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Prediction Pressure Drop-In KKTD Residential Colleges Pipeline using CFD

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ABSTRACT

Pressure drop in the pipeline can be caused by friction and obstruction in the pipe resulting in the loss in pressure. This predicament problem caused a shortage of water supply in the building, especially at the KKTDI residential college, especially in the morning. This problem may be caused the student a bit late in attending the lecture. Thus, this study is focused to determine the pressure drop in the pipeline of the KKTDI residential college due to the shortage of the water supply. The computational fluid dynamic (CFD) method was applied in this study. A three-dimensional pipe system from the actual KKTDI pipeline was developed in this study. The steady-state condition is considered in this study. The validation was made between the actual and the simulated data in pressure drop. From the observation, the pressure drop in the pipeline was approximately 30% dropped as compared to the normal system. The pressure drop has occurred from the fitting, junction, and elevation of the pipeline, and the pressure continues to drop from one junction to another junction.

1. Introduction

Pressure drop is defined as the difference in total pressure between two points of a fluid carrying network [1-18]. A pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube. The main determinants of resistance to fluid flow are fluid velocity through the pipe and fluid viscosity. Pressure drops increases proportionally to the frictional shear forces within the piping network.

A piping network containing a high relative roughness rating as well as many pipe fittings and joints, tube convergence, divergence, turns, surface roughness, and other physical properties will affect the pressure drop. High flow velocities and/or high fluid viscosities result in a larger pressure drop across a section of pipe or a valve or elbow.

A piping system can be vibration excited by several sources that are a consequence of the flow of the internal fluid, the pumps, and other ancillary equipment of the system. The vibrational power induced in the pipe structure will be partly radiated as noise and partly transmitted through the

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isolators attaching the quiet piping system to the supporting structure. The approach that is developed here is not limited to isolated straight pipe sections but can be applied to a few subsections joined together by components that can be represented by structural mobility terms. The influence of the different structural parameters of the pipe, isolators, and support structure can be clearly demonstrated [11].

1.1 Pipe Pressure Drop

Pressure drop can be defined as the reduction in mixture pressure from one point to one point. It occurs when there are obstacles in the pipelines. Tremendous pressure drop will affect low system performance and high energy consumption. High operating pressure drop means higher energy consumptions [9]. A flow of fluid through a pipe there will be a pressure drop occurs because of resistance to flow. There may also be a pressure gain or loss due a change in elevation between the start and end of the pipe. The factor that always influenced the pressure drop across the pipeline is friction between the fluid and the wall of pipe. Second is the friction occurs between the adjacent layer of fluid itself. Third, an elevation in piping system can be a major factor to the pressure loss in fluid flow through a pipeline. Forth, the most popular factor of pressure drop in piping system is friction loss, friction loss occurs when the fluid is passes through any pipe fitting, bends, valves, and components. The fifth factor is pressure gain due to any fluid head that is added b a pump.

1.2 Pressure Drops due to Pipe Fitting

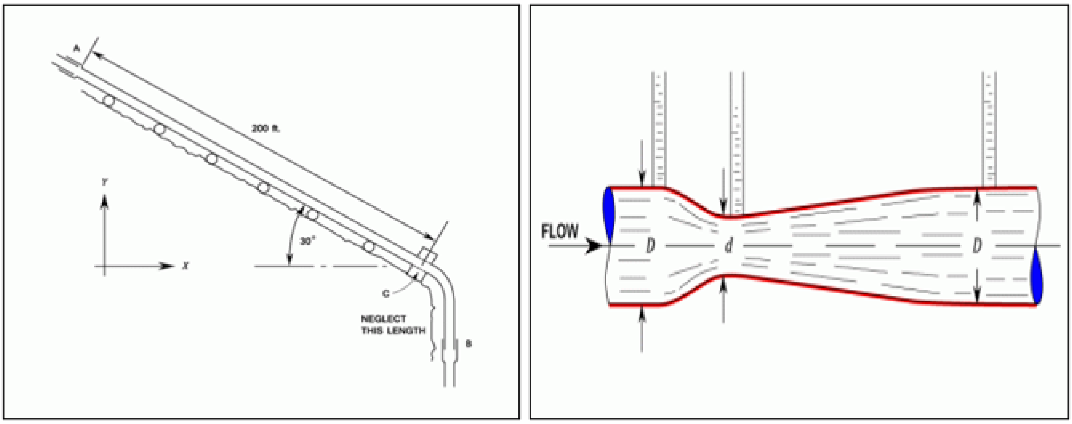
There are many pipe fittings such as Elbow, Tee, Reducer, Union, Coupling, Cross, Cap, Swage Nipple, Plug, Bush, Expansion Joint, Adapters, and valve. Contractions and expansion are integral part any piping system which also give effect on the pressure drop. These fitting are commonly used to control the flow rate and change the direction of flow, which causes energy loss in addition to that caused by the fluid flow through straight pipes. Flow of fluids in a piping system is accompanied by both skin and form friction, resulting in pressure or energy loss. This also result to form friction which is caused by pipe fittings as the fluid is subjected to sudden velocity and direction changes. The effect fitting losses normally referred as minor losses and commonly being ignore during analysis of piping system. When the piping is built up partially open valve, the effect and head loss through the valve should be included since the valve head loss may turn to be significant. The fluid head loss through the fitting can be calculated by this equation: $h=Kv^2/2g$. Where the h is the pressure loss in terms of fluid head. K is defined as manufacturer published K factor for the fitting. V stand for velocity of fluid and g is gravity acceleration. There were various of K factors in fitting such as gradual enlargement, gradual contractions, sudden enlargement, sudden contractions, rounded entrances, and long pipe bends [1].

