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The Study of Difference Piping Wall Thickness Against the Difference Pressure Applied at UTHM Biodiesel Plant Using Simulation Method

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Abstract: The study is concerned about the withstand of the piping system at the Universiti Tun Hussein Onn (UTHM) Biodiesel Plant during operation using different pipe thicknesses against the variation of applied pressure. The range of the wall thickness used is 2.77 mm, 3.91 mm, and 5.54 mm which follow the ASME B36.10 code and standard. Next, the piping selection characteristics are fully followed as actual at the UTHM biodiesel plant. The pipe material used is A53 B carbon steel pipe, actual dimension for length and height is at actual, the temperature design is 250 ^{o}C, and the 8 to 12 bars operating pressure are applied. This study is performed using the Solid Works 2020 software simulation method. Two methods in simulations are being used which are Computational Fluid Dynamics (CFD) for flow simulation and Finite Element Analysis (FEA) to analyze the static pressure. The CFD is functioning to recognize the highest point of the part along with the piping system for the selected applied pressure. The selected pipe is being tested and measured using the FEA simulation to investigate the maximum value of stress and strain to withstand the applied pressure. From the analysis, the elbow pipe is the highest-pressure point located for flow distribution along with the piping system. The study shows that the 3.9 1mm wall thickness for the piping system that is used at the UTHM biodiesel plant is acceptable and comply with the ASME B36.10 code and standard. The result for the 2.77 mm and 5.54 mm wall thicknesses, it also acceptable but not economical in terms of safety and cost of the material.

Keywords: Biodiesel Plant, Piping System, Wall Thickness, Pressure, CFD, FEA, Elbow Pipe

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1. Introduction

The plants consist of two categories of equipment which are rotating and static equipment[1]. The major equipment that is used in every type of plant is almost similar, but it depends on the process operation required. There are a lot of piping systems along with the pipe rack with a different working fluid and its pressure in the plant operation area. The piping system usually does not have specific detail drawings but comes out through a Piping and Instrumentation Diagram (P&ID). The piping is the system used to transport fluid or gasses mechanically from one location to another place [2].

This project aims to compare the capability of the piping system at different pressure tests. The pressure applied for this study is eight to twelve-bar. It is started by measuring the selected pipeline at the Biodiesel Pilot Plant of Universiti Tun Hussein Onn Malaysia. The pipeline is sketched using Solid Works 2020 software. Two method simulations are being used which are Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA). The purpose of this simulation is to investigate the capability of the wall thicknesses in the piping system based on the pressure applied. An elbow pipe usually has the highest-pressure stress located for the flow distribution pressure [3]. Meanwhile, this study also predicts the mechanical properties of the wall thicknesses using the FEA simulation method to minimize the maintenance cost for testing. It is more economical and practical by testing it using the simulation method. The pressure is applied from eight to twelve bars against the wall thickness selected for the A53B carbon steel pipe from the outlet boiler to the steam header at UTHM Biodiesel Plant.

Figure 1: 2-inch A53 B carbon steel pipe outlet boiler to the steam header

2. Materials and Methods

2.1 Materials

The material for the piping system selected is the A53 B Carbon Steel Pipe. This piping selected is the flow for the steam pressure from the outlet boiler to the steam header. This pipe is following The American Society of Mechanical Engineers (ASME) B36.10 piping code and standard. There are three different wall thicknesses of the pipe being analyzed which are 2.77mm, 3.91mm, and 5.54mm (*refer to appendix A)*. This A53 B carbon steel pipe used is 2 inches for its diameter nominal (DN). This material has an allowable pressure based on the American Society Testing Materials (ASTM) code and the standard depends on the size of the piping selection. For 2-inch nominal pipe size (NPS), the allowable pressure is 3177psi or 21905kPa. This material of pipe has various grades, and the most common industrial piping material is a low carbon steel used [4]. Moreover, the carbon steel material for making a pipe is also famous material that has been chosen for pipelines [5].

2.2 Research Flow Chart

The flow chart is one of the quality tools to understand the process by showing all the project flow. This flowchart below shows the starting of the project start until the end of the result is achieved.

