MUHAMMAD NUR AFIF DANIAL B.ENG (HONS) MECHANICAL ENGINEERING JANUARY 2020

COMPUTATIONAL FLUID DYNAMICS (CFD) SIMULATION OF BYPASS FRACTION FOR BYPASS PIG IN MULTIPHASE FLOW

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CERTIFICATION OF APPROVAL

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by

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A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

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(Dr. William Pao)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JANUARY 2020

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.

MUHAMMAD NUR AFIF DANIAL BIN MUHAMMAD NUR AZLEE STANLEY

ABSTRACT

The horizontal pipeline is a common piping system in the oil and gas industries that has been used to distribute two-phase flow. However, slug flow is one of the major problems in the two-phase flow. The slug generation occurs because of the increase in gas velocity that allows the liquid surface to move upward to the top of the pipe and to form an elongated bubble. It is important to understand the slug flow characteristics which could affect the pipeline system. The objective of this project is to study the effect of multiphase flow flowing through bypass fraction of a bypass PIG to decrease the capacity requirements of slug catcher and to correlate the bypass fraction of the PIG geometry inside the horizontal pipe. There will be three bypass fractions for the bypass pig which are 2%, 4%, and 6% in order to achieve the objective. Flow pattern simulation was assessed using FLUENT 19.1. The Volume of Fluid (VOF) and K epsilon method were used to obtain where the distribution pattern for different flow regime will be obtained. Validation of the present work will be validated with the flow map by Baker for 0.08 m diameter and 8 m length pipe. Finally, the water volume fraction to analyze the flow and velocity of the mixture was observed for every bypass fraction. The present result shows that 6% bypass fractions produce most steady flow whilst forming dispersed flow due to its lowerst velocity compared to 4% and 2% bypass fraction.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to Dr William Pao, my direct supervisor, for imparting his knowledge and expertise in this study. During my final year of project 1 and 2 he guides and provides necessary information regarding my project. Dr. Pao also gives me endless support in completing this endeavor.

I would also like to thank you to Dr. Nabihah Salih for her guidance, advice and contribution to my research work during final year project 1&2.

Finally, my deeply appreciation to my parents Muhammad Nur Azlee Stanley and Nor Azizah bt Abdullah, my brother Aniq Danish and my sisters Ainna and Anesa for helping me to get through all the challenges to finally finished my studies in Universiti Teknologi PETRONAS.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

In transporting the media between one or more remote stations, pipelines work as a means of transport. Inside horizontal pipes, the fluid flow pattern consists of gas including liquid that occurred in fuel and gas production and transport centres. The important thing about the transmission pipelines is the oil and gas business which continues to deliver on a daily basis.

Multiphase is the dynamic instant movement of many phases. Two phases are mixed which are the gas-gas, gas-liquid, and solid liquid. For a combined collection of the chemical and oil companies (gasoil vapour & oil and air & water) market demand, the typical two- flow between the two- flows is gas- flow. In several tube cases, the multi- oil and natural gas flow often takes place when hydrocarbons are formed upstream along the routine of the wells to the separators, where they are transported from the wells. Fluid flow is an important problem in the processing of oil and gas where necessary, because of the high pressure from slugs, it may jeopardize network structure and pipeline processes. The feasible fluid regime for spatial characteristics in oil- and gas transport systems is important in order to determine the configuration of the pipeline. A system must incorporate different quantities of fluid and pressure behaviors for varying fluxes in the pipeline. A number of fluid schemes, such as flat lines, can be implemented in the pipeline.

The presence of the slug process in the pipe system is because of the superficial velocities of both phases and of the fluid properties. Furthermore, the geometrical structure of the pipe that plays the key parameter of the fluid flow including the pipe diameter as well as the pipeline length.

1.2 Problem Statement

Once inside a pipe, the device will drive the pig through a pressure difference. Compared with bypass one, conventional PIGs tend to have a high speed. High velocity pigging can cause internal damage to the pipe. Additionally, conventional pigging can cause large liquid to build up in two-phase flow in front of the pig, called pig-generated slug. This can cause problems at the end of the pipeline, where slug catchers are used to separate phases. Conventional PIGs can also get stuck when the driving force could not surmount the friction force. The bypass fraction of the PIG and the resistance force along the pipeline must be balanced to avoid the problems caused by conventional PIG's. Next the PIG's velocity must be as constant as possible. PIGs must also overcome the friction force across the pipeline so that it does not get stuck.

1.3 Objectives

The main target of this research is to study the effect of multiphase flow flowing through bypass fraction of a bypass PIG to decrease the capacity requirements of slug catchers by using computational fluid dynamic (CFD). The research will be conducted on 2%, 4%, and 6% bypass fractions of the bypass pig Also, my objective for this project is to correlate the bypass fraction of the PIG geometry inside the horizontal pipe.

1.4 Scope of Work

The main objective of the analysis is to construct a two-phase flow simulation with specific geometric parameters in a horizontal pipe with ANSYS 19.1. The VOF model was used to model slug flow hydrodynamics. For circular, 0.08 m in diameter and 8 m in length, for the length of the pipeline was chosen. Isothermal conditions should be added to the wall inside of the container. Air and water remained like fluids for operations. The geometric parameter studies circumvented the bypass pig component while the operating parameter was superficial air and water intake. The bypass fraction for the PIG chosen are 2%, 4%, and 6% with a body length of 55 mm.

CHAPTER 2

LITERATURE REVIEW

2.1 Summary

Academic studies on straight and PIG pipes were performed in the region of fluid flow. Many studies and research in this field have therefore been reported. Much fundamental understanding, particularly slow flow in the pipeline, was needed for the characteristic conduct of gas and liquid in two-stage flows. With regard to conventional pigs, the advantages that bypass pigs have led to the use of bypass pigs in business. While the literature seldom finds experiments on (by-pass) scrapping, some experience of the operators in the scrapping process has been published.

2.2 Bypass Pigs

Enteban et. al. [1] shall be used with a fixed bypass hole equal to 12 percent in a two-phase flow using bypass pig. The pig slug developed was almost a factor two in traditional pig uses. The average speed has been decreased by more than a factor two throughout the process. The great advantage lies in maintaining the fluid flow rate at the same level. The flow rate was to be reduced and the economic profit for conventional pigs to be reduced. The same pigging was carried out by Wu et al.,[2] but the bypass was 15 percent. The reason for choosing the area ratio is that the speed of the pig is sufficiently reduced while the risk is considered sufficiently small. The findings are similar to those of Entaban et al. The usage, reported by Money et al. of a more complex one-phase bypass pig[3]. They have used a pig with a bypass hole that can be changed from 0 to 50 percent by rotating certain blades. When determining the opening area needed, the input from a speed sensor was quite easy. They were able to maintain pace throughout the pigging cycle using this method. These studies demonstrate that bypassing pigs can bring significant advantages while maintaining low risk. Further research is required to understand the characteristics of the bypass pig. The design can be optimised to achieve an adequate pig check based on this knowledge.

2.3 Pigging Models

The oil and gas industries are developing a scraping model for the pigs in their behavior. Newtons Second Law[4] describes the pig movement of the horizontal tube that the pig mass combined with an acceleration represents the net strength of the pig. The net force is then split into friction and movement. The pig's fluid(s) use this driving force when the pressure between the pig and the tube wall is opposite. The theory of friction is a distinct area of science. There are two major friction forms on the pig wall interface: (1) dry and (2) static[5]. Two primary sources of friction occur. Dry friction happens when two solids slide each other. All solids have a thin, liquid rubber layer, which lubricates the relative movement. Normally, this lubricating layer reduces friction considerably. The frictional strength of both forms depends on a variety of factors including the properties of fluids, animals, pipes, and relative speed and equipment used[9]. The pigging industry provides much of the contact elements of polyurethane. Friction is generally represented as a normal friction force.

This method also demands that the friction coefficients in pigging models are constant. However, experiments by Tan, etc.[6] have been used to demonstrate that in many cases this assumption does not apply. Dipstick contact elements and solid cast-pigs form a disk. These screen disks are generally bent rather than compressed. Zhu et al. [7] built a finite element model that had much more friction than a linear assumed friction. The fluids pull the sweeper engine. The flow phenomena must therefore be clearly understood. The models can be divided into a single-phase stream and two-phase stream models. It is easy to understand the flow of single phases and it is less accidental to predict the two phase phenomena. In addition, models for conventional pigs and models for bypass pigs should be distinguished. The underlying principles are fundamentally different for the conduct of these pigging activities. Please note that current research is focused on individual pigging phases. The regulatory equations for the description of one-phase flow are based on the law of mass preservation, impulse and power. The general formulations can be substantially simplified depending on the situation under discussion. In many cases the equations of Navier-Stokes can describe the flow conduct. In such equations, the principal parameter is the inertial force ratio, the so known Reynold number, divided by viscous forces. The pipeline industry often concerns only cross-sections. One-dimensional formulations are thus usually used to relatively simple description of the flow behaviour. In order to find the pressure at either side of the pig the balance equations must be integrated into the pigging model. Certain models use the entire pipeline as a fluid calculation domain.

Nguyen developed numerical models using the characteristic approach in collaboration with other researchers [8–12]. A final differential model for pig activity was used by Nieckele et al.[4], and by the other Tolmasquim et al.[12]. As the entire pipe is a fluid domain in the two methods, the input and output speed or pressure should be specified as limit conditions. This enables an inlet and outlet pigging cycle to be simulated. Models do have a pipe fluid part only. This model is continually inspired by Saeidbakhsh et al.[13]. Nevertheless, the effects of curvatures in pipes were introduced by them. The centrifugal force is balanced by a separate normal force with a curvature. It results in increased tension in trade. The Saeidbakhsh et al. adapted later on[13] by Lesani et al., adding a small portion and not compressing the movement of the fluid domains. Mirshami et al. have changed further. From the outset, the results of incompressibility[15] were changed to include longer pigs for measuring the friction force[16].

Some of the models mentioned are only for bypass pigs. They all have a similar model of pressure reduction to that of other works to integrate an effect of the bypass of the river [17]. Dynamic pressures for the bypass pig, as a general coefficient, usually multiply the formula for a pressure reduction [18]. The problem is determining the coefficient of pressure loss. The geometry of the bypass hole is very important. The factor is separated in the bypass box into pigging models according to contraction, expansion and possible valve. The bypass hole determines the contraction and expansion coefficients. The book Idelchik [18] provides an overview of pressure drops in numerous diverse configurations. Bypass pigs are comparable to internal valve and straight hole openings. By-pass pigs are different because on the tube walls they move toward the pig. Numerical simulations [7] from Singh & Henkes show, however, that the discrepancies are implied by the higher number of

Reynold. So Idelchik's expression can make a good prediction for a pig’s decreasing pressure.

The area of the bypass determines that the pig and the pig speed are under pressure. The pig speed can be adjusted if the bypass area may vary during the pigging process. These included Lesani et al. [19] and Nguyen et al. [10], which contained a control of these opportunities in their imagination. Both works found that the speed of the pig would be maintained within an acceptable range.

2.4 Bypass Flow Through Pigs

The sum of the bypass flow to the PIG depends on the valve, h, and pressure over the PIG as shown in Figure 2.1 below.:

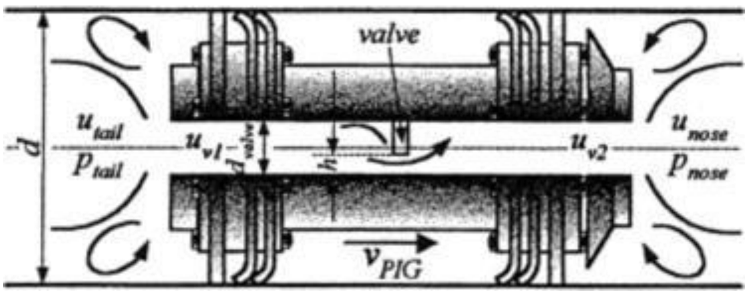


Figure 1: Figure shows parameters involved in bypass pigging

The pressure drop over the PIG results in the loss of the pressure of the valve due to a sudden streaming contraction on the PIG's doorstep and a sudden increase in the flow in the PIG's nose. If the speed or machine count of a natural gas is less than 0.45 or 200 m / s, less than 5% of the bug could be considered as incomprimable [21]. The pressure drop on the paper makes it possible to assume that the bypass stream is as compressible as the center bypass fraction inside the pig. The valve circumference causes the pressure on the PIG.

