STUDY ON SHOCK – ABSORBING PROPERTIES OF SQUARE TUBE STRENGTHENING STRUCTURE

ARINA BINTI ZAKARIA

A report submitted in partial fulfilment of the
requirements for the award of the degree of
Bachelor of Mechanical Engineering
(Structure and Materials)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

APRIL 2010

"I hereby declared that I have read through this report and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechanical Engineering (Material and Structure)"

Signature	: ……………………………………
Supervisor's Name	: MR. HAIRUL BIN BAKRI
Date	: ....

"I hereby declared this report is mine except summary and each quotation that I have mentioned the resources"

Signature : ……………………………………

Author's Name : ARINA BINTI ZAKARIA

Date : ....

To my beloved father and mother

ACKNOWLEDGEMENTS

In the name of Allah, the most Gracious and most Merciful,

I am really grateful as I have completed this Projek Sarjana Muda 2 (PSM 2) with the help and support, encouragement and inspirations by various parties. All the knowledge and information that they give are really helpful. Here I would like to express my gratitude to Mr. Hairul Bin Bakri for all his supports and advices during completion of this project and willing become my supervisor. All the helps, knowledge and advices through a few consultations especially in using ABAQUS 6.7-1 software from Mr. Firdaus and Mr. Amzatul to perform finite element analysis simulation are very treasured.

I also would like to thank my beloved parents and my family who have giving me support and motivation throughout my project. I am very appreciating of their understanding towards my commitment to finish this project. My big thank also to my all friends for their help and support to complete my PSM report. Lastly, thanks to all the people around me, who has giving support directly or indirectly for the contribution in this project.

Thanks.

ABSTRACT

Thin-walled tubular structures are commonly used as the strengthening members of a car body. The strengthening member of the vehicle body is designed in order to absorb the impact energy efficiently during collision. The effects of shock energy on tubular structure are numerically investigated under axial impact using the FEM (finite element method) program code of dynamic explicit version of ABAQUS. By installing the solid masses to the sidewall of the specimen, initial bending occurred to the specimen due to inertia force which produced by great velocity change during shock impact. In this study, rectangular solid mass that is steel SS400 was attached through aluminium alloy square tube A6063-T6. The tube was impacted against the stationary rigid plate at the velocity of 5 and 10 m/s. In order to get the best design, there were two cases was tested. The first one was square tube without solid mass and second was square tube which installing solid mass to the tube. The tube with solid mass clearly showed that the bending deformation occurs in the portion where the solid mass is attached.

ABSTRAK

Struktur bererongga kebiasaanya digunakan sebagai penguat rangka kenderaan. Kekuatan rangka kenderaan direka bertujuan untuk menyerap kadar kecekapan tenaga semasa pelanggaran berlaku .Kesan daripada daya kejutan keatas struktur berongga telah dikaji secara berangka dibawah hentaman pada paksi lurus dengan menggunakan kod program perisian daripada dinamik nyata iaitu versi ABAQUS 6. -1. Dengan mencantumkan jisim padat (solid mass) merentasi kedalam tiub, spesimen akan mengalami pembengkokan awal dimana berkadar terus dengan kuasa inersia setelah perubahan halaju terhasil semasa kesan kejutan. Dalam kaedah kajian ini, jisim padat segiempat iaitu bahan daripada besi SS400 dicantum merentasi tiub segiempat sama iaitu bahan daripada keluli aloi A6060-T6. Permukaan atas tiub dikenakan hentaman pada kelajuan 5 dan 10 meter per saat. Bagi mendapatkan rekaan bentuk terbaik, dua kes akan dikaji. Kes pertama adalah tube segiempat sama tanpa mencantumkan jisim padat. Manakala kes kedua adalah tiub segiempat sama dengan mencantumkan jisim padat. Dalam kajian ini jelas menunjukkan bahawa tiub segiempat sama akan mengalami pembengkokan pada bahagian di mana jisim padat dicantumkan.

