New Design Ideas
Vol.6, No.2, 2022, pp.257-265

MODELING LIGHT ELECTRIC CAR WITH NEW MATERIALS AND FUEL CELL

P. Vera-Serna[1*], F.N. Tenorio-González[1], D. Ramos-Peña[2], I.R. Barajas-Rosales[3]

[1]Direction of the Engineering Division, Universidad Politécnica de Tecámac, Tecámac de Felipe Villanueva, Estado de México
[2]Faculty of Engineering, Universidad Veracruzana, Ixtaczoquitlán, Veracruz
[3]Chemical Engineering Departament, Instituto Tecnológico de Pachuca, Pachuca de Soto, Hidalgo

Abstract. This research presents the analysis on mass and virtual model of a light vehicle for two persons, it will be use commercial fuel cell, we are presenting a proposal with greater autonomy regarding adequate price electrical vehicles in the market with major autonomy than others vehicles in low cost. The innovative aspect of the project is the use of the light material on body and the electric engine for power generation. It is powered by a system that includes the mentioned cell. Computer Aided Engineering was used to evaluate the pressure on electric car and obtained the adequate results for its functioning with light materials, motors, design and using fuel cells with hydrogen.

Keywords: *Electric vehicle, fuel cell, hydrogen, CAE modeling, simulation.*

Corresponding Author: *P. Vera-Serna, Direction of the Engineering Division, Universidad Politécnica de Tecámac, Tecámac de Felipe Villanueva, Estado de México, e-mail:* pedrovera.upt@gmail.com

Received: *3 April 2022;* ***Accepted:*** *7 June 2022;* ***Published:*** *3 August 2022.*

1. Introduction

The demand for energy and the increasing environmental problems have intensified the search for clean energies, as well as new alternatives to reduce environment pollution. This demand for energy has its origin in three important sectors to the human being, which are: the industrial sector, the transportation sector, and the building and construction sector (residential and commercial), sustainable energy is important way to the success of Agenda 2030 (Gielen *et al*., 2019). The transportation sector consumes approximately 26% of the total energy on the world, and cars could be almost double on 2050 (Mazurova & Galperova, 2018), that comes from fossil fuels and a low percent of electric power due to the cost and ratio with the demographic growth worldwide. There are different energy systems nowadays, there are electric, hydrogen, hybrid, ethanol vehicles, among others (Jannson *et al*., 2017). The proposal of the electric car as a transition to replace fossil fuels has had positive results since it was created because it uses chemical energy stored in rechargeable batteries to power the electric engine. Additionally, technologies continue to grow, consequently, the perspective of powering has changed, around on 2030 the penetration of electric vehicle in the sales market could be between 20% and 60% (Khurana *et al*., 2017). An example of this innovation is the fuel cell in car, which uses a fuel cell battery that is powered by hydrogen, which powers the electric engine, in this paper was developed a model using a light car with fuel cell and batteries. A novel design using specific lighter materials let this possibility using CAD-CAE.

The autonomy of electric cars can be of distances up to 386 Km and has a price that ranges from 48,067 USD to 64,641 USD (Butler, 2019). There are also low price vehicles that cost about 10,000 USD. Nonetheless, their autonomy is limited to distances shorter that 60 km, it let generate opportunities to develop new designs using alternative fuel, fuel cells on 2005 had a cost on 50,000 USD but on 2019 reduce to 10,000 USD (Stafell *et al*., 2019), it will be a possibility to use on the next decades.

2. Method and materials

For the modeling, the options of reducing the mass of the vehicle, developing the body of the vehicle with light materials, using an electric engine and fuel cells to increase the autonomy of the vehicle emerged, aiming at a competitive cost. In such a case, it would be recommended that the speed be no higher than 80 km/h.

❖ Materials

In order to develop the model, this is the initial list of materials considered for the power system.

- Hydrogen storage containers
- Electric engine
- Engine and internal components protection system
- Deep cycle battery
- Fuel cell power system

On table I is possible show the commercial materials with low density considered to specifics parts on the body.

Table 1. Commercial lights materials

Type	Density (g/cm^3)	Tensile Modulus (MPa)
LEXAN Gepax 8000	1.2	2300
LEXAN ULG 1003	1.2	2350
LEXAN F6000	1.2	2200

Regarding the material to reach the mechanical resistance and the low weight, the three materials LEXAN were chosen to different applications, Gepax 8000 to car body and F6000 to interior parts, in the case of the fuel cell power system, a prototype system was acquired to evaluate in physical way its functioning and interconnection, CAE software was used on simulation.

