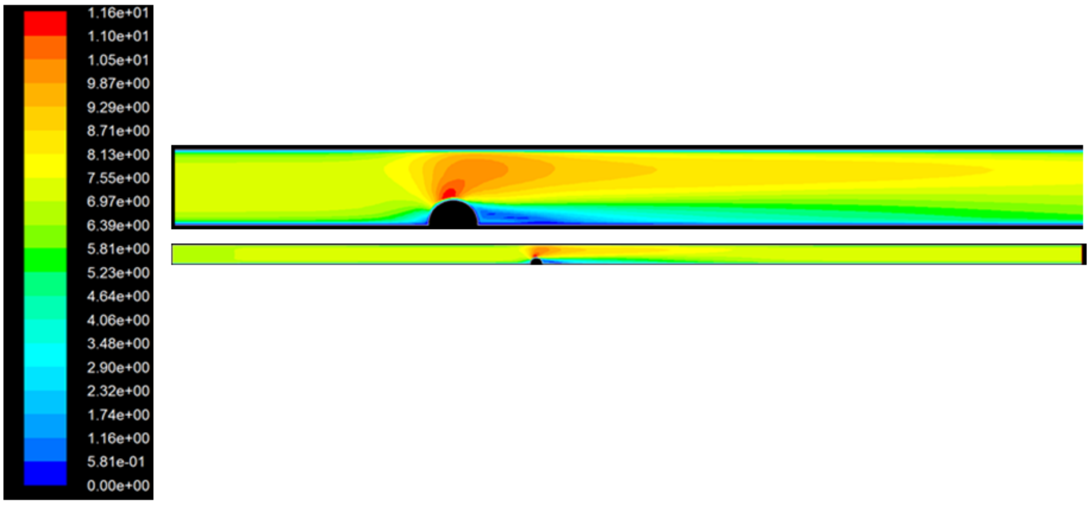


Figure 4.2.1: Small Size Hydrate (Velocity)

Fluent 6.3 (2d, dp, pbns, ske)

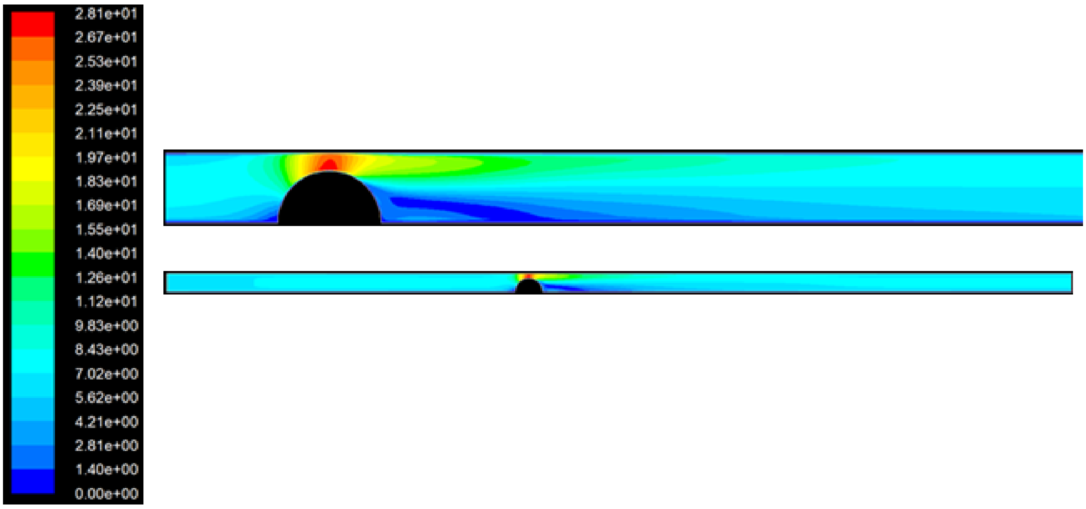


Figure 4.2.2: Big Size Hydrate (Velocity)

In the first part comparison was made in the aspects of velocity change between the two pipelines with different size of hydrate in each pipeline. In the diagram for the small hydrate effect, we can see generally the flow velocity of natural gas in the pipeline before the hydrate was in the region of 5.81 m/s to 8.71 m/s as have been pictured with the colour light green to yellow region in the scale. As the flow approach the hydrate the colour tones increase indicating increase in flow velocity of the natural gas. On the region where the natural gas flow went pass through the small hydrate the velocity increase sharply on the upper region of the pipe while on the lower region of the pipe after the hydrate there was a drop in velocity that reach 0m m/s. The sharp increase in flow velocity can be seen clearly with the colour of velocity flow increase from bright yellow to orange and red colour in the velocity magnitude contour. This area of velocity increase is in the region of 9.29 m/s to 11.6 m/s. As the flow continues past the hydrate, the velocity of the natural gas flow vary from near zero in the lower region to greener coloured region which indicate that the velocity was in the region of 5.23 m/s which is lower than before the flow hit the hydrate and lastly to yellow coloured region where it is the same as before the hydrate. But as the flow progress the velocity gradually stabilise back to the initial velocity before it went through the hydrate.

In the second part where the contour of velocity magnitude clearly depicted for the big hydrate size, we can see different set of colour tone if compared to the first part of the observation. In this second part we can see clearly the flow before the hydrate was coloured light blue in region of velocity of flow from 5.62 m/s to 8.43 m/s but as flow reach the big hydrate which occupy ¾ the pipe size diameter the velocity increase sharply same like in the small hydrate situation. The velocity near the hydrate vary from 12.6 m/s minimum to 28.1 m/s maximum at the region directly between the hydrate and upper pipe region. But as flow progress the same flow pattern can be seen between the small hydrate and the big hydrate which is the bottom region after the hydrate the flow velocity is nearing 0 to 1.4 m/s while near the middle and top region the flow is decreasing after the sharp increase in velocity. The region after hydrate show that the velocity is gradually stabilizing to its initial velocity before it hits the hydrate.

The velocity at the inlet is constant nearing the velocity set from the mass flow rate in to the pipe which is 1.7 kg/s and around 6 m/s to 7 m/s velocity. The hydrate cause the pipe size diameter to shrink thus disturbing the flow of the natural gas. This in turn disturbs the efficiency of the gas supply from producer to consumer. We can see the velocity is high directly above the hydrate. This is because of the shrinkage of area.

$$\text{Velocity}=\frac{Volumetric\ Flow\ Rate}{Cross\ sectioanl\ area\ of\ pipe}$$

Velocity is inversely proportional to cross sectional area. Decrease in area means increase in velocity. This high velocity area is dangerous as sudden increase in velocity of the natural gas flow can harm the structure of the pipe. Constant supply of this high velocity on that region of the pipe can cause pipe erosion as result constant bombardment of gas particle to the pipe wall. By time erosion can lead to pipe leakage. Comparison can be made with the bigger size hydrate. The high velocity region is much bigger and the velocity is much faster than the small size hydrate effect. This in turn can increase the erosion effect and cause the pipe integrity to easily disturbed.

