UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN ANALYSIS OF A CIRCULAR ALUMINUM CRASHBOX FOR A FRONTAL ACCIDENT PROTECTION

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

by

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DECLARATION

I hereby, declared thus report entitled “Design analysis of circular aluminium crash-box for frontal accident protection” is the results of my own research except as cited in reference.

Signature : …………………………………

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Date : 22th June 2017

APPROVAL

This report is summited to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Design Manufacturing) (Hons.). The members of the supervisory committee are as follow:

…………………………………

(Principle Supervisor) - Signature & Stamp

ABSTRAK

Kotak kemalangan mempunyai fungsi menyerap tenaga semasa kemalangan perlanggaran di hadapan. Ia direka untuk menjadi komponen struktur perlindungan penghuni semasa pelanggaran depan atau belakang. Ciri-ciri perlindungan kemalangan adalah faktor penting untuk mengelakkan daripada kecederaan tinggi kepada penumpang jika ia dibina dari bahan terbaik kerana boleh menyerap banyak tenaga semasa kemalangan. Walau bagaimanapun, ia terdapat bentuk yang berbeza seperti segi empat tepat dan bulat yang berbeza luas keratan dan bahan yang boleh digunakan seperti dengan menggunakan aluminium atau keluli. Kemudian, semua kriteria mempunyai momentum serta jumlah penyerapan tenaga berbeza bergantung kepada dimensi, panjang, lebar, ketebalan dan bahan yang digunakan. Tujuan projek ini adalah untuk mereka bentuk dan menganalisis kotak silinder aluminum untuk sistem perlindungan kemalangan hadapan kereta. Analisis keadaan kemalangan kereta dilakukan dengan menggunakan perisian ANSYS sebagai penyelesaian dan dengan mengikut analisis yang bersesuaian dengan kotak kemalangan perlindungan kemalangan.

Fokus utama kajian ini adalah untuk mereka bentuk dan membuat analisis pada kotak kemalangan dengan menggunakan perisian ANSYS. Untuk mengira penyerapan tenaga maksimum pada kotak kemalangan tersebut, pengoptimuman ke kotak kemalangan itu telah dilakukan secara manual. Empat jenis kotak kemalangan dengan diameter 50mm, 60mm, 70mm dan 80mm direka bentuk serta menjalani analisis simulasi menggunakan perisian yang sama untuk mendapatkan tenaga kinetik maka penyerapan tenaga maksimum boleh dikira dan dibandingkan. Dari hasil, tenaga penyerapan dengan meningkatkan diameter kotak kemalangan yang nilai 50mm, 60mm, 70mm dan 80mm adalah 9965J, 12123J, 13059J dan 14555J. Oleh itu, dengan meningkatkan diameter kotak kemalangan, tenaga yang banyak lagi boleh diserap,justeru penumpang boleh mengelakkan daripada kecederaan maut.

ABSTRACT

Crash box has function to absorb energy resulted of the crash during frontal collision. It typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. Crash protection features is an important factor to have high injury protection to the passenger if it was built from the best material which can absorb more energy during accident happen. However, crash box has different type of shape such as rectangular and circular, different cross sectional area and material that can be used like by using aluminium or steel. Then, all of that criteria had different momentum of impact and different amount of energy absorption depending on the dimension, length, width, thickness of material and loading condition used. The aim of this project is to design and analysis of a Circular Aluminium Crash box for Frontal Accident Protection system of car. An analysis of a car ordinary crash situation is performed by use of ANSYS software as a solver and with following analysis related to the accident protection crash box.

The main focus of this study is to design and do analysis on the crash box by using ANSYS software. In order to calculate maximum energy absorption to the crash box, optimization to the crash box was done manually. Four types of crash box with different diameter of 50mm, 60mm,70mm and 80mm was design and undergoes the same simulation analysis by using the same software to get the kinetic energy then the energy absorption can be calculated and compared to get the maximum energy absorption. From the result, energy absorption increase by increasing the diameter of the crash box which the value of 50mm, 60mm, 70mm and 80mm are 9965J, 12123J, 13059J and 14555J. Thus, by increasing the diameter of crash box, the more energy can be absorb so, passenger can be prevent from fatal injury.

