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Comparative Study of Gaskets Thickness in Piping System at UTHM Biodiesel Plant Using Finite Element Analysis (FEA)

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Abstract: This study is carried out as a matter of mechanism just to help the learning process to all students of University Tun Hussein Onn Malaysia (UTHM) generally and especially the students of Mechanical Engineering Technology (Plant). First, the objective of this project is to compare the von mises stress, displacement and equivalent strain of the gaskets thickness in the piping system. Next, the objective of this project is to study gaskets thickness in the piping system using the simulation technique. There are four thickness gaskets for this project that is 1mm, 2mm, 5mm and 8mm. Neoprene rubber is the material for the gaskets and the pressure in this piping system is 4bar. The thickness of gaskets will be studied by analysis using SolidWorks software to predict the mechanical properties of gaskets to reduce operation and maintenance cost. The method analysis that will be used is Finite Element Analysis (FEA). Through the data from analysis, the result show that gaskets 8mm has the maximum von mises stress and displacement but minimum for equivalent strain while gasket 1mm has the minimum von mises stress and displacement but maximum for equivalent strain. For the conclusion, it's found that 2mm gasket thickness is the standard used on piping systems using water as a working fluid.

Keywords: Gasket, Static analysis, Finite Element Analysis (FEA), Solidworks

1. Introduction

There are several kinds of plants, including chemical plants, refineries, and petrochemical plants. This plant is used pipes to transfer the fluid, gas, and liquid from one location to another. This system calls the piping system. The in-line component in the piping is known as fitting. Piping systems are documented in piping and instrumentation diagrams (P&IDs) [1].

The purpose of this project is to study the effectiveness and thickness of gaskets between flanges in the piping system to reduce the cost of production. As a result, thorough and systematic preparation

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is needed. Gaskets are an important thing in a piping system. The function of a gasket is not only to provide a seal to prevent fluids escaping, but it is also an important safety device [2]. If inappropriate gaskets are used it can cause a process to be interrupted due to leakage. Besides that, the objective of this project is to study gaskets thickness in the piping system using the simulation technique. Simulations are usually computer-based, using a software-generated model to provide support for the decisions of managers and engineers as well as for training purposes. Simulation techniques aid understanding and experimentation, as the models are both visual and interactive. Solidworks version 2020 is used to study the stress, displacement and strain on gaskets.

Process plant commissioning and start-up refers to both new facilities and restarting an existing plant after major modifications. When start-up the plant many types of equipment such as pumps will create a pressure difference. The different pressure can make the equipment such as pump damage. Besides that, the gaskets between the flanges also can be damaged and it can and can make a piping system not work properly due to leaks. Instant study experimentally, better study with simulation method to save time, main power, cost, and safety are also guaranteed.

2. Materials and Methods

2.1 Flowchart process

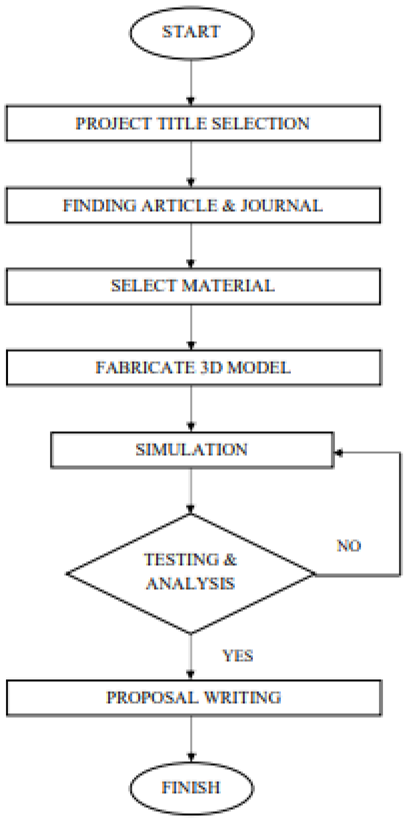


Figure 1: Flowchart

2.2 Carbon steel pipe

The material that uses for this project is carbon steel. Carbon steel is a special type of steel that has a higher concentration of carbon than other types of steel. In most steel pipe types; the carbon content is quite low between 0.05 % to 0.30 % while carbon steel pipe has a carbon content of up to 2.50 % [3]. This project uses carbon steel pipes. The standard pipe code for carbon steel is ASTM A106 [4]. Size pipe that has been used is 4 inches because it is affordable and can reduce cost.

