

Researching Diesel car CO₂ emissions in cold and warm-up transient test cycle

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Abstract. Research of CO₂ emissions is not only important, but it is standard practice for homologation, technical inspections, registration of vehicles and for environmental greenhouse effect. Different agencies are taking into consideration the fact that greenhouse emissions are seriously impacting the climate change and events on the planet. Road traffic and transportation are, beside animal agriculture, the most significant polluters in dense areas, with high values of emissions. For diminishing the impact of automotive sector in the emissions field, the present work approaches the practical side of this topic. During the testing, some results will allow the definition of those conditions in which the pollutant emissions fall into control and are drastically diminished. Main objective of the paper is to research the CO₂ emissions generated by a Diesel engine in a transient test cycle, both at cold operation and after warm-up phase. Second objective is to analyse the graphics from low speed and medium speed operation regimes. The CO₂ emission are influenced by fuel consumption, engine speed and coolant temperature. Highway testing of CO₂ emissions are to be made in further and advanced research.

1. Introduction

Internal combustion engines are those machines which transform the mixture of atmospheric O₂ and HC (hydrocarbons) fuel molecules through rapid oxidation reactions at high temperatures inside the combustion chamber in useful work and performance [1, 2].

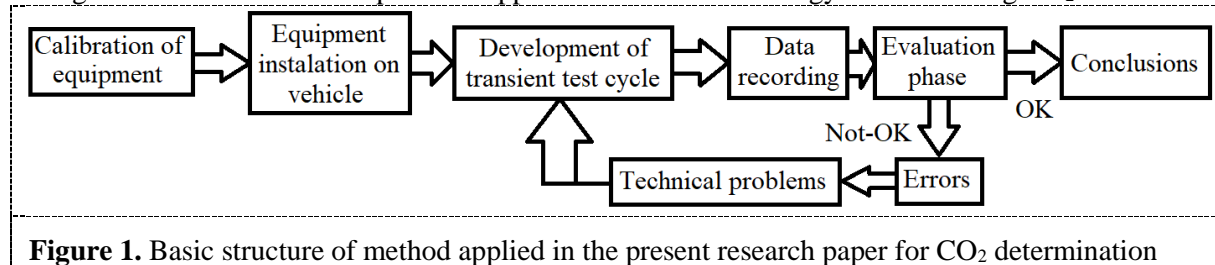
Digital management system of the engine takes the data from sensors and determines the fuel quantity to be injected [3]. Combustion and exhaust emissions influence the air quality and health risk [4, 5, 6]. Electronic control for fuel supply in dynamic conditions increases the operational efficiency [7]. Health management and environmental risk are closely related to carbon (CO₂, CO, and HC) emissions [8]. Injection systems, fuel quantity and air intake mass are important factors to be considered within the electronic control unit [9, 10, 11]. Friction in the bearings and between the wheels and road surface makes it difficult for engine to overpass the resistance torque, thus it takes more fuel to create higher gas pressures in the cylinders and affects the carbon footprint [12, 13]. Advances in software interfaces are supporting the improvement of control and management even through the end-user adaptive interactions and information exchange [14,15]. Electronic Diesel Control and management system provides the data regarding injected fuel quantity on dash-board screen in real time to facilitate some adjustments in operation and command [16,17]. Development of automated systems with remote control capability is making a step further to optimize the fuel-efficient use and to decrease CO₂ level [18, 19]. Significant advancements and contributions have been made in development of the fuel supply, even through injectors in the combustion chamber, to diminish the losses and increase performance [20].

In the present work is determined CO₂ emissions level corelated with engine and vehicle speed.

2. Applied research

Applied method in the present work is supported by the experimental tests which were structured within 3 cycles: Cycle 1 – transient testing in urban traffic using first three gear ratios at 10-12°C; Cycle 2 – transient testing in mixt urban and metropolitan traffic using first four gear ratios at 90°C; Cycle 3 – transient testing using all five gear ratios at 90°C (engine temperature) and 15-17°C.

