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Assessing Concentration of the toxic Impact of Components in the Exhaust Gas of a Diesel Engine on the Thermal State of the Warm-Up Mode.

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ABSTRACT

At present, reduction emissions of harmful substances and fuel consumption while maintaining power indicators are priorities of the global drive engineering. Cooling system has significant role in this direction. The temperature of the coolant effects the concentration of harmful substances in the exhaust gases, particularly at the warm-up modes of engine. In this regard we provide the results of experimental studies of the effect of coolant temperature on toxic components concentration and normalized specific fuel consumption of vehicle diesel engine at warming up mode.
Keywords: temperature, coolant, exhaust gases, toxic components, diesel, nitrogen oxides, hydrocarbons, carbon monoxide, smoke, specific fuel consumption.

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INTRODUCTION

Increasing numbers of vehicles with internal combustion engines (ICEs), leads to the necessity of constant tightening of legislation limiting allowable concentrations of harmful components in exhaust gases (EG) of ICEs such as carbon monoxide CO, hydrocarbons CH, nitrogen oxides NOx, and particulate matter, provided that operating costs are low. In this regard, one of the main tasks of the modern drive engineering is to reduce emissions of harmful substances (EHS) from the EG into the environment. Tightening of existing regulations and the introduction of advanced environmental standards in the Russian Federation regulating the maximum level of specific mass concentration of EHS and EG requires deep domestic modernization of engine enterprises producing ICE and development of new engines with high technical-economic and environmental indicators. Compliance to the stringent regulations to limit the EG toxicity is the essential condition for improving the competitiveness of domestic ICEs.

Particularly tough requirements are applicable for vehicle engines, due to the specifics of their application and the operation in a wide range of loads and rotation frequencies of a crankshaft, a significant proportion of their operation time within unsteady modes (up to 80-90% of the total time in service). Due to this, it is necessary to investigate a warm-up mode of a diesel engine in detail as the work in this mode is complicated by the fact that the efficiency of catalytic converters providing the convertibility degree of no less than 50% of the combustion products (NO, CO, CH) is provided at the exhaust gas temperature of 500 ... 6000K at the entrance to the active converter element of the converter [1]. It should be noted that the majority of the Russian Federation vehicle fleet is operated from 3 to 6 months at low temperatures, thereby increasing the ICE heating time and the neutralization system output with efficient conversion mode.

MAIN PART

The concentration of toxic components (TC) in the exhaust gas of the engine is determined by its working process, which depends on a combination of different factors: design, operating and maintenance. The process of TC formation ys performed into a combustion chamber (CC) in the exhaust gas flow (the last during the course of gas cooling, as by natural heat dissipation so as by the mixing with the atmospheric air). The efficiency of intrachamber processes is determined by the organization of the mixing process of mixing, which includes the development of fuel torches, the heating and evaporation of fuel droplets, the mixing of fuel vapors, the heating of mixture to the temperature of self-ignition. While improving the diesel working process organization the part surface thermal state (TS) surfaces of CC should be considered as the temperature factor has a significant impact on the mixing, heat generation and diesel engine start-up characteristics. As a rule, the TS of an engine vehicle is estimated by the coolant temperature t_{OZh} [2,3,4]. In more recent publications [5-10] the engine TS is measured at the temperature of the cylinder wall (sleeve), as a more objective value compared with t_{OZh}. When the heat flow is reduced into the cooling system the CC detail temperature is increased, thereby increasing the maximum temperature of the engine operating cycle T_{zmax}, which is the major factor influencing the concentration of the exhaust gases rated by CC during the combustion of the fuel-air mixture (FAM). The values of local temperatures in a diesel CC is a fundamental factor of nitrogen oxides NOX formation at the combustion of FAM. In its turn, T_{zmax} increase reduces usually the opacity (optical density) KX of exhaust gases, CO and HC emissions, the intensification of soot oxidation, solid particles and the dissociation of carbon dioxide CO2 with the formation of CO and soot C [11]. The degree of TS diesel influence on exhaust smoke depends on the type of mixing. The exhaust smoke diesels with volume mixing processes are the least affected by temperature regime, and the diesel engines with a body-film mixing are most affected by temperature regime [11].

At the increase of cylinder unit head the air temperature TK is increased at inlet. On the one hand the cylinder mass filling us reduced with a fresh charge due to the filling ratio value decrease (the inlet air density is reduced), but on the other hand there is the intensification of the fuel evaporation process during the injection and mixing. Thereby the FAM combustion efficiency is increased in the cylinder. C and CO production is reduced respectively. As a rule, the stiffness of FAM combustion process is reduced due to the smooth running of pre-ignition reactions at the expense of TK value increase.