2.5 Initial and Boundary Conditions

It is assumed that the continuous state variable distribution will be used under the initial conditions without field data on the initial change of the variable field[19]. There are two different options for setting boundary conditions at the inlet and outlet pipeline: Q(t) or p(t) pressures with T(t). In the previous work[14] both of these terms are set out. The PIG's limits, like its upstream and downstream flow tail, are here covered. The limits depend on the dynamic behavior of the PIG and the conditions of the opening valve. Only one characteristic, for example an upstream reverse border or an upstream forward feature, is available on a frontier. The average velocity of the PIG tail can be as follows in presence of the bypass flow:

$$utail = upig + (\frac{dvalve^2}{d})(uv - upig) \quad (1)$$

Where

$$uv = uv1 = uv2 \quad (2)$$

Equation (2), a pressure drop, when passed through the central PIG bypass opening, is believed to be incompressible by the bypass flow. The flow rate Un thus enters a valve equal to the flow leaves Uvz level. So, we have

$$unose = utail \quad (3)$$

Forces acting on PIG can be written in dynamic following Newtons's Second Law as follows:

$$M\frac{d^2(t)}{dt^2} + C\frac{dx(t)}{dt} + Kx(t) = Fp(t) - Ffp(t) - Fb(t) \quad (4)$$

In the previous equation (4) An upstream and downstream variation of the driving force is extracted from the specific pressure on the PIG tail and nose at each numerical stage. The friction force use and linear damping factor C experimentally. Equation (4) calculates PIG position and speed by means of the runge-kutta equation [3].

2.6 Characteristic of PIG

Because of the complexity of the topic, the number of two-phase / multi-phase documentation is very small. The problem of small liquid between 2 pigs is resolved with a standard Lax-Wendroffscheme in an isothermal 1-D flow field with a grid interval of an equally expanded pig. Thus the intervals in each volume were equal in the size of the train in order to improve the numerical stability, whether upstream 22 or downstream. Initial researchers submitted a pigging gas-fluid pipeline survey which indicated that pigging could increase transport efficiency by 30% to 70%[16]. Pig Model assumed that empirical correlations should be maintained in the standard stationary teo state stage and that pressure for successive periods should be reduced. This caused errors. Simple assumptions were removed from the original model, as well as the proposed procedure to model liquid slug acceleration when delivered to the separator / slug catcher[13,20]. A complete formulation of two phases of flux transition was used in the first model of piging[7]. The model contains the code based on the drift flux transient code [8]. The pigging model includes a pig, a slug holding, a pigmenting efficiency, a pig speed and a front limit on gas and fluid. This template uses flow patterns which are independent constant retention and pressure reduction to account for the difference between the phases. This model includes a transient drift flux code for the pipe fields and multiple links between pig movement and the flow, such as the pressure drop correlation in the pig, the fluid holding correlation in the tilt zone, etc. The two coordinates and the other adaptive method were fixed by a finite differentiation method to resolve a set of 23 equations [12].

Mixed Euler-Lagrangian approach were used in a transient two-phase gas / slug system [11]. The flow model equation was discreted using a grid system from Euler, while a grid system from Lagrange (moving) was used to create a pigging model equation. They also carried out extensive tests to validate the model. It is suggested that the quasi standard state approach to these systems would not be appropriate due to the high upstream gas accumulation [9]. For this purpose, the two transient hydraulics for pigging in two phases were developed, especially for pipeline riser systems [10]. This model is suitable for assessment. In order to determine the transient fluid behavior Lima et al. used the two fluid model. While the various flow regimens of the pipeline were taken into consideration, they assumed that the speed of the pig was determined by the mix speed that pushed the pig in the previous stage.

This can only occur if the pig flux is not circumvented. Once going through various operating environments in the tube, she discussed the PIG dynamic issue in more detail. A theoretical model has been developed for pig dynamics and the MOC computer system has been suggested. As pig and application development are very difficult, the reliability and accuracy of the MOC approach offered have only been demonstrated by 24 simulations tests. Real pigging is therefore important to test the solution's reliability. The latest awareness and importance of each pigging technology parameter have been provided with a good overview. They called strongly for guidelines to be developed and information coding to assist with the creation of scrub operations [4]. A simple model to simulate temporary flow behaviour, was presented in the two-phase pipeline under pigging. The gas stage of this model can be assumed to flow almost continuously and two fluid stages simplified. Nevertheless, substantial adjustments need be made to the model to simulate temporary flows inside the riser pipeline, if these structures do not have a quasi-state solution because of a significant accumulation of gas upstream of the pig. In particular, two fluid models, suitable for the estimation of double-phased hydraulic flux pigeons, have been developed for new transient pipeline risers. Because of the difficulty of the subject, the number of papers on a two-phase stream is extremely limited. With a uniform Lax- with the same extended pig grid interval for the isothermic 1-D flux field, a liquid between 2 pigs problem was resolved [15-17. The cycles in each volume were similar and helped to keep the numerical system stable upstream or downstream. The solution of the transient two-phase gas / slug system is based on a mixed Eulerian-Lagrangian method [22]. The flow model equation was discreted using the Euler grid system, while the Lagrange (moving) grid system was used to construct an equation of the pigment model. They have also carried out comprehensive model validation studies.

Two steps of the first scrub model included a complete transient flow formulation [13]. This model contains a transient drift stream code for the pipes and several connections between pig movement and flow, such as the correlation between the pig and the fluid, the fluid tilt zone correlation, etc[14]. With two coordination structures, one fixed and one adaptive, the resulting equation is determined by a finite method of difference. A dual-fluid model determined the transient behavior of the liquid. Even if numerous pipeline floods were taken into account, they presumed that "the speed of the process by the pig pushes the pig in the earlier step is determined by the pig speed." A good overview of the current knowledge and importance of each pigging technique parameter was given. They called strongly for guidelines to be developed and information coding to assist with the creation of scrub operations. Once going through various operating environments in the tube, she discussed the PIG dynamic issue in more detail. A theoretical model has been developed for pig dynamics and the MOC computer system has been suggested [15-17]. The reliability and precision of the proposed solution using MOC were verified only by the results of the simulation, as pig and field applications are very difficult to manufacture. Real pigging is therefore growing to test the reliability of the solution

2.7 Horizontal Flow Pattern in Pipeline

Gravity effects will contribute to smooth motion of the fluid pattern. 'Stratify Flow is a simple flow model in the gravity sector for 2-phase gas / liquid flows'[13]. Stratified flow is typically a relatively small mixing rate of horizontal flow. The wave starts to produce, move the fluid and spread with increased air speed. As the fluid begins to blend from the bottom with the gas stream, it becomes irregular [18]. This creates a tricky flow environment. The flow device evolves further into a pattern of air bubble that flows from the tube through a liquid field. If gas speed continues to increase, a ringed flow pattern may occur. The gas flow and fluid flow behavior of two phases as shown in figure 2.6.1.

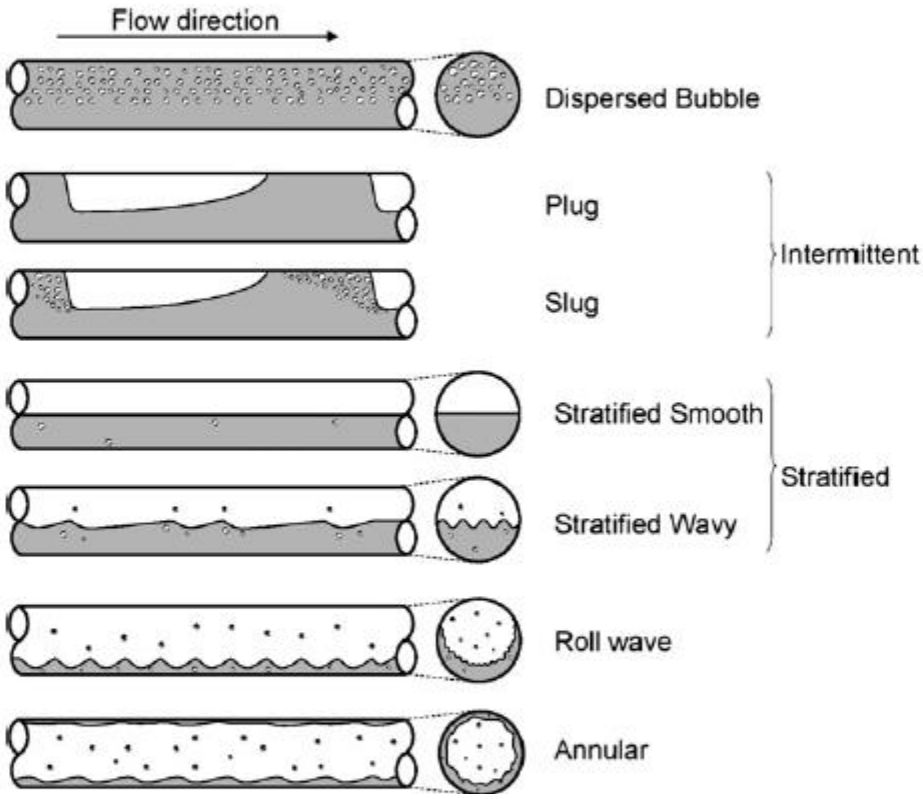


Figure 2: Flow pattern in horizontal pipe

In case of the two-phase flux pattern on the horizontal conduits, the liquid flows to the bottom and the gas to the top because of the gravity effect. There are many fluid and gas patterns in the horizontal type of pipes:

- Stratified flow: A complete two-stage gas-liquid flow division takes place at low gas and fluid speeds. Liquid flow into the bottom and gas pipe into a smooth horizontal interface separates the pipe from the top

- Intermittent Flow: When the speed of gas increases, the interfacial waves get larger. The flow also combines the plug and slow flow during intermittent flow.

- Plug Flow: A liquid plug is present in the flow system, isolated by a prolonged gas bubble. Plug flow is also known as extended flow of bubbles.

- Slug Flow: When gas speeds increase, the long diameter of the gas bubble is similar. The shape of the fluid slug occurs when the waves flow to the top and produce an elongated bubble.

- Bubbly Flow: Because of high bubble concentration in the top half of the pipe due to the buoyancy force the gas bladder is spread through the liquid. Usually this system occurs in horizontal flows at a high mass flow rate.

- Annular Flow: When the gas speed increases, the liquid structures a non-stop annular movement across the pipe area, then the liquid layer below is thicker than above.

2.7.1 Flow Regime Map for Horizontal Pipes

Different researchers have defined multiple flow pattern maps to evaluate each flow mechanism graphically. As the first patter developed by the researcher, the Baker flow model map is often used in the oil field[11]. No heat and diabatic condition are important in the two-phases flow for adiabatic flow patterns. Two phase adiabatic flows in pipeline transport [1], for example. Much of the region is isolated by the two-phased flow method (2-D).

2.7.2 Two Phase Baker Map

In the horizontal pipeline, gas and liquid are used in many oil transportations of the oil-gas mixing industry. It is difficult to predict the flow pattern of the pipeline and this gives the industry a big issue. The existing flow pattern maps are used to describe the flow pattern by pipeline distribution.

