The Design of Rolling Bearing Mountings

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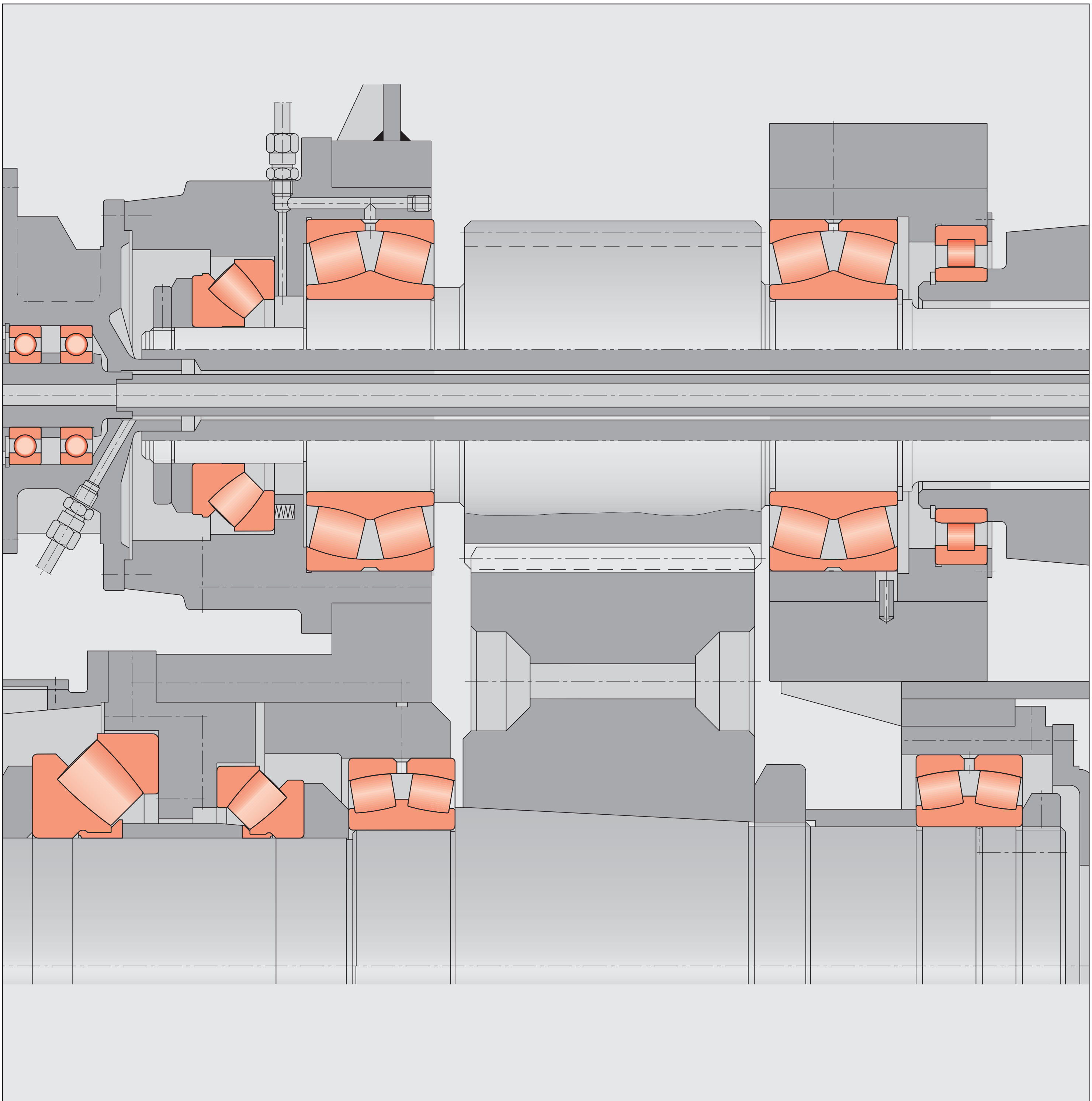
FAG
Rolling Bearings

FAG OEM und Handel AG

Publ. No. WL 00 200/5 EA



The Design of Rolling Bearing Mountings

Design Examples covering
Machines, Vehicles and Equipment

Publ. No. WL 00 200/5 EA

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Preface

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.

Contents

90 Driving axle of a construction machine

Modern construction machines feature planetary gears in the wheel hub. This yields a considerable step-down ratio in a limited space, in the example shown i_g = 6.35. As the considerable drive torque is generated immediately at the wheel, a light drive shaft is sufficient.

Planet wheel bearing arrangement

The planet wheel bearings must provide a high load carrying capacity in a limited space. This is achieved by means of assemblies where the outer ring raceway is integrated in the planet wheel. The *self-aligning* spherical roller bearing selected in the example smoothly compensates for small misalignments resulting from the deflection of the cantilever bearing journal under load. This yields a uniform contact pattern for the gearing, which is indicative of an optimal gear mesh. In the example shown the internal design of spherical roller bearing FAG 22309E.TVPB is used.

Wheel mounting

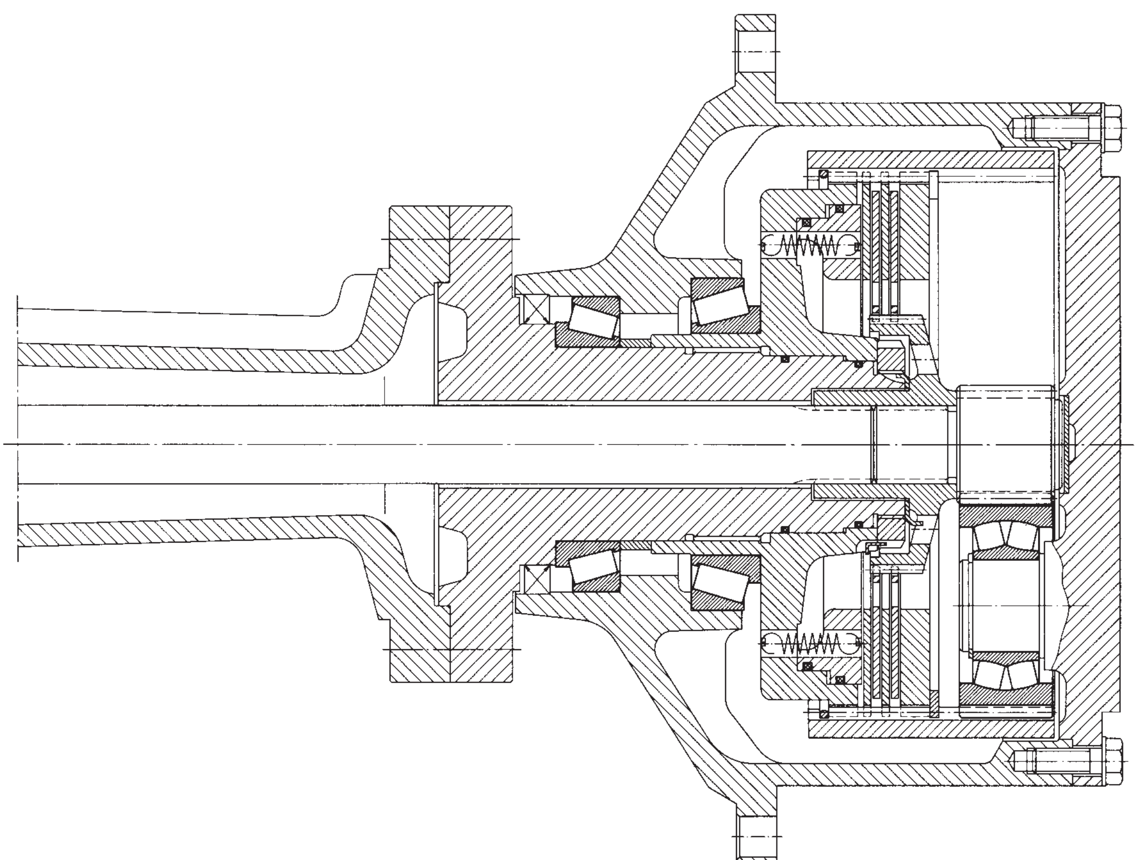
As a rule, the wheel mounting on rigid axles of construction machines consists of two tapered roller bearings which are axially *adjusted* against each other in *O arrangement* (larger *spread*) and with preload. In this way, deformations and tilting of the planetary gear are minimized and impermissible plastic deformations (brinelling marks) resulting from adverse operating conditions avoided.
The wheel bearings are tapered roller bearings FAG 32021X (in accordance with DIN ISO 355: T4DC105) and FAG 32024X (T4DC120).

Machining tolerances

The rotating outer rings of the wheel mounting are subjected to *circumferential load,* the stationary inner rings to *point load,* therefore: journal to k6; hub to N7.

Lubrication, sealing

Rolling bearings and gearing are washed around in the revolving wheel hub by the transmission *oil.*
Radial shaft *seals* protect the bearings from dirt and splash water.



90: Driving axle of a construction machine

91 Vibrating road roller

The vibrations of such road rollers are produced by an eccentric shaft.

Operating data

Speed of eccentric shaft n = 1,800 min^{-1}; radial load F_r = 238 kN; number of bearings z = 4; required *nominal rating life* $L_h \geq$ 2,000 hours.

Bearing selection, dimensioning

The centrifugal force from the imbalance weights on both sides of the roll are accommodated by two bearings each. The *equivalent dynamic load* per bearing is:

$P = 1/z \cdot F_r = 1/4 \cdot F_r = 59.5$ kN

For the above conditions, an *index of dynamic stressing* f_L = 1.52 and a *speed factor* of f_n = 0.302 are obtained. The adverse *dynamic stressing* is taken into account by introducing a supplementary factor f_z = 1.2. Thus, the required *dynamic load rating* of one bearing

$C = f_L/f_n \cdot P \cdot f_z = 1.52/0.302 \cdot 59.5 \cdot 1.2 = 359.4$ kN

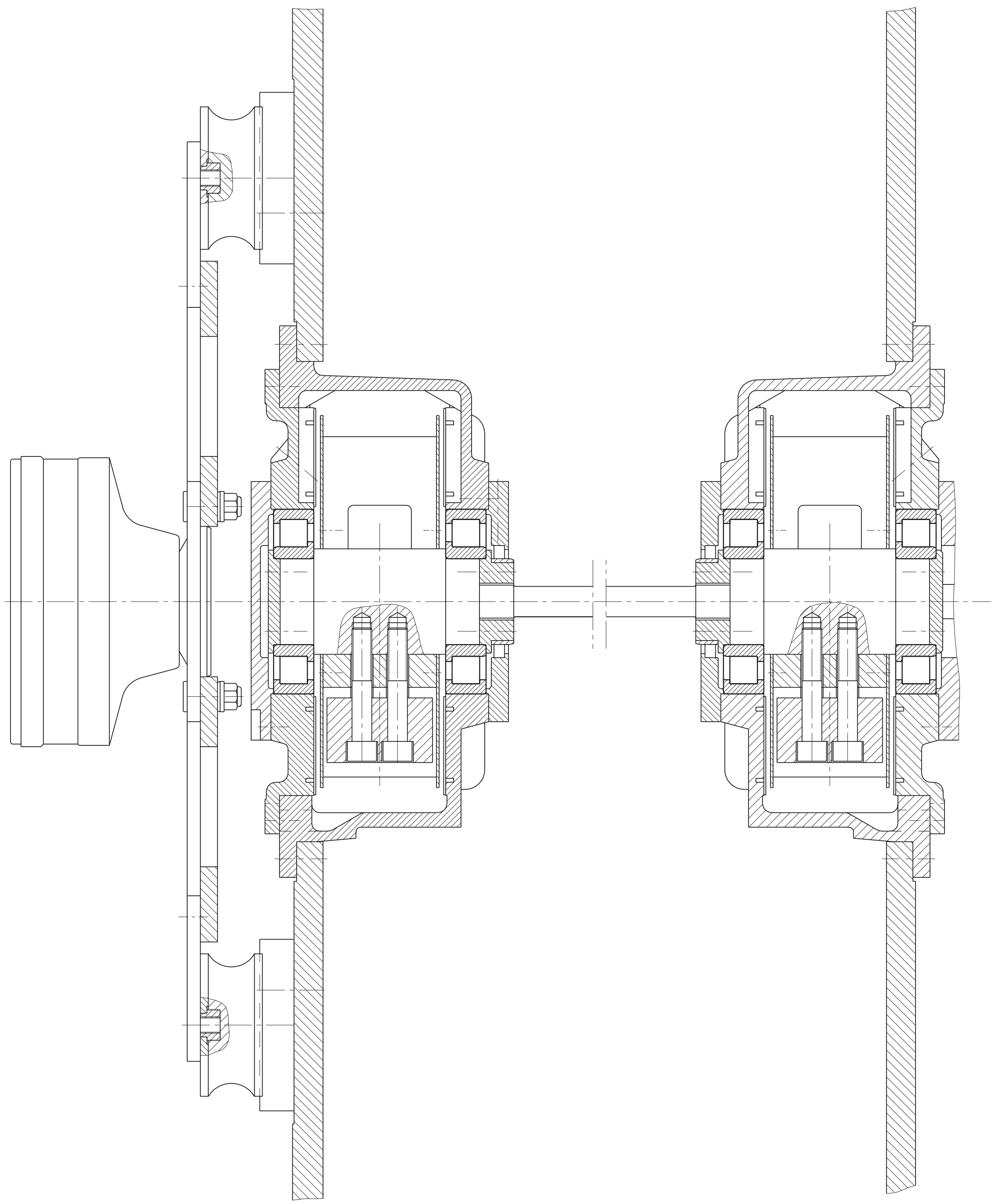
On each side of the imbalance weights a cylindrical roller bearing FAG NJ320E.M1A.C4 (*dynamic load rating* C = 380 kN) is mounted. Due to the vibratory loads the bearings are fitted with an outer ring riding *machined* brass *cage* (M1A). The misalignment between the two bearing locations from housing machining inaccuracies is less than that permissible for cylindrical roller bearings.

Machining tolerances

In view of the vibrations it is advisable to provide tight *fits* for both the bearing inner and outer rings. Axial guidance of the eccentric shaft is provided by the lips of the cylindrical roller bearings.
Eccentric shaft to k5, housing bore to M6.

Lubrication, sealing

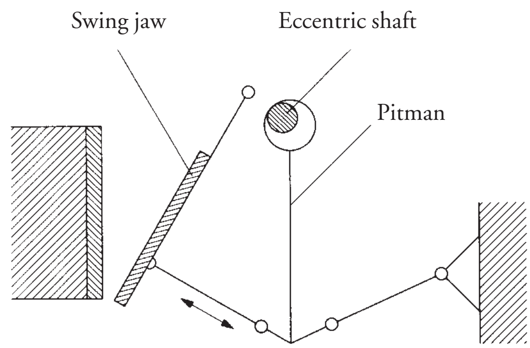
The bearings are lubricated by the *oil* splashed off from the imbalance weights. Additional guide plates improve lubricant supply to the bearings. *Mineral oils* with *EP additives* and anti-corrosion *additives* have proved to be suitable.
Internal *sealing* is provided by shaft seals, external sealing by O-ring seals.



91: Vibrating road roller

92 Double toggle jaw crusher

Double toggle jaw crushers have a large mouth opening. They are used, for example, as primary crushers to prepare ballast for road building. The coarse crushing is followed by further crushing operations until an aggregate of the size and shape required, e.g. gravel or grit, is obtained.



Operating data

Input power 103 kW; speed of eccentric shaft n = 210 min^{-1}; mouth opening 1,200 x 900 mm; eccentric radius 28 mm.

