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Measurement of Coefficient of Friction by Means of the PTR instrument

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Synopsis:

Friction measurements were carried out with the oil test instrument which had been developed by the PTR with the help of the DVL and which had been newly installed in the Institute B5. The variation in the results could be improved by changing the original experimental conditions. The coefficient of friction was subsequently measured for a number of substances, in the case of two oils this was done at higher temperatures.

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IV. Summary.

I. Experimental apparatus and performance

The instrument employed in the investigations has been developed by the Physico Technical Reichsanstalt (PTR) for the determination of the coefficients of friction of lubricants. A steel needle glides on a thin film of the oil under investigation on a plane disc which is lapped before each experiment. The force is measured with which the uniformly rotating disc tends to drag the needle with it. This force serves as a measure of the frictional quantity between disc and needle in the layer of oil under investigation. The instrument as well as the working method has already been described in detail at a different place. It is therefore not necessary to enter into it here.

First the experimental error had to be found for the instrument which had been newly installed in the DVL. For this purpose the two motor oils Rotring D (as a purely mineral oil) and Kompressol (as a very fatty oil) were chosen. These two have very different chemical constitutions and both have the same viscosity (18°E/50°).

In the course of numerous trials it was found that the reproducibility was very bad although the experimental conditions indicated by the PTR were kept to strictly. This is shown by the curves in figs. 1 and 2. Particularly in the region of higher velocities was there a large variation for different trials with the same oil.

II. Improving the reproducibility by changing the experimental conditions

From the above was derived the task of narrowing down the range of distribution by changing the experimental conditions (including pressure state of the oil film, material of the disc, grinding material, cleaning of the disc, length of needle).

a. Pressure.

The strong inclination of some curves seems to indicate that the pressure of 185 kg/cm^2 was insufficient to exclude hydrodynamic lubrication. According to all experiences gained so far the coefficient of friction has to remain constant for all velocities in the case limiting friction. This means that the curve would have to run horizontal. When the pressure was raised to 328 kg/cm^2 this condition was more nearly fulfilled. The curves in figs. 3 and 4 are considerably flatter than those shown in figs. 1 and 2, this also narrows down the range of distribution in the region of higher velocities.

b. State of the oil film.

The state of the oil film also proved to be of importance. Thick flowing films gave lower frictional quantities than thin films. This is especially true for Rotring (see figs. 1 to 4). The cause of this may be that in thick films there may still be some local hydrodynamical friction. Very thin films on the other hand, which have not been wiped sometimes yield very high values for the friction. These immediately went down to normal when the scraper was applied moist with oil. This shows, what has been confirmed by many experiments, that particularly in the case of thick oils it is important to provide the track of the needle with new oil continuously by putting down the scraper. Otherwise one may possibly get dry friction. It should be pointed out in this connection that, particularly after use for a fatty oil, one should wash the scraper carefully with a suitable solvent.

In consideration of the experiences made so far we obtained the following distribution limits for two series of control trials with Rotring and Kompressol (compare fig.5).

	Rotring	Kompressol
for 1 cm/sec. =	0.18 - 0.20	0.15 - 0.16
for 8 cm/sec. =	0.17 - 0.19	0.145 - 0.155
Range of distr. for 1 cm/sec	± 5%	± 3%
for 8 cm/sec	± 6%	± 4%

c. Type of disc.

The curves did still not show a completely horizontal course, this meant that one was not dealing with pure limiting friction. A different type of disc (G.19) was therefore ordered at the PTR in place of the previously used T5. This measure did not however meet with the desired success.

d. Abrasions.

Success was reached only when according to a proposal of the PTR Optolit 6 was used as an abrasive instead of Optolit 2. On the surface which was now noticeably rougher one now obtained a mean horizontal course at velocities above 2.5 cm/sec. for Rotring D and fatty oil Aero Shell which was now employed (Figs. 6 and 7). The limits of distribution change as follows:

	Rotring	Kompressol
at 2.5 cm/sec	0.172 - 0.182	0.168 - 0.180
" 8 cm/sec	0.172 - 0.182	0.168 - 0.180
Range of distribution	± 3%	± 4%

It thus became possible to attain pure boundary lubrication if all experience made so far was carefully used. The limits of distribution could be lowered down to ± 3 to 4%.

e. Cleaning.

As regards the cleaning it has become apparent that it is not necessary to grind with Optolit 6 after every trial. A thorough treatment with suitable easily volatile solvents (gasolene or benzene and distilled petrol ether purified over aluminium oxide if the other is not sufficient) was found to be quite satisfactory. The disc was covered successively with Rotring - Fettol - Rotring (with intermediate cleaning); the final Rotring value was the same as the initial value. No after effect is noticed when Autokollag or Tricresylphosphate were added.

f. Length of the needle.

