Analysis of hybrid electric vehicle behaviour in real traffic conditions

N. Fonseca*[1], T. Larrosa[1], J. Casanova[2] and J.M. López[3]

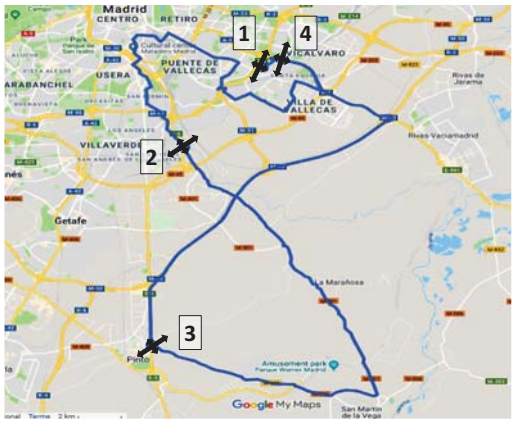
Objetives

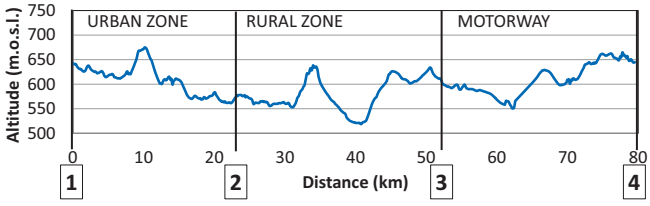
This study is a new contribution to investigate the behaviour of the hybrid powertrains of light-duty vehicles in real traffic, dealing with fuel consumption, CO_2 and NO_x emission factors measured in real driving emissions (RDE) tests in Madrid and its surroundings. It is analysed operative conditions: when the vehicle is in thermal engine and in zero emissions modes.

Measurement campaign

- One Euro 6b Toyota RAV4 Hybrid equipped with 114 kW - 2494 cm³ indirect injection gasoline engine and two electric engines (143 and 68 kW) with series-parallel hybrid configuration. Model year 2017 with 13600 mileage at the beginning of the tests. Vehicle equipped with EGR+TWC.

- The route was designed according to Real Driving Emissions (RDE) protocol (EU Regulation 2016/427), with a total of 79.4 km including urban, rural and highway track sections.



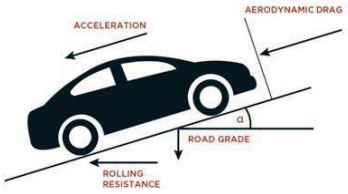


- Five tests were done in May 2017 using normal driving style.
- Exhaust gas flow, NOx and CO2 instantaneous emissions and vehicle kinematics were measured using MIVECO PEMS V3.0. Data was recorded and synchronized @ 10 Hz. [1, 2].

Data processing

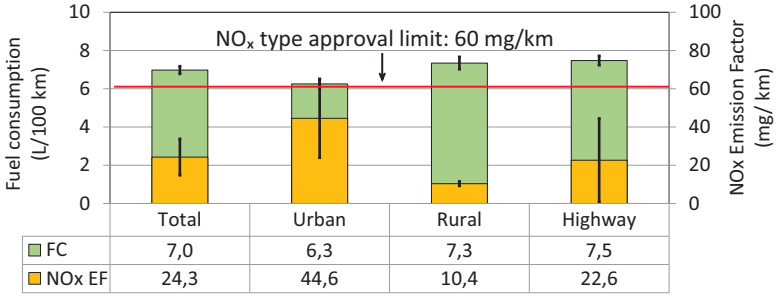
- Fuel consumption factor: $$FC[\mathrm{L/100\,km}] = \frac{\sum \dot{m}_F[\mathrm{g/s}]\Delta t}{dist[\mathrm{km}]} \cdot (\rho_F[g/L])^{-1} \cdot 100$$
- NOx emission factor: $$FE_{NOx}[\mathrm{g/km}] = \frac{\sum \dot{m}_{NOx}[\mathrm{g/s}]\Delta t}{dist[\mathrm{km}]}$$
- Traction power:

$$P_T = v \cdot F_T = v\left(m\frac{dm}{dt} + m \cdot g \cdot \sin a + m \cdot g \cdot f_r + \frac{1}{2} \cdot Cx \cdot A_{vb} \cdot \rho_a \cdot v_{viento}^2\right)$$



