UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CURVES AND SURFACE MODELING: A CASE OF TRUCK WIND DEFLECTOR DESIGN

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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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:

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ABSTRAK

Oleh kerana krisis tenaga, salah satu cabaran yang penting dalam industri automotif adalah untuk mengurangkan penggunaan bahan api kenderaan. Sebenarnya, penggunaan bahan api yang lebih telah diambil oleh seretan aerodinamik kerana kelajuan yang lebih tinggi daripada kenderaan itu. Kebanyakkanya, seretan aerodinamik terletak pada bentuk kenderaan. Oleh yang demikian, pembaikan aerodinamik pada bentuk kenderaan adalah lebih tepat untuk mengurangkan seretan aerodinamik, menjadi salah satu topik utama pada penyelidik automotif. Kajian ini membentangkan penggunaan perisian SolidWorks dalam fasa awal reka bentuk dimana seseorang boleh melakukan reka bentuk dengan data Reka Bentuk Berbantukan Komputer diberikan (tanpa prototaip kenderaan trak). Pemesong angin trak adalah alat tambahan yang digunakan di atas bumbung trak untuk mengurangkan seretan aerodinamik. Berdasarkan syarat-syarat pada bidang yang pemesong angin trak adalah tertakluk kepada keperluan, reka bentuk telah dirangka. Salah satu keperluan adalah mereka bentuk semula profil pemesong angin trak. Oleh itu, teknik pemodelan aspek digunakan untuk memperbaiki reka bentuk pemesong angin trak yang sedia ada untuk mendapatkan profil yang licin pada reka bentuk yang telah dibuat. Tambahan pula, menggunakan perisian ANSYS FLUENT, analisis dua dimensi pemesong angin trak telah dicapai, dan mungkin pembetulan geometri akan dibuat yang bertujuan untuk meningkatkan reka bentuk dari segi mengurangkan seretan aerodinamik dan meningkatkan aerodinamik. Di samping itu, proses pengesahan telah dilakukan untuk mengetahui perbezaan antara pemesong angin trak yang telah direka bentuk semula dan reka bentuk pemesong angin trak yang sedia ada. Susun atur telah dilakukan selepas membezakan hasil dari dua alat yang boleh didapati secara komersial, iaitu FEA dan ANSYS FLUENT.

ABSTRACT

Due to the energy crisis, one of the important challenges in the automotive industry is to reduce the fuel consumption of the vehicle. In fact, the higher speed of the vehicle, the more fuel consumption is taken by the aerodynamic drag. Mostly, the aerodynamic drag lies in the shape of the vehicle. Consequently, the improvement of the aerodynamics of vehicle shape, more precisely the reduction of their aerodynamic drag, becomes one of the main topics of the automotive researchers. This research presents the use of SolidWorks software in the early phase of design which one can do design iterations with a given CAD data (without having the prototype of the truck vehicle). The truck wind deflector is an add-on device used on top of the truck roof for reducing aerodynamic drag. Based on the field conditions that the truck wind deflector is subjected to, design requirements were formulated. One of the requirements was to redesign the profile of the truck wind deflector. Therefore, the facet modeling technique is applied to improve the existing design of the truck wind deflector in order to obtain a smooth profile of this design. Furthermore, using the software ANSYS FLUENT, 2D analysis of the truck wind deflector was achieved, and possible correction of the geometry was made in purpose to improve the design in terms of reducing drag and improve aerodynamics. In addition, the validation process was performed to find out the differences between the redesign and existing design of the truck wind deflector. The layout was finalized after comparing the results from two commercially available tools - namely, FEA and ANSYS FLUENT.

DEDICATION

For most I would like to dedicate and thank for my father, Mr. Abd. Latif Bin Samsi and my mother, Mrs. Jalilah Binti Sayuti and also for my beloved family who have helped me in mentally and materially, and to encourage and motivate me during my final year project is implemented.

