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OPERATIONAL CONDITIONS OF VEHICLES MOTION AND FORMATION OF URBAN DRIVING CYCLE IN THE CITY OF LVIV

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Abstract. To the greatest extent, the indicators of the motor vehicles being in the normative technical state are influenced by the operational conditions, which, in turn, are characterized by road, relief (terrain) and transport conditions. The transport conditions of large cities of Ukraine are characterized by the intensive increase of motor transport, especially individual (private) one, on the street-road network of the city caused a number of problems, such as increased waste of time needed for a trip, increased number of forced stops, increased number of emergencies and road-traffic accidents, the occurrence of traffic jams, chemical and noise pollution of the environment. As the special investigations indicated, the volume of traffic has increased by 1.5…1.8 times in comparison with the data of ten years ago [1]. All this caused the necessity to substantiate the rational use of the power of the motor vehicles engines and to control their ecological indexes in order to reduce the negative influence on the environment.

While evaluating the toxicity of the motor vehicles engines, two fundamentally different methods of investigations are being used: testing on steady-state operating conditions with constant parameters of the engine and testing on transient operating conditions when the input parameters are being changed. For the transient conditions, the main conditions of the motor vehicles motion have been identified: motion in the conditions of the city and motion out of its borders. Each of the conditions is characterized by the differences in the percentage of toxic components in the exhaust (burnt) gases.

While developing the technique of determination of ecological indexes and parameters of fuel economy (saving) for motor vehicles, a large number of factors, which varies depending on the operating conditions, are considered. This is expedient in the case when the operating conditions are very different considering the typical motion conditions in the region and the several aspects that affect the fuel consumption. One of the main reasons for this is the unsatisfactory state of planning, accounting and standardization of the efficiency of the motor vehicles use. In this approach, the operation indexes are estimated based on not always impartial reporting and statistical data, so the standards are not an impartial factor or a model for the motor vehicles operation. These circumstances substantiate the urgency of the subject of research.

While carrying out these investigations, the preliminary analysis of the motion conditions of the motor vehicles in different operating conditions is conducted and the peculiarities of the existing driving cycles of different countries of the world are considered.

In order to ensure the determination of the motion conditions of motor vehicles in the conditions of the city of Lviv, the technique of investigations carrying out was developed on the basis of available means. The results of changing the conditions of the motor vehicles motion in the conditions of the city of Lviv were obtained taking into account the motion speed of the motor vehicle, the rotation frequency of the engine crankshaft, the instantaneous fuel consumption and the amount of consumed air. According to the results of the experiments carried out, the main features of the operational conditions of motor vehicles motion in Lviv were determined, the driving cycle for testing the motor vehicle in the conditions of Lviv and the method of comparative analysis of existing and improved driving cycles were developed. The analysis of indexes of existing and developed driving cycles is carried out and the expediency of use of the developed driving cycle is substantiated.

Keywords: operational conditions, motor vehicle, driving cycle, comparative analysis, fuel consumption, motion speed, rotation frequency.

Problem statement

The operation of the motor vehicles engines may be estimated by the complex of operational and technical indexes: specific power and mass-dimensional indexes, fuel economy (saving), toxicity of exhausted (burnt) gases, dynamic qualities, etc. Currently, the most important ones are the indexes of toxicity of exhausted (burnt) gases, that is, the amount of harmful substances thrown into the air by the engine. This is due to both the degradation of the ecological situation and the increase of requirements for the internal combustion engines imposed by modern normative documents. Different methods of controlling the toxicity and smoke of exhausted (burnt) gases are used. They differ by testing programs and simulation of the engine operating conditions, as well as by the principle of operation of the measuring apparatus and by the testing techniques.

While evaluating the toxicity of exhausted (burnt) gases, two fundamentally different methods of investigations are being used: testing on steady-state operating conditions with constant parameters of the engine and testing on transient operating conditions when the input parameters are being changed.

