



# Finite Element Analysis on Wrapping Structure of Piping System

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**Abstract:** Pipelines system is one of the most important system in the world. Pipeline refer to a long pipe running over distance transporting liquid or gases. Defect in pipe become the critical problem that being faced in various industry. The defected pipeline requires repairs since it will be major problem in transporting liquid or gases. Composite wrapping helps to provide a continuous protective lining that helps save pipelines from the harmful defects. This study focused on wrapping structure and used the SolidWorks software to run the simulation analysis. The composite wrapper material that involved in this simulation is CFRP and GFRP. The finite element models were created to simulate all of the tests for the purposes of static analysis. The result revealed that the GFRP material provided high stress than CFRP. Therefore CFRP is the best pipeline wrapper material. The finding in this study is significant as it provides comprehensive understanding of the role and contribution of pipeline composite wrapper to the future of pipeline system repairs. This can serve as an initial step towards optimizing the traditional pipeline system repair by initiating the usage of composite layers wrapping system.

**Keywords:** Pipeline, CFRP, GFRP, Composite Wrapping, FEA, Static Analysis

## 1. Introduction

Pipeline refer to a long pipe running over distance transporting liquid or gases. The prime function of piping system is to transport fluids from one location to another. Pipelines are initially require higher costs but offer the most efficient, safe and secure means of moving liquid or gases from one location to another location. Pipelines also are very useful when it have to pass over hills in order transport of drinking water over long distances. The main components in a pipeline system are pipes, fittings which are valves and joints, pumps or compressor in gas pipeline and booster station. Pipelines can be classified as onshore pipelines and offshore pipelines. These pipelines have 3 types which are trunk line or gathering line, transmission or transportation and distribution. Gathering line is used to transport oil from field pressure and storage to large tank. These line are mostly buried in the underground and wrapped externally in order to prevent corrosion. Transportation pipelines are usually consist long pipe and bigger diameter and moves the product such as oil between cities and countries. Distribution

pipelines are consists small diameter of pipeline interconnected and takes the final products to the customers[1]

Defect such as corrosion, crack, dent, leakage and pipe flaws have become a major issue in a variety of industries. These flaws are sometimes small and have no impact on the pipeline's integrity or safety. However, in some cases, they might be considerable, requiring repairs[2]. It will be major problems as it transports liquid or gases[3]. One of the method used by industries in worldwide is pipeline wrapping as it is considered as most reliable. This wrapping helps to provide a continuous protective lining that helps save pipelines from the harmful defects. Composite wrap can be used to replace traditional pipeline repair methods. Traditional methods of repair are frequently more expensive, time consuming, and labour intensive than composite wrap repairs where provide less cost and less time consuming. [4].

All kind of fluid and gases type are transported worldwide by using pipelines system. The safety of the pipeline system should always be given the highest priority in such a case, as the pipeline system is designed to withstand different environmental conditions to ensure a secure and efficient delivery from one stage to the next. In term of sustainability pipeline system also do experience problems especially defects. Pipeline defects are the most serious issue, as they have the potential to cause significant environmental and economic impact[5]. Pipeline system that experiences defects will face low efficiency.

For pipelines, varieties of rehabilitation techniques and repair approaches are currently available. For many years, the most usual repair technique for a crack defected pipeline was to completely remove the pipe or removing localized section and replace it with a new one. Full-encirclement steel sleeve or a steel clamp are the traditional methods where these techniques are costly and time consuming[6][7].