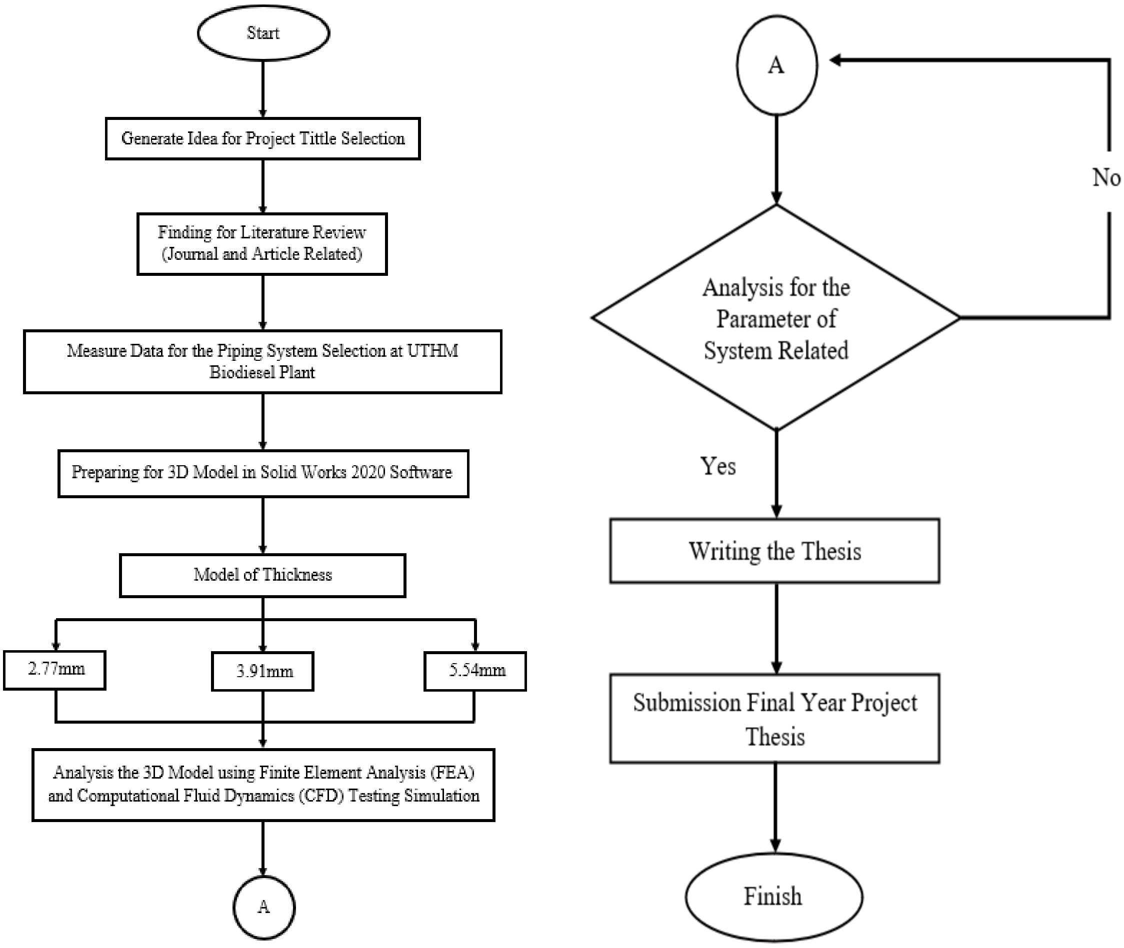


Figure 2: Process flowchart for this study

2.3 Collect for the Actual Data at the Area Selection

The first step to start for this project is by surveying the piping selection located at the UTHM biodiesel plant. Then the piping must be measured for the dimension, the material of the pipe, and the other parameter to simulate it using the actual value. The measuring tools that are used to measure all the dimensions are by using a measuring tape, ruler, vernier caliper, and the ballpen. Besides that, the P&ID also identify to recognize the material and the pipe size.

Figure 3: UTHM Biodiesel Plant

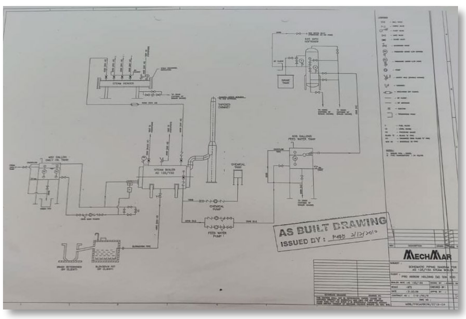


Figure 4: P&ID for UTHM Boiler

Figure 4: OD for Pipe Size

Figure 5: Flange Thickness

Figure 6: Flange OD Size

2.4 Data Collection

Table 1 shows the data collection for non-physically measurement. All the information collected is important to be used during the simulation process of Solid Works software.

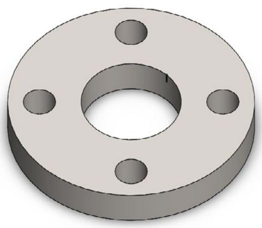
Table 1: Specification for the outlet boiler to the steam header pipeline

No.	Specification	Dimension / Information
1.	Working Fluid	Steam
2.	Maximum Allowable Working Pressure	10 Bar
3.	Design Temperature	250^{o}C
4.	Boiler Weight	Dry- 3940kg
5.	Fuel Used	Diesel

2.5 Preparation for 3D Model in Software

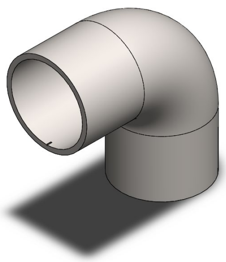
The parts of the pipeline were sketched using Solid Works 2020 software. All the dimensions of the parts are following the actual dimension that was already measured and recognized during the survey and collecting the data at the UTHM biodiesel plant. The table below shows the parts for this study before the assemble all the parts to be a complete model before testing.

Table 2: Parts of the piping system from outlet boiler to the steam header



a. Flange

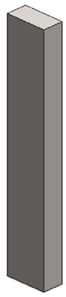
b. First Vertical Pipe Outlet the Steam Boiler



c. Elbow 90^{0}

d. Horizontal Pipe

e. Vertical Pipe attaches with the Steam Header



f. Pin

After all the parts are built up, then all the parts are assembled to be one piping system same as actual at the UTHM biodiesel plant. The figure below shows an example of a piping system related to one value of the wall thickness of the pipe. The model is very crucial to be finished to do the simulation and analysis of the model for the various pressure applied in the piping system.

Figure 7: Complete model for one piping system in Solid Works 2020 software

Figure 7 above shows the one complete piping system from the outlet boiler to the steam header, but it is only for one wall thicknesses. From this model, there is three wall thickness that is analyzed and simulated which is 2.77 mm, 3.91 mm, and 5.54 mm. These difference wall thicknesses will be analyzed against the differential pressure applied to predict the withstand of the piping system. As mentioned earlier in this study, there are two simulations used using Solid Works Software which are FEA and CFD. The CFD is simulated first to recognize the highest pressure located along with the piping system and FEA is to simulate the static pressure to get the result. This study is not toward the empirical method and only the simulation method being used.

2.6 Simulation Method

a) Computational Fluid Dynamics (CFD)

The CFD is a method of simulation to study the flow along with the piping system. The parameters measured for this study are pressure and velocity distribution. For the pressure distribution, the researcher could verify the highest point of the critical part to be carried forward that part to do simulation for static pressure. Meanwhile, the velocity distribution could identify the hypothesis between pressure applied against the velocity in the pipeline. Table 2 below show the pressure and velocity distribution form.

