STUDY OF MECHANICAL PROPERTIES ON FIBERGLASS REINFORCED PLASTIC PIPE UNDER TENSILE AND BENDING CONDITION

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Study of Mechanical Properties on Fiberglass Reinfoeced Plastic Pipe Under Tensile And Bending Condition" is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant & Maintenance).

Signature : .....

Name of Supervisor: .....

Date : .....

DEDICATION

To my beloved mother and father as well as all researchers specifically on composite materials.

ABSTRACT

Mechanical properties of a structure and materials is essential in designing a product to know the strength of the material as well as the structure. The purpose of this research is to study and analyze the mechanical properties of fiber reinforced plastic pipe. The research is collaborated with Pacific Advance Composites Sdn. Bhd. to know the mechanical strength of their pipe design and the 3 inch in inner diameter welded and plain pipe specimen was prepared by that company. In this study, tensile and bending test was done in order to know the tensile and bending strength of the FRP pipe. In conjunction to that, a jig has been designed according to ASTM D2105 to accommodate the pipe specimen with the Universal Testing Machine for tensile testing. A critical component of the jig has been analyzed with finite element analysis software in order to know the safety factor of the jig while targeted force is applied. The tensile test is conducted in accordance to ASTM D2105 which recommended by ISO 14692-2:2002 while bending test is conducted accordance to ASTM D790. From the tensile testing, it is found that the specimen does not fail despite the maximum force applied was 33.535 kN. Also, it is found that the failure is happening at the stress concentration area from the modification done to the specimen. Next, the bending test was done and found that the failure is happening due to the brittleness and shearing effect on the specimen. From both of the test, it is suggested that the jig need to be modify to have higher gripping pressure for the test and for bending test, the span length of the specimen need to be increase in order to give higher bending moment.

ABSTRAK

Sifat mekanikal sesuatu struktur dan bahan sangat penting dalam merekabentuk sesuatu produk bagi mengetahui kekuatan bahan dan juga struktur produk tersebut. Tujuan kajian ini adalah untuk mengkaji dan menganalisis sifat-sifat mekanik paip plastik bertulang gentian kaca. Kajian ini bekerjasama dengan Pacific Advance Composites Sdn. Bhd. untuk mengetahui kekuatan mekanikal reka bentuk paip mereka. Oleh itu, spesimen paip berdiameter dalaman 3 inci bersambungan dan biasa telah disediakan oleh mereka. Dalam kajian ini, ujian tegangan dan lenturan telah dilakukan untuk mengetahui kekuatan tegangan dan lenturan paip plastik bertulang gentian kaca tersebut. Bersempena dengan itu, sebuah jig telah direka mengikut ASTM D2105 untuk menampung spesimen paip dengan ujian tegangan menggunakan Mesin ujian Universal. Komponen penting bagi jig telah dianalisis dengan perisian analisis unsur terhingga untuk mengetahui faktor keselamatan jig semasa mengenakan daya yang disasarkan. Ujian tegangan dijalankan mengikut ASTM D2105 yang disyorkan oleh ISO 14692-2: 2002 manakala ujian lenturan dijalankan mengikut ASTM D790. Daripada ujian tegangan, didapati bahawa spesimen itu tidak gagal walaupun daya maksimum yang telah dikenakan adalah 33,535 kN. Juga, didapati bahawa kegagalan yang berlaku adalah di kawasan penumpuan tekanan daripada pengubahsuaian yang dilakukan terhadap spesimen. Seterusnya, ujian lenturan telah dilakukan dan mendapati bahawa kegagalan yang berlaku adalah disebabkan kerapuhan dan kesan ricih ke atas spesimen. Dari kedua-dua ujian, adalah dicadangkan bahawa jig perlu diubahsuai supaya mempunyai tekanan menggenggam lebih tinggi untuk ujian tegangan manakala untuk ujian lenturan pula, panjang rentang spesimen perlu ditingkatkan lagi untuk memberi momen lentur yang lebih tinggi.

ACKNOWLEDGEMENT

First of all, thanks to Allah Almighty because of His blessing, I am able to finish my project. Many people have involved and contributed in preparing this thesis. Therefore, I would like to express my sincere appreciation to my supervisor, Dr. Omar Bin Bapokutty for his guidance, supports and trust throughout this project. By showing his willingness to advise and motivate me, this project is going smoothly despites there are some risen issues.

