1. INTRODUCTION

To the main raw materials for manufacture plastic lubricants of various purpose serve:
1. mineral oils of various viscosity and a degree of clearing;
2. hydrocarbonic thickeners (petrolatums, cherezins, paraffins);
3. soaps of the fat acids allocated from natural fats, and natural fats of an animal and a phytogenesis;
4. soaps of synthetic fat acids;
5. various products of chemical synthesis (silicon-organic liquids, complex ethers, dyes, etc.).

Besides the additives improving their separate properties or some of different properties (multipurpose), and also inhibitors of oxidation are entered into plastic lubricants (PL), inhibitors of corrosion and other components.

In this connection plastic lubricants have the complex chemical compound defining their operational properties.

During the production process of any lubricant S, its manufacturer follows the requirements of the state standard. As any lubricant can be produced by a different manufacturer, that is why in a number of cases, it is necessary to compare the influence of different grades of lubricant S on tribotechnical characteristics of friction pair. Thus, the Department of Machine Science and machine Components of Saint-Petersburg State Polytechnic University carried out estimation of the influence of different grades of lubricant "Litol-24" on the tribotechnical characteristics of friction pair "steel-steel".

Complexity of chemical compound PL is one of the major factors influencing distinct properties of same products at different manufacturers.

2. RESEARCH METHODOLOGY

The research of the influence of the lubricating materials from the set \{Sm\}_{1, 2, ..., p} (S - name of the lubricant material, \(m_i\) - grade of the lubricating material \(S\), \(p\) - quantity of grades (manufacturers) of the lubricating material \(S\)) on tribotechnical characteristics of the friction pair "steel-steel" is carried on the basis of grades numbering scheme according to the following algorithm:

1. Wearing test of the lubricant \(S\) of the manufacturer "\(p\)" is carried out on the friction test machine CH_SH_M 3,2 (GOST 9490-88).
2. Microhardness measurement of the sample friction surfaces is conducted using microhardness-meter PMT-3 (GOST 9450-76).
3. Two best lubricants from \(p\) are selected and then tear index test is carried out (GOST 9490-88).
4. Selection of the best lubricating material in the examined set is performed.

Friction pair elements, which are used in the wearing tests and tear index tests, are balls of the bearings GOST 3722. These balls are made of material "steel SHKH15", with diameter \(d_{bo} = (12.70 +/- 0.01)\)mm. Normal ball loading at wearing tests is \(P = 196\) N. Time for one test operation is \(\Delta t = (60.00 +/- 0.50)\) min.

Length \(l(m_i)\) and width \(h(m_i)\) of the wear spot \(# j\) \((j = 1, 2, 3)\), which was formed at lubricant \(S\), tests, were measured with the microscope "Prima-expert". The diameter of wear spot \(# j\) corresponding to \(S\), is defined as follows:

\[
d_j(m_i) = \frac{l_j(m_i) + h_j(m_i)}{2}.
\]

Mean diameter of the wear spot for lubricating material \(S\) is calculated by the following formula:
The results of the measurements and calculations are listed in Table 2.

The diagonal length of $k$ ($k = 1, 2, ..., q$) indenter dent in the selected area is defined by the formula:

$$d_k = \frac{d_{1,k} + d_{2,k}}{2}.$$  (3)

Mean length of the indenter dent diagonal in the same area:

$$d = \frac{1}{q} \sum_{k=1}^{q} d_{1,k} + d_{2,k}.$$  (4)

After the measurement of obtained dents parameters and calculations using of relations (3) and (4), microhardness is defined by the formula (Glazov and Vigidorovich, 1969):

$$HV = 1854 \cdot \frac{F}{d^2},$$  (5)

where $F$ gf – force, acting on indenter, $F = 50gf$ const, $d$ – mean length of the indenter dent diagonal ($\mu m$), $HV$ – microhardness value (kgf/mm$^2$).

By comparing the results, listed in the Tables above, the selection of the two best lubricating materials $\{Sm_1; Sm_2\}$ is carried out from the set $\{Sm_i | i = 1, 2, ..., p\}$

Tear index tests of the selected lubricating materials $Sm_1$ and $Sm_2$ are conducted as per GOST 9490-75.