Bearing selection, dimensioning

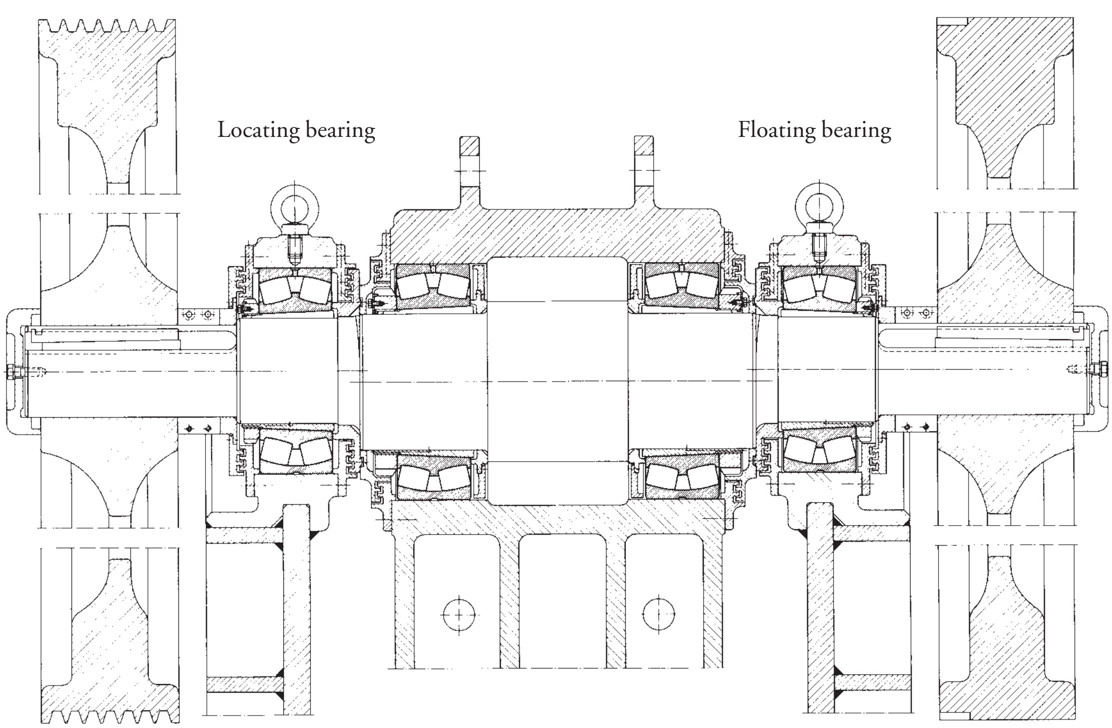
The pitman is fitted to the eccentric part of the horizontal shaft and actuates the swing jaw through a double toggle lever system. The inner bearings supporting the pitman must accommodate heavy crushing loads. The outer bearings transmit, in addition to these loads, the flywheel weight and the circumferential loads resulting from the drive. Due to the high loading and the rugged operation, spherical roller bearings are chosen. Spherical roller bearings FAG 23260K.MB are mounted as outer bearings and FAG 23176K.MB as inner bearings. The pitman bearing arrangement is of the *floating bearing* type. The outer bearing arrangement features a *locating bearing* at the drive side and the *floating bearing* at the opposite side. With an *index of dynamic stressing* $f_L \approx 4.5$ the bearing arrangement is safely dimensioned with regard to *nominal rating life.*

Machining tolerances

The bearings are mounted on the shaft with adapter sleeves FAG H3260HGJ and FAG H3176HGJ, respectively. The bearing seats on the shaft are machined to h7 with a cylindricity tolerance IT5/2 (DIN ISO 1101), and the bores of housing and pitman to H7.

Lubrication, sealing

Grease lubrication with a lithium soap base grease of *penetration class* 2 wit *EP additives* (FAG rolling bearing grease *Arcanol* L186V). The *relubrication interval* for the bearings is 2...3 months.
The bearings are *sealed* by multiple labyrinths. Once or twice a week, fresh *grease* is injected into the labyrinths.



92: Bearing mounting of a double-toggle jaw crusher

93 Hammer mill

Hammer mills are mainly used for crushing ores, coal, and stone.

Operating data

Hourly throughput 90...120 t of iron ore; input power 280 kW; rotor speed 1,480 min^{-1}, rotor weight including hammers approximately 40 kN; bearing centre distance 2,000 mm.

Bearing selection

Due to the high loads and rugged operation, hammer mill rotors are mounted on spherical roller bearings. This *self-aligning bearing* type can compensate for misalignments of the two plummer block housings, and possible rotor deflections. Two spherical roller bearings FAG 23228EASK.M.C3 are mounted, one acting as the *locating bearing,* the other one as *floating bearing.* The increased *radial clearance* C3 was selected because of the high speed. The bearing inner rings heat up more than the outer rings, causing the bearing clearance to be reduced during operation.

Bearing dimensioning

The rotor weight imposes a radial load on the bearings. Added to this are unbalanced loads and shock loads whose magnitude can only be estimated. These loads are introduced in the *nominal rating life* calculation by multiplying the rotor weight G_R with a supplementary factor f_z of 2.5...3, depending on the operating conditions. The thrust loads acting on the bearings are so small they need not be taken into account in the *life* calculation.
With the *dynamic load rating* C = 915 kN, the s*peed factor* f_n = 0.32 (n = 1,480 min^{-1}) and the rotor weight G_R = 40 kN, the *index of dynamic stressing* f_L for one bearing:

$$f_L = C \cdot f_n / (0.5 \cdot G_R \cdot f_z) = 915 \cdot 0.32 / (20 \cdot 3) = 4.88$$

An f_L value of 3.5...4.5 is usually applied to hammer mills. Thus the bearings are adequately dimensioned with regard to *nominal rating life* (L_h approximately 100,000 h).

Bearing mounting

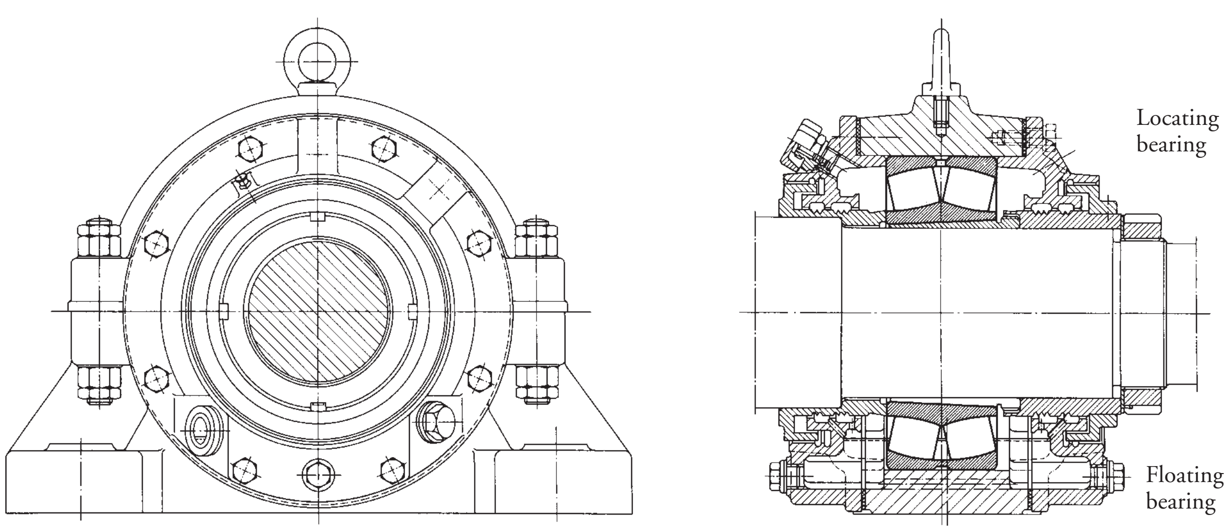
The bearings are mounted on the rotor shaft with withdrawal sleeves FAG AHX3228. They are fitted into plummer block housings MGO3228K. Both housings (open design) are available for *locating bearings* (design BF) and for *floating bearings* (design BL). The split housings of series MGO were especially developed for mill applications. They are designed for *oil* lubrication and feature particularly effective *seals.*

Machining tolerances

For mounting with sleeves, the shaft seats are machined to h7, with a cylindricity tolerance IT5/2 (DIN ISO 1101). The housing bores are machined to G6. Thus the requirement that the outer ring of the *floating bearing* must be displaceable within the housing is met.

Lubrication, sealing

For reliable operation at high speeds, the bearings are oil bath lubricated. *Grease*-packed labyrinths prevent the ingress of foreign matter. To increase the *sealing* efficiency, grease is replenished frequently. Flinger grooves on the shaft, and *oil* collecting grooves in the housing covers retain the oil within the housing.



93: Hammer mill mounting

94 Double-shaft hammer crusher

Double-shaft hammer crushers are a special type of hammer crushers or hammer mills. They feature two contra-rotating shafts to which the hammers are attached. This type is especially suitable for crushing large-sized material with a high hourly throughput and optimum size reduction.

Operating data

Hourly thoughput 350...400 t of iron ore; input power 2 x 220 kW; rotor speed 395 min^{-1}, rotor weight including hammers 100 kN; bearing centre distance 2,270 mm.

Bearing selection

Due to the rugged operation, spherical roller bearings are mounted which can compensate for misalignment between the two plummer blocks and for shaft deflections.

Bearing dimensioning

In addition to the loads resulting from the rotor weight, the bearings have to accommodate loads resulting from imbalances and shocks. They are taken into account by multiplying the rotor weight G_R by the supplementary factor $f_z = 2.5$. Small thrust loads need not be taken into account in the *life* calculation. The shaft diameter at the bearing locations determines the use of one spherical roller bearing FAG 23234EASK.M at each side. For the moderate speeds of this application normal *radial clearance* CN is satisfactory.
With the *dynamic load rating* C = 1,370 kN, the *speed factor* $f_n = 0.476$ ($n = 395\ min^{-1}$) and the rotor weight $G_R = 100$ kN, the *index of dynamic stressing* f_L per bearing:

$$f_L = C \cdot f_n/(0.5 \cdot G_R \cdot f_z) = 1{,}370 \cdot 0.476/(50 \cdot 2.5) = 5.2$$

With this f_L value, which corresponds to a *nominal rating life* L_h of approximately 120,000 hours, the bearings are very adequately dimensioned.

Bearing mounting

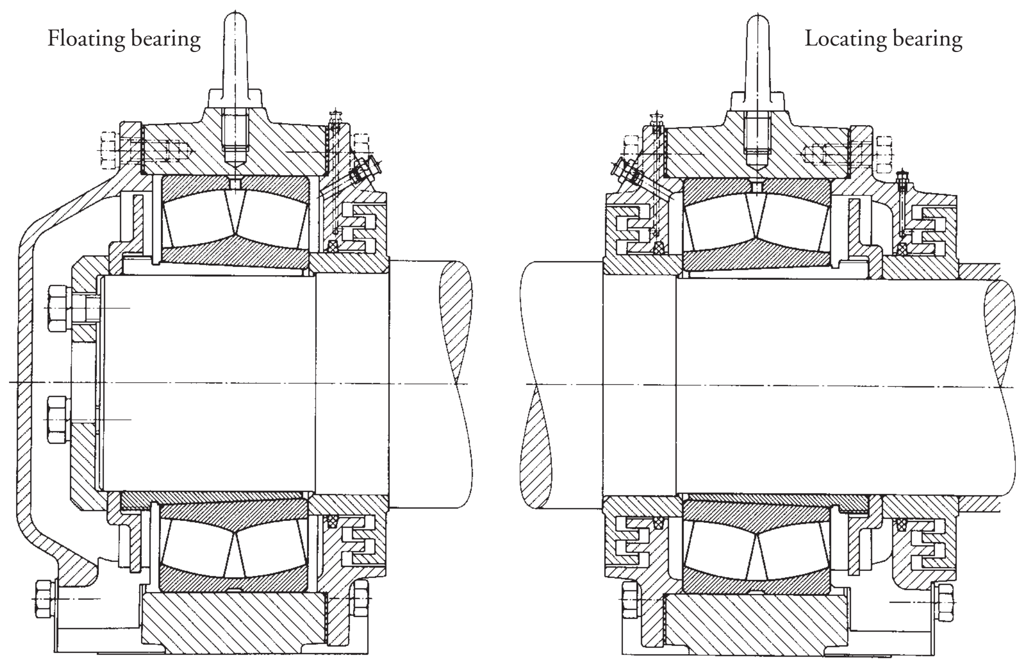
The bearings are mounted on the rotor shaft with withdrawal sleeves FAG AH3234 and mounted in FAG plummer block housings BNM3234KR.132887. One of the plummer blocks is designed as the *floating bearing* (closed on one side, design AL), the other one as the *locating bearing* (continuous shaft, design BF). The unsplit housings of series BNM were developed especially for hammer mills and crushers. They were designed for *grease lubrication* (grease valve) and feature particularly effective *seals.*

Machining tolerances

The shaft seats are machined to h7, with a cylindricity tolerance IT5/2 (DIN ISO 1101).
The housing bores are machined to H7; this allows the outer ring of the *floating bearing* to be axially displaced.

Lubrication, sealing

Grease lubrication with FAG rolling bearing grease *Arcanol* L71V is satisfactory for the speeds in this example. Relubrication is required at certain intervals. A *grease* valve protects the bearing against over-lubrication. Due to the adverse ambient conditions a double-passage labyrinth *seal* is provided. Frequent *grease* replenishment to the labyrinths improves sealing efficiency.



94: Double-shaft hammer crusher

95 Ball tube mill

Tube mills are mostly used in the metallurgical, mining and cement industries. The tube mill described is used in an Australian gold mine for grinding auriferous minerals (grain sizes 4...30 mm) into grit by means of grinding bodies (balls). The grain size of the material depends on the number of balls and the quantity of added water. The grinding drum, which revolves around its horizontal axis, is lined with chilled-cast iron plates. Charged with the grinding stock, it is very heavy.

Operating data

Drum: diameter 5,490 mm, length 8,700 mm; input power 3,850 kW; speed 13.56 min^{-1}; drum mass when loaded 400 t; maximum radial load per bearing F_r = 1,962 kN; maximum thrust load F_a = 100 kN; bearing distance 11,680 mm, throughput 250 t/h.

Bearing selection

Trunnion bearings

As the drum rotates, the bearings have to accommodate, in addition to the heavy weight, constant shock-type loads caused by the grinding bodies. Both drum trunnions are supported on spherical roller bearings of series 239, 248 or 249. The bearings compensate for static and dynamic misalignments that can be caused by misalignments of the bearing seats (large bearing distance) or drum deflections. In this example, spherical roller bearings with a tapered bore (K 1:30), FAG 248/1500BK30MB are mounted both as the *locating bearing* at the drive end and as the *floating bearing* at the feed end. The bearings are mounted on the trunnion with a wedge sleeve.

Drive pinion bearings

The drive pinion is supported on two spherical roller bearings FAG 23276BK.MB with adapter sleeve FAG H3276HG, in plummer block housings with Taconite-*seals* FAG SD3276TST.

Bearing dimensioning

The dimensioning of the drum bearings is based on half the weight of the loaded drum

(400/2 · 9.81 = 1,962 kN).

The shock loads are taken into account by a shock factor f_z = 1.5. The required *nominal rating life* is 100,000 h; this corresponds to an *index of dynamic stressing* f_L = 4.9.

The *equivalent dynamic load*

$P = f_z \cdot F_r + Y \cdot F_a = 2 \cdot 1.5 \cdot 1{,}962 + 4.5 \cdot 100 =$ 3,393 kN

With a *dynamic load rating* C = 12,900 kN the *index of dynamic stressing:*

$f_L = C/P \cdot f_n =$
$12{,}900/3{,}393 \cdot 1.31 = 4.98$ (L_h > 100,000 h).