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LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile butadiene styrene
BEM	-	boundary element method
CAD	-	Computer-Aided Design
CAE	-	Computer-Aided Engineering
CAM	-	Computer-Aided Manufacturing
CFD	-	Computational Fluid Dynamics
COE	-	Cabin Over Engine
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
FOS	-	Factor Of Safety
FVM	-	Finite Volume Method
IGES	-	Initial Graphics Exchange Specification
MPH	-	Miles Per Hour
NASA	-	National Aeronautics And Space Administration
PDE	-	partial differential equations
PA	-	Pascal
RANS	-	Reynolds-Averaged Navier–Stokes
2D	-	Two Dimensional
3D	-	Three Dimensional

CHAPTER 1
INTRODUCTION

This chapter presents the general idea of the research which provides an overview of the truck wind deflector. Basically, it consists of five main sections, such as the background of the project, background of truck wind deflector, problem statement, objectives of research and scope of research, which describe the overall process of the research.

1.1 Background of Project

Generally, this project is related to improvements in the wind deflectors as designed and as applied for use to present day types of closed body automotive vehicles such as, for example, truck, trailer, vans, and so on. However, this project more focus on the design of the wind deflector for trucks for effecting the deflection of slip stream air from the front area of the truck across its top-end roof for reducing aerodynamic drag. The primary purpose of this research is to provide the design of the truck wind deflectors for the above stated purpose that are easy to apply to a truck for easily adjustable to better serve their intended purpose of use on the truck.

Besides that, the design is related to a wind deflector device for mounting on the roof of a commercial truck in order to analyze this design by using ANSYS FLUENT software for the purpose of reducing the drag of the truck and of improving an aerodynamic characteristic of said commercial truck vehicle. Particular, it related to a wind deflector device for use on a driving cab of a truck vehicle, in which the truck comprises the load-carrying portion of said vehicle and exhibits a frontal profile which is substantially larger than that of the driving cab.

Further benefit advantages of this research reside in the details of construction of the present preferred and modified forms of the truck wind deflector: in the combination of parts thereof and in their mode or manner use, as will hereinafter be fully developed. In accomplishing these and other purposes of this research, the improved detail of construction, the preferred forms of which are illustrated in the accompanying drawing have been provided in this research. Therefore, the purpose of this research can be achieved in order to reduce the aerodynamic drag and further to improve an aerodynamic characteristic of the truck.

1.2 Introduction of Truck Wind Deflector

Nowadays, the wind deflectors are utilized in recent years for directing air over the frontal area of a moving vehicle. In the automotive industry, a truck wind deflector is an aerodynamic drag reducer device that attached to a truck with the intended design function to 'spoil' untoward air movement across a body of a truck in motion. An aerodynamics is the study of how air moves around the truck which can be a powerful force and how this force can be reduced or directed to increase performance. However, the aerodynamics were first studied and applied to the aviation industry, but it has since trickled across to the automotive industry such as, truck, trailer, house trailer and, etc. The atmosphere is filled with air and air pressure, especially close to sea level where most of the people live and drive. The vehicle or any object that moves must displace the air around it in the direction that it is traveling in.

This is almost a non-issue at low speeds as the air can easily move around any truck that travels at a slow enough space but as the speed continues to increase the air cannot be displaced fast enough so it adds a resistance to the truck. This resistance is called drag or aerodynamic drag. The faster a truck moves the thicker the air around it becomes so more than five times the horsepower is required for a truck to travel 200MPH than what it would need to travel at 100 MPH but aerodynamic features may have little or no effect at speeds of around and under 10 MPH.

Many high end trucks have a number of aerodynamic features fitted seamlessly into their exterior styling and design. Implementing the aerodynamic features can benefit to the truck in a number of ways. Acceleration and maximum speed can be increased resulting in better performance as more air can travel around the truck and reducing the effects of drag. The truck will need less horsepower and torque to move at the same speed compared to a truck with fewer aerodynamic features.

Besides that, the cost savings will benefit due to the lack of drag. The truck wind deflector doesn't give much resistance at low speeds but as the increase of truck speed, it will need a smaller amount of fuel to drive compared to whether the truck did not have the aerodynamic features. Vehicle aerodynamics further increases the performance of the truck as some aerodynamic features are used to create a down force at high speeds, which can reduce the chances of overturning.

