

RESEARCH OF RUNNING DISTANCES OF ELECTRIC VEHICLES IN URBAN AND EXTRA URBAN REGIMES

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Abstract. In order to research the running distance of an electrical vehicle in urban and extra urban regimes in dependence on the vehicle load Fiat Fiorino Elettrico HC-S was used. The car running distance was determined using the scientific data logger HOLUX GPSport245. The maximal driving distance of the electric vehicle with full charged battery in urban regime without load reached 99 km and the average driving speed $30.69 \text{ km}\cdot\text{h}^{-1}$, but with load the driving distance reached 90.7 km and the driving average speed $28.03 \text{ km}\cdot\text{h}^{-1}$. The maximal driving distance of the electric vehicle with full charged battery in extra urban regime with a driver and one passenger reached 95 km and the average driving speed $63.72 \text{ km}\cdot\text{h}^{-1}$. The running distances of the electric vehicle largely depend on the battery type, its condition (new or used), vehicle load and driving regime.

Key words: electric vehicle, running distance.

Introduction

Nowadays, a great part of manufacturers offer their own range of electric vehicle models. As of March 2012 series production models available in some countries include the Tesla Roadster, REVAi, Buddy, Mitsubishi MiEV, Tazzari Zero, Nissan Leaf, Smart ED and others. Cars with internal combustion engines can be considered to have indefinite range, as they can be refuelled very quickly almost anywhere. Electric cars often have less maximum range on one charge than cars powered by fossil fuels, and they can take considerable time to recharge. Running distances of electric vehicles largely depend on the battery type, its condition (new or used), vehicle load and driving mode. This is a reason why many automakers marketed electric vehicles as "daily drivers" suitable for city trips and other short hauls. The technical information of the manufacturers is often of electric performance parameters indicating a car that is not loaded with passengers or load. In addition, the distance parameters are obtained under laboratory conditions, which correspond to the real situation on the road. These parameters are obtained under laboratory conditions that are not fully compatible with the realities on the road. In this investigation a small duty electrical truck Fiat Fiorino Elettrica HC-S with a gross weight of up to 3500 kg was used. The main purpose of the experiments is to determinate the electric vehicle running distance in urban and extra-urban regimes.

Materials and Methods

The investigation in electric car acceleration characteristics was carried out in cooperation with the public limited company Latvenergo AS using their electric car Fiat Fiorino Elettrica HC-S. Fiorino is provided for build-up urban environments and small cities. It combines performance, agility and comfort with the load capacity, ease of loading and unloading, reliability and productivity of a light commercial vehicle. The experiments have been performed in urban and extra urban regimes of Jelgava. In order to research the running distance of electrical vehicle (Fig. 1) in urban and extra urban regimes in dependence on the vehicle load Fiat Fiorino Elettrico HC-S was used. The experiments were carried out with fully charged batteries in urban regime without load and a 500 kg load, but in extra urban regime without load.

The main technical parameters of the car [1]:

- category – M1;
- motor – asynchronous, nominal power 30 kW, maximal power (peak) 60 kW;
- brakes – energy recovery;
- recharging socket – 230 VAC, 16 A, 3 kW;
- battery – lithium up to 31.1 kWh;
- grade ability – 24 %;
- transmission – direct drive;
- maximum speed – up to $115 \text{ km}\cdot\text{h}^{-1}$;
- distance of run with a single full charge (range ECE 101 cycle) 100 km.



Fig. 1. Experimental electric vehicle *Fiat Fiorino Elettrico HC-S*

The experiments were performed on asphalt road surface with an average rolling resistance coefficient from 0.018 to 0.022 and with a fully charged battery. The experiments were carried out at time when the road surface was dry and the ambient temperature $+10 - 20^{\circ}\text{C}$. Wind speed did not exceed $3 \text{ m}\cdot\text{s}^{-1}$. The electric driving experiments are carried out in the center of Jelgava, which is more heavily loaded.

The experiments were carried out continuously, without significant car stop, except when required by the traffic conditions. For the electric vehicle battery discharged level illustration the indicator on the vehicle dash-board was used (Fig. 2).



