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MULTIPLE INVESTIGATIONS OF FUME EMISSIONS OF ENGINES WITH AUTOMATIC IGNITION

Bogdan Żółtowski

University of Technology and Life Science, BYDGOSZCZ
bogzol@utp.edu.pl

Abstract

The results of the investigations of the post and exploitation emissions of the harmful components of the fumes of diesel engines were introduced in the work. Obtained results were subjected to a statistical study according to new computer procedures. Qualitative and quantitative reports were established for the level and kind of emission in reference to the changes of the state of studied engines.

Keywords: combustion engines, toxic fume components, environmental protection

1. Introduction

The assumption for researches of this work was the performance of the analysis of the influence of starting phase and engine warming on the harmful emission at these states of engine's work, especially concerning climate conditions in Poland. In the range of researches, the analysis of the emission of harmful compounds was performed during the first few minutes after the start-up of a cold and warmed up engine in the neutral gear at different temperatures of the environment. The contribution of harmful components of fumes of diesel engines into total atmosphere pollution is as follows: there are mostly solid particles (PM) and nitro oxides (NOx) in fumes, whilst in smaller amounts there is carbon oxide (CO) and not burned hydrocarbons (HC).

The results of realized laboratory tests on a chosen group of diesel engines allow determine practically and cognitively important premises in the field of toxic effects of diesel engines on the environment.

2. Research objects

The researches of his work, in the field of recognizing toxic components generated by diesel engines for different modeled technical states and changeable external temperature, were performed on a stationary engine S-359 in the laboratory UTP (fig.1).

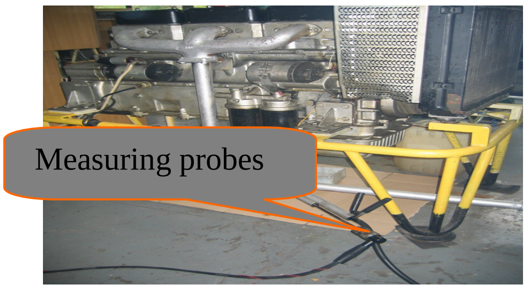

Fig. 1 General view of test stations

The object of research in this work was S-359 engine with self-acting fusion whose basic technical data is presented in Tab.1. It is an engine of a wide practical application, and characterized by small unitary fuel use, good dynamic characteristics and small damageability.

Tab.1. Basic technical data of the engine S- 359 [105]

Cylinder formation	row, vertical
Number of cylinders	6
Cylinder diameter	110 mm
Piston stroke	120 mm
Swept capacity	6,842 dm^3
Compression degree	17
Order of cylinder work	1-5-3-6-2-4
Maximum Power	110 KW with 2800 min^{-1}
Maximum turning moment	438Nm with 1800-2100min^{-1}
Minimum unitary fuel use	224 g/kWh
Statistical angle of pumping beginning	18,5^{0}OWK before GMP
Injection system	Direct
Injection pump	P-76G10
Injection pressure	22MPa

The engine is a running unit for trucks: Star 200 – street, Star 266 – cross-country, produced in Factory on Starachowice (at present: Star Trucks Sp.z o.o). These cars are widely used in the national industry, as well as military service.

The tested combustion engines belong to the group of exploitation objects, used in difficult training conditions of military service. Large and changeable loads of engines implied by inexperienced drivers diversified their technical state, which for the researches of his work posed a challenge in the range of preparing the experiment, its proper realization, and careful concluding and statistical work.

3. Testing stations

Stationary tests were performed in a laboratory of combustion engines located inside laboratory rooms, in order to obtain natural environment conditions. It mattered considering the acquisition of different temperatures, in which the engine S-359 was thermally stabilized, and considering the temperature of the air used for running the engine.

Before proceeding with the tests, the following were checked and regulated:

a. technical state of the engine,
b. injection pump at the probing station type PW-8, predestined for testing fuel equipment of high-pressure engines with regard to dosage, performing, according to BN-88/1301-16 velocity characteristics of fuel injection,
c. injectors used for the tests were checked and regulated on an injector probe type PRW-3, performing the evaluation of pressure of the injector’s opening, tightness and trickling of the sprayer, and the correctness of fuel spraying,
d. suction and exhaustion valves – according to the manufacturer’s suggestions,
e. during the test, the following were registered:
   - multi component composition of exhausted fumes of the engine,
   - smoking of fumes with a smoke-meter AVL.

