A reciprocating friction and wear tester

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Abstract. A reciprocating friction and wear tester based on Lab VIEW was designed and built to preliminarily test the friction and wear characteristics of different materials under different test conditions and lubricant additives. The mechanical structure and measurement, and control system were optimized. It carried out functional test studies. The test shows that the test results obtained by the tester conform to the tribological law, and the operational performance is relatively stable, which meets the needs of preliminary friction and wear test research.

Keywords: Reciprocating；friction and wear tester；Lab VIEW.

1. Introduction

Research shows that various forms of friction consume more than 30% of the world's energy [1], causing severe energy waste. At the same time, the "lubrication failure" between mechanical structures, such as the wear of high-pressure oil pump bearings in petrochemical plants, theruan abnormal wear of turbine unit bearings in nuclear power plants, and the wear of gearbox bearings and gears in wind power plants, has had a severe impact on the safe operation of mechanical equipment. Up to two-thirds of mechanical failures yearly are caused by this "lubrication failure." [2] In 2021, only China's friction economy will lose 4.58 trillion yuan.[3]

The friction and wear tester is a test instrument used to study friction and wear phenomena and conduct essential exploration in tribology. It can not only objectively evaluate the influence of various factors on friction and wear performance, but also can be used to evaluate the performance of lubricants. Currently, the friction and wear tester on the market mainly include the types of the reciprocating, end face, and ring block. There are a few multi-functional frictions and wear tester, such as the UMT TriboLab produced in the United States, which can carry out various friction and wear tests under the condition of highly imitating different working environments. However, its price is very high, which may negatively affect the development of the test. [4] However, the traditional vertical friction and wear tester performs poorly because of its large volume, heavy machine, and easily restricted test conditions. [5]

Under the background, a reciprocating friction and wear tester with a simple structure and low price has been designed. Compared with the traditional reciprocating friction and wear tester, the tester has been improved and optimized in terms of mechanical structure, data acquisition, and processing methods. This tester is particularly designed to serve the needs of preliminary testing of the friction and wear characteristics of different materials under different test conditions and lubricating additives.

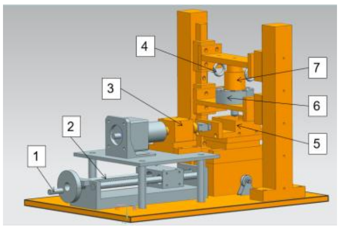
2. Overall layout of tester

2.1 Overall structure of the tester

The overall structure of the tester is shown in Figure 1, mainly composed of a power module, transmission module, loading module, and measurement and control module.

Physical picture of tester

3D picture of tester



(1-Handle；2-Screw；3-Sleeve；4- Rings；5-Oil tank；6- Pressure sonsor；7-Pin)

Fig. 1 Picture of reciprocating friction and wear tester.

2.2 Working principle of tester

During the test, fix the upper and lower test pieces in the fixture respectively, drive the lead screw 2 to rotate by turning the handle 1, and then pull the wire rope (not shown in the figure) to pull down the force application frame through the lifting ring 4. The upper and lower test pieces contact each other to generate a positive pressure in the vertical direction. The pressure is transmitted to load cell 6 through the buffer spring (placed in pin 7), and the test force can be obtained. The overstepping motor controller starts the motor, and the connecting rod drives the oil tank 5 to realize reciprocating motion with sleeve 3. The micro tension sensor can measure the friction force, and then the friction coefficient and other data can be obtained by conversion.

3. Module design of tester

3.1 Abbreviations and Acronyms

The tester uses Haydon 57 series stepping motor as the power source. It uses Haydon DCM8054/8027 high-performance digital subdivision driver to cooperate with KH-01 stepping motor controller to realize the start and stop of the stepping motor and the control of reciprocating stroke and frequency.

After the stepper motor is started, it drives the connecting rod to pull the oil tank for reciprocating motion with the cooperation of the sleeve. Compared with the crank slider mechanism, the design of this kind of transmission mechanism makes the speed of reciprocating motion more uniform, has less impact and vibration on the load, and improves the accuracy and stability of the test [6].

In addition, a micro tension sensor is set between the oil tank and the sleeve, which can measure the tension of the oil tank relative to the connecting rod during the test. The friction force generated by the upper and lower test pieces during the test can be obtained through conversion. The calculation formula is:

$$F_x = F - \mu_1 F_y$$

In the equation, F_x is the friction force generated between upper and lower test pieces during the test; F is the tension measured by the micro tension sensor; μ_1 is the friction coefficient between the oil tank and the guide rail; F_y is the positive pressure between the upper and lower test pieces during the test.

