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MEASURING THE OPERATING PARAMETERS OF ELECTRIC VEHICLES

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Abstract: Electric vehicles are growing in popularity and are reviving a much disused powertrain in the vehicle sector. This paper deals with the measurement of driving performance of electric vehicles. For twelve selected vehicles, the parameters given by the vehicle manufacturer and measured during individual runs were compared. The measurements were carried out on a predetermined route, divided into several parts. The data obtained here not only serve to compare the parameters, but also to determine the degree of dependence of the individual measured parameters on the range of the vehicles.

KEYWORDS: Electric vehicles, consumption, OBD

1 Introduction

Electric vehicles are currently the only way for vehicle manufacturers to meet the demands placed on them. Most vehicles on the road use internal combustion engines, either petrol or diesel, for propulsion. It is these vehicles that cause air pollution in both small and large urban areas. They have the greatest impact on human health in terms of breathing exhaust fumes, but also the noise that the vehicles produce. These are mainly HC, CO, CO2, PM and NOx. Options to reduce the impact of emissions in cities include banning specific vehicles from entering the city centre or diverting transit traffic through a ring road outside the city. Electromobility is now being considered as the adequate and only option to reduce local emissions from transport [1 – 3].

The current standard is EURO 6, which sets specific emission limits for the exhaust gases of conventional internal combustion engines. The incoming EURO 7 standard makes these values even stricter, and car manufacturers are being pushed towards alternatives to reduce the emissions produced. In the event of non-compliance with the set limits, manufacturers face financial penalties [4].

Electromobility is increasingly coming to the fore. Many car manufacturers have announced a complete switch to electric vehicles. This is also due to the European Parliament's decision that only electric vehicles may be sold in Europe from 2035. Alongside this trend, it is important to note the considerable strain on the energy grid associated with the rapid increase in electric [5 – 7].

Pure electric vehicles have the main advantage of local, purely emission-free operation. Moreover, when this parameter is combined with the generation of electricity from purely renewable sources, it is the best combination. Conversely, the batteries used to store the electricity can be a problem. They have a high weight, relatively low capacity, with an associated low range. They are also made in part from rare metals and are relatively expensive to produce and a burden on the environment [8, 9].

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Other issues for electric vehicles or a future challenge to be answered is the charging infrastructure or other means of supplying electricity to electric vehicles. The most discussed topic is charging speed. When, at best, vehicles can be charged in the order of the lower tens of minutes. However, the reality is currently more than one hour. Another issue is the large and instantaneous draw of electricity from the grid, where it is necessary to compensate for these surges. One way to eliminate these negative effects is to create so-called battery storage [10, 11].

The main objective of the experiment was to verify the operating parameters of the selected electric vehicles in real operation and to compare them with the manufacturer's stated parameters. The data obtained also serve to investigate the influence of individual parameters. Furthermore, to test the diagnostic devices in communication with different control units and vehicles from different manufacturers.

2 Materials and methods

Measurements of the operating parameters of electric vehicles were carried out on the proposed route. The measurement itself was carried out using TEXA, Bosch or VAG-COM diagnostic equipment, which communicated with the control units of individual vehicles during the measurement. Data was read from these units throughout the test run. In particular, voltage and current values were recorded when the batteries were drawing or returning power. Battery capacity and voltage or electric motor speed and vehicle speed. All vehicles were equipped with external devices for instantaneous position tracking - Garmin GPS 18x USB. All vehicles had a crew of 2 and diagnostic instruments. The same driver always drove and a defensive driving style was chosen. All measurements were always taken on a weekday and at the same time periods between 10am and 2pm. In all cases, the internal temperature was set at 22 degrees Celsius.

Tested vehicles

Several electric vehicles were loaned for the purpose of analysing the operating parameters of electric vehicles:

- Fiat 500e
- Škoda CITIGOe iV
- BMW i3
- BMW i3s
- VW e-Golf
- VW Golf GTE
- Peugeot e-2008
- Peugeot 3008
- Mercedes EQC
- Hyundai Kona

The technical parameters of the selected electric vehicles are shown in Table 1.