From the load series $\{P_\gamma | \alpha = 1, 2, ..., 23\}$ the set of adjacent loads $\{P_\gamma | 1 \leq \beta \leq 23\} = \{P_\gamma | \gamma = 1, 2, ..., n\}$ is selected. The elements of this set are renumbered and located in the monotone increase or monotone decrease order. The length of the tests at fixed load from the set is $\Delta t = (10.0 +/- 0.2)s$. The diameter of $j$ – wear spot for lubricating material $\{Sm_i | i = a, b\}$ at fixed load $P_\gamma$, taking into consideration (1), is defined as follows:

$$d_j(m_i, P_\gamma) = \frac{l_j(m_i, P_\gamma) + h_j(m_i, P_\gamma)}{2}.$$  (6)

Mean diameter of wear spots is similarly (2):

$$d_{ijy}(m_i) = \frac{1}{3} \sum_{j=1}^{3} l_j(m_i, P_\gamma) + h_j(m_i, P_\gamma).$$  (7)

According to GOST 9490-88 the limiting wear values series $d_{wps} = d_{wps} + 0.15\, mm$ is put as one-to-one depentanizer to the load series 1. Thereby, for the set:

$$d_{wp} = d_y + 0.15\, mm,$$  (8)

where $d_y$ – diameter of the balls’ elastic range of stress according to Herz (mm), at load $P_\gamma, H(\, kgf\,$).

Conditional load, corresponding to axial load $P_\gamma$, at lubricating material $\{Sm_i | i = a, b\}$ tests can be found from the following relation:

$$Q_j(m_i) = P_\gamma \cdot \frac{d_y}{d_{ijy}(m_i)}.$$  (9)

Tear index is calculated by the following formula:

$$H_j(m_i) = \frac{\sum_{i=1}^{n} Q_j(m_i)}{n}.$$  (10)
Initial data, measurement and calculation results are presented in Table 3.

Tab. 3. The results of tear index tests ($i = a, b$; this record means that this table is used twice)

<table>
<thead>
<tr>
<th>No (γ)</th>
<th>$P_i$ (kgf)</th>
<th>$d_i(m_i, P_i)$</th>
<th>$d_{a_{im}}(m_i)$</th>
<th>$d_{apm}$</th>
<th>$P_i - d_{apm}$</th>
<th>$Q_i(m_i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$P_1$</td>
<td>$d_1(m_1, P_1)$</td>
<td>$d_{a_1}(m_1)$</td>
<td>$d_{ap1}$</td>
<td>$P_1 - d_{ap1}$</td>
<td>$Q_1(m_1)$</td>
</tr>
<tr>
<td>2</td>
<td>$P_2$</td>
<td>$d_2(m_2, P_2)$</td>
<td>$d_{a_2}(m_2)$</td>
<td>$d_{ap2}$</td>
<td>$P_2 - d_{ap2}$</td>
<td>$Q_2(m_2)$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$n$</td>
<td>$P_n$</td>
<td>$d_n(m_n, P_n)$</td>
<td>$d_{a_n}(m_n)$</td>
<td>$d_{apn}$</td>
<td>$P_n - d_{apn}$</td>
<td>$Q_n(m_n)$</td>
</tr>
</tbody>
</table>

Tear index $H_i(m_i)$

By the difference $\Delta H_i = H_i(m_a) - H_i(m_b)$ the best lubricant can be found.

3. PROCESSING OF RESEARCH RESULTS

For comparative researches it is expedient to use the plastic lubricants most widely presented in the market. „Litol-24” was selected as tested lubricating material S. The grades quantity (the number of manufacturers) for the research was taken as $p = 4$. The lubricant material grades were as follows, $m_1$: “OLLRIGHT”, $m_2$: “Misma Ross”, $m_3$: “ARGO” and $m_4$: “BMP auto”.

After wear tests of the lubricants and calculations using equations (1) and (2) the following values of mean diameter of the wear spot were obtained:

1. $D_h(OLLRIGHT) = 0.50 \text{mm}$;
2. $D_h(\text{Misma Ross}) = 0.33 \text{mm}$;
3. $D_h(\text{ARGO}) = 0.35 \text{mm}$;
4. $D_h(\text{BMP auto}) = 0.41 \text{mm}$.

These data confirm distinctions of a chemical compound which can be caused not only character of productions, but also changes during ageing lubricants.

Influence test specifications of lubricants and render also properties of used metal samples.

For microhardness measurement the quantity of indenter dents in each of the tested surface area was taken as $q = 5$. After marking and measurement of indenter dents and calculations applying (3), (4) and (5), the following values of microhardness in the initial surface area were obtained:

1. $HV(\text{OLLRIGHT}) = 181.03 \text{kgf/\text{mm}^2}$;
2. $HV(\text{Misma Ross}) = 146.09 \text{kgf/\text{mm}^2}$;
3. $HV(\text{ARGO}) = 138.88 \text{kgf/\text{mm}^2}$;
4. $HV(\text{BMP auto}) = 188.05 \text{kgf/\text{mm}^2}$.

