Design of Solar Powered E-Rickshaw

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Abstract: There has been a growing concern regarding the use of fossil fuel, generally petroleum products, as the main source to drive our vehicles, two, three and four wheelers, resulting in making them one of the major sources of CO_2 and other gases that have contributed to the growing scrouge of global warming and greenhouse effect. Thus, it is high time that we start searching for an alternative source of fuel this is renewable, replenishable and non-polluting. Thus, taking this in view, the objective of the paper is to design a solar powered rickshaw by modifying the old model of manual rickshaw. This paper will also describe the working principle, design calculation and assembly of the rickshaw.

Keywords: Global warming, Solar power, rickshaw and design calculations.

I. INTRODUCTION

Auto rickshaws are small, three-wheeled vehicles which are used extensively in many Asian countries for transport of people and goods. Despite the apparent advantages in the vehicle design, auto rickshaws present a huge pollution problem in major Indian cities.Companies have come out with alternative models such as Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) rickshaws to mitigate the pollution problem caused by traditional petrol models. But the reality is that fuels like CNG and LPG are non-renewable and will be exhausted in future. In order to achieve the sustainable environment for all the living beings from the pollution caused by the combustion of petrol and diesel in automobiles, solar power should be used for the running of these vehicles [1]. The main advantage of using solar powered rickshaw is low cost and pollution free ride.

II. WORKING PRINCIPLE

In this proposed model, the solar panels will charge the battery and simultaneously provide voltage to the motor to fulfill the power requirement of the rickshaw. This is achieved by placing the solar panels, the battery and the selected motor in a parallel connection. The connection is shown in figure 1.

When the rickshaw is at rest and DC motor is switched off, the solar panels accumulate the sunlight and pass the generated electricity only through the battery circuit [2] This starts charging up the battery up to its full potential. After complete charging, the battery is ready to provide energy to the motor. When the rickshaw is working and DC motor is turned on, the current starts flowing through both the battery and motor circuit. Therefore, the solar panel simultaneously provides the voltage to battery to charge as well as voltage to run the motor. Since the connection is in parallel, the battery also provides motor the required power to run the rickshaw. As the DC motor can be turned on/off through a relay switch, its helps in saving a lot of energy and provides the action of charging whilst rickshaw is running.

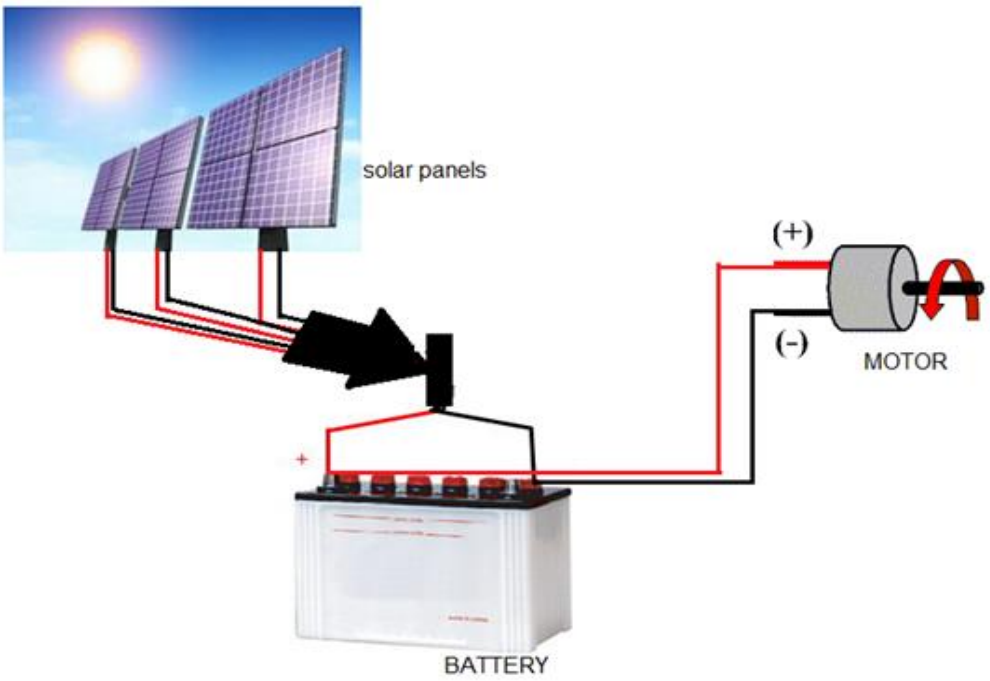


Figure 1: Principle of solar rickshaw

III. DESIGN CALCULATIONS

The design involves the calculation of driving torque and power required for the tricycle, rating of motor, selection of motor, battery and number of solar panels. Once again, to mention, that we are using a manual rickshaw as our base model and it will be modified as a solar powered rickshaw as per design convenience.

