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Specifications for applying high octane additives to the motor gasoline in hot climate

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Abstract: The article analyzes the use of high-octane additives to motor gasoline used in hot climates. We have studied anti-knock additives as additives to improve the octane number of gasoline. An additive based on alcohols, octane-Booster, was used as such additives. Laboratory studies were carried out on the physicochemical parameters of AI-80 and AI-92 gasoline with the addition of an anti-knock additive. The results of the studies show that when gasoline is used in hot climates, the addition of high-octane components based on alcohols increases the octane number, but at the same time the boiling point of the light fraction of gasoline decreases. With an increase in the percentage of additive, the boiling point of the light fractions reached 58°C. Taking into account all the experimental data obtained, we suggest adding a percentage of this additive of no more than 3%, which shows the optimal octane number and distillation temperature of 10% gasoline for hot climates. With a further increase in concentration to 5%, the octane number increases, but at the same time the distillation temperature of 10% gasoline sharply decreases, which can lead to increased friction losses. When the concentration increased above 5%, the octane number did not change. To ensure optimal engine operating conditions in hot climatic conditions, we suggest ensuring that the boiling point of gasoline at the beginning of distillation is not lower than 40°C ÷ 43°C, and the distillation temperature of 10% gasoline is not lower than 70°C.

1 Introduction

One of the main indicators of the quality of motor gasoline is their resistance to detonation, on which reliability, increased power, efficiency and service life of a car engine largely depend [1-4].

An internal combustion engine is not designed to operate with gasoline with an octane number below a certain value determined by the degree of compression of the combustible mixture in the combustion chamber. Low-octane fuel can spontaneously ignite in the combustion chamber before the desired moment, determined by sparking in the spark plug, which causes dangerous detonation. A discrepancy between the octane number of gasoline and engine parameters can cause detonation combustion of the fuel mixture, accompanied by a characteristic metallic knock, an increase in exhaust smoke and temperature in the

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engine cylinders. Detonation entails emergency breakdowns of engine parts: burnout of valves, destruction of pistons, breakdown of the cylinder head gasket [5-8].

Currently, to improve anti-knock properties and increase resources, high-octane components-oxygen-containing compounds - are added to motor gasoline. Ethyl and methyl alcohols (ethanol and methanol) can be used as oxygen-containing high-octane additives. The use of alcohol components in the form of additives to gasoline is promising not only in terms of preserving oil resources, but also improving the environmental properties of motor fuels. The amount of alcohol introduced allows to reduce the concentration of undesirable aromatic hydrocarbons. Alcohols have a higher-octane number (90÷94) than gasoline and a latent heat of evaporation, which reduces the thermal stress of engine parts (Table 1).

Table 1. Chemical composition and performance characteristics of alcohols and gasoline

Chemical composition and performance characteristics	Methanol	Ethanol	Gasoline
Chemical formula	CH_3OH	C_2H_5OH	C_5-C_{12}
Carbon (wt.%)	38 12 50	52 13 35	86 14 0
Hydrogen (wt.%)	798	794	690-740
Oxygen (wt.%)	65	78	35÷200
Liquid Density (kg/m^3)	0,74	1.2	
Boiling temperature	109	109	86-100

From an energetic point of view, the advantages of alcohols lie mainly in their high detonation resistance. By adding 10 percent ethyl alcohol, gasoline type AI-92 can easily be upgraded to AI-95. Alcohol, by increasing the charge density, simultaneously reduces the detonation rate and the effect of high temperatures on the engine. During trial operation of vehicles using a gasoline-methanol mixture containing 3-5% methyl alcohol, gasoline savings amount to 1.5-3%.

Along with the positive environmental efficiency of using alcohol additives, negative phenomena should also be noted, such as increased emissions of aldehydes and evaporation of hydrocarbon compounds. When using alcohols, the content of aldehydes in the exhaust gases increases by 2–3 times. The content of aldehydes increases with increasing concentration of alcohols in the fuel mixture. Methanol produces formaldehyde emissions, and combustion of ethanol produces acetaldehyde. On average, aldehyde emissions when running on alcohol are approximately 2–4 times higher than when the engine is running on gasoline. Disadvantages of alcohol additives are also low hydrolytic stability, low anti-wear and anti-corrosion properties. Alcohols penetrate into the material of the hoses and seals of the car's fuel system, which disables them, breaking the tightness.

