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РЕСПУБЛИКИ КАЗАХСТАН
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MODELING OF THE COMBUSTION PROCESS IN A DIESEL ENGINE

Abstract. The issues of combustion processes and the organization of the combustion workflow in diesel engines are relevant in view of the tightening of economic and environmental requirements for them. The problem of saving liquid fuels remains one of the most acute in the provision of fuel and energy resources. The development of highly efficient methods for organizing work processes when burning natural gas in a compressed or cryogenic state in the cylinders of internal combustion piston engines and determining ways to further reduce toxic emissions, increase fuel efficiency and reliability in promising gas engines is an urgent task. Mathematical modeling of liquid fuel combustion is a complex task, since it requires taking into account a large number of complex interrelated processes and phenomena. The article presents a simple 3-D model of cylinder diesel tractor engine D 144, the results of numerical simulation of combustion of liquid and gaseous fuel in the cylinder of the diesel engine D-144. The article presents the results of modeling, including graphs of the dependence of nitrogen oxides, particles in outgoing gases, depending on the consumption of gaseous fuel in the form of pure methane. Additionally, temperature and velocity contours are shown. The corresponding conclusions are made.

Key words: internal combustion engine, simulation, nitrogen oxides, liquid fuel.

Introduction. At the moment, a lot of work is underway to develop efficient internal combustion engines with high environmental performance. It is obvious that internal combustion engines, like all heat engines, are sources of both heat, sound and, most importantly, environmental pollution, since there is no alternative to burning fossil fuels. On the other hand, it is difficult to imagine a serious alternative to internal combustion engines at the moment, since modern electric vehicles do not have a sufficiently high reliability and economy.

At the moment, there are quite a lot of studies in the field of reducing harmful emissions of internal combustion engines, these include mixing hydrogen fuel [1, 3, 10, 12], using modern water injection control systems [2], swirling the flow [4], diluting various types of fuel with liquefied gas [5] or methane [6], diesel [7], catalysis [8], gas recirculation [9], "poor" burning [11].

From the point of view of the efficiency of the hydrogen fuel of course there has pros, this high flame temperature and the flammability limit low. However, hydrogen fuel is quite dangerous and more stringent safety conditions are required when using it. Water injection is a fairly widely used technology, but it has its drawbacks in the form of the possibility of formation of corrosion debugs, flame attenuation with uneven distribution. Water can also affect the formation of carbon monoxide, which can be formed in the event of a sharp "cooling" in the cold parts of the cylinder.

Twisting is a fairly effective technology, but it cannot radically solve the problems of toxic substances formation. The most appropriate way to reduce the formation of toxic substances can be considered the use of various fuels together with the main fuel.

In the article [12], such additives as methanol, ethanol, and n-butanol were used. The results showed that dilution of the main fuel with alkaloids leads to a decrease in the formation of CO and aerosol particles, which are integral products of combustion. However, the addition of alkaloids increased the formation of nitrogen oxides. The use of oxygen as an additive to the oxidizer [14, 16, 17, 18] in the combustion of methanol has shown greater efficiency in terms of carbon monoxide. At the maximum oxygen concentration, the CO content decreased from 48.59 to 30.9%. However, the concentration of nitrogen oxides has increased significantly from 38.7% to 112.2%. Adding nanoparticles in the form of oxides of titanium and zinc [15] have led to a decrease in hydrocarbon concentrations from 37 to 26%, the content of carbon monoxide from 36 to 26% and reduce the concentration of nitrogen oxides from 19 to 15%.

All of the above shows that the method of diluting the main fuel is quite a promising technology. On this basis the authors performed a numerical simulation of the combustion processes when adding to the fuel of natural gas.

The combustion process is a rather complex process that includes both chemical processes of fuel oxidation and physical processes of mixing of high-temperature gases in the combustion zone. To improve work efficiency the internal combustion engine, in particular the combustion process, a clear understanding of the processes that occur during the combustion of fuel.

From an economic point of view, the most suitable method is numerical modeling of combustion processes [3, 8, 11]. There are difficulties in the form of the influence of the temperature of the cylinder walls and the process of heat transfer from the walls to the gases, so an important aspect is to take into account heat exchange. Unfortunately, at the moment it is not possible to obtain a sufficiently accurate model in the form of the factors described above, but it is advisable to use models for approximate calculations.

Model. A simple 3-D model of the D 144 diesel tractor engine cylinder was used in the simulation (figure 1). The dimensions of the cylinder are 105x120 mm. Fuel was supplied from point 1, and an oxidizer in the form of air was supplied from point 2. When modeling, it was assumed that there is no swirl of the current. The initial modeling conditions are shown in table.

