Experimental Research on Anti-rust Performance of Drive Train Oils Used in Construction Machinery

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Abstract: Based on the working conditions of transmissions and drive axles used in the construction machinery, and combined with the current testing requirements for the anti-rust performance of lubricants, this paper test the oils commonly applied in the drive train of the construction machinery through the copper corrosion, rust preventing test and damp-heat test. The results show that the damp-heat test acted as a dynamic corrosion test, its parameters are closer to the real working conditions and it can better investigate the corrosion performance of oils in different quality grades and provides a reference for the selection of drive train oils.

1. Introduction

The gearbox and drive axle are core components of the transmission system applied to the construction machinery. When the transmission system is working, it is often attacked by foreign substances such as sand, sewage, humid air and dust. This may cause rust on the gears inside the transmission and drive axle. As the situation becoming serious, it most likely reduces the accuracy and sensitivity of the devices, and even causes the scrapping of the devices. Therefore, the drive train oils should have good anti-rust performance.

In order to improve the ability to resist water pollution and prevent metal corrosion of the drive train oils, major OEM manufacturers have made clear requirements in their own oil specifications [1-3], among which, Caterpillar TO-4 and Allison TES 439 are the most common. In addition to the standard test methods currently used in the laboratory, namely the copper corrosion and the rust preventing test, Caterpillar TO-4 gives a more stringent demand that the dynamic wet corrosion bench test using CEMS BT-9 must be passed. The Allison TES 439 requires to pass the corresponding humidity cabinet test, in which at least three of the four test surfaces are free of rust. Consequently, in this paper, the copper corrosion, rust preventing test and damp-heat test related to the actual working condition of the transmission system are carried out. The anti-rust performance of the oils under different test conditions are analyzed, which provides a reasonable reference for selecting the oils.

2. Copper corrosion and the rust preventing test

The components of gearbox and drive axle used in the construction machinery are mostly made of steel and a small amount of copper. Therefore, six common drive train oils for construction machinery are tested according to the standard methods of copper corrosion and the rust preventing test to investigate the anti-rust protection to copper and steel. The copper corrosion test is to immerse a polished standard copper sheet in a 30mL oil sample, heat it for 3h, take it out and wash it. The copper sheet is compared with the standard color palette to evaluate the corrosion. The results are shown in...
Table 1 and Figure 1-2. After the test, the copper sheets of No. 1, No. 3 and No. 4 oil samples are all light orange (Figure 1), so the corrosion levels are 1a. The copper sheets of No. 2, No. 5 and No. 6 oil samples are all dark orange (Figure 2), so the corrosion levels are 1b. These six oil samples have good anti-corrosion and anti-rust performance protection to copper transmission parts.

| Sample number | Test result |
|---------------|-------------|
| 1             | 1a          |
| 2             | 1b          |
| 3             | 1a          |
| 4             | 1a          |
| 5             | 1b          |
| 6             | 1b          |

The rust preventing test is to mix 300mL oil sample with 30mL distilled water, then immerse the cylindrical steel rod in it and stir at 60°C for 4h. After the test, rusty trace and extent of the steel rod are observed. The results are shown in Table 2 and Figure 3. There are no rust spots on the surface of these steel rods, so the corrosion grades are all no rusting, indicating that the six oil samples have good anti-rust performance on steel transmission parts.

Comparing the data in Table 1 and Table 2, two experimental results don’t have exactly same anti-corrosion trend. It is mainly because that the materials and conditions are different and the additives in the oil samples have various anti-rust protection capabilities for diverse metals. The copper corrosion focuses on investigating the anti-rust protection ability to copper under high temperature. The rust preventing test is primarily applied to judge the rust-preventing characteristic to steel in the presence of water.

| Sample number | Test result |
|---------------|-------------|
| 1             | no rusting  |
| 2             | no rusting  |
| 3             | no rusting  |
| 4             | no rusting  |
| 5             | no rusting  |
| 6             | no rusting  |
Both the copper corrosion and the rust preventing test are static corrosion tests, and they are tested with the standard parameters, which are quite different from the actual working characteristics of the drive train oils. They can’t perfectly reflect the anti-rust trend of the components. In this paper, the damp-heat test based on the actual operating conditions of the transmission system are carried out. The damp-heat box can simulate high temperature and high humidity atmospheric environment to compare and analyse the metal rust protection performance of different quality grade oils.