DEDICATION

For my beloved family member

my beloved father, Mohd Isa bin Jaafar

my appreciated mother, Aidah bt. Yusop

my adored sisters Fatin Amira and Fatin Adillah

To my supervisor, Mr. Wahyono Sapto Widodo (Pak Sapto)

For giving me moral support, cooperation, encouragement and also understanding along this project.

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LIST OF ABBREVIATIONS

CAD	-	Computer-Aided Design
CAM	-	Computer- Aided Manufacturing
IIHS	-	Insurance Institute for Highway Safety
ANCAP	-	Australasian New Car Assessment Program
Euro NCAP	-	The European New Car Assessment Programme
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
IGES	-	Initial Graphic Exchange Specification.

LIST OF SYMBOLS

mm	-	Millimetres
J	-	Joules
mJ	-	Millijoules
v	-	Velocity
kg	-	Kilogram
m/s	-	Meter per second
N.m	-	Newton meter
E	-	Energy
N	-	Newton
km/h	-	Kilometre per hour
MPa	-	Mega Pascal
F	-	Force

CHAPTER 1

INTRODUCTION

1.1 Project's Background

Car frontal protection systems can be categorised as original equipment or as separate technical units. It has function to absorb energy resulted of the crash during frontal collision. Crash box will be deform by absorb impact energy before strike another vehicle parts such as frame and cabin to ensure the overall integrity of chassis to make sure that the passenger will safe. The thin walled structure had been used widely as a car frontal protection due to the characteristics of it which can absorb more energy during impact. This part can be designed to minimise the damage of the vehicle by absorbing the maximum kinetic energy that it can at the same time can protect the occupant from the injury during accident happen. In addition, the effectiveness to a minimum the injury by optimum their shapes used. Square and rectangle tube have lower specific energy absorption compared to the circular tube which can be minimized crash energy on the car. They are various factors about energy absorption need to be aware during designing the crash box such as friction, fracture, torsion, plastic deformation and shear. For example, in past decades, Alexander who is first derived an analytical solution to calculate axial mean crushing force for circular tubes of aluminium metal conducted the new experiment to determined crash behaviour of the thin walled.

The basic concepts of vehicle safety, design and the evolution of body structures, a theoretical background and finite element modelling methods of the vehicle body design technology, analytical methods of determining occupant motion and some biomechanics issues of human injury are covered. In general, the crash box needs to be stiff, so it can produce higher stiffness which can produce small deformation. Moreover, one of the property moment of inertia is the high capability to absorb energy during a collision.

Some advantages of using aluminium alloy NL as a frontal protection system model are cost effective, lightweight with high stiffness and excellent potential crash of energy absorption. In addition, to give an optimum protection to the passengers during an accident, a frontal protection system surrounding deformation zones which are an Aluminium where the crash energy can be absorbed.

In order to attain the best of car frontal protection systems, research had been done to organise the parameters which can give the minimum effect to the passenger. In this report, the parameter that will be discussed in detail is energy absorption of aluminium alloy and plastic deformation which is the strength of the material and also the energy of conversation. The behaviour of circular crash box aluminium tubes that undergoes axial compressive loading is studied experimentally and numerically. Thus, the static and dynamic behaviour of circular thin-walled tubes is considered plus impact velocity of tubes and values of the mass are varied (Al Galib et al., 2004).

1.2 Problem Statement

Frontal accident protection had been built from many types of material and shape with different thickness. The thin walled tube was used from aluminium alloy NL as a frontal accident protection crash box due to the various perspective of this material such as can absorb high kinetic energy during impaction this is due to get high the velocity of the axial impact load. Then, this material also is corrosion resistor which is good to recycle. Referring to the crash box, it will optimise for offset collision conditions which are related to standard tests, such as at high speeds, a car suffers substantial damage, but it is important that the occupants do not have the fatal injury. In order to achieve the required crashworthiness of the vehicle, crash box is one of the parts that should be optimally designed in.

