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The Application of Virtual Instrument Technology in the Tester

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Abstract

Four-ball tester is a device which is used to evaluate the resistance of extreme pressure grease performance and wear resistance with simple structure, less fuel consumption and low cost. It has been widely used in Lubricants research. In this paper, the principle and testing equipment of four-ball tester are introduced. At the same time, some shortcomings such as inconvenient load mechanism and inaccurate measurements are presented. Friction testing and recording system is improved on the basic of the previous system to avoid the defects. Amplification ratio of the friction test result increases significantly. To improve precision and convenience for data storing, analysis and comparison, data acquisition system is established based on LabVIEW. Then friction measurement process is visualization to realize the measured results being observed visually.

Keywords: *tester, fiction, virtual instrument, LabVIEW*

1. Introduction

Boerlage designed the four-ball tester for the study of different types of materials and lubricants' carrying capacity in 1933.Four-ball machine test is one of the oldest and the most common evaluation methods of friction and wear in our application. It is divided into two categories, the one is used to assess extreme pressure performance as of oil, and the other one is used to assess oil anti-wear performance which is under a predetermined load, speed, oil temperature, and time, the average of the three milling spot diameter. Four-ball test is a sliding friction test with point con-action, whose structure is that the ball fixed on relative to the upper shaft to the three balls fixed to the lower shaft for rotating movement [1-4].The structure of the four-ball tester is just as Figure 1.

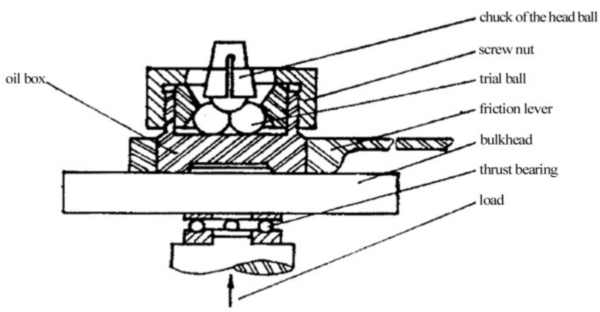

Figure 1. Main Structure of Four-ball Tester

Four-ball friction and wear tester is a common tester to test anti-wearing performance of oil, in which, friction that steel balls are given to is one of the important signals of the test. By improving the SM-800 friction force testing system, we also design the software and hardware systems for signal collection and test analysis based on LabVIEW to improve the testing precision, meanwhile, the system is convenient to analysis and compare on data.

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2. Testing Structure and Working Principle of Four-ball Tester

The testing elements of MS-800 four-ball tester are four steel balls which diameters are 12.7mm (Figure 2). The ball above is rolling and pressing on the three bottom immovable balls. The vertical load that subjected on the top ball W is undertaken by three points of contact B_1, C_1, D_1. The acting forces are N_1、N_2 and N_3 separately. Then the equilibrium of forces on vertical direction is as following:

$$N_1 \cos\theta + N_2 \cos\theta + N_3 \cos\theta = W \quad (1)$$

In the equilibrium, θ is the angle between the reaction N_1, N_2, N_3, and the head ball center of the sphere A, W is the vertical load to the head ball. The three acting forces have the same angle with the perpendicular through point A. So $N_1=N_2=N_3$, then we can get:

$$N_1 = N_2 = N_3 = W / 3\cos\theta \quad (2)$$

With the geometrical relationship of the diagram, the following is obtain $\cos\theta = AO/AB$.

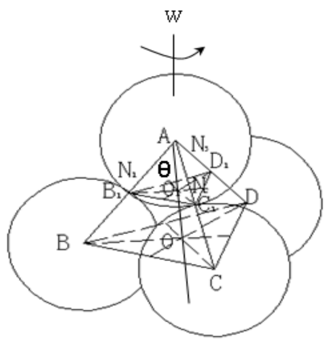
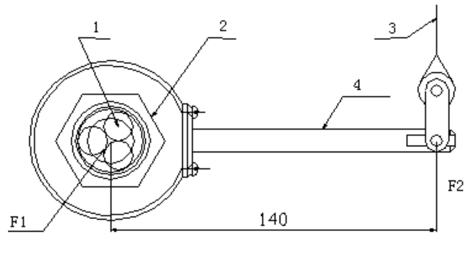


Figure 2. Stress Analysis on Balls of Four-ball Tester

In the equilibrium, AO is the tie line between the three ball centers O and the head ball center A, AB is the tie line of the two steel ball centers, then the friction forces that undertake by every steel ball are equal ,named as F_1, $F_1=\mu\times N=\mu W/3\cos\theta$.