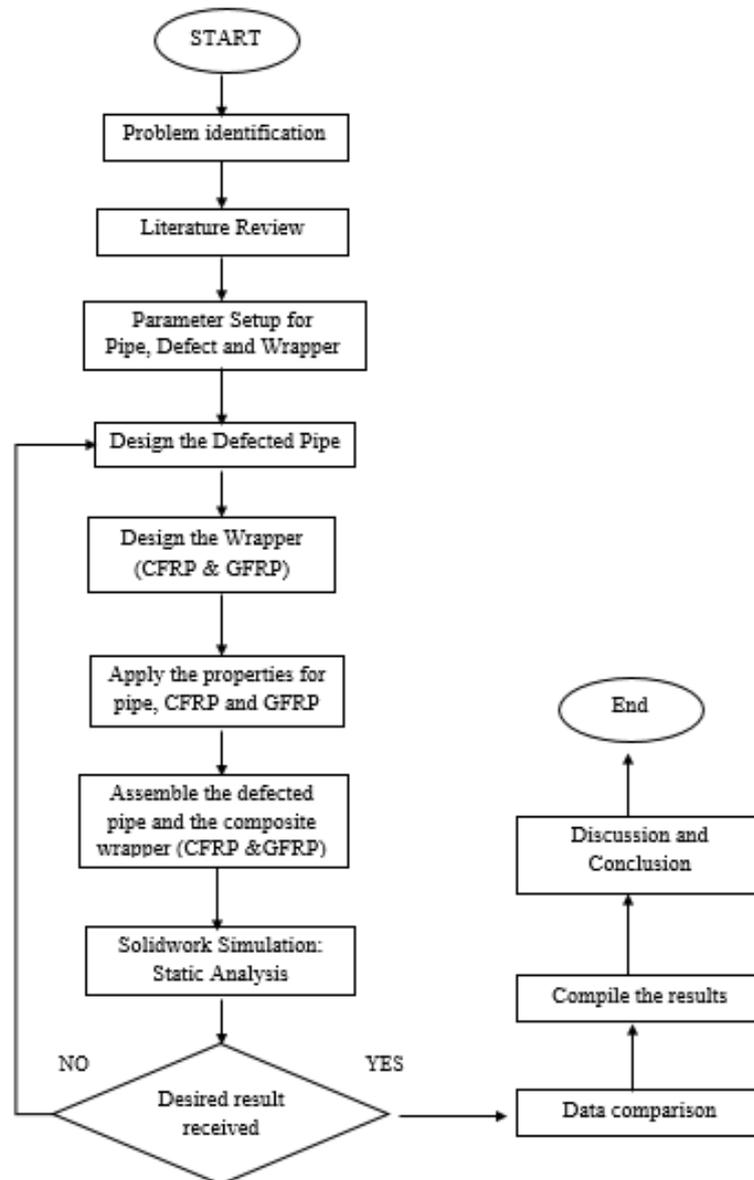
One of the long term solutions are by applying composite wrapping structure. Composite wrap can be performed on the operating pipeline without taking it out of service as it will affect the production process. However there are many variation of composite wrap system available. Composite wrap systems use different materials for wrapping system. There are 3 types of fiber that mostly used in the industry which are carbon fiber, glass fiber and aramid. The best material for the wrapping system will be identified in order to find the effective repair solution for the pipeline system [8][9][10].

The materials of wrapping structure such as CFRP and its durability on the pipeline are studied in order to propose that CFRP is the better material than GFRP to be used as wrapping structure will make the study a significant one. The amount of layers of wrapping structure also considered upon to provide high durability material to be used in pipeline system[11].

## **2. Methodology**

### **2.1 Flow Chart**

The flowchart of methodology process of this study has been developed as shown in the Figure 1 in order to achieve the objectives of this study.



**Figure 1: Methodology process flowchart**

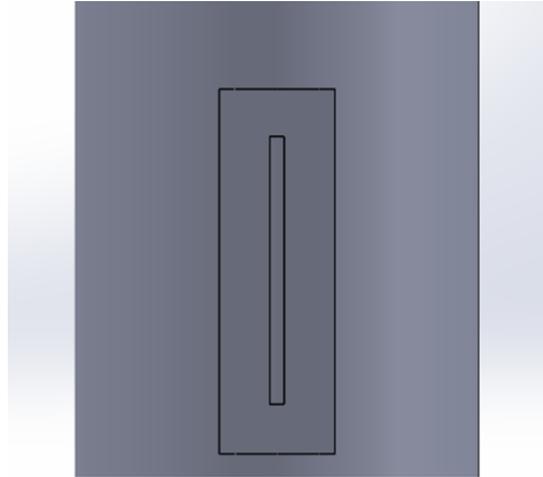
## 2.2 Parameter Setup

The material properties of the existing pipeline are shown in the table below, which are essential in the pipeline design process.