1.3 Pressure Loss due to Elevation

The piping system has various design based on the design engineer, due to design there must be a flaw in the design that lead to certain problem like pressure loss due to elevation. The flow in a rising pipe is referred as the start elevation of pipe is lower than the end of pipe. Pressure loss caused by the rise elevation may cause the frictional and other losses at the start of elevation of pipe. Other than that, if the flow in failing pipe the start of elevation is higher than the end of the elevation, which is the frictional and other losses might be higher at the end of elevation.

Vertical upward concurrent air-liquid flow was investigated under isothermal conditions in a test section of 1-in. schedule 40 pipe. Pressure drop was measured with a mercury manometer connected to two pressure taps 20 ft. apart in the section. Liquid was trapped between two quick shutoff valves activated by two solenoid valves. The liquid was drained from the section to provide the holdup data. Six liquids were used to determine the effect of density, viscosity, and surface tension.

The experimental holdup, and two-phase pressure drop data were not in agreement with Lockhart-Martinelli type of correlation for vertical flow. A statistical correlation for holdup was developed to include fluid physical properties, total mass velocity, and the air-liquid ratio entering the pipe. Similarly, a pressure drop correlation was developed which expressed the two-phase pressure drop as a function of the slip velocity, liquid physical properties, and total mass velocity [18]. Horizontal is concurrent air-liquid flow was investigated under horizontal conditions in piping. The liquid was drained from the section to provide the holdup data. The horizontal flow liquid also was used to determine the effect of density, viscosity, and surface tension [18]. Figure 1 shows the vertical liquid flow and horizontal liquid flow in piping system



(a) Vertical liquid flow (b) Horizontal liquid flow

Fig. 1. (a) Vertical liquid flow (b) Horizontal liquid flow in piping system

1.4 Flow Pattern in Piping System

The regimes encountered in vertical flows have Bubble Flow, where the liquid is continuous, and there is a dispersion of bubbles within the liquid; Slug or Plug Flow where the bubbles have coalesced to make larger bubbles which approach the diameter of the tube; Churn Flow where the slug flow bubbles have broken down to give oscillating churn regime; Annular Flow where the liquid flows on the wall of the tube as a film with some liquid entrained in the core and the gas flows in the centre; and Wispy Annular Flow where, as the liquid flow rate is increased, the concentration of drops in the gas core increases, leading to the formation of large lumps or streaks (wisps) of liquid. Horizontal flow however, as gravity acts normally to flow direction, separation of the flow occurs. The respective flow regimes are Stratified Flow, where the gravitational separation is complete; stratified-wavy flow; Bubble Flow, where the bubbles are dispersed in the liquid continuum (though there is some separation due to gravity as illustrated); annular dispersed flow, which is like that in vertical flow, though there is asymmetry in the film thickness due to the action of gravity; and a variety of intermittent flows. This latter category includes Plug Flow, in which there are large bubbles flowing near the top of the tube; semi-slug flow, where very large waves are present on the stratified layer; and Slug Flow, where these waves touch the top of the tube and form a liquid slug which passes rapidly along the channel. Pipe inclination is an important parameter in determining flow regimes and flows in inclined pipes and in other geometries.

