Research Regarding of the Autonomy of the Electric Vehicles in WLTC Test Cycle

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Abstract. Some of the most important objectives expected of today's electric vehicles, as well as from manufacturers and end-users, include electricity consumption, autonomy, which should be able to unequivocally substitute the results obtained by vehicles equipped with a thermic energy source. Based on these premises, a first part of the paper, presents aspects of the current testing methods applicable to electric vehicles, in order to calculate the electricity consumption and also in order to calculate the autonomy, respectively the World-wide harmonized Light duty Test Cycle, characterized by the four driving zones at low, medium, high and very high speed that the electric vehicle has to comply with. In the second part of the paper, as a result of testing the electric vehicle under research on the dynamometer bench, it is highlighted the specific areas from the test cycle, where the traction battery autonomy shows a significant decrease.The analysis of the evolution of the autonomy is corroborated with the acquisition of data from the main electronic control units of the electric propulsion system.

Keywords: WLTC · electric vehicle · autonomy · electrical energy

1 Introduction

Given the growing interest of automobile users for the new energy source, respectively the electric motor, the automotive manufacturing industry is advancing rapidly and is offering a multitude of solutions in order to satisfy the market request [1]. Obviously, the market for electrically powered vehicles is not very developed at the moment, as a result of a deficient traction battery charging infrastructure as well as at national level and at European level, but also because of manufacturing technologies for traction batteries that are still in their incipient stages [2]. Also, such criteria as maintaining the health of traction batteries at a high level for extended periods of time, which ensures the same autonomy after each charge, are very expensive, and attract high costs for their owners, whether we are talking about specific services provided by the manufacturers, or by their final users. At present, there are a number of differences between countries at European level regarding the treatment relating to the owner of the traction battery which serves the electric vehicle. There are countries where the owner of the traction battery is the manufacturer, and there are countries where the owner is the end user [3].

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As concerns the legislation applicable to the testing for the calculation of the electricity consumption and for the calculation of the autonomy at the European Level, it is applicable Commission Regulation (EU) 2017/1151 of 1 June 2017 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles. The speed profile which the electric vehicle being tested must follow is that described by the World-wide harmonized Light duty Test Cycle (WLTC), shown in Fig. 1 [4].

A simple analysis of the speed profile described by the WLTC test cycle shows that it is characterized by an increased dynamicity compared to previously applicable test cycles, and it has four speed zones with different running type percentages, respectively low speed 600 s, medium speed 400 s, high speed 500 s and very high speed 300 s.

Some of the principal characteristics of the cycle may include, the driving time during 30 min, the route length being approximately 23 kms, the maximum speed being 131 km/h, the average speed being approximately 47 km/h, the stationary percentage being 13%, the taking into account of the optional equipments, respectively gear shifting points when applicable, which can be individually defined based on well-defined elements that take into account the geometrical characteristics and the dynamic performance achieved by the tested vehicles [5].

The WLTC test cycle also introduced three different test classes specific to the mass-to-power ratio, the first class at up to 22 kW/t characterised by a maximum test speed of 70 km/h, the second class at up to 34 kW/t characterised by a maximum test speed of 90 km/h, respectively the third class at 35 kW/t, in which case the maximum test speed is approximately 131 km/h.

Today, the majority of the road vehicles comply with the specific testing requirements for the third class where the power is higher than 35 kW/t. Thus, for each cycle-specific speed zone, the average speed and the maximum speed are established [6].