**Table 1: Material Properties of the existing pipeline**

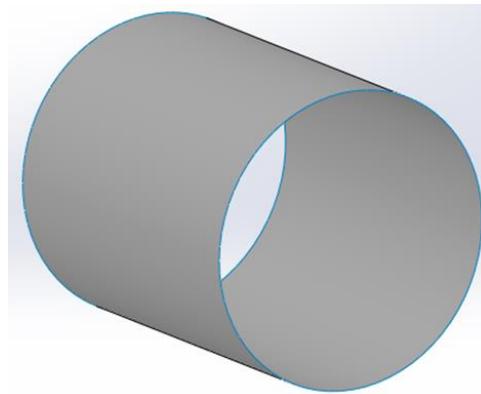
Parameters	Values	Units
Outer Diameter (OD)	168.3	mm
Inner Diameter (ID)	161.19	mm
Wall Thickness	7.11	mm
Pipe Length	1.52	m
Yield Strength	240	MPa
Tensile Strength	415	MPa

The type of defects that involved in this research is crack type. In this case the length of the defect on the pipe is 152.4mm x 152.4mm x 3.4mm. The size of defect on the designated pipe model is 152.4mm x 152.4mm x 3.4mm. The depth of the defect is 50% of the thickness of the pipe.



**Figure 2: The defect on the pipe**

The types of composite used as the wrapper structure in this study is Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP).



**Figure 3: The wrapper structure**

The minimum of the wrapping thickness is calculated by using this formula:

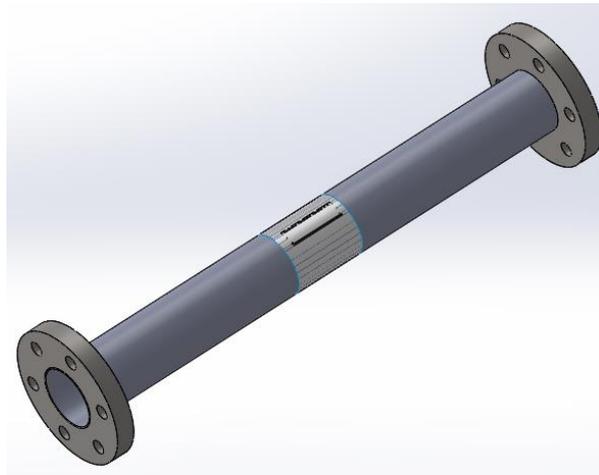
$$t_{min} = \frac{1}{E_c t_c} \left( \frac{PD}{2} - s t_s \right) \quad \text{Eq. 1}$$

### 2.3 Designing the Defected Pipe

For design and modelling, there are few part that needed to designated and modelled namely like the flanges, pipe and the defects on it. A sealer also designated to be placed on the defect before the applying the wrapper on it. All design and modelling are carried on the Solidworks software.



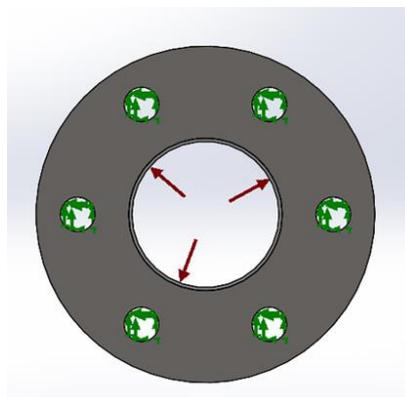
**Figure 4: Unrepaired Defected Pipe**



**Figure 5: Repaired Pipe with Composite Wrapper**

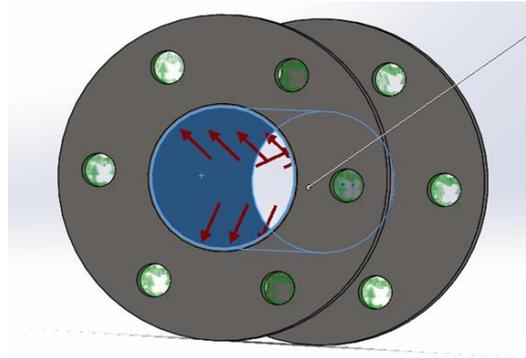
#### 2.4 Mesh, Fixed Geometry, External Load

In this analysis, the bolt holes on the flanges on the both side of the pipe are defined as fixed geometry.



