Determination of Vehicle Emissions in Operating Mode Using a Dynamometer

Simona Hesapchieva, Cvetan Yordanov, Georgi Yanachkov, Asen Mazgarev

***Abstract*—Vehicles are a serious source of air pollution, especially in urban areas. Real Driving Emissions (RDE) testing procedures have been introduced in the EU to determine emissions from cars during on-road operation. This study presents a method for determining emissions from a car under different driving modes using a dynamometer. The measuring equipment and testing methodology are presented. A number of experiments have been conducted to determine average emissions. The presented method can be used as an additional procedure to annual technical inspections and as a complement to real road conditions for a more accurate and correct determination of harmful substances emitted into the atmosphere.**

***Keywords*—emisions, RDE, Dynamometer, CO, HC**

I. Introduction

Internal combustion engines have undergone a long development path, a period of continuous improvement in order to increase their power, economic and toxic indicators. The direction of development is largely based on significant legislative requirements for the reduction of toxic components in exhaust gases. Reducing emissions of toxic components is associated with both improving the design and optimal flow of work processes, as well as with the effective neutralization of components in the exhaust system [1-4]. [1]

Often in internal combustion engines, methods for reducing fuel consumption and those for reducing toxic components are mutually exclusive, which creates a number of difficulties. Every large city suffers from high intensity of transport traffic, which has a negative impact on the health of the population [5]. According to the European Environment Agency, about 90% of the population of European cities is exposed to high concentrations of toxic components, higher than the permissible levels determining air quality [6]. Concentrations of in congested areas consistently exceed the annual limit value set in EU regulations. NO and NO_2, which are the main acid pollutants, are mainly formed in the engine cylinders as nitrogen oxides, which are rapidly oxidised to nitrogen dioxide in the exhaust manifold. [7]. This pollutant is also a precursor to ozone and particulate matter, which are formed in the air [8]. Emission standards currently apply to light vehicles, heavy transport vehicles and heavy mobile machinery. The Commission also supports technological developments that help to protect the environment and reduce air pollution [9]. Gradual reduction of emissions of – The EU sets mandatory emission targets for new car fleets to reduce emissions of from light vehicles. In order to improve testing procedures, from 1 September 2017 it is mandatory for new car models to undergo new and more robust Real Driving Emissions (RDE) tests. It is also mandatory for new vehicles to undergo the improved Worldwide Harmonised Test Procedure (WLTP). Once these tests have been passed, they can be approved for use on European roads [10].

The monitoring and reporting of CO emissions from light vehicles in Europe and other major markets is based on the New European Driving Cycle (NEDC) and its accompanying test protocol. This approach is unreliable for real-world vehicle performance and leads to differences between the officially reported emissions and those that occur in different vehicle operating modes. To address this, a new test protocol, the Worldwide Harmonized Light Commercial Vehicles Test Procedure (WLTP) and Light Vehicles, has been proposed. The results show that European passenger cars have a difference in certified and actual CO emissions of up to 40 g/km (~32% more than certified) for the average European passenger car. With the introduction of the WLTP, improvements have been observed, but a discrepancy of around 10–15% between official and real-world measurements may remain [11].

The latest emission regulations in Europe introduce the so-called Real-Driving Emissions (RDE), in which the vehicle is measured under real driving conditions using portable emission measurement systems (PEMS) [12]. Unlike the NEDC and WLTP driving cycles, the emission measurements are not carried out in laboratory conditions but in real traffic. The RDE test does not replace, but rather complements the WLTP laboratory tests. Emission studies for the concentration of toxic substances under real driving conditions, carried out using a portable measuring device, reflect the environmental performance of the vehicles.

The aim of this study is to quantify the production of exhaust emissions under different operating modes from a vehicle with a petrol engine with the Euro 6 emission standard by using a dynamometer simulating the movement of the vehicle under different conditions.

II. Experimental Methodology and Measuring Equipment

In this study, a low-voltage TEXA GASBOX 2 gas analyzer was used (Fig.1), operating on the principle of

Received: 01.07.2026
Published: 26.07.2026
https://doi.org/10.47978/TUS.2026.76.03.011

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selective absorption of non-dispersive infrared radiation. The device enables measurements and analysis of CO, CO_2, CH, O_2, NOx (optional), and calculation of λ. Its technical specifications are shown in Table 1 [13]. The analyzer does not include an NO sensor, which is not standardly installed. The device was calibrated according to applicable legislation, and results were processed with ETS TEXA software.

Fig. 1. Gaz analyzer TEXA GASBOX 2

To ensure the reliability and correctness of the measurement results, it is necessary to calibrate the measuring equipment. The equipment used has passed a control test by an accredited metrological measurement service. The gas analyzer is intended to be used for stationary measurements. One of the tasks of this study is to study the possibility of conducting measurements under different operating conditions. In [14], a methodology for determining vehicle emissions under different operating conditions is developed, using a gas analyzer for static measurements and additional diagnostic equipment to monitor engine load and some diagnostic parameters. In this study, a CV2 600 evo h dynamometer was used to simulate different operating modes. An external meteorological station with pressure, temperature and humidity sensors is connected to the dynamometer, through which the conditions under which the measurements were made are determined.

