UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EXPERIMENTAL INVESTIGATION OF ENERGY ABSORPTION CAPACITY OF MILD STEEL CYLINDER SUBJECTED TO AXIAL CRUSHING

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Maintenance Technolgy)

By

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TAJUK: **EXPERIMENTAL INVESTIGATION OF ENERGY ABSORPTION CAPACITY OF MILD STEEL CYLINDER SUBJECTED TO AXIAL CRUSHING**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirement for the Degree of Engineering Technology (Maintenance Technology) with Honour. The member of supervisory is as follow:

……………………………………..

(Project Supervisor)

DR. OLAWALE IFAYEFUNMI

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ABSTRACT

Cylindrical structure is widely used in engineering industry such as automotive, oil and gas, aeronautical etc. Cylindrical structure also saves the occupant of vehicles from axial collision by converting the kinetic energy of crash into another form of energy to minimize the impact of accident toward the occupants. This work presents a study on cylindrical shell under axial crushing through experimental approach to identify the energy absorption capacity. Mild steel cylinder shell was fabricated with three different diameters that are 80 mm, 100 mm and 120 mm and all specimen height is 100 mm. The crosshead speed used in this experiment is 1 mm/min, 10 mm/min and 20 mm/min. This experiment is to identify the effect of crosshead speed on energy absorption capacity of mild steel. The entire specimen will be tested under axial loading using Universal INSTRON machine.

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ABSTRAK

Struktur silinder digunakan secara meluas dalam industri kejuruteraan seperti automotif, minyak dan gas, penerbangan dan lain-lain. Struktur silinder juga mampu menyelamatkan penghuni kenderaan dari perlanggaran paksi dengan menukarkan tenaga kinetik kemalangan ke dalam satu lagi bentuk tenaga untuk mengurangkan kesan kemalangan ke arah penghuninya. Projek ini membentangkan kajian mengenai cengkerang silinder di bawah mampatan paksi melalui eksperimen untuk mengenalpasti kapasiti penyerapan tenaga. Cengkerang silider keluli telah dihasilkan dengan tiga diameter saiz yang berbeza yang 80 mm, 100 mm dan 120 mm dan ketinggian spesimen adalah 100 mm. Kelajuan mampatan yang digunakan dalam eksperimen ini adalah 1mm/min, 10 mm/min dan 20 mm/min. Eksperimen ini adalah untuk mengenal pasti kesan parameter dan kelajuan dari atas keatas kapasiti penyerapan tenaga. Seluruh spesimen akan menjadi ujian di bawah beban paksi dengan menggunakan mesin Universal INSTRON.

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DEDICATION

Dedicated to my father RAHIM BIN YAHAYA and my mother JURIAH BINTI MOHD YUSOF.

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TABLE OF CONTENT

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LIST OF TABLE

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

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LIST OF ABBREVIATIONS

FEA	Finite Element Analysis
CFRP	Carbon Fiber Reinforced Polymer
SEA	Specific Energy Absorption
RCSCT	Radial Corrugated Surround Circular Tube
CCT	Circular Composite Tub

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, structures in engineering are widely used in industry including mechanical engineering, civil engineering, marine engineering and chemical engineering. Shell structure is widely used in automotive industry, oil and gas industry, pipeline and etc. Energy absorption devices are used in all vehicles and moving parts such as road vehicle, railway couches, aircraft, ships, lifts and machinery. The aim is to minimize injury to people and to confine the damage to properties (Hosseinipour and Daneshi 2003). Shell structure as known as curve plate surface that transmit applied force by compressive, tensile and shear stress that act in the plane of the surface. The commons shell that has been study is conical shell, cylindrical shell and torispherical shell.

Investigations of crushing energy absorption are very important and are expected from the point of view of safety design of passenger vehicles. Cylindrical shells are the most commonly used thin-shell structure geometry. This is due to its simple geometry and relative ease of manufacture. Thus, it is not surprising that over the years, large amount of research work has been carried out for this shell geometry (Ifayefunmi, 2016). This research aims to study the experimental of energy absorption capacity of mild steel cylinder subjected to axial crushing.

Collision might occur either between two vehicles and the result will be deformation of the vehicle structure. When collision force surpasses the energy

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absorption, the capability of structure will lead to occupant's injuries or even death. From the two vehicle collision occur, researcher saw the improvement on the basic requirement, such as the headlamp to provide night visibility and reduce the tire pressure to prevent loss control vehicle and to fix the laminated glass to decrease facial accident.