Furthermore, the truck wind deflector will be compromised as the design of a production road truck must adhere with an imperative of automobile production, and interior space should remain practicable. The exterior design of the truck should also be attractive, but this is not that big of an issue as many aerodynamic features, curves and lines can add appeal to a truck. The ultimate performance trucks such as the super cars and the formula one car will have more obvious features like the specially angled spoilers, small wings and more in addition to the more discreet aerodynamic features.

1.3 Problem Statement

Over the past two decades, the architecture and design industry has undergone a digital revolution. Hambleton *et. al.* (2009) found that the CAD, 3D modeling, and script driven design software are commonly used by most major manufacturer and designer around the world. Modeling technology is now so advanced that it is possible to produce extremely complex geometrical forms from minimal design input. As a consequence, the free-form technique has grown rapidly during this time in the design industry.

Menzel *et. al.* (2005) stated that the free-form technique have been initially developed in the field of solid and surface modeling allowing intuitive shape modifications by moving the control points of a lattice which encloses arbitrary target geometry. Campbell and Flynn (n.d.) have both shown that the definitions of the free-form technique are often intuitive rather than formal. Despite the different application contexts of freeform object models in vision and graphics, some criteria apply to representations regardless of domain. According to Menzel *et. al.* (2005), the free-form technique allows decoupling the complexity of the design to be optimized from the optimization parameter. Besides that, the free-form technique promised a high geometric flexibility while keeping a low number of optimized parameters as well as a comfortable way of mesh generation.

Nowadays, the basics of this technique are the main method that the designer used to design the truck wind deflector. Although no doubt this new found freedom has given rise to some incredible and beautiful forms, it has also weakness and error where it is used to design the drawing without using the accurate data and accurate parameter. According to Hambleton *et. al.* (2009), this tension is especially apparent in the transport industry, especially for the manufacturer of the truck wind deflector, since it has been the medium of choice in a wide variety of projects involving freeform geometry. This means, if the free-form technique applied carefully to design the truck wind deflector, it can even handle these kinds of geometric features with accurate data or accurate parameter and in such a case, the possibility of omitting the re-meshing procedure is highly advantageous (Menzel *et. al.*, 2005).

Therefore, the facet modeling technique is applied to design the truck wind deflector for improving the free-form technique. Tico and Kuosmanen (n.d.) stated that the facet models had found various applications in computer vision and design software. Rock and Wozny (1992) have both shown that the facet models represent solid objects by spatial boundaries, which are defined by a set of planar faces. This is a special case of the more general boundary representation which does not require object boundaries be planar. In general, the term facet is used to denote any constrained polygonal planar region being used to define a model boundary.

According to Tico and Kuosmanen (n.d.), using a facet model, various local properties of the solid model can be interpreted by the corresponding properties of the underlying model surface. In this project, the facet modeling technique is applied to improve the existing design of the truck wind deflector in order to obtain a smooth profile of this design. Besides that, the facet modeling is used to define the curve in the truck wind deflector design. The command used to improve the profile of the curve is a spline command. When the curve is improved, the purpose of this project is achieved to have the cost reduction benefit and drag reduction, thus to improve an aerodynamically on the truck.

1.4 Objective Of Research

The main goal of this research is to provide the design of the truck wind deflectors in order to analyze this design for the purpose of reducing the aerodynamic drag and of improving an aerodynamic characteristic of the truck vehicles. To describe more details about this research, the objective was stated here to give a more comprehension to the problem statement. Basically, the objectives will clearly define that purpose to show the framework and also explains what to do next. The objectives of this research are listed as below:

(a) To redesign the profile of the truck wind deflector.
(b) To apply the facet modeling technique in the generated profile.
(c) To analyze the improved truck wind deflector using linear static, fatigue and ANSYS FLUENT analyses.
(d) To study the comparative model between the existing and the improved models of the truck wind deflector.

1.5 Scope Of Research

Substantively, the project activities, progress and outcomes will be well described in further detail in this scope of research. The explanation about each chapter in this research will be described in order to convey to the reader what the scope that was established in this project.