Figure 1 shows the main steps of the applied research methodology in determining CO₂ emissions.

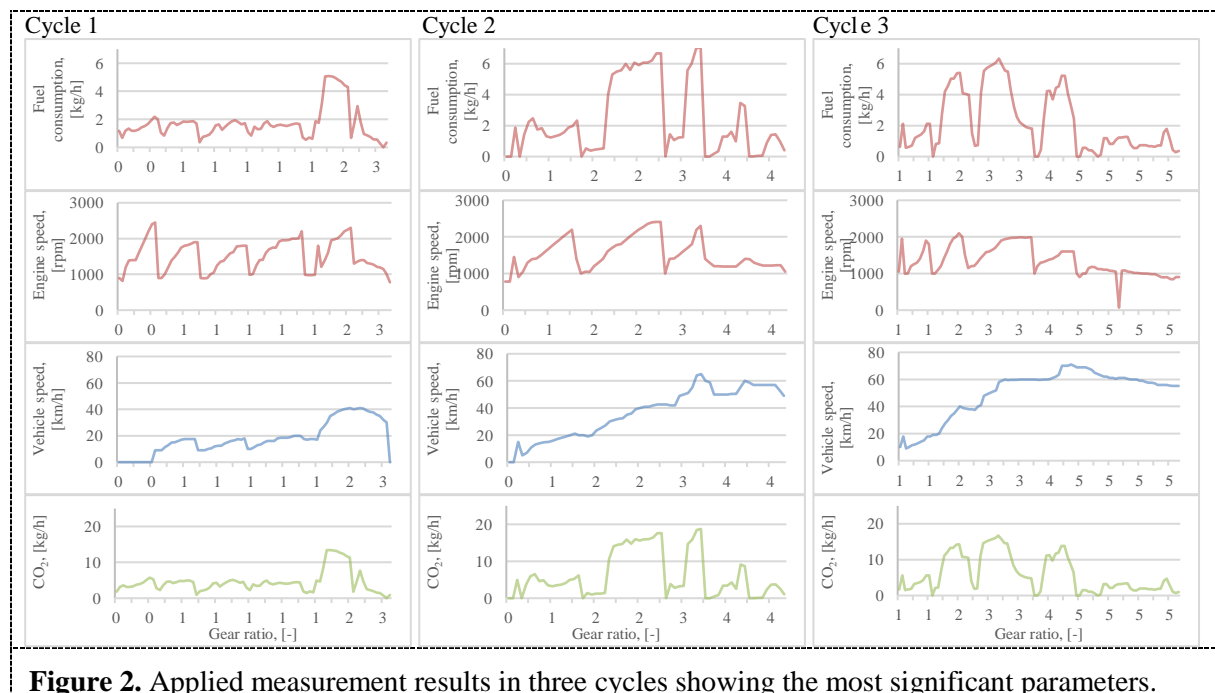


Applied methodology in research is using a Diesel car with technical data given in table 1.

Table 1. Technical data of the test vehicle

Platform	Actual value
Engine type	Diesel 1600 cm ³ / 4 cylinders in line
Fuel supply	High pressure injection
Transmission	5-gear ratio
Powertrain	Front drive, 4x2/VW Golf 6

Figure 2 presents the transient cycles for 3 tests versus the gear ratio, showing the CO₂ and speeds.



In figures 3 to 8 are shown the graph variations for average values of vehicle speed, fuel consumption, engine speed, oil temperature, coolant temperature and CO₂ emissions versus gear ratio determine and compared for the 3 cycles. The figures 9 to 14 present the CO₂ and engine speed vs. the vehicle speed.

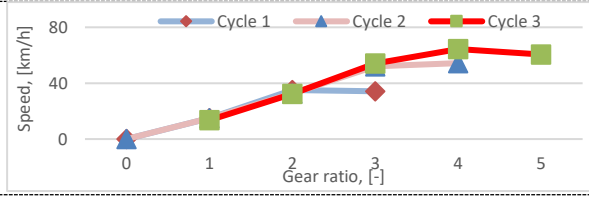


Figure 3. Vehicle speed versus gear ratio values.

