Thermal Friction Analysis of a Single-Nut Preloaded Ball-Screw

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1. ABSTRAT

High speed transmission table is wildly used in industry and its demand is increased. High speed ball-screw device is a major component. Traditional lubricant is oil used in a high speed ball-screw device. But now grease is a more convenient lubricant than oil and became more often used in high speed device. Operating in high speed condition brings high thermal effect, which lets viscosity of grease decreasing with temperature rising. This will let transmission performance of ball-screw device varies with operating time.

The work of this paper is to establish a thermal elastic-viscous hydrodynamic lubrication (EHL) analyzing model [1,2] for friction calculation. The thermal effect and the real reheology of grease are both considered in this model. Thickness of the oil film and friction force of each contact surface varying with operating conditions of ball-screw can be obtained and confirmed with driving torque of motor by experimental test. The study is useful in understanding thermal friction between ball and raceway.

2. RESULT AND DISCUSSION

In grease lubricating ball-screw system, driving torque is decreased before 10 mins, as shown in Figure 1, and also increases with raising rotational speeds. Temperature rising of nut is also increase with operating time. It means that contact temperature on ball and raceway is rising with time. The driving torque analyzing model is considered viscosity variation with thermal rising with different shear rate, as shown in Fig.2. The viscosity drops rapidly with temperature raising. Oil film and pressure distribution were calculated, as shown in Figs. 3(a) and (b) with different viscosities, 1 and 200 pa・s. Friction force can thus be obtained from different operating conditions and driving torque of ball-screw also can be calculated. If the viscosity of grease is 200 pa・s, minimum oil film is greater than 1.6×10^{-5} m, and it is also larger than roughness of raceway. Wear occurred at ball and raceway can thus be avoided. But friction forces, whose shown in Fig.3(b), are also ten times greater than those obtained from 1 pa・s. This reveals that high viscosity of grease brings high friction and thermal rising. The thermal effect also can decrease viscosity and lower friction force is obtained.

Driving torque of motor on a linear driving table is composited by the friction torque of ball bearings, screw and linear guiders. The torque of screw is calculated by the analysis and compared with experimental data as shown in Fig.4. It shows that the torque is decreased with the increase of operating distance. This is owing to the wear is occurred at ball and raceway contact area. Friction heat was estimated in order to do the iteration of viscosity varying with contact temperature and find out the wear condition. Comparing the trend between theoretical and experiment data is the same, and the value of them is similar. The calculating error is due to the variation of asperity cannot be estimated properly. This is the next step in the research.

3. REFERENCES

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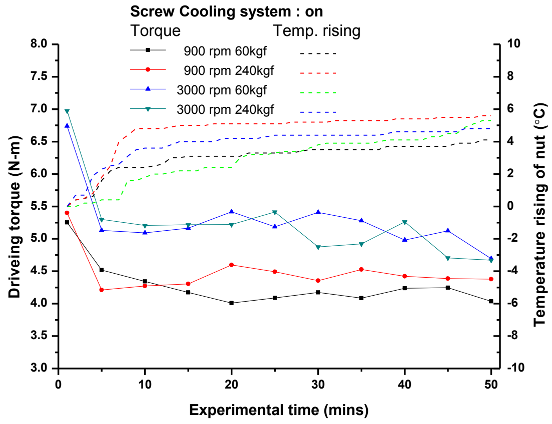


Figure 1 Driving torque of ball-screw

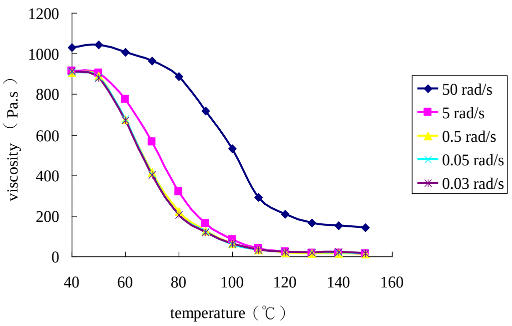
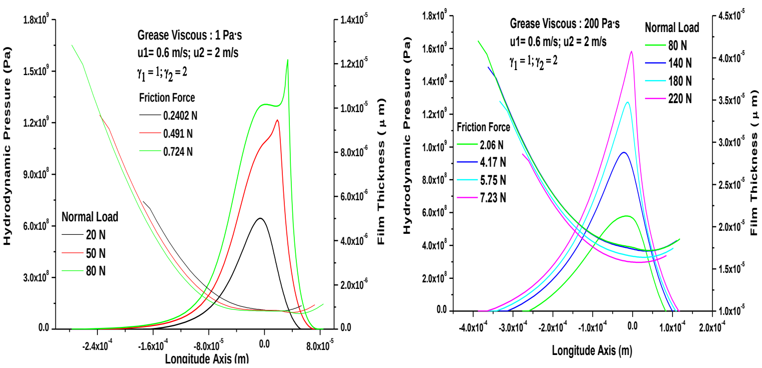


Figure 2 viscosity measurement result of Grease A



(a) (b)

Figure 3 lubrication and friction force varying with load.

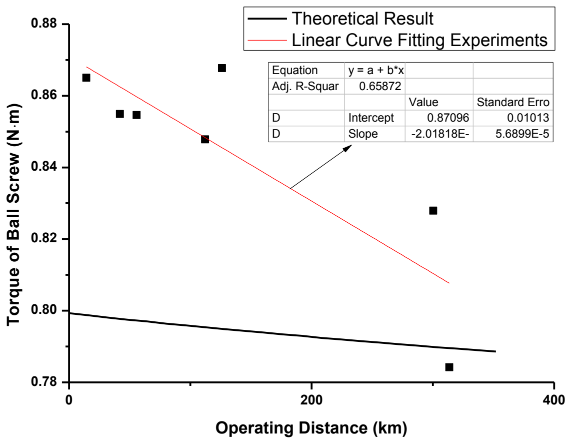


Figure 4 Friction force versus contact conditions