Innovation in Motion

Miba Industrial Bearings
Tilting Pad Journal Bearings

Content Page

Miba Industrial Bearings

Miba Industrial Bearings is one of the largest international hydrodynamic bearing supplier for turbomachinery. Our roots date back over 100 years when the German site first started producing bearings. Equipped with this experience we are now a center of excellence in bearing design, repair, troubleshooting and analysis as well as reversed engineering solutions.

The selection of a Miba Industrial bearing offers numerous benefits:

- A worldwide Miba Group with contacts in Europe, Americas and Asia is focused on customer support, competitive lead times and highest product quality
- Decades of technical experience helps us to understand and satisfy the needs of our customers
- Tailored bearings for specific applications, where catalog bearings reach their limits
- Comprehensive technical support, including bearing consultation and detailed calculations
- Up-to-date calculation tools for the prediction of bearing performance and to guarantee long-term operational safety
- Miba's in-house R&D test rig capacity and external research partners, to constantly validated and improve bearing performance

Tilting Pad Journal Bearings

Tilting pad bearings are designed for the most demanding turbomachinery applications, in terms of speed, load and rotordynamics. Due to the tilting capability of the individual pads, this bearing design does not tend to produce self-exited rotor vibrations and is suitable for highest sliding speeds and high bearing loads.

Technical Information

Anti-rotation pin
The anti-rotation pin defines the bearing orientation angle and secures the bearing against rotation. By standard two anti-rotation pin positions are existing, each at an angle of 18° from the bearing split line. For typical load directions from gearings one position leads to a load between pads orientation (LBP) and the other to a load on pad (LOP) orientation. Individual positions of the anti-rotation pin are possible upon request.

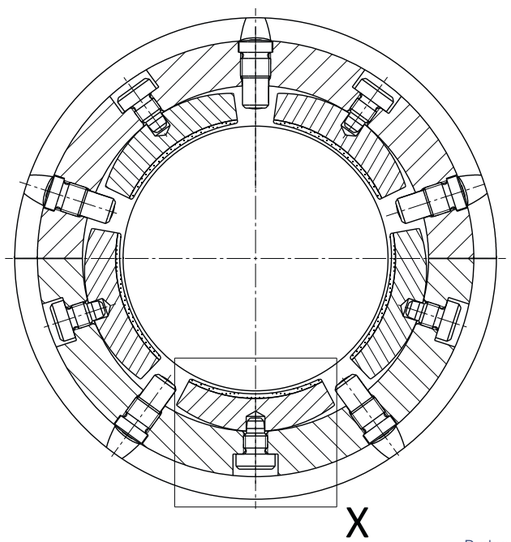
Insulation
All bearings can be insulated by adding special plates, insulation material or coatings, (depending on the application) to isolate electrical current to protect both, the rotor and bearing.

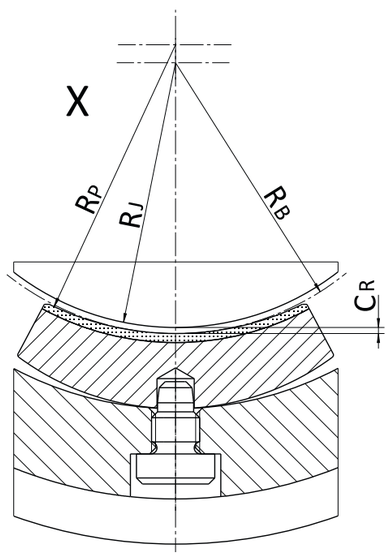
Length-to-diameter ratio (L/D)
The L/D-ratio is the ratio between the axial pad length L and the bore diameter D of a bearing. Miba Industrial Bearings offers two standard ratios, the nominal values are 0.6 and 0.9. For other L/D-ratios, please contact Miba's technical support.

Load direction
There are two main bearing installations:
- Load between pads (LBP) orientation: The load is distributed on two pads. This leads to the highest bearing load capacity.
- Load on pad (LOP) orientation: The load is carried mainly by one pad. For lower bearing loads, this orientation can be beneficial for the rotor dynamic properties.

Operating load
The permissible load depends on the operating conditions and specified limits and can be determined with a bearing calculation.