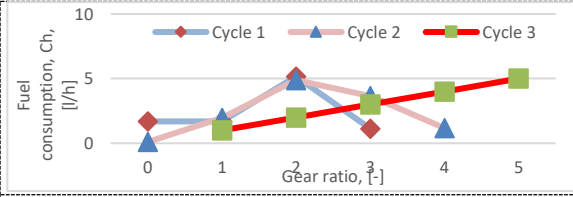


Figure 4. Fuel consumption versus gear ratio.

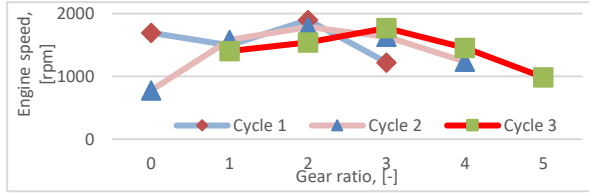


Figure 5. Average engine speed versus gear ratio.

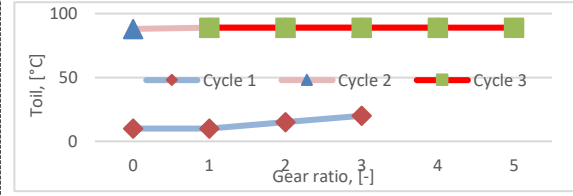


Figure 6. Oil temperature versus gear ratio.

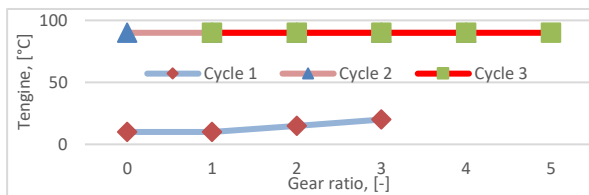


Figure 7. Coolant temperature versus gear ratio.

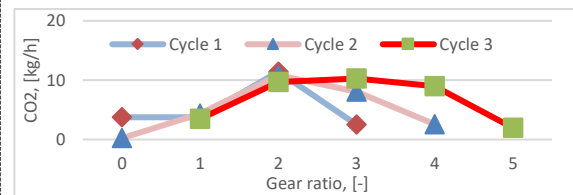


Figure 8. CO2 emissions versus gear ratio.

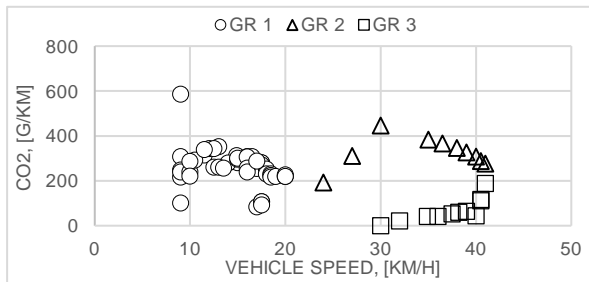


Figure 9. CO2 value vs. vehicle speed-Cycle 1.

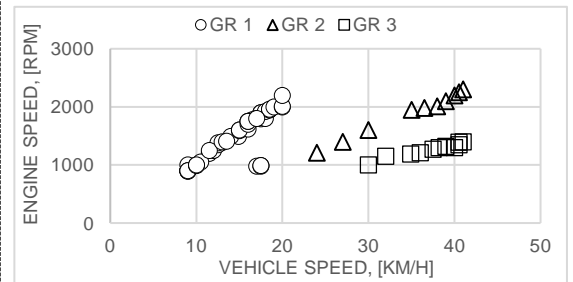


Figure 10. CO2 vs. vehicle speed-Cycle 1.