Instrumentation

The equipment used for the test runs is described in the following subsections. These were mainly TEXA, VAG-COM and BOSCH diagnostic devices for communication with the vehicle control units and storage of available instantaneous operating parameters.

Tab. 1 Technical parameters of tested vehicles

Vehicle	Weight	Torque	Power	Weight of battery	Capacity of battery	Range	Maximum speed	Consumption on 100 km
BMW i3	1 195 kg	250 Nm	125 kW	204 kg	33 kWh	160 km	150 km·h^{-1}	13,5 kWh
BMW i3s	1 365 kg	270 Nm	135 kW		42 (38) kWh	300 km	160 km·h^{-1}	13,1 kWh
CITIGOe iV	1 530 kg	212 Nm	61 kW	248 kg	36,8 kWh	252 km	130 km·h^{-1}	14,8 kWh
Fiat 500e	1 352 kg	200 Nm	83 kW	260 kg	24 kWh	135 km	142 km·h^{-1}	18 kWh
Hyundai Kona	1760 kg	395 Nm	150 kW		64 kWh	484 km	167 km·h^{-1}	14,7 kWh
Mercedes EQC	2495 kg	760 Nm	300 kW	650 kg	80 kWh	445 km	180 km·h^{-1}	21,5 kWh
Peugeot 3008H	1835 kg	300 Nm	165 kW		13,2 kWh	40 km	220 km·h^{-1}	1,5 l
VW e-Golf	1 585 kg	270 Nm	85 kW	312 kg	24,2 kWh	231 km	150 km·h^{-1}	12,7 kWh
VW Golf GTE hybrid	1 599 kg	400 Nm	250 kW		8,7 kWh	50 km	222 km·h^{-1}	12 kWh
VW ID3	1719 kg	310 Nm	150 kW		58 kWh	420 km	160 km·h^{-1}	16,1 kWh

TEXA diagnostics

The Texa diagnostic unit is designed to diagnose many makes of passenger vehicles. It allows monitoring and recording of selected values, from specific control units, in real time. The device is simply plugged into the OBD socket and then communicates wirelessly with the computer. Thanks to the continuous measurement, it is possible to monitor the vehicle's operating parameters instantaneously [12].

Vag-COM diagnostic system (HexCAN-V2)

This diagnostic device enables communication with VW vehicles (VW, Audi, Seat, Skoda) using the HexCan-V2 communication interface and the VAG-COM computer program, which is designed for vehicle diagnostics via serial diagnostics. The software allows the display and storage of instantaneous values of operating parameters by connecting to the relevant vehicle control unit [13].

BOSCH KTS 590

The Bosch Diagnostics KTS 590 is a device used for inspection, diagnosis, troubleshooting. The diagnostics enables real-time data reading and recording from individual control units. Connection to a personal computer can be made via USB cable or Bluetooth wireless technology [14].

GPS Garmin

A Garmin GPS-18x USB satellite receiver was used to capture the instantaneous position of the vehicles and an application was created in the ControlWeb environment to record the instantaneous values from the GPS sensor.

Test route

The proposed test route is 56.1 km. It was driven with each vehicle in both directions and the start and end point was always the CHS campus. It was designed to be based on the WLTP (World Harmonized Light-duty Procedure) homologation cycle where the test route must include urban, non-urban and motorway traffic according to precise specifications that further define the average speeds achieved, route elevation, route timing, climatic conditions and others.

Figure 1 below shows the test route. The orange part shows the urban traffic (ČZU-Letňany, Kralupy n. Vlt.), the dark blue the non-urban traffic (ČZU-Kralupy) and the light blue the motorway traffic (Kralupy-Letňany).