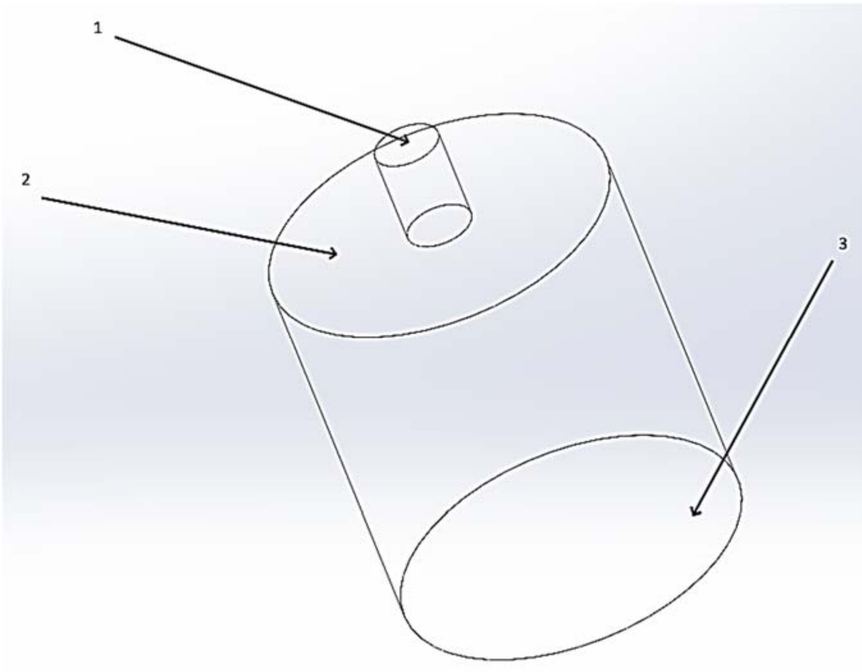

Figure 1 – Iisometric view of the burner device:
1 – fuel inlet nozzle; 2 – air inlet; 3 – outlet

During the simulation, it was assumed that the air flow rate was constant and equal to 20 m/s, and the flow rate of gaseous fuel varied in the range of 0-15 m/s. N-pentane (c5h16) was used as the main liquid fuel.

Initial parameters

Option No.	Gas fuel consumption, kg/hour	Air speed, m/s	Initial temperature of the oxidizer (air)/fuel, K	Number of tetrahedral elements in the simulated area
1	0	20	300	200 000
2	19.152			
3	38.16			
4	54			

To study the effect of liquid droplet flow, the injection function was used. The fuel consumption was 0.001 kg/s, the flow rate was 20 m / s, and the drop diameter was 0.0001 m. The k-ε turbulent model was used to model combustion processes.Gorenje The standard k-ε model is a model based on model transport equations for the kinetic energy of turbulence and its dissipation rate (ε) [6].

Results. Figure 2 shows the temperature contours at different speeds of the gaseous fuel. As can be seen from the figures, when the gas flow rate increases, the high-temperature zone moves lower to the cylinder. Moreover, the temperature contours do not change their structure.