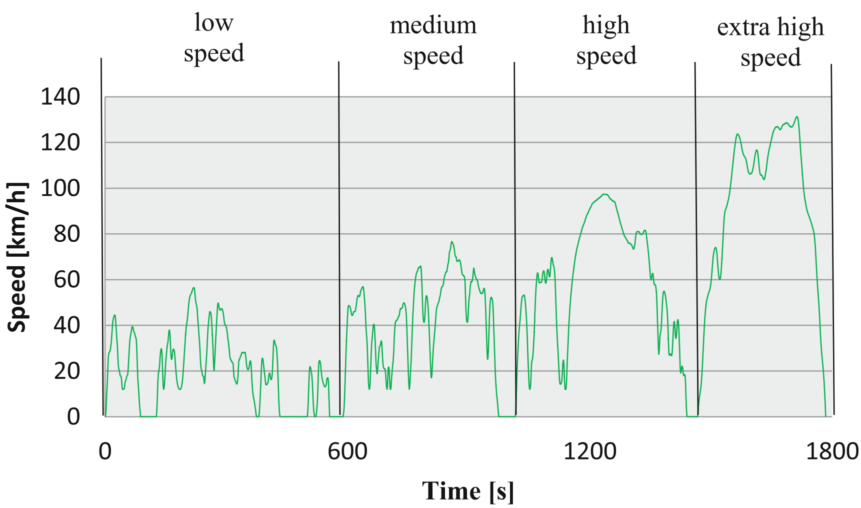

Fig. 1. World-wide harmonized Light duty Test Cycle (WLTC)

2 Experimental

As mentioned earlier, one of the biggest objectives expected from the current electric cars is the electric autonomy, respectively the number of kilometres driven after a single charge of the traction battery, which has certainly grown in the recent period but still doesn't completely satisfy all the demands of society.

Therefore, in the present paper, experimental research has been performed in order to highlight the evolution of the autonomy of the vehicle for that, being analysed how the charge level of the traction battery is depleted in relation to the specific driving zones of the WLTC test cycle, characterised by different speed regimes and by different dynamic solicitations (Fig. 2).

The experimental research was performed as a result of driving the vehicle on the dynamometer bench following the speed and load profile described by the WLTC. Before the test, the traction battery was charged to 100%, after loading, the vehicle being pre-conditioned which means it was maintained at a controlled temperature for approximately 12 h.

The vehicle submitted for testing is of a medium class, with a general architecture similar to that in the above diagram, with the following technical characteristics:

- Own mass: 1135 kg;
- Inertia: 1250 kg;
- Front-wheel drive;
- Electric motor type: synchronous with coiled rotor;
- Maximum power: 65 kW;
- Maximum torque: 200 Nm;
- Traction battery power: 22 kWh;

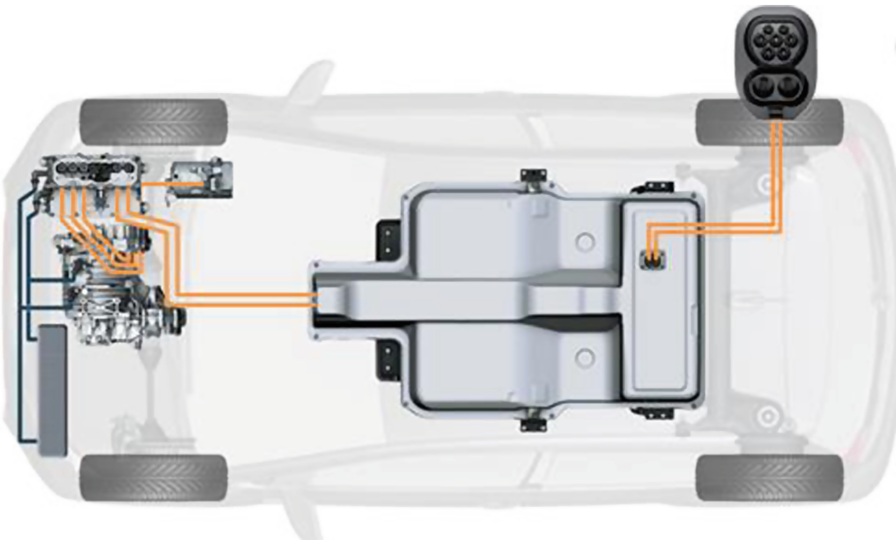

Fig. 2. General architecture of the vehicle submitted for testing

- Traction battery technology: Li-Ion, 400 V

For simulating the inertia and for simulation of the dynamometer bench loading requirements, the following data was used:

