

Influence of the Design Parameters of Electric Vehicles in the Optimization of Energy Efficiency in Urban Routes

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ABSTRACT

The analysis and decision making on design, behavior and use of a prototype electric vehicle is the main focus has been pursued in this paper. It was modeled a prototype electric vehicle, called Gorila EV, as from the software tool Adams/Car.

The dimensional parameters needed to create the model were obtained by measurements, calculations and approximations. Subsequently, it was determined a route to be travelled by the vehicle and proceeded to simulation of the vehicle on that route. Different modifications in the model were performed to compare their results with the original model through simulation in Adams/Car. These changes ranged from a simple change in the mass of the chassis until a change in the type of vehicle traction. After made the changes and simulations, it carried out the analysis of the most remarkable results. These results were studied subsystem by subsystem, beginning with the wheels, to suspensions and engine until vehicle chassis. In light of the results, it were identified the engine and chassis mass as very influential factors in the model behavior. Therefore further the study focused on these factors in order to optimize the use of the vehicle.

In this paper we show the design criteria for electric vehicles to optimize engine power, weight, battery and vehicle performance according to the characteristics of typical urban routes.

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INTRODUCTION

This paper is collaboration between the Research Group on Sustainable Means of Transport and Systems (SMITS) of the University of Zaragoza and the Spanish company, Zytel Automotive S.L. (ZYTEL). The main goal is to use a software simulation tool as Adams/Car for performing analysis and making decisions on the design, behavior and use of a prototype electric vehicle. ZYTEL, as part of the development process and production of an electric vehicle called 'Gorila EV', it decided to collaborate with SMITS for a study of the behavior and performance of the vehicle as well as to discuss possible improvements or changes in the architecture of same.

The way it decided to tackle this paper was by Computer Aided Engineering (CAE). Conduct an analysis of the vehicle by CAE allows increasing the quickness and convenience when getting results and reduce costs incurred testing with real prototypes.

In this study it considers urban driving, where the vehicle trajectory is constrained by the infrastructure (road signs) and other vehicles (traffic). These constraints have a major impact on the vehicle trajectory, and therefore the formalization of the problem is different. In [1] an approach to define and evaluate the energy efficiency of a travel for an electric car driven in such conditions has been proposed.

The United Nations estimated that over 600 million people in urban area worldwide were exposed to traffic-generated air pollution. Therefore, traffic related air pollution is drawing increasing concerns worldwide [2]. Electric vehicles (EV) are seen by many environmentally friendly groups and organizations as a potential solution to address the impact of transportation emissions in urban areas. Urban areas are also more suitable for the early adoption of electric vehicles due to the potential higher density of recharging stations. New vehicle technologies such as electric vehicles should be analyzed within a City Logistics framework as a holistic approach is needed to account for the multiple trade-offs in terms of initial purchase costs against life-long operating costs, emissions costs, and service restrictions [3, 4].

Objectives

1. Make a model of the Gorila EV as similar as possible to the real prototype and able to be simulated in software.
2. Make a model of an urban route that it can be used as a platform for simulation vehicle model created and which also capable of being used for the actual prototype for future trials and tests.

3. Simulate the behavior of the vehicle model on the route and analyse the simulation results with an emphasis on those most important parameters.
4. Suggest changes and possible improvements of the model and check its result and possible use in real life through simulation.

In order to achieve these objectives, collaboration of ZYTEL is needed primarily for the creation of a vehicle model that approaching as possible to reality.

Overview of Electric Vehicles

Although a study of EV demand was published thirty years ago [5], most model-based academic studies of the likely uptake of Alternative Fuel Vehicles (AFVs) have been conducted in the last 10-20 years [6]. Recent issues of exhausting fossil fuels and global warming caused by internal combustion vehicles (ICV) vehicles have led to considerable efforts to develop EVs as environment-friendly vehicles utilizing electrical energy sources [7, 8]. There is a large difference between the drivetrain system of EVs and ICVs. In contrast with conventional ICVs, the powertrain systems of EVs run electric motors through electrical energy stored in batteries [9]. EVs are developed today don't differ as much as it can think of ICV more common. The EV consists of main components (rolling elements, chassis and bodywork) are essentially similar to those used by ICV; even if in the case of chassis and bodyworks, for example, are making efforts reducing their weight to reduce energy consumption [10, 11]. However, it is in the functional components where the biggest differences are observed. The functional components are vehicle batteries (traction and auxiliary), electronic control and motor electric.

EVs consume about three times less energy, driving is much quieter and comfortable and consist of a large number of environmental benefits (more recyclable, cleaner, more sustainable, etc.) however they haven't the power, acceleration and top speed of a ICV. These features have caused that electric vehicle applications are, for now, as a car for transportation in cities, vehicle fleets, city bus, trucks garbage or electric motorcycles [12].