1.5 Pressure Drops due to Leakage

Based on Brunone *et al.,* [4], leakage was an important issue that currently concern about water utilities which was leak detection. Leakage can be represented as undesirable treated water loss and pumping energy. However, referring to Ferrante *et al.,* [5], inspect the available technologies for leak detection has its own advantages and disadvantages. All technologies appear capable of detecting leaks under some conditions, but none of them is a cure that can be used in all situations and users may want to consider a combination of technologies. Thus, procedures for leak detection and location that are not only faster and cheaper, but also do not require hold of pipeline operations for long periods of time as most of the existing methods do are strongly required by technicians. Leakage can be control by minimize the pressure excess, while accessible for reducing unnecessary waste, only forward the symptoms of the problem. Discussion on how leakage increases the energy expenditure of transmitting water through a pipe segment provides a useful passage point for analysis of leaky networks. The assumption made throughout this paper is that, whether the system leaks or not, the following demands and pressure condition must be met.

2. Methodology

2.1 Modelling Process

The design of pipeline is design based on the actual schematic plan of piping system at residential college KKTDI (see Figure 2). The length and diameter of piping is not actual with the KKTDI piping because the length of pipe was not stated in the KKTDI schematic plan. The inner diameter of pipe is 100 mm based on the schematic diagram from the PPH, which is the thickness of pipe wall is assumed 10 mm (see Figure 3)

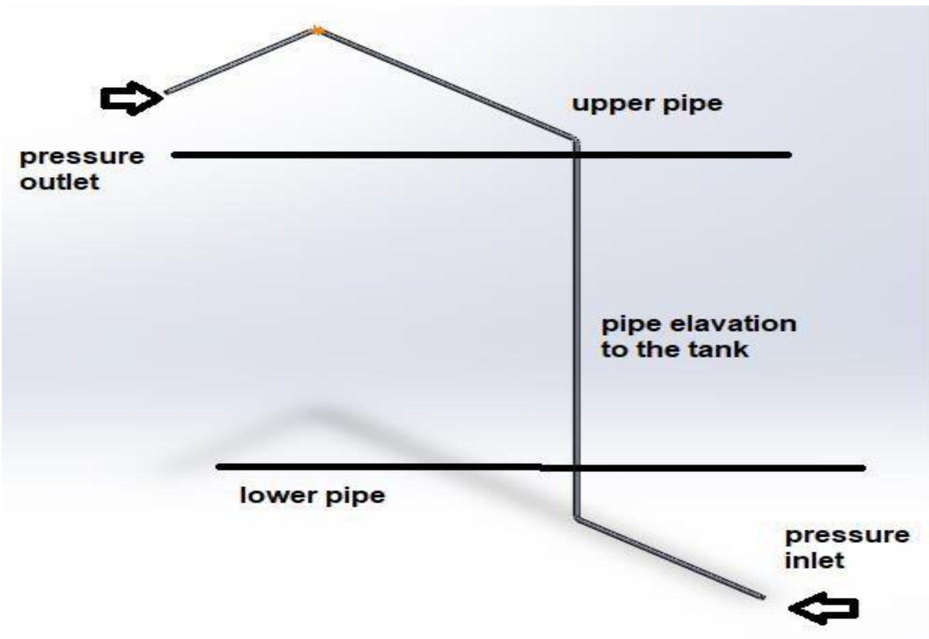
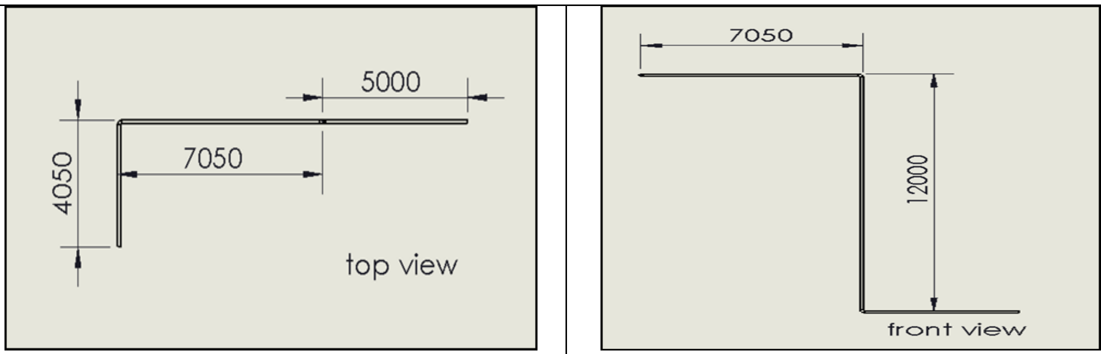


Fig. 2. The design of piping system at KKTDI residential colleges



(a) Top view (b) Front view

Fig. 3. The (a) Top view and (b) Front view of the pipeline (unit in mm) design of piping system at KKTDI residential colleges

