INFLUENCE OF GREASE GRADE AND WORKING REGIME ON THE STRUCTURAL MODIFICATIONS OF THE SUPERFICIAL LAYERS ON ROLLER-ROLLER TRIBOSYSTEMS

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ABSTRACT

A X-ray diffractometric method is used for analysing the distributions of the 1-st and 2-nd tension state and dislocation density in the superficial layers, after tests in different working and lubricating conditions, the focus being done on the optimisation of the lubricating processes under determined conditions taking into account the functioning regimes, the lubricant type, the working environment etc.

KEYWORDS: Pure rolling, grease lubrication, rolling+sliding, superficial layer, X-ray diffractometry.

1. INTRODUCTION

Lubricant catalogues do not contain recommendations for special applications, as high and low temperature in exploitation. This is the reason of this investigation, this paper presenting an original design solution of testing machine and some results. The tribomodel will keep the same materials as those for the triboelements and similar environment conditions, but there will be tested several lubricants (greases) in order to compare the results and to give a better solution for the actual tribosystem.

2. THE ROLLING AND ROLLING-SLIDING TRIBOSYSTEM CHARACTERISATION

This type of tribosystem (fig. 1) is characterised by three groups of parameters: external, internal and interacting ones and tribological behaviour will be similar if the testing conditions applied to the model, are close to the actual ones [2, 3, 4].

Microgeometry, hardness, structure, chemical composition, purity and tension state characterise the superficial layer of the materials.

Fig.1. The model of tribosystem [3].

Fig. 2. Elements’ dimensions for the tested rollers [5].

During the running-in process and in functioning there are taking place changes within the
superficial layers and, inevitably, the resulting complex wear having overlapping components. For the analysed case, thermal wear is predominant due to environment temperature and also to high loads and sliding component of the resulting motion [5, 6]. The high flash temperatures on the top peaks of the roller surfaces induce thermo-plastic deformations, softening and even local melting, the result being undesirable changes of the tribological behaviour of lubricant and tribolayers. The author will monitor the friction coefficient as this evolution reveals changes in lubricant and tribolayers [5, 6].

The experimental research was done on the linear contact roller/roller tribomodel (fig. 2). The dimensional characteristics of the pair of rollers are presented in table 1 (the rolling regime) and table 2 (the rolling+sliding regime).

The tested lubricants are grease grades UM170LiCaPb2 and UM185Li2EP and the rollers’ materials are steel grades OLC25 and OLC45 as coded in Romanian standardisation (STAS 880-80).

The sliding coefficient was calculated as:

\[ \xi = \frac{2(v_1 - v_2)}{v_1 + v_2} \cdot 100 \% \]  

\[ v_1 \text{ and } v_2 \text{ being the peripheral speeds for the roller 1 and 2, respectively.} \]

\[ \xi = 0 \] is for pure rolling.

3. THE TESTING MACHINE

The testing machine is presented in figure 3 (general view) and in figure 4 (the working zone), and it may be useful for three types of tests:

- lubricant testing at normal pressure and temperature and different working environment;
- lubricant testing at high temperature without supplementary cooling;
- lubricant testing at high temperature and controlled environment cooling (nitrogen) [5, 6, 7].

As for the third case, the testing machine is based on the principle of maintaining pressure in stocking vessel used for the cooling agent by the help of compressed air [5].

The machine have a friction coupling type Amsler in open circuit, a thermo-insulated box for achieving different working environments, a grease lubricant system with automatic control and a heating device with electric resistance, including a thermo-regulator.

Table 1. Roller dimensions [mm].

<table>
<thead>
<tr>
<th>Roller</th>
<th>D</th>
<th>B</th>
<th>d</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>59.5</td>
<td>12</td>
<td>22(^{+0.02}_{-0.02})</td>
<td>6(^{+0.078}_{-0.030})</td>
</tr>
<tr>
<td>2</td>
<td>42.5</td>
<td>10</td>
<td>22(^{+0.02}_{-0.02})</td>
<td>6(^{+0.078}_{-0.030})</td>
</tr>
</tbody>
</table>

Table 2. Roller dimensions [mm].

