Serbian Tribology Society

SERBIATRIB '11

12th International Conference on Tribology

Faculty of Mechanical Engineering in Kragujevac

Kragujevac, Serbia, 11 – 13 May 2011

LINEAR RECIPROCATING TRIBOMETER – EXAMPLES OF AN OBTAINED INVESTIGATION RESULTS

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Abstract: In present stage of development, hydraulic systems are often used solution in power transmission production and control processes. In order to carry out laboratory investigations of phenomena which characterize the processes of contamination in hydraulic systems, special form of tribometer is developed, which allows simulation of different real conditions in hydraulic and other similar systems that use lubrication oils, as well as monitoring of a defined group of diagnostic parameters. Some examples of an obtained investigation results are also presented in this paper.

Keywords: *Linear reciprocating tribometer, oil contamination, friction coefficient*

1. INTRODUCTION

Hydraulic power systems today are standard and often used solution in power transmission, production and control processes. Continuous improvement of performance of these systems is carried out primarily in order to increase the accuracy and reliability, improve efficiency coefficients, increase degree of performance control, increase strength, speed, pressure, flow, to expand area of use and enable longer life cycle. All this is followed by application of new materials and new methods of construction, reducing the dimensions of hydraulic components, increased production precision, introduction of electric and electronic components and its integration with hydraulics [1].

Conditions of tribological processes in real hydraulic systems are very complex and their full simulation in laboratory conditions could be a very complicated technical problem. Some conditions, such as, for example, pressure in the system (a few tenth to several hundred bars) are practically unattainable when using standard models and types of tribometers. Also, the different hydraulic components have considerable variation regarding the types and characteristics of wear contacts and their basic parameters. In literature can be find information on a number of specific laboratory tests conducted related to modelling of tribological contacts and specific conditions in hydraulic components [3], [4].

2. EXPERIMENTAL EQUIPMENT

The starting point for defining the type and concept of tribometer was an analysis of typical tribological pairs of hydraulic components (pumps, motors, cylinders and valves) and characteristics of wear processes that occur in them.

Coming from the fact that linear, alternately sliding movement, in condition of presence of oil, is dominant form of movement in hydraulic components and that abrasive wear mechanism is the most important one, tribometer type pin-on-plate (pin on the board) was selected where the pin slides on the board (cyclic and straight line) in oil's environment (Figure 1) [2], [5].

In addition, this tribometer should enable definition and control of basic parameters of tribology investigation. In this case those are: load in tribological contact, sliding speed, slide length or pin step in one cycle and the number of cycles.

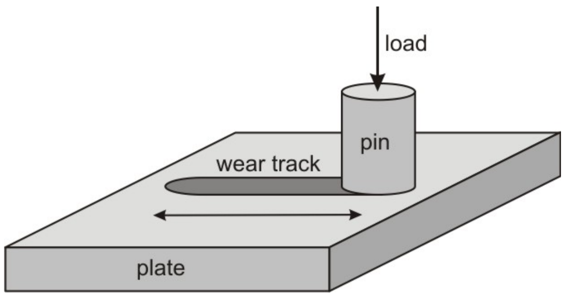

Figure 1. Basic principle of *pin-on-plate* tribometer

Special attention is devoted to the integration of measuring equipment and systems that allow continuous and simultaneous measurement of multiple parameters which characterize the dynamics and phenomena of tribological processes in the contact pair and which could be used as diagnostic parameters.

Result of laboratory prototype of pin-on-plate tribometer with a linear reciprocating motion development is shown in Figure 2.

Constructive solution is based on container with a plate and oil (1), placed on a horizontal linear guides (2), moving alternately, while pin is stationary. Pin bracket (3) is set to vertical linear guides (4) and given loads on the pin passed through the bar, which is also a dynamometer for measuring of friction force. Drive system for reciprocation motion is pneumatic (5) with pneumatic cycle counter (6).

On container with a plate (1) displacement transducer is fixed (7), with function to measure, in real time, container position and thus enable the accurate determination of velocity and moments when container change movement direction. On a tribometer base plate surface there is a connection panel for this transducer (8).