2.2 Simulation

The simulation was taken place after the geometry of pipe was completely draw. The drawing in the SolidWord 2016 software saved in IGS file before import to the design modeler. The simulation is using the Ansys Fluent which is as known as numerical method analysis. The software used was Ansys 19.2. The important element in Ansys Fluent simulation is the box of process, to achieved un error during the simulation and post processing a green tick in geometry, meshing and setup section is shown, if not there were error occur during the setting. First the simulation starts with the design modeler. Import the geometry in the design modeler after draw in the SolidWork 2016 saved as IGS file, because others format could possibly be read or invalid. Next, rename the pipeline such as inlet, outlet, and wall.

2.3 Meshing and Mathematical Formula

Table 1 shows the detail of meshing

Table 1
Detail of meshing

Detail of Mesh	Parameter
Default	
Physic preference	CFD
Solver preference	Fluent
Export format	Standard
Sizing	
Growth size	Default (1.2)
Max size	0.219.38 m
Capture Curvature	Yes
Capture Proximity	Yes
Proximity Size Function	Faces and Edges
Quality	
Smoothing	High
Mesh Matric (skewness)	Make sure below than 0.9 (0.84676)
Assembly Meshing	
Method	Tetrahedrons
Statistics	
Node	101301
Elements	464776

First the simulation starts with the design modeler. Import the geometry in the design modeler after draw in the SolidWork 2016 saved as IGS file, because others format possibly cannot be read or invalid. Next, rename the pipeline such as inlet, outlet, and wall. Figure 4 shows the meshing pipe system.

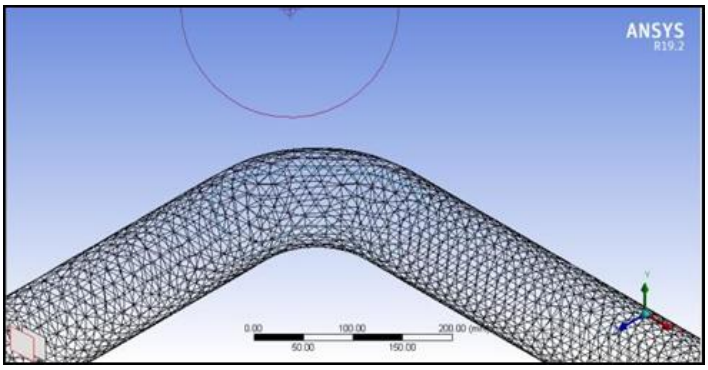


Fig. 4. Meshing pipe system

The mathematical formula was used after the simulations. The formula used was the pressure drop formula and flow rate equation. Bernoulli's equation to determine the volume flow rate of the flow after the simulation produce value of pressure at inlet and outlet.

$$Flow\ rate,\ Q = Av \tag{1}$$

$$Pressure\ Drop = P1 - P2 \tag{2}$$

$$Bernoullis\ Equation = P + pg + 0.5pv2 \tag{3}$$

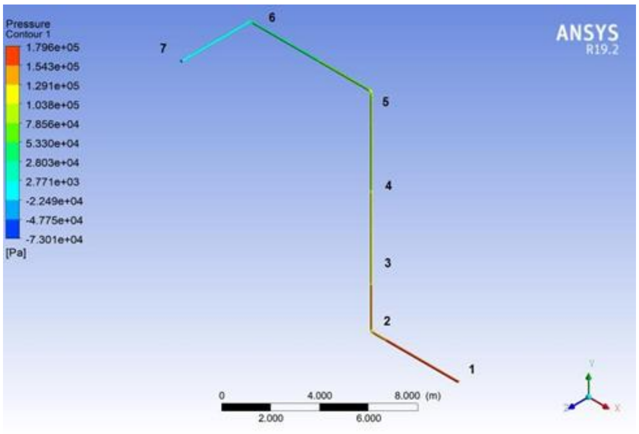
$$Time\ taken\ to\ fill\ the\ tank\ (s): = \frac{volume\ of\ tank}{volume\ flow\ rate} \tag{4}$$