Fig. 2. Charging position of electric vehicle battery indicator:

1-7 – various charging position of battery indicator; 8 – minimum volume of battery charge level; 9 – batteries fully discharged; 10 – warning lamp; 11 – battery warning lamp; 12 – battery voltage.

If the charge indicator has reached the red zone (see the 2nd Fig. 8), the average electric remaining mileage is 15 miles. At this moment, the yellow light illuminates, this shows some remaining mileage. If the electric vehicle was used further the vehicle speed reduction or dynamic parameters did not decrease. When the batteries are fully discharged the indicator is in the red area at the bottom line (see the 2nd Fig. 9), the yellow warning signal turns on and the electric vehicle stops to work. Charging the electric vehicle batteries approximately for 2 hours the batteries can be charged to the extent when the electric vehicle can take 30 – 35 km mileage.

The urban route of the experiment was incorporate of 28 controllable and 3 uncontrollable junctions. The urban route distance of the experiment was 14.6 km, but the extra urban was 45 km. The urban route is shown in Figure 3. The experiment route contains different driving intensity where the driving speed changes from 50 till $70 \text{ km}\cdot\text{h}^{-1}$.

Using the universal data collection and processing logger HOLUX GPSport245 [2], the electric car running distance, speed and time in urban and extra urban regimes of Jelgava is measured. After the experiment the mileage is compared with the odometer values.

The logger technical parameters [2]:

- weight – 72 g with battery;
- memory – RAM: 64KB;
- display – 128 x 128 dots;
- IO interface – Mini-USB charging;
- adaptor – input 100 – 240 VAC, 0.5 A max, DC output 5 V/1 A thought Mini-USB;
- function – save log data and 200,000 waypoints, show speed, time, routes, log, G-finder;
- environment temperature – operating temp. -10 °C to 60 °C, storage temp. -20 °C to 70 °C.

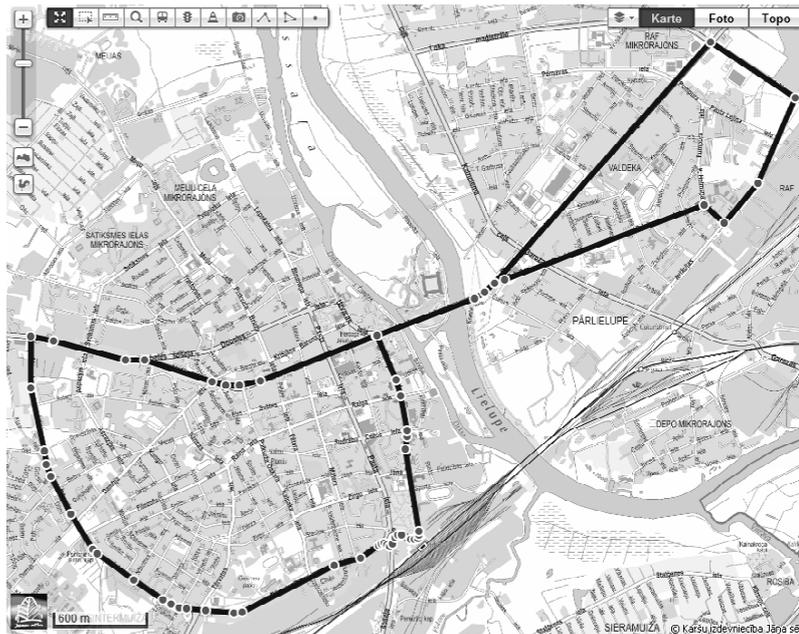


Fig. 3. Experiment route in urban regime

Each measurement was repeated three times [3] till fully discharged batteries. From all three repetitions the average values were calculated if the correlation level between the series data points was at least ($\alpha = 0.95$, $P = 0.05$, $t = \pm 3\sigma$).

Results and Discussion

Changing the electric vehicle load and the experiment route different driving distances and average driving speeds are acquired. The electric car different driving speed and load changes during the experiments in urban and extra urban regimes are shown in Figure 4.

