

UPPER BODY STRUCTURE DESIGN FOR SOLAR CAR

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This report presents on the design of upper body structure for solar car. Solar car uses solar energy from the sun to convert it into electrical energy in order to move the solar car. In order to move the solar car smoothly, the shape of solar car's body must be more aerodynamics to get low drag and reduce the friction at the same time. The objective of this report is to propose several design of solar car's body and analyze the models for drag coefficient and justify the most aerodynamics model. The report describes the aerodynamics concept use in common cars, computational fluid dynamics (CFD) analysis to calculate the drag coefficient and identify material and dimension of solar car. The dimension for the project is guided by World Solar Challenge regulations 2009 technical specifications. Fibreglass, kevlar and carbon fiber materials were studied in this report which is commonly used in nowadays solar car. The models of solar car were designed by using the computer-aided drawing software which is Solid Work. The CFD analysis was then performed using COSMOSFloWorks. Each model of solar car was analyzed using different mesh and speed of the air flow. Finally, the drag force of each model is obtained and used in the calculation to find coefficient of drag for each model. From the result, it is observed that frontal area and shape of the solar car's body are the most important parameter to be considered in order to design an aerodynamics car. Besides designing the aerodynamics shape of solar car, the choice of material for body can also affect the performance of the vehicle because different material will contribute the weight of the vehicle. As the vehicle is lighter, it will improve the vehicle power to weight ratio. Thus, improve the performance of the vehicle.

ABSTRAK

Laporan ini membentangkan tentang reka bentuk struktur tubuh bahagian atas kereta solar. Kereta solar menggunakan tenaga suria daripada matahari dan mengubahkannya menjadi tenaga elektrik untuk menggerakkan kereta solar. Untuk menggerakkan kereta solar dengan lancar, bentuk kereta solar hendaklah aerodinamik untuk mengurangkan daya rintangan dan geseran pada masa yang sama. Objektif laporan ini adalah mencadangkan dan mereka bentuk beberapa tubuh kereta solar dan menganalisis model kereta itu untuk mencari pekali geseran dan mengenalpasti model yang paling aerodinamik. Laporan ini menghuraikan mengenai konsep aerodinamik yang digunakan pada kebanyakan kereta, analisis perisian computational fluid dynamics (CFD) untuk mengira pekali geseran dan mengenalpasti bahan dan dimensi kereta solar. Dimensi kereta solar untuk projek ini adalah berdasarkan spesifikasi teknikal mengikut peraturan World Solar Challenge 2009. Bahan fiberglass, kevlar dan serat karbon adalah bahan yang digunakan untuk menghasilkan kereta solar dikaji dalam laporan ini. Model-model kereta solar telah direka bentuk menggunakan perisian Solid Work. Analisis CFD dijalankan menggunakan perisian COSMOSFloWorks. Setiap model kereta solar dianalisis menggunakan mesh dan halaju aliran udara yang berbeza. Akhir sekali, daya rintangan diperoleh daripada analisis dan digunakan dalam pengiraan untuk mencari pekali geseran untuk setiap model. Daripada keputusan yang diperoleh, luas permukaan hadapan dan bentuk tubuh kereta solar dikenalpasti sebagai antara parameter yang penting untuk mereka bentuk kereta solar yang aerodinamik. Selain bentuk kereta solar yang aerodinamik, pemilihan bahan untuk rangka kereta solar boleh mempengaruhi prestasi kenderaan kerana setiap bahan boleh mempengaruhi berat kenderaan. Kereta yang lebih ringan akan meningkatkan berat nisbah kuasa kenderaan. Oleh itu, prestasi kereta akan meningkat.

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LIST OF SYMBOLS

C_d	Drag coefficient
A	Frontal area
ρ	Density
v	Speed of the object relative to the air
F_r	Rolling resistance

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Solar technology is not new in nowadays world. Its history spans from the 7th Century B.C. until today. In 7th Century B.C., magnifying glass used to concentrate sun array to make fire and to burn ants. In 3rd Century B.C., Greek and Romans use burning mirrors to light torches for religious purposes. In 2nd Century B.C., the Greek scientist, Archimedes, used the reflective properties of bronze shields to focus sunlight and to set fire to wooden ships from the Roman Empire which were besieging Syracuse. Although there is no such feat proof exist, the Greek navy recreated the experiment in 1973 and successfully set fire to wooden boat at a distance of 50 meters (Hoyer, 2008). Today, there are a lot application uses solar technologies from solar powered buildings to solar powered vehicles.