<table>
<thead>
<tr>
<th>(\xi)</th>
<th>Roller</th>
<th>D</th>
<th>B</th>
<th>d</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.3%</td>
<td>1</td>
<td>55.40</td>
<td>12</td>
<td>22(^{+0.02}_{-0.02})</td>
<td>6(^{+0.078}_{-0.030})</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>46.56</td>
<td>10</td>
<td>22(^{+0.02}_{-0.02})</td>
<td>6(^{+0.078}_{-0.030})</td>
</tr>
<tr>
<td>33.6%</td>
<td>1</td>
<td>51</td>
<td>10</td>
<td>22(^{+0.02}_{-0.02})</td>
<td>6(^{+0.078}_{-0.030})</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>51</td>
<td>12</td>
<td>22(^{+0.02}_{-0.02})</td>
<td>6(^{+0.078}_{-0.030})</td>
</tr>
</tbody>
</table>

Fig. 3. The testing machine [5].

1-engine; 2-rigid coupling; 3-reducing gear; 4-rigid coupling; 5-torque transducer; 6-shafts; 7-thermal insulated system; 9-rigid coupling; 11-belt transmission; 14-engine acted system for circulating the grease; 15-gear transmission.
The testing block has a tribometer for rolling and rolling-sliding motion (roller/roller), including a simple mechanism with engine, belt and gear transmissions, the transducer for measuring the resistant (friction) torque (Hottinger-Baldwin®) and a device for fixing the tested rollers. The rollers are mounted on two shafts with ball bearings.

The machine has also an dynamic acquisition source for measurement data storage (Hottinger-Baldwin DMCplus®), connected at a PC. There are many utilities for using the testing machine. The advantages of this solution are simplicity of the design and the safety during exploitation.

4. EXPERIMENTAL RESULTS

The diffraction spectra were analysed by the help of a X-ray-diffractometer DRON 3, figures 5…9 presenting the obtained spectra for the tested rollers.

Figure 5 shows the initial diffraction spectrum for steel grade OLC45, after being tested under the following conditions: Q=1.1kN (normal load); T=100°C (environmental temperature); n=750 rot/min (rotational speed); pure rolling. [5, 8].

Obtained data allow establishing the optimal working conditions and selecting the grease grade for using as lubricant.

Figures 6…9 show diffraction spectra for the same steel grade, after being tested in different working conditions. Based on the analysis of the diffraction spectra (table 3) there were evaluated the behaviour of tritomodels in contact and the greases influence for different working conditions, as well as the structural modifications of superficial layers of the tested rollers [5].
Fig. 7. The diffraction spectrum for the steel grade OLC45; testing conditions: Q=1.1kN; T=100ºC; n₁=750 rot/min; rolling+sliding 33.6% [5, 8].

Fig. 8. The diffraction spectrum for the steel grade OLC45; testing: Q=1.3kN; T=100ºC; n₁=750 rot/min; pure rolling [5, 8].

Fig. 9. The diffraction spectrum for the steel grade OLC45; working conditions: Q=1.3kN; T=100ºC; n₁=750 rot/min; rolling+sliding 33.6% [5, 8].

The obtained data show that in pure rolling conditions the values of <D₁₁₀> are smaller as compared to those obtained for the initial state of the roller steel. In pure rolling conditions it is preferable to have a multifunctional lubricating grease as UM 185Li₂EP (fig. 11) and not a poor lubricating grease grade like LiCaPb₂. In rolling-sliding regime with a sliding coefficient of 40% it is recommended the grade UM185 Li₂EP as lubricating grease.

This aspect may be explained by the influence of the thermal field, which appears during sliding process, inducing a reorganisation of the crystalline grains.

Figure 10 presents the distribution of the X-ray diffraction (110) line width, B₁₁₀, in ferrite phase of steel, in relation to working conditions and type of lubricating grease.