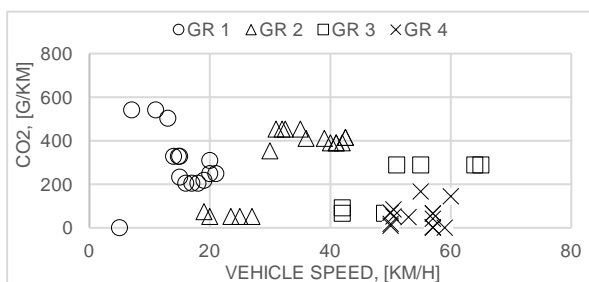


Figure 11. CO2 value vs. vehicle speed-Cycle 2.

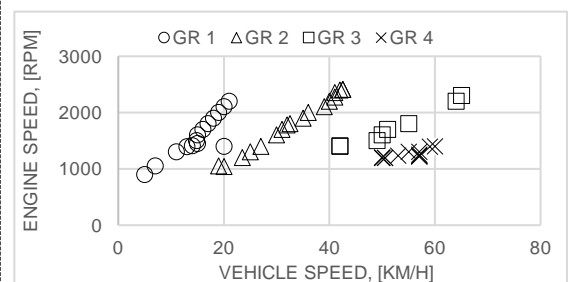


Figure 12. CO2 vs. vehicle speed-Cycle 2.

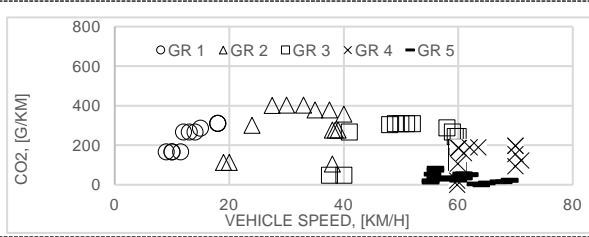


Figure 13. CO2 value vs. vehicle speed-Cycle 3.

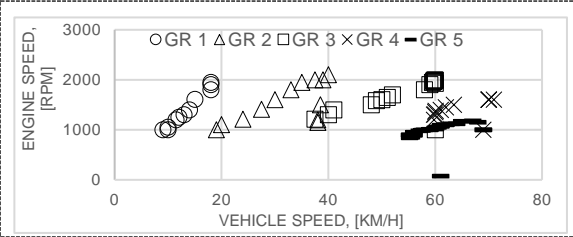
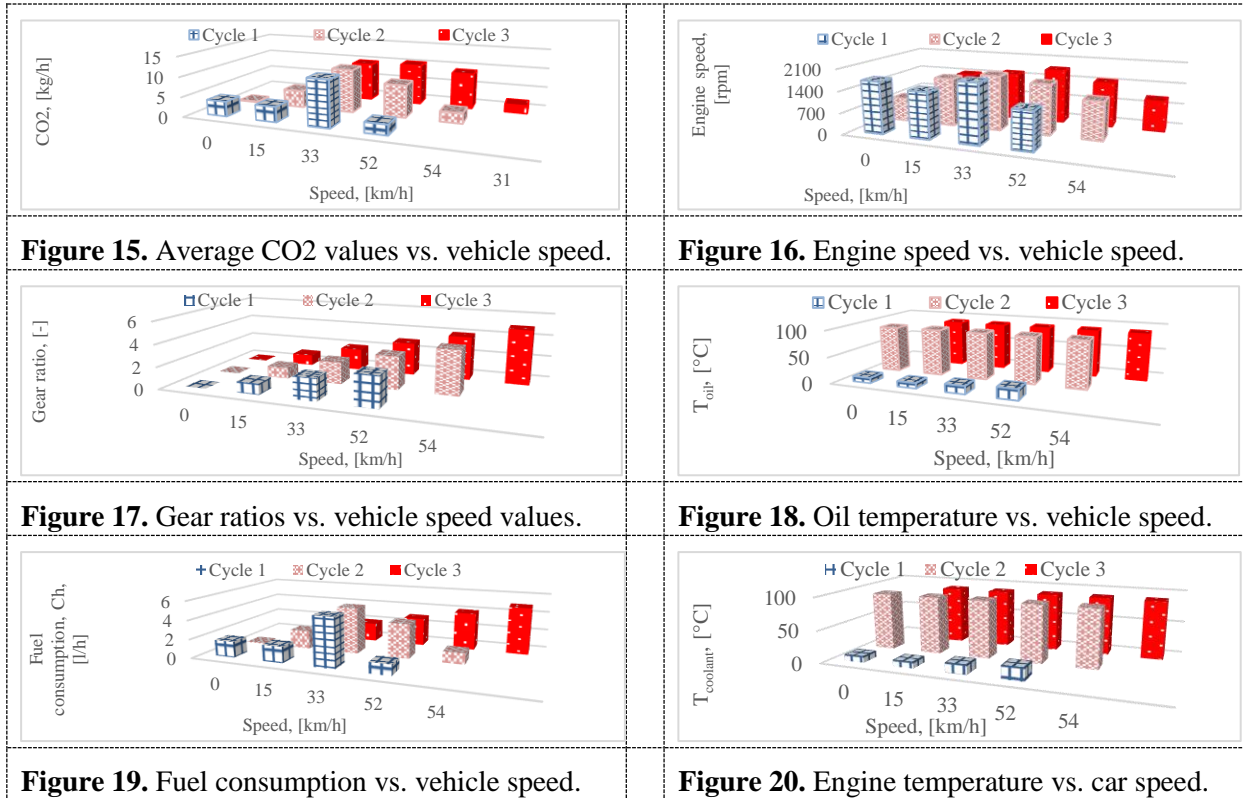