**Figure 6: The bolt hole of flanges defined as fixed geometry**

In this project, there will be an external load applied on the pipe. External loads are applied after the bolt hole of flanges are defined as fixed geometry. The type of external loads is the internal pressure acting in the pipe. The internal pressure is set as 20MPa.



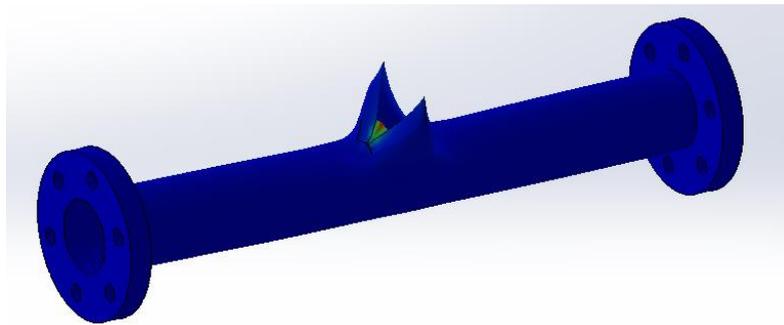
**Figure 7: The internal pressure applied in the pipe**

### 3. Results and Discussion

The simulation results for the defected pipe are obtained by running simulation in Solidwork software. The simulation for the defected pipe started by configuration set up and carried out with parameters and boundary condition. This simulation is done based on the static analysis method.

#### 3.1 Unrepaired Defected Pipe

The simulation is run with all the parameters and boundary conditions and obtained expected result where when the internal pressure applied on the defected pipe, the defected area which is crack area will burst out as in the image below.



**Figure 8: Unrepaired defected pipe burst out**

**Table 2: The mechanical properties of Unrepaired Defected Pipe**

Pressure (MPa)	Stress (MPa)		Resultant Displacement (mm)		Strain (MPa)	
	Min	Max	Min	Max	Min	Max
20.27	1.179	7.877E+4	0	5.488	6.239E-6	1.126E-1

#### 3.2 Defected Repaired Pipe

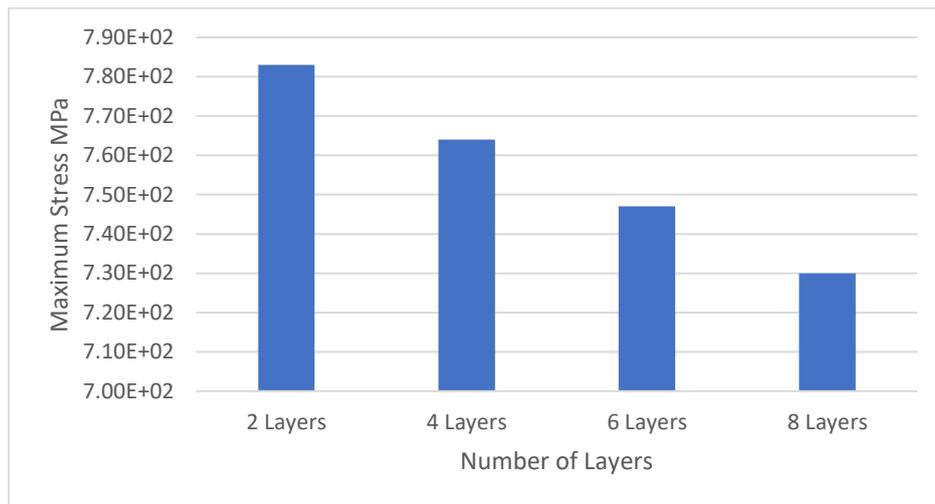
The simulation for the repaired defected pipe started by configuration set up and carried out with parameters and boundary condition. This simulation also done same as unrepaired defected pipe which is static analysis method. The bolt hole on both side flanges are set as fixed geometry and the pressure are applied in the pipe. Additionally a sealer is place right on the defect and wrapped with the composite

wrapping. In this research, the composite wrapper types are focused on carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP).