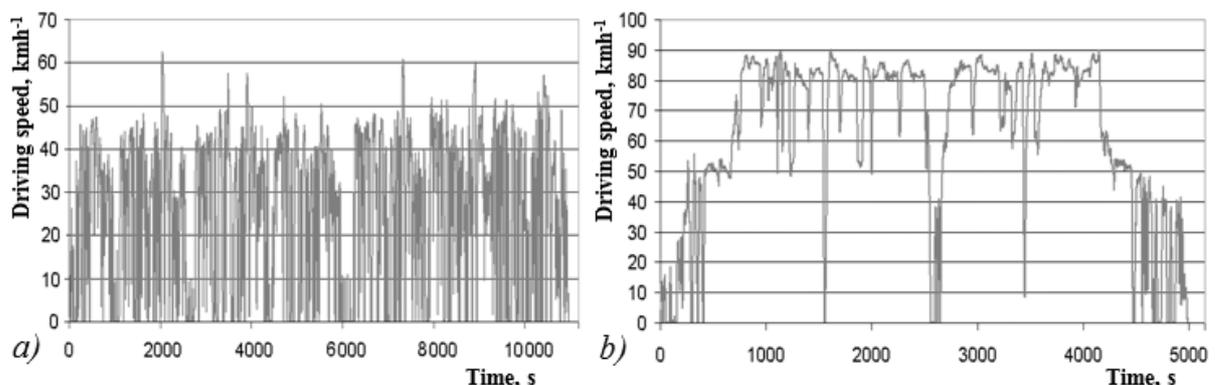


Fig. 4. Driving speed diagram of electric car:

a – driving speed in urban regime; b – driving speed in extra urban regime

Fig. 4a describes that the most cases of the experiment speeds did not exceed $50 \text{ km}\cdot\text{h}^{-1}$ in urban regime. At one stage of the experiment route the driving speed increased till $70 \text{ km}\cdot\text{h}^{-1}$. Fig 4b describes the average speed in extra urban route and movement and stops of the electric vehicle.

The odometer average value indication compliance with the discharge indicator at urban and extra urban mode is summarized in Table 1. If the electric vehicle batteries are fully charged their summary voltages do not exceed 300 V, but if the batteries are discharged the summary voltage decreases till 250 V.

In all experiment replicates the batteries charge indicator marks achievement of the mileage is not differing by more than $\pm 1 \text{ km}$, which allows a sufficiently accurate assessment of the remaining electric vehicle millage.

Table 1

Odometer value indication compliance with the discharge indicator

No	Position of Indicator (Fig. 2)	Urban running regime		Extra urban running regime	
		Running distance from beginning of experiment, km	Voltage according to dash-board, V	Running distance from beginning of experiment, km	Voltage according to dash-board, V
1.	1.	0.0	296.9	0.0	293.4
2.	2.	11.5	283.9	12.3	285.9
3.	3.	25.0	276.5	24.3	276.0
4.	4.	37.0	272.4	36.7	268.4
5.	5.	50.5	264.7	52.0	260.7
6.	6.	61.0	261.5	64.3	258.2
7.	7.	72.5	259.1	76.7	257.2
8.	8. light illuminate	81.5	256.4	86.7	252.4
9.	Experiment finish	90.5	254.3	95.0	251.4

In Table 8 the parameters of all three experimental repetitions and their average values are shown. After the complete series of the experiments conducted, data were collected and compared with the experiments in other mileage modes.

Table 2

Summary of exploitation parameters

No	Urban running regime (with load)			Extra urban running regime		
	Running distance, km according to odometer/ logger	Average speed, $\text{km}\cdot\text{h}^{-1}$	Driving time	Running distance, km according to odometer/ logger	Average speed, $\text{km}\cdot\text{h}^{-1}$	Driving time
1.	95/91.9	28.13	3 h 10 min	100/ 97.27	68.24	1h 25min
2.	86/83.3	26.27	2 h 54 min	92/88.36	60.06	1h 30 min
3.	91/81.1	29.68	3h 15 min	93/90.40	62.87	1h 26 min
Average	90.7/85.4	28.03	3 h 6 min	95/92.01	63.72	1h 27 min

The average running distance and average speeds of the two routes, testing the electric vehicle with fully charged batteries with load and without it, are shown in Figure 5. According to the image it is seen that in the experiments at different movement modes with load, and in extra-urban traffic the electric vehicle has similar tendencies as the internal combustion engine vehicle. The only difference – in the urban traffic the electric engine vehicle has a little more mileage that is not characterized to an internal combustion engine vehicle.

