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THE INFLUENCE OF THE DRIVING STYLE ON THE CO_2 EMISSIONS FROM A PASSENGER CAR

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Abstract

With the invention of specialized, portable research equipment, construction of which enabled road tests of vehicles, it has become possible to verify benefits ensuing from application of eco-driving rules outside the laboratory – the test stand measurements. Test of the vehicles' operation in terms of ecology are essential especially in case of toxicity of exhaust gases in dynamic, transient conditions of engine operation. Despite the attempt to reflect those conditions in dynamic research tests, it is not possible for fully reconstruct real conditions of operation of vehicles of different homologation categories. Due to this fact in recent years, the biggest research potential in automotive industry has been focused right on the road tests of vehicles in real traffic conditions.

The article presents the results of measurements of exhaust emissions of passenger car in real traffic conditions. The aim of this study was to initial verification how the driving style influences on the carbon dioxide emissions from vehicle engine and fuel consumption. The determinants were the measurements of the concentration of CO_2 emitted to the atmosphere from the power unit of the tested vehicle. In the measurements, a portable exhaust emission analyser was used.

Keywords: *transport, driving style, road tests, CO_2 emissions, fuel consumption*

1. Introduction

Recently in the automotive environment, gaining popularity the driving style defined as eco-driving [10]. As the creators of this driving style claim, the practical application of some rules should reduce fuel consumption and at the same time cause less pollution to the environment. One of the most important factors pointed out by the eco-driving instructors is the manner of accelerating. The period of acceleration, particularly its dynamic, to a large extent influences the fuel consumption (Fig. 1) and quantity of emitted harmful substances. The principles of eco-driving first came into being in Switzerland and Finland in the second half of the 90's in the 20th century. The main rules of eco-driving are based on smooth driving, avoiding unnecessary accelerating and braking. The popularity of this driving style among the drivers is constantly increasing. Basing on the examples of many European countries, also in Poland has recently been observed an increase of interest in hints and guidelines aiming at reduction of fuel consumption by vehicles.

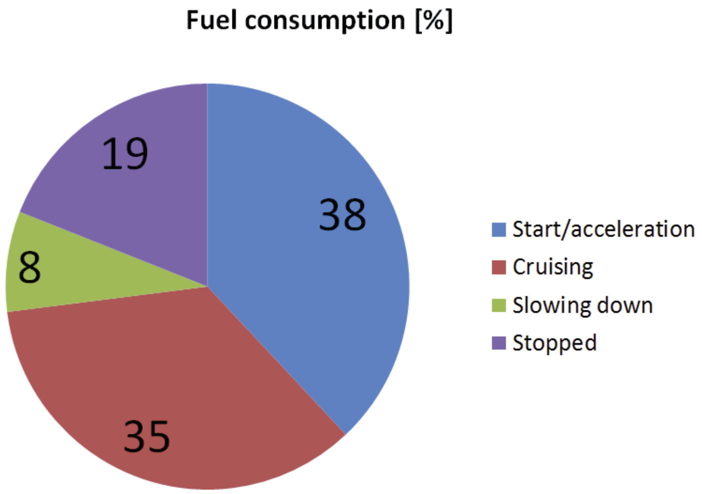

Fig. 1. Breakdown of fuel consumption when driving in the city [9]

The intention of the authors was to determine the impact of driver behaviour on the human environment and an indication of the impact of his driving style on the environmental and energy aspects of the vehicle use. Therefore in this article are presented results of tests of toxicity of exhaust gases (passenger car), conducted in road conditions. The tests provided information about emission of harmful gases in the dynamic conditions of urban traffic. The test were conducted in order to initial verify the influence of driving style on the emission of carbon dioxide and on the fuel consumption by the tested vehicle [6]. In tests, specialized, portable research equipment such as PEMS (Portable Emissions Measurement System) was used [3, 7]. With the invention of specialized, portable research equipment, construction of which enabled road tests of vehicles [1, 2, 5], it has become possible to verify benefits ensuing from application of eco-driving rules in real road conditions.

