Evaluation of Emissions Exhausted by Diesel Vehicles on Urban Routes

Adriana Tokar, Arina Negoitescu

***Abstract*—**Most important pollutant effect of internal combustion engines is due to harmful gases existing in exhaust emissions, which occur due to poor, incomplete fuel combustion in internal combustion engines. Compression-ignition engines produce smoke at high loads. Experimental researches on traffic simulation with a Volkswagen Caddy 1.7DTI car were accomplished in Road Vehicles Laboratory at the Politehnica University of Timisoara and aimed a large congested vehicles route from Timisoara downtown (a traffic light intersection and a non-traffic light one, 6 pedestrian traffic light crossings and 4 non- traffic light ones). The studied route is 2.3 kilometers length, where the traffic is carried on "bar to bar". As measurements results, the opacity values were obtained for the engine operating under transient conditions.

***Keywords*—** Diesel, exhausted emissions, opacity, smoke, traffic

I. Introduction

Nowadays, 80% of Europeans live in urban areas, facing a continuous degrading of the quality of the urban environment. The development of economy has reached high levels during the last decades, followed by an increase in the mobility of people around the city, the excessive use of passenger cars [10].

Transport is a major source of environmental pollution, especially with a major impact on air quality as a result of the increased number of vehicles and poor quality of many of these. The orientation towards more sustainable modes of transport requires more efficient means from energetic point of view and less damaging to the environment and public health.

Most of the emission of hydrocarbon residuals is due to gasoline and diesel-powered automobiles as well as petroleum operations. They may cause respiratory problems as well as cause irritation of the eyes and nose. Furthermore, they are carcinogenic as well. By replacing gasoline and diesel vehicles with natural gas vehicles, hydrocarbon emissions can be gained reduction [6], [8].

In order to reduce the impact on the urban environment are taken into account:

- The reduction of pollutant emissions by accepting in traffic vehicles in accordance with pollution and ecological fuels regulations;
- Ring roads construction;
- Strengthening (maintenance and repairs) of existing transit routes in order to flow and decongestion traffic on high traffic on congested streets in residential areas.

Rational solutions that lead to reduced pollution, minimum fuel consumption and an engine longer operation duration are: the engine periodic testing and adjusting, avoiding prolonged idling operation and at maximum power regime, avoiding unnecessary and excessive accelerations, compliance with economic speed. An efficient and flexible transport system is essential for the economy and quality of life.

At present, the transport system significantly threats the environment and human health. The main objective of transportation policy is to restructure the transport system and ensure its operation to achieve a uniform transport system, connected in terms of structure, at national and European transport networks [1].

Road transport, equipped with air and water are among the many sources of pollution. Urban traffic, characterized by a high density of vehicles and harmful exhaust emissions contribute significantly to environmental impairment.

Most important pollutant effect of internal combustion engines is due to emissions existing in noxious exhaust gases, which occur due to fuel poor (incomplete) combustion.

Naturally aspirated diesel engines excel in producing hydrocarbons and carbon monoxide, and the supercharged ones in producing nitrogen oxides. Compression ignition engines produce smoke at high loads [2], [9].

There are three smoke categories:

- White smoke, specific to starting moments when the engine is driven and eventually is heated up;
- Blue smoke, specific to idling and low loads;
- Black smoke, which occurs to heavy loads, large thermal stresses, irrespective of speed.

White and blue smoke consists of particles suspended in unburned or partially oxidized liquid fuel, with diameter about 1μm for white smoke to 0.5μm for blue smoke. Black smoke is composed of coal particles with a diameter of 1μm.

For white and blue smoke, partially oxidized fuel particles are due to the low thermal regime, which characterizes start, warm, idling or low loads. These disadvantage the combustion of the entire quantity of fuel, fuel condensing at low temperatures during the expansion process.

Manuscript received July 26, 2010: Revised version received July 26, 2010.

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Black smoke is formed only in mixtures with excess fuel, by following the stages:

- Formation of an intermediate precursor compound, acetylene, which occurs at 2500-3000K flame temperature;
- Formation of soot particles from this compound, which initially have 40Å, and grow rapidly by coagulating in order to reach the final size of 1µm.

II. THE INSTALATION USED TO RECORD THE OPACITY

The Chassis Dynamometer LPS3000 allows the engine performance testing (Fig. 1) [4]. The simulation on the Chassis Dynamometer is achieved with an eddy-current braking system.

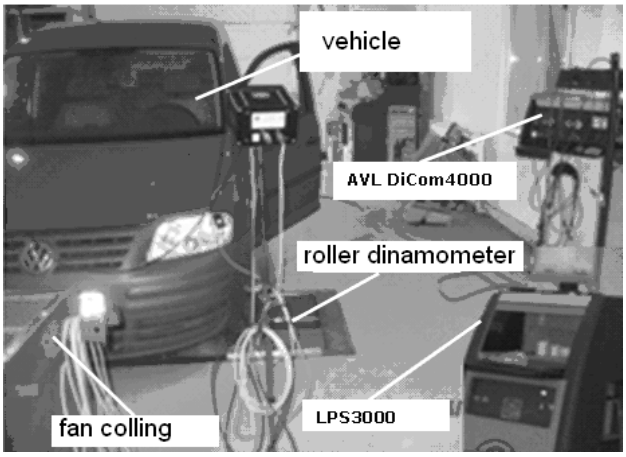

Fig.1 Experimental model organization

The software used for analysis allows the load simulation that enables the engine diagnosis and determining the development of the tested vehicle performance.