In Ukraine, in order to evaluate the operational characteristics and to calculate the toxicity level of exhausted (burnt) gases of motor vehicles, the traditional test cycles are used taking into account such traffic flow characteristics as the length of the waiting line (queue) for overtaking and before the traffic lights, the delay time while moving along the road with obstacles, the traffic capacity of the road sections, etc. [2]. Using these characteristics, one may obtain the sufficiently limited list of indexes that characterize the motion conditions, namely: time and distance of the motor vehicle acceleration (speeding-up), its motion speed, fuel consumption, time of operation in certain gears.

Taking into account the peculiarities of the development of Ukrainian cities, in particular, of the city of Lviv, when modern residential districts are formed around the historical part of the city, the problems of refinement (updating) of existing driving cycles, their adaptation or changing the certain motion conditions according to the results of the substantial investigations.

Taking into account the problems in the transport field of the cities of Ukraine, the purpose of the article consists in development of the driving cycle for the conditions of Ukrainian cities, which would allow to determine the real (substantial) operational modes of the motor vehicles in the conditions of cities and to define the refined values of the level of environmental pressure (pollution). Unlike the existing methods valid in Ukraine [2; 3], this technique will allow qualitative analysis of all problems and features of motor vehicles operation in large cities, in particular with the presence of the historical part, in a way that will allow to determine and standardize the emissions of harmful substances in exhausted gases.

The purpose and problems of research

The purpose of this research is to improve the operational characteristics of motor vehicles, to determine the level of environmental pollution of Ukrainian cities by investigating the characteristics of traffic flows of Ukrainian cities and by developing the city driving cycle based on existing ones.

In order to achieve this purpose, the following problems were formed in the research process:

– to carry out the analysis of operational conditions of the motor vehicles motion;

– to analyse the driving cycles of different countries taking into account the vehicles testing;

– to carry out the analysis of the characteristics of the transport flows of Ukrainian cities (on the example of the city of Lviv) on the basis of the results of the investigations carried out;

– to develop the driving cycle for the city of Lviv;

– to carry out the substantiation of the ecological expedience of development of the driving cycles.

Analysis of modern information sources on the subject of the article

The investigations of the level of toxicity of exhausted (burnt) gases of the motor vehicles and traffic flows were carried out by a great number of scientists, in particular, Gutarevych Yu. F. [4; 5], Mateichyk V. P. [6], Merzhyievska L. P. [7], Fornalchyk E. Yu. [8] and others. There were also attempts to take into account the real (substantial) conditions of the buses motion during the driving testing cycles [9]. The

investigations that concentrate on development of the simplified testing cycle for checking the technical state of the gasoline engine of the motor vehicle in various operational conditions are also interesting [10]. However, none of the scientists has developed the driving cycle for real (substantiate) operational conditions, although a great number of different commissions (committees) are involved in the development of various norms (standards) and restrictions [11, 12].

Main material presentation

While developing the methodology of conducting experimental investigations, the peculiarities of the motor vehicles testing according to the European driving cycle were taken into account. In order to develop the route and to conduct experimental investigations in Lviv, the detailed analysis of the traffic flow, routes of public transport, time diagrams of traffic volume on the streets of the city, features of building and presence of the historical part was carried out.

In order to achieve the preset goal, the methodology of investigations conducting was developed, the measuring apparatus was chosen and installed on the car.

The final stage in this part of the work was to carry out the experimental investigations of the influence of parameters of the motor vehicle motion in the traffic flow of the Lviv city on its operational characteristics with simultaneous determination of the motion conditions and with further analysis of the incompatibility of the existing driving cycles with the traffic situation in the cities of Ukraine.

While carrying out the experimental tests in the city of Lviv, the time interval of maximum motion intensity (volume) and specific features of the vehicles motion (the places of frequent traffic jams, the routes of public transport, the sections of the roads with the complicated transport passage) were taken into account. The experiments were conducted during the autumn of 2012, since it is the period of the largest traffic volume (intensity), which is due to the beginning of the new school (academic) year, the returning of people from the holiday, etc. Tests were carried out at different hours during the working day by each day of the week. The motor vehicle Chevrolet Aveo with automatic gearbox was used for full-scaled investigations.

In order to determine the real-time operational characteristics of the motor vehicle, the hardware and software complex Bosch KTS 540 (Fig. 1) was used. It allows to display the main performance indexes (operational characteristics) of the motor vehicle on the computer screen, in particular, its speed, rotation frequency of the engine crankshaft, instantaneous fuel consumption, mass of consumed air. The KTS 540 device was connected to the OBD-II diagnostic plug (connector).

