Grease Test System for Improved Life of Ball and Roller Bearings

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For-Life Lubrication, Ball Bearing, Test System, Grease Life

INTRODUCTION
A test system using the FE9 tester was developed for the mechano-dynamic testing of lubricating greases for rolling bearings. The German standard DIN 51 821, Parts 1 and 2 (1), (2), are working papers for this test system. The subject of the present paper is the assessment of the rolling bearing grease life with this system. It describes the structure and the mode of operation of the rig and the method of interpretation of test results. The grease life is evaluated for two separate ranges, in the range above 100°C and in the range below 100°C. To ensure the optimum lubrication of rolling bearings in both ranges, the test results must be applicable to practical conditions. The grease life values obtained with the test rig corresponded to or even exceeded the normal lubrication intervals. The grease lives reached with an appropriate selection of bearing type and design and under good lubricating conditions showed that for-life lubrication was possible even under extremely punishing operating conditions.

MECHANO-DYNAMIC TESTING OF LUBRICATING GREASES

Lubricating greases for rolling bearings are subjected to chemico-physical and mechano-dynamic tests. The test results are used to determine their application ranges. The combinations of operating conditions which are important for a particular grease must be taken into account, such as speed, load, and temperature, as well as bearing type and size, and the surrounding structure. Even when only the most important combinations are selected, the expenditure required for testing is rather high. Furthermore, the tests must be repeated several times in order to get statistically reliable results.

The tests should not take too much time and should include at least one extremely exaggerated parameter while all other conditions are normal. This measure keeps testing time and cost within acceptable limits. Of course, test conditions which deviate from practical conditions may impair the transfer of results to the practice. Deviating test conditions are only permissible if their effect on the result can be estimated fairly well.

Lubricating greases for rolling bearings must be tested with rigs which use rolling bearings as test elements. Test results obtained with model test rigs cannot be transferred to rolling bearings without restrictions (3).

All tests described in the following were made with angular contact ball bearings with a bore diameter of 30 mm. These bearings have proven to be suitable for evaluating lubricating greases.

FE9 ROLLING BEARING GREASE TESTER ACCORDING TO DIN 51 821, PART 1

The FE9 tester, shown in Fig. 1, was developed for the mechano-dynamic testing of rolling bearing lubricating greases of NLGI No. 1–4. Angular contact ball bearings similar to the 7206C were used as test bearings (4). A constant test bearing geometry and design are ensured, and the materials used for the bearing components are also kept constant. The bearing number is Z-Nr. 529 689. Test conditions and mounting arrangements can be varied, as listed in Table 1 and illustrated in Figs. 2–4.

CONSTRUCTION OF THE TEST RIG

The tester is equipped with five identical test units. The construction of a test unit is shown in Fig. 2. The shaft (2) is supported in the housing (1) by the test bearing (5) and the auxiliary bearing (6). The bearings, which are of the same size, are arranged opposite each other. The shaft nut (5) retains both bearings on the shaft. The test bearing must be mounted in such a way that the large shoulder of the inner ring faces the shaft nut and the large shoulder of the outer ring faces the test head (11). A central oil plant supplies all auxiliary bearings with oil. The axial test load is applied with Belleville springs (6) and a preloading device (7). The length of the back-stop (8) for the preloading device is determined after the Belleville springs have been calibrated. A multiple-speed motor (9) drives the shaft at the selected speed via a belt. The test head is electrically heated, and the temperature is measured by a resistance thermometer and controlled by a thermostat. The selected temperature can be maintained up to 250°C. The heat is retained by an insulation hood (13) around the test head and electric resistance heater (10). The mounting space is closed with the housing cover (12). The bearing temperature is constantly monitored with a thermoelectric couple which is pressed against the bearing outer ring by means of a spring.

Figure 2 shows test Variation A. The test bearing is unshielded on both sides so that the grease can freely escape.