The sprockets are so designed that they allow free rotation in the backward directions but only locked direction in the forward direction.

1) So, the pedals remain still even if the rear wheels along with the rear axle keep rotating thus protecting the driver from getting hurt.

2) If some day the driver wants to not use the motor, he can manually padel and in this case the motor shaft does not rotate thanks to the sprocket design which allows one way free rotation.

3) The model started with the understanding and observation of the basic three-wheeled rickshaw which was originally supposed to be pulled by manual labor but for ease of operation and assistance while extreme tasks like uphill pulling of the rickshaw the use of the electric motor is direly essential [3].

Table 1: Specifications of Solar Operated Rickshaw

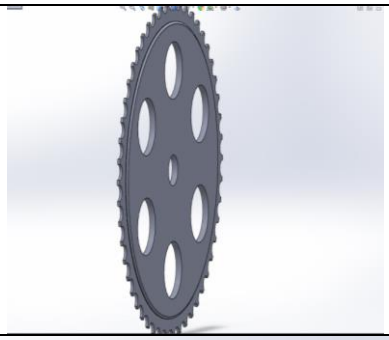
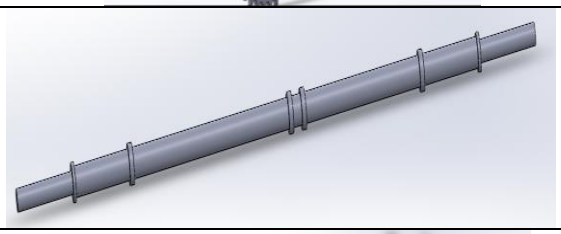
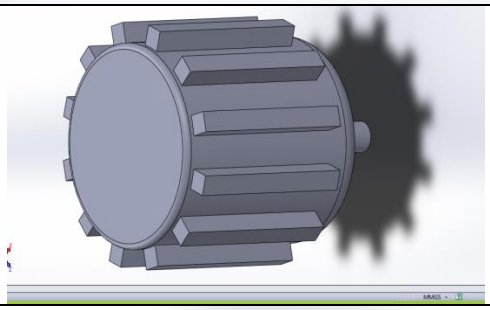
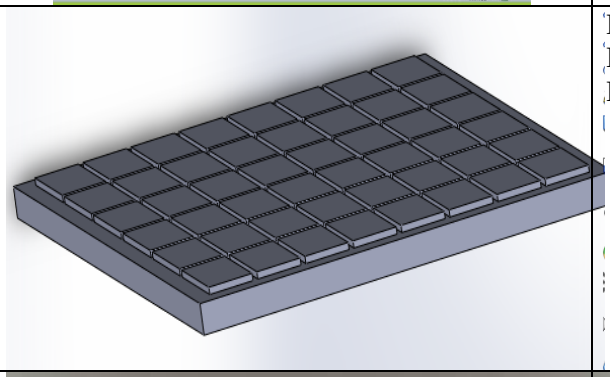
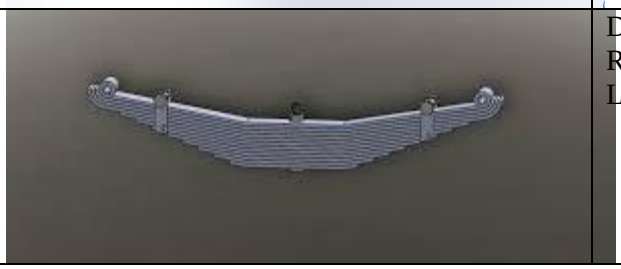
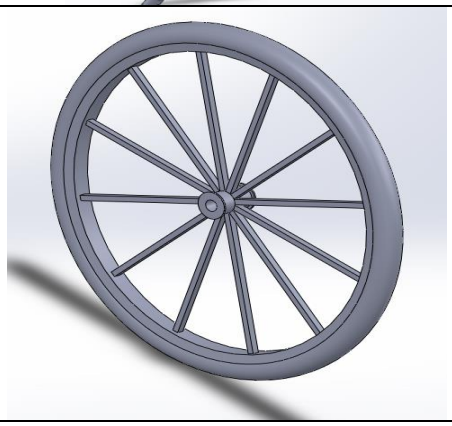
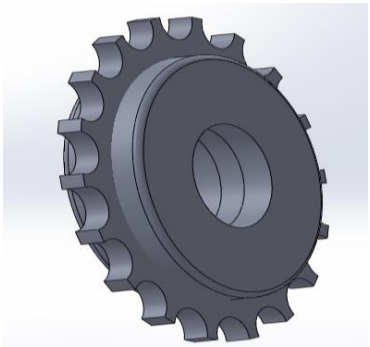
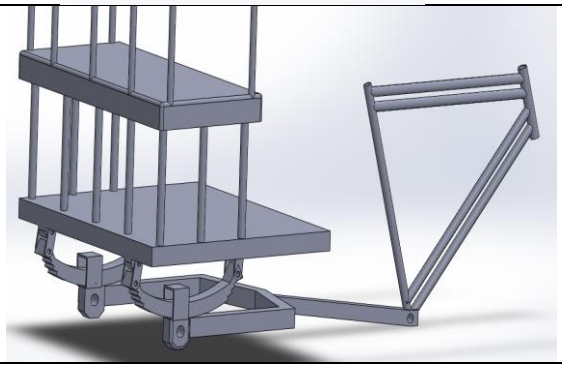
Part Name	*Model*	*Specifications*
Large Sprocket		Maximum diameter= 260mm (tip to tip) No. of teeth = 50 The teeth pitch and profile is same as smaller sprocket since has to share the common chain.
Rear axel		Length of whole shaft = 1009mm (1 meter approx.) Distance between 2 wheels = 790mm
DC motor		Length of whole motor = 270mm Length of shaft= 120mm Shaft dia. =30mm
Solar panel		Dimensions are Length = 700mm Breadth = 600mm
Leaf spring		Dimensions are Radius =40cm Length = 40cm

