



Adem Yılmaz, Selman Aydın, Rifat Yakut, Berat Fırat Dalğıç

Batman University, Batman-Tukey
adem.yilmaz@batman.edu.tr; selman.aydin@batman.edu.tr;
rifat.yakut@batman.edu.tr; bfiratdalgic@gmail.com

DOI	http://dx.doi.org/10.12739/NWSA.2019.14.1.1A0430	
ORCID ID	0000-0001-7266-0866	0000-0001-9685-9853
	0000-0003-0059-3785	0000-0002-8989-6995
CORRESPONDING AUTHOR	Rifat Yakut	

THE EFFECTS OF SOLAR CAR DESIGN ON PERFORMANCE

ABSTRACT

Solar energy has great importance since it is clean, reliable and renewable. Solar-powered cars enable the car to start with the solar energy by transforming the energy, which they receive from the sun, into the electrical energy by means of photovoltaic panels and giving that energy to the engine. In this study, a solar-powered vehicle was designed and its prototype was built. Apart from the design of the solar-powered vehicle, the materials used, its manufacture and driving performance were researched by doing tests.

Keywords: Renewable Energy, Solar Energy, Photo-Voltaic Battery, Solar-Powered Vehicle, PV systems

1. INTRODUCTION

The facts that petroleum and petroleum-based energy resources have been consumed away rapidly and their damages to the nature have increased have raised the question how usable renewable energy is in the automotive industry. Therefore, car companies have started the Works for hybrid vehicles. Hybrid vehicles use electrical engine at low speeds instead of internal combustion engines and thus decrease carbon dioxide emission. The energy of the internal combustion engine charges the electrical motor up to a certain speed, and we may also add, even if just a bit, storage of kinetic energy during braking also contributes to this. The opinion of obtaining the energy, which electrical engine needs, from solar panels has been welcomed more with today's technology and the relevant R&D activities have been carried out. Today, the necessary Works for increasing the efficiency of the low-efficient solar panels have been sped up. It is impossible to compare an electrical engine to move a vehicle via the energy received from the sun cells with the powers of the engines, which we use today. Therefore, the solar-powered car to be designed should be much more advanced, much lighter and much more aerodynamically efficient than today's automobiles [1]. It is naturally impossible to continuously use the solar energy at the same level. It is another study subject to develop the Works related to the suitable weight/power ratio and storage of energy by concentrating on the R&D Works about this matter [2 and 3]. In conclusion, the design of chassis to be manufactured in solar-powered vehicles is of great importance in order to efficiently use the energy since the energy is short. Due to the fact that the energy to be used should be used efficiently since it is short, it has paved the way for organizing the races based on productive use of the energy [4].

How to Cite:

Yılmaz, A., Aydın, S., Yakut, R., and Dalğıç, B.F., (2019). The Effects of Solar Car Design on Performance, **Engineering Sciences (NWSAENS)**, 14(1):46-54, DOI: 10.12739/NWSA.2019.14.1.1A0430.



2. RESEARCH SIGNIFICANCE

In this study, the design of the electric vehicle, which can move by using solar energy, was put emphasis on. Vehicles designed by utilizing photovoltaic cells, used to obtain the electrical energy by converting solar energy from the sun into electrical energy, on the vehicle are called solar cars. The studies on solar cars, whose historical development is new, were started almost in the 1980s. The order of solar vehicles is in the way that a single person can race. This is caused by the fact that efficiency of photovoltaic cells, used to obtain the energy from the sun, is very low although their surface area is wide and long. Thus, it is necessary to place a big panel (Photovoltaic cell group) on the vehicle in accordance with the circuits in order to produce electrical energy necessary for the vehicle to move. Power, which classical photovoltaic panels formed of cells can produce in terms of surface area, is around 0.1-0.2kW/m². Power level is around 0.4-0.5kW/m² in panels built with advanced cells. In this case, the power, which is produced when vehicle surface with 5m of height and 2m of width on average is completely covered with photovoltaic cells, is between the ranges of 2 and 5kW based on the cell type. Therefore, this power produced is not adequate for energy requirement of a normal today's vehicle; therefore, this technology is not used for today's passenger cars for now and the research, development and promotional activities have been continued today with various national or international competitions [5 and 6]. For example, we can show Alternative-Energy Vehicle Competitions held by TÜBİTAK (STRCT) in our country.

