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

(Material and Structure)"

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THE STUDY OF SQUARE PLATE UNDER COMPRESSION LOADING

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This report is submitted

to partial fulfillment of term for

Bachelor of Engineering Mechanical (Material and Structure)

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18 MAY 2009

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

Signature:…………………………

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Date:……………………………..

To my beloved father and mother

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ABSTRACT

The square plate is commonly use in many structural design especially in mechanical structure. This shape is being studied further to find out it suitability as energy absorption device in order to minimize the impact of the collision. The energy absorption device is a material that absorbs the kinetic energy during the collision which is the structure is designed on the mechanical structure elements that are risk in collision. The collision is always occurring in the transportation system and gives the negative impact that causes from this collision. So, the energy absorbing device plays an important function to at least minimize the impact of the collision. The square plate from mild steel is chosen and prepared to perform the hardness test to find it mechanical properties and structure. Then, the tensile test is performed in order to find out the mechanical properties. These properties are used in the theoretical calculation and ABAQUS analysis. The theoretical analysis is about to find out the value of buckling load. This value is compared with the experimental value which is compression test. From the test, the experimental value of buckling load and elastic strain energy is obtained. The value of this buckling load will be compare with the theoretical value. The ABAQUS analysis is performed in order to analyze the buckling of the plate graphically.

ABSTRAK

Plat yang berbentuk segiempat biasanya digunakan dalam kebanyakan rekabentuk struktur terutamanya dalam rekabentuk mekanikal. Bentuk plat segiempat ini akan dikaji dengan lebih mendalam untuk mencari kesesuaiannya sebagai alat penyerap tenaga yang bertujuan untuk meminimumkan kesan daripada pelanggaran. Alat penyerap tenaga adalah bahan yang berfungsi sebagai penyerap tenaga kinetic semasa palanggaran dimana ia direka dalam elemen struktur mekanikal yang mempunyai risiko dalam pelanggaran. Perlanggaran selalunya terjadi kepada system pengangkutan dan memberikan kesan yang negatif daripada perlanggaran tersebut. Oleh itu, alat penyerap tenaga memainkan peranan penting untuk sekurang-kurangnya mengurangkan kesan daripada perlanggaran tersebut. Plat segi empat dari jenis besi lembut telah dipilih dan disediakan untuk dijalankan ujian kekerasan bagi mendapatkan sifat-sifat mekanikal dan struktur plat tersebut. Kemudian, ujian ketegangan dijalankan bagi mendapatkan sifat-sifat mekanikal bahan tersebut. Data bagi sifat-sifat tersebut digunakan dalam pengiraan dari sudut teori dan juga analisis ABAQUS. Nilai teori yang dikira adalah nilai bagi daya bengkokan plat yang dikaji. Nilai yang diperolehi akan dibandingkan dengan nilai eksperimaen iaitu daripada ujian mampatan. Daripada ujian mampatan ini, nilai eksperimen untuk daya bengkokan dan tenaga anjal tegangan boleh diperolehi. Nilai daya bengkokan ini akan dibandingkan dengan nilai yang diperolehi daripada nilai teori. Analisis ABAQUS dijalankan bagi menganalisis bengkokan plat secara grafik.

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LIST OF SYMBOLS

F_0 = preliminary minor load in kgf

F_1 = additional major load in kgf

F = total load in kgf

e = permanent increase in depth of penetration due to major load F1 measured in units of 0.002 mm

E = a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter

HR = Rockwell hardness number

D = diameter of steel ball

t = the plate thickness,

v = the Poisson"s ratio and m is the number of half-waves in the compressive direction.

m = The buckling modes

σ_{ult} = Ultimate tensile strength

σ = Stress

L = Length

ε = Strain

E = Modulus of elasticity

τ = Shear stress

P_{cr} = Buckling load

U = Elastic strain energy

D =Flexural rigidity

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Bi	Drawing of square plate
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C	Hardness conversion table
D	Tensile data
E	Compression data

CHAPTER 1

INTRODUCTION

1.1 Background

Square plate is made from the mild steel with thickness between 1.5 mm and 30 mm length of each edge is used to study it properties and suitability as energy absorbing system in order to complete this report. The standard of the mild steel carbon content is approximately 0.16-0.29% and it has relatively low tensile strength, but it is cheap and malleable which is surface hardness can be increased through carburizing. Mild steel also called as soft steel typically are stiff and strong and also exhibit ferromagnetism. The square shape of the plate is the basic shape that almost used as a mechanism in many structures.

