The Design of Rolling Bearing Mountings

PDF 7/8:
Printing presses
Pumps
Ventilators, compressors, fans
Precision mechanics, optics, antennas

FAG OEM und Handel AG

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The Design of Rolling Bearing Mountings

Design Examples covering Machines, Vehicles and Equipment

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This publication presents design examples covering various machines, vehicles and equipment having one thing in common: rolling bearings.

For this reason the brief texts concentrate on the rolling bearing aspects of the applications. The operation of the machine allows conclusions to be drawn about the operating conditions which dictate the bearing type and design, the size and arrangement, fits, lubrication and sealing.

Important rolling bearing engineering terms are printed in italics. At the end of this publication they are summarized and explained in a glossary of terms, some supplemented by illustrations.
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Printing presses

Printing quality is created in the heart of a printing press, the printing group with its main cylinders. Plate cylinders, blanket cylinders and impression cylinders are, therefore, guided in rolling bearings which are particularly low in friction and which have a high degree of running accuracy and radial rigidity.

FAG has designed a number of highly efficient locating/floating bearing arrangements for the main cylinder bearings ranging from solutions with cylindrical roller bearings, tapered roller bearing pairs and spherical roller bearings to triple-ring eccentric bearing units.

Impression cylinders of a newspaper rotary printing press

Depending on the specific application, a variety of solutions can be adopted for supporting impression cylinders in a newspaper rotary printing press. Often the floating bearing at the operating end is a cylindrical roller bearing and the locating bearing arrangement at the drive end consists of a spherical roller bearing or a tapered roller bearing pair. The floating bearing accommodates only radial loads whereas the locating bearing takes up both radial and thrust loads. Differing spring rates (elastic deformation of rolling elements and raceways) and loads acting on the bearings can result in a differing vibration behaviour at each end of the cylinders (negative effect on printing quality).

Bearing selection

To rule out differences in vibration behaviour FAG has separated the accommodation of the radial and axial loads from the impression cylinders. At each end the radial loads are accommodated by a double-row cylindrical roller bearing FAG NN3024ASK.M.SP. A deep groove ball bearing pair 2 x FAG 16024.C3 provides axial guidance for the impression cylinder. The outer rings are radially relieved so that the ball bearings exclusively accommodate axial guiding forces in both directions. By providing identical bearing arrangements on both sides of the impression cylinder identical spring rates are obtained.

The separation of radial and thrust loads means that the radially supporting bearings are symmetrically loaded. This produces a uniform vibration behaviour on both sides of the impression cylinder.

Bearing clearance and adjustment

The low-friction precision bearings are accommodated on both sides by eccentric bushes which serve to control the "impression on" and "impression off" movements of the different impression cylinders independently of each other. This requires a high guiding accuracy and a minimal radial clearance. Heat development within the bearing is low, which helps achieve the required optimal guiding accuracy. The bearing clearance of 0...10 µm is adjusted via the tapered bearing seat. The temperature-related length compensation takes place in the cylindrical roller bearings between the rollers and the outer ring raceway so that the outer ring can be fitted tightly in spite of the point load.
The deep groove ball bearings are fitted in X arrangement with zero clearance (Technical Specification N13CA). The C3 radial clearance ensures a contact angle which is favourable for accommodating the axial guiding forces.

**Machining tolerances**

**Cylindrical roller bearings**
Inner ring: Circumferential load; interference fit on tapered shaft 1:12.
Outer ring: Point load; housing bore to K6.

**Deep groove ball bearings**
Shaft to j6 (k6), outer ring radially relieved in the housing.

**Lubrication, sealing**

The bearings are automatically supplied with lubricant. Through a circumferential groove and lubricating holes in the outer ring the lubricant is fed directly into the bearings. At the operator end the supply lines are usually connected to a central grease lubrication system. V-ring seals prevent both grease escape and dirt ingress. The bearings at the drive end are supplied with oil from the transmission oil lubrication system via feed ducts. The oil first flows through the cylindrical roller bearing and then through the deep groove ball bearing pair. At the cylinder end a pressure-relieved shaft seal retains the oil in the lubricating system.

