UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE STUDY OF AIR FLOW BEHAVIOUR WITH VARIOUS SPEED AND ANGLE TOWARDS BICYCLE HELMET DESIGN AERODYNAMICITY THROUGH CFD PROCESS

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

by

MUHAMMAD FASSIRIN BIN ISMAIL
B071210116
920802075357

FACULTY OF ENGINEERING TECHNOLOGY
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DECLARATION

I hereby, declared this report entitled **"The Study of Air Flow Behaviour with Various Speed and Angle towards Bicycle Helmet Design Aerodynamicity through CFD Process"** is the results of my own research except as cited in references.

Signature :………………………

Name : **MUHAMMAD FASSIRIN BIN ISMAIL**

Date : **25 JANUARY 2016**

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Maintenance Technology) (Hons.). The member of the supervisory is as follow:

……………………………….

(MR. MOHD AFDHAL BIN SHAMSUDIN)

ABSTRACT

Evaluation of drag force often requires wind tunnel experiments and can be prohibitively expensive if not impossible for large objects or systems. Computational Fluid Dynamics (CFD) aerodynamic analysis offers an alternative approach and can be used as a very effective tool in many industries: automotive, aerospace, marine, etc. The main objective of this research was design and analyze the effect of various speeds and angles of the air flow behaviour on the bicycle helmet in order to compare the results of drag force among three bicycle helmets using SolidWork Flow Simulation through CFD analysis. This research presents aerodynamic data for the three bicycle helmet model. The helmets were tested at a three different degree, from 0 degree to 30 degree, in increments of 15 degree. The helmets were tested at three speeds at each angle in order to best mimic actual riding conditions. A control road helmet was used to serve as a comparative tool. The testing results showed that Helmet 1 is the best helmet at all angles that offer drag reduction more than Helmet 2 and Helmet 3.

ABSTRAK

Penilaian daya seretan sering memerlukan eksperimen terowong angin boleh menjadi terlampau mahal untuk objek besar atau sistem. Computational Fluid Dynamics (CFD) analisis aerodinamik menawarkan alternatif yang boleh digunakan sebagai alat yang sangat berkesan bagi menggantikan eksperimen terowong angin dalam pelbagai industri: automotif, aero angkasa, marin, dan lain-lain. Objektif utama kajian ini adalah untuk mereka bentuk dan menganalisis kesan kelakuan aliran udara pada topi keledar basikal untuk membandingkan keputusan daya seretan antara tiga topi keledar basikal menggunakan SolidWork simulasi aliran melalui analisis CFD pada pelbagai kelajuan dan sudut. Kajian ini membentangkan data aerodinamik bagi tiga topi keledar model basikal. Topi keledarbasikal telah diuji pada tiga sudut yang berbeza, dari 0 darjah hingga 30 darjah, dalam kenaikan 15 darjah. Topi keledar basikal ini juga telah diuji pada tiga kelajuan di setiap sudut berdasarkan keadaan penunggang sebenar. Satu topi keledar basikal dijadikan sebagai kawalan telah digunakan untuk bertindak sebagai alat perbandingan. Keputusan ujian menunjukkan bahawa topi keledar basikal 1 adalah yang terbaik pada setiap sudut yang menawarkan pengurangan daya seretan yang lebih berbanding topi keledar basikal 2 dan 3.

DEDICATIONS

To my beloved parents, my siblings and my friends who give me support and guidance to complete my final year project work.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

2D	=	Two Dimension
3D	=	Three Dimension
CAD	=	Computer Aided Design
CFD	=	Computational Fluid Dynamic
EPS	=	Expanded Polystyrene
FEA	=	Finite Element Analysis
ICF	=	Insulated Concrete Form
m/s	=	Meter per Second
MMT	=	Montmorillonite
N	=	Newton
PU	=	Expanded Polyurethane

CHAPTER 1

INTRODUCTION

1.0 Background

The sport of cycling has been witnessed to numerous technological advances over the years. In exact, engineering field performance in this sport has driven riders to speeds that were seems to be beyond possible one hundred years ago. It can be said that most of the advancement can be attributed to advancements in the field of aerodynamics and the importance of this subject in the branch of cycling (Sidelko, 2007).

Aerodynamic evaluation of larger systems, from bicycles to airplanes, is an important topic and requires significant effort and financial investment in today's efficiency-driven world. Bicycle helmets aerodynamicity are becoming an important factor in bicycle helmet designs and marketing (Doval, 2012). Whether the application of the product is racing, where speed is key, or it is commercial transportation, where efficiency of moving goods around the country may be the highest priority. As for competitive cyclist, aerodynamic drag contributes the majority of the resistance experienced. Low aerodynamic drag is a key quality of high performance equipment. Many aerodynamic helmets have been developed to reduce the aerodynamic drag experienced by cyclists (Jenkins and Sims, 2011). With the correction on the selection of bicycle helmet and right angle of body position, this may help a cyclist in reducing aerodynamics resistance.