❖ Methodology

An investigation about the costs and the materials was performed, evaluating a material which has been launched onto the market recently called Lexan. This material was used for the calculations and the simulations, taking into account its characteristics and costs. Unlike other projects previously developed by the authors, the reduction of mass was emphasized in order to reduce costs when a lower power engine is used, which reduces the cost drastically. Below is a comparative chart of fuel cells costs in Mexico, it is important to mention that the costs are high for they are educational, and they are sold by unit.

Table 2. Costs of fuel cells

Power output	Approximate price in USD
1000 W	6,125
2000 W	10,795
3000 W	15,262
5000 W	24,789

In the case of use of CAD-CAE were used files of parts using solids, surface and CFD simulation.

Table 3. Simulation Parameters

Basic Mesh Dimensions	Number
Number of cells in X	14
Number of cells in Y	16
Number of cells in Z	13
Analysis Mesh	Number
Fluid Cells:	6990
Solid Cells:	1923
Partial Cells:	1428
Additional Physical Calculation Options	Considerations
Heat Transfer Analysis:	Heat conduction in solids: Off
Flow Type:	Laminar and turbulent

3. Results

The article shows the results on modeling and use of the alternative energies, in the present work were developed the shape, the mass vehicle and a novel energy system on a electric car.

❖ Modeling

The modeling of an electric car with hydrogen cell system has a 10 mm thick solid surface which is held onto a rectangular metallic structure, which provides support to the structure and main sheet of the vehicle. The joints of the components of the structure are made of solder. The superficial design is made in five pieces, where in the joints in the assemble are held with screws, bolts, and anti-vibration nuts. It has two adjustable movement seats, front trunk, space in the rear for a hydrogen fuel tank, an engine and fuel cells as it can be observed in Figures 1 and 2.

The parts are associated in the following list and showed in Figures 3 and 4:

1. Hydrogen container
2. Electric engine
3. Aerodynamic design rear surface
4. Gear protection cover for power distribution of the rear tires
5. Front surface
6. Tire
7. Engine and internal components protection system
8. 10 mm thick solid sheet
9. Door

10. Deep cycle battery
11. Fuel Cell

Fig. 1. Perspective on front view

Fig. 2. Perspective on back view

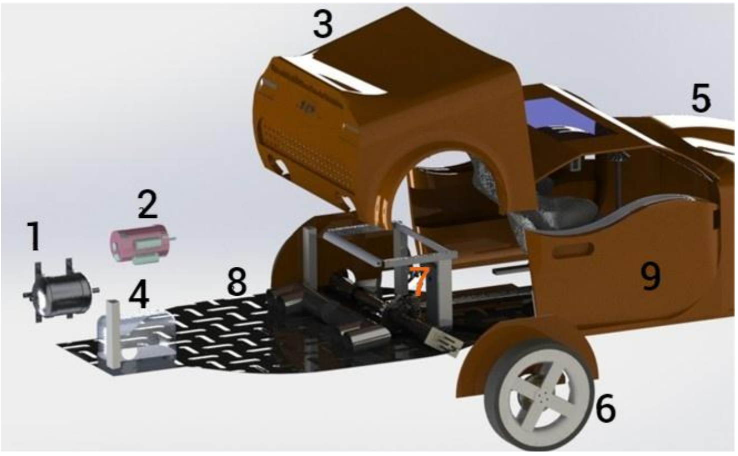

Fig. 3. System elements

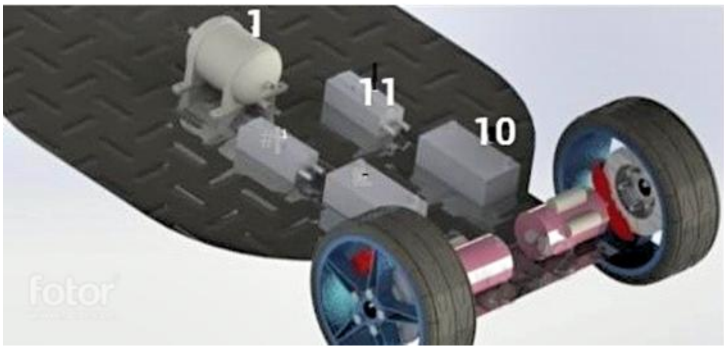

Fig. 4. Engines position

❖ Engine

In order to choose the engine, the following aspects were taken into account: the physical characteristics of the car modelling, the weight, and the torque and additional necessities required.

