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Influence of Grease Consistency on the Wear of Gear Surfaces

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Abstract – This paper selected three kinds of grease with the same type but different consistency for the experiment. The purpose of the experiment is tested the effect of different consistency of grease on the wear of the gear surface. Different torque test groups were selected in the test, and the lubrication effect of different greases was tested in the test groups with the same torque. After each set of tests, the wear of the gear surfaces was observed and recorded. The data recorded in the experiment included the area of the wear area on the gear surface, the type of wear and the volume of wear. After the test, the gear surface roughness was measured. By calculating the wear volume, the effects of different concentrations of grease on the gear surface wear were compared. The experimental results show that under different stress conditions, the consistency of the grease has a great influence on the lubricating effect of the gear surface and the gear wear. Under the condition with low speed and high torque, different grease consistency affect the gear surface wear, the high consistency grease can reduce the wear of the gear surface, so that the gear can get better lubrication effect during the work.

Keywords – Consistency, Gear, Grease, Pitting, Surface wear

1. Introduction

Gear surface wear is an important failure mode. Under the different working conditions, the wear of gear is different. Lubricating oil or grease is usually used to reduce wear and tear. Grease is usually used to lubricate gears running at low speed to reduce wear and tear during operation[1-2]. Höhn et al[3] showed that the composition of different lubricants had an important influence on gear surface wear, such as the viscosity of lubricating oil, the type of base oil and different additives. Some studies have pointed out the influence of consistency of base oil on gear surface wear degree and analyzed the influence of different additives in lubricating oil on gear wear behavior[4-5]. Grease has the same lubrication characteristics as lubricating oil, but the higher consistency and different additives are the main differences between them. Therefore, the characteristics of grease also have an important correlation with the surface wear of gears[6]. According to reference [7], It is known that the composition of various greases, including the viscosity and type of base oil, the type of additives, the concentration and type of thickener, and so on[8-9]. The type and proportion of each component will affect the lubrication performance of the grease. This paper analysis the wear of gear surface in different grease consistency. Under the high torque and low-speed conditions, tested the grease with different consistency. The test obtained wear characteristics of the gear surface under different conditions. Without considering the influence of wear particles on gear surface wear, analyzed the surface of gear in each wear stage.

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The experimental results show that under the conditions of high stress and low speed, the consistency of grease has a great correlation with the surface wear of gear. Without changing other conditions, the consistency of grease is positively correlated with the lubrication effect of grease, grease with higher consistency has a better lubrication effect and less wear on the gear surface.

2. Research Methods and Contents

In the experiment of this paper, selected the gear is inside the gearbox. In Fig. 1, two torque sensors are installed at both ends of the gearbox, they record the torque changes of the tested gear during the test. The reducer on the right is connected an electric motor. The leftmost damper provides the load.

Table 1 shows the gear structure parameters. The tested gear surface is from driving wheel. Table 2 shows the test conditions. Table 3 shows the grease parameters. The parameters of the three kinds of greases all the same except the penetration. That ensuring the single variable in the experiment is only the penetration of grease. And the grease penetration is a degree of grease's consistency. The smaller value of penetration means grease is harder.

3. Results and Discussion

In this experiment, the wear of the gear surface is photographed by electron microscope (Leica DVM6A) in the Fig. 2.

Fig. 2 (a) shows the wear of the gear surface before the test: the surface is smooth without any scratches or wears marks. Fig. 2 (b) shows the gear's surface after the test. These picture shows pitting marks and wear on the gear surface. To verify the accuracy of the experimental results, the gear surface roughness

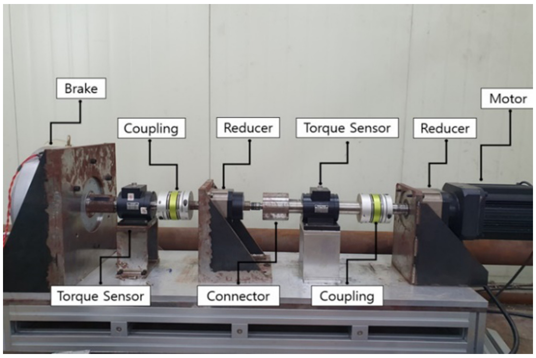


Fig. 1. Test bench.

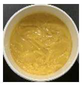
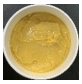
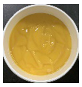
Table 1. Gear structure parameters

	Gear Teeth	Modulus	Helix angle	Accuracy class	Material
Driving wheel	12	2.5	18.19	7	42CrMo4
Driven wheel	48	2.5	18.19	7	42CrMo4

Table 2. Test conditions

Torque (*N·m*)	RPM	Time(h)	Total time(h)
100	360	12	
200	360	12	
300	360	12	60
400	360	12	
450	360	12	

Table 3. Grease parameters

Test project		01	02	03
Appearance				
Base Oil	Type		PAO + Mineral	
Thickener	Type		Lithium Soap	
Additives (Content,wt%)	Anti-Oxidant		0.50	
	Metal deactivato		0.02	
	Anti-Wear		1.00	
	Friction Modifier		2.30	
	Dispergent		2.00	
Unworked Penetration, 0W （0.1 mm）		326	241	445

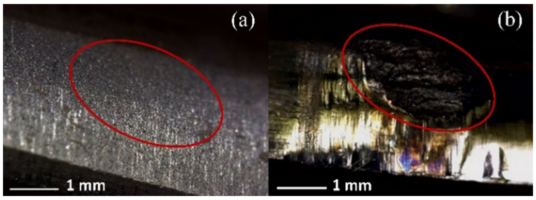


Fig. 2. Gear surface, (a) surface before test, (b) surface after test.

also be tested. In the surface roughness test, selected three teeth of the same gear randomly. And each tooth is test by three areas: top area, middle area, and bottom area. This maximizes the accuracy of the surface roughness test.

