# STUDY OF ENERGY ABSORPTION OF BICYCLE SAFETY HELMET

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THIS THESIS IS SUBMITTED AS PARTIAL FULFILMENT OF REQUIREMENTS FOR THE DEGREE OF THE BACHELOR OF MECHANICAL ENGINEERING

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"It is hereby certified that I have read this project paper entitled "Study of Energy Absorption of Bicycle Safety Helmet" by Mohamad Farhan Bin Zulkipli and in our opinion it is satisfactory in terms of scope, quality and presentation as a fulfillment of the requirements for the course Degree of The Bachelor of Mechanical Engineering (Automotive)".

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"I admit that the *Study of Energy Absorption of Bicycle Safety Helmet* is my own work except every statement and passage that I have already mention its source"

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Date : .....

*Dedicate...*

*Sincerely toward,*

*My loving family...*

*My parent and my younger sisters...*

*Helpful and kind Mrs Zakiah; my supervisor...*

*All my friends...*

*Thank You...*

*Everything...*

*Hope that god give bless toward the person above...*

*Ameen...*

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# ABSTRACT

This project is carried out to study about the energy absorption of the bicycle safety helmet during the impact with the rigid wall surface using simulation software. There are several impact positions that are considered in this analysis which are frontal, side and top impact. The different type of impact position will give the different value of energy absorption due to several factors which are the material used, the area of contact, force on loading and so on. The project is carried out by using the ABAQUS/ Explicit 6.8. The existing model of helmet is modeled in the CATIA V5R10 is imported into ABAQUS/ Explicit 6.8 through the IGES file consist of CAD data. The impact simulation of bicycle helmet is simulated and analyzed in the ABAQUS/ Explicit 6.8 to find the energy absorption of the bicycle helmet during impact with the flat rigid wall surface. The result and simulation is then compared with the existing research data. It is found that the top impact gave higher energy absorption compared to front and side impact.

# ABSTRAK

Projek ini dijalankan untuk mendalami tenaga penyerapan oleh topi keselamatan basikal apabila menghentam permukaan dinding tegar dengan menggunakan perisian simulasi. Terdapat beberapa posisi hentaman yang harus dipertimbangkan di dalam kajian ini iaitu hentaman depan, tepi dan atas. Posisi hentaman yang berlainan memberi tenaga penyerapan yang berlainan dan ianya disebabkan oleh beberapa faktor seperti penggunaan bahan, luas kawasan sentuhan dan daya yang bertindak semasa perlanggaran berlaku. Tambahan lagi, projek ini dijalankan dengan menggunakan perisian ABAQUS/ Explicit 6.8. Model topi keselamatan yang telah di lukiskan di dalam CATIA V5R10 akan diserasikan di dalam ABAQUS/ Explicit 6.8 menerusi fail IGES yang mengandungi data CAD. Simulasi hentaman akan dianalisa di dalam ABAQUS/ Explicit 6.8 untuk mencari tenaga penyerapan oleh topi keselamatan basikal apabila menghentam permukaan dinding tegar yang rata. Di dalam projek ini, didapati bahawa tenaga penyerapan oleh hentaman atas adalah yang tertinggi berbanding hentaman tepi dan depan.

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| | | |
|---|---|---|
| A | = | Area of surface contact, $mm^2$ |
| V | = | Velocity, m/s |
| F | = | Force, kN |
| $\upsilon$ | = | Poisson Ratio |
| $\rho$ | = | Density, $kg/m^3$ |
| E | = | Modulus Elasticity, MPa |
| t | = | Thickness of shell, mm |
| R | = | Radius of Curvature, mm |
| $m_{total}$ | = | Mass of helmet and head, kg |
| $\sigma_y$ | = | Yield Stress, MPa |
| $E_a$ | = | Energy Absorption, J |
| $E_k$ | = | Kinetic Energy, J |
| $E_d$ | = | Plastic Dissipation, J |
| T | = | Time, s |
| K | = | Stiffness, kN/mm |

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# CHAPTER I

# INTRODUCTION

## 1.1 Safety Bicycle Helmet Overview

Bicycle safety helmets have been introduced since 250 years ago to protect head of the user. However, many of the bicyclists do not aware of the risk of head injury if they do not wear safety helmet. Adult, teenager and children should wear this head protection to suffer less severe injury if accident happens. The design of the helmet also makes it as a fashion and trend to show an elegant while riding the bicycle beside of the safety factor. The safety bicycle helmet is very significant for the bicyclists to prevent head injury especially toward children which are the future of the country.

## 1.2 Background Of Project

The general function of bicycle safety helmets is to protect the head. However, the actual function of the helmet is to reduce the rate accelerated or decelerated by an impact towards the skull and the brain. Many reports have been published and suggested that 85% head injury will be reducing and 88% brain injury will be reducing if the bicycle user wore a helmet while cycling. One of the reports was published during 1980s by Thompson, Rivara & Thompson [2].