To carry out in energy absorption on the cylindrical shell structure, the understanding toward the factors that contribute to energy absorption is essential. Today, automakers seek to focus on the crashworthiness, which is defined as passive safety to save the occupant's life by withstanding the structure of the static and dynamic load. The requirements of the vehicle structure should involve formability, recyclability and adequate strength when undergoing crash load to absorb the energy of crash, to provide survival space for occupants.

1.2 Problem Statement

Numerous materials and structural components have been investigated over the years for their suitability as impact energy absorbers. Modeling the crushing of single structural components and assemblies of such components has resulted in the solution of a range of challenging large deflection, structural plasticity problems (Harrigan et.al 1999). The geometry structures of cylinders are important factor in influencing the results. Nowadays, increase in the number of transportation vehicles has resulted in a greater number of road accidents. Therefore, study of energy absorption to be carried out here to find the effect of crushing under axial crushing. From the literature review, it is evident that there are no study been done on the effect of crushing speed on axial loading of 1mm mild steel cylinder. The energy absorption structure required a wide range of studies and additional analysis to achieve the desire purpose. This study to find out the effect of cylindrical shell with different diameter and different crosshead speed toward to the energy absorption capacity.

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1.3 Objective

The objectives of this study are

1. To manufacture cylindrical shell with different diameter.
2. To investigate the energy absorption capacity on mild steel subjected to axial loading using different crushing speed

1.4 Scope

This research is focusing on the energy absorption capacity of cylindrical shell structure that is comparing the different cylinder diameter and different crosshead speed. The material select for this study is mild steel. The thickness of the mild steel specimen is 1.0 mm. The tensile testing is using 6 tensile coupons that are 3 specimens are horizontally direction and 3 specimens are vertically direction. This research produces a total of 18 cylindrical specimens with 3 different diameters. First 6 specimens diameters is 80 mm, second 6 specimens diameters is 100 mm and last 6 specimens diameters is 120 mm. The entire specimen in this study has the same height that is 100 mm. All the specimen is subjected to axial loading testing using Universal INSTRON machine.

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CHAPTER 2

LITERRATURE REVIEW

2.1 Energy absorption of cylindrical shell

Energy absorption structure is the core part of crashworthiness structure. The energy dissipation mechanism of circular tube is widely studied for its stable maximal force and high energy absorption efficiency (Li. et.al, 2016). The increasingly interest in the safety and crashworthiness of vehicles has resulted in extensive researches on the structural response of thin-walled metallic tubes, which are the most conventional and effective energy-absorbing devices and have been widely employed in the vehicle design and manufacture (Azarakhsha and Ghamarian et.al 2017). These metallic thin-walled structures have capability to convert the kinetic energy to strain energy by irreversible plastic deformation. Most of the reported works in the literature on such tubes have used mild steel as the base material for understanding the energy absorption efficiency (Khalili et.al 2015).

The Progressive buckling mechanism is anticipated in the optimum design of cylindrical tubes to promote them for maximum energy absorption response (Nalla et.al 2017). Metallic cylindrical shells are commonly used structural elements. Besides their high stiffness and strength combined with a low weight they offer a high specific energy absorption capacity when subjected to axial loading. This energy absorption capacity can be used for the purpose of controlled absorption of kinetic crash energy, for example in automobile and train structures to protect passengers from major injuries and to limit severe structural damage to a localized deformation of crash elements (Marsolek and

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Reimerdes et.al 2004). Metallic cylindrical shells are commonly used structural elements. Besides their high stiffness and strength combined with a low weight they offer a high specific energy absorption capacity when subjected to axial loading. This energy absorption capacity can be used for the purpose of controlled absorption of kinetic crash energy, for example in automobile and train structures to protect passengers from major injuries and to limit severe structural damage to a localised deformation of crash elements (Marsolek and Reimerdes 2004).

