Monotonic Burst Pressure of Non-Metallic Filament Wound Composite Pipe

BY

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17298

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical)

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CERTIFICATION OF APPROVAL

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Approved by,

____

Dr. Mohamad Zaki Abdullah,

Project Supervisor.

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

MAY 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Sue Wei Ping

ABSTRACT

Due to relatively low cost and combination of ductility and strength, metal is preferred material for pipeline in oil and gas industry. However, metal can easily get corroded which is the major problem faced by the industry. To tackle the issue, non-metallic composite pipe was proposed. Since the non-metallic composite is relatively new, studies on the monotonic burst pressure is quite rare. Efforts were made to study the monotonic burst pressure last semester but failed due to the leaking problem. The objectives of this project are to design end caps without any leakage problem and to evaluate the monotonic burst pressure of the composite pipe. In this project, high density polyethylene (HDPE) was used as the liner, epoxy was applied as matrix and glass fiber was employed as the reinforcement. Filament winding was used to fabricate the composite pipe. In the process of fabrication, the composition used was 50:50 (epoxy/ glass fiber). The pipe underwent preliminary leak test using the manual hydrostatic pump at UTP and monotonic burst test at Sirim Venture Tech (SVT). Sdn. Bhd, Penang. The preliminary leak test was done successfully without any leakage at 30 bar. The average monotonic burst pressure was 102.5 bar which is higher than the design pressure for similar pipe made from carbon steel [2].

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CHAPTER 1

INTRODUCTION

This chapter presents the background, problem statement, objectives and the scope of study of this project.

1.1 Background of Study

In oil and gas industry, the onshore and offshore pipelines have served as the arteries for the petroleum plant and have been widely accepted as one of the most economical ways of transporting the oil and gas over the long distance. These pipelines typically connect an inlet, such as an offshore platform or an onshore compressor station, to an outlet, which can be another offshore platform or an onshore receiver station. The first carbon steel pipeline was employed in the late 19th centuries by Vladimir Shukhov and the Brannobel Company. By the late 1920, the pipeline materials had started to evolve from the low-carbon steel to mild carbon steel. By the late 1990 until present day, most of the companies in oil and gas industry still use steel pipeline in offshore and onshore platform [1]. The main problem of carbon steel pipeline that faced by the oil and gas industry is corrosion. Many oil and gas companies have to invest a lot of money every year to maintain the pipelines. Thus in this project, the non-metallic composite materials is proposed as the alternative materials for the replacement of the carbon steel pipe. The non-metallic composite material selected for this project is glass fiber reinforced polymer. This is because the cost of glass fiber is relatively inexpensive compare to carbon and Kevlar fiber. It has unique mechanical properties such as high stiffness, high ductility and strength.

1.2 Problem Statement

Due to the advantages of non-metallic pipe such as non-corrosive, light weight and high mechanical properties, the non-metal composite pipe is a very promising alternative material to carbon steel pipe. However, the performance of the non-metallic pipe especially monotonic burst pressure is rarely studied. Efforts were made last semester to study the monotonic burst pressure. Unfortunately, the results could not be repeated due to leaking problem in the end caps.

1.3 Objectives

The objectives of this project are:

1. To design and fabricate end caps of composite pipe for monotonic and cyclic burst pressure test.
2. To evaluate monotonic burst pressure of non-metallic filament wound composite pipe.

1.4 Scope of Study

The non-metallic composite pipe consists of two layers. The first layer is known as liner and the second layer is the composite layer. The liner was made up of high density polyethylene (HDPE) while the composite was glass fiber and epoxy. The composite was attached to the linear through filament winding method. The composition for the filament winding was 50/50 (epoxy/ glass fiber). Filament winding was done in SIRIM Tech Venture (SVT) Sdn. Bhd. SIRIM, Penang, Malaysia. The composite pipe was tested for monotonic pressure test in SVT, Penang.

CHAPTER 2

LITREATURE REVIEW

Literature review is focused on research work that has been done on end cap and monotonic burst test. The work should be done on pipe or tubular section. Preferable material for the pipe is non-metallic composite. If no work is done on non-metallic composite pipe, work on other materials can be cited as well.

2.1 Pipeline

Pipeline is referred to a long and continuous joint of pipe in a line that is used to convey the fluid or gases from one place to another place. Pipeline is a safe and efficient mean of transporting large quantities of crude oil and natural gas onshore or offshore. It requires a small space to transport the crude oil. There are 4 categories of pipelines which are gathering line, production line, transmission line, and distribution pipeline.

The gathering lines collect gas from multi flow lines and move to the processing plant. Transmission pipeline is the large diameter pipeline which was used to transport crude oil from the platform to the refinery, processing, or storage. It can be also transported refined product to the customer. Production or feeder pipeline was used to transport the crude oil from the oil well to the platform. The examples of production line are riser. Distribution pipeline represents the ends to ends flow of resources from supplier to customer.

2.2 Riser

Riser is under the category of production pipeline. Riser is defined as the vertical or near vertical segment pipe connecting from the oil well to the platform. Riser pipe was divided into two sections, receiver and launcher. The receiver was the top section and the launcher was the bottom section of the riser pipeline. The receiver section was connected to the platform and the launcher section was connected to the oil well. The focus in this project is the receiver part of the riser pipeline.

This is because less hydrodynamic force in that part compare to the launcher part. Figure 2.1 shows an example of specification of the receiver section which is supplied to Petronas CariGali (PCSB). Sdn. Bhd., Kertih, Terenganu [2].

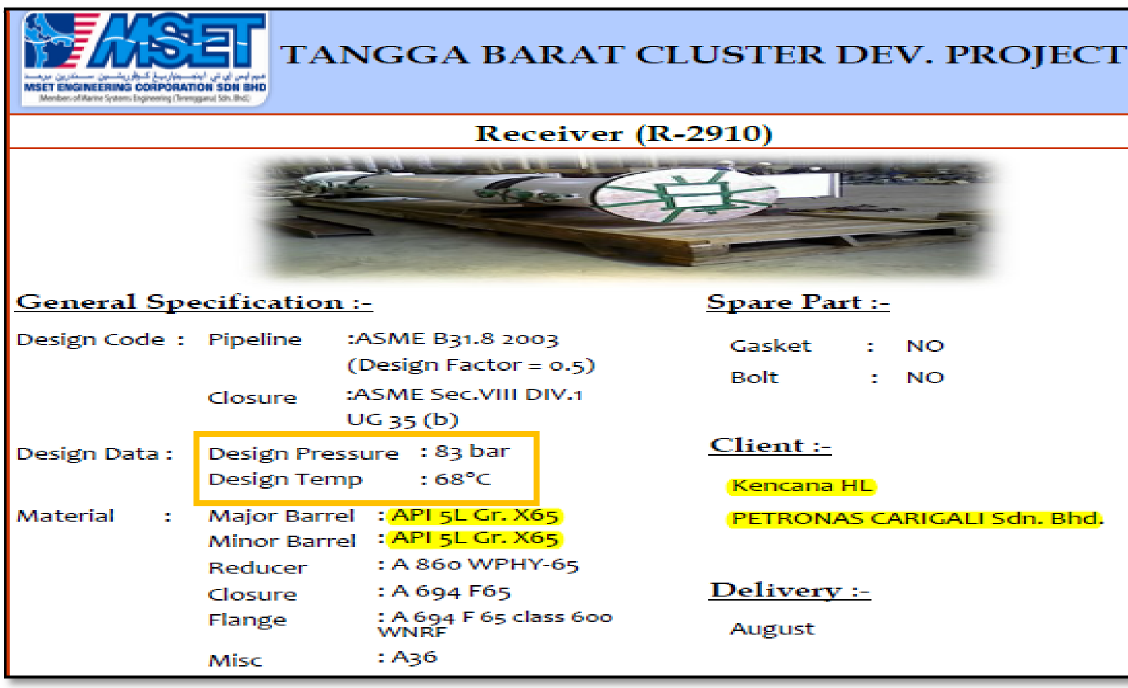

Figure 2.1: Receiver pipe system [2].