113: Impression cylinder of a KBA Commander newspaper rotary printing press
To date it was common practice to integrate cylindrical roller bearings, needle roller bearings or other designs in a sliding bearing supported sleeve and to accurately fit this complete unit into an opening in the sidewall of the machine frame; this required an elaborate technology and was costly. Both the considerable cost and the risk of the sleeve getting jammed during the “impression on” and “impression off” movements of the blanket cylinder are eliminated by using a new triple-ring eccentric bearing unit. It offers the benefit of absolute zero clearance which is not possible with the conventional unit as the sleeve always requires some clearance. Another significant advantage is the adjustable preload which allows its radial rigidity to be considerably increased compared to bearings with clearance.

Bearing arrangement

The FAG triple-ring eccentric bearing units (floating bearings) are available both with a cylindrical and with a tapered bore. The ready-to-mount unit is based on an NN cylindrical roller bearing design which is used as a low-friction precision bearing in machine tools, and a double-row needle roller bearing which guides the eccentric ring. Axial guidance of the cylinder is provided by angular contact ball bearings (FAG 7207B) in X arrangement, or by a thrust ball bearing.

Operating data

Roll weight; press-on force; nominal speed

Bearing dimensioning

An index of dynamic stressing \( f_L \) of 4...4.5 would be ideal. This corresponds to a nominal life \( L_h \) of 50,000 - 80,000 hours. Under the given conditions the bearings are adequately dimensioned so that an adjusted rating life calculation is not required.

Machining tolerances

The inner rings are subjected to circumferential load. A tight fit is obtained by machining the cylinder journal to k4 (k5). With a tapered bearing seat, an interference fit is also obtained by axial displacement. The outer ring is mounted with a K5 or K6 fit or reduced tolerances (with a slight interference).

Lubrication, sealing

The eccentric units can be lubricated both with grease and with oil. Thanks to the favourable ambient conditions, the lubricant is only very slightly stressed so that long grease relubrication intervals and thus a long service life are possible. A non-rubbing gap-type seal prevents grease escape. With oil lubrication, the oil flows to the bearing rollers through feed ducts. Via collecting grooves and return holes the oil returns to the oil circuit.

114: Triple ring bearing for a blanket cylinder
Centrifugal pump

Operating data
Input power 44 kW; delivery rate 24,000 l/min; delivery head 9 m; speed n = 1,450 min⁻¹; axial thrust 7.7 kN.

Bearing selection, dimensioning
The impeller is overhung. The coupling end of the impeller shaft is fitted with a duplex pair of contact ball bearings FAG 7314B.TVP.UA mounted in X arrangement. The suffix UA identifies bearings which can be universally mounted in tandem, O and X arrangement. When mounted in O or X arrangement, if the shaft is machined to j5 and the housing to J6, the bearings have a slight axial clearance. The bearing pair acts as the locating bearing and accommodates the thrust \( F_a = 7.7 \text{ kN} \). The radial load \( F_r \) is approx. 5.9 kN. Since \( F_a/F_r = 1.3 > e = 1.14 \), the equivalent dynamic load \( P \) of the bearing pair
\[
P = 0.57 \cdot F_r + 0.93 \cdot F_a = 10.5 \text{ kN}
\]
Thus the index of dynamic stressing
\[
f_L = C/P \cdot f_n = 186/10.5 \cdot 0.284 = 5.03
\]
The nominal life amounts to approximately 60,000 hours. The speed factor for ball bearings
\[
f_n = 0.284 \quad (n = 1,450 \text{ min}^{-1})
\]
and the dynamic load rating of the bearing pair
\[
C = 1.625 \cdot C_{\text{individual bearing}} = 1.625 \cdot 114 = 186 \text{ kN}.
\]
The impeller end of the shaft is fitted with a cylindrical roller bearing FAG NU314E.TVP2 acting as the floating bearing. This bearing supports a radial load of approximately 11 kN. Thus, the index of dynamic stressing
\[
f_L = C/P \cdot f_n = 204/11 \cdot 0.322 = 5.97
\]
corresponding to a nominal rating life of more than 100,000 hours.

With the speed factor for roller bearings
\[
f_n = 0.322 \quad (n = 1,450 \text{ min}^{-1}),
\]
the dynamic load rating of the bearing
\[
C = 204 \text{ kN}
\]
The recommended \( f_L \) values for centrifugal pumps are 3 to 4.5. The bearings are, therefore, adequately dimensioned with regard to fatigue life. The service life is shorter if formation of condensation water in the bearings or penetration of contaminants is expected.

