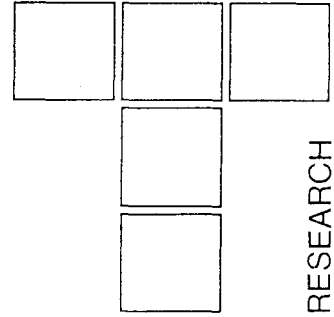


P. TODOROVIĆ, S. GOJKOVIĆ, B. IVKOVIĆ, B. TADIĆ

Tribometer Tpd-2000 - Data Acquisition Software



RESEARCH

As a part of modern measurement system, like Tribometer TPD-2000, is appropriate software, as well. This paper deals with software for programmable data collecting from tribometer, graphical displaying of the measured values, and for preview and printing of the results of experimental investigation. Software is Windows 95/98 application for PC compatible computers with design and functionality which is not behind a world trends in software production.

It is necessary to notice that Tribometer TPD-2000 with this software is already in use at Mechanical Engineering Faculty in Mondragon, Spain.

Keywords: Tribometer TPD-2000, software, data acquisition

This paper is done as a result of Project titled "The Development of domestic non-conventional tribologically improved materials", (No. MHT.2.02.0012.B), which has been financed by Ministry of Science, Technology and Development of Republic of Serbia.

1. INTRODUCTION

Software package under the commercial name of "Tribometer Monitoring Station V.2.1." is an integral part of modern measurement system of Tribometer TPD-2000 (Figure 1.).

Tribometer TPD-2000 is a result of many years' activities of members of Yugoslav Tribology Society. He has certain constructive specifications, which makes it one of a kind in a world. Tribometer TPD-2000 shown in Figure 1., is in operative practice at Mechanical Engineering Faculty in Mondragon, Spain.

Tribometer is a device used for friction and anti-wear characteristics (tribological characteristics) measurement for solid materials (metal and non-metal materials) and for all kinds of lubricants (fluid and solid lubricants and greases). Applied measurement procedures for friction and anti-wear characteristics are in accordance with ASTM standards of D and G groups (D 2625, D2670, D 2714, G 77, G 99).

Contact types, which are possible to realize with Tribometer TPD-2000, are shown in Figure 2.

*Mr Petar Todorović, dipl. ing.
Saša Gojković, apsolvent
Prof. dr Branko Ivković, dipl. ing.
Docent dr Branko Tadić, dipl. ing.
Faculty of Mechanical Engineering,
Kragujevac, Yugoslavia*

With these kinds of contacts, the largest number of real tribomechanical contacts, which occur in modern technical systems, can be modeled.

