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SOLUTION OF THE PROBLEM OF FUEL COMBINATION IN MAINTENANCE

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Abstract

In article, the solution of problem of the combined use of fuel in operation is considered. It is shown that during the operation of the gasoline automobile engine the requirement to octane number of fuel changes depending on engine operation mode: at increase in rotary speed the required octane number of fuel decreases, and at increase in loading increase in octane number of fuel is necessary. The combined use of low-bracket gasoline with high-octane liquefied gas is given. The condition supporting necessary octane number of fuel on various modes for ensuring without detonation work and optimization of combustion procedure is defined. At all engine operating modes in operation on combined fuel, only a high-octane component should be supplied. To control the change in the ratio of the supplied components of the combined power system, it is necessary and sufficient to use any combination of the following parameters: p_i *– vacuum in the intake manifold;* n_i *– is the engine speed;* β *– is the degree of opening of the throttle valve of the carburetor, or others, which are functionally dependent on the above. As a result, the feasibility of choosing one or another option is determined by the design features of the fuel combination implementation system.*

Key words: *fuel combination, octane number, gasoline, gaseous fuel, operating mode, design features.*

Transport on the road performing an essential factor of the economy of the country, being the most power-intensive industry. In terms of market interaction, the quality and consistency of its function acquires an extremely important economic, socio-economic importance. Most cars are equipped with gasoline internal combustion engines (ICE). The tasks of reducing operating costs and environmental pollution are both important and complex.

One of the important field for reducing the operational costs and toxicity of ICE is their conversion to gas motor fuels (GMF). All over the world, the problems of energy supply of transport are escalated every year [1].

There is a minor decrease in maximum power when converting petrol ICE to GMF, but at the same time the toxicity of exhaust gases is significantly reduced and the cost of fuel and lubricants is almost halved. It has become a practice to re-equip petrol ICE for powering GMF in operation by installing a set of gas-cylinder equipment (GCE), as a result of which the car becomes dual-fuel [2, 16]. In the present research we consider the improvement of the process of operation of gas balloon cars (GBC) with dual-fuel power supply system when using gas liquefied petroleum (GLP) in ICE with spark ignition.

The existing theoretical provisions and methods of converting petrol ICE to power GMF, which are the basis for the development and operation of gas-cylinder equipment (GEC), do not take into account the mutual influence of gas and petrol power systems. The question of the possibility of their joint (combined) use in order to increase the reliability of power systems and improve the operating processes GBC when using GMF is insufficiently covered. Therefore, we investigated the theoretical basis of fuel combination in operation.

It is known [3, 4] that when a car petrol engine is running, the requirements for the octane number of fuel vary depending on the operating mode of the engine. In general, it comes down to the following. As the speed increases, the required octane number of fuel decreases. At the same time, when the load increases, i.e. when the degree of opening of the throttle valve increases, it is necessary to increase the octane number of fuel.

From the previous studies [5, 9] it is known that when mixing fuels with different octane numbers (ON) it is possible to obtain fuel with a given ON.

$$ON_{Fm} = C \cdot ON' + (1 - K) \cdot ON,$$

Where C - the fraction of a component with an octane number ON

ON_{FM} - Octane number of fuel mixture consisting of fuel with ON and fuel with ON.

Therefore, the share of one of the components can be expressed in the form:

$$C = \frac{ON" - ON_{FM}}{ON" - ON'} \quad (2)$$

This is graphically reflected in Fig. 1. Given the above, let's consider the option of combined use of low-octane petrol with high-octane liquefied gas. With such a combination of fuels, it is possible to maintain the necessary ON fuel at different modes to ensure detonation-free operation and optimization of the combustion process. In modes with high speed of rotation the necessary speed of combustion of the working mixture is provided by low octane petrol. Non-detonation operation with high load and low crankshaft speed is ensured by high-octane gas fuel. At the same time, the recommended by the manufacturer for passport fuel ignition timing adjustment is retained.

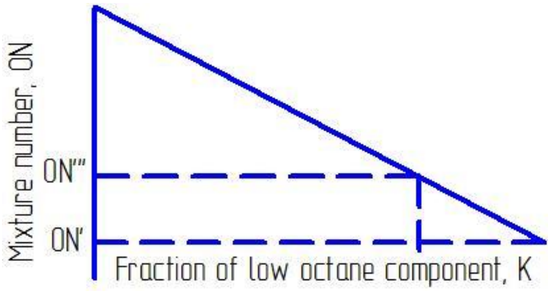

Fig. 1. Dependence of the octane number of the mixture on the fraction of the low-octane component

The reliability of the combined power supply system is improved compared to the universal power supply system due to the fact that the two systems are constantly in working condition.

The cost of the total mileage at full fueling is reduced in comparison with the universal power supply system due to the use of cheaper low-octane petrol while maintaining the advantages (economy and power) of a highly accelerated engine.

