ENERGY ABSORBING BEHAVIOUR OF GLASS FIBRE REINFORCED PVC TUBE UNDER QUASI-COMPRESSION

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This report is submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this project entitled "Energy Absorbing Behaviour of Glass Fibre Reinforced PVC Tube Under Quasi-Compression" is the result of my own work except as cited in the references.

Signature: ……………………….

Name of student: Ahmad Ridzuan Bin Sulaiman

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 requirements of Bachelor Project.

Signature: ………………………

Name of lecturer: Prof. Madya Ir Dr. Sivakumar A/L Dhar Malingam

Date: ………………………

DEDICATION

Every difficult task necessitates our own efforts as well as the wisdom of seniors, particularly those who were dear to us in our upbringing. It is with great gratitude that I devote my little effort to my lovely and loving father and mother who's care, love, support, and pray throughout the day and night have enabled me to achieve such achievement and honour, as well as to all the hardworking and respected lecturers.

ABSTRACT

Throughout the years, the use of composite materials has increased significantly, owing to its good properties such as lightweight, excellent energy absorption capabilities, and excellent corrosion resistance. In this study, the polyvinyl chloride (PVC) tube with the glass fibre reinforced plastic (GFRP) as the reinforcement were tested to determine the crashworthiness parameter under quasi-compression test. There were four type of configuration for PVC/GFRP composites tube; PVC tube without fibreglass, with 0º/90º, -30º/60º and -45º/45º orientation of plain weave fibreglass. Thus, for each of the configuration type of composite tube, two different trigger mechanism were utilized that is composite tube without chamfer and with 45º internal single chamfer. The hand lay-up process was exploited for the fabrication of PVC/GFRP composite tube. From the finding, the reinforced PVC tube show better performance than the PVC tube alone. While, composites with 0º/90º oriented fibres parallel to the direction of compression had the highest specific energy absorption values, whereas PVC with no GFRP had the lowest specific energy absorption values. Thus, this study shows that by using trigger also can reduce the peak load value for all the specimen without drastically reducing the specific energy absorption value.

ABSTRAK

Sepanjang tahun, penggunaan bahan komposit telah meningkat dengan ketara, disebabkan sifatnya yang baik seperti ringan, keupayaan penyerapan tenaga yang sangat baik, dan rintangan kakisan yang sangat baik. Dalam kajian ini, tiub polivinil klorida (PVC) dengan plastik bertetulang gentian kaca (GFRP) sebagai tetulang telah diuji untuk menentukan parameter kebolehlanggaran di bawah ujian separa mampatan. Terdapat empat jenis konfigurasi untuk tiub komposit PVC/GFRP; Tiub PVC tanpa gentian kaca, dengan orientasi kaca gentian tenunan biasa 0º/90º, -30º/60º dan -45º/45º. Oleh itu, bagi setiap jenis konfigurasi tiub komposit, dua mekanisme pencetus yang berbeza telah digunakan iaitu tiub komposit tanpa chamfer dan dengan 45º internal single chamfer. Proses meletakkan tangan telah dieksploitasi untuk fabrikasi tiub komposit PVC/GFRP. Daripada penemuan, tiub PVC bertetulang menunjukkan prestasi yang lebih baik daripada tiub PVC sahaja. Manakala, komposit dengan gentian berorientasikan 0º/90º selari dengan arah mampatan mempunyai nilai penyerapan tenaga tentu yang tertinggi, manakala PVC tanpa GFRP mempunyai nilai penyerapan tenaga spesifik yang paling rendah. Oleh itu, kajian ini menunjukkan bahawa dengan menggunakan picu juga boleh mengurangkan nilai beban puncak bagi semua spesimen tanpa mengurangkan secara drastik nilai penyerapan tenaga spesifik.