TABLE OF CONTENT

CHAPTER	TOPICS	PAGE

CHAPTER 2 LITERATURE REVIEW

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

w	= width of a square tube
E	= Young's modulus
G	= attached mass
h	= thickness of a tube
I	= impulse
γ	= length of a tube
P	= Force
V	= velocity
σ_y	= yield stress
ν	= poison ratio
n	= exponent
C	= multiplier
ρ	= density
a	= acceleration
A	= cross-section
t	= time
Pa	= Pascal
m	= meter
kg	= mass
E	= energy
δ	= displacement
ε	= strain

CHAPTER 1

INTRODUCTION

1.1 Overview

Thin-walled tubular structures are commonly used as the strengthening members of a car body. The strengthening member of the vehicle body is designed in order to absorb the impact energy efficiently during collision. The member is usually tubular and the deformation pattern with a cyclic plastic buckling takes place when it is axially compressed.

Many researchers have been paid considerable attention on the crush behaviour of such kind of structure during the past two decades. The energy absorption efficiently is relatively low. Therefore, the V-shaped dent as a geometrical imperfection is usually formed in the production process, at which the strength is weaker. The effect of such kind of dent on the deformation behaviour was also investigated. In addition, for the case of light collision, the damaged portion should be restricted near the impact edge to minimize the damage so that the repair cost is less.

Declaration Kyoto stated that the decreasing of carbon dioxide is important in manufacturing and transportation sector. Transportation sector in Malaysia exactly was produced very high carbon dioxide and the most contribute is car. Therefore, the need to reduce the weight of car body is important in order to tackle the environmental issue in recent years.

1.2 Objective:-

i) To design shock-absorbing structure.
ii) To study/analyze the effect of shock energy of design structure.
iii) To control the deformation of designed structure when the shock impact applied.

1.3 Scope:-

i) To design the best strengthening structure via FEM. (to check whether the deformation can be controlled or not).
ii) To analyze the effect of shock energy to the structure.

1.4 Problem Statement

The road accident is an unfortunate but common occurrence. It is becoming apparent that, in the future, transport structures will have to be designed to withstand impacts and crashes. The current trend is thin wall tubular structure where it's commonly used as the strengthening members in car body in order to absorb the impact energy efficiently. But until today, tubular structure still cannot control deformation with effectively. However in this research, solid masses will be attached through square tube wall to analyze weather deformation can be control or not during the shock impact (dynamic impact).

CHAPTER 2

LETERATURE REVIEW

2.0 LITERATURE REVIEW

In this chapter, literature review has been done to explore the previous research related to energy absorption. On the vehicle crashes there are some phenomena where the collision always occurs. Energy absorption was applied to the vehicle to reduce the vehicle collision. In addition, from the previous paper, the researcher was making some analysis to find the solution to decrease the phenomena. On the other hand, the literature review has been continued to discover the previous research which related to the analysis that was done.

2.1 Collapsible impact energy absorbers

During the second half of the last century a great number of impact engineering problems were investigated, especially in the field of the dynamic response of structures in the plastic range. This contributed towards a better understanding of the modes of failure and the energy dissipation patterns during impact in such structures.

2.1.1 Definition

An energy absorber is a system that converts, totally or partially, kinetic energy into another form of energy. Energy converted is either reversible, like pressure energy in compressible fluids and elastic strain energy in solids, or irreversible, like plastic deformation energy. Energy dissipated in plastic deformation of metallic energy absorbers is the absorbing system reviewed in this paper.

When designing a collapsible energy absorber, absorbing the majority of the kinetic energy of impact within the device itself in an irreversible manner, thus ensuring that human injuries and equipment damages are minimal. The conversion of the kinetic energy into plastic deformation depends, among other factors, on the magnitude and method of application of loads, transmission rates, deformation or displacement patterns and material properties.

The components of deformable energy absorbers include such items as steel drums, circular tube , tubular rings , square tubes , corrugated tubes, multicorner columns, frusta , struts , honeycomb cells , sandwich plates and some other special shapes such as stepped circular thin-walled tubes and top-hat thin-walled sections .