4.2.2 Pressure

Contour of Total Pressure (Pascal)

Fluent 6.3 (2d, dp, pbns, ske)

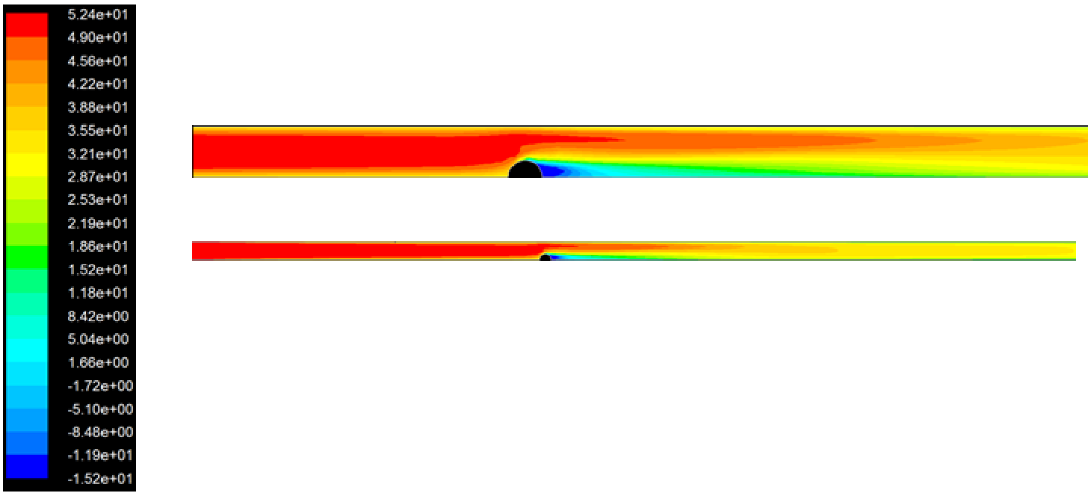


Figure 4.2.3: Small Size Hydrate (Total Pressure)

Big Size Hydrate

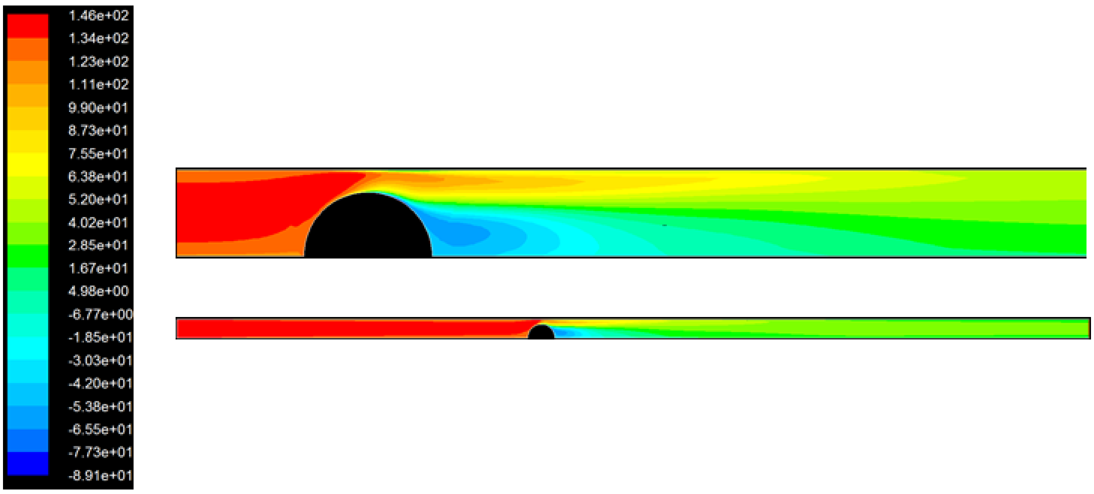


Figure 4.2.4: Big Size Hydrate (Total Pressure)

After going through the velocity contour now we will analyze the total pressure contour. For the small size hydrate the pressure at the pipe inlet was 52.4 Pascal from top to bottom, but when flow progress nearing the hydrate, the pressure decrease near the bottom and upper region of the pipe. As the flow hits the hydrate there was big change in pressure. The region after the hydrate has negative pressure region depicted with blue color. Progressing through the flow, the pressure decrease gradually to around 49 Pascal and 32.1 Pascal. Exception given to the lower region, where the pressure increases gradually from the negative pressure around the hydrate. The pressure increase steadily to create stable pressure with the upper region of pipe. For the big size hydrate, the pressure pattern before hydrate is the same like the small hydrate situation. Initially with pressure 146 Pascal but when flow nears the hydrate region the pressure decreases sharply especially directly after the hydrate upper region. The bottom region created a negative pressure region but gradually increase its pressure back to the same level as the upper region of the pipe. The upper region pressure decrease to around 16.7 Pascal to 28.5 Pascal.

The significant result that we can see from the total pressure contour is that the pressures build up before the hydrate is much higher for bigger hydrate compared to the smaller hydrate. High pressure build up is the result of the hydrate that block the flow of natural gas decreasing the area of which gas can flow causing pressure to increase before the hydrate. Not just that, the pressure drop for the big hydrate is bigger after the flow pass through the hydrate. The high pressure build up before the hydrate can also cause harm to the pipe integrity as this is because the pipe is expose to constant high pressure stress. Constant stress can lead to the pipe material reach its limit. For example Polyethylene pipe has high ductility but constant stress can lead to the pipe swollen. Consequences of deposition of wax, hydrates, or other substances are firstly inner diameter will be reduces the effect is restricted flow in the pipeline that lead to higher pump capacities for compensation in result cause rise in operation costs. (Stolze B., 2007)

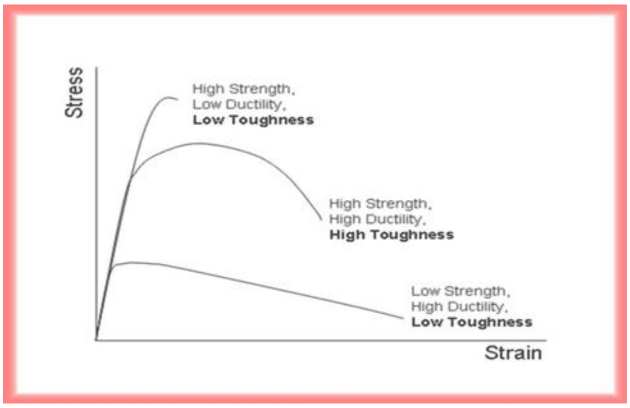


Figure 4.2.5: Stress vs. Strain

4.2.3 Turbulence Intensity

Contour of Turbulence Intensity (%)

Small Hydrate

Fluent 6.3 (2d, dp, pbns, ske)

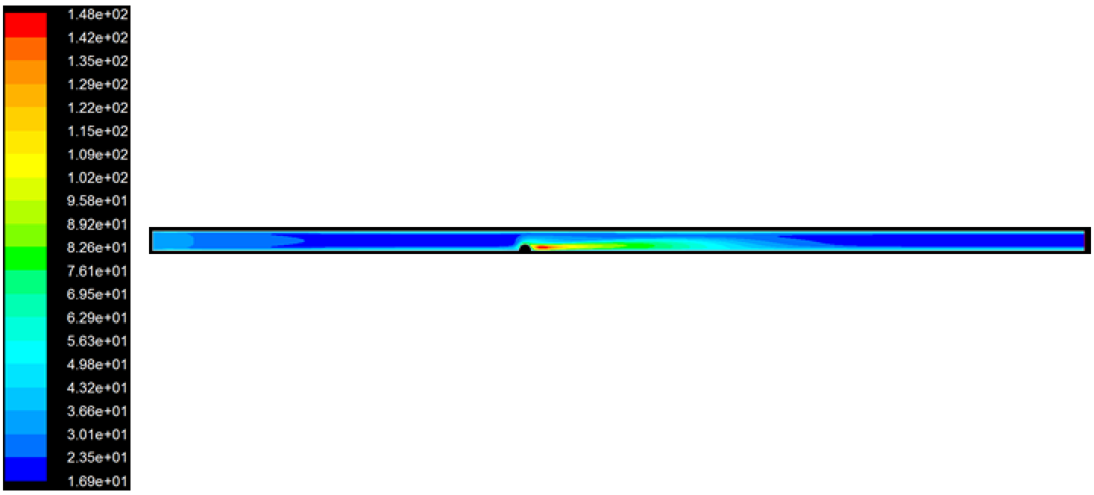


Figure 4.2.6: Small Size Hydrate (Turbulence)