The critical part considered in this experimental study is the crash box system that supports bumper beam of a car which will undergo during frontal impact are countless. Accordingly to the Euro NCAP, IIHS, ANCAP standard test, the crash box was designed to improve the collision conditions when the vehicles will hit a wall 40% offset and 64 km/h speed. The occupant will not suffer a serious injury at crucial but the car will incur substantial damage at high speeds. Thus, to achieve the requirement of the vehicle, crash box is one of a part that should be designed optimally. This is because the crashworthiness vehicle depends on the impact of force transferred and the ability of the important parts to absorb energy.

From the literature, Alghamdi (2001) had said that there are many different types of energy absorbing, for example tubular, laminate and honeycomb structures that can be found, materials from different solid metals to plastics also foams which are to absorb the impact energy with several different design possibilities exist. In the current study based on technological and economic reasons simple energy absorbing components made from sheet metal are investigated. In conclusion, the impact loading starts once the high peak of the reaction force is considering then, followed by smaller peaks or more constant level of reaction forces.

1.3 Objective

1) The main objective is to design the different parameters of circular crash box by using CAD software.

2) To do simulation of the crash box by using simulation on ANYSYS software.

3) To analyse and compare the energy absorption of the crash box.

1.4 Scope of Project

This project is focused on the design of the crash box used for car frontal accident by using SolidWorks CAD software and the simulation analysis will be conducted by using ANSYS. The FEA analysis will be performed to validate the result obtained. This project is being given to expose with the writing the report and facing the working environment for the future whenever handling project

1.5 Significant Study

This research study have been provide all the information on the design and analyse crash box to reduce the fatal to the occupant. Further, this study would also review on the crash box present and do an optimisation to get the maximum of energy absorption. This study would be beneficial because to enhance the knowledge about the possible issues of the design of crash box by using an aluminium alloy NL with conducted FEA calculation analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Crash box

Crash box or car frontal protection system was categorised as an original equipment or as separate technical units. This system is used as energy absorption during the crash event with thin walled structures mounted between automotive chassis and bumper. These elements with a benefit of the crashworthy system used to reduce the harshness of accidents due to frontal crash and also play an important role to absorb the maximum of impact energy of the frontal crash box which cause plastic deformation to protect the occupants. From the past study the material of steel and aluminium, both are the most common materials used in automotive due to its strength and the other hand for aluminium is lighter and corrosion resistant. In addition, to give the minimum of impact to the passenger, a crash box is deformed with a benefit of absorbing impact energy before striking another vehicle parts such as frames and cabins to ensure the overall integrity of chassis. Thus, the plastic deformation process must be controlled to absorb as much energy as possible so, the severity of injury could be minimised.

2.1.1 Definition and function of Frontal Accident Protection, Crash box

Crush box is structural areas that are designed with a function to absorb the maximum number of energy as possible upon impact in a predictable way. Crush box which is largely made from metal components is one of the major automotive parts in dissipating the initial crash energy. Once the car crashes, it will function to absorb as much of the impact energy and protect the occupants and this called "controlled crush." In addition, from the result of crash test by National Highway Traffic Safety Administration's New Car Assessment Program (NCAP), it show that by designing vehicle with softer front end structures resulting in larger "maximum crush," so long as there is no intrusion, so it can reduce the injury and fatality of the occupant.

Newton's first law of motion states that an unbalanced force causes the object in motion at a constant speed and at same direction moves. For an example, if the vehicle is going 80km/h, the bodies inside also moves at 80km/h but if the vehicle hits a solid wall and comes to a stop immediately, the bodies still want to continue going in the same direction at 80km/h.