Based on the receiver pipe specification in Figure 2.1, the design pressure of the riser is 83 bar and the design temperature is 68^{o}c. The type of material used is carbon steel.

2.3 Conventional Pipe

The conventional pipe was the carbon steel pipe. Carbon steel pipes used in the gas pipeline systems generally referred to API 5L and 5LX specification. The grade of the carbon steel pipe that is commonly used in the oil and gas pipeline is X42 to X90. API 5L X65 was the type of carbon steel pipe that applied in the riser system. Tables 2.1 and 2.2 show the properties chemical and mechanical properties of API 5L X65 steel, respectively.Table 2.3 shows the pressure internal pressure design for API 5L X65 pipe. The class location shown in the table refers to the location of the pipeline situated. The class location 1 is for the offshore pipeline and whereas for onshore pipeline can be tested with under any class 2 - 4 depends on the situation.

Table 2.1: Chemical composition of API 5L X 65[3].

Element (wt %)						
C	P	Mn	S	Si	Fe	Ceq
0.08	0.019	1.45	0.03	0.31	Balance	0.32

Table 2.2 Mechanical Properties of API 5L X 65[3].

Young's modulus E (GPa)	Poisson's Ratio v	Yield strength α_y (MPa)	Tensile Strength α_u (GPa)
210.7	0.3	464.5	563.8

Table 2.3: Steel Pipe Specification – API 5L X65, 34 in & 36in, 65k SMYS [3].

Nominal Pipe Size (Inches)	Outside Diameter [1, 2] (Inches)	Wall Thickness [1, 2] (Inches)	Pressure at % of SMYS (psig)							
			Class Location:		1	2	3	4		
			100%	90%	72%	60%	50%	40%	30%	20%
34	34.0	0.375	1,434	1,291	1,033	861	717	574	431	287
		0.406	1,553	1,398	1,118	932	777	621	466	311
		0.438	1,675	1,508	1,206	1,005	838	670	503	335
36	36.0	0.406	1,467	1,320	1,056	880	734	587	440	294
		0.438	1,582	1,424	1,139	949	791	633	475	317
		0.469	1,694	1,525	1,220	1,017	847	678	509	339
		0.500	1,806	1,625	1,300	1,084	903	723	542	362

2.4 Non- Metallic Pipe

The non-metallic composite pipe is divided into two types, one is bonded and another one is un-bonded. The properties of the non-metallic bonded composite pipe also depend on the type of materials used. The non-metallic composite pipe have several advantages over the traditional engineering materials such as high stiffness, high specific strength, high cyclic burst pressure strength, corrosion resistance, and good impact properties.

Beside the mechanical properties, non-metallic bonded composite provide a good dimensional stability and design flexibility. The most common type of industrial application of bonded composite pipe is fiber reinforced polymer. Fiber that commonly used in the composite pipe was glass fiber, carbon fiber and Kevlar fiber. Mechanical properties and cost of the fiber reinforced polymer (FRP) depend on feature of the fiber bundle. The fiber reinforced polymer consists of three layers; the first layer is the liner, second layer is the composite layer and the third layer is the jacket layer. Figure 2.2 presents the figure for the schematic diagram of the bonded composite pipe [4].

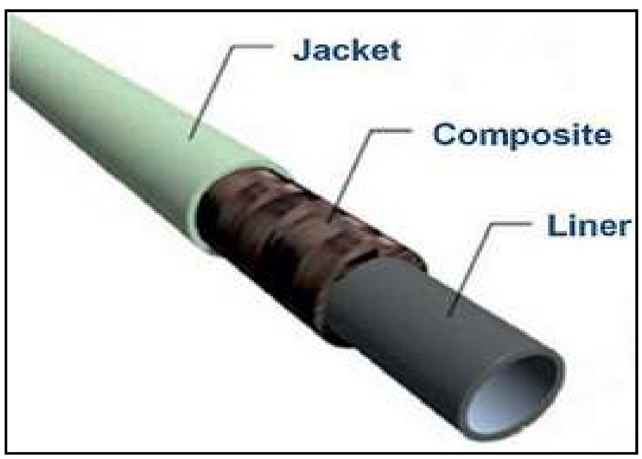

Figure 2.2: Fiber reinforced polymer structure [4].

2.4.1 Liner

The liner serves as the barriers properties for the composite layer. It can withstand a small load on the tensile load of the composite structure. There are two type of non-metallic liner such as thermosets and thermoplastics. Thermoplastic polymer can be reshaped many times by application of heat. In thermoset polymer, it cannot be reshape or melt by application of heat. This is because the thermoset consist of cross links that form a rigid network of molecule that cannot be broken. Thermoplastics polymer was an attractive liner to be applied by the industry application. This is because thermoplastic polymers offer unique mechanical properties such as high impact strength, and high fracture resistance compared to the thermoset polymer. The most common thermoplastic matrix composite that used in composite industry was:

- Nylon: high toughness and impact resistance but low ductility.
- High density polyethylene (HDPE): high toughness strength, high impact resistance high ductility, and low cost.
- Polyetheretherketone (PEEK) : high chemical resistance and wear resistance but expensive
- Polypropylene (PP) : low cost, high specific strength, good chemical resistance, ductility but low temperature.
- Polyimide (PAI) : high specific strength, high service temperature range and expensive material.

In this project, the liner used was high density polyethylene (HDPE). This is because it has a good mechanical properties and high availability in market. HDPE pipe is widely as the water pipeline to transport from the processing plant to the consumer.

2.4.2 Composite

The composite layer was also known as the reinforcement for polymer matrix composite (PMC). The reinforcement of PMC can be fibers, particle or whiskers. In this project, the fibers were chosen because of the market availability. As mention earlier the glass fiber is chosen in this project. Each has its own unique properties to the specific application. Most fiber reinforcement for PMC has their common characteristic. Table 2.4 presents the type of fiber glass and their common characteristic.

Table 2.4: Type of fiber glass

Type of glass fiber	Characteristic
E - glass	High electrical insulating, good strength, inexpensive, high durability
S - glass	High strength, good ductility, high temperature, expensive
S_2 – glass	Similar properties to S-glass with lower cost but higher cost then E-glass
C- glass	High chemical resistance, high degradation resistance, low cost, low temperature

The E-glass is more preferable as the composite layer in this project because of the less expensive good strength, high durability and market availability.

2.4.3 Jacket

Jacket wasthe most outer layers for the fiber reinforced polymer pipe. The function of jacket was used to protect the composite layer from any mechanical abrasion. In this project, the jacket is not included because the study was focus on the monotonic burst pressure of the non-metallic filament wound composite pipe.

2.4.4 Process of Composite Pipe

Filament winding is intended to produce a more strength tolerant composite under a stress ratio occurring in structure loading (i.e. internal cyclic burst pressure). According to Takayanagi et al. [5], he stated that filament winding composite pipes made of reinforce polymer of the have many potential advantages over pipes made from conventional materials such as high specific stiffness and strength, good corrosion resistance and thermal insulation.

