Research on the influence of fuel detergent synergist on engine fuel supply system

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Abstract. This paper selects 6 gasoline detergent synergists and 6 diesel detergent synergists that are mainstream in the market. The changes in mass, volume, hardness, size and surface morphology of the main components of the engine fuel supply system after being immersed in fuel containing detergent synergists for 28 days were studied,and these changes are compared with the benchmark fuel. The results show that most of the fuel detergent synergists have almost no corrosive effect on the engine fuel supply system components or are close to the reference fuel, but some gasoline detergent synergists have a slight corrosive swelling effect on the gasoline fuel supply system.

1 Background

Generally speaking, the fuel supply system of the engine must meet the requirements of high temperature resistance and corrosion resistance, while the swelling property should be small and have a certain degree of hardness [1]. Sulfides, chlorides, organic acids, moisture, etc. in the oil can cause corrosion of the metal parts of the engine oil supply system and affect the durability of the car [2, 3]. In addition, the acidic components in the oil may have certain corrosion and swelling effects on rubber and plastic parts. Among them, plastic products will swell and become sticky, and rubber products will swell, become hard, become brittle or soften [4-9]. The fuel detergent synergist contains sulfur, chlorine and other substances, so it is necessary to conduct an experimental study on the corrosion effect of gasoline and diesel containing detergent synergist on engine fuel supply system components.

In this paper, we selected 6 gasoline detergent synergists and 6 diesel detergent synergists on the market, and carried out a 28-day immersion test on the main components of the engine fuel supply system with the national VI fuel containing detergent synergists, and investigated the metal materials. Changes in quality and surface morphology, changes in quality, volume, hardness and size of non-metallic materials. The results show that the use of most detergent synergists has no corrosive effect on the components of the fuel supply system, and individual fuel detergent synergists have corrosion and swelling effects after being added to the benchmark fuel that meets the National Sixth Standard.

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2 Test program

2.1 Fuel and fuel detergent synergist

The benchmark fuels selected for the corrosion test are commercially available National VI gasoline and National VI diesel. The physical and chemical properties of the reference fuels are shown in Table 1 and Table 2, respectively. In order to explore the impact of different energy-saving and emission-reduction effects of fuel cleaning synergists on the engine fuel supply system, this study selected gasoline and diesel cleaning synergists as shown in Table 3 for experiments.

Table 1. The physical and chemical properties of the benchmark National VI gasoline for corrosion test.

Project	Numerical value	Experiment method
Knock resistance:		
Research Octane Number(RON)	96.0	GB/T 5487
Antiknock Index(RON+MON) /2	90.3	GB/T 5487
Distillation Range:		
10 % Evaporation temperature /℃	52.7	GB/T 6536
50 % Evaporation temperature /℃	99.9	
90 % Evaporation temperature /℃	159.2	
Final boiling point /℃	194.5	
Residue(Volume fraction) /%	1.1	
Vapor Pressure / kPa	58.2	SH/T 0794
Gum content/ mg/100 mL		
Unwashed gum content	2.5	GB/T 8019
Solvent wash gel content	1.0	
Induction period / min	>960	GB/T 8018
Sulfur content /(mg/kg)	7.8	SH/T 0689
Benzene content(Volume fraction) / %	0.4	SH/T 0713
Aromatic content(Volume fraction) / %	31.3	GB/T 30519
Olefin content(Volume fraction) / %	12.4	GB/T 30519
Density /(20 ℃) / kg/m³	747.4	SH/T 0604

Table 2. The physical and chemical properties of the benchmark National VI diesel for corrosion test.

Fuel specification / Test items	Index	Experiment method
Oxidation stability (Based on total insoluble matter) /(mg/100mL)	<0.1	SH/T 0175
Density (20℃) , kg/m³	831	GB/T 1884
Sulfur content (mg/kg)	7.3	SH/T 0689
Polycyclic aromatic hydrocarbon content (Quality fraction) /%	1.7	SH/T 0806
Cetane number	52.4	GB/T 386
Copper sheet corrosion (50℃, 3h) / level	1a	GB/T 5096
Flash point /℃	67.0	GB/T 261
Solidifying point /℃	-36	GB/T 510
Cold filter plugging point /℃	-24	SH/T 0248