A special thanks go to Pacific Advance Composites Sdn. Bhd. which a subsidiary of Dialog Group Berhad for providing this research the manufacturing of jig and specimen. A good collaboration between Faculty Mechanical Engineering and Pacific Advance Composites Sdn. Bhd. makes this project more beneficial to be used in industry. I am also indebted to Universiti Teknikal Malaysia Melaka for providing me a good environment and sufficient facilities in completing this project.

Next, a million thanks towards my fellow undergraduate students and my colleagues for their assistant and cooperation in various occasion. Finally, I want to thank my parents for their endless support and spirit for continuing my studies. Without their continued support and interest, this project maybe would not be completed.

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LIST OF ABBEREVATIONS

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FRP	Fiber Reinforced Plastic
GRP	Glass Reinforced Plastic
ISO	International Organization for Standardization
MEKP	Methyl Ethyl Ketone Peroxide
PLC	Programable Logic Controller
RPMP	Reinforced Polymer Mortar Pipe
RTRP	Reinforced Thermosetting Resin Pipe
UTM	Universal Testing Machine

LIST OF SYMBOL

r_i	=	Inner radius
A	=	Area
F	=	Force
t	=	Wall thickness
P	=	Pressure
σ	=	Nominal Stress
σ_1	=	Hoop stress
σ_1	=	Longitudinal stress
σ_B	=	Breaking Strength
σ_u	=	Ultimate Tensile Strength
σ_y	=	Yield Strength
σ_f	=	Flexural Stress
σ_{max}	=	Maximum Stress
σ_{min}	=	Minimum Stress
E	=	Modulus of Elasticity
ϵ	=	Strain
$\emptyset$	=	Diameter
FoS	=	Factor of Safety

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The common structural materials are basically classified into four categories which is metals, ceramic, polymers, and composites. To form a composite structure, two or more materials is bonded together to form a solid material. FRP is one of example of composite material which the glass fiber act as the reinforcement and the resin (plastic) is the binder, this composition form a compound of composite material. The defined manner of composite brings the fact that any composite material have to be particularized in macroscopic perspective (Schmit, 1998) . Moreover, FRP is a heterogeneous material, the composition varies in different places in the structure.

The FRP has been used in various kind of application including piping material especially in the marine and oil & gas industry. The advantage from both fiberglass and polymer resin material properties makes it superior in handling corrosion and weight problems in comparison with traditional metallic piping in salty offshore environment. (Schmit, 2001) also said that FRP pipe have a good fatigue properties thus making the life of that material is longer.

A tensile test is the fundamental of mechanical test and widely used in selecting the material for engineering purpose (Davis, 2004). In this experiment, the tensile test is conducted using ASTM D2105 procedures. The force required by the specimen is measured until it reach the breaking point. The results of the tensile test and the crack surfaces of the FRP can be used to support the failure analysis (Paiva et al., 2006). From the tensile test, the mechanical

properties such as strength and modulus value of the FRP can be determined to fit for the quality control of intended application.

Other than that, the bending properties is also one of the mechanical properties that is crucial in designing the pipe. In the research, the bending test is done by following the recommendation of ASTM D790 for bending testing method that specified for fiber reinforced plastic materials. High precision universal testing machine, the Instron 5585-140kN floor column screw movement machine is used in both tensile and bending testing throughout this experiment. However, most structure have weak point and mostly at the joint of the structure. In this report, the weld of the pipe is selected to be the focus of testing since it suspected to have the weakest point of the design. However, the method of joining selected by the manufacturer exhibit supreme strength for FRP piping. Figure 1.1 below illustrate the butt and strap joint of the piping.

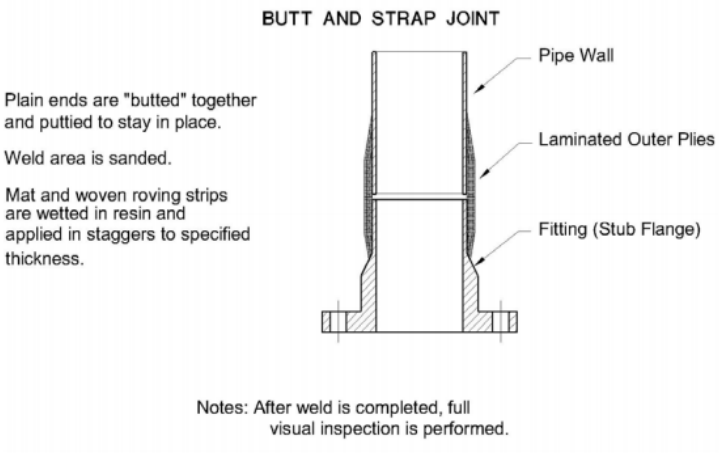

Figure 1.1: Typical butt weld joint

Source: EDO Specialty Plastics, Engineering Series ES-010; The Adhesive Bonded vs The Butt and Strap, 2014