3. WORKING PRINCIPLE AND BASIC STRUCTURE OF THE SOLAR CAR

By transforming the solar energy into electrical energy and using it, it is aimed to bring cars a momentum alternative to the fossil-fuel energies. Electrical energy taken from the sun is stored in sun batteries. Electricity flows into batteries from the aforementioned photovoltaic cells. Energy coming to batteries is transferred to the motor. Control circuit adjusts the amount of energy given to engine. The design of the solar car is done in the way that it should minimize its friction, weight and aerodynamic efficiency. In order to minimize weight and resistance rates for a solar car; light materials, such as titanium and various alloyed metals, are being used. In every solar car, there should be two brake systems independent from each other. Light tyres are used, which are specially designed only for solar cars and have low friction. Solar panel can be regarded as the single energy resource of solar car; however, the energy brought by torque makes a contribution in some engines used (hub) even if just a bit. Power produced by panels depends on weather conditions, the position of the sun and solar panel. The time during which the angle of the sun is the best is the noon time and a good solar panel can produce power over 1000 watt (1, 4 bg) at the mentioned time [9].

A solar car basically consists of solar panels (PV), body (chassis), moving part, battery group, electrical engine, control circuits (mppt circuit and engine drive). Solar batteries (also known as photovoltaic batteries) produce electricity. This produced electricity is made regular and stored in batteries by means of mppt circuit. Later, engine driver and engine use the energy in batteries and generate mobility by giving a torque to the vehicle. Thus, vehicle starts to move forward. Afterwards, it directly uses the energy, which it receives from the sun while moving, and transfers the surplus to batteries and stores. The basic working principle of a solar car is like this way.

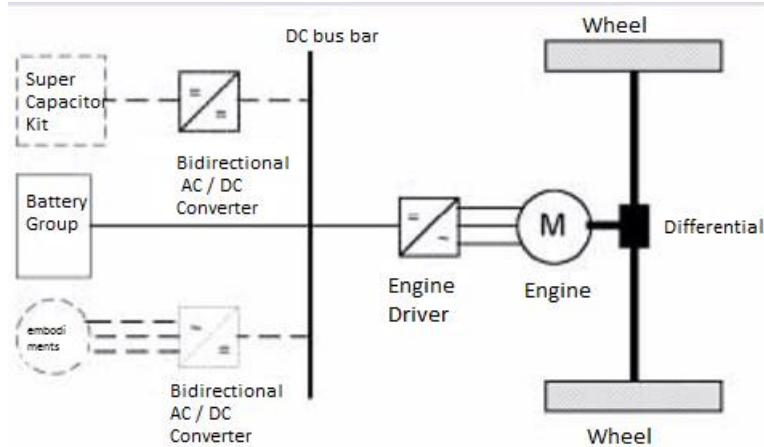


Figure 1. The way of work of the solar vehicle (schematic representation)

3.1. Body (Chassis)

It is the most important part, which should be specially designed in order to best obtain electrical energy from the sun and should be also designed in accordance with aerodynamic calculations in order to minimize air friction while moving and to maximize its road-holding by getting on the ground. This part, which should be long and wide in accordance with aerodynamic rules in order to receive maximum energy from the sun, should also be as light as possible for it to be moved with a low-power energy [7]. It is the healthiest and the best way to use composite materials, also used in outer body of planes, in chassis of solar cars. Shaping this material, coming closer to steel resistance in very thin layers and wall thickness, as required is one of its most important advantages. Disadvantage of this material is very high price and a material not well known yet for manufacture in our country. Materials generally used in chassis of solar vehicles are Carbon Fiber, Plastic, Glass Fiber, Cloth and Wood. The commonly used ones of those materials are Carbon Fiber and Glass Fiber. Method of use is moulding and covering that mould with them. This is as in the known composite technology. These procedures carried out are much cheaper than the composite but the body formed with this method is 2-3 times heavier than the one formed with the composite material. Although the bodies formed by using wood and its derivative products are sound, they are heavier than the fiber and its derivatives and problems occur during manufacture. Since cloth and plastic moulds do not have good resistance and usability, they are not preferred much.