The statement made by Takayanagi et al. had been verified by Alderson and Evans [6], by stated that the strength of filament winding composite had a higher weight ratio compares to the other method of forming pipes in their research. There are two types of filament winding that well knows, single and multi-layered filament winding.

According to Xia et al. [7] in his multi-layered filament winding, he found the off-axis in multi-layered pipe can be used to match potential loading direction so as to offered design of various structure and can provide a better strength compare to the single layer filament winding. The process of multi-angle filament winding is as shown at Figure 2.3 [8].

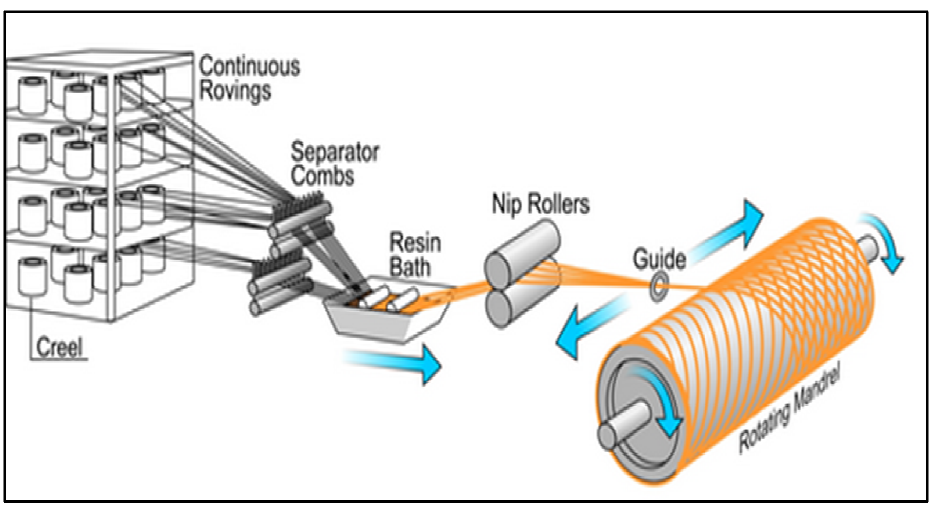

Figure 2.3: Multi-angle filament winding [8].

2.4.5 Filament Winding Angle of Fiber Glass

Frost [9] studied the long-term cyclic burst pressure behavior of a $[+55/-55]_n$glass fiber/epoxy filament wound pipe and concluded that the failure mechanisms for both short and long term cyclic burst pressure were seepage as a result of matrix cracking. The damage found after long term cyclic tests was notably less than that of the short term. Based on his research, he concluded that the best angles for plying the multi-angle filament winding are [$30^o/60^o$].

2.5 End caps

End caps is one of the main apparatus that used to conduct this experiment and the main function of the end caps is used to covey the pressure from the equipment to the composite pipe. Based on the research study on “hydrostatic burst test of multi-angle filament wound composite pipe”, one of the main problems that affect the experiment fail is the improper design of the end caps. Thus, a new design and fabrication is needed for the end cap. Figure 2.4 shows the design of the end caps from the previous study entitle “hydrostatic burst test of multi-angle filament wound composite pipe”.

Figure 2.4: End caps from previous studies [10].

The new design of the end caps is based on the Fiber Reinforced Polymer (FRP) connector as shown in Figure 2.5, research paper from Savannah River National Laboratory (SRNL) for cyclic burst pressure and burst test on fiber composite [11]. In this testing, there are two complete set of end caps is used for coupling at both ends of the composite pipe.

In each set of the end caps there are three components such as stopper fitting, ferrule, and coupling. There is two set of the end caps, thus there are two stopper fitting. One of the stopper fitting consist of quarter inch hole so that it can used to convey the pressure and the other ends stopper fitting does not have it. Both of the stoppers consist of male thread in the middle parts of the component. The main function of the stopper fitting is to prevent the pressure leak from the composite pipe.

Ferrule is a metal ring that strengthens the end of a handle. The main function of the ferrule is act as a clamp to grip the composite pipe for prevents splitting when the pressure is applying. The design coupling consists of female thread for the male thread on the stopper fitting. The main function is to connect with stopper fitting. When the coupling is tightening to stopper fitting, the mechanical compressing the ferrule on the piping as the result the compression made a grip on the seal, thus the composite pipe is grip tightly to the stopper fitting.

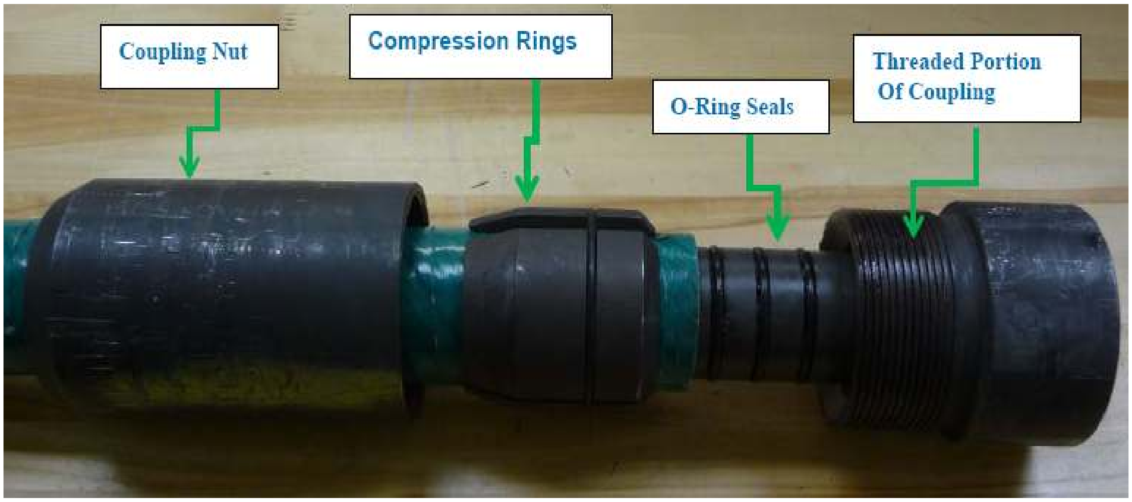

Figure 2.5: Fiber reinforced polymer connector [11].

2.6.Monotonic Burst Test

Monotonic burst test was to determine the burst pressure of the composite pipe. Monotonic burst pressure was defined as the point at when the hose will fail as a result of pressure, and it may also be defined as the point right before failure will occur. The ends are sealed using end caps.

The pipe has filled with water and expelling all air. Internal water pressure is applied and increased gradually up to two times of nominal working pressure. According to the ASTM D-1599, short-term hydraulic failure pressure test has conducted on all pipes. In these tests, pressure was increased uniformly till the failure occurred.

Table 2.4 has presents the monotonic burst pressure test of a conventional pipe (API 5LX 65). This information was taken from the research paper from University Malaysia Pahang [12].

Table 2.4: Burst pressure result for API 5L X65 [12].

Case No.	Pipe Diameter (mm)	t/D (%)	Defect Dimension, (mm)			Burst Pressure	Intact Burst Pressure
			Depth, d	d/t	Length, l		
CS1	508	3.44	4.375	0.25	500	34.8	34.4
CS2			8.75	0.5		28.8	
CS3			13.125	0.75		20.8	
CS4	762	2.29	4.375	0.25		24.0	22.4
CS5			8.75	0.5		19.2	
CS6			13.125	0.75		15.6	
CS7	1016	1.72	4.375	0.25		18.4	16.6
CS8			8.75	0.5		16.8	
CS9			13.125	0.75		13.8	

CHAPTER 3

METHODOLOGY

Research flow chart, materials and equipment used for this project are presented in this chapter. The fabrication of composite pipe and testing of the samples are explained details here. Finally, Gantt chart of key milestones and project activities is tabulated here.