The bearings are very safely dimensioned with regard to *nominal rating life.*

The bearings are mounted in split FAG plummer block housings SZA48/1500HF (*locating bearing*) and SZA48/1500HL (*floating bearing*). The outer rings are tightly fitted into shell sleeves (e.g. made of grey-cast iron) in the lower housing half. They facilitate compensation of axial length variations. The sliding effect is enhanced by *grease* injected into the shell sleeve/housing joint.

Machining tolerances

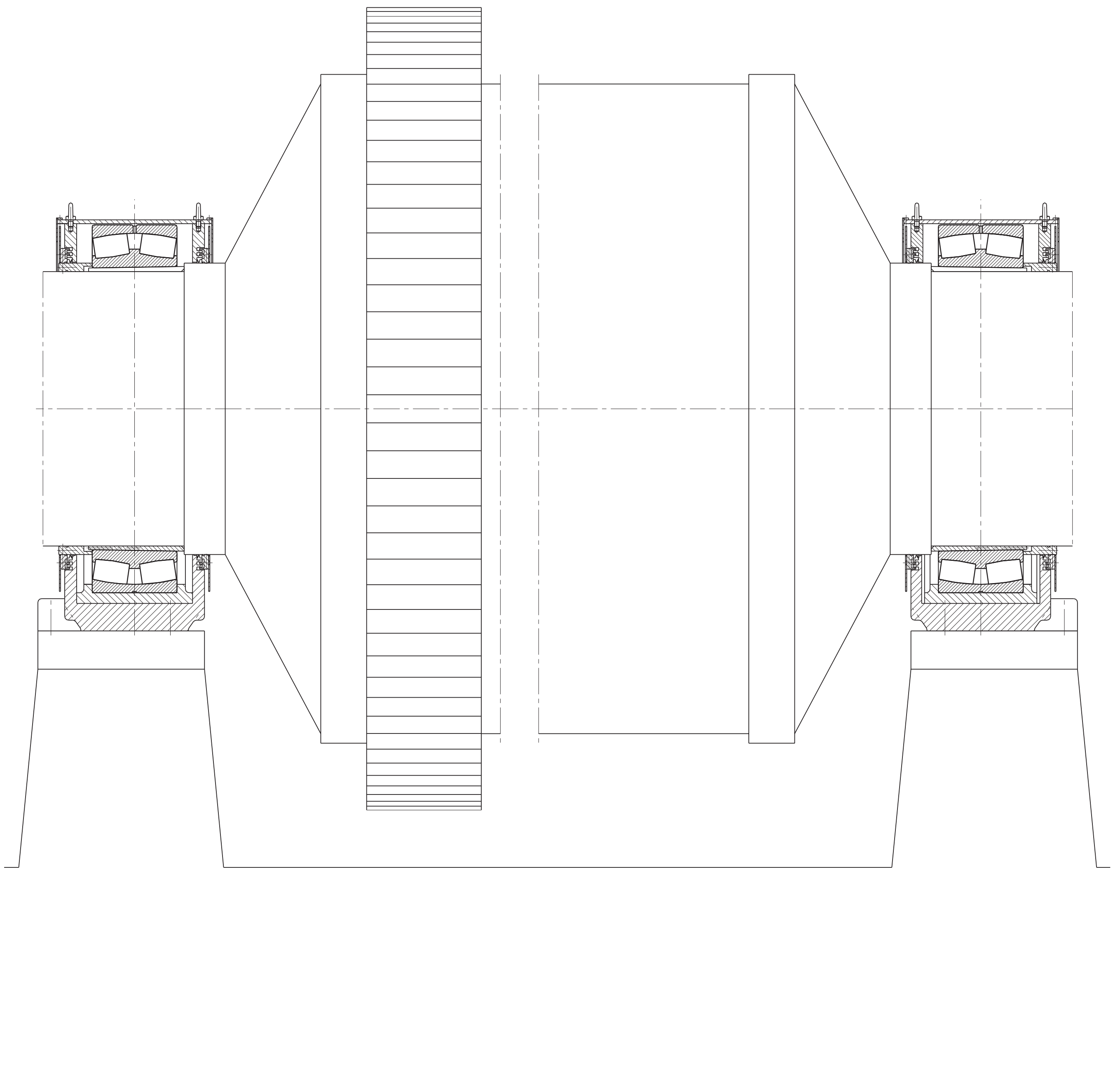
The *circumferentially loaded* inner rings are press-fitted on the trunnion. This is easily achieved by mounting them hydraulically on wedge sleeves. The *radial clearance* reduction and the *radial clearance* of the mounted bearing have to be observed (see table in FAG catalogue WL 41 520, chapter on spherical roller bearings).

The trunnions are machined to h9, with a cylindricity tolerance IT5/2 (DIN ISO 1101); the housing bores to H7.

Lubrication, sealing

Grease lubrication with a lithium soap base grease of *penetration class* 2 with *EP additives,* e. g. FAG rolling bearing grease *Arcanol* L186V. Continuous replenishment (approx. 5 g/h per bearing) ensures adequate lubrication.

The bearings are *sealed* by multiple labyrinths. Due to the extreme ambient conditions, the labyrinths are preceded by dirt baffle plates and rubbing seals (V-rings). This combination is also referred to as Taconite *sealing.* The labyrinths are also continuously replenished with approx. 5 g/h per labyrinth.



95: Ball tube mill mounting

96 Support roller of a rotary kiln

Rotary kilns for cement production can extend over a length of 150 m or more. The support rollers are spaced at about 30 m intervals.

Operating data

Kiln outside diameter 4.4 m; support roller diameter 1.6 m; support roller width 0.8 m; radial load per support roller 2,400 kN; thrust load 700 kN. Speed 5 min^{-1}; mass of support roller and housing 13 t.

Bearing selection, dimensioning

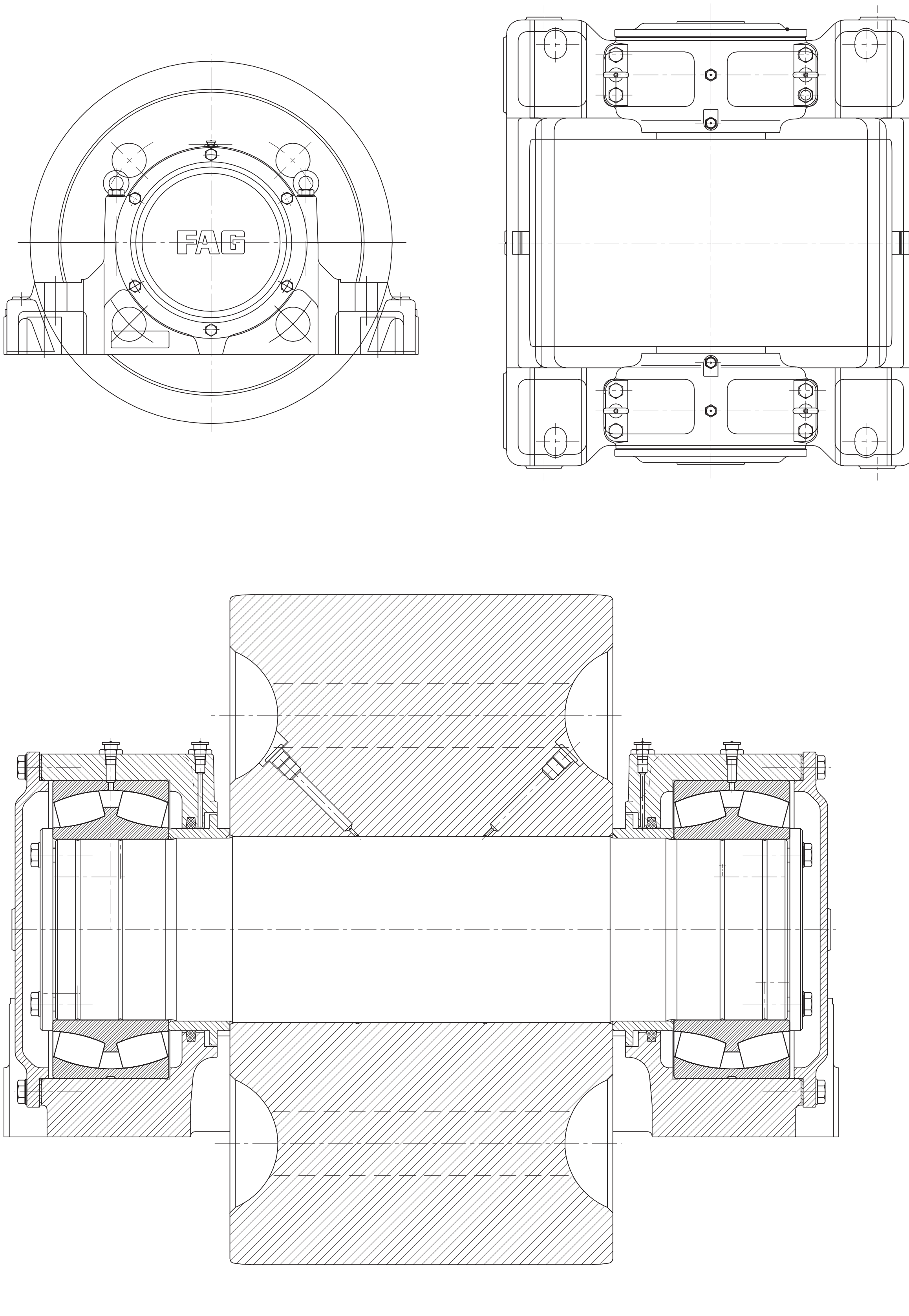
For such rotary kilns FAG offers complete assemblies consisting of a twin housing SRL, the support roller with axle LRW, and the bearings. In this example the two support-roller bearings are mounted into split plummer block housings with a common base (frame) made of grey-cast iron. Spherical roller bearings FAG 24184B (*dynamic load rating* C = 6,200 kN) are mounted in a *floating bearing arrangement,* i. e. the shaft can be displaced relative to the housing by a defined *axial clearance.*
In addition to the radial loads, the spherical roller bearings accommodate thrust loads resulting from displacements of the rotary kiln.
With an *index of dynamic stressing* f_L = 4.9, corresponding to a *nominal rating life* L_h = 100,000 h, the bearings are adequately designed.

Machining tolerances

Shaft to n6 (*circumferential load* on inner ring); housing bore to H7.

Lubrication, sealing

Grease lubrication with a lithium soap base grease with *EP additives* (e. g. rolling bearing grease *Arcanol* L186V).
At the roller side the bearings are *sealed* with felt strips and *grease*-packed labyrinths.



96: Support roller of a rotary kiln

Vibrating machines

Vibrating screens are used for conveying and grading bulk material. They operate in mines, quarries, stone crushing plants and foundries, in the foodstuff and chemical industries, and in many other preparation and processing plants.
The main vibrating screen types are: two-bearing screens with circle throw, two-bearing screens with straight-line motion, and four-bearing screens.
Vibrator motors and vibrating road rollers also come under the category of vibrating machines.

Selection of bearing type and bearing design

Rolling bearings in vibrating screens are stressed by high, mostly shock-type loads. To compound matters, the bearings, while rotating about their own axis, perform a circular, elliptical or linear vibrating motion. This results in high radial accelerations (up to 7 g) which additionally stress the bearings, and especially the *cages*. High operating speeds, usually with inaccurately aligned bearing locations, and pronounced shaft deflections are additional requirements which are best met by spherical roller bearings.

For these adverse operating conditions FAG spherical roller bearings with reduced bore and outside diameter tolerances and an increased *radial clearance* are used:
The FAG standard design E.T41A is used for shaft diameters of 40...150 mm. The centrifugal forces of the unloaded rollers are accommodated by two pressed-steel, window-type *cages* and radially supported by a *cage* guiding ring in the outer ring.
Shafts with diameters of 160 mm and more are supported on vibrating screen bearings A.MA.T41A. These bearings have a fixed centre lip on the inner ring and retaining lips on both sides. The split *machined* brass *cage* is of the outer-ring riding type.

Bearing dimensioning

Vibrating screen bearings which are comparable with field-proven bearings can be dimensioned on the basis of the *index of dynamic stressing* f_L, provided that the boundary conditions are comparable as well. f_L values between 2.5 and 3 are ideal.

97 Two-bearing screen with circle throw

Operating data

Screen box weight G = 35 kN; vibration radius r = 0.003 m; speed n = 1,200 min^{-1}; number of bearings z = 2 ; acceleration due to gravity g = 9.81 m/s^2.

Bearing dimensioning

Two-bearing screens work beyond the critical speed; thus the common centroidal axis of the screen box and the unbalanced load does not change during rotation. The bearing load due to the screen box centrifugal force is:

$F_r = 1/z \cdot G / g \cdot r \cdot (\pi \cdot n/30)^2 =$
$= 1/2 \cdot 35 / 9.81 \cdot 0.003 \cdot (3.14 \cdot 1{,}200/30)^2 = 84.5$ kN

To allow for the unfavourable *dynamic stressing,* the bearing load should be multiplied by the supplementary factor $f_z = 1.2$. Thus, the *equivalent dynamic load*

$P = f_z \cdot F_r = 1.2 \cdot 84.5 = 101.4$ kN

With the *index of dynamic stressing* $f_L = 2.72$ (L_h = 14,000 h) and the *speed factor* $f_n = 0.34$ (n = 1,200 min^{-1}) the required *dynamic load rating*

$C = f_L/f_n \cdot P = 2.72/0.34 \cdot 101.4 = 811.2$ kN

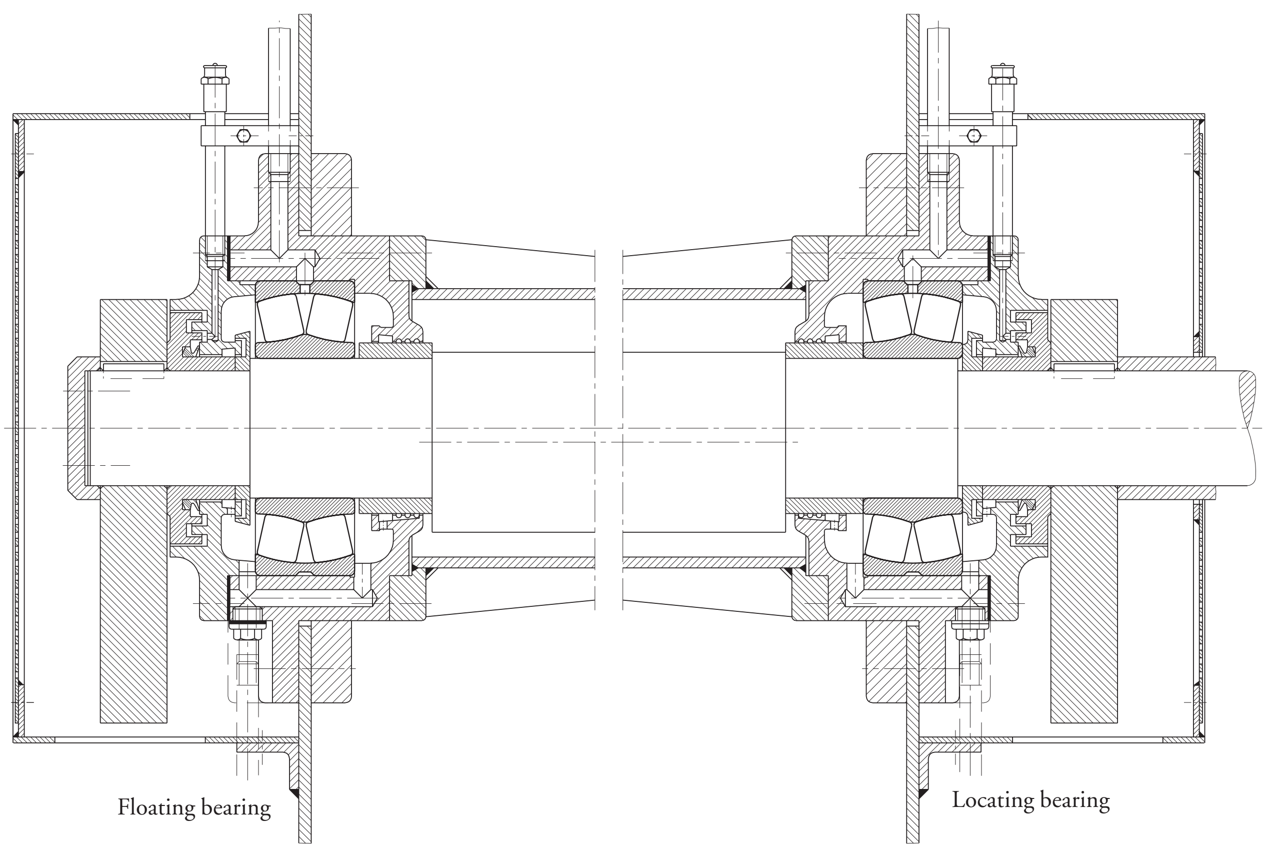
The recommended *index of dynamic stressing* f_L for vibrating screens is 2.5...3, corresponding to a *nominal fatigue life* L_h of 11,000 to 20,000 hours. Spherical roller bearings FAG 22324E.T41A with a *dynamic load rating* of 900 kN are chosen.