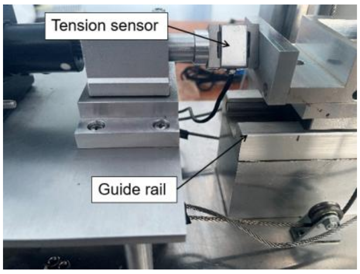
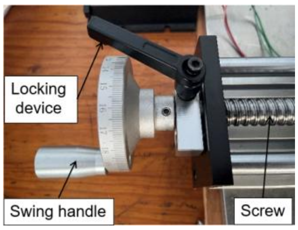


Fig. 2 transmission mechanism

3.2 Loading module

3.2.1 Force application mechanism

The force application mechanism mainly comprises a swing handle, a locking device, a lead screw, a steel wire rope, a force application frame(namely force palte), a lower board, and a buffer spring (placed in the pin). The primary function is to provide the test force in the vertical direction for the test.



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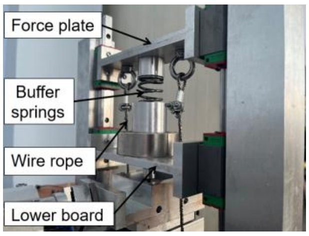


(b)

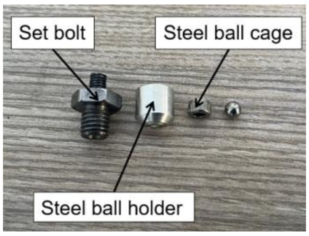
Fig. 3 Force application mechanism

The swing handle is marked with a scale, so the test force can be accurately controlled by simply rotating the handle during the test. After reaching the required test force, tighten the locking device clockwise to maintain the stability of the test force during the test.

3.2.2 Clamping mechanism

The clamping mechanism consists of two parts: the upper and lower specimen clamp. The design structure is simple, and only simple disassembly and installation operations are required when replacing the test piece, which significantly saves the test time and simplifies the test steps.

The upper test piece clamp is shown in Figure 1, including the fastening bolt, steel ball rack, and steel ball cage. Before the test, the steel ball shall be placed in the steel ball rack, then the cage shall be placed on the steel ball, and the cage shall be fixed by tightening the compression bolt to fix the steel ball. When starting the test, screw the upper test piece clamp into the lower plate.



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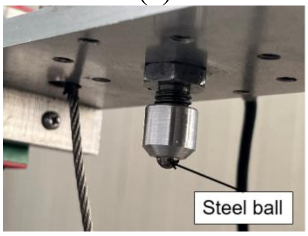

(b)

Fig. 4 The upper specimen and its fixture

The lower test piece is a clamping groove. During the test, tighten the screws to fix the test piece and adjust the position of the test piece. Both ends of the clamping groove are fixed in the oil groove by fastening screws.

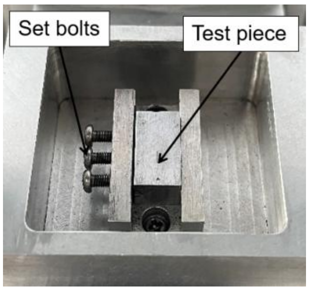

Fig. 5 The lower specimen and its fixture

The oil tank is the lubricating mechanism of the machine. During the test, the upper surface of the lower test piece can be evenly coated with a lubricant, or the oil tank can be filled with lubricant to control the test conditions.

3.3 Measurement and control module

3.3.1 The working principle of the tester measurement and control module is shown in the below.

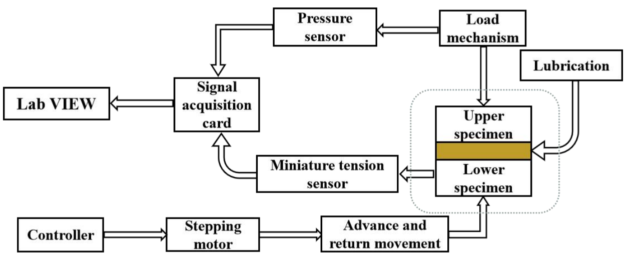

Fig. 6 Operating principal

In addition to the stepper motor controller and motor control card mentioned in Section 2.1, the hardware of the data acquisition part of the tester consists of the sensor data collector, data acquisition card, 12V DC power supply, and 24V DC power supply. The details are shown in Table 2 below:

Table 1.hardware models and technical parameters

Hardware	***Technical parameter***
data acquisition card	USB_DAQ V5.1
12V DC power supply	110/220V 50-60Hz 12V2A
Sensor data collector	BSQ-12
24V DC power supply	100-264V 50-60Hz 24V6.5A

3.3.2 Software

The software part adopts the measurement and control system based on Lab VIEW. Applying Lab VIEW to the measurement and control system of the friction and wear tester can realize the real-time acquisition, synchronous display, and data storage of the multi-channel signals of the tester. The dynamic curve generated by the system interface can intuitively understand the change law of the test data. After running the program, its initialization interface is as follows:

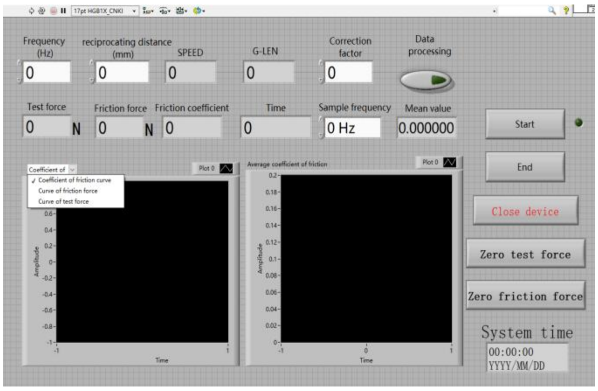

Fig. 7 Measurement and control system interface

It can be seen from the figure that the system can display the load test force, friction force, and other data measured by the tester during the test, as well as the processed and modified friction coefficient, and can show the real-time curve to the tester. [7] After the test, you can export and save data and images.

In addition, the tester will inevitably be interfered with by various factors during the test, affecting data accuracy. The average arithmetic method is used to reduce the influence of external factors on the data acquisition of the tester when compiling the data processing program of the system.

4. Functional verification of tester

4.1 Test design

The developed reciprocating friction and wear tester was used to carry out the test under base oil to test the working performance of the tester.

4.1.1 Test materials and test methods

500SN was used as the base oil, 6mm GCr15 steel ball and 10×10×20mm #45 steel block were used as the upper and lower specimen, namely the friction pair. The friction pair was soaked in the base oil for the test, and the test was repeated three times.The test parameters are shown in the table below.

Table 2.test parameters

Test force/N	***Reciprocating distance/mm***	***Speed/ m·s^{-1}***	***Reciprocal time***
440	1	2	5000

During the test, Lab VIEW recorded the friction coefficient in real time and generated the image.

4.2 Test results and analysis

500SN base oil medium is used for the test, and the mean friction coefficient data obtained are shown in Fig.8.

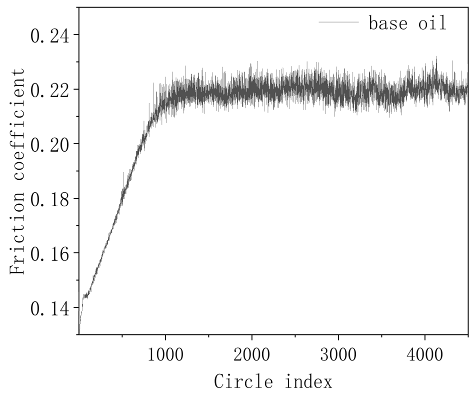

Fig. 8 Friction coefficient of 500SN base oil

From the test results, it can be seen that under the above test conditions, when 500SN base oil is used as a lubricant, the friction coefficient is stable at about 0.22, and the friction force is stable at about 98.8N, which satisfies the friction coefficient calculation formula. Therefore, the developed test machine meets the basic test requirements.

Conclusion

A reciprocating friction and wear tester is designed, which consists of a mechanical structure and testing system. It is small in size, simple in structure, low in cost, straightforward in working principle, and optimized in sample replacement and data collection and processing. The measurement and control system based on Lab VIEW is adopted to realize real-time data acquisition, processing, storage, and visualization, improving the experiment's efficiency.

It is found that the friction and wear tester developed can correctly measure the friction coefficient between the friction pairs, the friction coefficient is stable, and the accuracy meets the requirements.

In conclusion, the results obtained from the tests are consistent with the theory. The operational performance of the designed friction and wear tester has been verified, showing excellent reliability in the reciprocating friction and wear test research and efficacy in relevant tribological test research.

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