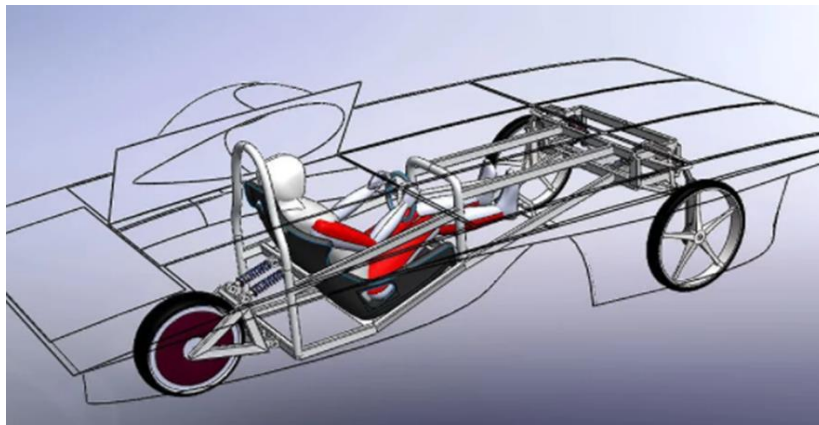


Figure 2. Design of the body



3.2. Moving Part

This part is actually an automotive application. This part, which enables a proper movement and control of the solar vehicle, takes shape based on number of tyres to be used for vehicle and on the tyres to which torque shall be applied. In international and national competitions, solar cars generally use 3 tyres: 2 directing tyres on the front and 1 engine at the back. In some designs, there are 4 tyres as in the known vehicles. As suspension system, the free suspension ones are preferred. If there are two electrical engines, they shall be in the way that there is a hub engine within rim of each rear wheel and it requires the use of electronic differential gear. When single engine is used, single wheel moves the vehicle by using hub engine. Since hub engine is small in those vehicles, diameters of wheels should be small. While disc brake system is used in two front wheels of vehicle, drum can be used in single wheel at the back. While three brakes or two brakes are controlled from single pedal, their rates and response times should be the same. The used discs are aluminum alloy and they have been mounted into wheel housing on the front alignment by using bolts and nuts. Vehicle can stop within 5 meters in case of braking while being under way with 50km/h of speed [3]. 1 stop lamp connected to disc brakes has been placed at the rear of vehicle for warning the vehicle following it.

3.3. Solar Panels (PV)

The efficiency of converting sunlight into usable energy is at very low level for the current technology. In industry, this problem has been solved with a large number of solar panels by using wide and big areas. However, since solar cars have limited areas, it has been obliged to prefer the high efficiency panels. Therefore, both their low efficiency and high cost are the biggest problem in manufacture of solar cars. The cost of high efficiency panels is too much. The more efficient your energy resource is, the more power you shall obtain. Efficiency of today's best solar batteries is approximately 24%. This value is the value in theory, of course. This is around 17% in practice [5]. Solar cells, mounted on the panel one after another for solar panels to convert sunlight into electricity, are produced from semiconductor silicon materials. When radiation is absorbed by those substances in the cells, the electrons in the substance separate off from atoms in which they exist and they become free. Thus, an electric current occurs. However, any radiation at a certain wavelength can be converted into electrical energy and other types of radiation are reflected from the surface. Therefore, efficiency in solar batteries is very low. These batteries consist of semiconductor groups which transform photons from sunlight into electrical current. They can be used as a cell not only one by one, but also in group. It is formed by placing photovoltaic cells on the upper side of the vehicle body in accordance with circuits and connecting them in parallel and serially together.

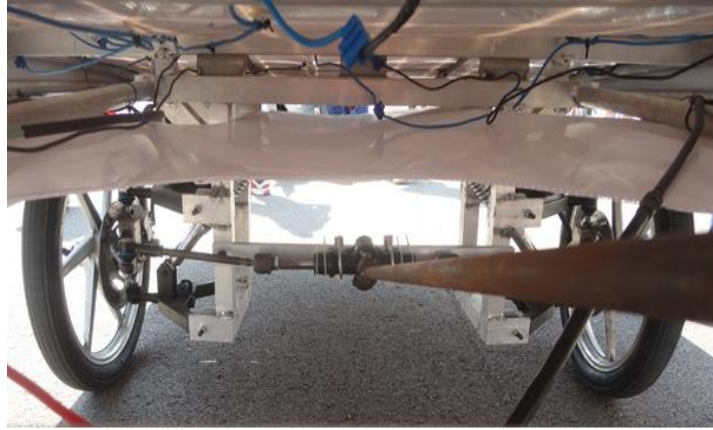


Figure 3. Moving part (front alignment - brake system)



