SOLAR CAR PROJECT IN UNIVERSITI TEKNOLOGI MALAYSIA: SOME FUNDAMENTAL ASPECTS OF SOLAR CAR DESIGN

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Universiti Teknologi Malaysia's solar vehicle, SURIA KAR 2

INTRODUCTION

Universiti Teknologi Malaysia (UTM) has been actively involved in research and development of solar vehicle design since mid-1990's. The principal aims of the research work are to develop a strategy for the transformation of electric-vehicle technology and to develop local expertise in the design and fabrication in automotive, composite materials as well as renewable energy.

The research work enables the team to develop design and construction methods and to develop a database for designing a solar powered car, while other areas may benefit as well from the technology developed. This also involves system engineering project management where it is important for every team member to have a knowledge of design methodology and appreciate the importance of teamwork.

In 1999, the UTM solar car project team took part in the inaugural World Solar Challenge in Australia with the first prototype car bearing the name "SURIA KAR 2020". Knowledge acquired from the development work on the first solar car and race experience in Australia has taught the team the importance of designing the second prototype "SURIA KAR 2" from ground up, paying attention to overall efficiency. The design requirement of the solar car was based on the World Solar Challenge rules and regulations.

The solar car that competed in the World Solar Challenge or any other solar powered car race is generally very different from conventional vehicles. The energy available from the sunlight at usual radiation intensities (about 1000 Watts/m^2) is far too low to power a conventional motor vehicle. Solar powered vehicles make the most of the energy that is available by using highly efficient solar cells, lightweight batteries, super-efficient traction systems, and motors and aerodynamic bodies with ultra-low drag coefficients. This project will definitely continue to inspire not only advances in electric vehicle design but it will also spur technology development.

FUNDAMENTAL ASPECT OF SOLAR CAR DESIGN

The solar panel converts the sunlight radiation into electrical power. Peak power trackers optimise and stabilise power according to the desired voltage and current to run the motor and to charge the battery if there is excess power available. The power available is about 800 to 1000 Watts (slightly more than 1 hp). A battery is used to store energy and provide extra power during acceleration and climbing. The electric motor turns the wheel via a transmission system such as a direct chain with gear ratio.

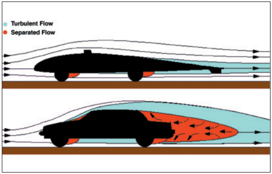
In order to design and build a fast and high performance solar car, there are literally hundreds of things that must be accomplished successfully. However, there are several essential design features that outweigh the importance of all others. In order of priority, they are:

- Reliability
- High Solar Panel Power and Efficient Power Electronics
- Low Aerodynamic Drag
- Low Weight
- Low Tyre Rolling Resistance

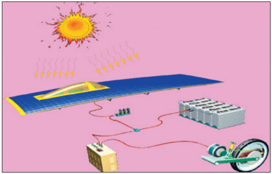
HIGH EFFICIENCY OF THE SOLAR CELL ARRAY

In the World Solar Challenge, solar cars race for 8 hours and are allowed to charge their batteries with solar panels for 2 hours in the morning and 2 hours in the evening. On most days we might not be able to fully charge the batteries. For this reason, about 80% of solar vehicle propulsion power during race is provided by the solar panel and the remaining of 20% from the batteries.

Our study has shown that a small increase in the efficiency of the cell can improve performance



Comparison of flow through a solar car and a normal passenger car



Schematic of a solar car system

substantially. This simply means that the “SURIA KAR 2” would probably have to be installed with solar cells with an efficiency of at least 18% to be among the contenders. The solar array design must consider the influence of the aerodynamically curved shape of the body that may reduce the production of electrical power.

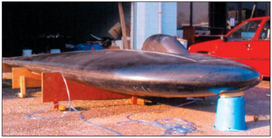
LOW AERODYNAMIC DRAG

An average sized normal passenger car has a drag coefficient six times more than a good solar car. The first prototype “SURIA KAR 2020” has a, C_d (coefficient of drag) of about 0.28, which provides good performance for a normal road passenger car but is certainly not good enough for solar car vehicles. Designing the shape of a solar car is a critical part of building a fast and high performance vehicle. If we could lower the aerodynamic drag of a 30km/h car by 25%, then the car would gain almost 2 km/h and be about 6 hours ahead at the finish. For a 60km/h car, the effect would be even more dramatic, since aerodynamic drag increases as the square of the velocity and becomes a higher percentage of the total drag. In order to travel at over 70 km/h with 800 to 1000 Watts of power, the C_d should be in the order of 0.12, with a drag area of around 1-m^2 (a normal passenger car has a C_d of around 0.35 and a drag area of around 3-m^2). Therefore, extreme care with every detail of the vehicle’s shape is necessary to achieve this low drag.