Table 2: Pressure and velocity distribution form

Wall Thickness (mm)	Pressure Distribution		Velocity Distribution	
	Min	Max	Min	Max
2.77				
3.91				
5.54				

b) Finite Element Analysis (FEA)

The FEA test is simulated to test the static pressure for the part that is selected. There is a two-parameter that needs to be analyzed for this study which is the stress and strain. Usually, the weak point for the part during pressure test in CFD is the elbow part.[3] Table 3 below shows the FEA result form for 8, 10, and 12 bars pressure applied for these difference wall thicknesses measured.

Table 3: FEA Simulation Test

Wall Thickness (mm)	Stress		Strain	
	Min	Max	Min	Max
2.77				
3.91				
5.54				

2.7 Equation for Flow in Pipe

The equation for the flow in the pipeline is Reynold Number. Reynold number is stated as the value that could be reference the flow in the system whether it is laminar, transient, or turbulent. Moreover, this equation also could be a reference as the effect of pressure applied toward the rate of velocity in the piping system. The equation that is used is shown below [6].

$$Re = \frac{Inertial\ forces}{Viscous\ forces} = \frac{V_{avg}D}{\text{v}} = \frac{\rho V_{avg}D}{\mu} \quad Eq. 1$$

ρ = density of fluid (kg/m^3)
v = velocity (m/s)
D= diameter inlet pipe (m)
μ = viscosity (kg/m. s)
v = kinematic viscosity (m^2/s) $= \frac{\mu}{\rho}$

3. Results and Discussion

There is two simulations method are applied for this study to recognize the result for the condition of the piping system selected. The pressure and the velocity distribution will be applied in CFD first to get the result. Then the part selected will be analyzed and investigated in static pressure simulation called FEA test which it the certain pressure selected are applied. Then the withstand of the structure behavior could be found whether it is already fixed and suitable as the actual UTHM biodiesel plant or could be some improvement or vice versa.

3.1 Computational Fluid Dynamics Result

a) Pressure Distribution

Table 4 below CFD simulation is for the pressure distribution from the outlet of the fire tube boiler to the steam header. The pressure applied is 10 bar and applied for three different wall thicknesses of the piping system. The result shows that the first elbow part is the highest point of the maximum stress or the weak point among the other parts in the piping system. The value of pressure distribution that is approximately using the manual probe which is nearest to the maximum value is the elbow parts for all the wall thicknesses being tested. The pressure applied is 10 bar, meanwhile for the 8 and 12 bars pressure distribution applied, the result still gets the same. The maximum stress occurred at the elbow of pipelines so that the failure of the elbow was before that of straight pipes, and the elbow was the weakest in the pipelines[3].

Table 4: Pressure distribution at 10 bar pressure

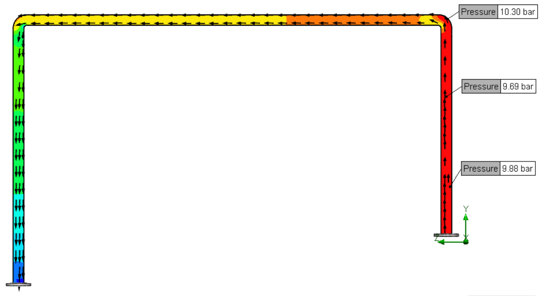
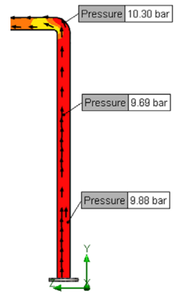
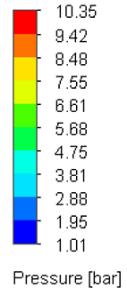
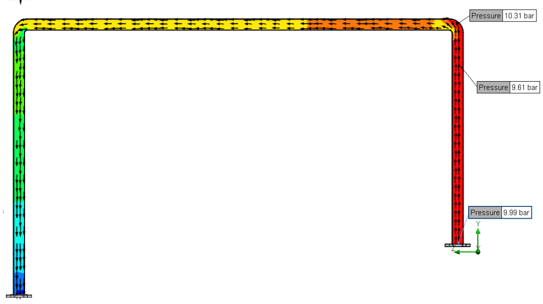
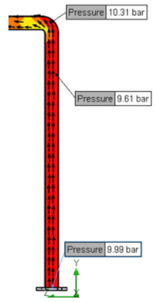
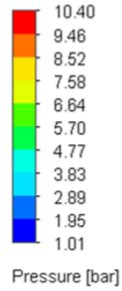
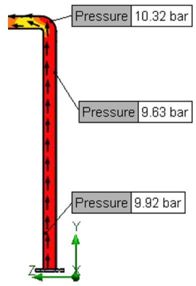
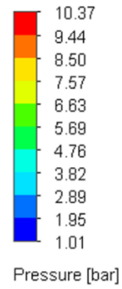
Wall Thickness	Flow in Pipeline (Pressure Distribution)	Manual Probe	Minimum to Maximum Value
2.77mm			
3.91mm			
5.54mm			

Table 4 above shows the elbow is the part that recognizes to be simulated using the FEA test for the static pressure which represents the withstand for the whole piping system. Besides that, this figure shows that the earlier stage in the pipeline is critical for the pressure that starts to build up and the pressure will drop or reduce at the end of the piping system due to the pressure loss in the pipeline. Although there is a red contour at the earlier stage which represents the highest part for the pressure distribution, the manual probe proved that the highest-pressure distribution located is at the elbow joint for all the different thicknesses of the pipeline.

b) Velocity Distribution

This comparison is to investigate the rate of velocity against the pressure applied. Besides that, the wall thickness selected is 2.77 mm as the constant data. The simulation is comparing the simulation method and the calculation to identify the trend of the velocity when pressure is applied in the piping system. Table 5 below shows the pressure applied and the result for the velocity distribution in the piping system.