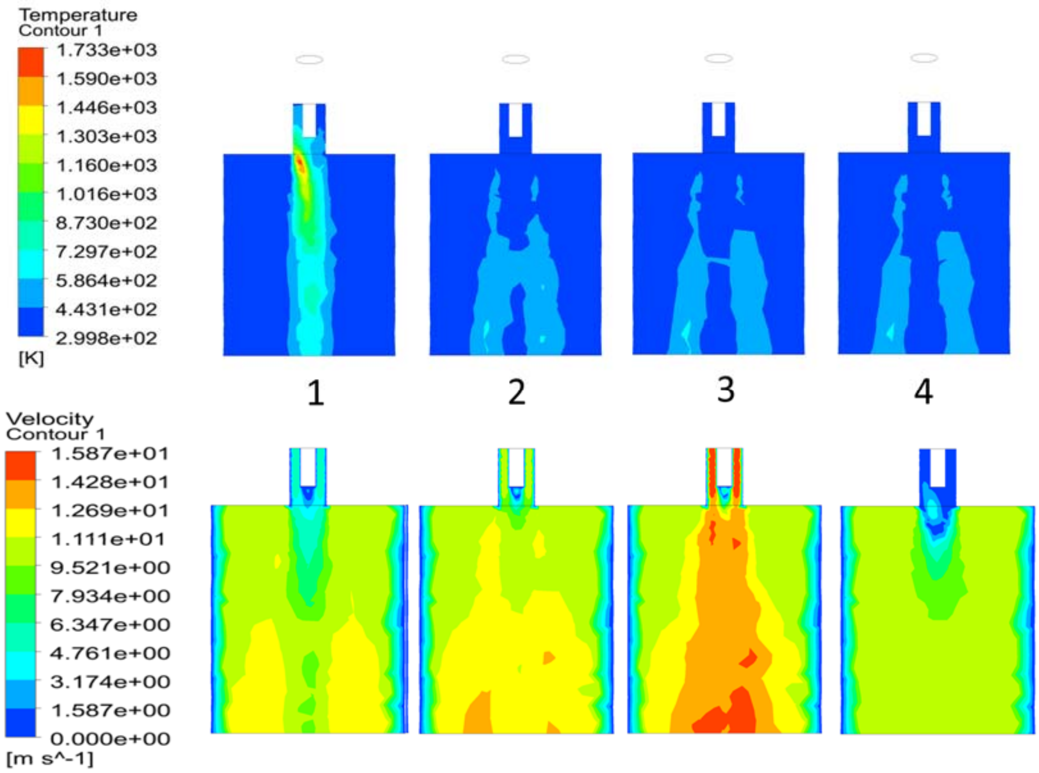

Figure 2 – Temperature and speed contours at different fuel consumption

Nitrogen oxide. Figure 3 shows the dependence of the concentration of nitrogen oxides on the consumption of organic fuel. As can be seen from the figure, the maximum concentrations of oxides are observed when pure liquid fuel is supplied. When the gas flow rate increases, the concentration of nitrogen oxides decreases, but after a certain value, the concentrations increase. This is because when a certain concentration increases, the temperature in the combustion zone increases, and the completeness of combustion increases accordingly, which leads to an increase in the concentration of nitrogen oxides [17, 18].

Figure 4 shows the dependence of the particle concentration in the outgoing gases on the flow rate of the gaseous fuel. This graph shows that as gas consumption increases, the number of particles with underburned increases.