MODELING OF GORILA EV'S ARCHITECTURE

Simulation Tool (Adams/Car)

To perform the analysis Gorila EV vehicle required simulation software that would allow the construction of a model vehicle with high degree of detail and at the same time, the freedom to create our own analyses. For these two reasons was chosen the Adams software, which among its modules has one specialized in the analysis of cars: Adams/Car.

With Adams/Car can quickly build and test functional virtual prototypes of complete vehicles and subsystems that form. Working with Adams/Car, it can submit different vehicle designs to various driving conditions like tests would be carried out in laboratories with real prototypes [13]. Adams/Car makes the construction of vehicle models such as the assembly of the various subsystems that form it.

Therefore, each subsystem should be constructed as closely as its real counterpart for subsequent assembly results in a complete vehicle similar to the real prototype and can be simulated accurately.

The Gorila EV model, whose behavior is simulated with Adams/Car, consists in assembly of the following subsystems: Wheels; Brakes; Front and rear suspension; Steering; Engine; Chassis; To approximate each subsystem to reality as possible, Adams/Car allows configuration of various parameters (different for each of the subsystems). These parameters were obtained in three ways: provided by ZYTEL, calculated or approximated.

This study supports on previous work that consisted of a vehicle model made with a CAE program, SolidWorks (a design program for mechanical computer aided modeling), containing the representation of some of the above subsystems but could not be simulated. The graphical information of the Gorila EV was initially in Initial Graphics Exchange Specification (IGES) format. In Figure 1 it can see the representation of the Gorila EV importing the IGES file with the SolidWorks software.

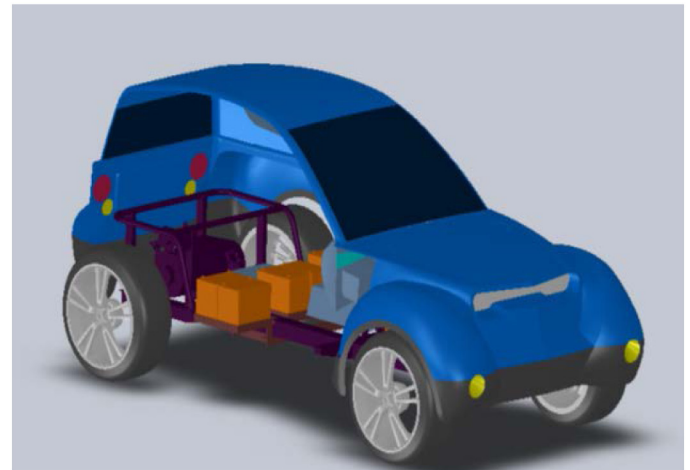


Figure 1. Gorila EV model.

Adams/Car provides a library with simple models of all subsystems that requires the vehicle to be simulated and will be used as the basis for create the own Gorila EV.

Subsystems Modeling

Since the powertrain system of an EV is a complex system with both the electrical and the mechanical sub-systems, it is necessary to model and analyse the powertrain systems of the EV in consideration of the two subsystems, to clearly address the vehicle dynamics. In particular, integrated modeling and analysis of the entire EV powertrain system is required to discover how a variety of vehicle dynamic characteristics are related with electrical quantities [15].

The configuration of the subsystems that form complete vehicle assembly has been determined from the data in each case as described below. The necessary parameters were obtained through the company ZYTEL, taking the necessary measures or approximations, and using mathematical formulations [16].

1. Wheels configuration: Vertical rigidity; Lateral rigidity; Vertical damping; Rolling resistance; Width; Aspect ratio; Radio unloaded; Mass; Inertia I_{xx} , I_{yy} and I_{zz} .
2. Brakes configuration: Disc radio; Disc thickness; Width of the wheel hub; Moving the wheel hub; Area of the brake pad; Distribution of braking; Friction coefficient.
3. Front and rear suspension configuration (independent): Angle of convergence; Camber; Mass; Inertia I_{xx} , I_{yy} and I_{zz} ; Elastic constant K_d (spring); Free length of load (spring); Length installed (spring); Damping constant R_d ; Centers of gravity: lower arm, upper arm, spindle and tie rod.
4. Steering configuration: Mass; Inertia I_{xx} , I_{yy} and I_{zz} ; Reduction ratio between: steering wheel/steering column, steering column/pinion and pinion/zip; Maximum displacement of the zip; Maximum force of the zip; Maximum turning angle; Maximum torque; Centers of gravity: steering wheel, steering column, zip and the zip housing.
5. Engine configuration: Revolutions Per Minute (RPM) of the engine idling; RPM torque curve of the differential; RPM limit of the engine; Number of gears; Relationship first gear; Relationship reverse; Relationship reducing group; Regarding the Regulation System of Engine Power Electronics (EMS): gain, maximum acceleration and zero acceleration; Rotational inertia of the engine; Regarding the clutch: capacity, damping, stiffness, time constant, fully engaged/disengaged point; Map engine; Mass; Inertia I_{xx} , I_{yy} and I_{zz} ; Center of gravity: differential and engine.
6. Chassis configuration: Mass; Inertia I_{xx} , I_{yy} and I_{zz} ; Center of gravity; Drag coefficient; Front Area.