Fig. 3 shows the surface roughness test results of the gear top area with three different greases. Fig. 3(a) shows the surface roughness measurements of three different teeth (A, B, C) of the same gear with grease-01. The surface roughness is mainly displayed through the variation range of A, B, C lines. The magnitude of the change is positively correlated with the surface roughness. Fig. 3(b) shows the surface roughness measurements of three different teeth (A, B, C) of the same gear with grease-02. Fig. 3 (c) shows the surface roughness measurements of three different teeth (A, B, C) of the same gear with grease-03. The test results

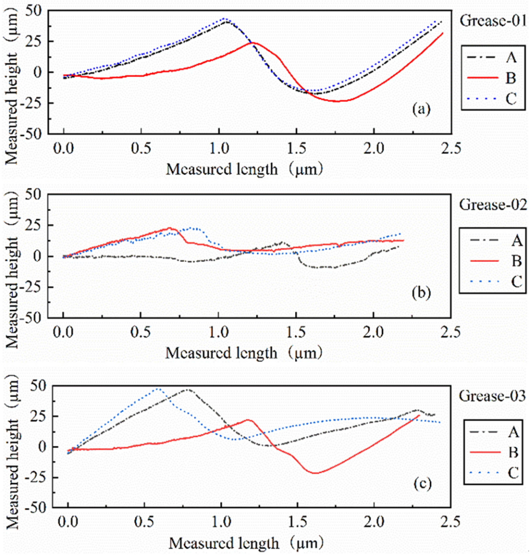


Fig. 3. Gear surface roughness of top area with different grease, (a) Test results of Grease -01, (b) Test results of Grease -02, (c) Test results of Grease -03.

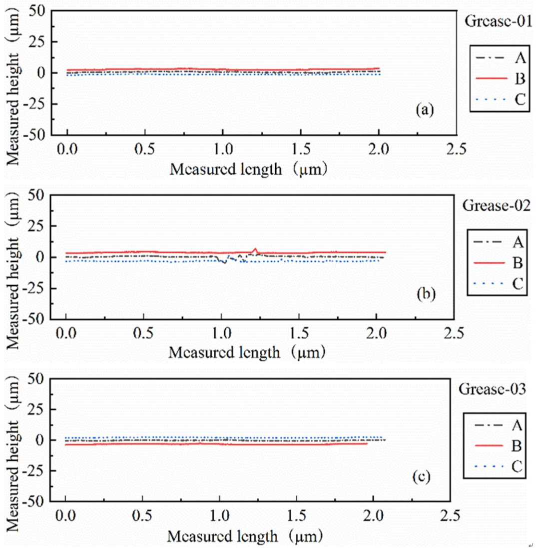


Fig. 4. Gear surface roughness of mid area with different grease, (a) Test results of Grease -01, (b) Test results of Grease -02, (c) Test results of Grease -03.

show that the wear trends of different tooth surfaces of the same gear at the same position are very similar, and the slope changes of the three curves are also very similar.

Fig. 4 shows the surface roughness test results of the middle area of the tooth surface. In Fig. 4, the roughness curves of three gear surfaces are very similar, that means every tooth surface wear is same.

Fig. 5 shows the surface roughness test results of the bottom area. The test results show the gears surface wear are similar, the curve changes in the figure show the same trend, means the test results are accuracy.

According to the analysis in Fig. 3 to Fig. 5, the wear patterns in different area of the gears are consistent to a certain extent. The same specification gear surface shows different wear after test with the different consistency grease. In the test, increased grease consistency, the gear wear are decreases. To determine the actual wear amount of gear surface after test, measured and counted the wear amount of wear area. The wear areas of different shapes can be approximated to rectangular or triangular areas.

Fig. 6 shows the approximate results of wear area under the two conditions. The Fig. 6 (a) shows the calculation method of the pitting area of the approximate parallelogram, and the Fig. 6 (b) shows the calculation method of the pitting area of the approximate triangle.