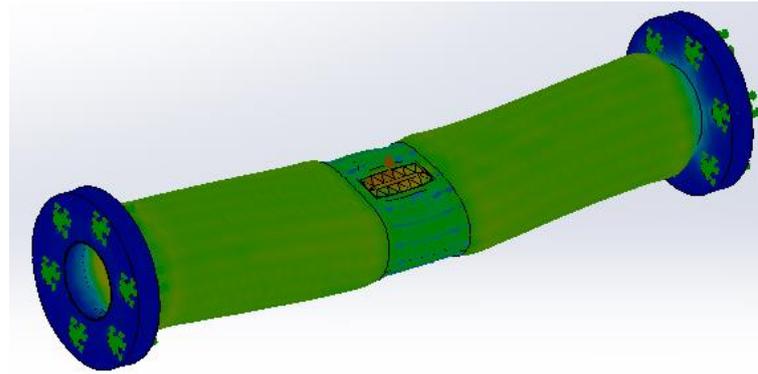
In this simulation, 4 types of plies are applied which are 2 layers, 4 layers, 6 layers and 8 layers. All these plies are set as carbon fiber reinforced polymer. Each plies obtained different results.

**Table 3: Mechanical Properties Values for Different Layers of CFRP**

CFRP Wrapper						
Number of Layers	Resultant					
	Stress (MPa)		Displacement (mm)		Strain (MPa)	
	Min	Max	Min	Max	Min	Max
2	1.244	7.564E+2	0	8.543E-1	7.164E-6	8.832E-3
4	1.244	7.211E+2	0	6.561E-1	7.142E-6	4.184E-3
6	1.24	6.894E+2	0	5.722E-1	7.122E-6	3.180E-3
8	1.245	6.584E+2	0	5.242E-1	7.103E-6	2.644E-3



