UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EVALUATION OF NON-STOCHASTIC LATTICE STRUCTURES ON DROP TEST APPLICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

by

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I hereby, declared this report entitled “The Evaluation of Non-Stochastic Cellular lattice structure on drop test application” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The members of the supervisory committee are as follow:

………………………………
(Principal Supervisor)

………………………………
(Co-Supervisor)

DEDICATION

Especially dedicated to my beloved parents, family and supervisor,

and all my friends who have encouraged guided and inspired me throughout my journey of education.

Also inspired those who involved and not involved in completing this project report

ABSTRACT

This project is intended to create design and analysis of non-stochastic lattice cellular structure on the drop test application. The objective of this study is to design three types of non-stochastic cellular structures for drop test application, to identify the mechanical properties of different cell structures for drop test application and to determine the suitable structural arrangement of the cell structure in impact energy absorbers. This project will focus primarily on the design and analysis of three types of non-stochastic cellular structures which are rhombic dodecahedral, hexagonal and octahedral. The outcome of this study in terms of drop test application and the most suitable cell structure that can withstand the drop test analysis that the product being drop at certain height in normal gravity. This project started by generating a design concept in CAD Software. The finite element analysis which is drop test analysis using SOLIDWORKS are the analysis that be chosen to analyze the toughness of the three types of cell structures. The parameter had been set up to implement in the analysis of the three types of non-stochastic cellular structures. The honeycomb structure has been divided into three different dimensions which are 1 mm pore size, 3 mm pore size and also 5 mm pore size. Based on the findings, both materials; Aluminium 3003-H18 and hybrid material shows that hybrid material (combination of EPS Foam and Aluminium honeycomb) has toughness structure when it undergo the drop test analysis in Solidworks. Furthermore, the octahedral 3 mm pore size using hybrid material is the safe structure to implement in the inner liner of the helmet after factor of safety was calculated. This is because, the structure pass the factor of safety after undergoing the drop test analysis.

ABSTRAK

Projek ini bertujuan untuk menghasilkan rekaan dan analisis untuk “non-stochastic cellular structure” untuk diaplikasikan ke dalam aplikasi ujian kejatuhan. Objektif kajian ini adalah untuk menghasilkan rekaan tiga jenis “non-stochastic cellular structures” untuk aplikasi ujian kejatuhan, untuk mengenal pasti ciri-ciri mekanikal bagi struktur sel yang berbeza mengikut aplikasi dan untuk mengenalpasti struktur yang sesuai untuk sel . Kajian ini memberi fokus kepada reka bentuk dan analisis tiga jenis struktur iaitu “rhombic dodecahedral, hexagonal and octahedral”. Hasil dari kajian ini adalah dalam bentuk impak tinggi untuk impak penyerap tenaga dan mencari struktur yang paling sesuai untuk menguji daya ketahanan adalam bentuk “drop test analysis”. Kajian ini dimulakan dengan menghasilkan rekabentuk menggunakan konsep “CAD software”. “Finite element analysis” adalah analisis menggunakan produk yang dijatuhkan dalam ketinggian tertentu menggunakan “SOLIDWORKS software”. Ia dipilih bagi menguji daya ketahanan struktur bagi tiga jenis tersebut. Parameter telah disusun untuk analisis tersebut. Struktur ini telah terbahagi kepada tiga iaitu “1 mm pore size, 3 mm pore size dan also 5 mm pore size”. Selular struktur yang paling baik akan dipilih sebagai rekabentuk untuk diadaptasi di dalam helmet. Keputusan ini didapati daripada dua bahan iaitu “Aluminium 300-H18 dan bahan hybrid”.. Akhir kajian ini, octahedral bersaiz 3mm dipilih sebagai struktur yang selamat kerana telah melepasi faktor keselamatan.

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Bismillahirrahmanirrahim,

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Firstly, thanks to Allah S.W.T who give me the strength and opportunity to complete my final year project. The most special thanks to my supervisor, Encik Hazman Bin Hasib who had guided me a lot to complete a task during these projects period. Besides, the final year project make me realized the value of working and experience in project writing and the analysis.

