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RESEARCH

New Universal Tribometer as Pin or Ball-on-Disc and Reciprocating Pin-on-Plate Types

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A B S T R A C T

The present paper contains a description of a new Universal Tribometer design which enables simulation of different contact and test types such as pin-on-disc, ball-on-disc and linear reciprocating tests. There are many models of wear Tribometer in the world market. These devices are manufactured by various companies abroad and are imported to our country. Cost of this devices start from 50.000 euros and goes to hundreds of thousands of euros. One of the most commonly used of this device is Reciprocating Pin-on-Plate Tribo Test Machine. This wear tester is produced at a low limited cost within the KAP (Scientifical Research Project Coordinator) of Yıldız Technical University. The test machine can work including three types of Tribotest rigs (Reciprocating Pin-on-Plate, Pin-on-Disc and Ball-on-Disc). It is designed to operate also at high temperatures up to 500 °C. The new piece of equipment allows instrumented tribological testing of piston ring and cylinder liner samples at low and high temperatures and boundary lubrication conditions of any typical gasoline or Diesel engines. Some friction results were shown in boundary lubricating conditions between piston ring and cylinder liner sliding pairs describing Tribotest machine is driven by AC servo motor which is more accurate than DC motor.

1. INTRODUCTION

The term tribology is derived from the Greek tribos, which means rubbing, and includes all of the sciences and technologies of interacting surfaces in relative motion. The main areas of research and application are friction, wear, and lubrication. The term was first used 1966 in the Jost Report, a study conducted in the United Kingdom which investigated the amount money lost annually due to friction and wear [1].

Tribology is an experiment-oriented branch of a complex, interdisciplinary science, in which testing plays a major role in the solution of technical problems, in the field as well as in the development of tribomaterials. It involves the recording of chemical, electronic and structural information from wear debris and surfaces. Tribological problems are often complex and their understanding and solution rely on experimental data obtained from laboratory tests. Various test methods are used for this purpose, and the results are sensitive to the choice of test method and test conditions. Research in the field of tribology is associated with rapid transfer and applicability of the results of experimental tests into praxis. Among important factors accelerating tribological research the use of computer technology belongs. Tribological parameters of sliding pairs (friction coefficient, normal load, temperature, etc.), especially their changes over time, must be continually analyzed with aim to predict the wear. Documenting and monitoring the tribological processes should be continuous. Automated checking systems for sensing and control of testing, improving the test methods and laboratory techniques are current challenge of tribology. Conventional measuring devices are based on mechanical principles, which are from a mechanical point of view interesting; but on the other hand; from the perspective of development they are obsolete [2].

A tribometer (tribotester) is the general name given to a machine or device used to perform tests and simulations of wear, friction and lubrication which are the subject of the study of tribology. Often tribometers are extremely specific in their function and are fabricated by manufacturers who desire to test and analyze the long-term performance of their products [3].

This paper presents the design of a computer-controlled tribometer for friction characterization of various friction sliding pairs. The tribometer setup comprises one high-bandwidth servomotor for the control of the rotating disc, as well as two force sensors for normal forces measurement of two reciprocating sliding direction.

2. DESIGN AND CONSTRUCTION OF THE TRIBOMETER

The control of the friction and wear in movable pieces of machines is a critical element to face in the industry. It is important to have comparable data of analyses obtained during years, with variable humidity and temperature and/or in the presence of lubricants. The fields of application of these tests are, among others:

- New materials (ceramic, metals, polymers),
- Lubricants and oil additives in auto-lubricating systems,
- And quality assurance.

The most common test rigs employ a pin or a ball pressed against a disc or plate surface (pin-on-disc or ball-on-disc, pin-on-plate).

The pin-on-disc tribometer serves for the investigation and simulation of friction and wear processes under sliding conditions. It can be operated for solid friction without lubrication and for boundary lubrication with liquid lubricants. Thus both material and lubricant tests can be executed.

According to the standard test (ASTM G99) principle a stationary test specimen (pin or ball) with a defined normal force is pressed against the surface of another test specimen placed on the rotary disc.

Linear Wear option allows tribometer to reproduce linear movement typical from a high variety of real mechanisms. The entirely option allows the measure of frictional movement in that specific movement as well.