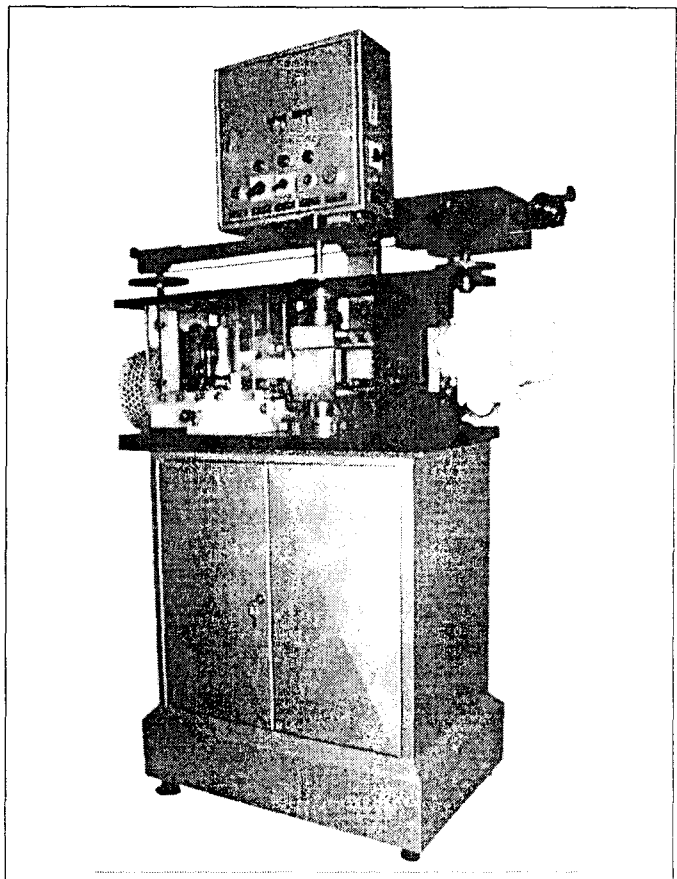


Figure 1. Tribometer TPD-2000

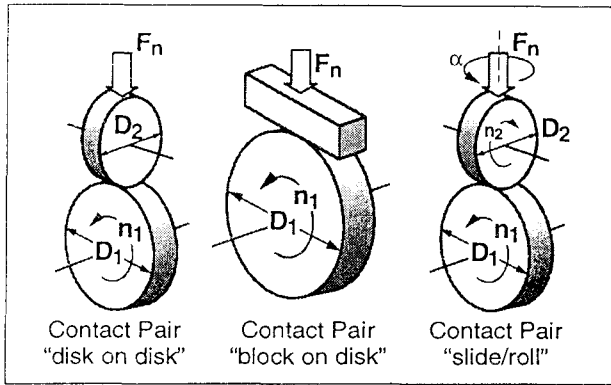


Figure 2. Contact types

One new characteristic for Tribometer TPD-2000 is the possibility of "slide/roll" contact realization with application of appropriate adapter.

2. SOFTWARE ROLE IN A MEASUREMENT SYSTEM OF TRIBOMETER TPD-2000

For monitoring of tribological processes, which occurs during experimental investigations done by Tribometer TPD-2000, it was necessary to use specific data acquisition system. Flowchart of data acquisition system from which a role and a place of "Tribometer Monitoring Station V.2.1" software can be seen, is shown in Figure 3.

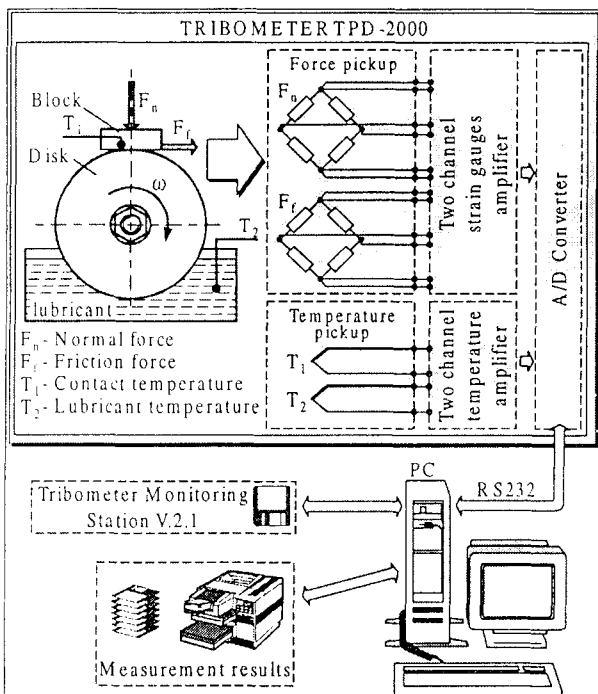


Figure 3. System for monitoring of tribological processes at Tribometer TPD-2000

Measuring of external load of contact zone, that is, of F_n (normal force) and of friction force F_f is

done by force pickup, which is based on strain gauges connected in Wheatstone bridge. Contact temperature, T_1 and lubricant temperature, T_2 , are measured by thermocouples. Measuring signals from all of these pickups are strengthened through appropriate amplifiers up to the level necessary for input of A/D converter. Control of A/D converter working, as well as the measuring process of described values necessary for determination of tribological processes at Tribometer TPD-2000 is done by PC computer and "Tribometer Monitoring Station V.2.1" software.

3. MAIN CHARACTERISTICS OF "Tribometer Monitoring Station V.2.1" SOFTWARE

"Tribometer Monitoring Station V.2.1" software is a Windows 95/98 based application. Software design and functionality is in accordance with today's world trends.

The main idea from which a software development started is explained in following text. The final product (software) must be as simple as possible, thus understandable for the largest number of end users, that is from investigator beginner, through investigator in production, all up to students, postgraduate and professors who will always ask for more than plain results and their way of presentation. Authors built in many years of practice with various experimental methods in this software.

"Tribometer Monitoring Station V.2.1" software is aimed for:

- data collecting from Tribometer TPD-2000 during experimental investigations,
- presentation of measuring data real-time values on PC monitor during experimental investigations,
- (auto)calibration of physical values which are measured at Tribometer TPD-2000,
- text files creation where measuring results are saved and
- presentation or/and printing of experimental investigations results.