1.2 Problem Statement

Nowadays, the cases of the collision of the mechanical system especially that related with the transportation system are become higher. All the transportation systems which are including the aerospace, ships, cars, buses, trains and lifts system are very important and commonly used by human are involved.

So, energy absorption system is designed in order to minimize the collision and also to decrease number of the human death causes by the collision. This collision is called the crashworthiness.

Crashworthiness is the ability of a structure to protect its occupants during an impact. This is commonly tested when investigating the safety of vehicles. Depending on the nature of impact and the vehicle involved, different criteria are used to determine the crashworthiness of the structure. Crashworthiness may be assessed either by using computer models or experiments or by analyzing crash outcomes. Several criteria are used to assess crashworthiness prospectively including the deformation patterns of the vehicle structure, the acceleration experienced by the vehicle during an impact, and the probability of injury predicted by human body models.

1.3 Objectives

The objectives of this study are to study about the theoretically and experimentally value of the buckling load of the mild steel plate subjected to compression load. In addition, the elastic of strain energy also will be calculated by the graph obtained from the compression test. Besides, the objectives of this study also to make the analysis about the buckling of the plate graphically by using the ABAQUS software.

1.4 Scope

According to the objectives, the scope of this report include the preparing the specimen which is cut from the plate into the required size. Then, the graph of the load versus displacement is plotted from the experimental result to find out the elastic strain energy and the buckling load where it will be compare with the theoretical value. The analysis by ABAQUS is performed in order to analyse the buckling of the plate graphically.

1.5 Chapter Outline

The square plate from the mild steel is designed to study it structure of ability to absorb the energy. In the chapter 1, basically is describing about the background, problem statement and also the objectives of the report. All the introduction of this report is discussed in this chapter in more detail. The detail proposal can be seen in Appendix A. For the chapter 2, the discussion is more on the literature review. It is described about the previous projects that have been done by some individual that related to this study. In chapter 3 is about the methodology processes that include in order completing this report. It is contain the material selection, the test involved and also the figure related. Then, in chapter 4, it is about the ABAQUS analysis on the square plate subjected to the compression loading. The deformation of the plate is illustrated in this analysis. Next is the chapter 5 where the discussion is about the result obtained from the experimental and the theoretical value. The comparison between these two values is discussed in this chapter. Finally, in chapter 6 are concluding the remark for the whole report of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There have been much written on the study of the energy absorber and the crashworthiness that can be found in the sources whether in internet, journal, books and others. The research about the square plate also included.

2.2 Crashworthiness

Based on the web side of Cranfield University, Department of Structure, they had made a researched of crashworthiness on a helicopter. This researched is using a method for modelling helicopter impact on water including cavitations and water ingression into the failing structure based on non-linear finite element – Smooth Particle Hydrodynamic, SPH coupling. The new understanding of structural response on water resulted in a new protection concept based on multiple load paths in the main energy absorbing structure.

The objective of this research is to investigate the structure of the helicopter during the collision. They had begun the researched by focussing on the simulation of individual structural components or small sections. The examples are including the collapse of a helicopter lift frame and the impact of a section of an underfloor structure on water. Figure 2.1 show the initial and deformed shapes of this section and Figure 2.2 show the deformation of the underfloor of the helicopter. These simulations were limited by the computer power then available. This work was sponsored by Westland Helicopters. [1]

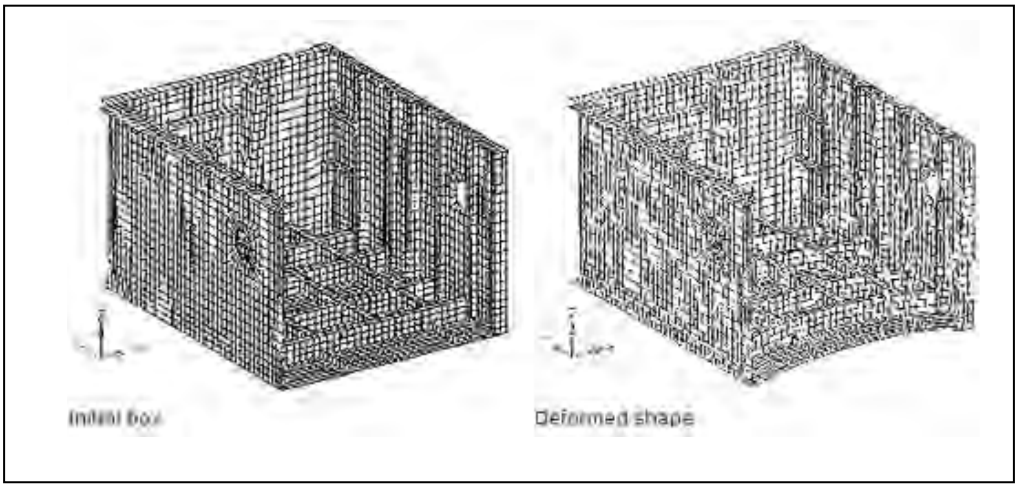

Figure 2.1: The initial and deformed shapes [1]

