THE MODEL OF DEFORMING MODE TUBE UNDER AXIAL LOADING

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A report submitted

in fulfilment of the requirements for the degree of

Bachelor of Mechanical Engineering (Structure & Materials)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

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).

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Supervisor's Name : PROF. DR. MD. RADZAI BIN SAID

Date : ……………………………………….

DECLARATION

I declare that this project report entitled "The model of deforming mode tube under axial loading" is the result of my own work except as cited in the references.

Signature : ………………………………………………...

Name : MUHAMAD SYAFIQ BIN ABDUL WAHAB

Date : …………………...…………………………

DEDICATION

To my beloved family especially my father, Abdul Wahab Bin Bujang and my mother, Ah Binti Haji Dali.

ACKNOWLEDGEMENTS

Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this search. To the great prophet Muhammad (Allah peace be upon him) a prophet of mercy and the light of the Worlds.

Firstly, I would like to sincerely thank my supervisor Prof. Dr. Md Radzai Bin Said for his guidance, advices and support. Without his valuable assistance, this work would not has been completed. I am also indebted to my friends for their contributions. I takes this opportunity also to thank the Faculty of Mechanical Engineering's laboratory management for their cooperation especially to the technicians during performing experimental works at the laboratory.

Most importantly, I am forever grateful my family who understands the importance of this work, none of this would have been possible without their patience and help.

Lastly, specials thanks are due to all who was has involved in helping to finish this project.

ABSTRACT

Thin-walled tube is one of the energy absorbing structure that has been used to dissipate energy and increase the efficiency of crashworthiness. During an accident occurred, thin-walled tube dissipates the kinetic energy and convert it into other form of energy. Therefore, this energy absorbing structure gives enough energy dissipation before hitting the human. This study examines the square aluminium tube and circular Polyvinyl chloride (PVC) tube subjected to quasi static loading by using universal compression machine or Instron machine. The deforming modes for both tubes is observed. The paper model is developed by using a thick paper to illustrate the deforming mode for square aluminium tube only. Tensile test is conducted for both tubes in order to obtain the mechanical properties of the tubes. There are three difference in length for each types of tubes has been tested under quasi static loading. The experimental results obtained from the testing have been compared with theoretical results that obtained from mathematical equations. From the comparison, a good agreement has been achieved between the theoretical and experimental results. The analysis of load-displacement curve includes peak load, energy absorption, mean load and plastic folding results. Plastic folding for PVC tube is greater than aluminium tube because of the ductility behaviour. As a result, the circular PVC and square aluminium tubes deformed in progressive diamond mode for all three difference length. A series of paper model is developed for various stage of the deformation process in order to illustrate the phenomenon of compression process of square aluminium tube occurred during testing. As a conclusion, the results obtained from this study such as the series of paper model for deforming mode of square tubes can be used as a new product of learning tools in order to increase the understanding about the phenomenon of compression test.

ABSTRAK

Tiub berdinding nipis merupakan salah satu struktur menyerap tenaga yang telah digunakan untuk menyebarkan tenaga dan meningkatkan kecekapan kebolehtahanan hentakan. Semasa kemalangan berlaku, tiub berdinding nipis menyerap tenaga kinetik dan menukar kepada bentuk tenaga lain. Oleh itu, struktur menyerap tenaga ini memberikan penyerapan tenaga yang mencukupi sebelum memukul manusia. Kajian ini adalah untuk mengkaji tiub aluminium persegi dan tiub PVC bulat yang tertakluk kepada beban statik kuasi dengan menggunakan mesin mampatan universal atau mesin Instron. Mod perubahan bagi kedua-dua tiub diperhatikan. Model kertas dibentuk dengan menggunakan kertas tebal untuk menggambarkan cara perubahan bagi tiub aluminium persegi sahaja. Ujian tegangan dijalankan bagi kedua-dua tiub untuk mendapatkan sifat-sifat mekanik tiub. Terdapat tiga perbezaan panjang untuk setiap jenis tiub telah diuji di bawah beban statik kuasi. Keputusan eksperimen yang diperolehi daripada ujian telah dibandingkan dengan keputusan teori yang diperolehi daripada persamaan matematik. Dari perbandingan, satu persetujuan yang baik telah dicapai di antara keputusan teori dan ujikaji. Analisis terhadap graf jarak beban termasuk keputusan beban puncak, purata beban, penyerapan tenaga dan plastik lipatan. Lipatan plastik untuk tiub PVC adalah lebih besar daripada tiub aluminium kerana sifat kekenyalannya. Hasil daripada ujian, tiub PVC bulat dan aluminium persegi tiub berubah dalam mod diamond untuk ketiga-tiga perbezaan panjang. Siri model kertas dibentuk untuk pelbagai peringkat proses perubahan untuk menggambarkan fenomena proses pemampatan tiub aluminium persegi berlaku semasa ujian. Kesimpulannya, keputusan yang diperoleh daripada kajian ini seperti siri model kertas perubahan bentuk tiub aluminium segi empat sama akan digunakan sebagai alat bantu pembelajaran yang baru untuk meningkatkan kefahaman tentang fenomena ujian mampatan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBEREVATIONS

IEA	-	Impact Energy Absorption
PVC	-	Polyvinylchloride
PC	-	Personal Computer

LIST OF SYMBOLS

P_{cr}	-	Critical Buckling Load
P_m	-	Mean Load
E	-	Young's Modulus / Energy Absorb
σ_u	-	Tensile stress at yield
I	-	Moment of Inertia
L	-	Length of Tubes
S	-	Deformation
H_m	-	Half plastic folding
t	-	Thickness
v	-	Poisson Ratio
OD / d	-	Outer Diameter
mm	-	Millimetre
w	-	Width
LO	-	Overall Length
WO	-	Overall Width
GPa	-	Giga Pascal
MPa	-	Mega Pascal

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In recent time, the number of vehicles on the road has rapidly increased year by year due to the advanced technologies in automotive industry (Ahmad, 2009). Afterward, vehicle crushing become a major worldwide problem that claimed many lives of road users. This phenomenon occurred due to high impact from the crushing on the body of vehicles to human body. Nowadays, impact energy absorption (IEA) device has contributed much in reduce of damage occurred on the bumper or body of vehicles during crushing especially in automotive or aerospace industries. The impact energy absorption (IEA) devices are expendable mechanical structural elements which are will action in the event of unwanted collision. IEA devices are single shot devices which is have to be replaced after they has been used for their purpose such as collision or crushing.

Polyvinylchloride (PVC) and aluminium are most popular material that are suitable in making the IEA device. This is because the material provide significant benefit such has high strength and durability, lightweight materials and lower in cost of processing or machining process. PVC was introduced in industry on 1832 and the first PVC pipes and tubes were produced on 1932 using a roll mild and hydraulic extruder (Pled et al., 2007). While, the first aluminium was produced in 1885 that containing iron and copper (Sheasby & Pinner, 2001). Too many application using this material due to low density and high mechanical strength.

One of the testing to deform the PVC and aluminium tubes is by using quasi-static testing (Ahmad, 2009). In this testing, the tubes are compressed at a constant rate using conventional tensional testing machine (INSTRON 8802). Tubes are compressed at a very slow constant speed in range of 0.0015 m/s up to 0.1 m/s. The height of the collapse modes of the tubes depend on the long of the tube before testing (Meng et al., 1983).

The results of collapse modes for both materials will be modelling by using a thick paper as a purpose of learning tools. Manila paper has been choose as a modelling material because of the lower in cost, accessible and also easy to handle in making of modelling of the collapse tubes. This paper typically made from semi-bleached wood fibres. It not as strong as craft paper but it most suitable paper in making of paper model of the deforming mode of the tubes. Paper model is describing the pattern or deforming mode of the tubes occurred from starting until the end of the tubes undergoes testing. Paper model will shows how the phenomena of the movement of the plastic hinges on the sides and the middle parts of the tubes. The movement of the plastic hinges is started from the tubes start to collapse under the apply load until the tubes is completely collapse. Only square in shape of the paper model will be modelling by using a thick paper as a purpose of teaching tools.

1.2 PROBLEM STATEMENT

One of the objective of this topic is expose to the students on how the deforming modes occurred on the tubes after undergoes an impact test. Nowadays, additional tools is needed to understand on how the phenomena of the deforming mode of the tubes occurred during the testing. So, study and research about the properties of PVC and aluminium is needed in identifying the behaviour of deforming modes for both materials. Then, modelling the results of the deforming mode for square aluminium tubes only by using thick paper which it can be used as a teaching and learning purpose. The series of paper model is developed for presentation in order to increase the understanding of students on phenomenon occurred during compression test is various stages.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To perform and observe the deforming mode of PVC and aluminium tubes with different length under quasi-static loading.
2. To model the deforming mode of the square aluminium tube only by using a thick paper.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Carry out a preliminary study and review past research on the scope of study about quasi-static loading and deforming modes which is based on standard.
2. Perform a quasi-static loading on PVC and aluminium tubes and observe their deforming mode.
3. Result of deforming mode for square aluminium tube only are modelling by using the thick paper.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter study about the paper model of the square aluminium tubes under quasi-static loading testing, axial loading on both types of materials used (aluminium and polyvinyl chloride, PVC) and high speed digital camera to capture the impact event.

Axial loading of the tubes becomes one of the major part of the energy absorbing process employed by the designer. There are many publications on the behaviour of circular and square tubes under axial loading. From the view of energy absorption capacity, circular tubes under axial loading provide a better device compared with square tube (Meng et al., 1983).

2.2 ENERGY ABSORPTION

Energy absorption means that the required energy to cause the collapse of the structures or tubes under the impact loading (Andrews et al., 1983). The energy firstly transformed into elastic strain energy in the deformed tubes and the remainder of the energy is dissipated in plastic deformation on the tubes during collapse occurred (Alghamdi, 2001). There are seven types of collapse modes on tubes that has been identified which are concertina, axisymmetric concertina, diamond, concertina/diamond, Euler, tilting of tube axis and 2-lobe diamond (Albert et al., 2016).

