The use of light fractional composition fuels in the electric flame jet of a diesel engine

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Abstract. In recent years, there has been an increased interest in the development of the polar territories of our planet. A large number of minerals on land and in the shelves attracts the attention of our contemporaries. Development of these territories with a harsh climate is possible by using modern vehicles and mechanisms that ensure the exploration of sediment layers, extraction of deposits, transportation of rocks and raw materials. The most common mode of transportation in these conditions are motorized vehicles. One of the most important aspects in the operation of automotive equipment in conditions of temperatures below freezing point in a cold climate is the startup of the diesel engine after a long period of parking. The industry produces auxiliary equipment. In this regard, heat generators are widely used. There are individual and group heaters of various types, including flame and infrared heaters that can provide support in the pre-starting procedure. In addition, there are means to facilitate the start-up. The reliable start of a diesel engine is influenced by factors such as the temperature of the air charge, the operating torque of the crankshaft, the conditions of fuel spraying, the activity of heat exchange processes and the tightness of the mating of the cylinder-piston group parts. The use of fuels of light fractional composition with an electric flame jet or the so-called gas-electric flame jet can constitute an effective solution to the problem.

I. Introduction

Most commercial vehicles are equipped with diesel engines, which have a number of advantages and disadvantages in relation to gasoline engines. The advantages include such indicators as low fuel consumption, high efficiency, high torque. The disadvantages include the high cost of production and repair, high concentration of gases, start-up problems and prolonged warming up in conditions with temperatures below freezing point [1].

To ensure the reliability of starting-up a diesel engine in such conditions, specialized equipment is used. In the modern automotive industry, various kits are used as pre-start preparation tools and means to facilitate the startup of diesel engines, which can be integrated into the design, as well as used as auxiliary equipment. The existing tools of pre-start preparation of a diesel engine include devices that perform timely thermal preparation of mechanisms and systems. Tools for facilitating the start-up improve the ignition conditions of the fuel-air mixture directly at the start-up modes and lead to a stable speed of the crankshaft in the engine. Such tools include energy sources of high-power electric starting systems, the use of starting liquids of light fractional composition, and means of heating the intake air [2].
Special laboratories in Russia, Europe and the United States are engaged in the research of problems of operating equipment in conditions of temperatures below freezing point. In this area the following works should be noted: Briling N R, Mikkil M L, Blouza D F, Rikardo G R, Smolin A A and others. Despite scientific achievements, the practice of using technology with diesel engines in the Arctic continues to highlight the problematic issues in this scientific field.

In the automotive industry, built-in systems for heating the inflowing air in the intake manifolds are widely used. The air in our atmosphere is a mixture of gases: (nitrogen-78%, oxygen-21.95 %, carbon-0,0407 %, neon-0.001818 %, helium-0.000524 %, methane-0.00018 %, hydrogen-0.000055 %, krypton-0,000114 %) [4]. The main tool for increasing its temperature is an electric flame jet. In accordance with the guidelines, the use of the electric flame jet of the KAMAZ-740.10 engine is effective at an ambient temperature of not lower than minus 10 °C [2, 3]. It is experimentally proven that the repeated use of an electric flare device as a means of facilitating the startup of a diesel engine is accompanied by a number of negative consequences that affect the engine service life and environmental performance indicators.

The main disadvantages of using an electric flame jet include:

- low reliability of starting the electric flame jet itself, uneven (pulsating) flame condition, due to unstable fuel supply by a piston-type pump to the heating element of a pin electric flame jet;
- necessity of energy consumption of batteries for the process of evaporation of diesel fuel in an electric flame jet;
- deposition of fuel resins on the surfaces of metering jets with a change in the flow sections;
- emission of incomplete combustion products, that can be visually determined by the presence of black smoke, soot and liquid deposits of black color on the inner surface of the intake manifolds [5].

These disadvantages make a search for new scientific solutions necessary to improve the reliability of the operation of electric flame jetes and the start-up of diesel engines as a whole.

As an alternative to the electric flame jet, it is possible to use electric means of heating the air charge. But the latter implies difficulties in changing the design of intake manifolds and additional consumption of electric energy.

II. Setting tasks

Until now, light fractional composition fuels have been used to kick-off the start-up cycle in conditions of temperatures below freezing. The air charge was heated by burning diesel fuel inside of the intake manifold with an electric flame jet and a simultaneous rotation of the crankshaft. The intake manifold is a pipe of irregular shape with side outlets. The design of the shapes and sizes of the outlets ensures tight coupling with the cylinder heads, good filling with air charge, even in conditions of atmospheric construction of the air supply system.