**Table 1—FE9 Testing System for Rolling Bearing Greases; Test Bearings, Test Conditions, and Variations**

<table>
<thead>
<tr>
<th>Grease for ball and roller bearings</th>
<th>Test rig</th>
<th>Test bearing:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog no. 529689, corresponds to 7206B angular contact ball bearing, may only be used once</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1**—FE9 rolling bearing grease tester.
**Fig. 2**—FE9 rolling bearing grease testing unit, Variation A. 1 = housing, 2 = shaft, 3 = test bearing, 4 = auxiliary bearing, 5 = shaft nut, 6 = Belleville springs, 7 = preloading device, 8 = back-stop, 9 = electromotor, 10 = resistance heater, 11 = test head, 12 = housing cover, 13 = insulation hood

**Fig. 3**—FE9 rolling bearing grease testing unit, Variation B. 1 = spacing washer, 2 = cover, 3 = washer

**Fig. 4**—FE9 rolling bearing grease testing unit, Variation C. 1 = spacing washer, 2 = cover, 3 = washer, 4 = angle ring

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This variation represents very punishing operating conditions for the bearing with regard to grease retention. Figure 3 shows test Variation B. A cover (2) is arranged in front of the bearing, and a washer (3) is set behind it. They contact the outer ring face and form a narrow gap with the rotating shaft. The grease is well retained in the bearing. A spacing washer (1) must be inserted between shaft shoulder and shaft out.

Figure 4 shows test Variation C. It has an angle ring (4) instead of the cover shown in Variation B. Additional lubricating grease can be put near the test bearing into the space formed by the angle ring.

TEST PROCEDURE

The test bearing which has been filled with 2 g of lubricating grease is mounted and loaded with the axial load \( F_a \). When the machine is started at the selected speed \( n \), the resistance heating is also started. The test temperature is set at the thermostat. The test run is stopped when the lubrication has deteriorated to such an extent that for at least six seconds, the friction moment increases to twice the friction moment at steady state. Such an increase of energy consumption is usually caused by testing bearing failure. The DIN standards (1), (2) specify details on the appropriate preparation of test bearings, test rig, grease fill, and test procedure.

EVALUATION OF RESULTS

A minimum of five test runs is required to judge the lubricating grease. The stressing periods of the five bearings or the grease lives obtained in the test runs are entered in a Weibull failure distribution diagram, shown in Fig. 5, in the sequence of increasing grease life. The failure probability is calculated as follows:

\[
\text{Failure probability} = (i - 0.3)(n + 0.4)
\]

where

- \( i \) = failure number of bearing (1st, 2nd, etc. to fail)
- \( n \) = total number of test bearings, five in the case described

By connecting the points, a nearly straight line is obtained in the Weibull diagram. The \( F_0 \) and \( F_0h \) values, i.e. the grease lives at 10 percent and 50 percent failure probability can be read from this line. The test conditions are noted as follows:

- Test DIN 51 821-02
- \( F_a = 1,500 \) N / 6,000 - 140
- DIN sheet variation axial speed temperature load [N] [min\(^{-1}\)] [°C]

The precision of this method was ascertained in cooperative tests. The individual results obtained in one laboratory under identical test conditions deviate by a maximum of 10 percent from the arithmetic average of results. A deviation of the results by 55 percent must be taken into account with two different laboratories.

GREASE LIFE AT HIGH TEMPERATURES

A reliable lubrication of greased bearings is ensured only if the grease is exchanged before the grease life has terminated or if grease is replenished in time, after approximately half the grease life.

In the temperature range from 100° to 200°C, grease life can be determined with the FE9 tester in a fairly short time. Tests run at various temperatures show the effects of temperature changes on the grease life, illustrated in Fig. 6. The results recorded were obtained with the standard grease L71, made of lithium soap and mineral oil, with \( n = 76 \) mm/h, and classified as NLGI No. 3. Limits for the application of current lubricating greases were assessed from the multitude of test data available, and entered into the same diagram.