This device (Fig. 1, b) was connected to the OBD-II diagnostic plug (connector) in such a way that it does not interfere with the access to the pedals of the motor vehicle during its motion. The software and hardware complex Bosch KTS 540 does not have the ability to save data in the real-time mode, therefore the devices for video registration (recording) of the diagnostic parameters from the computer screen were used (Fig. 1, d). These devices were fixed on the body of the laptop computer with a help of the holder.

The processing of results of the conducted experiments made it possible to construct the plots of time dependences of operational indexes of the motor vehicle. For example, in Fig. 2, there is presented the fragment of the plot of fuel consumption of the motor vehicle engine as a function of time, during which the experimental investigations were carried out.

The obtained plots of time dependencies of operational indexes of the motor vehicle allowed to make preliminary conclusions about the character and features of the vehicles motion in the traffic flows of the Lviv city, as well as about the main drawbacks and advantages of the road-street network of the city. The significant differences between urban motion conditions and European driving cycles (NEDC) and other testing cycles [13; 14; 15].

This caused the necessity to carry out more profound analysis of the obtained results and to develop the regional driving cycle for Ukrainian cities. The main differences in the distribution of vehicles motion conditions between the results of the conducted experimental investigations and the norms (standards) and restrictions of various countries are presented in Fig. 3.

a *b*

c *d*

Fig. 2. *The general view of the used equipment: a – complex Bosch KTS 540; b – connection of equipment to the diagnostic plug (connector) OBD-II of the motor vehicle; c – auto scanner Bosch KTS 540 in the cabin of the motor vehicle; d – display of the laptop with the installed software*