2. Research methodology

Tests in real road conditions were conducted with the use of a passenger car. It was Skoda Fabia combi with 4-cylinder compression ignition (CI) engine with capacity of 1.9 dm^3 (Fig. 2). The tested vehicle was equipped with 5-speed manual gearbox. The vehicle was also equipped with an exhaust aftertreatment system, such as Diesel Oxidation Catalyst (DOC). Detailed technical specification of the vehicle is as follows:

- engine: diesel,
- cylinder number and configuration: straight 4,
- displacement: 1.9 dm^3,

- fuel injection system: Unit Injector System,
- maximum power output: 74 kW at 4000 rpm,
- torque: 240 N·m at 1800 rpm,
- supercharging: turbocharger,
- transmission: manual, 5 gears,
- vehicle weight: 1190 kg,
- aftertreatment system: Diesel Oxidation Catalyst.

Fig. 2. Skoda Fabia combi prepared to the road tests

For measuring concentration of CO_2 in the exhaust gases, a portable system PEMS was used (Fig. 3). The system – Semtech-DS – consists mainly of the set of chemical analysers corresponding to given substances, the exhaust flow meter, the module recording data from the On-Board Diagnostics system (OBD) and the module for communication with the Global Positioning System (GPS) [8]. One of the analysers included in this equipment is the Non-Dispersive Infrared analyser (NDIR). It enables to determine, essential for the analysis conducted in the article, concentration of the carbon dioxide in the exhaust gases (NDIR measures also concentration of carbon monoxide). The Semtech-DS system also allows determining e.g. mileage fuel consumption for the tested vehicle utilizing so-called carbon balance method.

Fig. 3. Measuring equipment (PEMS type) mounted on the vehicle

The values of road emission of carbon dioxide were obtained as a result of the performance of road tests in the city of Poznan. The vehicle test route is shown in Fig. 4. The length of the route was about 15 km (Tab. 1). The route was diversified, and included a typical urban portion, and an extra-urban portion where it was possible to drive with higher speeds (70-80 km/h).

Fig. 4. The test route located in Poznan [4]

Due to the variability of the traffic parameters, the route was divided into five measurement portions:

– urban traffic with high intensity – a large part of stoppage of the vehicle (approximately 4.5 km – 30% of the tested route),
– urban traffic with low intensity (2.5 km – 16% of the tested route),
– extra urban traffic – expressway, speed limit of 70 km/h (1 km – 6% of the tested route),
– mixed traffic – part of the portion is an expressway, speed limit of 80 km/h (approximately 4 km – 26% of the tested route),
– mixed traffic – part of the portion are internal roads (approximately 3 km – 22% of the tested route).

Tab. 1. The characteristics of the tested route

The portion	The beginning	The end	The type of traffic	The distance [km]
1A–2	Shopping centre	Poznan University of Technology	Urban	4.6
2–3	Poznan University of Technology	Staroleka traffic circle	Urban	2.5
3–4	Staroleka traffic circle	Zegrze traffic circle	Extra urban	1.0
4–5	Zegrze traffic circle	Viaduct	Mixed	3.9
5–1B	Viaduct	Shopping centre	Mixed	3.2
The whole route 1A–1B	Shopping centre	Shopping centre	Mixed	15.2

During the test, driving conditions and concentrations of harmful substances of exhaust gases were measured in three test runs named, respectively: eco-driving, normal and aggressive. Definitions of particular driving styles are as follows:

– eco-driving – moderate acceleration, change of gear at n = 2000-2500 rpm, driving in the 5th gear if only possible, engine brake – reduction of gears while e.g. approaching traffic lights,
– normal – slow acceleration, change of gear at n = 2500-3000 rpm, driving maximum in 4th gear, driving in neutral position of gearbox, (engine idling) while approaching e.g. traffic lights,

– aggressive – dynamic acceleration, change of gear at engine speed over 3000 rpm, driving maximum in 4th gear, approaching traffic lights – sharp braking from relatively high speed in the final phase of approaching.

