"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree Bachelor of Mechanical Engineering (Structure & Material)"

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A STUDY OF SQUARE RING UNDER LATERAL COMPRESSION USING EXPERIMENTAL AND FINITE ELEMENT METHODS

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I declared that this thesis entitled "A Study of Square Ring under Lateral compression using experimental and Finite Element Method" is the result of my own research except as cited in the references.

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Dedicated to my beloved parents and my special one

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ABSTRACT

This research is focused on to the capability of the square ring to absorbed energy during the compression. The purposes of this research are to observe and determine the energy absorbed by the square ring when undergoing the plastic deformation when compressed laterally at the two principles directions. The deformation of the square ring is also observed and result getting from the experiment is compared with the Finite Element Analysis (FEA) by using ABAQUS 6.2-4 student edition.

This thesis layout begins with a short introduction to the project and followed by the literature review of the relevant topics with thc project. And then the experimental work has done for the project, analyses of the experiments and results of the experiments. Behaviour of the deformations during the compression also presented and the results and data were provided.

A finite element analysis is presented for the purpose of providing a comparison with the experimental results.

Discussions for the comparison between two methods were made and summary whether the different occurred by using the both method presented and the thesis is concluded by the conclusion and appendices.

ABSTRAK

Kajian ini mengfokuskan tentang kebolehan gegelang segiempat sama di dalam menyerap tenaga semasa menerima beban tekanan. Tujuan kajian ini adalah untuk menentukan tenaga yang diserap dan juga memerhatikan perubahan bentuk yang dialami semasa mampatan dua arah principal oleh gegelang segiempat sama ketika mengalami perubahan plastik. Perubahan bentuk yang di alami dan keputusan yang diperolehi akan dibandingkan dengan Analisis Unsur Terhingga dengan menggunakan ABAQUS student edition 6.2-4.

Tesis ini bermula dengan penerangan atau pengenalan serba ringkas tentang projek atau kajian yang dilakukan dan diikuti dengan kajian ilmiah yang berkaitan dengan projek ini. Kemudian diikuti dengan penerangan tentang kerja-kerja eksperimen yang dilakukan untuk mencapai objektif projek, bersertakan dengan analisis dan juga keputusan daripada eksperimen yang dilakukan. Kelakuan perubahan yang dialami oleh gegelang segiempat ketika dimampatkan secara lateral juga diterangkan dan keputusan yang diperolehi dilampirkan.

Kajian unsur terhingga juga diterangkan bertujuan untuk melakukan perbandingan dengan kerja eksperimen.

Perbincangan tentang perbezaan bagi kedua-dua kaedah yang digunakan dan ringkasan dan perbincangan disertakan dan kesimpulan bagi keseluruhan projek.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOTATIONS

SYMBOL	DEFINITION
H	Height
w	Width
t	Thickness
W	Energy Absorbed
E	Young's Modulus
ρ	Density

GREEK	DEFINITION
δ	Displacement
σ	Stress
ν	Poisson's ratio
ε	Strain

SUBSCRIPT	DEFINITION
ult	Ultimate
Y	Yield

APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Objectives

Goal of this study is to analyse the plastic deformation behaviour and energy absorbed by the square ring under lateral compression using experimental works and also by using Finite Element Analysis (FEA). In order to achieve this goal, there is several objectives need to be reach. The objectives are:

i. To study the behaviour of square rings under lateral loading (in across corner and across faces orientations).
ii. To obtain the energy absorbed by the square ring, the displacements and collapse load.
iii. To study the parameter those influence the deformation of the square rings under lateral compressed.
iv. To study the Load -Deflection responses of square ring both using Finite Element method.