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Thank you.

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Al	-	Aluminium
TiH_2	-	Hydride
PP	-	Polypropylene
PVC	-	Polyvinyl Chloride
PUR	-	Polyurethane
FEA	-	Finite Element Analysis
BSI	-	British Standard Instruction
EPS	-	Expanded Polystyrene
HIC	-	Head Injury Criterion
3D	-	Three Dimension
N/mm^ 2	-	Newton per millimeter square
Kg/m^3	-	Kilogram per meter cube
N/m^ 2	-	Newton per meter square
N	-	Newton
Kg	-	kilogram
m^3	-	meter per cube
MPa	-	mega Pascal
mm	-	millimetre
FoS	-	Factor of Safety
PE	-	Potential Energy
M	-	mass
G	-	Gravity
H	-	Height
J	-	Joules

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CHAPTER 1
INTRODUCTION

The first chapter discusses about the introduction of the application of Non-stochastic cellular structures on impact energy absorbers. In this part, the briefing of the background, problem statement, objectives, scope and the expectation of the study are discussed

1.1 Project Background

Cellular structure or (metal foams) contain solid metal commonly aluminium (Al), Aluminium Alloys or Nickel. The selection of material is done to improve the better quality of the foamed material. Powder metallurgical called Fraunhofer process producing metal foam. A different kind of cellular structure can be obtained. It can be categorized based on the arrangement of empty space and the architecture of the space. It also can be divided by two which are open foam cell (sponges) and closed foam cell (foams). In the open foam cell, every connected pore can be sealed whereas, in a closed foam cell can form an interconnected network (Banhart, 2001). Many applications can be applied based on the lightweight construction. The compression of aluminium foams has been examined about 20 years ago. Figure 1.1 shows that aluminium foam from various aluminium alloys.

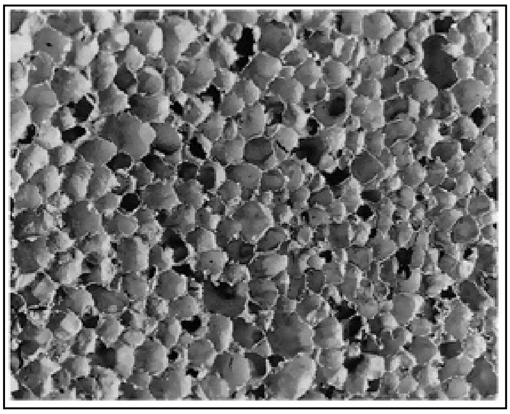

Figure 1. 1: Pore structure of an aluminium foam of different aluminium alloys

(Simancik *et al*., 2000)

There are some potential applications of metal forms (Ashby *et al*., 2003). There is:

a) Lightweight structures
b) Sandwich Cores
c) Strain Isolation
d) Mechanical Damping
e) Vibration Control
f) Acoustic Absorption
g) Filters

In general, stochastic or non- stochastic geometries can be distinguished as cellular metal structures. Open or closed cell structures have in stochastic foams, whereas repetition lattice structures have in non-stochastic foams. Other than that, stochastic structures have random variation in the size and shape of the cells. Every imperfections based on loading deformation can cause localized deformations (Cansizoglu *et al*., 2008). Figure 1.2 shows that stochastic and non-stochastic foam at its own shape.

