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INFLUENCE OF ENERGY CAPACITY REGARDING BATTERY PACK ON IMPROVING ELECTRIC VEHICLE RANGE

Sibiceanu Adrian Razvan[1], Iorga Adrian[1], Ciroianu Constantin[1]
[1] University of Pitesti-Romania, Str. Targu din Vale No. 1, 110040 Pitesti, Romania

Abstract : *Looking at the data from the past years of car manufacturers, we find that the current hybrid and electric vehicle market is steadily increasing, practically doubling the number of sales. When it comes to the performance of hybrid or electric vehicles, we need to consider the range, the loading time, the energy consumption, the mass and the purchase or maintenance cost, these being the biggest problems of modern hybrid and electric vehicles. Costs are an important part of these propulsion solutions, so using simulation software reduces both the cost of acquiring batteries and other equipment and the time it takes to determine theoretical results as close as possible to reality. For this, the simulation will be carried out with AVL Cruise's specialized testing software, using an teoretical model.*
Keywords : *electric vehicle, battery electric parameters, simulation, AVL Cruise software, range extender*

1. INTRODUCTION

One of the greatest challenges of recent years is air pollution caused by emissions of road vehicles. These emissions and the pollutants that they contain affect not only human health but also the air, water, soil, vegetation and fauna. In densely populated areas such as cities where there are many cars, the effect of pollution is even more drastic and air quality becomes a serious issue. Due to harsh regulations, modern cars have low emissions. This is not enough because the number of cars keeps growing from year to year. These tough emission regulations mean that automotive manufacturers have to invest more and more money on exhaust treatment systems, thus increasing the cost of the vehicle. Electric vehicles represent a viable solution to this issue, as they have no emissions and also they are very quiet. They could also help reduce noise levels found in big cities. The major disadvantages of electric vehicles are low range and high acquisition cost. In a battery electric vehicle (BEV) all energy to propel the vehicle is carried in batteries, which has major consequences for the vehicle design and performance [1]. Also, charging these batteries is a problem since it takes time. Most likely, EV drivers will use EV charging stations where they work [2], so this is a way to solve this problem. Developing these vehicles is an expensive and time consuming process and that’s why computerized simulations are used in order to obtain results before carrying out experimental tests.
According to context, the simulated model proposed in this paper has different characteristics since it is a full electric vehicle, compared with a classic car, who used an thermal engine. It has an electric motor instead of the petrol engine and a battery pack placed in the trunk.
A globally harmonized standard for the determination of energy consumption and electric range from light duty vehicles (passenger and light commercial vehicles) is defined through the Worldwide harmonized Light vehicles Test Procedures (WLTP). The conditions regarding dynamometer tests and vehicle load were provided through a strict guidance from the WLTP test procedure with WLTC test cycle [3].
Due to the fact that the initial simulation model has an electric battery with a capacity of 15 kWh, the results are not quite impressive in terms of range, as it may be seen in chapter 3.1. Increasing the capacity of the battery and adding a range extender will contribute to the vehicle's self-propulsion.

2. PRESENTATION OF THE INITIAL ELECTRIC VEHICLE MODEL

This vehicle was chosen as a base model because it could be a low cost vehicle that can accommodate five passengers. It has a simple design that made the electric vehicle conversion a more easier process. It also provides enough space for the electric equipment; after the conversion the room for the passengers is not affected.

After the removal of all the elements that are specific to the petrol engine (engine, gearbox, fuel system and exhaust) the components for electric propulsion could be installed. A proposed liquid cooled electric motor can be made which features two running modes: normal and boost. In normal mode the maximum power output is 18kW (24.5 HP) between 2850 – 9000 rot/min and maximum torque is 90 Nm at 2850 rot/min. In boost mode (short periods of time) the maximum power output is 31kW (42 HP) between 2850 – 9000 rot/min and maximum torque is 160 Nm at 1400 rot/min. The transmission features a fixed ratio reduction and has a shift lock for parking. The electronic management unit for the electric vehicle is already on the market, specially designed for electric and hybrid vehicles.
Initial battery data proposed:

- Maximum charge: 60 Ah
- Nominal voltage: 3.2 V / cell
- Minimum voltage: 2.8V / cell
- Maximum voltage: 4V / cell
- Battery pack consists of 64 cells

The nominal voltage of the battery pack is 205V; minimum voltage is 179V and maximum voltage is 256V. The battery can be charged while driving, by regenerative braking or plug-in to the grid. Regenerative braking was implemented because stopping a 1500kg vehicle from 100 km/h to zero speed dissipates about 0.16kWh of energy [$(1/2)MV^2$] in a few tens of meters. If this amount of energy is dissipated by coasting and only by drag forces (rolling resistance and aerodynamic drag) without braking, the vehicle will travel about 2 km [4].
From the vehicle we find that the maximum weight (vehicle + load) could be 1550 kg.
All these represent the input data for the simulation.

