THE IMPORTANCE OF HYBRID VEHICLES IN URBAN TRAFFIC IN TERMS OF ENVIRONMENTAL IMPACT

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Abstract

Many large cities in Europe are currently trying to reduce the amount of harmful substances for the sake of residents. Road transport is also an important source of air pollution. One way to reduce pollutant production is to operate more environmentally friendly vehicles. The paper analyses data obtained during practical tests of a hybrid vehicle in urban traffic. The individual components of the exhaust gases are calculated in g/km and they are compared with the values for conventional vehicle propulsion. The data was obtained through a commercially available exhaust gas analyzer and a calculated amount of emissions produced from available data from the engine control unit. The results have shown that using this type of propulsion has its importance in cities with increased air pollution. During urban operation, the hybrid-powered vehicle was powered by an electric engine up to 67.70% (75.40% of the time). As a result of operating such a vehicle in the city, emissions of CO_2, HC and NOX are significantly lower.

Keywords: hybrid vehicles; emission; carbon dioxide; carbon monoxide

1. Introduction

Despite the reduced air pollution from road transport, there are still serious air quality problems in urban areas. Further initiatives are needed to minimize the effect of pollutants that affect the health of residents. Transport in relation to the environment is a source of emissions (basic pollutants or greenhouse gases), source of noise and vibration, creating pressure on the soil, affecting the spatial arrangement and causing health and safety risks. The negative environmental impacts of transport are conditioned by the increasing transport demands of society in the context of the globalization process, which translates into demands for transport infrastructure. In terms of greening transport, the use of renewable energy sources in transport needs to be introduced and developed. It is also necessary to focus on the promotion and development of non-motorized and environmentally friendly modes of transport [15].

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Transport has a negative impact on the environment in two basic aspects: the construction of transport infrastructure and in terms of harmful impacts from transport operations. Increasing traffic volumes lead to increased pressure on the environment, particularly in relation to climate change and biodiversity loss. On the positive side, technological improvements ensure a reduction in air pollution from road transport despite an increase in traffic volumes. Air pollution by emissions contributes significantly to global environmental problems such as climate change. The transport sector is one of the major factors causing energy problems and environmental problems. It is because transport is one of the largest consumers of fossil energy sources [15].

The number of road vehicles in operation significantly affects the amount of emissions produced and thus the fuel consumption in the transport sector [4]. In the transport sector, especially in road transport, an increase in the number of road vehicles can still be observed. The number of registered vehicles in Europe is constantly growing at a rate of around 2% year-on-year. The negative environmental impact of road traffic is mitigated by the introduction of new technologies in powertrains, but their increasing number eliminates this advantage [9, 11].

The composition of vehicles in service is a significant factor that affects the environmental impact of road transport. Road vehicles can be classified in terms of the mode of transport (passenger cars, trucks, buses and others), the type of propulsion (petrol engine, diesel engine, alternative type of propulsion) or their age structure. The driving performance of individual types of road vehicles is also an important factor [1, 2].

All these factors are the basic input for calculating the environmental burden of road vehicles. Passenger cars account for almost 87% of all vehicles in operation. The EU motor vehicle fleet is getting older year-on-year. Passenger cars are now on average 11.1 years old, vans 11 years and heavy commercial vehicles 12 years (year 2017). In 2018, diesel's share of the market fell from 44.0% to 35.9%, while petrol continued to further expand its share of new car registrations (from 50.3% to 56.7%). The market share of hybrid-electric vehicles in the EU was 2.7% of all new car sales in 2017. In 2017, plug-in hybrid (PHEV) and battery- electric vehicles (BEV) made up about 1.4% of vehicle registrations in the EU. This is a slight increase compared to the previous year [2]. In the area of reducing the negative environmental impacts caused by humans, a significant increase in the number of vehicles with alternative propulsion types would be expected.

2. Methodology

In order to assess the impact of a hybrid vehicle in urban traffic, two measurements were made in Žilina during the traffic peak hours of the day. The route led from the campus of the University of Žilina to the city center and back as shows Figure 1. The route had approximately 10 km. While driving, the exhaust gas parameters were recorded and selected data from the engine control unit was recorded via OBD diagnostics.