2.2.1 COLLAPSE MODES

Results from the axial loading to the test tubes produced seven types of collapse modes which is (Andrews et al., 1983):

Table 2. 1: Collapse modes under axial loading

Collapse modes	Description
Concertina	At one end of the tube where starting point of axisymmetric and sequential folding.
Axisymmetric concertina	Simultaneous type of collapse will occurred along the length of the tubes.
Diamond	Change in the cross section shape of the tubes affected by the sequential folding.
Concertina / Diamond	Folding first occurred in concertina mode and changing to diamond mode.
Euler	Tubes bending during the testing.
Tilting of tube axis	Shearing occurred on the tubes with platen surface at the one end.
2-Lobe diamond	Simultaneous type of collapse will occurred along the length of the tubes in form 2-lobe diamond configuration.

There are four different regions in the force-displacement curve for the collapse mode as shown in the Figure 2.1 which is the post-buckling stage, elastic stage, the crippling stage and the collapse stage.

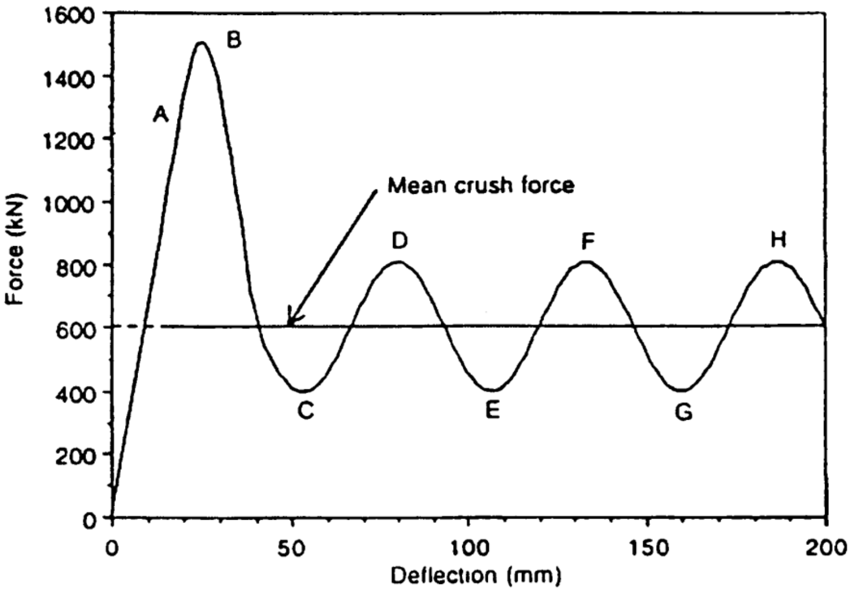

Figure 2. 1: Force displacement curve for collapse mode
(Source : Junning Sun, 2000)

According to the Figure 2.1, point A represented the elastic buckling load. For the point B, it is referred to maximum crippling load means that the maximum load-carrying capacity of the tube. This point also indicated as maximum peak force for the testing where at the corners of the tubes, plastic collapse will happened. As the applied loads is decreases to the point C, the first fold is appeared at the corner of the tubes. When the load increasing, second crippling load is reached at point D. It is also followed by the loading increasing from the point E to F and G to H. the process of folding occurred at the corner of the tube is repeated from the point D to E and F to G until the folding happens at the end of the tubes (Junning Sun, 2000).

2.3 QUASI-STATIC TEST

The quasi-static test was carried out by using INSTRON 5585 testing machine (accuracy ± 1% of applied load) as shown in Figure 2.2. The plate at the lower part of the machine was fixed and not move (Trondheim, 2005). To ensure uniform load distribution of the test specimens, the load was applied through a rigid steel plate that connected to the hydraulic actuator. The friction between the rigid steel plate and the upper end surface of the test specimens is very important to prevent from any movement during the testing process. The axial load was applied at a constant speed during the testing which the speed in a range of 1.5×10^{-3} m/s to 0.1 m/s. The actual crush condition didn't be able represent by doing this quasi-static tests because during the crush, the structures of the tubes will dissipate energy over the entire period until the tubes are completely collapses. It means that the speed of the tests is one of the major factor influences on the capability of energy absorption. So, materials selection under the quasi-static tests are usually not represent the real performance of the structure in the event of a crash.

There are some advantages of the quasi-static tests (Junning Sun, 2000):

i. Lower maintenance and reduce the risk of damage on the crosshead of the tubes.
ii. Test's equipment usually easy to conduct and operate.
iii. This test usually run to understand the different failure modes of the different materials used based on the crush rate.

There are some disadvantages of the quasi-static test:

i. This quasi-static tests usually represent not an actual characteristic of the selected materials as a real performance of the structure in the event of a crash. This is because this test usually conducted to investigate the failure modes of the tubes.