This technique ("reciprocating") results very useful for the study of frictional coefficient variation in time compared with frictional coefficient measured it pin-on-disc disposition. Most contact geometries are suitable to be simulated with tribometer including "pin-on-plate" or "ball-on-plate" [4].

This Tribometer is driven by servo motor which is more advantageous than DC motor with very precise movements that can be well performed use in hard drives and automation. The advantage of a servo motor is precise rotational control which is based upon the number of steps/revolutions and any associated gearing. The series of servo motors are permanent AC servo motors, capable of combining with 200 V series AC servo drives from 100 W to 3 kW. There are 40 mm, 60 mm, 80 mm, 86 mm, 100 mm, 130 mm, 180 mm seven kinds of frame sizes available. The motor speed is from 1 r/min to 3000 r/min and the torque output is from 0.32 Nm to 14.32 Nm. They provide brake and oil seal to fully support offering two different shaft selections, round shaft and keyway, for various applications.

The technical specification of servo motor is given in Table 1.

Table 1. Servo motor technical specification.

Specification	Value
Rated output power (kW)	1.5
Rated Voltage (V)	220
Rated speed (r/min)	2000
Maximum speed (r/min)	3000
Rated torque (N-m)	7.16
Maximum torque (N-m)	21.48
Rated current (A)	8.3
Maximum current (A)	24.81
Encoder Type	17bit
Motor Frame Size (mm)	130
Shaft Type	Keyway
Oil Seal	W/O Brake, with Oil Seal
Vibration grade (μm)	15
Vibration capacity	2.5G
Operating temperature (°C)	0...40
Weight (kg)	7.5

Tribometer provides three types of tribological tests:

1. Pin on disc test,
2. Ball on disc test,
3. Linear reciprocating test.

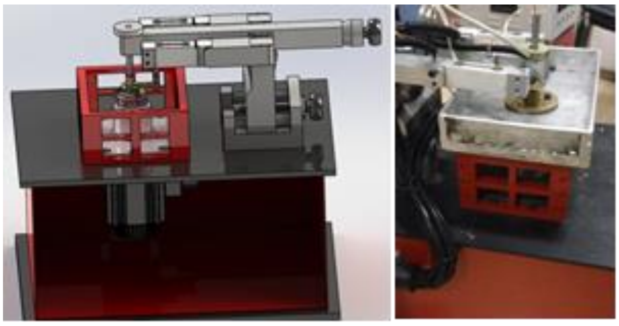


Fig. 1a. General view.

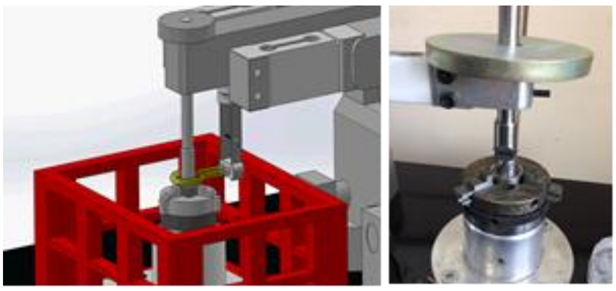


Fig. 1b. Pin on Disc or Ball on Disc type.

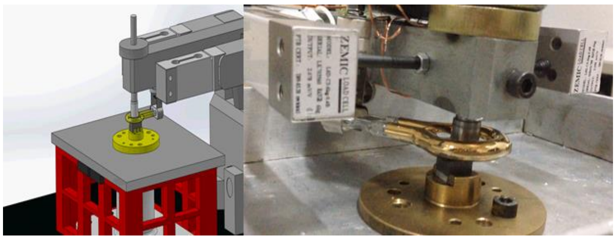


Fig. 1c. Linear reciprocating type.

Appearance of the unit for three types (pin-on-disc and reciprocating) for normal load assurance is given in Figure 1.a, b and c.

During test continually measurement of:

1. Normal load in N,
2. Friction force in N (2 load cells are mounted for reciprocating motion),
3. Friction coefficient,
4. Temperature of upper and lower part,
5. Temperature control up to 500°C,
6. Maximum Applied Load FN = 100 N.;

have to be performed.

2.1 Tribometer Design

Fig. 2. Appearance of cabinet for electronic equipment and Control Panel working page.