Solar technology has developed from a century to another century. In 20th century, Wilhelm Hallwachs discovered that a combination of copper and cuprous oxide is photosensitive. Albert Einstein published his paper on the photoelectric effect and wins the Nobel Prize for his theory explaining the photoelectric effect in 1921. In 1954, photovoltaic technology was born in the United State when Daryl Chapin, Calvin Fuller and Gerald Pearson develop the silicon photovoltaic (PV) cell at Bell labs where it is the first solar cell capable of converting enough of the sun's energy into power to run everyday electrical equipment (Smestad, 2007).

In 21st century, the First Solar begins production in Perrysburg, Ohio, at the world's largest photovoltaic manufacturing plant with an estimated capacity of producing enough solar panels each year to generate 100 megawatts of power. At the International Space Station, Astronauts began installing solar panels on what will be the largest solar power array deployed in space. The National Space Development Agency of Japan (NASDA) announces plans to develop a satellite based solar power system that would beam energy back to earth (Hardy, 2009).

Solar cars combine technology typically used in the alternative energy and automotive industries. The solar car owes its existence to photovoltaic cell, a tiny piece of silicon which transfers the power of the sun to the batteries. The photovoltaic cell made its appearance in the United States in 1954. Solar cars depend on PV cells to convert sunlight into electricity. Approximately, 51% of sunlight enters the Earth's atmosphere. When sunlight or photons strike PV cells, they excite electrons and allow them to flow, creating an electrical current (Smestad, 2007).

In the early years of automobiles, the races were use as the laboratories where car development often took place. In 1983, Hans Tholstrup and Larry Perkins opened up solar car racing when they went on an epic Solar Trek from Perth to Sydney in Australia. This vehicle was the world's first solar powered car. And its name fit the exploit 'Quiet Achiever'. After that, the solar car races started crude and helped to propagate solar energy as an alternative. The success of his first venture across the Australian outback led Hans Tholstrup to start the World Solar Challenge in 1987. There are 23 participants inaugurated the Australian World Solar Challenge. The leapfrog over the first effort showed in 1987 when GM's Sunraycer won the event with an average speed of 67 km/hour. Today, the event is a biannual jamboree and also a barometer for the developments in the field of solar cars. For instance, 2005 witnessed cars touching speeds in excess of 100 km/hour. This lead to some major regulation changes concerning safety (West, 1999).

The World Solar Challenge started it and soon others followed the lead. The North American Solar Challenge brings numerous of University teams putting their idea, creativity and brains as well as their skills against each other. The challenge started from Dallas, Texas to Calgary, Alberta. General Motors had followed up its success in the World Solar Challenge by starting this American/Canadian version. It was an inspirational effort in order to promote auto engineering and solar energy among students (Hoyer, 2008). It may not intruded into the popular races of Formula One but with the races around the world such as Suzuki Circuit (Japan), World Solar Rally (Taiwan) and others.

Nowadays, the solar car has become the popular mechanics. Practical on road applications are looking to use solar energy in hybrid configurations. The France's Venturi AstroLab is being known as the world's first electro solar hybrid car where it has a top speed of 120 km/hour and a continuous run of 110 km. There are solar taxis or Solartx in Swiss vision where the car attempts to be a trendsetter for a dependable everyday automobile. It is powered by a 6 m² area of solar array and it can go about 400 km without recharging. It also includes a trailer and its maximum speed hovers around 90 km/hour. Big company like Toyota is looking to add solar panels on its Prius. Innovatively, the optional attachments can deliver 300 watts of energy and also act as sunshades (Hoyer, 2008).

1.2 PROBLEM STATEMENT

Aerodynamics is a branch of dynamics concerned with studying the motion of air, particularly when it interacts with a moving object such as solar cars. When drag is high, the drag force will increase. Thus a lot of energy will use to overcome it. To reduce amount of energy use when moving, the solar car must be more aerodynamics as it can affect drag and friction. In order to overcome it, most solar car have been designed more aerodynamics and streamline to get low drag.

1.3 PROJECT OBJECTIVE

There are two main objectives to achieve in this research. Firstly, the objective is to design solar car's body in order to get low the drag. Secondly, the objective is to analyze drag coefficient of the models and justify the most aerodynamics model.