ACKNOLEDGEMENT

IN THE NAME OF ALLAH
THE MOST GRACIOUS AND THE MOST MERCIFUL

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LIST OF ABBREVIATIONS

ECO	-	Economic Cooperation
CFRPs	-	Carbon fibre reinforced plastic composite
NC	-	No trigger/No chamfer
SC	-	45º internal single chamfer
PVC	-	Polyvinyl chloride
A	-	No fibreglass
B	-	Fibreglass with 0º/90º orientation
C	-	Fibreglass with -30º/60º orientation
D	-	Fibreglass with -45º/45º orientation
PVC/GFRP	-	PVC tube reinforced with GFRP
PMCs	-	Polymer matrix composites
MMCs	-	Metal matrix composites
CMCs	-	Ceramic matrix composites
NFCs	-	Natural fibre composites
PP	-	Polypropylene
PE	-	Polyethylene
UP	-	Unsaturated polyester
VE	-	Vinyl ester
GRP	-	Glass reinforced plastic
GFRP	-	Glass fibre reinforced polymer
GSRPCs	-	S-glass fibre reinforced polymer composites
IVI	-	Intermediate-velocity impact
SEA	-	Specific energy absorption
UD	-	Unidirectional
Pmena	-	Mean load
Pmax	-	Max load
CFE	-	Crush force efficiency

IPF	-	Initial peak force
EA	-	Energy absorption

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, vehicle manufacturers compete with one another in the automotive sector to make better vehicles that are of substantial quality in terms of performance and safety. Thus, the study of vehicle crashworthiness has become an important subject matter within the research domain, as automobile manufacturers attempt to build safer automobiles that are capable of preventing fatal injuries to passengers in the event of a collision. In order to determine crashworthiness, which is the study of plastic deformation of structures, tests have been conducted on a number of critical structures found on vehicles, including the frame of the vehicle, the subfloors of helicopters, and the highway barrier. The fundamental goal of doing such research is to ensure that individuals are protected in the case of tragic events such as impacts, crashes, and collisions occur (Abdullah et al.,2020)

There are a variety of products available to help drivers stay safe when they come to an abrupt stop or accident. These products include bumpers, seat belts, airbags, and anti-lock braking systems (ABS). Aside from safety, pollution is a significant and critical issue. The automobiles emit large amounts of toxic gases such as Nitrogen Dioxide (NO2) and Carbon Dioxide (CO2), which were a significant contributor to global warming. Vehicles for economic cooperation (ECO) are becoming increasingly popular as a result of the pressing need to conserve energy while also safeguarding the environment. It is an effective method of increasing fuel efficiency by lowering the weight of automobiles on the road. Traditional metal materials, on the other hand, have a difficult time achieving strong energy absorption qualities while remaining lightweight. As a result, it was suggested that novel material systems may be used to replace traditional metal materials in the production of next-generation cars. Particularly in this field, fibre reinforced composites (CFRPs) have gained a lot of attention (Ma et al.,2015)

In addition, CFRP feature high stiffness to weight and strength to weight ratios, as well as outstanding fatigue and corrosion resistance, which makes them ideal for aerospace applications. They are extremely desirable as materials for crashworthiness applications because of their combination of characteristics. Composite materials that are reinforced with glass fibres account for an important share of composite applications. For one thing, composites containing additional types of reinforcing materials, such as carbon and aramid fibres, are significantly more expensive than those having only glass fibres. GFRP composites have a higher rigidity than aluminium and a specific gravity that is one-quarter that of steel when the composition and fibre orientation are appropriate (Khan et al.,2015). GFRPs have been employed in a variety of industries, including automotive applications, aerospace applications, civil infrastructures, marine applications, and the pipe industry. While employing composites for crashworthiness, the issue is to use precise geometry and materials to permit higher safety standards while keeping weight as low as possible. This should be accomplished while not surpassing what would be deemed acceptable production costs in the industry (Khan et al.,2021).

1.2 Problem Statement

The weight of a vehicle accounts for approximately 75% of the total gasoline utilised by the vehicle (Khan et al.,2021). On the basis of current estimates, it should be able to reduce a vehicle's weight by approximately 10% while simultaneously reducing its fuel consumption by up to 8%. This reduction translates into a large reduction in the amount of carbon dioxide emitted by a vehicle over the course of its operational life. By using GFRP composites, the weight can be reduced while maintaining the crashworthiness properties parameter. Thus, experiment need to be conduct to find the properties of energy absorption and crashworthiness parameter under quasi-loading.

1.3 Objectives

The objectives of the project are:

1. To study the effect of different trigger mechanism.
2. To study the effect of different degree orientation for plain weave fibreglass.