Besides that, the community also do not aware of safety of their toddler whenever the child is riding the bicycle without wearing of safety helmet. The child is more risky to get head injury rather than the older. If the accident happens and the kid does not wear a safety helmet, there is high potential for side effect such as suffering the permanent learning disabilities due to impact. The consequences concentration of the kids during studying will be disrupting always have headaches and so on. Countries like United States of America (USA), Canada, Australia and Europe already have setup their own standard to standardize the bicycle safety helmet that is safe for children and adult. They created the standard after undergoing a certain test as a guideline for the manufacturer to meet the standard before producing the product and manufacture the bicycle helmet.

There are few standards that were very influence in the modern countries such as Canadian Association CAN/CSA D113.2-M89, Consumer Product Safety Commission (CPSC), Standards Australia/Standards New Zealand 2063-1996 and many more. Unfortunately, in Malaysia there is none standard of the bicycle helmet as other modern countries. So far, this is very bad sign to make sure the bicycle helmet that is already in the market is exactly meet the standard and safe for the community.

## 1.3 Problem Statement

A safety helmet is designed to provide protection to the head and comfortable to its user. The helmet that already meets the approved standard have a capability to reduce the impact of a common speed of cycling within 15 kilometres per hour by 90% reduce the energy absorbed by the skull. Unfortunately, the community do not aware and consider the significant of the bicycle helmet was made. Bicycle safety helmet is very important and the study in 1993 on bicycle hazards indicated that the injury toward children who are under age of 15 compared to the adult was over 5 times the risk of the adult [3]. This is because the victim children younger than 15 do not take a precaution and concern about the significant of wear a helmet which is less compared the adult.

There is very few bicyclist wears a bicycle helmet even though there is plentiful of evidence to support that facts. Educational campaigns focusing for different from differ category of primary and secondary up to adult population to promote the significant of the helmet resulted in only moderate increases in usage. There is no important result shown increases in counselling to encourage the community to wear a safety helmet when compared to a control group [4]. The effect to the user, especially children has a negative effect to their future life such as headaches, aggressiveness and so on if they have a small injury on their head once accident without wear a safety bicycle helmet. Besides it will also cause death because of brain injury [5]. Children always have an injury whether they fall from the bicycle or they impinge a static object such as tree, the road divider or they lost control of the bicycle while try to ride the bicycle for the first time. Almost 30% of the accidents involve the underage children who are age below than 15 years and also involve with the head injury especially to the children that is male gender. From overall of the head injury at hospital in Malaysia 1/4 relevance to the head injury cause by bicycle accident [6]. So, this study is carried out to analyze the safety helmet performance that cannot be judged in a store like the impact performance and strap strength and how a safety helmet works when it is subjected to impact.

## 1.4 Objective

The objective of this project is to study the energy absorption of bicycle safety helmet for the children and analyze its impact performance to the riders. In additional, the project also is including how the helmet works when it is subjected to impact.

## 1.5 Scope

The scope of this project is to measure the dimension of a EW-HELMET-10 safety bicycle helmet and modelling the bicycle helmet by using the software like CATIA V5R10. Then, the existing data of drawing is imported into ABAQUS 6.8 to develop Finite Element Model (FEM). The model is analysed by using an explicit finite analysis. From the analysis, the energy absorption of bicycle helmet is analysed.

## 1.6 Project Synopsis

This project is due to the Projek Sarjana Muda (PSM) for the final year student. This project is to study the energy absorption of the bicycle safety helmet. It is very significant whereby most of our community do not care and take seriously the effect of the impact towards the bicycle riders when the accident happens, especially towards the children who are always in a risk if they do not wear a safety helmet to protect their head at least.

In addition, this task is carried out to study the energy absorption to the helmet and analyze its impact performance. In order to fulfil all tasks in this project, the model of helmet in the market is chosen as a guide to draw and model it by using CATIA V5R10. After that, the model of bicycle helmet is simulated by using

ABAQUS 6.8 and all data is collecting as prove. The energy absorb by the helmet is determine by using explicit Finite Element Analysis (FEA). Finally, the result is validated with the established journal.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Introduction

Bicycle fatalities constitute about nearly 4% of road fatalities in Malaysia according to the statistic in 1995 by National Road Safety. Table 2.1 below showed the statistic of accident regarding bicyclist and among other road user in 1995 [7].