Wind tunnel experiments and CFD simulations must be an area of serious consideration. Wind tunnels have been used many times in various studies because they allow for testing to occur in a controlled environment. Sidelko (2007) stated that capable of changing the apparent wind velocity and also the direction in which the wind hits the rider. This advancement has led to the testing of more and more cyclist's equipment. This work addresses the need for development of a virtual wind tunnel, to be used as a design instrument for large-scale systems.

1.1 Problem Statement

In a related aspect of cycling, a common goal across the sport of cycling includes maximizing the aerodynamic efficiency of the bicyclist and the bicycle helmets to achieve faster speeds, greater control and better overall results. In the sport of cycling, even one second can have a profound impact on the outcome of a race. The power generated by a bicyclist has its human limitations. Aerodynamics is an area where cycling enthusiasts and researchers look to improve performance.

While new bicycles are being designed with better aerodynamics in mind, the human body is simply not well designed to maneuver through air (Doval, 2012). The main obstacle to aerodynamic efficiency at high speeds is wind resistance. Every bicyclist has to overcome wind resistance. Subsequently, this research is attempted to study the existing bicycle helmet in order to understand their aerodynamic performance. In specific, this is to study the effect of angle and speed on the resistance behaviour of the bicycle helmet.

1.2 Objective

Different helmet design will shows different air flow behaviour subjected to different speed and the angle. Therefore, the objective of this research is to study the existing bicycle helmet in order to understand their aerodynamic performance and for future works. The specific objectives of this research are listed as follow:

1. To design and analyze the effect of various speeds and angles of the air flow behaviour towards bicycle helmet.
2. To compare the drag force among the bicycle helmet with different speeds and angles.

1.3 Work Scope

1. Designing bicycle helmet using SolidWork.
2. Analyzing the effect of various speed and angles of the air flow behaviour by using Solidwork Flow Simulation.
3. Comparing the drag force value between bicycle helmets based on data collected.

CHAPTER 2

LITERATURE REVIEW

2.1 Bicycle Helmet

The helmet has been in existence since 1975 (Alam et al., 2014). They were originally ’spin-off' products from expanded polystyrene foam development in motorcycle helmets, intended to replace the 'hair net' old-style head gear was used in cycle sport. However, the protection offered by the helmet cycle is very much less than that provided by a motorcycle helmet as compromises in weight and ventilation necessary to make them acceptable for activities such as cycling, which involves a lot of physical exertion. In fact, changes to the design to address concerns about comfort, modern helmet with new design and soft leather is considered to provide less protection than the original design with a hard shell.

The first helmet was promoted mainly by their manufacturers, with competing claims about its effectiveness. Then, in the 1980s, began to broadcast reports suggest that if cyclists wear helmets they can avoid injuries in the head. Since then, the campaign by wearing a helmet cyclist has been a major thrust of road safety practitioners in many countries (Alam et al., 2014). Figure 1 show several types of bicycle helmet.

Figure 2.1: Examples of existing bicycle helmet. (Alam, et. al., 2014)

2.2 Plastic Part

Nowadays plastic materials have replaced metals in many applications and more than 15% of the market of existing metal products, such as automotive engine components subjected to lead as the valve cover, the brakes and the radiator. Plastic materials are used as internal and external hardware and the use of plastic body panels to reduce the cost and weight of the car. Moreover, plastic can maintain the reliability and the safety standard (Gordon, 2003).

Plastic is one of the main factors in daily life, because the plastic monopoly in a large variety of industrial applications exhibited by plastic and facilitate their processing, it is not surprising this plastic one of the options available for use today exist. Plastic properties that can change the structure of the atomic composition repeatedly, the molecular weight and molecular distribution suited to meet special needs. The flexibility of the plastic can be one of the presences of side chain branches, through s length and polarity side chains. During processing, the degree of crystal orientation can be controlled through committed against plastic (Barry et. al., 2006)

2.2.1 Expanded Polyurethane (PU)

There are various polymer materials which are used, among unique and have different physical characteristics and chemistry is Polyurethane (PU). Polyurethane can meet different demands with its unique characteristics for various applications such as coatings, adhesives, fibers, thermoplastic elastomers, and foams. However, Polyurethane also has some disadvantages, such as low thermal stability and low mechanical strength, etc. To overcome these drawbacks, much effort has been devoted to the development of nanostructured Polyurethane (PU) / montmorillonite (MMT) composites in recent years (Cao et al., 2005).