Table 5: Pressure Applied for the Velocity Distribution

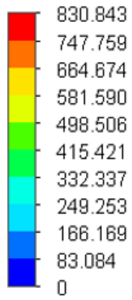
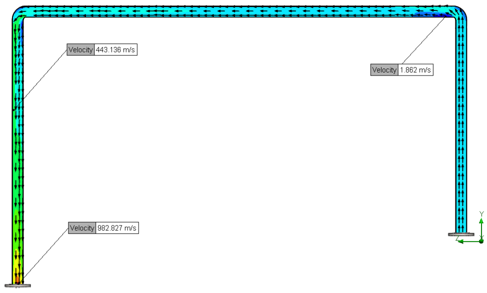
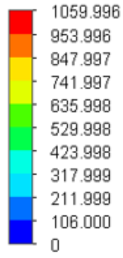
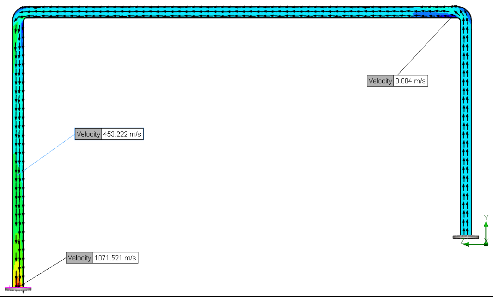
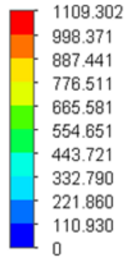
Pressure Applied	Fluid in Pipeline (Velocity Distribution)	Minimum and Maximum Value
8 bars		
10 bars		
12 bars		

Table 5 shows the differential pressure applied to one of the wall thicknesses for the piping system. The wall thickness selected is 2.77mm as the constant data. The difference in velocity of flow is shown by the color of the contour scale. At the earlier stage, the velocity starts from low to high. The pressure started to build up at the initial and increase in ascending order. At the end of the pipeline for all the different wall thicknesses is the highest of the velocity distribution. The more pressure or force for velocity distribution applied, the increase of the velocity occurs. Meanwhile for the pressure, when the pressure is applied in constant condition and continuously applied, so that, the velocity also will increase according to the value of pressure applied.

Then, the calculation method is generated to compare the trend of the simulation for the velocity distribution against the pressure that is continuously applied. The calculation is used the Reynold Number's equation for the constant wall thickness and differential pressure applied.

For 8 bars pressure,

$$\frac{\rho V_{avg} D}{\mu}$$

ρ = 4.162 kg/m^3 ***(refer Appendix B)***
v = 369.767 m/s
D= 0.00277 m
μ = 0.000015 kg/m.s ***(refer Appendix B)***

$$= \frac{(4.1627 kg/m^3)(369.767 m/s)(0.00277 m)}{0.000015 kg/m.s}$$

$$= \mathbf{284196.507}$$

For 10 bars pressure,

ρ = 5.147 kg/m^3
v = 369.767 m/s
D= 0.00277m
μ = 0.000015 kg/m.s

$$= \frac{(5.1627kg/m^3)(369.767m/s)(0.00277m)}{0.000015kg/m.s}$$

$$= \mathbf{351455.892}$$

For 12 bars pressure,

ρ = 6.147 kg/m^3
v = 369.767 m/s
D= 0.00277m
μ = 0.000015 kg/m.s

$$= \frac{(6.147kg/m^3)(369.767m/s)(0.00277m)}{0.000015kg/m.s}$$

$$= \mathbf{418373.8582}$$

As the data obtained for the simulation and the velocity distribution calculation, it can be proved that the result for each method is directly proportional, and the trend increases. The higher the value of the pressure constantly applied, the more the velocity is occurring increment according to the value of the force that applied. As mentioned by Qin (2017), when more flow distribution of the fluid is applied, it is related to its velocity which is the higher the velocity of working fluid and vice versa [7].

3.2 Finite Element Analysis Result

The FEA test is the next procedure for the part selected to be analyzed for the static pressure. This part is being simulated to identify the capability for the pipe to weak stand the pressure or vice versa. In this FEA simulation test, there are a few parameters that are required to collect the data which are the stress and strain analysis. All the thicknesses are being simulated and analyzed. Then, the comparison for the thickness against the parameters will be analyzed to recognize the most reasonable for the thickness used at the piping system. The result could be achieved by analyzing the contour scale for the maximum and minimum values of each of the thicknesses.

a) Stress Analysis

The stress simulation is one of the static pressures that is applied for the elbow fitting to identify the withstand for this pipe. The stress analysis is related to the strength of the material which is called yield strength, so the withstand of the pipe fitting could be recognized when the simulation is tested. Table 6 below shows the example for 8 bars pressures against all the pipe wall thicknesses to recognize the withstand of the elbow pipe. The other pressure applied is not mentioned due to the same trend result for the bar chart. Moreover, all the stress data against the pressure applied selected are combined at the comparison between the data obtained for stress analysis.

Table 6: Stress Simulation Result for 8 bars pressure

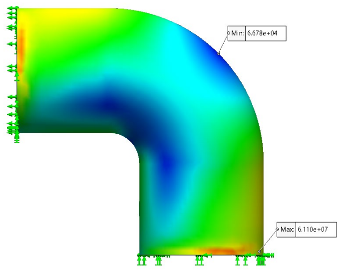
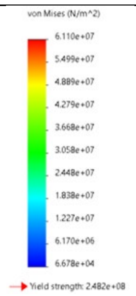
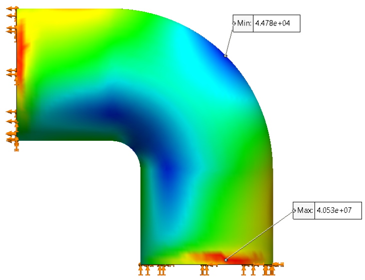
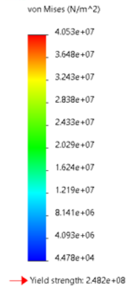
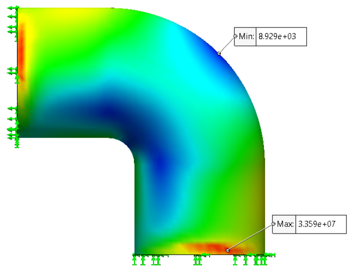
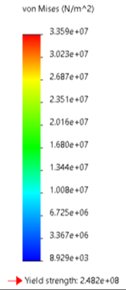
Wall Thickness	Condition of Elbow	Scale of Probe
2.77mm		
3.91mm		
5.54mm		

