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Design Analysis and Theoretical Study of Solar Energy Conversion in an Electric Car

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Abstract - *This paper explains how the energy produced by solar radiation able to generate electricity by using solar cells. Solar energy that are generated arising from reception rate of solar radiation are evaluated by different types of solar panels of different sizes and power. The multi crystalline solar panel used in this work. The development of design for the working model is through several design concepts by taking into consideration the basic factors of car components. Various significant factors like gyroscopic forces, maximum allowable speed during a turn are determined using the physical tests. The final model is the examined under various other tests including load-velocity relationship and load bearing efficiency. The comparison between fuel efficiency of the solar car and conventional cars has also been done to emphasise on the profit which can be derived by giving a preference to the solar cars.*

Key Words: Solar panel, Multi crystalline, Fuel efficiency, Gyroscopic effect.

1.INTRODUCTION

Due to the energy crisis, renewable energy sources have been deeply concerned as possible solutions to remain resources on the earth. Among these energy sources, solar energy one of the undisposed energy are to be concerned. A free conversion, non-polluted and inexhaustible energy source and has been use to generate electricity for decades. The solar energy is produced by sunray and converted to electricity energy by using solar cell. Solar cell is a device that converts the energy of sunlight directly into electricity by the photovoltaic effect. The main focus of this work is to design the mini car with environmentally friendly materials and powered by solar panel. The energy produced may be stored or directly used to run the motor.

This work consists of three main elements which are panel solar, motor and rechargeable battery. The solar panel is used as power source, the motor is used run to wheel shaft and battery is used as reserve power. The solar panel connections are such designed that the power from solar panel can perform the tasks of running the motor and charging the battery individually as well as simultaneously. In this project, the main objectives should be given attention is how to design a solar car that has the potential to run on solar energy. Further, these project requirements are made even more complex because many possibilities of the design may involve. In part, this means identifying and testing a broad range of tools and techniques. This study is adopting the renewable energy program to improve and acknowledge the energy sources and counteract the greenhouse effect. In part, it also means investigating the ramifications of participatory made for and to realise the importance of preserving the earth and pollution control. A key issue for this project is condition of the track and the situation during the day. The outcomes of this project are expected to produce a single solar car among the others prototype which every aspect is measured according the objective required.

2. METHODOLOGY

The methodology is a process for implementation and developing the project. The goal and the successfulness of the project is depending on how the plans is conduct to achieve the result. Methodology is to describe each step to accomplish the sequence of the flow work from the beginning until the result is obtained and success. All the results obtain were evaluated and improved till the best result came out and to be taken. This implementation would be and getting the worst result where try and error is happening here. Where any ideal decision may reconsider and repeating to satisfy the best result.

Phase to process developing and fabricating. Discuss about the theories review, calculation, project specifications and etc. In order to achieve all this, the Understand the objective of the project and search for the best result to solve the problem statement. Experimentation and simulation where certain experiments are needed to be done in order to collect and to take note the data and record for improvement. Generate conceptual design and concept selection where meet the characteristic require and final conceptual design obtained. Phase to detail design process where concept will be enhanced and optimized if there is disability and problems to produce the final design.

Fabrication and implementations is brought to life from the detail design drawing that have chosen. Next step is to test run whether the prototype can work properly and meet the objective. Thus, the problem found will be analyse and need to be rework. The last process is product realization and verification where it will be send to presented and enter the competition whether the product achieve the goals of the project.

3. MATERIAL PROPERTIES AND ANALYSIS

Wooden Logs Used: Balsa Wood
Moisture Content = 12%
Specific Gravity (w.r.t. water) = 0.37
Shear Parallel to Grain = 6800 kPa
Tension Perpendicular to Grain = 2400 kPa
Compression Parallel to Grain = 6800 kPa
Aluminium Channel: Ultimate Strength = 40-50 MPa
Yeild Strength = 15-20 MPa
Young's Modulus = 70 GPa
Ply: Beach Plywood
Thickness = 10mm (5 ply)
Area Density = 7.4 kg/m2
Tyres: Polychloroprene Rubber
Rubber Persentage = 47%
Tensile Strength = 8.02 MPa
Strain at Break = 240%
POWER INPUT BY BATTERY
Voltage Supply = 12 Volts
Current Supply = 7.2 Ah
Power Supply = 86.4 Watt hr.

3.1. Determining the velocity of car

Following observations were taken in an optimal track to determine the velocity of the car.

