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DESIGN AND VALIDATION OF EQUIPMENT FOR TESTING THE LOAD CAPACITY OF LUBRICANTS

Popa-Müller Izolda,[1] Lőrincz Norbert[2]

[1] Sapientia Hungarian University of Transylvania, Faculty of Technical and Human Sciences, Târgu Mureş,-Department of Mechanical Engineering, Romania, ipmuller@ms.sapientia.ro

[2] Hamorform Industry, Vlahita, Romania, lorincz.norbert@yahoo.com

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Abstract

To test the load carrying capacity of lubricating oils, we designed a device based on a modelling model of a tribological system in line contact. Under different loads and in contact with different materials, the wear rate is monitored. We investigate at what force load and over what time the wear occurs. It is an important tool in tribological laboratory practice because it can be used to determine the load capacity of a lubricating oil under test conditions and to determine the maximum load at which no wear will occur.

Keywords: *lubricating oil, wear mark, force, time.*

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1. Introduction

The most important role of lubricant is to reduce friction, which prevents wear on surfaces.

The use of lubricants according to their state of aggregation [1]:

- liquid lubricants (lubricating oils);
- plastic lubricants (greases);
- solid lubricants (graphite, molybdenum disulphide, etc.);
- gaseous lubricants (air, any inert gas).

In technical practice, liquid lubricants, lubricating oils, are most commonly used.

The parameters describing the most important properties of lubricants are [2]:

- viscosity, used to measure the fluid's ability to flow;
- consistency: a measure of the stiffness of grease;
- film-forming ability, a film of lubricant separating moving parts.

Lubricants should ensure that the optimum lubrication condition is maintained for as long as possible.

Causes of fatigue:

- internal changes in the lubricants;
- external contamination of lubricants;
- loss of efficiency of additives.

A kenőolaj összetétele alapolajból és a hozzáadott adalékokból áll.

The composition of a lubricating oil consists of a base oil and added additives.

The additives greatly alter the properties of the lubricating oil, improving its wear, friction, oxidation, foaming and corrosion properties.

Classification of lubricating oils:

- Vegetable and animal oils
- naphthenic and mixed base oils
- Synthetic lubricating oils, used in special cases, mainly at temperatures above 90°C or at very low temperatures. The most common synthetic oils are ester, poly-alpha-olefin, silicone and fluorinated oils and polyglycols.

2. Tribological studies

2.1. Design of equipment for testing the load carrying capacity of lubricants

The tribological tests are designed as follows: [3–7]

- to design a structure optimised for long life;
- design of an optimum structure in terms of operation
- to determine the data needed to establish maintenance and overhaul periods;
- monitoring the machine's operating condition;
- to simulate the wear of components by means of model tests;

- determining the factors influencing the behaviour of the tribological system;
- selection of the pair of materials and lubricants required for the construction and operation of a given friction structure;
- checking the quality of materials and lubricants.

For our application, we used the slotted disc tribological model, **Figure 1.**

One part of our system provides the rotary motion of the ring, while the other part is made up of a mechanism that provides a gradual load on the test piece.

The ring is locked at one end of the shaft and rotates in line contact with the test piece. The ring rotates at a constant speed of 800 [r/pm]. A lubricant is applied to the lubricant reservoir below the ring, forming a lubricating film between the two contact surfaces.

At the other end is a belt pulley **[1, 8]**, attached by a latch, to which an electric motor is connected by a belt drive. From the point of view of speed adjustment and transmission, a belt drive is required **[9]**. During operation, the minimum load at which the lubricant film breaks and fatigue starts is determined by gradually increasing the load, **Figure 2.**

The test impactor is loaded by a pair of force arms. One of the two levers locks the impactor in position, while the other lever presses the impactor against the ring. The progressive loading provided by the force arms is achieved by weights of different masses, **Figure 3.**

During operation, the minimum load at which the lubricant film breaks and starts to crack is determined by gradually increasing the load.