3.1 Research Strategy

Research strategy was established to capture critical milestones required to complete this project. Figure 3.1 shows the flow chart of this project.

3.2 Specimen, Apparatus, and Equipment

Specimen, apparatus and equipment that required for this project is presented in this sub-chapter of the reports.

3.2.1 Specimen

Tubular specimens were cut from 1.5 m sections of a filament wound Glass reinforced polymer (GFRP) to a finished length of 500 mm each. The thickness of the GRP filament winding is 1mm. The polymer that used for GRP or liner is the HDPE pipe. The pipe had an inside diameter of 72 mm and 9.2 mm of thickness. The outer surface had a nominal diameter of 94 mm. The resin bath that applied in the HDPE pipe is epoxy. Epoxy had a mechanical characteristic corrosion resistance, high strength and dielectric.

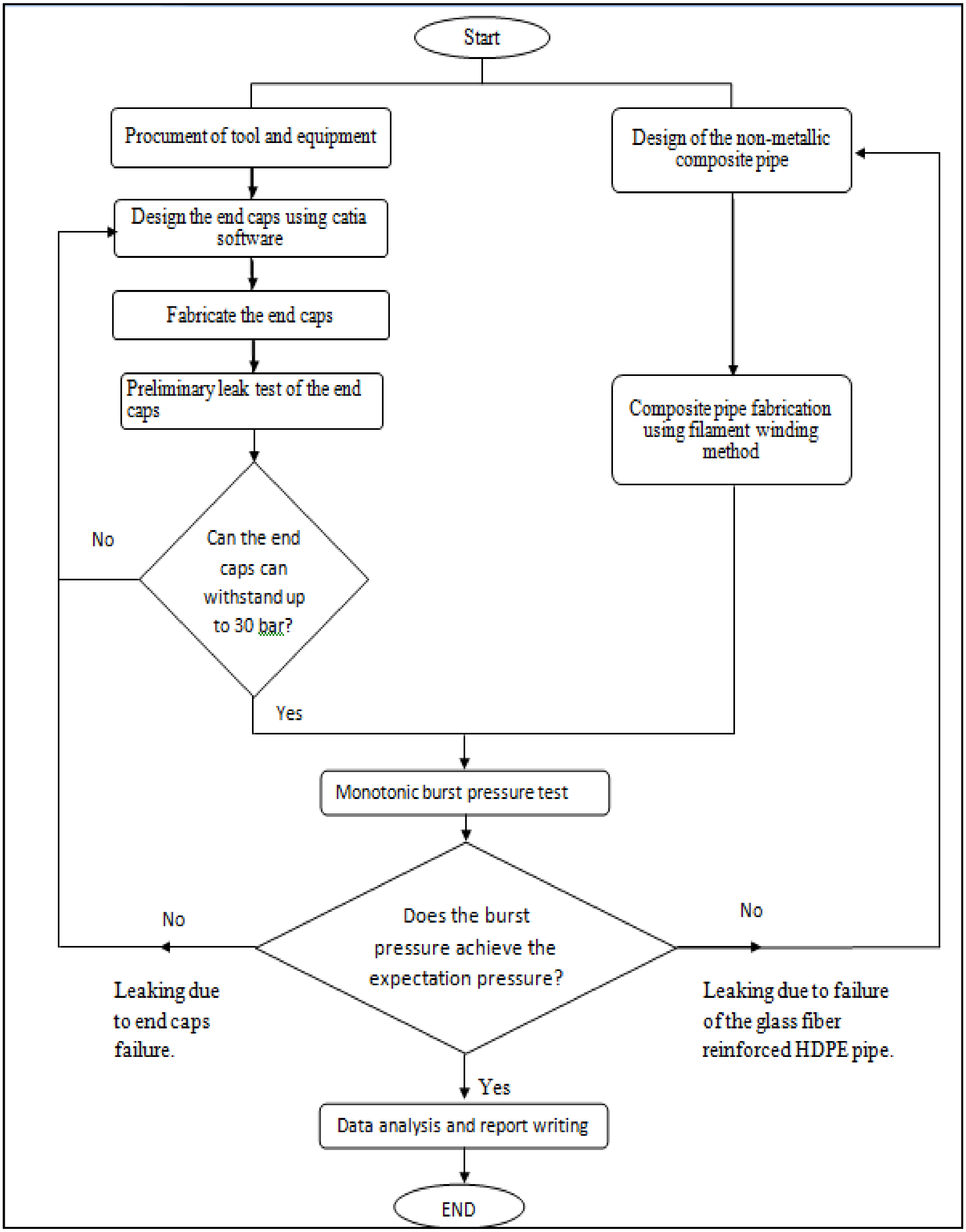

Figure 3.1: Project flow chart

3.2.2 Apparatus

The apparatus required for the monotonic burst pressure test is the end cap. The end cap main function is to ensure no leak in both ends of the pipe during the monotonic test. Pressure is pumped through one of the end caps. For this project, the expected burst pressure was slightly above 100 bar due to the composite material chosen. The internal diameter was relatively large which was 72 mm. To ensure no leakage, expected burst pressure and dimensions of the pipe especially internal and external diameters must be taken into account when designing the end cap.

3.2.3 Equipment

The pipe are manufactured at a three axial computer controlled wet filaments winding machine. Maximum winding diameter of the machines is 500 mm and the maximum winding length is 4500 mm. The system capable to utilizing winding angles from 0^o to 90^o and its carriage receives the fibers from three creels. The maximum winding speeds of the system 60 m/min and it can carry mandrel of maximum one tons during the process. The system controls the tension and the temperature of the resin bath, up to 100^oC.

3.3 Process of the Glass Fiber Reinforced HDPE Composite Pipe

Step one, insert the steel mandrel of the filament winding machine into the 3" in high density polyethylene (HDPE) pipe and place it back to the filament winding machine. Step two, two rove of fiber glasshas placed in the roving part of the filament winding machine. Step three; fill the resin tank with epoxy. Step four, filament winding continuous strands of closely spaced glass fiber, automatically impregnated with resin, and are wound onto the cured liner by the computer controlled machine. The pre-programmed machine will carry out the winding pattern to the required thickness. The process of the glass fiber reinforced HDPE composite pipe has shown in Figure 3.2.

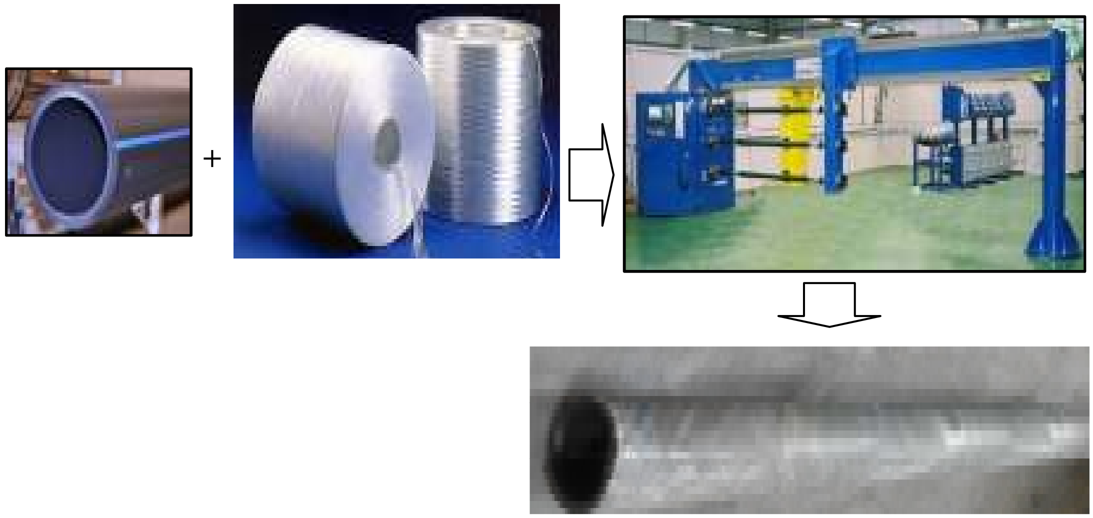

Figure 3.2: Process of Glass Fiber reinforced HDPE Composite Pipe.