"Tribometer Monitoring Station V.2.1" software is collecting data from A/D converter about values of measuring data during experimental investigation process. Those data are about the following values:

- normal force,
- friction force,
- contact pair temperature,
- lubricant temperature,
- rotating speed of lower disk and
- rotating speed of upper disk.

After software starting, the working environment as in Figure 4 is shown at PC monitor.

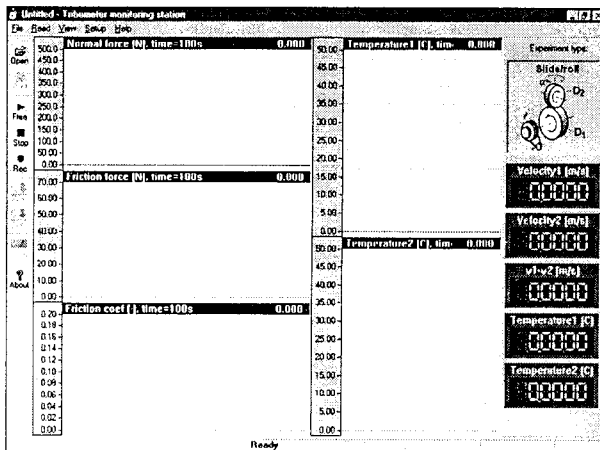


Figure 4. Working environment

Working environment is organized in such a way that enables the possibility of monitoring of all important parameters during the experiment. There is a toolbar with the most common command buttons, then there is a central part where normal force, friction force, friction coefficient diagrams are drawn and also, if needed, a contact temperature and/or lubricant temperature diagrams can be drawn.

On the right of the working environment the choice of contact pair type can be made or monitoring of sliding (rotating) velocity of upper and lower disks can be done or monitoring of above-mentioned temperatures.

4. SOFTWARE WORKING REGIMES

"Tribometer Monitoring Station V.2.1" software has two main regimes in which it can operate:

Free run regime. In this working regime monitoring of all measuring values are done on the computer's monitor, but measuring results are not saved. This working regime is recommended just after the tribometer is started in order to check whether the complete measurement system is working properly.

- *Recording data* regime. The main difference between this and the previous working regime is in the fact that in this regime recording of the measuring values at the computers hard disc is done.

With the selection of *Recording data* regime the procedure with dialog boxes that should be entered is needed (Figure 5. and Figure 6.).

Figure 5.

Figure 6.

In Figure 6. the dialog box with the parameters selection, which completely determines the way of data collecting during the experiment, is shown. The main characteristic of tribological properties is certainly the change of friction coefficient during the experiment. In order to obtain the more precise picture of friction coefficient character in particular time periods it is possible to take a "sample " of friction coefficient and present it in more details along the time axis (as shown in Figure 7.).

This way the more complete information of process dynamics, which is done at the tribometer during the experiment running.

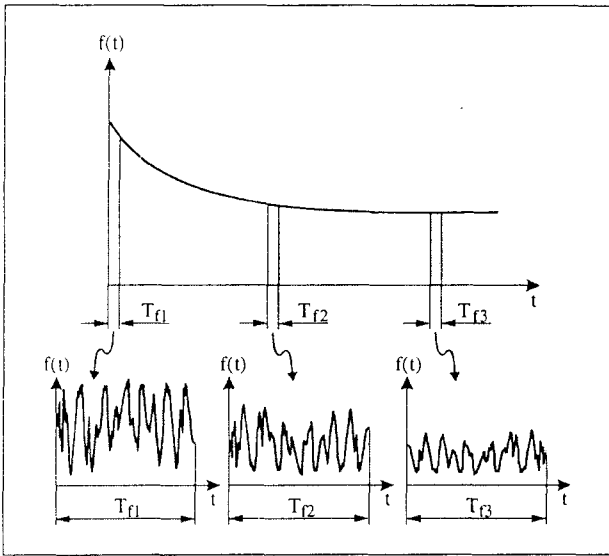


Figure 7.

4. MEASUREMENT SYSTEM CALIBRATION AT TRIBOMETER TPD-2000 BY SOFTWARE

Under the term calibration the procedure of calculation of measured data (the most usual is voltage) into the unit of the physical value which is measured. The simplest way of calculation is by the following equation (linear dependence):

$$A = K U + \text{offset}$$

where,

- K, proportion factor,
- U, V, measured values in volts,
- offset, offset or zero deviation
- A, calculated value of physical unit, which is measured.