Each energy absorber system has its own characteristics and special features which one needs to be familiar with in order to be able to understand how metallic structures respond to impulsive loads. Because of the extreme complexities of collapse mechanisms, some of these performance characteristics were determined only through experimental procedures. Consequently, the resulting empirical relations are confined to limited applications.

The study of deformation in energy absorbers accounts for geometrical changes, and interaction between various modes of deformation such as the concertina (axisymmetric) mode of collapse and the diamond (non-axisymmetric) mode of collapse, for axially loaded tubes, as well as strain hardening and strain rate effects.

2.2 Absorber shape

There are numerous types of collapsible impact energy absorbers that are cited in the open literature. In this section the most common shapes are reported.

2.2.1 Tubes

Thin tubes represent the most widespread shape of collapsible impact energy absorbers, owing to their high frequency of occurrence as structural elements.

2.2.2 Frusta

Frustum (truncated circular cones) has wide ranges of applications. The occurrence of frusta as structural members has drawn some attention, especially due to their stable plastic behaviour when crushed axially. The literature on this topic, however, is generally meagre. (Postlethwaite HE and Mills B (1970).

$$Pav = 6Yt^{\frac{3}{2}}\sqrt{d + 2x\sin(\emptyset)} + 5.69Y\,t^2 \tan(\emptyset) \qquad (1)$$

Where *Y* is the yield strength,

t is the frustum thickness,

x is the deformation,

d is the small diameter of the frustum and f is the semi-apical angle of the frustum.

Mamalis and Johnson experimentally investigated the quasi-static crumpling of aluminium tubes and frusta under quasi-static compression. Their main objective was, among other things, to determine the experimental details of the failure modes of frusta. It was observed that load–deflection curves of the frusta are more regular than those of cylinders. Also, post-buckling load increases in a parabolic manner with increases in wall thickness, and, as expected, post-buckling load decreases with an increase in semi-apical angle. It was observed that thin frusta deformed into a diamond shape whereas thick ones deformed into axisymmetric rings. The authors fitted empirical equations to their results for both concertina and diamond modes of deformation. Mamalis W and Johnson W (1983)

Mamalis repeated the same experimental study using low-carbon steel and at elevated strain rates (2.5 m/min). It was observed that the initial axisymmetric bellows changes into non-symmetric diamond shapes and the number of lobes of the diamond shape increased as the ratio of the mean diameter/thickness increased. Mamalis proposed an extensible theoretical model to predict the plastically dissipated energy and the mean post-buckling load for axially crumpled thin walled circular cones and frusta for the concertina mode of deformation. The theoretical model was based on a consideration of the plastic work dissipated in plastic hinges and in stretching of material between them without considering their interaction. The model gave the average crushing load in the form: Mamalis W and Johnson W (1983).

$$Pav = 56Yt^{\frac{5}{2}}\sqrt{d}+0.95\sqrt{t}\tan(\emptyset) \quad (2)$$

Predicted average crushing loads were in fair agreement with experimental results. Mamalis developed a theoretical model to predict the mean crushing load for axially loaded circular cones and frusta deformed into the diamond mode of deformation. The model was based on the in extensional model developed by Johnson. Mamalis W and Johnson W (1983).

2.2.3 Multi corner columns

The crushing of thin-walled multi corner structures are made from plate elements by considering stationary plastic hinges and narrow toroidal regions of circumferential stretching and bending which travel through the structure. As a special case of the multi corner column, the mean crushing load (*P*av) for the symmetrical collapse mode of a square tube made of rigid–plastic material takes the form. Abramowicz W and Wierzbicki (1989).

Wierzbicki and Abramowicz (1989) analyzed the crushing of thin-walled multicorner structures made from plate elements, by considering stationary plastic hinges and narrow toroidal regions of circumferential stretching and bending which travel through the structure. As a special case of the multicorner column, the mean crushing load (*P*av) for the symmetrical collapse mode of a square tube made of rigid–plastic material takes the form. Abramowicz and Wierzbicki (1989).

$$P\mathrm{av}=9.56Yt^{5/3}C^{1/3} \quad (3)$$

Where *C* is the width of the square tube

t is the column thickness.