A suitable length for the needle was 2 cm. If the needle is shorter oil easily creeps into the needle mounting. This entails a change in the cross-section of the gliding area and therefore in the specific pressure.

III. Measurement of the Coefficient of Friction of various Liquids according to the "Sector Method".

In spite of the most careful attention to the new experimental conditions the limits of distribution were still toowide to allow of reproducible measurements to be taken when it was necessary to determine the small differences between oils of the same type. A simplified "sector method" was therefore worked out for comparison purposes. Half of the disc is covered with Rotring D as comparison oil and the other half is covered with the oil under test. In order to prevent any dragging over of one oil into the other there is a short distance between the two halves which is not covered at all. For the same reason one has to take care that no oil creeps up the needle into the mounting; this is particularly prone to occur with thick oils. The test velocity is taken at from 2 to 4 cm/sec. n = 300 to 600 revs/min. At lower velocities there is a disturbing effect of the curvature tending to the value of the adhesion friction. At higher velocities there is not enough time to allow the pendulum to come to rest on any one of the sectors.

The coefficients of friction were now measured for a number of substances; the results have been summarized in Table 1. From it, it emerges that it is possible to determine even small differences between the coefficients of friction. One has to realize however that the values determined thus are only relative. They can be considered absolute only where distribution of from 3 to 4% is taken into account.

Mention should also be made here of the results obtained with evaporating gasoline, benzene, and petrol ether. The deflections of the galvonometer have been plotted as a function of time, in fig. 8. A remarkable characteristic of these curves if that an increase of the frictional value occurs immediately after the test - material has been put on to the dry disc. For this there is no explanation as yet. The decrease which occurs afterwards may be explained by an enrichment of the heavier constituents having better lubricating qualities caused by the evaporation of the lighter constituents. Subsequently friction increases again because the part due to dry friction gains in importance as compared with the part due to the very small oil residues.

Finally, it was investigated whether one could also observe certain phenomena with the PTR instrument; this included the sudden change in the adhesion, observed by Tabor, which occurred on exceeding a certain critical temperature which was different for each oil. No change in the coefficient of friction was observed for Rotring D and Derop-Dieseloil when preliminary experiments with improvised heating were carried at temperatures up to 80°C.

IV. Summary

It was found that there was little difference (within the limit of error of the instrument) between the coefficients of friction of numerous mineral motor lubricants which have the same viscosity but which have different origins. Additions such as graphite, tricresylphosphate and calcium chlorostearate did not effect any change in the coefficient of friction; oils with fatty additions show lower values. Raising the temperature up to 80°C had no measurable effect on the coefficients of friction of Rotring D and Derop Diesel Oil.

TABLE I

	Coefficients of Friction (Observed)		Converted to Rotring = 0,175
[illegible]ein	0,133	compared with Rotring =0,162	0,131
Rotring + 1% Oil	0,145	" " " =0,183	0,137
Kompressol	0,14-0,16	" " " = -	-
Derop-Diesel Oil	0,153	" " " = -	-
ASM 18/39	0,158	" " " =0,172	0,161
ASM 358/40	0,158	" " " =0,170	0,163
ASM 188/39	0,163	" " " =0,170	0,168
DA 200	0,169	" " " =0,178	0,166
NP II	0,171	" " " =0,176	0,170
ED 24	0,167	" " " =0,172	0,170
SDR	0,170	" " " =0,175	0,170
	0,170	" " " =0,172	0,173
Brightstock	0,175	" " " =0,177	0,173
	0,173	" " " =0,173	0,175
Rotring+Calcium dichlorstearate	0,178	" " " =0,178	0,175
Grunring	0,169	" " " =0,169	0,175
Rotring+Auto-kollag	0,187	" " " =0,187	0,175
Stanavo 100	0,176	" " " =0,172	0,179
Gulfpride	0,172	" " " =0,167	0,180
Glycerin	0,217	" " " =0,172	0,220
Petroleum	0,18-0,19	" " " = .	.
Petroleum Ether	ca.0,23		
Dist.Water	0,29		
Dry friction	0,30-0,35		

Plate 1. Friction values of Rotring D in dependence of the gliding velocity

Plate 2. Friction values of Kompressol in dependence of the gliding velocity

Plate 3. Friction values of Rotring D as a function of the gliding velocity at increased loads.

Plate 4. Friction values of Kompressol as a function of the gliding velocity at increased loads.

Plate 5. Friction curves of Rotring D and Kompressol for determining the limits of distribution.

Plate 6. Gliding velocities of Rotring D and O[illegible] after a rougher abrasive had been used.

Plate 7. Friction curves of Aero Shell oils after using the abrasive Opolit 6.

Plate 8. Friction characteristics of gasoline, benzene and petrol ether as a function of time.