# INCREASE IN THE FUEL TEMPERATURE OF AN INJECTOR BODY OF A SELF-IGNITION ENGINE IN THE THERMAL-CATALYTIC FUEL TREATMENT

**Oleh Klyus**

*Maritime University of Szczecin*
*ul. Wały Chrobrego 1/2, 70-500 Szczecin, Poland*
*tel.: +48 91 4809425, fax: +48 91 4809575*
*e-mail: olegklus@o2.pl*

***Abstract***

*This article presents an analysis of thermodynamic processes taking place in the fuel nozzle holder equipped with a fuel preheating system containing catalytic material. The analysis results show that it is possible to raise the effectiveness of self-ignition engine operation and, at the same time, to reduce the emission of toxic compounds into the atmosphere.*

***Keywords:*** *self-ignition engine, fuel injector, catalytic and thermal fuel treatment*

## 1. Introduction

The reduction of toxic compound emission into the atmosphere and decreasing fuel consumption are at present basic directions in combustion engine developments. Designs of engines and their systems have reached limits in terms of working process parameters and possible control of these processes. However, future standards of exhaust gas toxicity and fuel consumption are expected to be even stricter. Research done at the Institute of Technical Operation of Marine Power Plants, Maritime University of Szczecin (4T12D06029) also includes the application of methods which will make it possible to reduce exhaust gas toxicity and fuel consumption in self ignition piston engines without introducing significant changes in the construction of fuel injectors. To this end preliminary thermal and catalytic fuel treatment may be applied directly before the fuel is sprayed into the combustion chamber.

## 2. Catalytic fuel treatment

It is known that obtaining better operational parameters of internal combustion engines is possible by increasing the speed of initial chemical reactions in fuel in the process of ignition lag. These reactions in internal combustion engines are characterized by dehydrogenation and can be accelerated by contacting fuel with catalytic material (mostly metals belonging to the platinum group) [1]. The process can be made possible in the nozzle holder by allowing contact between the fuel flowing through injector passages and catalytic material placed directly on the surface of fuel passages. Besides, in order to increase the contact area in injector passages additional elements can be put in, such as balls, wire or springs coated with a catalyst. It should be underlined that the catalyst action is accelerated at higher temperatures. Therefore, a new positive effect of enhancing the engine performance parameters can be gained by simultaneous action of catalytic material and increased fuel temperature.

## 3. Effect of temperature of injected fuel on the combustion process

A positive effect of injecting preheated fuel on the processes occurring in the combustion chamber of a self-ignition engine has been presented in works [1, 4, 6]. The following parameters have been observed to decrease: rate of pressure increase and maximum combustion pressures in cylinders, exhaust gas smoke content , as well as unit fuel consumption.

As fuel temperature increases, reactions of fuel cracking in the combustion chamber accelerate; besides, due to shortened fuel heating time, the ignition lag period is reduced. In addition, injecting preheated fuel into the combustion chamber causes the intensity of toxic compound emission to lower. This is explained by the fact that the toxic emission level in exhaust gases, particularly soot, is connected with the process of cooling off the flame by cold fuel injected into the combustion chamber. Another reason for soot content decrease is the increased combustion rate, which is equivalent with the reduction of heated fuel combustion period, so that the time of possible burning of soot in the engine chamber increases.

However, fuel preheating systems have not been used in internal combustion engines so far. This can be explained mostly by the fact that fuel in these systems is heated before the injection pump in high pressure pipes or directly before the injector. This changes working conditions of those elements through which preheated fuel flows, thus the working conditions of precision elements change, because the clearances are changed and so does the durability of construction materials [7]. This leads to accelerated wear of injection system components as well as engine elements and nodes. However, the most negative effect on engine performance characteristics in such fuel heating system turns out to occur after a change in fuel injection characteristics [3, 8].

