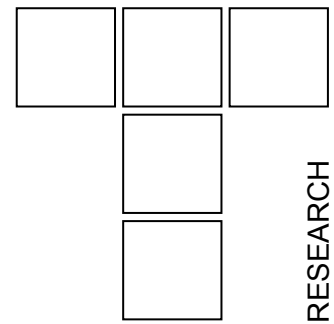


# Design of Modern Concept Tribometer with Circular and Reciprocating Movement



*This paper considers construction and advantage of modern tribometer conception. Tribometer TPD-04 enables simulation of different contact and test types. Special device enables pin on disk, circular and linear reciprocating test types. The main purpose of tribometer was investigation of friction and wear of polymer 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. Measure system and software for data acquisition and processing results are specially described.*

**Keywords:** tribometer, design, concept,

## 1. INTRODUCTION

The word tribology was first reported in a landmark report by Jost (1966.) [1]. The word is derived from the Greek word tribos meaning rubbing, so the literal translation would be "the science of rubbing". Dictionaries define tribology as the science and technology of interacting surfaces in relative motion and of related subjects and practices. Tribology 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 requires 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.

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By theoretical analysis of friction process and wearing and different tribometer construction [2], [3], [4], [5] it could be concluded that the tribometrical problems are related not just to tribology, but 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.

A large number of tribometers for different applications were realized by Faculty of Mechanical engineering in Kragujevac in Metal processing and tribology laboratory. Design of this tribometer is realized by Yugoslav Tribology Society and Faculty of Mechanical Engineering in Kragujevac.

## 2. CONCEPT OF THE TRIBOMETER

Tribometer TPD '04 is designed according to purchaser's request. The main purpose of tribometer was investigation of friction and wear of polymer materials with or without lubricant.

### 2.1. Design demands and requirements

For concrete experimental investigations purchaser defined following demands:

- Maximum  $PV = 300$  Mpa m/min,
- Maximum velocity  $v = 65$  m/min,
- Maximum Applied Load  $FN = 200$  N,

- Maximum dimensions of pin contact surface  $\varnothing 10$  mm or  $10 \times 10$  mm
- Minimum dimensions of pin contact surface  $\varnothing 4$  mm or  $4 \times 4$  mm
- Disk diameter: 100 mm
- Linear movement distance: 100 mm
- Contact temperature measurement: maximum  $200^{\circ}\text{C}$
- Lubrication by grease possibility in linear movement.

Tribometer have to provide three types of tribological tests:

- Pin on disk test
- Linear reciprocating test and
- Pin on disk test in oscillation motion.

During test continually measurement of:

- Normal load in N
- Friction force in N
- Friction coefficient
- Temperature in contact zone and
- Temperature in pin contact layer.

has to be performed.

For the additional requests and robust design reasons next parameter values were adopted:

Pin on disk test:

- Normal load:  $5 \div 450$  N
- Sliding speed:  $1 \div 200$  m/min
- Motor power (from simple calculation): 750 W
- Disk diameter:  $50 \div 100$  mm
- Pin dimensions:  $\varnothing 4 \div \varnothing 10$  mm, or square  $4 \times 4 \div 10 \times 10$  mm (also it can used other dimensions)

Linear reciprocating test:

- Moving range:  $60 \div 100$  mm
- Sliding speed:  $1 \div 100$  m/min (average speed) or  $2 \div 200$  m/min (maximum speed)

For pin on disk test with oscillation motion were used the same parameters as for pin on disk test.

## 2.2. Tribometer function structure

According to design theory or design methods [6], [7] the first step in construction development is

establishing function structure. Measuring of tribological characteristics of a material in defined conditions is tribometer overall function. Overall function is break down into sub-functions. The object of breaking down is the determination of sub-functions facilitating subsequent search for solution and combination of these sub-functions into a simple and unambiguous function structure. Hence, function structure represents overall function, sub-functions and relations between particular sub-functions. One of the possible function structure of tribometer is given in Figure 1.