Simulation of drag and running under traffic conditions can be achieved in "constant speed" and "constant traction" operating modes.

In "constant speed" operating mode the Chassis Dynamometer is adjusted as the running speed to remain constant, irrespective of traction created by the vehicle (from minimum to maximum acceleration), meaning that only the preset speed can be used. Only the effectiveness of eddy current braking system increases to maximum acceleration but not the vehicle speed.

A preset value of traction activates the eddy current braking system instantly and this maintains a constant traction during the measurement. The setting values are established depending on:

- The tested vehicle model and dimensions;
- The desired tilt angle.

The AVL Dicom 4000 gas analyzer (Fig. 2) was used for exhausted emissions sampling during the experimental tests [3].

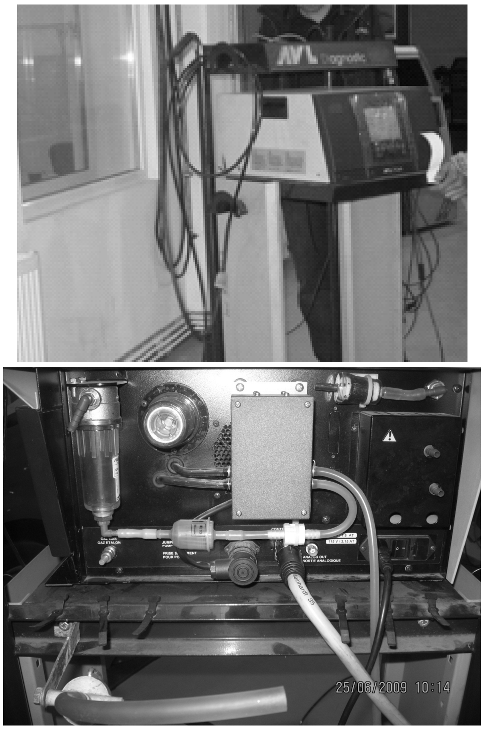

Fig. 2 AVL Dicom 4000 gas analyzer

Some technical data of the AVL Dicom 4000 analyzer are the following:

- Measurement principle:
  - CO, HC, CO_2 - Infrared measurement;
  - O_2 - Electrochemical Measurement;
  - NO - Electrochemical measurement;
- Working temperature:
  - 5 ... 45°C - Retention of measurement accuracy;
  - 1 ... 50°C - Ready for measurement
  - 5 ... 35°C - with NO integrated sensor;
- Humidity: 90% maximum without condensation;
- Opacimeter room
- Opacimeter room heating: 80°C
- Effective length: 0.215 ± 0.002 m
- Maximum exhaust gas temperature: 200 °C
- Measuring devices of 4 gases:
  - 3601 / h - Nominal flow
  - 1801 / h - Minimum flow
  - 180 ... 5001 / h - Total flow
  - 90 ... 1801 / h - Gas flow calibration

III. EXPERIMENTAL RESULTS

Although human progress and technological development are the goal to reach, awareness of the environmental situation and a suitable action plan, on the part of mankind, is by now necessary in order not to further damage the atmosphere. City centers are the main cause of this scenario, just because of the incessant production of polluting substances coming from an uncontrolled use of the mass of cars and from thermal energy production systems presents in residential centers and in the various inhabited structures [7].

For this purpose there were performed tests that have allowed collecting a number of experimental data recorded in traffic with the equipment fitted to the vehicle. To these data are added those obtained by measurement under simulation conditions on the Chassis Dynamometer. Experimental researches were accomplished in the Road Vehicles Laboratory from the Politehnica University of Timisoara. Experimental investigations concerning the traffic simulation have aimed traffic congestion areas both in peak hours and reduced service. The studied route (Fig. 3) is 2.3 kilometers length, where the traffic carried on “bar to bar” [1].

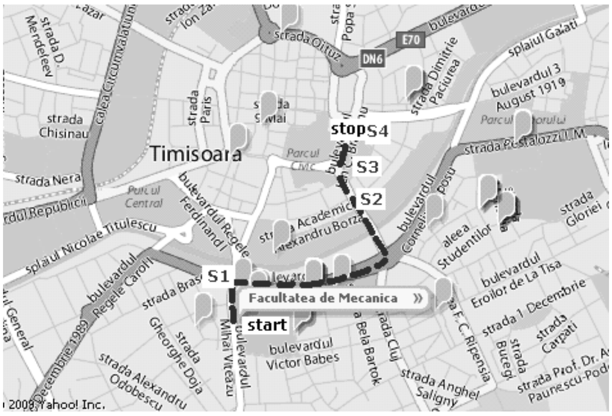

Fig. 3 The analyzed route

Four traffic lights intersections (S1, S2, S3, S4), a roundabout (Fig. 4) and six pedestrian crossings without traffic lights on a relatively short distance, are creating areas of high congestion with obvious effects on environmental pollution.