3. Road tests results

Based on the measured concentration of carbon dioxide in exhaust gases, the intensity of its emission for all five-measurement routes was calculated. Exemplary characteristics of carbon dioxide emissions intensity for one of the portions of the tested route are presented in Fig. 5. For clarity differences in the emission, intensity values in the graph are only two "extreme" driving styles.

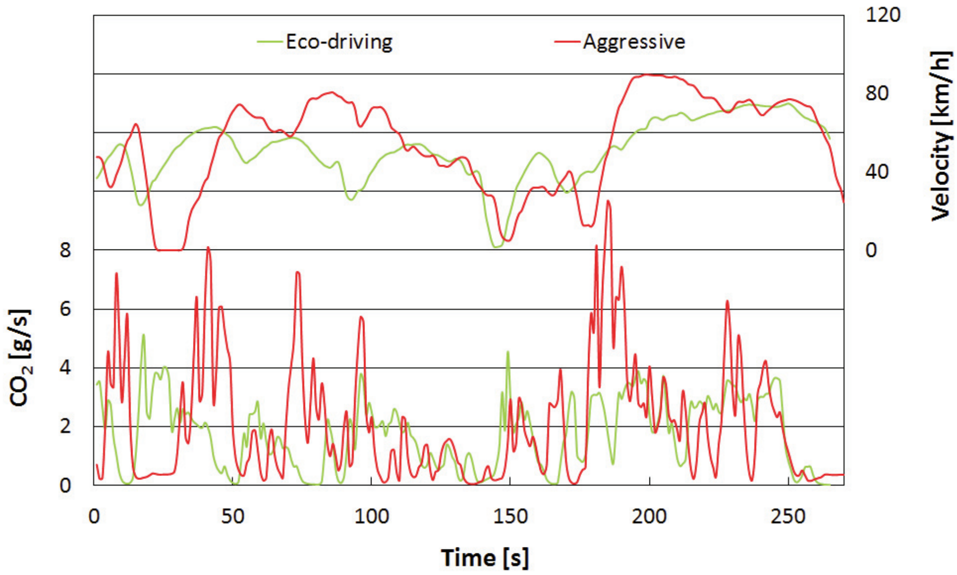

Fig. 5. Emission intensity of carbon dioxide for portion 4-5

On the basis of the calculated emission intensity, the road emission of the analysed gaseous substance (expressed in g/km) was determined for each part of the measurement route separately as well as for the whole route (Fig. 6). It can be observed that rides for individual measurement routes for different driving styles widely vary in terms of emissions characteristics of harmful component of exhaust gases such as CO_2.