- The power and the load taken by the roller stand at 80 km/h: 6.7 kW;
- The coefficients for the rolling resistance: a (N) 6,8; b [N/(km/h)2] 0,0460;

The acquisition of the information concerning the compliance of the testing conditions, respectively the required speed profile, was performed at the frequency of 10 Hz [7]. This type of information validates the quality of the test and allows deviations from the speed profile of maximum 2 km upper or lower limit.

In Fig. 3, it may be seen that during the entire test period the speed profile was respected, which indicated that the vehicle has been able to satisfy from a dynamic point of view, the solicitations to which it has been subjected. For a correct analysis of exactly how the drop of the charge level of the traction battery has occurred, which implies a diminution of the autonomy, were made multiple rounds, being established average values for each of all four specific WLTC cycle zones.

Based on the information provided by the electronic control units that manage the traction battery, was possible to analyse the energy balance, as well as the ratio between the energy transferred to the traction system by the battery and the energy recovered by the battery as a result of regenerative braking.

The traction battery of the vehicle being researched, can only support as well as, the slow and the fast alternative current charging. The charging mode applied to the traction battery before the tests, was the slow charge mode, thus ensuring a correct and complete charge until the 100% level [8] (Fig. 4).

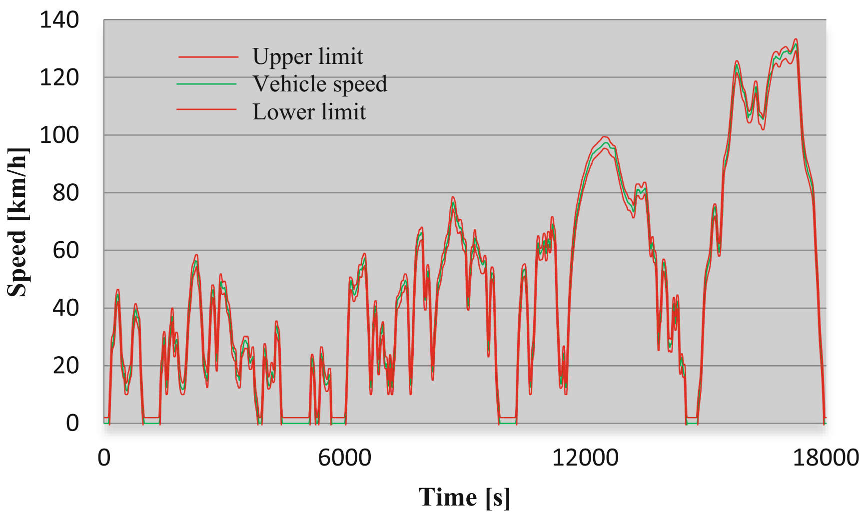

Fig. 3. WLTC speed profile followed by the vehicle that is under test

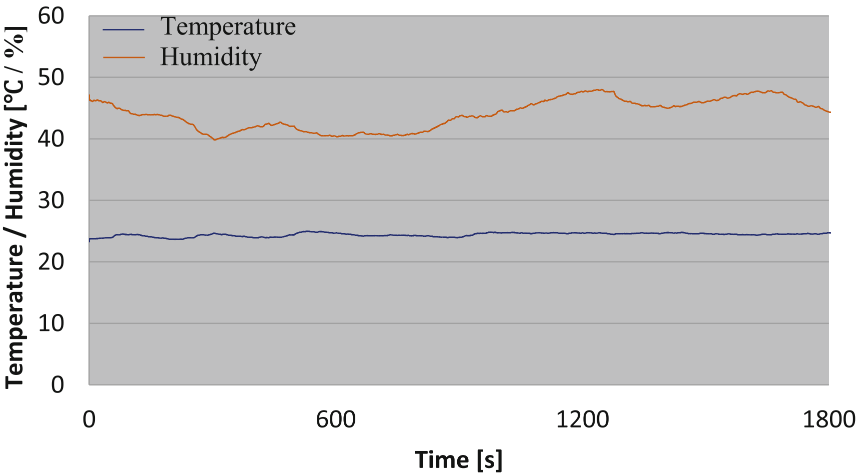

Fig. 4. Variation of the temperature and of the humidity during the WLTC test

Regarding the conditions in which was carried out the test of the vehicle under research, from Fig. 4 it can be observed that the temperature during the entire experiment period was around 23 °C, and the relative humidity recorded fluctuations between 40% and 50%. In this way, it meets the requirements regarding the temperature and the humidity of the test chamber, which must also be maintained during the whole testing period.