Table 1: velocity of car

Distance (d)	Time (t)	Velocity (v=d/t)
4m	10.3	0.388 m/sec
4m	10.5	0.381 m/sec
4m	10.4	0.385 m/sec

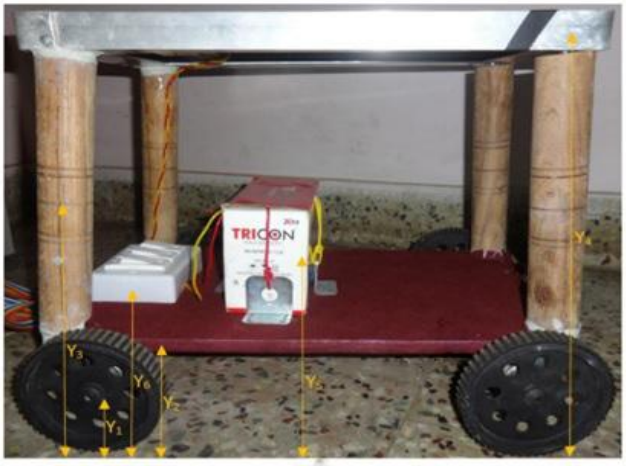
Taking mean of all observations:
V_{mean}= (0.388 + 0.381 + 0.385) ÷ 3
V_{mean} = 0.3846 m/sec

3.2. Determination of centre of mass:

The observations for the determination of centre of mass are tabulated as follows:

Table 2 : position of components with respect to ground

Component	Mass (gm)	Position of centre of mass from ground (mm)
Wheel with motor	M_1=712	X_1=50
Plywood base	M_2=792	X_2=80
Wooden pillar	M_3=800	X_3=205
Panel with frame	M_4=1736	X_4=330
Battery	M_5=86	X_5=100
Switch board	M_6=2140	X_6=135



$$Position\ of\ center\ of\ mass\ (Y) = \frac{M_1Y_1 + M_2Y_2 + M_3Y_3 + M_4Y_4 + M_5Y_5 + M_6Y_6}{M}$$

$$(Y) = \frac{1133340}{6266} = 180.87\ mm$$

Position of components with respect to back plane

Table 3 :Position of component with respect to back plane

Component	Mass (gm)	Position of centre of mass from ground (mm)
Rear wheel with motor	M_1=356	X_1=50
Rear wheel with motor	M_2=356	X_2=370
Rear wooden pillar	M_3=400	X_3=30
Panel with frame	M_4=1736	X_4=330
Battery	M_5=2140	X_5=180
Switch board	M_6=86	X_6=50
Front wooden pillar	M_7=400	X_7=370
Plywood	M_8=792	X_8=1736

$$Position\,of\ center\ of\ mass\,(X)=\frac{M_1X_1+M_2X_2+M_3X_3+M_4X_4+M_5X_5+M_6X_6}{M}$$

$$(Y)=\frac{1218580}{6266}=194.57\,mm$$

The center of mass of the solar car model is positioned at 180.87 mm above ground level and 194.57 mm from the back plane of the car.

Calculation of Gyroscopic effect on the Solar Car model (left turn):

Mass of the vehicle = 6.266 kg (M)
Centre of mass of vehicle = 19.45 cm (a) from tail end & 18.09 cm (h) high from road (base/ground)
Velocity of vehicle = 0.3846 m/sec (V)
Turning radius = 5m (R)
Motor rpm 150 rpm (N)
Radius of wheel = 10.5 cm (r)
Moment of inertia (MOI) = 3.925×10^{-3} (I_M)
Centre distance between wheels = 28 cm (W)

Reaction on Weels:
Reaction on Front Wheels: $R_{W1}=R_{W2}$
= (6.266 x 9.81 x 19.45) ÷ 42
= 28.46 N
Reaction on Rear Wheels: $R_{W3}=R_{W4}$
= (6.266 x 9.81 x 22.55) ÷ 42
= 33 N

Reaction due to Centrifugal Couple:
(Centrifugal Couple) C_c
= M v^2 h ÷ R= 6.266 x v^2 x 0.W1809 ÷ 5= 0.227 v^2
R_{C1} =R_{C3} =C_C÷ (2 x w) = 0.227 v^2 ÷ (2 x 0.28)
= 0.405 v^2 (downward, -ve)
R_{C2} =R_{C4} =C_C÷ (2 x w) = 0.227 v^2 ÷ (2 x 0.28)
= 0.405 v^2 (upward, +ve)

Reaction due to Gyroscopic Couple:
(Gyroscopic Couple) C_G= 4 I_w ω_w ω_p = 4 I_w v^2 ÷ (r R) C_G=4 x 3.925 x 10^{-3} v^2 ÷ (0.105 x 5) = 0.0299 v^2≈ 0.03 v^2
R_{w2} =R_{w4}= C_G/2w= 0.03 v^2/ (2 x 0.28)
= 0.0536 v^2 (upward, +ve)
Rw1 =Rw3= CG/2w= 0.03 v2/ (2 x 0.28)
= 0.0536 v 2 (downward, -ve)

Total reaction in wheel:
R_1=28.46-0.405V^2-0.0536V^2
R_2=28.46-0.405V^2-0.0536V^2
R_3=33+-0.405V^2-0.0536V^2
R_4=33+-0.405V^2-0.0536V^2
Minimum reaction is seen in wheel no. 1, so for finding the maximum possible velocity of car, R_1=0

R_1=28.46-0.405V^2-0.0536V^2
So V= 62.06m/sec
Hence maximum allowable velocity of car while taking a turn about 5m radius is 62.06m/sec