TABLE I
TECHNICAL CHARACTERISTICS TEXA GAS BOX 2

Measured gases	*CO*	*CO_2*	*CH*	*O_2*	*NO_x*
Measuring range (resolution)	0÷9.99% *Vol* (0,01)	0÷19,9 % *Vol* (0,1)	0÷10000 *ppm Vol* (1)	0,5÷21,4% *Vol* (0,1)	0÷5000*ppm* Vol (5)
Measurement accuracy	0,06 Vol%	0,5 Vol%	12 ppm	0,1 Vol%	32–120 ppm Vol
Measurement principle	Infrared	Infrared	Infrared	Electro-chemical	Electro-chemical
Resolution	0,001	0,01	0,1	0,01	1
Measurement range		Less than ± 0.6% of the final value of the measuring range			
Debit		Approx. – 2,5 l/min			

Operating pressure		750–1100 mbar	
External power supply		Maximum consumption – 80 W	
Serial port		Standard RS 232	
Wireless output		Bluetooth	
Zero and calibration:		Electronic and automatic	
ETS software		NDIR technology	
Condensate drying:		Continuous and automatic	
Response time:		Less than 10 seconds	
Warm-up time:		Maximum 60 seconds	
M.I.D. European approval Accuracy class:		"0" ISO 116141999	
Zero		Automatic and manual	
Graphical visualization of measured results		Printing	

Measurements were carried out on a Hyundai i20 powered by SI engine. Technical specifications of the vehicle are shown in Table 2. Tests were performed under hot start conditions at a coolant temperature of 87 ± 2 °C.

TABLE II
TECHNICAL CHARACTERISTICS OF THE TESTED VEHICLE

Brand	HYUNDAI
Model	I20
Year of manufacture	2022
Engine type	SI
Displacement	1197 cm3
Power	62 kW
Torque	115 Nm
Transmission	Mechanical 5-speed
Drive	Front wheel drive
Acceleration 0-100 km/h	13,1 s
Top speed	173 km/h
Fuel consumption	5,9/100 km

The measurements were carried out in two stages. Measurements were made when the engine was idling (without load) and at a speed of about 3500 rpm with the engine warmed up to nominal temperature. The front end of the probe was located in the exhaust pipe at a depth of about 300 mm. The measurement was made according to the requirements of Regulation H 32 [15].

The vehicle's drive axle was mounted on the dynamometer rollers. Calibration was performed and the gear ratio between the speed of the drive wheels and the rollers was determined. The measurement was carried out in fourth gear with a smooth increase in the speed of the crankshaft. In order to prevent the engine from overheating, an additional cooling fan was used (Fig. 2).

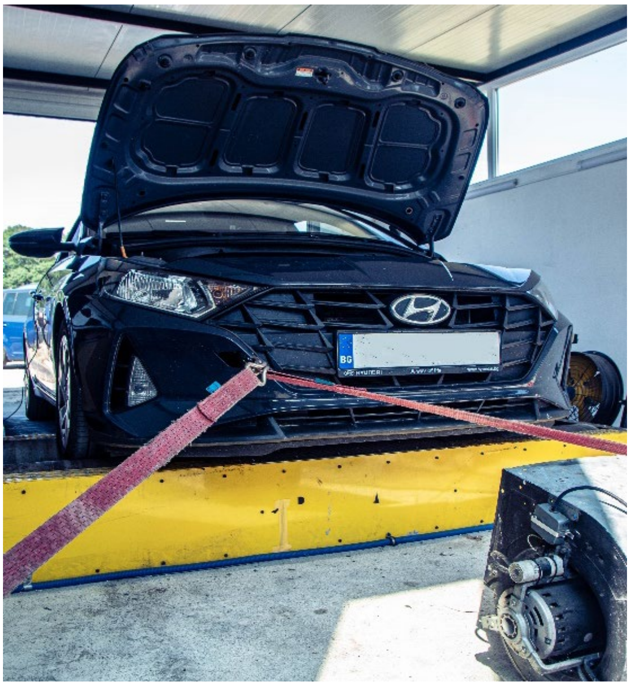

Fig. 2. Experimental setup

The values from the gas analyzer were read on a personal computer using specialized software ETC TEXA. On another personal computer, the readings from the dynamometer were monitored, such as the revolutions of the crankshaft, the revolutions of the driving wheels, power and torque, etc. (Fig. 3). .Several tests were performed. The results of the study show the average values from the measurements.

Fig.3. Dynamometer Values.