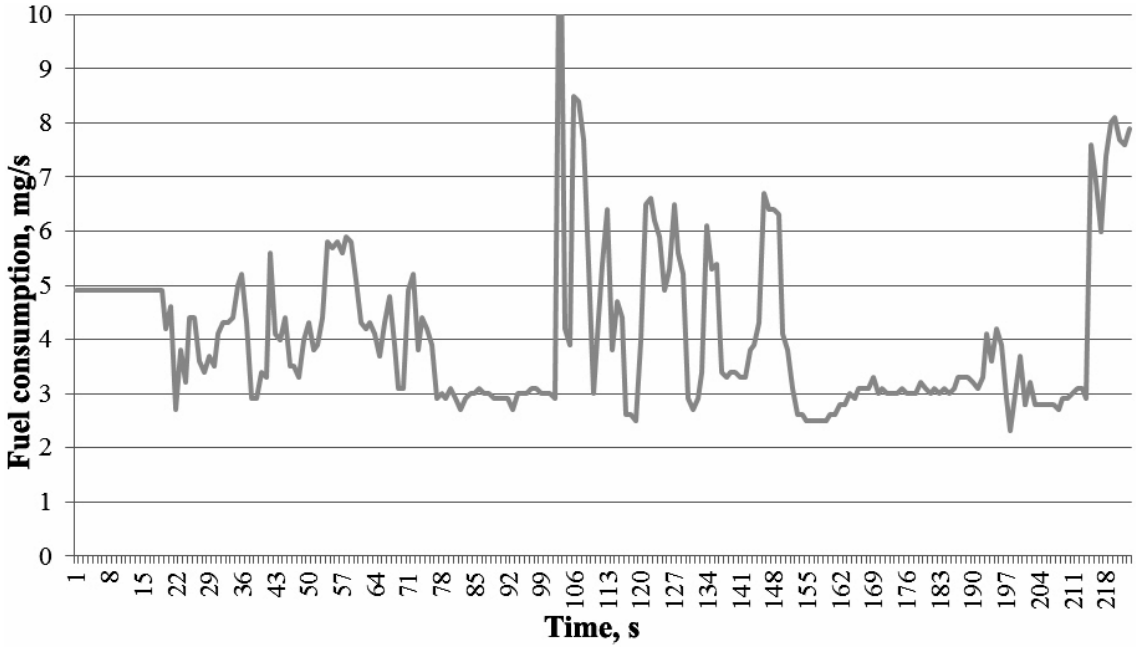

Fig. 2. *Time dependence of fuel consumption of the motor vehicle*

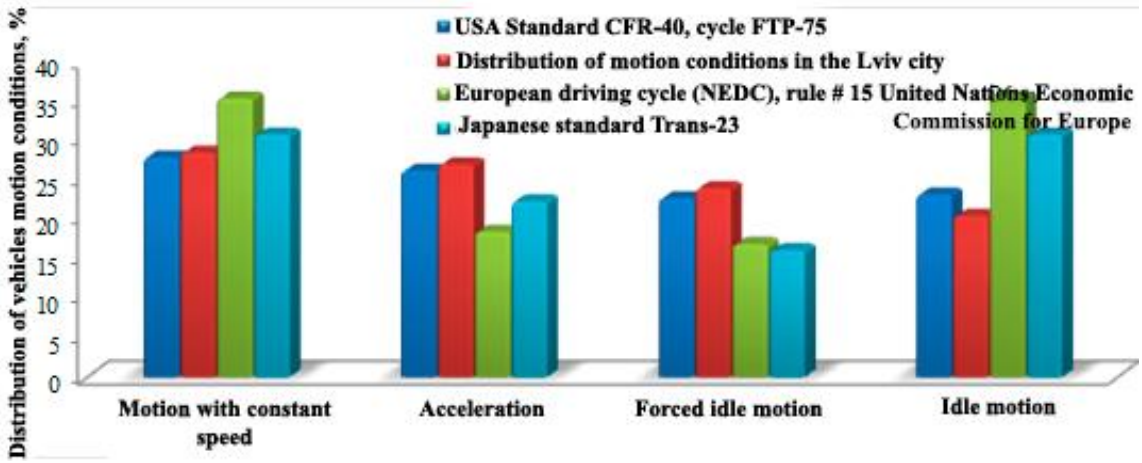

Fig. 3. *Comparative characteristic of the motion conditions according to the driving cycles*

The European driving cycle (NEDC) is universal one. It is used both for calculating the fuel consumption of typical motor vehicles and for determining the energy consumption and the distance endurance of hybrids and electric vehicles (Rule ECE R101), as well as for determining the toxicity of exhausted (burnt) gases according to the Rule ECE R83 [14].

The American cycle FTP-75 is more similar to the operating conditions of the motor vehicle in the city of Lviv [15]. This may be explained by the testing method: firstly, this cycle involves the activation of the air conditioner (cycle SC 03), and secondly, the acceleration to peak speeds is significantly larger. During the first 505 s, or during the so-called cold start phase, the motor vehicle manages to pass a significant distance in the urban cycle at speeds up to 56 km/h. After a short stop, it accelerates up to 90 km/h, and then it returns to the urban cycle, but already with a higher permitted speed up to 60 km/h.

The next phase of the testing is the transient phase of the duration of 864 s (at which the speed exceeds 56 km/h), and after a pause to cool the engine (it turns off for 10 minutes), the cold start phase is repeated again, but with a pre-warmed engine. The total cycle time equals 1874 seconds, the distance is 17770 meters, the average speed is 34.1 km/h. The average speed of such tests is not significantly larger than the speed of the European driving cycle, but fuel consumption is larger by 15–30 %.

In the process of implementation of the comparative characteristics of the vehicle motion conditions according to their driving cycles, it has been established that the features and the character of the vehicles motion in the Lviv city are the most similar to the USA FTP-75 driving cycle. According to this driving cycle, the testing is carried out in two stages: the Federal Test Procedure that lasts 55 % of the total time and Highway Test Cycle that lasts 45 % of the total time. This driving cycle represents the motor vehicle motion conditions at high engine loadings.

The main problem while developing the driving cycle, which will represent the characteristic features of the motor vehicles motion in the city of Lviv, is to take into account the existing historical building, a large number of slopes and grades, features of the routes of public transport, motion on the roads sections with different coverings (pavements) and coefficients of the tyre-road grip, the presence of tram tracks, changes in traffic volume (intensity) depending on the season, day of the week, and the period of the day, traffic peculiarities on cross-roads with imperfect traffic organization (management), etc.