EFFECT OF FRICTION

Theoretical/Rated Velocity (Vt):
Motor rpm (N) = 150 rpm
Diameter of wheel (d) = 10.5 cm = 0.105 m
So, theoretical velocity is given by,
V_t = ω x d/2 = (πN/60) x d/2
Vt = 0.412 m/sec = 1.484 km/hr
Co-efficient of Friction (on concrete surface) = μ = 0.68
Reaction on Wheels:
Reaction on Front Wheels: RW1=RW2= 28.46 N
Reaction on Rear Wheels: R_{W3}=R_{W4}= 33 N
Friction Force on Front Wheels: FW1=FW2
= 0.68 x 28.46 = 19.35 N
Friction Force on Rear Wheels: F_{W3}=F_{W4}
= 0.68 x 33 = 22.44 N
Friction Torque on Font Wheels: TW1=TW2
= 19.35 x 0.105 = 2.032 Nm Friction Torque on Rear Wheels: T_{W3}=T_{W4}= 22.44 x 0.105 = 2.356 Nm
Friction Power:
Taking Rear wheels under consideration as they would experience higher frictional force as seen above,
Friction Power = Friction Torque x ω
= 2.356 x (150π/60)
=18.503 Watt

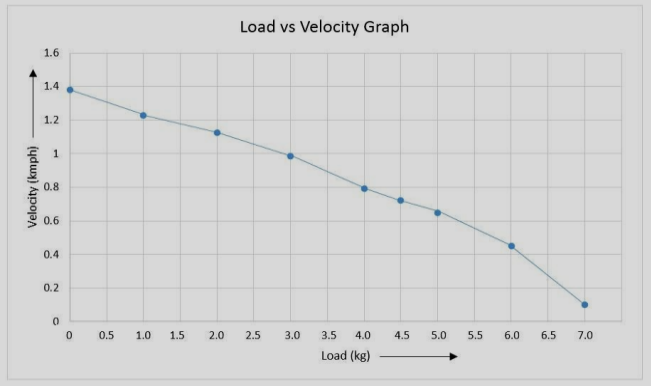
3.3. Load vs. velocity analysis

Solar cars can be used to carry moderate loads without generating noise and emitting gases. Although it is not recommended for carrying very heavy loads.
The solar car model was tested for different load conditions. The observations for variation in velocity with change in load conditions are tabulated as follows:

Table 4: Load and velocity

Additional load (kg)	Velocity (km/hr)
0	1.3846
1	1.23
2	1.125
3	0.986
4	0.791
4.5	0.72
5	0.649
6	0.45
7	0.12

On the basis of the observations, the load-velocity graph is plotted as follows:



From the analysis of the graph, following conclusions can be derived:
The solar car model has load bearing capacity higher than its own weight.
Initially the velocity moderately decreases with increase in load.
In the middle stage, the rate of decrease in velocity is lower.
With further increase in load, the velocity falls rapidly.

3.4. Efficiencies

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Load Carrying Efficiency (η_C):

$$\eta_C = (\text{Load carried by car}) \div (\text{Total mass of car})$$
$$= (4.5\,\text{kg}) \div (6.266\,\text{kg})$$
$$\eta_C = 71.81\%$$

Mechanical Efficiency (η_m):

$$\eta_m = (\text{Actual Velocity}) \div (\text{Theoretical Velocity})$$
$$= (0.3846\,\text{m/ sec}) \div (0.412\,m/\text{sec})$$
$$\eta_C = 93.34\%$$

4. CONCLUSIONS

India was the fourth-largest energy consumer in the world after China, the United States, and Russia in 2011, and despite having notable fossil fuel resources, the country has become increasingly dependent on energy imports.
Solar technology is an alternative that can be commercialized in order to replace non-renewable fuel sources. Based on solar technology, many applications have been produced like, solar car, solar heater and solar street light and many more. In order to develop the solar technology, many factors must be considered like weather, the environment factor, reliability of solar module, and also the load. So, this solar technology still needs improvement in order to achieve higher performance
It is clear that this work was able to get acquainted with this new area of photovoltaic solar energy applications. Unfortunately, it was not possible to build a sample Solar Electric Vehicle because of the low budget and lack of mechanical engineering expertise. Equipment's purchased for this project were also used in the solar car project and were very useful in building and testing in the solar car. In addition, if the power station generating the electricity to recharge batteries uses solar energy, air pollution is also reduced. Based on the models that has been fabricated, every tests carried out has been done in detail in every aspect. It does not matter in terms of component best selection, but also in terms of design as well. The best model is built between the two models is the model 1. The best time recorded was 3.92 second with an angel of 0° and 9.0V of solar panel capacity. Best DC motor in terms of capability is 5.9V instead than 3.0V. As a conclusion, the designed in this work can contribute to the energy saving and meet the energy efficiency guideline. It operates efficiently and can be used in order to save the energy consumption just not only to solar car, but for another application.

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