Research on Load-Carrying Capacity of Loader Transmission Oil Based on Driving Axle Bench Test

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Abstract. The drive axle of loader is often in the state of low speed and high torque when it works, the tooth surface contact pressure is large, the tooth surface load is high, and the oil needs to have good load-carrying capacity. However, the bench test used to evaluate the load-carrying capacity of the drive axle oil adopts the drive rear axle of the truck, and the test conditions are different from the actual working conditions of the drive axle of the loader. In this paper, based on the actual working conditions of the loader drive axle, the bench test of simulated working conditions is carried out, and the load-carrying capacity of the oil is evaluated according to the changes of the oil performance parameters and the tooth surface damage. The results show that the established bench test method can effectively investigate the load-carrying capacity of the oil and provide support for the selection of oil in transmission system.

1. Introduction

As an important transmission part of the loader, the drive axle mainly transmits power through gears and drives the loader by reducing speed and increasing torque. Its quality and performance directly affect the safety and reliability of the whole vehicle. At present, the loader is developing towards high power and high torque, and the working condition is also complex and bad. The drive axle is often in the state of low speed and high torque. Because most of the gear parts are made of metal, the contact pressure between the meshing tooth surfaces is high, the load of the tooth surfaces is high, and the rolling and sliding of the meshing tooth surfaces coexist, resulting in a high friction and working temperature between the tooth surfaces, which is easy to cause friction and wear, as well as gear fracture failure. Therefore, the oil with good load-carrying capacity is needed to prevent the tooth surfaces from sintering, biting and scratching, avoid premature failure of gears and bearings, and reduce transmission noise and vibration [1-4].

At present, the bench test method to evaluate the load-carrying capacity of drive axle oil is CRC L-37[5-6]. L-37 specifies that under the condition of low speed and high torque, hypoid gear drive axle is used to evaluate the load-carrying capacity of the drive axle oil. The rear axle of the truck is used as the test unit in the test. The test conditions are different from the actual working conditions of the loader drive axle, and the test results can not reflect the load-carrying capacity of the loader drive axle oil. Therefore, in order to effectively examine the oil to protect the drive axle from wear under the condition of low speed and high torque, this paper uses the drive axle of the loader and converts the actual working condition of the drive axle into testing parameters to carry out the test. The load-carrying capacity of the oil is evaluated according to the change of the oil performance parameters and the tooth surface damage.
2. Calculation of bench test parameters

When the whole bench test is carried out with the drive axle, the test torque is 0.7 times of the maximum working torque of the driving bevel gear. The calculation of the maximum working torque of the driving bevel gear is shown in formula (1):

$$ T_{\text{max}} = \frac{G_i \varphi r_k}{in\eta} $$  \hspace{1cm} (1)

Where:
- $T_{\text{max}}$ - the maximum working torque of the driving bevel gear, N\cdot m;
- $G_i$ - drive axle load at full load (rated axle load), N;
- $\varphi$ - adhesion coefficient between tire and ground, selected according to design value;
- $r_k$ - tire rolling radius, m;
- $i$ - total transmission ratio of drive axle (including wheel side deceleration);
- $\eta$ - the total transmission efficiency of the drive axle.

In a certain type of drive axle for the loader, the parameter values in formula (1) are shown in Table 1. Therefore, the test torque = $0.7 \times 170000 \times 0.8 \times 0.75 / (22.85 \times 0.9) = 3472$ N\cdot m.

| Parameter                                      | Value           |
|------------------------------------------------|-----------------|
| Drive axle load at full load (rated axle load) | 170000 N        |
| Adhesion coefficient between tire and ground  | 0.8             |
| Tire rolling radius                            | 0.75m           |
| Total transmission ratio of drive axle         | 22.85           |
| Total transmission efficiency of drive axle    | 0.9             |

Under the full load condition of the loader, the maximum input speed of driving bevel gear of the main reducer is 200r/min, so the test input speed is 200r/min. The test oil temperature is controlled between 60°C and 80°C. Before the formal test, run for 2 hours from small to large respectively according to the load of 25%$T$, 50%$T$ and 75%$T$ ($T$ is the test torque), and then the driving bevel gear of the main reducer meshes 500000 cycles, and the test is over.

3. Test bench

The schematic diagram of the test bench is shown in Figure 1, including driving motor, loading motor, power box, speed-torque meter, transmission shaft and other parts. It can simulate the actual power transmission and torque distribution.