Table 7: Von Mises at 8 bar pressure applied

Wall Thickness (mm)	**Stress Analysis (N/m^2)**	
	Minimum	**Maximum**
2.77	6.68E+04	6.110E+07
3.91	4.48E+04	4.053E+07
5.54	8.93E+04	3.359E+07

Table 6 and 7 above shows the stress value at 8 bars applied against the different wall thicknesses for the elbow part. The result shows that the lowest the wall thicknesses so that the highest the value of the stress obtained on the elbow pipe. However, the stress is related to the strength of the materials which is called the yield strength. As shown at the contour scale above, the value of the yield strength is 2.482E+08 N/m^2. So, that, the static pressure testing at 8 bars pressure applied for all the piping systems with different wall thicknesses is still in good condition and not occur failure due to the value of the maximum for all the piping system is not over that the value of yield strength. All the other pressure tested for von misses stress are obtained at the analysis for the comparison later.

a) Strain Analysis

The analysis for the strain is done to recognize the change of the shape of the pipe fitting when the pressure is applied. It is important because it can define the deformation of the pipe fitting during in simulation test. The result for strain analysis is shown for the 8 bars pressure applied. Meanwhile, for the other pressure selected are obtained at the bar chart for the comparison between the strain analysis against pressure applied which is combined it for all the strain data. It is because the trend is same for the strain result for the other pressure applied.

Table 9: Strain simulation result for 8 bars pressure

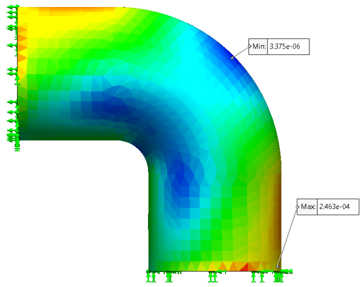
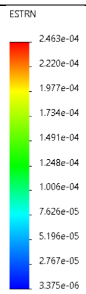
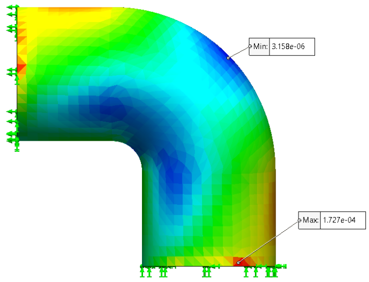
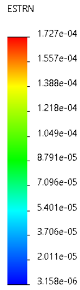
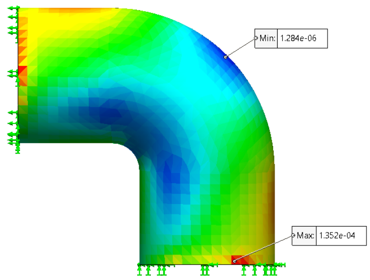
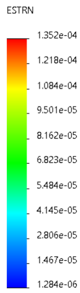
Wall Thickness	Condition of Elbow	Scale of Probe
2.77mm		
3.91mm		
5.54mm		

Table 10: Strain analysis at 8 bars pressure

Wall Thickness (mm)	**Stress Analysis (N/m^2)**	
	Minimum	**Maximum**
2.77	6.68E+04	6.110E+07
3.91	4.48E+04	4.053E+07
5.54	8.93E+04	3.359E+07

Table 9 and 10 above shows the example of the strain analysis result for 8 bar pressure applied against the different wall thicknesses of the elbow part. As the values are obtained, when the wall thicknesses of the elbow pipe are high or thickest, the maximum value for the strain is the lowest among the other wall thicknesses being tested. It is because, when the material has the highest thickness so that the deformation occurs for the elbows is the minimum and the lowest among the others and it could be proved by the data obtained after the static pressure simulation is tested.

3.3 Comparison Between Data Collection

a) Comparison on von mises stress against wall thicknesses for 8, 10, and 12 bar pressure applied

All the data are obtained and analyzed for each of the wall thicknesses against all the pressure applied, then the comparison also being made to make it clear and more accurate. All the data of the stress analysis are combined to discuss the condition for each wall thicknesses of the elbow part that represented also for the piping system. Figure 8 below shows the bar charts for the comparison of the stress analysis being made.