1.2 General

Energy absorbers are systems that convert kinetic energy into other forms of energy, such as pressure energy in compressible fluids, elastic strain energy in solids, and plastic deformation energy in deformable solids. The converted energy may be reversible, as in pressure energy in compressible fluids, and elastic strain energy in solids, or irreversible, as in plastic deformation. The process of conversion for plastic deformation depends, among other factors, on the magnitude and method of application of loads, transmission rates, deformation displacement patterns, and material properties [Alghamdi et al (1992)].

Familiar deformable energy absorbers include steel drums, liquid and sand filled cells, including sand bags, barrels made of plastics, vermiculite concrete with voids, honeycomb cells filled with polyurethane from, and tubular elements in a variety of shapes and arrangements. The active absorbing element of an energy absorption system can assume several common shapes such as tubes, rings, honeycombs, frusta, strips, and rods.

The predominate domain of applications of deformable energy absorbers is that of crash protection. Such systems are installed in high-risk environments with potential injury to humans or damage to property. The aim is to minimize by controlling the deceleration pulse during impact. This is achieved by extending the period of dissipation of the kinetic energy of the system over a finite period of time. Cushioning devices on vehicle bumpers, crash retarders in emergency systems of lifts, and some crash barriers used as road blocks are every-day examples. Energy absorbers are likewise utilized during the installation of machinery, including household appliances, to minimize foundation-related vibrations.

Development of mechanical devices that help dissipate kinetic energy at predetermined rates has been receiving substantial attention for several decades [Alghamdi et al (1992)]. When designing a collapsible energy absorbing (dissipating) device, the prime aim is to absorb the majority of the kinetic energy of impact within the device itself in an irreversible manner, and in such a way as to ensure that injuries to humans and damages to equipment is minimum. The absorbing system must exhibit force-deflection characteristics which result in decelerations that are within allowable limits. These limits may be dictated either by human tolerance levels or by the maximum force the structures themselves can withstand [Alghamdi et al (1992).].

Axisymmetrical and circular shapes provide perhaps the widest range of all choices for use as absorbing elements because of their favourable plastic behaviour under axial crumbling forces, as well as their common occurrence as structural elements.

For the past few decades, development and design of energy devices of metallic devices and structure which functioning to dissipate the kinetic energy during the impact were focused by many authors i.e Gupta, Reid, Khullar, Reddy. In reducing the impact during the accidents, as we can see the installation of the roadside furniture at the accidents potential place which acting as impact energy absorber and safety step to the road users if accidents happen. Elevator shaft pits also applied the same principles. So here, by doing these steps of precautions, the damages due the low speed collisions can be avoid and those the higher speed collisions can be reduce.

The failure process characterised by the progressive formation of buckles can be utilised to produce absorbers with sections whose typical dimension can vary from tens to hundreds of millimetres, with average failure loads variable from thousands to hundreds of thousands of Newton.

1.3 Introduction to the problem

In designing energy absorbing system, consideration of the lateral compression or loading is the one of the important aspect. Normally in assessing the energy absorbing capacity of these devices, behaviour of the devices under quasi-static loading is usually examined. The study of this square under static loading is the one of important thing because this structural element can ideally comply with the six general principles in the design of the energy absorbing devices. Those principles are i) Irreversible energy conversion. ii) Restricted and constant reactive Force, iii) Long stroke to achieve maximum work done, iv) Low cost, v)Stable and repeatable deformation mode, vi) Light weight and high energy absorbing capacity.

In this case, experiments were carried out by the author on the square ring loaded with the lateral compression on the principle direction. The behaviour of the square ring under the lateral compression is studied. Experiments and analyses are carried out for the two type of loading i) Lateral compression across corner, ii) Lateral compression across faces. Square rings made of mild steel used in this experiment, and some of them were annealed and some of them were in the original conditions (as-received). Lateral compression of the square rings was carried between the rigid plate on the universal testing machine and the behaviour of square ring during the compression also studied.

Graph plotted are studied, the area under the curve represent capacity energy absorbed by the square ring and from there author could determined the value of the energy absorbed. Then comparisons are made between the numerical analysis by using the Finite Element Analysis software.