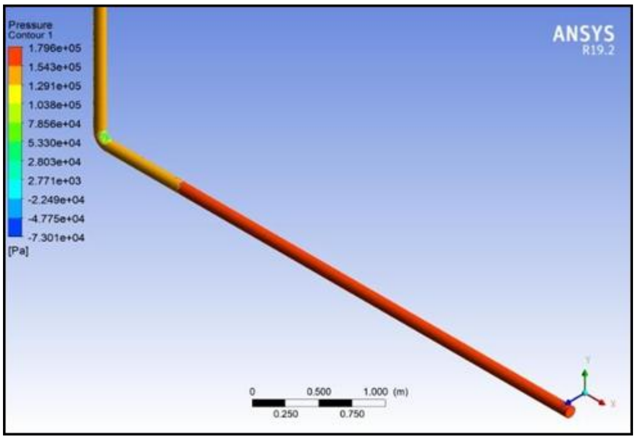
3. Results

3.1 Pressure Contour

Pressure contour in the post processing result shows the variation of colour of pressure to differentiate the pressure occurred in the pipeline**.**

The Figure 5 (a) shows the of overall pressure contour represent the inlet pressure of the pipeline. The pressure in the pipe start to loss along the pipe before the junction. The factor can be predicted was the friction in the pipe along the inlet. The pressure show by the simulation was 179 kPa at the inlet. The Figure 5(b) shows the pressure contour represent at the first junction of the pipeline before elevation upward to the building. The pipeline experienced pressure loss when at junction of pipe due to the fitting and elevation. The pressure contour shows at the junction the pressure contour green was appeared at the junction due to pressure more experienced at the arrow in the figure. The simulation captures the pressure was drop 179 kPa to 154 kPa.

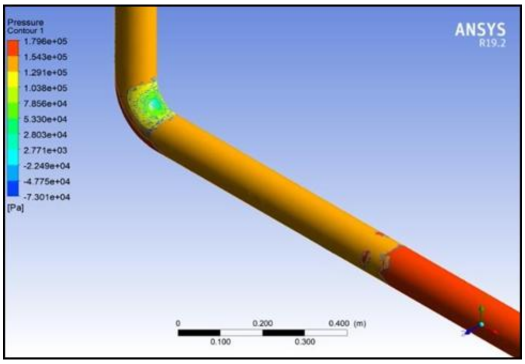




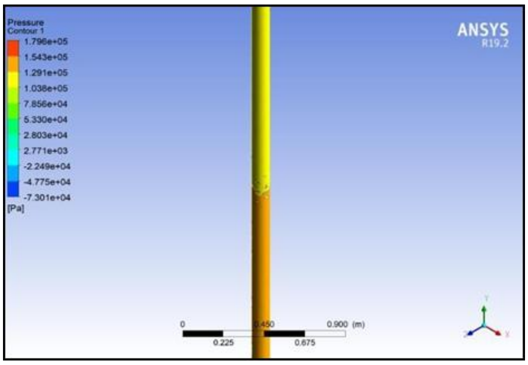
(a) Overall pressure contour of pipeline (a) Pressure inlet

Fig. 5. The pressure (a) overall pressure contour and (b) pressure inlet of pipeline

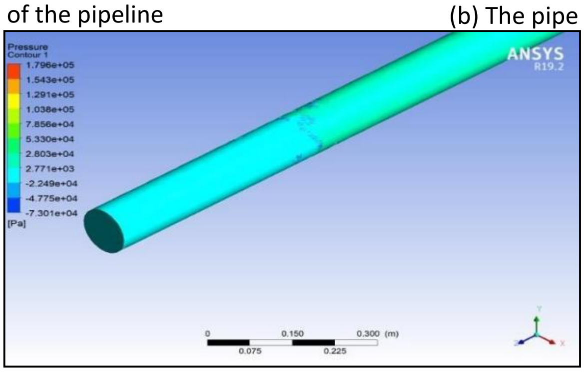
The Figure 6 (a) and (b) is represent the pipe junction and elevation to upper pipe. The pressure continuing to loss due to elevation and friction along the pipeline calculate by the turbulence model k-omega SST. The simulation shows the pressure continuing to loss from 154 kPa to 129 kPa. The Figure 6 (c) represent the pressure outlet of the pipeline. The pressure contour at the outlet pipe shows the pressure become decrease compared to the pressure before the outlet. The pressure contour shows the pressure drop occurred due to friction in pipe. The outlet pressure captured by the simulation was decrease from 28 kPa to 27 kPa. From the pressure contour a conclusion can be made, the pressure drop was affected from the friction along the pipeline, the elevation of pipeline and the junction of pipeline. Therefore, if the pipeline is longer and have more junctions or elevation, the predicted pressure drop will increase.