3.4 Design and Fabricate of End Caps

The design of the end caps start with measured all the actual dimension of the specimen. Second step of the end caps design is started with stopper fitting. The stopper fitting has made up of three parts. The first part is the part used to place the tool for tighten the stopper and the coupling and the second part is design with thread. The thread is used to connect the coupling with the stopper fitting. The third part is design to fit the size of the inner diameter of the specimen with two grooves. The groove is design to place the O-ring seal for the pipe. Third step is to design the ferrule. The ferrule consists of two part front and back.

The front part of ferrule is a metal ring with 10 mm thickness and the internal diameter is same as the outer diameter of the composite pipe. The front parts of the ferrule also consist of groove at the middle. The purpose of design the groove is to place the O-ring seal. The back part is the tapper metal ring. The equation that uses to calculate the angle of the tapper is based on the pressure grip calculation and it has shown in below:

$$\text{Tapper angle, } \tan \text{ø} = \frac{\text{Lenght of compression}}{\text{Length of tapper metal ring}} \qquad \text{- Eqn3.1}$$

Final step is to design the coupling. The design of coupling is made up of two internalparts. The first part is thepart that consists of internal thread which is used to connect the stopper fitting. The second part is design to fit the dimension of ferrule. This is because ferrule will place in the second part of the coupling. All the details drawing of the end cap has been produce using CATIA software.

3.5 Testing

The testing method of the sample such as preliminary leak test, burst test, cyclic burst pressure failure test has explained details in this sub-chapter.

3.5.1 Preliminary Leak Test

Preliminary leak test for the end caps was performed to ensure that ends caps can withstand the required pressure for test without any leaking in the end caps. First step, install the end caps at both ends of the composite pipe. Second step, connect the pressure hose from the manual hydrostatic test pump to the end caps. Third step, placed water into the provide tank in the manual hydrostatic test pump. Final step, started to pump the water into the composite pipe by the level provided at the pump. Figure 3.3 shows the setup of the preliminary leak test for the end caps.

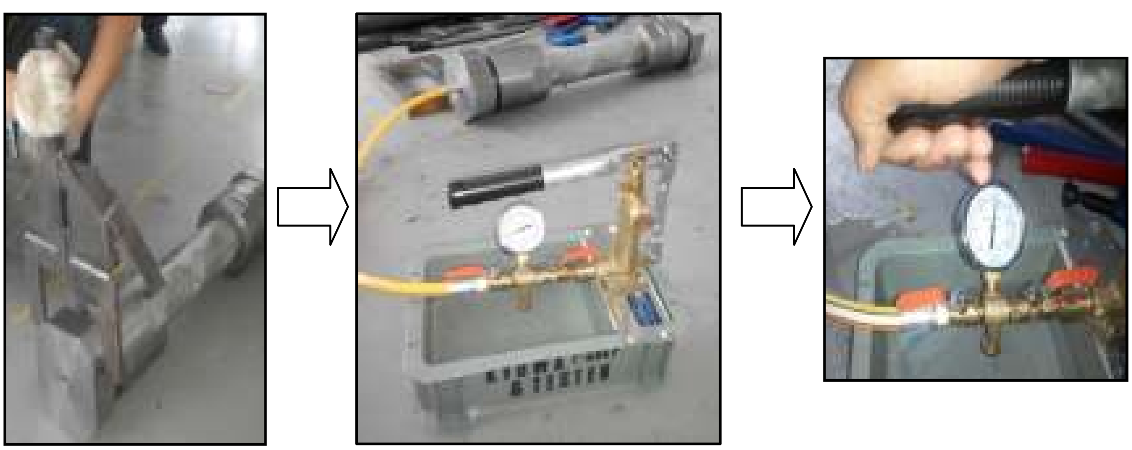

Figure 3.3: Setup of preliminary leak test.

3.5.2 Monotonic Burst Test

The purpose upon this testing is determine the maximum pressure of the glass fiber reinforced HDPE pipe and the pressure is used to decide the pressure for the cyclic loading test. This test is required at least two test to obtain the average of the burst pressure result. In this test, the end caps were used to enclosure at the both ends of the pipe. Then, installed the test jig and fill in the specimen with the water. Next, placed the sample inside the bunker as shown in Figure 3.4 and connect the join from the high pressure pump (as shown in Figure 3.5) to the specimen. The pressure is then monitoring using the IVS impulse monitoring software in the central controlled room (CCR) as shown in Figure 3.6.

Figure 3.4: Testing bunker.

Figure 3.5: High pressure pump.

Figure 3.6: Central control room (CCR).

3.6 Gantt Chart of Key Milestone and Project Activities for FYP 1 and 2

The Gantt chart present the project schedule of the project progress for FYP 1 and 2 as shown in Tables 3.1 and 3.2, respectively.

Table 3.1: Gantt chart of key milestones and project activities for FYP 1.

Final Year Project 1															
No	**Item/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	**Procurement of composite pipe materials.**							22/2							
	Selection of materials														
	HDPE Liner														
	Epoxy and glass fiber														
2	**End cap design**									6/03					
	Conceptual design														
	End cap design using Catia														
3	**Fabrication of composite pipe**														17/4
	Design of non-metallic pipe e.g. composition, winding angle, and etc.														
	Fabricating filament wound														

Table 3.2: Gantt chart of key milestones and project activities for FYP 2.

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**End caps fabrication**						26/6								
	Material procurement														
	Fabrication in R&R Tool.														
2	**Preliminary leak test**									17/7					
	Procurement of small hydrostatic test pump														
	End cap assembly and leak test														
3	**Testing**												07/8		
	Monotonic burst test														
	Verification of physical evidence e.g. test result, physical specimen, etc.														
4	**Data analysis and report writing**														21/8

CHAPTER 4

RESULT AND DISCUSSION

This chapter presents the full engineering drawing of the end cap, preliminary leak test result and monotonic test results.

4.1 End cap design

There were three components of the end cap, namely stopper fitting, ferrule, coupling. The first component was a stopper fitting which is presented in Figure 4.1. The head of the stopper is 140 mm, which was the same size as the outer diameter of the coupling. The middle part of the stopper has the same diameter as the internal diameter of the first part for the coupling which was 120 mm. The third part was the joint between composite pipe and the stopper fitting. It had the same diameter as the internal diameter of composite pipe which was 72 mm. The second component was the ferrule. The internal diameter of the ferrule had the same diameter as the outer diameter of the composite pipe which was 92 mm. The thickness of the ferrule was 10 mm. The groove size of the middle for the front part of the ferrule was 3 mm diameter. The total length of the ferrule was 69 mm. The length of the front part was 44 mm and the back part was 25 mm. By using the formula in equation 3.1 and assuming that the compression length was 7 mm, the angle of taper for the ferrule was 15^{o}. Figure 4.2 shows the drawing for the ferrule component. The third component was the coupling. The dimension of the internal diameter on the first part was the same as the middle part of external diameter for the stopper fitting which was 120 mm and the second part was designed to fit the dimension of the ferrule. Figure 4.3 shows the drawing for the coupling component. The assembly drawing of the three components is shown in Figure 4.4.