Both parts are fixed on a structure made of a lock section welded together, **Figure 4.**

The implemented device can be observed in **Figure 5.**

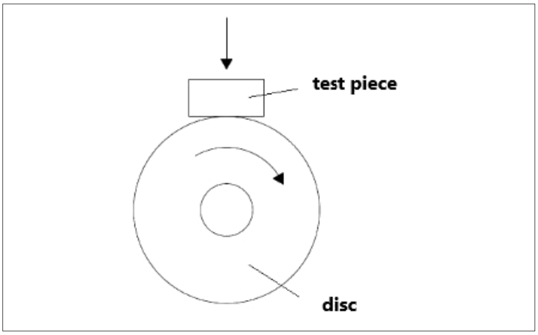

Fig. 1. *Bloc-disc model.*

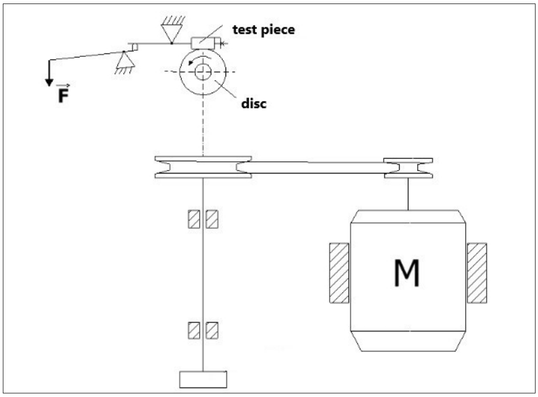

Fig. 2. *Kinematic sketch of the equipment.*

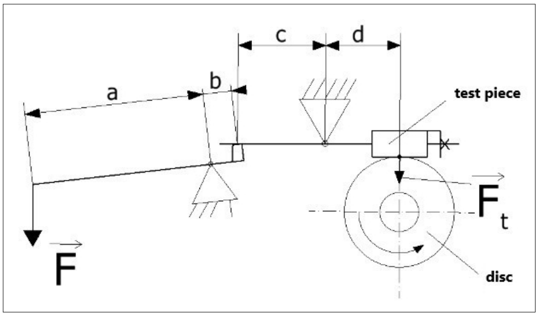

Fig. 3. *Kinematics of the power arm of the equipment.*

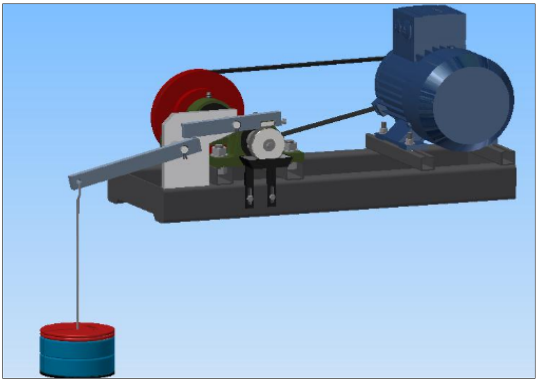

Fig. 4. *Spatial model of equipment.*

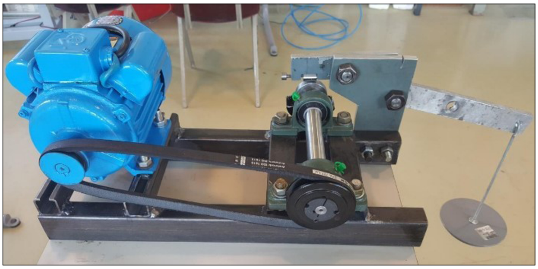

Fig. 5. *Completed equipment*

2.2. Subject of the study

The aim of the test is to study the load carrying capacity of lubricating oil on different contact surfaces. This is done by investigating the force load and the time after which wear occurs.

To determine, under given test conditions, the maximum load at which the burr does not yet appear.

The tests were carried out on specimens of Cu, CuZn, C45 using a steel ring. T90 type oil was used in the tests. This is a transmission oil used in low speed industrial gears with a viscosity index of 90.

Properties of lubricating oil:

- kinematic viscosity 40°C, $\nu = 160 mm^2 /s$;
- kinematic viscosity 100°C, $\nu = 16.5–18 mm^2/s$;
- density 15°C, $\varrho = 0.91 g/cm^3$.

Test procedure: the load is gradually increased every minute until a crack appears on the test specimen, indicated by a characteristic sound.

The wear marks on the surfaces of Cu, CuZn, C45 specimens are observed in **Figure 6.**

2.3. Measurement results

Table 1 shows the measurement results obtained during the study.