Once it has completed the modeling of all subsystems then they are assembled to form a complete vehicle and ready to be simulated and analyzed. In the case of the Gorilla, there isn't an asymmetry with respect to the longitudinal load level exceeding 3%. In Figures 2 and 3, the center of gravity position of the Gorilla EV and resulting assembly are shown.

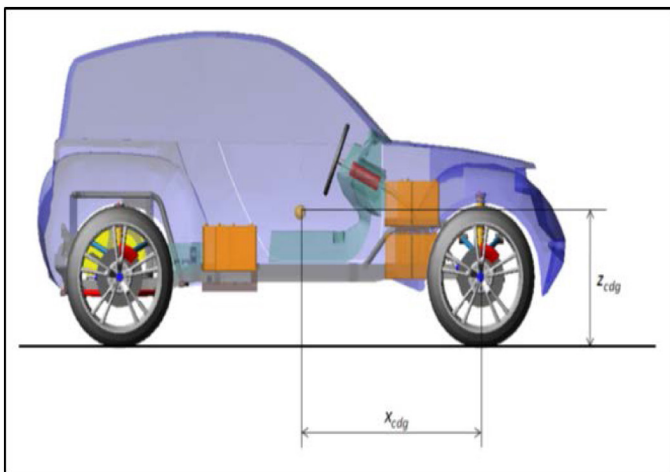


Figure 2. Center of gravity position of the Gorilla EV.

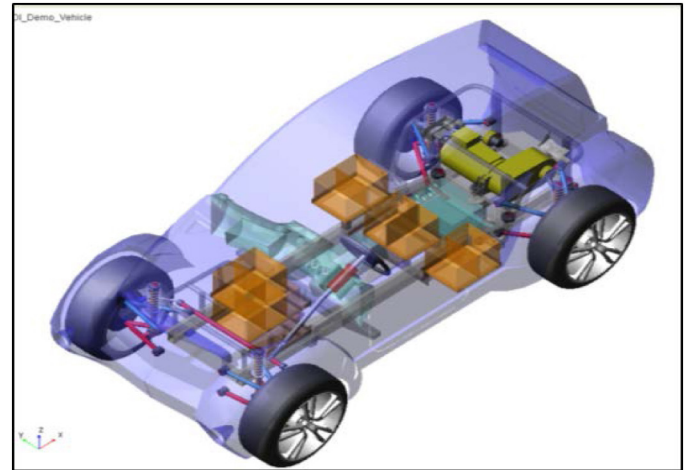


Figure 3. Assembly Gorilla EV.

MODELING OF URBAN ROUTE

The simulation, analysis and verification the dynamic behavior of the Gorilla EV were performed by scanning the vehicle model through a road created from an urban route that passes near the Campus 'Río Ebro' of the University of Zaragoza and whose modeling explained in this section. Figure 4 shows a map of the area referred to Zaragoza and the route followed by the vehicle.

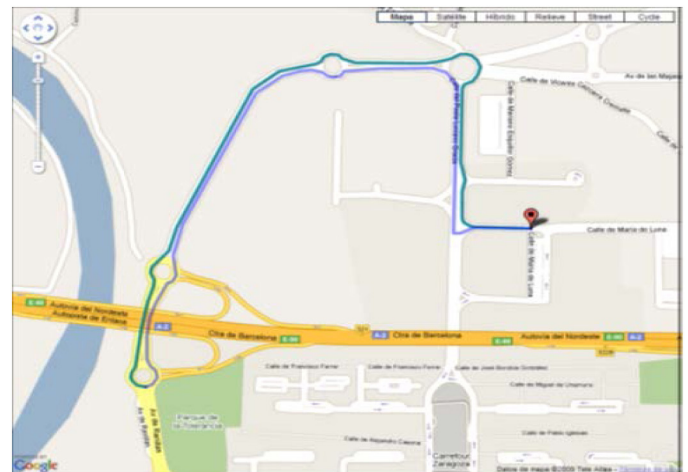


Figure 4. Map of urban route.

The main reason for making a computer model of a real route as described is that allows check and implement the simulations performed with the vehicle and compare the results.

To create the model in Adams/Car was mainly taken two steps. First, it was created a route model in two dimensions, i.e. a circuit completely flat. And secondly has provided height on model to resemble as closely as possible to the actual route. Modeling of roads in Adams/Car was done with the Road Builder tool. It chooses to simplify the construction of model dividing the drive straight and curved sections, and each setting so as close as possible to the actual route. To configure the straight sections only are needed the start and end points as well as the desired number of points that form this stretch, its width, its steepness and its friction coefficient. A