3. SIMULATION FOR THE INITIAL ELECTRIC VEHICLE MODEL PROPOSED ON WLTC TEST CYCLE IN AVL CRUISE

3.1. Simulation and results for the initial electric vehicle model

The WLTC test cycle was adapted to the Cruise software for the electric vehicle model. The first step was to create a model in AVL Cruise starting from the similar electric vehicles concepts. The Cruise model can be seen in the following figure 1.

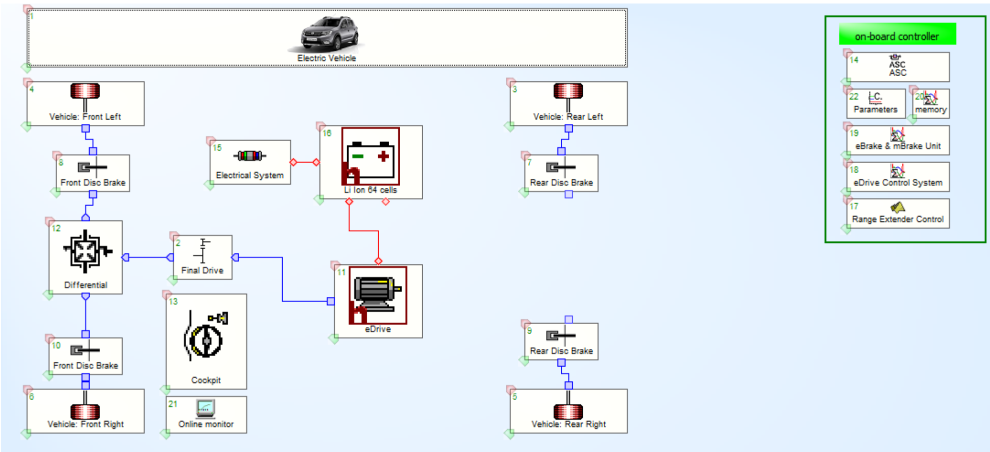

Figure 1. The initial electric vehicle model created in AVL Cruise (Source: AVL Cruise) [1]

The main characteristics of the WLTC test procedure are (data extracted from [1]):

- Total distance of 23.27 km
- Duration is 1800 s
- Mean velocity is 46.5 km
- Maximum velocity is 131.3 km/h
- 9 Number of stop phases

After the WLTC simulation in AVL Cruise, the results are shown in Table 1.

- **Table 1:** Initial simulation results

Cycle distance	Energy consumptiom	Cyle consumption	Maximum voltage	Battery capacity	Range

23271.47 m	15.19 kWh/100 km	3.3538 kWh	256 V	15.36 kWh	101 km

3.2 Simulation of the improved electric vehicle model

The newly proposed model with improved battery capacity and range extender has the following form, shown in figure 2.

