EXAMINATION OF POLLUTANT EMISSIONS AND FUEL CONSUMPTION AT TESTS SIMULATING THE REAL CONDITIONS OF OPERATION OF A PASSENGER CAR

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Summary

The paper presents results of examination of pollutant emissions and fuel consumption at tests simulating the real conditions of operation of a passenger car. The examination was carried out with the use of PIMOT simulation driving tests developed at the Automotive Industry Institute (PIMOT) on the grounds of analyses of motorcar velocity processes empirically recorded in the conditions of driving the car in urban traffic congestions, urban traffic without congestions, extra-urban traffic, and high-speed traffic (on motorways and fast roads). The pollutant emission and fuel consumption tests were performed on a vehicle chassis dynamometer, where a Honda Civic car with a spark-ignition engine was used as a test specimen. The scope of the examination covered the emissions of carbon monoxide, hydrocarbons, nitrogen oxides, and carbon dioxide. The unrepeatability of the pollutant specific distance emission and the operating fuel consumption values determined was evaluated with the use of the coefficient of variation of the results of measurement of specific quantities. Significant unrepeatability was revealed in the results of measurements of the specific distance emission of carbon monoxide, hydrocarbons, and nitrogen oxides, while the unrepeatability of the results of measurements of carbon dioxide emission and the operating fuel consumption was relatively low. Characteristic curves of the pollutant specific distance emission and the operating fuel consumption as functions of the average vehicle velocity were also determined at the PIMOT tests. The characteristic curves plotted were found to be consistent with the dependences determined on the grounds of the databases incorporated in specialist software packages, such as INFRAS or COPERT.

Keywords: motor vehicles, internal combustion engines, driving tests, pollutant emissions, fuel consumption

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1. Introduction

The operational properties of internal combustion (IC) engines are determined by the engine operation state [14]. The state of operation of an IC engine may be described by its thermal state and the quantities defining the engine energy parameters that characterize the engine work intensity [14]. Usually, engine torque output, representing the engine load, and engine crankshaft speed are taken to play the role of such quantities [14]. In the conditions of stable thermal state of an IC engine, the state of an automotive engine in the conditions of engine operation in a moving vehicle is determined by the vehicle velocity process [14]. Therefore, vehicle driving tests are used to examine the operational properties of automotive IC engines. Most commonly, results of examination of pollutant emissions and fuel consumption are available from the driving tests carried out within vehicle type-approval procedures. Such tests include, first of all [24]:

- in Europe, NEDC (New European Driving Cycle),
- in the USA, FTP-75 (Federal Test Procedure) and, for fuel consumption evaluation, HWFET (Highway Fuel Economy Test),
- in Japan, Japan 10 15 Mode.

The conditions of real vehicle operation may differ very much from those adopted for the type-approval procedures. In certain conditions, the characteristics of IC engines, above all the pollutant emissions, may significantly deviate from those determined in the conditions of type-approval tests, especially in the case of severe traffic difficulties, which frequently occur in the central parts of large urban agglomerations [2, 4, 6–8, 14, 17, 19, 23]. In this connection, researchers often try to determine the characteristics of IC engines in conditions differing from those applied at the type-approval procedures [2–4, 6–9, 11, 12, 14, 15, 17, 19–23]. At some of the research works, attempts are also made to treat the properties of automotive IC engines as stochastic processes [1, 5, 6–10, 13, 14, 16, 18].

At the work reported in [8], a task was undertaken to develop driving tests that would represent the mode of operation of motor vehicles in Polish conditions. The tests were designed in compliance with the rule of faithful simulation in the time domain. A Honda Civic passenger car with a spark-ignition engine was operated on roads of Mazowieckie and Łódzkie Voivodships. The vehicle velocity processes were examined with the use of an OBDII/EOBD scanner manufactured by AUTOMEX Sp. z o.o., model AMX530, and a Racelogic Performance Box.

In result of the investigations carried out, four PIMOT tests were prepared for each vehicle operation mode, with treating them as realizations of stochastic processes of vehicle velocity characterizing the vehicle operation modes in the following conditions (Figs. 1–4, respectively):

- urban traffic congestions (denoted by „CT"),
- urban traffic without congestions (denoted by „UT"),
- extra-urban (rural) traffic (denoted by „RT"),
- high-speed traffic (on motorways and fast roads, denoted by „HT").