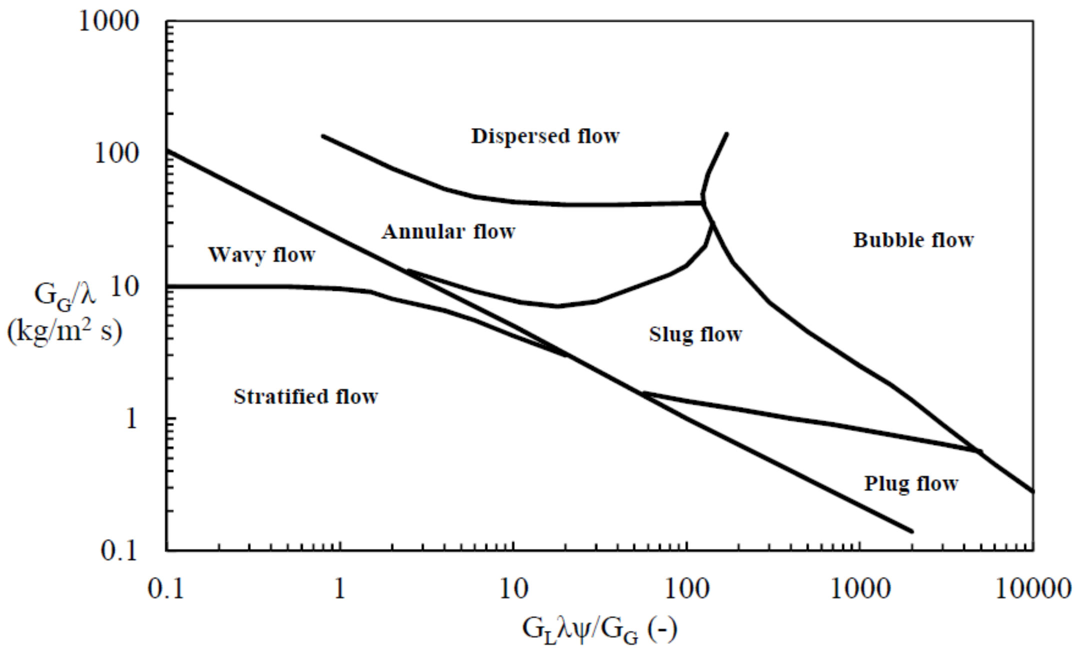


Figure 3: Horizontal Flow pattern map of Baker [4

Figure 3 shows that a new rate of flow into layered flux, plug flow, slug flow, bubble flow, wavy flow and ring flow is shown in the baker flow pattern. The first flow pattern reported on baker flow map calculates pressure drop, vacuum fraction, mass speed and other tube flow [11].

The sidelines showed the mass flow rate (GG) for gas and the mass flow ratio (GL / GG) of fluid with gas for various forms of flow patterns. The correction factor of air and water at atmospheric pressures are α and ād. The structure of gas (GG) and liquid (GL) flows is calculated by the same map using μ and μl at various temperatures and pressures.

The first step to estimating the flux pattern is to control fluid and gas mass flows in order to use the map. There are two parameters of μ (gas phase) and μis (fluid phase). No two parameters are available. After measuring both parameters, each pinpoint was then calculated on the basis of the respective flux pattern.

The parameters of gas and liquid mass flow rate:

$$\lambda = \left[\left(\frac{\rho_G}{\rho_a} \right) \left(\frac{\rho_L}{\rho_W} \right) \right]^{0.5}$$

$$\psi = \frac{\sigma_W}{\sigma} \left[\left(\frac{\mu_L}{\mu_W} \right) \left(\frac{\rho_W}{\rho_L} \right)^2 \right]^{1/3} \qquad (2.2)$$

- λ & ψ: Dimensionless parameter.
- (ρ_G): Density of gas.
- (ρ_L): Density of Liquid.
- (ρ_a): Density of Air.
- (ρ_W): Density of water.
- (μ_L): Viscosity for Liquid.
- (μ_W): Viscosity for water.
- σ_W: Water surface tension.
- σ: Gas-liquid surface tension.
- Fluid properties (ρ_G, ρ_L, μ_L, σ).

Fluid	Density, kg/m^3	Viscosity, Pa	Surface tension, N/m
Water-liquid	998.2	0.001003	0.072
Air	1.225	0.000018	-

Table 2. 1: Material Properties.

CHAPTER 3
METHODOLOGY

In this section, the numerical technique for computer fluid dynamics (CFD) is used and the methodology is presented. Two-phase flows for the horizontal pipe are modeled using ANSYS. The simulation runs under various geometry designs on the horizontal pipeline to solve the sluggish flow pattern.

3.1 Modelling Two-Phase Flow Gas-Liquid using CFD

"The correct CFD method is needed to solve the fluid flow problem. Pre-processor, solver and post-processor requirements for computational fluid dynamic simulation."

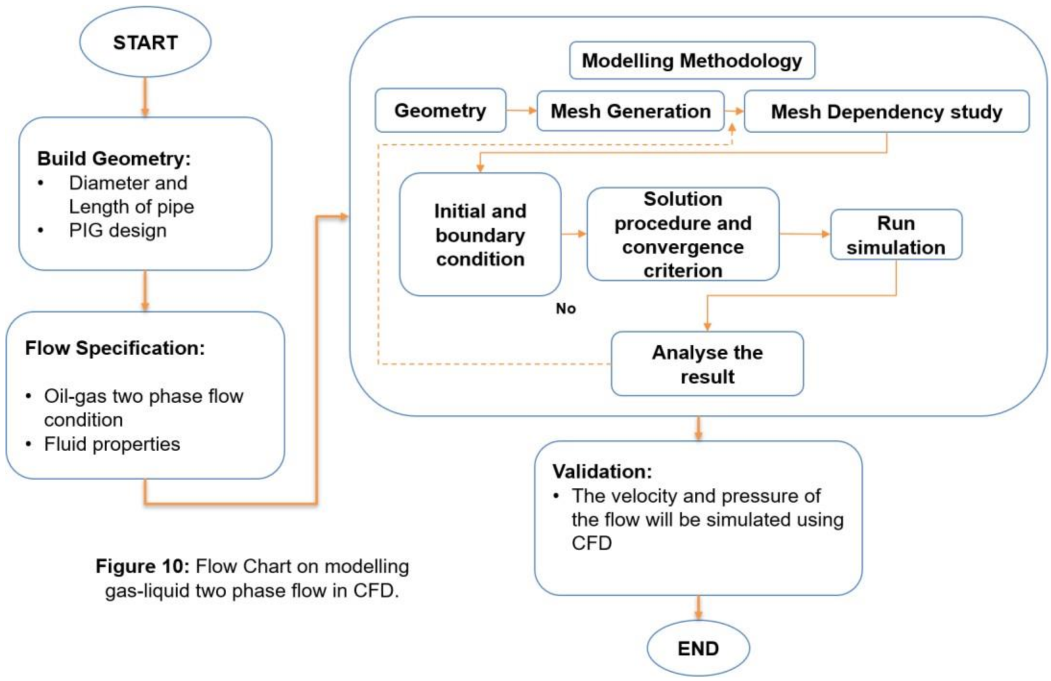


Figure 4: Flow Chart of Research Methodology

3.1.1 Modelling of bypass PIG

The PIG is modeled accordingly to a size of 0%, 2%, 4%, and 6% bypass fraction. The optimization of bypass is defined as the ratio of the pig to cross-sectional area of minimum bypass. On the basis of the optimum speed and pig volume generated at the end of the pipeline the optimal bypass fraction is chosen. If the result remains insufficient, the simulation shall be performed by interpolating the bypass fraction.

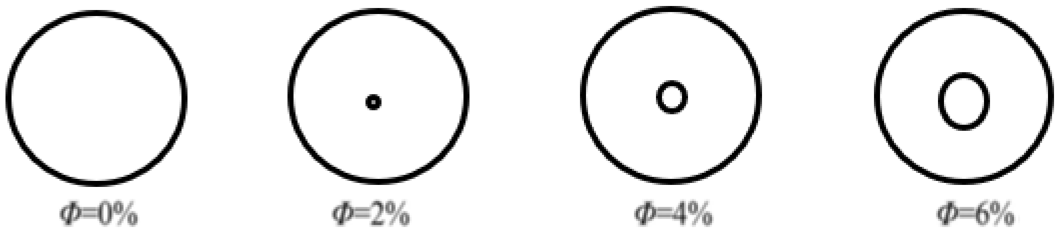


Figure 5: Bypass fractions for the bypass pig

Do note that the size of bypass pig is merely an estimated one which is why the size of bypass seems too big to be compared to real one although the bypass fraction is small. This is because it is quite hard to differentiate the size of bypass fraction in paper if it is according to real life scale.

3.1.2 Characteristics of Pig Velocity

It is possible to achieve the average pig velocity by measuring the pipeline distance ratio between P1 and P11 to pigging time. The differences between the average pig velocity and other bypass fractions are clearly shown. The average pig speed decreases with the rise in the bypass fraction. The average pig velocity increases with rising gas flow volume. A smaller average pig rate is produced by additional liquid charges. Apparently, the existence of a bypass fraction will reduce the pig speed significantly. The pressure connection from the gas through the bypass pig can therefore be defined to explain how the pig bypass mechanism reduces the speed of the pigs. K is the coefficient of pressure loss which mainly depends on the structure of the pig bypass. The density is the kg / m3 bypass gas density. Ubp is the speed of the gas by the bypass terminal, as opposed to the pig speed m / s Here, Ug is a gas speed underneath the pig, m / s, Upig is a pig pace, m / s and § We can figure out from equations (1) and (2) that the rise in the bypass fraction at all would result in the reduction of the Ubp bypass gas velocity. Consequently, the disparity between driving force and resistance force is rapidly decreased by breaking the balance. Due to the decreased differential pressure P (DP) the pig moves more slowly, leading to a successive rise in Ubp and PP of gas bypass pace.

3.2 Modelling Methodology

FLUENT is used to model the trend transaction in order to overcome the governing equation.

3.2.1 Mesh Generation

For simulation of multi-phase flow, mesh output is extremely necessary before the simulation is carried out. In the application of geometry, many ways of meshing are available including tetrahedral, hexahedral or ply mesh.

Tetrahedral meshes are the simplest meshing to produce, but their drawback results in precise performance. In study by Baker [11], however, hexahedral meshes were made, resulting in better results than tetrahedral meshes. Tetrahedral grids can be generated quicker and easier but the consistency and skewing of the grid are difficult to change. Further, it is difficult for the solver and high error choice to produce the solution when applying the meshes in the FLUENT 19.1Figure 3.2 indicates improved grid (hexahedral mesh) for the mesh generation. The product of this mesh generation will achieve maximum precision. The hexahedral mesh was selected in this research from these two forms of mesh generation.

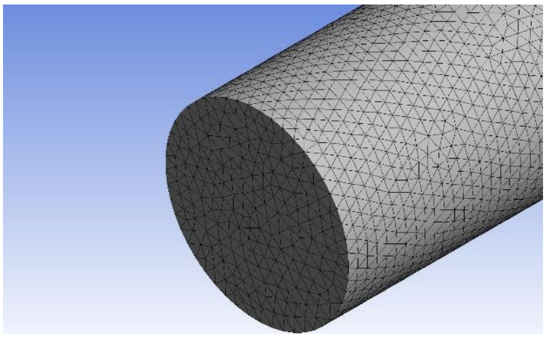


Figure 6: Hexahedral mesh on the pipe

3.2.2 Pipe Geometry

The circular cross-sectional pipe parameters are 0,08 m in inner diameter and 8 m long. A pipe length of 16 m is determined to reduce the computational time for the simulation.

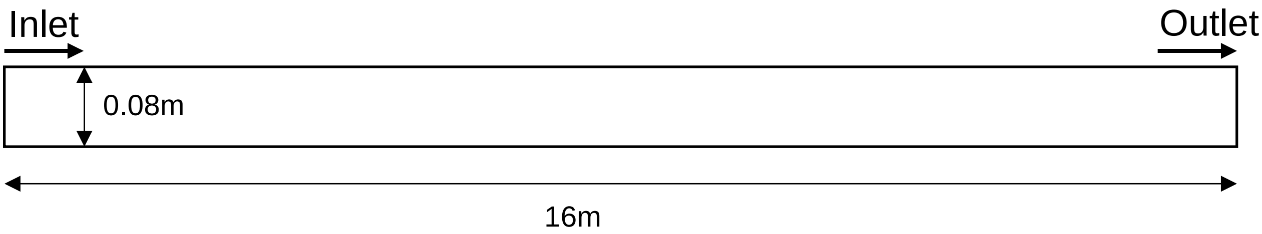


Figure 7: Geometry of Pipe

3.2.3 Mesh Dependency Study

Inner diameter of the 0.08 m horizontal geometry pipe with a length of 8 m and also a bypass pig with the parameters of 0.055 and bypass diameter of 0.0195 were meshed. The mesh is created by the ANSYS. The hexahedral mesh is completely finished for the pipe and pig. Body sizing of the whole body of the pipe and pig model are with the size of 5mm, 10mm, 25mm, and 50 mm are used in this mesh dependency study.