1.4 Scope of Project

Scope of this project are:

1. Produce two type of trigger geometry, no trigger (NC) and 45º internal single chamfer (SC)
2. Produce PVC pipe with four different plain weave fibreglass orientation, (A) no fibreglass, (B) 0º/90º, (C) -30º/60º and (D)-45º/45º,
3. To conduct the quasi-static compression test.
4. To analysed the mechanical properties and crashworthiness parameter for each of the specimen tested.

1.5 General Methodology

The strategy begins with the objective and the problem statement as a first step. After the purpose already defined, it needs to do some literature review to gain more knowledge or facts about this project. Then fabricating the specimen to with two different trigger mechanism with different degree orientation lay-up of plain weave fibreglass. Test the specimen by using quasi static loading to get the desired data for the energy absorption and crashworthiness parameter.

After the researcher gets the data that shows the mechanical properties of each of the PVC/GFRP tube composites, the analysis will be done by calculation and graph from the data collect during the experiment to obtain the final result of the experiment. Finally, after all step have completed, the researcher can make a conclusion. Figure 1.1 show the general flowchart.

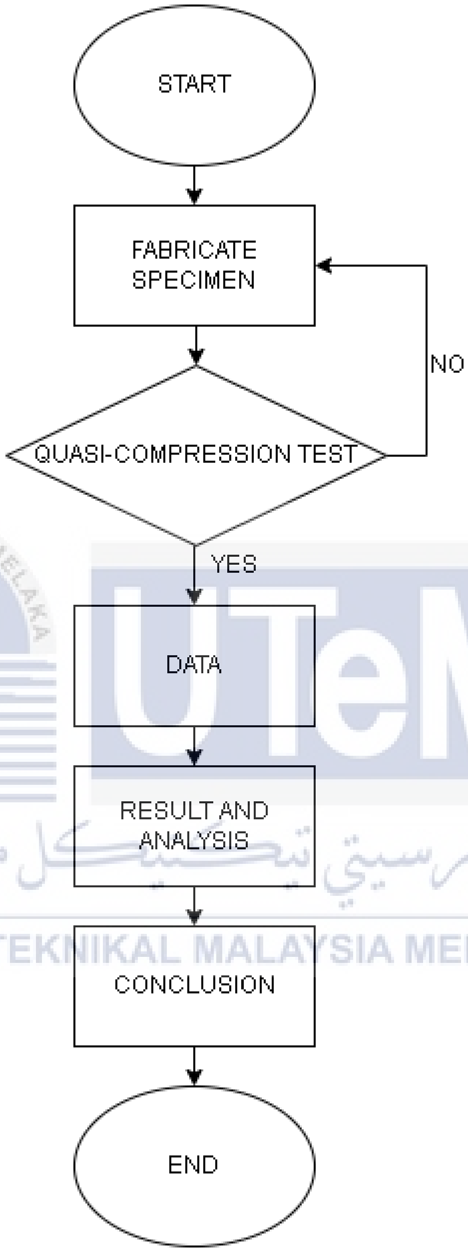

Figure 1.1: General Flowchart

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will broaden the understanding and compare the assessment of various researchers for tube composites fibre based on its constituents, manufacture method, mechanical properties and failure by using compression test. On top of that, this chapter also provide the potential results of the research and present comprehension of the subject.

2.2 Composites

A composites material is made up by combining two or more chemically or physical dissimilar material that have a discrete interface. The elemental materials retain their individual identity in the composite at least microscopically, although they have different qualities and characteristics than the elements, their combination produces attributes that are diverse from those of constituents**.** The matrix is one of these constituents that forms a continuous phase. The other major component is a reinforcement in the form of fibres or particulates that is added to the matrix in order to improve or change its properties. The reinforcement is dispersed uniformly throughout the matrix in a discontinuous phase. The reinforcement surface may be chemically treated or coated with a very thin layer of polymer to facilitate wetting of the reinforcement by the matrix, as well as control or enhance interfacial bonding between the reinforcement and the matrix. It is also possible that the surface treatment will protect the reinforcing surface from deterioration caused by external attack, such as moisture and chemicals, or by an undesirable chemical reaction with the matrix when exposed to high temperatures (Mallick,1997).