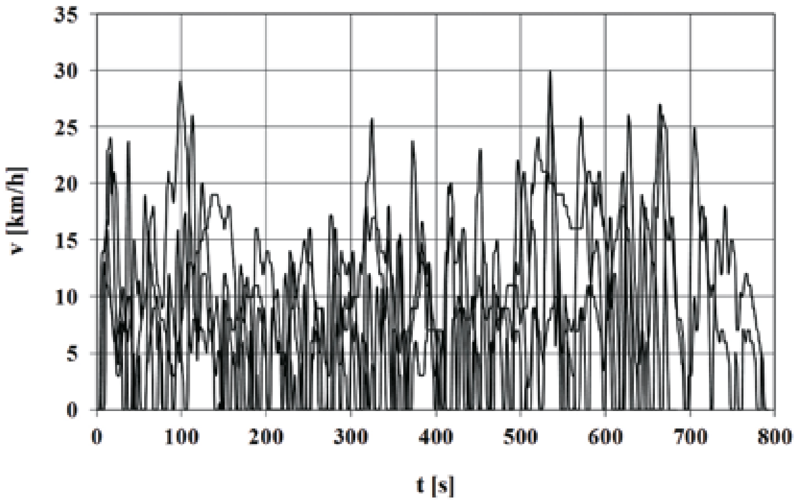

Fig. 1. The vehicle velocity – v for test drives in urban traffic congestions – the driving tests CT

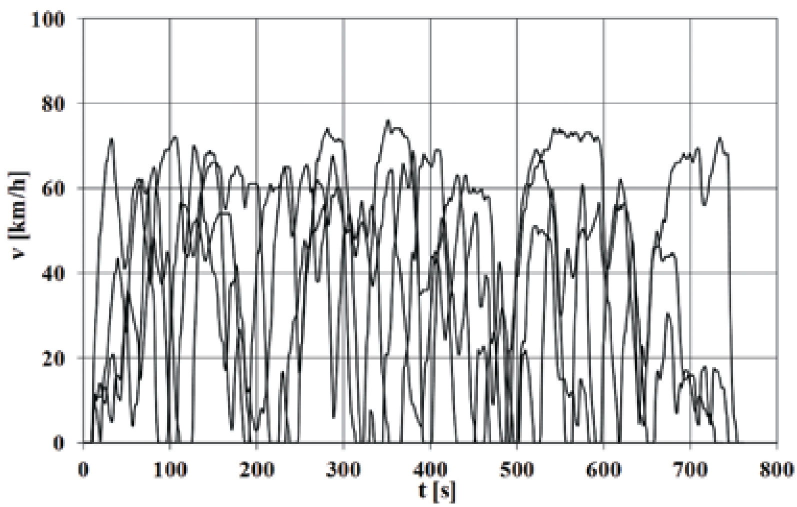

Fig. 2. The vehicle velocity – v for test drives in urban traffic – the driving tests UT

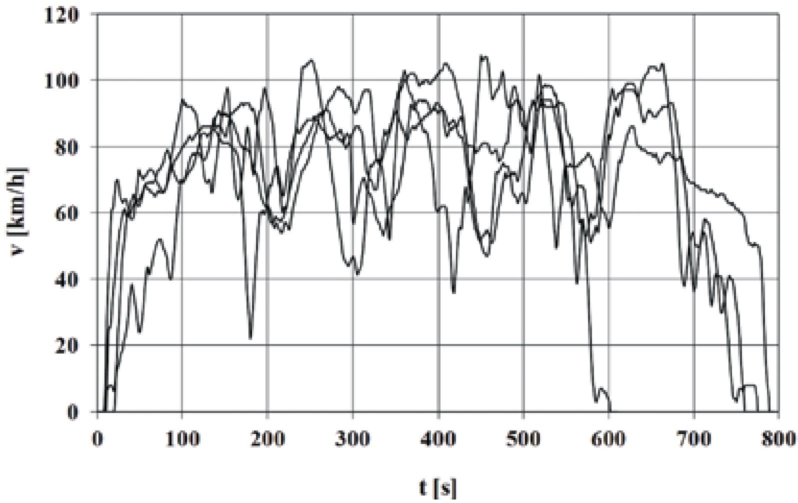

Fig. 3. The vehicle velocity – v for test drives in extra-urban traffic – the driving tests RT

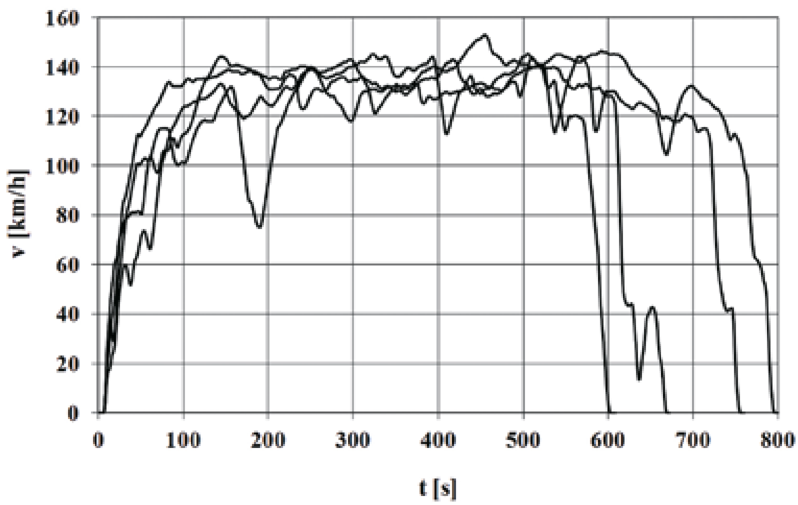

Fig. 4. The vehicle velocity – v for test drives in high-speed traffic – the driving tests HT