Fig. 4 The roundabout from the analyzed route

Traffic air pollution levels can be evaluated by two different means: measurements and prediction. The measurement method is only feasible when applied to existent situations; the prediction methods are used with advantage from the very start of the planning process to the final detailed design of air pollution abatement measures [5].

The analyzed route creates vehicle operating conditions under transient regime, which involves idling state or slow motion, used to start the engine (cold engine) and for waiting situations (traffic lights, congestion, etc.), acceleration, deceleration, etc. Simulation conditions of the real traffic for the vehicle equipped with compression ignition engine (diesel engine) were created in the laboratory.

The main technical characteristics of the testing vehicle, VOLKSWAGEN CADDY 2SDI-EURO III, are the following:

- engine type MAC
- engine displacement 1968cm^3
- cylinder number 4L
- maximum power 51kW
- manufacturing year 2006
- maximum load 2035kg
- maximum torque 210Nm
- on board kilometers 25000km
- ITP number 1
- urban consumption 7,8l/100km
- extra urban consumption 5,4l/100km
- mixed consumption 6,3l/100km

There were accomplished estimations on a vehicle equipped with compression ignition engine (diesel), in terms of passenger compartment with the air conditioned unit on and off. The estimation of the simulation possibility of the vehicle running in traffic on the Chassis Dynamometer was achieved by the following steps:

- Establishing a route including at least one traffic lights intersection and one without traffic lights, traffic lights pedestrian crossings and without traffic lights;
- Transiting the route with the required equipment for pollutants evaluation and recording emission to vehicle board;
- Simulation of the route on the Chassis Dynamometer;
- Creating laboratory climatic conditions similar to those of traffic.

Experimental tests in real traffic were achieved on Mihai Viteazu Blv. - Continental Hotel route in Timisoara, for different congestion periods of traffic:

- at 14.00 p.m., congested traffic;
- at 21.00 p.m., flowing traffic.

The following parameters were recorded: opacity, linear coefficient k, time, speed and gear by following two different situations: air-conditioned unit on and off.

The first situation referred as CASE I corresponds to a rush hour (14.00 p.m.) when the route was transited in 698 seconds and the air-conditioned unit was necessary to be coupled.

In Fig. 8 is presented the percentage of gears used.

The same conditions were simulated in the laboratory on the Chassis Dynamometer for the same vehicle and the errors minimization due to human factor was accomplished driving the car by the same driver, CASE II.

The opacity variation versus time for real traffic conditions is presented in Fig. 5 and for simulation on Chassis Dynamometer in Fig. 9.

High values are recorded in acceleration regime and the average value obtained in traffic was of 4.25% (Fig. 7) and 1.7% on the Chassis Dynamometer (Fig. 11). Also, the coefficient k variation versus time for real traffic conditions is presented in Fig. 6 and for simulation on the Chassis Dynamometer in Fig. 10.

The second situation referred as CASE III corresponds to a flowing traffic hour (21.00 p.m.) when the same route was transited in 365 seconds and the air-conditioned unit was unnecessary to be coupled. The percentage of gears used is presented in Fig. 15.

The same conditions were simulated in the laboratory on the Chassis Dynamometer for the same vehicle and the errors minimization due to human factor was accomplished driving the car by the same driver, CASE IV.

The opacity variation versus time for real traffic is shown in Fig. 12 and for the simulation on Chassis Dynamometer in Fig. 16. Opacity high values are recorded in acceleration regime and the average value obtained in traffic was of 2% (Fig. 14), respective of 1.5% on Chassis Dynamometer (Fig. 18). Also, the coefficient k variation versus time for real traffic conditions is presented in Fig. 13 and for simulation on the Chassis Dynamometer in Fig. 17.

The analyzed comparative CASE V (Fig. 19 and Fig. 20) emphasizes the fact that when starting from standstill up to stabilization of the engine thermal operation, the opacity curve for the traffic case is situated above the curve plotted in the laboratory. After reaching the engine thermal regime the traffic opacity curve is similar to that plotted by simulation in the Lab, and after about 10 minutes, the values measured in traffic are below those measured in the Lab.

CASE I Real traffic route: Mihai Viteazu Blv. - Continental Hotel (air conditioned unit on)