The choice of the engine was a key factor. The energy generated by the chosen hydrogen cells were 2 KW to 2 motors that demand 1KW everyone.

When creating an independent system, it is proposed to color the traction system in each tire, (tire, battery, fuel cells). The fuel tank and the control system are the parts that would be shared.

This way, the decision of implementing a push start system in the light vehicle was made. And so as to lower the price of the vehicle, it was decided to design a car with less power characteristics. It is cheaper to use two electric motors. In order to do the aforementioned, at least 4 batteries are required (Figure 4), an important consideration in the electric car is the reduction on the cost in batteries since 2008 to 2015, the high cost was 230 USD/kWh (Faizal *et al*., 2019).

The light electric vehicle has an optimized distribution of weight and internal space.

Table 4. Engine characteristics

Characteristic	Type
Model number:	QS MOTOR CC
Voltage:	48 V
Energy:	1000 W
Application:	Electric car
Torsion:	150n-m
Construction:	Aluminum

The vehicle comes with a fuel tank of 34 liters, considering the fact that the gap between a liter of hydrogen compared to the water and the deep cycle battery is that of 48V 50Ah.

❖ Fuel Cells

The choice of hydrogen cells depends on the energy required, there are hydrogen cells available from 100w to a higher range of 15kW as is showed on Figure 5 (300W). The following is a description of possible candidates for the proposed model. The most convenient fuel cells for vehicles should be of at least 1000W, in previous projects 5000W fuel cells have been used with higher power engines. In this project, the masses have been reduced, accordingly, an engine with a low energy demand was proposed. Keeping in mind that one cells would be used, as a reference the commercial power system installed in our institution was used, which allowed its observation, and then, a design in accordance was achieved. The system uses the hydrogen tank, the deep cycle battery previously mentioned, a control device for the cell (Figure 6), other battery that powers the control device, a container for the hydrogen flow after passing through the cell, the Fuel Cell is commercial on 2KW (H-2000 PEM FUEL CELL).

Fig. 5. Representative Fuel Cell in Lab

Fig. 6. Control Device

❖ Vehicle Body

The Lexan Gepax 8000 was used in the body of the vehicle, considering the aerodynamic design to improve the air flow through the main components. It also has ventilation openings for a better response to the wind tunnel, in Figures 7 and 8 the modeling can be observed.

❖ Materials for the Vehicle Interior Design

Lexan F6000 material was used for the vehicle interiors having a range of opaque fire retardant sheets, available in standard and customized colors. In addition to its excellent fireproof properties, it offers en elevated resistance to impacts, rigidity and excellent formality.

Fig. 7. Vehicle body

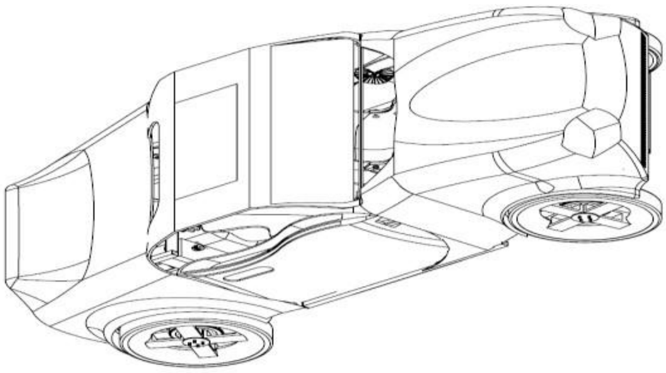

Fig. 8. Contours of the body vehicle

❖ Vehicle weight

The weight of vehicle was determined with the materials used and the mass of elements, in the next table were showed the weights.

Table 5. Weights

Qty	Part	Weight (Kg)
2	Electric Motor	15
2	Seats	15
1	Structure	45
4	Batteries	25
1	Suspension and direction	55
1	Car body	227
1	Transmission	40
1	Tank	16
5	Wheels and tires	79
1	Brake system	29
1	Fuel cell system	14
1	Other parts and accessories	80
	Total weight	600

❖ **Aerodynamic Analysis with Flow Simulation**

After the modeling of parts and assemble, the analysis of the Flow Simulation was performed, using air as the fluid. The results are presented in Figure 9. It is possible to observe that the stress values are very low compared to the material mechanical resistance.