When developing the city driving cycle, the first step is to analyse the speed conditions of the motor vehicle and to develop the simplified driving cycle, which is characterized by average values of engine performance indexes. The simplified model of the driving cycle (Fig. 4) was formed on the basis of results of experimental investigations taking into account the testing methods of European urban driving cycle ECE R15, which consists of four tests of a total duration of 800 seconds. The total distance passed by the vehicle is 4052 m. However, taking into account the characteristics of the traffic flow in the city of Lviv, which directly affect the motion character of the motor vehicle, the distance passed was not set, but was proportional to the speed of the motor vehicle. The simplified model of the driving cycle represents the tests that were carried out both on the pre-warmed and on the cold engine.

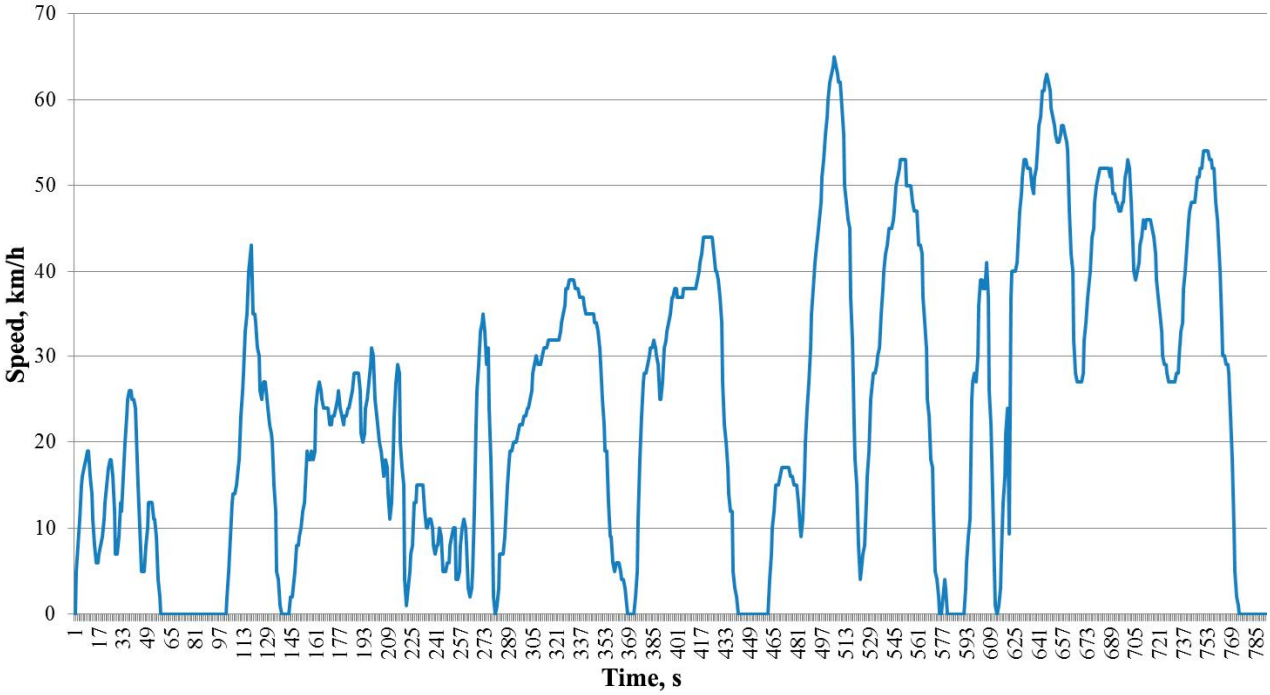

Fig. 4. *The model of the simplified driving cycle of the vehicle in the motion conditions of the Lviv city*

The main parameters of the motor vehicle motion and their main differences from the European driving cycle are obtained. In particular, the difference of fuel consumption is 10.38 % (according to the NEDC testing taking into account the vehicle's certificate (data sheet), the fuel consumption is 9.5 l per 100 km, and according to the results of the carried out experimental investigations in the city of Lviv, the fuel consumption is 10,6 l per 100 km). The difference of the average speed is 26.9 % (18.7 km/h and 26.9 km/h, correspondingly), and the difference of the passed distance is 26 % (4052 m and 5475 m, correspondingly).