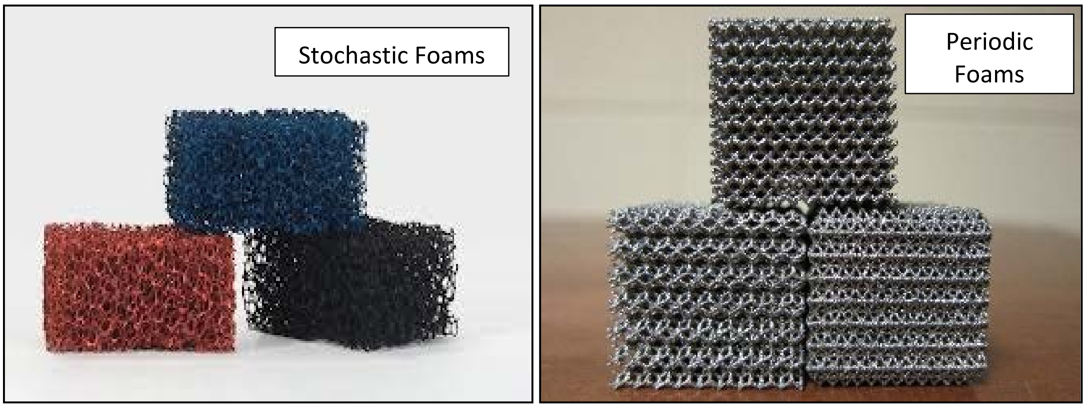

Figure 1. 2: Stochastic foam and Non-stochastic (periodic) foam (Hazman, 2011)

For non-stochastic open-cell structures, it can give better mechanical properties in evaluation to stochastic foams. Several processes can be used to manufacture non-stochastic open cell structures. As for the manufacturing methods, many approaches are being developed. It will lead to size of each cell of the material and variability in cell size (stochastic or periodic), the relative density of the structure and the pore type of open and closed cellular structures (Cansizoglu *et al*., 2008). Figure 1.3 shows the process of powdered metal foaming using blowing agent.

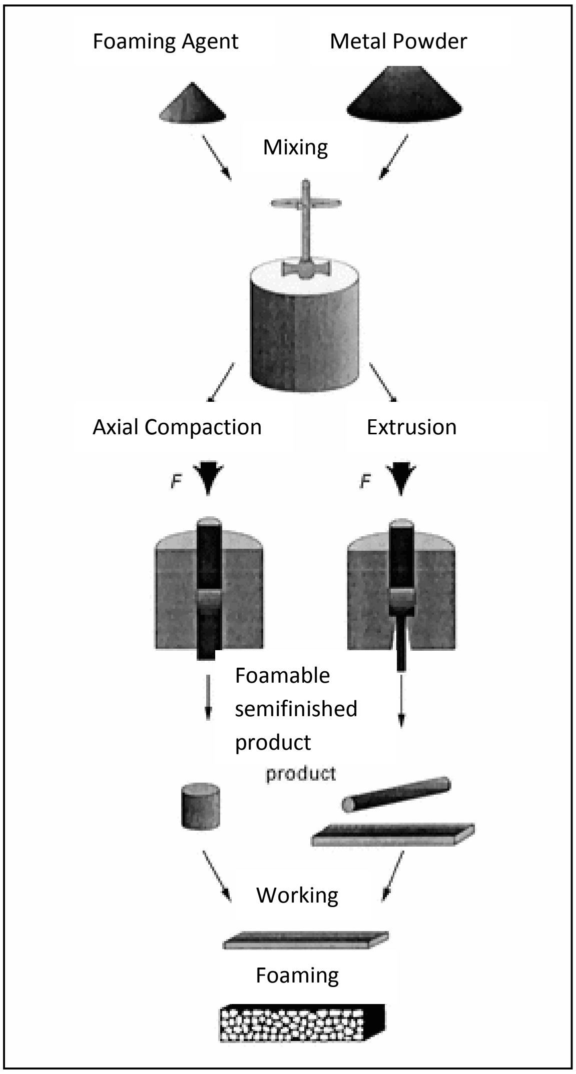

Figure 1. 3: Powdered metal foaming with a blowing agent (Srivastava and Sahoo, 2007)

Several processes can be done to produce metal foams and one of them is foaming process. To produces closed-cell stochastic foams are by mixing a foaming agent into the metal alloys and the function is to release the gas when heated. The foaming agent that is broadly used is titanium hydride (TiH_2) and it will begin to decay at temperature 465 ℃ when heated. Through that, titanium hydride is adding to the melting aluminium because large volumes of hydrogen gas can be obtained (Srivastava and Sahoo, 2007).

1.2 Foaming Process

The foaming process of a liquid metal is also one of the manufacturing methods. It can be done either by injecting a gas (the CYMAT process) or by the decomposition of gas releasing particles. For making stochastic cellular aluminium, the decomposition of gas releasing particles using Alporus or Alulight materials is broadly used.