Besides, a composite's matrix material can be a polymer (PMC), metal (MMC), or ceramic (CMC). Composite materials are classified as PMCs, MMCs, or CMCs depending on matrix apply. The majority of commercially available composites are made of polymer matrices; however, MMCs and CMCs are gaining high demand in high-temperature applications. Figure 2.1 show how the composite can be formed.

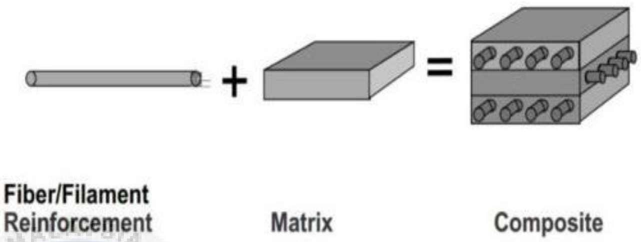

Figure 2.1: composites ((Kumar and Lohchab, 2016)

2.3 Matrix

The processing characteristics are heavily influenced by the matrix used. The time needed to complete the chemical or curing reaction that alter the liquid thermosetting polymer into a solid polymer, for example, determines the moulding time of a thermosetting polymer matrix composite. Besides, the chemistry and stoichiometry of the reactants, which include the prepolymer and the curing agent, determine the curing time. The viscosity of the thermosetting polymer is also significant, as it influences the polymer's flow characteristics in the mould. This, in turn, affects the matrix's wetting of fibres, as well as the void content in the matrix (Mallick,1997). Table 2.1 show the type of matrix that commonly used nowadays.

Table 2.1: Matrix Materials Commonly Used in Advanced Composite

(Mallick,1997)

Polymeric

- Thermoset resins
  - Epoxies: Principally used in aerospace, aircraft, and sporting goods applications
  - Polyesters and vinyl esters: Principally used in automotive, marine, chemical, electrical, and consumer goods applications
  - Polyurethanes and polyurea: Principally used in reaction injection molding process for manufacturing automotive body parts
  - Phenolics: Used in both aerospace and automotive applications
  - Bismaleimides, polyimides, polybenzimidazoles, etc.: Used for high-temperature aerospace applications
- Thermoplastics
  - Nylon 6,6, Nylon 6, thermoplastic polyesters (such as PET and PBT), polycarbonate, polyacetals, polypropylene, etc.: Used with discontinuous fibers in injection molded articles
  - Polyether ether ketone (PEEK), polyphenylene sulfide (PPS), polysulfone (PSUL), polyamide-imide (PAI), polyether imide (PEI), etc.: Used with both continuous and discontinuous fibers for moderately high-temperature applications

Metallic

- Aluminum alloys, titanium alloys, magnesium alloys, copper-based alloys, nickel-based alloys: Used for moderately high-temperature applications

Ceramic

- Silicon carbide (SiC), aluminum oxide (Al_2O_3), silicon nitride (Si_3N_4), carbon: Used for high-temperature applications

Polymeric matrices are currently the most commonly used in natural fibre composites (NFCs) because they are light weight and can be processed at low temperatures. For natural fibre matrices, both thermoplastic and thermoset polymers have been used. Most natural fibres used for reinforcement in natural fibre composites are thermally unstable above 200 ºC, though they can be processed at higher temperatures for a short time under certain conditions. Indeed, the thermoplastic matrices PP and PE are the most commonly used for NFCs. Unsaturated polyester (UP), epoxy resin, phenol formaldehyde, and VE resins are the most commonly used thermosets. Thermoplastics can be repeatedly softened and hardened by heating and cooling, and they have the potential to be the most easily recycled materials (Pickering et al.,2016).

2.4 Synthetic Fibres

Synthetic fibres are form by polymers that do not occur naturally and are made entirely in the lab, usually from petroleum by products. Synthetic fibres are made from a variety of chemicals, each with its own set of characteristics. Nylon, polyesters, acrylics, polyurethanes, and other polymers are used to make fibre. Synthetic fibres have a longer length and are more durable. In Figure 2.2, Kevlar (aramid), carbon, and glass fibres are the three most common synthetic fibres used in composites (Saba and Jawaid,2017).