Lubrication, sealing
Oil bath lubrication. The oil level should be no higher than the centre point of the lowest rolling element. The bearings are sealed by shaft seals. At the impeller end of the shaft a labyrinth provides extra sealing protection.
Cylinder block A accommodates a number of pistons B symmetrically arranged about the rotational axis. Piston rods C transmit the rotation of drive shaft D to the cylinder block. They also produce the reciprocating motion of the pistons, provided that the rotational axis of cylinder block and drive shaft are at an angle to each other.

Fluid intake and discharge are controlled via two kidney-shaped openings E in pump housing F. Bore G establishes connection from each cylinder to openings E. During one rotation of the cylinder block, each bore sweeps once over the intake (suction) and discharge (pressure) openings. The discharge opening is subjected to high pressure. Consequently, the pistons are acted upon by a force. This force is carried by the piston rods to the drive shaft and from there to the drive shaft bearings.

Bearing selection

At relatively high speeds, bearings H and J have to accommodate the reactions from the calculated resultant load. The bearing mounting should be simple and compact.

These requirements are met by deep groove ball bearings and angular contact ball bearings. Bearing location H features a deep groove ball bearing FAG 6208, bearing location J two universal angular contact ball bearings FAG 7209B.TVP.UA in tandem arrangement. Suffix UA indicates that the bearings can be universally mounted in tandem, O or X arrangement.

Bearing dimensioning

Assuming that half of the pistons are loaded, piston load

\[ F_K = \frac{z}{2} \cdot p \cdot \frac{d_K^2}{4} \cdot \frac{\pi}{4} = 3.5 \cdot 10 \cdot 400 \cdot 3.14/4 = 11,000 \text{ N} = 11 \text{ kN} \]

For determination of the bearing loads the piston load \( F_K \) is resolved into tangential component \( F_{Kt} \) and thrust load component \( F_{Ka} \):

\[ F_{Kt} = F_K \cdot \sin \alpha = 11 \cdot 0.4226 = 4.65 \text{ kN} \]
\[ F_{Ka} = F_K \cdot \cos \alpha = 11 \cdot 0.906 = 9.97 \text{ kN} \]

The two components of the piston load produce radial loads normal to each other at the bearing locations. The following bearing loads can be calculated by means of the load diagram:

**Bearing location J**

\[ F_{Jx} = F_{Ka} \cdot \frac{e}{l} = 9.97 \cdot 19.3/90 = 2.14 \text{ kN} \]
\[ F_{Jy} = F_{Kt} \cdot \frac{1 + \alpha}{l} = 4.65 \cdot (90 + 10)/90 = 5.17 \text{ kN} \]
\[ F_J = \sqrt{F_{Jx}^2 + F_{Jy}^2} = \sqrt{4.58 + 26.73} = 5.59 \text{ kN} \]
In addition to this radial load $F_{rJ}$, bearing location J accommodates the thrust load component of the piston load:

$$F_{aj} = F_{Ka} = 9.97 \text{kN}$$

Thus, the equivalent dynamic load with $F_a/F_r = 9.97/5.59 > e = 1.14$ and $X = 0.35$ and $Y = 0.57$.

$$P = 0.35 \cdot F_{rJ} + 0.57 \cdot F_{aj} = 0.35 \cdot 5.59 + 0.57 \cdot 9.97 = 7.64 \text{kN}$$

With the dynamic load rating $C = 72 \text{kN}$ and the speed factor $f_n = 0.265 \ (n = 1,800 \text{ min}^{-1})$ the index of dynamic stressing

$$f_L = C/P \cdot f_n = 72/7.64 \cdot 0.265 = 2.5$$

Here the load rating $C$ of the bearing pair is taken as double the load rating of a single bearing.

**Bearing location $H$**

$$F_{Hx} = F_{Ka} \cdot e/l = 9.97 \cdot 19.3/90 = 2.14 \text{kN}$$

$$F_{Hy} = F_{Kt} \cdot t/l = 4.65 \cdot 10/90 = 0.52 \text{kN}$$

$$F_{rH} = \sqrt{F_{Hx}^2 + F_{Hy}^2} = \sqrt{4.58 + 0.27} = 2.2 \text{kN}$$

The equivalent dynamic load for the deep groove ball bearing equals the radial load:

$$P = F_{rH} = 2.2 \text{kN}$$

With the dynamic load rating $C = 29 \text{kN}$ and the speed factor $f_n = 0.265 \ (n = 1,800 \text{ min}^{-1})$ the index of dynamic stressing

$$f_L = C/P \cdot f_n = 29/2.2 \cdot 0.265 = 3.49$$

The index $f_L$ for axial piston machines selected is between 1 and 2.5; thus the bearing mounting is adequately dimensioned. Loads occurring with gearwheel drive or V-belt drive are not taken into account in this example.