The driving tests having been developed were used to examine the operational properties of the car in respect of pollutant emissions and fuel consumption. The examination, in the form of a series of repetitions of the PIMOT tests having been prepared, was carried out on a vehicle chassis dynamometer to get to know not only the operational properties of the car in conditions simulating real car operation but also the unrepeatability of results of such tests.

2. Empirical examination of pollutant emissions and fuel consumption of a passenger car in the conditions of the PIMOT driving tests

The tests were carried out on a Honda Civic car with a spark-ignition engine of 1396 cm^3 capacity, meeting the requirements of the Euro 3 exhaust emission standard.

The Honda Civic car was tested on a vehicle chassis dynamometer Schenk Komeg EMDY 48.

The pollutant emissions were examined with the use of an exhaust gas analysing test stand, which incorporated a Horiba Mexa 7200 system provided with analysers (the analyser models are specified here in brackets) to measure the concentrations of carbon monoxide (AIA–721A), carbon dioxide (AIA–722), hydrocarbons (FIA–725A), nitrogen oxides (CLA–755A), and oxygen (MPA–720).

The car was tested with its IC engine having been heated to a stable temperature.

Figs. 5–9 show the average value and the standard deviation of the pollutant specific distance emission (of carbon monoxide, hydrocarbons, nitrogen oxides, and carbon dioxide) and the operating fuel consumption in individual realizations of the PIMOT driving tests:

- urban traffic congestions (CT1 ,CT2, CT3, and CT4),
- urban traffic without congestions (UT1, UT2, UT3, and UT4),
- extra-urban (rural) traffic (RT1, RT2, RT3, and RT4),
- high-speed traffic (on motorways and fast roads, HT1, HT2, HT3, andHT4).

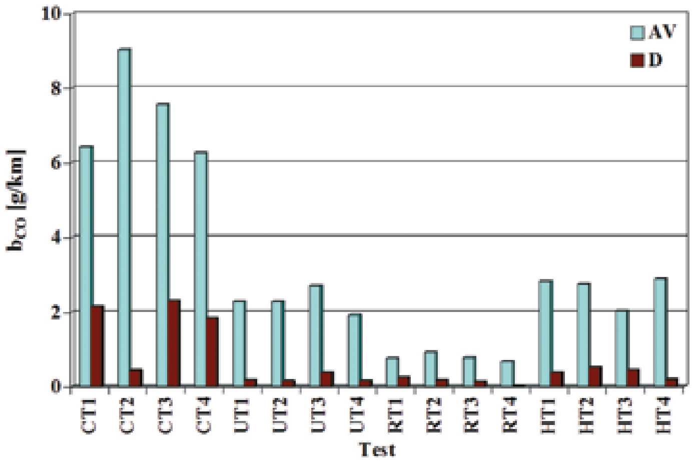

Fig. 5. The specific distance emission of carbon monoxide – b_{CO} in individual realizations of the PIMOT driving tests: AV – average value, D – standard deviation

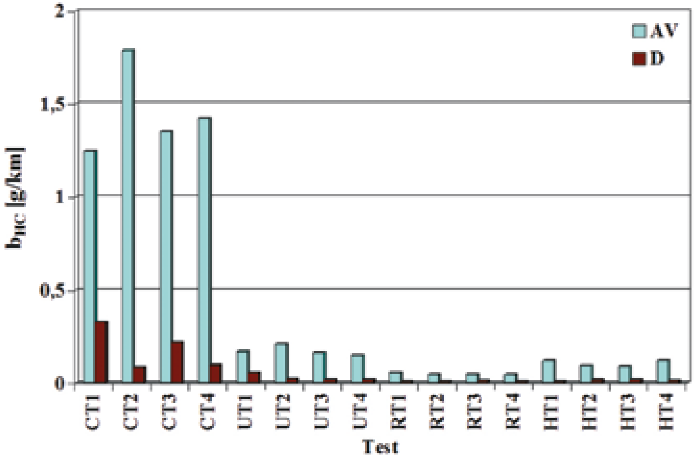

Fig. 6. The specific distance emission of hydrocarbons – b_{HC} in individual realizations of the PIMOT driving tests: AV – average value, D – standard deviation

