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EVALUATION OF LUBRICATION BETWEEN PISTON AND CYLINDER OF RECIPROCATING COMPRESSORS BY ELECTRICAL INSTRUMENTATION

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ABSTRACT

Lubrication efficiency between piston and cylinder of reciprocating compressors is evaluated through electrical instrumentation. The technique is based on the measurement of the electrical resistance between the two components when partially insulated by the lubrication film during operation. An electric potential difference is imposed by a proper circuit, and the measured voltage decreases with the increase of the total area of metallic contact between the surfaces of the components.

This principle was successfully used to evaluate semi-quantitatively the behavior of lubrication in different working conditions. A computer simultaneously processes the input from the circuit, stores data and presents the lubrication curve on screen.

The profile of the lubrication curve indicates the influence of compressor operation parameters such as compressor housing temperature, discharge pressure, type of lubricant, etc. The curve obtained from the moment the compressor starts permits estimating the delay time for the regeneration of the lubricant film after a stop period.

INTRODUCTION

The causes investigation of wear problems in reciprocating compressors is usually done through the standard wear tests defined for the compressor approval cycle. These tests are effective to indicate if the wear level in each bearing is acceptable or not. However, wear tests sometimes do not allow to identify the specific circumstances in which lubrication breakdown occur.

In the case of standard wear tests, the whole test is performed under determined operation conditions and lubrication deficiencies are indirectly evaluated through the analysis of the components wear level after the end of the test. The present technique objectives to allow the instantaneous evaluation of the influence of variations in working parameters directly over lubrication behavior. The rubbing pair chosen for experimentation was piston x cylinder, but it is possible to apply it on other couples as well.

The monitoring is done through the application of an electric potential difference between the rubbing parts of a bearing by a suitable circuit and measurement of the response voltage between
them. The lubricant is an intrinsic electric insulator, and the dynamic lubrication tends to reduce the contact between the components asperity peaks. Thus, the better the separation between the components by lubrication, the lower will be the obtained voltage.

**EXPERIMENTAL APPARATUS**

The electric potential difference generator was joined to the cylinder in the negative pole and to the piston, in the positive. The electrical connection to the piston demanded the use of a fatigue resistant spring, due to the high compressor operating frequency. The establishment of electric current just through the clearance piston x cylinder demanded the insulation of the connecting rod. Thus, this component was carefully cut into two parts, that were joined with structural glue. The electrical connections scheme is shown in the figure 1.

The electric input was converted into digital sign by an AD converter, and transmitted to a computer. Each 5 seconds the computer processed 10,000 inputs from ten shaft revolutions, presented a scanning curve (figure 2) on screen and calculated the mean value.

The shape of the scanning curve allowed to identify systematic lubrication deficiencies manifested in specific positions of the piston course (close to the valve plate, for example). The curve formed by the mean values calculated each 5 seconds described the lubrication behavior evolution during the whole test. In the case of recording data since the compressor started, the delay time for recomposing the lubricant film could be calculated from the curve. The comparison between the two curves in the figure 3 indicates different delay times for lubrication film recovery after the start.

The conversion of the voltage data into lubrication efficiency (in percentage) considered 100 % lubrication the voltage relative to open circuit, and 0 % lubrication the short circuit situation.

**RESULTS**

The experimentations were performed using six reciprocating compressors from the same model. The parameters tested were: type of lubricant, housing temperature and stop period. Each specific work condition was tested 8 times per compressor, during 8 minute test periods. All the values were obtained for -10 oC evaporation temperature and 70 oC condensation temperature. The results were calculated as the average of the available data.

The curves were approximated by the following function:

\[ L = R + A \times \exp\left(-\frac{t}{B}\right) \]

were \( L \) is the lubrication efficiency (in percentage) after \( t \) seconds since the start; \( R \) is the average lubrication in the regime condition; \( A \) and \( B \) are regression coefficients.
The table 1 presents the mean values of the results obtained for each test condition. The parameter [R] comes directly from the regression equations and [D] is the delay time for reaching the regime condition, arbitrarily defined as the instant in which the calculated function is equal to 99% of [R].

<table>
<thead>
<tr>
<th>Stop Period</th>
<th>Housing Temp.</th>
<th>Lubricant (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55 oC</td>
<td>75 oC</td>
</tr>
<tr>
<td>30s</td>
<td>60s</td>
<td>120s</td>
</tr>
<tr>
<td>R</td>
<td>83.6±5.2</td>
<td>87.6±7.9</td>
</tr>
<tr>
<td>D</td>
<td>41.9±9.1</td>
<td>50.8±10.2</td>
</tr>
</tbody>
</table>

Table 1 - Effect of operation conditions over lubrication level [R] (in percentage) after reaching regime condition and time delay [D] (in seconds) to reach lubrication regime condition.

(*) Note: LMO (mineral oil VG ISO 10) and SMO (mineral oil VG ISO 22) tested with CFC 12; POE (polyol ester oil VG ISO 10) tested with HFC 134a.

In all the experiments, the scanning curves showed variable degrees of systematic lubrication loss in a specific position of the piston course, as can be seen in the figure 2. An electromagnetic position detector was assembled on the big end of the connecting rod, allowing to identify the position of lubrication loss as the region close to the valve plate. This behavior does not impair wear performance, and can be explained by a very little delay of the suction valve to open and lubricate the piston with the oil plus refrigerant mixture.

DISCUSSION OF RESULTS

According to the table 1, there was a little tendency of increase of the parameter [R] in function of the stop period, what can be due to oil cooling during the stops. The decrease of [R] with the increase in compressor housing temperature derives from viscosity reduction. The comparatively worse results obtained with the POE oil (only 58.4% lubrication efficiency) were unexpected, because this kind of lubricant usually present good performance in wear.

The high standard deviation among the values of time delay [D] for reaching regime arises from observed instabilities in the lubrication film regeneration just after the start. The increase of this parameter with the stop period is in accordance to the expected, because the lubricant film breakdown is progressive with the stop time. The results also demonstrated that the viscosity loss caused by increasing housing temperatures accelerates the loss of lubrication film during the stop, consequently improving the time delay [D].
CONCLUSIONS

The experiments allowed to evaluate the effects of compressor stop period, housing temperature and type of lubricant over lubrication efficiency between piston and cylinder in regime conditions. It was also studied the influence of these parameters on the delay time for regenerating the lubricant film after a period of stop.

The lubrication curve shape indicated some lubrication loss when the piston is close to the valve plate, due to a delay of the suction valve to open and supply the oil / refrigerant mixture to the cylinder. The curves showed some instability in the lubrication film regeneration just after the compressor start.

ACKNOWLEDGMENTS

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REFERENCES


Figure 1 - Electrical connections scheme.

Figure 2 - Aspect of the scanning curve.

Figure 3 - Time delay for lubrication film recovery higher in the curve on the left than in the one on the right.