The next stage of development of the urban driving cycle of motor vehicles in the conditions of the Lviv city was to create the motion model for the tests, which are divided into four sequential stages of the duration of 200 seconds each. These models do not differ and are carried out sequentially. The main task of them is to reproduce the distribution of motor vehicles motion conditions for the driving cycle of the total duration of 800 s. When developing the simplified and the final models of the motor vehicle testing for the driving cycle in the conditions of the Lviv city (Fig. 5), the Statistic 6.0 software was used. The obtained model of the driving cycle in the conditions of the city of Lviv represents the percentage distribution of the vehicles motion conditions and takes into account the main features of the street network of the city.

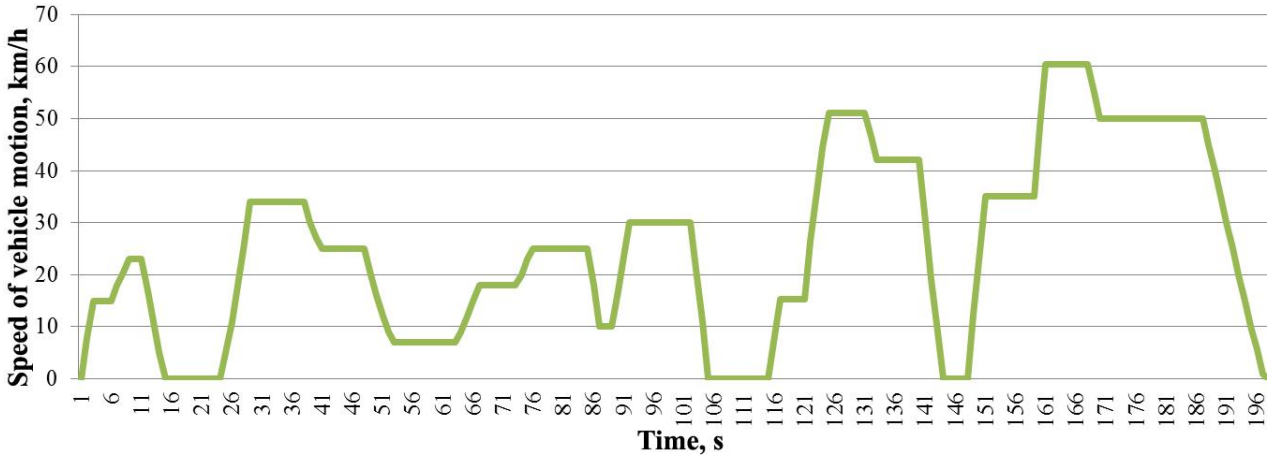

Fig. 5. *The model of the simplified driving cycle of the vehicle in the motion conditions of the Lviv city*

Conclusions

In order to develop the methodology for carrying out experimental investigations with the aim to form the driving cycle for the city of Lviv, the peculiarities of vehicles testing with a help of the European driving cycle were taken into account. The main feature and advantage of the obrtained model is the possibility of its using for investigation of the vehicle motion conditions, for standardization of the substantial fuel consumption, and for determination of the substantial level of toxicity of harmful substances in exhausted (burnt) gases, both during the full-scale testing and with a help of laboratory equipment.

The determination of fuel consumption for each motion cycle in the urban conditions is carried out. The typical motion conditions of the motor vehicles in Lviv are defined. The analysis of dependence of the motor vehicle motion speed changing, which is typical for the city of Lviv, and the comparison of the obtained results with testing models of various countries are carried out. It is established that the peculiarities and the character of the motor transport motion in Lviv are the most similar to the USA FTP-75 driving cycle, which represents the motor vehicles motion conditions at under large internal combustion engine loadings. In order to standardize the fuel consumption and to determine the substantial environmental pollution, the sufficient model of vehicles testing for the urban driving cycle in the conditions of the Lviv city was developed. The proposed model will allow to evaluate the substantial economical operation and exhausted (burnt) gases toxicity of the motor vehicles.

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