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Solar Vehicles Design For Urban Use: Case Adapted To Cuitláhuac Veracruz

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Abstract

Solar energy has now proved, surprisingly, an excellent alternative energy. Particularly Mexico and Veracruz area lies within the world's sunbelt sun being an invaluable source of energy that has not been exploited in all its aspects.

The main objective of this paper is to show the efficiency of a prototype electric car for urban use powered by a photovoltaic system. This car must have a minimum of 4 hours autonomy with a speed of 70 km / h and be able to carry four persons weighing not more than 800 kg. During the first stage is the design of a sedan car with a direct current electric motor, the design is very important for mechanical components are light as it is vital to save energy.

The next study explains the calculations about braking force between the tire and the road and validates the forces applied to the vehicle steering system.

This paper is proposed by the Technological University Center in Veracruz and Industrial Maintenance Area, through this project seeks to raise awareness of the benefits and advantages in the use of renewable energy sources to boost vehicles.

Keywords: Solar; Vehicule; Cuitlahuac, Validation, Steering worm.

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1. Introduction

Has also been shown that the electric motor drive is more suitable for not only automobiles but also trains, robots, among others, because this type of engine achieves a 90% efficiency (power produced / consumed energy) [1]. Instead, the combustion engine takes advantage of 40% less energy. That is, for every 10 liters of petrol, six liters are lost as gases, heat, noise, vibration, waste [2]. It is considered more viable electric car use for transportation, and this, a new field of development.

In Europe it was determined determined that only 0.25% of people occupying an electric car for their daily activities a 2.67% hybrid and an overwhelming majority of 97.08% petrol cars [3]. The case of our country is no more encouraging is electric cars can mention only the case of the prototypes proposed by the UNAM in Mexico City [4].

In Mexico most cars are powered by gasoline, it is recognized as one of the main pollutants in the world, the state of Veracruz has one of the top nationally in greenhouse gas emissions into the atmosphere. An electric vehicle does not emit pollutants and certainly does not take gasoline. It has been shown that the electric motor drive is more convenient for not only automobiles but also trains, robots, among others, due to this type of engine that achieves a 90% efficiency (power produced / consumed energy). Instead, the combustion engine takes advantage of 40% less energy. That is, for every 10 liters of petrol, six liters are lost as gases, heat, noise, vibration, waste. It is considered more viable electric car use for transportation, and this, a new field of development [5].

The combined use of electric cars to solar energy, compared to internal combustion is cheaper, suppose you live in the city of Veracruz Fortin de las Flores and works at the Technological University of Central Veracruz is the daily journey of 70 kilometers, the consumption of a four-cylinder car translates to 12 kilometers per liter of petrol and whereas the price of gasoline is approx. $ 10.00 has to be the commuting cost is a minimum of $ 60.00.

Furthermore, exposure to air pollution at current levels of pollution causes serious health effects on people: irritation of eyes, mucous membranes and lungs surfaces, increases in total mortality, mortality from respiratory and cardiovascular diseases, pulmonary function loss and risk of lung cancer incidence [6].

According to the Environmental Protection Agency of the United States (EPA), driving a car is the single most polluting activity than most people realize. Motor vehicles release millions of tons of pollutants into the atmosphere each year. In many urban areas, vehicles are primarily responsible for the presence of ground-level ozone [7]. This is one of the main components of smog. The car exhaust also cause environmental problems such as acid rain and global warming. All this is to eliminate the use of electric vehicles, it does not contribute to noise pollution, reduction of natural resources and general environmental degradation, thereby improving the environment and quality of life [8].

2. Approval of vehicle steering system.

The direction of an electric vehicle is composed of: moving worm screw, engaged steering column movement to a roller which drives the control arm for guiding the wheels. Finally the roller screw and roller are staying in a closed box. The worm is not cylindrical, but tapered at the front (globoid). Thus the direction roller driven by the worm, you can make a move on its midpoint to turn the wheel, turning the control arm shaft and quickly, rocking motions of up to 90 degrees.

The advantages of this system are the low wear, smoothness of operation and reduced space requirements.

1) Screw Auger direction.
2) Axis of the steering column.
3) Roll direction.

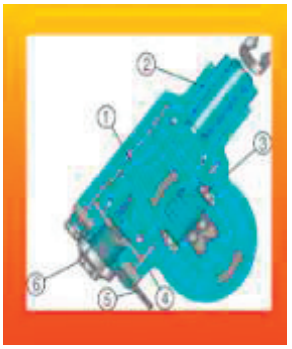

Fig. 1. (a) first picture Steering Worm.