Figure 2: Carbon Steel Pipe

2.2 Neoprene rubber

Neoprene gaskets are a highly adaptable material used in a wide range of industries, including industrial, electrical, medical, and scientific. With pressure-sensitive adhesive choices, it may be die cut and transformed into bespoke gaskets and seals. The thickness for the neoprene gaskets that are usually used is 1.00 mm, 1.50 mm, 2.00 mm, 3.00 mm, 4.00 mm, 5.00 mm, 6.00 mm, 8.00 mm, 10.00 mm, 12.00 mm, 15.00 mm, 20.00 mm, and 25.00 mm. It is depending on the pressure of the system. ASME B16.21 is the standard code for non-metallic gasket. Neoprene gasket material is available in several formulations, grades, and forms. It also exhibits excellent resistance to flexing and twisting and broad temperature suitability (-40 °F to +230 °F, intermittent to +250 °F) [5].

Figure 3: Neoprene Rubber Gaskets

2.2 Codes and standard

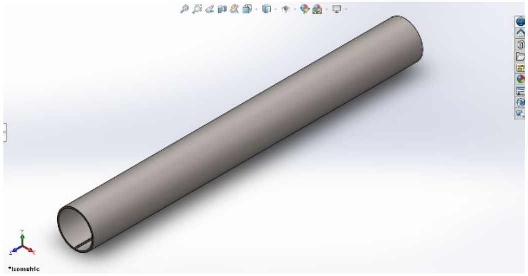
The aim is as a guideline to ensure that proposed design and technical theory are acceptable, inherent efficiency and legitimate. In this study and design only limited to:

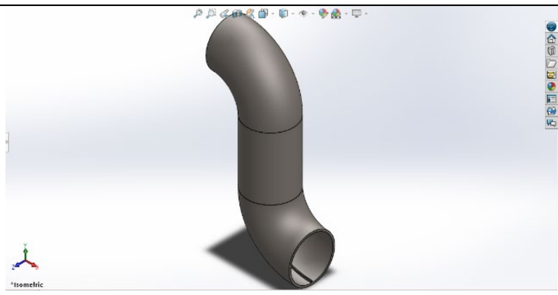
i. America Petroleum Institutes (API 650)
ii. American Society Testing Materials (ASTM)

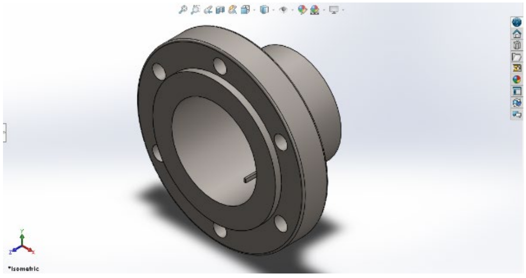
2.3 Fabricate 3D model

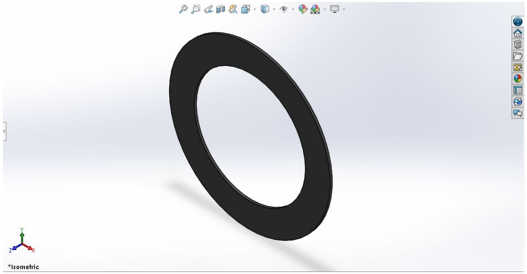
SolidWorks software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings. SolidWorks helps in sketching complex shape products or parts with dimensioning and other experimentation analysis [6]. SolidWorks software version 2020 is use for this project to fabricate 3D model and do the simulation analysis. pipe cooling tower located in biodiesel plant UTHM will be used as a reference. There are four part for the 3D model thar have to fabricate and decides the material and the dimension for each part. The part that has to fabricate is pipe, elbow, flanges and gasket. Before continue for the simulation process, the part needs to mate to be an assemble.