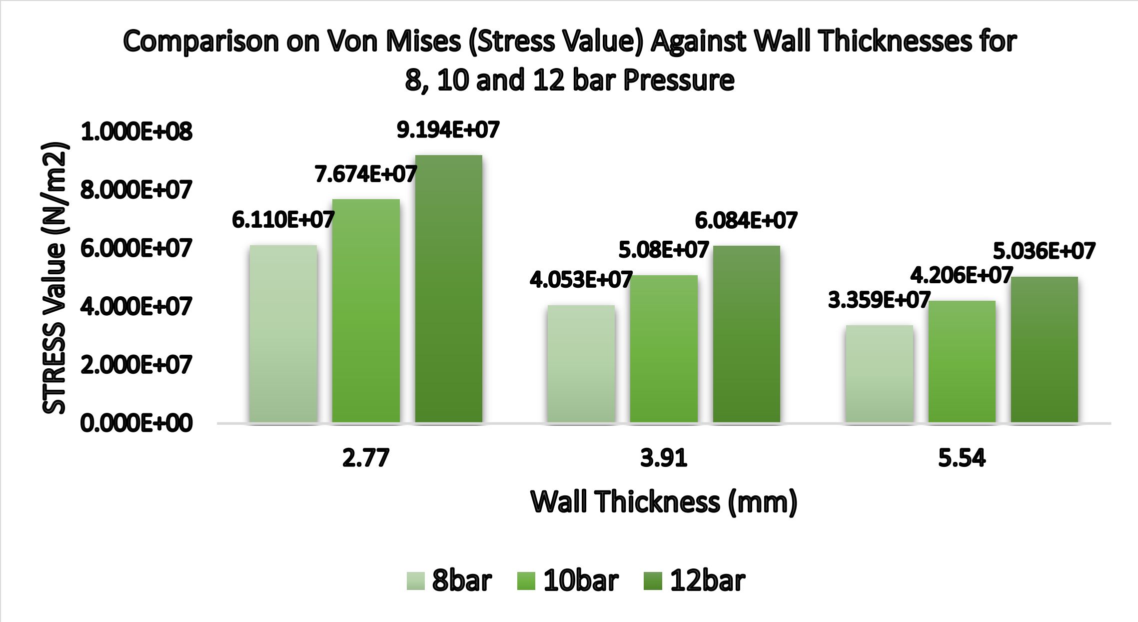


Figure 8: Table Comparison for stress analysis among the different thickness and pressure

Figure 8 above shows the bar graph shows all the wall thicknesses against the pressure applied are tally for the trend of the graph. It means the bar chart show for each of the wall thicknesses, when the pressure applied is increased so that the stress value also will increase. For example, the 3.91mm wall thickness at 8 bar pressure is at 4.053E+07 N/m^2 then, when 10 bar pressure is applied for this thickness, the stress value increase to 5.08E+07 N/m^2, and for the highest pressure applied which is 12-bars, the stress value for this wall thickness is6.084E+07 N/m^2. Moreover, this result is the same goes for the other thicknesses measured. However, all of these wall thicknesses are still in good condition during plant operating and not occur any failure for the pipe fitting because of the stress value still not achieved or over the limit value of the yield strength of this material.

b) The comparison of strain value against wall thicknesses for 8, 10, and 12 bar pressure applied.

The second comparison is made for strain value against the wall thickness as the pressure applied for 8, 10, and 12 bars. All the strain values for each of the wall thicknesses are combined to verify and identify it for more detail.

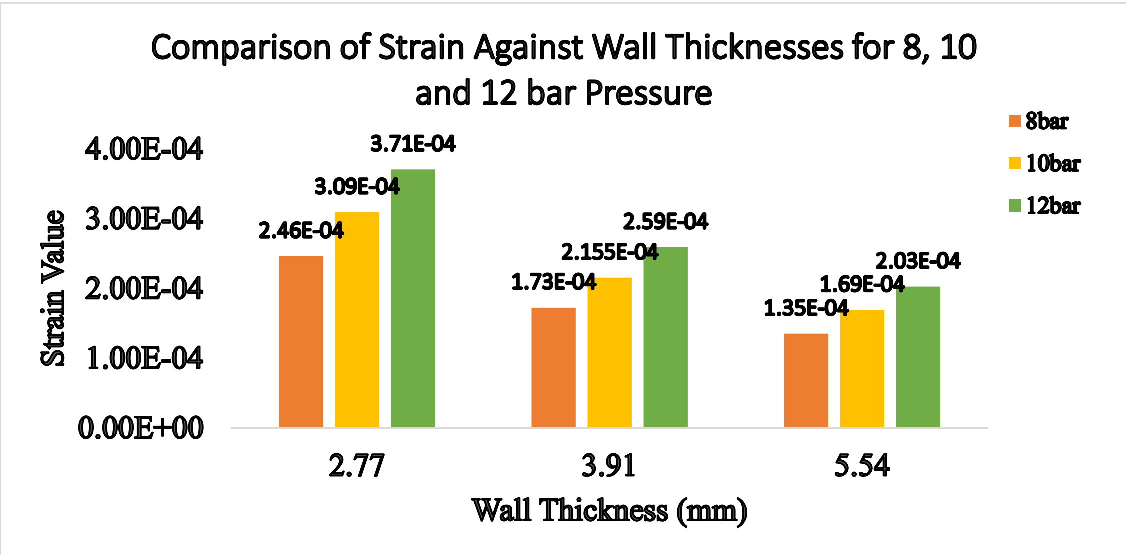


Figure 9: Comparison for strain analysis among the different thickness and pressure

The figure 9 above show the bar chart for the comparison of the wall thickness against the strain value for all the pressure applied. This chart is constructed to become more clear to see the visual of the value for each of the thickness of elbow against the result of the strain value. As the discussion that is being made, all of the thicknesses are a mostly same trend which is in ascending order. However, the thinnest of the wall thickness is the highest value for the strain parameter, or called deformation for the pipe when each pressure is applied. As the chart obtained, the condition for these wall thickness against the strain value could describe it as the higher the wall thickness, the less the deformation occurs while when the pressure applied increases, the strain value is also proportional to it.

4. Conclusion

The study concludes that the wall thickness for the default piping system outlet the boiler that is used at the UTHM biodiesel pilot plant is already the exact and acceptable selection. As the pressure is applied at the normal operating procedure, which is 10 bars, the yield strength of the material is still not over than it. When the highest pressure for this study is applied in the pipe system, the wall thickness still has capability on it. As the piping system is not failed. It is tally with the B36.10 ASME code and standard that has applied at the UTHM biodiesel pilot plant.

For the wall thicknesses, the 2-inch schedule 40 is the most efficient among the others. The 3.91mm wall thickness for the piping system that is already used at the UTHM biodiesel plant is acceptable and comply with the ASME B36.10 code and standard as it is successful to withstand the pressure applied. For 2.77mm and 5.54mm wall thicknesses, it also not fails but must consider the safety factor and also the over-specification factor-related for the cost of the material. This study is in the right path due to the result obtained which is when the pressure applied is increase, so that the strain increase, and when the strain increases, so that the stress value also increases. The appropriate design safety factors should be prescribed to reach this target safety level, but also to avoid unnecessary conservatism [8].