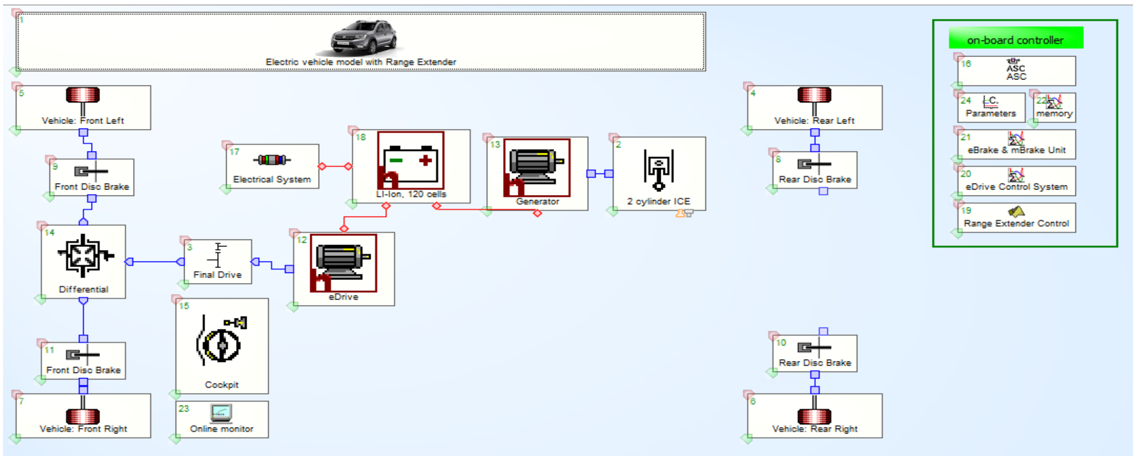

Figure 2. The improved electric vehicle model in AVL Cruise (Source: AVL Cruise)

In order to increase the energy capacity of the battery, it is requiered to raise the number of cells from 64 to 120 cells. As can be seen in figure 2, for further improvement, a range extender was attached to the vehicle. The characteristics of the thermal engine used on the range extender are shown in figure 3.

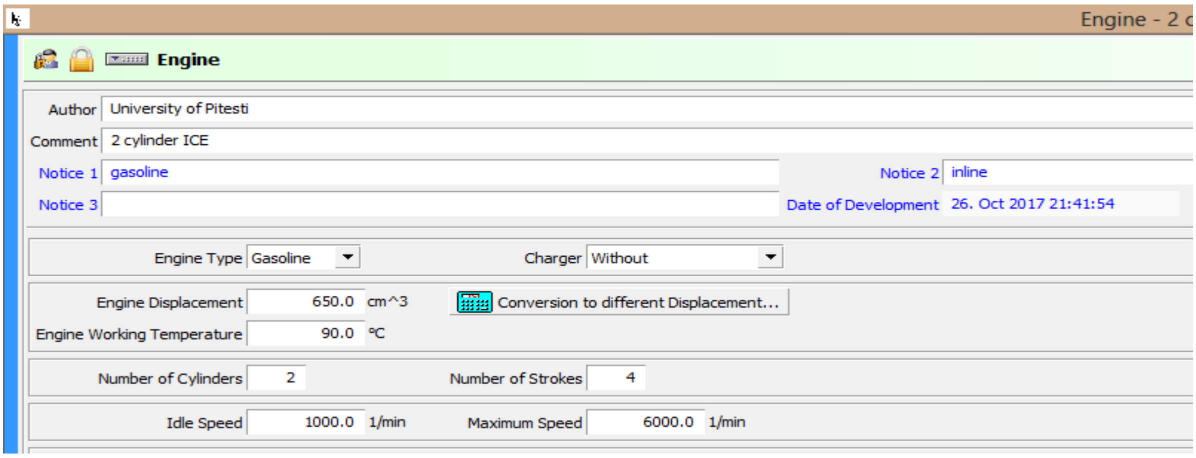

Figure 3. Characteristics of the thermal engine used for range extender (Source: AVL Cruise)