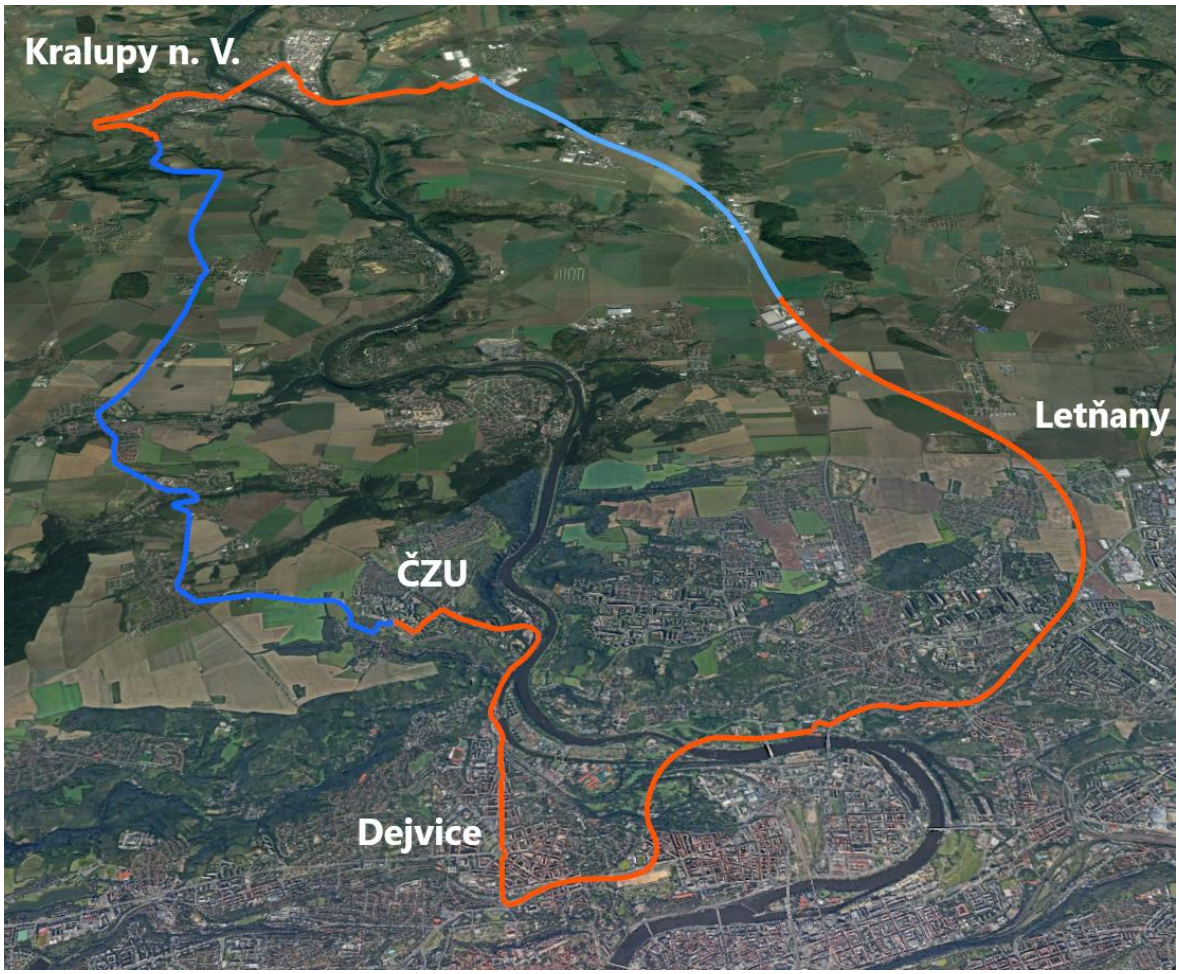


Fig. 1 Tested route

RESULTS

Table 2 summarizes the basic summary results of the experiments performed. The aim was to verify the declared driving characteristics of the vehicles in real operation. The actual measurements were mainly carried out at temperatures above 0°C. In one test run the temperature was -10°C. The average energy consumption during the tests for all vehicles was 11.63 kWh/100 km. The VW e-Golf achieved the lowest pure electricity consumption of 11.9 kWh/100 km, while the VW ID3 achieved the highest (22.4 kWh/100 km), but the weather conditions played a significant role, with a severe frost of -10°C in the case of the VW ID3. Another car with high consumption was, as expected, the Mercedes ECQ (20.5 kWh/100 km) due to its size and especially weight. The experiments further showed that the declared driving parameters were essentially met in real life operation, although the immediate climatic conditions had a significant effect, with up to a one-third decrease in the estimated range at low outdoor temperatures.