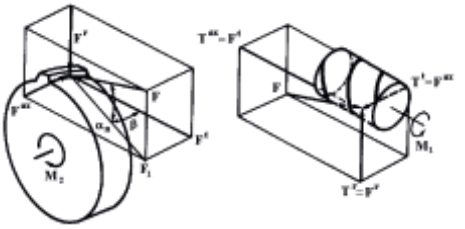

Fig. 2. (b) Second picture worm gear system.

To Browse and select a mechanical steering system, with the right features for Solar Electric Vehicle needs taking into account the operation, maintenance and costs should be determined torque and force applied to the elements of the mechanism.

Following analyze forces at the worm gear system.

Total Force Worm.

$$F^t = \frac{W}{V_2} \quad (1)$$

Driven Gear Total Force.

$$T^t = \frac{W}{V_1} \quad (2)$$

Speed Gear Driven.

$$V_1 = \frac{2*r_2*n_2}{60} \quad (3)$$

Worm Speed.

$$V_2 = \frac{2*r_1*n_1}{60} \quad (4)$$

Torsion Worm.

$$M_1 = T^t * r_1 \quad (5)$$

Driven Gear Torsion

$$M_2 = F^t * r_2 \quad (6)$$

Force

$$F = \frac{\mathrm{T}}{\mathrm{d}} \quad (7)$$

Below can see the information for get the first analysis:

$r_1 = 0.0127\text{m}$

$r_2 = 0.019\text{m}$

Relationship between arrow and gear: 13:1
Arrow on the flywheel: 30 rpm
Driven gear: 2.3 rpm
Torque applied to the shaft of the steering wheel = 40.5 N.m

Substituting values in equation 3 and 4 yields the following:

$$M_1 = \frac{2\pi(0.0127m)(30\text{rpm})}{60} = 0.0398\ \text{m/s}$$

$$V_2 = \frac{2\pi(0.019m)(2.3\text{rpm})}{60} = 0.004576\ \text{m/s}$$

To calculate the force on the arrow auger is necessary to clear the variable T^t in the formula 5.

$$T^t = \frac{M1}{r1} \qquad (8)$$

$$T^t = \frac{40.5\ N.m}{0.0127m} = 3{,}188.97\ \text{N}$$

To calculate the power applied to the auger cleared arrow W in formula 2:

$$\text{W} = T^t.\text{V1} \qquad (9)$$

$$\text{W} = (3{,}188.97\ \text{N})\ (0.0398) = 124.13\ \text{watts}$$

Now calculate the force transmitted to the gear:

$$F^t = \frac{124.13\ N.m/s}{0.004576m/s} = 27{,}126.31\text{N}$$

Therefore the torque applied to M2 is:

$$M_2 = F^t * r_2$$

$$M_2 = (27{,}126.31\text{N})\ (0.019\text{m}) = 515.39\ \text{N.m}$$

Finally calculate the force applied at the end of the support arm of the direction of the vehicle using the equation 7.

$$\text{F} = \frac{T}{d} = \frac{515.39N.m}{0.18m} = 2{,}263.27\text{N}$$

Divide the force obtained in between the two arms of the address.

$$\frac{2263N}{2} = 1131.6\ \text{N}$$

1131.6 N is the load that is applied to the steering arms.

Then the values obtained were used to validate the software components using solidwork.

3. Analysis using solidwork

Table 1. Parameters used in the analysis of the first component.

Volumetric properties:	**Material properties:**	**Mesh information**	**Mesh information - Details**
Mass: 0.657481 kg Volume = 8.37555e-005 m^3 Density: 7850 kg / m^3 Weight: 6.44331 N	Name: ASTM A36 Steel Model type: linear elastic isotropic Default failure criterion: maximum von Mises Stress Yield: 2.5e +008 N/ m^2 Tensile Strength: 4e +008 N / m^2 Modulus of elasticity: 2e +011 N / m^2 Poisson's ratio: 0.26 Density: 7850 kg / m^3 Shear Modulus: 7.93e +010 N / m^2	Mesh type: solid mesh Mesh used: Standard Mesh Jacobians Points 4 Points 4.37664 mm element size Tolerance 0.218832 mm Quality mesh high order quadratic elements	Total number of nodes 17504 Total number of elements 10289 21,095 maximum aspect ratio % Of elements whose aspect ratio is <3 89.4 % Of elements whose aspect ratio is> 10 0.398