Big Hydrate

Fluent 6.3 (2d, dp, pbns, ske)

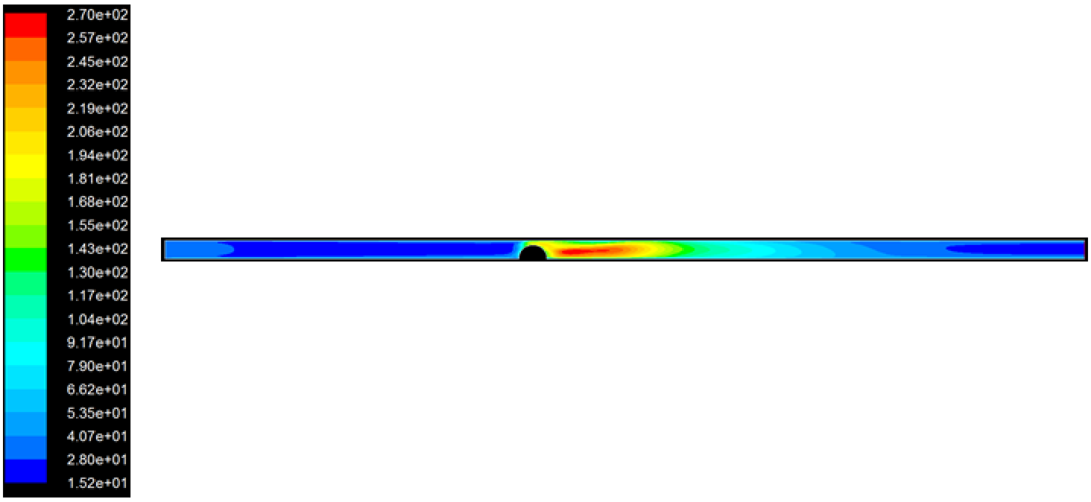


Figure 4.2.7: Big Size Hydrate (Turbulence)

For the small hydrate the turbulence intensity at the upper and bottom region of the inlet was constant, but at the middle region the intensity gradually decreased from the inlet to nearing the hydrate. When the flow went through the hydrate the turbulence intensity spike to maximum of 148 % near the bottom region of the hydrate. But when flow continues the intensity normalize back to 16.9 %.

For the big hydrate situation, the pattern mimics the small hydrate situation but differs in size of the turbulence intensity region. Directly before the flow hits the hydrate the intensity increased to that of 117% and as flow pass through the hydrate the intensity maxed out at 270% of the flow. After the flow pass through the hydrate the intensity normalize back to its initial condition.

The size of hydrate also has high impact on turbulence intensity. The bigger the hydrate the higher the intensity magnitude and region in the pipeline. The gases flowing through the hydrate as an obstacle cause it to swirl and produce a turbulent flow. High turbulent intensity affects the pipe wall. As the swirling effect can erode the pipe by time a pit will appear on the pipeline wall. The pit can increase the erosion rate. “The increased turbulence caused by pitting on the internal surfaces of a tube can result in rapidly increasing erosion rates and eventually a leak. For example, burrs left at cut tube ends can upset smooth water flow, because localized turbulence and high flow velocities, resulting in erosion corrosion. A combination of erosion and corrosion can lead to extremely high pitting rates.” (Erosion Corrosion, 2012).

4.3 Pipeline Inspection Gauge (PIG)

Pig was used for many purposed in pipeline but the first and most important role of Pig was for cleaning purpose. For the job of cleaning the inside surface of a pipeline, several types of Pig can be used. In this section we will be looking on the criteria needed to choose the best type of Pig between two types of Pig that is Polly-Pig or solid cast pig.

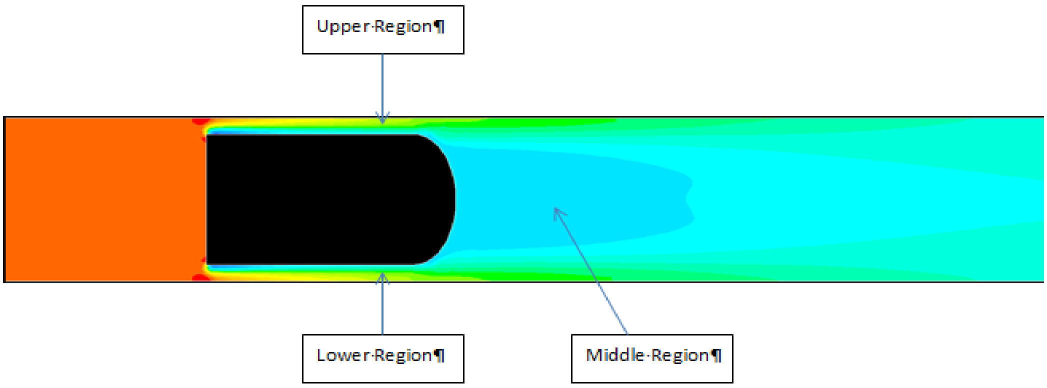


Figure 4.3.1: Pipeline Region

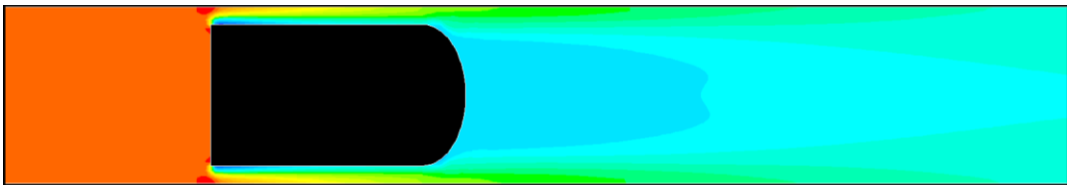


Figure 4.3.2: Foam Pig

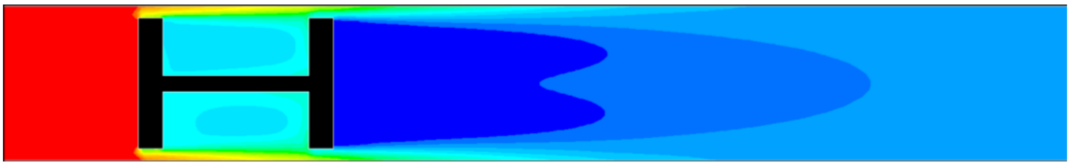


Figure 4.3.3: Solid Cast Pig

4.3.1 15% Shrink Percentage

4.3.1.1 High Velocity (4.4181 m/s)

Upper and Lower Region (Both Upper and Lower Have Same Pressure Gradient)