Fume tests with respect to the quantity of toxic substances were performer with the use of a multi-component analyzer of fumes LANCOM, whose general image is presented on the Fig.2.

The analyzer LANCOM enables the measurements of: CO, CH, NO_x, SO_2, fumes temperature and environment temperature.

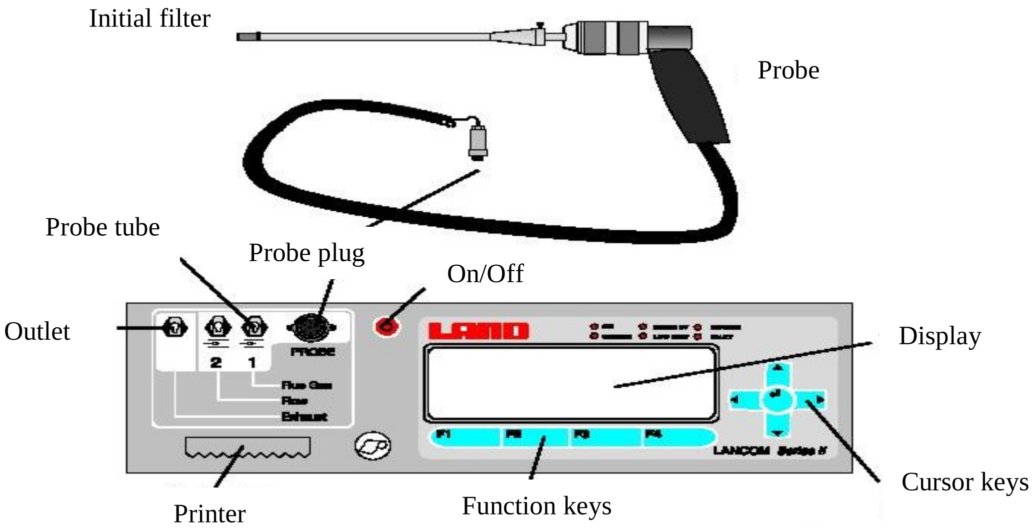

Fig.2. General image of fume analyzer LANCOM with fume acquisition probe

The measurements of smoking degree of fumes of diesel engines were performer with the use of a smoke-meter AVL-4000 for the need of further statistical processing the measured values were saved in a sheet (Excel).

4. Testing conditions

In order to obtain a wide range of temperatures of engine start-up, the tests were being performed throughout a dozen of months, taking into account summer and winter months. The engine, before each test, was subjected to thermal stabilization, thanks to which all elements of the engine and exploitation liquids and exhaust system had the same temperature equal to the environment temperature. Environment temperature and motor oil temperature were measured directly prior to each measurement, and if the temperature differences did not exceed 1°C, the measurement began. Also performed were tests in the conditions of a hot start-up. i.e. during a start-up of an engine beforehand warmed up to a normal temperature (oil temp. 80°C) in certain environment conditions. During the measurement, registered were (LANCOM, AVL) the contents of carbon oxides (CO), hydrocarbons (HC), nitro oxides (NO_x) in fumes, motor oil temperature, rotational speed of the crankshaft, environment temperature, and fumes smoking.

Considering the aim of the work, stationary researches were performed in the conditions of cold and hot start-up of the engine for the recognized seven states:

1. apt engine (with regulation settings suggested by the manufacturer),
2. values of the advance angle of fuel injection of 10°OWK (delayed injection – nominal advance angle of fuel injection advance has 18,5°OWK),
3. values of the advance angle of fuel injection of 24°OWK (advance injection),
4. for the pressure of injection processes beginning in cylinders: first 20MPa, fifth 18MPa and third 16MPa (nominal injection pressure – 22MPa),
5. for the pressure of injection processes beginning In cylinders: sixth 23MPa, second 24MPa and fourth 25MPa (in the other cylinders nominal injection pressure – 22MPa),
6. for inlet valves clearings in cylinders: first, fifth and third 0.15mm each,

7. for inlet valves clearings in cylinders: first, fifth and third 0,45mm each (nominal inlet valves clearing – 0.3mm).

