THE SAW DUST FILLED TUBE UNDER AXIAL LOADING

ONG XIONG HUI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE SAW DUST FILLED TUBE UNDER AXIAL LOADING

ONG XIONG HUI

This report is submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering (Structure and Material)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project report entitled “The Saw Dust Filled Tube under Axial Loading” 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 (Structure & Materials).

Signature : ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father

ABSTRACT

Impact energy absorption device is one of the essential structural components used in safety application. It performs its services by reducing and absorbing the excessive kinetic energy to protect users from injury. Due to this safety purpose, impact energy absorption device is explored. Occasionally, metallic tubes are mostly used as the impact energy absorbing elements. Aluminium tube, as one type of the metallic tube is investigated and analyzed in this project. A development idea is laid out by introducing saw dust as filled material into the impact energy absorption device. This project was carried out to study the effect of saw dust on the collapse behavior and energy absorption performance to enhance the energy absorption device. Three different types of aluminium tubes were used, one circular and two different sizes of square aluminium tubes are filled with saw dust at different density and compressed axially by quasi-static loading. This project started with reviewing the previous researches to understand the theories and information which related to the present study. It was found that the material properties, mechanical properties and size of the tube greatly affect the deformation behavior and energy absorption performance. Following with this, tensile test and axial compression test experiments have been conducted in this project. Tensile test was carried out to investigate and determine the mechanical properties of aluminium tube. From the tensile test result obtained, the mechanical properties were later used to evaluate the theoretical mean load. While axial compression experiment involved the density setup for tube filled with saw dust and the observation of tube deformation pattern. Both hollow and saw dust filled aluminium tubes were compressed by INSTRON testing machine to obtain the load displacement characteristics. From load displacement curve, the densification point, plastic wavelength, mean load, energy absorption, and specific energy were determined and analyzed. Theoretical calculation for mean load, plastic wavelength and energy absorbed were also evaluated as well and compared with the experimental result. Both results show that the presence of saw dust affects the mean crushing load and energy absorption.

ABSTRAK

Peranti penerapan daya hentaman merupakan satu komponen struktur yang penting digunakan dalam aplikasi keselamatan. Peranti ini menlaksanakan perkhidmatannya dengan cara mengurangkan dan menyerapkan tenaga kinetic yang berlebihan untuk melindungi pengguna dari kecederaan. Disebabkan oleh tujuan keselamatan ini, peranti penerapan daya hentaman diterokai. Kebiasaannya, kebanyakan tiub logam digunakan sebagai unsur penerapan daya hentaman. Tiub aluminium adalah salah satu jenis tiub logam yang disiasat dan dianalisis dalam projek ini. Satu idea telah dibangunkan dengan memperkenalkan kayu habuk sebagai bahan digunakan dalam peranti penyerapan daya hentaman. Projek ini telah dijalankan untuk mengkaji kesan kayu habuk dalam sifat keruntuhan dan tenaga penyerapan prestasi untuk meningkatkan peranti penyerapan daya. Tiga jenis tiub aluminium yang berbeza telah digunakan, iaitu tiub bulatan dan dua jenis berbeza saiz tiub segi empat dipenuhi dengan berbeza ketumpatan kayu habuk sebelum dimampatkan oleh daya kuasi-statik. Projek ini bermula dengan penyelidikan pengajian untuk memahami teori dan maklumat yang berkaitan dengan kajian masa kini. Selepas penyelidikan pengajian, didapati bahawa sifat-sifat bahan, sifat-sifat mekanikal dan saiz tiub amat memberi kesan kepada perubahan sifat bentuk dan tenaga penyerapan prestasi. Berikutan dengan ini, ujian tegangan dan ujian mampatan eksperimen telah dijalankan dalam projek ini. Ujian tegangan dijalankan untuk menyiasat dan menentukan sifat-sifat mekanikal pada tiub aluminium. Daripada hasil ujian tegangan yang diperoleh, sifat-sifat mekanikal ini akan digunakan untuk menilai teori beban purata. Manakala ujian mampatan eksperiment melibatkan persediaan ketumpatan kayu habuk yang dipenuhi di dalam tiub dan pemerhatian untuk tiub perubahan sifat bentuk. Kedua-dua aluminium tiub berongga dan tiub yang diisi kayu habuk telah dimampatkan dengan menggunakan INSTRON ujian mesin untuk mendapatkan persifatan daripada graf kebebanan lawan keanjakan. Daripada graf kebebanan lawan keanjakan, titik pemadatan, plastik gelombang kepanjangan, purata kebebanan, tenaga penyerapan dan tenaga spesifikasi telah ditentu dan dianalisis. Teori pengiraan bagi purata kebebanan, plastic gelombang kepanjangan dan tenaga penyerapan juga telah dinilai lalu dibandingkan dengan keputusan hasil daripada eksperimen. Kedua-dua keputusan hasil daripada eksperimen dan teori pengiraan menunjukkan bahawa kewujudan kayu habuk mendatangkan kesan kepada purata kebebanan dan tenaga penyerapan.