Acknowledgment

The authors would like to thank Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

Appendix A (Pipe Schedule)

Diameter Nominal		Schedule		Outside Diameter - D - (mm) (in)	Wall Thickness - t - (mm) (in)	Inside Diameter - d - (mm) (in)	Inside Area (cm^2)	Pipe Weight (kg/m) (lb/ft)	Water Weight (kg/m)
(inches)	(mm)								
1/8	6	10S		10.3	1.245	7.811	0.479	0.277	0.048
		Std	40		1.727	6.846	0.368	0.364	0.037
		XS	80		2.413	5.474	0.235	0.468	0.024
1/4	8	10S		13.7	1.651	10.398	0.846	0.489	0.085
		Std	40		2.235	9.23	0.669	0.630	0.067
		XS	80		3.023	7.654	0.460	0.794	0.046
3/8	10	10S		17.145	1.651	13.843	1.505	0.629	0.151
		Std	40		2.311	12.523	1.232	0.843	0.123
		XS	80		3.2	10.745	0.907	1.098	0.091
1/2	15	5S		21.336	1.651	18.034	2.554	0.799	0.255
		10S			2.108	17.12	2.302	0.997	0.230
		Std	40		2.769	15.798	1.960	1.265	0.190
		XS	80		3.734	13.868	1.510	1.617	0.151
			160		4.75	11.836	1.100	1.938	0.110
		XXS			7.468	6.4	0.322	2.247	0.032
3/4	20	5S		26.67	1.651	23.368	4.289	1.016	0.429
		10S			2.108	22.454	3.960	1.273	0.396
		Std	40		2.87	20.93	3.441	1.680	0.344
		XS	80		3.912	18.846	2.790	2.190	0.279
			160		5.537	15.596	1.910	2.878	0.191
		XXS			7.823	11.024	0.954	3.626	0.095
1	25	5S		33.401	1.651	30.099	7.115	1.289	0.712
		10S			2.769	27.863	6.097	2.086	0.610
		Std	40		3.378	26.645	5.576	2.494	0.558
		XS	80		4.547	24.307	4.640	3.227	0.464
			160		6.35	20.701	3.366	4.225	0.337
		XXS			9.093	15.215	1.818	5.436	0.182
1 1/4	32	5S		42.164	1.651	38.862	11.862	1.645	1.186
		10S			2.769	36.626	10.536	2.683	1.054
		Std	40		3.556	35.052	9.650	3.377	0.965
		XS	80		4.851	32.462	8.276	4.452	0.828
			160		6.35	29.464	6.818	5.594	0.682
		XXS			9.703	22.758	4.068	7.747	0.407
1 1/2	40	5S		48.26	1.651	44.958	15.875	1.893	1.587
		10S			2.769	42.722	14.335	3.098	1.433
		Std	40		3.683	40.894	13.134	4.038	1.313
		XS	80		5.08	38.1	11.401	5.395	1.140
			160		7.137	33.986	9.072	7.219	0.907
		XXS			10.16	27.94	6.131	9.521	0.613
					13.335	21.59	3.661	11.455	0.366
					15.875	16.51	2.141	12.645	0.214
2	50	5S		60.325	1.651	57.023	25.538	2.383	2.554
		10S			2.769	54.787	23.575	3.920	2.357
		Std	40		3.912	52.501	21.648	5.428	2.165
		XS	80		5.537	49.251	19.051	7.461	1.905
			160		8.712	42.901	14.455	11.059	1.446
		XXS			11.074	38.177	11.447	13.415	1.145
					14.275	31.775	7.930	16.168	0.793
					17.45	25.425	5.077	18.402	0.508

Appendix B (Steam Table Properties)