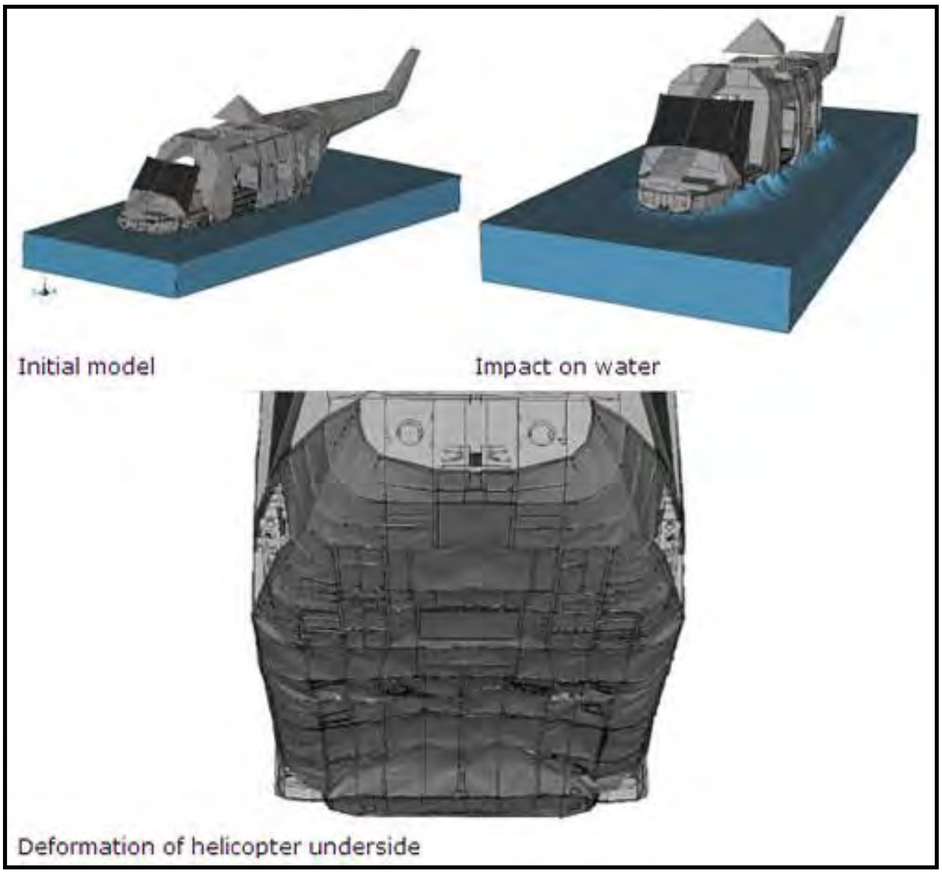

Figure 2.2: Deformation of helicopter [1]

The results from this analysis have been compared with experimental results and the deformation shows good agreement. This work has been funded by the European Union, EU.

A second area of their research has been on improving the capability of analysis codes to model fluid-structure interaction. A method for modelling helicopter impact on water including cavitations and water ingression into the failing structure has been developed based on non-linear finite element - SPH coupling. Figure 2.3 shows the impact of a subfloor section on water, where the water is represented by SPH particles. [1]