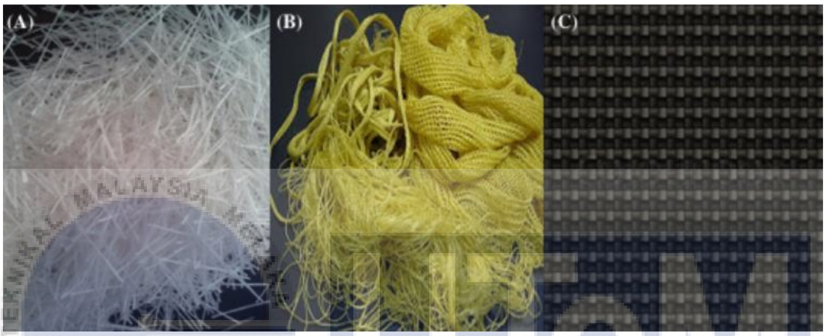

Figure 2.2: A(glassfibre), B(Kevlar) and C(Carbon). (Saba and Jawaid,2017)

Synthetic fibres are more durable than natural fibres and will take on a variety of colours quickly. Furthermore, many synthetic fibres provide benefits to consumers such as stretching, waterproofing, and stain resistance. All fibres break down and erode as a result of sunlight, dampness, and human skin oils. Hence, mechanical strength of synthetic fibre-based materials is far superior to that of natural fibre-based composites (Chandrasekar et al.,2018). Figure 2.3 show the type of fibre class and subclassification.

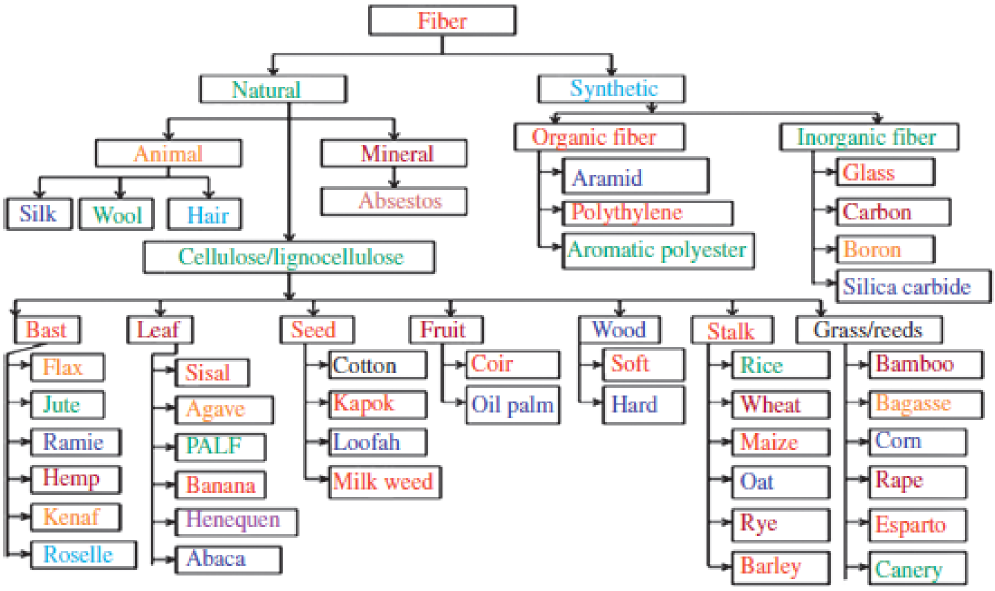

Figure 2.3: Class and subclassification of fibre. (Saba and Jawaid,2017)

2.4.1 Glass Fibre

Glass fibres (GF), which have a high percentage (50%) of silica content, as well as diverse mineral oxides, are the most versatile and inexpensive synthetic fibres compared to Kevlar and carbon, and are widely utilised in the polymer composites industries (Saba and Jawaid,2017). GF is made up of very fine glass fibres. Extrusion of very thin strands of silica-based or other formulation glass is used to create it. When compared to carbon fibre or other plastic fibres, glass fibre is substantially less expensive and less fragile. It can be used as a reinforcing ingredient to boost the strength and reduce the weight of numerous polymer composites. Glass reinforced plastic (GRP), commonly known as 'fibreglass,' is one such material. E-glass, an alumina-borosilicate glass used mostly in glass reinforced plastics, is the most common glass fibre utilised. A-glass, E-CR-glass, C-glass, D-glass, R-glass, and S-glass are some of the other varieties of glass used (Batabyal et al., 2018). Figure 2.4 shows