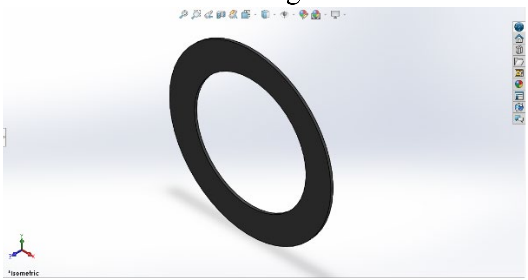
Table 1: List of 3D model parts

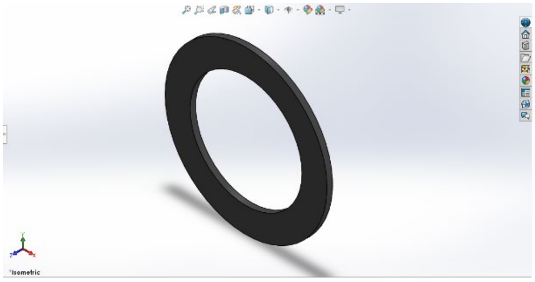

a. Pipe

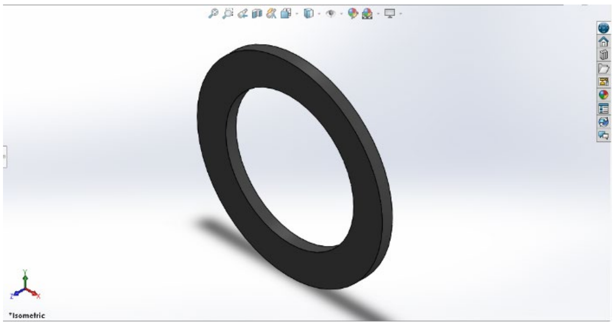

b. Elbow


c. Flanges


d. Gaskets 1mm


e. Gasket 2mm


f. Gasket 5mm


g. Gasket 8mm

2.4 Simulation process

Simulation analysis is a method, wherein infinite calculations are made to obtain the possible outcomes and probabilities for any choice of action [7]. After completing the process mate and making an assemble, then the analysis process can be done. The result can in the process analysis pressure will be applied to all gaskets to determine the stress, displacement and strain for the gasket. The pressure that applied for each gasket is 4bar. The data from the analysis can be generate to word to make it easy to read.

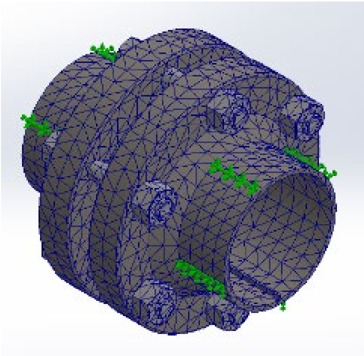


Figure 4: Meshing Process

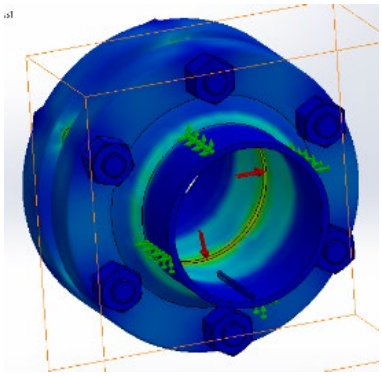


Figure 5: Complete Analysis

In design analysis, meshing is an important phase. The software's automated mesher creates a mesh using global element sizes, tolerances, and local mesh control criteria. Components, faces, edges, and vertices may all be specified in varying sizes using the Mesh control. The type of meshing that used in this simulation analysis is shell element. Shell elements are suitable for thin parts such as gaskets.