One of the most important classes of cellular plastics is polyurethane foams. Its allow to produce a wide range of materials ranging from extremely soft flexible foams, through tough rigid foam, to film, fibers and molded devices depending on the starting ingredients with versatility of the polyurethane chemistry (Lingoure et. al., 2005)

2.2.2 Expanded PolyStyrene (EPS)

The most common polymeric foam is Expanded Polystyrene (EPS) that widely used as the insulation core in the structural insulated panels. EPS is plastic material that rigid, tough, recyclable and closed-cell cellular, which has been used in a various application including impact mitigation packaging, structural crashworthiness, protective helmet, construction material filling road embankments, insulated concrete form (ICF) structures as well as lightweight EPS foamed concrete (Chen et. al., 2015).

Expanded Polystyrene (EPS) are one most of the common type of polystyrene and has two major production steps. Firstly, suspension polymerization produces solid beads of polystyrene. To soften the polystyrene, the bead is heated to about 100°C in steam. Secondly, the beads are cooled and pentane slowly migrates into the beads to replace the vacuum caused expansion in the process of expanded. (Threepopnatkul et al., 2014)

2.3 Design

Design or redesigned for the new products will be developed with the assumption of linear and isotropic behaviour of materials in engineering design equation. It shows that the equation was developed based on feedback and metals and how the properties they react in the event of power. Most of their basic material is uniform in all directions, under point one of them (Gordon, 2003).

The designer must have the use of the data specific to the conditions of use of the product and material suppliers will develop the material properties. Team designer can use the parts and test prototype products in different materials to determine the most successful material (Harper, 2006).

2.3.1 Computer Aided Design (CAD)

Creativity is vital to engineers. At any stage in the design process is crucial to solve creative problems at the design stage but the concept is very critical. Most of the research has been carried out to improve the interface design to produce creative output; it has been observed that the commercial CAD tools can miss one or two decades behind the first demonstration of new ideas in this field. CAD users must also be sufficient to use the same design and interface for the design concept as it is used for detailed design. The competitiveness of the commercial sector and the growing complexity of the system create greater pressure for innovative solutions and creative performance (Robertson and Radcliffe, 2009).

Among the engineers, especially mechanical engineers will solve many of their experimental work using sophisticated use of CAD system in a situation where workers like draughtsmen who lack the knowledge, skills and training. For example, a mechanical engineer uses CAD system to use finite element analysis (FEA) in an unprecedented large scale (Field, 2004).

2.4 Computational Fluid Dynamic (CFD)

Computational Fluid Dynamics (CFD) analysis is now becoming tractable as improved access to high performance computing to solve problems in determining resistance (Subbaiah et. al., 2015). Aerodynamic drag can be studied and analyzed by field tests, wind tunnel measurements and numerical simulation by Computational Fluid Dynamics (CFD). In years past, some researchers have reported detailed CFD simulation in cycling and other sports discipline (Blocken et. al., 2013).

Computational Fluid Dynamics (CFD) was used for the practice of two-dimensional (2D) and recently through a three-dimensional (3D) perspective (Goncalves et. al., 2012). The first application of CFD to optimize the mostly limited to two-dimensional geometry, however CFDs have grown larger and advance in computer technology, numerical approach made an application to form a more complex three-dimensional as possible (Farrokhfal and Pishevar, 2013).

There are a lot of numerical simulation techniques for offshore applications and was developed among all but the Computation Fluid Dynamics (CFD) seems to have the most easy and promise and can provide very useful information from the engineering point of view compared with the traditional analysis model. CFD between different methodology, there is (e.g. a full simulation with Large Eddy Simulation) than they need supercomputing be used for large wind farms, some (e.g. Direct Numerical Simulation) are not even at that stage. In addition, the possibility to achieve a result is strictly related to convergence conditions of the iterative solution process (Castellani et. al., 2013).

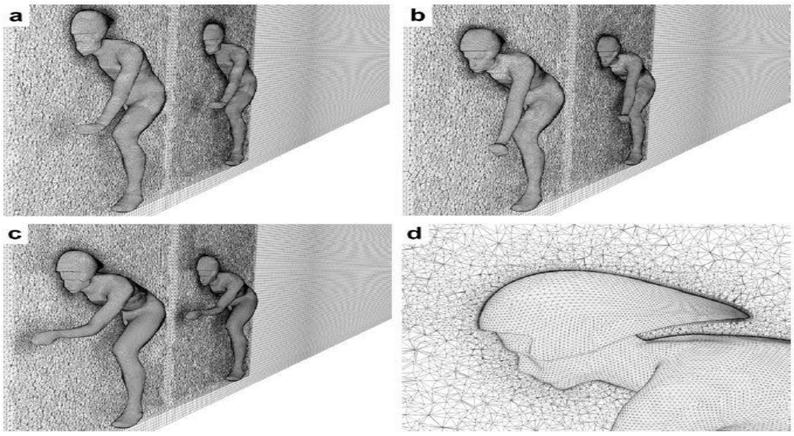

Figure 2.2: Hybrid computational grid on cyclist bodies and in vertical centreplane for two drafting cyclist. (Blocken et. al., 2013)

