SUPERVISOR DECLARATION

"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 Structures)"

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ANALYTICAL STUDY ON CONTROL OF BUCKLING LOBE ONSET FOR HOLLOW CIRCULAR TUBE UNDER AXIAL IMPACT

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A report submitted in partial fulfillment of

the requirements for the award of the degree of

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"I hereby declared that this report entitled "Analytical Study on Control of Buckling Lobe Onset for Hollow Circular Tube under Axial Loading" is written all by me and it is my own effort except the summary and each quotation that I have mentioned their resources"

Signature : …….

Name of Candidate : DZULHUSNI BIN OTHMAN

Date : …….

To my beloved father and mother

Othman bin Awang Kechil and Shamsiah binti Abdul Latiff

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

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ABSTRACT

Nowadays, the thin-walled tubular structures are commonly used as the strengthening members of a car's body in automotive industry. In car's body, the strengthening members are the most critical and important parts because it can protect the car's users from suffering the bad injury during accident by absorbing the impact energy that arises during the collision. In order to control the deformation of the solid structure due to impact energy, the solid mass is attached to that structure. The buckling lobe is expected to be occurring at the position where the solid mass is attached. This is due to the inertia forces that causes the bending deformation occur due to a great velocity change during collision at the solid mass attached area. Thus, the deformation of the solid structures can be control. This project will focus on the analytical study on control of buckling lobe onset for hollow circular tube under axial impact. The hollow cylindrical tube is used in this project and the solid mass that use the material of steel SS400 is attached to it. The aluminum A6063-T6 is used as a material of hollow cylindrical tube because it is used widely in automotive industry to replace the steel. The analysis of the deformation of the hollow cylindrical tube will be carry on by using the ABAQUS analysis software. The main focus of the analysis is to compare the deformation pattern result between the hollow cylindrical tube that attached with solid mass and without solid mass attachment. At the end of the project, the analysis result shows that the first buckling lobe onset is occur at the location where the solid mass is attached. The velocity of the impact also affect the deformation pattern of the hollow cylindrical tube where high velocity of the impact will bring large deformation to the hollow cylindrical tube compared to the small impact velocity. Finally, this project show that the deformation of the aluminum A6063-T6 hollow cylindrical tube structure can be controlled and predicted and further study need to be to this mechanism before it can be applied in real world especially in automotive and construction sectors.

ABSTRAK

Pada masa kini, struktur bererongga yang mempunyai dinding nipis kebiasaanya telah digunakan sebagai penguat rangka kereta dalam industri automotif. Pada rangka kereta, penguat rangka kereta merupakan komponen yang paling kritikal dan penting kerana ia dapat melindungi pengguna kereta daripada menanggung kecederaan yang serius sewaktu kereta mengalami pelanggaran dengan menyerap tenaga hentaman yang timbul sewaktu perlanggaran tersebut. Dalam usaha untuk mengawal pencacatan struktur pepejal disebabkan tenaga hentaman, jisim padat disangkut pada struktur berkenaan. Lobus pembengkokan pertama dijangka berlaku pada kawasan di mana jisim padat diletakkan. Ini adalah disebabkan daya inersia yang menyebabkan pencacatan lengkungan berlaku disebabkan perubahan kelajuan yang sangat besar di kawasan jisim padat disangkut sewaktu perlanggaran. Oleh itu pencacatan struktur pepejal boleh dikawal. Projek ini akan member fokus kepada pembelajaran analitikal untuk mengawal pembentukan lobus pembengkokan untuk tiub silinder yang berongga apabila hentaman berlaku pada paksi lurus. Tiub silinder berongga digunakan dalam projek ini dan jisim padat yang diperbuat daripada besi SS400 disangkut pada silinder tersebut. Aluminium A6063-T6 digunakan sebagai bahan untuk tiub silinder berongga kerana ia digunakan secara meluas dalam industri automotif menggantikan besi. Analisa kecacatan pada tiub silinder berongga dijalankan dengan menggunakan perisian analisa ABAQUS. Fokus utama analisa adalah untuk membandingkan keputusan corak kecacatan di antara tiub silinder berongga yang disangkut dengan jisim padat dan tiub yang tidak disangkut. Di akhir projek, keputusan analisis menunjukka lobus pembengkokan pertama berlaku di lokasi di mana jisim padat diletakkan. Kelajuan hentaman juga memberi kesan kepada corak kecacatan pada tiub silinder di mana kelajuan yang tinggi memberi kecacatan yang besar berbanding kelajuan yang perlahan. Akhirnya, projek ini menunjukkan bahawa kecacatan pada struktur tiub silinder boleh dikawal dan dijangka.

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w	=	width of square tube
ρ	=	density
l	=	length of square tube
a	=	acceleration at solid mass
x	=	distance
P	=	force push the wall
Q	=	force acts along the wall
E	=	Young Modulus
V	=	Poisson ratio
σ	=	yield stress
n	=	exponent
C	=	multiplier
d0	=	outer diameter
di	=	internal diameter
t	=	thickness

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter will cover on the objective of the project, the problem statement, and the project scope. Furthermore, the information of the project will be stated clearly to enhance the understanding as a method to achieve the project goal. In this research, the focus is given on investigating the deformation of hollow circular tube subjected to the axial impact.