The simulation of the air speed was performed with the aid of high capacity air blowers, which use electric motors as the drives elements, and paddle plates, with the rectangular exit, for suction and pushing of the air in the direction of the vehicle being tested. In order to perform the experimental research specific tests of this publication, the blower has been programmed to follow on an automatic mode the speed profile of the vehicle, as indicated in the specific application procedure of the testing method.

Even if the car has only front axle traction, its fixation on the dynamometer bench was performed in the all wheels drive mode, in order to ensure the correct functionality of the braking assistance systems, which allowed finally to recover the energy where it was necessary in correlation with the established rolling profile.

3 Results and Discussions

As a result of the experimental research, were also highlighted the graphs of the specific traction battery loading level, that is specific to each speed zone that enters into the component of the WLTC. At the same time, based on the data acquisitions performed with the specific equipments, it has been possible to establish how the energy of the traction battery is consumed respectively how the energy of the traction battery is recovered (Fig. 5).

The low speed vehicle driving zone is described in Fig. 5, being characterised by a very low load level. As it can be observed, this type of driving simulates the specific

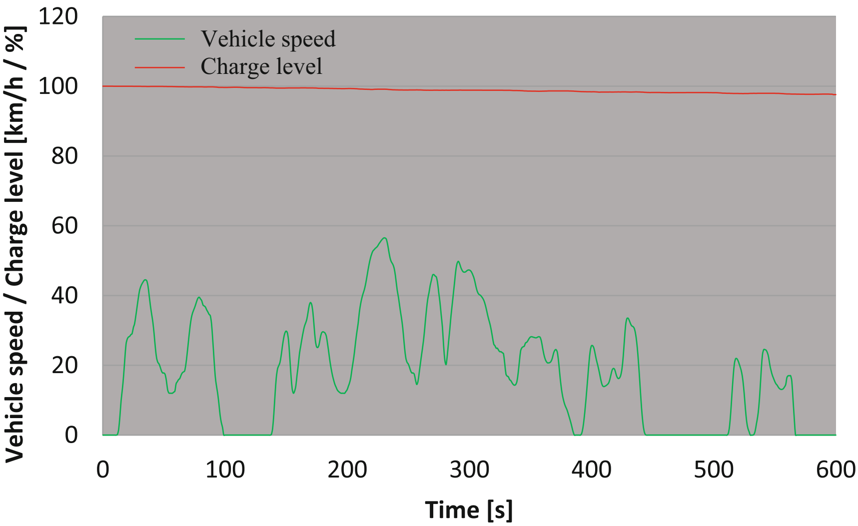

Fig. 5. Level of the traction battery charging, in the low speed zone

towns with intensive traffic, the average speed being about 18.9 km/h and the maximum speed approximately 56.5 km/h.

In this situation, the traction battery behaviour is a very good one, characterized by reduced energy consumption and the multiple recuperative breaking, where obviously the impact on the charge level and therefore on the autonomy is not significant.

