Simulation of an electric vehicle model on the new WLTC test cycle using AVL CRUISE software

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Abstract. Nowadays, environmental pollution has become a general issue and the automotive industry is probably the most affected. The principal air-quality pollutant emissions from petrol, diesel and LPG engines are carbon dioxide, oxides of nitrogen, un-burnt hydrocarbons. Modern cars produce only quite small quantities of the air quality pollutants, but the emissions from large numbers of cars add to a significant air quality problem. Electric vehicles are an answer to this problem because they have absolutely no emissions. These vehicles have some major disadvantages regarding cost and range. In this paper, an electric vehicle model will be created in the AVL Cruise software. The constructed model is based on the existing Dacia Sandero. Also unlike the real car, the model presented has different characteristics since it is a full electric vehicle. It has an electric motor instead of the petrol engine and a battery pack placed in the trunk. The model will be simulated in order to obtain data regarding vehicle performance, energy consumption and range on the new WLTC test cycle. The obtained know-how will help on later improvements of the electric model regarding methods to increase the vehicle range on the new WLTC test cycle.

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.

At the “Automotive Engineering” Research Center of the University of Pitești there is the Sandero Electron concept. This concept was developed starting from a Dacia Sandero series model. Unlike the original model, the Electron concept is a full electric vehicle.
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]. Since there is no information regarding the range and energy consumption of the Electron concept and because the WLTC will become a mandatory procedure for homologating vehicles, the decision was made to simulate a model of the Electron concept using AVL Cruise software. This software is an excellent tool to determine vehicle range and energy consumption.

2. Presentation of the Sandero Electron Concept
This vehicle was chosen as a base model because it is 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.

The Sandero Electron concept can be observed in figures 1 and 2 below.

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 were installed. The liquid cooled electric motor is made by MES-DEA Switzerland and 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 motor is TIM 400 (Traction Inverter Module), made by the same manufacturer as the motor. It is specially designed for electric and hybrid vehicles. The battery pack that empowers the electric system can be seen in figure 3 below.
Battery data:
- 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

3. Simulation for the Sandero Electron model on WLTC test cycle in AVL Cruise
In order to achieve this simulation, the WLTC test cycle will be adapted to the Cruise software for the Electron model. This test cycle was chosen because it will become mandatory. Also in the WLTC significant higher velocities have to be driven for longer periods and the acceleration values are corresponding to real driving conditions [5]. Previously, vehicles were homologated using the NEDC but numerous complaints regarding optimistic numbers of fuel consumption lead to this change. It is estimated that, if in 2001 the difference between the theoretical and the real consumptions was 7 – 8%, 10 years after these differences are 3 – 4 times higher. For example, in 2013 was found a difference of 31% for private cars [6] between announced and real fuel consumptions. That’s why the WLTC is used here for obtaining data that is as close to real running conditions as possible.
The first step is creating a model in AVL Cruise starting from the real Electron concept. The Cruise model can be seen in the following figure 4.
Figure 4. Sandero Electron model created in AVL Cruise (Source: AVL Cruise 2014)

The main characteristics of the WLTC test procedure are (data extracted from [6]):

- 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

These characteristics are better shown in the following figure 5.
Figure 5. WLTC characteristics (Source: AVL Cruise 2014)

Figure 6. Voltage and current variations (Source: AVL Cruise 2014)
Figure 6 shows the variations of voltage and current. During acceleration phases, battery voltage drops because it is under load. As shown in the figure, during decelerating phases, the current has negative values. This happens because the vehicle has regenerative braking, the battery is being during these phases.

4. Results
After the WLTC simulation in AVL Cruise, the results are shown. In figure 7 the most important data is covered distance and the energy consumption achieved by the model.

![Figure 7. Results of energy consumption and covered distance (Source: AVL Cruise 2014)](image)

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 64 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 256 V. Knowing the maximum charge of 60 Ah, it is possible to determine the power capacity of battery which is maximum voltage times the maximum charge. The power capacity of the battery pack is 15.36 kWh. Considering a mean energy consumption of 15.19 kWh / 100 km and a maximum battery capacity of 15.36 kW, this leads to the maximum range of 101 km.

5. Conclusions
The use of computerized simulation with the help of AVL Cruise offers many advantages like reduced time and costs for vehicle development. It helps to refine the stage of the model at any step of the process. The obtained results show a relatively small range compared to other electric vehicles but the testing conditions were harsh: fully loaded vehicle and severe transitory regimes. Since the range is small, this vehicle model is clearly suitable for commuting or city driving. It is not suitable for driving on the highway, at high speeds. The model presented shows energy consumption of an electric vehicle and it is possible to determine the range afterwards. The obtained results will help on later improvements of the electric model, such as ways to increase the range by using a higher capacity battery or aerodynamic improvements.
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