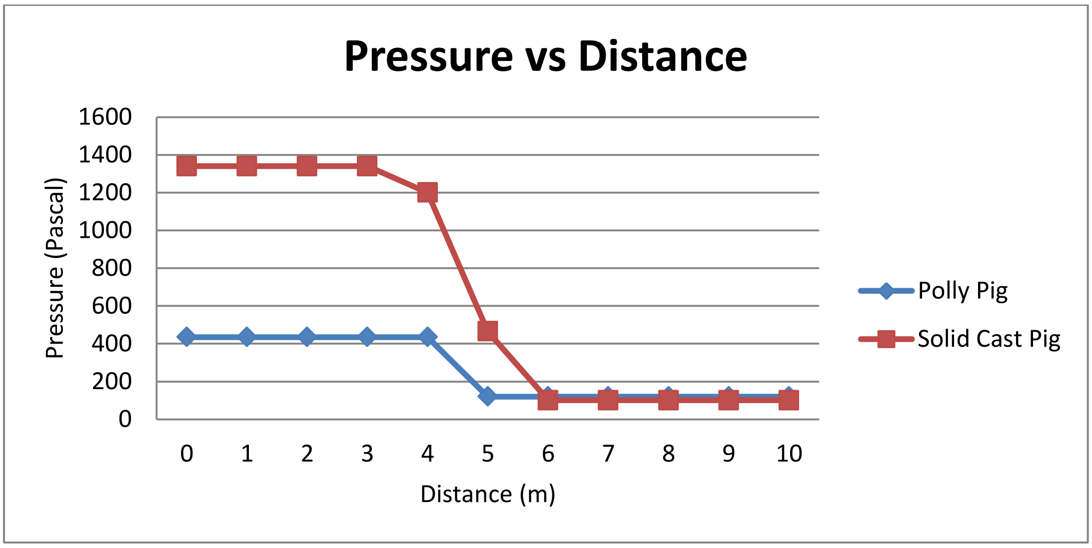


Figure 4.3.4: Upper and Lower Region (High Velocity)

Middle Region

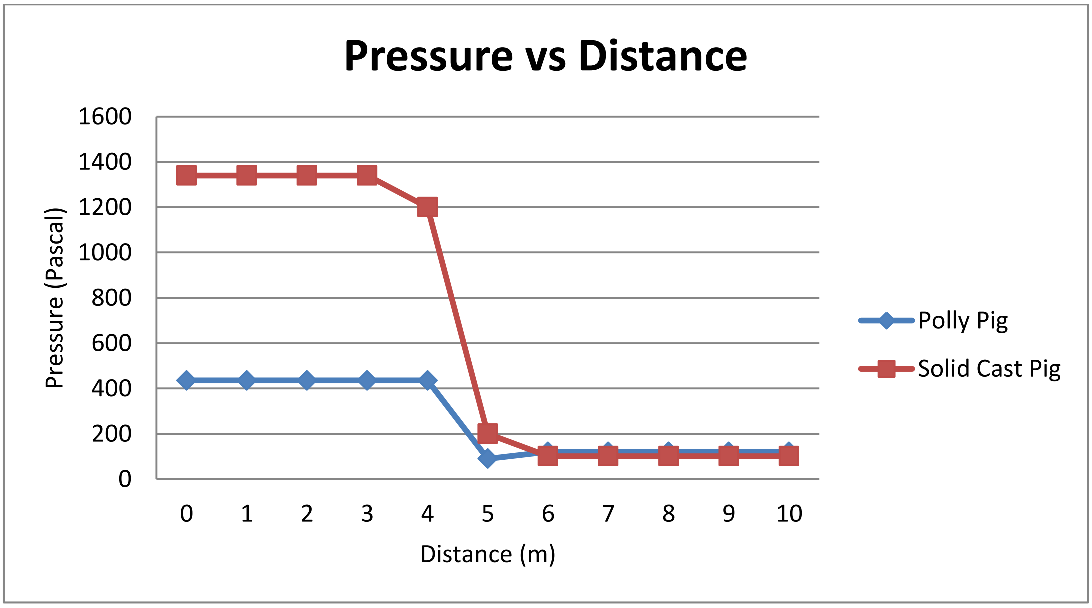


Figure 4.3.5: Middle Region (High Velocity)

4.3.1.2 Medium Velocity (2.5582 m/s)

Upper and Lower Region (Both Upper and Lower Have Same Pressure Gradient)

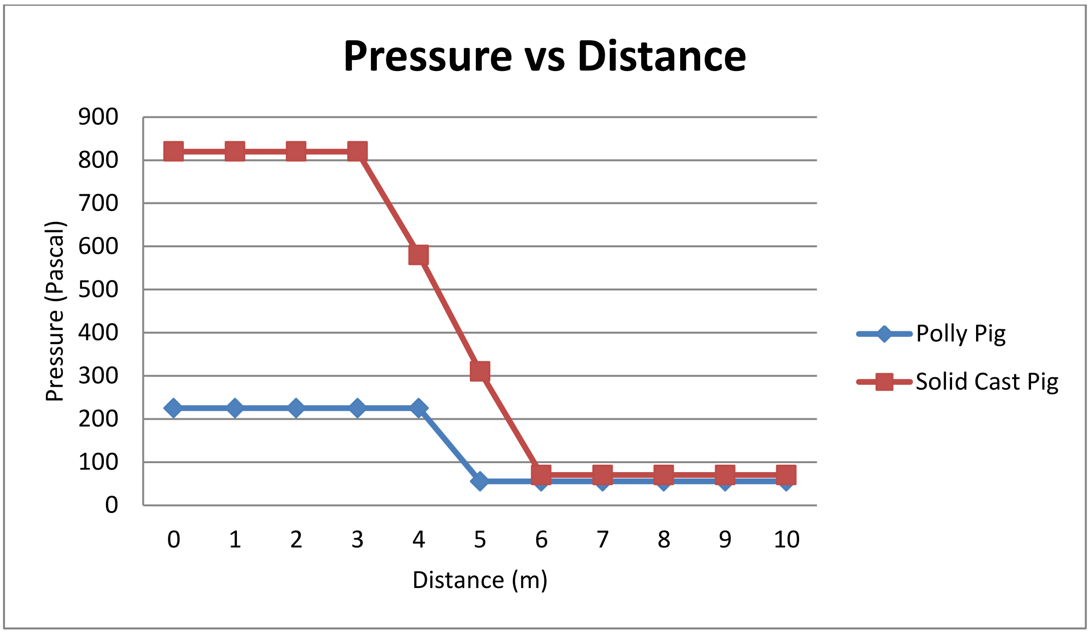


Figure 4.3.6: Upper and Lower Region (Medium Velocity)