(a) Junction of the pipeline



(b) The pipe elevation



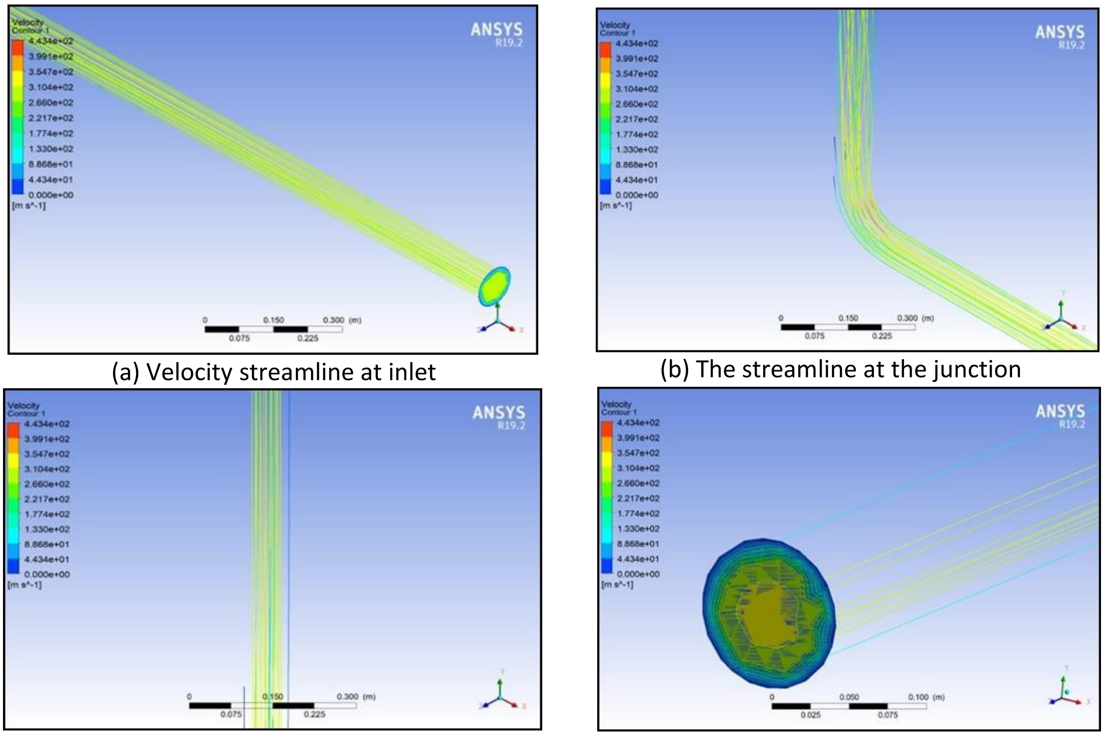
(c) Pressure outlet

Fig. 6. (a) junction (b) elevation and (c) pressure outlet of pipeline

3.2 Velocity Streamline

The Figure 7 (a) shows the velocity streamlines at the inlet of the pipe where there were many numbers of streamline start from the inlet. The velocity capture from the simulation was around 310 m/s to 354 m/s. The Figure 7 (b) shows the velocity streamline of the flow at the first junction pipeline. The simulation shows the number of streamlines start to decrease due to the junction of the elevation. The velocity streamline shows there were high velocity occur at the arrow in the figure. From figure also shows the velocity start to decrease from 354 m/s to 266 m/s.

The Figure 7 (c) shows the velocity streamline of the start to lose the number of streamline due to the elevation of the pipe for 12 meters. The velocity indicates the green color of the streamline start exist and combine with the yellow streamline. The velocity of the flow starts to drop from 310 m/s to 221 m/s.



(a) Velocity streamline at inlet
(b) The streamline at the junction
(c) The velocity streamline at the elevation
(d) The streamline at outlet of pipeline

Fig. 7. (a) velocity streamline inlet (b) the streamline at junction and (c) velocity streamline at elevation and (d) streamline outlet of pipeline

The Figure 7 (d) shows the number of streamlines was few at the outlet. This due to the friction along the pipeline calculates by the k-omega Shear Stress Transport around the pipe. The velocity of the streamline still shows around 266 m/s to 310 m/s at the outlet but the number of streamlines very few compares to the inlet.

3.3 Pressure Drop

Through the simulation, the inlet and outlet pressure are determined. The pressure drops occur in the pipeline can be seen through the pressure contour where the pressure continues drop through the length of pipe, junction, and pipe elevation. Figure 8 shows the pressure drop against gauge pressure. Table 2 shows the pressure drop.