Figure 4. PV solar panels

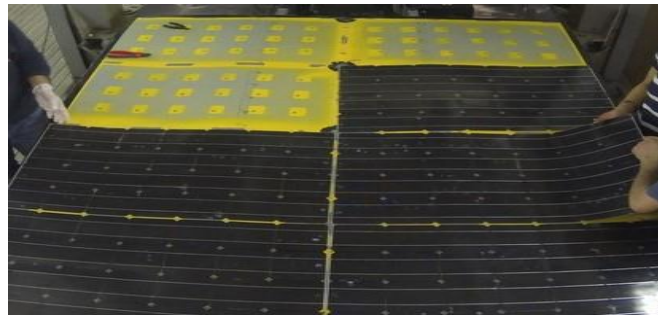


Figure 5. Panel array



Figure 6. Battery Group-Samsung

3.4. Battery Group

Battery group is actually the most important part of solar cars. This part is used to store the produced energy. Exactly like fueling up for the known cars, we fill it up at a charging station; the energy from solar batteries is regulated in solar cars and it provides the necessary energy stored in batteries when there is no energy generation. Batteries used in solar vehicle should be light and store much energy. A battery group is seen in Figure 7. Battery group types mostly used in electrical vehicles are lead-oxide (Lead-Acid), NiCad, zebra (NaAlCl₄), nickel-metal hydride (NiMH), lithium-ion (Li-Ion) and lithium polymer (Li-Poly). Although the lead-acid, NiCad, nickel-metal hydride battery types have advantages over each other, their Wh/kg rates are at low levels, i.e. They are battery groups with high weights. On the other hand, prices of these battery groups are lower than other groups and their provision is easier. Wh/kg rates of Li-Poly, Zebra and Li-Ion battery groups are better than the other group, i.e. their usability is better and they are also lighter battery groups. In spite of these advantageous conditions, their disadvantages are that their prices are very high and their provision is more difficult and their charge and discharge should be checked very sensitively by the electronic circuits for their reliability [2].

3.5. Electrical Engine

Mostly direct current (DC) engines are used in solar cars. They are available in vehicles for which alternating current (AC) is used but in this case, control elements are needed to transform direct current energy from battery group into alternating current and this is both a loss of energy and increases the costs. Therefore, direct current engines mostly used are divided into 2 groups: brush and brushless. Brush direct current engines have not been preferred recently since their efficiency is low and their collector and brush systems extremely require maintenance and repair. Brushless direct current engines are preferred more since they are very high efficiency and do not require much maintenance and repair due to the fact that they do not have collector and brush system [8]. An engine (hub) of solar cars is seen in Figure 2.

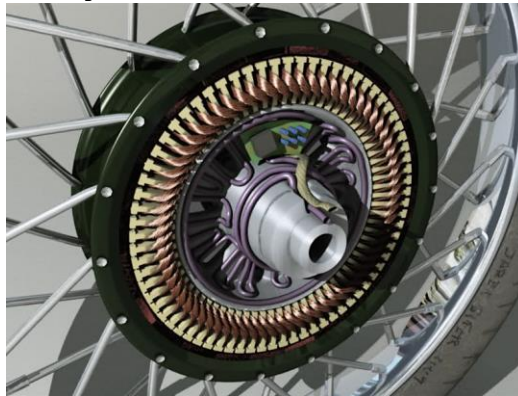


Figure 7. The Hub of engine

Advantages of brushless direct current (DC) engines in solar cars are these: their weight is low due to the fact that they are manufactured from less copper, the risk of spark does not occur since there is not a brush, no failure is encountered during rotation of the engine by means of microcontrollers and they are smaller than other engine types. Their most important feature is that they have very high efficiency. However, such options depend on the appropriate choice of engine and the track. Sloped roads can decrease efficiency of the

engine. Engine and road analyses should be carried out together [9 and 10]. The brushless direct current (DC) used in solar cars is embedded in rim as is seen in Figure 9.



Figure 8. Anka 2014- Hub engine (2.5kW)

3.6. Control Elements

Solar cars have a structure which extremely contains electronic circuit. Thanks to circuits on the car, all the things from energy generation to power output and brake system are controlled here. These control circuits receive the energy from the sun at the highest level and this energy received is used with maximum efficiency and is transformed into motional energy [8]. Electrical energy produced on solar panels charges the battery group with maximum power point tracking (mppt) control of photovoltaic charging circuit. While doing this, it does direct feeding. Engine driver controls electrical engine which provides movement to the vehicle. Engine driver transfers the energy from the battery to the engine with signals coming from the vehicle control circuit and it regulates the movement of the car, such as forward, reverse and braking. Vehicle control circuits, auxiliary elements such as warning lamp and a horn receiving energy from the battery exist on the vehicle and these can be used by means of control circuits.