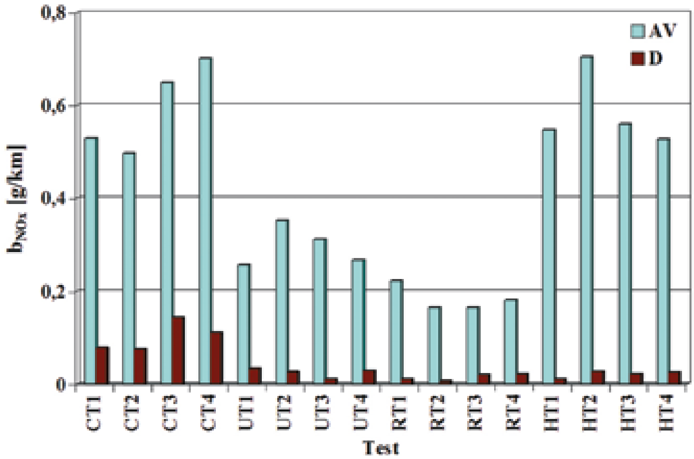

Fig. 7. The specific distance emission of nitrogen oxides – b_{NOx} in individual realizations of the PIMOT driving tests: AV – average value, D – standard deviation

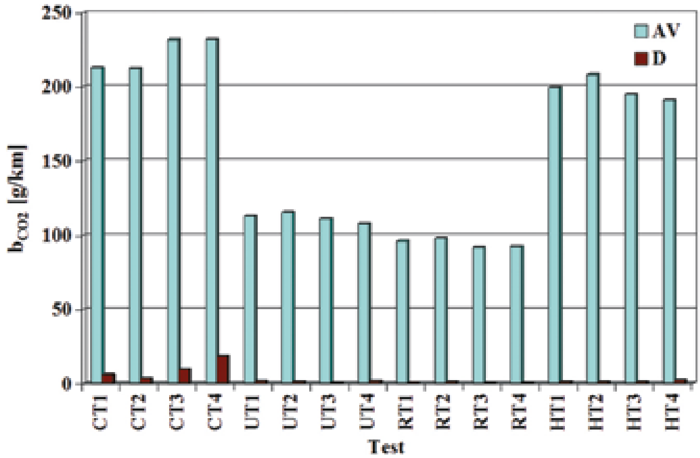

Fig. 8. The specific distance emission of carbon dioxide – b_{CO2} in individual realizations of the PIMOT driving tests: AV – average value, D – standard deviation

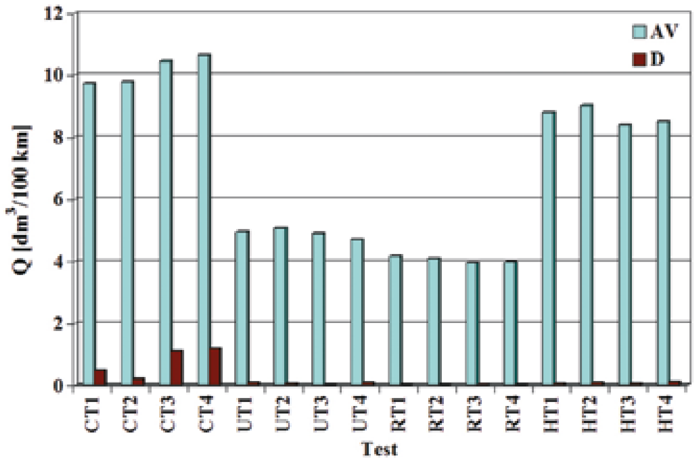

Fig. 9. The operating fuel consumption – Q in individual realizations of the PIMOT driving tests: AV – average value, D – standard deviation

The average value and the standard deviation of the pollutant specific distance emission and the operating fuel consumption determined for the whole sets of realizations of the PIMOT driving tests have been presented in Figs. 10–14.

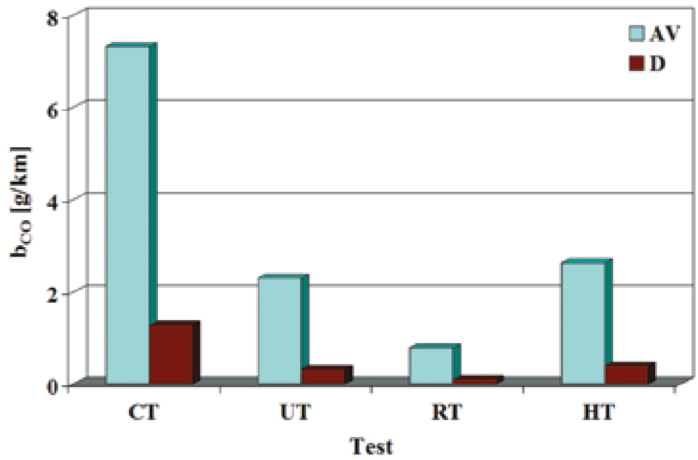

Fig. 10. The specific distance emission of carbon monoxide – b_{CO} at the PIMOT driving tests: AV – average value, D – standard deviation