10% evaporative carbon residue (Quality fraction) /%	<0.1	GB/T 268
Ash (Quality fraction) /%	<0.001	GB/T 508
Kinematic viscosity(20℃) /(mm^2/s)	3.726	GB/T 265
Acidity (Calculated in KOH) /(mg/100mL)	1.23	GB/T 258
Water content (Volume fraction)/%	痕迹	GB/T 260
Mechanical impurity content	无	GB/T 511
Lubricity Wear scar diameter (60 ℃) /μm	326	SH/T 0765
Fatty acid methyl ester content (Volume fraction)/%	<0.1	GB/T 23801
Distillation Range : 50% recovery temperature / ℃ 90% recovery temperature / ℃ 95% recovery temperature / ℃	 250.4 324.8 340.4	GB/T 6536

Table 3. Gasoline and diesel detergent synergist samples selected for corrosion test.

Serial number	Recommended dosing ratio	Serial number	Recommended dosing ratio
Gasoline agent 1	1000 ppmw	Diesel agent 1	350 ppmw
Gasoline agent 2	825 ppmw	Diesel agent 3	1000 ppmw
Gasoline agent 3	642 ppmw	Diesel agent 5	350mL/bottle, Can be mixed with 40-100L oil
Gasoline agent6	80 mL/bottle, Can be mixed with 50～60 L oil	Diesel agent 6	500mL/bottle, Can be mixed with 40-70L oil
Gasoline agent9	295 mL/ bottle, Can be mixed with 55 L of oil	Diesel agent 9	250mL/bottle, Can be mixed with 40-70L oil
Gasoline agent10	60mL/ bottle, Can be mixed with 40-60L oil	Diesel agent 10	200mL/bottle, Can be mixed with 55-80L oil

2.2 Selection of test materials

The engine fuel supply system is mainly composed of fuel tank, oil float, fuel pump, fuel filter, fuel pressure limiting valve, fuel pipe and fuel injector. In this test, the parts shown in Table 4 and Table 5 are selected for testing. Among them, in order to facilitate the observation of surface topography changes, the metal materials used in the test are all cut into square test pieces.

Table 4. Parts immersed in corrosion test-metal materials.

	Parts	Soaking material
Gasoline engine fuel supply system	Gasoline pressure limiting valve	metal
	diesel pump	aluminum
Diesel engine fuel supply system	Diesel filter	metal
	Diesel pressure limiting valve	metal

Table 5. Parts immersed in corrosion test-non-metallic materials.

	Parts	Soaking material
Gasoline engine fuel supply system	Gasoline float	plastic
	Gasoline filter	plastic
	Gasoline pipe	rubber
Diesel engine fuel supply system	Diesel float	plastic
	Diesel pipe valve	rubber

2.3 Test method and evaluation index

2.3.1 Experiment method

Ordinary beakers for the test were respectively filled with National VI gasoline, gasoline containing gasoline detergent synergist, National VI diesel fuel and diesel fuel containing diesel detergent synergist. The materials of Table 4 and Table 5 fuel supply system were fully tested at room temperature. Immersion test. The test uses plastic film to seal the beaker to prevent the volume, composition and concentration of the solution from changing. The test period is 28 days. After the immersion, the fuel supply system materials are tested as follows, and the corrosion of the fuel cleaning synergist on the engine fuel supply system is judged according to the changes of the parameters. Among them, rubber parts refer to the requirements of my country's current GB/T 1690-2010 "Test Methods for Liquid Resistance of Vulcanized Rubber or Thermoplastic Rubber", and plastic parts refer to my country's current GB/T 11547-2008 "Determination of Resistance of Plastics to Liquid Chemical Reagents" Requirements, metal parts refer to my country's current GB/T 4334-2016 "Corrosion of metals and alloys, stainless steel intergranular corrosion test method" requirements..

Table 6. Corrosion test items of fuel cleaning synergist.

Project	metallic material	Non-metallic materials
Quality change rate	Detect	Detect
Volume change rate	--	Detect
Surface topography changes	Detect	--
Hardness change	--	Detection (rubber material only)
Size change	--	Detect

2.3.2 Evaluation index

The evaluation indicators of each test item are as follows:

（1） Mass change rate Δm

$$\Delta m=(mi-m_0)/m_0\times 100\%$$

In the formula: m_0 is the mass of the sample before soaking, and mi is the mass of the sample after soaking.

（2） Volume change rate ΔV

$$\Delta V=(Vi-V_0)/V_0\times 100\%$$

In the formula: V_0 is the volume of the sample before soaking, and Vi is the volume of the sample after soaking.