Absolute pressure	Boiling point	Specific volume (steam)	Density (steam)	Specific enthalpy of liquid water (sensible heat)		Specific enthalpy of steam (total heat)		Latent heat of vaporization		Specific heat	Dynamic viscosity
bar	°C	m3/kg	kg/m3	kj/kg	Kcal/kg	kj/kg	Kcal/kg	kj/kg	Kcal/kg	kj/kg.K	kg/m.s
0.02	17.51	67.006	0.015	73.45	*17.54*	2533.64	605.15	2460.19	*587.61*	1.8644	0.000010
0.03	24.10	45.667	0.022	101.00	*24.12*	2545.64	608.02	2444.65	*583.89*	1.8694	0.000010
0.04	28.98	34.802	0.029	121.41	*29.00*	2554.51	610.13	2433.10	*581.14*	1.8736	0.000010
0.05	32.90	28.194	0.035	137.77	*32.91*	2561.59	611.83	2423.82	*578.92*	1.8774	0.000010
0.06	36.18	23.741	0.042	151.50	*36.19*	2567.51	613.24	2416.01	*577.05*	1.8808	0.000010
0.07	39.02	20.531	0.049	163.38	*39.02*	2572.62	614.46	2409.24	*575.44*	1.8840	0.000010
0.08	41.53	18.105	0.055	173.87	*41.53*	2577.11	615.53	2403.25	*574.01*	1.8871	0.000010
0.09	43.79	16.204	0.062	183.28	*43.78*	2581.14	616.49	2397.85	*572.72*	1.8899	0.000010
0.1	45.83	14.675	0.068	191.84	*45.82*	2584.78	617.36	2392.94	*571.54*	1.8927	0.000010
0.2	60.09	7.650	0.131	251.46	*60.06*	2609.86	623.35	2358.40	*563.30*	1.9156	0.000011
0.3	69.13	5.229	0.191	289.31	*69.10*	2625.43	627.07	2336.13	*557.97*	1.9343	0.000011
0.4	75.89	3.993	0.250	317.65	*75.87*	2636.88	629.81	2319.23	*553.94*	1.9506	0.000011
0.5	81.35	3.240	0.309	340.57	*81.34*	2645.99	631.98	2305.42	*550.64*	1.9654	0.000012
0.6	85.95	2.732	0.366	359.93	*85.97*	2653.57	633.79	2293.64	*547.83*	1.9790	0.000012
0.7	89.96	2.365	0.423	376.77	*89.99*	2660.07	635.35	2283.30	*545.36*	1.9919	0.000012
0.8	93.51	2.087	0.479	391.73	*93.56*	2665.77	636.71	2274.05	*543.15*	2.0040	0.000012
0.9	96.71	1.869	0.535	405.21	*96.78*	2670.85	637.92	2265.65	*541.14*	2.0156	0.000012
1	99.63	1.694	0.590	417.51	*99.72*	2675.43	639.02	2257.92	*539.30*	2.0267	0.000012
1.1	102.32	1.549	0.645	428.84	*102.43*	2679.61	640.01	2250.76	*537.59*	2.0373	0.000012
1.2	104.81	1.428	0.700	439.36	*104.94*	2683.44	640.93	2244.08	*535.99*	2.0476	0.000012
1.3	107.13	1.325	0.755	449.19	*107.29*	2686.98	641.77	2237.79	*534.49*	2.0576	0.000013
1.4	109.32	1.236	0.809	458.42	*109.49*	2690.28	642.56	2231.86	*533.07*	2.0673	0.000013
1.5	111.37	1.159	0.863	467.13	*111.57*	2693.36	643.30	2226.23	*531.73*	2.0768	0.000013
1.5	111.37	1.159	0.863	467.13	*111.57*	2693.36	643.30	2226.23	*531.73*	2.0768	0.000013
1.6	113.32	1.091	0.916	475.38	*113.54*	2696.25	643.99	2220.87	*530.45*	2.0860	0.000013
1.7	115.17	1.031	0.970	483.22	*115.42*	2698.97	644.64	2215.75	*529.22*	2.0950	0.000013
1.8	116.93	0.977	1.023	490.70	*117.20*	2701.54	645.25	2210.84	*528.05*	2.1037	0.000013
1.9	118.62	0.929	1.076	497.85	*118.91*	2703.98	645.83	2206.13	*526.92*	2.1124	0.000013
2	120.23	0.885	1.129	504.71	*120.55*	2706.29	646.39	2201.59	*525.84*	2.1208	0.000013
2.2	123.27	0.810	1.235	517.63	*123.63*	2710.60	647.42	2192.98	*523.78*	2.1372	0.000013
2.4	126.09	0.746	1.340	529.64	*126.50*	2714.55	648.36	2184.91	*521.86*	2.1531	0.000013
2.6	128.73	0.693	1.444	540.88	*129.19*	2718.17	649.22	2177.30	*520.04*	2.1685	0.000013
2.8	131.20	0.646	1.548	551.45	*131.71*	2721.54	650.03	2170.08	*518.32*	2.1835	0.000013
3	133.54	0.606	1.651	561.44	*134.10*	2724.66	650.77	2163.22	*516.68*	2.1981	0.000013
3.5	138.87	0.524	1.908	584.28	*139.55*	2731.63	652.44	2147.35	*512.89*	2.2331	0.000014
4	143.63	0.462	2.163	604.68	*144.43*	2737.63	653.87	2132.95	*509.45*	2.2664	0.000014
4.5	147.92	0.414	2.417	623.17	*148.84*	2742.88	655.13	2119.71	*506.29*	2.2983	0.000014
5	151.85	0.375	2.669	640.12	*152.89*	2747.54	656.24	2107.42	*503.35*	2.3289	0.000014
5.5	155.47	0.342	2.920	655.81	*156.64*	2751.70	657.23	2095.90	*500.60*	2.3585	0.000014
6	158.84	0.315	3.170	670.43	*160.13*	2755.46	658.13	2085.03	*498.00*	2.3873	0.000014
6.5	161.99	0.292	3.419	684.14	*163.40*	2758.87	658.94	2074.73	*495.54*	2.4152	0.000014
7	164.96	0.273	3.667	697.07	*166.49*	2761.98	659.69	2064.92	*493.20*	2.4424	0.000015
7.5	167.76	0.255	3.915	709.30	*169.41*	2764.84	660.37	2055.53	*490.96*	2.4690	0.000015
8	170.42	0.240	4.162	720.94	*172.19*	2767.46	661.00	2046.53	*488.80*	2.4951	0.000015
8.5	172.94	0.227	4.409	732.03	*174.84*	2769.89	661.58	2037.86	*486.73*	2.5206	0.000015
9	175.36	0.215	4.655	742.64	*177.38*	2772.13	662.11	2029.49	*484.74*	2.5456	0.000015
9.5	177.67	0.204	4.901	752.82	*179.81*	2774.22	662.61	2021.40	*482.80*	2.5702	0.000015
10	179.88	0.194	5.147	762.60	*182.14*	2776.16	663.07	2013.56	*480.93*	2.5944	0.000015
11	184.06	0.177	5.638	781.11	*186.57*	2779.66	663.91	1998.55	*477.35*	2.6418	0.000015
12	187.96	0.163	6.127	798.42	*190.70*	2782.73	664.64	1984.31	*473.94*	2.6878	0.000015
13	191.60	0.151	6.617	814.68	*194.58*	2785.42	665.29	1970.73	*470.70*	2.7327	0.000015
14	195.04	0.141	7.106	830.05	*198.26*	2787.79	665.85	1957.73	*467.60*	2.7767	0.000016
15	198.28	0.132	7.596	844.64	*201.74*	2789.88	666.35	1945.24	*464.61*	2.8197	0.000016
16	201.37	0.124	8.085	858.54	*205.06*	2791.73	666.79	1933.19	*461.74*	2.8620	0.000016
17	204.30	0.117	8.575	871.82	*208.23*	2793.37	667.18	1921.55	*458.95*	2.9036	0.000016
18	207.11	0.110	9.065	884.55	*211.27*	2794.81	667.53	1910.27	*456.26*	2.9445	0.000016

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