Analysis of Performance and Stability Factors of Vehicle Ethanol Gasoline for Motor Vehicle

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Abstract. Ethanol gasoline is a new type of clean energy which is formed by mixing fuel ethanol and ordinary gasoline in a certain proportion. The use of ethanol gasoline in motor vehicles can reduce the emissions of exhaust pollutants and improve the engine performance, but there are also problems such as low combustion calorific value, strong corrosion and easy stratification. Based on the comparison of physical and chemical properties of ethanol and gasoline, the octane number, calorific value, oxygen content, latent heat of vaporization and ignition limit of ethanol gasoline were analyzed. The main problems are discussed in this paper, and the factors affecting the stability of ethanol gasoline are analyzed from three aspects of temperature, water content and ethanol content.

1. Introduction
With the lack of oil resources and the increasing pollution of the environment, researchers have paid more and more attention to the research on alternative fuels for automobiles. Ethanol gasoline is a new type of mixed fuel formed by adding a certain proportion of ethanol into gasoline. Compared with ordinary gasoline, ethanol gasoline has the advantages of high-octane number, good explosion resistance and high oxygen content, which could significantly reduce the emission of harmful substances in automobile exhaust. It is a relatively clean fuel, which has been used as automobile fuel in many countries [1-4]. At present, China has vigorously promoted ethanol gasoline, and specific actions have been carried out in many provinces and cities, among which Tianjin has fully promoted the use of E10 gasoline (the amount of fuel ethanol is 10%) in 2018.

However, there are still a series of problems in the use of ethanol gasoline, for example, easy stratification, hard storage, difficult engine starting, low output power and easy corrosion. At the same time, the high cost of ethanol gasoline also restricts the promotion of ethanol gasoline for vehicles [5-6]. Therefore, how to improve the stability of ethanol gasoline and reduce the cost of ethanol gasoline is the key to be solved. In this paper, the physical and chemical properties of ethanol are analyzed and the main properties and problems of ethanol gasoline and the factors affecting the stability of ethanol gasoline are discussed.

2. Physical and chemical properties of ethanol
Ethanol, commonly known as alcohol, can be made from the raw materials of corn, wheat, potato, sugarcane and other crops through fermentation, distillation, and hydration of ethylene. It belongs to a renewable energy. Ethanol has high oxygen content and can be infinitely soluble in water, but it has poor solubility with hydrocarbon fuel. Ethanol can be used as automobile fuel alone, and can also be
mixed with gasoline and diesel to form a mixed fuel. As one of the alternative fuels with good application prospects, ethanol has many good physical and chemical properties. The comparison of its physical and chemical properties with those of gasoline is shown in Table 1.

| Characteristics               | Ethanol          | Gasoline         |
|-------------------------------|------------------|------------------|
| Chemical formula              | C₂H₅OH          | C₄₋₁₂ Hydrocarbons |
| Carbon content (%)            | 52.2             | 85-88            |
| Hydrogen content (%)          | 13.0             | 12-15            |
| Oxygen content (%)            | 34.7             | 0                |
| Saturated vapor pressure (kPa)| 18               | 45-100           |
| Viscosity (mm²/s)             | 1.2              | 0.6              |
| Molecular weight              | 46               | 58-180           |
| Boiling point (°C)            | 78.32            | 30-220           |
| Density (kg/L)                | 0.785            | 0.70-0.78        |
| Vaporization (kJ/kg)          | 904              | 310              |
| Volume coefficient (Vv)       | 1                | 1.54             |
| LHV (MJ/kg)                   | 26.78            | 44.15            |
| Specific heat (kJ/kg)         | 2.72             | 2.3              |
| Octane number (RON)           | 100-112          | 88-89            |
| Octane number (ROM)           | 90-94            | 77-79            |
| Ignition energy (mJ)          | 0.63             | 0.25-0.3         |
| Ignition temperature (°C)     | 434              | 260-370          |
| Ignition limit (%)            | 3.5-18.0         | 1.3-7.6          |
| Air fuel ratio (A/F)          | 9.0              | 14.8             |