The distances between the contact points of head and bottom ball and the perpendicular through the head ball center are O_1B_1, O_1C_1, O_1D_1, from the geometrical relationship in the diagram, we can know:

$$O_1B_1 = \frac{1}{\sqrt{3}} R_1 = \frac{D}{2\sqrt{3}} = 0.5774 R_1 = \mathrm{O1C1} = \mathrm{O1D1} \quad (3)$$



1. Steel Ball 2. Oil Cup 3.Wire Rope 4.Hand Shank

Figure 3. Friction Test System Structure of Four-ball Tester before Improvement

The force data is recoded by self-driven stress recorder in common four ball tester, but it is not just the friction force through friction between the four balls, instead it is obtained through transported and enlarged by hand shank, can be calculated as below.

In Figure 3, the arm of friction force is:

$$L_1 = O_1B_1 = 0.577\, R_1 \approx 3.67\, mm \tag{4}$$

The torque of force system $\sum M_0 = 0$,

$$3F_1L_1 - F_2L_2 = 0 \tag{5}$$

From diagram 2, L_2 =140mm, so the force measured through self-driven stress recorder is:

F_2

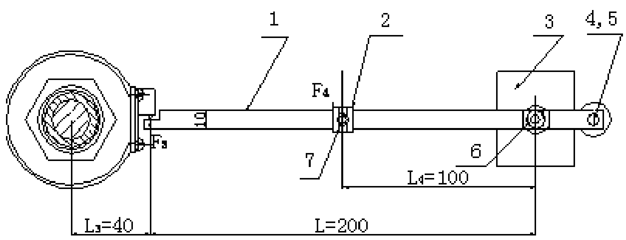
$$F_2 = \frac{3F_1L_1}{L_2} = \frac{3F_1L_1}{140} \approx 0.079F_1 \tag{6}$$

Thus, the data recorded by stress recorder is only about 0.079 of the actual friction force.

3. Improvement of the Force Transporting System

For the friction of four-ball tester is very small and variable with rotation of the motor and abrasion of the steel balls, data that recorded by traditional mechanical recorder are only about 0.079 of the actual value, for its inaccurate and poor reliability, the tester can't reflect the minute variations. So the data offset the true results, due to its structure stiffness that result in negative effects of the stability of the data, the system with poor sensitivity and short precision is not suitable to present precision measurement.

To solve these problems, we improve the dynamometric system of four-ball friction and wear tester and develop data processing system. At first, we improve the friction force test system. The length of the hand shank is designed again to shorten. The force is transported by dowel steel, at the same time; load detector of bk-3 is used to replace the self-driven stress recorder to collect data, just as in Figure 4 and Figure 5.



1.Dowel Steel 2.Joint Bolt 3.Anchorage 4. Mounting Hole for Balance Wight 5.Balance Weight 6.Munting Hole for Supporting Frame 7.Mounting Hole for Sensor

Figure 4. Force Transmission Mechanism of Four-ball Tester after Improvement

In Figure 4, by analyzing the Figure 3, $\sum M_0 = 0$.

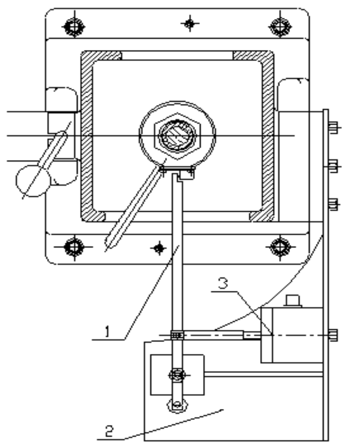
$$F_3 = \frac{3F_1L_1}{L_3} \tag{7}$$

$$F_3L = F_4L_4 \tag{8}$$

$$F_4 = \frac{F_3 L}{L_4} = F_3 \times 2 = \frac{3F_1 L_1}{20} \quad (9)$$

By contrasting the Equation (6), (9), we can find that measurement of friction force can be enlarge 7 times to record data more conveniently, inaccuracy of measurement is reduced greatly, so measurement accuracy improves largely.

It is explained that the length 100mm of L_4 is not a fixed value , it can be adjusted as required by adding more holes, so the magnification times can also be enlarged to increase the measurement precision.



1.The dowel bar 2. Supporting Frame 3.Sensor

Figure 5. Structure Installations after Improvement

4. Friction Testing System Structure

Load detector of bk-3 is applied to replace the self-driven stress recorder to collect data, which is transported to data acquisition board after amplified, handled and displayed by computer. Installation of sensor section of MS-800 systems, after improvement as shown in Figure 5. After implementation, the friction force test system is a typical system of signal collection, composed of sensor, amplifier, data acquisition board and computer [5-6]. Gathering process is as shown in Figure 6.

Figure 6. Signal Acquisition System Diagram

5. The Friction Test Software System

Data acquisition and processing are fulfilled mainly by LabVIEW, which is based on a graphic development, commissioning and operation procedures of integrated environment, is the only type of international graphical compilation of programming language, is a complete, open virtual instrument system application software development, meeting the realization of virtual instruments [7].

LabVIEW is a graphical program language development environment, which is widely used by industries, academies and research laboratories to accept, as a standard data acquisition and instrument control software [8]. LabVIEW integrates full functionality which includes the GPIB, VXI, RS-232 and RS-485 protocol hardware and communications data acquisition card [9] .It is also built to facilitate application software such as TCP / IP, ActiveX standard library functions. This is powerful and flexible software. It can be conveniently established virtual instruments, and its graphical interface makes programming and the interesting process [10].