Table 1. 1: Classification of stochastic and periodic cellular metal (Wadley, 2002)

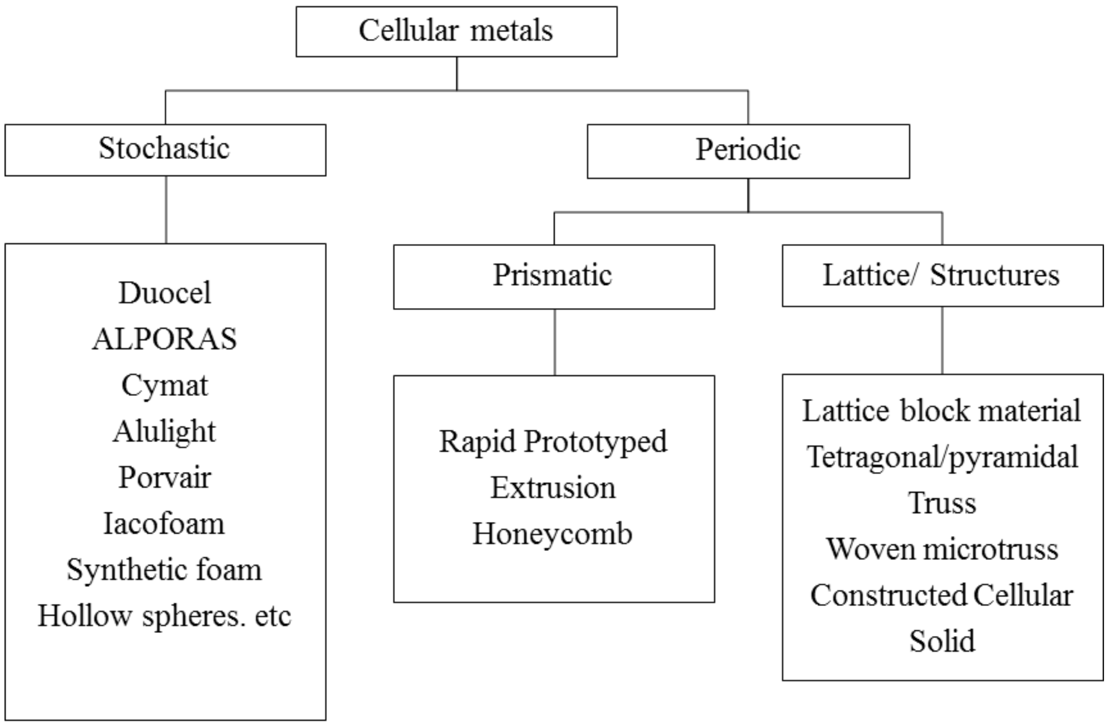

Table 1.1 shows the classification of stochastic and periodic materials. Those materials are not a single unit cell and it is known as stochastic foams. For the periodic materials, it is divided by two which are prismatic and lattice or truss. For prismatic, the cell is translated into three dimensions in the periodic materials which are rapid prototyped, extrusions and honeycomb. The lattice/ truss have tetragonal or pyramidal in shape. Also have lattice block material, truss, woven micro truss, constructed cellular and solid (Wadley, 2002).

In the field of energy absorption, substantial growth already been made. Many techniques or devices been built to reduce the unwanted energy at the metallic foams, or honeycomb structures (Lupoi, 2008). The absorber is a material that absorbs radiation that causes it to lose energy. The energy absorber is like a panel to dampen spring rebound. It is done by expanding work force a fluid through port and hence will change it to mechanical energy to heat. It also is a material to dissolve impact energy such as bumper of car, protective helmet, mount guards, ballistic vest also road metal divider.

For the body protection, energy absorber in the ballistic vest is very vital because it uses to stop the bullet from penetrating to human. Basically, ballistic vest or armor uses only a single material from high hardness steel. But today, it produces by ceramic and composite that has low densities, high hardness and high rigidity.

On the other hand, head protection such as the protective helmet also designed to withstand the impact energy from outside. It commonly uses polyurethane or PVC as the main material from outside impact (Lupoi, 2008). Figure 1.4 and Figure 1.5 show an example of a product that implements stochastic cellular structures.