（3） Hardness change ΔH

$$\Delta H=(Hi-H0)/H0\times 100\%$$

In the formula: H_0 is the hardness of the sample before soaking, and Hi is the hardness of the sample after soaking.

The quality is measured by electronic balance (precision 0.0001g), volume is measured by measuring cylinder (precision is 1mL), hardness is measured by Shore A hardness tester (precision is 0.1A), size is measured by scale (precision is 0.01cm), metal surface The morphology was measured by the German Zeiss EVO 15 scanning electron microscope. Among them, the tests of mass, volume, hardness and size are all measured 3 times, and the average value is taken.

3 Test results and analysis

3.1 Analysis of corrosion of metal materials

3.1.1 Gasoline Engine Fuel Supply System-Gasoline Pressure Limiting Valve

Figure 1 shows the mass change rate of gasoline pressure limiting valve after soaking in gasoline containing different gasoline detergent synergists. It can be seen from the figure that after soaking, the mass change rate of the gasoline pressure reducing valve in the base gasoline does not exceed 0.7%. In the gasoline containing gasoline agent 9, the mass change rate is overall higher than that of other additives, but it does not exceed 0.9. %, within the allowable range of error. In comparison, gasoline containing detergent synergist and benchmark gasoline have the same degree of corrosion on gasoline pressure reducing valve.

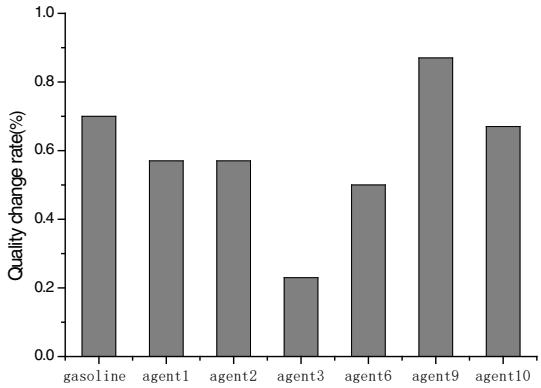


Fig.1. The effect of gasoline containing detergent synergist on the quality of gasoline pressure limiting valve.

3.1.2 Diesel engine fuel supply system-diesel pump, diesel filter, diesel pressure limiting valve

Figure 2, Figure 3, Figure 4 show the mass change rate of diesel pump, diesel pressure limiting valve, and diesel filter after immersing in diesel fuel containing different diesel detergent synergists. It can be seen from the figure that the quality change range of the three parts in the benchmark diesel and diesel with diesel detergent synergist does not exceed 1%. Compared with the benchmark diesel system, it can be considered that there is basically no corrosion after the diesel pump, diesel pressure limiting valve, and diesel filter are immersed in the benchmark diesel containing different diesel detergent synergists.

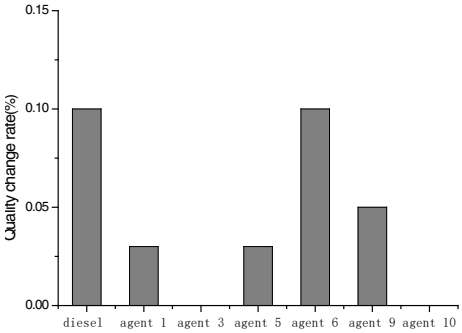


Fig. 2. The effect of diesel fuel containing detergent synergist on the quality of diesel pump.

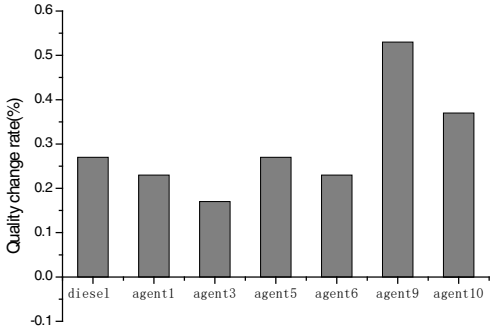


Fig. 3. The influence of diesel fuel containing detergent synergist on the quality of diesel pressure limiting valve.