Middle Region

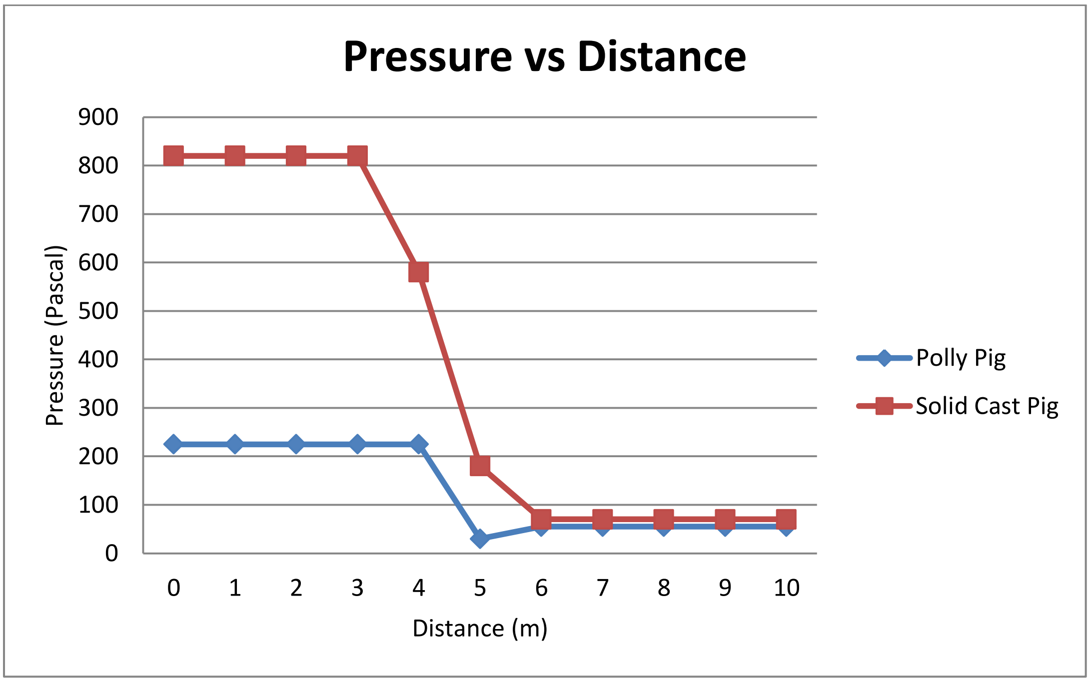


Figure 4.3.7: Middle Region (Medium Velocity)

4.3.1.3 Low Velocity (0.8945 m/s)

Upper Region

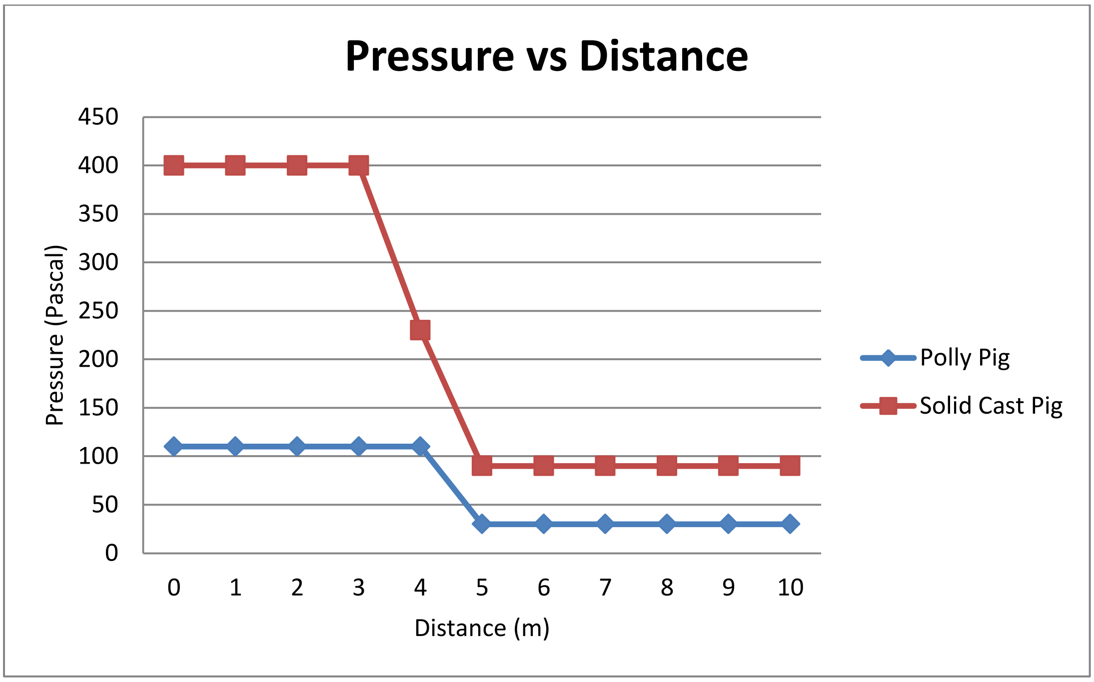


Figure 4.3.8: Upper and Lower Region (Low Velocity)

Middle Region

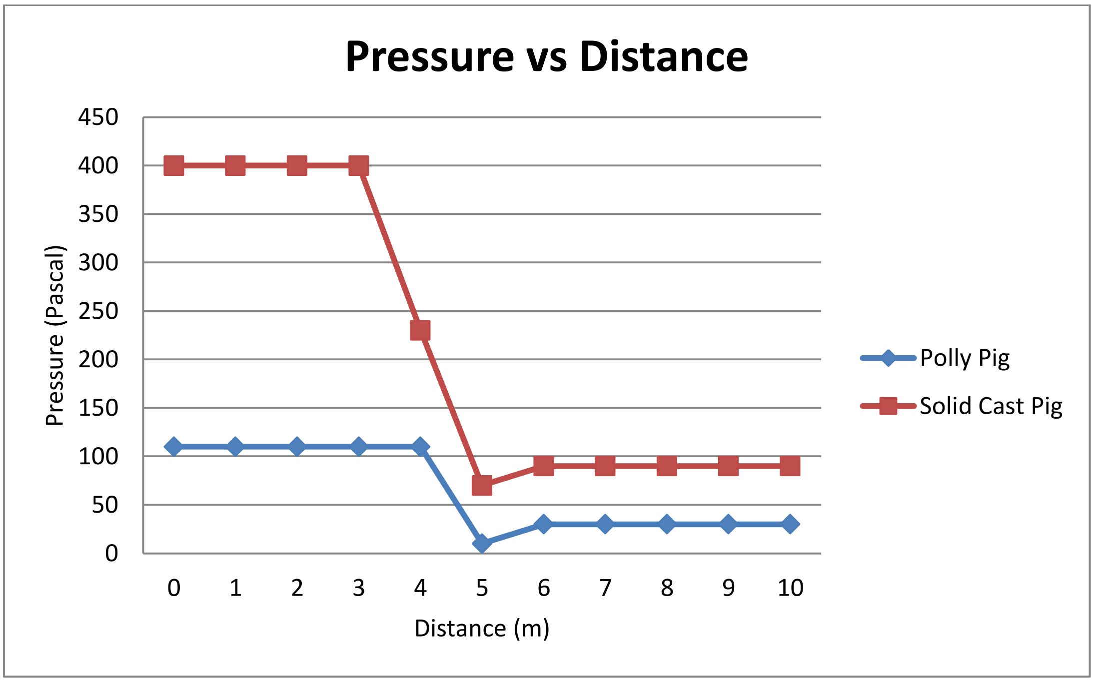


Figure 4.3.9: Middle Region (Low Velocity)

4.3.2 10% Shrink Percentage

4.3.2.1 High Velocity (4.4181 m/s)

Upper and Lower Region (Both Upper and Lower Have Same Pressure Gradient)