According to [5] the value of B₁₁₀ is inversely proportional to the average dimension, <D₁₁₀>, of mosaic blocks in [110] crystallographic direction.

Figure 11. The distribution of the X-ray diffraction (110) line width [5].

The obtained data show that in pure rolling conditions the values of <D₁₁₀> are smaller as compared to those obtained for the initial state of the roller steel. In pure rolling conditions it is preferable to have a multifunctional lubricating grease as UM 185Li₂EP (fig. 11) and not a poor lubricating grease grade like LiCaPb₂. In rolling-sliding regime with a sliding coefficient of 40% it is recommended the grade UM185 Li₂EP as lubricating grease.

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Figure 10 presents the distribution of the X-ray diffraction (110) line width, B₁₁₀, in ferrite phase of steel, in relation to working conditions and the grade of lubricating grease. The value of B₂₂₀ is directly proportional to the level of 2nd order tensions, σ₂₂₀, into mosaic blocks. In pure rolling regime the deviation of the second order state tensions is higher, this corresponding to rolling-sliding condition (fig. 13). This may be explained due to fact that the contact pressure is presented like a superposition of several pressures oriented in many directions. The test recommends the lubricating grease grade LiCaPb₂ (fig. 13).
Figures 14 and 15 present the distribution of the X-ray diffraction (220) line position, \(2\theta\), in relation to the working conditions and the grade of lubricating grease. This position depends on the first order tension state level obtained from tested rollers.

The obtained data show that lubrication with poor grease is advantageous in both working conditions. The author appreciates that for tested greases in determined working conditions the changes of 1-st order stress state are not significant for characterising their tribological behaviour.

Table 3. Calculated parameters for \(T=100^\circ C, n=750\)rot/min.

<table>
<thead>
<tr>
<th>Code of tested roller/testing conditions</th>
<th>(110)</th>
<th>(220)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I_t)</td>
<td>(I_{t\text{max}})</td>
<td>(B_{110})</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Initial state</td>
<td>269</td>
<td>54.5</td>
</tr>
<tr>
<td>UM170LiCaPb2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4b/pure rolling, (Q=1.1)kN</td>
<td>188.5</td>
<td>38</td>
</tr>
<tr>
<td>UM185Li2EP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5d/rolling+sliding, (Q=1.3)kN</td>
<td>192.5</td>
<td>47</td>
</tr>
<tr>
<td>UM185Li2EP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5b/pure rolling, (Q=1.3)kN</td>
<td>174.5</td>
<td>33</td>
</tr>
<tr>
<td>UM170LiCaPb2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4d/rolling+sliding, (Q=1.1)kN</td>
<td>173.5</td>
<td>44</td>
</tr>
</tbody>
</table>

**LEGEND.** \(I_t\) - integral intensity of the diffraction line; \(I_{t\text{max}}\) - maximum absolute intensity of the diffraction line (maximum height of the line); \(B_{110}\) - diffraction line width in the plane \([110]\); \(B_{220}\) - diffraction line width in the plane \([220]\); \(2\theta_{CG}\) - position (abscise) of the weight centre of the diffraction line; \(I_{\text{max}}\) - maximum intensity of the line (downwards measuring), \(I_f\) - background intensity in the point \(2\theta_{CG}\).
Using the X-ray diffraction method the structural changes in the superficial layer of tested materials in rolling and rolling-sliding conditions were investigated.

Structural changes are correlated to the working condition and the lubricant grade.

The obtained data allow establishing the optimal working conditions and selecting the grease grade.

This study gives a solution for monitoring and increasing the lubrication capacity of industrial greases.

REFERENCES

2. Crudu, I., 1985. On the concept of tribosystem and a tribomodelling criterion, 4-eme Congres European de tribologie, Ecully France.

5. CONCLUSIONS

The paper presented an original testing machine in order to characterise the superficial layers of tested materials in determined working and lubricating conditions and on roller/roller tribomodels.