**Figure 9: Graph of Maximum Stress VS Number of Layers of CFRP**

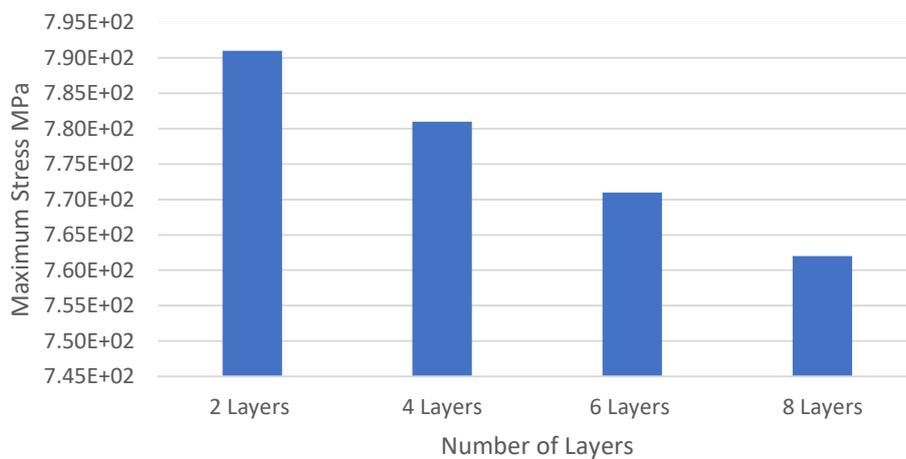


**Figure 10: Stress on the repaired pipe CFRP**

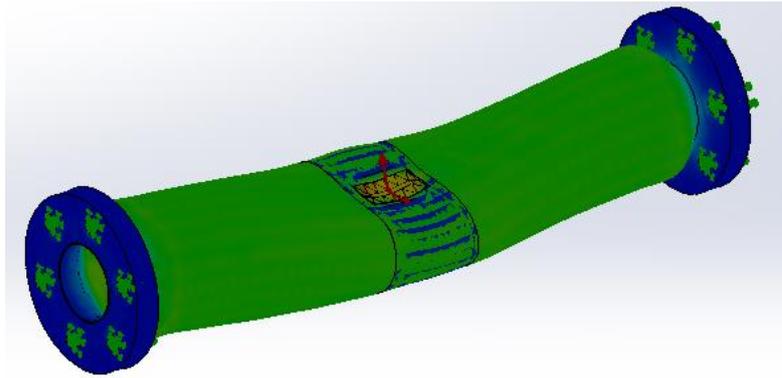
Next the simulation is continued with the same procedure as before which is 4 types of plies involves where 2 layers, 4 layers, 6 layers and 8 layers. All these plies are set as glass fiber reinforced polymer (GFRP).

**Table 4: Mechanical Properties Values for Different Layers of GFRP**

GFRP Wrapper						
Number of Layers	Resultant					
	Stress (MPa)		Displacement (mm)		Strain (MPa)	
	Min	Max	Min	Max	Min	Max
2	1.244	7.909E+2	0	7.062E-1	7.192E-6	3.026E-3
4	1.244	7.807E+2	0	5.448E-1	7.2E-6	3.164E-3
6	1.243	7.714E+2	0	4.731E-1	7.213E-6	3.135E-3
8	1.243	7.624E+2	0	4.421E-1	7.215E-6	3.103E-3



**Figure 11: Graph of Maximum Stress VS Number of Layers of GFRP**



**Figure 12: Stress on the repaired pipe GFRP**

From the results of unrepaired defected pipe, the maximum stress is  $7.877E+4$  MPa. Based on the Figure 4-2, when the pressure was applied in the internal of pipe, the defected area in the simulation shows red section where it indicates at that specific area has high stress. Thus when the defected area has high stress, the pipe will burst out. As expected, the unrepaired defected pipe could not withstand higher pressure as the crack defect affecting the pipeline.

Based on the simulation of the repaired pipe, we can say that for both type of composite, CFRP and GFRP, the more layers applied on the defected area, the stronger the pipe can withstand the pressure from burst out. Graph 4-1 and Graph 4-2 shows the amount of layers influence the stress value of the pipe. This results also shows that tensile strength is greatly influenced by the layers of composite as well.

However in order to find the best composite material between CFRP and GFRP, a comparison has to be made first. The effect of CFRP and GFRP layers applied on the pipeline system analysed. As shown in the Figure 4-14, the effect maximum stress of CFRP and GFRP as a wrapping structure provide different results based on the layers applied. Based on the results, the wrapping structure of CFRP provides better result than GFRP. As we can see the maximum stress of CFRP for the 4 types of layers are below the yield strength value which is 800MPa. Meanwhile, the maximum stress of GFRP for 4 types of layers are almost reaching the exceeding point of yield strength value. When the maximum stress in the pipe exceeded the yield strength, the failure of pipeline will occur (Street, 2003). Therefore the maximum stress for GFRP for the 4 types of layers can be considered as at the failure zone and the risk of failure is there. Hence the CFRP wrapping structure provide better result since the maximum stress in the pipeline system was controlled below the yield strength

#### **4. Conclusion**

In conclusion, the study's objective has been accomplished. Based on the 2 different composite material of wrapper for pipeline, CFRP is the best material for the wrapping since it is on optimum condition. The wrapping thickness at 8 layer with various angle of fiber orientation proven that it is the best material as the wrapper of the pipeline. The mechanical studies from the Solidworks software such as static analysis where the maximum stress result for the CFRP has better results than GFRP. CFRP is the best composite wrapping material since the mechanical properties of CFRP provides high strength and stiffness. This properties is suitable for the pressure pipeline application. According to the results of static analysis by using finite element analysis, the analysed results showed that the thickness of the wrapper and the number of composite material layers influence the strength of CFRP to withstand the pressure of the pipeline. Maximizing the number of thickness and the layers of the composite material will give a better result.

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