The problem can be solved by replacing diesel fuel with light fractional fuel in the electric flame jet. Such a replacement can have a positive impact on the efficiency of the latter. Hypothetically, this increases the combustion efficiency of the fuel as well as raises the temperature of the flow gases inside the intake manifold and, as a result, it increases the temperature of the air charge in the combustion chamber. Significant changes in the combustion efficiency of the fuel will improve the ecological indicators in the operation of the electric flame jet and thus make it environmentally more friendly.

By changing the cross section of the fuel jet of the spark plug of the electric flame jet and by installing control cocks into the supply lines, it is possible to obtain a steady flame with a rational coefficient of excess air, reduce the loss of electrical energy of a battery because there is no necessity to change aggregate states of the fuel, eliminate deposits of incomplete fuel combustion products on the surfaces of the pin plug of the electric flame jet and intake manifolds. Thus, an electric flame jet that uses gas fuel can be called a gas- electric flame jet.

III. Experiment

An experiment was conducted to test the presented hypothesis. The purpose of the experiment was to compare the temperatures of flow gases in the cylinder outlets of intake manifolds when the standard electric flame jet and gas-electric torch are operating in the mode of starter rotation of the crankshaft and in the mode of real cycle implementation.

Table 1 shows the conditions of the experiment.

| Table 1. Conditions of the experiment. |
|----------------------------------------|
| Temperature, °C | minus 22 |
| Pressure, mm Hg | 0.35     |

2
Wind velocity, m/s
Relative air humidity, %

| Volume | Value |
|--------|-------|
| Wind velocity, m/s | 3 |
| Relative air humidity, % | 91 |

In accordance with the classification system, this experiment can be classified as a full-scale experiment. The experiment was a comparative one. The caloric efficiency of the electric flame jet and gas-electric flame jet were compared.

During the experiment, the conditions remained steady. Acetylene, hydrogen, methane, propane-butane mixture, etc. can be used as a fuel of light fractional composition in a gas-electric flame jet. These combustible gases have their own advantages and disadvantages. For example, hydrogen and acetylene have wide inflammability limits, which provide a stable flame in the active air flow, and the ability to control the excess air coefficient in a significant range. The caloric value is also of importance.

The experiment was equipped with: a KAMAZ - 740.10 engine mounted on a stand, platinum TSP 0501-01 resistive temperature transducers, a terminal connection plate, a multi-channel MIT-12 temperature meter, a propane-butane mixture cylinder, a reduction gearbox adjusted to a pressure of 2.5 MPa, a SG-1 gas meter, regulating valves, hoses and communication pipelines. The temperature transducers were installed in the cylinder outlets as shown in Figure 1. The position where the temperature transducers were installed, ensured the determination of the temperature of the flow gases directly at the inlet to each cylinder.

![Figure 1. Experiment Equipment](image)

Figure 1. Experiment Equipment

1–intake manifolds; 2–sight glasses; 3–platinum resistive temperature transducers (TSP-0501-01); 4–pin gas-electric glow plug; 5–gas fuel supply adjustment valve; 6–gas meter (SG-1); 7–gas cylinder; 8–gas reducer with pressure gage; 9–terminal connection plate; 10–multifunctional temperature meter (MIT-12).

Table 2 shows the characteristics of the platinum TSP 0501-01 resistive temperature transducers according to TU 4211-093-02566540-2011.

| Technical characteristics | TSP 0501-01 |
|---------------------------|-------------|
| Measured temperature range, °C | -40……+250 |
| Admission class | B |
| Material of protective fittings | 12X12H10T |
| The range of the conditional pressure, MPa | 0.4 |
| Weight, kg | 0.07 |
The experiment forest-up was as follows: starting the engine after a long standstill (36 hours) without preheating, measuring the temperatures of the flow gases in the cylinder outlets in the mode of rotation of the crankshaft by the starter with a frequency of 100 min⁻¹ for 1 minute and in the mode of implementation of the actual cycle with a frequency of 1200 min⁻¹ for 1 minute. To be able to build a graphical dependency, 8 measurements were performed on each mode. The first measurements were made when using diesel fuel in a standard electric flame jet. The second – at the end of the first, after holding the engine at rest for 36 hours. A successful startup was provided by the support of a gas-electric flame jet running on fuel called "automobile propane". Some characteristics of the latter are shown in table 3.

### Table 3. Characteristics of automobile propane used in Gas-electric flame jet.

| Characteristics                                    | Value |
|---------------------------------------------------|-------|
| Mass fraction of propane, %                       | 85    |
| Mass fraction of unsaturated hydrocarbons, %      | 6     |
| Saturation vapour pressure at minus 30 °C, MPa    | 0.07  |
| Mass fraction of hydrogen sulfide, including mercaptans, % | 0.01  |

The parameters of the experiment were divided into fixed and varied. The fixed parameters were the speed of rotation of the crankshaft, the gas supply pressure, the flow rate of which was 0.001 m³/min. The varied parameters included the temperature of the flow gases in the cylinder outlets of the intake manifolds and the rotation time of the crankshaft. The numbering of the resistive temperature transducers corresponded to the numbering of the cylinders, as shown in Figure 2.