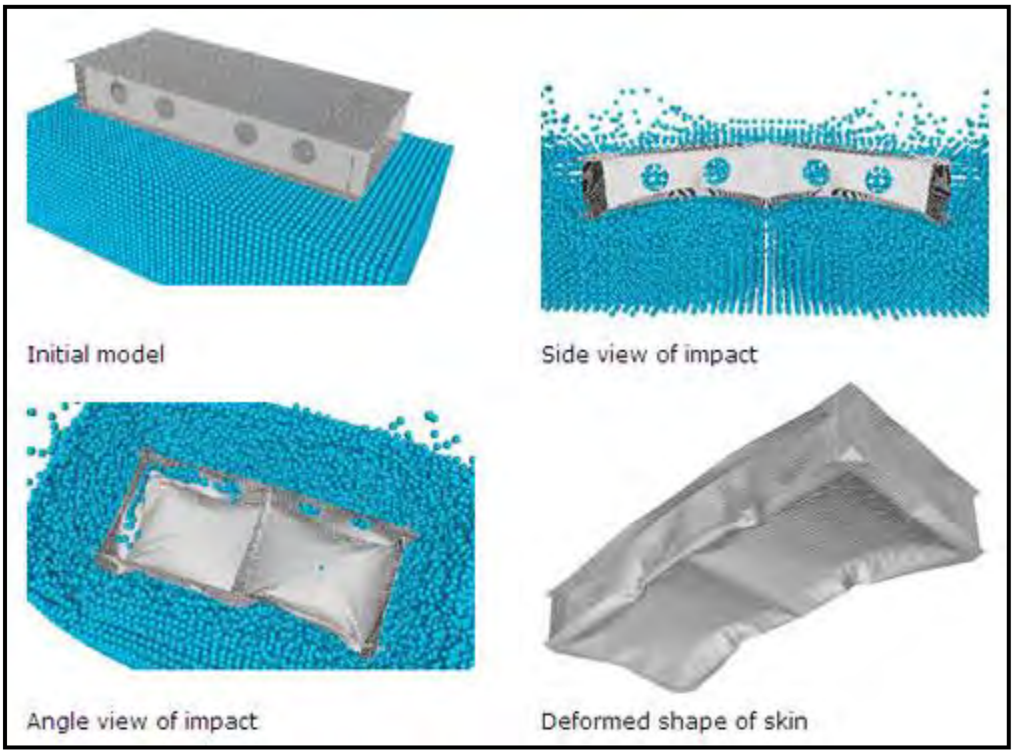

Figure 2.3: The impact of a subfloor section on water [1]

The new understanding of structural response on water resulted in a new protection concept based on multiple load paths in the main energy absorbing structure. This work has been funded by the EU under the Council for Agricultural Science and Technology, CAST project. [1]

2.3 Energy Absorption

The high strength levels ensure a potential for good energy absorption, favourable in a car crash situation. A relevant measure when it comes to determining the potential energy absorption from a tensile testing curve, as depicted in Figure 2.4, is the area below the stress-strain curve up to limited level of strain. Integrating the complete curve is not relevant. As a consequence there is in many cases a good correlation between the tensile strength and the energy absorption. For instance for axial crushing of a quadratic tube, the absorbed energy depends on the gauge and the tensile strength. See equation (1).

$$\mathbf{E} = \propto \boldsymbol{R_m^{0.5} t^{1.5}} \qquad (1)$$

This relation indicates the potential for weight reduction. If the tensile strength is doubled from a reference case the weight may be reduced by about 20% with equivalent energy absorption. [2]

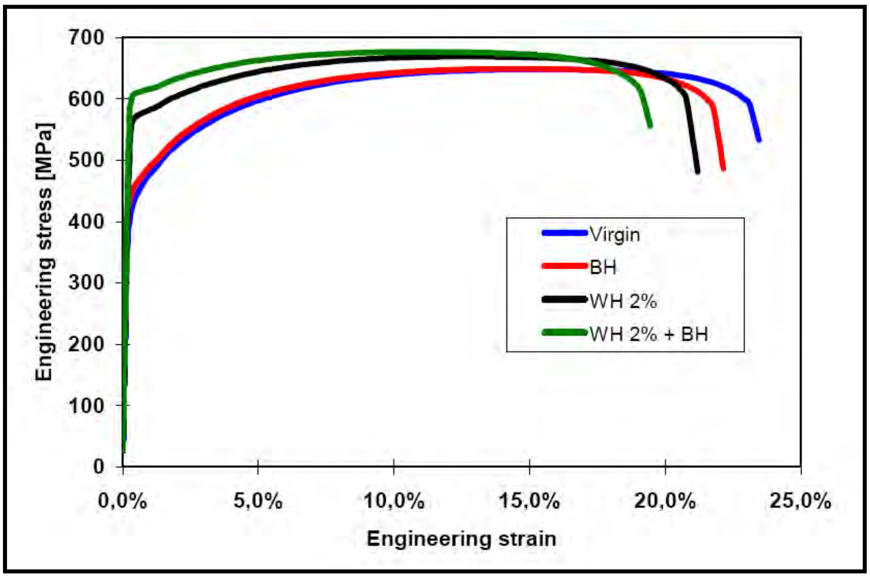

Figure 2.4: Graph of engineering stress versus engineering strain [2]

As can be seen in Figure 2.4, the level of work hardening is significant already at moderate levels of strain; i.e comes into play also when mapping the result from the forming stage. Typically the work hardening effect is about 200 MPa at a strain of two percent and the corresponding bake hardening effect about another 50 MPa for a typical painting process. [2]

2.4 Duocel Foam for Impact Absorption Application

Energy absorbers are a class of products that generally absorb kinetic mechanical energy by compressing or deflecting at a relatively constant stress over an extended distance, and not rebounding. Springs perform a somewhat similar function, but they rebound, hence they are energy storage devices, not energy absorbers.