3. Result and Discussion

3.1 Data result of the Gaskets

Table 2: Data result for gasket 1 mm

	Gasket (1mm)	
Stress (N/m^2)	**Displacement (mm)**	**Strain**
3.027e+02	2.395e-05	4.845e-05
1.883e+04	3.601e-03	1.341e-03
3.766e+04	7.203e-03	2.634e-03
5.649e+04	1.080e-02	3.927e-03
7.532e+04	1.441e-02	5220e-03
9.415e+04	1.801e-02	6.513e-03
1.130e+05	2.161e-02	7.806e-03
1.318e+05	2.521e-02	9.099e-03
1.506e+05	2.881e-02	1.039e-02
1.695e+05	3.241e-02	1.168e-02
1.883e+05	3.601e-02	1.298e-02

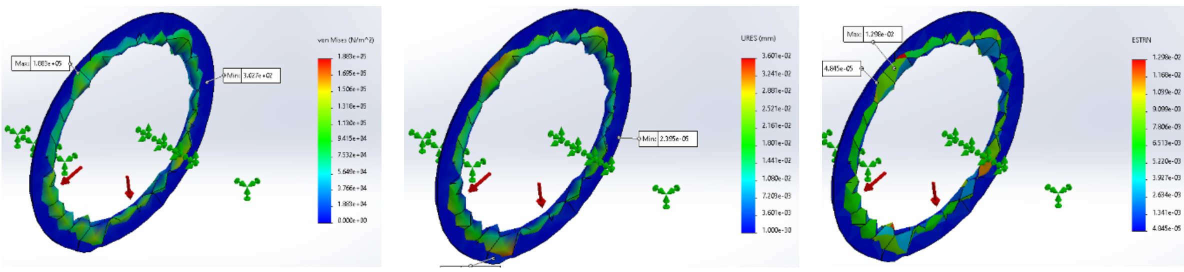


Figure 6: a) von mises stress result, b) displacement result, c) equivalent strain result for gasket 1 mm

Table 3: Data result for gasket 2 mm

Gasket (2mm)		
Stress (N/m^2)	**Displacement (mm)**	**Strain**
2.411e+05	1.000e-30	4.086e-05
2.411e+04	7.483e-03	1.987e-03
4.822e+04	1.497e-02	3.933e-03
7.233e+04	2.245e-02	5.878e-03
9.644e+04	2.993e-02	7.824e-03
1.206e+05	3.741e-02	9.770e-03
1.447e+05	4.490e-02	1.172e-02
1.688e+05	5.238e-02	1.366e-02
1.929e+05	5.986e-02	1.561e-02
2.170e+05	6.735e-02	1.755e-02
2.411e+05	7.483e-02	1.950e-02

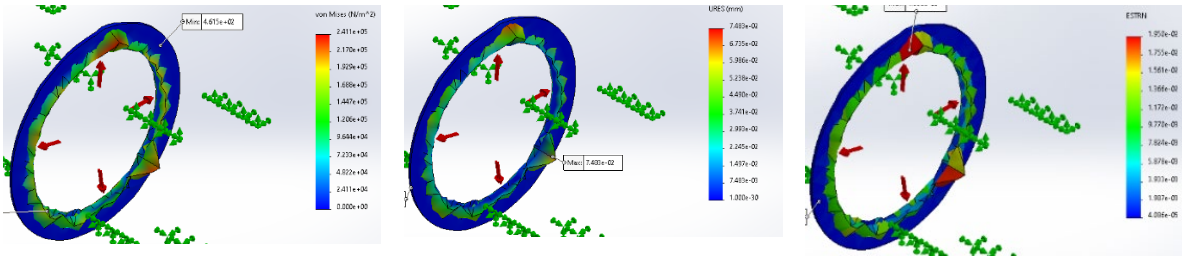


Figure 7: a) von mises stress result, b) displacement result, c) equivalent strain result for gasket 2 mm

Table 4: Data result for gasket 5 mm

Gasket (5mm)		
Stress (N/m^2)	**Displacement (mm)**	**Strain**
2.851e+05	1.000e-30	1.473e-04
2.851e+04	1.147e-02	2.041e-03
5.703e+04	2.295e-02	3.935e-03
8.554e+04	3.442e-02	5.829e-03
1.141e+05	4.589e-02	7.722e-03
1.426e+05	5.736e-02	9.616e-03
1.711e+05	6.884e-02	1.151e-02
1.996e+05	8.031e-02	1.340e-02
2.281e+05	9.178e-02	1.530e-02
2.566e+05	1.033e-01	1.719e-02
2.851e+05	1.147e-01	1.909e-02