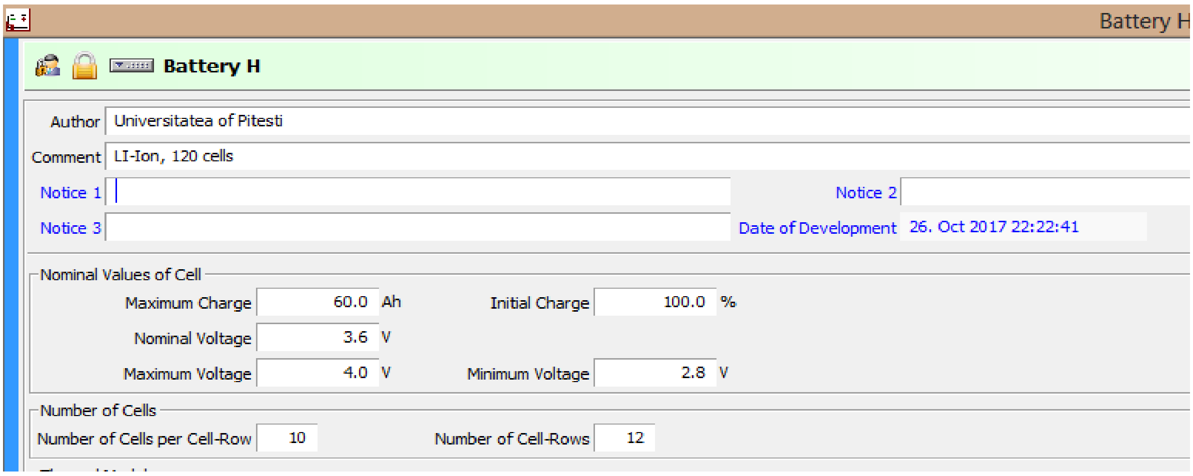

Figure 4. Characteristics of the improved battery with 120 cells

Table 2: Comparison between initial and improved battery

Number of cells		Maximum voltage [V]	
Initial	Improved	Initial	Improved
64	120	256	480

4. RESULTS

After the WLTC simulation in AVL Cruise, the results show that the covered distance is 23271.47 m and the mean energy consumption is 15.19 kWh / 100 km. The energy consumption needed to perform a WLTC test cycle is 3.3538 kWh.

Knowing these consumption figures and the battery capacity, it is possible to determine the maximum range. Each cell has a maximum voltage of 4V and the battery pack features 120 cells. This means that the maximum voltage of the battery pack is the voltage of each cell times the number of cells. The maximum voltage of the battery pack is 480 V. Knowing the maximum charge of 60 Ah, it is possible to determine the energy capacity of battery which is maximum voltage times the maximum charge. The energy capacity of the battery pack is 28,8 kWh.

Considering a mean energy consumption of 15.19 kWh / 100 km and a maximum battery capacity of 28,8 kW, this leads to the maximum range of 190 km. This value was obtained without using the range extender, which generates fuel consumption of 8.44 l/100 km, as can be seen in figure 5 when it is used. Considering that the model has a 9 liter fuel tank, the range extender will provide an extra range for about 106 km, which leads to a total range of 296 km.

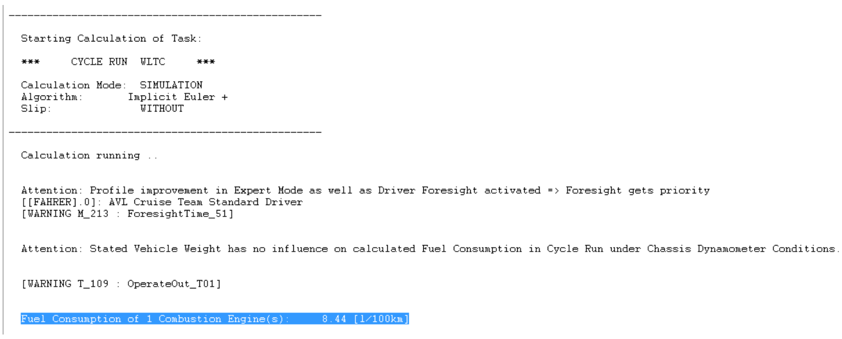

Figure 5. Fuel consumption for the range extender

5. CONCLUSIONS

The initial electric vehicle model had a small range of 101 km, this making it suitable for commuting or city use. In order to extend its range, new features were needed, such as extra battery capacity and range extender. The battery capacity was increased from 15.36 kWh to 28.8 kWh. This was achieved by raising the number of cells from 64 to 120. After this improvement the range went to 190 km. This is enough for regular daily use, but still inadequate for highway use. That is why a range extender was installed and it added an extra 106 km, making the total range climb up to 296 km. The dissadvantages of this solution are related to the thermal engine of the range extender. With a fuel consumption of 8.44 l/100 km (when used) the electric vehicle model is no longer a zero emmission vehicle. According to specialized literature the range is obtained with fully charged battery and full tank of gasoline. That's why the fuel consumption is divided throughout the entire range. Therefore, the mean fuel consumption is 2.85 l/100 km. The model presented shows energy consumption of a hybrid vehicle and it is possible to determine the range . The obtained results will help on later improvements of the hybrid electric model, such as ways to increase the range by using a higher battery capacity, a more efficient range extender or aerodynamic improvements.

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