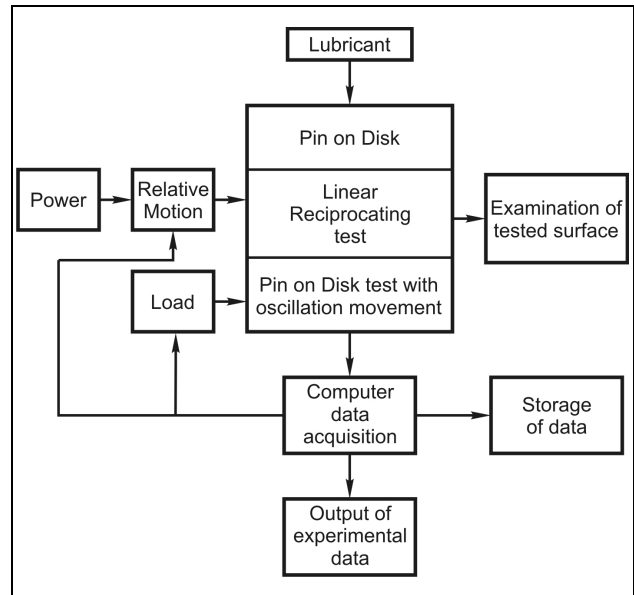


Figure 1: Tribometer function structure

Next step is to choose solution's principles and executers to fulfill the sub-functions. It will be done throughout design description of tribometer.

## 3. TRIBOMETER DESIGN

Tribometer design will be described in next part of the paper. Design of tribometer is done according to sub-functions defined in function structure and description of design is illustrated by photographs of realized tribometer.

It is necessarily to assure normal load in given range for all three types of tribological tests and also to measure and regulate its value. For that purpose BiSlide motor driven positioning system with DC step motor drive was used. Pin holder is assembled on flaying part of BiSlide. There are two pin holders. One for round pin and other for pin with square cross section. In both cases design of pin carrier assures pin axes adjustment and proper transmission of normal load on contact surfaces.

Measuring equipment, that registered normal load and friction force very precise, is situated on pin holder.

Whole unit for normal load can be mounted in two different position on basic plate, for realization of different test types. For pin on disk and circular oscillatory tests this unit is mounted on the left side of basic plate, and for linear reciprocating movement on the right side. Appearance of unit for normal load assurance is given in Figure 2.



Figure 2: Unit for normal load assurance

For relative motion in each of three types of test the AC motor with reducer and belt drive was used. Motor of 750 W powers with reducer gives rotational speed of 180 rpm. Wide range of velocities is fulfilling by using three step belt drive and frequency inverter. Belt drive facilitate ratio from 1:3 to 3:1. Frequency inverter facilitate continually change of electric frequency (and rotational speed of motor shaft) in range from 5 to 60 Hz.

For the reasons of stability and result accuracy robust housing and bearing of disk were made. Drive and all electronic equipment are located in a cabinet which is shown in Figure 3. In this figure is also shown pin on disk tribometer configuration. For additional cooling of all equipment in cabinet few extra coolers are used.

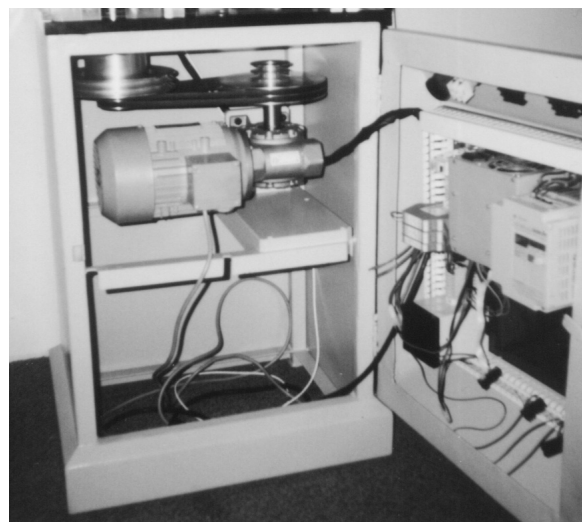


Figure 3: Appearance of cabinet

Oscillatory circular motion is realized by using special disks and rod. Special disks are mounted on the motor shaft and specimen disk shaft under basic plate. Disks are connected by road with adjustable length. Design of this components fulfill given requirements of velocity.

For linear reciprocating moving special disk, road and plate holder are used. Plate holder is mounted on guide pillars trough guide bushes with balls, 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 six different lengths: 100, 90, 80, 70, 60 and 50 mm. Appearance of unit for reciprocating moving is shown in Figure 4.

