

Protective Material of the Security Mechanism Friction Surface on the Ship Lift

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Abstract. The security mechanism of the ship lift has the needs of increasing the friction and being anti-corrosive. This article tried an antirust grease used on wire rope with high friction coefficient (Alice IRIS-400M grease) and rayed it with ultraviolet. We find that ultraviolet rays can effectively accelerate the speed of solidification. It needs to ray at least 12h before the friction coefficient of the surface can meet the requirements (more than 0.1).

1 Introduction

With the vigorous development of China's water conservancy project, ship lift is increasingly being used, the screw and the nut column friction surface of security mechanism give self-locking condition to ensure the safety operation of ship lift. The self-locking conditions of safety mechanism is: screw friction surface's frictional angle must be greater than the helix angle ($\gamma=5.64^\circ$), which means the equivalent coefficient of friction $f_v > \arctan\gamma=0.1$. Considering the need of practical application, the safety mechanism is in an open environment. It is necessary to stop them rusting.

Before leaving the factory, people coated the spiral surface of safety mechanism with antirust oil. In the test, a set of security mechanism could not be self-lock. While after draining the water, with antirust oil thoroughly removed, mechanism self-locked successfully. Thus, the actual situation of spiral surface has a great influence on self-lock. If we daub the general oil, it is difficult to achieve both the requirements of antirust and self-locking. In this article, we want to explore a suitable protective material, without changing the structure of the safety mechanism. The material can not only ensure the equivalent coefficient of friction >0.1 , but also be antirust and convenient for construction.

2 Testing program

2.1 Sample preparation

Considering the actual materials of the screw and nut column of security mechanism on ship lift (screw's is 42CrMo4, nut column is material GS-25, CrNiMo4), we made friction specimens using the similar material 40Cr. And we daub the protective material on it to do the test of rust and friction. Making Ra3.2 to ensure the surface roughness of the sample is similar to that of the reality. The direction of the surface working is the same with that of sliding in the test. The size of our slip samples: $30 \times 20 \times 20$ mm; the stationary samples: $160 \times 75 \times 8$ mm. Shown as Figure1.

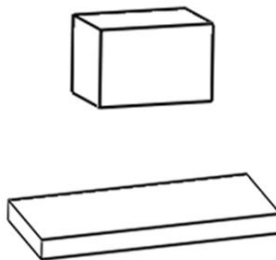


Fig. 1. Slip sample and stationary sample.

2.2 Protective material selection

The wire rope used in coal mine has the same need: increasing the friction, and antirust. In order to solve this problem, people developed an antirust grease used on wire rope with high friction coefficient, as the literature [1-5] introduced. It can protect the wire rope from rust, and the friction coefficient between wire rope and the friction pad (whose material is polyurethane) can reach 0.25, which is able to meet the requirements of lifting. But the environment is the friction between steel and the friction pat, which is different from the friction between steel itself like that on ship lift. So it is still necessary to have some experiment to exam whether the protective material is feasible.

We choose the Alice IRIS-400M grease produced by Alice Technology (Yangzhou) Co .Ltd, which is "black oil" in liquid state at normal temperature. The protective material is daubed on the surface of the sample, and then gradually solidified. In experiment (January 2015), we found it need 20 days before the friction coefficient of protective material to go over 0.1, which is not acceptable in actual construction. So, it is necessary to explore a new method to accelerate the consolidation.

In the experimental observation, we found that the weather affected the velocity of concreting, so we think that ultraviolet radiation may be useful to accelerate the concreting, which can shorten time. We used OSRAM UV bulb (OSRAM ULTRA-VITALUX), 300W. Light the bulb facing the sample, and the ultraviolet radiation eradiate the protective coating materials directly. Keep the distance: 15~20cm, the temperature at 60~80°C. We tested how coating thickness and the ultraviolet irradiation time affected the frictional behavior. It is shown as Figure 2.



Fig. 2. Ray the samples with ultraviolet.

2.3 Frictional behaviour test

Common used friction testing machine in china cannot meet our needs because of the special working load and environmental condition requirements. So we developed a static friction testing machine with digital display. Shown as Figure 3.

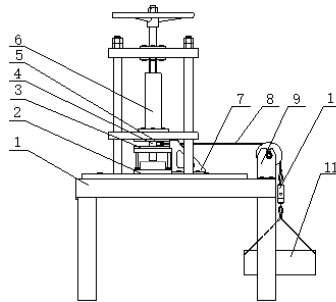


Fig. 3. Friction testing machine.