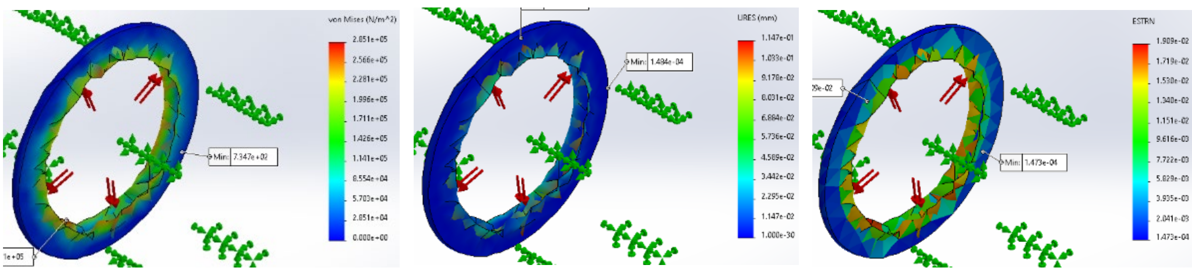


Figure 8: a) von mises stress result, b) displacement result, c) equivalent strain result for gasket 5mm

Table 5: Data result for gasket 8 mm

Gasket (8mm)		
Stress (N/m^2)	**Displacement (mm)**	**Strain**
3.841e+03	1.000e-30	1.071e-03
7.657e+04	3.035e-02	4.779e-03
1.531e+05	6.071e-02	8.487e-03
2.297e+05	9.106e-02	1.220e-02
3.063e+05	1.214e-01	1.590e-02
3.829e+05	1.518e-01	1.961e-02
4.594e+05	1.821e-01	2.332e-02
5.360e+05	2.125e-01	2.703e-02
6.126e+05	2.428e-01	3.074e-02
6.891e+05	2.732e-01	3.445e-02
7.657e+05	3.035e-01	3.815e-02

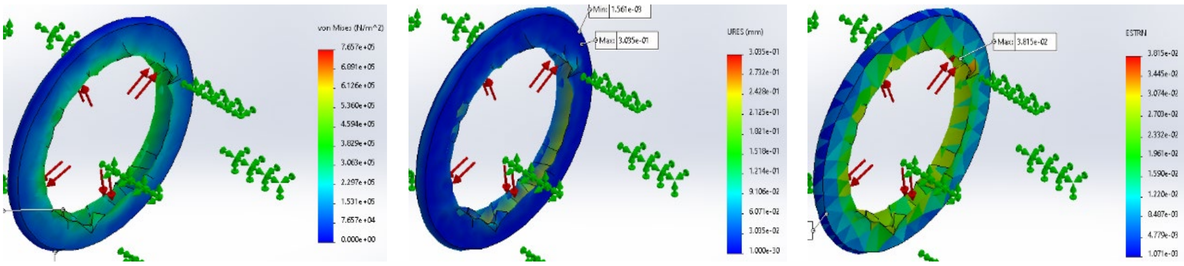


Figure 9: a) von mises stress result, b) displacement result, c) equivalent strain result for gasket 8 mm

3.2 Maximum and minimum result data

Table 5: Result Maximum and minimum Von mises stress, displacement and equivalent strain

Gasket thickness	Von mises stress (N/m^2)		Displacement (mm)		Equivalent strain	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**
1mm	1.883e+05	3.027e+02	3.601e-02	2.395e-05	1.298e-02	4.845e-05
2mm	2.411e+05	4.615e+02	7.483e-02	3.266e-05	1.950e-02	4.086e-06
5mm	2.851e+05	7.347e+02	1.147e-01	1.484e-04	1.909e-02	1.473e-04
8mm	7.657e+05	3.841e+03	3.035e-01	1.561e-03	3.815e-02	1.071e-03

The 8 mm gasket has the maximum von mises stress (7.657e+05). Among the factors why von mises high stress on 8 mm gaskets because the pressure applied to the gaskets is more than other gaskets namely 5 mm, 2 mm, and 1 mm. Moreover, 1mm thickness gaskets have the least von mises stress (3.027e+02) because the pressure applied to 1mm gaskets is less. Besides that, other factors that can occur in von mises stress is also the compressive stress applied to the gaskets by the flange and bolt, and nut [8]. The more surface gaskets that are exposed to pressure, the higher the von mises stress [9]. High stress can cause a piping system to vibrate and be dangerous to people around. The appropriate thickness of gaskets in a piping system is determined by the working fluid [10].