Table 2
Pressure drop

Gauge Pressure (Bar)	Gauge Pressure (kPa)	Inlet Pressure (kPa)	Outlet Pressure (kPa)	Pressure Drop (kPa)
2.3	230	179	24.9	154.1
2.2	220	171	24.0	147.0
2.1	210	163	23.1	139.9
2.0	200	156	22.2	133.8
1.9	190	148	21.3	126.7

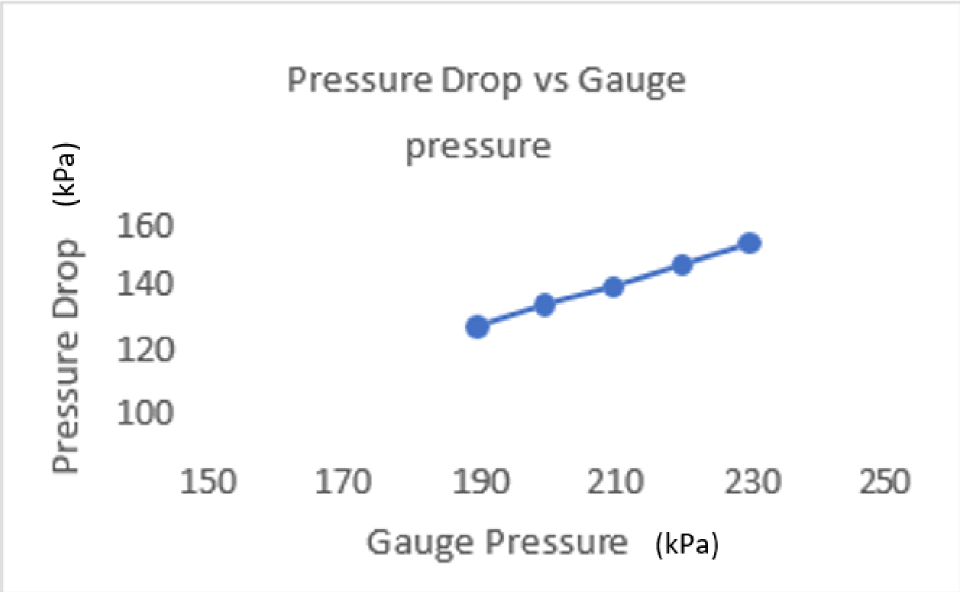


Fig. 8. Pressure drop against Gauge pressure

3.4 Time Taken to Fill the Tank

The residential colleges have 3 tanks was used on the building based on the schematic plan (see Table 3). The problem occurred was the time taken the water to fill the tank is longer and not sufficient. Table 4 shows the flow rate from calculation. Table 5 shows the time taken water to fill the tank.

Table 3
Capacity of tank

	Gallon	m^3
Tank 1	8800	33.311
Tank 2	7040	26.649
Tank 3	8800	33.311

Table 4
Flow rate from calculation

Inlet pressure (kpa)	Flow rate for outlet, m^3/s	Flow rate for each pipe to the tank, m^3/s
230	0.00672	0.00224
220	0.00605	0.00202
210	0.00528	0.00176
200	0.00449	0.00150
190	0.00342	0.00114

Table 5
Time taken water to fill the tank

Pressure gauge (kpa)	Tank 1 (min)	Tank 2 (min)	Tank (min)
230	247.8	198.3	247.8
220	274.8	219.8	274.8
210	315.4	252.4	315.4
200	370.1	296.1	370.1
190	487.0	389.6	487.0

3.5 Compare the Simulation Data with Actual Pump Specification

The actual pump installed on the ground of KKTDI residential colleges has a flow rate 6-12 m^3/h. Thus, a comparison can be made from the actual specification and simulation of the flow rate of the pipeline.

From Figure 9, the plotted shows the actual pump specification and the simulation have a large different gradient. However, the line of plotted shows the line of the simulation and the actual pump specs was connected. Thus, the actual pump spec shows a correlation toward the simulation data and the data of simulation can be considered acceptable. The different always occurs between the pump specification and the real-life situation, therefore it is normal if the simulation data show different if compare with the actual specification.

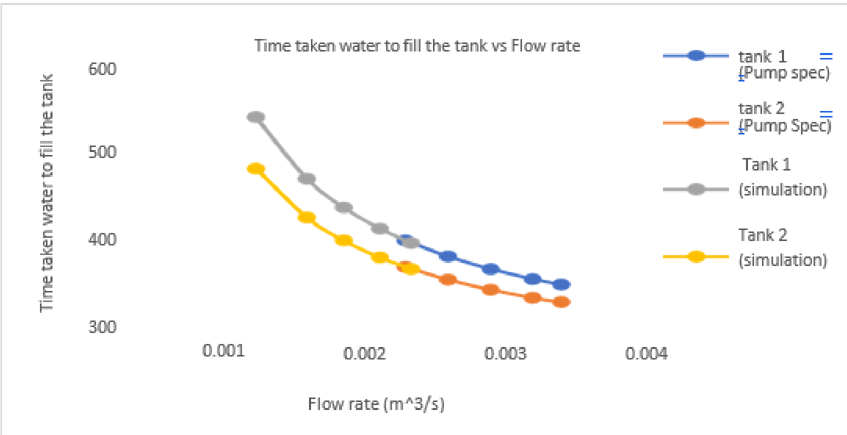


Fig 9. Time taken water to fill the tank vs Flow rate (simulation and actual pump specification)