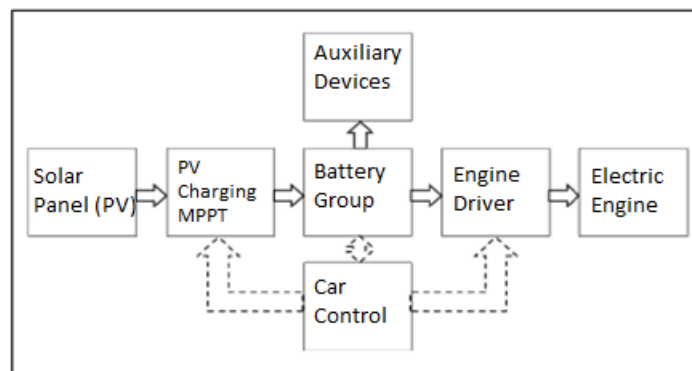


Figure 9. Electronic control circuit diagram



Figure 10. Maximum power point tracke (MPPT)



Figure 11. Engine Driver

3.7. Test of the Vehicle

Mersin University has taken part in the competitions since 2007 with Mersin University ANKA-Alternative Energy Vehicles Team, which was formed with the participation of students and instructors from various Institutes, Faculties and Colleges and Vocational Schools at the university. In this process, the ANKA team has manufactured 5 solar-powered and 2 mobile vehicles. Respectively, Anka-1 (2007) Anka-2 (2010) Anka-3 (2011) Anka-3 v2. (2012) Anka-4 (2013) Anka-5 (Electric Car) (2014) and Özgecan (ANKA-6 Electromobile) (2015) were manufactured and they placed in competitions. This study aimed to the design and manufacture a solar-powered at different stages vehicle which can race in these competitions.

4. RESULTS AND RECOMMENDATIONS

Among today's cars, the use of solar cars means providing a renewable energy supply, decreasing the emission products, harmful to human health and environment, such as carbon dioxide, nitrous oxide, unburned hydrocarbon and carbon monoxide, of toxic gases caused by the engines with carbon emission and forming alternatives to fossil fuels which shall run out. Weight of the vehicle increases its resistance en route. The most important recommendation to the ones who shall design new solar cars is to make the material out of composite material. When the car is made out of composite material, the weight can decrease by around 90-110kg. When very high efficiency battery group, such as li-ion or li-po, is used in order to store the electrical energy produced from the sun in the car, the stored energy amount is high and the weight of battery group shall decrease evenly. When belt pulley system (cvt) transmission is used in the moving part of the car, the torque taken from the engine shall be at a suitable value for all kinds of road conditions and the current shall be used in a more balanced way. Additionally, the range distance of the vehicle shall increase and the car shall be able to start under more severe conditions. Another recommendation is that when small wheel dimensions and rim diameters are chosen, the efficiency shall increase much more since this choice shall decrease the rotation resistance. The R&D Works on composite materials, battery group and solar batteries should also be followed. In conclusion, even if the solar-powered electric cars are not usable now, they shall become usable in the near future when the relevant R&D Works are continued in this way.



REFERENCES

- [1] Güleç, K., (1974). Kayaçların Fiziksel ve Mekanik Özelliklerinin Su Muhtevası İle Değişimi, Madencilik Dergisi, Cilt:XVIII, Sayı:3, Maden Müh. Odası Yayını, Ankara.
- [2] Hoyer, K.G., (200). The History of Alternative Fuels in Transportation: The Case of Electric and Hybrid Cars. Science Direct, Utilities Policy 16, pp:63-71.
- [3] Thomas, C.E., (2009). Fuel Cell and Battery Electric Vehicles Compared. International Journal of Hydrogen Energy 34, pp:6005-6020.
- [4] Knipping, E. and Duvall, M., (2007). Environmental Assessment of Plug-In Hybrid Electric Vehicles Volume 2: United States Air Quality Analysis Based on AEO-2006 Assumptions for 2030. Electric Power Research Institute and Natural Resources Defense Council'
- [5] Sasaki, K., Yokota, M., Nagayoshi, H., and Kamisako, K., (1997). Evaluation of Electric Motor and Gasoline Engine Hybrid Car Using Solar Cells. Solar Energy Materials and Solar Cells 47, pp:259-263.
- [6] Kayegama, Y., (2009). Toyota works in secret on solar vehicle. Associated Press. <http://www.wheels.ca/reviews/article/492639>.
- [7] Shacklock, A., Duke, M., and Burgess, M., (1999). The 1998 World Solar Rallye: Akita, Japan. Journal of Power Sources, 199-206.
- [8] Gupta, N., Alapatt, G.F., Podila R., Singh, R., and Poole K.F., (2009). Prospects of Nanostructure-Based Solar Cells for Manufacturing Future Generations of Photovoltaic Modules. International Journal of Photoenergy.
- [9] Yang, Y.P. and Pin Lo, C., (2008). Current Distribution Control of Dual Directly Driven Wheel Motors for Electric Vehicles. Control Engineering Practice 16, pp:1285-1292.
- [10] Najib, A.K., (2007). Ranges of Applicability of a Solar-Battery Car with Single and Double Solar-Trailers, Solar Energy, 144, 619-628.