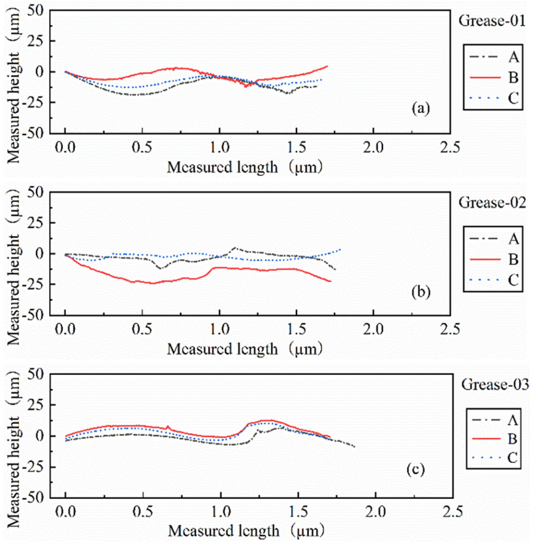


Fig. 5. Gear surface roughness of bottom area with different grease, (a) Test results of Grease -01, (b) Test results of Grease -02, (c) Test results of Grease -03.

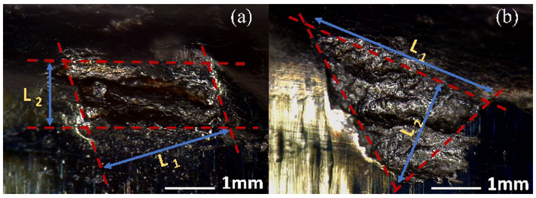


Fig. 6. Calculation of surface pitting area, (a) Approximate rectangular region calculation, (b) Approximate triangle area calculation.

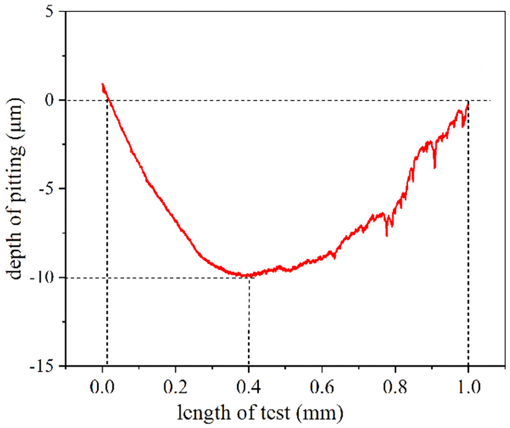


Fig. 7. Depth test of rectangular pitting area.

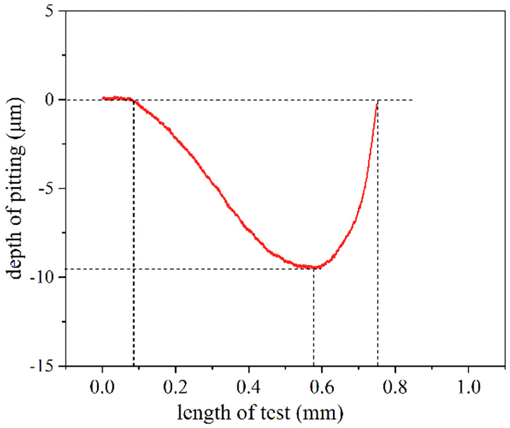


Fig. 8. Depth test of triangular pitting area

Wear area calculation:

$$S_{P1} = L_1 \times L_2 \quad (1)$$

$$S_{p2} = L_1 \times L_2 * \frac{1}{2} \quad (2)$$

$$V = S_{P1} * h \text{ or } S_{P2} * h \quad (3)$$

In equations (1) and (2), S_{P1} represents the area of rectangular wear, and S_{P2} represents the area of triangular wear. L_1 is the length of the base, L_2 is the height of the side length. In equation (3), V is the volume of wear quantity. h is the depth of the pitting.

Fig. 7 shows the depth measurement results of the approximate parallelogram of pitting area. The average depth value obtained from the data is 10.12.

Fig. 8 shows the depth measurement results of the

Table 4. Surface results and calculations

Grease	L_1 (mm)	L_2 (mm)	Pitting area (mm^2)	Pitting depth (μm)	Wear Volume (mm^3)
01	1.34	1.45	1.94	9.88	0.0096
02	1.40	0.87	1.21	9.45	0.0057
03	1.26	1.38	1.83	10.12	0.0185

approximate triangle pitting area. According to the data, the average depth is 9.45.

Table 4 shows every gear tooth surface average value of pitting area after test, and the calculation results of wear amount. Surface roughness test results and calculation show that the wear amount of grease-02 is significantly less than the other grease, and the wear amount of grease-01 is better than grease-03. Therefore, the lubrication effect of the three kinds of grease is determined in order of grease-02 is better than grease-01, and the grease-01 is better than grease-03. The result also proves that the lubrication effect of grease is indeed closely related to its consistency.

4. Conclusions

This experiment tested the influence from gear surface wear with three different consistency grease. The test results show that the condition of high torque and low speed, the grease consistency has an obvious positive correlation with lubrication performance.

The experimental results show that the same grease has the same wear on the different areas of gear surface. However, different grease with consistency has different wear in the same area of the gear surface. Under the conditions of low speed and high torque, different grease consistency affect the gear surface wear. with the increase of grease consistency, the wear amount of the gear surface decreases gradually, and has a better lubrication effect. At the same time, the surface roughness test results show that the surface of gear with high consistency grease is smoother, which is more conducive to prolong the service life of gear.

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