The research [6] showed that the best effect from using preheated fuel can be achieved when an engine works at power output up to 50% of its maximum power, where each load condition corresponds to a specific temperature of injected fuel. Heating of fuel leads to changes in its thermodynamic parameters, which in fact means that physical properties of the fuel are changed: density, viscosity, surface tension decrease; compressibility, volatility and other properties increase; as a result:

- lowered viscosity and surface tension enhance the quality of atomizing;
- increased volatility is basically connected with load changes, i.e. engine thermal conditions;
- increased compressibility at higher temperature results in the reduction of pressure waves in pipes, which combined with increasing leaks in discharging steam changes the characteristic of fuel injection, increase of injection lag period and fuel injection time.

Enhancing the effectiveness of engine performance at low loads by heating the fuel can be explained by the fact that the quality of atomization and combustion is of major importance, whereas worsened operating parameters when loads are higher than 50% are due to the major role of the injection lag and increase in fuel injection time.

It has been found [6] that the variation of heated fuel temperature which results in better effectiveness of diesel engines ranges from 40 to 60 °C (Fig. 1).

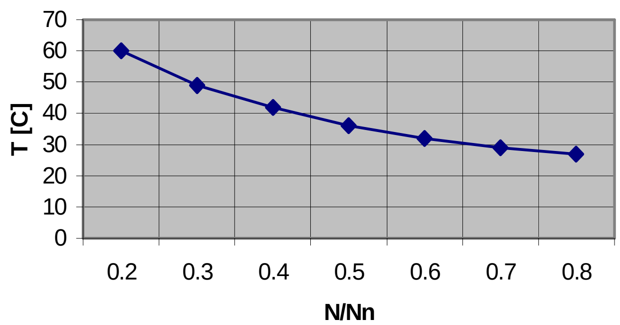


*Fig. 1. Recommended change in temperature of injected fuel dependent on combustion engine load [6]*

## 4. Heating fuel in the nozzle holder

From the point of view of heating fuel, it is better to use a system that would be placed outside the area of precision elements, which is achieved in the case of heating fuel directly in the nozzle holder (Fig.2) [3,7].

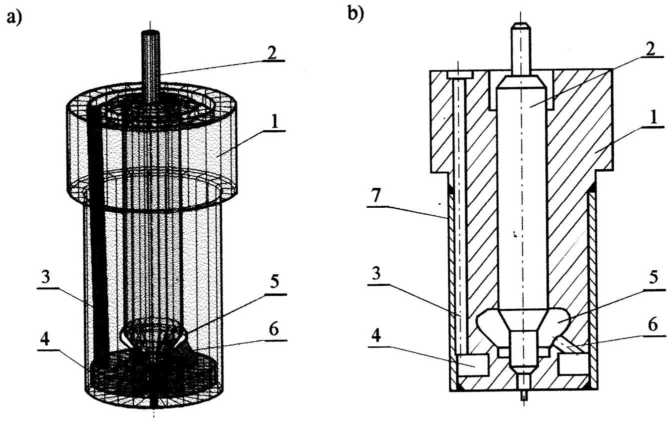


*Fig. 2. Diagram (a) and cross-section (b) of an injector with cooling-heating fuel system 1 – nozzle holder, 2 – needle, 3 – inlet passage, 4 – ring passage, 5 – under-needle space, 6 – connecting passage, 7 – external skirt*

Heating fuel is possible when one fuel feeding passage is joined with a ring passage made in the lower part of the holder and with outlet from that ring passage to the under-needle space. As a result of such modifications, fuel flows into the ring passage where it absorbs heat from the hottest parts of the holder cooling it at the same time. Fuel then goes to the under-needle space and due to increased pressure it raises the needle as it happens during the normal process of fuel injection.

In order to calculate the quantity of fuel flowing through the cooling passages of the atomizer the general Bernoulli's equation for fluid flow was used [5]. Considering two cross-sections of the injector at the passage 3 inlet and passage 6 outlet (Fig. 2) we can write:

$$\frac{v_1^2}{2g} + \frac{p_1}{\gamma} = \frac{v_2^2}{2g} + \frac{p_2}{\gamma}, \tag{1}$$

where:

$g$ – gravitational acceleration,
$v_1, v_2$, $p_1, p_2$ – velocity and pressure of fuel at the inlet (1) and outlet (2) of passages,
$\gamma$- fuel specific gravity.