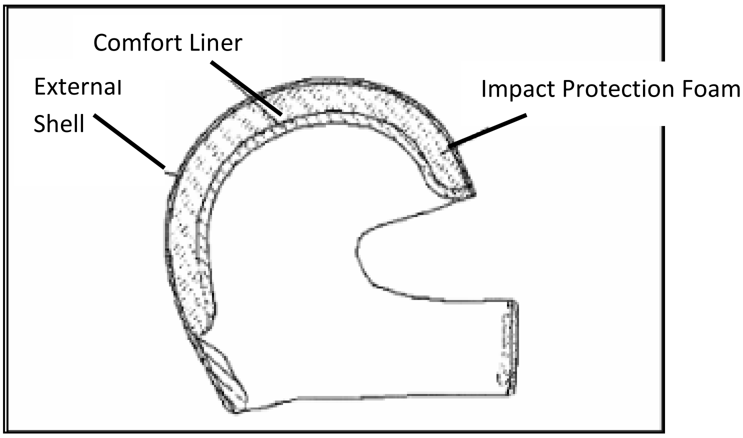

Figure 1. 4: Typical helmet design (Lupoi, 2008)

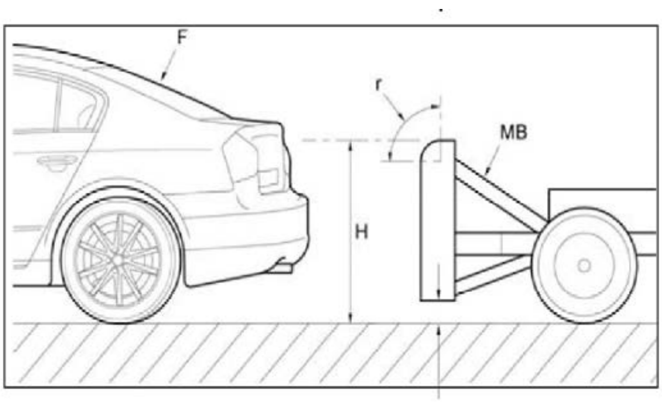

Figure 1. 5: Bumper of car that applied impact of energy absorber (Duffy, 2004)

1.3 Problem Statement

Based on this study, there are several significant problems regarding the current issues on the impact energy absorber. One of the challenges faced by designers is to create an energy absorber that could absorb the maximum amount of energy within a minimum amount of space. In the industry, the drop test application is investigated to find the most appropriate type of cellular structure. The structure must greatly reduce the risk of structural damage to withstand the impact and crashes. The current trend is to produce lighter structures and the aspect of designing the structures become critical as the weight has to be reduced. The design must meet the requirements of low densities, high rigidity and high hardness to applied in liner of helmet.

1.4 Objective of the project

The objectives of this project are:

a) To design three types of different non-stochastic cellular for drop test analysis.
b) To identify the mechanical properties of different cell structures for drop test analysis through simulation.
c) To determine the suitable structural arrangement of the cell structure in drop test analysis focusing on inner liner helmet.

1.5 Scope of the project

The study only utilizes three types of non-stochastic cellular structures namely hexagonal lattice, rhombic dodecahedral and octahedral honeycomb. The pore size is 5 mm based on three types of each of the non-stochastic cellular structures. Hence, only the simulation in drop test will be covered in the study. No experiments will be done. The outcome of the study will be in terms of high impact loading on the energy absorber, the most suitable cell structure based on requirements and the toughness of the design in cell structure to withstand through drop test analysis. The impact of energy absorber only focuses on a cellular structure of the hexagonal lattice, rhombic dodecahedral and octahedral honeycomb.

1.6 Summary

This project is about the application of non-stochastic cellular structure on the impact energy absorber. This chapter mention about the problem encountered, objective of the project and the scope of works. Next chapter will review all the information regarding this project. The review process is based on the research from books, journal, websites about the non-stochastic cellular structures, design of three specimens, analysis using SOLIDWORKS sofware and the design selection.