The work [12] performs the studies of t_{OZh} impact on BBB with exhaust gases. The studies were conducted in relation to the tractor diesel engine with liquid cooling 3CHN12/10.5. The influence of t_{OZh} is rated at crankshaft rotation frequencies n = 2000, and 1500 min^{-1}, corresponding to the nominal power and the maximum torque of a diesel engine. It is noted that the maintaining of EF temperature of the coolant at the range of 90 ... 100 °C of the CH and CO concentration in the exhaust gases decreased correspondingly by 110% and 20%. The most decrease was noted at low load modes, where the EF heating had the highest value. The increase of t_{OZh} led to increased concentration of NO_X and K_X in EG. The concentration of NO_X and K_X increase made 5 and 7%, respectively within a maximum load mode.

The examinations of the CT sleeve assembly details influence on TC with EG emissions [13] carried out with the car diesel 8CH11/11.5 (ZIL-645) show that the temperature rise of the cylinder wall from 100 to 150 °C leads to the specific emissions of carbon monoxide CO reduction by 18%, to the specific emissions of hydrocarbons CH increase by 18% and nitrogen oxides increase NOX by 23% [10]. The exhaust opacity K_X increased with the increase of the effective pressure proportion P_e in all modes of engine operation and made 4-34 units according "Hartridge" scale. The cylinder wall temperature increase has almost no effect on the EG K_X.

It should be noted that the TC TSPG ICE has a decisive influence on the formation of different types of deposits, the strength characteristics of part materials and the processes of the part surface wear. In this regard, it is necessary to know the temperature thresholds of TSPG parts, the excess of which leads to the formation of scale, varnish and sludge on the CC part surfaces. Therefore, it is important to keep the engine CT in the range of operation temperatures at which the compromise concerning the number of emissions regulated by TC, fuel consumption and the reliability (service life). The reduced values of BBB with EG are possible by maintaining optimal CT at each ICE mode.

The aim of this study is to explore the coolant temperature t_{OZhv} influence within the engine stand conditions on the environmental and economic performance of a diesel engine within a warm-up mode.

The object of this study is four-eight-piston diesel engine, equipped with gas turbine supercharge, the intermediate cooling of charge air and the fuel type battery system "CommonRail" KAMAZ 740.75-440 with the operation volume of V = 11,76 l, the compression ratio ε = 16,5, the rated power N = 323,5 kW at the crankshaft engine speed n = 1900 min^{-1}. The studies were conducted at the station of transient testing engine of RDC "KAMAZ" OJSC under the contract with the Russian Federation Ministry of Education № 02.G25.31.0004 dated on 12/02/2013.

The experimental studies of t_{OZh} influence on the smoke, NO_X, CO, CHB EG concentration and the specific fuel consumption was determined at the partial load operation within the engine speed of n = 1000 min^{-1} and N_e = 125 kW. This mode is an optimal one based on the fact that the diesel engines of this type are heated during the operation, usually at a minimum sustainable rotation frequency of a crankshaft (in order to minimize wear of friction pair nodes) with the load providing the desired heat flow into CO. t_{OZh} measurement was conducted between the third and the fourth cylinders.

SUMMARY

The obtained results of the diesel pilot study indicate a substantial t_{OZh} influence on the environmental indicators and a slight influence on economic indicators. The experimental results are presented by Fig. - 1a, b, c, d and 2. So, the increase of t_{OZh} from 40 to 90 0C significantly reduces the K_X opacity and the carbon monoxide (CO) concentration by 41% (from 0.355 to 0.21 m-1 according to Bosch scale) and 79.5% (from 830 to 168 ppm), respectively. The concentration of CH incomplete combustion products at t_{OZh} from 40 to 80 0C is increased by 8.9%, and at the increase of 90 0C it is increased slightly. The dependence of nitrogen oxides concentration NO_X has a more complex character. At the increase of t_{OZh} from 40 to 45 ^{0}C the output is increased from 595 to 640 ppm, i.e. by 7%, at the increase of t_{OZh} to 75 ^{0}C the output id reduced by 27% (from 640 to 467 ppm) and with the further increase to 90 ^{0}C it is slightly increased again by 4.6% (from 490 to 467 ppm). It should be noted that the t_{OZh} increase did not have a material ge impact. A slight decrease of no more than 1% was noted.

CONCLUSIONS

Finally, it should be noted that the presented data of experimental studies confirm the possibility of TC and EG concentration by controlling the CT of the motor vehicle, thereby reducing the negative impact on the environment.