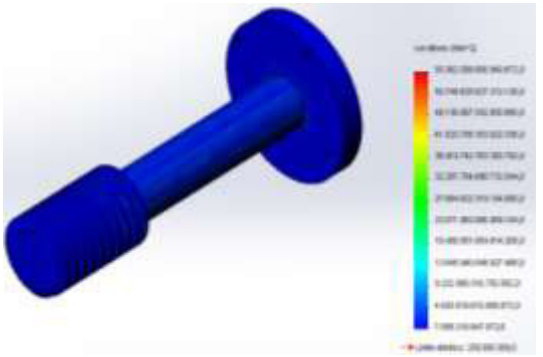

Fig. 3. (c) Third picture tension.

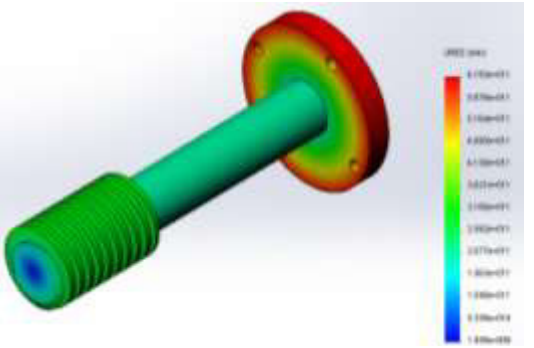

Fig. 4. (d) Fourth picture displacement.

Figure 3 shows the stress analysis using Tension theory of von Mises, same as going 7.05821e+012 N/ m^2 and 5.53626e+016 N/m^2 so you can say that does not exceed acceptable limits. Therefore it is an insurance element to the vehicle to develop. The displacement of the element goes from 1.93613e+009 mm-6.1929e+011 mm therefore considered negligible, Figure d the area marked with blue the node 6031 is where there is minimum material displacement and the red the node 11182 shows the maximum displacement, it is not significant for the performance element in the vehicle. The unit deformation of the element goes from 26.2913 minimum to 91912.2 maximum, this not represents a problem for the performance of steering system, and the deformation is present in an isolated area of the part.

Table 2. Parameters used in the analysis of the roll direction.

Volumetric properties:	**Material properties:**	**Mesh information**	**Mesh information - Details**
Mass: 3.84178 kg Volume: 0.000489399 m^3 Density: 7850 kg / m^3 Weight: 37.6495 N	Name: ASTM A36 Steel Model type: linear elastic isotropic Yield: 2.5e +008 N / m^2 Tensile Strength: 4e +008 N / m^2 Modulus of elasticity: 2e +011 N / m^2 Poisson's ratio: 0.26 Density: 7850 kg / m^3 Shear Modulus: 7.93e +010 N / m^2	Mesh mesh type solid Maesh used: Standard Mesh Jacobians Points 4 Points 7.88251 mm element size Tolerance 0.394126 mm Quality mesh high order quadratic elements	Total number of nodes 15034 Total 9087 items 14,943 Maximum aspect ratio % Of elements whose aspect ratio is <3 91.5 % Of elements whose aspect ratio is> 10 0.121

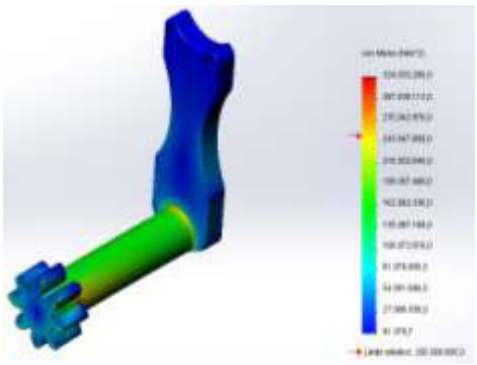

Fig. 5. (e) Sixth picture tension.

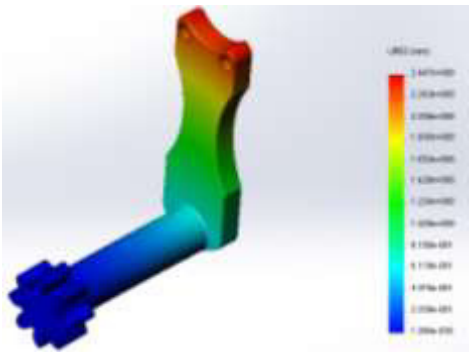

Fig. 6. (f) Seventh picture displacement.

