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DESIGN OF MODERN UNIVERSAL TRIBOMETER WITH ROTATING AND RECIPROCATING MOVEMENT

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ABSTRACT

This paper considers construction and advantage of modern tribometer conception. Universal Tribometer enables simulation of different contact and test types. Special device enables pin-on-disc (rotational), ball-on-disc and linear reciprocating test types. The main purpose of tribometer was investigation of friction and wear of different materials with or without lubricant according to appropriate standards. Tribometer concept and design solution of same subassemblies that provide defined requests fulfill were described in details. System design and construction with data measurement information are specially described.
Keywords: Tribometer, design, universal.

ROTASYON VE PİSTONLU (DOĞRUSAL) HAREKETİ YAPAN MODERN ÜNİVERSAL TRİBOMETRE TASARIMI

ÖZET

Bu makale modern Tribometre kavramının tasarım ve avantajını ele almaktadır. Üniversal Tribometre farklı temas ve test tiplerinin simulasyonunu sağlamaktadır. Özel cihaz Pim-Disk (Dönel hareket), Bilya-Disk (Dönel hareket) ve Pim-Plaka (doğrusal git-gel hareketi) olan test tiplerini sağlamaktadır. Tribometrenin temel amacı, uygun standartlara göre yağlı veya yağsız ortamda farklı malzemelerin sürtünme ve aşınmasını incelemektir. Tribometre kavramı ve tasarımı, tanımlanan istekleri yerine getiren aynı kısmi montajların sonucu olarak ayrıntılı tarif edildi. Sistem tasarımı ve yapımı veri ölçüm bilgileri ile özel olarak açıklanmıştır.
Anahtar Sözcükler: Tribometre, tasarım, üniversal.

1. INTRODUCTION

The word Tribology comes from the Greek (1966) tribos « τριβειν » (Tribein), meaning rubbing and « λόγος » logos, meaning vocable, study or science. So that: the Tribology is the study or the science of Friction.
It was first reported in a landmark report by Jost (1966). According to his report the concept of Tribology was enunciated in 1966 in a report of the UK Department of Education and Science. It encompasses the interdisciplinary science and technology of interacting surfaces in relative motion and associated subjects and practices. It includes parts of physics, chemistry, solid mechanics, fluid mechanics, heat transfer, materials science, lubricant rheology, reliability and performance.

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Tribology, involves scientific research of friction, wear and lubrication and the technical application of the tribological knowledge. Technical systems which in wear and friction events substantiating called as tribological system. In searching of wear and friction behaviours at engineering metarials, mechanical systems have to be considered as tribological system. In other words wear handles in system integration.

Because of difficulties in analysing of the considerations and making the measurements in long times and hardly in real systems, tribological testing machines have entailed developing model systems. Researchers usually choose and design wear testing machines with considering examined system which they will use in their works. In these choose and design, it's important to determine the machines which can repeat the results substantially and assure the tribological factors that composing real system. Wear testing machines have been standardized partially but it's not possible to find every systems conditions in standard testing machines [1].

It is the art of applying operational analysis to problems of great economic significance, namely, reliability, maintenance, and wear of technical equipment, ranging from spacecraft to household appliances. Surface interactions in a tribological interface are highly complex, and their understanding require knowledge of various disciplines including physics, chemistry, applied mathematics, solid mechanics, fluid mechanics, thermodynamics, heat transfer, materials science, rheology, lubrication, machine design, performance and reliability.

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.

By theoretical analysis of friction process and wearing and different tribometer construction it could be concluded that the tribometrical problems are related not just to tribology, but also to many other theoretical sciences (dynamics, construction theory, electronics and other). All this implies to necessity of multidisciplinary approach to this problem, from both theoretical and engineering aspects [2, 3, 4, 5].

There are a lot of different models wear testing machines in the market. These machines are produced in a wide range by the companies in foreign countries and are imported to our country and their prices starts from 50.000 EU and they can sold up to thousands Euros. Those which is used mostly and common one is reciprocating pin on plate wear test machine. It has been inevitable to design with compatible technical qualifications, manufacturing this wear test machine at very low price in our country's conditions. There is a high demand and request from the market on that subject. This research in laboratory environment and requests which comes from the market will be planned to recovery most efficiently. The necessity of the device and the continuity of the forward looking of the works display here the importance of the work.

A large number of tribometers exist in the world market for different applications but their prices are extremely high which a simple Tribometer starts from 50 000 EU. The Universal Tribometer was realized limited financial support (KAP project) by Automotive Division, Faculty of Mechanical Engineering, in Yıldız Technical University- Istanbul Turkey.

2. CONCEPT OF THE TRIBOMETER

Tribometers determine the magnitude of friction and wear as two surfaces rub together. In one measurement method a flat or a spherical probe is placed on the test sample and loaded with a precisely known weight. The sample is either rotating or recipricating in a linear track. The resulting frictional forces acting between the probe and the sample are measured. Additionally, the wear for both the sample and probe is calculated from the volume of the material lost during the term of the test.

Users in the field of automotive engine oils are not necessarily interested only in the lifetime of a particular lubricant but also in a quantitative method of determining the service frictional properties.

Using a standard pin-on-disk Tribometer together with the liquid option allows both the rotating and static partners to be submerged in the lubricant to be tested. An integral heating element and thermocouple can heat up to 500°C.

Simulative testing is often used to model in-service conditions. For example, the sample could be a section of the engine cylinder bore and the static partner a piece of a piston ring. Both are submerged in engine oil and a suitable load applied.

Engine operating temperatures can be simulated with the High Temperature Tribometer which is capable of heating the material pair up to 800°C [6].