**Machining tolerances**

<table>
<thead>
<tr>
<th>Seat</th>
<th>Deep groove bearing</th>
<th>Angular contact ball bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>j5</td>
<td>k5</td>
</tr>
<tr>
<td>Housing</td>
<td>H6</td>
<td>J6</td>
</tr>
</tbody>
</table>

116: Drive flange of an axial piston machine
### Axial piston machine

#### Operating data

Rated pressure $p = 150$ bar; maximum speed $n_{\text{max}} = 3,000$ min$^{-1}$, operating speed $n_{\text{nom}} = 1,500$ min$^{-1}$; piston diameter $d_K = 25$ mm, piston pitch circle = 73.5 mm; angle of inclination $\alpha = 25^\circ$; number of pistons $z = 7$; distance between load line and rotational axis $e = 24$ mm.

#### Bearing selection, dimensioning

The bearing loads are determined as in example 116.

- **Bearing location H**: Deep groove ball bearing FAG 6311
  - Index of dynamic stressing $f_L = 2.98$

- **Bearing location J**: Angular contact ball bearing FAG 7311.TVP
  - Index of dynamic stressing $f_L = 1.19$

In examples 116 and 117 the axial load is accommodated by angular contact ball bearings mounted near the drive flange end. Counter guidance is provided by a deep groove ball bearing.

To minimize shaft tilting due to the radial clearance of the deep groove ball bearing, Belleville spring washers keep the bearing under light axial preload, thus ensuring zero clearance. A comparison of the $f_L$ values determined for the two pumps shows that the pump described in example 117 is designed for only a short operating life (rating fatigue life 850 h). This life span is, however, sufficient for many applications (e.g. dump trucks).

#### Lubrication, sealing

The bearings are lubricated by leakage oil from the pump. A shaft seal is satisfactory.

#### Machining tolerances

<table>
<thead>
<tr>
<th>Seat</th>
<th>Deep groove ball bearing</th>
<th>Angular contact ball bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>h6</td>
<td>j5</td>
</tr>
<tr>
<td>Housing</td>
<td>J6</td>
<td>J6</td>
</tr>
</tbody>
</table>

117: Drive flange of an axial piston machine
The exhauster is of the double-flow type; rotor weight 22 kN; speed 1,200 min⁻¹; exhaust gas temperature approx. 180 °C.

**Bearing selection, dimensioning**

The use of plummer blocks for mounting the rotor shaft is simple and economical. The shaft diameter is dictated by strength considerations, and determines plummer block and bearing size.

The shaft is mounted on spherical roller bearings FAG 22226E.C3 fitted in housings FAG LOE226BF and FAG LOE226AL. Due to the exhaust gas temperature of +180 °C and the relatively high exhauster speed, the bearings feature an increased *radial clearance* C3. This prevents the bearings from running under preload when there are major temperature differences between inner and outer ring. In addition, cooling discs are required to limit the bearing temperature. The plummer block at the drive end is designed as the *locating bearing* with a shaft opening (design BF), and that at the opposite end as the *floating bearing* with end cap (design AL).

With the specified operating data the calculated *index of dynamic stressing* $f_L \approx 10$; an $f_L$ value of 4...5 (corresponding to 55,000...100,000 h) would be adequate. Thus, the bearings are very safely dimensioned with regard to *fatigue life*. However, premature *wear* can be caused by slippage, ending the actual *service life* of the bearings before the *calculated fatigue life* has been reached.

The plummer blocks are made of grey cast iron. The housing bodies are split to simplify mounting.

**Machining tolerances**

Shaft to m6; housing to G6.

**Lubrication, sealing**

The LOE housings feature an *oil* bath. A ring oiler supplies the bearings with *oil*. The design of the lateral housing covers (oil collecting pockets and return ducts) allows excess *oil* to return to the sump. A grease chamber is provided as an additional *sealing* between cover and labyrinth ring; the chamber is replenished with *grease* at regular intervals.

---

118: Rotor mounting of an exhauster
Gas temperature 150 °C; thrust 3 kN; operating speed 3,000 min⁻¹.