ACKNOWLEDGEMENT

Throughout two semesters of the final year project, it would never have done without assistance of many fine individuals. Therefore, it is the opportunity to thanks all the people who help in the final year project.

First of all, among the people it is the great for me to express my deepest appreciation and thanks with gratitude to my final year project supervisor, Prof Dr. Md. Radzai bin Said, who is always giving all his effort during consultation to ensure the project is done and organized perfectly. His supervision, enthusiastic helps and guidance in this report greatly enhance me to do every task successfully.

Besides that, it is very special thanks to Prof Madya Dr. Azma Putra, the chairman of final year project, who always reminds us the date to summit the report and presentation in the group. The guideline on how to write the report and the important format for us to follow had been given by him. Because of it the progress report and the final draft report can be summited before due date and the presentation slide also can be prepared early before the presentation.

At the same time, it is also thanks to En. Faizol Bin Kamarul Zahari, En. Wan Saharizal Bin Wan Harun and En Habirafidi Bin Ramly, the technicians from structural laboratory Faculty of Mechanical Engineering, En Ghazalan Bin Mohd Ghazi, the technician from Faculty of Manufacturing Engineering, for their advice, assistance and helpful in the fabrication and lab experimental works. Because of it, the experimental work by using the mechanical equipment can be completed successfully.

There are a lot of knowledge about the impact mechanics that I had learnt and gained during carrying out this final year project. All the knowledge is very precious to me because some of tools and machines are the first time for me to experience it. Some of the knowledge also I cannot obtain from reference books. Besides that, it is also thanks to the people that help me directly or indirectly to complete this final year project.

Lastly, it is also thanks to my mother, father and siblings due to their encouragement and supporting in this project and throughout this degree program.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBEREVATIONS

IEA	Impact Energy Absorber
PVC	Polyvinyl Chloride
FFT	Foam-filled Tube
ASTM	American Society for Testing and Materials
CAD	Computer-Aided Design
LED	Light Emitting Diode

LIST OF SYMBOLS

P_{mm} = Theoretical mean crushing load

M_p = Full plastic bending moment per unit length

N = Number of lobes in multi-lobe collapse

D = Tube mean diameter

t = Tube wall thickness

P_w = Wood crushing load

σ_w = Wood strength

ρ = Average density of tested wood

ρ_s = Density of wood sawdust solidification state

F_{max} = Maximum axial force for first peak

F_{avg} = Average axial force

σ_{normal} = Normal stress

F = Internal force

A = Cross-sectional area

ρ_s = Density of filler

m_c = Combined mass of filler and volumetric cylinder

m_e = Mass of empty volumetric cylinder alone

V_o = Volume of filler displaced in the volumetric cylinder

E	=	Modulus of elasticity
σ_{ys}	=	Yield strength
σ_{ut}	=	Ultimate tensile strength
P_{cr}	=	Critical load
K	=	Stiffness
L	=	Length
EA	=	Energy absorption
$F(\delta)$	=	Instantaneous crush force with respect to displacement
c	=	Side length
D_o	=	Outer tube diameter
π	=	Pi
H_m	=	Half plastic wavelength