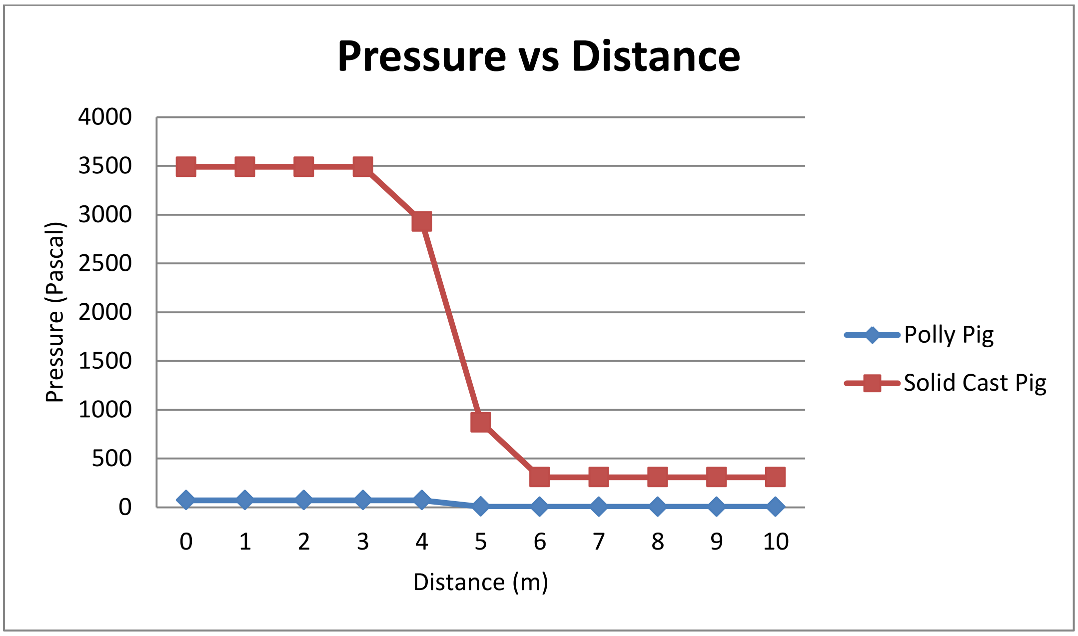


Figure 4.3.10: Upper and Lower Region (High Velocity)

Middle Region

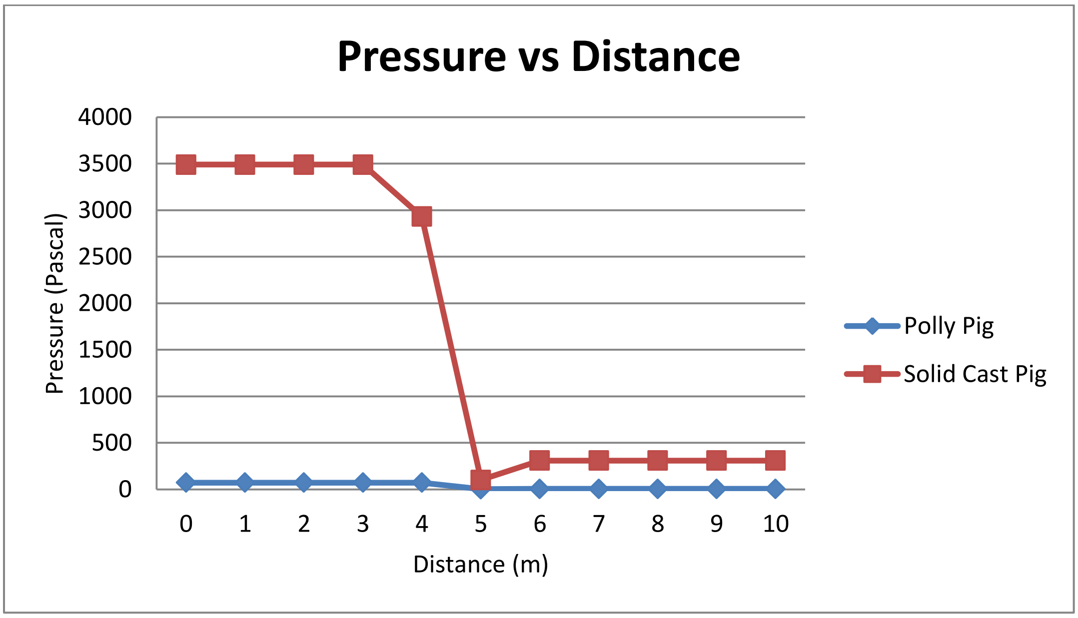


Figure 4.3.11: Middle Region (High Velocity)

4.3.2.2 Medium Velocity (2.5582 m/s)

Upper Region

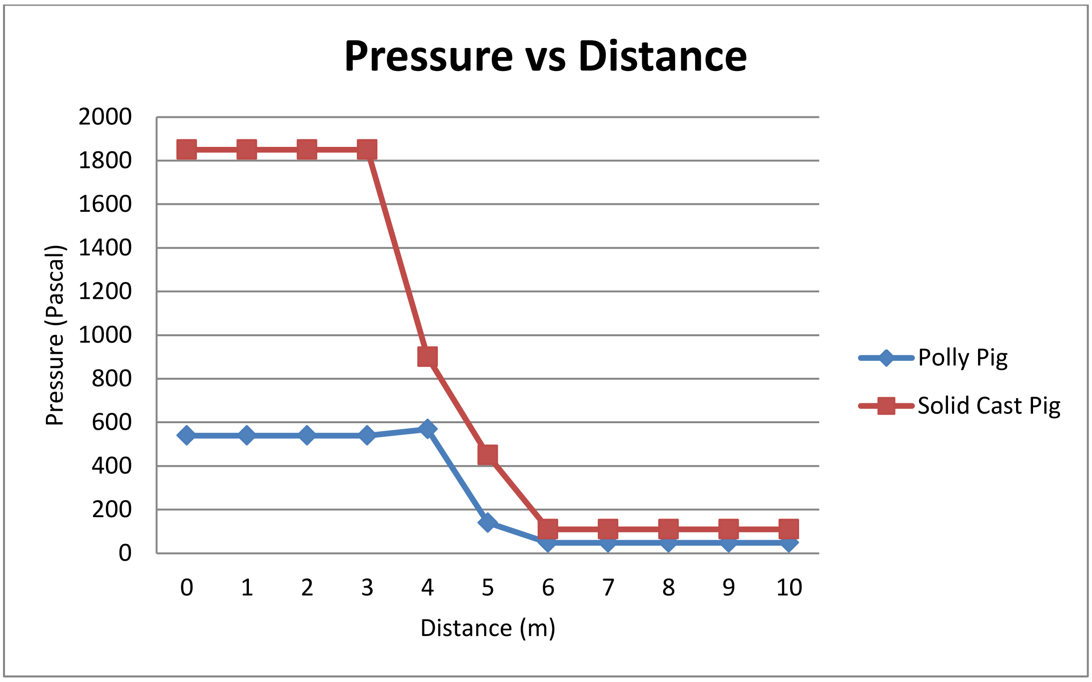


Figure 4.3.12: Upper and Lower Region (Medium Velocity)