To implement a combined fuel supply it is enough to upgrade the existing universal power supply system. Supplementing the universal power supply system with elements that allow changing the ratio of gaseous and liquid fuels supply, we obtain a combined power supply system.

Thus, by adding some elements to the existing universal power supply system using liquefied petroleum gas and petrol, it is possible to obtain a universal combined power supply system [6, 21]. This increases the efficiency of the engine with a universal power supply system.

In the case of combined fuel supply, the required ratio of components should be determined by the engine operation mode and octane numbers of the supplied components. In this case, two conditions must be met: non-detonation engine operation and the optimal combustion rate of the fuel-air mixture.

The following conditions are sufficient for the engine to operate without non-detonation:

$$\boldsymbol{ON_{FM}} \geq \boldsymbol{ON^{C}}, \quad (3)$$

Where ON_{FM} – octane number of the fuel mixture supplied;

ON^{C} – minimum allowable octane number at which detonation-free operation of the engine is ensured for the current mode.

To ensure optimal combustion speed (which is especially important at high speeds), a minimum allowable octane number of fuels is required.

Therefore, to meet both conditions, it is necessary and sufficient to observe the following:

$$\mathrm{ON_{FM}} = \mathrm{ON}^{\boldsymbol{C}}, \quad (4)$$

If we take into account expression (3), then

$$C = \frac{\mathrm{ON"} - ON^{C}}{\mathrm{ON"} - \mathrm{ON}'}, \quad (5)$$

Where C_R is the required proportion of the low-octane component;

ON is octane number of high-octane component;

ON' is octane number of the low-octane component;

ON^{C} is minimum allowable octane number at which non-detonation operation is provided.

Taking into account that the ON^{C} is a function that depends on the engine operation mode, it follows that C_R – the required proportion of low octane component is also a function of the engine operation mode. Therefore, to implement the combined fuel supply it is necessary to have a gauge that detects the engine operation mode and an actuator that changes the ratio of the fuel supply depending on the signal provided by the gauge. The gauge should be a functional analogue of the C_R.

There are three options for changing the ratio of the supplied components:

- Linear change in ratios;
- Discrete component replacement;
- step change of components.

The possibility of combined use of fuels can be most fully realized by a variant with a linear change in the ratio of supplied components depending on the engine operation mode [7, 18]. Graphically, the variant with a linear change in the ratio is indicated in Fig. 2 This option eliminates the possibility of detonation on the low-octane component, only the low-octane component is supplied in its pure form. In the modes in which detonation becomes possible, the low-octane component is partially replaced by a high-octane component until the required ON mixture is achieved, at which detonation is absent.

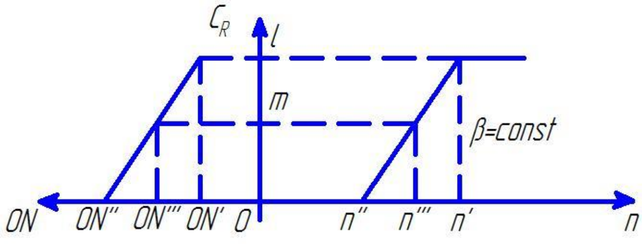

Fig. 2. Variant of linear change in the ratio of components

Substitution can be performed until the low octane fuel supply is completely eliminated when the high octane component is supplied in its pure form. In this case, the change in the ratio of the supply of fuels with different ON occurs linearly, by tracking changes in engine operating modes [8, 12].

The simplest option for combining fuels is the discrete substitution of components (Fig. 3).

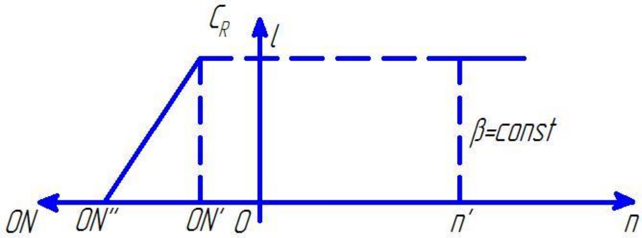

Fig. 3. Discrete component replacement option

The variant of discrete component substitution is that when the engine is running in the subcritical mode ($n_i > n_i^{''}$), a low-octane component with an ON' is used. And when the critical mode is reached ($n_i = n_i^{''}$), that is, the mode when detonation on low octane fuel is possible, the low-octane component is completely replaced with high-octane one. Component substitution is performed discretely, and some of the modes will be supplied with fuel with an octane number [15, 17, 20].

With the above method, the conditions of non-detonation operation are fulfilled completely, and the conditions for optimizing the combustion rate only at particularly critical conditions, i.e. at high speeds of rotation.