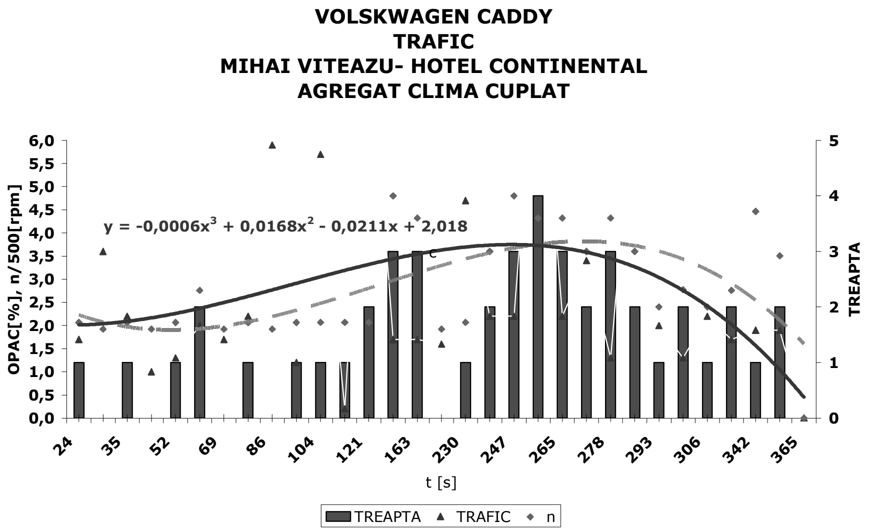

Fig. 5 Opacity variation versus time, for 1.7 DTI Volkswagen Caddy running in traffic (air - conditioned unit on)

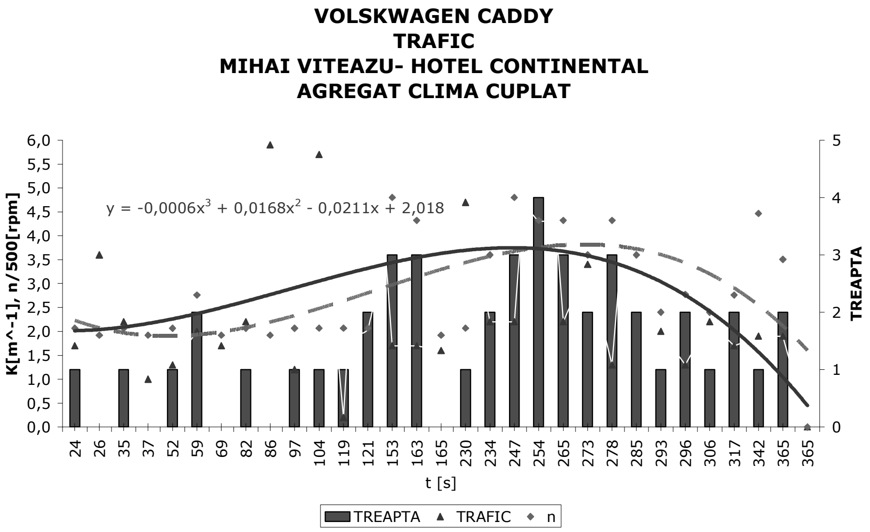

Fig. 6 Coefficient k versus time, for 1.7 DTI Volkswagen Caddy running in traffic (air - conditioned unit on)

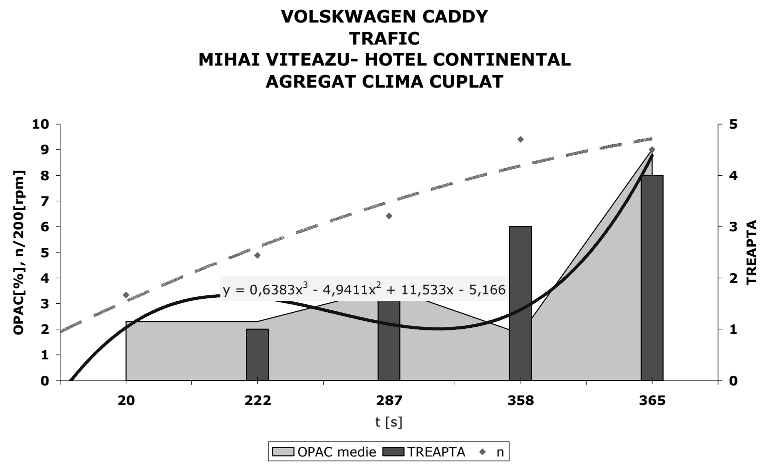

Fig. 7 Average opacity variation versus time, for 1.7 DTI Volkswagen Caddy running in traffic (air-conditioned unit on)

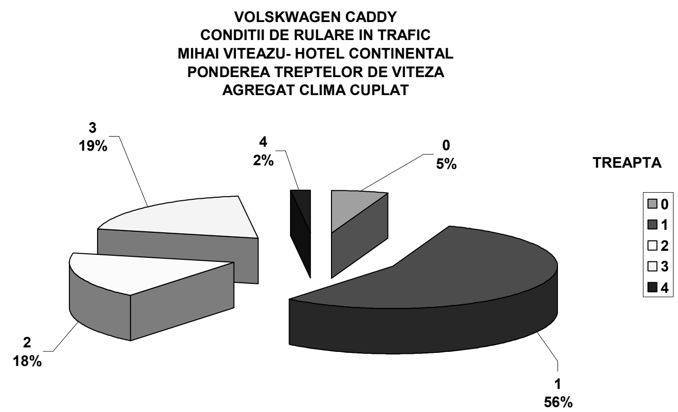

Fig. 8 Percentage of gears used for Volkswagen Caddy 1.7 DTI running in traffic (air - conditioned unit on)

CASE II Traffic route simulation on Chassis Dynamometer: Mihai Viteazu Blv.- Continental Hotel (air conditioned unit on)

