Theoretical calculations of the volume content of nitrogen oxides in a diesel cylinder when operating on methanol

A A Anfilatov and A N Chuvashhev
Department of thermal engines, Vehicles and tractors, Vyatka State Agricultural Academy, October prospect, 133, Kirov, 610017, Russian Federation

E-mail: anfilatov001@mail.ru

Abstract. The results of theoretical calculations on the change in the volume content of nitrogen oxides in the cylinder of a base diesel engine when operating on methanol with separate supply of two fuels, depending on the angle of rotation of the crankshaft, are presented. Their specific values have been determined, for the base engine, allowing to ensure an acceptable value of the concentrations of nitrogen oxides in the combustion products, by improving the design and adjustment characteristics of the diesel engine.

At present, the reduction of atmospheric air pollution by toxic substances of automobile transport is one of the most important problems facing mankind. Air pollution has a harmful effect on humans and the environment. Material damage caused by air pollution by vehicles is difficult to assess. With intensive urbanization and the growth of megacities, auto-mobile transport has become the most unfavorable environmental factor in protecting human health and the environment.

The exhaust gases (EG) of internal combustion engines (ICE) contain about 200 harmful components, of which more than 160 are hydrocarbon derivatives resulting from incomplete combustion of fuel in an ICE. The exhaust gas toxicity of gasoline engines is mainly determined by the content of carbon oxides (CO), and of diesel engines by nitrogen oxides (NOx) and smoke (C). Among the harmful components are solid emissions containing soot particles, on the surface of which polycyclic hydrocarbons are adsorbed, which have carcinogenic properties. The formation of toxic substances - products of incomplete combustion and NOx in the engine cylinder during the combustion process occurs in fundamentally different ways. The first group of toxic substances is associated with chemical reactions of oxidation of the fuel, proceeding both in the pre-flame period and in the combustion process - expansion. The second group of toxic substances is formed by the combination of nitrogen and excess oxygen in the products of combustion. Therefore, it is advisable to separately consider the mechanism of formation of these toxic substances [1-4].

The emission of NOx with exhaust gas, in accordance with the classical theory of the formation of nitrogen oxides, depends on the temperature in the combustion chamber (CC) of the ICE. The higher the engine load, the higher the temperature in the CC, and accordingly the greater the emission of NOx. In addition, the temperature in the CC largely depends on the composition of the mixture. A mixture that is too depleted or enriched during combustion releases less heat, the combustion process slows down and is accompanied by large losses of heat into the walls, i.e. under such conditions, less NOx is released. Emissions of toxic components increase when the composition of the mixture is close to stoichiometric. For diesel engines, the composition of NOx depends on the installation angle of the...
advance of fuel injection (AAFI) and the delay period of ignition of the fuel. With an increase in the installation of the AAFI, the ignition delay period lengthens, the uniformity of the air-fuel mixture improves, more fuel evaporates, and the temperature rises sharply during combustion, i.e. the amount of NOx increases [5-9].

The authors carried out theoretical calculations of the volumetric content of r NOx calc nitrogen oxides in the cylinder of a diesel engine 2H 10.5 / 12.0 when operating on diesel fuel (DF) and on methanol with a separate feed depending on the angle of rotation of the crankshaft at nominal load mode rotational speed (n = 1800 min⁻¹). The results of theoretical calculations on the change in the volumetric content r NOx of nitrogen oxides in the diesel cylinder 2H 10.5 / 12.0 when working on diesel fuel and methanol with a separate feed depending on the angle for a nominal speed of 1800 min⁻¹ at the values of the installation AAFI Θdf = 30 °; Θm = 30 ° are shown in figure 1, a.

The curves presented in the graphs show that the maximum value of the theoretical calculated volumetric content r NOx max calc of nitrogen oxides in the diesel cylinder when working on DF is 602 ppm at ϕ = 22.0 ° of crankshaft rotation after TDC [10,11].

The value of the theoretical calculated volumetric content r NOx calc of nitrogen oxides in the diesel cylinder when operating on diesel fuel at ϕ = 140.0 ° of crankshaft rotation after TDC (output calculated value r NOx out calc at the time the exhaust valve opens) is 464 ppm.

The graphs show that the maximum value of the theoretical calculated volumetric content r NOx max calc of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 402 ppm at ϕ = 27.5 ° crankshaft rotation after TDC. The decrease is 33.2%.

The value of the theoretical calculated volumetric content r NOx calc of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at ϕ = 140.0 ° of crankshaft rotation after TDC (output calculated value r NOx out calc at the moment of opening the exhaust valve) is 310 ppm. The decrease is 33.2% [12-14].