The variant of the stepwise change of the component ratio is that when the critical mode is reached, there is a partial discrete replacement of components, with the provision of some excess of the ON mixture of supplied fuels over the minimum required ON, which ensures non-detonation operation [10, 19]. When reaching the critical ($n_i = n_i^t$) mode, when detonation for a given fuel mixture is possible, the next stage of substitution takes place, etc., until the low octane component is completely replaced with high-octane one. Graphically, the variant of the stepwise change in the ratio of components is indicated in Fig. 4.

The higher the number of replacement stages, the closer this option is to the variant of linear substitution of components.

Since the required ON fuel must be determined by the operating mode of the engine, to determine the ratio of the supplied fuels, which determines the ON mixture, control parameters characterizing the operating mode of the engine are needed.

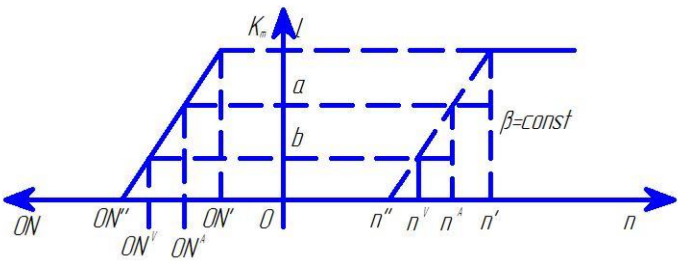

Fig. 4. The variant of the step change of the component ratio

The control parameters must meet the following requirements:

- The parameters must be informative and reflect the motor operating mode, i.e. they must be a function of the motor operating mode;

- The parameters must be unambiguous, i.e. each parameter value or combination of parameters must have one defined motor operating mode;

- The parameters must be reliable and have a sufficient excess of the useful signal level over the noise level;

- The parameters should be capable of converting the useful signal for use in various actuators.

The following parameters correspond to the above requirements:

p_i – is vacuum in the intake collector;

n_i – is the crankshaft rotational speed;

β – is the carburetor throttle opening degree

and other parameters that are functionally dependent on the above parameters.

The compliance criterion is a necessary condition for using at least two of the above parameters [13, 14]. Only in this case, the condition of unambiguous determination of the engine operation mode is met.

The use of only one of these parameters is not sufficient to ignore the unambiguous condition. This can be seen in the following examples.

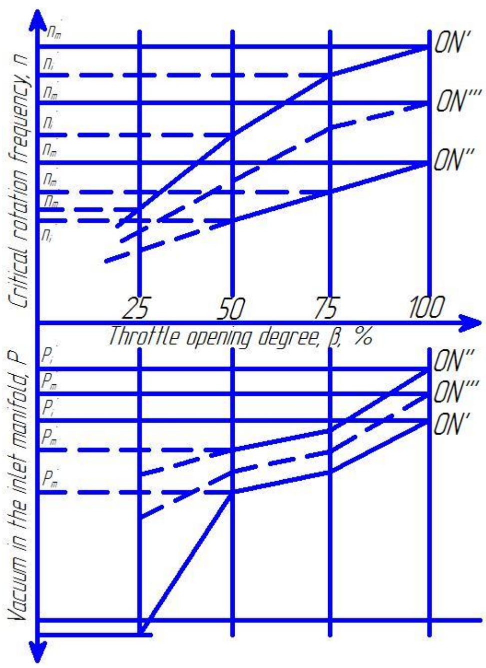

Fig.5. The beginning of detonation when working on fuel with ON' and ON".

If the control parameter is taken only n – the frequency of rotation of the crankshaft, then under the condition of non-detonation operation, in all modes at $n_i \leq n_m 100$ (where n_i – current speed; n_m 100 – critical speed at which the detonation begins when operating on fuel with a frequency converter ON = t and 100% opening of the throttle valve) it is necessary that $ON_{FM} > t$ (Fig. 5). At the same time, a significant part of the engine operation modes $(n_i^m < n_i < n_v 100; \beta_i 100\%)$ will be supplied with fuel with unreasonably high octane number and possibility of non-detonation operation on lower octane fuel [11].

A similar picture appears also if we take only p_i vacuum in the inlet collector as the control parameter.

When we take the missing Δn for the ON_m power mixture owing to the likely event of detonation.

Moreover, the larger β (the degree of opening of the throttle at which the regulator is triggered), the greater is the ratio Δn/ΔON, with the shift of the detonation start to higher speeds. In order to ensure non-detonation operation in all modes, it is necessary that:

$$ON_m = ON'' = const \tag{6}$$

In other words, only the high-octane component should be supplied in all modes.

The following conclusion can be made based on the above.

Any combination of at least two of the following parameters should be used to control the change in the ratio of the supplied components of the combined power supply system:

p_i – is vacuum in the intake collector;

n_i – is engine crankshaft rotational speed;

β – the degree of throttle opening, or others that are functionally dependent on the above.

Thus, the expediency of choosing this or that variant is determined by the design features of the fuel combination system.

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