After a transformation, we obtain:

$$\frac{\Delta p}{\gamma} = \frac{v_2^2 - v_1^2}{2g}. \tag{2}$$

The following condition has to be satisfied for the fuel to flow through cooling passages of the atomizer:

$$\frac{\Delta p}{\gamma} = \sum h_{str}, \tag{3}$$

where: $\sum h_{str}$ – sum of linear and local losses of flow through cooling passages.

Comparing the right-hand sides of the equations 2 and 3 we can calculate the quantity of fuel flowing through the circuit of cooling passages.

Knowing the fuel flow rate in cooling passages of the injector we can calculate the change in temperature of injected fuel. To do this, the finite elements method was used as it allows to determine the temperature in computational nodes and formulas defining the absorption of heat in a heat exchanger:

$$t_2 = T - (T - t_1) e^{-\frac{kF}{Qc}}, \qquad (4)$$

where:

$t_1$ and $t_2$ – fluid temperatures at the inlet and outlet from the exchanger;
$T$ – heating surface temperature $F$,
$k$ – convection coefficient,
$Q$ – fluid flow intensity,
$c$ – fluid specific heat.

To determine the temperature of the atomizer body (heat exchanger) the finite elements method was used, assuming that the temperature at the combustion chamber corresponds to a specific engine load. For a pintle injector of a DN0SD type the temperature distribution is presented in Fig. 3.

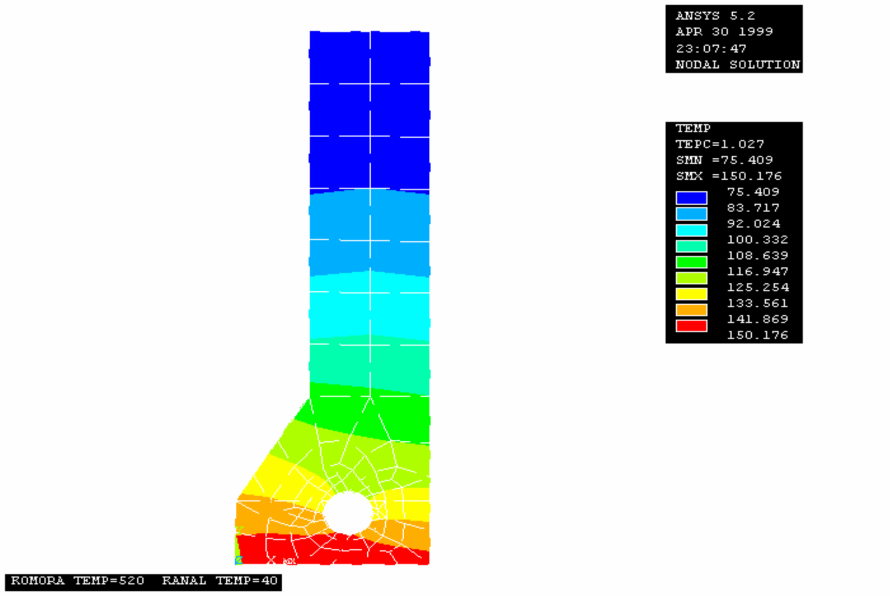


*Fig.3. Distribution of temperatures in an injector element for the temperature in the fuel passage T=40 °C and the temperature in the combustion chamber $T_{ks}$=520 °C*

Analytical research aiming at the determination of quantities of fuel flowing through passages and the changes in its temperature in the nozzle holder was done in two series: at continuous fuel flow and taking into account fuel stoppage in injector passages due to cyclical character of the injection process. The variable parameters were the dose of fuel injected and the temperature of heat exchanger (i.e. nozzle holder), depending on the engine load (temperature in the combustion chamber).

The results of this investigation which made use of the equations (1) – (4) are presented in the form of temperature field in Fig. 4. It should be emphasized that the recommended temperature change of injected fuel aimed at obtaining the most effective indicators of engine performance (Fig. 1) is located in that field.

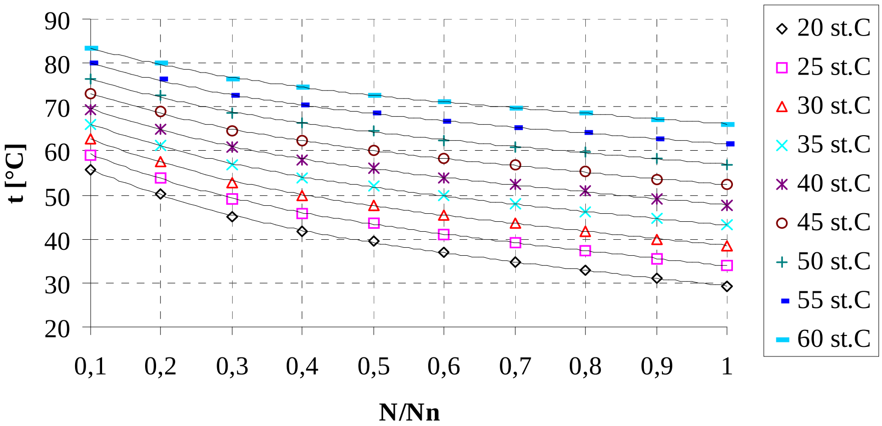


*Fig. 4. Changes in the temperature of injected fuel dependent on fuel temperature at the inlet to nozzle holder passages*

## Conclusions

The following conclusions can be drawn from the analysis:

– application of a cooling system in the fuel injector using injected fuel allows to reduce the working temperature of the precision elements:- needle-nozzle holder body, and at the same time increasing the temperature of injected fuel;
– heating fuel fed into the atomizer eliminates a number of negative phenomena connected with heated fuel flow through the fuel devices as in this solution the heating of fuel takes place directly before the injection of fuel into the combustion chamber;
– up to 50% of the fuel injected into the engine combustion chamber can flow through the cooling passages;
– the temperature of fuel used for the heating of injector cooling passages can range from 40 °C to 60 °C, recommended to improve the effectiveness of engine performance in its working conditions nor higher than 50 % of the maximum power output.

## Literature


[1] Гаврилов, Б.Г., *Химизм предпламенных процессов в двигателях*, Изд. Ленинградского университета, 1970, 98с..
[2] Klyus, O., *Termiczna i katalityczna obróbka paliwa w silnikach z zapłonem samoczynnym*, Wyd. KGTU, Kaliningrad, 2006, 154s.
[3] Klyus, O., Niziński, S., Wierzbicki, S., *Obniżenie temperatury rozpylaczy silników z zapłonem samoczynnym*, Sil-Woj'95, Materiały konferencyjne, Warszawa 1995, s. 164-171.
[4] Kowalczyk, M., *Wpływ temperatury wtryskiwanego paliwa na wybrane wskaźniki procesu cieplnego silnika wysokoprężnego*, Silniki spalinowe Nr.2/1975, 2. 14-19.
[5] Лышевский, А.С., *Системы питания дизелей*, Машиностроение, Москва 1981, 179с.
[6] Маркова, И.Б., Циулин, В.Н, *Повышение экономичности дизеля на долевых режимах*, Труды КТИРПиХ, Калининград, 1991, с. 79-97.
[7] Niziński, S., Klyus, O., Wierzbicki, S., *Sterowanie warunkami cieplnymi wtryskiwaczy*, Autoprogres'95, Materiały konferencyjne, Jachranka 1995, s. 98-107.
[8] Орлин, А.С., Круглов, М.Г., *Двигатели внутреннего сгорания*. Т 2, Машиностроение, Москва 1984, 297с.