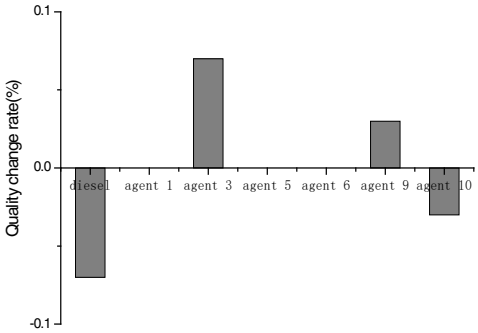


Fig. 4. The effect of diesel fuel containing detergent synergist on the quality of diesel filter.

Figure 5 shows the original sample of the diesel pump and the SEM image after it has been immersed in diesel fuel containing different diesel detergent synergists for four weeks.

Before the corrosion test, the original surface of the diesel pump had relatively clear streaks, accompanied by irregular scales. After immersing in basic diesel fuel and diesel fuel containing different detergent synergists, the scales are slightly reduced, and streaks still exist. According to the electron microscope picture, after immersing in diesel fuel, the corrosion degree of the sample surface is basically equivalent to that of the reference diesel.

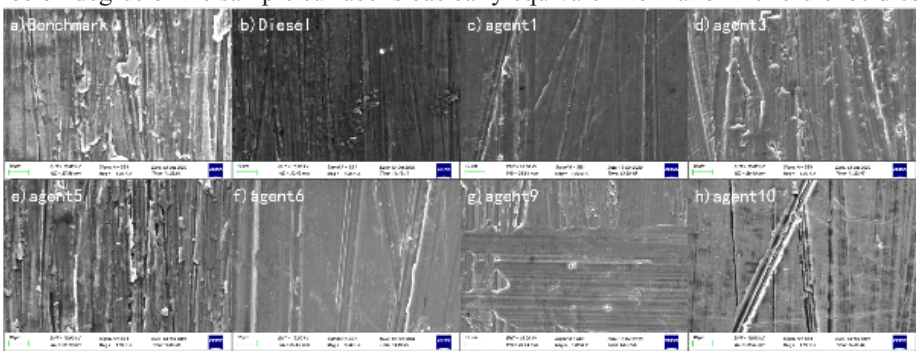


Fig. 5. The effect of diesel fuel containing detergent synergist on the surface morphology of diesel pump.

Figure 6 shows the original sample of the diesel filter and the SEM image after it has been immersed in diesel fuel containing different diesel detergent synergists for four weeks. Comparing the original sample and the sample immersed in diesel fuel containing different detergent synergists, the flakes stacked on the surface did not change significantly. It can be considered that the corrosion degree of the diesel filter after soaking in diesel fuel containing different diesel detergent synergists is similar to that the benchmark diesel is close.

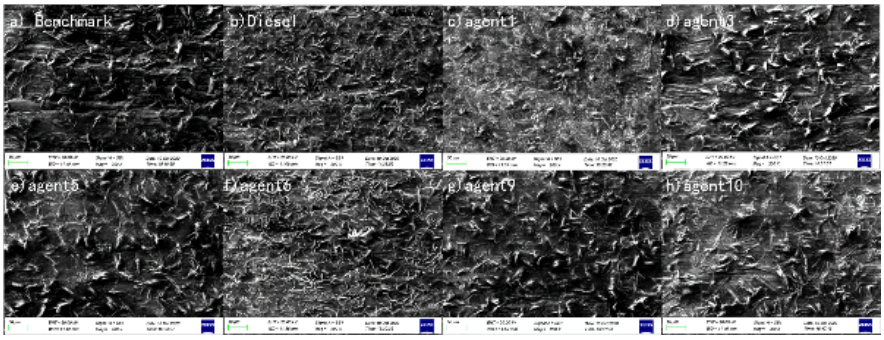


Fig. 6. The influence of diesel fuel containing detergent synergist on the surface morphology of diesel filter.

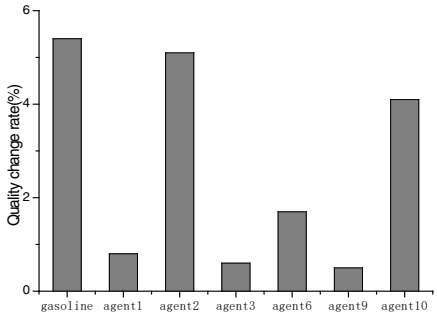
3.2 Analysis of corrosion of non-metallic materials