3. Performance of ethanol gasoline

3.1. Octane number
It can be seen from table 1 that the octane number of ethanol is higher than that of gasoline, so the octane number of the mixed fuel of ethanol gasoline is higher than that of gasoline. At present, the compression ratio of gasoline engine is about 8, while the compression ratio of ethanol engine can be as high as 10 to 12. For every 3-5 units increase in gasoline octane number, the compression ratio of gasoline engine can increase by 1 unit. When the compression ratio of gasoline engine is increased, the power will increase and the fuel consumption rate will decrease. Ethanol has a good antiknock property. Adding ethanol to gasoline not only improves octane number, but also can be used as a substitute of tetraethyl lead, which could effectively reduce lead emissions. Using ethanol gasoline hybrid fuel and without engine modification, the power performance is basically similar but the carbon monoxide and hydrocarbons in exhaust emissions are reduced by more than 30% on average, which effectively reduces harmful exhaust emissions, and has positive significance for environmental protection.

3.2. Calorific value
The calorific value of ethanol is lower than that of gasoline and equivalent to 60.9% of gasoline. So the calorific value of ethanol gasoline is lower than that of gasoline, and it decreases with the increase of ethanol content. That is to say, when ethanol and gasoline are mixed, the total calorific value of the fuel is actually reduced, and the mileage of the car is reduced. However, the proportion of ethanol in the mixed fuel of ethanol gasoline is very low, generally not higher than 15%, and the oxygen content of ethanol is higher which means full fuel combustion, so the effect of low calorific value of ethanol gasoline is not very obvious in practical application.
3.3. Oxygen content
The oxygen content of gasoline is 0, while the oxygen content of ethanol is as high as 34.8%. The high oxygen content means that the air quality required for the full combustion of fuel is relatively less. The improvement of thermal efficiency can improve the power, economy and exhaust emission of engines. When ethanol is mixed with gasoline, the mixed fuel can also turned into oxygenated fuel, and the oxygen content of ethanol gasoline will increase with the increase of ethanol content. However, the increase of oxygen content will also lead to some problems, such as oxidation deterioration of lubricating oil caused by O\textsubscript{2} molecules and cylinder wear increasing.

3.4. Latent heat of vaporization
The latent heat of vaporization refers to the energy required for an object to change from liquid to gas at its boiling point. The latent heat of vaporization of ethanol is about three times that of gasoline. When ethanol is added to gasoline, the latent heat of vaporization of the mixed fuel increases, and the low-temperature start-up and operation performance deteriorate. If the engine is not equipped with preheating device, it will be difficult to start.

3.5. Ignition limit
From table 1, it can be seen that the ignition limit of ethanol is wider than that of gasoline, which enables ethanol to work in a dilute mixture state, and it will not cause intermittent ignition due to the lack of accurate control of air-fuel ratio, which is conducive to exhaust purification and fuel consumption reduction. The ignition limit of ethanol gasoline widens with the increase of ethanol content, which is beneficial to exhaust purification and fuel consumption reduction.

4. Problems in the use of ethanol gasoline

4.1. Difficult cold start-up
There are two main reasons for difficult cold start-up performance of ethanol gasoline. One is that the specific heat capacity of the mixed fuel is larger than that of the gasoline, which is easy to cause the temperature in the cylinder to be lower than that of the gasoline; the other is that the latent heat of the gasification of the mixed fuel is larger than that of the gasoline, which absorbs more heat during gasification, and the final cylinder temperature is lower than that of the gasoline. At the same time, low cylinder temperature will lead to insufficient ethanol atomization, affect the formation and combustion rate of the mixture, and increase the unconventional emissions of unburned alcohol aldehyde [7]. In addition, poor atomization of the mixture may result in dilution and emulsification of the lubricating oil and wear of engine parts. In order to solve the problem of cold start-up of ethanol gasoline, the temperature of intake pipe should be increased properly or the strong ignition device should be used.

4.2. Stratification of mixed fuel
Ethanol has strong hydrophilicity and it is easy to absorb water to reduce its purity. When the water content of ethanol gasoline reaches a certain amount, the stratification would occur. The stratification of ethanol gasoline will result in the uneven proportion of ethanol and gasoline in the fuel tank, poor combustibility, difficult start-up and the power decline of the vehicle, and even the engine damage. At present, one of the ways to solve the problem of stratification is to emulsify the ethanol gasoline with a specific emulsifier, so as to keep it in a uniform mixing state.