For calculation of unknown values for calibration constants (K and offset) from equation J-1 it is necessary to determine (to measure) two points, (U₁, A₁) and (U₂, A₂), as shown in Figure 8. These two points are usually selected in such a way that they are the end points of measuring interval.

The procedure of unknown calibration constants determination is done by the J-2 and J3 equations.

$$K = \operatorname{tg} \alpha = \frac{\Delta A}{\Delta U} = \frac{A_2 - A_1}{U_2 - U_1}$$

$$\text{offset} = A_1 - K \cdot U_1$$

"Tribometer Monitoring Station V.2.1" software offers the possibility of automated calibration (calculation of unknown values K and offset) for all physical units that are measured by it. Dialog

box for automated calibration procedure is shown in Figure 9.

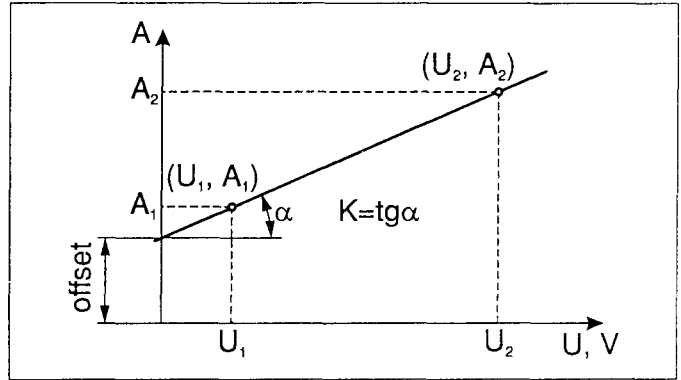


Figure 8. The measurement points for calibration selection

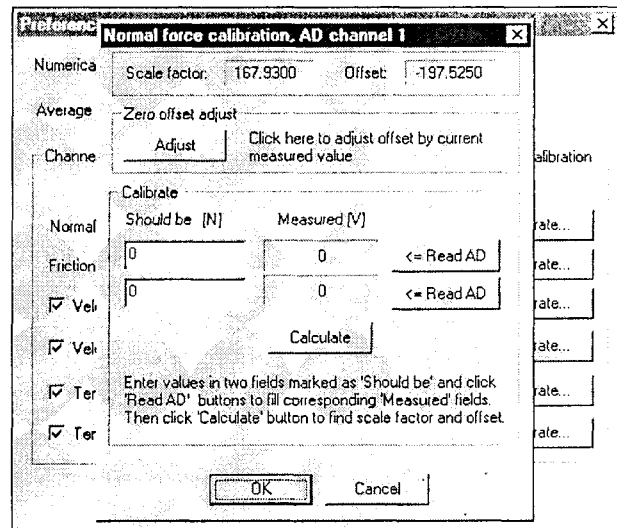


Figure 9. Dialog box for auto-calibration procedure

6. DATA STORAGE

Measured values of appropriate parameters during the experiment are stored at the computers' hard disc like ASCII files. A small part of one file is given below.

```

% *** Tribometer Monitoring Station - slow mode output file ***
% - Date: Thursday, August 17, 2000, 19:14
% - Experiment No: B01
% - Measured by: P. Todorovic
% - Comment:
% Sliding Speed V1=1.5 m/s
% Fn=300 N
% Experiment Time T=10 min

% - Experiment configuration:
% Experiment type : 1 (Block on disk)
% Disk1 info : Disk 9
% Disk2/Pin/Block info : Block
% Lubricant : Oil
% Diameter1 : 80.000000
% Belt ratio : 1.500000
% Experiment time : 00:00:10:00
% Slow mode period : 2s
% Fast mode recording : ON
  
```

% - Calibration constants :						
% Scale factor Offset						
% Normal force	167.93	-197.702				
% Friction force	26.3972	-25.626				
% Temperature1	113.64	-100				
% Temperature2	113.64	-100				
% Measured data:						
% Time	Normal F	Frict. F	Frict. Coef.	t1	t2	
% [s]	[N]	[N]	[]	[C]	[C]	