The tests were performer for two variants of the engine's thermal states: cold and hot start-up on environment temperatures of 5°C, 10°C and 20°C. During the tests constant registration of fumes emissions during work in neutral wear from the moment of starting for the first 6 minutes of the engine's work.

5. Stationary tests results

The measurements of emissions of fumes toxic components and smoking of the engine with self-acting fuse S-359 in the laboratory were realized for specified states, at slow rotations of the crankshaft for three environment temperatures (5°C, 10°C, 20°C), with cold and hot start-up.

The results of stationary tests in the range of estimating toxic components emissions (*NOx*, *CO*, *HC*) o fan apt engine for cold and hot start-up at environment temperatures: 5, 10 and 20°C. The coefficient of fumes smoking (*k*) for the examined conditions is given of Fig. 3.

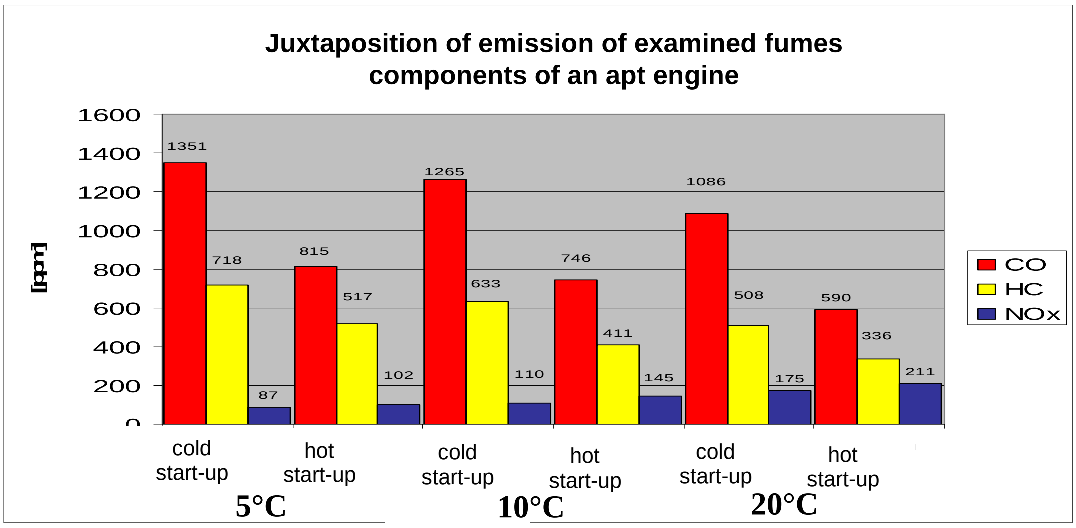

Fig. 3. Juxtaposition of emission of examined fumes components of an apt engine

Research results of smoking of an apt engine in a cold and hot start-up are presented the Fig. 4.

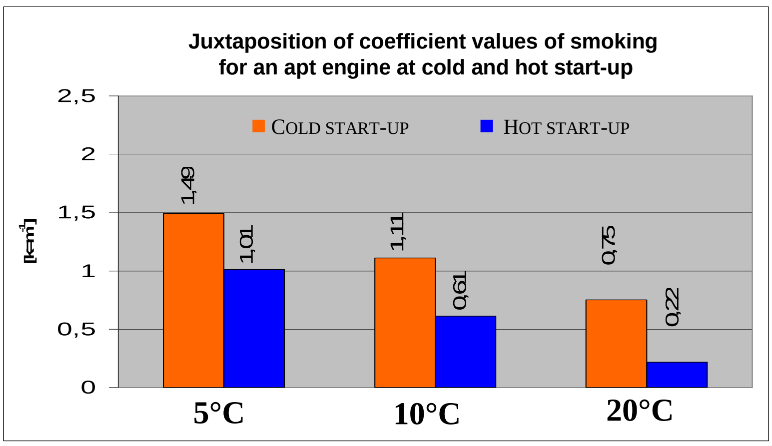

Fig. 4. Juxtaposition of coefficient values of smoking for an apt engine at cold and hot start-up

The volume of separate components of fumes and smoking for the start-up of a cold and hot engine, with a specified angle of injection advance 10°OWK was shown in the Fig. 5.