8mm gaskets have the maximum displacement (3.035e-01) while 1 mm has the lowest displacement (2.395e-05) among all the gaskets that have been studied. This is because 8 mm gaskets have a lot of movement. After all, a pressure of 58.0151 has been applied to them. The force of the pressure has hit the inner surface gaskets. For the gasket, 1 mm force pressure has also been applied to the inner surface of the gasket but the small surface has made a little movement of the gaskets. In addition, movement of gaskets can occur in a piping system due to compressive load from flanges and bolts, and nuts [11]. If the bolts and nuts installed on the flanges are loose, it can make the gaskets free play and can indirectly cause leakage [12].

8 mm-thick gaskets showed the highest strain (3.815e-02) while 1mm-thick gaskets showed the lowest strain (1.298e-02) among the gaskets studied. The factor that causes high strain to 8mm gaskets is because the pressure applied to them has made the elastic gaskets grow large and numerous. The thickness of the gaskets as thin as 1mm will make the elastic expand as well but in small quantities. Elastic can occur because the material used on these gaskets is rubber (neoprene). Rubber is a soft material [13] and easy to strain but rubber material is very good to be used as a gasket as long as the working fluid is water.

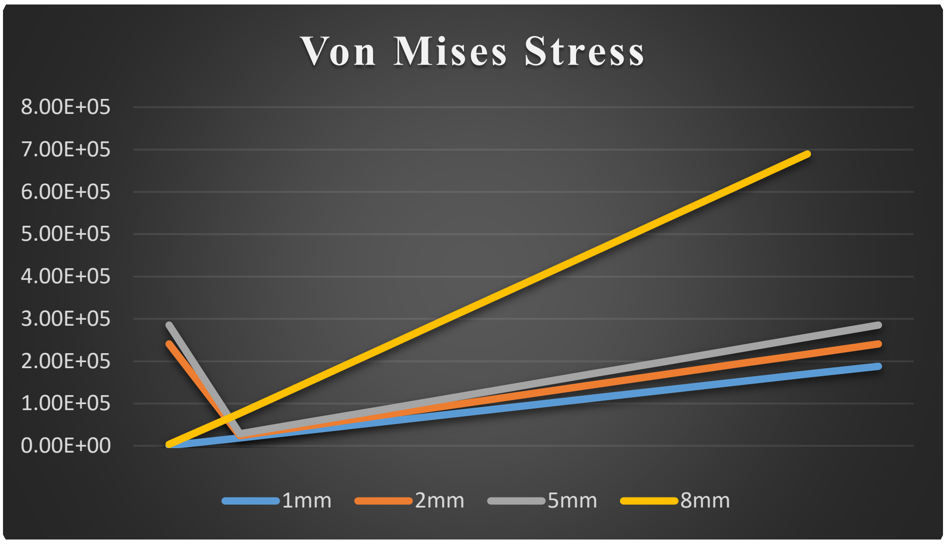


Figure 10: Graph von mises stress (N/m^2)