Figure 14. CO2 vs. vehicle speed-Cycle 3.

The CO₂ emissions were calculated based on fuel consumption and partial combustion model. All the rest of parameters were measured using the electronic Diesel control system sensors and capabilities.

The average hourly CO₂ emissions versus the vehicle speed is given in figure 15. In the rest of graphics from 16 to 20 are presented the engine speed, gear ratio, fuel consumption, oil and coolant temperatures average values versus vehicle speed.



CO₂ calculation is supported by air and fuel consumption measured values with the following equation:

$$CO_2 = 0.2306 * 10^{-2} * v^2 - 37.013 * v + 1074.1; CO_2 = C_h * E_c, [g/km] \quad (1)$$

where v is the vehicle speed, in [km/h]; CO_2 – carbon dioxide, in [kg/h] or [g/km]; C_h – fuel consumption, in [l/100]; E_c – emission concentration, in [g/l/100km].

3. Observations and conclusions

Density of supplied diesel fuel is 838 g/litre. This type of fuel has 86% Carbon. There are almost 720 g of C chemical element in each litre of diesel fuel. To combine the available carbon molecules to CO₂ are required around 1920 grams of O₂. Addition of the two numbers results in 2640 of CO₂ g/l. Taking into consideration the average consumption of tested car being 6 l/100 km, it leads to 6x2640 g/l/100 (per km) = 158.4 CO₂ g/km. Temperature in the cycle 1 was 10 ± 1 °C. Temperatures in the cycle 2 and 3 were 90 °C for engine coolant, and 16 ± 1 °C for the intake air. CO₂ research indicated that level of emissions is affected by the engine temperature, engine, and vehicle speed.

In cycle 1, at cold start and operation, the average CO₂ value was 5 kg/h, average speed was 21 km/h, average engine speed was 1578 rpm, fuel consumption (Ch) was 2 l/h, average temperature of coolant and oil was 14 °C. In cycle 2, the average CO₂ was 5.216 kg/h, average speed 30.8 km/h, average engine speed was 1402 rpm, Ch was 2.35 l/h, 90 °C coolant temperature and 88.8 °C temperature oil. In cycle 3, the average CO₂ was 6.88 kg/h, v=44.97 km/h, n=1430 rpm, Ch=3 l/h, T_{engine}=90 °C, and T_{oil}=88.8 °C. Measurements allow the researcher to determine trendlines of CO₂ emissions in different operational regimes. Those trendlines to be defined need more tests and research.

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