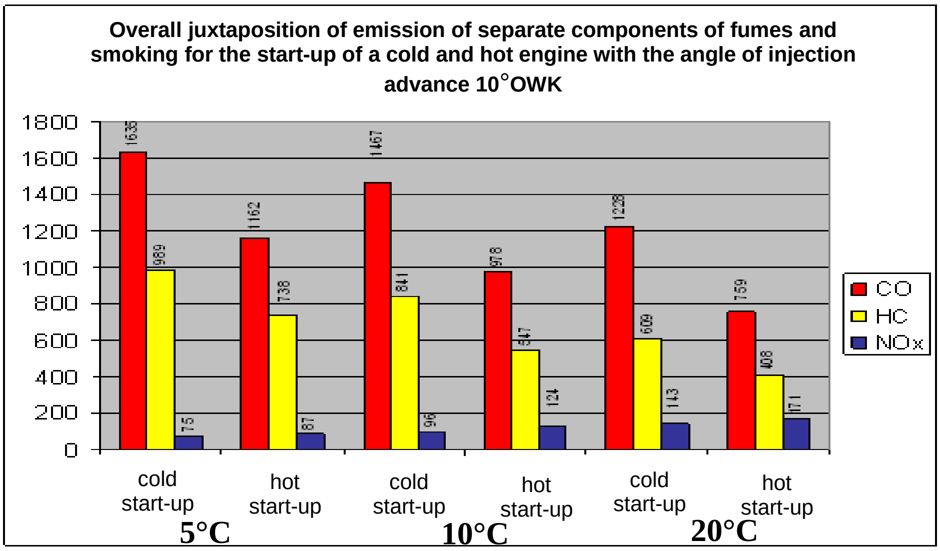

Fig.5. Overall juxtaposition of emission of separate components of fumes and smoking for the start-up of a cold and hot engine with the angle of injection advance 10°OWK

In the Fig. 6 shown below, research results of smoking of the engine for the start-up of a cold and hot engine with the angle of injection advance 10°OWK are shown.

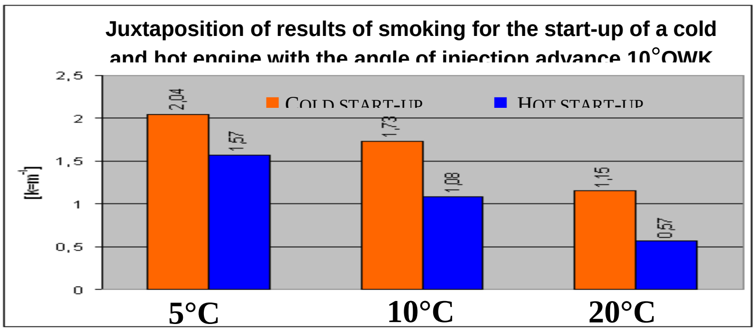

Fig.6. Juxtaposition of results of smoking for the start-up of a cold and hot engine with the angle of injection advance 10°OWK

Quantity comparison of the emission of toxic components: CO, HC, NOx and smoking, during cold and hot start-up of the engine for the angle of injection advance 24^{O}OWK – accelerated (nominal 18,5^{O}OWK) is presented in the Fig.7.

