20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

INJECTOR OF LIQUID LPG

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Abstract: *The formation of the mixture by injecting liquid LPG into the intake manifold of vehicle SI engine (conception MPI) is a perspective variant for alternative fuel system for operating the engine on LPG. This paper summarizes the results of theoretical and experimental research aimed at solving problems for injecting liquid LPG and presents a new design of the end part of the injector of liquid LPG.*

Keywords: Alternative fuel LPG injector, Icing of injector, Computational and experimental research, New design of the icingless liquid LPG injector.

1. Introduction

The LPG injector is assembled from the electromagnetic valve (EV) and the end part (EP) with the channel for LPG leading to the outlet nozzle (ON) – see scheme at Fig. 1 (schema contains modifications LPG injectors for experimental research). After injection of LPG from the EV the LPG pressure extremely drops in the channel, the intensive evaporation of the LPG in the channel changes of liquid state to gaseous state and before outlet nozzle there is the damp steam of LPG with the very low temperature (temperature of damp steam of LPG at discharge by outlet nozzle is reduced to below -30 °C). The geometric parameters of the channel (the volume of the channel before outlet nozzle VBON) and the outlet nozzle (the area of the outlet nozzle SON) have the very important influence both on the state of LPG and its physical quantities in the channel and the spray duration of the LPG to the manifold air.

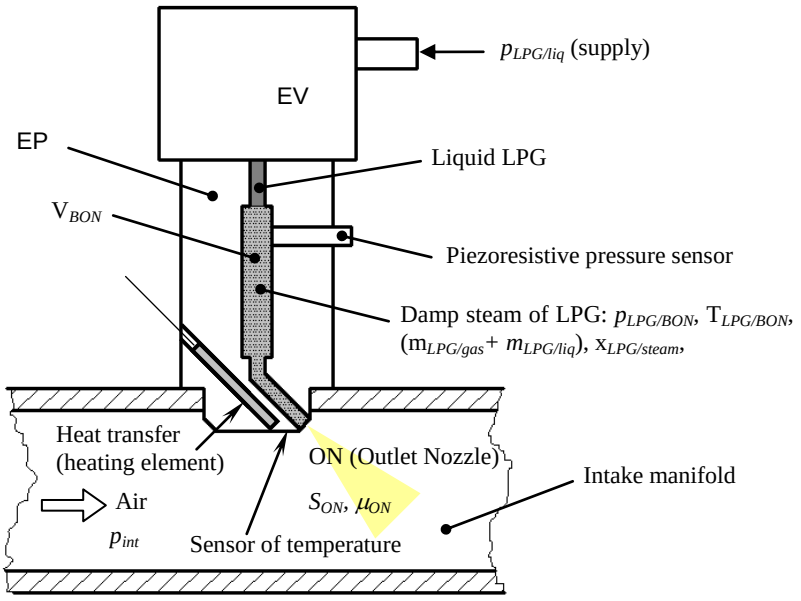

Fig. 1: The scheme of the injector for the liquid LPG injection.

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By the effect of very low temperature of the LPG spray raises the icing from the humidity of the atmospheric air on the external surface of the outlet nozzle. The icing fractures off from the outside of the outlet nozzle is the risk for the trouble-free engine running (misfire chance) (Mareš et al., 2007). Trouble-free operation of the spark-ignition engine with liquid injection LPG therefore must be secured in such a structural solution to the end part of the injector of liquid LPG into the intake manifold to prevent freezing of the discharge nozzle of the injector. The design of the end part of LPG injector must be arranged against the icing forming.

The authors of this paper accomplish the original theoretical studies about the liquid LPG injection to the manifold air: the results of this research works are contained in (Beroun et al., 2013) and (Nguyen, 2013). Illustration from theoretical studies of processes in a channel in the EP is in Fig. 2.

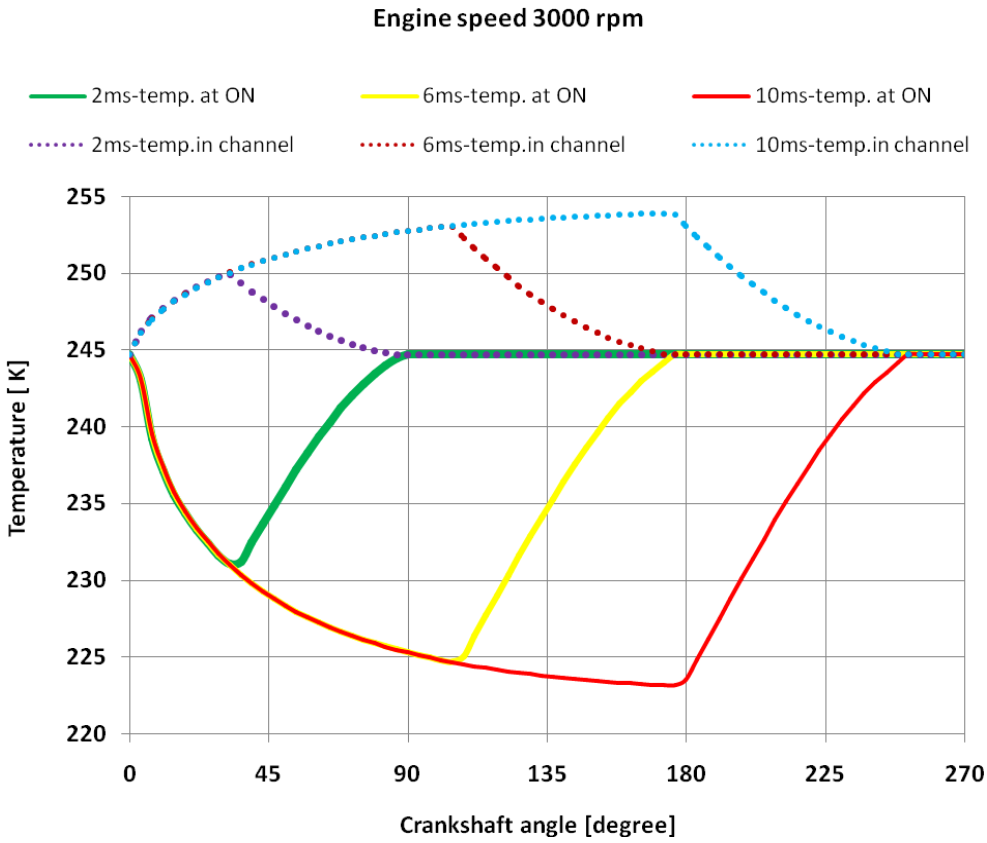

Fig. 2: The courses of the calculated temperature of LPG in the channel EP and outlet nozzle ON. The temperature of the damp steam of LPG in the channel is very low at the beginning of the injection of LPG into the empty channel, temperature damp steam of LPG in the channel increases with the increasing pressure of LPG in the channel, and the temperature of the damp steam of LPG in the channel again decreases during emptying the channel. Very low temperature damp steam of LPG in the outlet nozzle is intended expansion of damp steam of LPG (discharge takes place mostly critical speed).

2. Experimental Research of Liquid LPG Injector

In the end part of the liquid LPG injector was installed heating element and into the channel of end part of the injector liquid LPG was placed a pressure sensor. In the vicinity of the outlet nozzle is mounted the thermocouple on a wall. Liquid LPG injector was mounted in the intake manifold model and measurement was performed in all operating modes (motor speed-frequency injection, injection dose-opening time EV). Experimental works were carried out with the assembly of the fuel system (pressure tank for LPG with pump, injection pressure regulator and LPG solenoid valve) from company Vialle and the own (special) control unit for controlling the EV. Measurements were performed under laboratory conditions ($t_a \cong 20$ °C). A selection of experimental results with a commentary is in Fig. 3. The programme of the measuring was performed both without the heating (marking „normal“) and with the heating of the end part of injector (with the intensity control of the heating to reach the temperature on the external surface of the outlet nozzle to 5 °C – marking „reg.5C“).

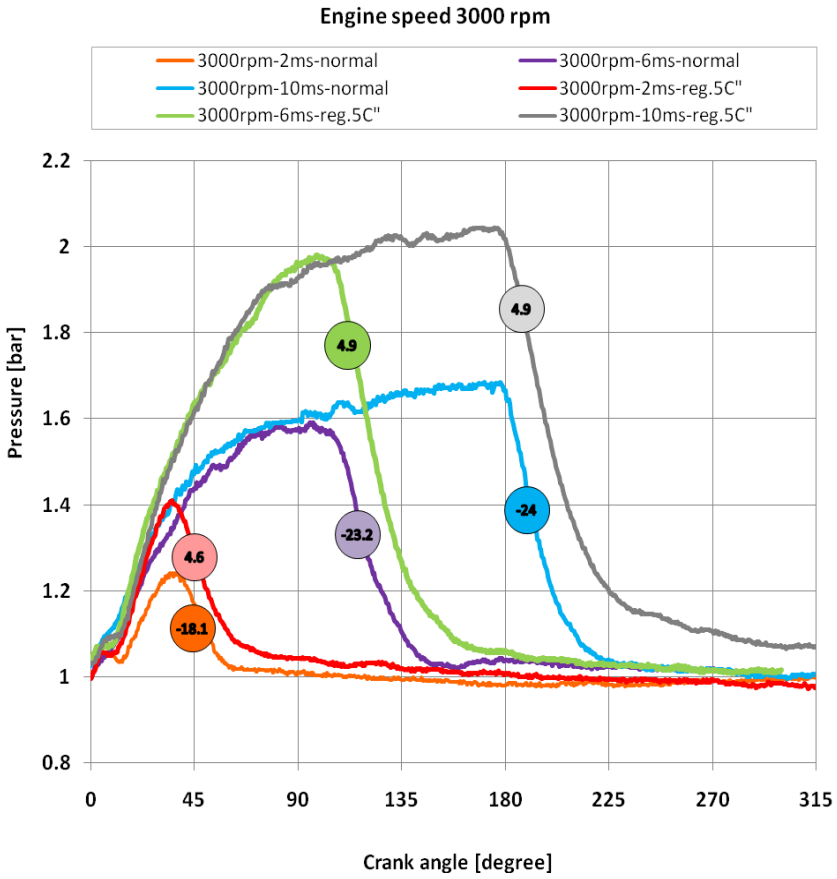

Fig. 3: Pressure courses in the channel of the EP of the injector there are significant influenced by the temperature in the EP of the injector (the numbers in the circle are the measured temperature near the outlet nozzle). The heating of the end part of the injector increases both the temperature and the pressure LPG in the channel. The extension of time for spray duration of LPG into the intake manifold was due to an increasing the value of the steam quality "x" (coefficient of the steam saturation) and thus decreases the mass flow of LPG through an outlet nozzle into the intake manifold. Pressure course (especially evident in the region around zero) might be affected by cold temperature while the pressure sensor was exposed to very low temperature over a long period of time (temperature drift).

The experimental results showed that for elimination of the risk of "icing" is sufficient heat output for warming EP about 20 - 25 W. Measurements also showed that the heat input into the channel of end part of the injector extends the time of a flow of damp steam of LPG from the channel and is therefore ineffective - if the heating of end part of the injector is only in the region of outlet nozzle, required heating power will be then reduced to about 10 - 15 W. These findings led to the proposal of a new structural configuration of end part of the injector.

3. Construction of the End Part of the Liquid LPG Injector with Heating of Nozzle

The new design of the end part of the injector for the liquid LPG is designed so that the heat flow of heating had been directed to part of the outlet nozzle. This arrangement significantly reduces the required heating capacity to ensure the injection of liquid LPG without icing. Heating of the outlet nozzle is secured to either the flow of liquid from the engine cooling system or electrical heating. Both variants are structurally resolved, variant of heating the flow of liquid from the engine cooling system is already prepared as a specimen to verify on the engine (see Fig. 4). For the variant with electric heating is looking for a suitable heating element.

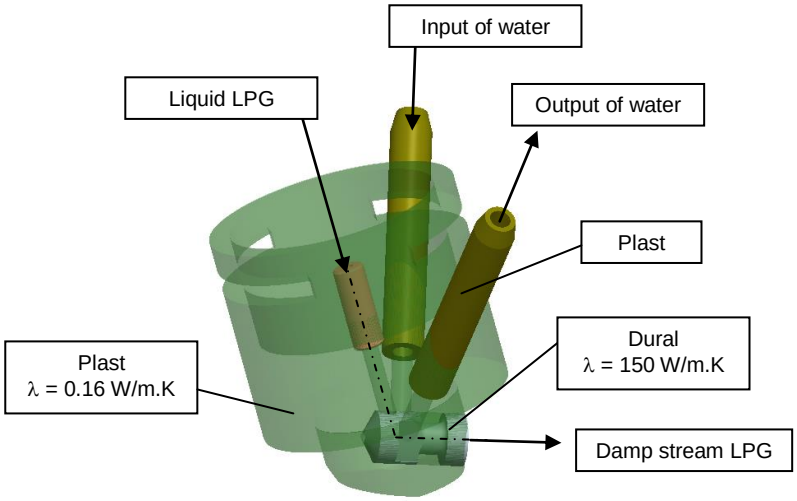

Fig. 4: The new design of the end part of the injector for the liquid LPG - heating of the outlet nozzle is secured by the flow of liquid from the engine cooling system.

4. Conclusions

The reliable solution for the troublefree variant of the liquid LPG injector for alternative fuel system for operating the engine on liquid LPG is the heating of the wall near the outflow nozzle: either by flow of the coolant from the cooling system of the engine, or using of the local electric heating. The research works show, that the sufficient heating power for heat flow of heating, which had been directed to the wall near the outflow nozzle, is for prevent of icing about 10 – 15 W (the solution is founded on the different values of the material heat conductivity for the end parts of injector). Fig. 4 shows the concept of such variant of LPG liquid injector with the heating using flow of coolant.

Acknowledgement

This research has been realized using the support of Technological Agency, Czech Republic, programme Centres of Competence, Project # TE01020020 Josef Božek Competence Centre for Automotive Industry

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