CHAPTER 1

INTRODUCTION

1.1 Background of study

The deforming mode of empty and filled metal tubes subjected to axial loading is studied. Axial loading is applied until the deformation is formed at a characterised force magnitude. The deformation mechanism describes the instabilities of structure which leading to failure by a higher force beyond to the limit load (Bardi et al, 2006). In the present investigation, the collapse and axial crushing behavior of tubular structure is obtained from a series of experiments with considering to various properties such as length to diameter ratio, radius to thickness ratio, geometrical shape and material properties (Guillow et al, 2001). Besides that, the influence of filler in hollow tube also changes the modes of deformation and crushing behaviour.

Based on the past researchers, the foam-filled on the tubular structure has been studied analytically and experimentally, which brings saw dust into the investigation to determine its energy absorption and deformation characteristic. Saw dust is a solid residue, biodegradable and non-abrasive material usually produced in the timber industry. Saw dust is a wasted product, recyclable and cheap material thus it extracted and used to enhance the energy absorption capacity of tube (Singace, 2000). In application, saw dust are useful in manufacturing industry due to its mechanical and physical properties to produce insulators, multi plugs, mobile casings, accessories, hardboards, switchboards and automotive parts. Besides that, saw dust can be chemically treated to improve the tensile strength and water absorption characteristics at the same time increase the biodegradability of polymer matrix composite (Hossain et al., 2014).

Tubes structures are one of establish passive energy absorbing equipment in the automotive, aerospace and transportation application. Different types of tubular absorbing structures are produced such as circular, triangular, hexagonal, honeycomb, foam filled and cellular. The most frequently used in energy absorber are square and circular tubes. Usually, metallic tubes are the majority consideration type due to manufacturing easiness and feasible. Comparing between the structures, aluminium circular tubes are greatly used as energy absorbing structures due to the structure has low density, high strength and well deformability (Emin, 2016). Besides that, filled tube structure is also greatly used in car front bumpers and front beam (Gan, 2016).

In mechanics, axial loading is a force that is directed along the longitudinal axis of the member. Axial loading tends to elongates or shorten a member are termed tension force and compression force respectively. During axial loading applied, stress acts on the surface that is perpendicular to the direction of the internal force (Timothy, 2014). Under axial loading, deformation and collapse mode usually occurred on the tubes structure during crashing event. Axial and bending collapses are the classical types of collapse mode (Liu et al, 2015). Quasi-static and dynamic loading are the types of axial loading.

1.2 Problem statement

Nowadays, the importance of personal safety and protection from impact has been concerned in the safety application. The research and development on impact energy structure has been studied earlier, especially for automotive industries to design the various types of vehicles. Impact energy absorber (IEA) is one of the important mechanical structural components used in this application eliminating and reducing the excessive kinetic energy when the collision is occurred. In order to achieve the quality for this application, the installed IEA device has to attain its crashworthy performance. Due to this purpose, the IEA device is studied in this project. To study the impact energy absorption (IEA) device, metal tube is used as the medium to evaluate and analyse its deforming mode, energy absorption characteristics and compare the results with theory. Besides that, metal tube is also inserted with the filling material to study and analyse deformation characteristics as well. It is expected that the material filled tube would have higher crashworthiness in this project.

1.3 Objectives

The aim of the project is as followed:

i. To observe and study the deforming mode of circular and square aluminium tube under axial loading.

ii. To determine the mean load and plastic wavelength of circular and square aluminium tube and compare with the theory.

iii. To study the load-displacement characteristics and the energy absorption of empty and saw dust filled circular and square aluminium tube.

1.4 Scope of project

The experimental project will focus on the deforming mode, mean load, plastic wavelength, load-displacement characteristic and the energy absorption performance of empty and saw dust filled of circular and square aluminium tube under axial loading. Besides that, the experimental project will also focus on comparing three types of densities of saw dust filled of the circular and square aluminium tube under axial loading. The other aspects such as the cost and will not be covered in this project.