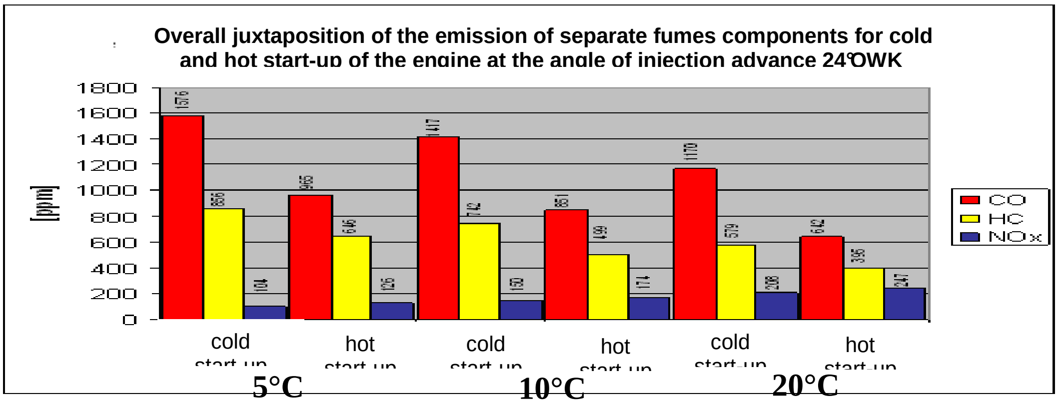

Fig.7. Overall juxtaposition of the emission of separate fumes components for cold and hot start-up of the engine at the angle of injection advance 24°OWK

Next Fig. 8 presents research results of smoking of the engine for cold and hot start-up At different environment temperatures (5°, 10°, 20°C), at the angle of injection advance of 24°OWK.

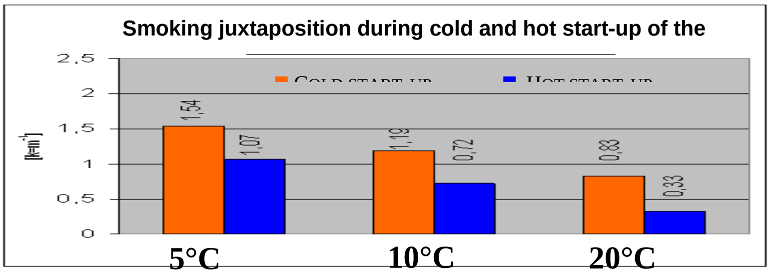

Fig.8. Smoking juxtaposition during cold and hot start-up of the engine for the angle of injection advance 24°OWK

The volume of the emission of separate fume components at the start-up of a cold and hot engine for the injection pressure of 20MPa, 18MPa, 16MPa in cylinders 1, 5, 3, with sustaining nominal values of pressure (nominal 22MPa) in the other cylinders, is shown in the Fig. 9.

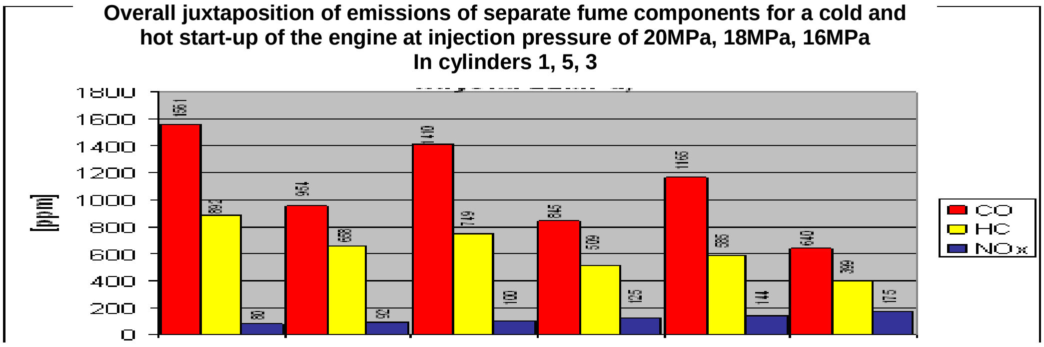

Fig. 9. Overall juxtaposition of emissions of separate fume components for a cold and hot start-up of the engine at injection pressure of 20MPa, 18MPa, 16MPa In cylinders 1, 5, 3

Overall juxtaposition of results of smoking tests of the engine at cold and hot start-up at different temperatures of the environment for modeled injection pressures in cylinders 1, 3, 5 is shown in the Fig. 10.