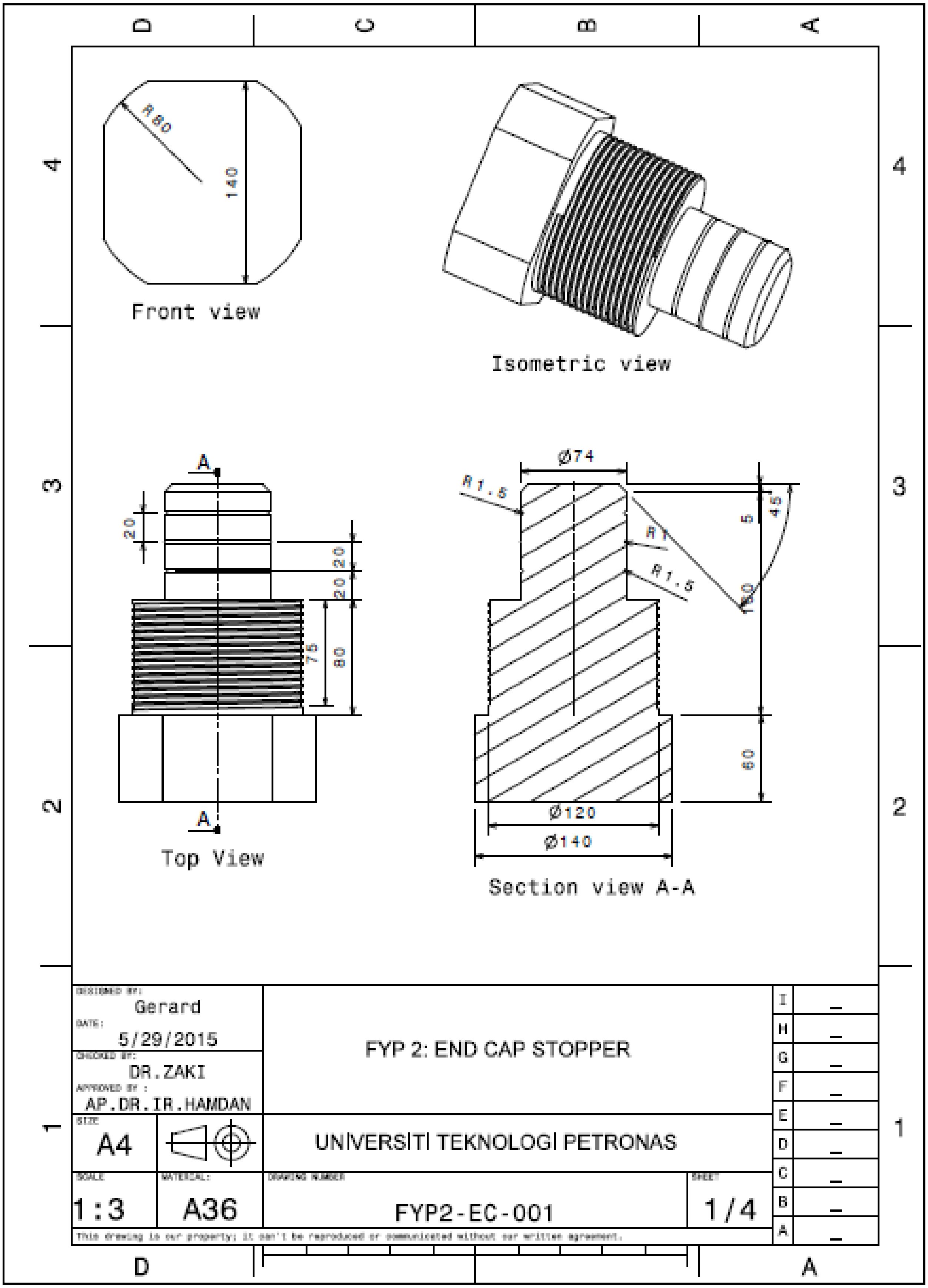

Figure 4.1: Stopper fitting.

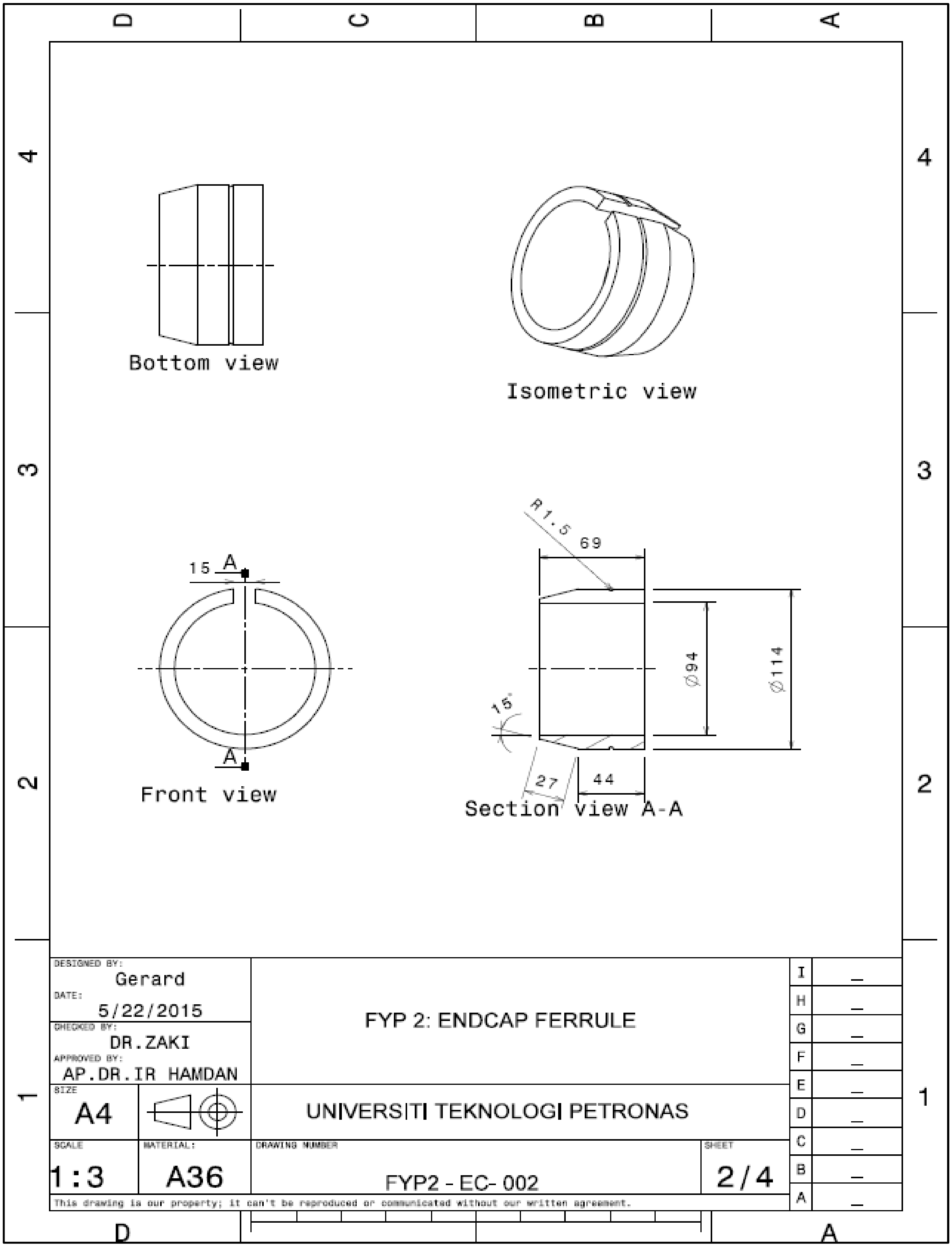

Figure 4.2: End cap ferrule.