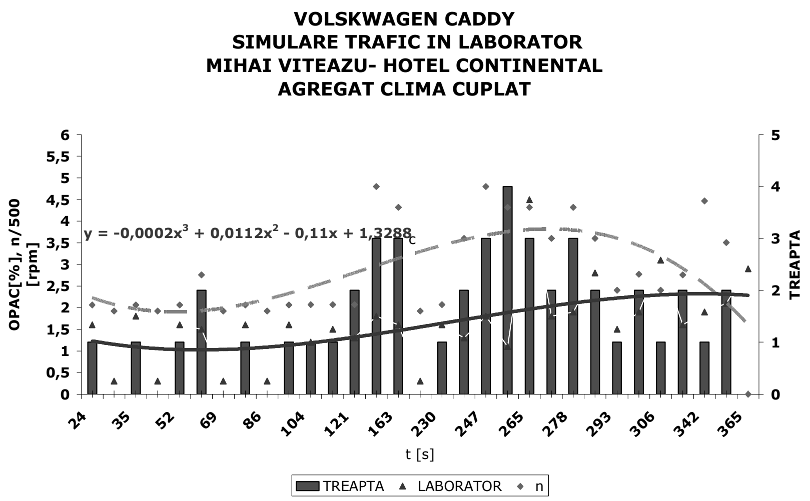

Fig. 9 Opacity variation versus time in experimental simulation of traffic for Volkswagen Caddy 1.7 DTI (air-conditioned unit on)

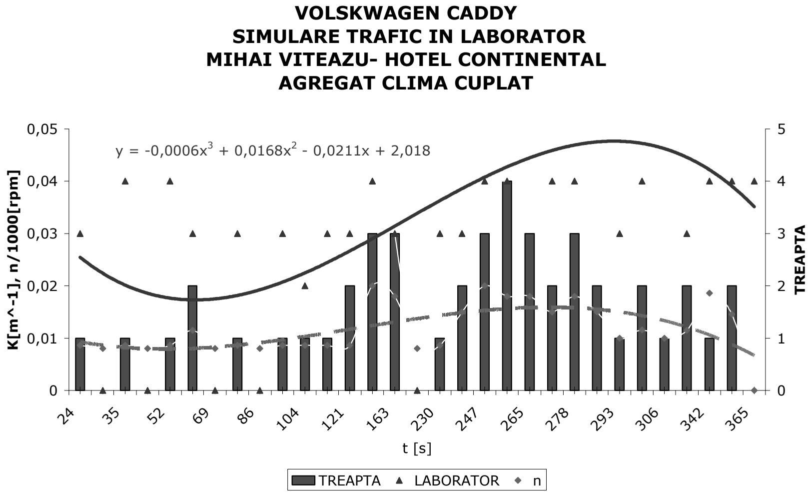

Fig. 10 Coefficient k variation versus time in experimental simulation of traffic for Volkswagen Caddy 1.7 DTI (air-conditioned unit on)

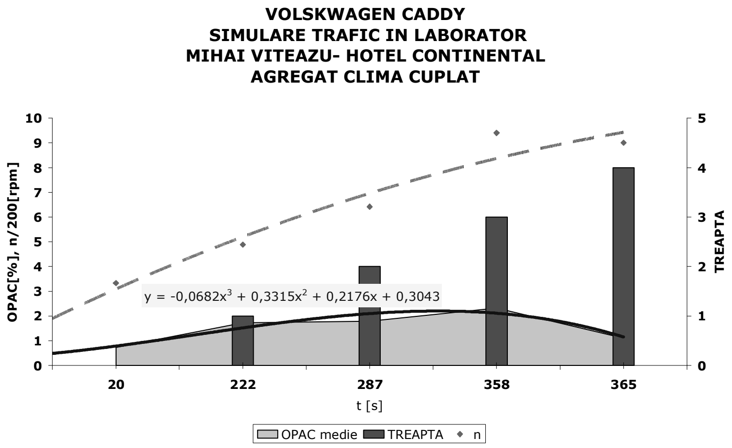

Fig. 11 Opacity average variation versus time in experimental simulation of traffic for Volkswagen Caddy 1.7 DTI (air-conditioned unit on)

CASE III – **Real traffic route**: Mihai Viteazu Blv. - Continental Hotel (air conditioned unit off)

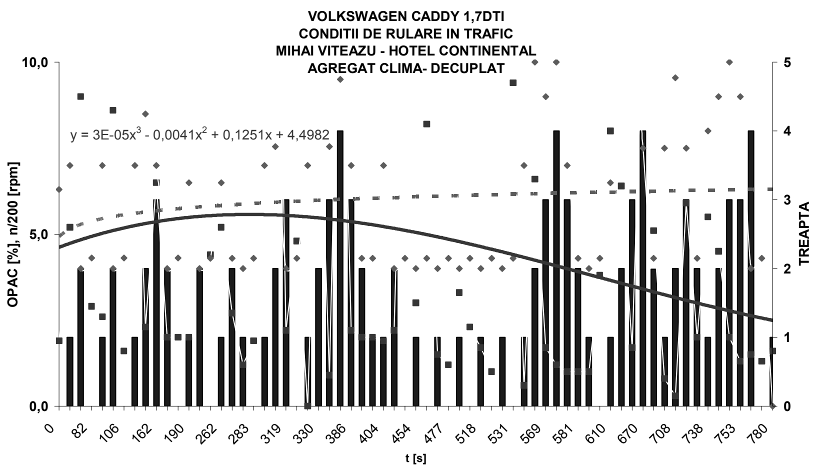

Fig. 12 Opacity variation versus time, for 1.7 DTI Volkswagen Caddy running in traffic (air - conditioned unit off)