Machining tolerances

The eccentric shaft features two spherical roller bearings, one as the l*ocating bearing,* the other as *floating bearing.* The inner rings are *point loaded* and mounted with a shaft tolerance of g6 or f6. The outer rings are *circumferentially loaded* and *fitted* tightly in the housing bore to P6.

Lubrication, sealing

Circulating *oil* lubrication. *Mineral oils* with a minimum *viscosity* of 20 mm^2/s at operating temperature are recommended. The oil should contain *EP additives* and anti-corrosion *additives.*
Outer *sealing* is provided by a *grease*-filled, replenishable labyrinth. A flinger ring with an *oil* collecting groove prevents oil leakage. A V-ring is provided between flinger ring and labyrinth to separate *oil* and *grease.*



97: Two-bearing screen with circle throw

98 Two-bearing screen with straight-line motion

Basically, a two-bearing screen with straight-line motion consists of two contra-rotating, synchronous circular throw systems.

Operating data

Screen box weight G = 33 kN; imbalance weight G_1 = 7.5 kN; amplitude r = 0.008 m; speed n = 900 min^{-1}; number of bearings z = 4 ; acceleration due to gravity g = 9.81 m/s^2.

Bearing dimensioning

The bearing loads of a linear motion screen vary twice between the maximum value F_{rmax} and the minimum value F_{rmin} during one revolution of the eccentric shafts.

For calculation of these loads, the distance R between the centres of gravity of imbalance weight and the pertinent bearing axes is required. Weights G and G_1, amplitude of linear vibration r and distance R have the following relationship:

$G \cdot r = G_1 \cdot (R - r)$

In this example R = 0.043 m

When the centrifugal forces act perpendicular to the direction of vibration, the maximum radial load F_{rmax} is calculated as follows:

$F_{rmax} = 1/z \cdot G_1 / g \cdot R \cdot (\pi \cdot n/30)^2 =$
$= 1/4 \cdot 7.5 / 9.81 \cdot 0.043 \cdot (3.14 \cdot 900/30)^2 = 73$ kN

The radial load is at its minimum (F_{rmin}) when the directions of centrifugal forces and vibration coincide. The radial load is then
$F_{rmin} = 1/4 \cdot G_1/g \cdot (R - r) \cdot (\pi \cdot n/30)^2 =$
$= 1/4 \cdot 7.5/9.81 \cdot 0.035 \cdot (3.14 \cdot 900/30)^2 = 59.4$ kN

Since the radial load varies between the maximum and minimum according to a sinusoidal pattern, the *equivalent dynamic load* P with the supplementary factor f_z = 1.2 is thus:

$P = 1.2 \cdot (0.68 \cdot F_{rmax} + 0.32 \cdot F_{rmin}) =$
$= 1.2 \cdot (0.68 \cdot 73 + 0.32 \cdot 59.4) = 82.4$ kN

With the *index of dynamic stressing* f_L = 2.53 (L_h = 11,000 h) selected for vibrating screens and the *speed factor* f_n = 0.372 (n = 900 min^{-1}) the required *dynamic load rating*

$C = f_L/f_n \cdot P = 2.53/0.372 \cdot 82.4 = 560.4$ kN

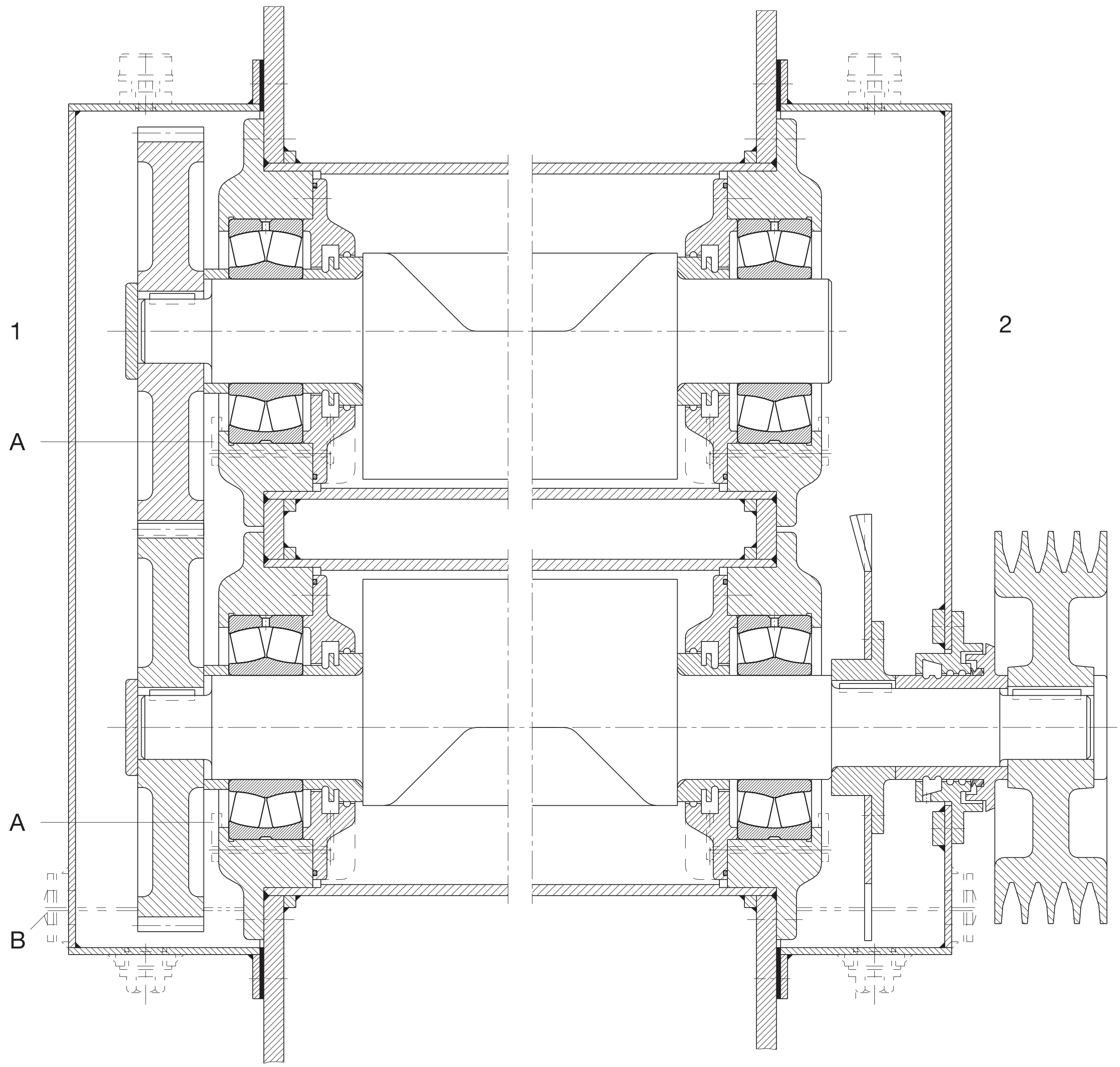
The spherical roller bearing FAG 22320E.T41A with a *dynamic load rating* of 655 kN is chosen.

Machining tolerances

The *locating bearings* of the two eccentric shafts are at the gear end, the *floating bearings* at the drive end. The inner rings (*point load*) are have loose *fits,* i. e. the shaft is machined to g6 or f6. The outer rings are *circumferentially loaded* and tightly fitted in the housing bore (P6).

Lubrication, sealing

Oil lubrication. For lubricating the spherical roller bearings at the locating end, the *oil* thrown off by the gear suffices. A flinger ring is provided for this purpose at the opposite end. Baffle plates (A) at the housing faces maintain an oil level reaching about the centre point of the lowest rollers. The oil level is such that the lower gear and the flinger ring are partly submerged. The oil level can be checked with a sight glass.
A flinger ring and a V-ring in the labyrinth provide *sealing* at the drive shaft passage.



1 Locating bearing
2 Floating bearing
A Baffle plates
B Sight glass

98: Bearing mounting of a two-bearing screen with straight-line motion

99 Four-bearing screen

The vibration radius of a four-bearing screen is a function of the shaft eccentricity. It is not variable; therefore these screens are also called rigid screens.

Operating data

Screen box weight G = 60 kN; eccentric radius r = 0.005 m; speed n = 850 min-1; number of inner bearings z = 2; acceleration due to gravity g = 9.81 m/s^2.

Bearing dimensioning

Inner bearings
For the two inner bearings of a four-bearing screen, which are subjected to vibration, the *equivalent dynamic load* P is the same as for the two-bearing screen with circular throw

$$P = 1.2 \cdot F_r = 1.2/z \cdot G/g \cdot r \cdot (\pi \cdot n/30)^2 =$$
$$= 1.2/2 \cdot 60/9.81 \cdot 0.005 \cdot (3.14 \cdot 850/30)^2 = 145.4 \text{ kN}$$

The required *dynamic load rating*

$$C = f_L/f_n \cdot P = 2.93/0.378 \cdot 145.4 = 1{,}127 \text{ kN}$$

Spherical roller bearings FAG 22328E.T41A (*dynamic load rating* C = 1,220 kN) are chosen.

Outer bearings
The stationary outer bearings are only lightly loaded since the centrifugal forces of the screen box are balanced by counterweights. Generally spherical roller bearings of series 223 are also used. The bearing size is dictated by the shaft diameter so that the load carrying capacity is high and *fatigue life* calculation unnecessary. Since these bearings are not subjected to vibration, the standard design with normal clearance is satisfactory. In the example shown spherical roller bearings FAG 22320EK (*dynamic load rating* C = 655 kN) are chosen.

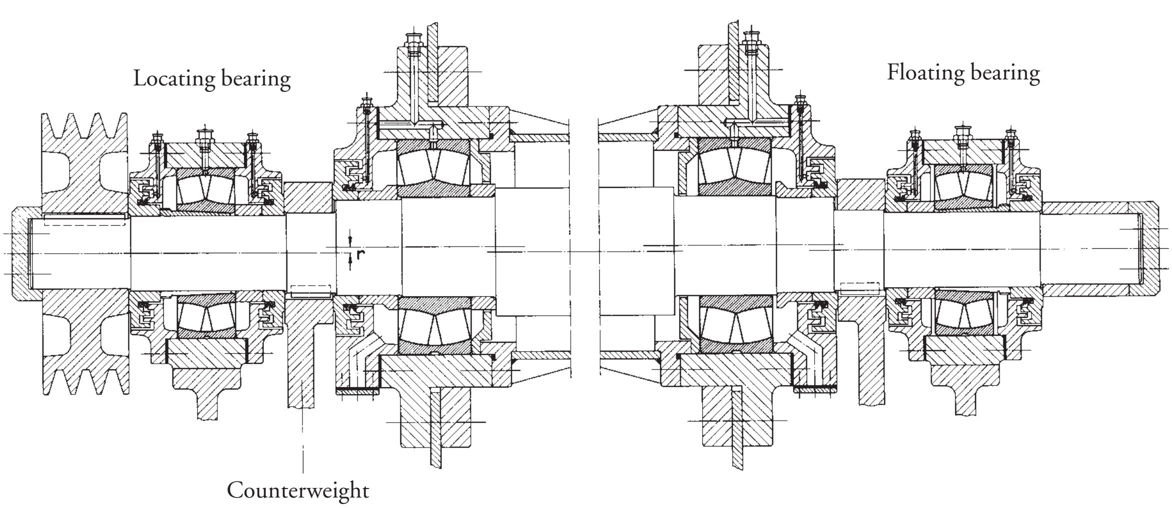
Machining tolerances

Inner bearings
The inner bearings (a *locating-floating bearing arrangement*) feature *point load* on the inner rings: The shaft is machined to g6 or f6. The bearings are fitted tightly into the housing (P6).

Outer bearings
The outer bearings – also a *locating-floating bearing arrangement* – are mounted on the shaft with withdrawal sleeves. The shaft is machined to h8, the housing bore to H7.

Lubrication, sealing

Grease lubrication with a lithium soap base *grease* of *penetration* class 2 with anti-corrosion and extreme pressure *additives.* Grease supply between the roller rows through lubricating holes in the outer rings. *Sealing* is provided by grease-packed, relubricatable labyrinths.



99: Four-bearing screen

100 Vibrator motor

The vibrations of vibrating equipment are generated by one or several activators. An electric motor with an imbalance rotor is an example of such an activator. It is referred to as a "vibrator motor". Vibrator motors are primarily mounted in machinery for making prefabricated concrete parts, in vibrating screens and vibrating chutes.

Operating data

Input power N = 0.7 kW, speed n = 3,000 min^{-1}.
The bearings are loaded by the rotor weight and the centrifugal forces resulting from the imbalances: maximum radial load on one bearing F_r = 6.5 kN.

Bearing selection, dimensioning

Due to the high centrifugal forces, the load carrying capacity of the deep groove ball bearings usually used for medium-sized electric motors is not sufficient for this application. Vibrator motors are, therefore, supported on cylindrical roller bearings. The arrangement shown incorporates two cylindrical roller bearings FAG NJ2306E.TVP2.C4; the *dynamic load rating* of the bearings is 73.5 kN.
The adverse dynamic bearing stressing by the centrifugal forces is taken into account by a supplementary factor f_z = 1.2. Considering this supplementary factor, the *equivalent dynamic load*

$P = 1.2 \cdot F_r = 7.8$ kN.

With the *speed factor* f_n = 0.26 (n = 3,000 min^{-1}), the *index of dynamic stressing*

$f_L = C/P \cdot f_n = 73.5/7.8 \cdot 0.26 = 2.45$

This f_L value corresponds to a *nominal rating life* of 10,000 h. Thus the bearings are correctly dimensioned.

