

# The operating conditions of the internal combustion engine with high temperature cooling

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**Abstract.** This paper presents the analysis of the experimental data on the cylinder bushing and 21/21 engine piston temperature level, as well as the possibility of converting the engine operation mode to the high-temperature cooling mode. The power plant bench tests results confirming the efficiency of the engine with high-temperature cooling mode are represented.

**Key-words:** power plant, internal combustion engine, engine parts thermometry and its results, high temperature cooling

## 1. Introduction

Power plants energy efficiency issues receive both domestic industry and European Union attention. This fact can be proved by quoting from the paper [1] by E. Bernsen the Implementation of the EU Directive for promoting the use of cogeneration «The sustainable development of the European energy sector, both in terms of enhancing the environment and energy supply saving and reliability is closely associated with the energy efficiency improvement.

Cogeneration is recognized as one of the main technologies to achieve the European Union (EU) objective in respect of increasing the energy efficiency. The primary energy savings, losses elimination and emissions reduction (especially greenhouse gases emissions) are considered to be the cogeneration advantages. The efficient use of energy produced by cogeneration, inter alia, can have a significant beneficial impact on the competitiveness of the EU and its Member States».

These activities apply to the power plants including plants of the oil and gas economy sector.

The given oil and gas economy sector can be considered as a special one as it has its own specificity. This is due to conducting the hydrocarbon fuel exploration, extraction and transportation, especially in small compact and remote areas where the district heating and power supply are not established. Therefore, heat and electricity to such remote facilities should be supplied by the effective small power utilities. Alternatively, energy mixes of that kind can be implemented on the basis of the internal combustion engines.

The efficiency improvements of the small power complexes based on the internal combustion engines make a specific contribution to the hydrocarbon reserves saving and according to experts by 2020 the fuel consumption is planned to be reduced by 40–48%, equivalent to 360–430 mln tons of reference fuel per year.



## 2. Problem statement

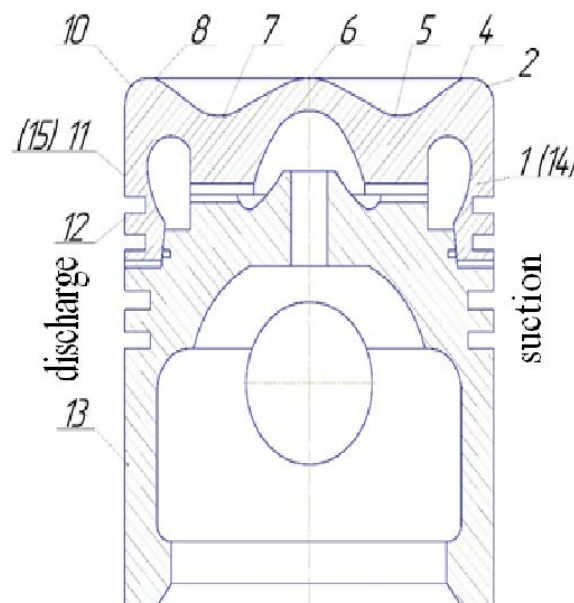
The engines with the high temperature cooling mode, when the cooling fluid temperature at the engine outlet is more than 373 K (100 °C), have a number of advantages over the engines with the traditional cooling systems and are described in the scientific and technical literature. The paper [2] presents the experimental studies of the engine cooling system 6ChN 21/21.

For analysing the possibility of changing the engine mode and ensuring the efficiency of its systems and components, when changing to this cooling mode, it is necessary to conduct a complex of experimental design and research works. These include: determination of the cylinder bushing and piston temperature by thermomentering these nodes during engine operation at different loads and modes of cooling.

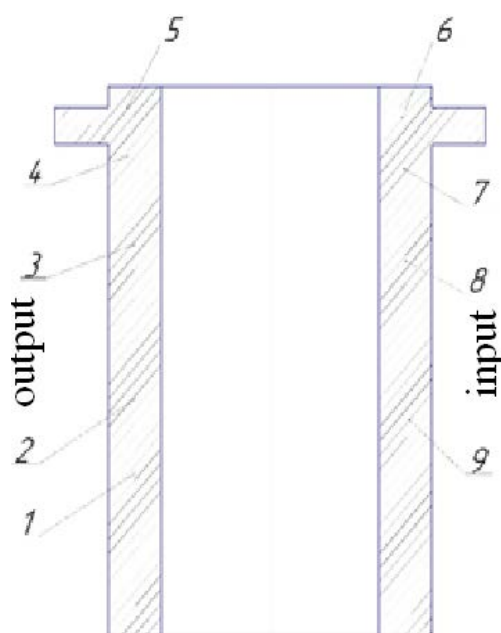
The cylinder cover is one of the engine critical component, thereby the research results on this node are described in [4].