The results of theoretical calculations on the change in the volumetric content r NOx calc of nitrogen oxides in a 2H 10.5 / 12.0 diesel cylinder depending on the angle of rotation of the crankshaft when operating on methanol with a separate feed for a rotational speed of 1800 min⁻¹ at Θdf = 30 °; Θm = 34 ° of crankshaft rotation are also presented in figure 1, a.

It can be seen from the graphs that the maximum value of the theoretical calculated volumetric content r NOx max calc of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 426 ppm at ϕ = 28.5 ° of crankshaft rotation after TDC. The decrease is 29.2%.

The value of the theoretical calculated volumetric content r NOx calc of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at ϕ = 140.0 ° of crankshaft rotation after TDC (output calculated value r NOx out calc at the moment of opening the exhaust valve) is 328 ppm. The decrease is 29.2%.

The calculation results on the change in the theoretical volumetric content r NOx calc of nitrogen oxides in the cylinder of the diesel engine 2H 10.5 / 12.0 depending on the angle of rotation of the crankshaft during operation on diesel fuel and on methanol with a separate feed for a rotational speed of 1800 min⁻¹ at Θdf = 38 °; Θm = 30 ° of crankshaft rotation are shown in figure 1, b.

It can be seen from the curves presented in the graphs that the maximum value of the theoretical calculated volumetric content r NOx max calc of nitrogen oxides in the diesel cylinder when working on diesel fuel is 602 ppm at ϕ = 22.0 ° of crankshaft rotation after TDC [15-18].

The value of the theoretical calculated volumetric content r NOx calc of nitrogen oxides in the diesel cylinder when operating on diesel fuel at ϕ = 140.0 ° of crankshaft rotation after TDC (output calculated value r NOx out calc at the time the exhaust valve opens) is 464 ppm.

It can be seen from the graphs that the maximum value of the theoretical calculated volumetric content r NOx max calc of nitrogen oxides in the cylinder of the diesel when working on methanol with a separate feed is 411 ppm at ϕ = 26.0 ° of crankshaft rotation after TDC. The decrease is 31.7%.
The value of the theoretical calculated volumetric content $r_{NO \times \text{calc}}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at $\phi = 140.0^\circ$ of crankshaft rotation after TDC (output calculated value $r_{NO \times \text{out calc}}$ at the moment of opening the exhaust valve) is 316 ppm. The decrease is 31.8% [19-22].

![Graph of NOx content](image)

**Figure 1.** The results of theoretical calculations on the change in the volumetric content of nitrogen oxides in a 2H 10.5 / 12.0 diesel cylinder when operating on methanol with a separate feed depending on the angle of rotation of the crankshaft at $n = 1800 \text{ min}^{-1}$: | |; | ; | ;

- $\Theta_{df} = 30^\circ$, $\Theta_m = 30^\circ$; $\cdots \cdots \Theta_{df} = 30^\circ$, $\Theta_m = 34^\circ$;
- $\Theta_{df} = 38^\circ$, $\Theta_m = 30^\circ$; $\cdots \cdots \Theta_{df} = 38^\circ$, $\Theta_m = 34^\circ$; $\cdots \cdots \Theta_{df} = 38^\circ$, $\Theta_m = 38^\circ$.

The results of theoretical calculations on the change in the volumetric content $r_{NO \times \text{calc}}$ of nitrogen oxides in a 2H 10.5 / 12.0 diesel cylinder depending on the angle of rotation of the crankshaft when operating on methanol with a separate feed for a rotational speed of 1800 $\text{min}^{-1}$ at $\Theta_{df} = 38^\circ$, $\Theta_m = 34^\circ$ are also presented in figure 1, b.

From the graphs it can be seen that the maximum value of the theoretical calculated volumetric content $r_{NO \times \text{max calc}}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 380 ppm at $\phi = 24.0^\circ$ of crankshaft rotation after TDC. The decrease is 36.8%.

The value of the theoretical calculated volumetric content $r_{NO \times \text{calc}}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at $\phi = 140.0^\circ$ of crankshaft rotation after TDC (output calculated value $r_{NO \times \text{out calc}}$ at the moment of opening the exhaust valve) is 293 ppm. The decrease is 36.8%.
The results of theoretical calculations on the change in the volumetric content $r_{NO\times calc}$ of nitrogen oxides in a 2H 10.5 / 12.0 diesel cylinder depending on the angle of rotation of the crankshaft when operating on methanol with a separate feed for a rotational speed of 1800 min$^{-1}$ at $\Theta_{df} = 38^\circ$, $\Theta_{m} = 38^\circ$ are also presented in figure 1, b.