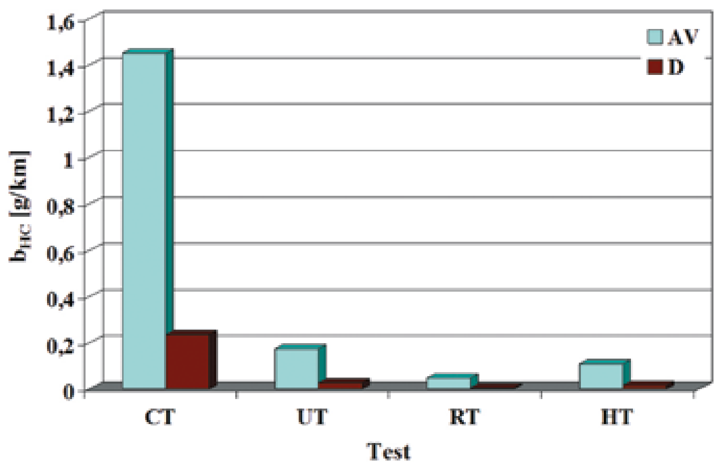

Fig. 11. The specific distance emission of hydrocarbons – b_{HC} at the PIMOT driving tests: AV – average value, D – standard deviation

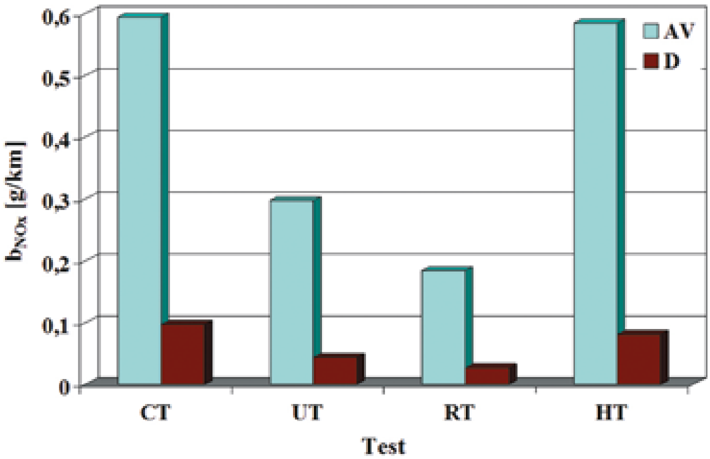

Fig. 12. The specific distance emission of nitrogen oxides– b_{NOx} at the PIMOT driving tests: AV – average value, D – standard deviation

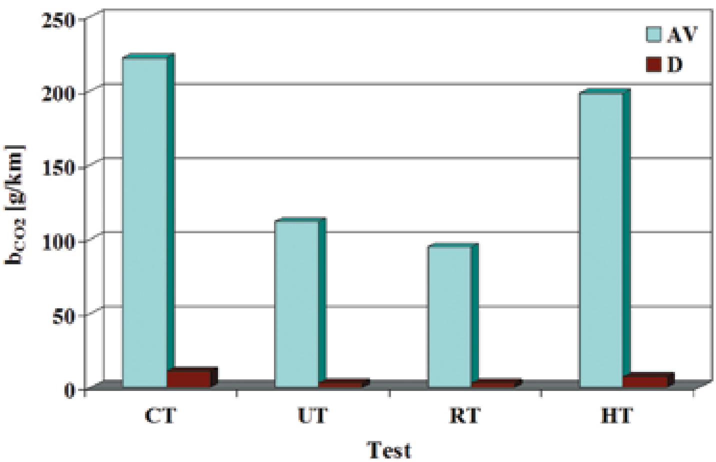

Fig. 13. The specific distance emission of carbon dioxide – b_{CO2} at the PIMOT driving tests: AV – average value, D – standard deviation

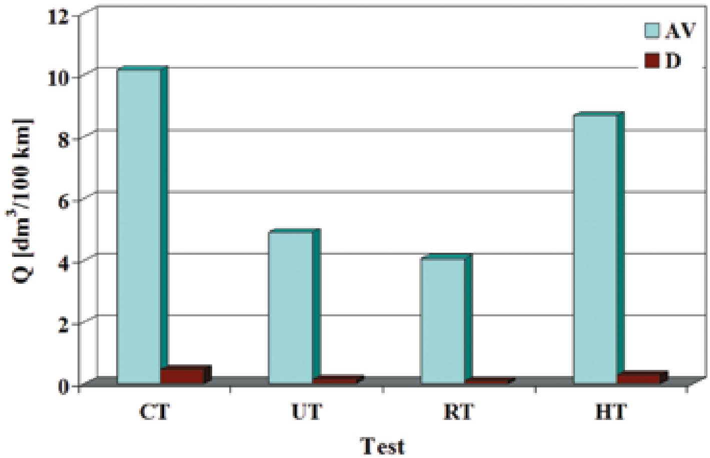

Fig. 14. The operating fuel consumption – Q at the PIMOT driving tests: AV – average value, D – standard deviation