3.2.1 Gasoline engine fuel supply system

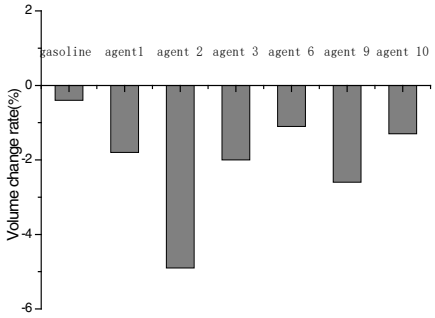
3.2.1.1 Plastic materials-gasoline floats, gasoline filters

Figure 7 shows the mass change rate and volume change rate of the plastic part gasoline float of the gasoline engine fuel supply system after soaking in gasoline containing different detergent synergists. After soaking, the mass change rate of the gasoline float in the reference gasoline is larger than that in the gasoline containing gasoline agent. It can be seen from Figure 7(b) that after immersing in gasoline-containing gasoline, the volume

decrease is greater than that of the reference gasoline, and the volume change in gasoline agent 2 is more obvious. In general, it is believed that the gasoline agent 2 gasoline float used in the test has a corrosive effect.



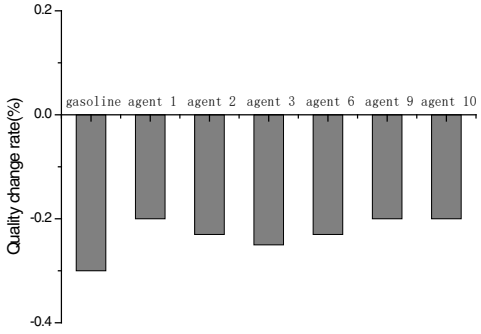
(a) Quality change rate



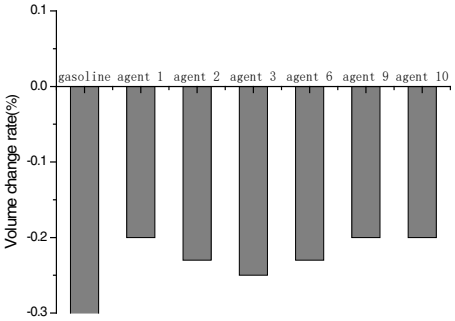
(b) Volume change rate

Fig. 7. The effect of gasoline containing detergent synergist on gasoline float.

Figure 8 shows the mass change rate and volume change rate of the plastic part gasoline filter element of the gasoline engine fuel supply system after soaking in gasoline containing different detergent synergists. It can be seen from the figure that the gasoline filter element has a similar trend in the mass change rate and volume change rate in the benchmark gasoline and the detergent synergist containing different gasoline, and both do not exceed 1%. Within the allowable range of error, it can be regarded as the gasoline filter element. The corrosion degree after soaking in gasoline containing different gasoline detergent synergists is close to that of the benchmark gasoline.



(a) Quality change rate

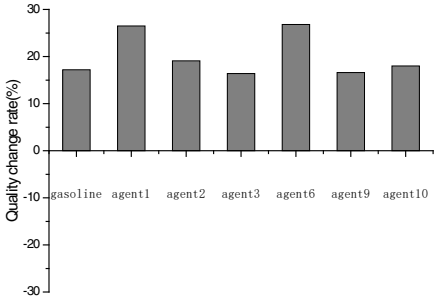


(b) Volume change rate

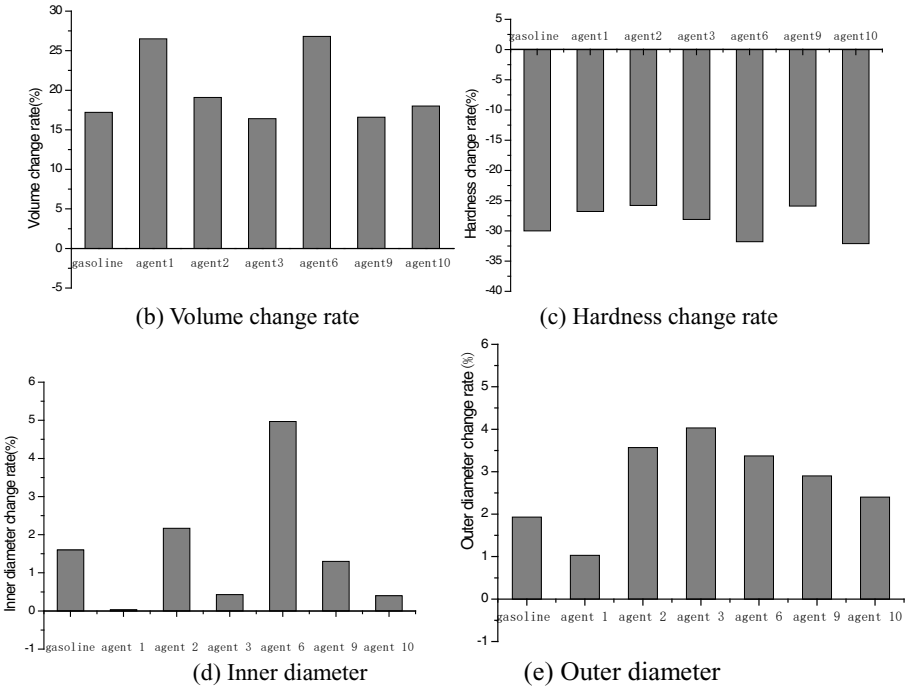
Fig. 8. The effect of gasoline containing detergent synergist on gasoline filter element.