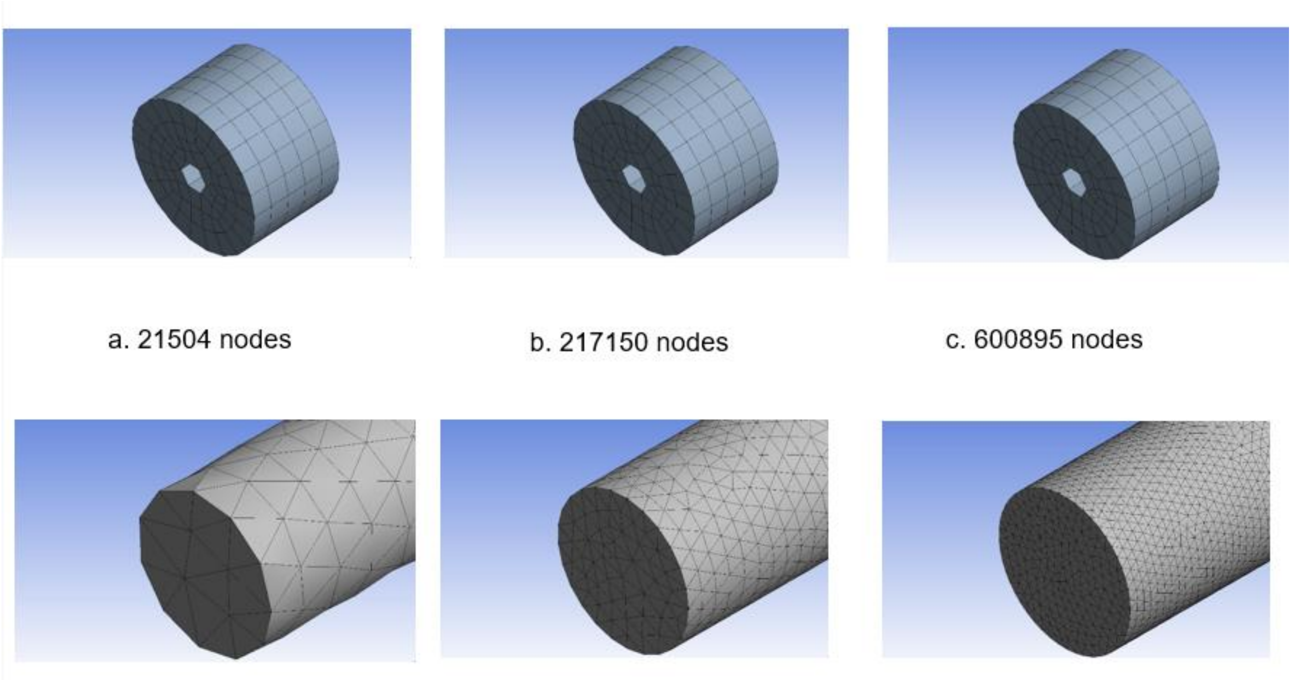


Figure 8: Hexahedral Mesh generation with nodes

Poor mesh consistency results in an incorrect outcome and the solution converges gradually. Minimum angle and minimum determination are two of the key factors to assess the appropriate mesh size. The specifications for the optimum mesh are greater than 0.2, for the minimum determinant, although the minimum angle ideally reaches 18 degrees.

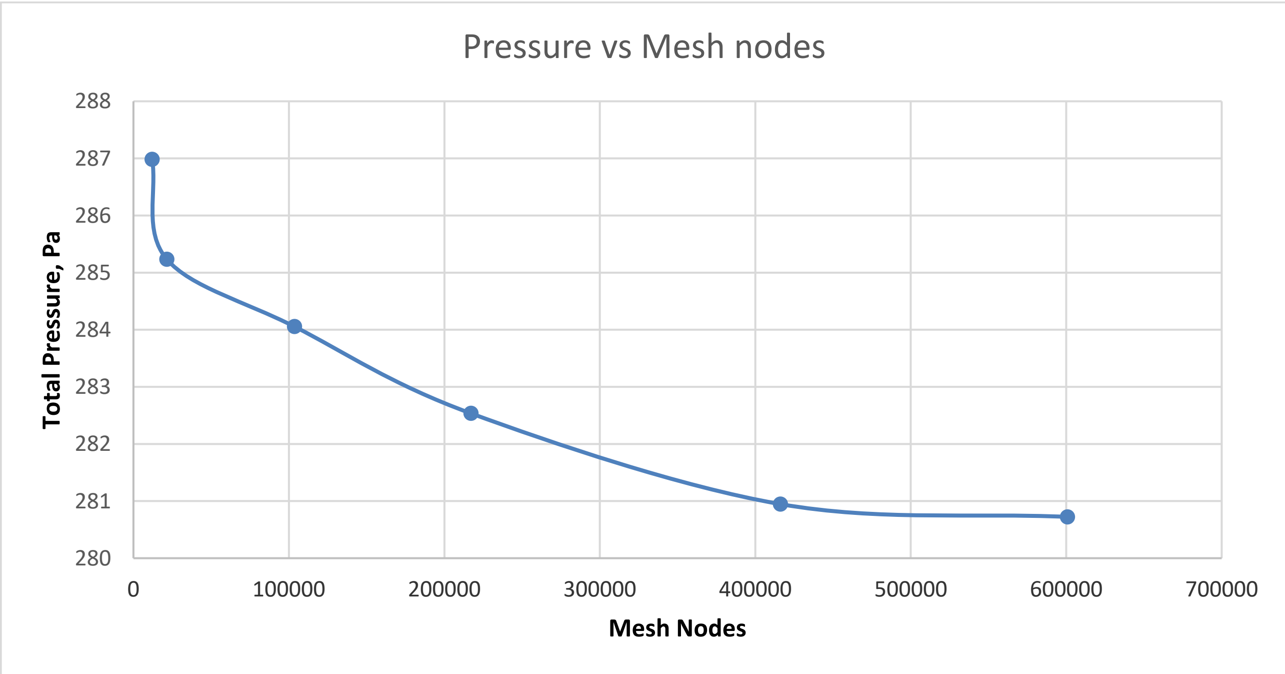


Figure 9: Total pressure convergence against number of nodes

The total pressure convergence was obtained from the mesh dependence test when the number of elements increased. A larger number of elements must not be used as it may take longer to carry out the simulation

3.3 Project Gantt Chart and Key Milestones

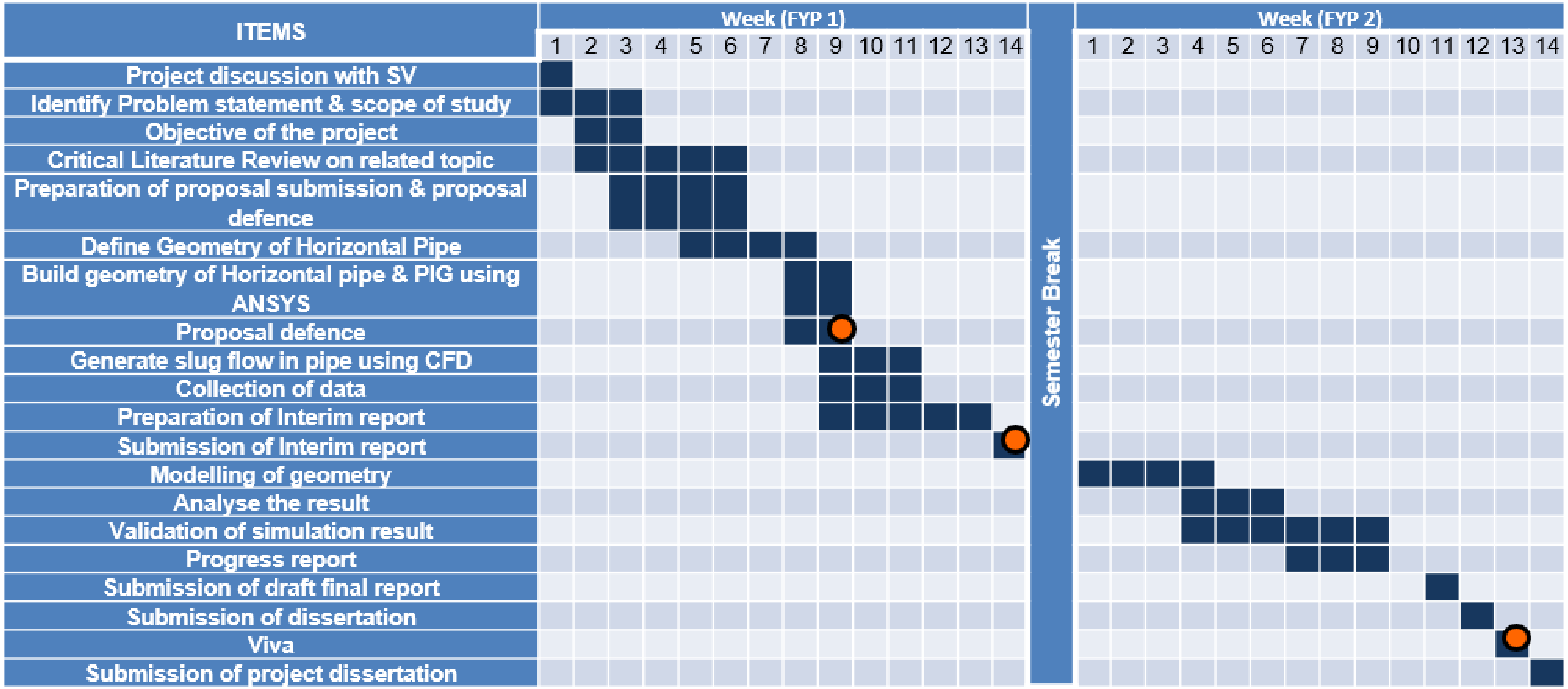


Figure 10: Gantt Chart for FYP 1 & FYP 2

: Key milestone

CHAPTER 4
RESULT AND DISCUSSION

4.1 Validation of flow pattern on Baker's map

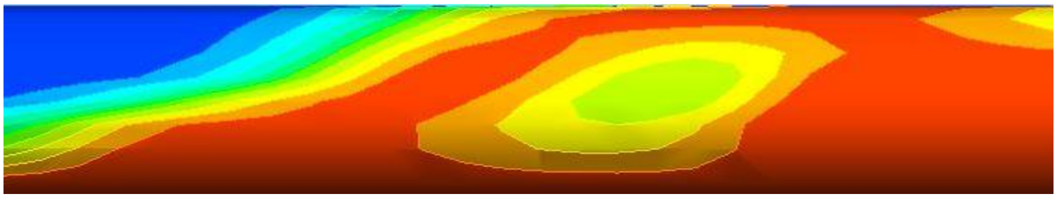


Figure 11: Present Model

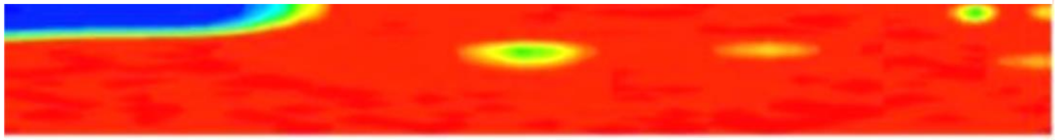


Figure 12: Ban Sam (2017)

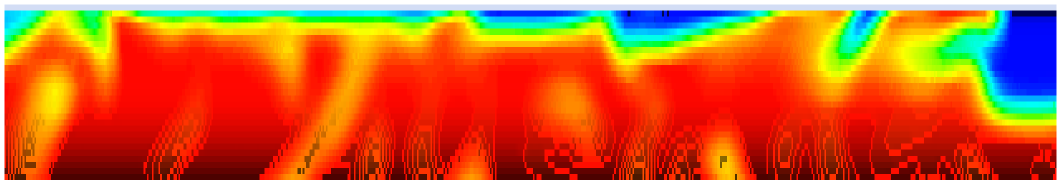


Figure 13: Amir (2018)

The figures above indicate slug flow in different simulations. Compared to Ban Sam (2017) and Amir (2018), the new model shows similar slow progress. Two phase flows in the tube, water and air, trigger the slug wave. The traffic bubbles fly at the speed V and overtake a slower moving liquid in the separated figure. The fluid is released from the back of the slug at the same rate as the fluid is stored on the front during steady flux. Therefore, when the pipe travels, the slug length remains constant. The through waves bridge the top of a pipe, form liquid bows and fill the entire tube section, Baker (1954) said. The slugs affect the top of the pipe. Present model has succeeded in generating a slow-down, according to Baker. The liquid shed at the back decelerates and forms a layer under the impact of the wall shear on horizontal or near horizontal pipes. The liquid shapes and accelerates as it descends to a falling annular film for vertical or near vertical tubes. The segment with a large gas bulb has a duration through which much of the gas is expressed in such massive gas bubbles.