Table 1: Continued next page…

Table 1: Continue…

Front wheel mounting		Distance between wheel hole and upper = 330 mm (Has to be larger than the tyre radius)
Wheel		Outer diameter = 700mm Inner diameter= 24mm Number of spokes= 12
Small sprocket		External max. diameter = 92.2 mm No. of teeth = 18 NOTE: The ratio of big and small is almost 3 hence a huge Velocity ratio too.
Rickshaw main frame		Undoubtedly a very important part of the rickshaw. The seat is around 720mm broad thus can comfortably house 2 passengers. The dimensions are complex and model is 99% accurate as the real rickshaw.

A. Selection of Dampers

- The rickshaw is equipped with leaf springs. Due to the sheer amount of metal layered together, leaf springs offer a large amount of support between the wheels, axles and the frame of rickshaw. They can take huge vertical loads being applied to them due to their tight-knit structure. Vertical

loading is also distributed throughout the length of the leaf spring rather than acutely through a small spring and damper.

- The use of leaf damper in the rickshaw is that it will wallow and bounce around well after hitting any bump or pot hole in the road. Leaf springs coped much better with vehicle damping due to the friction between each plate of steel which made the response time after a vertical flex in the suspension much quicker, thus making for a much more controllable car.

- The major advantage of installing leaf spring is that it adds to the comfort of the passengers. It prevents them from jerks and discomforts that the rickshaw offers while moving on the road. It absorbs the shocks and maintains a comfortable drive.

B. Selection of the Motor

Selection of motor depends on the power requirement which has already been calculated as 1 HP. Two types of motors are available, mechanically commuted D C motor and Brushless electronically commuted D C motor (BLDC motor).Among these two types, BLDC motor is preferred because it provides noiseless operation , more efficient , gives under and over voltage protection and are waterproof.

C. Battery Specifications

The Selection of the battery depends upon the folowing calculations:

- Battery of voltage 48 V is selected and the current rating is calculated.
- Power = Voltage x Current P = V.I ;
- I = P/V= 31.05 Ah.
- Hence according to the above calculations, to drive a motor of 1490.7 W, 48 V capacity; 2 batteries of 24V, 20Ah are connected in series. The total voltage supplied to the motor is 24V.

D. Specifications of Solar Panels

The specifications of the solar panel is shown in Table 2.