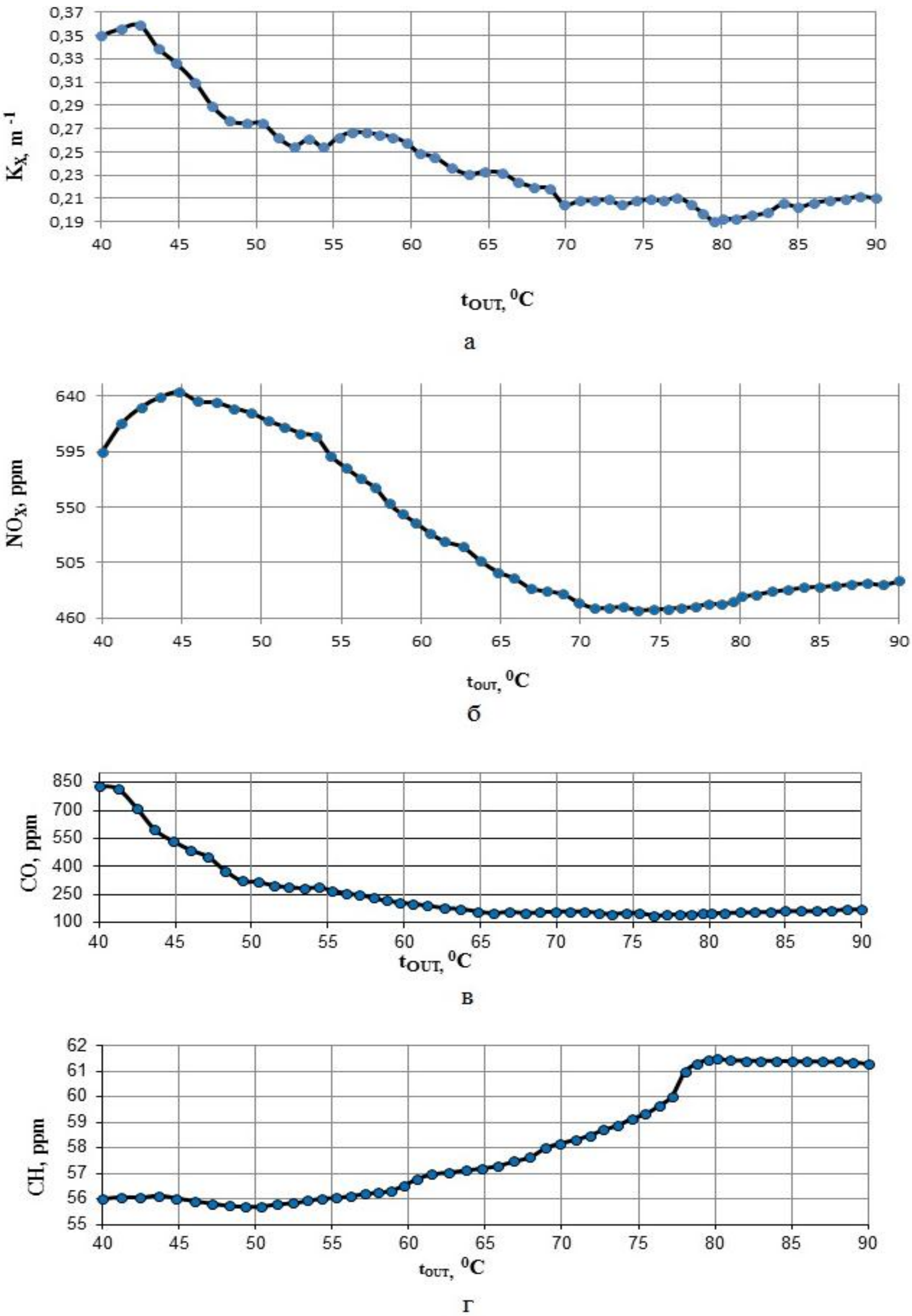

Figure 1: Dependence of TC concentration on CF temperature

a - opacity K_X;б – nitrogen oxide NO_X; в - carbon monoxide CO; г – carbohydrates CH