The experimental research indicate that within these types of driving at low speed and low load it achieves the best performance regarding the autonomy of the traction batteries, this being also the reason for which some types of the electric vehicles are destined to be used for urban conditions with intensive traffic. Neither running in the average speed zone described in Fig. 6 is not problematic from an autonomy point of view, because in this situation we can talk about low loads and moderate speed, the average speed having the value of 39,5 km/h and the maximum speed being approximately 76.6 km/h.

Also in this situation there are sufficient profiles available in which it is possible to brake recuperatively, ensuring therefore a positive contribution in the traction battery.

Completely diferent, could be placed under discussion, the performance of the traction battery in the high-speed driving zone (see Fig. 7). In these situations, when we are talking about an average speed of 56.6 km/h and about a maximum speed of approximately 97.4 km/h, usually, the contribution of the recuperated energy is practically insignificant, the reduction of the charging level and therefore of the autonomy happening gradually and progressively (Fig. 8).

Very high-speed driving zone, graphically represented in Fig. 8, has a special character regarding the maintaining of the charge level of the traction battery. At such speeds the average speed reaches 92 km/h and the maximum speed reaches 131.3 km/h. As a general rule, in this area the majority of electric series production vehicles reach their maximum constructive speed, characterised by high dynamic solicitation where energy recovery is non-existent.

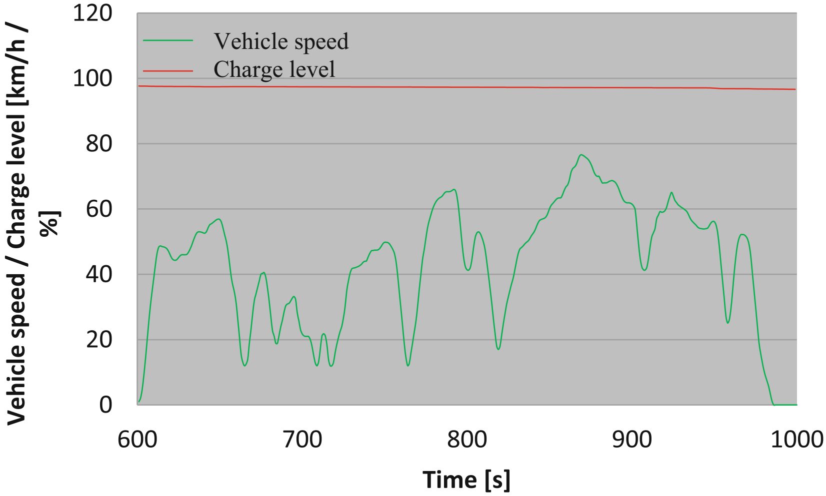

Fig. 6. Level of the traction battery charging, in the medium speed zone

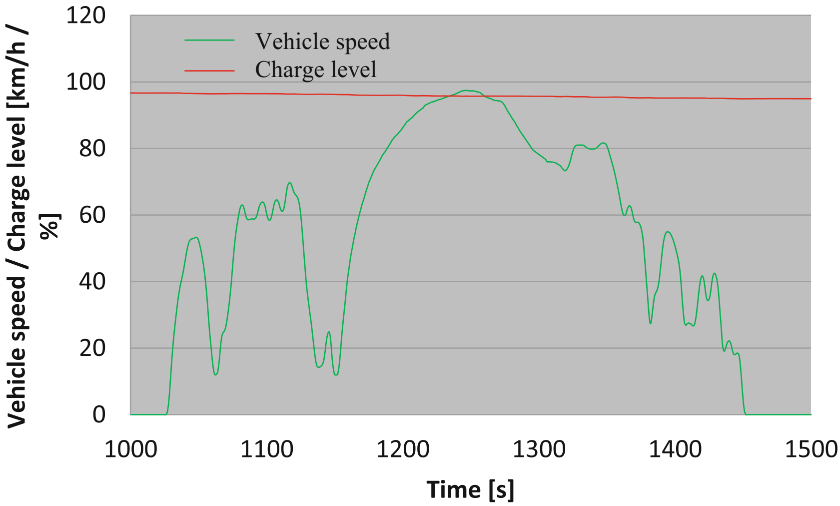

Fig. 7. Level of the traction battery charging, in the high speed zone

At this driving speed the charge level of the traction battery decreases quickly, the autonomy being affected immediately. That is the most disadvantageous situation for the energy accumulated in the traction battery, as a result of the very high consumption generated by the electric traction motor.