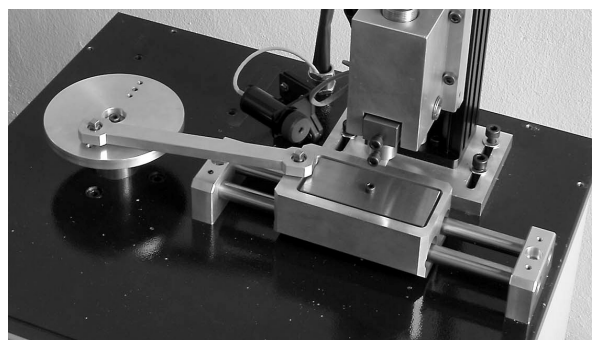


Figure 4: Unit for reciprocating moving

The range of rotational velocity of disk is the same as for pin on disk test. Meanwhile, linear velocity of plate holder is changeable according to corresponding mathematical function. Dependency of movement and velocity on time obtained by using of this unit is shown on diagrams given in Figure 5.

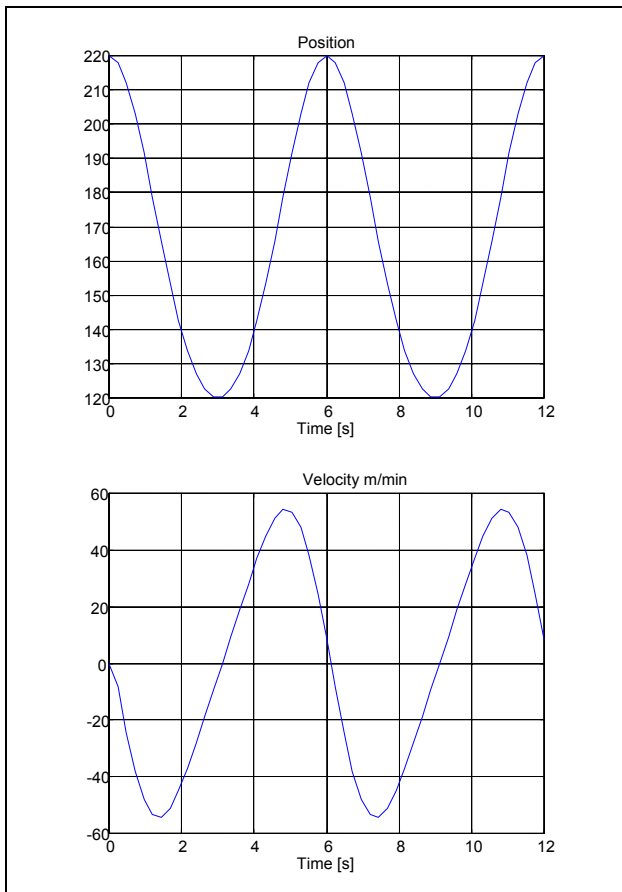


Figure 5: Movement and velocity of plate holder

Temperature in contact zone is measured by IR (infra red) sensor, which is shown in figure 2, 4, and 6. Temperature in pin contact layer is measured by termocouple.



Figure 6: IR sensor and termocouple

All of main parts of tribometer are made of stainless steel and aluminium alloys. Overall appearance of realized tribometer with control panel and PC is shown in Figure 7.



Figure 7: Tribometer overall appearance

#### 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,
- 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 with two tabs, "Measurement" and "Hardware diagnostics", which is shown in Figure 8. The first tab is aimed for experiments only and the second for maintenance purpose.

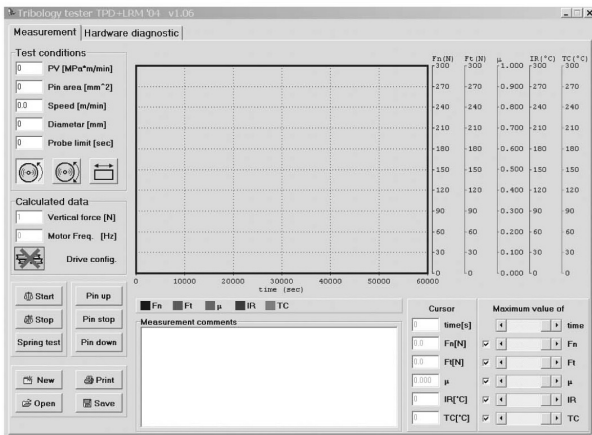


Figure 8: Measurement tab of software

User must enter proper values before the start of experiment, in “Test conditions” area for following test variables:

- PV – product of pressure and speed in units MPa m/min,
- Pin area in units of mm<sup>2</sup>.
- Disk diameter in units of mm.
- Probe limits in units of seconds. This parameter determines duration of experiment. User can change this value even after experiment is started.
- Experimental type can be selected by using one of three buttons on bottom of “Test conditions” area: “Rotational motion”, “Reciprocating rotational motion” and “Reciprocating linear motion”.