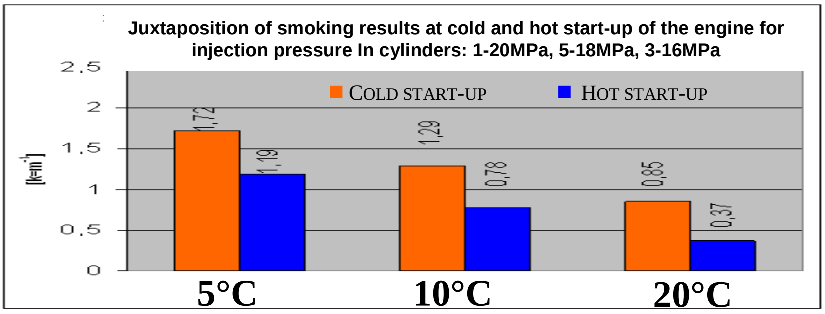

Fig. 10. Juxtaposition of smoking results at cold and hot start-up of the engine for injection pressure in cylinders: 1-20MPa, 5-18MPa, 3-16MPa

The contents of separate fume components and smoking at the start-up of a cold and hot engine at injection pressure of 23MPa, 24MPa, 25MPa in cylinders 6, 2, 4 (in the other cylinders nominal 22MPa) is shown in the Fig. 11.

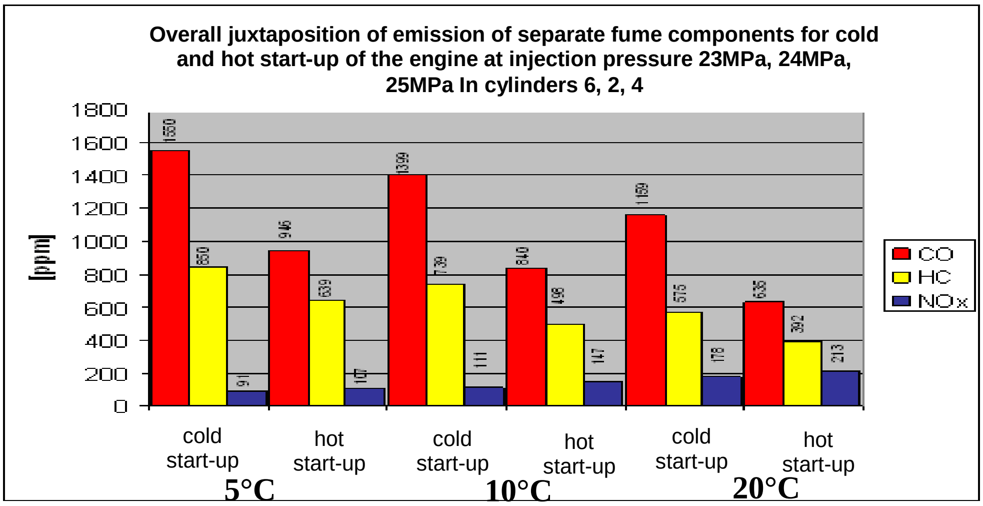

Fig. 11. Overall juxtaposition of emission of separate fume components for cold and hot start-up of the engine at injection pressure 23MPa, 24MPa, 25MPa In cylinders 6, 2, 4

The values of fume smoking at cold and hot start-up of the engine for modeled injection pressures in cylinders: 6, 2, 4 at different temperatures of the environment, is shown in the Fig. 12.

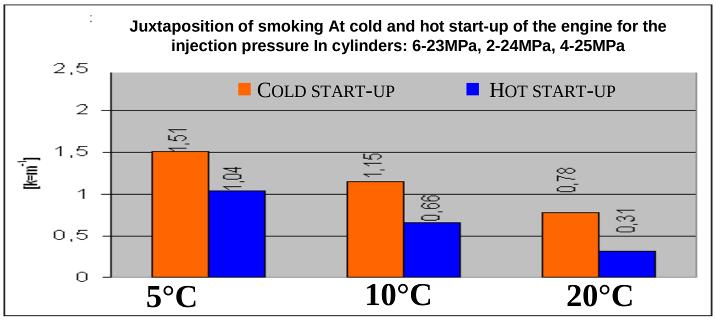

Fig. 12. Juxtaposition of smoking At cold and hot start-up of the engine for the injection pressure In cylinders: 6-23MPa, 2-24MPa, 4-25MPa

The contents of emissions of separate fume components and smoking at the start-up of a cold and hot engine for clearing of inlet valves of 0.15mm in cylinders 1, 5, 3 (nominal clearing 0.3mm) at different temperatures of the environment, is shown in the Fig. 13.