Machining tolerances

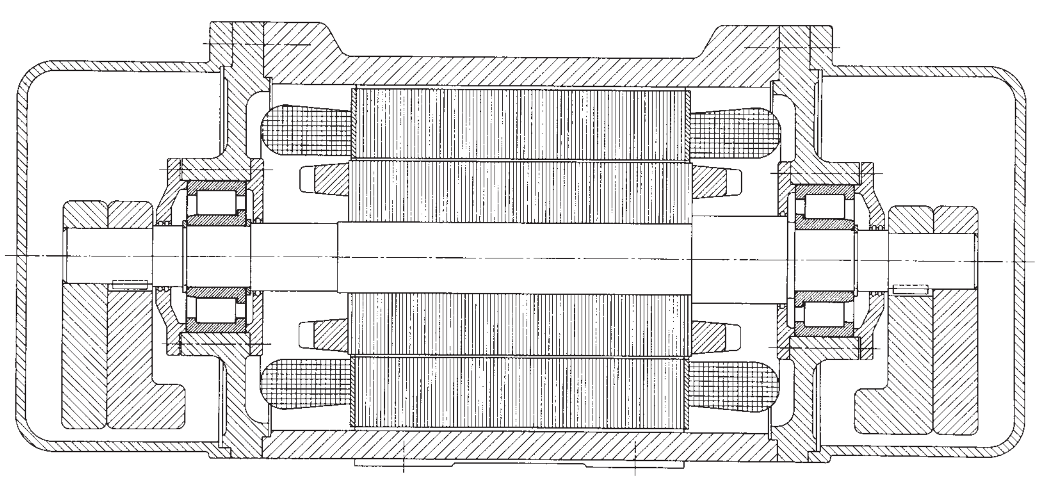
Shaft to k5; housing to N6.
The bearing outer rings carry *circumferential load* and are, therefore, tight *fits.* Since the inner rings are subjected to *oscillating loads,* it is advisable to fit them tightly onto the shaft as well. With non-*separable bearings* this requirement would make bearing mounting and dismounting extremely complicated. Therefore, *separable* cylindrical roller bearings of design NJ are used.

Bearing clearance

The initial *radial clearance* of the bearings is reduced by tight *fits.* Further *radial clearance* reduction results from the different thermal expansion of inner and outer rings in operation. Therefore, bearings of *radial clearance* group C4 (i. e. *radial clearance* larger than C3) are mounted.
To prevent detrimental axial preloading, the inner rings are assembled so that an *axial clearance* of 0.2...0.3 mm exists between the roller sets of the two bearings and the lips (*floating bearing arrangement*).

Lubrication, sealing

Both bearings are lubricated with *grease.* Lithium soap base greases of *penetration* class 2 with *EP additives* have proved successful. Relubrication after approximately 500 hours.
Since the vibrator motor is closed at both ends, gap-type *seals* with grooves are satisfactory.



100: Imbalance rotor bearings of a vibrator motor

101–103 Large capacity converters

Converters perform swinging motions and are occcasionally rotated up to 360°. Bearing selection is, therefore, based on static load carrying capacity. Important criteria in bearing selection are, besides a high *static load rating,* the compensation of major misalignments and length variations. Misalignment invariably results from the large distance between the bearings and from trunnion ring distortion and deflection. The considerable length variations are due to the large differences in converter temperature as the converter is heated up and cools down.

Bearing selection

Example 101 – showing the conventional design – features one spherical roller bearing each as *locating bearing* and as *floating bearing.* The housing of the *floating bearing* is fitted with a sleeve. This simplifies axial displacement of the spherical roller bearing. To minimize the frictional resistance, the bore of the sleeve is ground and coated with dry lubricant (molybdenum disulphide).
For thrust load calculation a coefficient of friction of $\mu = 0.1...0.15$ is used.

Example 102 shows two spherical roller bearings mounted in the housings as *locating bearings.* Axial displacement is permitted by two collaterally arranged linear bearings (rollers) which provide support for one of the two housings. With this design the amount of friction to be overcome during axial displacement is limited to the rolling contact friction occurring in the linear bearings (coefficient of friction $\mu \approx 0.05$).

Bearing dimensioning

For converters, the *index of static stressing* $f_s = C_0/P_0$ should be more than 2; see calculation example.
C_0 = *static load rating* of the bearing
P_0 = *equivalent static load*

Operating data

Calculation example: two spherical roller bearings and two linear bearings (example 102).
Locating bearing: Radial load F_{rF} = 5,800 kN;
Floating bearing: Radial load F_{rL} = 5,300 kN;
Thrust load from drive F_a = 800 kN and from axial displacement $0.05 \cdot F_{rL}$ = 265 kN;
trunnion diameter at bearing seat 900 mm.

Two spherical roller bearings FAG 230/900K.MB (*static load rating* C_0 = 26,000 kN, thrust factor Y_0 = 3.1) are mounted.

Locating bearing

$$P_0 = F_{rF} + Y_0 \cdot (F_a + 0.05 \cdot F_{rL})$$
$$= 5{,}800 + 3.1 \cdot (800 + 265) = 9{,}100 \text{ kN}$$

Index of static stressing $f_s = 26{,}000 / 9{,}100 = 2.85$

Floating bearing

$$P_0 = F_{rL} + Y_0 \cdot 0.05 \cdot F_{rL}$$
$$= 5{,}300 + 3.1 \cdot 265 = 6{,}120 \text{ kN}$$

Index of static stressing $f_s = 26{,}000 / 6{,}120 = 4.24$

Both bearings are thus safely dimensioned. Five cylindrical rollers (80 x 120 mm) each are required for the two linear bearings. The hardness of the guide rails (raceways) is 59...65 HRC.

Machining tolerances

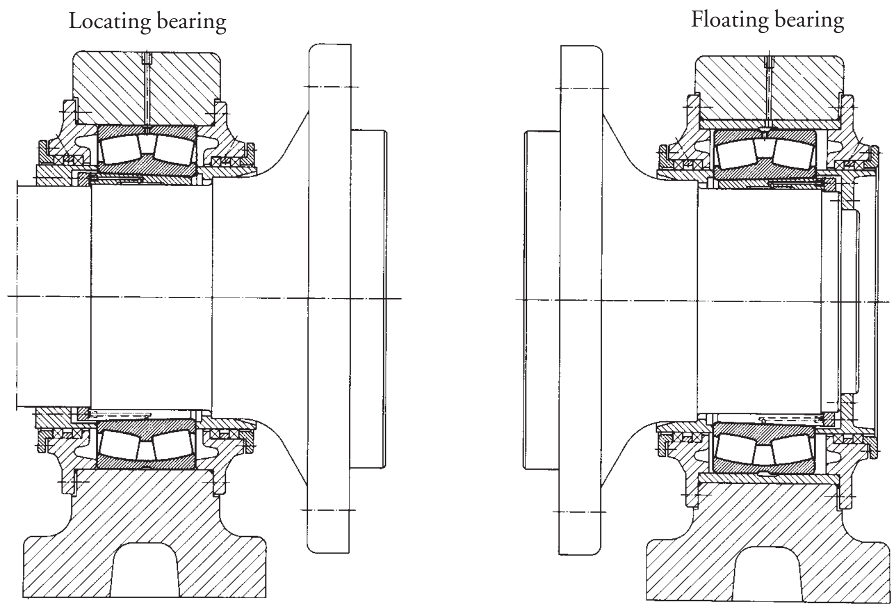
Bearings with a cylindrical bore: trunnion to m6.
Bearings with a tapered bore and hydraulic sleeve: trunnion to h7. The trunnions are machined with a cylindricity tolerance IT5/2 (DIN ISO 1101).
The support bores in the housing have H7 tolerance. Tighter *fits* should not be used in order to prevent bearing ovality which might otherwise result from the split housing.

Lubrication, sealing

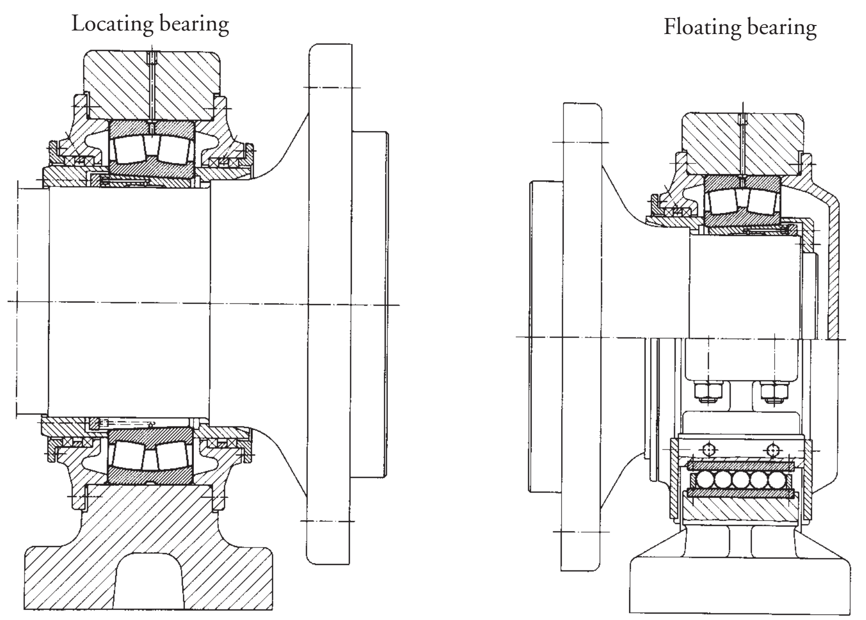
Converter bearings are lubricated with *grease.* Lithium soap base greases of *penetration* class 2 with *EP* and anti-corrosion *additives* (e. g. FAG rolling bearing grease *Arcanol* L186V) are a good choice. Efficient *sealing* is achieved by graphited packing rings.

Split rolling bearings

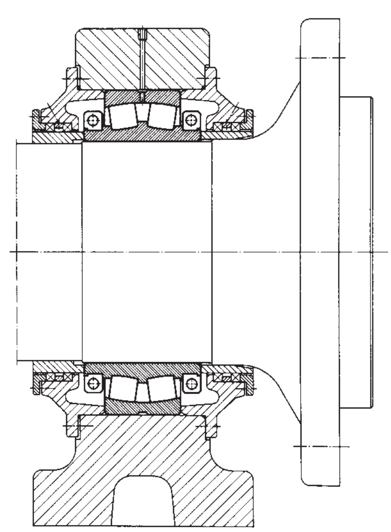
Steel mills often demand that the bearing at the converter drive end are replaceable without dismounting the drive unit. This requirement is satisfied by split spherical roller bearings (example 103).
For cost reasons, split bearings are usually used as replacement bearings.



101: Converter bearings
(two spherical roller bearings)



102: Converter bearings
(two spherical roller bearings,
two linear bearings)



103: Locating bearing end with split
spherical roller bearing

104 Roll bearings of a four-high cold rolling stand for aluminium

Operating data

Back-up rolls: roll diameter 1,525 mm
roll body length 2,500 mm

Work rolls: roll diameter 600 mm
roll body length 2,500 mm

Maximum rolling load 26,000 kN
Maximum rolling speed 1,260 m/min

Selection of the back-up roll bearings (fig. 104a)

Radial bearings
The high radial loads are best accommodated, in a limited mounting space and at high speeds, by cylindrical roller bearings. One four-row cylindrical roller bearing FAG 527048 (dimensions 900 x 1,220 x 840 mm) is mounted at each roll end. The bearings feature pin-type *cages* and reach a *dynamic load rating* of C = 31,500 kN.

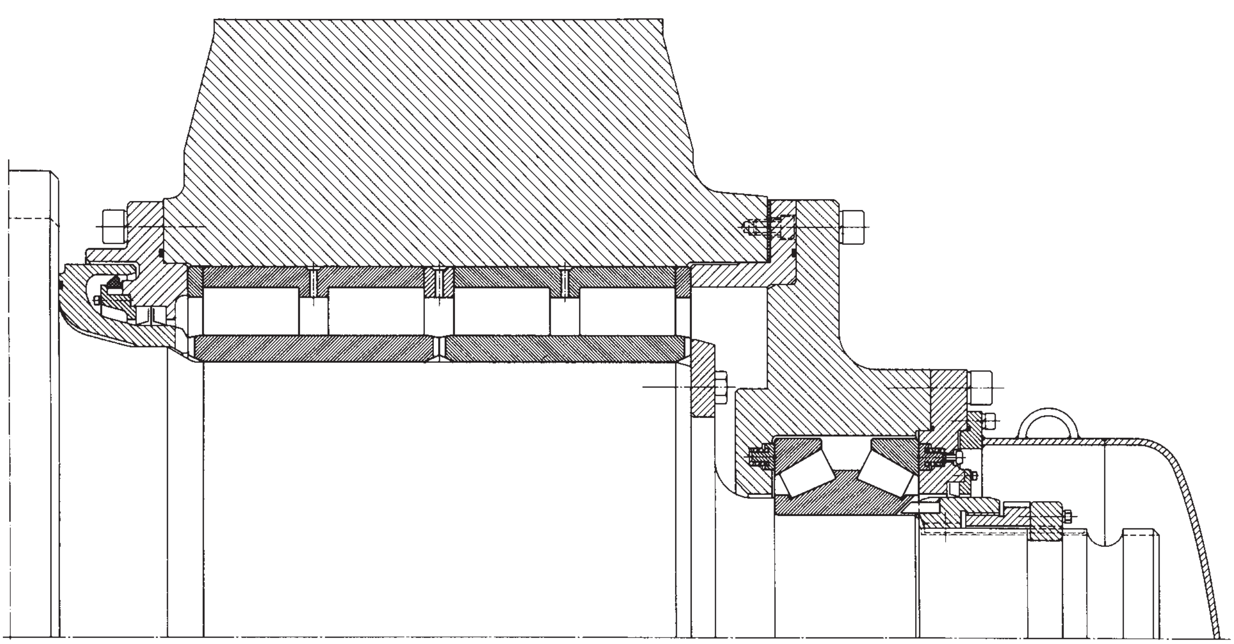
The increased *radial clearance* C4 is required as the inner rings are fitted tightly and heat up more in operation than the outer rings.

Machining tolerances:
Roll neck +0.350 / +0.440 mm, chock to H7.

Thrust bearings
Since thrust loads in strip rolling stands are low, *thrust bearings* are used that are small compared to the *radial bearings*. The back-up roll is supported at both ends by a double-row tapered roller bearing FAG 531295A (dimensions 400 x 650 x 240 mm) with a *dynamic load rating* C of 3,450 kN.

Machining tolerances: Shaft to f6.

The cups are not supported radially; axially, they are *adjusted* by means of helical springs.



104a: Back-up roll mounting of a four-high cold rolling stand for aluminium (identical bearing arrangements at drive end and operating end)

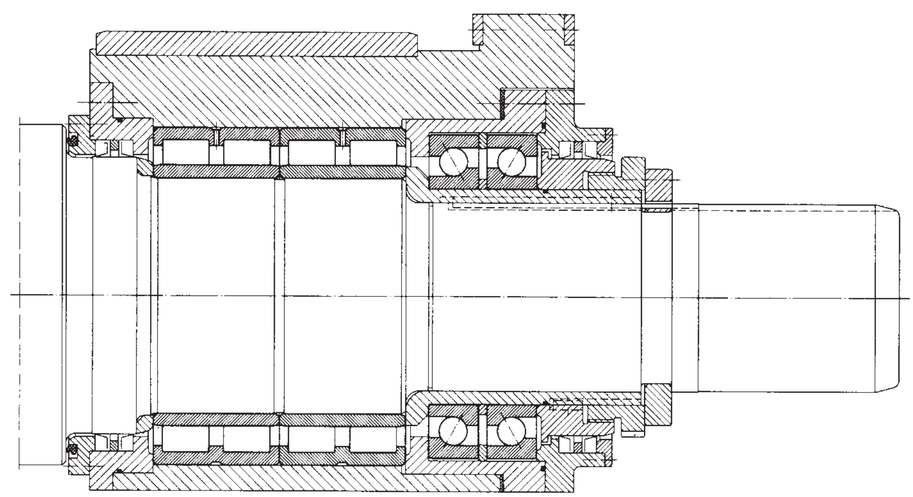
Selection of the work roll bearings (figs. 104b, c)

Radial bearings
Each roll end is supported on two double-row cylindrical roller bearings FAG 532381.K22 (dimensions 350 x 500 x 190 mm). The bearings feature reduced *tolerances* so that all roller rows are evenly loaded, *machined* brass *cages* and an increased *radial clearance* C3.
Machining tolerances
Roll neck to p6; chock bore to H6.