For the reasons of stability and result accuracy robust housing and heavy bottom support were made. Drive, electronic equipment and control panel working page are located in a cabinet which is shown in Fig. 2.

Circular motion is realized by using special disks. They are mounted vertically on the motor shaft and specimen disk shaft under basic plate. Design of this components fulfill given requirements of velocity.

For linear reciprocating moving special disk and plate holder are used. Plate holder is mounted on guide pillars trough guide bushes with ball-bearing, which assure precise movement with very small friction. Plate specimen is positioned and joined with screw on plate holder. The length of reciprocating moving depends on diameter of the disk. There are ten different adjustable lengths: 100, 90, 80, 70, 60, 50, 40, 30, 20 and 10 mm. Appearance of unit for reciprocating moving device is shown in Fig. 3.

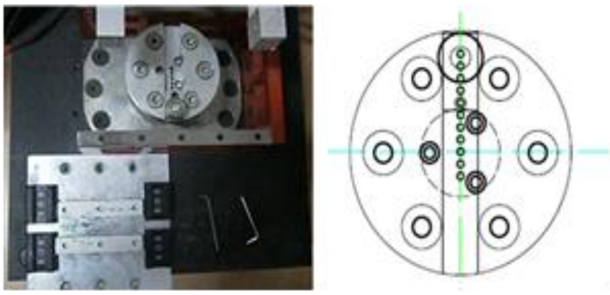
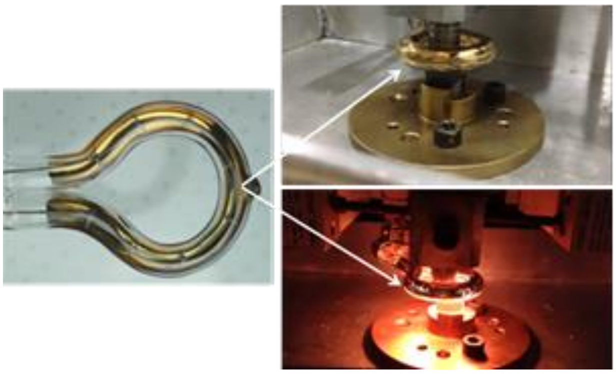


Fig. 3. Unit for reciprocating moving device and its schematic.



a) b)

Fig. 4. a) Gold reflector of IR lamp b) Lamp installation to heat the pin.

Temperature of the pin is measured by thermocouple. The pin is heated by infrared lamp and controlled according to the temperature variation as shown in Fig. 4. The infrared heating is a gold reflector that can emit heat directly to materials, meanwhile the gold coating can reflects the infrared radiation, so that it can double the infrared radiation. It is non-contact and has got important advantages:

- **Fast Response:** they can start working within 1 second and transfer a large amount of energy within seconds,
- **Precisely Heating:** heat is applied to where it's needed,
- **Controllable Heat:** the heating time is controllable as it's required,
- **Tailor made:** wavelength, dimensions, filaments and others can be adjusted to meet the requirements,
- **Energy Saving:** less energy consumption, smaller footprint and better heating results compared with conventional heating methods.

All of main parts of tribometer are made of stainless steel and aluminum alloys.

2.2 Measurement And Guidance Software

For the purpose of measurement and tribometer guidance special software (Windows application) is developed. Program is aimed for:

- Collection of data from tribometer during experiments such as friction load, load, coefficient of friction, motor revolution, temperature, operation duration (time), Fig. 5 shows control panel for data tunning page.
- Observation of measured values collected in real time during experiments, Figure 6 shows the software and communication display of load cell module.
- Creation of text data files where the measured values are stored.
- View and printing of previously measured data.

Program is organized as tabbed notebook collecting data from hardware diagnostics and measurements.

Fig. 5. Control Panel for Data Tunning Page.