Table 2: Specifications of Solar Panel

Surface area	12 sqft
Power produced	250 watts
Voltage	24 V
Current	4.23 A
Cost	Rs. 13000
Type	Mono crystalline silicon

E. Power of the Motor

The Power can ve determined by the relation:

P= F * v

here the force 'F' is the force which the motor has to produce every moment inorder to overcome the various resistances offered by the road surface, the grade of the road , and the acceleration happening of the rickshaw body as a whole. So the power requirement of the motor this time is calculated as following:

P = 100 N * 8 m/sec

P = 800 Watts.

After examining it comes out that it is not very accurate but we would still insist on using a 1 HP motor i.e 745N considering the facts like, Not all the roads are made of coarse macadam instead most of the roads are made up of asphalt and cement, which offer much lesser coefficients of rolling friction and thus the extra power left with the motor goes to more accelerations or reduced times in reaching top speeds.

F. Force Analysis

On accommodating one passenger along with one driver leads to a total mass of 250kg. The 3 factors left to be calculated are Rolling resistance, Grade resistance and Acceleration force [4].

1) Rolling Resistance

The least resistance is offered by concrete with a rolling friction factor of 0.02 and the highest is offered by dune sand which resists with a rolling resistance coefficient of 0.3.

When it comes to sandy surfaces, the rickshaw puller is ideally supposed to prevent these types of surfaces and even if he encounters such a surface, he will make the passengers to debar and will pull the rickshaw manually. Next comes grass which offers the second highest rolling resistance, just next to dune sand with a factor of 0.075. Still the rickshaw is not meant to be ridden on grass surfaces. Now next important surface comes mud, this surface cannot be overlooked because it is very commonly found and seen in INDIA, typically during the monsoon seasons and sometimes even the entire year. A muddy surface at its highest offers a resistance coefficient of 0.15. So now considering the reality that is the material on which the rickshaw will be ridden is either cement, graphite or macadam. Now macadam at most offers a resistance of 0.037, let's take an even 0.035 as our coefficient of rolling resistance.Now since this rickshaw can move on any road surface with this coefficient, so 0.03 looks like a great choice!

Therefore, $\mathbf{C_{rr} = 0.035}$

And hence the magnitude of corresponding rolling resistance comes out to be

$RR = GVW * C_{rr}$

RR = 250 * 9.81 * 0.035 ; RR = 80 N

2. Recommended Grade Resistance

GRADE RESISTANCE = GR = M * g * sinα

We know that the grade is 0

Sinα = 0

GR = 250 * 9.81 * 0

GR = 0 N

3. *Acceleration*

Now it is rather easy to calculate the acceleration force required. the maximum velocity/speed to be attained by the rickshaw is 30kmph or 8 m/s in metric units [5]. In order to do that, the rickshaw must take only 100seconds. So, the acceleration comes out to be 0.5 m per sec^2.

Acc = (8 – 0)/100 = 0.08 m/s^2

Acceleration force = F_A = M * Acc

F_A = 250 * 0.08

F_A = 20N

4. Total Tractive Force

This is the total force required to be generated by the power train/ power supply mechanism in order to accelerate the vehicle at the required units. Now as obvious the upper three forces all finally act towards retarding the vehicle so, the total tractive effort has to be the sum total of all the three above forces and thus

TTE = RR + GR + FA

TTE = 80 + 20 N

TTE = 100 **N**

5. Torque Required

$\tau = R_f * TTE * R_{wheel}$

The new term $R_f$is the friction factor accounting for frictional losses between bearings and axles.

τ = 0.15 * 100 * 0.34

τ = 5.145 Nm = 5 Nm **=** Required torque rating of the motor.

IV. FINAL ASSEMBLY OF THE RICKSHAW

Figure 3 shows the final assembly of the solar powered rickshaw. The parts described in the table 1 were assembled together to get a final model of the rickshaw.

Figure 3: Final Assembly of the solar powered rickshaw

V. CONCLUSION

The above calculations reveal that the solar powered rickshaw can be a good alternative for a diesel run or a CNG run rickshaw. These rickshaws have the capability to work with a consistent speed and this will also result in less fatigue of the driver. Not only it will contribute nil to air pollution, they will not contribute to the raging noise pollution, which has become another big problem off lately. They will also usher in more green jobs and help a country become less and less dependent on foreign fuel.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities

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