When it is working, a vertical load F_N is applied to the test sample by means of screw pressure, and the horizontal direction load F_T is applied by adding a heavy load on the tray. In the sensor, pressure and pulling force were measured. The horizontal force increases gradually, through the observation of the tension we can see whether the sample is sliding. Shown as Figure 4. A glass cover is arranged on the upper part of the friction testing machine. We can change the environment temperature and humidity by using heater and humidifier.

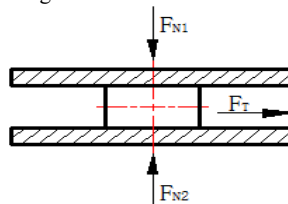


Fig. 4. Force diagram.

Coefficient of friction between materials

$$f = \frac{F_T}{2F_N} \quad (1)$$

Equivalent friction coefficient of screw nut column friction pair

$$f_v = \frac{f}{\cos \alpha} = \frac{F_T}{2F_N \cos \alpha} \quad (2)$$

$\alpha = 20^\circ$ is the angle of tooth of nut column mechanism

The self-locking condition of screw nut column friction pair is:

$$\gamma \leq \arctan f_v = \arctan\left(\frac{F_T}{2F_N \cos \alpha}\right) \quad (3)$$

$\gamma = 5.64^\circ$ is the helix angle of friction pair of screw nut

2.4 Test in different thickness and time

We did test of friction coefficient of no protective material and shell motor oil, and friction coefficient of different thickness and different irradiation time. The results are shown as the Table 1 and Table 2.

Table 1. Friction coefficient of no protective material and shell motor oil.

State of friction surface	Temp [°C]	relative humidity	f_v
Clean, no protective material	13.2	85%	0.126
Daub shell motor oil	13.2	85%	0.048

2.4.1 Thickness at 30~50 μ m, ultraviolet light at 12h

Protective coating thickness is controlled at 30~50 μ m, the time of using ultraviolet light is 12 hours, test the friction coefficient of the sample surface (ambient temperature 13 degrees, relative humidity 83%). When the pressure is 298Kgf, pull force is 61Kgf the sample started sliding. After sliding a distance of about 0.5mm the sample become static. When the coating thickness is 30~50 μ m, ultraviolet irradiation for 12 hours, in the case of micro sliding, the equivalent friction coefficient of the protective materials $f_v = 0.109$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

2.4.2 Thickness at 30~50 μ m, ultraviolet light at 24h

Protective coating thickness is controlled at 30~50 μ m, the time of using ultraviolet light is 24 hours, test the friction coefficient of the sample surface (ambient temperature 13.6 degrees, relative humidity 61%). When the pressure is 309Kgf, pull force is 70Kgf the sample started sliding. After sliding a distance of about 0.3mm the sample become static. When the coating thickness is 30~50 μ m, ultraviolet irradiation for 24 hours, in the case of micro sliding, the equivalent friction coefficient of the protective materials $f_v = 0.120$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

2.4.3 Thickness at 50~70 μ m, ultraviolet light at 12h

Protective coating thickness is controlled at 30~50 μ m, the time of using ultraviolet light is 12 hours, test the friction coefficient of the sample surface (ambient temperature 13.2 degrees, relative humidity 85%). When the pressure is 300Kgf, pull force is 58Kgf the sample started sliding. After sliding a distance of about 1mm the sample become static. When the coating thickness is 50~70 μ m, ultraviolet irradiation for 12 hours, in the case of micro sliding, the equivalent friction coefficient of the protective materials $f_v = 0.103$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

2.4.4 Thickness at 50~70 μ m, ultraviolet light at 24h

Protective coating thickness is controlled at 50~70 μm , the time of using ultraviolet light is 24 hours, test the friction coefficient of the sample surface (ambient temperature 13.6 degrees, relative humidity 61%). When the pressure is 301Kgf, pull force is 64Kgf the sample started sliding. After sliding a distance of about 0.5mm the sample become static. When the coating thickness is 50~70 μm , ultraviolet irradiation for 24 hours, in the case of micro sliding, the equivalent friction coefficient of the protective materials $f_v=0.113$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change. Those results are shown at Table 2 together.

Table 2. Friction coefficient of different thicknessn and different irradiation time.

