PAPER • OPEN ACCESS

Priming dose in distributed injection systems of overheated alcohol fuel

View the article online for updates and enhancements.

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Priming dose in distributed injection systems of overheated alcohol fuel

A V Egorov[1], A V Lysyannikov[2], Yu F Kaizer[2], V G Shram[2], N N Lysyannikova[2], A V Kuznetsov[3], V L Tyukanov[2] and O A Kaizer[3]

[1] Volga State University of Technology, Yoshkar-Ola, Russia
[2] Siberian Federal University, Krasnoyarsk, Russia
[3] Krasnoyarsk State Agrarian University, Krasnoyarsk, Russia

E-mail: kaiser170174@mail.ru

Abstract. The expansion of the use of alcohol-containing fuels is evidenced by the release to the market of vehicles operating on benzoethanol mixtures E85 and E90, as well as on pure fuel ethanol E100. For regions with a temperate and cold climate (Russia, USA, Canada, Western Europe), the lack of fuel systems, which make it possible to launch and operate engines on pure alcohols (n-propyl, isopropyl, n-butyl, sec-butyl, iso-butyl, tert-butyl), restrains, among other reasons, the widespread use of alcohols as motor fuels. According to numerous studies, an engine operating on pure alcohols can be started at temperatures above 10 ° C, at lower temperatures it becomes impossible to start and for its implementation at least 10-15% of the priming dose of gasoline is introduced into alcohols. The priming dose of gasoline in gas-alcohol mixtures can be replaced by a priming dose of alcohol injected into the intake manifold in a superheated state. This technical solution is proposed in patents for inventions of the Russian Federation of the authors. This article is devoted to the scientific and technical rationale for the efficiency of the use of pure superheated alcohols in injection systems and their impact on the effective performance of internal combustion engines with forced ignition.

1. Introduction

The constant rise in prices for petroleum products and the prospects for the imminent depletion of oil reserves are pushing engine and motor vehicle manufacturers to look for ways to reduce consumption of petroleum products and ways to transfer vehicles to alternative fuels derived from renewable sources of energy, in particular alcohols (n-propyl, isopropyl, n-butyl, sec-butyl, iso-butyl, tert-butyl).

The transfer of vehicles to alcohol fuels has recently become more and more relevant, as evidenced by a significant amount of research into the influence of the composition of gasoline - alcohol mixtures on the characteristics of internal combustion engines with forced ignition [1-3].

For regions with a temperate and cold climate (Russia, USA, Canada, Western Europe), the lack of fuel systems, which make it possible to launch and operate engines on pure alcohols, restrains, among other reasons, the widespread use of alcohols as motor fuels.

According to numerous studies, an engine running on pure alcohols can be started at temperatures above 10 ° C, starting at lower temperatures becomes impossible and for its implementation up to 20% of the priming dose of gasoline is introduced into alcohol [4-8].

The priming dose of gasoline in gasoline -alcohol mixtures can be replaced by a priming dose of alcohol injected into the intake manifold. This technical solution is proposed in the patent for the invention of the Russian Federation [9] and a number of patents for the authors' inventions.

The essence of the technical solution lies in the fact that alcohol fuel is injected into the intake manifold of an atmospheric engine at a temperature exceeding its boiling point at atmospheric pressure, while the amount of fully evaporated fuel depends on the degree of overheating of the fuel.

2. Study of vaporization in the systems of distributed injection of superheated alcohol fuel

Neglecting the processes of heat exchange with air at the moment of injection and assuming that after injection all fuel in one or another state of aggregation will be in a suspended form the law of energy conservation will be written in the following form:

$$c_{p_{s.al.}} M_{s.al.} T_{s.al.} = c_{p_{al.}} M_{al.} T_{al.} + \lambda_{al.} M_{al.},$$
(1)

where $c_{p_{s.al.}}, M_{s.al.}, T_{s.al.}$ - specific heat, weight and temperature of superheated alcohol; $c_{p_{al.}}, M_{al.}, T_{al.}$ - specific heat, weight and temperature of the alcohol in a state of saturated liquid after injection into the intake manifold; $\lambda_{al.}$ - the heat of vaporization of alcohol at a pressure equal to the pressure in the intake manifold; $M_{al.}$ - the weight of steam formed in the intake manifold after the injection of superheated alcohol.

Knowing the absolute pressure of the fuel in the system of distributed injection of traditional design (0,5 MPa) [10], knowing the thermophysical parameters on the saturation line of alcohols, namely the heat capacity and specific heat of vaporization, we determine the temperature of their overheating required for evaporation of a certain proportion of injected alcohols, calculations put in table 1.

Table 1. Overheating temperature for boiling out a mass fraction of alcohol.

Substance	T_{boil}, °C, with pressure, MPa		Overheating temperature for boiling out a mass fraction of alcohol, %										
	0,1	0,5	100	90	80	70	60	50	40	30	20	10	5
ethanol	78,3	123	411,9	370,7	329,5	288,3	247,1	205,9	164,7	123,6	82,4	41,2	20,6
n-propyl alcohol	97,8	149	326,5	293,9	261,2	228,6	195,9	163,3	130,6	97,9	65,3	32,6	16,3
isopropyl alcohol	82,5	130	238,7	214,8	191,0	167,1	143,2	119,3	95,5	71,6	47,7	23,9	12,0
n-butyl alcohol	92,7	172,6	250,4	225,4	200,3	175,3	150,2	125,2	100,2	75,1	50,1	25,0	12,5
sec-butyl alcohol	87	-	193,3	174,0	154,6	135,3	116,0	96,7	77,3	58,0	38,7	19,3	9,7
iso-butyl alcohol	88,5	-	205,9	185,3	164,7	144,1	123,5	102,9	82,3	61,8	41,2	20,6	10,3
tert-butyl alcohol	79,9	-	176,7	158,9	141,2	123,6	105,9	88,3	70,6	53,0	35,3	17,7	8,8

Using the same method, we determine the amount of alcohol that can be transferred to the vapor fraction immediately after injection into the intake manifold, provided that the alcohol overheating temperature was the maximum allowable for the operating pressure of fuel in the injection system, the results are shown in figure 1.
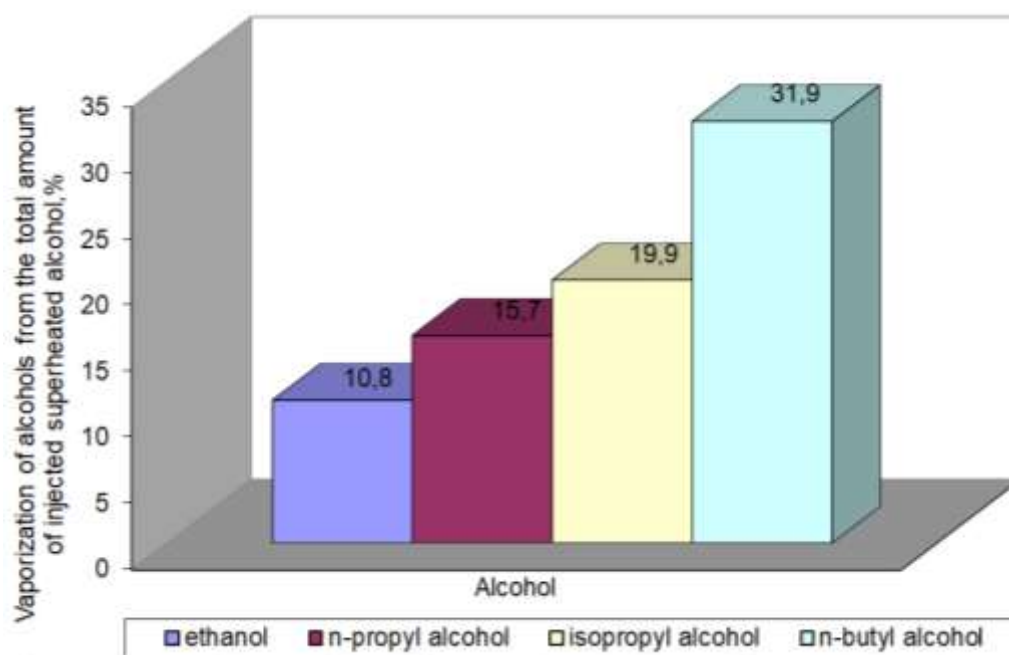
Figure 1. The percentage of vaporization of alcohols when injected in a superheated form in the system of distributed injection.

As can be seen from the figure, higher alcohols (n-propyl, isopropyl, n-butyl) have advantages over ethyl alcohol. The proportion of the vapor fraction in such alcohols after injection is significantly greater than the proportion of the vapor fraction of ethyl alcohol.

Thus, using the preliminary overheating of alcohols in distributed injection systems, it is possible to get priming doses of alcohols that are in the vapor state. Moreover, the priming dose by mass will be no less than the priming dose of gasoline in gas-alcohol mixtures of the E90 brand.

The injection of superheated alcohol into the intake manifold causes an increase in the average temperature of the fuel-air mixture entering the engine cylinders, which leads to an increase in the specific effective fuel consumption.

For the traditional system of distributed fuel injection (fuel pressure 0.5 MPa), the average temperature increase of the fuel-air mixture during the injection of overheated alcohols will be:

- at injection of ethyl alcohol ~ 42 ° C;
- at injection of n-propyl and isopropyl alcohols ~ 45 ° C;
- at injecting n-butyl alcohol ~ 23 ° C.

3. The study of the influence of alcohol overheating on the effective performance of the engine, equipped with a distributed injection system

The growth of the specific effective fuel consumption determined on the basis of the results of the thermal calculation of the effective performance of the base engine VAZ-2115 (8 valves, 1,5 l, working volume, compression ratio 9,8) equipped with a system of distributed injection of superheated alcohol fuels is shown in figure 2.
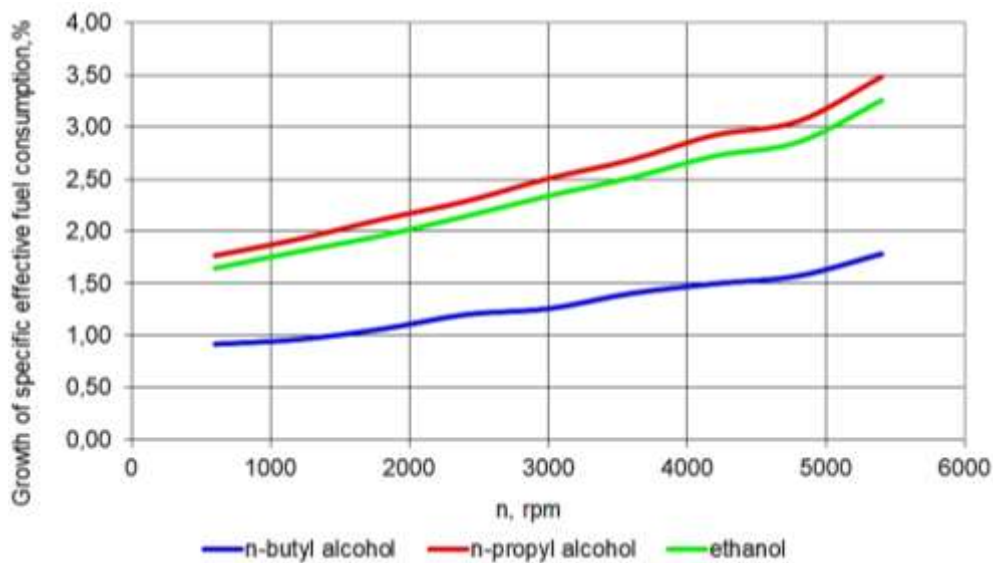
Figure 2. The growth of the specific effective fuel consumption of the engine with the injection of superheated alcohols in the systems of distributed injection.

As can be seen from figure 2, the use of superheated n-butyl alcohol leads to a smaller increase in the specific effective fuel consumption, therefore, its use is preferable.

As shown by experimental studies conducted during the operation of the base engine on superheated n-butyl alcohol, the process of overheating and preheating can be completely eliminated after the engine is brought to a stationary thermal regime at a coolant temperature of more than 90 ° C without loss of stability and throttle response of the engine.

4. Conclusion

On the basis of the conducted research in the systems of distributed injection of superheated alcohol fuel of internal combustion engines with forced ignition, it is advisable to use n-butyl alcohol from the points of view:

- ensuring the maximum proportion of alcohol, passing into the vapor fraction during injection;
- ensuring a minimum increase in the specific effective fuel consumption of the engine when superheated alcohol is injected;
- enabling the engine to work without loss of stability and acceleration after the engine is brought to a stationary thermal regime at a coolant temperature of more than 90° C.

Reference

[1] Abdullah N R, Zaharin M S M, Mamat A M I, Nawi M R M, Sharudin H 2015 Effects of ethanol blends on gasoline engine performance and exhaust emissions *Jurnal Teknologi* **76(11)** 107-12

[2] Agarwal A K, Karare H and Dhar A 2014 Combustion, performance, emissions and particulate characterization of a methanol-gasoline blend (gasohol) fuelled medium duty spark ignition transportation engine *Fuel Processing Technology* **121** 16-24

[3] Altun S, Oztop H F, Oner C, Varol Y 2013 Exhaust emissions of methanol and ethanol-unleaded gasoline blends in a spark ignition engine *Thermal Science* **17(1)** 291-7

[4] Balaji D, Govindarajan P and Venkatesan J 2010 Emission and combustion characteristics of SI engine working under gasoline blended with ethanol oxygenated organic compounds *American Journal of Environmental Sciences* **6(6)** 495-9

[5]   Hsieh W-D, Chen R-H, Wu T-L and Lin T-H 2002 Engine performance and pollutant emission of an SI engine using ethanol-gasoline blended fuels *Atmospheric Environment* **36(3)** 403-10

[6]   Balki M K, Sayin C, Canakci M 2014 The effect of different alcohol fuels on the performance, emission and combustion characteristics of a gasoline engine *Fuel* **115** 901-6

[7]   Al-Hasan M 2003 Effect of ethanol-unleaded gasoline blends on engine performance and exhaust emission *Energy Conversion and Management* **44(9)** 1547-61

[8]   Turner D, Xu H, Cracknell R F, Natarajan V, Chen X 2011 Combustion performance of bio-ethanol at various blend ratios in a gasoline direct injection engine *Fuel* **90(5)** 1999-2006

[9]   Egorov A V 2006 *Air-fuel mixture preparation system for internal combustion engine with forced ignition* RF Patent 2.278.990

[10]   Egorov A, Kozlov K and Belogusev V 2016 Development of a multi-point injection system operating on superheated alcohol fuels and evaluation of toxicity of their combustion products *Periodica Polytechnica Mechanical Engineering* **60(4)** 220-7