![Figure 1. The schematic diagram of the test bench](image-url)
4. Result discussion

Two different types of transmission system oil are selected for testing, namely oil A and oil B. Each oil is tested using a new wheel edge assembly. After the test, the left and right wheel edge covers of the drive axle are disassembled, the surface condition of the wheel edge gears is observed, and the oil samples are taken to detect the kinematic viscosity, acid value and the content of Fe.

The conditions of the left and right wheel edge gears after the test of the two oils are shown in Figure 2 and Figure 3 respectively.

![Figure 2. The left and right wheel edge gear of oil A](image)

![Figure 3. The left and right wheel edge gear of oil B](image)

It can be seen from Figure 2 and Figure 3 that no abnormal damage such as pitting, peeling, discoloration and wear occurs on the tooth surfaces on the left and right edge gears after the test of the two oils, which indicates that the two oils can establish high-strength lubricating oil film between the meshing gears. This kind of oil film includes not only the oil film thickness established by the oil viscosity itself, but also the chemical reaction film formed by the interaction between the extreme pressure additive and the tooth surface in the oil. Both of them work together to improve the load-carrying capacity of the oil. By retaining the oil film between the gear pairs, on the one hand, the pressure distribution on the friction interface becomes relatively uniform, on the other hand, the micro convex concave on the surface of the gear pair is covered by the oil film, which is conducive to reducing the direct contact of the tooth surface. Moreover, the formation of the oil film will also have a buffer effect on the external load changes, reducing the impact on the gear. Therefore, the two oils can effectively avoid the direct contact between the two friction surfaces under the condition of low speed.
and high torque, so as to reduce the friction coefficient, reduce wear and protect the gear from damage. The changes of the performance parameters of the two oils are shown in Table 2.

|                      | 40℃ Kinematic viscosity (mm²/s) | 100℃ Kinematic viscosity (mm²/s) | Acid value (mgKOH/g) | Fe (mg/kg) |
|----------------------|---------------------------------|----------------------------------|----------------------|------------|
| Change value (Oil A) | 1.11                            | 0.16                             | 0.03                 | 89         |
| Change value (Oil B) | 2.10                            | 0.10                             | 0.18                 | 50         |

It can be seen from Table 2 that the kinematic viscosity and the acid value of the two oils before and after the test are basically unchanged, and the change of Fe content is relatively low, both within the normal wear value range, indicating that the two oils have good viscosity retention, thermal stability and metal protection ability, so that the lubricating oil can continuously maintain effective lubricating oil film, resist high temperature oxidation deterioration and avoid the direct friction between gear working faces, maintain the work efficiency and prolong the service life of the gear mechanism.

The whole process of the test is a complex physical-chemical process, which can test the oxidation resistance of the oil under the conditions of high temperature, contacting with various metals and ventilation, as well as the pitting corrosion resistance and wear resistance of the gear pair. The indexes of fatigue wear, adhesive wear, corrosion wear and thermal oxidation stability of the oil are integrated. Through the change of the performance parameters of the oil and the tooth surface conditions, it shows that the two oils have good load-carrying capacity, which can provide effective protection for the drive axle gear under the condition of low speed and high torque, and improve the reliability and economy of the equipment.

5. Conclusion
(1) The established bench test method based on the actual working conditions of the loader drive axle can effectively investigate and evaluate the load-carrying capacity of the oil, and provide support for the selection of oil products in the transmission system.
(2) In order to further check the good correspondence between the test results of this method and the actual oil consumption results, it is necessary to carry out real vehicle verification to enhance the accuracy of the test results.

References
[1] D.X.Wang, J. Liu, Y.Q.Xia. (2000)Research on load carrying capacity and friction-reduction of extreme pressure lubricants. Journal of Shenyang University of Technology, 22(6): 456-458.
[2] X.Shi. (2019)The latest changes in foreign industrial gear oils technical standards. Synthetic Lubricants, 46(2): 38-41.
[3] W.M.Liu, Y.Q.Xia, X.G.Fu. (2005)Lubricating material for gear transmission.Chemical Industry Press, Beijing.
[4] X.Liu, X.S. Fu, Y.Q. Pan, J.Xu, L.P.Mi. (2012)The New Progress of Gear Lubrication Technology. Lubricating Oil, 27(3): 10-13.
[5] C.Li. (2020) Interpretation on “Automotive Gear Lubricants for Commercial and Military Use”: SAE J2360 Specification. Synthetic Lubricants, 47(3): 14-17.
[6] J.Y.Cai, Z.Q. Hu, X.C. Han. (1990) Research on bench test method of simulating automobile gear oil CRC L-37. Lubricating Oil, (5): 41-44.