1.4 PROJECT SCOPE

In order to achieve the objectives, there are two scopes of project. Firstly, sketch and design several solar car models according to aerodynamics concept by using Solid Work engineering tool. Secondly, analyze the drag coefficient (C_d) of the model by using COSMOSFloWorks software.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The design of solar car upper body is one of the important part in developing a complete solar car. The upper body is the part where solar panel is being mounted and gains power by transfer the sun light energy into electric energy. In designing a solar car, as in any project, firstly is to identify the purpose of the car. For example the purpose is to be race in the biennial American Solar Challenge. This specific goal will shape the design priorities of the car and will impose in the form of the race regulation. The regulation provides maximum dimensions, safety requirement and performance requirements.

The most important part in understanding the design problem is how to design the solar more aerodynamics in order to reduce the drag. The design of solar car is connected with aerodynamics drag. When the aerodynamics drag is reduced, it will improve fuel economy and higher top speed.

2.2 HISTORY OF SOLAR RACING

In the early years of automobiles, the races were used as the laboratories where car development often took place. In 1983, Hans Tholstrup and Larry Perkins opened up solar car racing when they went on an epic Solar Trek from Perth to Sydney in Australia. The vehicle practically resembled a 16 foot open boat. But it did 4052 km in 20 days, at

an average speed 23 km/hour. This vehicle was the world's first solar powered car and its name fit the exploit 'Quiet Achiever'. After that, the solar car races started capture eyeball and helped to propagate solar energy as an alternative. The success of his first venture across the Australian outback led Hans Tholstrup to start the World Solar Challenge in 1987. There are 23 participants inaugurated the Australian World Solar Challenge. The leapfrog over the first effort showed in 1987 when GM's Sunraycer won the event with an average speed of 67 km/hour (West, 1999). Today, the event is a biannual jamboree and also a barometer for the developments in the field of solar cars. For instance, 2005 witnessed cars touching speeds in excess of 100 km/hour. This lead to some major regulation changes concerning safety (Feinberg, 2006).

The World Solar Challenge started it and soon others followed the lead. Table 2.1 shows the previous winners of World Solar Challenge. The North American Solar Challenge brings numerous of University teams putting their idea, creativity and brains as well as their skills against each other. The challenge started from Dallas, Texas to Calgary, Alberta. General Motors had followed up its success in the World Solar Challenge by starting this American/Canadian version. It was an inspirational effort in order to promote auto engineering and solar energy among students. It may not intrude into the popular races of Formula One but with the races around the world such as Suzuki Circuit (Japan), World Solar Rally (Taiwan) and others (Feinberg, 2006).

Table 2.1 : Previous winners of World Solar Challenge

Place	Winners
2003 Event	
1st Place	Nuon "Nuna II" (NL) average speed 97.02 Km/h
2nd Place	Aurora "Aurora 101" (AUS) average speed 91.90 Km/h
2005 Event	
1st Place	Nuon "Nuna III" (NL) average speed 102.75 Km/h
2nd Place	Aurora "Aurora 101" (AUS) average speed 92.03 Km/h
3rd Place	University of Michigan "Momentum" (USA) average speed 90.03 Km/h
2007 Event	
1st Place	Nuon "Nuna 4" (NL) average speed 90.87 Km/h
2nd Place	Umicore "Umicar Infinity" (Belgium) average speed 88.05 Km/h
3rd Place	Aurora "Aurora 101" (Australia) average speed 85 Km/h

Source : <http://www.globalgreenchallenge.com.au/wsc-evolution/previous-winners>

2.3 DEFINITION OF SOLAR CAR

A solar car is an electric vehicle powered by solar energy obtained from solar panels on the car. Actually solar car is not a form of transportation yet because they can only be operation during the day and can carry one or two passenger only. Solar cars rely on Photovoltaic (PV) cells to convert sun energy into electricity which according to the fact, 51% of sunlight actually enters the Earth's atmosphere. When the sunlight strikes PV cells, they will activate electrons and allow them to flow by creating an electrical current (Kalm, 2007). Nowadays, there are a lot of competition around the worlds such as the American Solar Challenge, South African Solar Challenge and World Solar Challenge. These events are usually sponsored by government agencies such as the United State Department of Energy in order to promote the development of alternative energy technology such as solar cell. Besides, it is also to promote the use of clean and sustainable energy. As we know the energy we use now such as petrol is depleting. The

competitions are often participated by the universities to develop their students engineering and technology (Dawson, 2007).

2.4 DESIGN CONCEPT

2.4.1 Aerodynamics

Low aerodynamic drag on land vehicles has been developed almost as long as automobiles have graced our roads. Reducing aerodynamics drag is important for improved fuel economy and higher top speeds, for a given power. There are usually two ways to approach aerodynamics drag reduction for land vehicles (Kalm, 2007).