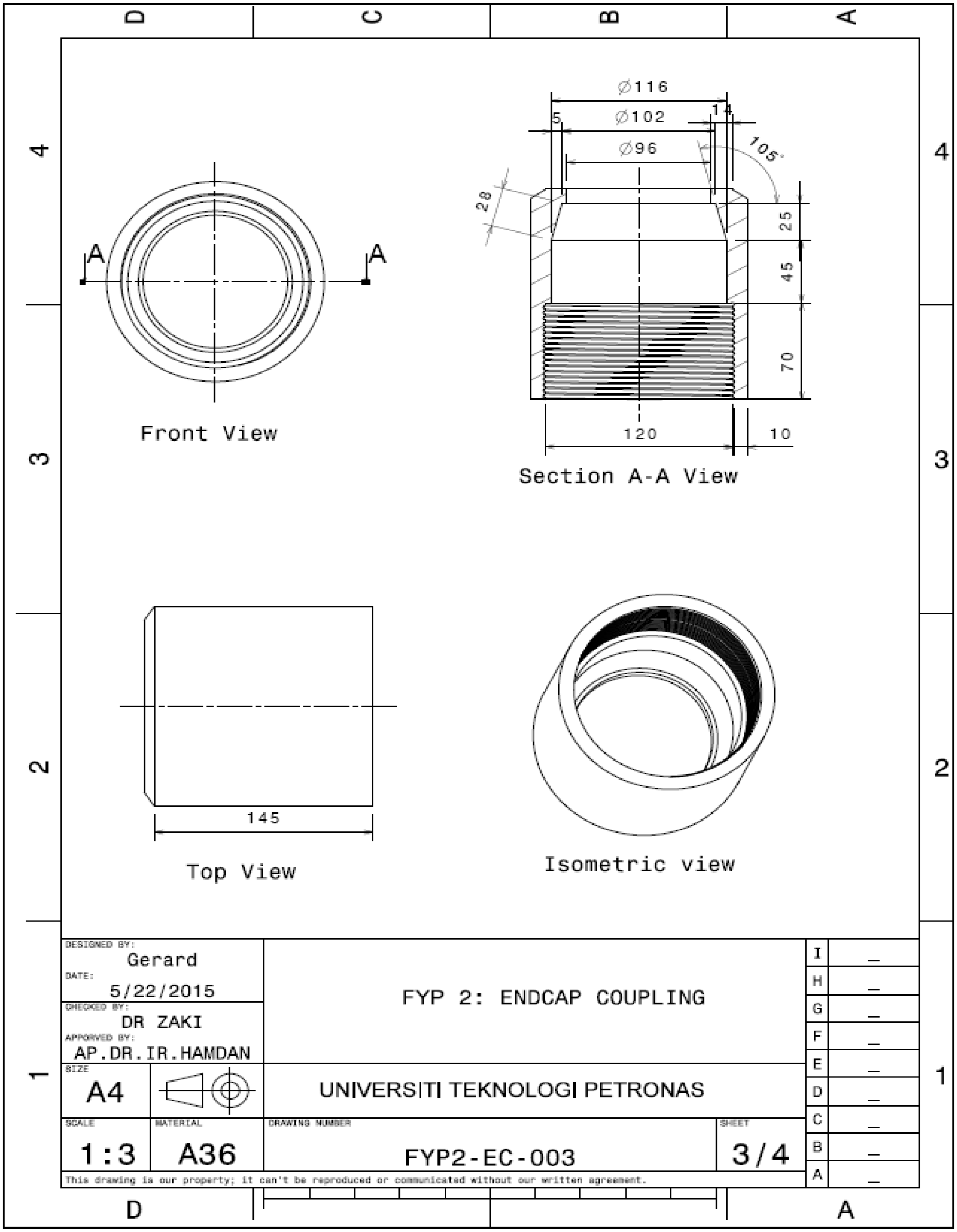

Figure 4.3: End cap coupling.

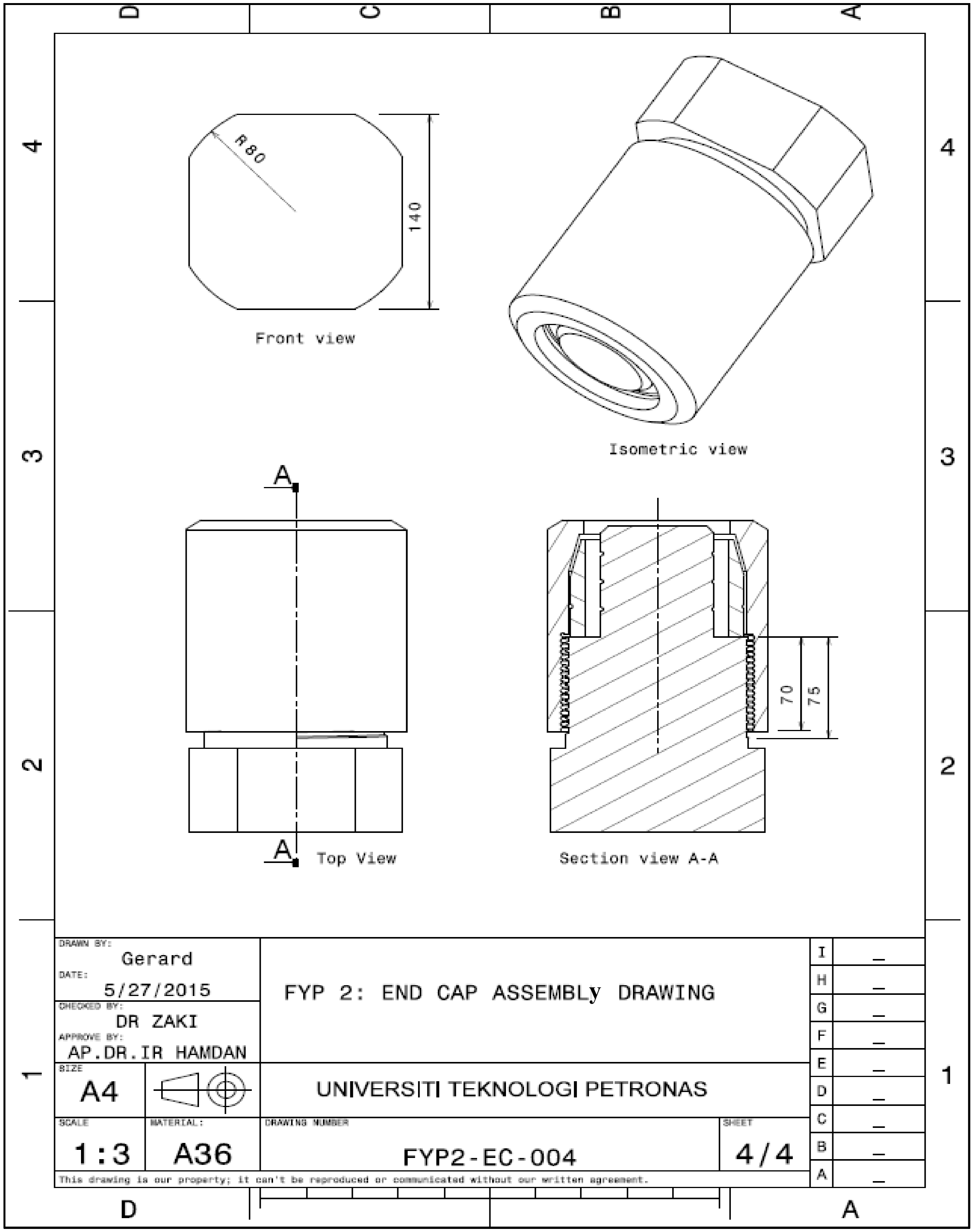

Figure 4.4: Assembly drawing for end caps.