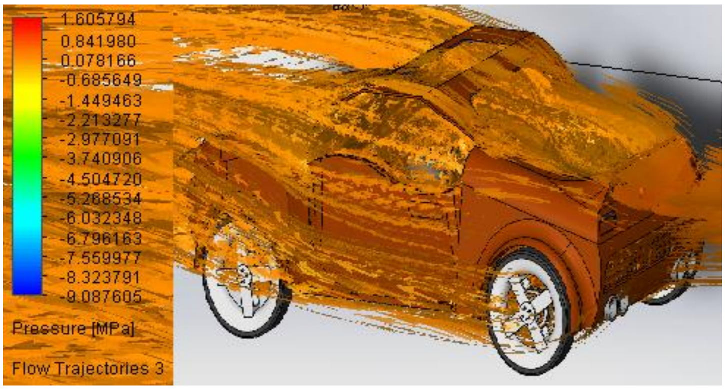

Fig. 9. Fluid Simulation with stress values

The pressure generated by the air currents and the temperature would not affect the structure of the Vehicle Model. The speed in boundary conditions is 100 Km/h, consequently, the geometry and the material would not be affected, taking into account the air and temperature, this would only generate a most critical pressure over the surface of 1.6 MPa.

4. Conclusion

Based on the analysis performed on this vehicle, the estimations of the special materials reduced the costs in a considerable way for this electric car powered by fuel cells with low weight 600 Kg. Additionally, the current demand of this type of materials allowed the reduction of weight in a considerable way with 2 motors of 1KW.

The implementation of the new cells enhanced better efficiency in this vehicle model. The design developed over the course of this investigation improved the reduction of weight. The vehicle, being lighter, is going to have a better movement and performance that was not as meaningful in other vehicles.

The study performed by CFD showed that the models proposed at the beginning of the project had a deficiency in certain parts. Then, the necessary modifications and the new simulations were performed again. As a result, the improvement was significant. Being able to prove with CFD, the proposed models is an improvement for the car engineering. It can even provide a different perspective. Likewise, it helped to decrease the pressure on surfaces.

Acknowledgement

The Program PFCE for their support in the acquisition of the power cell bank and the Summer Program of Investigation Delfín, Special recognition to David Benjamin Romero Almeida for his participation on this analysis.

References

Butler, C. (2019). Electric vehicle prices finally in reach of millennial, Gen Z car buyers. https://www.cnbc.com/2019/10/20/electric-car-prices-finally-in-reach-of-millennial-gen-z-buyers.html

Faizal, M., Feng, S.Y., Zureel, M.F., Sinidol, B.E., Wong, D., & Jian, G.K. (2019). A review on challenges and opportunities of electric vehicles (evs). *J. Mech. Eng. Res. Dev*, *42*(4), 130-137.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energ. Strat. Rev.*, 24, 38–50.

CoacHyfied project to trial fuel cell coaches. *Fuel Cells Bulletin*, *2021*(4), doi: https://doi.org/10.1016/S1464-2859(21)00174-7

Jansson, J., Pettersson, T., Mannberg, A., Brännlund, R., & Lindgren, U. (2017). Adoption of alternative fuel vehicles: Influence from neighbors, family and coworkers. *Transportation Research Part D: Transport and Environment*, *54*, 61-73.

Khurana, A., Kumar, V.R., & Sidhpuria, M. (2020). A study on the adoption of electric vehicles in India: The mediating role of attitude. *Vision*, *24*(1), 23-34.

Mazurova, O., Galperova, E. (2018, October). Energy consumption in the transport sector: Trends and forecast estimates. In *2018 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)* (pp. 1-7). IEEE.

Staffell, I., Scamman, D., Abad, A.V., Balcombe, P., Dodds, P.E., Ekins, P., ... & Ward, K.R. (2019). The role of hydrogen and fuel cells in the global energy system. *Energy & Environmental Science*, *12*(2), 463-491.

Stellantis hydrogen fuel cell light commercial vehicles with Symbio and Faurecia technology. *Fuel Cells Bulletin*, *2021*(4), doi: https://doi.org/10.1016/S1464-2859(21)00171-1