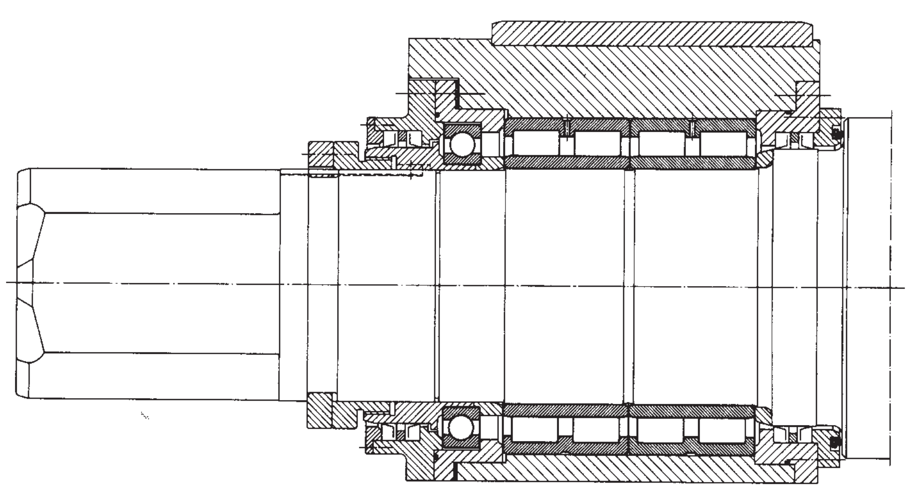
Thrust bearings
Locating bearing end (operating end): two angular contact ball bearings FAG 7064MP.UA in *X arrangement.* Any two bearings of *universal design* UA can be matched in *X or O arrangement,* yielding a bearing pair with a narrow *axial clearance.* The angular contact ball bearings accommodate the thrust loads from the rolls.
Floating bearing end (drive end): a deep groove ball bearing FAG 61972M.C3 merely provides axial guidance for the chock.
Machining tolerances: Sleeve to k6; outer rings not radially supported.

Lubrication

All bearings supporting the back-up rolls and work rolls are *oil*-mist lubricated. A high-*viscosity oil* with *EP additives* is used as the cylindrical roller bearings – especially at the back-up rolls – are heavily loaded and have to accommodate operating temperatures of up to 70 °C.



104b: Work roll bearings, operating end



104c: Work roll bearings, drive end

105 Work rolls for the finishing section of a four-high hot wide strip mill

Work roll bearings are often exposed to large amounts of water or roll coolant. In addition, considerable amounts of dirt have to be accommodated in hot rolling mills. Therefore, the bearings must be efficiently *sealed.* As a rule, they are lubricated with *grease,* which improves *sealing* efficiency. Operators of modern rolling mills endeavour to reduce *grease* consumption and damage to the environment caused by escaping grease-water emulsion.

Operating data

Roll body diameter 736 mm; roll body length 2,235 mm; rolling speed 3.5...15 m/s.

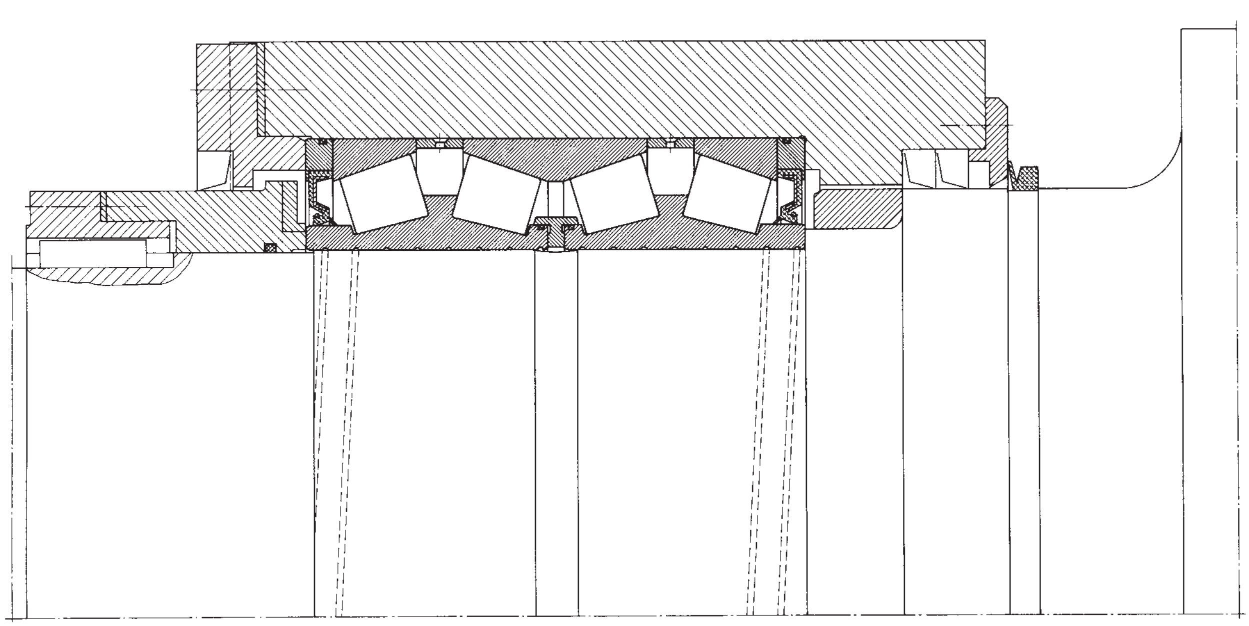
Bearing selection, dimensioning

Four-row tapered roller bearings have proved to be a good choice for work rolls. They accommodate not only high radial loads but also thrust loads, and they require only little mounting space. The bearings have a sliding fit on the roll neck, allowing rapid roll changes. In the example shown, sealed four-row tapered roller bearings FAG 563681A (dimensions 482.6 x 615.95 x 330.2 mm) are used.

The *service life* of work roll bearings is mainly dictated by the loads, rolling speed, lubrication and cleanliness. Open bearings, as a rule, do not reach their *nominal rating life* due to adverse lubricating and cleanliness conditions. On the other hand, the *modified life calculation* for sealed bearings usually yields a_{23} *factors* > 1, i. e. the *attainable life* exceeds the *nominal rating life.* In spite of the lower *load rating,* the value is generally higher than that reached by an open bearing of the same size.

Lubrication, sealing

The bearings are filled with relatively small amounts of high-quality rolling bearing *grease.* On each side they feature a double-lip rubbing *seal.* The inner lip prevents *grease* escape from the bearing; the outer lip protects the bearing from moisture that might have penetrated into the chock. No relubrication is required during rolling operation and roll change. The amount of *grease* provided during assembly usually suffices for the duration of one chock regrinding cycle, i. e. for 1,000...1,200 hours of operation. The chocks are fitted with the conventional external *seals* (collar seals). These are filled with a moderately priced, environmentally compatible sealing grease.



105: Work roll mounting for the finishing section of a four-high hot wide strip mill

106 Roll mountings of a two-high ingot slab stand or ingot billet stand

Operating data

Roll diameter 1,168 mm (46"); roll body length 3,100 mm (122"); rolling speed 2.5...5 m/s; yearly output of 1 million tons. The mill operates as a reversing stand, i.e. the rolled material moves back and forth, and the sense of rotation of the rolls alternates from pass to pass.

Roll bearings

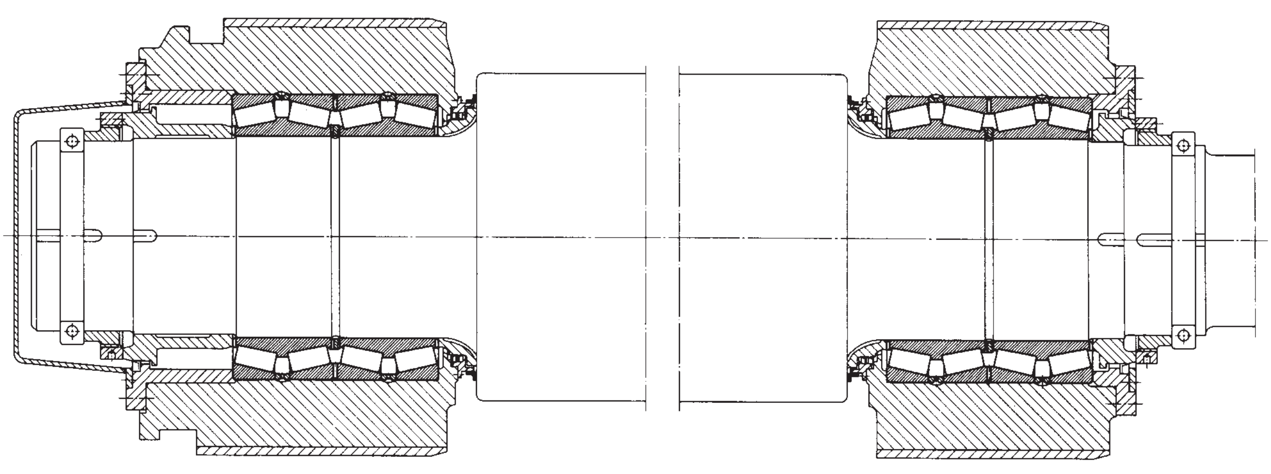
The work rolls in this example are also supported on multi-row tapered roller bearings. These bearings require relatively little mounting space and accommodate high radial and thrust loads. The rolls are supported at each end on a four-row tapered roller bearing FAG 514433A (dimensions 730.25 x 1,035.05 x 755.65 mm).

The bearing rings are loosely fitted on the roll neck and in the chocks for easy mounting and dismounting. The cones creep on the roll neck in circumferential direction. To reduce *wear* and heat generation, the fitting surfaces are usually supplied with *grease* through a helical groove in the bearing bore.

Lubrication

The tapered roller bearings are lubricated with *grease* which is continually supplied through grooves in the faces of cone and spacer ring.

Excess *grease* escapes through the bores in the central cup and in the spacers.



106: Roll mounting of a two-high ingot slab stand or ingot billet stand

107 Combined reduction and cogging wheel gear of a billet mill

Operating data

The billet mill is designed for a monthly output of 55,000 tons. The mill comprises a roughing and a finishing section, each with two vertical and two horizontal stands in alternate arrangement. The drive of the vertical stands is on top; with this arrangement the foundations are not as deep as for a bottom drive; on the other hand, the top drive involves a greater overall height.

Rated horsepower 1,100/2,200 kW;
motor speed 350/750 min^{-1}.

Bearing selection, dimensioning

Radial loads and thrust loads are accommodated separately: the radial loads by cylindrical roller bearings, the thrust loads by angular contact ball bearings and four point bearings. Cylindrical roller bearings offer the best radial load carrying capacity in a limited mounting space, thus keeping the distance between the gear shafts to a minimum. One decisive factor in the selection of the bearing size is the diameter of the individual gear shafts determined in the strength calculation. The two largest cylindrical roller bearings of the gear are situated on the cogging wheel side and have the following dimensions: 750 x 1,000 x 250 mm. Axial location of the four gear shafts is provided by one four point bearing each which are double direction angular contact ball bearings.

Compared to two angular contact ball bearings, a four point bearing offers the advantage of smaller width and, compared to a deep groove ball bearing, the advantage of smaller *axial clearance* and higher thrust carrying capacity. The use of four point bearings is, however, limited to applications where the thrust load is not constantly reversing. The bevel gear shafts feature the smallest possible *axial clearance* to ensure perfect meshing of the spiral-toothed gears. This is achieved by one duplex pair of angular contact ball bearings each on the pinion shaft and on the bevel shaft. They also accommodate the thrust load whereas the radial load is taken up by cylindrical roller bearings.

Machining tolerances

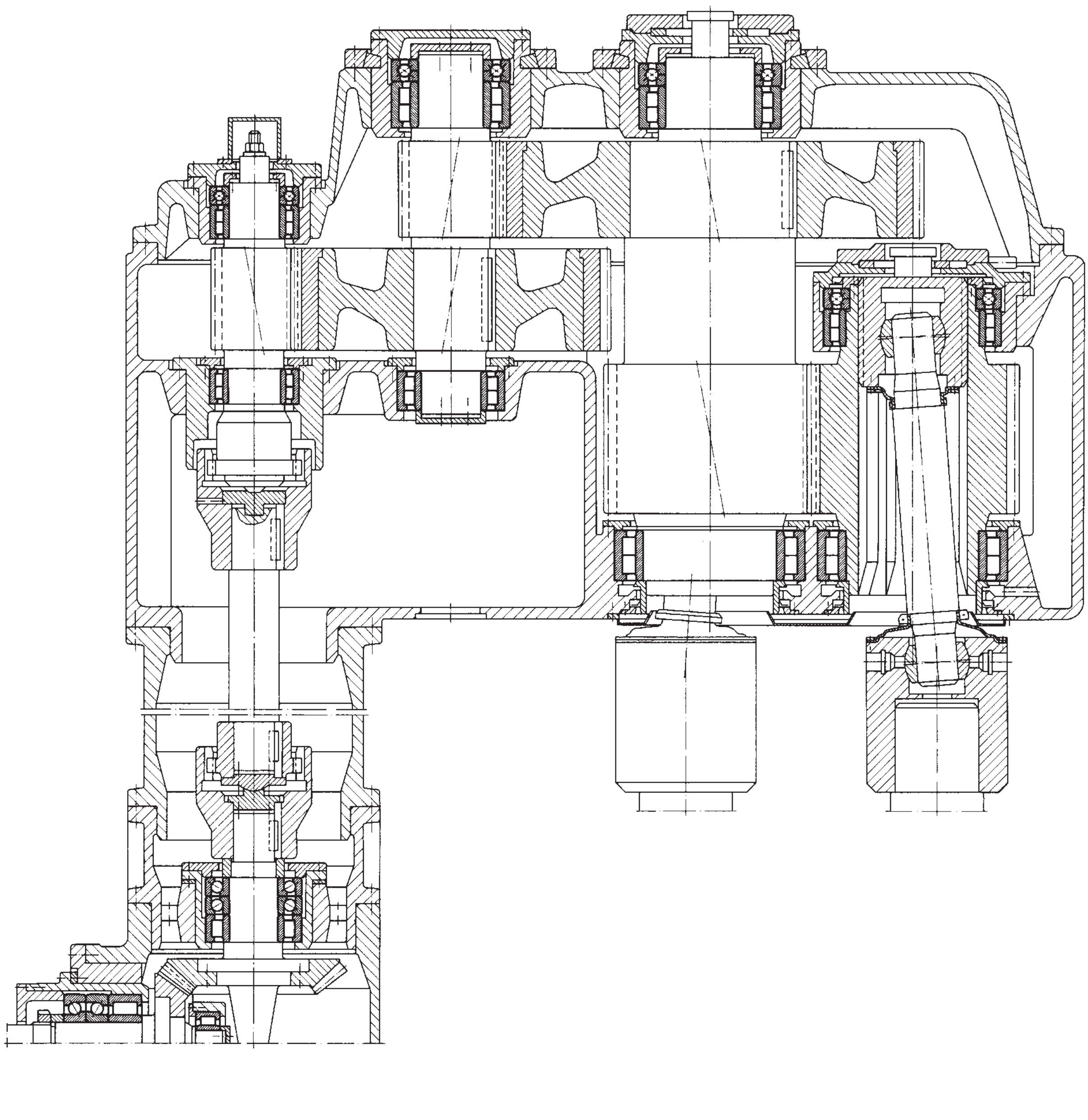
Cylindrical roller bearings: Shaft to p6; housing to H6/H7.