Fig. 1. Driving route of hybrid vehicle. (Source: authors)

Exhaust emissions measurement in real vehicle operation was performed on a TOYOTA RAV4 vehicle with hybrid drive and gearbox CVT - Continuously Variable Transmission. This vehicle has four-wheel drive. The vehicle is powered by a petrol engine VVT-i (2AR) with a displacement of 2494 cm^3 with a power of 114 kW and a torque of 206 Nm. This hybrid vehicle has two electric engines. The front electric engine has a power of 105 kW and a torque of 270 Nm and the rear high-speed electric engine has a power output of 50 kW and a torque of 139 Nm, which provide electric drive for both axles. The total combined power of the hybrid system is 145 kW. The vehicle has the following emission values (EURO 6) with an average fuel consumption of 5.1 l/100 km: CO 0.2670 g/km, NOX 0.0090 g/km, CO2 118 g/km, HC 0.0490 g/km.

The Department of Road and Urban Transport has its own measurement technology, with which it is possible to determine the amount of exhaust gas emissions produced while driving a vehicle in grams per kilometer using known calculation procedures [12, 13]. The main measuring device is the Maha MGT 5 exhaust gas analyzer. This gas analyzer is capable to measure HC, CO, CO_2, O_2 and NOX emissions. The analyzer operates on the principle of selective absorption what means that each component of the exhaust is assessed in the infrared range. The exhaust gases tested are conducted from the vehicle's exhaust pipe to an exhaust probe that is connected to the analyzer by a hose [7]. The whole scheme of data acquisition and processing is shown in the Figure 2. At first, the H_2O water vapor is separated from the exhaust gases and then the exhaust gases are led to the measuring chamber. The infrared light beam in the direction of the measuring element is weakened by the gas. The amount of attenuation of this light beam is manifest by a different wavelength depending on the type of gas. Such a method is the measured amount of HC, CO, CO_2. On the other hand, O_2 and NOX are measured by electrochemical detection. The measured data is from the emission analyzer evaluated on a portable computer with Maha Emission Viewer software, which allows emissions to be recorded during the vehicle's whole driving [5, 14].

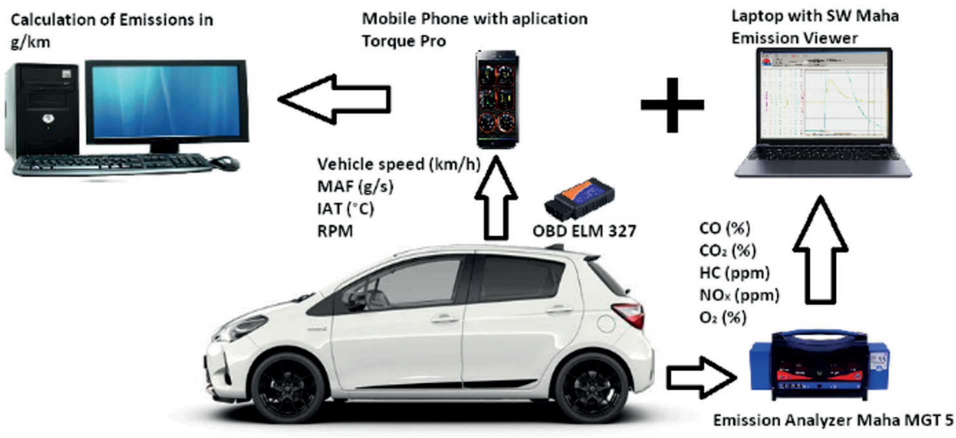

Fig. 2. Scheme of data acquisition and processing. (Source: authors)

A simple Bluetooth OBD ELM327 paired with a mobile phone was used to record data from the engine control unit. The mobile phone was processing and storing data through application Torque Pro. During the measurement data about the intake air mass MAF (g/s), vehicle speed (km/h), and RPM engine speed and intake air temperature IAT (°C) were recorded and stored. The used application also allows to record the GPS position of the vehicle from which you can evaluate the vehicle route data [16, 17]. All measured and stored data are transferred to an evaluation computer, where vehicle emissions in g/km are evaluated according to known methodologies. The data from emission analyzer is delayed by 8 seconds because of transmission of emissions from the exhaust pipe to the analyzer. The data recording frequency is 1 Hz [7, 19].