The lower limit is formed by greases which were developed for special applications, e.g. high speeds, without considering their heat resistance. The upper limit is formed by greases which have either a heat-resistant base oil or a heat-resistant thickener, or both.

The grease lives obtained with test Variation B are approximately the same as those obtained with Variation A, and some of them are higher. The decisive criterion is whether the grease needs the retaining effect of a baffle plate as in Case B. The longest lives are obtained with Variation C, where an extra grease volume is kept in a space next to the bearing. Polyurea greases are especially suitable for Variation C. The differences between standard and special greases in the high-temperature range are remarkably large. Even standard greases of different manufacturers vary widely in their lives, up to a factor of 10.

To assess the suitability of a grease for high temperatures, the grease life values are entered in Fig. 6 and compared with the limit curves and the position of standard grease L71.

Figures 7 and 8 are also useful in judging a grease. In Fig. 7, the grease life is plotted vs. bearing temperature at varying loads, and in Fig. 8 at varying speeds. A small decrease of the grease life at an increase of the load or the speed is indicative of the suitability of a grease for the corresponding operating conditions. The life curve pattern at constant load or speed vs. temperature shows the change of suitability with increasing temperature.

1. Variation A represents the application with the bearing in the housing with free grease escape. Variations B and C are, as a rule, less critical with regard to possible starved lubrication.

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**TABLE 2—SOME GREASE LIFE VALUES OBTAINED WITH THE TEST METHOD STANDARDIZED TO DIN 51 821, PART 2 (VARIATION A, 1.5 KN, 6,000 min\(^{-1}\))**

<table>
<thead>
<tr>
<th>Lubricating Grease</th>
<th>Temp. °C</th>
<th>( F_0 ) k</th>
<th>( F_0h ) k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard grease</td>
<td>120°</td>
<td>60</td>
<td>170</td>
</tr>
<tr>
<td>lithium soap</td>
<td>140°</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>NLGI class 5</td>
<td>140°</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Special grease</td>
<td>120°</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>for high temperatures</td>
<td>140°</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Special grease</td>
<td>120°</td>
<td>200</td>
<td>500</td>
</tr>
</tbody>
</table>

*\( F_0h \) and \( F_0 \) are the grease lives at 10 percent and 50 percent failure probability.
Lubricating grease and rolling bearing manufacturers. In such diagrams (5), (6) and calculations (7) lubricating intervals depending on the speed index are indicated, usually on a 70°C basis. These intervals represent the minimum capacity of rolling bearing greases. Maintenance specifications which are based on such data should be sufficiently reliable, even for the use of medium-quality greases. The lubricating interval curve (8), shown in Fig. 12, provides a noticeable safety margin for the efficient L1 standard grease. The life of the L1 grease is much longer. The lubricating interval calculated by (7) in Fig. 12, corresponds to the equation for the lubricating interval

\[ t_p = 20 \cdot (4 \cdot 10^6) (a \cdot \sqrt{d} - 4d) \]

where
- \( t_p \) = lubricating interval in hours
- \( d \) = bearing bore in mm
- \( u \) = speed in min⁻¹

In the range of high speed indices, this curve is even below the lubricating interval curve recommended by the author's company; i.e. it is even safer. The lubricating interval curve determined according to (9) corresponds well to the grease lives obtained with L1 standard grease. It thus produces a suitable lubricating interval curve without a large safety margin. The reduction factors for Bearing \( h_x \), which are shown in Table 5, take into account bearing type and size.

For lubrication with standard grease, reduction factors \( f_2 = f_3 \) must be entered in the lubricating interval calculation if stresses exceed the standard range. These factors were assessed by comparing laboratory test results with experience from practical operation and are shown in Table 4. The reduced lubricating interval \( t_p \) amounts to:

\[ t_p = f_1 \cdot f_2 \cdot f_3 \cdot f_4 \cdot f_5 \cdot t_p \]

Special greases for high stressing caused by load, speed, temperature and for certain bearing types have generally longer grease lives than standard greases. Special greases

**REFERENCES**

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