DISCUSSION

At this time, there is great pressure to reduce the negative environmental impact of using conventional internal combustion engines. A study from Bloomberg New Energy Finance (BNEF) reports that automakers are being forced to accelerate the production of electric vehicles for the market. This has been slowed by the emergence of COVID-19, but it is thought that more than 500 electric vehicle models will be available globally by the end of 2022. Correct identification of the target customer and pricing of each model will be key to expanding these vehicles to the general public [15].

Tab. 2 The measurement results

Vehicle	Consumption on 100 km	Average consumption during the test kWh/100 km	Average speed km/h	Date	Outside temperature °C
BMW i3	13,5 kWh	-	39	22.10.2020	13
BMW i3s	13,1 kWh	13.9	46	13.01.2021	1
CITIGOe iV	14,8 kWh	12.6	42	14.10.2020	6.5
Fiat 500e	18 kWh	12.3	40	21.10.2020	12
Hyundai Kona	14,7 kWh	12.2	45	25.08.2020	23
Mercedes EQC	21,5 kWh	20.5	45	03.06.2020	19
Peugeot 3008H	1.5 l	8.3 kWh + 4.1 l benzínu	40	18.08.2020	24
VW e-Golf	12.7 kWh	11.9	42	06.10.2020	12
VW Golf GTE hybrid	12 kWh	2.2 kWh + 3.9 l benzínu	48	11.06.2020	19
VW ID3	16,1 kWh	22.4	47	11.02.2021	-10

Studies have also found that the WLTC homologation driving cycle does not correspond to actual driving in different regions and local test cycles need to be developed. Therefore, China has already announced its local CLTC (China Light Commercial Vehicle Test Cycle) in 2019. To evaluate the vehicle emissions in different driving cycles, one conventional gasoline vehicle and its hybrid counterpart were tested on a vehicle dynamometer according to the CLTC, WLTC and RDE (Real Driving Emission) driving cycles. The fuel consumption between WLTC and RDE is at the same level. While conventional fuel consumption is 8.41% higher for CLTC than WLTC, it is 20.23% lower for hybrid than WLTC [16]. Studies also report that hybrid electric vehicles are more economical than conventional vehicles, even though they produce almost the same energy [17]. Compared to conventional gasoline vehicles, hybrid electric vehicles can reduce extra cold start emissions by 30% to 85% [18].

During the measurements, there were also problems with the connectivity of the different diagnostic devices and the vehicles being measured. For some of them, it was not possible to establish communication and therefore to make measurements. In some cases, communication was not reliable and data was lost. The newest vehicles on the market were also a problem, as they were not yet established in the database of diagnostic instruments. Where possible, data was captured not only from the vehicle control unit but also from the vehicle infotainment system. The average speed of the vehicles was only influenced by the immediate traffic situation, with a defensive driving style and compliance with traffic regulations.

In the case of the VW ID.3, the measured consumption was 6.3 kWh/100 km higher than declared. This was probably due to the very low outside temperature (-10°C) during the measurement. Low temperature affects battery capacity, as shown in a study by the Norwegian Automobile Federation (NAF) [19].

CONCLUSION

A total of 12 electric or hybrid vehicles were tested in the experiments, some of them repeatedly (depending on the immediate situation and availability of the vehicles). The biggest problem in measuring electric vehicles is the need to use diagnostic equipment. In most cases, direct measurements are not possible due to operating voltages up to 400 V and high current draws during driving of up to hundreds of amperes. The vehicles are protected against external access to these units. However, data availability is often dependent on the compatibility of the diagnostic equipment and the vehicles. It is not always certain whether it will be possible to connect to the correct control unit and obtain specific data.

In spite of these difficulties, experiments have confirmed that the vehicle performance data verified during the homologation of the vehicle according to the new WLTP methodology corresponds to real-life operation, although of course ambient traffic, the driving style of the driver and the immediate weather conditions play a major role. Given the statements made by the world's leading vehicle manufacturers, we can expect a rapid development of electromobility and a shift away from conventional combustion engines. Unfortunately, neither the charging station infrastructure nor the electrical transmission system is currently fully prepared for this development. The environmental friendliness of electromobility is closely linked to the sources for generating electricity, which are unlikely ever to be as clean and environmentally friendly as is often presented.

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