3. Results

Hybrid vehicle TOYOTA RAV4 in measurement No. 1 was moving at an average speed of approximately 27.4 km/h and in the measurement No. 2 the average speed of the vehicle was even lower, namely 22.4 km/h. The total time duration of the first emission measurement was

1329 seconds, of which up to 900 seconds (which is 67.70%) of the time, the petrol engine was switched off and the propulsion was ensured by two electric engines. The total time duration of the second measurement on the test route was 1620 seconds and from that time up to 1221 seconds (which is 75.40%) of the time, the petrol engine was switched off (Table 1). When the petrol combustion engine is switched off, there is no emission of exhaust gases [6, 10, 20]. During these measurements, it was mainly when driving at low speed, driving at steady speed, decelerating the vehicle, when the vehicle was standing at intersections, and so on. The petrol engine was switched on again for request to higher vehicle acceleration.

Tab. 1. Measurements results

Drive	Duration [s]	Electro duration [s]	Average speed [km/h]	Maximum speed [km/h]	Measured distance [km]	Electric engine duration [s]
1	1329	894	27.4	57.8	10.153	900
2	1620	1220	22.4	61.4	10.122	1221

From the recorded data from the engine control unit (vehicle speed and engine speed) and from the emission values, it is possible to analyse in which operating states were the electric engine and petrol engine during the operation. The course of vehicle speed and engine speed is shown in Figure 3 for measurement No. 1.

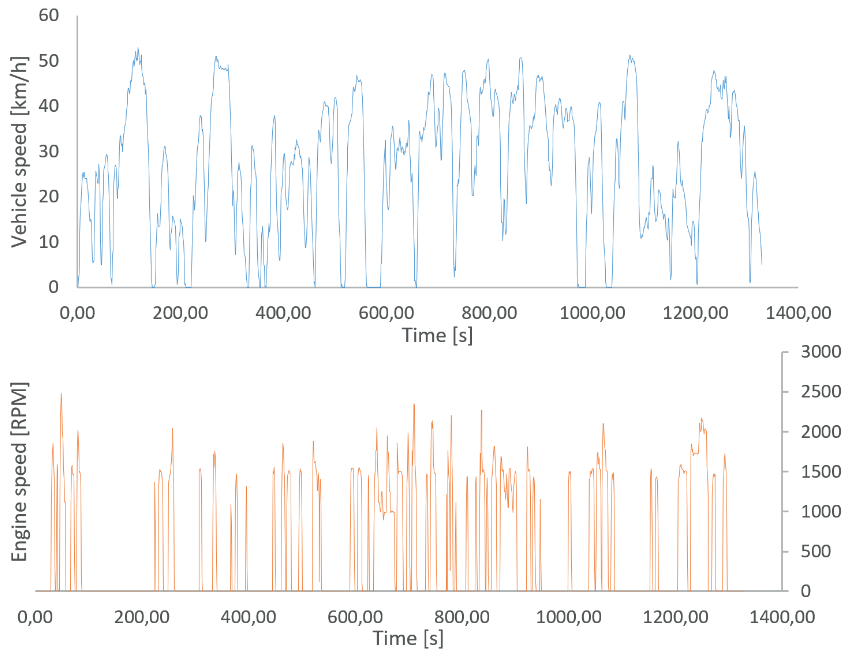

Fig. 3. Vehicle and engine speed (Source: authors)

In urban traffic, the duration of vehicle´s zero speed was 102 seconds for the measurement No. 1 and 208 seconds for the measurement No. 2. Figure 4 shows the distribution of the operation of the electric engine and the petrol engine as a function of the vehicle speed. The vehicle speed was divided into intervals of 10 km/h with a separate speed separation for speed 0 km/h (the part when the vehicle was stationary). In this case, the vehicle produced no exhaust emissions [8, 3]. At speeds of up to 30 km/h, especially during the acceleration phases, the vehicle was predominantly powered by an electric engine.