Figure 5 shows the stress analysis using Tension theory of von Mises, same as going 91378.7 N/m^2 and 3.24033e+008 N/m^2 so you can say that does not exceed acceptable limits. Therefore it is an insurance element to the vehicle to develop. The displacement of the element goes from 0 mm to 2.4473 mm therefore considered negligible, Figure 6 the area marked with blue the node 65 is where there is minimum material displacement and the red the node 8298 shows the maximum displacement, it is not significant for the performance element in the vehicle. The unit deformation of the element goes from 5.4155e-007 minimum to 0.00128134 maximum, this not represents a problem for the performance of steering system, and the deformation is present in an isolated area of the part, this area is marked in red.

Table 3. Parameters used in the analysis of the third component.

Volumetric properties:	**Material properties:**	**Mesh information**	**Mesh information - Details**
Mass: 1.45414 kg Volume: 0.00018524 m ^{3} Density: 7850 kg / m ^{3} Weight: 14.2506 N	Name: ASTM A36 Steel Model type: linear elastic isotropic Yield: 2.5e +008 N / m ^{2} Tensile Strength: 4e +008 N / m ^{2} Modulus of elasticity: 2e +011 N / m ^{2} Poisson's ratio: 0.26 Density: 7850 kg / m ^{3} Shear Modulus: 7.93e +010 N / m ^{2}	Mesh mesh type solid Mesh used: Standard Mesh Jacobians Points 4 Points 5.70212 mm element size Tolerance 0.285106 mm Quality mesh high order quadratic elements	Total number of nodes 13495 Total 7577 items 27,593 maximum aspect ratio % Of elements whose aspect ratio is <3 94.6 % Of elements whose aspect ratio is> 10 0.172

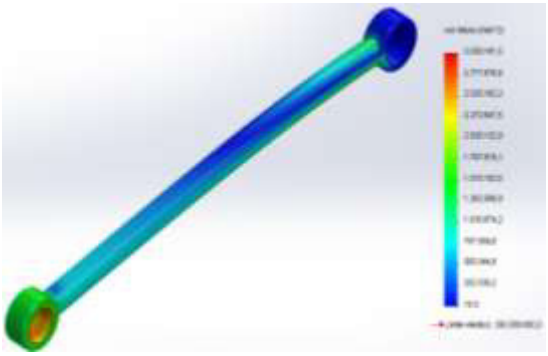

Fig. 7. (g) Ninth picture tension.

Fig. 8. (h) Tenth picture deformations.

Figure 7 shows the stress analysis using Tension theory of von Mises, same as going 15.5028 N/ m^2. And 3.03019e+006 N/m^2 so you can say that does not exceed acceptable limits. Therefore it is an insurance element to the vehicle to develop. The displacement of the element goes from 0 mm to 0.0348818mm therefore considered negligible, Figure 8 the area marked with blue the node 65 is where there is minimum material displacement and the red the node 8298 shows the maximum displacement, it is not significant for the performance element in the vehicle.

4. Validate at electrical circuit at electrical vehicle

Following is the electric power diagram, this system will to mobilize an electric car of 900 kilograms at velocity maxima of 75 km/hr.

The vehicle autonomy is 4 hours, then is appreciated the most important parts as those batteries and motor.

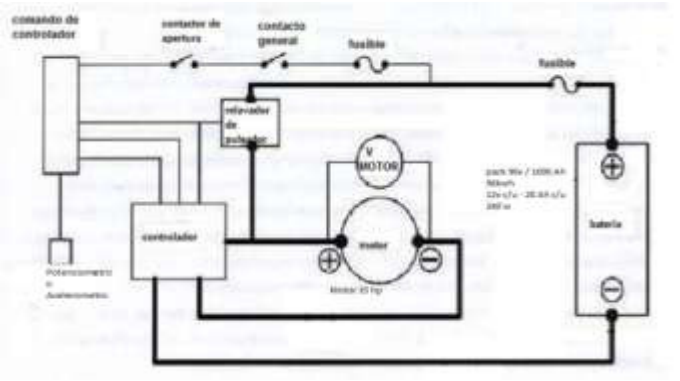

Fig. 9 (i) Power diagram.