### IV. Results of the experiment

The results of measuring the temperature of the flow gases in the cylinder outlets of the intake manifolds are shown in Table 4.

### Table 4. Temperatures in the cylinder outlets of the intake manifolds when using electric torch and gas-electric flame jet in the starter mode of rotation of the crankshaft, as well as in the mode of implementation of the actual engine cycle (note: all temperatures measured in celsius).

The average temperature of the flow gases in the cylinder outlets of the intake manifold with the use of electric flame jet in the mode of starter rotation of the crankshaft

| Collector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------|---|---|---|---|---|---|---|---|
| Right     | +89.0 | +65.7 | +19.7 | -18.3 | +27.3 | +13.3 | +29.6 | +3.4 |
| Left      | +39.8 | +18.4 |

The total average temperature of the gases: +29.1

Average temperature of flow gases in the cylinder outlets of the intake manifold with the use of electric flame jet in the real cycle mode

| Collector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------|---|---|---|---|---|---|---|---|
| Right     | +47.1 | +24.5 | +0.2 | -12.6 | +10.8 | +7.5 | +4.8 | +1.8 |
| Left      | +11.3 | +6.2 |

The total average temperature of the gases: +8.7

Average temperature of the flow gases in the cylinder outlets of the intake manifold using gas-electric torch in the mode of starter rotation of the crankshaft

| Collector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------|---|---|---|---|---|---|---|---|
| Right     | +121.3 | +101.7 | +5.0 | -17.6 | +66.9 | +56.1 | +50.1 | +15.6 |
| Left      | +121.3 | +101.7 | +5.0 | -17.6 | +66.9 | +56.1 | +50.1 | +15.6 |
### Average gas temperature of the right collector

| Collector | Average Gas Temperature |
|-----------|-------------------------|
| Right     | +76.4                   |
| Left      | +47.2                   |

**The total average temperature of the gases**

+61.8

### Average temperature of flow gases in the cylinder outlets of the intake manifold with the use of gas-electric flame jet in the real cycle mode

| Cylinder | Average Gas Temperature of the Right Collector | Average Gas Temperature of the Left Collector |
|----------|-----------------------------------------------|----------------------------------------------|
| 1        | +91.2                                         | +79.7                                        |
| 2        | +79.7                                         | +27.7                                        |
| 3        | +27.7                                         | -10.8                                        |
| 4        | +27.5                                         | +33.7                                        |
| 5        | +33.7                                         | +37.9                                        |
| 6        | +37.9                                         | +1.8                                         |
| 7        | +27.5                                         | +33.7                                        |
| 8        | +33.7                                         | +37.9                                        |

**The total average temperature of the gases**

+40.3

The temperature of flow gases in the cylinder outlets depends on the caloric value of the fuel, on the structure of the flame, the direction of gas movement and location of the spark plug. For example, the operation of the spark plug does not affect the temperature of the flow gases of the fourth cylinder. At the same time, the maximum temperatures of flow gas were measured in the outlet of the first cylinder.

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**Figure 2.** Platinum TSP 0501-01 resistive temperature transducers installed in the cylinder outlets of the intake manifolds in accordance with the cylinder numbering.
Figure 3 shows graphical dependences of changes in the flow gas temperatures in the cylinder outlets, in accordance with the location and numbering of the cylinders, under the operating conditions of the standard electric torch and gas-electric flame jet during the starter rotation of the crankshaft and in the mode of implementation of the actual engine cycle.

**Figure 3.** Graphical dependences of continuous gas temperatures in the cylinder outlets of the intake manifolds of the KAMAZ-740.10 diesel engine in the low-temperature start-up mode.
V. Discussion of the results
As a result of the experiment, it was found that the caloric efficiency of the gas-electric flame jet prevails over the caloric efficiency of the standard electric flame jet in all cylinder outlets (with the exception of the fourth cylinder). A rise of temperature in the inflowing air can have an increasing effect on the temperature of the air charge in the combustion chamber. During the operation of the gas-electric torch the presence of black smoke, soot, and liquid deposits of black color were visually not determined. The characteristic features of the gas-electric flame jet were reliable ignition as well as a steady and stable flame characteristics. These advantages are explained by the capability of the light fractional composition fuel to work in temperatures below freezing point in the cold climate, the lack of heavy fractions, the fact that no electrical energy of batteries is consumed in order to change the aggregative states of the fuel and due to high combustion efficiency.

VI. Conclusion
The use of a gas-electric flame jet in the operation of vehicles with diesel engines increases the reliability of start-up, reduces the minimum start-up temperature in conditions of temperatures below freezing point and reduces the concentration of environmentally harmful elements and compounds in the combustion products.

VII. References
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