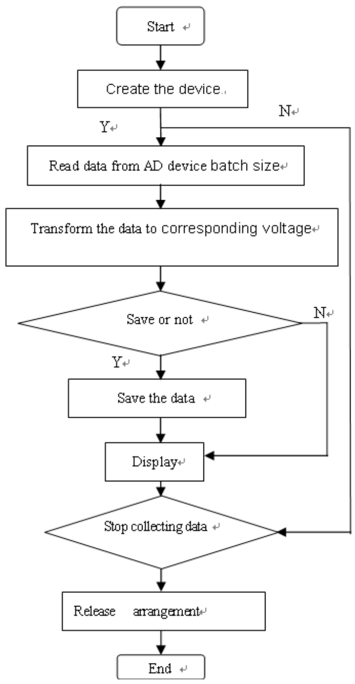


Figure 7. Program Flow Chart of Collecting and Testing Friction Force

Friction test software system is composed by three main programs as follows: friction test procedures, reading programs and data processing program. Three procedures are separated which can be used all or only one or two according to the requirement [11-12].

5.1. Friction Data Collection Procedures

Friction test procedures are used to collect simulation signal from data acquisition card and translate them into the corresponding voltage and display afterwards. Flowcharts are shown in Figure 7. The process of single channel of the front panel testing procedures is shown in Figure 8, can add or remove channel window according to actual needs. The first panel consists of two main windows as wave data output interfaces. Y-coordinate of above display window output is fixed to show the general tendency of outputs curves. Y-coordinate of below display window output is auto scale Y, to show the minor changes of the display output. According to need, press the save button and start to save the data.

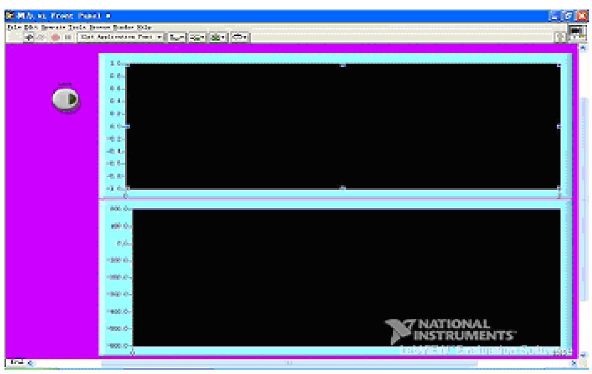


Figure 8. Front Panel of Single Channel Friction Collection Procedures

5.2. Signal Reading Procedure

Mechanical testing in many cases requiring multiple measurements, so in the end of the test, we need a test program to read preservation data of measurement results of signals directly, also it can break up and leach the useless signals. Font panel with two interfaces to read single signal process is shown in Figure 9. The above output is the window to show reading test data and friction. The data reading or segmentation image are displaying in the below output window. The starting point of data segmentation and length of the data can be set according to needs.

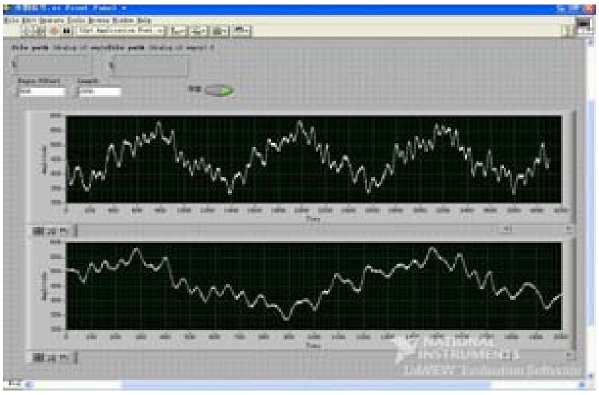


Figure 9. Front Panel of Signal Reading Procedure

5.3. Data Processing Program

After collecting, multiple data processing can be done for different needs. As shown in Figure 10, it is the front panel of spectral analysis procedures. The signal after segmented is shown in the above window. The image after spectrum analysis is shown in the below window.

Figure 10. Front Panel Data Processing Procedures

6. Conclusion

Firstly, by improving the friction force transport structure, measurement of friction force can be enlarge 7-14 times or more to record data more conveniently, inaccuracy of measurement is reduced greatly, so measurement accuracy is improved largely .

Sencondly, after the dynamometric system of four-ball tester has been improved, analog signals that received by sensors are converted to electric signals that characterize the friction force. In this system, the lowest voltage is 1mv that equals to 0.002N, so the resolution is much higher than that of self-driven stress recorder.

Thirdly, signals can be shown and saved currently, and then they can be analyzed and processed quickly and accurately.

Fourthly, the procedures can be used in measurement of multiple channel physical quantity, such as force, acceleration and velocity for its good scalability.

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