In the area marked as “Calculated data” vertical force, motor frequency and picture with belt drive configuration are displayed.

Vertical force and motor frequency are here for information purpose only. Drive configuration must be select properly. If not, achieved speed will be different from desired.

When tribometer is in rest state, it is possible to manually move pin up and down. It can be done by using buttons “Pin up”, “Pin down” and “Pin stop”.

Experiment start by click on “Start” button. AC motor will start immediately, and pin will start moving downward. When vertical force (load) reaches desired value, data acquisition starts.

Experiment will be stopped after predefined probe time, or if during experiment user presses the “Stop” button. AC motor will stop and pin will go up.

After experiment is finished, user can write down comments in “measurement comments” memo field. All data together with this comment can be saved in ASCII file.

Buttons “New”, “Open”, “Print” and “Save” represent standard Windows commands.

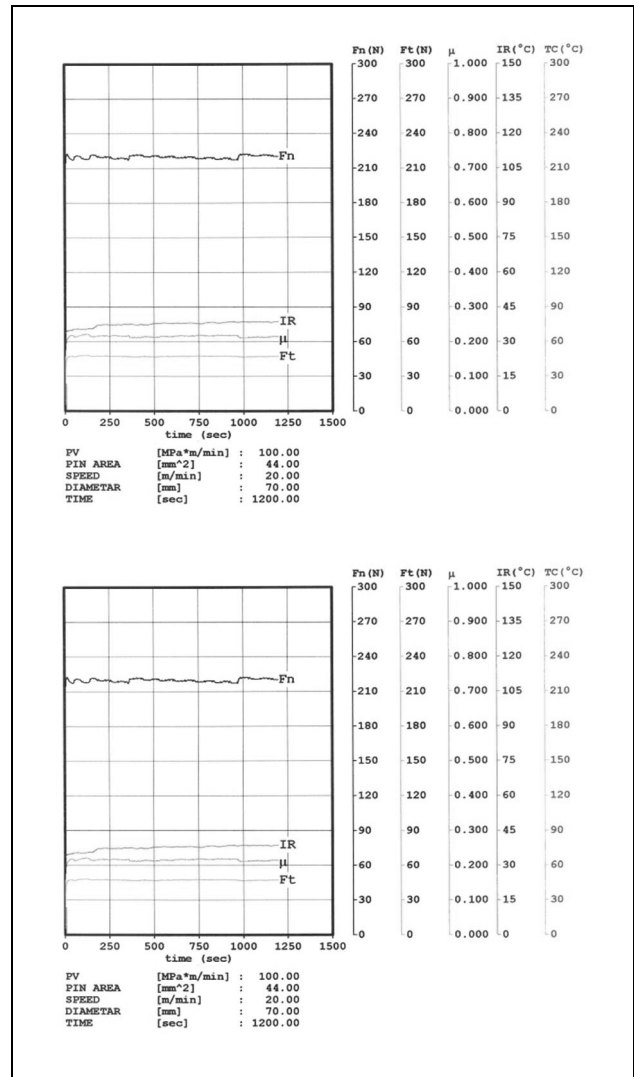


Figure 9: Examples of data traces

User can choose number of data traces on the computer screen and maximum value for each data. Graph adjustment is possible during experiment or after it. Each data trace can be selected via corresponding check box. Maximum axis value can be selected via scroll bar. State of check boxes do not influence on data acquisition, i.e. all data are collected during experiment. Graph adjustment

influence only to appearance of data on the screen. Examples of data traces are shown in Figure 9.

Cursor area is aimed for reading of data values directly from computer screen. When cursor is moving over graph area, data in appropriate fields are updating immediately.

Spring test is aimed as aid for spring preloading adjustment. It is case after disassembly of the measure head.

Hardware diagnostic tab is aimed for diagnostic of data acquisition hardware. It is not used in regular daily work. Must operate, since all commands are under direct control of operator, only person with good knowledge of machine operation can operate with hardware diagnostic tab.

## 5. CONCLUSIONS

Concept and design of tribometer TPD 04 which is realized by Yugoslav Tribology Society and Faculty of Mechanical Engineering in Kragujevac is shown in this paper. It has fulfilled all demands, request and expectation and it stands in the world professional tribometer class. This was contributing 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 enables using this tribometer

for other types of tribological experiments by its upgrade with new, specific units.

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