In this case, author also looked into and examined the mode deformation of the square ring. In examining and studying the modes of deformation of the square ring under the lateral compression several things or parameters are considered. The

of collapse load, location of hinges, plastic compression load-compressive extension curve and history of deformation are observed for this experiment. The result will compare with the FEA result by using ABAQUS student edition 6.2-4.

1.4 Finite Element Method

The finite element method is the numerical technique that employs the idea of discretization or philosophy of constructing piece wise and evaluates differential equation to an approximate solution. Another method involves in approximating are functional approximations and finite element method. In a numerical technique of physical process, a numerical method and computer is used to evaluate a mathematical model of the process. In many engineering problem involving complex shapes, material properties and complicated boundary conditions, it is difficult to obtain analytical solutions that satisfy the governing different equation.

The basic concept of FEM is that the body or structure may be divided into smaller elements of finite dimension called 'finite element'. The original body or structure is then considered as a assemblage of these elements connected at finite number of joints called 'nodes' or 'nodal point'.

Formulating and combining the properties of elements may be obtained the solution for the entire body or structure. For example, in the displacement formulation 'shape functions' as simple function are chosen to approximate the variation of displacement in terms of displacement at the nodes of elements.

This follow Rayleight-Ritz procedure of functional approximating variable of the element level. The strain and stresses within an element will also expressed in term of nodal displacements. Then the principle of virtual displacement or minimum potential energy is used to derive the equilibrium equations for the element and the nodal displacement will be the unknown. The equilibrium equations for the entire body are then obtained by combining this equations for each element such that the continuity of displacement is ensured at each node where the element is connected.

CHAPTER 2

LITERATURE REVIEW

2.1 Simple lateral compression of non-circular tubes and rings

Interest has centred on those metallic devices and structures that depend upon the absorption of energy by production of plastic deformation. Many authors have carried out plastic collapsed and post collapse analyses of tubes and rings in this past few decades.[Reid and Reddy (1977)] However, the greatest attention have been given to circular tubes and rings. Moreover, for past decades, the several authors gave concerning on non-circular tubes and rings. But, the applications are still same as a circular tubes and rings which is using as impact energy absorber.

In this literature review, basically are the brief explanations about the previous authors who had a similar interest in this study.

2.1.1 Square tubes and ring

An analysis of the plastic collapse of a square tube when compressed between two short widths indenters was studied. [Gupta and Khullar (1994)]. On this analysis, they considered that the indenters were place orthogonal on to the tube. Gupta and Khullar (1994) was studied the energy absorbed in stationary and rolling plastic hinges which are formed in collapsing square tubes under lateral compression

between two parallel narrow width indenters placed non-orthogonally. Gupta and Ray (1998) have performed experiments on thin-walled and filled square tubes laterally compressed by using rigid plates. The analysis on the plastic hinges and deformation of the tubes are an emphasized on this experiment.

2.1.2 Hexagonal rings

Said and Reddy (2002) was studied on the load-compression and energy absorbed characteristic of a laterally simple crushed hexagonal rings or quasi-static response of laterally simple compressed hexagonal rings. In their study, they make a comparison their experimental results with the numerical analysis study by using ABAQUS. In their study, hexagonal ring was compressed laterally with two different orientation; i) Lateral Compression across-corners and ii) Lateral compression across-faces. And some of the hexagonal rings were ground at the corners for make a comparison with the as-received specimens.

2.1.3 Simple lateral compression of circular tubes and rings

Reid (1983) was performed an experiment on metal tubes under laterally compressed as impact energy absorbers. In this experiment, he concerned on the deformation characteristics of the thin-walled tubes and plastic bending within regions of the tubes wall. Reid and Reddy (1977) also was studied on the effect of the strain hardening on the lateral compression of tubes between rigid plates. But they just detailed in strain hardening effect to the energy absorption device.