1.2 PROBLEM STATEMENT

Pacific Advance Composites Sdn. Bhd. has providing FRP piping system service mainly in offshore and other petrochemical industry for many years. This company is a subsidiary of Dialog Group Berhad which is one of the giants in oil & gas industry that provide many other services and product. Pacific Advance Composites Sdn. Bhd. introducing new pipe product and the design has been validated in calculation based on international standard in designing FRP piping. In conjunction to that, tests need to be done to their material in order to find the mechanical properties of that new FRP piping product. Moreover, the reliability of the material is also an important factor in developing piping product thus, tensile and bending test is proposed to them as an objective in this collaboration with the industry.

1.3 OBJECTIVE

The objectives of this project are as below:

1) To design a jig according to ASTM 2105 test method for gripping pipe specimen to the Universal Testing Machine (UTM).
2) To conduct and analyze a tensile test in which according to ASTM D2105 in order to study the mechanical behavior of the fiberglass reinforced plastic material.
3) To conduct and analyze a bending test for the fiberglass reinforced plastic material in order to study the bending properties of it.

1.4 SCOPE OF PROJECT

In this study, the mechanical properties of the material are defined by neglecting the effect of vibration, temperature fluctuation, and other effect caused by surrounding. Other than that, the effect of internal pressure is also neglected during the experiment thus, hoop and radial stress is not covered in this research. Other than that, all the calculations are calculated in SI units.

1.5 GENERAL METHODOLOGY

This project discusses on mechanical strength and fatigue properties of FRP material. The research methodology is an important part that shows the work procedure in order to complete the project. There are some research methodologies: -

1) **Literature review:** The methods, fundamentals, and pass research is reviewed in order to produce a quality results.
2) **Proposal:** The research project was proposed to Pacific Advance Composites Sdn. Bhd. for this collaboration so that both side will have clear vision and same understanding.
3) **Design of experiment:** The experiment will be designed according to standard test method and other journals.
4) **Jig detail design:** The design and analysis of jig in order to have robust jig.
5) **Sample preparation:** The sample will be prepared by the company by the design of experiment specifications.

6) **Tensile testing:** This test is need to be done in order to have the material's mechanical properties to do fatigue and finite element analysis.
7) **Report writing:** A report will be written in the end of this research to be evaluated by the university and to hand over to the company.

Figure 1.2 will be summarizing the activity in this whole research methodology.