4.3. Corrosion and wear
Ethanol is corrosive to metals. Acetic acid, acetaldehyde and other substances produced in the combustion process are especially corrosive to automobile engines, especially copper. At the same time, ethanol gasoline has a high latent heat of vaporization, which is easy to dilute or emulsify the lubricating oil, resulting in increased corrosion and wear of engine parts. A large number of experiments show that when the ethanol content in the ethanol gasoline is less than 10%, the corrosion effect on metal is so
small that can be ignored. But when the ethanol content is more than 15%, a certain amount of corrosion inhibitor must be added or the engine must be modified. E10 ethanol gasoline (10% ethanol) is widely used in China, which has little corrosiveness and can be directly used without any engine modification.

5. Factors affecting the stability of ethanol gasoline
Ethanol, water and gasoline can be soluble, but gasoline and water are mutually insoluble liquids. If the water content in ethanol gasoline increases, the phenomenon of stratification of ethanol gasoline will occur, namely phase separation. Phase separation will lead to a series of complex problems in the storage and use of ethanol gasoline including engine damage. Environmental factors have a great influence on the stability of ethanol gasoline, which directly affects the production, storage and use of ethanol gasoline [9]. The research on the influence of environmental factors on the stability of ethanol gasoline is undoubtedly of positive significance for the promotion and use of ethanol gasoline.

5.1. Temperature
Temperature is an important factor affecting the stability of ethanol gasoline. Temperature affects the interfacial tension of oil and water. When temperature increases, the interfacial tension of oil and water decreases, and the tendency of phase separation also decreases. The higher the temperature is, the less likely the oil-water phase separation will occur, that is to say, the better the stability of ethanol gasoline is. On the contrary, the lower the temperature is, the worse the stability is. Different components of ethanol gasoline have different phase separation temperatures. When the temperature is higher than it, ethanol gasoline will not occur, when the temperature is equal to or lower than it, phase separation occurs. It can be seen that the stability of ethanol gasoline can be revealed by the level of phase separation temperature. The higher the phase separation temperature is, the worse the stability will be. The lower the phase separation temperature is, the better the stability will be.

5.2. Water content
Water content refers to the percentage of water in ethanol used to produce ethanol gasoline, which is one of the main factors affecting the stability of the mixed fuel of ethanol gasoline. The higher the purity of ethanol is, the higher the stability of ethanol gasoline is, but the cost of raw materials is also increased accordingly. Therefore, the ethanol used in the production of ethanol gasoline is water-containing ethanol. Only when the water content is very low can phase separation not occur. The relationship between the water content of ethanol gasoline and the phase separation temperature is shown in Figure 1. The higher the ethanol water content is, the higher the phase separation temperature of ethanol gasoline is, and the easier the stratification is. The amount of stratification increases with the increase of water content. The phase separation temperature of ethanol gasoline with different water content is shown in Table 2. It can be seen that phase separation can occur at room temperature when the water content is high.

![Figure 1. Relationship between different water content of ethanol and separation.](image-url)
Table 2. Phase separation temperature of ethanol gasoline with different water content.

| Water Content% | 0–0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 |
|---------------|-------|-----|-----|-----|-----|-----|-----|
| E7.7          | <-40  | -26 | 1   | 8   |     |     |     |
| E10           | <-40  | -40 | -12 | 6   | 10  |     |     |
| E15           | <-40  | <-40| <-40| -28 | -17 | -6  | 13  |

5.3. Ethanol content
The ethanol content in ethanol gasoline is also an important factor affecting the stability of ethanol gasoline. The increase of ethanol content is conducive to the formation of homogeneous system of oil, alcohol and water, and enhances the stability of mixed fuel. It can be seen from table 2 that under the condition of equal water content, the higher ethanol content, the lower phase separation temperature and the higher stability of ethanol gasoline.

6. Conclusion
Compared with gasoline, ethanol has the properties of high octane number, low calorific value, high oxygen content, high latent heat of vaporization and wide ignition limit, which determine the performance difference between ethanol gasoline and ordinary gasoline. Ethanol gasoline has the advantages of less pollutant emission, full fuel combustion and good power performance, but it also has the disadvantages of low calorific value, difficult cold start-up and corrosion. The stability of ethanol gasoline should be solved first in the use of it in motor vehicles. The higher the temperature, the lower the water content and the higher the ethanol content, the better the stability of ethanol gasoline.

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