A={						
0.000000	0.681809	-0.088550	0.000000	31.512774	29.359829	
2.000000	175.684052	17.808828	0.101368	31.645947		
29.284920						
4.000000	296.900299	27.918518	0.094033	31.598782		
29.320988						
6.000000	296.822418	27.685867	0.093274	31.637623		
29.376476						
8.000000	297.076599	27.671690	0.093147	31.507225		
29.404219						
10.000000	296.957703	27.547953	0.092767	31.307468		
29.540165						
12.000000	297.052002	27.591131	0.092883	31.529421		
29.523520						
14.000000	296.929016	27.462238	0.092488	31.548841		
29.612301						
16.000000	297.027405	27.367502	0.092138	31.679239		
29.587332						
18.000000	297.064301	27.332703	0.092009	31.698660		
29.645594						
20.000000	296.978210	27.273411	0.091836	31.740276		
29.875870						
22.000000	297.605499	27.275345	0.091649	31.981649		
29.920261						
24.000000	297.753082	27.255365	0.091537	31.973328		
29.953554						
26.000000	297.642395	27.207031	0.091408	31.909515		
30.128342						
28.000000	297.593201	27.098763	0.091060	32.089851		
30.247641						
30.000000	297.703888	27.085228	0.090980	32.031590		
30.294806						
32.000000	297.789978	27.147097	0.091162	32.106499		
30.378038						
34.000000	298.671448	27.198009	0.091063	32.184181		
30.536180						
36.000000	298.732941	27.216698	0.091107	32.428329		
30.588894						
38.000000	298.667358	27.236032	0.091192	32.472721		
30.616638						
...						
};						

Lines that begin with % are representing a heading where the basic information about the experiment is given. After the heading there is the table (matrix) with values measured. The first column in the table is the time column. In the second column are values for normal force, in the third are values for friction force, in the fourth column are values for friction coefficient etc.

Text files in which the experiment results are saved can be easily opened by some of the standard software packages for table manipulation and/or flowchart drawing (Excel, MatLab or similar).

7. EXPERIMENTAL INVESTIGATIONS RESULTS PRINTING

By choosing the appropriate option, the results of experimental investigation are possible to be printed in a predefined form. Before the experimental investigation results printing the report can be previewed and checked (preview mode) and then in options select what we want to be printed.

Beside the previous, the report can be faxed somewhere if the computer has the modem attached.

The first three pages of a report printed by "Tribometer Monitoring Station V.2.1" software are shown in Figures 10., 11. and 12.

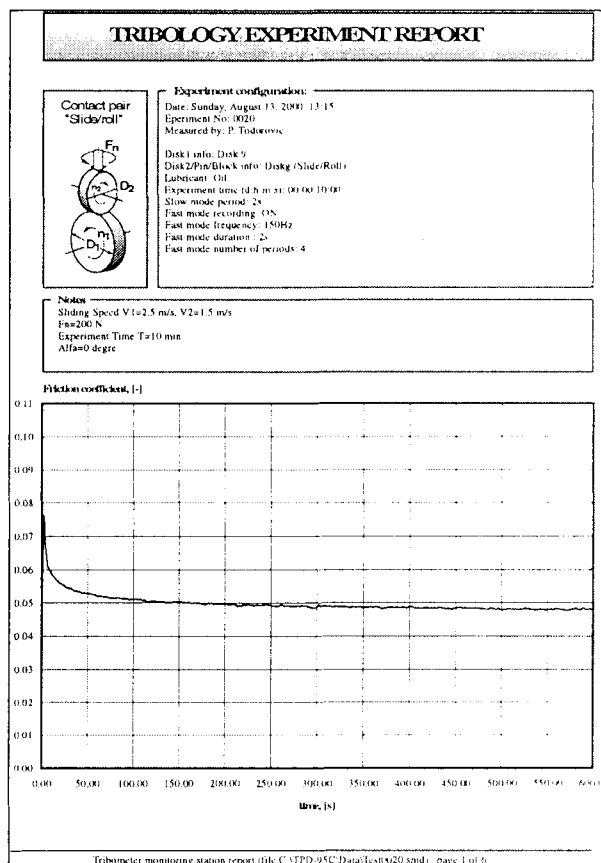


Figure 10. The first page of the printed report

The first and the second page (Figures 10. and 11.) represent one standard part of the report after the experiment is finished. Here, the basic parameters, which more closely determine the experiment, the friction coefficient, normal force and friction force change diagrams, during the experiment running, are shown.