Thickness	Irration time[h]	Force [Kgf]	Pressure [Kgf]	f_v
30~50 μm	12	61	298	0.108
30~50 μm	24	70	309	0.121
50~70 μm	12	58	300	0.104
50~70 μm	24	64	301	0.113

2.5 Test in different Loading Conditions

2.5.1 Loading Conditions is 2.3MPa

The contact area between slip sample and stationary sample is 600mm².When the pressure force is 140Kgf, the corresponding pressure is 2.3MPa. When the pressure is 140Kgf and the pull force is 37Kgf, the sample started sliding. After sliding a distance of about 0.5mm the sample become static. When the Loading Conditions is 2.3MPa, the equivalent friction coefficient of the protective materials $f_v=0.143$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

2.5.2 Loading Conditions is 3.1MPa

When the pressure force is 190Kgf, the corresponding pressure is 3.1MPa. When the pressure is 190Kgf and the pull force is 44Kgf, the sample started sliding. After sliding a distance of about 0.5mm the sample become static. When the Loading Conditions is 3.1MPa, the equivalent friction coefficient of the protective materials $f_v=0.119$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

2.5.3 Loading Conditions is 4.8MPa

When the pressure force is 293Kgf, the corresponding pressure is 2.3MPa. When the pressure is 293Kgf and the pull force is 54Kgf, the sample started sliding. After sliding a distance of about 0.5mm the sample become static. When increase the pull force to 66Kgf, the sample started sliding. After sliding a distance of about 1.1mm the sample become static. When the Loading Conditions is 4.8MPa, the equivalent friction coefficient of the protective materials $f_v=0.119$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

2.5.4 Loading Conditions is 9.7MPa

When the pressure force is 596Kgf, the corresponding pressure is 9.7MPa. When the pressure is 596Kgf and the pull force is 103Kgf, the sample started sliding. After sliding a distance of about 1mm the sample become static. When increase the pull force to 122Kgf, the sample started sliding. After sliding a distance of about 1mm the sample become static. When the Loading Conditions is 9.7MPa, the equivalent friction coefficient of the protective materials $f_v=0.110$.

Repeatability: after scratching the surface repeated friction test (static) showed there is little change.

Those results are shown at Table 3 together.

Table 3. f_v in different Loading Conditions.

Loading Conditions	Temperature [°C]	relative humidity	f_v
2.3 MPa	20.4°C	78%	0.143
3.1 MPa	20.4°C	78%	0.119

4.8 MPa	20.4°C	78%	0.119
9.7 MPa	20.4°C	78%	0.110

2.6 Salt spray test

The resistance to corrosion can obviously increase of the service life of metal work [6]. Salt spray test can effectively simulate the corrosion of the workpiece under actual conditions [7,8]. One sample was not coated with protective material and the other was coated with protective material. we put them into salt spray test, to compare the performance of protective materials. The thickness of protective material is 50~70 μ m, and the time of using ultraviolet light is 24 hours. Set temperature at 35 degrees Celsius, humidity at 95%-98%, mass fraction of the saline water is 5%. After 3h, 5h, 10h, 24h, have observation of corrosion.

(1)After 3-hours test, the samples without coating protective materials had began to be corroded, with time going by, the corrosion has become more and more serious;

(2)After 24 hours in the salt spray test, the surface coated with protective material has serious corrosion, and the other coated with a protective material is not corroded. After removing of the protective material, no corrosion on the surface of the substrate found.

3 Analysis

We can see from the test results above, all of them can meet the needs. Because screw friction surface's frictional angle must be greater than the helix angle ($\gamma=5.64^\circ$), which means the equivalent coefficient of friction $f_v > \arctan\gamma=0.1$. Antirust grease are developed to protect the metal material better [9,10]. It works well n different thickness and different load conditions. So we think the antirust grease works well both in protect the material and increase friction.

4 Conclusions

1.The thickness of the protective material coating has little effect on the friction coefficient of the friction pair.

2.Ultraviolet radiation is conducive to the solidification of protective materials.

3.We did a twenty-four hour salt spray test.(35°C, humidity 95%-98%, percentage of salt water 5%): IRIS-400M protective material has good corrosion resistance, which can meet the needs. Put the sample in the laboratory for one hundred days (From February 8th to May 20th), the surface kept in good condition. It shows that the protective material has good ability of oxidation resistance in the air.

4.IRIS-400M protective material can meet the needs of the security mechanism friction surface on the ship lift, and has great application prospect.

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