Abramowicz and Jones (1989) predicted the average static crushing force for asymmetric collapse of a square tube to be,

$$P\mathrm{av} = Y\,t\,(9.69C^{1/3}t^{2/3} + 0.84C^{2/3}t^{1/3} + 0.58t^{2}) \quad (4)$$

Abramowicz and Wierzbicki (1989) improved their previous model by assuming an arbitrary angle between the adjacent plates of the structure. Accordingly, the average crushing load (*P*av) for the square tube is,

$$P\mathrm{av} = 13.06Yt^{5/3}C^{1/3} \quad (5)$$

2.2.4 Struts

Postlethwaite HE and Mills B (1970) were among the first researchers to use simple struts made of mild steel as impact energy absorbers. A simple strut with an initial imperfection(deflection) was also used as an energy absorber by Grzebieta and Murray (1986). Because of the limited zone of plastic deformation, i.e. one plastic hinge, the absorbed energy in static tests was minimal. The initial imperfection amplitude was used to control the absorbed energy, the maximum force, and hence the deceleration rate of the impacting mass. Harris and Adams (1985) investigated both theoretically and experimentally the crushing behaviour of structures made by bonded and spotwelded lap joints. Mild steel and aluminium tubular specimens made by a single lap joint were tested. Grzebieta and Murray (1984), repeated their previous work but for a dynamic loading condition. Recently, Reid and Sicking (1998) have studied large plastic deformations of sequential kinking in guardrail terminals. A non-linear, large deformation finite element package (LS-DYNA) was used to model the deformation sequence. (Drazetic et al. 1993) modelled the crushing of S-frames using finite element analysis.

2.2.5 Sandwich plates

The energy absorbing mechanisms of impacting events in sandwich structures made of composites are quite unusual. Sandwich structures are widely used in a variety of applications. They are common in transport vehicles, such as aircraft, trains, cars and boats and also in the construction industry for buildings.

A sandwich structure is constructed from a core with a skin attached to each side, and is analogous to an I beam, where the core represents the web and the skin the flanges. Since there is a wide range of materials that can be considered for the skin and core, there exists considerable flexibility for the designer, presenting an overwhelming combination of materials for the construction of sandwich structures. This is one reason why it is necessary to develop a validated theory for the design of sandwich constructions. This theory could then be used with confidence by designers to predict the behavior of a wide range of sandwich constructions and thus select the best combination for a given design problem. With increasing interest in the design of structures to withstand impact, considerations of energy absorption are becoming important. A.A.A Alghamdi (2000).

The impact and energy absorption of sandwich structures has drawn the interest of many workers. A.A.A Alghamdi (2000). Thus Gilkie and Sundararaj (1971) investigated the effect of laminate thickness, core thickness, facing thickness and support span on the impact strength of the sandwich. Some tests were also conducted on glass fiber laminates to provide a comparison. They reported that sandwich panels were substantially more resistant to impact failure than simple laminates. Results show that the impact strength of the front skin is independent of the core thickness but the rear skin impact strength increases as the core thickness increases.

Wray (1993) of UMIST aimed to use sandwich structures in the offshore industry. Three failure modes were observed in the experiments on the quasi-static loading of sandwich structures, local indentation at the loading point, core shear failure and skin compressive failure. No tensile skin failures were observed. Some of the core shear failures were also accompanied by delaminating at the skin to core interface. The thick skin sandwich beams with transverse core ribbon direction appeared to crush along the whole length of the panel due to severe shearing of the core. It was concluded that the sandwich structures with thin skins (0.67 mm) and thick cores(19.5 mm) tended to fail by the indentation mode at short spans. Typically compressive skin failures tended to occur in sandwich structures with long spans (430 mm) and thin skins (0.67 mm). The failure modes observed in the impact tests were similar to those for the quasi-static tests.