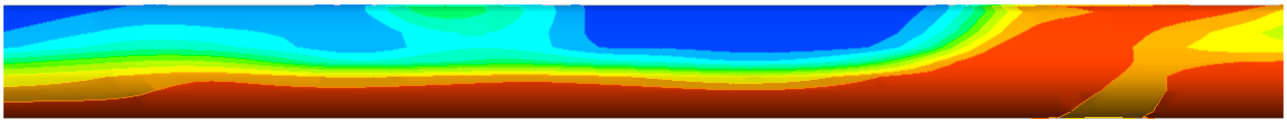


Figure 14: Stratified layer after slug flow

The stratified flow is primarily due to major impact of gravity, where water and air velocity are naturally low for this flow regime and then make the water phase to flow steadily. Nonetheless, slight waves will start to occur when air velocity increases. There will be two forces acting between the fluid that is Bernoulli force and gravity at the exact moment.

4.2 The transition of slug flow pattern in a horizontal pipe

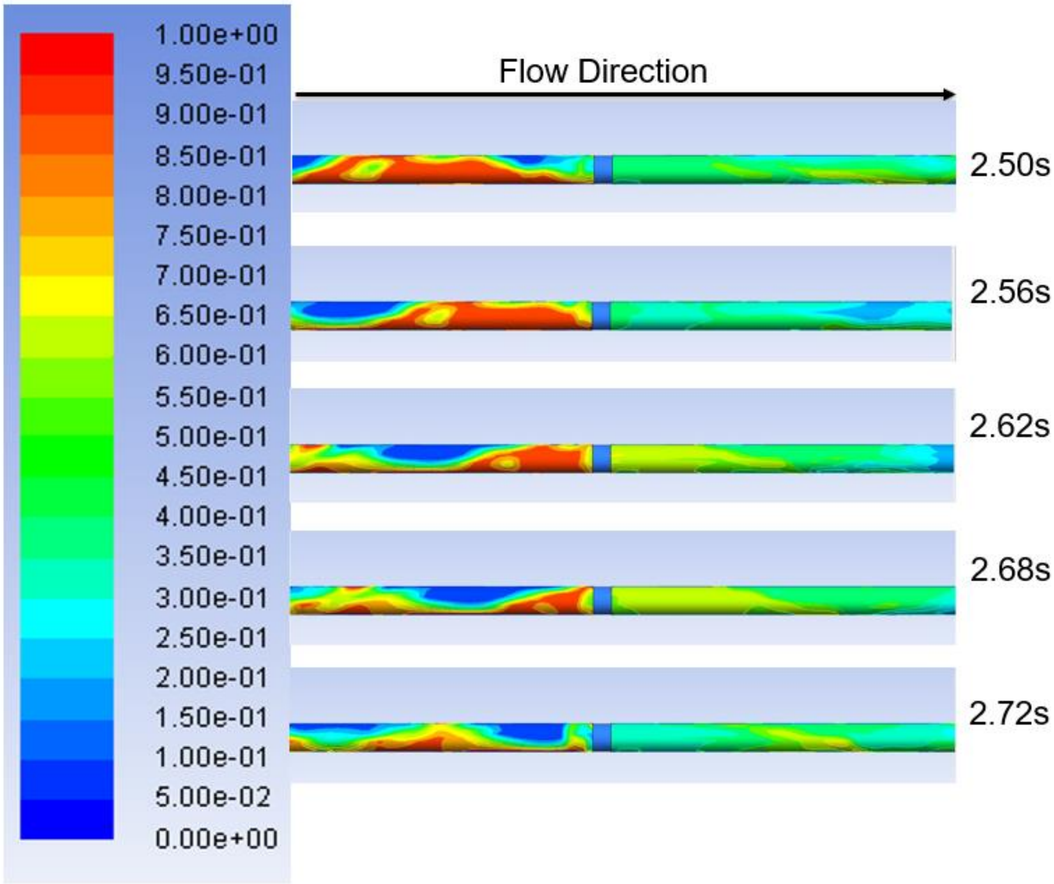


Figure 15: Slug flow through the bypass pig by using water volume fraction contour (U_SA=2.86 m/s and U_SG=0.9 m/s)

The slug was observed at between 2.5 and 2.72 s. These disturbances have been captured by the model and as the simulation continues in time, they have become slugs that completely block the pipe cross section.

Identifying the presence of slug flow in the current situation is difficult due to the properties of slug and its related criteria such as velocity, slug formation, and frequency. Figure 4.2 presented the formation of a slug at superficial velocity, U_{SG} = 2.86 m/s and liquid superficial velocity U_{SL} = 0.9 m/s as in inlet boundary condition. The elongated form of the bubble is different in length along the pipe where there were some with small bubble gas throughout the pipe. At slug at the front of the air bubble will penetrate more.

Red contour means liquid whilst blue is gas. For this figure the direction flow is from left inlet to right outlet. The slug flow occurs which allows the pipe to be clearly observed based on time evolution. The red liquid slug contour moves to the upper part of the horizontal pipe.

Initially, the pipe is filled with air and water with equal volume fraction and zero velocity. Slug was not formed immediately after air and water was injected into the pipeline. The mixture takes some time in simulation to ensure the slug is formed when the first crest was formed. The formation of slug starts to grow at time 1.56 second and then continue growing more along the pipe. The slug continued to travel along the pipeline until it meets the pig (as shown in figure 4.2). This turbulence was taken from the current model and can be observed to form the flow pattern when the slug passes through 6% bypass of the bypass pig.

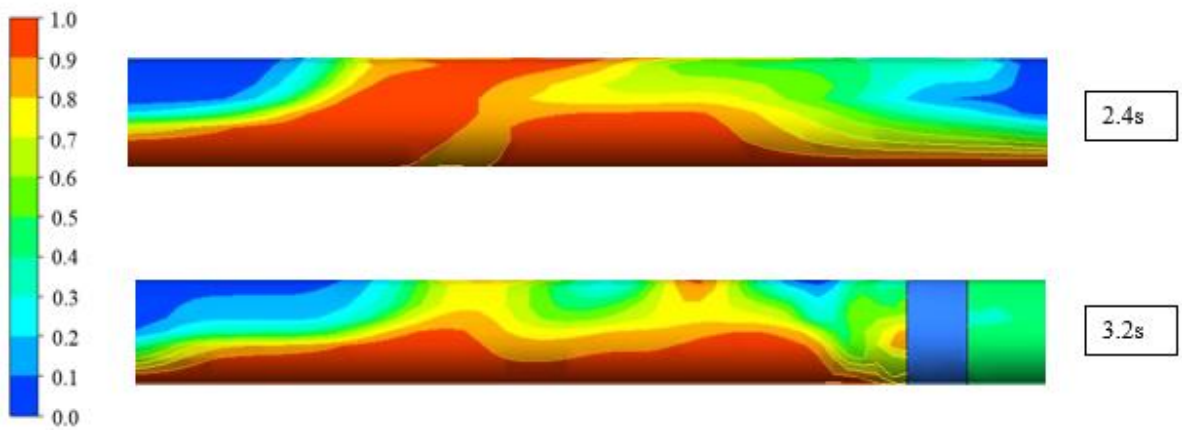


Figure 16: formation of mini slug

As shown in figure 16, a mini slug was recorded at about 2.4s. However, the slug disappears before arriving at the pig at around 3.2s.

4.3 Validation of model against Experimental figures

The present model of CFD model simulation was used for this part to compare with the experimental result as for validation to ensure the correctness and assurance of current work. CFD simulation predictions were observed using an experimental photograph.

4.3.1 The Experimental test methodology

The present model will be validated based on the concept below. The geometry of pipeline for this simulation is 0.08m of internal diameter and length of 16m with the pig is in the middle of the pipeline. The pig model was taken from the experiment made by Chen et. al. (2018). The geometry of the pig was taken exactly as the experiment which are 0.055m of length, and by using 2%, 4%, and 6% of bypass fraction. Type of fluid used for this simulation is air-water which are two-phase flow. The atmospheric pressure was set at 101.3 kPa and room temperature was set at 24 ^{o}C. Figure 4.3.1 illustrate the boundary condition and test section of this simulation model.

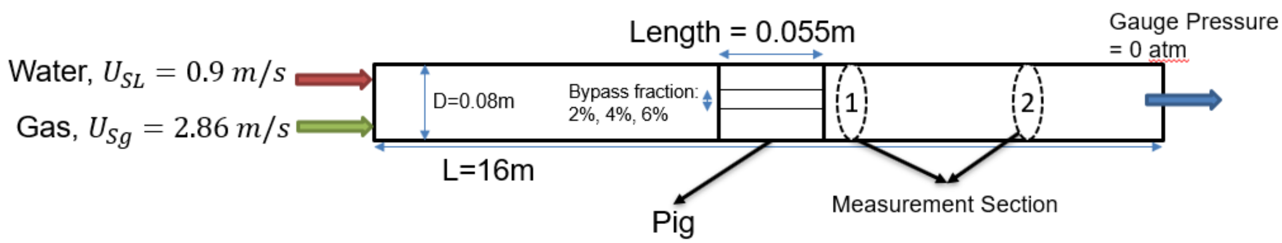


Figure 17: Geometry and boundary condition of the model

The measurement section was set at 0.5m and 5m respectively after the mixture went through the bypass of the pig.

4.3.2 CFD of slug development comparison between Experiment photographs.

Figure 4.5 provides a contrast between the stage of slug formation between the current model simulation and experimental photographs. At the outset, slug development began with the outset of the slug, which in the test section was initially equivalent to 50% water volume, as shown in Figure 18(a) with the slug beginning. The red contour for the water volume fraction indicates a red eclipse, as shown in Figure 18(b), after the hydraulic leap, the slug was begun to increase its liquid flow.

As the surface fluid velocity grew to 0.93 m / s, the fluid's momentum increased, which may have contributed to a sluggish pattern.

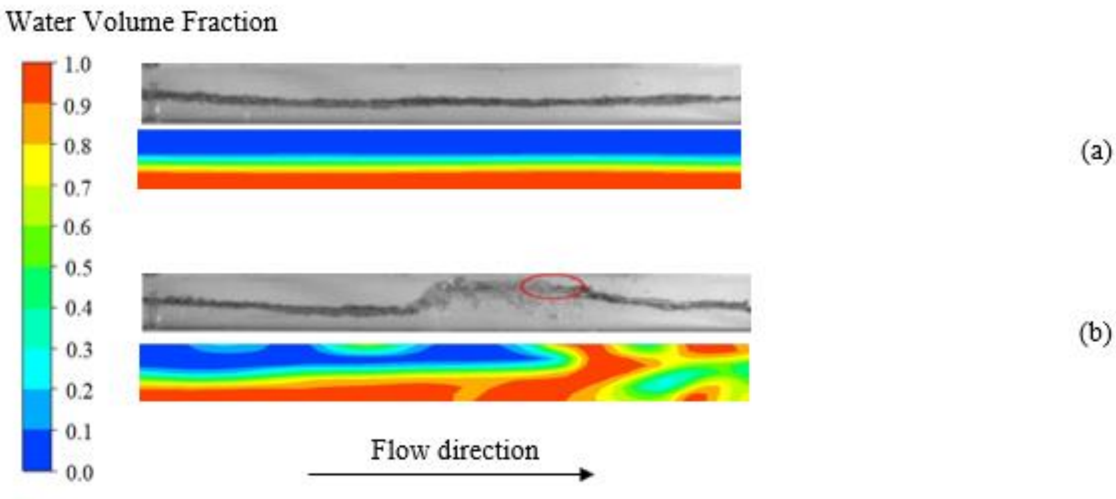


Figure 18 : Display of slug progression between experimental data and CFD for USA = 2.86 m/s, USW = 0.9 m/s

The evaluation of the slug flow pattern throughout the horizontal pipeline was recorded between the current CFD simulation work model and the experimental model as shown in Figure 4.6. The boundary condition for the slug in the pipe are at U_{SG} = 2.86 m/s and U_{SL} = 0.96 m/s. There is reasonable agreement between experimental photographs and present liquid phase contours, indicating that the VOF model was properly used to capture the gas and liquid interface

Figure 19 shows the slug flow and can be interpreted as the slug flow being extended. The image of the slug flow pattern is taken using the experimental methodology based on the camera resolution of 960 x 480 px and has a length of 1.24 m. Each 1 cm in size was 0.034 m real for Figure 19. The length of the slug is thus 0,105 m, as can be seen in Figure 19, from the first photograph taken.