Table 2.1: Statistic of National Road Safety in 1995 [7].

| Type | No. Of Casualties | Percentage (%) |
|---|---|---|
| Pedestrian | 3,523 | 7.49 |
| Motorcycle | 31,222 | 66.41 |
| Bicycle | 1,679 | 3.57 |
| Car | 7,372 | 15.68 |
| Van | 824 | 1.75 |
| Bus | 359 | 0.76 |
| Lorry | 1,032 | 2.2 |
| 4 Wheel Drive | 585 | 1.24 |
| Other | 416 | 0.88 |
| Total | 47,012 | 100 |

The majority of casualty of accident is the motorcycle with the 31,222 cases (66.41%) followed by car with 7,372 cases (15.68%), pedestrian with 3,523 cases (7.49%) and bicycle with 1,672 cases (3.57%). In additional, the lorry accident with 1,032 cases (2.2%), van with 824 cases (1.75%), 4 wheel drive with 416 cases (1.24%) and other cases such as off road vehicle with 416 cases (0.88%). As we can see the Table 2.1 the data showed that the bicyclist had a small percentage but actually the majority of the bicyclists are the children.

## 2.2 Data and Statistic in Malaysia

The Table 2.2 and Table 2.3 below shows the statistic of accident involved of death to the all road user in May 2008. The data are from the Jabatan Keselamatan Jalan Raya (JKJR). Table 2.2 show the statistic of accident and the sum of death for 15 days of May 2008. Table 2.3 also shows the statistic of accident and include the overall of statistic accident in May 2008. There are many road users in Malaysia with the different categories which are motorcycle rider, pillion rider, car driver, car passenger, driver and passenger of van, driver and lorry assistant, pedestrian, bicyclist, taxi, driver and bus passenger. Table 2.3 shows clearly the statistic among road user in Malaysia, motorcycle rider is the highest rate of death with 246 cases (54.6%) and 7.9 people died in average a day followed by the car driver and the car passenger with 46 cases (10.2%), pedestrian with 39 cases (8.9%), pillion rider with 28 cases (6.2%), driver and lorry assistant with 17 cases (3.8%), driver and passenger of van with 12 cases (2.7%), bicycle user with 9 cases (2.0%), taxi and bus are both with zero cases in May 2008 [8]. Bicyclist is the minor road user in Malaysia with just 9 cases of death in May. Even though, the statistic show the small percent cases of death for the bicyclist but in the reality the community do not take a serious action even the accident happen. The report has not been log and all cases are closed [8].

Table 2.2: Report of Sum of Death for 15 days in May 2008 According To Different Road User [8].

| Date | 1/5 | 2/5 | 3/5 | 4/5 | 5/5 | 6/5 | 7/5 | 8/5 | 9/5 | 10/5 | 11/5 | 12/5 | 13/5 | 14/5 | 15/5 | Sum of death for 15 days | % | Average of death per day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | |
| motorcycle rider | 9 | 4 | 8 | 12 | 9 | 5 | 6 | 8 | 7 | 11 | 10 | 4 | 8 | 5 | 10 | 116 | 56.6 | 7.7 |
| pillion rider | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 1 | 1 | 0 | 1 | 14 | 6.8 | 0.9 |
| car driver | 2 | 0 | 1 | 1 | 2 | 2 | 0 | 3 | 1 | 2 | 1 | 1 | 0 | 2 | 2 | 20 | 9.8 | 1.3 |
| car passenger | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 0 | 2 | 1 | 2 | 0 | 1 | 1 | 4 | 17 | 8.3 | 1.1 |
| driver and passenger of van | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 6 | 2.9 | 0.4 |
| driver and lorry assistant | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 2.0 | 0.3 |
| pedestrian | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 19 | 9.3 | 1.3 |
| bicyclist | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1.5 | 0.2 |
| Taxi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 |
| driver and bus passenger | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 |

Table 2.3: Report of Overall Death in May 2008 According To Different Road User [8]

| Date | 16/5 | 17/5 | 18/5 | 19/5 | 20/5 | 21/5 | 22/5 | 23/5 | 24/5 | 25/5 | 26/5 | 27/5 | 28/5 | 29/5 | 30/5 | 31/5 | Overall of death | % | Average of death per day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | | |
| motorcycle rider | 12 | 7 | 10 | 7 | 6 | 4 | 3 | 9 | 9 | 12 | 9 | 9 | 11 | 6 | 6 | 10 | 246 | 54.6 | 7.9 |
| pillion rider | 2 | 1 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 1 | 2 | 28 | 6.2 | 0.9 |
| car driver | 1 | 1 | 1 | 3 | 2 | 0 | 1 | 3 | 4 | 1 | 1 | 3 | 4 | 0 | 1 | 0 | 46 | 10.2 | 1.5 |
| car passenger | 0 | 2 | 3 | 1 | 0 | 2 | 0 | 2 | 4 | 2 | 3 | 2 | 3 | 1 | 2 | 2 | 46 | 10.2 | 1.5 |
| driver and passenger of van | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 12 | 2.7 | 0.4 |
| driver and lorry assistant | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 17 | 3.8 | 0.5 |
| pedestrian | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 2 | 4 | 1 | 0 | 3 | 2 | 1 | 1 | 39 | 8.6 | 1.3 |
| bicyclist | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 9 | 2.0 | 0.3 |
| Taxi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| driver and bus passenger | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |