Studies of the process of heating air in the inlet pipe for starting a diesel engine at low temperatures

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Abstract. Starting a diesel engine at low ambient temperatures presents significant difficulties due to low temperature of the air charge; increased resistance due to increasing viscosity of the oil, turning the crankshaft and moving other kinematically connected parts; deterioration of fuel atomization conditions; enhanced heat transfer to the cylinder wall; loss of part of the air charge. This article is devoted to experimental studies on heating the air at the inlet of a small-sized 1H9.5/8.0 diesel engine with air cooling at ambient temperatures of -20 ℃, -40 ℃, -60 ℃. As the result of experimental studies, the time of stationary values of air temperature in the combustion chamber, as well as in the inlet and outlet pipes was determined. Temporal patterns of changes in air temperatures in the combustion chamber, in the inlet and outlet pipes when scrolling the diesel engine with a starter are obtained.

1. Introduction

At present, at low negative ambient temperatures, the problem of starting diesel engines is often solved by using means of facilitating start-up [1]. To improve the starting and operational qualities of a diesel engine at low temperatures, heating of the main functional diesel systems is most effective: power systems, lubrication systems and inlet tract. In practice, as a rule, the fuel is heated in the fuel tank and fine fuel filters, the engine oil is heated in the diesel boat and the air is heated at the inlet. In this case, the preheating time of engines in low negative ambient temperatures with the use of heaters of various capacities varies over a very wide range [2, 3].

At the same time, for a reliable start of the diesel engine, it is necessary that the temperature at the end of the compression stroke exceed the temperature of the auto-ignition of fuel. Since the temperature at the end of the compression stroke is determined primarily by the temperature at the end of the intake stroke, this condition can be satisfied by preheating the air entering the cylinder [4 - 7]. In published works devoted to research and development of air heating systems in the intake pipeline to facilitate the start-up of diesels, minimum temperatures are considered not lower than -40 ℃, which makes it difficult to use these results for low negative ambient temperatures.

In this work, experimental studies on heating the air at the inlet in a 1H9.5/8.0 diesel engine at ambient temperatures of -20℃, -40℃, -60 ℃ were carried out in order to measure the air temperature at the inlet, in the diesel combustion chamber and at the exhaust. Warm air was supplied to the diesel inlet to evaluate and analyze the effect of its heating on the temperature in the combustion chamber before starting, as well as during the starter scrolling process.
2. Preparation and conduct of experimental studies

An electric heat source was installed in the inlet pipe at a distance of 5-7 cm (figure 1) from the inlet channel in the cylinder head. Warm air was pumped into the cylinder by a fan. The flow rate of warm air generated by the device was determined using an air pressure receiver and an MMN-240 micromanometer according to the following formula:

\[ V = \frac{2}{\sqrt{\rho}} (p_s - p_e) \xi \]

where \( p_s \) – total pressure; \( p_e \) – static pressure; \( \rho = p / RT \) – air density; \( p, T \) – pressure and ambient temperature; \( R \) – gas constant of air; \( \xi \) – coefficient of the receiver of air pressure (0.02-0.04).

According to the flow velocity under the conditions of a developed turbulent flow regime, volumetric productivity was determined, the technical characteristics of the supercharger were checked, and therefore the possibility of its use.

![Figure 1. The location of thermocouples in a diesel engine.](image)

A chromel-kopel thermocouple was installed between the inlet channel in the cylinder head and the heat source at a distance of 2-3 cm along the channel axis, which recorded the temperature of the air supplied to the combustion chamber.

To ensure a more intense heating of the combustion chamber and to prevent surging, the diesel crankshaft was scrolled so that the gas distribution mechanism ensured full opening of the intake valve and, accordingly, the maximum possible opening of the exhaust valve. Full opening of the intake valve was achieved by installing the piston in the TDC and scrolling the crankshaft pulley a quarter of a turn in the opposite direction. The exhaust valve was forced to open with a decompressor.
The second thermocouple was installed in the combustion chamber of the nozzle body, at the end of which there was a sensitive element isolated from the nozzle and non-touching with the details of the piston-cylinder group. The third thermocouple was installed in the exhaust pipe at a distance of 2-3 cm from the cylinder head.

When conducting an experiment in a climatic chamber under conditions of an ambient temperature of -20 °C, the diesel oil heater was turned on for 15 minutes, at -40 °C and -60 °C for 25 minutes, accordingly. Next, the oil heater was turned off and the glow plug was turned on for 40 s.

After 40 s, they were scrolled by the starter, emitting a diesel start for 10 with three attempts with an interval between attempts of 30 s. The glow plug did not turn off.

The hot air blower was turned on in advance of the engine shaft scrolling by the starter, and corresponded to the steady state temperature in the combustion chamber.

The power of the hot air blower during all experiments remained constant and corresponded to a temperature of the heating element of 300 °C at maximum fan performance.

3. The results of experimental studies

As a result of the experiments, the time of the onset of the stationary value of the air temperature in the combustion chamber, as well as in the inlet and outlet pipes, was determined (table 1). Temporal patterns of changes in air temperatures in the combustion chamber, in the inlet and outlet pipes when scrolling the diesel engine with a starter (figure 2-5) are obtained.

Table 1. Stationary temperatures.

| Ambient temperature \( t_0 \), °C | Combustion chamber temperature \( t_2 \), °C | Inlet temperature \( t_1 \), °C | Exhaust temperature \( t_3 \), °C |
|---------------------------------|---------------------------------|-----------------|-----------------|
| 4.0                            | -20                             | 124.5           | 219.1           | 66.6            |
| 5.5                            | -40                             | 101.3           | 192.3           | 42.6            |
| 7.0                            | -60                             | 91.9            | 176.2           | 33.2            |

Figure 2. Warm-up schedules at supply of heated air and ambient temperature –20°C.
Figure 3. Warm-up schedules at supply of heated air and ambient temperature –40°C.

Figure 4. Warm-up schedules at supply of heated air and ambient temperature –60°C.
Figure 5. Reducing the temperature of the air in the combustion chamber between scrolls by the starter.

The obtained results allow us to develop recommendations for facilitating the start-up of a diesel engine at low negative ambient temperatures due to the use of an air heating system in the intake pipe. In particular, for the diesel in question, heating the air in the intake pipe allows increasing the temperature in the cylinder when scrolling the diesel with the starter by 75 °C (at ambient temperature –60 °C). Also, the results can be used to analyze the correspondence of the temperature in the cylinder to the temperature of self-ignition of the air-fuel mixture.

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