The unrepeatability [11, 12, 15] of properties of the IC engine in dynamic states was evaluated by analysing the sets of values of the specific distance emission and the operating fuel consumption determined at the type-approval and special tests under consideration.

Fig. 15 shows the coefficient of variation of the pollutant specific distance emission and the operating fuel consumption determined for individual realizations of the PIMOT driving tests; the coefficient of variation of the pollutant specific distance emission and the operating fuel consumption determined for the whole sets of realizations of the PIMOT driving tests has been presented in Fig. 16.

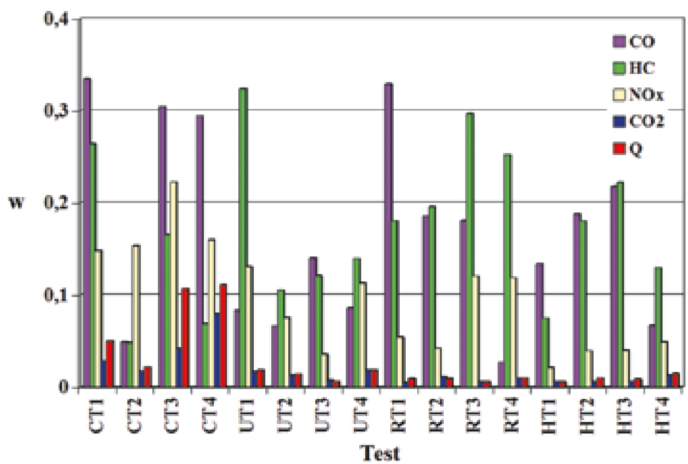

Fig. 15. The coefficient of variation – w of the specific distance pollutant emissions and the operating fuel consumption in individual realizations of the PIMOT driving tests

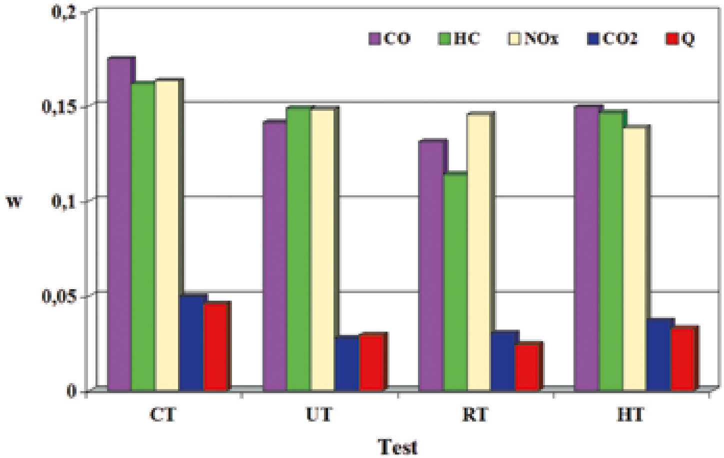

Fig. 16. The coefficient of variation – w of the specific distance pollutant emissions and the operating fuel consumption at the PIMOT driving tests

When the results of measurements of the pollutant specific distance emission and the operating fuel consumption are examined for unrepeatability, the conclusions are ambiguous and difficult for interpretation. In some cases, the determined unrepeatability of the measurement results should be assessed as particularly high, e.g. for carbon monoxide, hydrocarbons and nitrogen oxides. Conversely, the unrepeatability of results of the examination of the carbon dioxide specific distance emission and the operating fuel consumption was very low, even less than 1 % in many cases. The significant unrepeatability of the specific distance emission of carbon monoxide, hydrocarbons, and nitrogen oxides confirms high vulnerability of pollutant emission processes to the processes of IC engine