1.1 Problem Statement

Nowadays, in car manufacturing industry, the vehicle body is properly designed to absorb the impact energy efficiently during the collision. The vehicle body must be built properly using the proper designs and materials to ensure that the life of the vehicle users is protected. The two main factors that need to be focus when designing the car body are the safety factor and the environmental factor. In terms of safety factor, the structure of the vehicle body must have the capability to control the buckling during the collision. For example, the car body can be set to deform at the frontal part only so that the car's users life can be protected.

To enhance the capability of the vehicle body to absorb the impact energy during the collision and save the life of the vehicle users, the well strengthening member of the car body need to be designed and built. One of the methods is to attach the solid mass at the structure to control the deformation of the structure.

In terms of environmental factor, the car's body must have lighter weight and build by the material that can be recycled. The lighter weight of a car's body can help reducing the raw material usage and thus can save the energy used in moving cars. Thus, the production of the green house gases can be reduced. This gas is known as Carbon Dioxide (CO_2). In Malaysia, the air pollution is the main environmental problem that is yet to be totally solved. The bus and lorry is the main vehicles that produce a lot of CO_2 gases. If the car's body weight is heavy, then, a lot of the energy is needed to move the car. So, the selection of the material needed to build the car's body is also important in term of safety factor and environmental factor.

The three important criteria that are used to select the material of the car's body are the strength of the material, the weight, and the recycle capabilities. Therefore, the aluminum material is widely used in automotive industry to replace the steel because it is not only give the lighter weight to the car's body but can also efficiently absorb the impact energy well.

1.2 Objectives

1.2.1 To investigate whether buckling process of the hollow cylindrical tube can be controlled or not

1.2.2 To design numerical model by using FEM or ABAQUS in order to control the deformation of the hollow circular tube when the axial impact is applied.

1.3 Scope

The scope of the project will mainly focus on:

1.3.1 Literature review on buckling mechanism and method to control buckling

1.3.2 Design numerical model and conduct numerical analysis on controlling the deformation of hollow cylinder tube when the solid mass is attached

1.3.3 Investigate and conclude the mechanism of deformation of hollow circular tube

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will cover on the overview of the project which consists of the buckling mechanism of cylindrical shells under axial impact, the inertia force theory, and the material selection. Besides that, this project will review about the characteristics of the aluminum alloy in terms of its deformation pattern, strength, and its performance behavior. Furthermore, this chapter will also cover the deformation control using the solid mass attached.

2.2 Buckling Mechanism

In the structure analysis, the buckling mechanism is the critical part that must be exactly determined by the designers and engineers. The buckling of the structure must be properly controlled to avoid failure in the structure when the load or force is applied to the structure.

According to the (Xinsheng, X et al. 2009), the buckling mechanism of the cylindrical shells under axial impact are divide into two categories which are the short-wave buckling and the long-wave buckling. The short-wave buckling is also known as dynamic local buckling and the long-wave buckling is known as global buckling.

Wang (2002) stated that the axisymmetric and non-axisymmetric buckling mechanism will depend on the axial impact velocity and the cylindrical shells thickness. Cylindrical shells that have very thin walls are easy to bulk when the axial compressive loads are subjected to the structure. Mandra and Mazzolani (1997) stated that the cylindrical shells are very sensitive to initial geometric imperfections.

2.3 Aluminum Alloy tube used in car body

The movement towards using light weight vehicles body represents a significant engineering challenge to the design and manufacturing sectors of the automotive industry. Nowadays, the automotive industry needs to consider aluminum alloy as a potential replacements for low-strength steel structural components. The change of the material used to replace the steel must not risk the structural integrity of the parts or sacrifice the energy absorption characteristics of the vehicle in a collision event. (Dong, K. et al. 1998)

Several automotive parts are being fabricated from the tube-stock and undergo various stages of forming that can consume a considerably degree of material ductility. According to the Oliveira and Michael (2005), the two main types of energy absorption structures used in automobiles are axial crush and s-rail structures. S-rails are used in side-rail support frames and may be stamped from sheet metal and welded together or fabricated from the tube stock using a pre-bending and hydro-forming operation. (Dong, K. et al.1998)

Bouchet and Jacquelin (2002), review about the value of impact force and the acceleration that must not exceed a certain impulse span. The objective is to reduce the disparities between the initial and the final level of deceleration and force by increasing the energy absorption capacities within the free crushing space available in the vehicle front part. Thus, the damage of the people and the structure can be minimized.

During a collision, the longitudinal girders are the one of the most important components for absorbing the energy. (Dong, K. et al. 1998)

Tubes based on steel and aluminum alloys collapse by plastic buckling in a concertina or diamond mode with the formation of a series of progressive plastic folds absorbing typically in range of 15 to 30kJ/kg in energy.

Wang (2002) state that the development of body parts and structural elements based on the aluminum alloy can cause some problems in the case of external stresses due to the shock or impact besides extreme environmental conditions. (Dong, K. et al. 1998)

The type of aluminum alloy that used in designing the car body space frame is an A6063 alloy. The aluminum A6063 alloy are the major precipitation strengthening alloys and have the merit of high extrusion efficiency compared with the other types of aluminum alloy. The behavior of the aluminum A6063 alloy used in the car body has been analyzed.

2.4 Aluminum A6063 Alloy used in car body Space Frame

Instead of replacement of the use of the steels with the aluminum alloys in saving the weight of a vehicle body, space frame has recently been developed and is use widely in designing the structure of a car body. The space frame use the aluminum alloys extruded in the form of thin tube that has the dimension approximately within 1 to 3 millimeters thickness with the same width, and complicated geometry to carry the load.