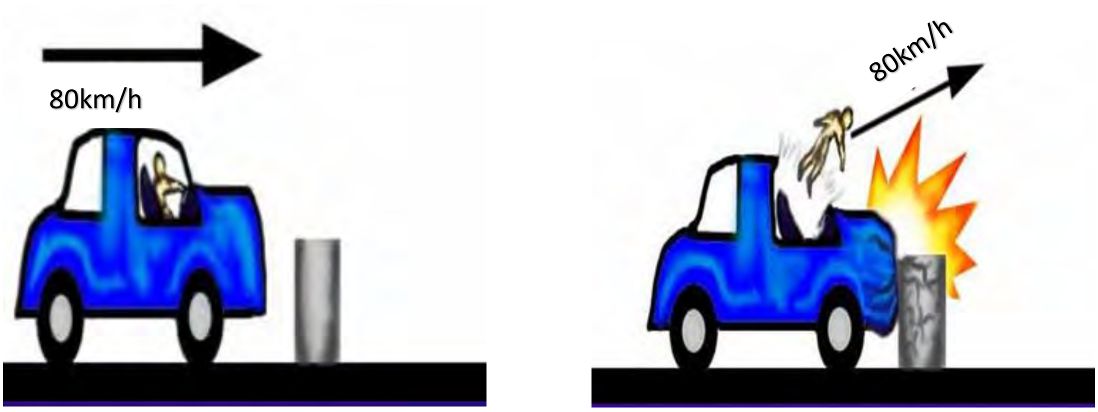

Figure 2.1: Example of car have an accident with velocity 80km/h

Newton's second law of motion is force = mass x acceleration (F=ma), carries that as the time taken for an automobile to come from at rest or change direction is increased, the force experienced by the automobile (and its occupants) is decreased. Conversely too, if the time to stop is shorter, the force experienced is greater. Crash box takes only a few time during a crash to absorb energy.

Referring to the Newton's first law and Newton's second law of motion, passenger will move forward at the same speed even when the car stop when hitting, but the body still move forward that will cause impact, often injury or death. Crash box allows the vehicle to crush by absorb some impact of the collision and give some off in term of heat and sound. Thus, it will take a few times for the vehicle to come and stop completely by applying less force on passengers which possibly will help save their lives.

2.2 Mechanical Properties

Mechanical properties of a material were defined as the properties that involve any reaction after the load was applied. It can be defined by the laws of mechanism that is the science deals with energy and forces and their effect on bodies. The function of mechanical properties are used to help classify and identify the type of material. Strength, impact resistance, ductility, hardness and fracture toughness are most common properties that had been considered. The strength of the part is another concern of this project. Strength is a mechanical property that can be investigated that should be related to any material.

2.2.1 Material Used

In this project, the material used is aluminium alloy NL. Aluminium alloy NL is one of the metals with the benefit of corrosion resistant, can be recycling, lightweight and very good for energy absorption. The circular tube of crash box used for the finite element model that are designed for crashworthiness application in vehicles which are liable to crushing and the kinetic energy released has to be converted to plastic deformation energy. In addition, according to Reyes (2002) using aluminium as a body structure of a vehicle, weight of vehicle can be saving 25% compared with conventional steel structure also fuel consumption can be reduced and carbon dioxide (CO_2) emission can be minimised.

Table 2.1: Different type of material and shape of crash box

No.	Material	Shape of tube	Analysis Method- Quasi-static/Dynamic	Impact Velocity	Thickness of tube (mm)	Width of tube (mm)
1)	Aluminium	Circle	Dynamic	33.825 km/hr.	1.25, 1.5	Side- 50
2)	Aluminium alloy	Square	Dynamic	18.792 to 25.812 km/hr.	1.25	44.3
3)	Aluminium	Square	Quasi-static	80 mm/min	35	1.5
4)	Aluminium alloy	Circle	Quasi-static	5 mm/min	1.3	OD-50.5
5)	Aluminium alloy	Square (Tapered & straight)	Dynamic	36 km/hr.	2	80
6)	Aluminium alloy	Square	Quasi-static	700 mm /hr.	1.9, 2.46	Side-80
7)	Aluminium alloy	Circle	Quasi-static	10 mm/min	0.8, 1, 1.2	ID-30, 39,44
8)	Aluminium alloy	Rectangle	Quasi-static & Dynamic	54 km/hr.	1.5,2,2.5	60 x 100 80 x100 100 x100

The table above represents some of the properties of an aluminium by using the different method to test the material to find the specific energy absorption. In this project, the circular aluminium alloy NL with thickness is 2mm, diameter 50mm, 60mm, 70mm and 80 mm. The length of all type of crash box is constant which is100mm.