The figure 9 shows the connection diagram and can see the batteries, which are the electric vehicle charging whose connection is as follows the negative pole of the battery is connected to the controller, the positive goes through a fuse and hence land to closing the main relay, this in turn derives a smaller line that passes through a second protection that goes to a main contact and then the starting and ending swhic in controller command. Relay likewise derives the driver command, closing the relay passes the current through the motor is regulated by the controller via manipulation potentiometer to vary the speed, this will enable us to control acceleration and also our better handling.

Will perform an array of batteries to finance consumption required for a motor workload is approximately 4 hours mind.

To design of the battery, is necessary calculate the number of cells to provide 30 kW that will allow the vehicle a autonomy 4 hours, it is considered that a cell provides 3.2v and a current of 100 Ah [9]. First it generates an in series adjustment to provide the 48 volt electric motor consumes 10 kW Peak 48v, this will have to connect 16 cells series which generates 52 volts with 5.2 kw It therefore supplies must be connected 3 arrangements of 52 volts in parallel for 15.6 kw which are not yet sufficient. To solve this problem are connected in 2 packs of 15.6 kw [10]. Therefore requires 31,200 watts-hour for the vehicle having a functionality of at least 4 hours.

The graph performance and power of the electric motor shows the maximum and minimum peaks based on the behavior of consumption in watts motor and torque generated It is observed that a peak consumption of 10 kW motor is providing approximately 33 Nm of torque, with the following was found to be sufficient to mobilize the vehicle [11].

$$T\ (F)(d) \tag{10}$$

$$T\ = (m)(g)(d) \tag{11}$$

Isolate the variable m in the following equation being as follows

$$m = \frac{T}{(g)(d)} \tag{12}$$

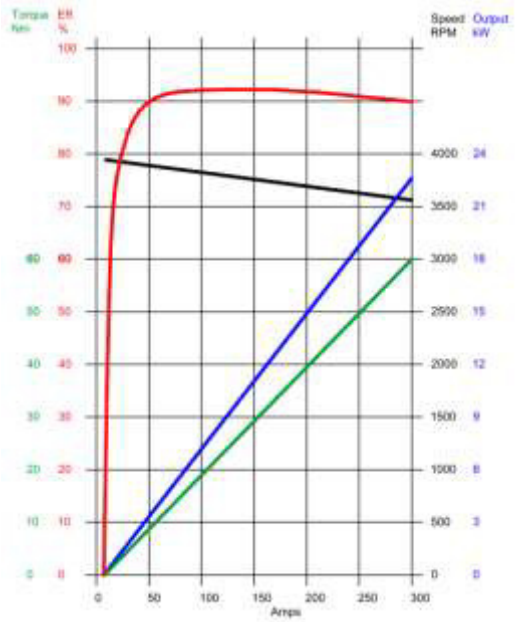

Fig 10 (j) Graphics performance and power of the electric motor.

Values are substituted in the above equation 12:

$$m = \frac{33\ Nm}{\left(9.81\frac{m}{s^2}\right)(.0095m)}$$

$$m = 354.046\ kg$$

Thus the motor can lift 354 kilograms fully loaded. Considering the weight of the vehicle plus four passengers has a total of 900 kilograms.

Given that the data transmission in the first speed relation is 3.6 to 1, [12] has the following equation:

$$T = (33\ Nm)(\ RT\ ) \qquad (13)$$

T = Torque

Where: **T** is torque and **RT** is gear ratio

Therefore:

$$T = (33Nm)(3.6)$$

$$T = 118.8\ Nm$$

Values are substituted in equation 3

$$m = \frac{118.8\ Nm}{\left(9.81\frac{m}{s^2}\right)(.0095m)}$$

$$m = 1274.746\ kg.$$

Therefore can say that the engine power is enough to mobilize the vehicle with four passengers inside.

5. Conclusions

After examining the various components of the steering system, its mechanical properties are suitable according our needs.

In the mechanical system and roller screw, has a compact design, which benefits the development of the project, and because of the simplicity of the mechanism is relatively simple maintenance.

In terms of management, this mechanism provides excellent handling due to its mechanical simplicity and control of the facility, smoothness and stability.

In the maintenance part of the system have a low cost, but more often the system with Re-Circulating balls but due to the low cost of the parts is more likely their support.

After having performed several studies in SolidWorks Simulation, we determined that the mechanism have to be have properly in the vehicle.

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