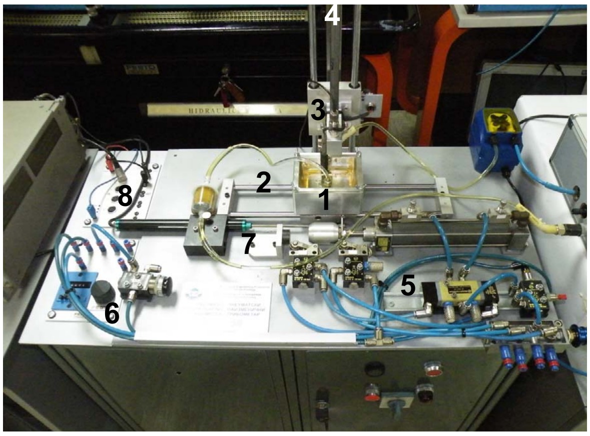

Figure 2. Tribometer *pin-on-plate* with linear reciprocating motion

Pneumatic system for tribometer (Figure 3 a)) consists of pneumatic cylinder (1), air-operated distribution valve 5/2 (2), two pneumatic limit switches (3), pneumatic logic valve 3/2 (4), pneumatic cycle counter and the reset button (6) (Figure 2). Limit switches limit stroke of cylinder piston which is fixed to container. Switches are fixed and the stroke length is determined by varying the length of a cylindrical end part of cylinder (7) which activated limit switches. At both command lines, which bring compressed air to the cylinder, set of throttle valves that regulate the speed of the cylinder (and consequently the bowl with the board) in both directions.

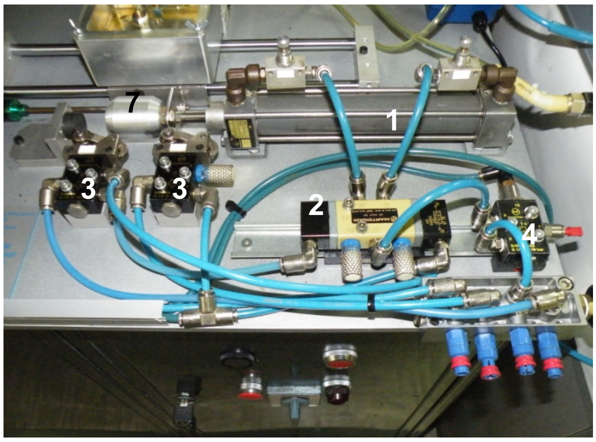

Figure 3. Pneumatic drive system

Normal load, and corresponding value of normal force in the contact zone (Figure 4) is defined by calibrated weights (1) where the forces transferred through the shaft (2) with a spherical end is to the pin bracket (3) (Figure 4). Compensation of own mass elements which are located on the pin bracket is performed through a spring with a threaded spindle (4) (Figure 4).

On pin bracket (3) set the single-axis piezoelectric vibration sensor (6) which measures vibrations in the tribological contact in the vertical direction.

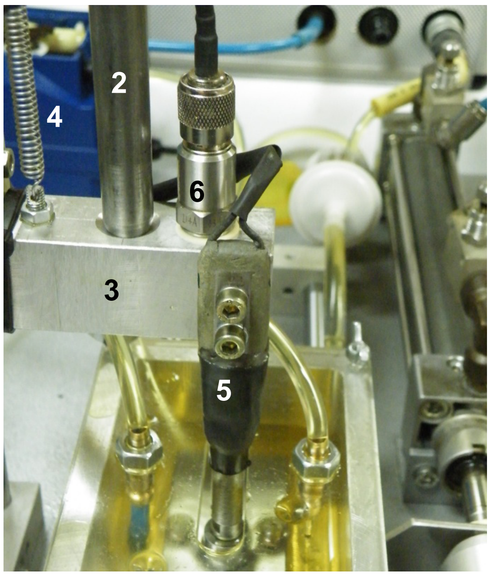

Figure 4. System for setting load and force measurement

At bottom of aluminium container (1) (Figure 5) plate (2) is attached. Pin (3) has cone top that fits into a spherical end of the dynamometer bar (4) and thus carries the normal force evenly over the entire surface of contact. Container (1) has a volume of 500 ml and is filled oil up with oil to about 1/3 of its height. Container is covered with a transparent cover on which there are connections for oil circulation - suction (5) and return (6).

Suction line takes oil from the bottom of container on one side and returns oil back to the surface on the other side of container. This is to ensure adequate oil mixing during circulation.