The microhardness values in the abrasive wear area:

1. $HV_{ad}(\text{OLLRIGHT}) = 153.85 \text{kgf/\text{mm}^2}$;
2. $HV_{ad}(\text{Misma Ross}) = 126.04 \text{kgf/\text{mm}^2}$;
3. $HV_{ad}(\text{ARGO}) = 95.36 \text{kgf/\text{mm}^2}$;
4. $HV_{ad}(\text{BMP auto}) = 151.21 \text{kgf/\text{mm}^2}$.

The microhardness values in the adhesive wear area:

1. $HV_{ad}(\text{OLLRIGHT}) = 138.91 \text{kgf/\text{mm}^2}$;
2. $HV_{ad}(\text{Misma Ross}) = \emptyset$; (The sign $\emptyset$ (empty set) means the absence of adhesive wear area.)
3. $HV_{ad}(\text{ARGO}) = \emptyset$;
4. $HV_{ad}(\text{BMP auto}) = 174.40 \text{kgf/\text{mm}^2}$.

Fluctuations of microhardness are caused by anisotropy of mechanical properties of metal samples and character of adsorption of surface-active substances on a surface of friction. Influence can render and the maintenance polarly active products of oxidation of components PL.

Considering the values of wear spot mean diameter and microhardness values (the absence of adhesive wear areas) the following lubricating materials were selected for tear index tests – $Sm_2$: Lifol – 24(Misma Ross) and $Sm_5$: Lifol – 24(ARGE). From the load series 1 the set of employment $\{P_1 \gamma = 1, 2, ..., 6\} = \{32 \text{ kgf}, 40 \text{ kgf}, 50 \text{ kgf}, 63 \text{ kgf}, 80 \text{ kgf}, 100 \text{ kgf}\}$ was chosen. Its elements were arranged in the monotone increase order.

After tear index tests of these lubricating materials and taking into consideration the formulas (6), (7), (8), (9) and (10) the following values of tear index were received:

1. $H_i(\text{Misma Ross}) = 323N$;
2. $H_i(\text{ARGO}) = 343N$.

Material: Lifol – 24(Misma Ross) has less tear index than material. The difference is the following: $\Delta H_i = H_i(m_a) - H_i(m_b) = 343 \text{ N} - 323 \text{ N} = 20 \text{ N}$.

Thus, in case of lubricating material change from lubricant: Lifol – 24(ARGE) to lubricant $Sm_2$: Lifol – 24(Misma Ross) the tear index decrease, by $5 - 6\%$.

It is possible to assume, that in lubricant Lifol - 24 (ARGO) contains more anti-adhesion polarly-active components, than in plastic lubricant Lifol - 24 (Misma Ross). It can be caused both production, and process of ageing during storage of a product.

As products of ageing there can be such polarly-active components as:
1. Fat acids;
2. Spirits;
3. Complex ethers;
The given products are formed and change properties of plastic lubricants.

4. CONCLUSIONS

1. The developed generalized methods allow us to estimate the influence of any liquid or semisolid lubricating material of different grades on tribotechnical characteristics of friction pair “steel-steel” and choose the best lubricating materials.
2. The lubricating material Sm: Litol – 24 (Misma Ross) has the best anti-wear properties, mean diameter of wear spot – 0.33mm.

3. Anti-adhesion properties lubricant Litol - 24 (ARGO) has shown the best.

4. In communication with complexity of a chemical compound of the given lubricants there is a distinction anti-adhesion properties and character of influence of surface-active substances on a surface of friction of examinees of samples.

5. Differs and the bearing ability of the lubricant layer expressed in occurrence of zones of adhesive deterioration in case of use of one lubricants and absence of given zones at use of others.

6. In communication with complexity of a chemical compound of the given lubricants there is a distinction anti-wearing properties and character of influence of surface-active substances on a surface of friction of examinees of samples.

7. Differs and the bearing ability of the lubricant layer expressed in occurrence of zones of adhesive deterioration in case of use of one lubricants and absence of given zones at use of others.

8. Following the executed analysis of microhardness measurements in the three areas it was established that:
   - initial surface has the highest microhardness;
   - microhardness of the worn area with abrasive type of wear is 15 – 20% lower than microhardness of the initial surface;
   - microhardness of the adhesive wear areas differs in extensive limits between the microhardness of the above mentioned areas.

REFERENCES


4. Qhruschov M. M, Berqovich E. S. (1953), Microhardness, that is defined by indentation method. M. – L., Publishing house of Academy of Science.