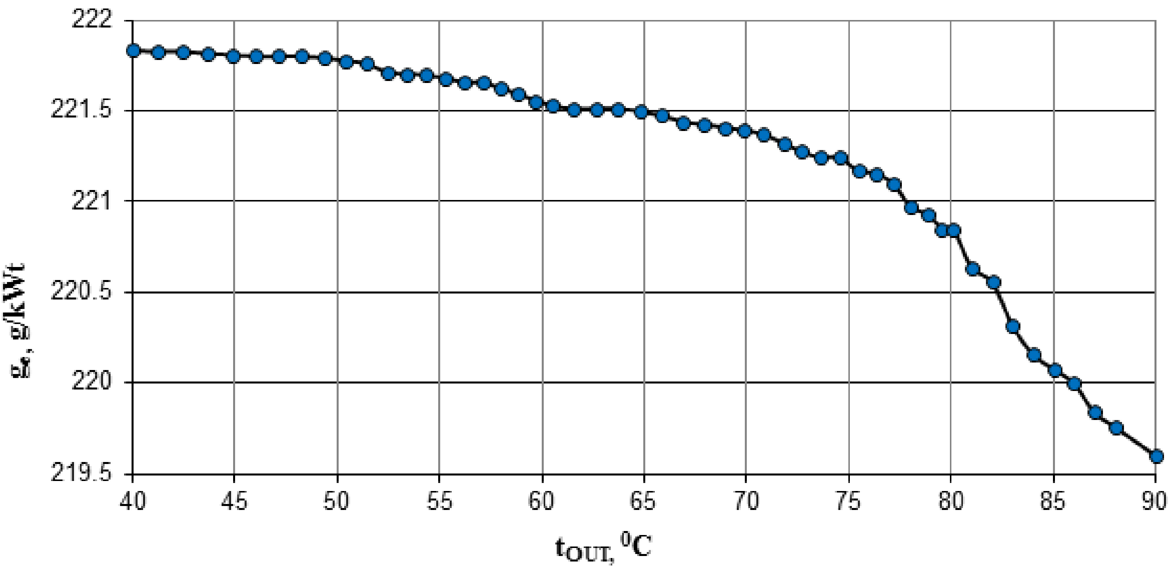

Figure 2: Dependence of specific fuel consumption on the CF temperature

References

[1] Medvedev G.V., Novoselov A.L., Novoselova T.V., Melbert A.A. Effect of diesel exhaust gas temperature on the quality of their cleaning from harmful substances // Bulletin of AltSTU named after I.I. Polzunov. - 2012 - # 3 -S. Pages: 150-154.

[2] Liquid cooling of automobile engines / A.L. Kriger, M.E. Diskin, A.L. Novennikov., V.I. Pikus.- M.: Machinery, 1985, 176 pages.

[3] Markov V.A., Bashirov R.M., Gabitov I.I. Exhaust emissions of diesel engines toxicity. - M.: publ. of MSTU named after N.E. Bauman, 2002 - 376 pages.

[4] A.K. Kostin, Larionov V.V., Mikhailov L.I. Thermal stress of internal combustion engines. L.: Engineering, 1979 - 222 pages.

[5] Allen, D., and Lasecki, M., "Thermal Management Evolution and Con-trolled Coolant Flow", SAE paper no. 2001-01-1732, 2001 .- 18 pp

[6] Chalgren, Jr, R., and Allen, D., "Light Duty Diesel Advanced Thermal Management," SAE paper No. 2005-01-2020, 2005.

[7] Chanfreau, M., Gessier, B., Farkh, A., and Geels, P., "The Need for an Electrical Water Valve in a Thermal Management Intelligent System", SAE paper no. 2003-01-0274, 2003.

[8] Gureev V.M., Salahov R.R., Khayrullin A.H., Salahov I.R., Sosnowski A.P. Cogeneration power plants improvement by applying an adaptive cooling system // Energy system of Tatarstan. - 2011 - # 1. -Pages 33-36.

[9] Salahov R.R., Gureev V.M., Khayrullin A.H., Salahov I.R. Adaptive control system for internal combustion engines cooling system // Trudy MAI. -2012. # 61 P. 16.

[10] Gureev V.M., Sosnowski A.P., Yunusov R.R., Gureev M.V., Salahov R.R. Modernization of series oil cooler engine "KAMAZ" // Bulletin of Kazan State Technical University named after A.N. Tupolev. -2012. C # 3. 41-45.

[11] Cortona, E., Onder, C.H., "Engine Thermal Management with Electric Cooling Pump," SAE Paper 2000-01-0965, 2000.

[12] Efros V.V. Lazarev V.M. The effect of coolant temperature on the values of three-cylinder tractor diesel // "Tractors and agricultural machinery" .- 2008 # 5 S.18-19.

[13] Nesiolovsky O.G. Improvement of car diesel engine efficiency by controlling its thermal state. // Abstract of the t.s.c. thesis, YPU. Yaroslavl, 1995.