**Bearing selection**

The impeller of small and medium-sized fans is generally overhung. A particularly simple and economical arrangement is achieved by providing a one-piece housing incorporating two bearing mountings. The overhung impeller arrangement produces, however, a tilting moment from the impeller weight and unbalanced forces acting at the impeller. The radial loads resulting from this moment can be minimized by providing a large distance between the bearing locations in relation to the distance between the impeller and the first bearing location. This requirement is satisfied by plummer block housings of series FAG VR(E) (grease lubrication) or FAG VOS (oil lubrication) which were especially developed for fan applications. Since the operating speed is relatively high, bearings with a high speed suitability are used, e.g. cylindrical roller bearings for accommodating the radial loads and angular contact ball bearings for combined (i.e. radial and thrust) loads. The shaft diameter, dictated by strength considerations, is 85 mm.

The mounting consists of a plummer block housing (series VOS) for oil lubrication FAG VOB317. At the impeller end a cylindrical roller bearing FAG NU317E.M1.C3 acts as the floating bearing, at the drive end two universal angular contact ball bearings FAG 7317B.MP.UA are mounted in O arrangement. Suffix UA identifies bearings which can be universally mounted in tandem, O or X arrangement; the X and O arrangements feature a small axial clearance. The axial clearance combined with oil lubrication prevents overheating of the bearings and thus preloading.

**Machining tolerances**

Cylindrical roller bearing: Shaft to m5; housing to K6. Angular contact ball bearings: Shaft to k6; housing to J6.

**Lubrication, sealing**

*Oil lubrication*. The oil sump in the housing contains approximately 4 l of oil. Flinger rings feed the oil to the bearings. The sleeves mounted on the shaft feature flinger grooves. Oil collecting grooves and replenishable grease chambers are provided in the housing covers.
Weight of impeller 0.5 kN, weight of shaft 0.2 kN, thrust 0.3 kN; speed 3,000 min⁻¹.

Bearing selection

Since a simple and economical mounting is required, a plummer block FAG SNV120.G944AA with a self-aligning ball bearing FAG 2311K.TV.C3 is arranged at either side of the impeller. Self-aligning bearings are necessary because of the difficulty in aligning two separately mounted housings so accurately that the bores are exactly aligned.

The housing is suitable for grease replenishment (suffix G944AA). A grease nipple is provided at the housing cap and a grease escape bore at the opposite side of the housing base.

As long as the impeller is satisfactorily balanced the inner rings of the bearings are circumferentially loaded.

They are mounted on the shaft with adapter sleeves FAG H2311. However, when the imbalance forces exceed the weight of impeller and shaft the circumferential load is transmitted to the outer ring.

Calculation of the rating fatigue life shows that the bearings are more than adequately dimensioned.

The SNV housings are made of grey-cast iron. The housing bodies are split to simplify mounting.

Machining tolerances

Shaft to h9, cylindricity tolerance IT6/2 (DIN ISO 1101); housing to H7.

Lubrication, sealing

The bearings are lubricated with FAG rolling bearing grease Arcanol L71V.

The housing is sealed on each side by an FSV felt seal.
Operating data

The telescope is approximately 7 m high, 8 m long and weighs about 10 t, corresponding to 100 kN. The mirror diameter is 1 m. Due to the extremely low speed of rotation of the yoke axle (1 revolution in 24 hours), a very low and uniform bearing friction is required. Moreover, the yoke must be guided rigidly and with absolute zero clearance. Deflection of the yoke axle under the effect of the overhanging load must also be taken into account.

Bearing selection

The locating bearing at the upper end of the yoke support is a high-precision double-row angular contact ball bearing with split outer ring. Its dimensions are 600 x 730 x 98 mm. The gap width between the two outer rings is such that, when adjusting the bearing axially, a preload of 35 kN is obtained. The lower end of the yoke axle is supported by a cylindrical roller bearing FAG NU1044K.M1.P51 acting as the floating bearing.

Bearing assembly

Despite the large diameter of the yoke axle, the deflection still existing would result in increased friction in the preloaded angular contact ball bearing unless suitable countermeasures were taken. The problem was solved by mounting the cylindrical roller bearing in two outer shroud rings whose inside diameters are eccentric to the outside diameter. These shroud rings are rotated in opposite directions during mounting (D) until the shaft deflection at the angular contact ball bearing location is equalized. The crowned inner ring raceway of the cylindrical roller bearing allows for slight misalignments and shaft deflections.