Industrial progress and energy shortage have called for the auto manufactures to produce lighter vehicles but not at the expense of safety under impact. This can be accomplished by using lightweight materials with higher ultimate strength. Appropriate candidates are thin-walled members because they are superior in absorbing energy (Tai et.al 2010). Karaviogoza et.al (2005) analyzed the importance of the initial compressive phase for the prediction of the energy absorbing characteristics of tubular elements subjected to axial dynamic loads. Particular attention is paid to the influence of the material and geometrical characteristics of square and circular tubes on their response characteristics when subjected to axial explosive load and used as energy absorbers. Tubular structural members of different geometries and materials have been widely used as energy absorbers. They have the ability to absorb and convert large amount of kinetic energy into plastic strain energy when deforming under compression in impact situations. Kavi et.al (2006) was study the energy absorption in foam filled tubes based on the experimental by determined strengthening coefficient of foam filling. For this purpose, relatively high and low density foams of Aluminium and polystyrene closed cell foams were used to fill a circular thin-walled Aluminium tube. The energy absorption in Aluminium foam filled tubes was then predicted as function of tube mass for the fillers of higher densities. The predicted energy absorption was finally compared with that of wall-thickening of empty tube in order to analyze the efficiency of foam filling.

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2.2 Effect of material type on energy absorption of cylinder

Salehghaffari et.al (2010) develops two design methods with the aim of improving main energy absorption characteristics of circular metal tubes such as sensitivity to external parameters like loading uniformity and direction, crushing stability, crush force efficiency and collapse modes while subjecting to axial compression. Press fitting an expanding rigid ring on top of circular tubes is proved experimentally to be as the first efficient structural solution.

The objective of the previous study was to characterize the energy absorption and post-crushing integrity of continuous fiber composite materials. The recent work previously cited has dealt exclusively with static crush behavior of composites. This study is directed almost exclusively at the axial impact behavior of these materials. A limited number of static crush tests were conducted to compare with the dynamic test results (Schmueser and Wickliffe, 1987).

Obradovic et.al (2012) studies the procedure to follow during the design of a specific impact attenuator. After the mechanical characterization of the CFRP material, it is possible to calibrate the numerical material model, to properly design and to perform experimental tests on thin-walled tubular structures. The good correlation between experimental and numerical test represents efficient modeling of composite laminates. Also, the numerical simulation has been coupled with a simplified analytical model, able to predict the energy absorption of thin-walled composite structures with circular cross section. Based on these findings, composite materials if designed properly, i.e. to fail in a progressive manner, can possess good specific energy absorption capabilities. Although, much work has been done on polymer composite materials, little has been done to investigate the role of composite sandwich structures as energy absorbing devices (Tarlochan et.al, 2012).

Based on Jiancheng and Xinwei (2009), quasi-static tests were conducted on carbon reinforced composite tubes first to examine their axial crushing response and also to serve as comparison purpose. Then numerical simulations were performed and compared with experimental data to investigate how to establish an effective model for

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predicting energy absorption behavior of composite tubes. The energy absorption characteristics of materials play a major role in determining the crashworthiness of automotive structures. Metallic cylindrical tubes made of steel and aluminium are used as energy absorbers due to their high stiffness and strength combined with the low weight and ease of manufacturing process (Bade et.al 2014). In the previous study, pressurized thin-walled circular tubes are considered as adaptive energy absorbers (or metal air bags) and their energy absorption behaviors under axial crushing are investigated (Zhang and Yu 2009).

Palanivelu et.al (2010) study to understand the crushing behavior and the corresponding energy absorption of these small-scale composite tubes quasi-static axial crushing tests. Ferreira and Chattopadhyay (1994) use formal design optimization procedures to maximize the energy absorbing capability of axially compressed composite cylindrical shells with constraints on the individual ply stresses and the critical buckling load. Both the pre- and post-failure responses are modeled analytically. Additionally, a sensitivity analysis is performed to examine energy absorption with respect to material constitutive properties and geometry.

2.3 Effect of triggering mechanism on energy absorption of cylinder

An experimental deformation test and its simulation were conducted for seven extruded tube specimens on which various types of triggering dents were introduced, and the test data of deformation mode, maximum repulsive force, and absorbed energy were investigated via observation (Sunghak et.al 1999). Tubes with chamfered-ends, inward folding or outward-splaying crush-caps, or combined (chamfered-end and crush-cap) failure trigger mechanisms, were investigated to identify the optimal configuration that would result in the lowest initial peak load while providing the highest possible Specific Energy Absorption (SEA) (Deepak et.al 2014).

An experimental study on the energy absorption capacity of two different composite profiles. For each one of the two profiles, six different trigger geometries are

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