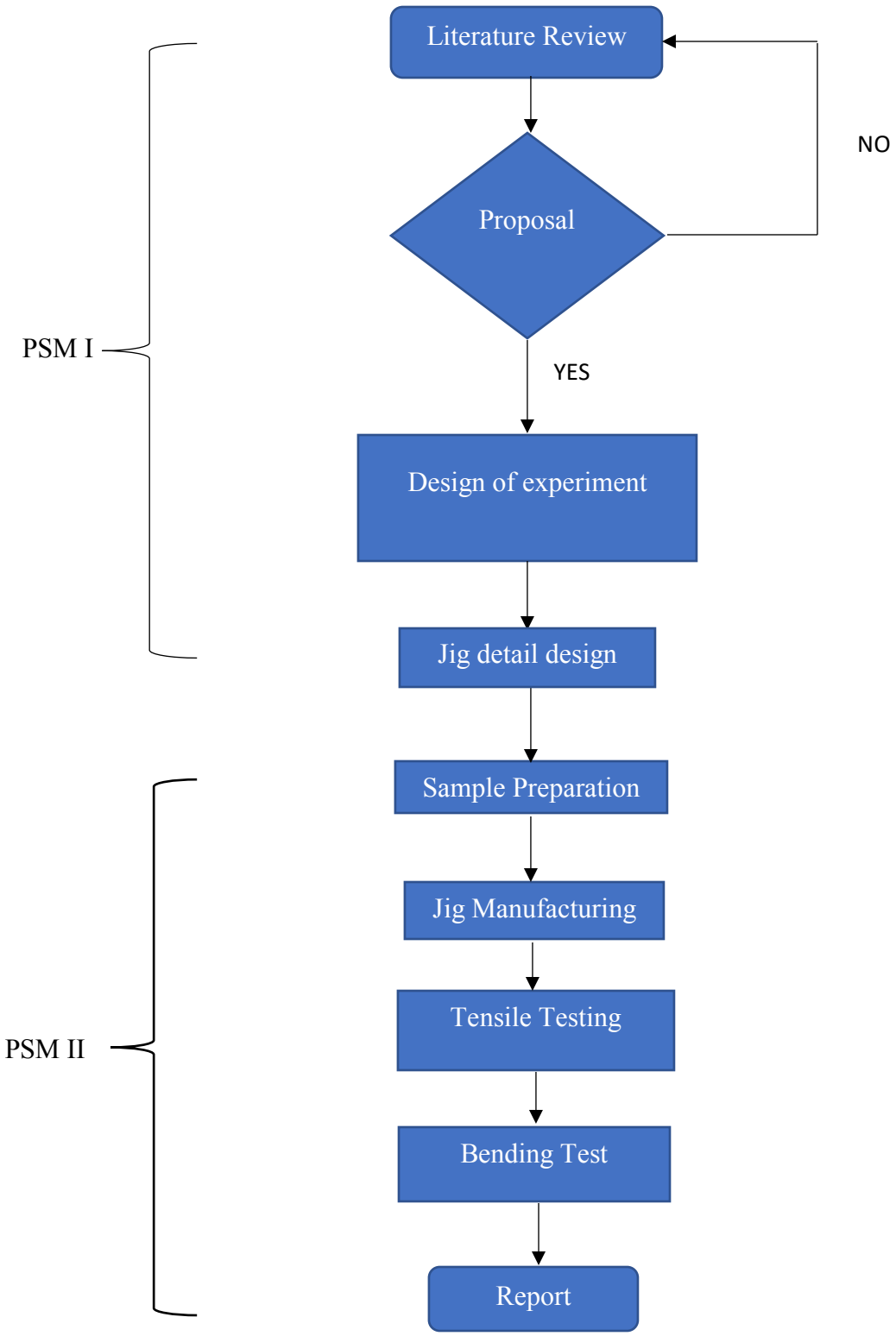

Figure 1.2: Flowchart of the Research

1.6 THESIS OUTLINE

Chapter 1 contains an overview of the research project includes material use and approaches techniques in determining the material properties. The problem statement, objectives, scopes and general methodology are clearly stated.

Chapter 2 provides a review of previous research of FRP piping, standard test method for tensile properties and mechanical properties for fiberglass. This literature review has gathered information and gives an idea for the material and method that suits to be used in this project.

Chapter 3 discusses the flow of the process includes specimen preparation and specification, jig design and design of experiment which is a tensile test. This chapter has explained the procedures that are used to complete this project.

Chapter 4 presents the results of this project. This chapter is explained about the results of a jig analysis. Moreover, the result of the tensile test and bending test is explained in the chapter as well. From there, the findings and outcome of the experiment is discussed.

Chapter 5 explains the conclusion and recommendation based on the results of the research. A specific recommendation is recommended due to the issue that has been raised by the previous researchers and from the obtained results.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

In this chapter, in order to gain enough information to recommend the appropriate method that can be used to complete the research, comparison between certain techniques is required to ensure the data is reliable. On top of that, the basic principal and fundamental of the scope also has been reviewed as describe in the following subchapter.

There are a lot of mechanical properties that can be obtain in various tests such as tensile, bending, fatigue, compression, shearing, and bearing stress. In order to start the testing outlined in the objective above, a comprehensive research need to be done at the related area of study to perform smooth and reliable data towards the end of the experiment. On the other hands, there is some papers and journal in this chapter will be the guidance of the experiment in term of the data that they have collected so that by the end of the experiment, the result can be compared.

2.2 COMPOSITE

The term of composite can be mean by most of material exists if taken at face value such as metal alloys, concrete, even polymer. Composite means combining two or more constituent materials with different mechanical properties to gain the strength of the material to adapt the application of it. (Roylance, 2008) said in modern advance materials, the term “matrix” is usually define a material that reinforced with fibers. For more clear understanding, Fiberglass