Oil suction pipe lead to peristaltic pump (7) (Figure 5 b)) that provides oil circulation through tribomechanical system in tribometer and through mobile device which measure contamination of oil by solid particles and water (8). Oil that passes through the device returns back to tribometer where can optionally pass through a filter or cartridge with water absorbent (9) or go directly into the container without filtration or dehydration.

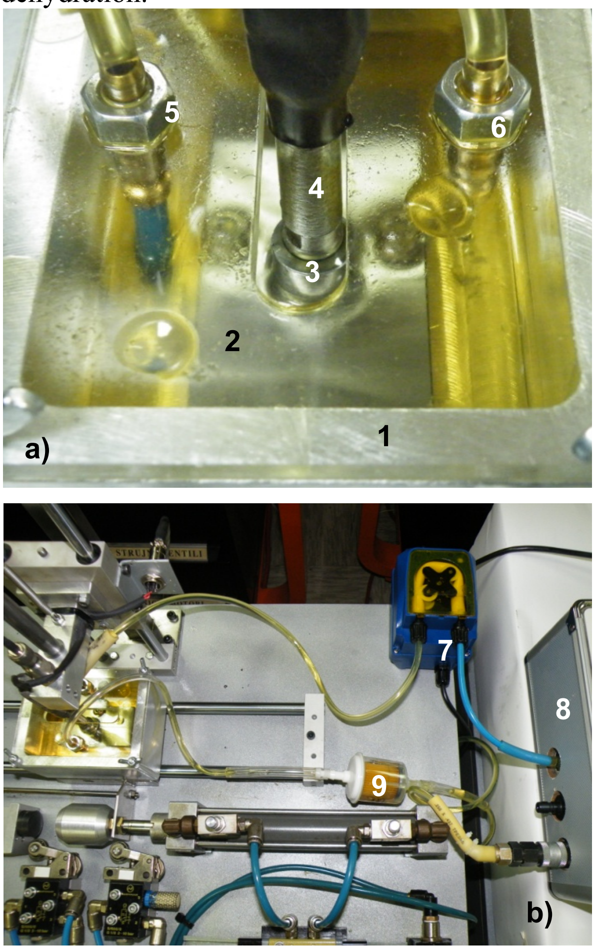

Figure 5. System for oil circulation

Complete laboratory installation (Figure 6) consists of the previously described tribometer with connected measuring equipment (1), laptop PC with A/D converter, software for data acquisition and measurement bridges for measuring vibration and friction forces (2) and mobile devices for control of oil contamination (3) for monitoring of oil contamination by solid particles and water.

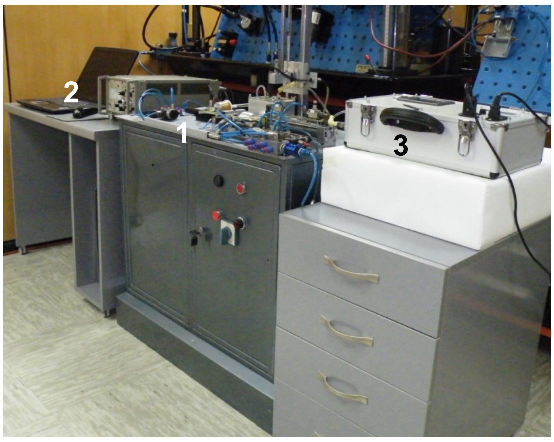

Figure 6. Complete tribometer installation

3. EXAMPLES OF OBTAINED INVESTIGATION RESULTS

In these chapter examples of typical results of performed laboratory tests of wear will be presented. Parameters monitored during tribological tests have specific, periodic diagrams that could not be used for conducting analysis and making conclusions in its original form. Therefore mathematical and statistical signal processing was carried generating of new parameters that indicate a nature and characteristics of wear process in more details.

Figure 7 shows the original shape of the measured signal of friction force (1), container displacement (2) and vibration in the tribological contact (vibration acceleration (3) and vibration velocity (4)). Marked parts on diagrams correspond to one whole cycle.