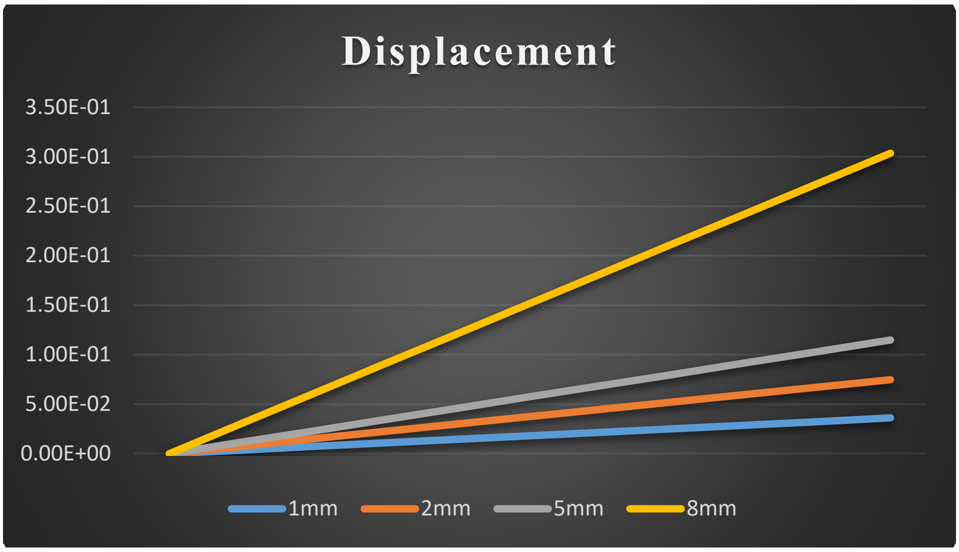


Figure 11: Graph displacement (mm)

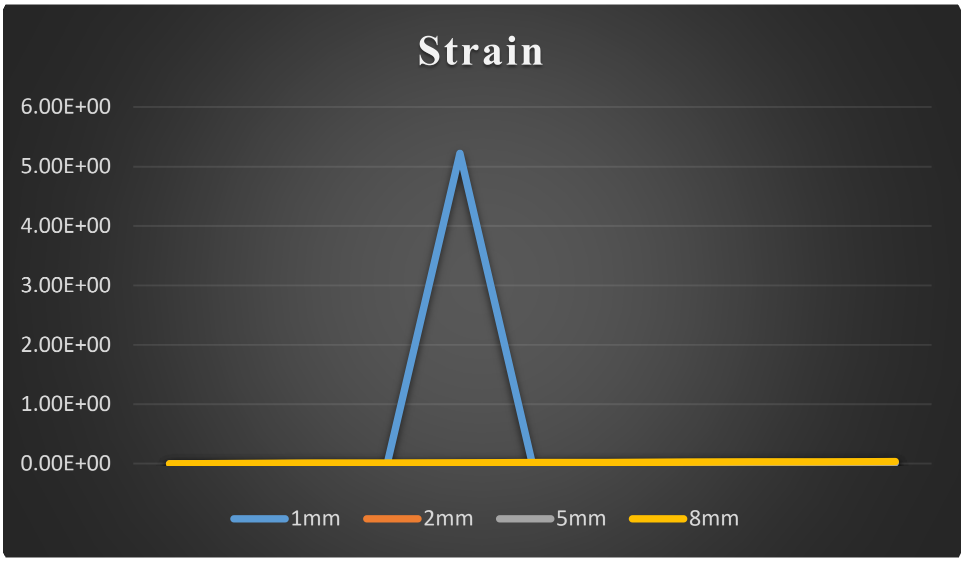


Figure 12: Graph equivalent strain

4. Conclusion

Gaskets are a very important seal in a piping system. If an inappropriate type of gasket is used it can cause a serious problem in a system. In selecting a gasket, it is important to evaluate the process fluid pressure and temperature. Through the analysis, 8mm gaskets are the best gaskets and can be used in piping systems because they have high pressure resistance. But the thinness gaskets such as gasket 1 mm, 2 mm and 8 mm does not mean it is not good to seal in piping system, but the level of strength to absorb pressure is less and can cause frequent process maintenance that can indirectly increase the cost of spending.

The analysis is very helpful in this project because it can help to determine what gasket is suitable for use in a piping system. The result from the analysis can show the critical part of the gaskets during the process. In addition, from the analysis by using SolidWorks software can reduce time, manpower, and safety compare to the experimental method. Analysis to compare thickness gaskets is made to find the optimum gasket that is suitable for use with the existing pressure [14]. The simulation process provides a satisfactory result for different gasket thickness against applied pressure for water as the working fluid.

Acknowledgement

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