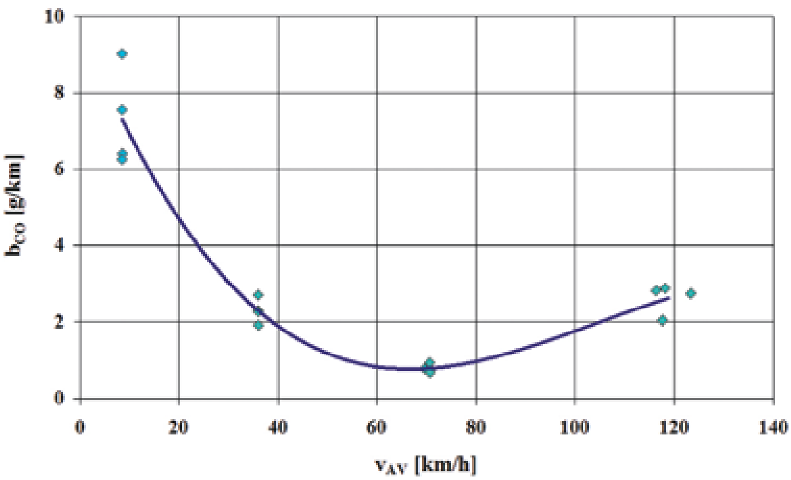

Fig. 17. Dependency of the specific distance emission of carbon monoxide – b_{CO} in the PIMOT driving tests on the average velocity – v_{AV}

operation states and, in consequence, to the vehicle velocity processes [4, 10, 13, 14, 16, 19], even if the average velocity values were close to each other in the cases under consideration.

Figs. 17–21 show the pollutant specific distance emission and the operating fuel consumption as functions of the average vehicle velocity, as obtained from the PIMOT driving tests [8].

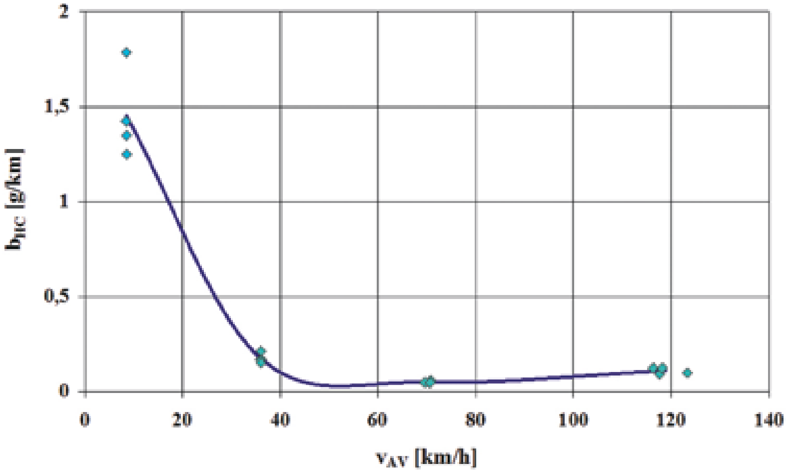

Fig. 18. Dependency of the specific distance emission of hydrocarbons – b_{HC} in the PIMOT driving tests on the average velocity – v_{AV}

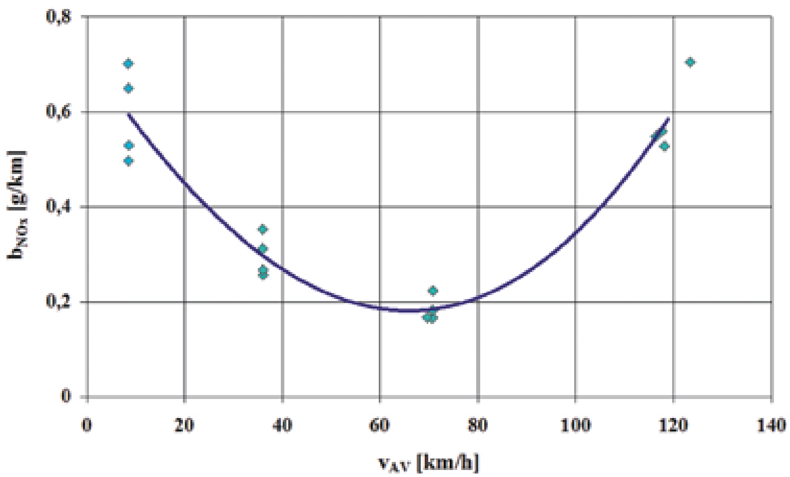

Fig. 19. Dependency of the specific distance emission of nitrogen oxides – b_{NOx} in the PIMOT driving tests on the average velocity – v_{AV}