3.2.1.2 Rubber material-gasoline pipe

Figure 9 shows the mass change rate, volume change rate, hardness change rate and size (inner diameter, outer diameter) change rate of the gasoline pipe of the gasoline engine fuel supply system after being immersed in gasoline containing different detergent synergists. It can be seen from Figure 9(a) that the mass change rates of gasoline agents 2, 3, 9, and 10 after four weeks of soaking are equivalent to those in the benchmark gasoline. After being immersed in gasoline-containing agents 1 and 6, the surrounding mass change rate is greater than that of the benchmark gasoline. The corrosion of the liquid to the rubber is mainly manifested in the rubber inhalation of the liquid, the extraction of the soluble components in the rubber, and the chemical reaction between the two. Swelling occurs when the amount of liquid is greater than the amount of the extracted rubber component, and the mass increases accordingly. It can be seen from Figure 9(b) that the volume change rate is basically the same as the mass change rate. It can be seen from Figure 9(c) that the hardness change rate is equivalent after soaking in the benchmark gasoline and the gasoline containing detergent synergist. It can be considered that the detergent synergist used in the test basically does not cause changes in the hardness and toughness of the gasoline pipe. It can be seen from Figure 9(d) that the change rate of the inner diameter of the gasoline pipe after being immersed in the gasoline containing gasoline agent 6 is larger, and the swelling property is more obvious than that of the standard gasoline. This is because the high stability of rubber makes the rubber macromolecules dissolve Difficult, the entry of small molecules in the solution causes the rubber tube to expand continuously [10]. It can be seen from Figure 9(e) that the outer diameter change rate of gasoline agents 2, 3, and 6 used in the test is greater than that of the benchmark gasoline. On the whole, the corrosion effect after immersion in gasoline agent 6 is greater than that of the benchmark gasoline. It can be considered that the two detergent synergists have a slight swelling effect on the gasoline pipe compared to the benchmark gasoline.