Four point bearings and angular contact ball bearings: Shaft to f6; housing to D10.

The outer rings of the four point bearings and angular contact ball bearings are *fitted* into the housing with clearance to relieve them of radial loads; thus, they accommodate only thrust loads.

Lubrication

Circulating *oil* lubrication. The bearings and gears share the same lubrication system. The *oil* is directly supplied to the bearings via an *oil* filter which prevents contamination of the bearings by particles abraded from the gears.

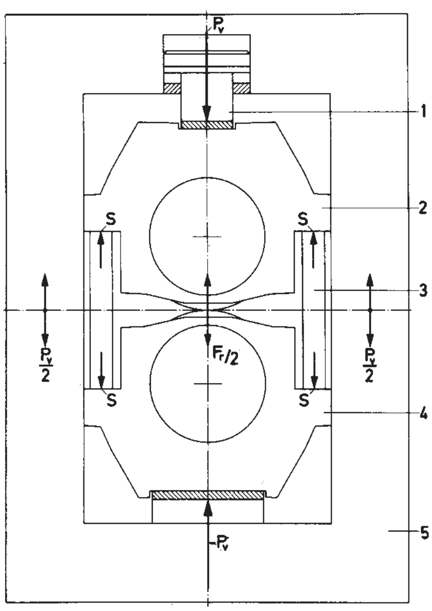


107: Combined reduction and cogging wheel gear of a billet mill

108 Work rolls of a section mill

The roll stand frames expand under the influence of high rolling loads, which can have a negative effect on the quality of the rolled material. This is usually prevented by means of elaborate roll adjustment mechanisms. Another way to compensate for the negative effect of the material's elasticity is to hydraulically preload the chocks which support the rolls and their bearing mountings against each other via the roll stands (see schematic drawing).

9 of the 13 in-line stands of a section mill are fitted with such hydraulically preloaded chocks. Five of the nine preloaded stands can also operate as universal stands. For this purpose they are equipped with two vertically arranged roll sets.



1 Hydraulic piston
2 Upper chock
3 Piston ram
4 Lower chock
5 Frame

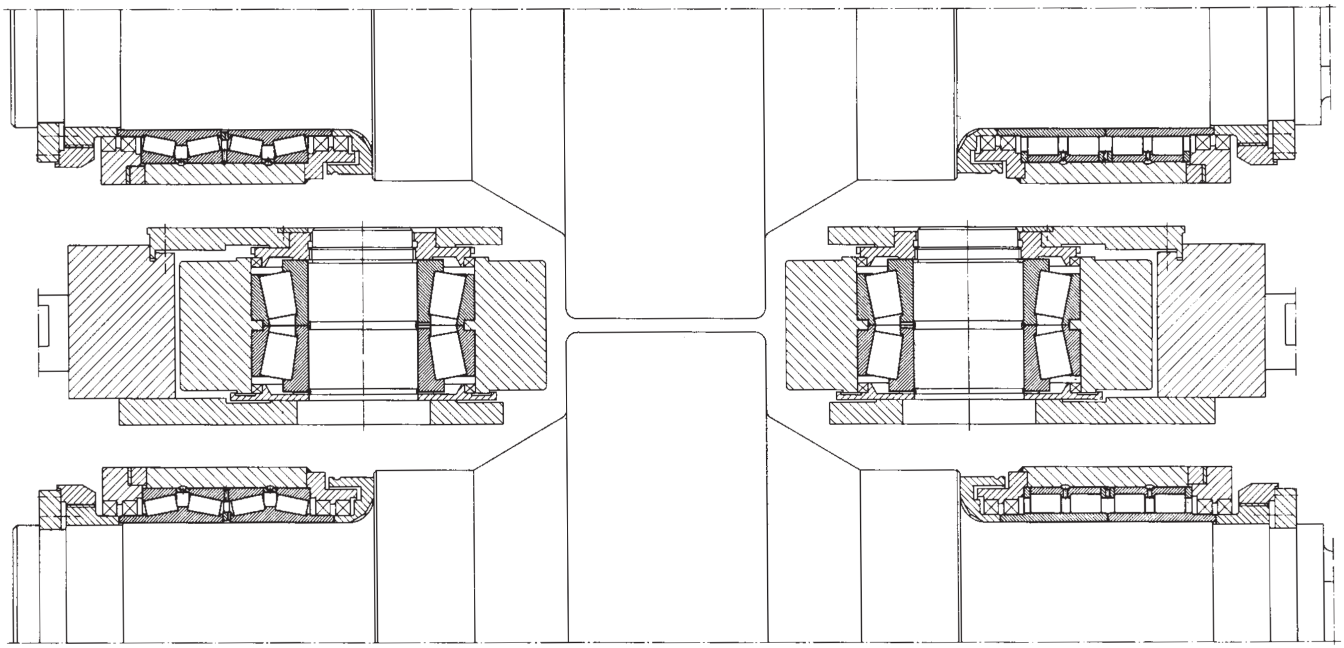
Roll neck mountings

The horizontal rolls are supported by multi-row cylindrical roller bearings and tapered roller bearings. The cylindrical roller bearings at the drive end compensate for the length variations caused by heat expansion. Compensation of length variations through the chock axially floating in the stand at the drive end is not possible with preloaded chocks.

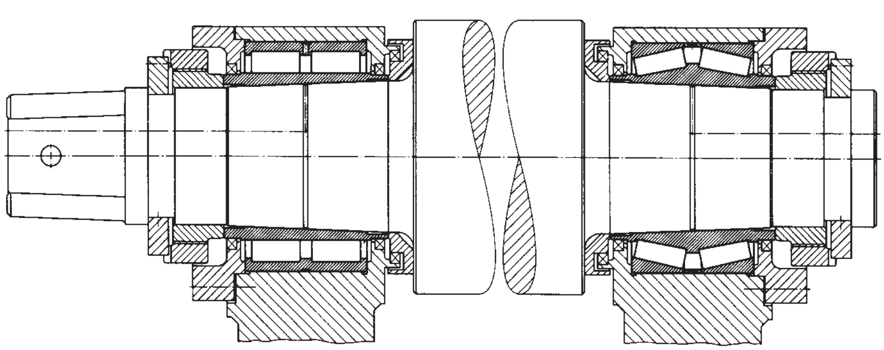
The horizontal rolls in the roughing stands, which are loaded with 3,150 kN, are supported in four-row cylindrical roller bearings and four-row tapered roller bearings of 355.6 x 257.2 x 323.8 mm (fig. a). The bearings have a loose *fit* on the roll neck (e7), which simplifies mounting.

No loose *fit* can be provided in those stands where section steels are finish-rolled as the required quality can only be achieved with accurately guided rolls. For this reason cylindrical roller bearings and tapered roller bearings with a tapered bore were selected and press-fitted onto the tapered roll neck. The hydraulic method used simplifies mounting and dismounting. Due to the lower rolling load (2,550 kN), the horizontal rolls in this case are supported by double-row cylindrical roller bearings and tapered roller bearings of 220.1 x 336.6 x 244.5 mm (fig. b).

The vertical rolls are each supported by a tapered roller bearing pair (dimensions 165.1 x 336.6 x 194.2 mm) in *O arrangement* (fig. a). The bearings sit directly on the rolls. As the rolling stock enters, the vertical rolls and their bearings are accelerated to operating speed very quickly. The tapered roller bearings are preloaded to ensure that the *rolling elements* always maintain contact with the raceways at these speeds. This is achieved by matching the tolerances of the bearings and bearing seats in such a way that the bearings after mounting have the right preload without any fitting work.



108a: Bearing mounting of horizontal rolls in the preloaded roughing stands
and bearing mounting of the vertical rolls



108b: Bearing mounting of horizontal rolls for stands in which section steel is finish-rolled

109 Two-high rolls of a dressing stand for copper and brass bands

On this dressing stand copper and brass bands with widths between 500 and 1,050 mm are rolled. The maximum initial thickness is 4 mm, and the minimum final thickness is 0.2 mm.

"Counterbending" is one special feature of this stand. The rolling forces cause an elastic deflection of the rolls. This deflection is hydraulically compensated for by counterbending forces. The counterbending forces are applied to the roll necks on both sides and outside the roll neck mounting via spherical roller bearings. This counterbending ensures a uniform band thickness over the entire band width.

Operating data

Two-high roll diameter 690/650 mm; roll body length 1,150 mm; maximum rolling speed 230 m/min; maximum rolling force 8,000 kN; maximum counterbending force 1,300 kN per roll neck.

Counterbending bearings

The counterbending forces are applied via spherical roller bearings FAG 24068B.MB.
Machining tolerances: roll neck to e7, housing to H6.

Accommodation of radial loads

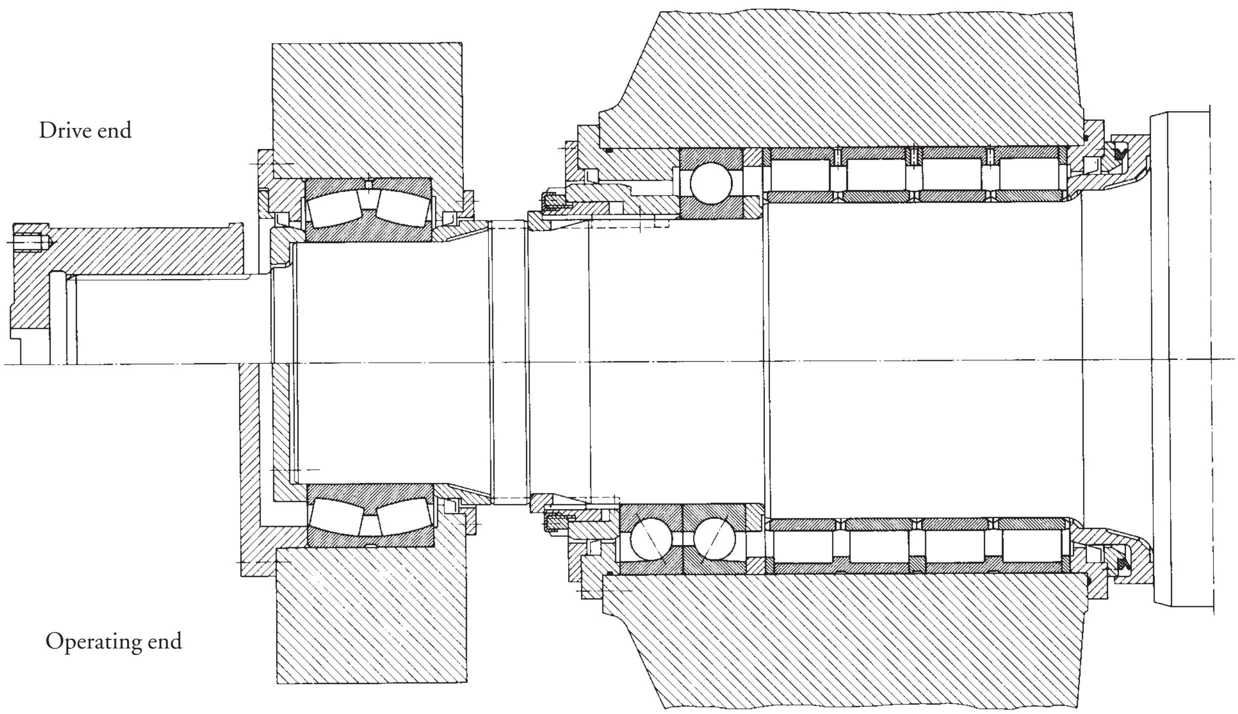
One four-row cylindrical roller bearing FAG 547961 (dimensions 445 x 600 x 435 mm) is mounted at each end. The cylindrical roller bearings are fitted with pin-type *cages* consisting of two side washers to which the pins passing through the rollers are fastened. Grooves in the inner ring faces facilitate dismounting.
Machining tolerances:
roll neck +0.160 / +0.200 mm, chock H6.

Accommodation of thrust loads

At the operating end the axial forces are accommodated by two *O arranged* angular contact ball bearings FAG 507227.N10BA (dimensions 400 x 600 x 90 mm).
At the drive end the chock is located on the roll neck by a deep groove ball bearing FAG 6080M.C3.
Machining tolerances: roll neck to f6, outer ring radially relieved.

Lubrication

The cylindrical roller bearings, like the other bearings, are lubricated with a lithium soap base *grease* with *EP additives*. They can easily be lubricated through lubricating holes and lubricating grooves in the outer rings and spacers.

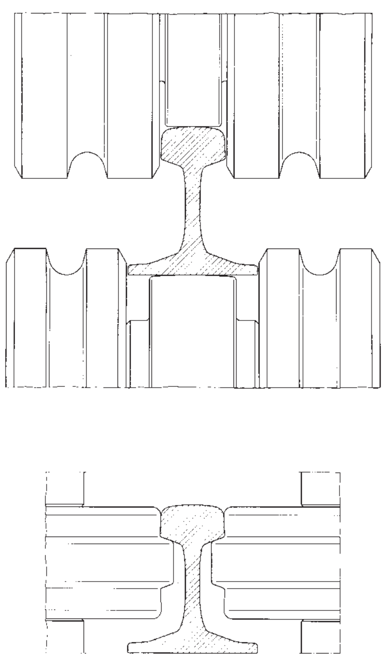


109: Two-high rolls of a dressing stand

110 Straightening rolls of a rail straightener

Rails for railway track systems or for craneways are hot rolled in rolling mills. After rolling the rails cool down on cooling beds but not uniformly, resulting in warping. Afterwards they have to be straightened in rail straighteners between horizontal and vertical rolls.

The straightening plant consists of two machines one installed behind the other. In the first machine the rails run through horizontally arranged rolls, in the second machine through vertically arranged rolls. Thus the rails are straightened in both planes after having passed through the two machines.



Each machine features nine straightening rolls, four of which are being driven. The straightening rolls with diameters of 600...1,200 mm form an overhung arrangement in order to allow easy replacement.

Demands on the bearing assembly

The mounting space for the bearings is dictated by the distance of the straightening rolls. In this mounting space bearings are accommodated which have such a high load carrying capacity as to allow for reasonable running times.
The bearing assembly for the straightening rolls must have maximum rigidity since this determines the accuracy of the rolled stock.
The roll position must be adjustable to the position of the rolled stock. For this reason the bearing assembly had to be designed such as to allow for a change of the position of the straightening rolls by ±50 mm in the axial direction.

Horizontal straightening rolls
The maximum rolling force at the horizontal rolls is 4,200 kN. Depending on the type of rolled stock, thrust loads of up to 2,000 kN have to be accommodated.
Speeds range from two to 60 min^{-1}.

Double-row cylindrical roller bearings have been provided to accommodate the radial forces and because of their high load carrying capacity. The higher loaded cylindrical roller bearing, which is situated directly beside the roll, was especially developed for supporting the straightening rolls (dimensions 530 x 780 x 285/475 mm). The less loaded cylindrical roller bearing has the dimensions 300 x 460 x 180 mm.

The cylindrical roller bearings are fitted with bored rollers which are evenly spaced by pins and *cage* side washers.

As this design allows the distance between the rollers to be indefinitely small, the largest possible number of rollers can be fitted and, adapted to the mounting space, the highest possible load carrying capacity can be obtained for the bearing.