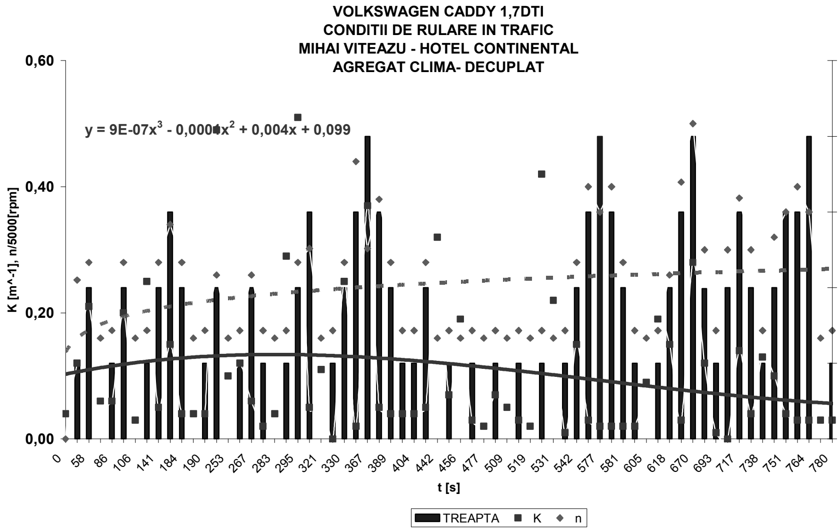

Fig. 13 Coefficient k variation versus time, for 1.7 DTI Volkswagen Caddy running in traffic (air - conditioned unit off)

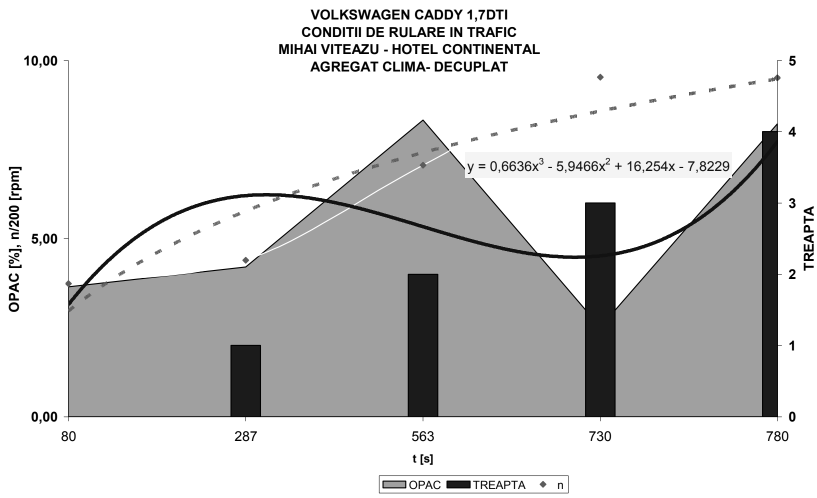

Fig. 14 Average opacity variation versus time, for 1.7 DTI Volkswagen Caddy running in traffic (air - conditioned unit off)

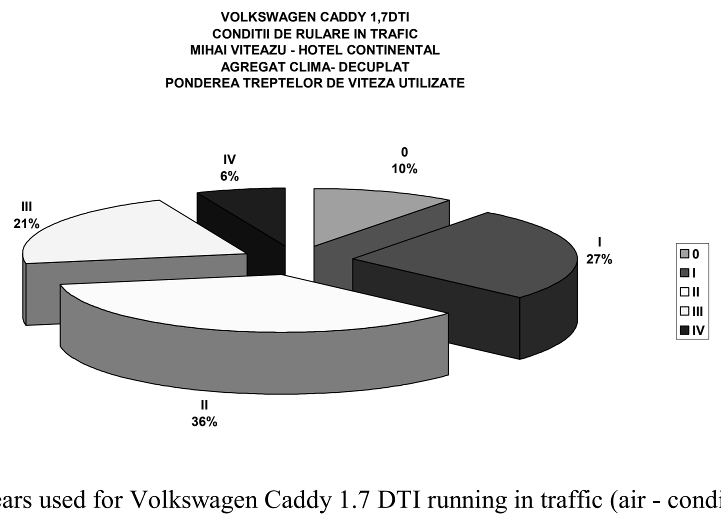

Fig. 15 Percentage of gears used for Volkswagen Caddy 1.7 DTI running in traffic (air - conditioned unit off)