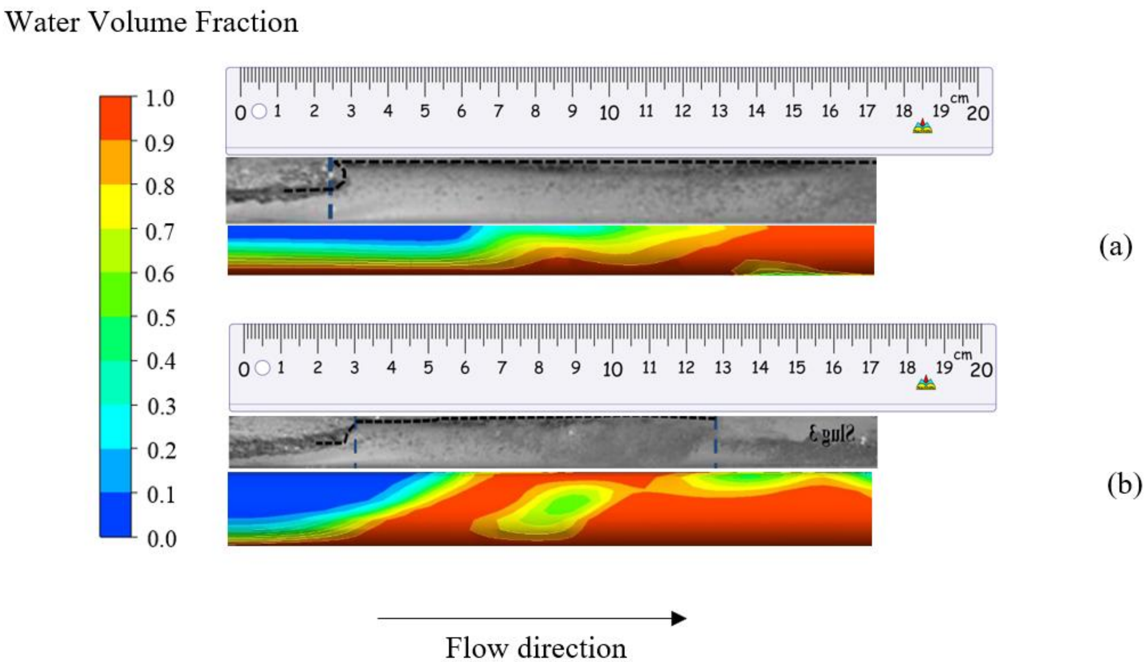


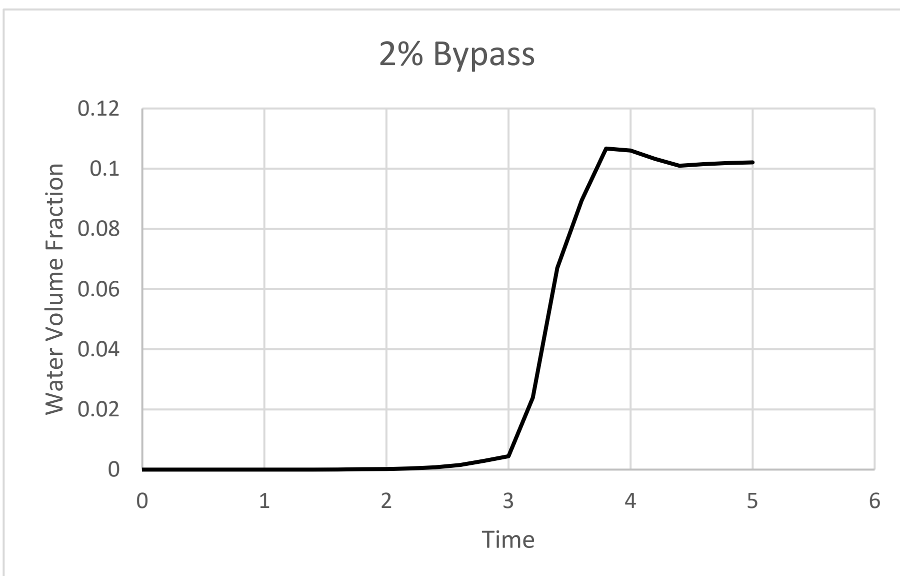
Figure 19: Contour of slug formation, compared to the experimental setup for USA = 2.86 m/s, USW = 0.9 m/s

4.4 Parametric analysis on bypass fraction of the bypass pig

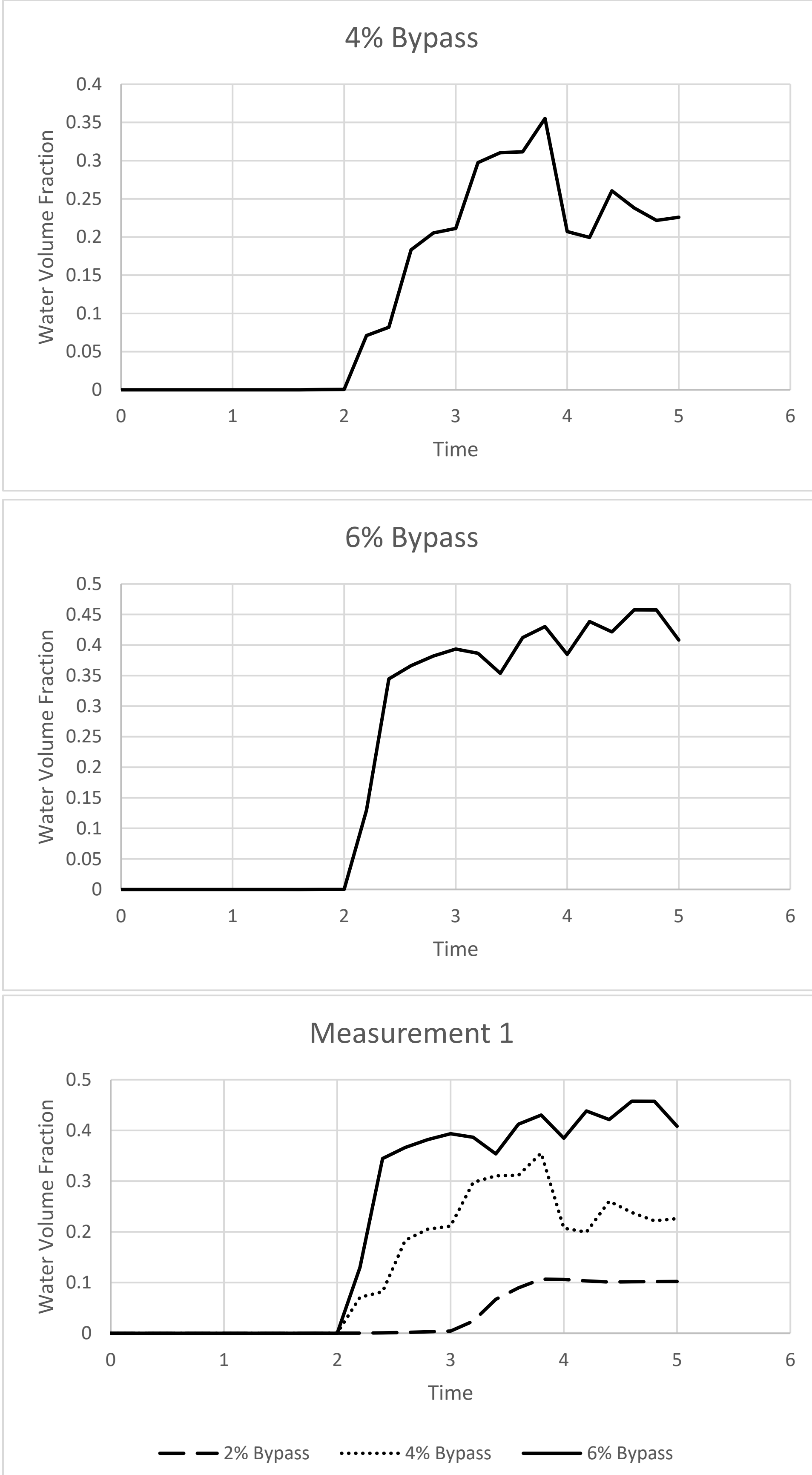
The parametric analysis was studied was directed for different bypass fraction of the bypass pig geometry in a horizontal pipeline. The length of bypass pig was 0.055 m long located 8m away from the inlet. The main diameter for the horizontal pipe was 0.08m in diameter. There are three different bypass fractions of 2%, 4% and 6% which are 0.01 m, 0.016 m and 0.0195m for the pig bypass diameter. The water and air inlet superficial velocity is 0.9 m/s and 2.86 m/s which total of three grouping of velocities.

4.4.2 Parametric analysis of bypass fraction on water volume fraction

The result was recorded 0.5m and 5m away from the pig. The measurement is to show the mixture behavior after they are through the bypass of the pig. Also, the measurement can also show the duration of the behavior of the mixture. All of the data below is recorded by using U_{SA} = 2.86 m/s, U_{SW} = 0.9 m/s