The thrust loads are accommodated by two spherical roller thrust bearings FAG 29448E.MB (dimensions 240 x 440 x 122 mm). They are spring-*adjusted.*

When positioning the straightening rolls, the bearings must be able to compensate for axial displacements by up to ±50 mm. This is made possible by providing an extended inner ring for the cylindrical roller bearing located beside the straightening roll. The inner ring width is such that the lips of the two *seals* always slide safely on the inner ring even with maximum axial displacement.

The second cylindrical roller bearing is seated, together with the two spherical roller thrust bearings, in a sleeve which is axially displaceable within the hollow cylinder. The position of the straightening rolls relative to the rolled stock is adjusted by means of a ball screw.

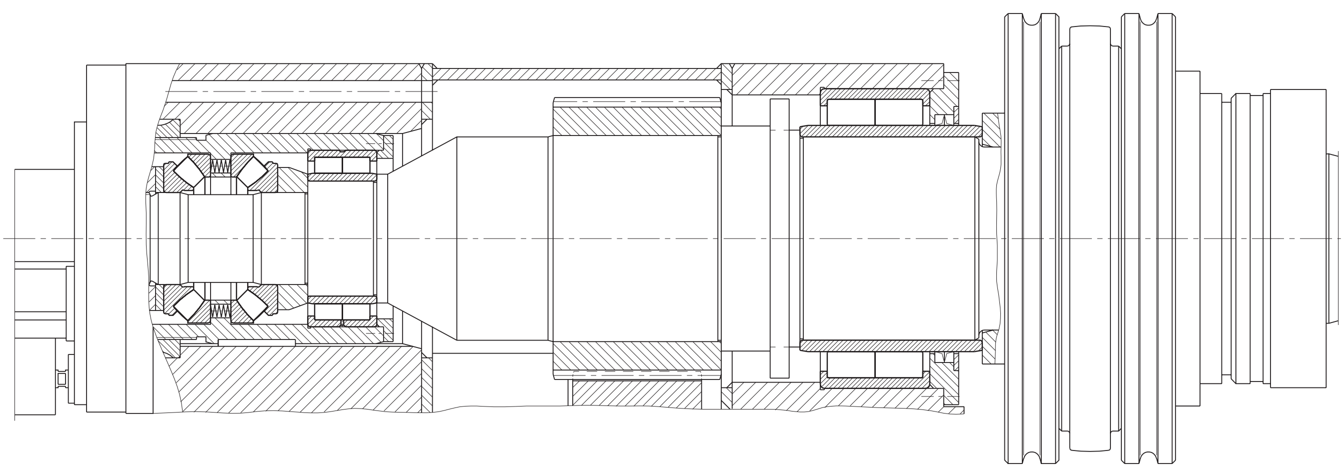
Vertical straightening rolls
The vertical straightening roll bearing arrangement is in principle identical to that of the horizontal straightening rolls. Due to the lower straightening loads, however, smaller bearings can be mounted.
Radial bearings: one axially displaceable double-row cylindrical roller bearing (dimensions 340 x 520 x 200/305 mm) and one single-row cylindrical roller bearing FAG NU2244M.C3 (dimensions 220 x 400 x 108 mm).

Thrust bearings: two spherical roller thrust bearings FAG 29432E (dimensions 160 x 320 x 95 mm).

Lubrication, sealing

In spite of the high loads and the low speeds it would be possible to lubricate the cylindrical roller bearings with *grease*. However, the spherical roller thrust bearings must be *oil*-lubricated. Therefore, all bearings are supplied with *oil* by means of a central lubricating system. The *oil* flow rate per straightening roll unit is about 10 l/min.

At the spherical roller thrust bearing end the unit is closed by a cover. At the shaft opening in the direction of the straightening roll two laterally reversed, *grease*-lubricated *seal* rings prevent oil escape and penetration of contaminants into the bearings.



110: Horizontal straightening rolls

111 Disk plough

In a disk plough the usual stationary blades are replaced by revolving disks fitted to the plough frame. The working width of the plough is determined by the number of disks.

Bearing selection

During ploughing both radial and axial loads are imposed on the bearings. Bearing loads depend on soil conditions and cannot, therefore, be exactly determined. For safety reasons roller bearings with the maximum possible load carrying capacity are used. One tapered roller bearing FAG 30210A (T3DB050 *) and one FAG 30306A (T2FB030 *) are installed in *O arrangement* and *adjusted,* via the cone of the smaller bearing, with zero clearance. This cone must, therefore, be able to slide on the journal.

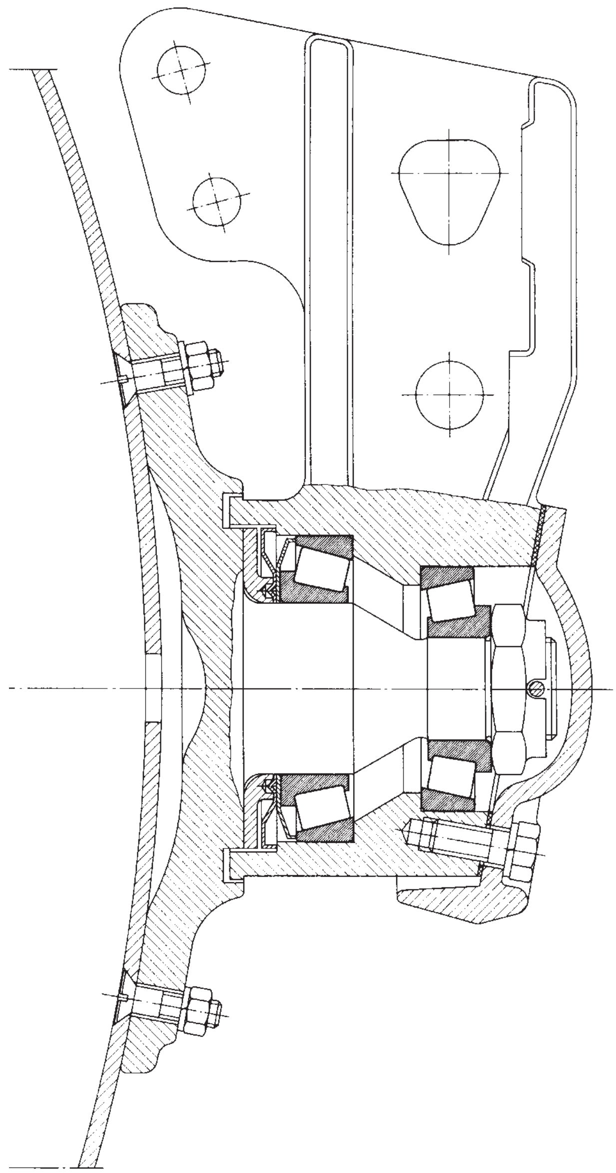
*) Designation to DIN ISO 355

Machining tolerances

on the journal:
– j6 for the smaller bearing,
– k6 for the larger bearing;
in the housing: N7.

Lubrication, sealing

Grease lubrication (FAG rolling bearing grease *Arcanol* L186V). The bearings are adequately protected from dirt and atmospheric influences by means spring steel *seals* and an additional labyrinth seal.



111: Disk plough

112 Plane sifter

Sifters are used in flour mills to segregate the different constituents (e.g. groats, grits, flour). The plane sifter described in this example consists of four sections, each comprising 12 sieves fastened to a frame. An eccentric shaft induces circular vibrations in the frame-sieve assembly.

Operating data

Starting power 1.1 kW, operating power 0.22 kW; speed 220...230 min^{-1}; total weight of balancing masses 5.5 kN; distance between centre of gravity of balancing masses and axis of rotation 250 mm; total weight of frame and sieves plus material to be sifted 20...25 kN.

Bearing selection

The drive shaft with the balancing masses is suspended from the top bearing. The supporting bearing must be *self-aligning* in order to avoid preloading. The bearings mounted are a self-aligning ball bearing FAG 1213 (65 x 120 x 23 mm) and a thrust ball bearing FAG 53214 (70 x 105 x 28,8 mm). The spherical housing washer FAG U214 compensates for misalignment during mounting.

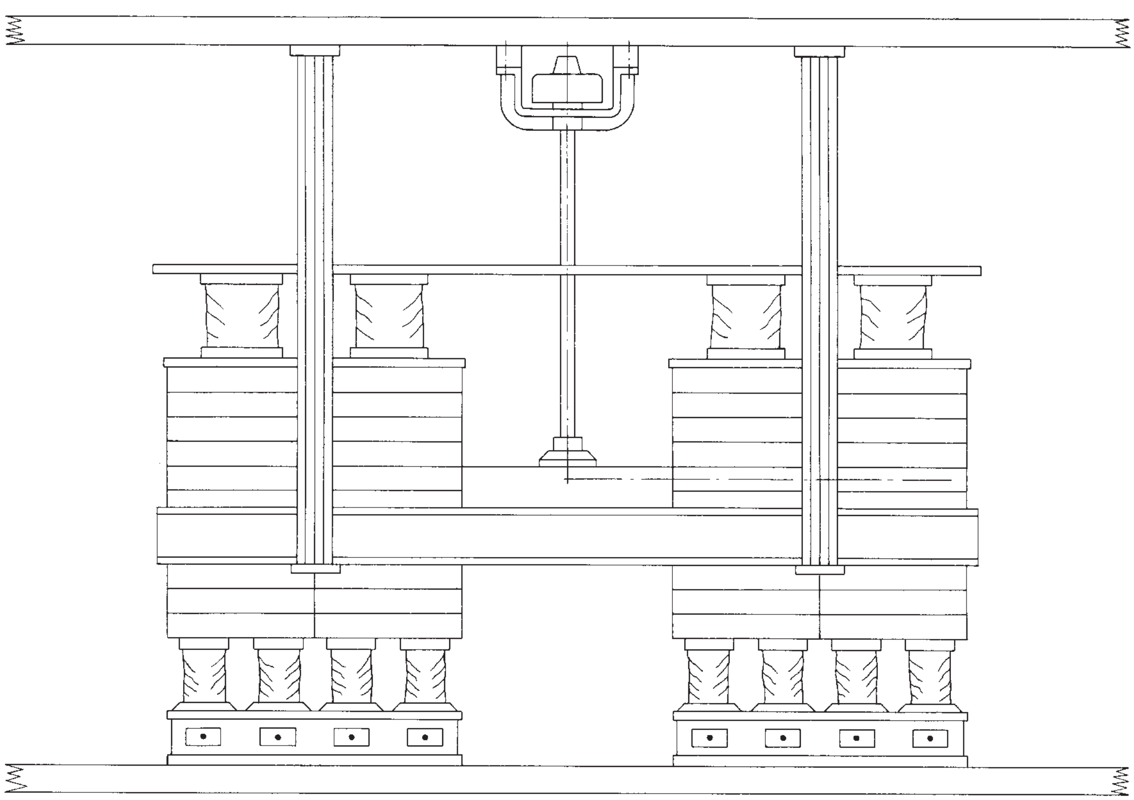
The *thrust bearing* has to accommodate the weight of the drive shaft and balancing masses. The eccentric shaft of the sifter frame is supported by a spherical roller bearing FAG 22320E.T41A. This bearing accommodates the high centrifugal forces resulting from the circular throw of the sifter frame and sieves. Sleeve B is a loose fit on the eccentric shaft; thus the spherical roller bearing is axially displaceable together with the sleeve and cannot be submitted to detrimental axial preloading.

Machining tolerances

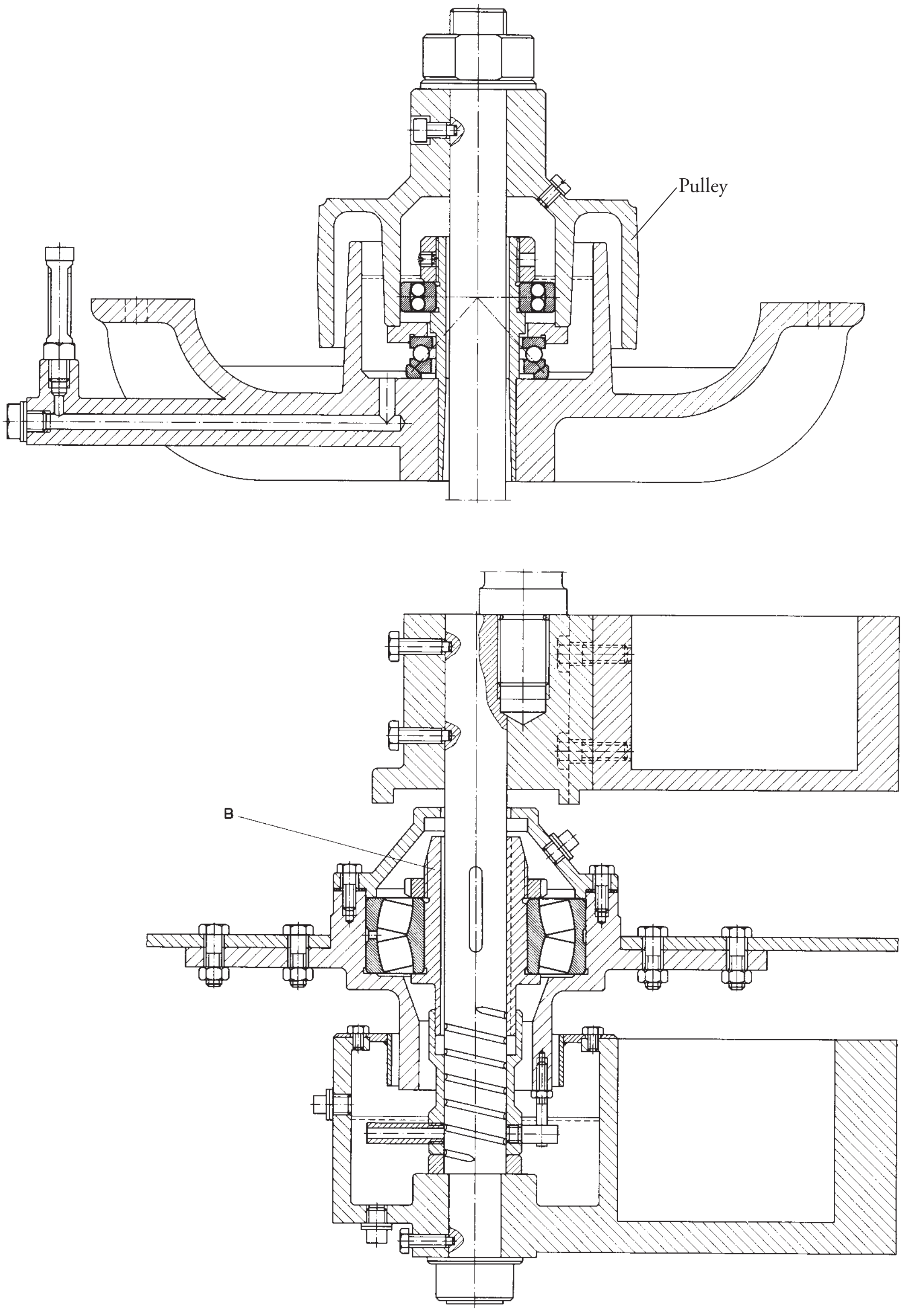
– Self-aligning ball bearing.
  Hollow shaft to k6, pulley bore to J6.
– Spherical roller bearing.
  Sleeve to k6, frame housing bore to K6.

Lubrication

The ball bearings at the top mounting run in an *oil* bath. The spherical roller bearing at the bottom mounting is lubricated by circulating *oil.* A thread cut in the eccentric shaft feeds the oil upward through sleeve B. From the top the oil passes through the spherical roller bearing and back into the oil bath.



Layout of a plane sifter



112: Plane sifter