Middle Region

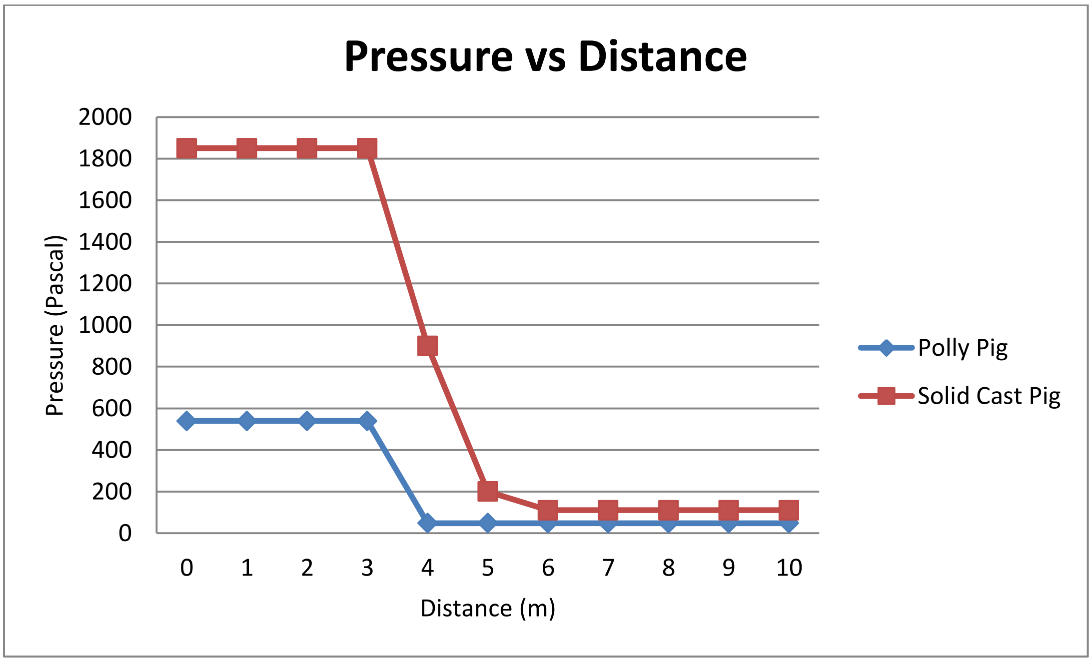


Figure 4.3.13: Middle Region (Medium Velocity)

4.3.2.3 Low Velocity (0.8945 m/s)

Upper Region

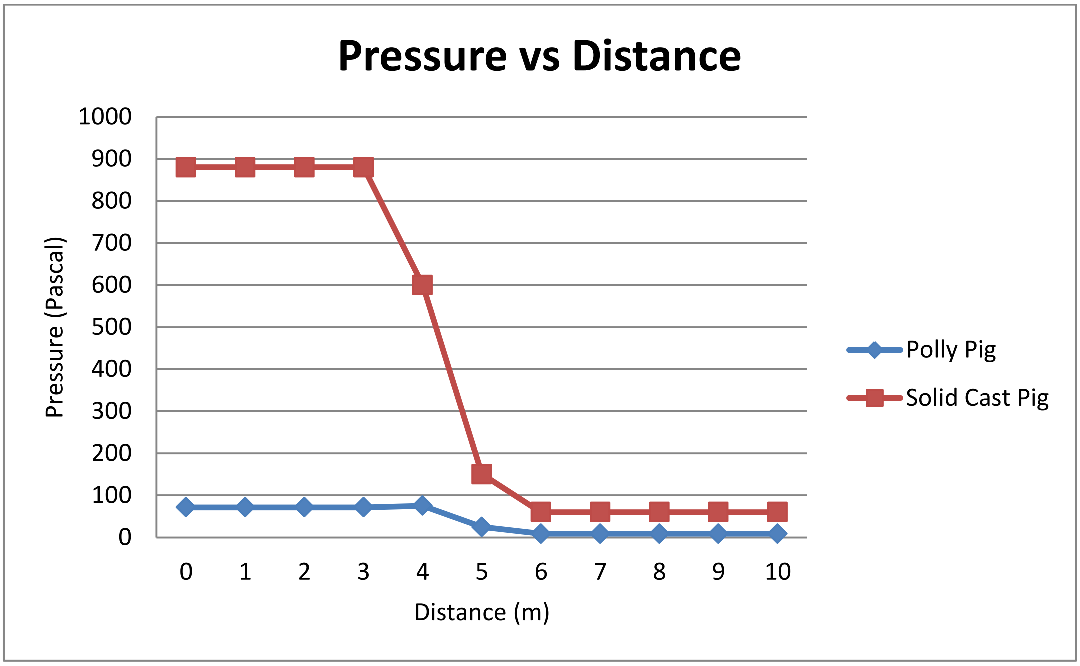


Figure 4.3.14: Upper and Lower Region (Low Velocity)

Middle Region

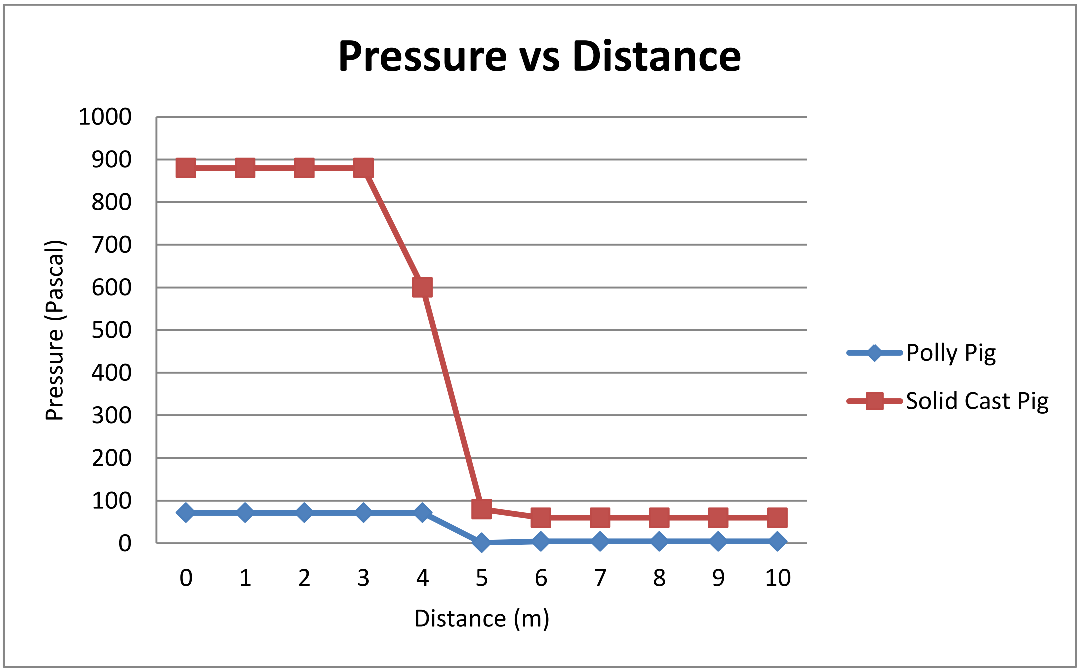


Figure 4.3.15: Middle Region (Low Velocity)

The trend we can see from both at 15% and 10% pipe worn percentage at all high, medium and low velocities were that the solid cast pig has bigger pressure drop than Polly pig. Since the pig favorable for effective pigging was the one that run close to constant velocity and less sudden acceleration and deceleration. We could decide that Polly pig is better than solid cast pig in doing the cleaning processes when there are worn out.

The big pressure drop can lead to pig move in a sudden acceleration and deceleration movement. This in turn led to less effective pigging. This is maybe because of the pig physical structure and shape. The shape of solid cast pig that consist of hollow space in the middle between the cup cause the flow to be trapped, creating turbulent flow in the hollow middle thus the pressure drop due to the momentum lost in. While in the Polly pig the pressure drop is not too significant this is because of the shape of Polly pig that has straight shape on both side of the pig thus creating less turbulent flow in front of the pig. Pressure drop was decreased.