Achieving a good aerodynamic design or, a low C_d does not merely involves designing through aerodynamic simulation and physical visualisation. The solar car has to undergo through numerous wind tunnels aerodynamic testing including characterising crosswind effects.

LOW WEIGHT

The main target of any construction technique is to strive for minimum weight and still achieve reliability. All systems in a solar car contribute to its weight, including the chassis and the shell. The lightweight alloy suspension, wheels, tyres, batteries, lightweight motors, control systems, wires, etc. are all chosen for their lightness. Low weight permits faster acceleration, low tyre rolling resistance and higher hill climbing speeds. Therefore, weight is one of the affect hill climbing but also handling performance. It has been estimated that for a speed of 70 km/h on a level road, a 1 kg increase in weight will require an additional power about of 1.5 Watts.



The body shell of “SURIA KAR 2” is fabricated from carbon composite material

Evaluation results are important when deciding on the material for the “SURIA KAR 2”. The use of aircraft aluminum and composite materials such as carbon fibre and honeycomb would be an excellent choice for weight optimisation.

The body shell of “SURIA KAR 2” fabricated from carbon composite material

LOW ROLLING RESISTANCE

The motion of a solar car is also hampered by road rolling resistance between the wheels and the road surface. This road rolling resistance consumes power and therefore affects the performance of the vehicle. Rolling resistance

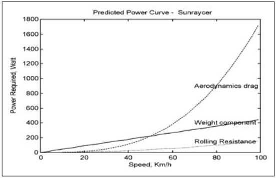


Figure 1 – Predicted Power Curve for Sunrayer Solar Vehicle

On-road testing of the "SURIA KAR 2"

impede free rolling of the vehicle, and is influenced by irregularities on the road, the flexing of tyres, compaction or deformation of the road surface, gross weight and speed. The choice of tyres, either threaded or slick, its size and its pressure during operation contribute to the reduction of rolling resistance. Other aspects of the design of the solar car are the suspension and transmission systems, including bearings and lubrication. The targeted rolling resistance is around 0.006, compared to that of a normal passenger car which around 0.028.

The comparative importance of each energy-related design features is shown in Figure 1. The contribution of each feature is an important criterion towards design optimisation of the power required to propel the car.

Table 1 shows the comparison of baseline technical specifications between the old and new solar car design:

Having designed a possible solar car, next will be the process of optimising and managing the power available. Whether the car is competitive for the race will depend on how well the team manages power in planning race strategy for the entire length of the race, which is 3010 km. For example, how fast to travel on a cloudy situation, how much power to be used on an inclined slope, or on a decline or when to floor the accelerator pedal all situations and strategies have to be carefully planned prior to the race. During the actual race the team has to continuously monitor the car's performance for immediate change of action for optimum use. The best strategy can only be predicted accurately if we really understand the actual performance and behavior of the solar car. This can only be achieved through the real actual testing of the car under specified conditions that matches the race requirements. This means that the car must be fully tested before the actual strategy can be defined. Planning for the race also include considering the reliability of mechanical and electrical components, and accessibility and maintainability of the car during operation and in the case of failures.

Table 1: Basic Technical Specifications for first the prototype, SURIA KAR 2020 and the second prototype, SURIA KAR 2

Baseline Technical Specification	SURIA KAR 2020	SURIA KAR 2
Solar cell efficiency	14%	17%
Solar array area	6.67 m2	8.00 m^2
Drag coefficient	0.29	0.12
Frontal Area	1.12 m^2	0.99 m^2
Rolling resistance	0.016	0.006
Weight	426 kg	230 kg
No. of Wheels	4	3

CONCLUSION

We conclude that there are two missions in designing solar cars. First, it is a strategy for the transformation of electric-vehicle technology. Secondly, it is to develop local expertise in automative design and fabrication, composite materials, as well as renewable energy. The research work will also enable the team to develop design and construction methods and to develop a database for designing solar powered cars or any other areas which may benefit from the technology developed. This is a system engineering project management where it is important for every team member to have a knowledge of design methodology and appreciate the importance of teamwork. ■