(a) Quality change rate



(b) Volume change rate (c) Hardness change rate

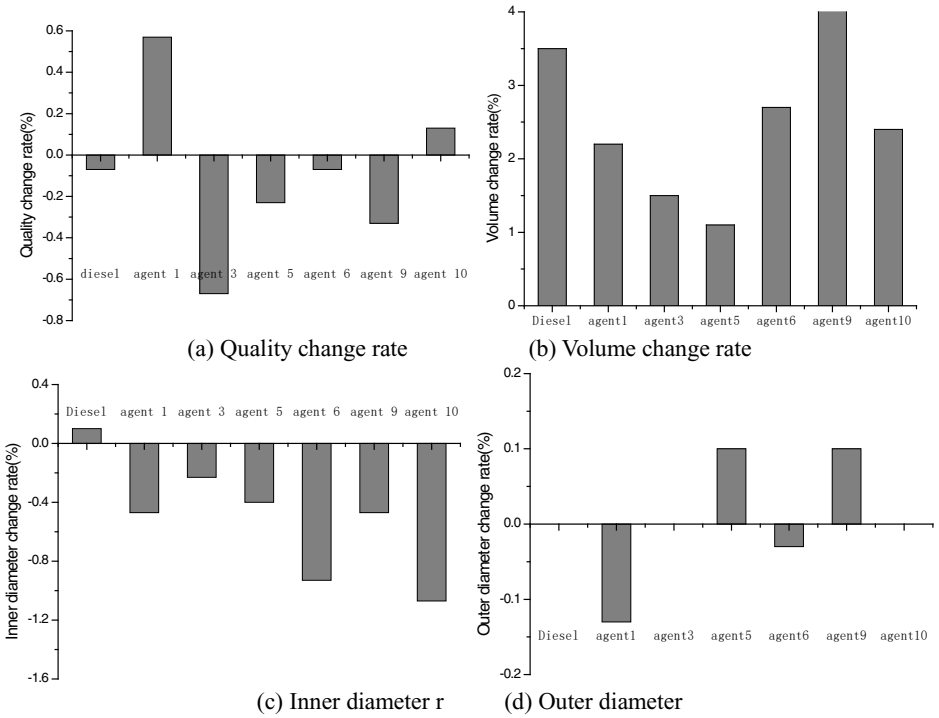
(d) Inner diameter (e) Outer diameter

Fig. 9. The effect of gasoline containing detergent synergist on gasoline pipes.

3.2.2 Diesel engine fuel supply system

3.2.2.1 Plastic material-diesel float

Figure 10 shows the mass change rate, volume change rate and dimensional change rate of the plastic parts diesel float of the diesel engine fuel supply system after immersing in diesel fuel containing different detergent synergists. It can be seen from Fig. 10(a) that compared with the benchmark diesel, the quality of soaking in gasoline containing diesel agents 3, 5, 6, and 9 is reduced. This may be because the polar groups in diesel fuel containing these additives are close to the polarity of the diesel float, which dissolves some substances in the diesel float, resulting in a decrease in mass [2], but the mass reduction is within 1%. ,Less affected. The mass change rate of diesel agent 1 is greater than that of the reference diesel, and it can be considered that the diesel agent has a slight swelling effect on the diesel float. It can be seen from Figure 10(b) that the volume change rate of the benchmark diesel and diesel containing detergent synergists 6, 9, and 10 is not much different; the volume change of diesel fuel containing detergent synergists 1, 3, and 5 The rate is less than the benchmark diesel. It can be seen from Fig. 10(c) that, compared with the benchmark diesel, the reduction of the inner diameter of the diesel fuel containing the detergent synergist is slightly greater than that of the benchmark diesel, which can be considered to have a certain degree of corrosive influence on the inner diameter. It can be seen from Fig. 10(d) that the outer diameter of the reference diesel oil does not change after being immersed, and the outer diameter change rate of the diesel fuel containing diesel agents 1, 5, 6, and 9 is greater than that of the reference diesel, but the change rate is very small, about 0.1%; in general, it can be considered that the detergent synergist used in the test has almost no corrosive effect on the diesel float.



(a) Quality change rate (b) Volume change rate

(c) Inner diameter r (d) Outer diameter

Fig. 10. The effect of diesel fuel containing detergent synergist on diesel oil float.

3.2.2.2 Rubber material-diesel pipe

Figure 11 shows the mass change rate, volume change rate, hardness change rate and dimensional change rate of the diesel pipe after soaking in gasoline containing different detergent synergists. It can be seen from Figure 11 (a) and (b) that after soaking in the benchmark diesel and diesel fuel containing detergent synergists, the mass change rate and volume change rate are equivalent to those of the benchmark diesel. It can be seen from Figure 11(c) that the hardness change rate of the benchmark diesel containing diesel fuel is slightly greater than that of the benchmark diesel after soaking. The reason may be that the molecules in the oil enter the three-dimensional network structure of the diesel pipe rubber, which changes the swelling degree and crosslinking density of the diesel pipe and affects its hardness [1]. It can be seen from Figure 11(d) that after immersing in the reference diesel fuel containing No. 1 and No. 5 diesel fuels, the rate of change of the inner diameter of the diesel pipe is negative. The rate of change of the inner diameter after immersion in the reference diesel containing diesel fuels 3, 6, 9, and 10 is positive. The reason is that there will be an interaction force between the solution molecules and the rubber molecules. When the force is greater than the cohesive force between the rubber molecules, the rubber molecules will separate from each other and dissolve in the solvent [11]; when the force is less than the rubber molecules At the time of cohesion, it is manifested by the inhalation of liquid, and the inner diameter increases. It can be seen from Fig. 11(e) that the diesel agent used in the test has less influence on the outer diameter of the diesel pipe than the benchmark diesel, within 1%. Generally speaking, it slightly corrodes the diesel pipe, but it is not obvious.