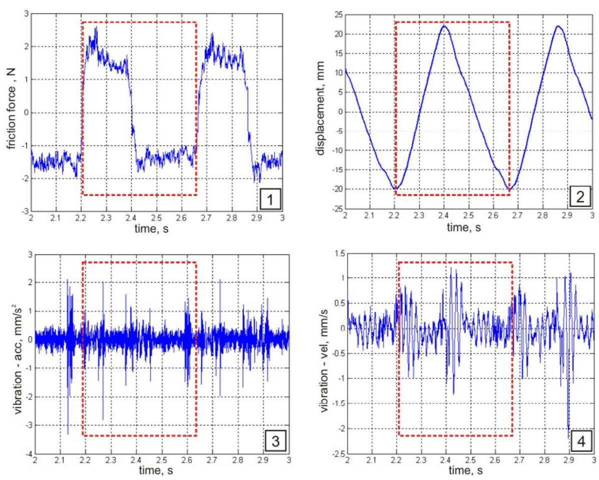

Figure7. Original shape of signals for one cycle

According to periodic repetition of measured signals it was necessary to determine the parameters that will describe the trend of change in friction force (friction coefficient). For each cycle maximum value of the friction (both positive and negative part), was determined, then mean value and standard deviation. The obtained values for each cycle were averaging for measuring intervals of 50 seconds or about 100 cycles. These three parameters were used to define trend of friction coefficient during conducted tribological experiments.

The shape of the measured vibration signals was not suitable for direct analysis in time domain or frequency analysis. Besides the mean-square value of vibration (RMS), an analysis was also amplitude in one cycle and are defined by the parameters of maximum and mean "peak to peak" values for one cycle. Figure 8 shows the part of the signal spectrum that corresponds to the time interval of 0.05 seconds with marked local maximum and minimum values - peaks.

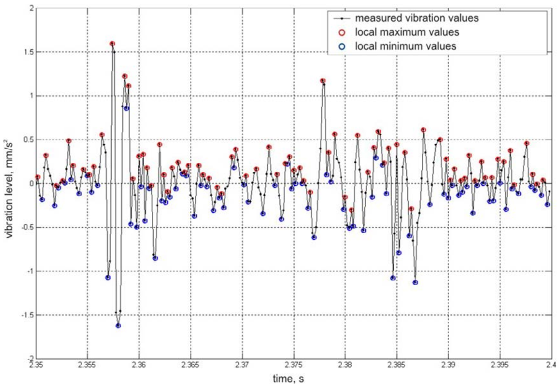

Figure 8. Identification of local peaks values in vibration signal

Typical results of one tribological test are presented below. Test lasted for 20,000 cycles. Figure 9 shows trend parameters of friction coefficient in the regime of running-in

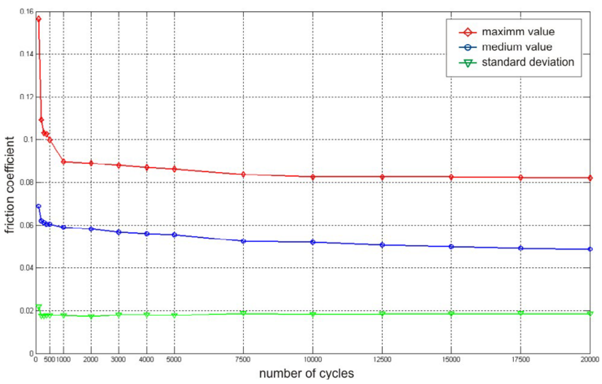

Figure 9. Trend parameters of friction coefficient

Figure 10 shows the original shape of measured values for friction coefficient for this regime.

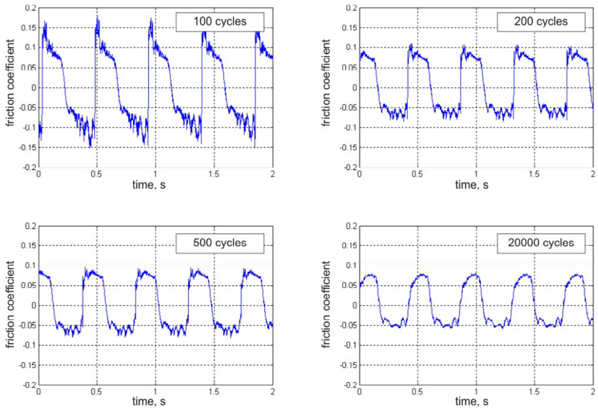

Figure 10. Original signals of friction coefficient

4. CONCLUSION

Presented tribometer has been developed to simulation linear motion that occurs in hydraulic systems as well as monitoring of tribological parameters in different testing conditions.

Some examples of an obtained investigation results are presented. Results are presented in their original form and after statistic analyses of measured signals.

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