The equipment allowed precise monitoring of the wear process, while providing reproducible and reliable data for a specific lubricating oil on two different contacting materials.

The maximum load capacity of the lubricant is the highest for steel-steel. Here, an average load of 2350 grams and an average load time of 320 s result in a wear width of 0.5 mm.

During lubrication, the wear marks for steel-steel contact of the same materials occur at higher loads than for steel-red brass or steel-brass.

2.4. Data processing

Load force and load duration affect the size of the indentation mark, **Table 1.**

For data processing, a variable including both the load force and the load time was introduced. The variable is the ratio of load force to load time, F/t ratio, where: F is load force [N]; t is load time [s].

As a function of the variable, the wear rate of different materials Cu, CuZn, C45 in the presence of the lubricant can be monitored.

The data are given in **Table 2**.

Figure 7 shows the measured wear widths as a function of the F/t ratio.

The effect of the hardness of the material on the wear width is shown in **Figure 8**. The correlation

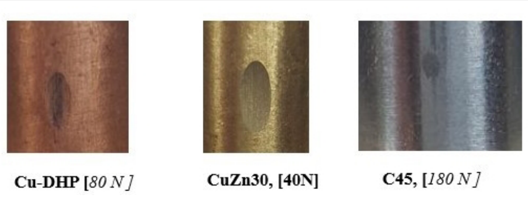

Fig. 6. *Abrasions on the surfaces of Cu, CuZn, C45 test pieces.*

Table 1. *Measurement data values*

		Load mass [g]	Load force [N]	Duration, [s]	Wear width
Steel	**Cooper**	1000	80	240	1
		1250	100	270	1.5
		1250	100	270	1.5
average		1166.(6)	93.(3)	260	1.(3)
Steel	**Brass**	500	40	120	1
		500	40	180	1.75
		500	40	180	1.75
average		500	40	160	1.5
Steel	**Steel**	2300	200	330	0.5
		2250	180	300	0.5
		2300	184	330	0.5
average		2283.(3)	188	320	0.5

Table 2. *Data processing values*

HB	Load force [N]	Appearance of wear sound t[s]	Force/ time	Wear width [mm]
60	93.(3)	260	0.358974	1.33
95	40	160	0.25	1.50
250	188	520	0.5875	0.50

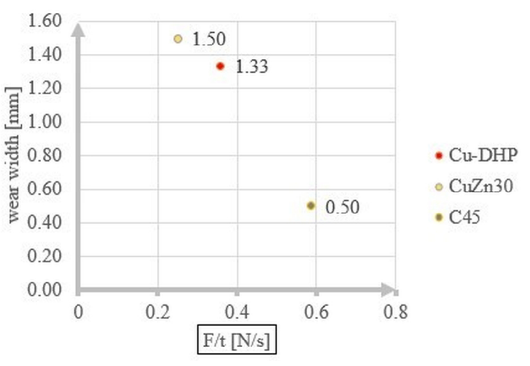

Fig. 7. *Variable influence of load-time on wear width.*

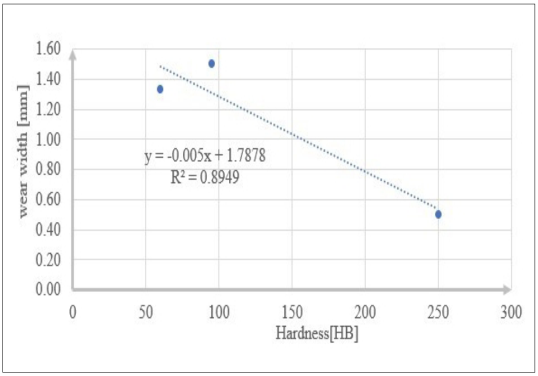

Fig. 8. *The effect of material hardness on wear width.*

in his figure, $R_2 = 0.89$, shows a strong relationship between the hardness of Cu, CuZn, C45 materials and the wear widths.

The regression line shows that the higher the hardness of the materials the lower the wear width.

3. Conclusions

It has been shown that the wear trace when using a lubricant depends on the material of the contact surfaces.

The validation experiments carried out have demonstrated that this tribological laboratory apparatus is suitable for testing the load carrying capacity of lubricants, supporting the selection and optimisation of the appropriate lubricant for different industrial applications.

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