- (i) The ground-up approach, where the main body is shaped for low drag and then non-aerodynamics elements are designed within the body constraints
- (ii) The improvement approach, where the designer starts with a vehicle that already satisfies the non-aerodynamics constraints and finesses the details to lower the drag as much as practical.

Figure 2.1 shows two body shapes where to prevent the drag in body shape (a) increase, the body can be cambered just like in body shape (b).

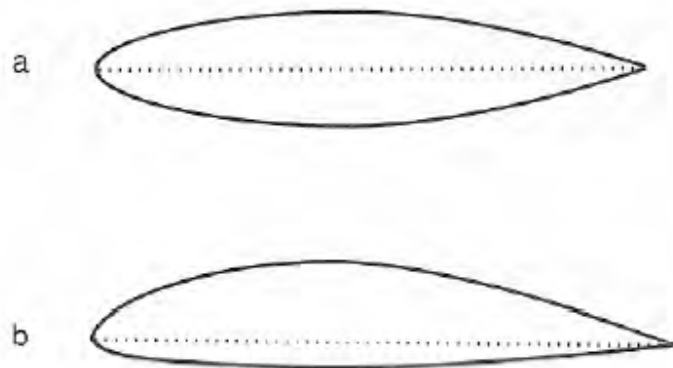


Figure 2.1: Body shape

Source : Elle Kalm (2007)

The first known streamlined land vehicle was developed by Jaray and Klemperer in 1920. They have discovered that, though an axisymmetric teardrop body has the lowest drag in free air, when that body is brought close to the ground, the drag increases dramatically. For example, in the ground clearances found in automobiles, the drag of torpedo shape can increase 50%. If the ground clearance nears zero, the drag of a torpedo shape car increase as much as 500%. To preserve the robustness, Jaray and Klemperer invented the solution by cambering the body. To camber the body, the belly can be flattened or the topside of the body can be arched higher as in figure above (Kalm, 2007).

Around 1980s, a professor of the Turin Technical University (Italy), Professor A. Morelli investigated whether it was possible for basic body, near the ground, to have a drag equivalent to streamlined body in free air. The Morelli body achieved a minimum drag coefficient, based on frontal area of under 0.05, matching that streamlined bodies in free air (Kalm, 2007).



Figure 2.2 : Morelli's streamlined car

Source : Elle Kalm (2007)

Aerodynamic problems can be classified in external and internal aerodynamics. External aerodynamics is the study of flow around solid object of various shapes. Evaluating the lift and drag on an airplane, the shock wave that form in front of the nose of a rocket or the flow of air over a hard drivehead are examples of external aerodynamics. Internal aerodynamics is the study of flow through passages in solid objects. For instance, internal aerodynamics encompasses the study of the airflow through a jet engine or through an air conditioning pipe. (Kalm, 2007)

2.4.2 Air flow between underside and ground

The motion of the car on the ground introduces problem which differ greatly from those of an aircraft, primarily because of interference with air flow between the car underside and the ground. That is because the car moves very closely to the ground this interference is one of the most important features of the air flow pattern around it (Genese, 2006). Biggest problem with many cars on the road today is that most of them have very rough undersides due of course to the presence of exhausts pipe and silencers,

overhung petrol tanks, wheel axels, differentials, suspensions, shock absorbers, brake cables and wheel cavities. The average roughness is approximately 15 cm considered from a main surface level. Airflow between the underside and the ground is therefore affected by (Kalm, 2007),

- (i) The distance between the undersides and the ground
- (ii) The width, length and height ratio of the vehicle and the styling of the body shape
- (iii) The roughness of the underside
- (iv) The lengthwise and crosswise curvature of the underside panel

2.4.3 Internal Airflow

The internal airflow is the problem which analyses of car aerodynamics cannot avoid. In fact the car engine and sometimes the brakes, requires a quite considerable mass of air to be drawn through the inside of the car. This mass of air is taken from the outside flow and induced to pass through a system of internal ducts and cavities. A fan operating within the internal duct is either assisted this airflow or it utilizes the external pressure differences between the inlet and the outlet of the internal duct. The internal airflow has a two-fold effect on the external airflow pattern (Kalm, 2007).

2.4.4 Styling Streamlined Back

In order to reduce the intensity of turbulence through discussing the general airflow pattern over the car, the size of the wake behind the car is called 'bobtailing'. Therefore, it is better to style the rear surface because it can slope gently backwards to avoid premature flow separation. The separation would be inevitable at a line due to viscous friction the shape is cut or 'bobtailed' (Kalm, 2007) in Figure 2.3.