Machining tolerances

<table>
<thead>
<tr>
<th>Bearing</th>
<th>Seat</th>
<th>Diameter tolerance</th>
<th>Form tolerance (DIN ISO 1101)</th>
<th>Axial run-out tolerance of abutment shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular contact ball bearing</td>
<td>Shaft j5</td>
<td>IT2/2</td>
<td>J6</td>
<td>IT2</td>
</tr>
<tr>
<td></td>
<td>Housing J6</td>
<td>IT3/2</td>
<td></td>
<td>IT2</td>
</tr>
<tr>
<td>Cylindrical roller bearing</td>
<td>Shaft, tapered</td>
<td>IT2/2</td>
<td>K6</td>
<td>IT2</td>
</tr>
<tr>
<td></td>
<td>Housing taper 1 : 12</td>
<td>IT3/2</td>
<td></td>
<td>IT2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IT2</td>
</tr>
</tbody>
</table>
121: Optical telescope

Floating bearing

Locating bearing

Bending moment

Shroud rings
For radioastronomy highly sensitive radiotelescopes are used for picking up radio waves from the universe. The radiotelescope antenna is a huge reflector in the form of a paraboloid. The reflector is slewable about an axis parallel to the earth surface, the elevation axis. The whole telescope slews about the vertical axis, the azimuth axis.

**Operating data**

Total mass of the radiotelescope 3,000 tons (load approximately 30,000 kN); reflector diameter 100 m, reflector mass 1,600 tons (load approximately 16,000 kN); speed of track rollers $n_{\text{max}} = 8 \text{ min}^{-1}$, $n_{\text{min}} = 0.01 \text{ min}^{-1}$; track diameter 64 m.
The reflector is supported on two spherical roller bearings FAG 241/850BK30.P62 (static load rating $C_0 = 49,000$ kN). Each of the two bearings has to accommodate a radial load of 8,000 kN. Added to this are the loads resulting from the effects of wind and snow on the reflector. Maximum loads in the horizontal direction may be 5,500 kN, in the vertical direction 3,000 kN. Bearing centre distance is 50 m. The bearings feature tolerance class P6 and radial clearance C2 (smaller than normal clearance CN). The bearings are mounted onto the journals with tapered sleeves by means of the hydraulic method. During mounting the radial clearance is eliminated by driving in the sleeves.

**Machining tolerances**

Journal to h7 / housing to H6

**Lubrication, sealing**

The spherical roller bearings are lubricated with FAG rolling bearing grease Arcanol L135V.

The bearings are sealed by a rubbing seal.
The radiotelescope with its complete superstructure is supported on a circular track of 64 m diameter. The roller track assembly, comprising four groups of eight rollers each, transmits the weight of approximately 30,000 kN. Every second roller of a roller group is driven. Each roller is supported on two spherical roller bearings FAG 23060K.MB.C2. The bearings are mounted on the journal with withdrawal sleeves FAG AH3060H. In the most adverse case one bearing has to accommodate approximately 800 kN. With the static load rating $C_0 = 3,550$ kN the bearings are safely dimensioned. The outer rings of the bearings are mounted into the housings with axial clearance so that a floating bearing arrangement is obtained. Since low friction is required the rollers to not incorporate wheel flanges. Thus it is necessary to radially guide the superstructure on a king pin bearing. The FAG cylindrical roller bearing provided for this purpose has the dimensions 1,580 x 2,000 x 250 mm. The cylindrical roller outside diameters are slightly crowned in order to avoid edge stressing. By mounting the bearing with a tapered sleeve the radial clearance can be eliminated, thus providing accurate radial guidance.

**Machining tolerances**

Track rollers: Housing to H7  
King pin: Journal to h7/ housing to M7

**Lubrication, sealing**

The spherical roller bearings in the track rollers are lubricated with FAG rolling bearing grease Arcanol L135V. The cylindrical roller bearing for the king pin features circulating oil lubrication. Sealing by multiple labyrinths.
The data wheel is supported on a clearance-free FAG four-point bearing with the dimensions 1,300 x 1,500 x 80 mm.
Radial runout < 10 µm,
Axial runout < 25 µm.

Machining tolerances

The four-point bearing is fitted according to the actual bearing dimensions.

Lubrication, sealing

The four-point bearing is fully immersed in oil.

Sealing by a multiple labyrinth.