The testing performed on the electric vehicle under investigation, have been repeated until complete discharge of the traction battery's autonomy, respectively, until the speed profile could no longer be maintained by the vehicle. From electronic point of view, the vehicle has been constantly monitored to ensure the test quality by maintaining

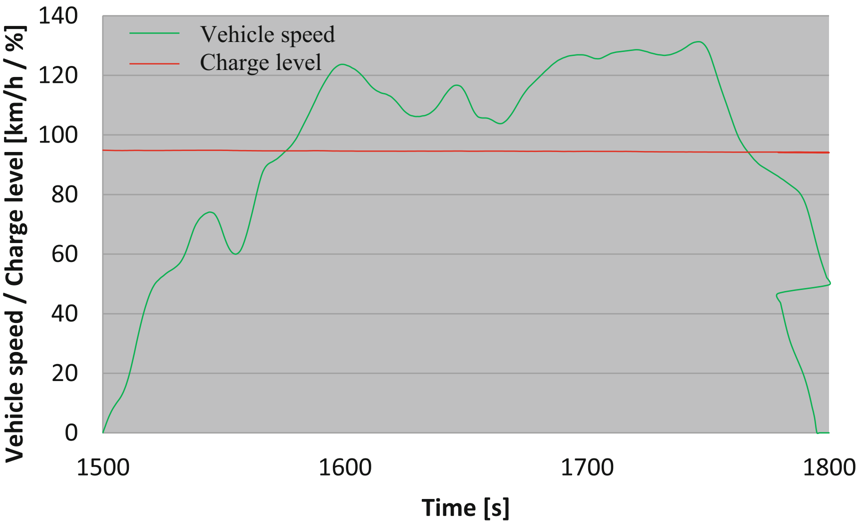

Fig. 8. Level of the traction battery charging, in the verry high speed zone

dynamic performance, they were not registered electronic problems in the case of electronic control units that manage the electric traction system. Also, regarding the traction battery, there were no overheating problems, its internal temperature being maintained throughout the test period within the correct limits.

4 Conclusions

The experimental research indicates that the state of charging, respectively the autonomy of the traction batteries, shows a very good behaviour in the low and medium speed driving conditions, specific of the urban agglomeration characterized by an intensive road traffic. Furthermore, the maximum performance regarding the recuperation of the electrical energy by the regenerative braking, are also happening under the same conditions.

In the case of high-speed driving, the decrease of the charging level of the traction batteries, is performed gradually and progressively, and the contribution of the recuperated electrical energy is insignificant. This kind of situations leads it to a rapid decrease of the autonomy, as a result of the increased electricity consumption generated by the electric traction motor.

The most unfavourable situation for the electric autonomy, is represented by the use of the vehicles under very high speed. In these conditions of the high load and of the high electric motor revolution, the consumption is very high, the electric energy recuperation is practically non-existent, this type of driving leads to the immediate depletion of the charging level of traction battery.

It is noted that the main objectives of the research in terms of traction batteries must be focused on increasing the performance regarding the charge level at high and very high speeds. Obviously, this performance is not just about the traction battery, additional research is needed in the area of constructive optimization of electric motors, on the transmission or on passenger comfort system, which play an extremely important role in such situations.

The evolution of the automotive market, equipped with the electric propulsion systems, brings with it the necessity of increasing the electrical power of the traction batteries, which have to perform the new assignments, like the dynamics and the economy, in order that it can satisfy even the most demanding needs of the modern society.

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