Computational Fluid Dynamics (CFD) has proved to be very useful in predicting and analyzing the flow of multiple systems and design tools for the system. CFD method has proven to be successful for modelling complex multiphase flow, such as circulating fluidized bed, transport bed, pneumatic and demo released (Chen and Wheeler, 2015).

In addition to high-resolution CFD simulations, we investigate the utility ignores the detailed structure of the solid border barriers in the array and consider them only as an aggregate effect (ie., We take into account the consolidation of the group of buildings that are and describe them simply by drag circulated on air flow the entrance to the array) (Lien et. al., 2004).

2.4.1 Drag Force / Aerodynamic

In a study of transport, among which attracted a number of major application is the analysis of aerodynamic forces and moments (essentially drag components), including aerodynamic aircraft, ferrohydrodynamics, marine engineering, and particularly in the automotive industry torsor. Important parameters in the development of the new car are aerodynamics of the vehicle. Literature review showed that the tendency has been to reduce aerodynamic particularly torsor drag (Khaled et. al., 2012).

High resolution CFD simulations give the results to be used as diagnoses drag coefficient values for use in a distributed drag representatives of the obstacles in array (Lien et. al., 2004). Some researchers use two additional factors for determining the sphericity in the longitudinal direction and one in the horizontal direction to make effective sphericity orientation depending on the orientation dependence of the correlation introduces drag (Zastawny et. al., 2012).

Aerodynamics has great potential to increase the speed of cycling. At a speed race (about 54km/h or 15m/s in the footsteps of the time), aerodynamic resistance or drag is about 90% of the total resistance. To investigate the aerodynamic drag with field testing, wind tunnel measurements and numerical simulations use Computational Fluid Dynamics (CFD). Recent years, some researchers have reported detailed CFD simulation in cycling and other sports discipline. In cycling, many studies focus on the aerodynamic drag of a cyclist and some effort and research has been done to assess the effect of "draft". In the formulation, reducing aerodynamic drag can be reduced if two or more cyclists riding close behind each other (Blocken et. al., 2013).

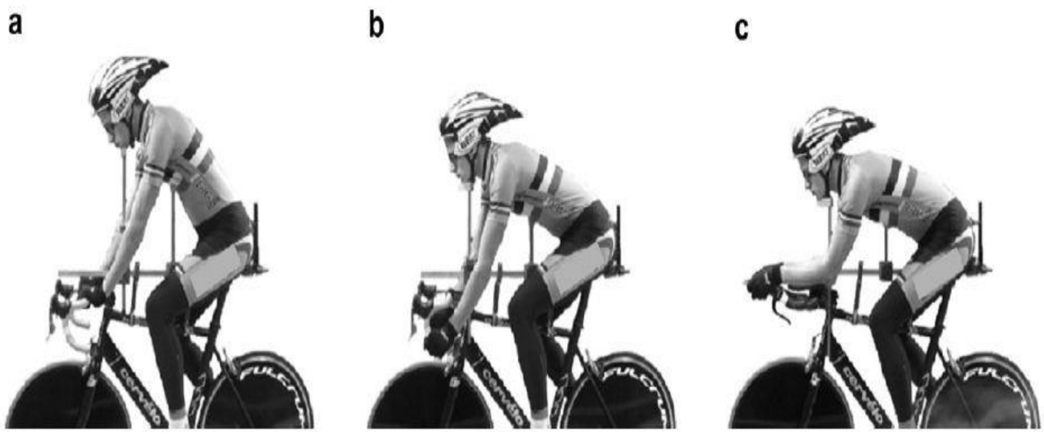

Figure 2.3: Two or more cyclist riding close behind each other to reduce aerodynamic drag. (Blocken et. al., 2013)

The resulting pressure drag is higher than the aerodynamic drag resulting from the friction surface. Therefore, the biggest reduction in the drag coefficient can be achieved when the pressure drag is reduced by maintaining attached airflow

$$D = C_D \times d \times \frac{V^2}{2} \times A$$

Figure 2.4: Drag equation.

Drag can be reduced by reducing the area and / or a reduction in the drag coefficient. To assist in maintaining attached airflow, the aerodynamic bicycle helmet production design with a long tapering tail like an airfoil (Sims and Jenkins, 2011).