a



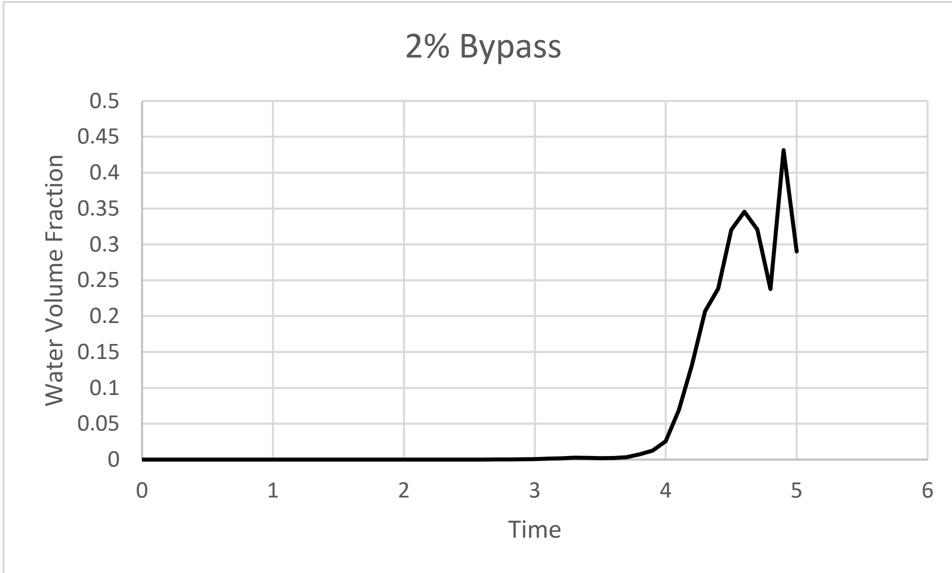
b

c

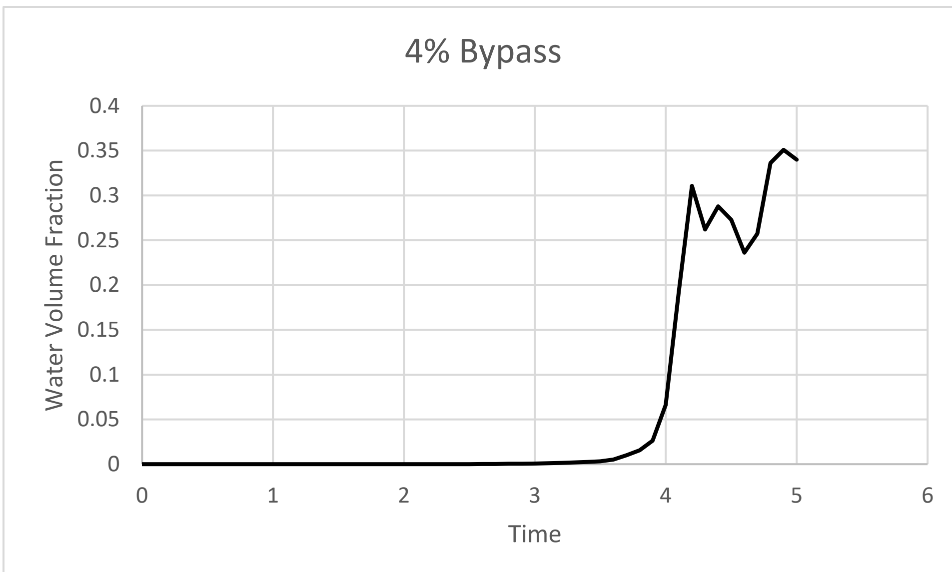
d

Figure 20: Mixture behavior after 0.5m from the pig

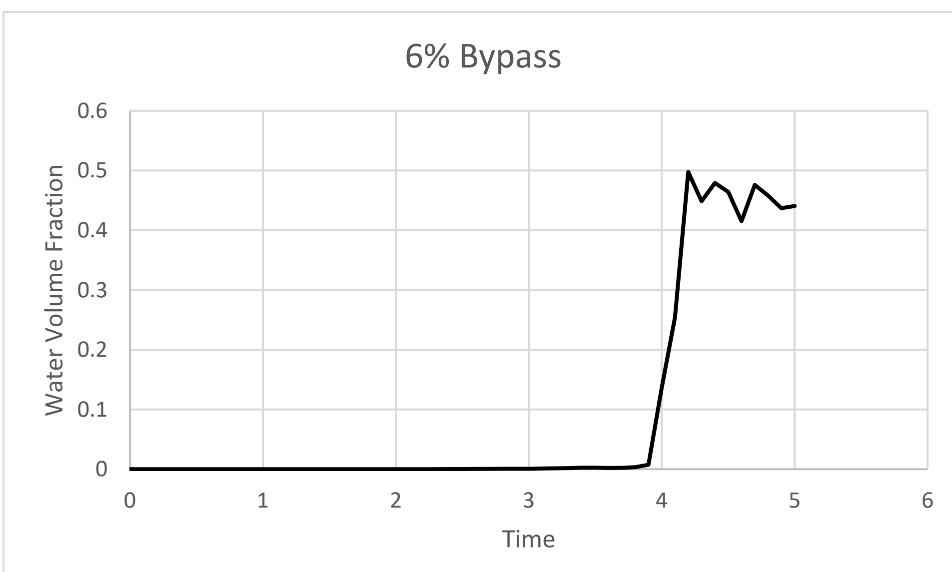
Based on figure 20, the graphs show the behavior of the mixture after getting through the bypass of the pig. Figure 20 (a) shows that the water volume fraction of the mixture after getting through the 2% bypass fraction is just over 0.1%. From the data interpreted, this means that there are about 90% air composition which makes them the majority after the mixture flows right through the pig. Figure 20 (b) shows that the mixture behavior is gradually increasing as the water volume fraction is higher than the 2% bypass fraction. Figure 20 (c) shows that the water volume fraction is almost at 50%. This shows that the 6% bypass fraction forms steady mixture composition faster.


2% Bypass
Water Volume Fraction
Time
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6

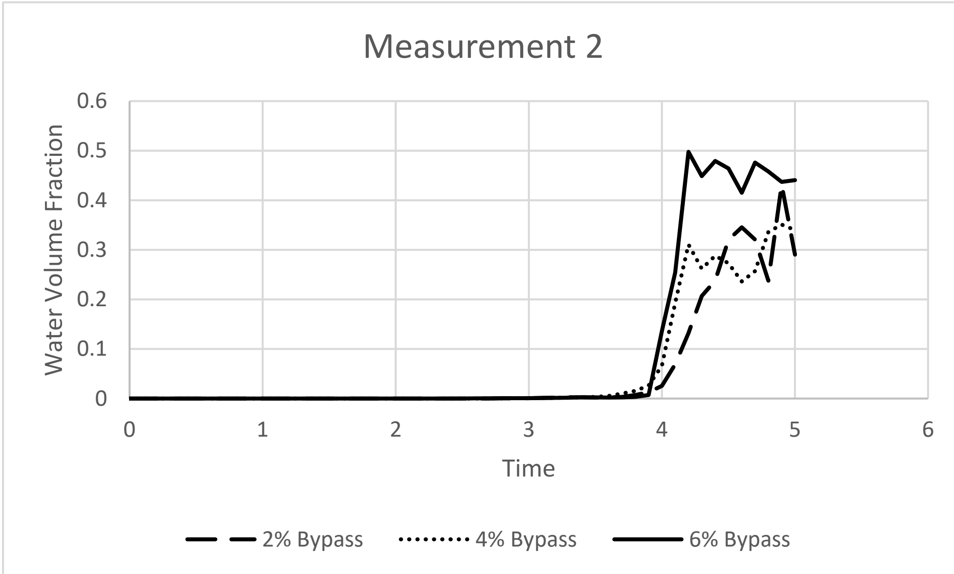
a


4% Bypass
Water Volume Fraction
Time
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6

b


6% Bypass
Water Volume Fraction
Time
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6

c



d

Figure 21: Mixture behavior after 5m from the pig

Based on figure 21, the graphs show the behavior of the mixture after getting through the bypass of the pig after 5m. Figure 21 (d) shows that the mixture which went through the 6% bypass fraction maintains the volume fraction from 0.5m while the mixture from 2% and 4% are quite unstable. The dispersed flow after the pig shows that the higher the bypass fraction of the pig, the less dispersion the flow will form.

4.4.3 Parametric analysis of bypass fraction on velocity in the bypass fraction

The data was recorded when the mixture is going through the bypass of the pig as shown below. All of the data below is recorded by using U_{SA} = 2.86 m/s, U_{SW} = 0.9 m/s.

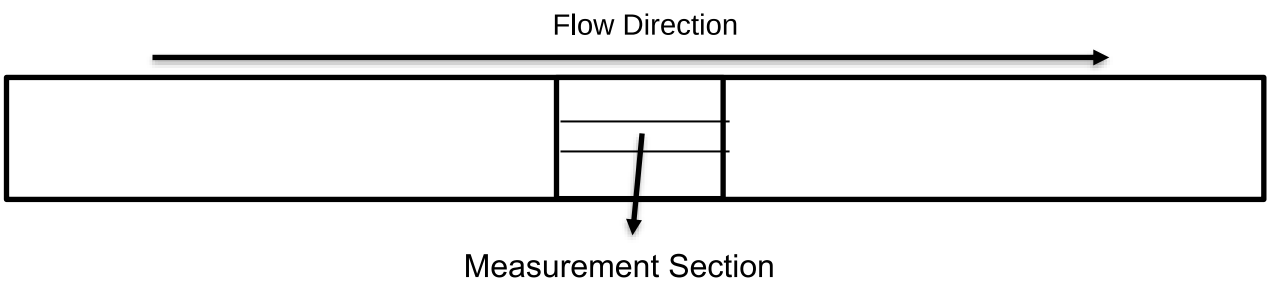
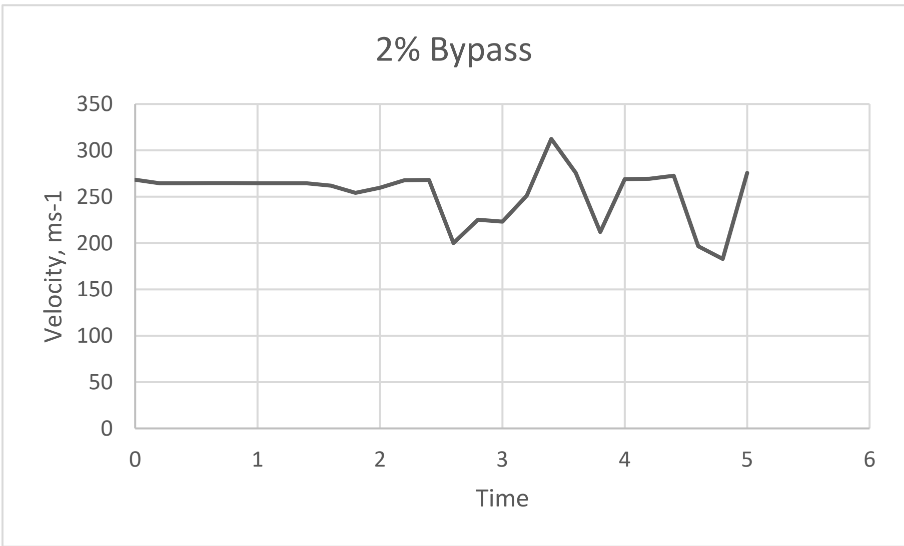
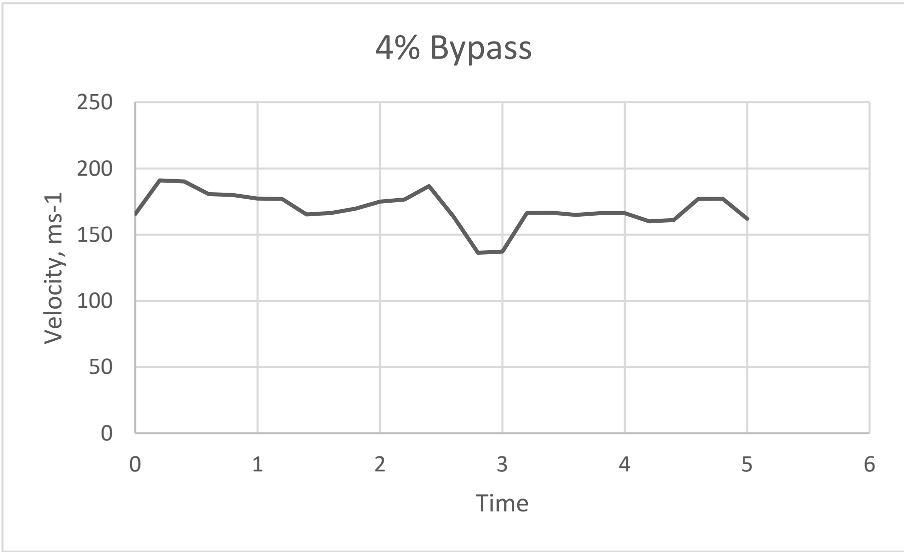


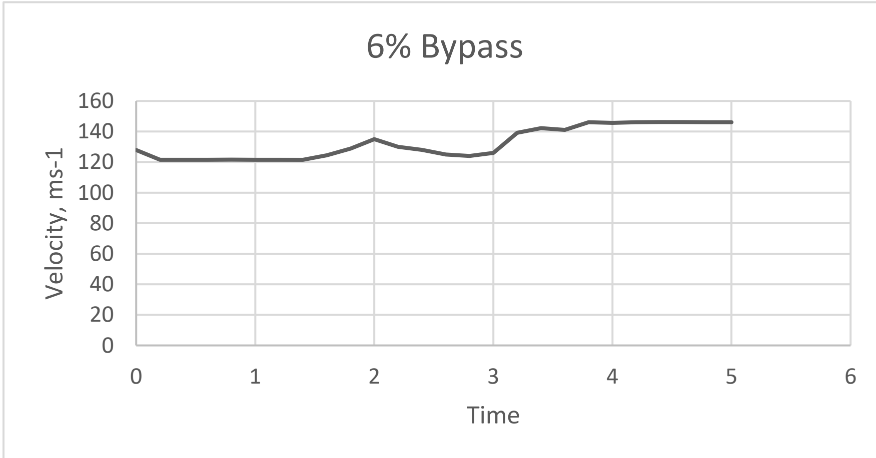
Figure 22: Measurement setup which takes place inside the bypass of the pig



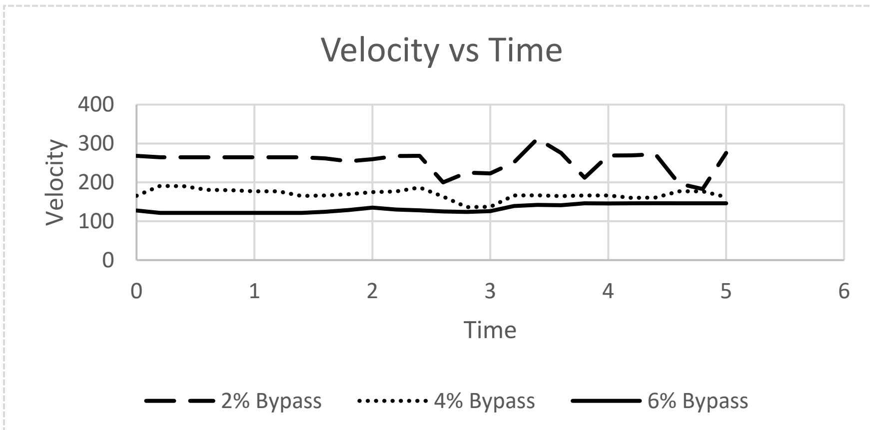
a



b



c



d

Figure 23: The velocity against time graph when the point of measurement is in the bypass of the pig to record the behaviour of the mixture velocity

Figure 23 shows the velocity profile when the mixture flows through the bypass pig with bypass fraction of 2%, 4%, and 6%. The graph shows that 6% bypass fraction has the lowest velocity profile followed by 4% and 2%. Note that the larger the bypass fraction, the slower the velocity of the mixture flowing through the bypass fraction. Also, figure 23 (c) shows that the velocity behaviour of the 6% bypass fraction is more steady compared to the 2% and 4% bypass fraction. The observation can be made primarily at the time frame between 2s and 3s where the slug are flowing through the bypass fraction. 6% bypass fraction only showed a little velocity dent whereas 2% and 4% showed a much larger dent.