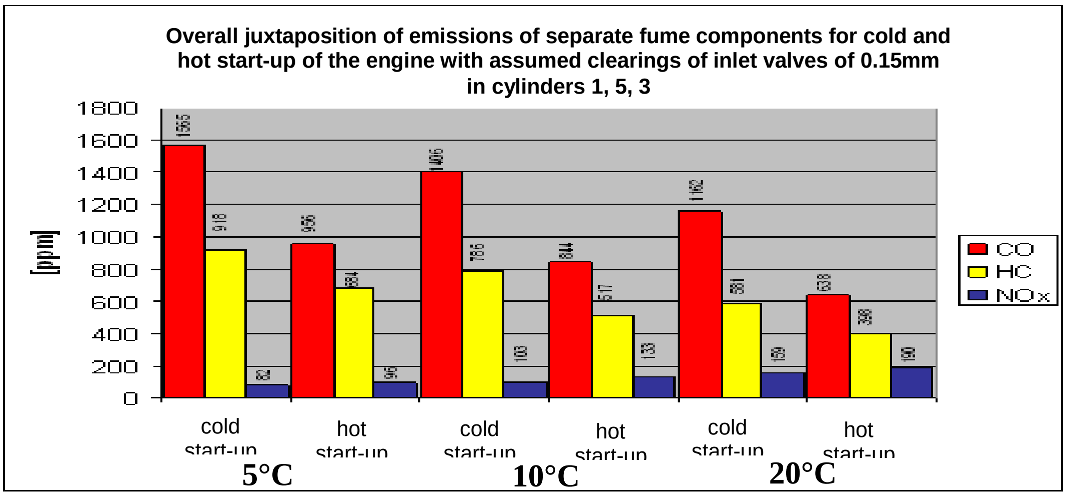

Fig. 13. Overall juxtaposition of emissions of separate fume components for cold and hot start-up of the engine with assumed clearings of inlet valves of 0.15mm in cylinders 1, 5, 3

The values of fume smoking at cold and hot start-up of the engine for modeled valve clearings in cylinders: 1, 5, 3 at different environment temperatures is shown in the Fig. 14.

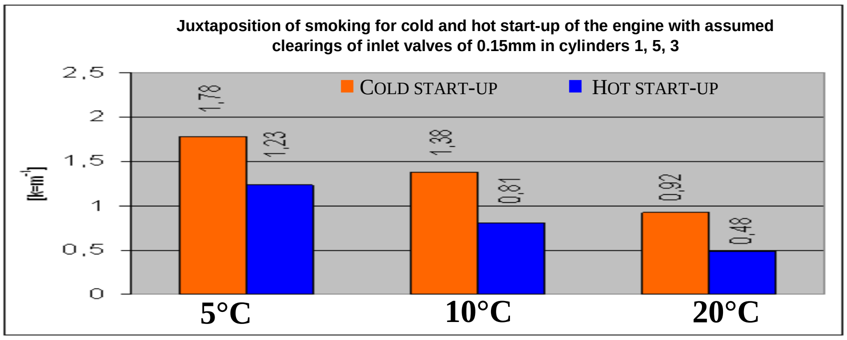

Fig.14. Juxtaposition of smoking for cold and hot start-up of the engine with assumed clearings of inlet valves of 0.15mm in cylinders 1, 5, 3

The contents of emissions of separate fume components and smoking at the start-up of a cold and hot engine for clearing of inlet valves 0.45mm in cylinders 1, 5, 3 (nominal clearing 0.3mm) at different environment temperatures is shown in the Fig. 15.