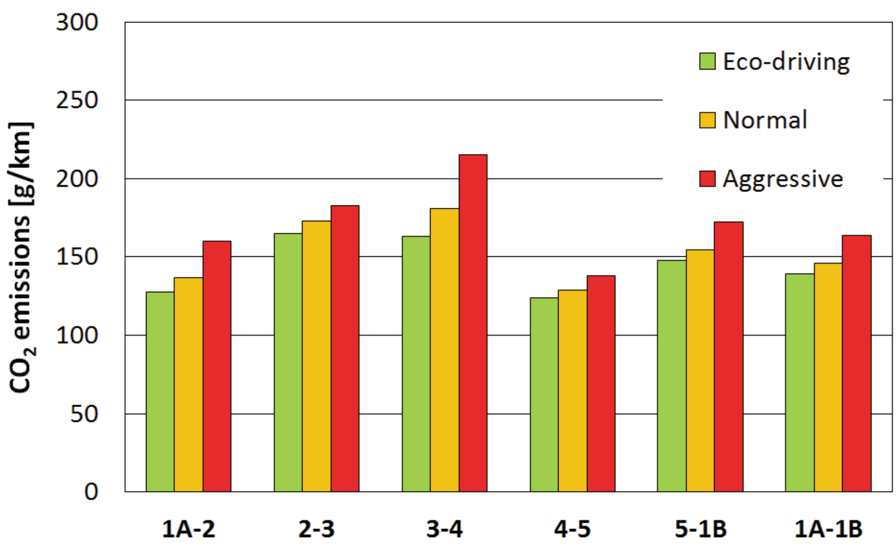

Fig. 6. Road emission of carbon dioxide for each measurement portions

As a result of the tests conducted, for driving style called eco-driving were observed the lowest, and for aggressive driving – the highest road emissions of carbon dioxide, emitted by the exhaust system of the tested vehicle. Visible, smaller or bigger differences in the levels of emission of components of exhaust gases, determined for the analysed measurement routes, can be influenced by slightly different road conditions during test runs, such as bigger road congestion meaning bigger share of vehicle stoppages. In case of road emission of carbon dioxide for the entire test route, the respective values recorded for each driving style were approximately: 139, 146 and 164 g/km. The difference in percentage compared to normal driving is –4.5% for eco-driving and +12.4% for aggressive driving (Fig. 7).

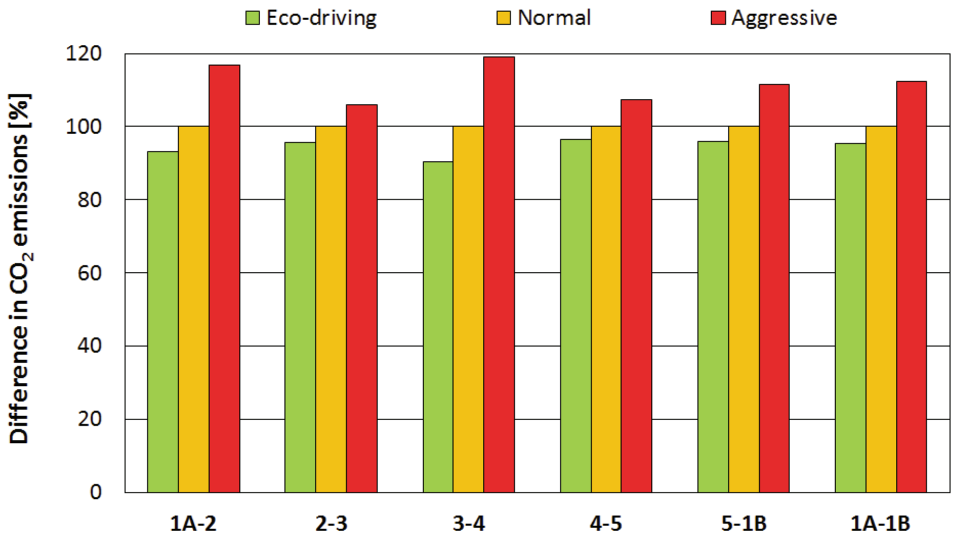

Fig. 7. Percentage difference in carbon dioxide emissions as a result of different driving style (normal driving = 100%)

Apart from determining the influence of the applied driving style on the emission of CO_2 in the exhaust gases of the tested passenger car, also its influence on the fuel consumption was checked. The mileage fuel consumption value (expressed in dm^3/100 km) for the entire test route, against the average acceleration, is illustrated in Fig. 8. The differences compared to normal driving are respectively: –0.25 and +0.67 dm^3/100 km. It results in reduction of fuel consumption by 4.6% (for eco-driving) and increase by 12.2% (for aggressive driving).