The maximal running distance of the electric vehicle Fiat Fiorino Elettrica HC-S with full charged battery in urban regime without load reaches 99 km and the average driving speed $30.69 \text{ km}\cdot\text{h}^{-1}$, but with load the driving distance reaches 90.7 km and the driving average speed $28.03 \text{ km}\cdot\text{h}^{-1}$. The maximal running distance of the electric vehicle with full charged battery in extra urban regime with a driver and one passenger reaches 95 km and the average driving speed $63.72 \text{ km}\cdot\text{h}^{-1}$. Due to the fact that the exploitation parameters are regulated by the Electronic Control Unit of the electric vehicle the average running distance of the electric vehicle at all experimental modes was within 90 to 100 km.

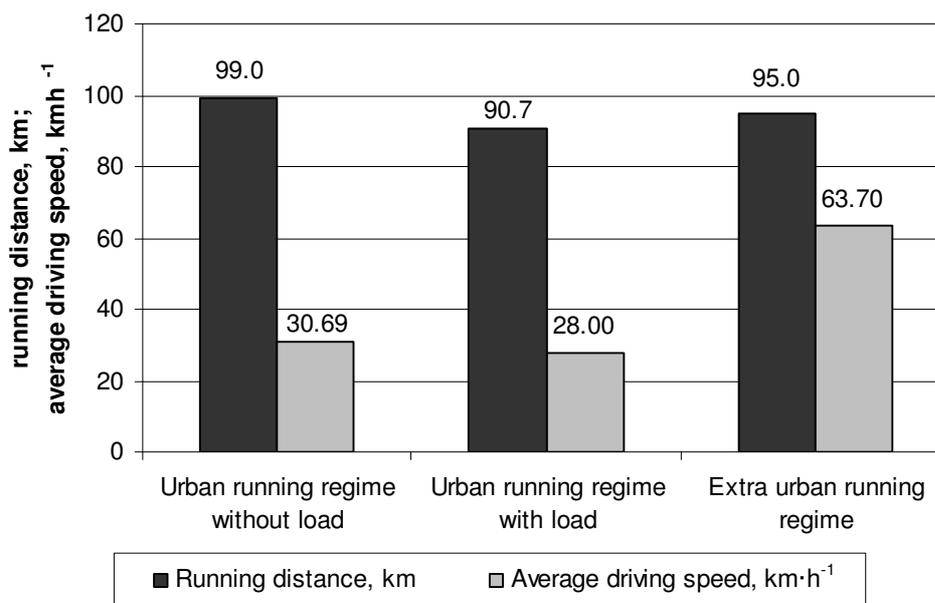


Fig. 5. Electric vehicle parameters of running distance at different route regimes

Because of the full electric vehicle load, the mileage has decreased about 8.4 % in comparison with urban mode without load (driver and passenger -150 kg). This is due to the resistance of inertia to overcome in the vehicle run-up mode with the load that reduces the electric vehicle millage. A similar trend should be observed with heavier batteries, for example, lead-acid batteries.

Conclusions

1. In the experiments with fully charged batteries without load the car Fiat Fiorino Elettrica HC-S shows enough good dynamic performance in urban regime and the electric car dynamics with partially discharged batteries is close to fully charged batteries.
2. Loading the car, the running distance decreased by approximately 8.4 %, but the average speed – till 8.7 %.
3. The maximal running distance of the electric vehicle Fiat Fiorino Elettrica HC-S with full charged batteries in urban regime with load reached 99 km and the average driving speed $30.69 \text{ km}\cdot\text{h}^{-1}$, but with load the driving distance reached 90.7 km and the driving average speed $28.03 \text{ km}\cdot\text{h}^{-1}$.
4. The maximal running distance of the electric vehicle with a full charged battery in extra urban regime with a driver and one passenger reached 95 km and the average driving speed $63.72 \text{ km}\cdot\text{h}^{-1}$.

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