III. Results and Discutions

In the first stage of the measurement, the engine is idling at about 800 rpm without load. During the second stage of the test, the vehicle accelerates smoothly with gear changes. The measurement was carried out at about 3550 crankshaft revolutions in fourth gear, which achieves a power of 33 kW and a torque of 90 Nm, at about 50% engine load. Using the signal from the MAF sensor, the values of the exhaust gas components can be converted to g/km. The measurement values are presented in Table 3.

TABLE III
Measured Emisions

Idle Engine Speed	Value	3560 rpm, partially loaded	Value
CO, %	0,04	CO, %	0,03
CO_2, %	14,5	CO_2, %	13,7
HC, ppm	20	HC, ppm	15
O_2, %	0,01	O_2, %	1,38
Λ	0,99	Λ	1,07

The engine speed and load have a direct impact on the amount and composition of exhaust gases. Depending on the operating mode, the emissions of carbon monoxide, hydrocarbons, nitrogen oxides and fine dust particles change significantly. When the engine is idling at minimum speed, it achieves low fuel consumption, but incomplete combustion, as a result of which the amount of hydrocarbons increases. The carbon monoxide values are higher as a result of the lack of oxygen and the low temperature in the combustion chamber at idle (Fig. 4). The carbon monoxide values at idle are marked with CO, and with CO' at partial engine load. With increasing load and lean mixture, the carbon monoxide values decrease. This also leads to low levels of nitrogen oxides, which were not measured in the present study.

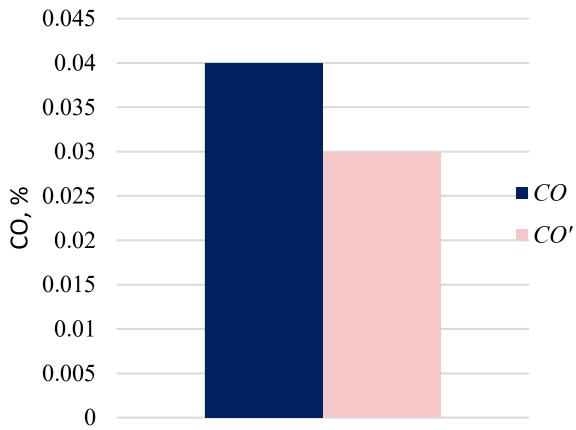

Fig.4. *CO* emission values at idle and at partial load

At average engine speeds (2500 - 3500 rpm) an economical operating mode of the internal combustion engine is achieved, which is why the study was conducted in this mode. The internal combustion engine works optimally, and combustion is more complete due to good mixture formation and properly regulated fuel injection. This leads to lower values of carbon monoxide and hydrocarbons (Fig. 5). The temperature in the combustion chamber is high, but has not reached critical values. In this range, the engine achieves minimal emissions, and the catalyst works most effectively at medium and high speeds, when it has reached operating temperature. With increasing engine speed and load, the temperature and pressure in the cylinders increase, which will lead to an increase in nitrogen oxides.

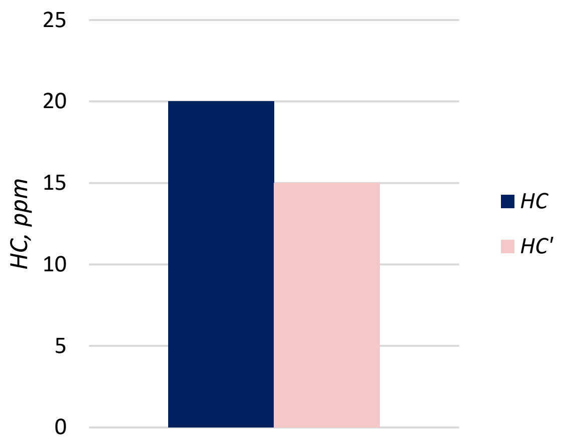

Fig. 5. *HC* emission values at idle and at partial load

IV. CONCLUSIONS

This study presents the possibilities of applying a different approach to measuring vehicle exhaust emissions. The application of this method allows for comparing the values measured using the methods regulated by legislation and the actual emissions from vehicles into the environment. The presented methodology takes into account the atmospheric and climatic conditions during the test, which is of great importance for the accuracy and correct reporting of the actual vehicle exhaust emissions into the environment. The measuring equipment used in this method allows for the unification of measurements and their performance by the technical services that determine the technical condition of vehicles. As a supplement to the methodology, diagnostic equipment can be used to monitor a number of engine indicators in real time, such as signals from a lambda probe, MAF and MAP sensor, amount of fuel injected, and others. Since the tested vehicle was too new and required specialized software, this additional study was not included in the present study. Since it is known from the theory of internal combustion engines that the greatest influence on the concentration of harmful emissions in the exhaust gases of an internal combustion engine is exerted by the air ratio λ, in order to determine their amount in real operating conditions and their change, it is necessary to conduct road tests at different engine loads. The presented methodology does not completely replace road tests, but can supplement them. This type of test is particularly suitable for retrofitting equipment for measuring nitrogen oxides and also for diesel engines, where a significant increase in the concentration of emissions occurs with increasing engine load

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