From the graphs presented, it can be seen that the maximum value of the theoretical calculated volumetric content $r_{NO\times max\; calc}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 425 ppm at $\phi = 22.5^\circ$ of crankshaft rotation after TDC. The decrease is 29.4%.

The value of the theoretical calculated volumetric content $r_{NO\times calc}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at $\phi = 140.0^\circ$ of crankshaft rotation after TDC (output calculated value $r_{NO\times out\; calc}$ at the moment of opening the exhaust valve) is 327 ppm. The decrease is 29.5% [23,24]. The results of theoretical calculations on the change in the volume content $r_{NO\times calc}$ of nitrogen oxides in the cylinder of a diesel engine 2H 10.5 / 12.0 depending on the angle of rotation of the crankshaft during operation on diesel fuel and on methanol with a separate feed for a rotational speed of 1800 rpm at $\Theta_{dt} = 34^\circ$; $\Theta_{m} = 30^\circ$ are shown in figure 2.

It can be seen from the graphs that the maximum value of the theoretical calculated volumetric content $r_{NO\times max\; calc}$ of nitrogen oxides in the diesel cylinder when working on diesel fuel is 602 ppm at $\phi = 22.0^\circ$ of crankshaft rotation after TDC.

The value of the theoretical calculated volumetric content $r_{NO\times calc}$ of nitrogen oxides in the diesel cylinder when operating on diesel fuel at $\phi = 140.0^\circ$ of crankshaft rotation after TDC (output calculated value $r_{NO\times out\; calc}$ at the time the exhaust valve opens) is 464 ppm. It can be seen from the curves presented in the graphs that the maximum value of the theoretical calculated volumetric content $r_{NO\times max\; calc}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 415 ppm at $\phi = 27.5^\circ$ of crankshaft rotation after TDC. The decrease is 31.0%. The value of the theoretical calculated volumetric content $r_{NO\times calc}$ of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at $\phi = 140.0^\circ$ of crankshaft rotation after TDC (output calculated value $r_{NO\times out\; calc}$ at the moment of opening the exhaust valve) is 319 ppm. The decrease is 31.2%.

The results of theoretical calculations on the change in the volumetric content $r_{NO\times calc}$ of nitrogen oxides in a 2H 10.5 / 12.0 diesel cylinder depending on the angle of rotation of the crankshaft when operating on methanol with a separate feed for a rotational speed of 1800 min$^{-1}$ at $\Theta_{df} = 34^\circ$, $\Theta_{m} = 34^\circ$ are also presented in figure 2.

![Figure 2](image-url)
The graphs show that the maximum value of the theoretical calculated volumetric content \( r_{NOx_{max}}^{calc} \) of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 399 ppm at \( \varphi = 25.0^\circ \) of crankshaft rotation after TDC. The decrease is 33.9%.

The value of the theoretical calculated volumetric content \( r_{NOx_{calc}}^{calc} \) of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at \( \varphi = 140.0^\circ \) of crankshaft rotation after TDC (output calculated value \( r_{NOx_{out calc}}^{calc} \) at the moment of opening the exhaust valve) is 307 ppm. The decrease is 33.8% [25-27].

The results of theoretical calculations on the change in the volumetric content \( r_{NOx_{calc}}^{calc} \) of nitrogen oxides in a 2H 10.5 / 12.0 diesel cylinder depending on the angle of rotation of the crankshaft when operating on methanol with a separate feed for a rotational speed of 1800 rpm at \( \Theta_{df} = 34^\circ \); \( \Theta_{in} = 38^\circ \) are also presented in figure 2.

From the curves presented in the graphs, it can be seen that the maximum value \( r_{NOx_{max}}^{calc} \) of the theoretical calculated volumetric content of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed is 476 ppm at \( \varphi = 24.0^\circ \) of crankshaft rotation after TDC. The decrease is 20.9%.

The value of the theoretical calculated volumetric content \( r_{NOx_{calc}}^{calc} \) of nitrogen oxides in the diesel cylinder when operating on methanol with a separate feed at \( \varphi = 140.0^\circ \) of crankshaft rotation after TDC (output calculated value \( r_{NOx_{out calc}}^{calc} \) at the moment of opening the exhaust valve) is 367 ppm. The decrease is 20.9%.

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