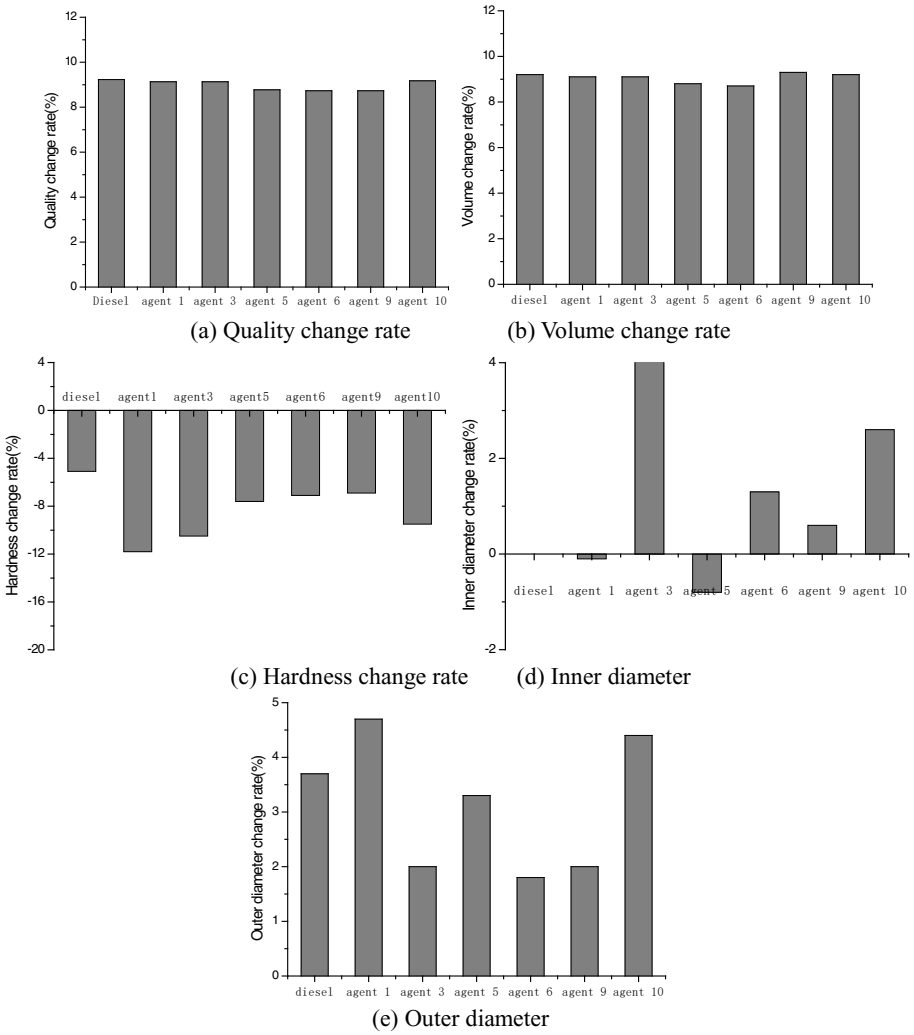


Fig. 11. The influence of diesel fuel containing detergent synergist on diesel pipe.

3 Summary and outlook

This research carried out an experimental study on the corrosion effects of metal and non-metal materials in the fuel supply system on the 6 mainstream gasoline detergent synergists and 6 diesel detergent synergists in the market, and explored their corrosion effects on the fuel supply system. The test results show:

(1) After the immersion test of the metal material gasoline pressure limiting valve, diesel pump, diesel filter, and diesel pressure limiting valve of the engine fuel supply system, from the mass change rate and the results of the scanning electron microscope, the fuel used in the test is clean The synergist basically has no corrosive effect on the metal material of the engine fuel supply system or its corrosion condition is close to that of the benchmark fuel;

(2) The immersion test results of non-metallic plastic material gasoline floats, gasoline filters and diesel floats, rubber material gasoline pipes and diesel pipes show that gasoline agents 1, 2, and 6 slightly corrode and swell in the gasoline fuel supply system influences;

(3) In order to promote the use of fuel detergent synergists and avoid the corrosion or swelling effect of certain components in the synergist on the engine fuel supply system, it is recommended to add corrosion inhibitors in the production process of the detergent synergist to alleviate its corrosiveness.

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