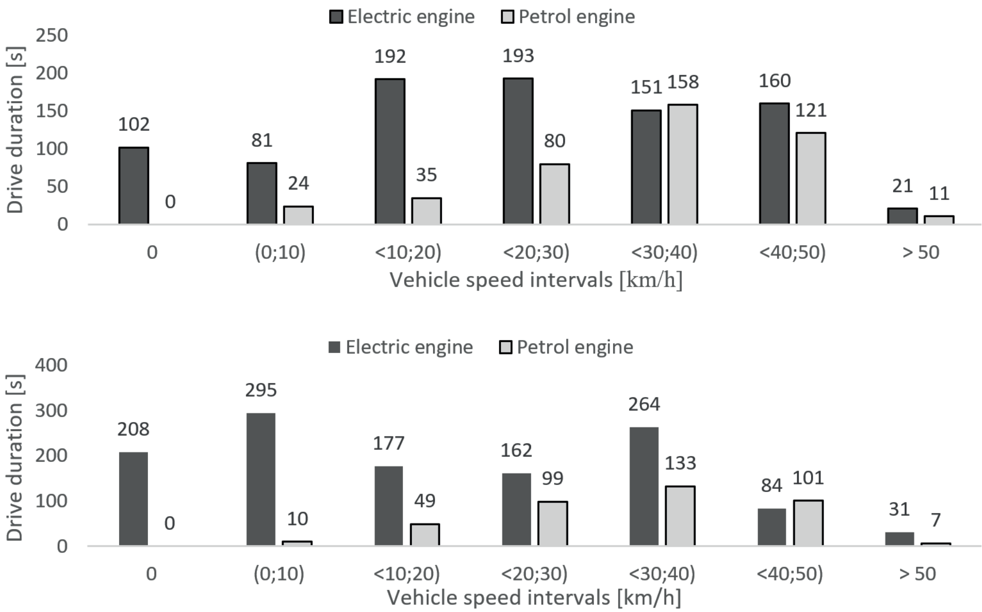

Fig. 4. The distribution of the operation of the electric engine and the petrol engine (Source: authors)

Exhaust emissions were recorded by a Maha MGT 5 emission analyzer with Maha Emission Viewer software. Emission values in g/km were calculated using the already published methodology using data from the engine control unit. The basic parameter needed for the calculation is the amount of intake air. The amount of intake air was measured by the air quantity sensor in the intake manifold and expressed in g/s. In Table 2, the resulting calculated amounts of CO_2, CO, HC and NOX emissions are expressed in grams per kilometre of drive.

Tab. 2. Emissions results Toyota RAV 4 Hybrid

Drive	CO_2 [g/km]	O_2 [g/km]	CO [g/km]	HC [g/km]	NOX [g/km]
No. 1	136.354	0.027	0.301	0.134	0.00015
No. 2	123.214	0.025	0.156	0.015	0.00001

In previous research work, the author published the results of emissions measurements during the operation of the Toyota RAV 4 on the same urban route with the following results (Table 3). Compared to the operation of a hybrid vehicle, the production of CO2, HC and NOX pollutants is significantly lower.

Tab. 3. Emissions results Toyota RAV 4

Drive	CO_2 [g/km]	O_2 [g/km]	CO [g/km]	HC [g/km]	NOX [g/km]
No. 1	169.2647	0.0164	0.1653	0.0168	0.0067
No. 2	156.4008	0.0128	0.1253	0.0178	0.0074
No. 3	170.3572	0.0151	0.1039	0.0240	0.0101

4. Conclusion

Emission standards are increasingly stricter and the limit values for the individual exhaust components of road vehicles are also stricter. For this reason, emissions are becoming the most watched element of road vehicles [7, 18]. This is mainly because harmful constituents such as carbon dioxide CO_2 and nitrogen oxides NOX are the part of the greenhouse gases and they contribute to the global warming, which is currently considered to be the most serious global environmental problem. That is why the European Union continues to strive for cleaner transport by imposing strict emission limits for road vehicles. If the emission limits are not respected, car manufacturers will be charged a fee of € 95 for each gram of carbon dioxide produced per kilometre of CO_2 above the set limit of 95 g/km. Other restrictions include the exclusion of older vehicles (which meet lower emission standards) from urban centres for better air quality in cities.

In order to categorize vehicles according to the individual emission standards that they meet, it is important to know the emissions and components of the exhaust gases they produce, and especially to what extent. Therefore, road vehicles must be approved for emissions production before being placed on the market. At present, emissions are measured under laboratory conditions, where the emissions of a vehicle placed on a roller dynamometer are measured by simulating the driving cycle WLTP. The results of such measurement are emission values in grams per kilometer. It is understandable that laboratory emission values so measured may differ from the emissions actually produced in real operation. From 2017, laboratory measurements are also complemented by measurements during the actual driving of a vehicle in traffic called RDE - Real Driving Emissions. It is for more accurate emission determination.

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