Chapter 1 will explain about the background of project, background of truck wind deflector, problem statement, objectives of research and scope of research. Background of the truck wind deflector evaluates the benefits for the truck when implementing the aerodynamic features. By identifying and pinpointing the problem statement, research can be launched in order to improve the existing design of the truck wind deflector. On top of that, the objectives of research play a significant role in the success of the whole research. Scope of research provides an overview that is essential to the success of this research. All those elements become the initial step before going through this research.

Furthermore, Chapter 2 will discuss about the literature review related to truck wind deflector such as the overview and the application of wind deflector, overview and history of truck wind deflector, basic model, general aerodynamic principles, an aerodynamic feature on trucking, air flow pattern around wind deflector, and the advantages when using the truck wind deflector. In this chapter, the suitable method of research is used to collect information that related to this project title. It is mainly involved the study of journal, books, research paper, and online resources that are related to the title searching. Throughout the study, evidence can obtain to support the facts stated in this research. For this research, the information collection is being used to that will be help in terms of an understanding and the accuracy of information that will be received.

Chapter 3 will be described about the methodology of this project and also explained the structure of how the project was done. In this chapter, it generally shows the process of accomplishing this work from beginning to end. Basically, this project has taken into consideration the important works, mostly on making a drawing and conducting analysis on the both designs of the truck wind deflector. Therefore, this chapter covers the process flow charts and methods used to construct the research. The process flow charts such as the main flow chart in truck wind deflector design, process flow diagram of 3D of truck wind deflector design, flow chart of the truck wind deflector facet modeling, linear static analysis using Solidworks Simulationxpress, flow chart of the fatigue analysis, flow chart of the simulation process and process flow diagram using ANSYS FLUENT.

Besides that, the linear static analysis and fatigue analysis of the truck wind deflector will be discussed in Chapter 4. In this research, the linear static analysis is used to define the stress and displacement distribution on the facet truck wind deflector design. Basically, the result that gets from the linear static analysis is used to make a calculation of interpolation polynomials where to define the safety factor is one. Therefore, when the safety factor for the design of the truck wind deflector is one, the fatigue analysis will be done. After the result of fatigue analysis is gotten, the design optimization method is applied when the structure of the truck wind deflector in the failure condition in order to ensure the truck wind deflector design have high performance and high reliability.

Chapter 5 is explained about the result of the dynamic analysis for the design of the truck wind deflector. For this dynamic analysis, a truck wind deflector design is used ANSYS FLUENT software where 3D analysis of the side contour of the truck was achieved, and correction of truck geometry was made in purpose to improve the existing design of the truck wind deflector. The purpose of the dynamic analysis is to improve an aerodynamically efficient spoiler and side extenders for the truck vehicle. Besides that, this analysis is conducted to analyze the design of the truck wind deflector to have cost reduction benefit and further drag reduction in the truck. However, the pressure distributions and velocity of airflow of the truck wind deflector will get from the result of the ANSYS FLUENT analysis.

CHAPTER 2
LITERATURE REVIEW

In this chapter literature review has been performed in order to review and examines all the information associated with development projects of the truck wind deflector. Taylor, (n.d.) has defined a literature review as an account of what has been published on a topic by accredited scholars and researchers. Basically, Chapter 2 is written in an essay format that discusses the topics related the title of this project. This chapter is not a summary; rather, it referred previous and current research in regard to how relevant and useful it is and how it relates to my research. This literature review will explore about information of the truck wind deflector from scholarly articles, books and other sources relevant to a particular issue, area of research, or theory, providing a description, summary, and critical evaluation of each work.

2.1 Wind Deflector

2.1.1 Introduction of Wind Deflector

Wind deflectors that used as a vehicle have been available for many years. Rich (1987) found that the wind deflector is mounted on the roof of an automobile or the truck to reduce "drag" due to air friction as the car or truck moves forwardly by creating a laminar airflow over the top of the vehicle. The wind deflector relates to devices for deflecting air streams striking vehicle and the likes, air streams caused by the wind or forward movement of a first prime mover vehicle moving ahead and in front of said trailing vehicle.