It is possible to increase the octane number of gasoline and reduce the risk of detonation by adding an additive to the fuel called an octane corrector, which is a mixture of ethanol. Octane corrector (octane booster) increases the octane number of fuel by 3-6 units. Thus, gasoline with an octane number of 92, after adding an additive, will be equivalent in its anti-knock properties to gasoline with an octane number of 98. Its operating principle is based on changing the chemical structure of the fuel, which allows increasing combustion efficiency and improving the quality of the fuel.

2 Materials and methods

The purpose of this work is to study the performance characteristics of motor gasoline used in hot climates with the addition of the anti-knock additive Octane Booster. To achieve this goal, we selected samples of motor gasoline AI-80, AI-95 and anti-knock additive and were analyzed according to main quality indicators. The physicochemical properties of motor gasolines AI-80 and AI-95 without additives were previously determined for comparison. Laboratory physical and chemical analyzes were carried out according to established methods and are shown in Table 2, 3.

Table 2. Basic physical and chemical indicators of AI-80 gasoline

Quality indicators	**AI-80**	
	According to GOST	**In fact**
1. Knock resistance: octane number	80	80
2. Fractional composition:		
temperature at the beginning of distillation of summer gasoline, °C,	35	37
boiling point of 10% gasoline, °C	70	69
boiling point temperature of 50% gasoline, °C	115	112
boiling point temperature of 90% gasoline, °C	185	184
end of boiling point of summer gasoline, °C,	205	195
residue in flask,%,	1,5	1,9
balance and losses,%,	4,0	4,2
3. Saturated vapor pressure of summer gasoline, kPa	66,7	66
4. Acidity, mg NMH per 100 cm^3 of gasoline	1,0	1,1
5. Water-soluble acids and alkalis	Absence	
6. Density at 20 °C, kg/m^3	690-760	760

Table 3. Basic physical and chemical indicators of AI-92 gasoline

Quality indicators	**AI-92**	
	According to GOST	**In fact**
1. Knock resistance: octane number	92	92
2. Fractional composition:		
temperature at the beginning of distillation of summer gasoline, °C	35	37
boiling point of 10% gasoline, °C	70	70
boiling point temperature of 50% gasoline, °C	115	115
boiling point temperature of 90% gasoline, °C	185	184
end of boiling point of summer gasoline, °C,	205	198
residue in flask,%,	1,5	1,7
balance and losses,%,	4,0	4,1
3. Saturated vapor pressure of summer gasoline, kPa	66,7	65
4. Acidity, mg NMH per 100 cm^3 of gasoline	1,0	1,05
5. Water-soluble acids and alkalis	Absence	
6. Density at 20 °C, kg/m^3	690-760	755

Subsequently, laboratory tests were carried out with an anti-knock additive separately for AI-80 and AI-92 gasoline. The recommended concentration of this additive in gasoline is 3–7%. Based on this, we prepared samples with 3–7 percent concentrations of AI-80 and AI-92 gasoline and then determined the main physical and chemical indicators of the fuel (Table 4.5).

Table 4. Basic physico-chemical parameters of AI-80 gasoline with octane-Booster additive

Quality indicators	AI-80 +3%	AI-80 +5%	AI-80 +7%
1. Knock resistance: octane number	83	86	86
2. Fractional composition:			
temperature at the beginning of distillation of summer gasoline, °C	37	37	36
boiling point of 10% gasoline, °C	68	65	58
boiling point temperature of 50% gasoline, °C	108	105	105
boiling point temperature of 90% gasoline, °C	178	175	175
end of boiling point of summer gasoline, °C,	195	193	193
residue in flask,%,	1,9	1,9	1,9
balance and losses,%,	4,2	4,2	4,2
3. Saturated vapor pressure of summer gasoline, kPa	66	70	75
4. Acidity, mg NMH per 100 cm^3 of gasoline	1,1	1,1	1,1
5. Water-soluble acids and alkalis		Absence	
6. Density at 20 °C, kg/m^3	760	758	752