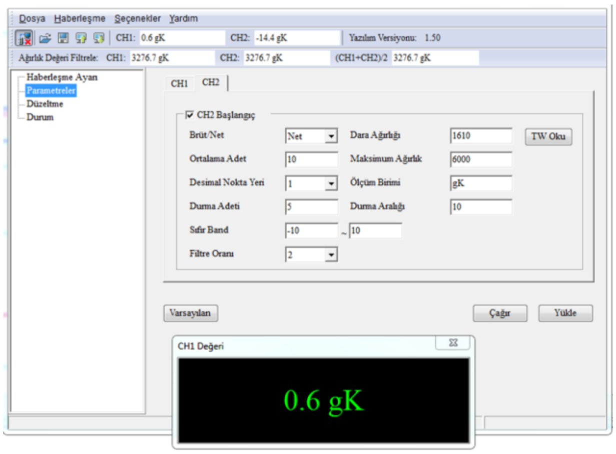
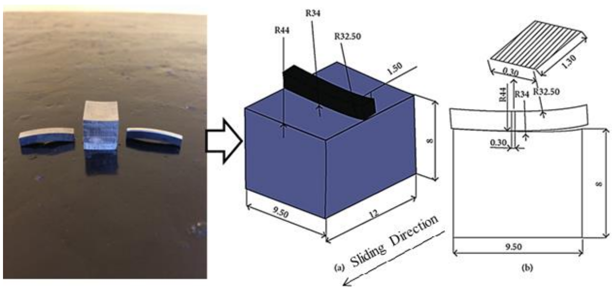


Fig. 6. Software and communication display of Load cell module.

3. EXPERIMENTAL PROCESS AND RESULTS

Some preliminaries experiments were carried out to diagnose the tribometer. Figure 7 shows the configuration of piston ring specimen that was rubbed against cylinder liner under boundary lubricating conditions for reciprocating test. The conventional SAE 5W40 crankcase oil was employed to generate boundary lubrication condition and determine friction behaviour at 25 °C and 100 °C.



a) b)

Fig. 7(a) Piston ring and cylinder liner configuration of test specimens; (b) Contact configuration of piston ring and cylinder liner.

As the viscosity is a function of temperature, the effectiveness of the lubricants is considerably diminished with increasing temperature. Test carried out at high temperature (100 °C) showed high coefficient of friction profile than the test at low temperature (25 °C). Red color trendline plots friction value as a function of time according linear regression. The friction profile was showed in Figs. 8 and 9. Surface examination of the specimens (ring and liner) are on the way of microscopic examination for wear mechanisms.

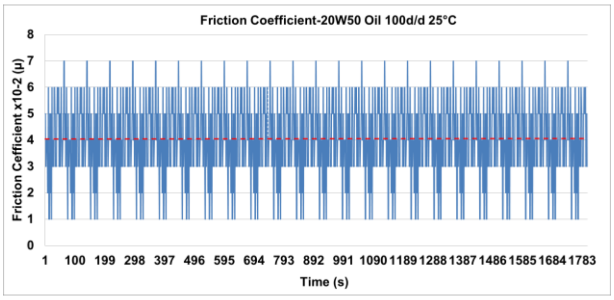


Fig. 8. Coefficient of friction as a function of time for 5W40 Motor Oil at 25 °C.

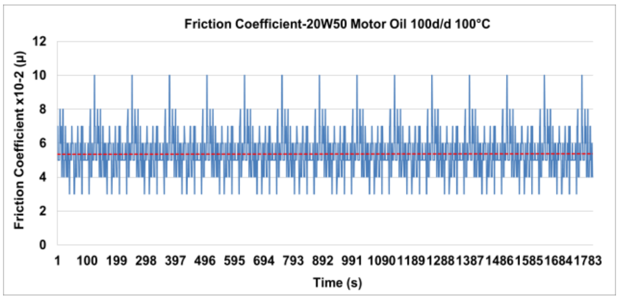


Fig. 9. Coefficient of friction as a function of time for 5W40 Motor Oil at 100 °C.

4. CONCLUSIONS

Concept and design of the universal tribometer which is realized by the limited financial support of KAP project by Automotive Division, Faculty of Mechanical Engineering, in Yıldız Technical University- Istanbul Turkey [5].

This tribometer has fulfilled all demands, request and expectation and it stands in the world professional tribometer class. This was contribute by interdisciplinary approach and theoretical analysis, using system design approach, concept solution and solution of specific sub-functions. Tribometer is robust design and can fulfill very wide range of velocities and loads, so it can be used for various tests conditions. Modular design enable using this tribometer for another types of tribological experiments by its upgrade with new and specific units.

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