New universal Tribometer is designed according to research and development request. The main purpose of tribometer was investigation of friction and wear of different materials with or without lubricant [7, 8].

2.1. Design Demands and Requirements

New design universal 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 200V series AC servo drives from 100W to 3kW. There are 40mm, 60mm, 80mm, 86mm, 100mm, 130mm, 180mm 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 N-m to 14.32 N-m. 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. Specifications

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.

Figure 1. a.

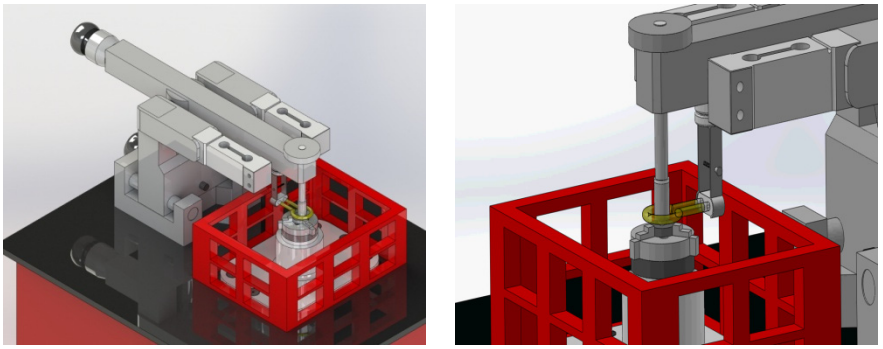

Figure 1. b.

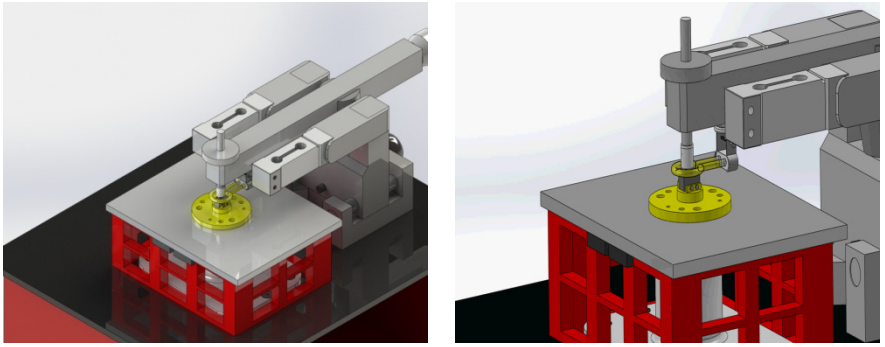

Figure 1. c.

Figure 1. Appearance of the unit for three types

Appearance of the unit for three types for normal load assurance is given in Figure 1. a) General view, b) Pin on Disc or Ball on Disc type c) Linear reciprocating type.

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.

3. TRIBOMETER DESIGN

Figure 2. Apperance of cabinet for electronic equipment

For the reasons of stability and result accuracy robust housing and heavy bottom support were made. Drive and all electronic equipment are located in a cabinet which is shown in Figure 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.

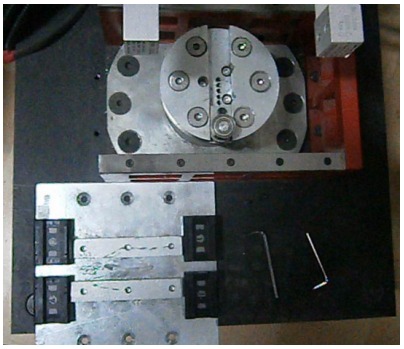

Figure 3. Unit for reciprocating moving device

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 Figure 3.

Figure 4.a.

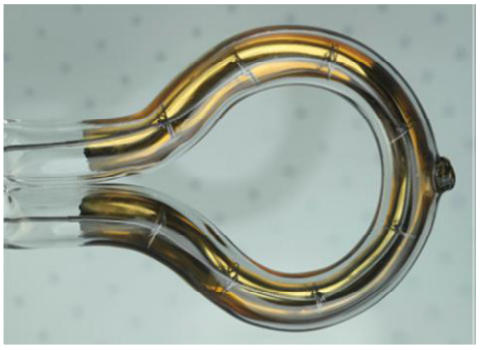

Figure 4.b.

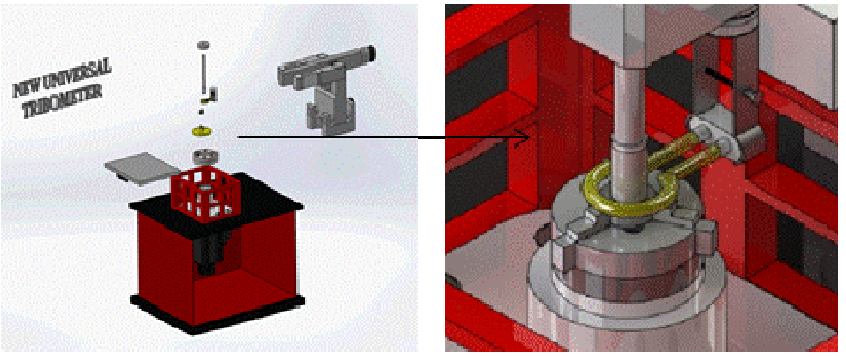

Figure 4.c.

Figure 4. a) Infrared lamp with its ceramic holder b) Gold reflector of IR lamp c) 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 Figure 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.

4. 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),
- Observation of measured values collected in real time during experiments,
- Creation of text data files where the measured values are stored and
- View and printing of previously measured data.

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

5. 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 Yidiz Technical University- Istanbul Turkey.

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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