4.2 Preliminary Leak Test

The preliminary leak test was carried out using manual hydrostatic pump with a maximum pressure of 50 bar. The test was done in Block 21, UTP. The result showed that the end cap could withstand the pressure of 30 bar without any leaking. Figures 4.5 and 4.6 show the preliminary test assembly and the pressure value during the test, respectively. The pressure indicator remains constant at 30 bar, during the test, indicating that there is no leakage.

Figure 4.5: Preliminary leak test.

Figure 4.6: Test pressure indicated in the barometer.

4.3 Monotonic Burst Result

The monotonic burst tests were carried out in SVT, SIRIM Penang. The results obtained from the first and second monotonic burst tests were 92 bar and 113 bar, respectively as shown in Figures 4.7 and 4.8. The monotonic burst test was conduct at room temperature. The mean burst pressure was 102.5 bar. The burst test result is in agreement with the expected fiber glass reinforced polymer pipe which was about 100 bar, providing confident to the test result.

Several deductions can be made from the monotonic burst pressure test which was clearly justified that the advantages of the glass fiber reinforced composite compare to the conventional carbon steel pipe that used in the receiver of the riser system. In term of internal pressure, the mean of the maximum pressure that can withstand for the glass fiber reinforced HDPE was 102.5 bars and the design pressure of the riser using conventional material (API 5L X65) was 83 bars.

Figure 4.7: Pressure value of first monotonic test before the pipe was ruptured.

Figure 4.8: Pressure value of second monotonic test before the pipe was ruptured.

At the beginning of the monotonic test, the end caps were assembled to both ends of the composite pipe. During the test, one of the end caps dislocated at approximately 36 bar, causing the failure of the test. Figure 4.9 shows the test assembly with one dislocated end caps. To solve the dislocated problem, supporting jig with six threaded rod was employed as shown in Figure 4.10. With this assembly, the monotonic tests were performed successfully.

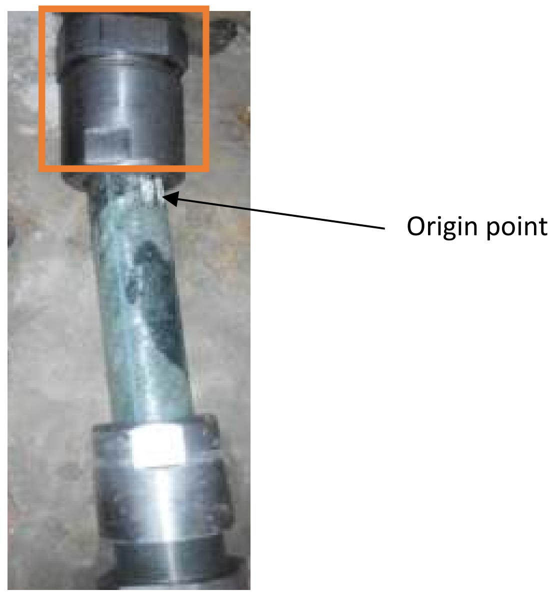

Figure 4.9: Dislocate of the end caps.

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Figure 4.10: End caps with test jig.

Figure 4.11 shows the burst pattern at 113 bar. Similar burst pattern was observed for the other test which failed at 92 bar. The burst pattern of the composite pipe had shown the glass fibers raptured, suggesting that the internal pressure has been transferred from the liner to the glass fiber reinforcement. The burst also happens in the middle of the pipe sample, indicating that there is no or very minimal leakage. Therefore, the maximum strength of reinforcement, which is glass fiber, has been ulitilized.

Figure 4.11: Burst pattern at 113 bar.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the results of this project, the following conclusion can be made:

i) The project was successfully achieved its objectives.

ii) The new designed end caps could withstand the burst pressure test without any leakage.

iii) The average monotonic burst pressure achieved by the composite pipe was 102.5 bar.

5.2 Recommendation

To complete the research work on non-metallic composite pipe, the following recommendations are proposed:

i) Cyclic burst test should be done on the pipe since the monotonic was carried out successfully.

ii) The hoop tensile properties of the composite pipe should be carried out to understand further mechanical properties of the pipe.

iii) Different materials for liner, matrix and fiber can be further studied. For example, polypropylene (PP), polyamide (PA), Polyetherketone (PEEK), can be used as liner. Other than glass fiber, carbon, Kevlar fiber can be employed as the reinforcement.

References

1. A. Ghamblor, Offshore Pipelines, Kansas: Springer Link, 2012.
2. MSET,(2014), Receiver pipe specification, retrieved from http: www.mset.com.my/catalogue/pipeline.pdf
3. API 5L (2004), "Plain-end Line Pipe Dimensions, "Weights per Unit Length, and Test Pressures", "API Specification," API, Washigton D.C,
4. Retrive data from:www.airborneoilandgas.com. Retrieve date: 18/6/2015. “Thermoplastic pipes-lighter,more flecible solutions for oil and gas extraction”.
5. H.Takayangi. Composite fiber reinforcement plastic composites. *Composite Part B: Engineering,73,*pp166-188.
6. Alderson and Evan (2014). Flexural and tensile strengths of unidirectional hybrid e composites reinforced by S-2 glass and T700S carbon fibres. *Materials & Design, 54*,pp. 955-966.
7. M. Xia , Hernández-Moreno, H., Douchin, B., Collombet, F., Choqueuse, D., & Davies, P (2001). Influence of winding pattern on the mechanical behavior of filament wound composite cylinders under external pressure. *Composites Science and Technology, 68*(3-4), pp.1015-1024.
8. Retrieve data from: www.netcomposite.com. Retrieve date: 25/02/2015. "multiangle filament winding".
9. Frost. Surface damage of unidirectional carbon fiber reinforced epoxy composites under reciprocating sliding in ambient air. *Composites Science and Technology, 71*(15), pp. 1769-1776.
10. Ammar,"Hydrostatic Burst Test of Multi angle Filament Wound Composite Pipe".FYP, University Technology Petronas, 2015
11. George & Adam, (2014). Fiber Reinforced Composite Pipelines (SRNL), retrieved from "www.hydrogen.energy.gov/pdfs/review14/pd022rawl2014pdf.
12. M.Zulfadli, "Determination of Burst Pressure of Defective Steel Pipes" FYP, University Malaysia Pahang, (2012).

13. ASTM D 1599-04, 2004, “Standard Test Method for Monotonic Burst Pressure Strength of Reinforced, Thermosetting Plastic Pipe,” ASTM, Philadelphia,

14. Kujawski (2013). Repairing impact damaged fiber reinforced composite pipes by external wrapping with composite patches. *Composite Structures,* pp.123, 1-8.

15. Lockett & Lau, K.-t. (2013). "Long-term cyclic burst pressure behavior of a [+55/-55] $_n$glass –fiber/ epoxy filament wound pipe". *Oil industry technical specification,*pp 100, 40-54.