Table 5. Basic physical and chemical parameters of AI-92 gasoline with octane-Booster additive

Quality indicators	AI-92 +3%	AI-92 +5%	AI-92 +7%
1. Knock resistance: octane number	95	98	98
2. Fractional composition:			
temperature at the beginning of distillation of summer gasoline, °C,	37	36	35
boiling point of 10% gasoline, °C	68	65	61
boiling point temperature of 50% gasoline, °C	108	110	105
boiling point temperature of 90% gasoline, °C	180	180	178
end of boiling point of summer gasoline, °C,	195	195	195
residue in flask,%,	1,9	1,9	1,9
balance and losses,%,	4,2	4,2	4,2
3. Saturated vapor pressure of summer gasoline, kPa	65	68	70
4. Acidity, mg NMH per 100 cm^3 of gasoline	1,05	1,05	1,05
5. Water-soluble acids and alkalis		Absence	
6. Density at 20 °C, kg/m^3	755	753	750

3 Results and discussion

As a result of the research, it is clear that with an increase in the percentage of additives added to gasoline, the octane number of the fuel increases, but at the same time, the boiling point of the light fraction of gasoline and the density of the fuel decrease.

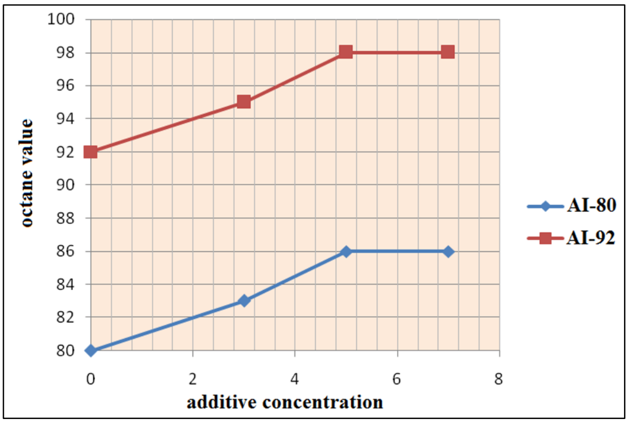

Fig-1. Change in fuel octane number depending on additive concentration.

The volatility of gasoline must ensure the optimal composition of the air-fuel mixture in all engine operating modes.

The starting temperature ($t_{n.k}$) of summer and winter gasoline is standardized at 35°C. The boiling point of 10% ($t_{10\%}$) gasoline to ensure optimal engine operating conditions should be: for summer gasoline - not lower than 70°C, for winter gasoline - not lower than 55°C. At values below those indicated, the formation of steam and steam-air plugs in the fuel system is possible. In the summer, a decrease in this temperature inevitably leads to large losses from the evaporation of gasoline, as well as the occurrence of an explosion and fire hazard during the operation of such gasoline.

Boil-off of 10% of summer gasoline should occur at a temperature not lower than 70°C. In our example, when adding a 3% additive to AI-80 fuel, the boiling point of 10% gasoline decreased by 68°C, respectively, at 5% - 62°C, and when adding 7% additive, the boiling point decreased by 58°C. The boiling point of 10% AI-92 gasoline decreased from 70°C to 68,65,61°C (Fig. 1)

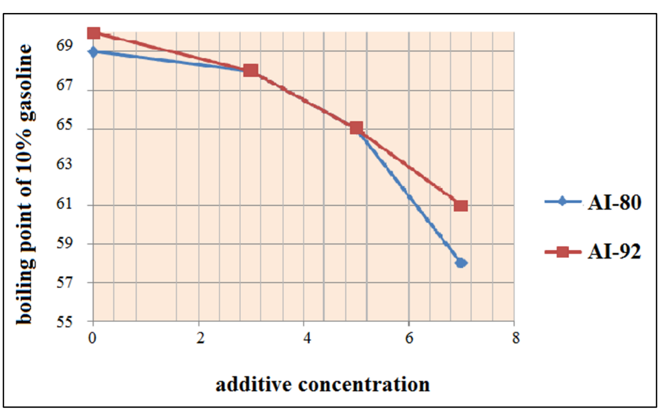

Fig-2. Change in boiling point of 10% fuel depending on additive concentration.