CASE IV Traffic route simulation on Chassis Dynamometer: Mihai Viteazu Blv.- Continental Hotel (air conditioned unit off)

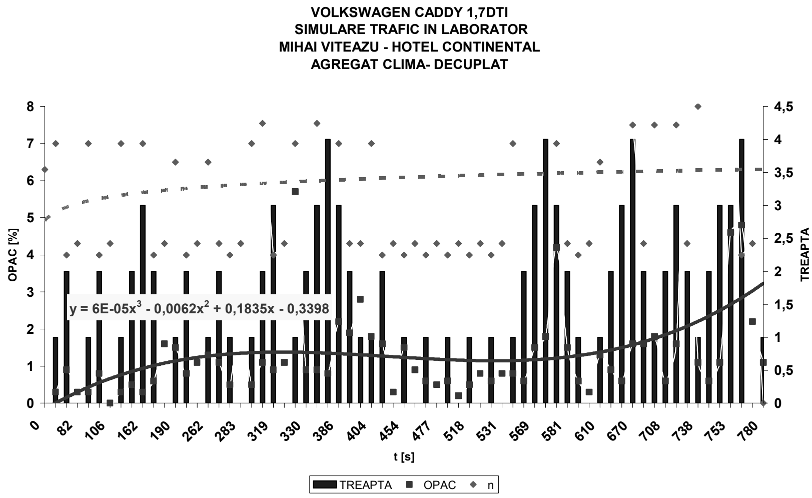

Fig. 16 Opacity variation versus time in experimental simulation of traffic for Volkswagen Caddy 1.7 DTI (air-conditioned unit off)

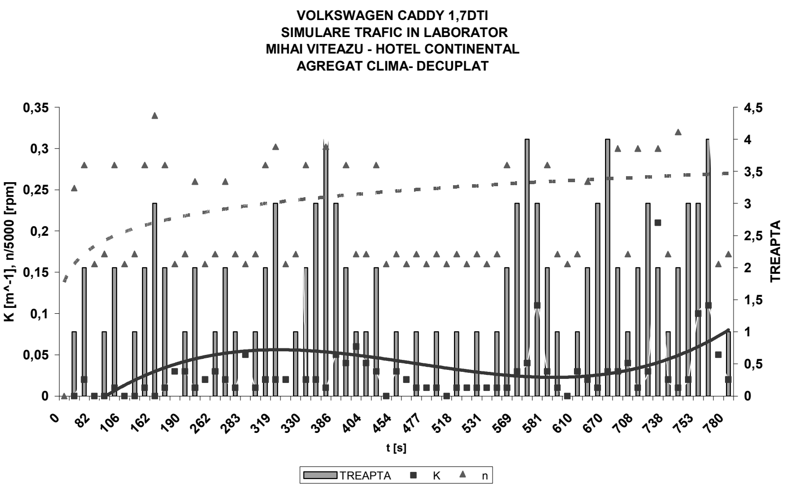

Fig. 17 Coefficient k variation versus time in experimental simulation of traffic for Volkswagen Caddy 1.7 DTI (air-conditioned unit off)

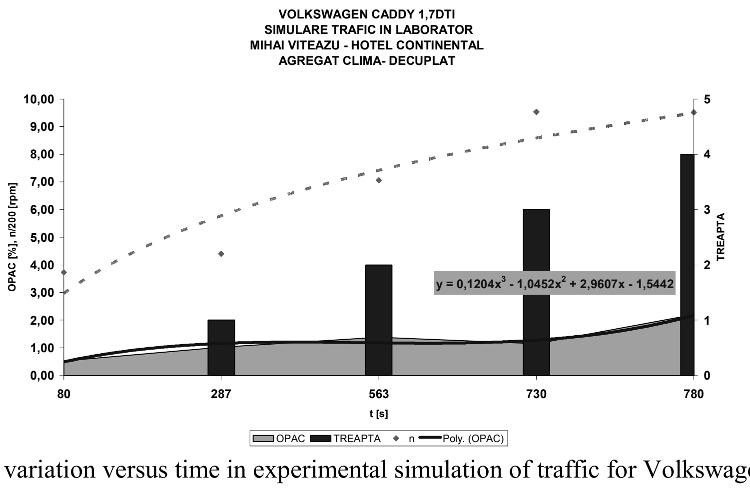

Fig. 18 Opacity average variation versus time in experimental simulation of traffic for Volkswagen Caddy 1.7 DTI (air-conditioned unit off)

CASE V Comparison between real traffic route and traffic route simulation on Chassis Dynamometer: Mihai Viteazu Blv.- Continental Hotel (air conditioned unit on)