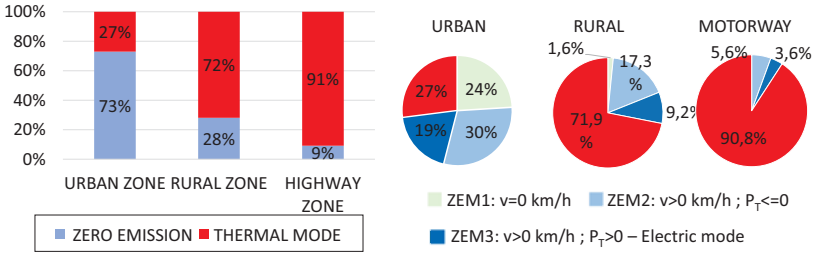
Results

- **Fuel consumption and NOx emission factor**

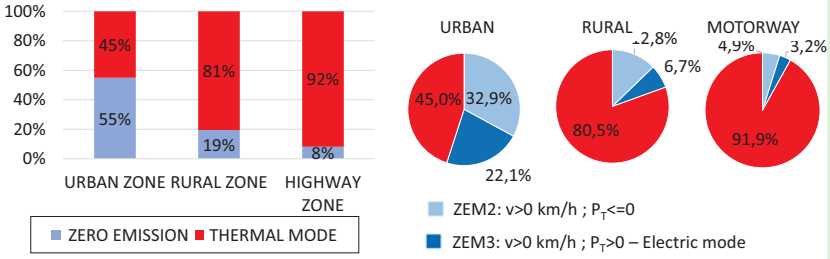


	Total	Urban	Rural	Highway
FC	7,0	6,3	7,3	7,5
NOx EF	24,3	44,6	10,4	22,6

- **Time percentage in Zero Emissions Mode (ZEM)**



- **Distance percentage in Zero Emissions Mode (ZEM)**



Conclusions

- Hybrid vehicles that combines gasoline engines with electric motors in series-parallel configuration has great environmental advantages especially in urban traffic because of its lower NOx emissions, lower fuel consumption and therefore lower CO_2 emissions, with high time and distance percentages in zero emissions mode.

References

1. Fonseca González, N., Casanova Kindelán, J., López Martínez, J.M. (2016) Methodology for instantaneous average exhaust gas mass flow rate measurement. Flow Meas. Instrum. 49, 52–62. https://doi.org/10.1016/j.flowmeasinst.2016.04.007.

2. Casanova Kindelán, J. & Fonseca González, N. (2013) Dispositivo universal, no intrusivo, de medida en tiempo real de emisiones contaminantes de motores, embarcable en vehículos. Spanich Patent ES 2398837_B2.

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This study is a new contribution to investigate the behaviour of the hybrid powertrains of light-duty vehicles in real traffic, dealing with fuel consumption, CO_2 and NO_x emission factors measured in real driving tests in Madrid and its surroundings. It is aimed to give numbers of the percentage of time of operative conditions when the vehicle is in zero emissions mode. Those periods are when the vehicle is stopped (does not travel any distance), is decelerating or braking; or is in only electric propulsion mode, therefore the relation between time and distance travelled is analysed.

A Toyota RAV4 Hybrid equipped with 114 kW, 2494 cm^3 indirect injection gasoline engine and two electric engines (143 and 68 kW) with series-parallel hybrid configuration has been used. The route used was designed according to Real Driving Emissions (RDE) protocol (EU Regulation 2016/427), with a total of 79.4 km including urban, rural and highway track sections. Five tests were done using always a normal driving style. Exhaust gas flow, NO_x and CO_2 instantaneous emissions and vehicle kinematics were measured using MIVECO PEMS V3.0 [1, 2].

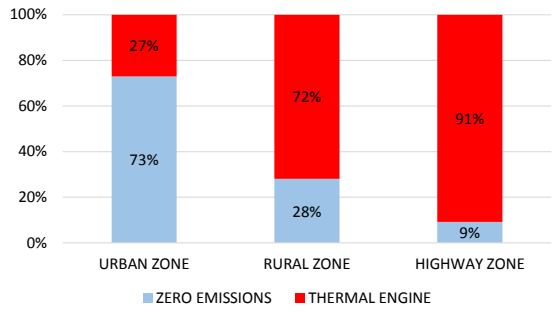

Figure 1. Percentage of time in zero emissions mode

It can be seen from these tests that most of the time the hybrid vehicle is in zero emissions mode (54% of the total RDE test) and therefore, does not emit pollutants. This is partially due to the fact that the vehicle is stopped or is decelerating, which also happens in other non-hybrid power trains. This condition occurs mainly in the urban zone, where more than 70% of the time the vehicle is in zero emission mode. In rural and highway zones, the percentage of time is significantly lower due to greater power demand and less stops and decelerating periods. (see figure 1). This facts makes the consumption factor in urban traffic significantly lower (only 6.3 L/100 km) compared to the consumption factor in rural traffic and motorway (7.3 and 7.5 L/100 km respectively), as is shown in figure 2.

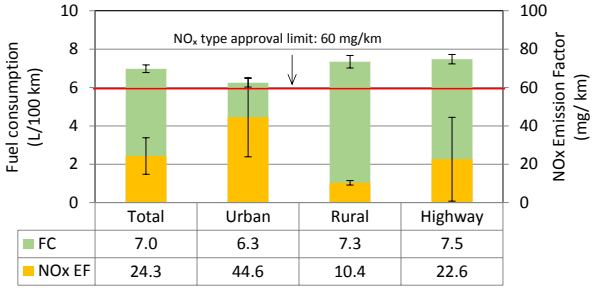

Figure 2. Consumption factors by zone and average

This tests also show (figure 2) that NO_x emissions are very low, even lower than the currently strictest type approval limit for gasoline engine vehicles (60 mg / km) in all traffic zones: urban, rural and highway.

In addition, it is revealed that most of the start-ups (up to 88%) are in electric mode, and therefore, fuel consumption, that is high in thermal engine mode, is significantly reduced in urban traffic conditions. On the other hand, it has been seen that start-ups in thermal mode occurs in high acceleration conditions, over 3.6 m/s^2; demonstrating that avoiding intense accelerations prolongs electric mode operation, and therefore, increases zero emissions time.

In conclusion, hybrid vehicles that combines gasoline engines with electric motors in series-parallel configuration has great environmental advantages especially in urban traffic because of its lower NO_x emissions, lower fuel consumption and therefore lower CO_2 emissions, with high time and distance percentages in zero emissions mode.

1. Fonseca González, N., Casanova Kindelán, J., López Martínez, J.M. (2016) *Methodology for instantaneous average exhaust gas mass flow rate measurement*. Flow Meas. Instrum. 49, 52–62. https://doi.org/10.1016/j.flowmeasinst.2016.04.007.

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