2.2.2 Deformation

Deformation is when the sample of material is placed under load. That's mean, the material will changes in shape and possibly also in volume. However, when the load is removed, the deformation instantly and totally goes, the material is elastic. Deformation has the relationship between stress and strain which is often linear. Crash-box has a high strength which is very attractive to use in automotive industry to enhance the energy absorption during impact. To absorb a maximum amount of energy during an accident and to assure the security of passengers by limiting the maximum deceleration level, the structure must deform by a process of collapse and sequential folding during deformation. In this case. If a circular aluminium crash box length,l is loaded by stress σ applied at the top of the circular crash box, the length maybe reduced from actual amount, dl and it can be calculated by using the formula of strain,ε

Strain,ε $$\varepsilon = \frac{dl}{l} = \frac{length\ decrease}{original\ length}$$ Equation 2.1

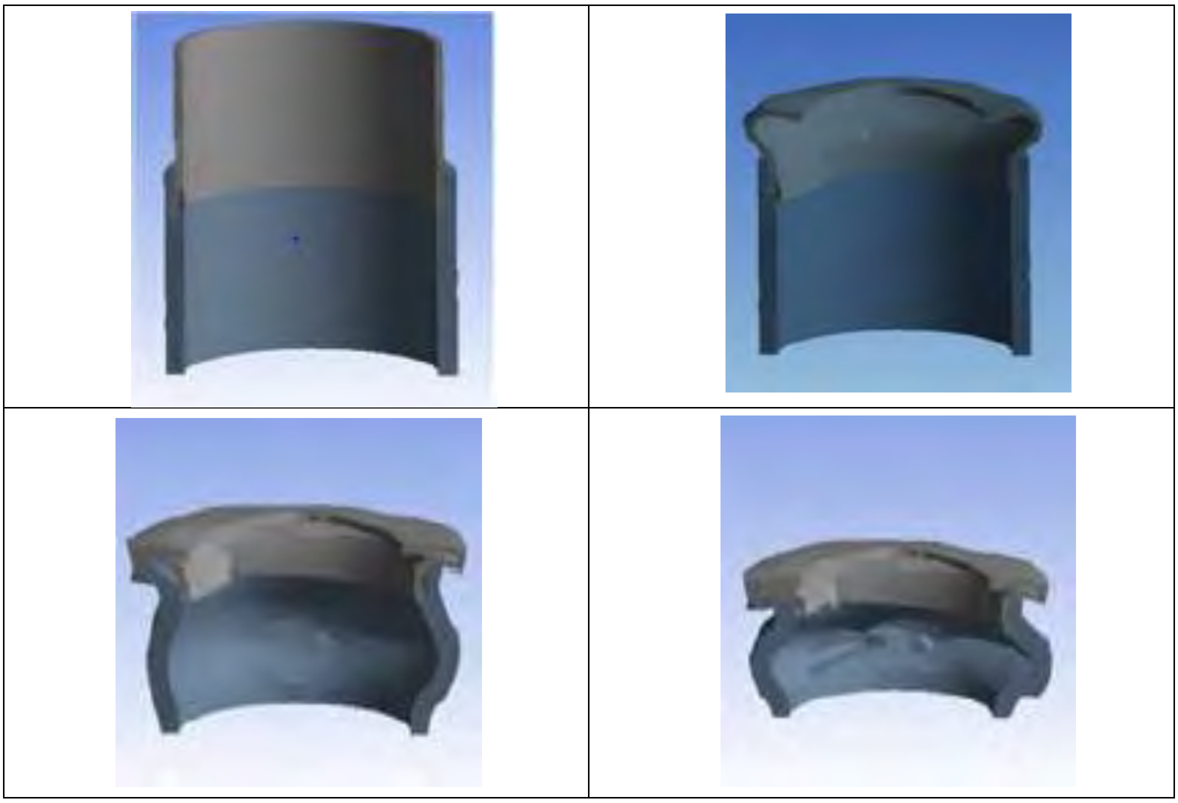

Figure 2.2: Symmetrical deformation process of a circular crash box (Moch.Agus Choiron and Sudjito,2016)

2.3 Johnson Cook- Theory

Johnson-Cook model is a combination of material to develop a model that capturing rate-dependent plasticity and ductile damage, impact development and penetration problems.