## 3. Theory

Moreover, the cylinder piston and bushing are important parts. 21/21 engine piston is a prefabricated structure. The piston head is made of alloy steel, the piston skirt is made of aluminium alloy, which are pulled together by four studs - screws. The cylinder piston and bushing longitudinal section designs are shown in Fig. 1 and Fig. 2 correspondingly.



**Figure 1.** The piston design (longitudinal section).



**Figure 2.** The cylinder bushing design (longitudinal section).

#### 4. Experimental results

The analysis of changing the engine operating parameters at the modes close to the rated power, when increasing the cooling fluid temperature was conducted. The following dependencies were obtained. For example, for every 10 K (10 °C) of the cooling fluid temperature increase  $T_{cool}$ , the exhaust gas temperature rises by 2.5...3 K (2.5...3 °C), the boost pressure is slightly increased, due to the turbocharger rotor speed rising. When the cooling fluid temperature rises by every 10 °C, the efficient specific fuel consumption is reduced by 1.36 g/kWh and reaches its minimum value, respectively, when the cooling fluid temperature increases to 373...383 K (100...110 °C). However the fuel economy decreases as the cooling fluid temperature further increases. On the one hand this nature of the specific fuel consumption changing can be explained by the mechanical friction losses reduction, and on the other hand by the indices values decrease as a result of decreasing the filling ratio and air flow through the engine.

When  $T_{cool}$  rises from 333 to 288 K (60 to 115 °C), providing the constant oil temperature in the engine, the excess air coefficient and turbocharger efficiency remained fairly constant. The lowest specific fuel consumption is recorded at the cooling fluid temperature from 373 to 383 K (from 100 to 105 °C).

Water temperature increasing for every 10K (10 °C) results in the temperature increase of the piston over the first ring (point 11, Fig. 1) by 3...4 degrees, at the periphery on the upper edge of the bottom on the exhaust side (point 10) by 3 ...4 degrees, in the center of the bottom (point 6, Fig. 1) by 2.5...2.0 degrees, as well as in the temperature increase of the cylinder bushing in the stop zone of the first compression ring (3 mm lower) at the point 4 on the exhaust side and at the point 7 on the suction side, respectively, by 7 degrees and by 4...7 degrees in the uncooled zone (point 5) on the exhaust side and at the point 6 on the suction side, respectively, by 7 degrees and by 4...7 degrees.

#### 5. Results discussion

The long bench tests of 21/21 engine having worked at the nominal power with the cooling fluid temperature level at the engine outlet of 395 K (122 °C) during 45 minutes were carried out.

All the systems functioned properly including: the liquid in the cooling system was not boiling, the engine and bench seals under this cooling system withstood the required pressure, as well as there was no piston and cylinder bushing scuffing due to the reduction of the thermal gap between them. The given experiment is significant and suggests that the engine design can operate at this temperature

cooling mode. These results are required to be confirmed during long-term operational tests as a part of the power plant.

## 6. Conclusions

The following main conclusions were drawn from the conducted studies analysis:

The minimum specific fuel consumption was recorded at the cooling fluid temperature from 373 to 383 K (from 100 to 105 °C). It should be noted that only increasing the cooling fluid temperature up to 373...383 K (100...105 °C) relative to the standard temperature of 366 K (93 °C) according to the requirements specifications reduces the engine specific fuel consumption and gives the opportunity to improve the operational efficiency of the entire power plant.

The cylinder piston and bushing thermometry results demonstrate their temperature insignificant increase when the cooling fluid temperature at the engine outlet rises from 333 to 288 K (60 to 115 °C). This suggests that the expansion gap of the piston-bushing assembly performance is provided and experimentally confirmed by the engine operation at the temperature of the cooling fluid of 395 K (122 °C).

On the basis of the above, it may reasonably be considered, therefore, that the use of the high temperature cooling mode makes it possible to improve the efficiency of the internal combustion engine application in various power plants, including as an engine - generator for the autonomous generation of electric energy, and as a part of the cogeneration plant for obtaining very cheap thermal energy.

## 7. References

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