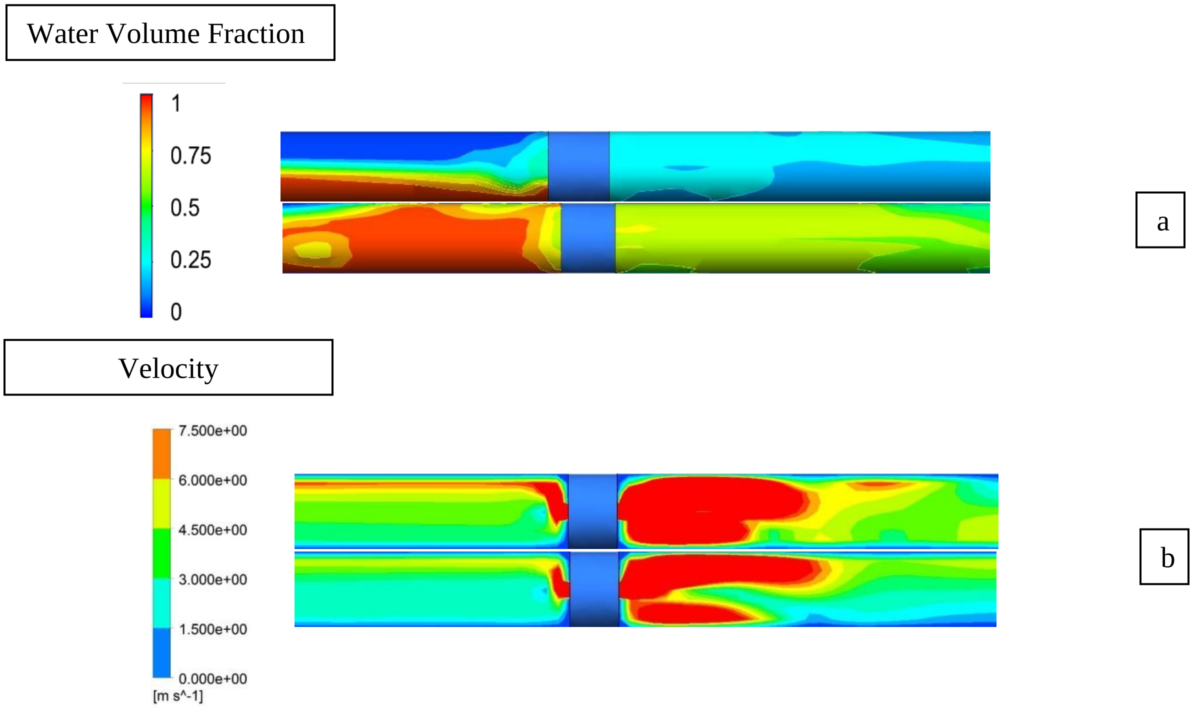


Figure 24: water volume fraction and velocity contour for bypass fraction of 2%

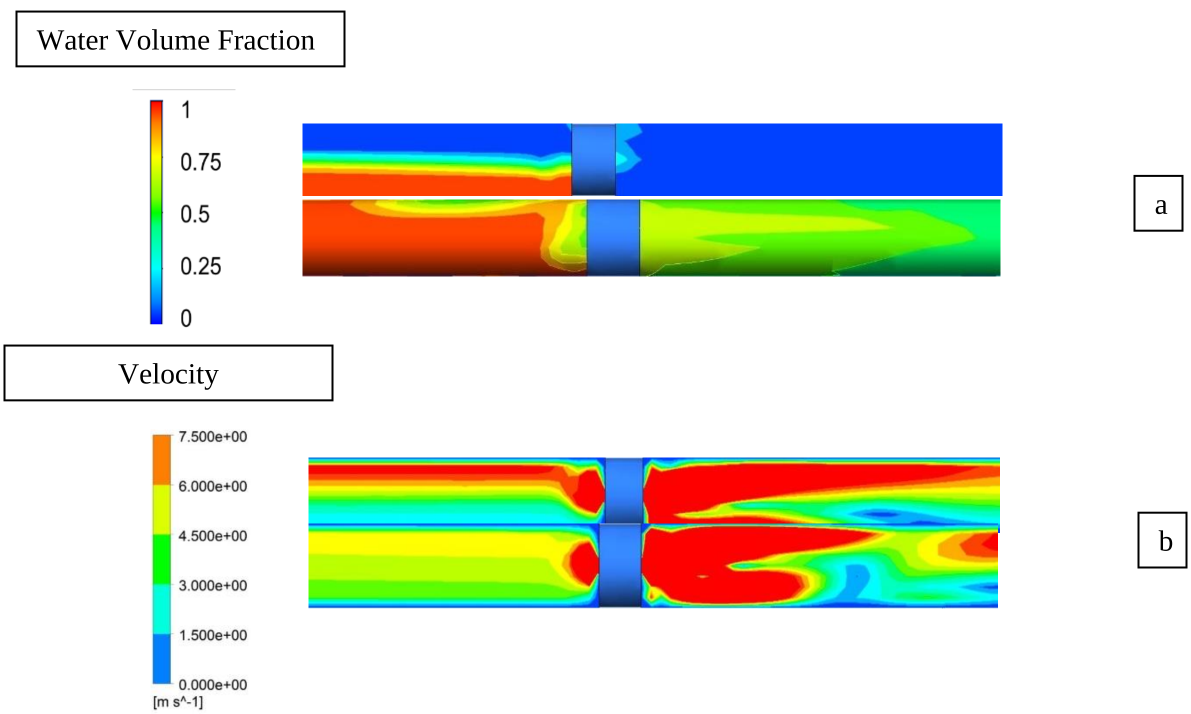


Figure 25: Water volume fraction and velocity contour for bypass fraction of 4%

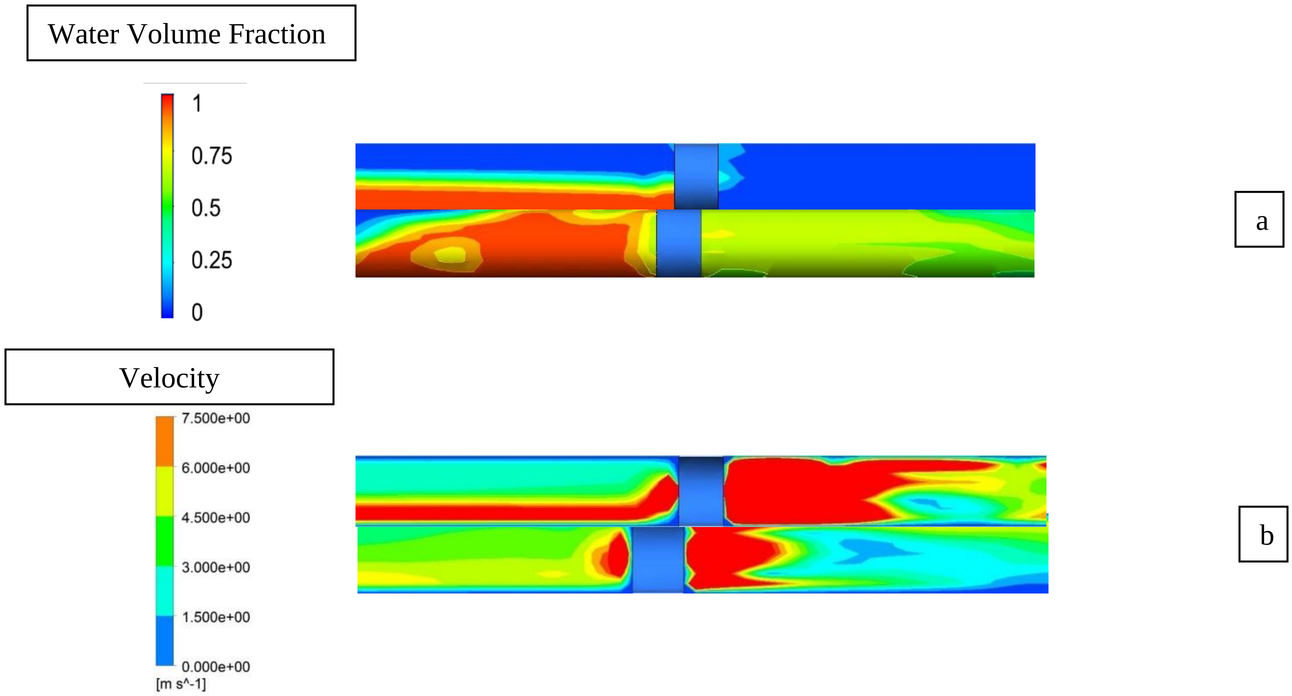


Figure 26: Water volume fraction and velocity contour for bypass fraction of 6%

Figure 24, 25, and 26 show the contours of volumetric fraction and velocity. From all of the contours, it is recorded that whenever the slug flow is flowing through the bypass, the velocity of the surrounding mixture decreases. 6% bypass fraction shows the shortest contour when the mixture is flowing through the pig. This is because the velocity of the mixture is the lowest compared to 2% and 4%. In addition, this can also explain the graph in figure 20 and 21 where the 6% bypass fraction produces less dispersion level compared to the bypass fraction of 2% and 4%.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Pipelines work as a means of transport in carrying medium between or more remote stations. Fluid flow pattern inside horizontal pipes is made of gas and liquid produced in the fuel and gas industries. Piping is the common medium for transporting the liquid to these types of industry. Orifice plate geometry was chosen as a research to transition the slug flow pattern to laminar flow. Thus, different diameter ratio was selected to split the two-phase flow. For these investigations, the fluid volume (VOF) method was used where it is the model that can produce excellent simulation of surface results for stratified flow, annular flow, slug flow and bubble flow where each flow has a different interface. The air and water were chosen as operating conditions in the horizontal pipe for these projects.

The validation result of the current flow regime model is equivalent to Ban Sam's research paper which refers to the flow regime map from Baker. For the present model, the simulation was conducted using the VOF method. In addition, a similar slug flow pattern in the horizontal pipe was obtained in the present work. The research then covers the bypass fraction in a horizontal pipeline with different bypass diameters.

In addition, he dispersed flow after the pig shows that the higher the bypass fraction of the pig, the less dispersion the flow will form.

The larger the bypass fraction, the slower the velocity of the mixture flowing through the bypass fraction. Also, that the velocity behaviour of the 6% bypass fraction is more steady compared to the 2% and 4% bypass fraction. This also means that 6% bypass fraction will produce the least velocity of mixture which flows through it. Current problem statement stated that the velocity of the pig has to be as constant as possible to make sure the pig travels smoothly across the pipeline. From the data gathered in figure 4.4.3.2, the problem can be resolved if a bypass pig with bypass fraction 6% is used.

As part of the recommendation, future improvement work that could be done in the future is to further research into the three-phase flow considered in the simulation by oil, gas and water. The studies will be akin to the map flow regime of the baker. Other than that, use a different length of orifice geometry to observe the effect of orifice plate length to the flow pattern as the parametric study does. Finally, use more data points to get a better output trend.

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