The pig that has the less pressure drop has the more constant velocity. The Polly pig flow velocity was more constant also due to the fact of pig shape that influence the velocity and pressure drop.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The aim of this study was to choose between two types of pig that was the most suitable for cleaning purpose base on different worn out percentage. For comparison two models of pig was designed. One is foam pig or also known as Polly-pig and the second is solid cast pig. Both pigs have been put through the same pipeline and flow condition. The characteristic was determine based on velocity, pressure drop and turbulence intensity. The second objective was to identify the effect of different size of hydrate on the flow characteristics of natural gas flow in pipeline.

Simulation results showed that the best pig between foam pig and solid cast pig for cleaning purpose was foam pig. This decision was made by analysis on gas velocity that flows through the pig slit opening between pig and the wall. The gas velocity flow that was near the constant operational velocity would be chosen. Other than that, the factor of pressure drop. The lowest pressure drop in pipeline is preferable as this cause less disturbance to the flow.

The second objective which is the hydrates effect shows that the bigger the size of the hydrate the bigger the influence on the natural gas flow. The bigger hydrates size cause the highest velocity increase, bigger pressure build up, higher pressure drop and higher intensity of turbulent. Thus bigger hydrates present bigger risk and danger to pipeline integrity. Other than that bigger hydrates cause increase in power consumption of the pump thus increase operating cost to operate the pipeline.

5.2 Recommendations

For future improvements, in order to gain ideal results, the composition of natural gas could be made according to the typical pipeline natural gas composition in the market. Other than that the effect of temperature on the flow could be studied and also flow behavior on pipe bends or pipe height change.

5.2.1 More Pig Types

Other than foam pig and solid cast pig, there are many more other types of pig in the market that was used. For example, mandrel pig, spherical pig, geometry pig and smart pig. Each pig has different characteristic and each pig has different purpose and function in the pipeline. Future research can compare the performance of different types of pigs.

5.2.2 Hydrates Characteristics

In terms of hydrates variability, we can improve on the characteristic of the hydrates. A more accurate design of hydrates is that hydrates are porous solid that growth on size by time. Thus a porous solid have different result on the pipeline flow compared to a real solid hydrates.

REFERENCES

Adewumi M., (December 2012) The Hydrate Problem retrieved from https://www.e-education.psu.edu/png520/m21_p3.html Gas Hydrates Page 2-3

BMT Fluid Mechanics. (n.d.) Flow Assurance (Oil & Gas Consultancy Service). Retrieved May 12, 2012.

Chi U. Ikoku. (1992) Natural Gas Production Engineering.

E. Shashi Menon, Ph.D., P.E. (Book),Barry G. Bubar, P.E. (Chapter 15) ,William E. Bauer,Hal S. Ozaime, Glenn A. Wininger. (2011). Pipeline Planning and ConstructionField Manual.

Devold H. (2006). Oil and Gas Production Handbook.

Donald W. Schroeder, Jr. (2001). A Tutorial on Pipe Flow Equations.

Dutra M. S., Archila Diaz J. F. (August 2008). Numeric Simulation of a PIG Move inside Service Pipes.

Erosion Corrosion (2012) retrieved from http://www.corrosion doctors.org/Forms- Erosion/erosion.htm

Esam J., M. Abedinzadegan Abdi, Y. Muzychka (2010). A new approach to investigate hydrate deposition in gas-dominated flowlines. Retrieved 14 September 2012.

Guide to Natural Gas in Ghana. (2006). Resources Centre for Energy Economics and Regulation (RCEER). Retrieved March 13, 2012.

Havre K., 01e Stornes K., Stray H. (April, 2000). Taming Slug Flow in pipeline. Retrieved March 14, 2012

Natural Gas Background (n.d.) Retrieved 15 December 2012 from http://www.naturalgas.org/overview/background.asp

Kyu Kim D., Ho Cho S., Soo Park S., RyuonYoo H. Woo Rho Y. (2003). Design & Implementation of 30" Geometry PIG.

Lyndsie Mewett, (April 2010) cleaning pipes with pigs, retrieved from http://trenchlessinternational.com/news/cleaning_pipes_with_pigs/0348/#

Mr. Thomas L. Lumley, Mr. Marc D. Voisine P. Dr. Henry V. Krigmont (n.d.) Computational Fluid Dynamics for Engineering Solutions.

Minami K. (1991). Transient flow and pigging dynamics in two phase pipelines. Retrieved March 17, 2012.

Natural Gas Distribution (n.d.) Retrieved March 14, 2012 from http://www.naturalgas.org/naturalgasldistribution.asp.

Natural Gas Background (n.d.) Retrieved September 26, 2012 from http://www.naturalgas.org/overview/background.asp

Obanijesu, E.O. (2009). Modeling the HS Contribution to Internal Corrosion Rate of Natural Gas Pipeline.

Petrosystem Sri (n.d.) Foam Pigs PE, Retrieved April 5, 2012 from www.petrosystem.it

Petrosystem Sri (n.d.). Slick-S, Retrieved April 5, 2012 from www.petrosystem.it

Pigging- What, Why, and How. (2011). Retrieved March 14, 2012 from www.safan.com

Randy L. Roberts, (August 2009) Vol. 236 No. 8, WHAT DO WE REALLY KNOW ABOUT PIPELINE PIGGING AND CLEANING? Retrieved from http://www.pipelineandgasjournal.com/what-do-we-really-know about-pipeline-pigging-and-cleaning?page=show on 11 December 2012

S.M. Hosseinalipour, A. Zarif Khalili and A. Salimi. (2007). Numerical Simulation of Pig Motion through Gas Pipelines. Retrieved May 8, 2012

The Transportation of Natural Gas. (n.d.) http://www.naturalgas.org/naturalgas/transport.asp . Retrieved March 14, 2012 from http://www.naturalgas.org

Tan Tien Nguyen", Sang Bong Kim, Hui Ryong Yoo, Yong Woo Rho. (2001). Modeling & Simulation for PIG Flow Control in Natural Gas Pipeline. Retrieved March 14, 2012.

Tolmasquim S.T., A.O. Nieckele. (2008). Design and Control of PIG Operations through Pipelines. Retrieved April 1, 2012.

Tohidi B., 2012, Gas Hydrate Challenges in Oil and Gas Industry, Retrieved 12 December 2012 from www.pet.hw.ac.uk/research/hydrate

Valentine F. (Jan, 2000). Effects of Pipeline Debris on Geometry Tool Data. Retrieved March 15, 2012.

Varghese C., (2011), Intelligent Pig Technology for Inline Inspection of Pipeline & Indigenous capabilities Development, Wint D., (2012) Difficult to Pig Pipelines, retrieved on 2012

Wilkinson G. (August 2011) Automatic Multiple Cleaning Pig Launching System Passes Test. Retrieve on April 14, 2012 from http://www.pipelineandgaijournal.comJautomaticamultjpleIegpjglachig * system-passes-test? Page=show.

Xuan Xu X., Gong J. (2005). Pigging Simulation for Horizontal Gas Condensate Pipelines with Low Liquid Loading.

Yanfeng Geng , Feifei Ren , Chenquan Hua, (Aoril 2012) An auxiliary measuring technology of wet gas flow based on the vibration signals of the pipe, Flow Measurement and Instrumentation Volume 27 2012 113 – 119, http://dx.doi.org/10.1016/j.flowmeasinst.2012.04