If during the selection of options for Recording Data mode, Fast mode for data collecting was also chosen, (see Figure 7.), it is then possible to print the diagram representation of dynamical behavior for friction coefficient, normal force and friction force as shown in Figure 12.

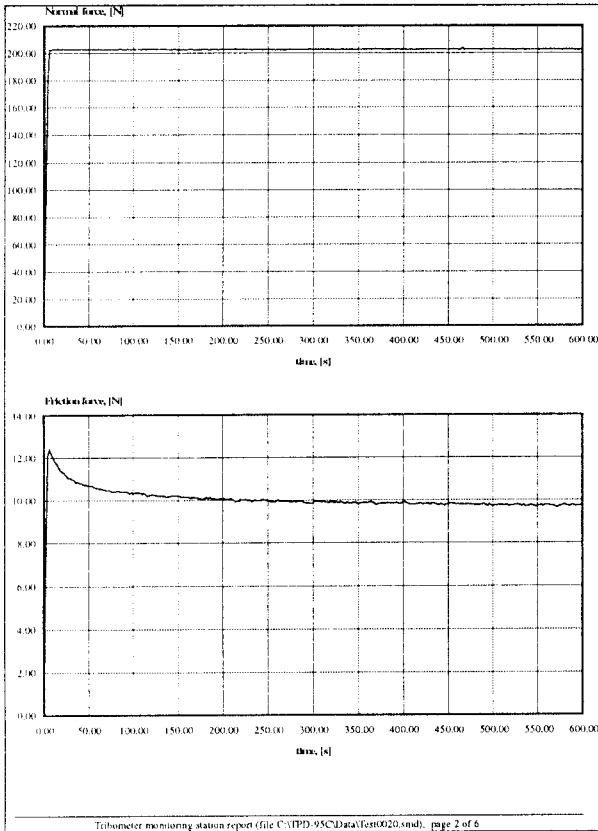


Figure 11. The second page of the printed report

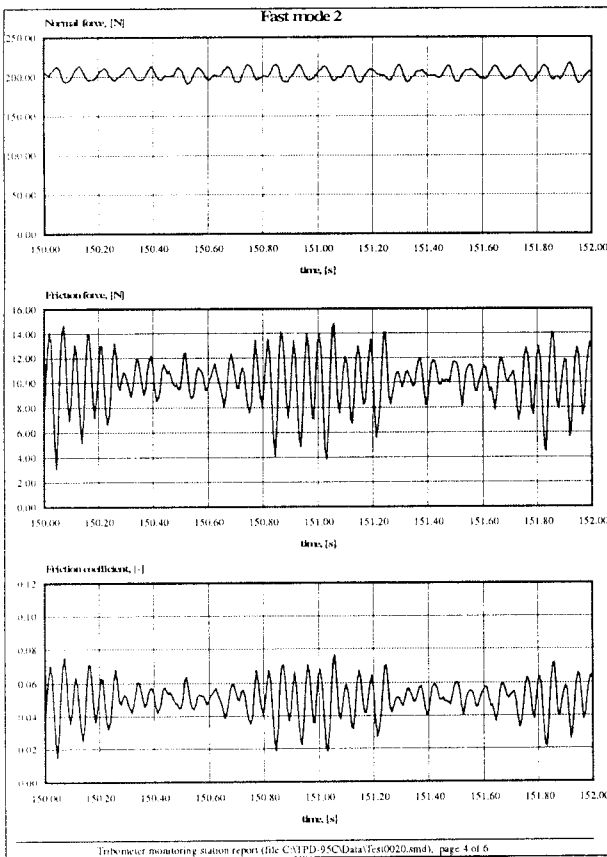


Figure 12. The third page of the printed report

8. CONCLUSION

At the world market today, it is possible to find a large number of software packages, which deal with data acquisition and measuring results printing. However, specific application of software for Tribometer TPD-2000 have implied the need for the development of special software, which have been described in this paper.

"Tribometer Monitoring Station V.2.1" software, together with Tribometer has been applied for a year now, at the Mechanical Engineering Faculty in Mondragon, Spain, without any failures or complaints by users.

REFERENCES

- [1.] Tribometer Monitoring Station v.2.1, Software Support for Tribometer TPD-2000, User's manual
- [2.] P. Todorović, Development of the system for technical diagnostics of the gear pump, M. Sc. Thesis, Faculty of mechanical engineering Kragujevac, 1997.