It is undesirable to have too many light fractions in the fuel, which easily evaporate. The use of very light gasolines causes other operational difficulties, such as the formation of vapor locks in the power system, especially in the summer. At a low temperature of the light fraction of gasoline, especially in hot weather, vapors are formed in the power system, the volume of which is 150–200 times greater than the volume of gasoline, which causes interruptions or engine shutdown. In this case, vapors become clogged in the fuel pipes of gasoline engines, as a result of which the engine does not operate normally (overheats, loses power, sometimes stops, and cannot be started without cooling).

From the point of view of the starting properties of gasoline, it is desirable to have a higher content, and from the point of view of the formation of vapor locks, it is preferable to have a lower content of low-boiling fractions. Their optimal maintenance depends on the climatic conditions of the vehicle's operation.

The dependence of the maximum air temperature at which the engine stops due to the formation of vapor locks (t^{1}_{v}) on the initial boiling point ($t_{n.k}$) of gasoline can be determined by the following formula:

t^{1}_{v}=1,85 $t_{n.k}$ – 29 (1)

For the southern regions of the country in the summer, at an ambient temperature of +400C ÷ +500C, if gasoline begins to boil at 350C, then vapor locks form in the power system, which can lead to disruption of the fuel pump.

Based on formula (1), we determine the temperature at which the boiling point begins at which the engine can stop due to the formation of vapor locks (t^{1}_{v}):

t^{1}_{v}=1,85 $t_{n.k}$ – 29 = 1,85·35– 29 = 35,75^{0}C;

t^{1}_{v} =1,85 $t_{n.k}$ – 29 = 1,85·40– 29 = 45^{0}C;

t^{1}_{v} =1,85 $t_{n.k}$ – 29 = 1,85·43– 29 ≈ 50^{0}C.

So, the obtained result shows that for an air temperature of 450C in the summer, the starting boiling point ($t_{n.k}$) of gasoline should not be less than 400C, and for an air temperature of 500C, the starting boiling point (($t_{n.k}$) of gasoline should not be lower than 450C.

Maximum evaporation can be controlled in one of two ways:

– the maximum temperature at which the vapor-liquid ratio equals 20;;

- volatility index or vapor lock index, which is a function of saturated vapor pressure and the amount of fuel in% evaporated at 70°C:

I_{PP} = 10 ·D_{svp} + 7 ·V^{70},

Where: D_{svp}– saturation vapor pressure, kPa,

V^{70} – amount of fuel evaporating at 70°C, %

4 Conclusion

Thus, to ensure optimal engine operating conditions in hot climatic conditions, we suggest that the boiling point of gasoline at the beginning of distillation should be no lower than 400C ÷ 450C, and the distillation temperature of 10% of gasoline should be no lower than 700C. The results of the studies show that when gasoline is used in hot climates, the addition of high-octane components based on alcohols increases the octane number, but at the same time the boiling point of the light fraction of gasoline decreases. With an increase in the percentage of additive, the boiling point of the light fractions reached 58°C. Taking into account all the experimental data obtained, we suggest adding a percentage of this additive of no more than 3%, which shows the optimal octane number and distillation temperature of 10% gasoline for hot climates. With a further increase in concentration to 5%, the octane number increases, but at the same time the distillation temperature of 10% gasoline sharply decreases, which can lead to engine malfunctions. When the concentration increased above 5%, the octane number did not change.

In conclusion, to ensure optimal engine operating conditions in hot climatic conditions, we suggest ensuring that the boiling point of gasoline at the beginning of distillation is not lower than 40°C ÷ 43°C, and the distillation temperature of 10% gasoline is not lower than 70°C.

The quality of motor gasoline can be improved by dividing gasoline by fractional composition and saturated vapor pressure into classes, taking into account the operating season of the vehicle and the ambient temperature characteristic of a specific climatic zone. The presence of classes allows us to produce gasoline with properties that are optimal for real ambient temperatures, which ensures engine operation without the formation of vapor locks at air temperatures up to +550C.

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