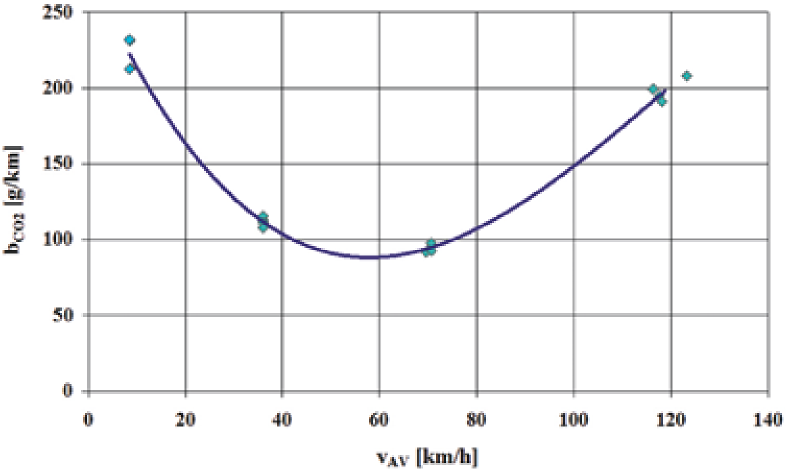

Fig. 20. Dependency of the specific distance emission of carbon dioxide – b_{CO2} in the PIMOT driving tests on the average velocity – v_{AV}

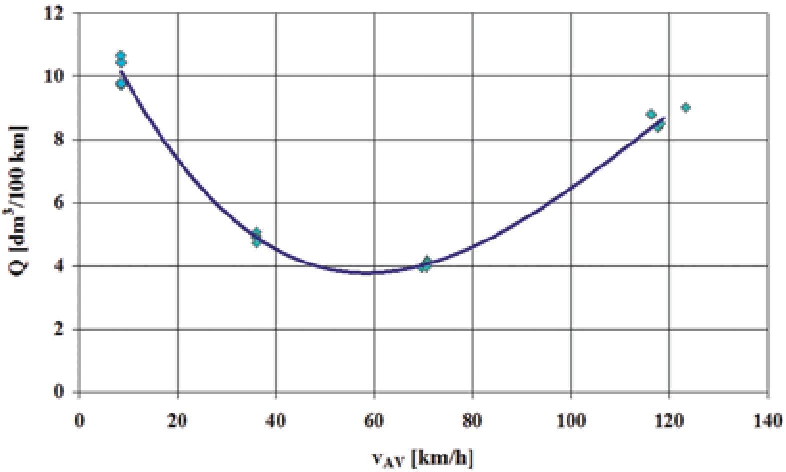

Fig. 21. Dependency of the operating fuel consumption – Q in the PIMOT driving tests on the average velocity – v_{AV}

The curves having been determined as pollutant emission and fuel consumption characteristics show regularity consistent with that of the characteristic curves plotted on the grounds of the databases incorporated in specialist software packages, such as INFRAS [19] or COPERT [17]. They are also similar to the characteristic curves plotted for empirical test results [10]. In the conditions of low average vehicle velocity, which correspond to severe traffic difficulties, the fuel consumption and the pollutant specific distance emission, especially the hydrocarbons and the carbon monoxide specific distance emission, reach their highest values. The dependence of this kind is less conspicuous for the specific distance emission of nitrogen oxides and carbon dioxide and for the operating fuel consumption. It is noteworthy, in spite of marked scatter of measurement results for different test realizations, that the averaged characteristics show regularity and conformity with the current state of the knowledge. This proves the reasonability of treating the vehicle velocity in the tests as a stochastic process.

3. Recapitulation

The operational properties of internal combustion engines depend on the engine operation state. This dependence may be very distinct in the case of fuel consumption and, above all, pollutant emissions. The state of operation of an automotive IC engine is chiefly determined by the vehicle velocity process. Significant diversity in the conditions of operation of automotive engines gives good reasons for examining the engine properties in conditions differing from those of the standard tests carried out within type-approval procedures. This paper presents the PIMOT driving tests that have been developed for the purposes of simulating the operation of passenger cars in the conditions of urban traffic congestions, urban traffic without congestions, extra-urban (rural) traffic, and high-speed traffic on motorways and fast roads. The said tests have been prepared in the form of a set of realizations of stochastic processes characterizing the motorcar operation cases under consideration. The tests have been built on the grounds of results of empirical investigations, in compliance with the rule of faithful simulation in the time domain.

The driving tests having been prepared were tried for a Honda Civic car on a chassis dynamometer and results of the examination of pollutant emissions and fuel consumption at the driving tests have been presented herein. The results of measurements of the pollutant specific distance emission and the operating fuel consumption were in some cases found to show significant unrepeatability, which particularly applies to the carbon monoxide and hydrocarbons specific distance emission. Conversely, the unrepeatability of results of the examination of the carbon dioxide specific distance emission and the operating fuel consumption was very low, even less than 1% in many cases.

Characteristic curves representing the pollutant specific distance emission and the operating fuel consumption at the PIMOT driving tests vs. the average vehicle velocity have also been included here. The characteristic curves presented show regularity consistent with the dependences that can be found in the literature and the dependences determined from the databases incorporated in specialist software packages.

The research work results obtained have given grounds for a statement that at tests aimed at the evaluation of operational properties of automotive IC engines in the conditions that correspond to real vehicle use, the vehicle velocity should be treated as a stochastic process.

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