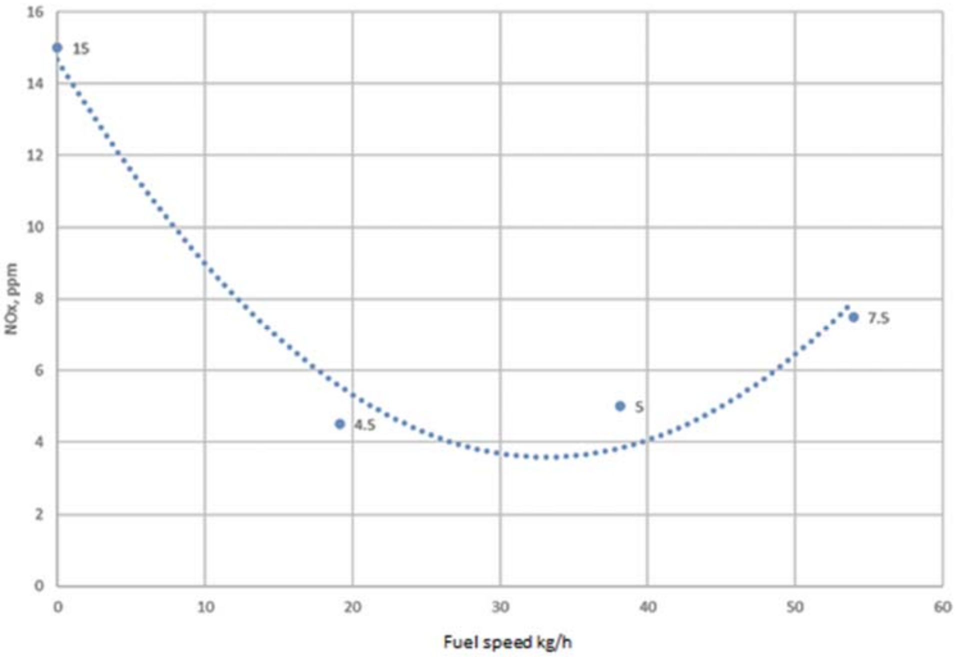

Figure 3 – Dependence of nitrogen oxide concentrations on fuel consumption

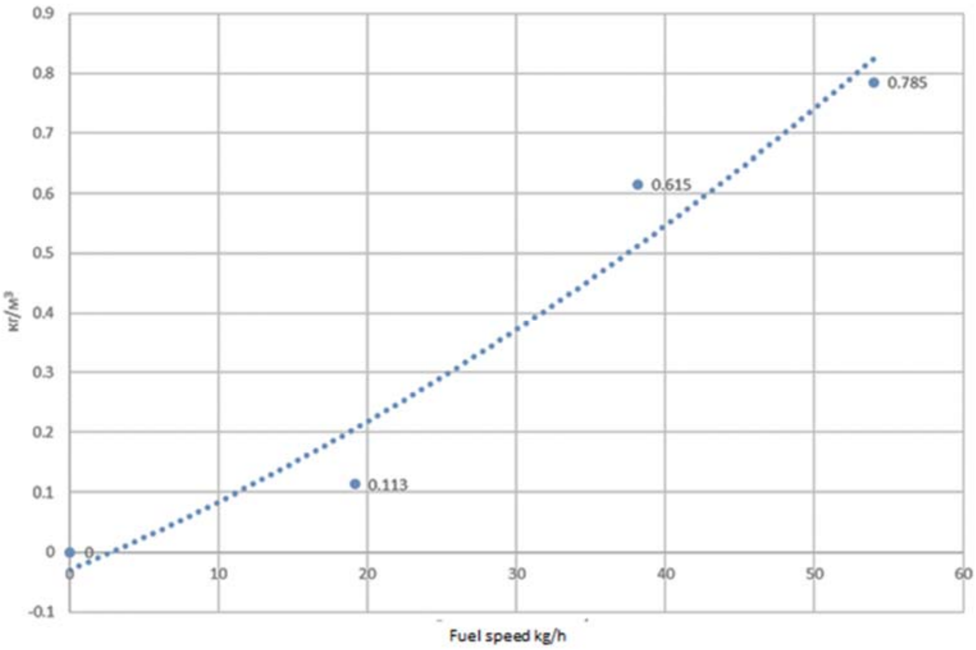

Figure 4 – Concentration particle in exhaust gases depending on fuel consumption

Conclusion. The article presents the results of modeling the combustion of liquid fuel with dilution with gaseous fuel (methane). From the presented results, we can say that the most optimal flow rate is 20 kg/s. This flow rate is optimal from the point of view of nitrogen oxides, as well as from the point of view of the concentration of particles at the exit of the cylinder.

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ДИЗЕЛЬДІ ҚОЗҒАЛТҚЫШТАҒЫ ЖАНУ ПРОЦЕСІН МОДЕЛЬДЕУ

Аннотация. Дизельді қозғалтқыштардағы жану процестерінің және жұмыс процесін ұйымдастырудың мәселелері оларға қойылатын экономикалық және экологиялық талаптарды қатаңдату тұрғысынан өзекті болып табылады. Сұйық отынды үнемдеу проблемасы отын-энергетикалық ресурстармен қамтамасыз етудегі ең өткір мәселелердің бірі болып қалуда. Сығылған немесе криогендік күйдегі табиғи газды ішкі жану қозғалтқыштарының цилиндрлерінде жағу кезінде жұмыс процестерін ұйымдастырудың жоғары тиімді әдістерін жасау және улы шығарындыларды одан әрі азайту, перспективалық газ қозғалтқыштарында отын тиімділігі мен сенімділігін арттыру жолдарын анықтау өзекті мәселе болып табылады. Сұйық отынның жануын математикалық модельдеу қиын міндет, өйткені ол көптеген күрделі өзара байланысты процестер мен құбылыстарды ескеруді қажет етеді.

Мақалада модельдеу нәтижелері, соның ішінде таза метан түріндегі газ тәрізді отынның шығынына байланысты азот оксидтерінің, шығатын газдардағы бөлшектердің тәуелділік графигі келтірілген. Сонымен қатар, температура мен жылдамдықтың контурлары келтірілген. Тиісті қорытындылар жасалды.

Түйін сөздер: ішкі жану қозғалтқышы, модельдеу, азот оксиді, сұйық отын.

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МОДЕЛИРОВАНИЕ ПРОЦЕССА СГОРАНИЯ В ДИЗЕЛЬНОМ ДВИГАТЕЛЕ

Аннотация. Вопросы процессов горения и организации рабочего процесса горения в дизельных двигателях являются актуальными в виду ужесточения экономических и экологических требований к ним. Проблема экономии жидких топлив остается одной из самых острых в обеспечении топливно-энергетическими ресурсами. Разработка высокоэффективных способов организации рабочих процессов при сжигании природного газа, находящегося в сжатом или криогенном состоянии, в цилиндрах поршневых двигателей внутреннего сгорания и определение путей дальнейшего уменьшения токсичных выбросов, повышения топливной экономичности и надежности в перспективных газовых двигателях является актуальной задачей.

Математическое моделирование горения жидких топлив является сложной задачей, так как требует учета большого количества сложных взаимосвязанных процессов и явлений.

В статье представлены результаты моделирования горения жидкого топлива с разбавлением газообразным топливом (метан), в том числе графики зависимости оксидов азота, частиц в уходящих газах в зависимости от расхода газообразного топлива в виде чистого метана. Кроме того, показаны контуры температуры и скорости. Сделаны соответствующие выводы.

Ключевые слова: двигатель внутреннего сгорания, моделирование, оксид азота, жидкое топливо.

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