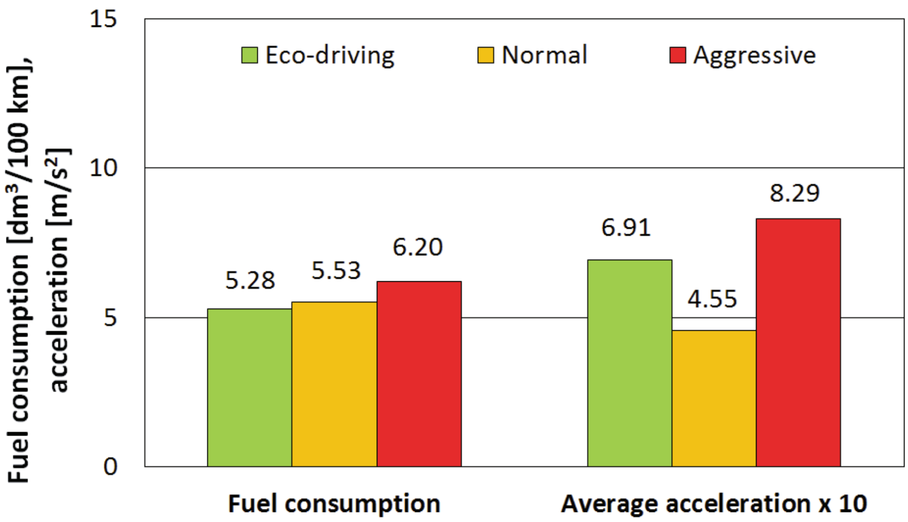

Fig. 8. Fuel consumption specified for the entire test route

4. Conclusions

The conducted road tests of passenger car in real conditions of its operation visualized significant influence of the driving style employed by a driver on the road emission of carbon dioxide and on the fuel consumption. A significant increase of road emissions values of this harmful substance should be pointed out for aggressive driving style and a noticeable decrease for ecological and economical driving style – so-called eco-driving.
Based on the road tests a driving style index was defined (Fig. 9):

$$k_{style,FC} = \frac{FC_{test}}{FC_{normal}}, \tag{1}$$

where:
FC_{test} – fuel consumption in any drive [dm^3/100 km],
FC_{normal} – fuel consumption for a drive with "normal" style [dm^3/100 km].

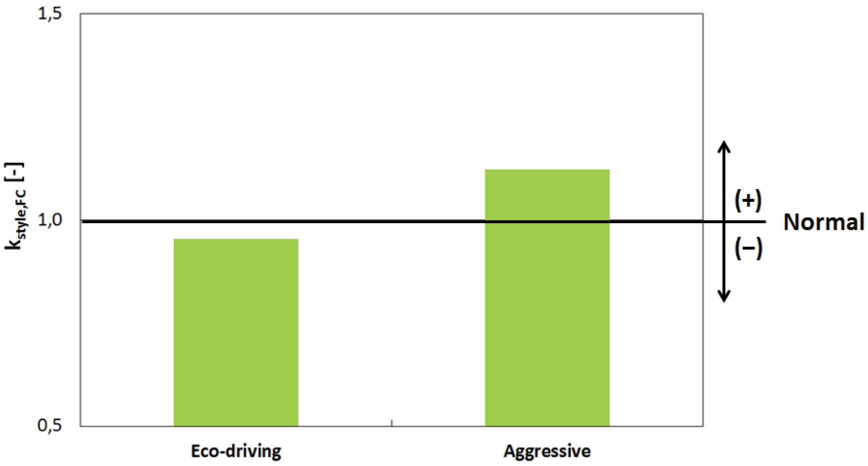

Fig. 9. Driving style index appointed on the basis of emissions tests under real operating conditions of vehicle

On the basis of the study, the authors proposed the adoption of the following values of driving style index:

– eco-driving – $k_{style,j} \leq 0.95$,
– normal – $k_{style,j} = (0.95\text{-}1.10)$,
– aggressive – $k_{style,j} \geq 1.10$.

Using the index can be estimated, at the performance of only one pass with a driving style referred to as "normal" (road tests), the decrease/increase of the level of exhaust emissions and fuel consumption of vehicles fleet as a result of the application of the principles of eco-driving or dynamic driving (identification of the potential). It will be useful, inter alia, in determining the overall environmental pollution by automotive – modelling of vehicles emissions, whereas their number and age structure (meeting of Euro standards).

It should be pointed out that the conducted tests were just introductory. In order to fully determine the influence of the manner of exploitation of vehicles on their ecological characteristics and energy consumption, the test should cover bigger number of vehicles and the tests of toxicity of the exhaust gases should be conducted on routes with different characteristics, including motorway traffic.

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