3.6 The Dimensionless Time Taken to Fill Tank Vs Flow Rate

The plotted graph in Figure 9 had a huge difference between the actual pump specification and the simulation data. Thus, a dimensionless plotted has been done to see the trend of the curve between actual pump specification and the simulation data. From Figure 10 the curve shows between the dimensionless 'time taken to fill tank' and the 'dimensionless flow rate' has the same gradient but slightly different in the curve. Therefore, data simulation shows the correlation between the actual specification of the pump. The conclusion can be made from this plotted is the time taken water to fill the tank will longer if the flow rate was low.

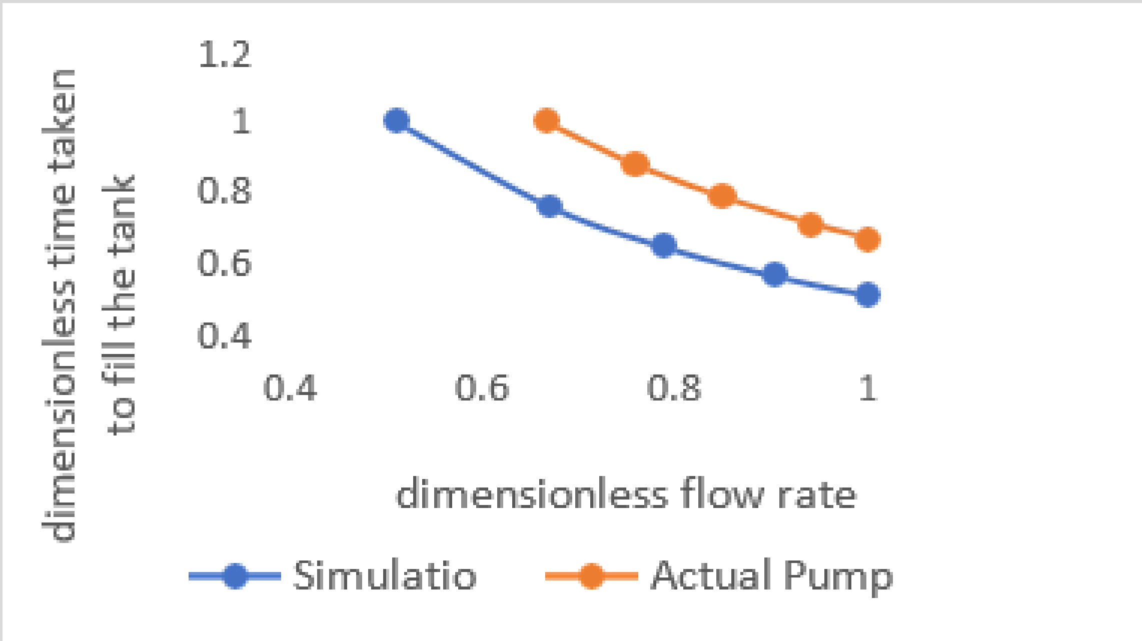


Fig. 10. The dimensionless curve

4. Conclusions

The objective of this study is to carry out the prediction of pressure drop occur at KKTDI residential colleges which has many complaints about the water is not sufficient to the residential. From this simulation of the pipeline, a conclusion can be made that the piping system at KKTDI residential colleges experienced huge pressure drop from the pump to the tank. The pressure drop was address from the fitting, junction and elevation of pipeline, the pressure continuing to drop from one junction to another junction. The pressure contour from the simulation shows the pressure start to drop with different color and conclude the pressure drop occurred due to friction along the pipe, fitting, and elevation.

Next, the time taken water to fill the tank was calculated from the data simulation. the time taken between the actual pump specification and simulation data has huge different gradient, but the line of plotted between actual pump specs and simulation was connected. Thus, the data shows correlation and the data considered as acceptable. The different time taken water to fill the tank between actual pump specification and data simulation show huge different, and the different was above 2 hours. This study was successfully achieved both objectives.

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