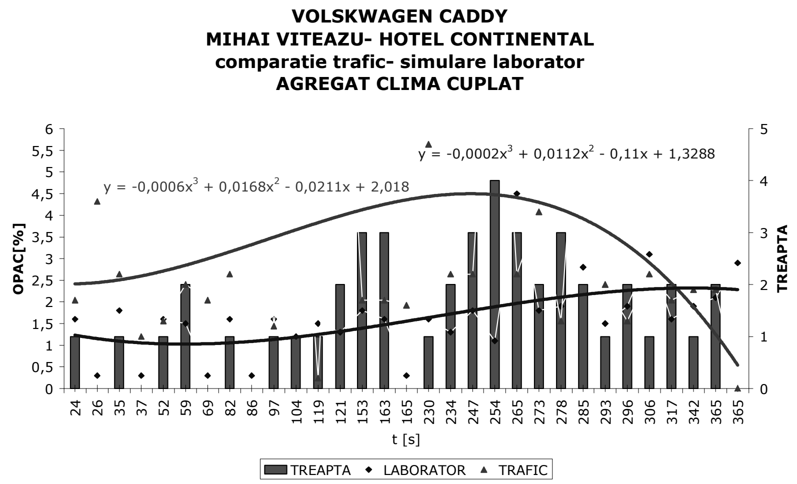

Fig. 19 Opacity variation versus time, for Volkswagen Caddy 1.7 DTI running in traffic and experimental simulation of traffic (air conditioned unit on)

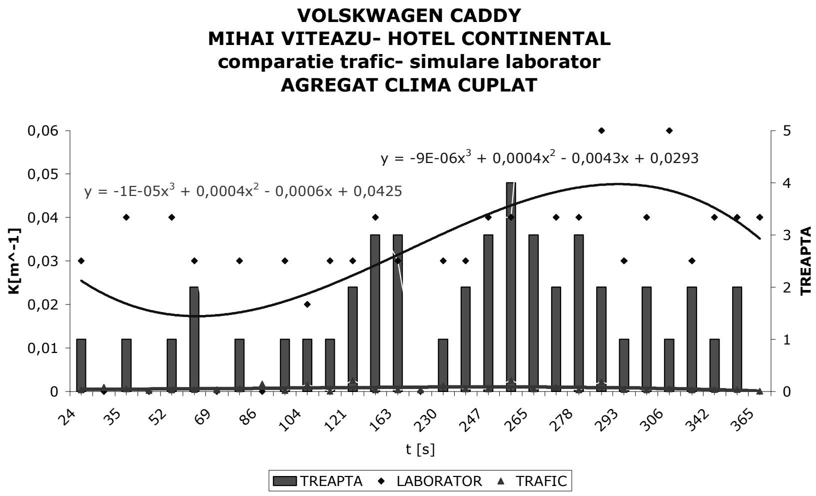

Fig. 20 Coefficient k variation versus time, for Volkswagen Caddy 1.7 DTI running in traffic and experimental simulation of traffic (air conditioned unit on)

As a general observation regarding the previously presented diagrams the signification of the following terms is: *TREAPTA*-***gear***, *AGREGAT CLIMA CUPLAT*-***air conditioned unit on***, *AGREGAT CLIMA DECUPLAT*-***air conditioned unit off***, *MEDIE*-***average***.

IV CONCLUSION

Traffic organization requires understanding the dynamics of vehicle traffic, the network's critical points and critical time periods of traffic. All these data are obtained from tests on traffic and define the laws that govern this phenomenon.

As results of experimental researches performed on Chassis Dynamometer in Road Vehicles Lab at the "Politehnica" University of Timisoara, values of opacity and linear coefficient k for transitory operation regime of the diesel engine were obtained.

In urban traffic the idling regime is used in proportion of about 20-30%, the acceleration regime of 20-25%, deceleration regime about 17-20% and at constant velocity regime of 30-40%, but all those highly depend on the vehicles technical characteristics, traffic nature, road quality, fuel, weather, driver physical condition, etc.

It results that, moving at a constant speed, the cars equipped with Otto engines eliminate pollutants substances at lowest levels but it is well known that moving at constant speed occurs only when routes are long, fluent and without significant restrictions. Urban traffic can provide a constant speed travel only by creating green light routes, which is not easy and does not suite any urban configuration.

The urban traffic can provide moving at constant speed only by creating green light routes, which is not easy to accomplish and is not suitable to any urban configuration, thus for urban traffic remains to exploit the vehicle in the most polluting operation modes.

The start off and idling operation modes were used in order to simulate traffic jams and stationary at traffic lights. Diesel engines, in this operation mode, produce carbon monoxide and unburned hydrocarbons in large quantities. Following the start up and acceleration simulation, the engine burns better the fuel of the lean mixture (λ>1.05-1.2), but exhausts a nitrogen oxides significant amount due to the increase of speed and temperature in the combustion chamber, resulting the increase in thermal efficiency. On deceleration, engine speed and combustion temperature decrease occurring the mixture enrichment (λ<0.8-0.9) which leads to incomplete combustion, power reduction and specific fuel consumption increase. Thus, during this operation mode the emitted pollutants consist of large quantities of unburned hydrocarbons and considerable quantities of carbon monoxide.

As a result of these researches it can be noted that for vehicles equipped with diesel engines, the opacity and k coefficient (absorption coefficient), had recorded significantly higher values when running in traffic in comparison with the simulation on Chassis Dynamometer.

It can be concluded that a real appreciation of the smoke level emitted by diesel engine requires a correlation of values recorded on the Chassis Dynamometer.

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