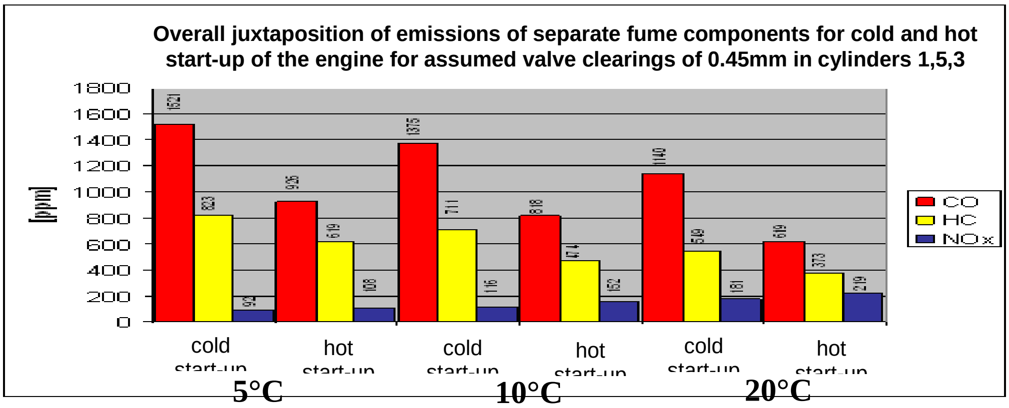

Fig. 15. Overall juxtaposition of emissions of separate fume components for cold and hot start-up of the engine for assumed valve clearings of 0.45mm in cylinders 1,5,3

The results of engine smoking tests at cold and hot start-up for different environment temperatures with modeled values of valve clearings is show in the Fig. 16.

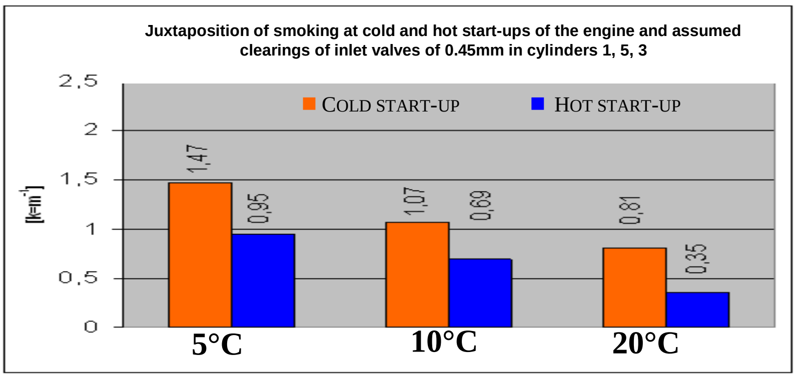

Fig. 16. Juxtaposition of smoking at cold and hot start-ups of the engine and assumed clearings of inlet valves of 0.45mm in cylinders 1, 5, 3

From the examined maladjustments, the highest influence on the increase of emissions of toxic fume components compared to an apt engine has the delayed angle of injection advance $\alpha_{ww} = 10^0 C$ before ZZ (nominal $\alpha_{ww} = 18{,}5^0 C$ before ZZ).

The second, deciding on the number of the volume of emitted toxic substances in fumes, is a maladjustment consisting in the acceleration of the injection advance angle ($\alpha_{ww} = 24^0 C$ before ZZ). More toxic compounds in fumes are emitted at a delayed angle of injection advance ($\alpha_{ww} = 10^0 C$ before ZZ) regardless the kind of the engine start-up and environment temperature.

Another maladjustment considerably affecting the volume of emitted toxic fume components is the decrease of clearing of 3 inlet valves from 0.3mm to 0.15mm. The analysis of separate periods of the engine's work showed that a considerable role for a cold and hot start-up of the engine is played by the first 60-70 seconds of work, in which maximum quantities of CO, HC, NO_x and smoking are emitted.

6. Summary

The presented results were submitted to statistical analysis, where the methods OPTIMUM and SVD were used, as well as correlation and regression methods. It gave the possibility of quality and quantity comparison of results of fumes contents from stationary tests and exploitation researches. The results of this research allow a model (mathematical relations) determination of relations between smoking and the quantity of toxic fume components of a high-pressure engine.

The performed tests and analyses in his work's researches indicate to the conclusions:

1. In the engine of self-acting fuse (ZS), the emission of carbon oxide (CO), hydrocarbons (HC) and smoking are considerable, especially during start-up and engine warming.
2. Along with the decrease of environment temperature, the emission of CO, HC and smoking increase, whilst the quantity of NOx goes down providing premises confirming the specified regulations of forming dangers on the side of engine fumes emission.
3. The phases of start-up and warming up of the ZS engine are characterized by increased fuel usage and increased emission of carbon oxide – CO, giving information and sensitizing vehicle users to these harmful for the engine working conditions.
4. The influence of environment temperature on the emission and smoking of fumes during hot start-ups is weaker than during cold start-ups.

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