Foam materials are porous structures, and as discussed in the crush strength section of foam properties, they have a unique stress strain curve as reproduced in Figure 2.5. [3]

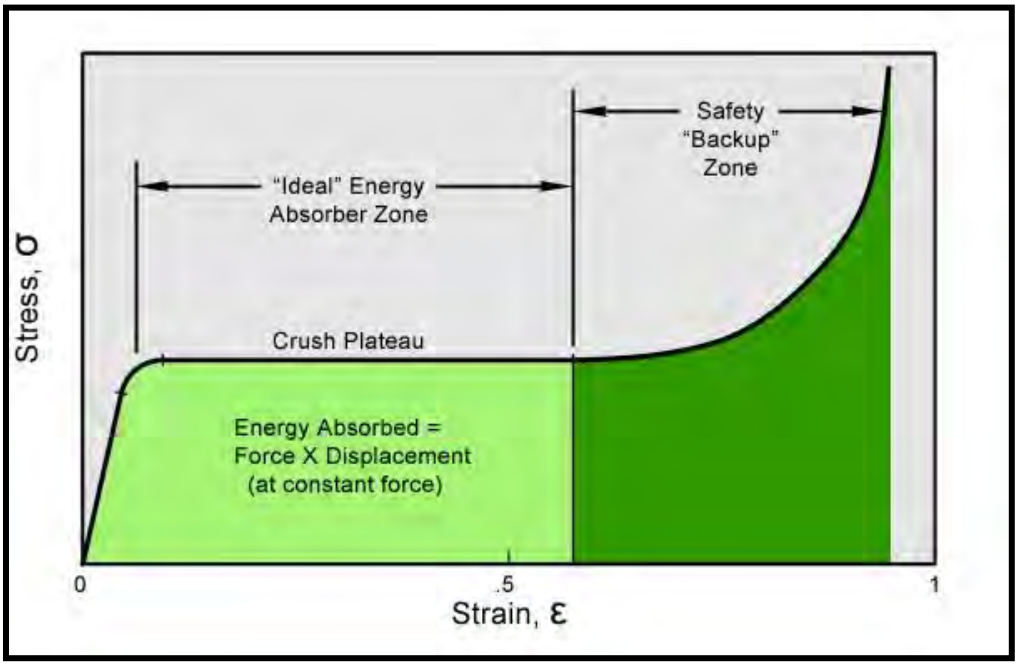

Figure 2.5: Graph of stress versus strain [3]

Once an applied stress exceeds the crush plateau, foam will begin to compress at a fairly constant stress out to about 50-70% of strain. This extended section of the stress / strain curve defines the behaviour of an ideal energy absorber. In this zone, the area under the curve represents the product of stress × strain, or "work". In an actual foam block of finite size this would be represented as:

Force × Displacement

Recognizing that

$$\text{Force (N)} \times \text{Displacement (m)} = \text{Work (Nm)} \quad (2)$$

and

$$\text{Work (Nm)} = \text{kinetic energy (Nm)} \quad (3)$$

It can be seen that the work that is done by compressing a foam block is equivalent to the kinetic energy of a mass that might impact that block. If properly designed with appropriate thickness and compression strength, a foam block could absorb all of the energy of an impacting mass. Most importantly, the structure the foam block was attached to (and protecting) would never see a force higher than the foam crush strength. Thus, by absorbing the energy of the impacting mass over a controlled distance with a constant force, the protected structure would not have to endure a concentrated high-energy / high force impact that would occur if the mass impacted the structure directly, with potentially catastrophic results.

This is the theory behind extended automobile bumpers that stroke with a fixed force under impact load to eliminate or minimized damage to the vehicle and its occupants.

While the first half of the foam stress / strain curve is the section generally used in the design of any foam energy absorber, the second half, or safety "back-up" zone section represents a special energy absorption reserve. When designing energy absorbers, you have to proceed with the best data available. If the situation is critical enough to need an energy absorber in the first place, it is also prudent to provide some form of reserve capacity in the event the impact loads are not fully known, and could be significantly exceeded. By using the increasing stress / strain curve in the densification section, this allows unexpected energy to be absorbed with an increasing resistance. The payload being protected might experience higher than normal loading and minor damage in this case. However, it is less than would be