3. Damp-heat test

The damp-heat test is an accelerated method that artificially simulates the damp and heat conditions of the natural environment. Temperature and humidity are two key factors of the test \cite{4}. At present, the general bench test for investigating the anti-rust performance of transmission system oils is CRC L-33 test. It needs to be carried out on the drive axle in a clean laboratory. At the end of the test, the drive axle is required to be disassembled and scored by the professional personnel. Based on the above, the test conditions are strict and the process is complicated.

In this paper, the damp-heat box is used to test the anti-rust performance of six oil samples at temperature of 52°C and relative humidity of 95%. The box is composed of a test piece rotating frame, an air supply device, a heating regulator, an air filter, and a flow meter. Among them, the test piece rotating frame provides convenience for the dynamic contact between test pieces and humid air. The air supply device, air filter and flow meter continuously provide fresh air for the test environment to balance the temperature and humidity. During the experiment, two sides of the 10# steel sheet are polished along the parallel direction of the long side to a surface roughness of 0.2~0.4µm. The steel sheet is washed, dried, and coated with an oil sample. It is hung vertically on the test rack and dried naturally for 24 hours. Then it is moved to the test piece rack. After continuous operation for 162 hours, it is taken out to wash and dry out. After the test, the piece is overlapped on the evaluation board and the number of grids occupied by the rust points in the effective area is observed. Through the number of rust, the rust degree (%) is determined, and the rust level is evaluated according to Table 3. The results of six oils are shown in Table 4.

| Rust degree(%) | Rust level |
|---------------|-----------|
| 0             | A         |
| 1~10          | B         |
| 11~25         | C         |
| 26~50         | D         |
| 51~100        | E         |
Table 4. Damp-heat test results of drive train oils

| Sample number | Rust degree(%) | Rust level | Test piece picture | Sample number | Rust degree(%) | Rust level | Test piece picture |
|---------------|----------------|------------|-------------------|---------------|----------------|------------|-------------------|
| 1             | 0              | A          |                   | 4             | 13             | C          |                   |
| 2             | 0              | A          |                   | 5             | 100            | E          |                   |
| 3             | 8              | B          |                   | 6             | 5              | B          |                   |

It can be seen from Table 4 that under the same condition, the test pieces coated with No. 1 and No. 2 oils have no rust spots, and rust level is the lowest; the test pieces coated with No. 3, No. 4 and No. 6 oils have little rust spots; the test piece coated with No. 5 oil has full rust spots in the effective grid, and rust level is the highest. This shows that in the high-temperature and high-humidity atmospheric environment, in terms of anti-rust protection of steel components, No. 1 and No. 2 oils are the best, No. 3, No. 4 and No. 6 oils are the middle, and No. 5 oil has the worst performance. Compared with the results of copper corrosion and the rust preventing test, the rust resistance of six oil samples after the damp-heat test is significantly different. This is because that the damp-heat test is a dynamic corrosion process, and the rotating steel sheets contact with the opposite moist air. The test parameters are more stringent than the static test, which makes the anti-rust performance of different quality grade oils greatly.

4. Conclusions
(1) In this paper, the copper corrosion, the rust preventing test and the damp-heat test are utilized to determine the anti-rust performance of drive train oils commonly used in construction machinery. The anti-rust protection performance of oils is investigated, which provides basis for evaluating the anti-rust performance of drive train oils in the laboratory.

(2) Compared with the copper corrosion and the rust preventing test, the damp-heat test is carried out in an atmosphere of high temperature and humidity, which is closer to the actual working condition. The damp-heat test can better estimate the corrosion performance of different quality grade of oils.

(3) Only the steel sheet is measured in this paper. There are other materials in the transmission system, hence the subsequent damp-heat tests of different materials are needed to be accomplished to fully reflect the metal anti-rust protection performance of the oils.

References
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