Pivot position
There are two common pivot positions:
- Center pivot: Pivot at 50% of the circumferential pad length. Bi-directional operation possible.
- 60% offset pivot: A pivot position at 60% of the circumferential pad length is suitable for uni-directional operation. One benefit is the reduced temperature level compared to center pivot. Reverse rotation is still possible at reduced loads.





Preload

Preload
The bearing preload is a geometrical value of the bearing. It is based on the bearing bore radius R_B, the pad radius R_P and the journal radius R_J. The pad radius R_P is defined for preload values in the range of 0,25 – 0,5, depending on the journal diameter. This range ensures a low oil consumption in combination with high dynamic damping values. For other preload values, please contact Miba's technical support. The preload m is defined as $m = 1-(C_R/(R_P- R_J))$ with the radial bearing clearance $C_R = R_B- R_J$.

Sliding (circumferential) speed
The sliding or circumferential speed v [m/s] is defined by $v=n*d*\pi/60000$ with n = rotor speed [rpm], d=rotor diameter [mm].

Slow roll / turning gear operation
Depending on the individual operating conditions of a machine, Miba can specify a minimum slow-roll or turning gear speed to avoid wear. For lower speeds, a hydrostatic jacking device is recommended.

Specific bearing load
The specific bearing load $\bar{p}$ [MPa] is defined by $\bar{p}=F/(D*L)$ with F = bearing load [N], D = bearing bore diameter [mm], L = axial pad length [mm]. Permissible bearing loads can be stated for the machine start-stop and during operation.

Start-up load
The maximum start-up load is 2,0 MPa for load between pads orientation and 1,5 MPa for load on pad orientation. For higher start-up loads Miba recommends a hydrostatic jacking device.

Start-up temperature
Miba recommends a minimum oil inlet temperature at the machine start-up of 20 °C. For lower temperatures a tank heating is recommended.

Temperature limits
Miba recommends a temperature limit based on the bearing calculation. E.g. the alarm temperature could be set 10 °C above the prediction and the shut-down temperature 15 °C above the prediction. The absolute limits for the bearing are typically higher.

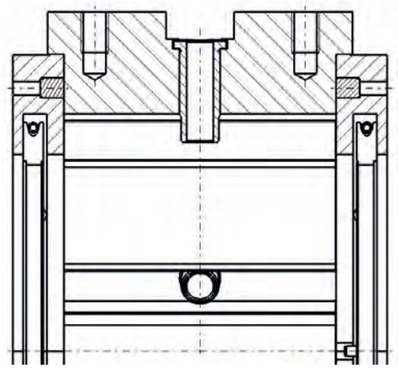
Lubrication

The various Miba bearing models contain two main types of oil supply:

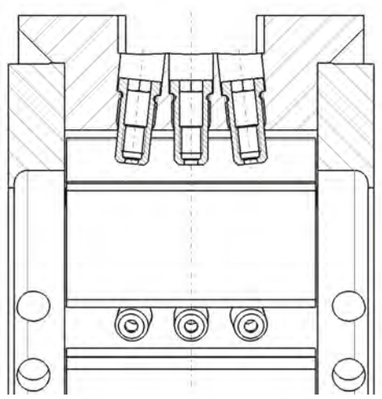
Directed lubrication:
Oil inlet nozzles control the flow. Directed lubrication reduces the power loss and leads to lower pad temperatures. The end plate design is open (non-sealing) for the cavity evacuation. As an addition, if requested, direct lubrication with a pad oil distribution feature at the pad inlet can be provided.

Flooded lubrication:
- Option 1: Equipped with lateral floating seals, rate of oil flow controlled by outlet orifices.

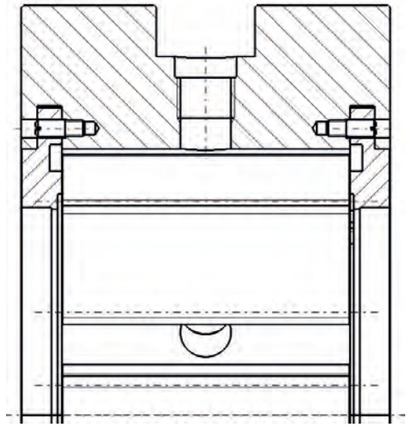
- Option 2: Laterally sealed by throttle rings with a defined gap to the shaft. Oil flow control by inlet nozzles.



Flooded lubrication (floating seals)



Directed lubrication



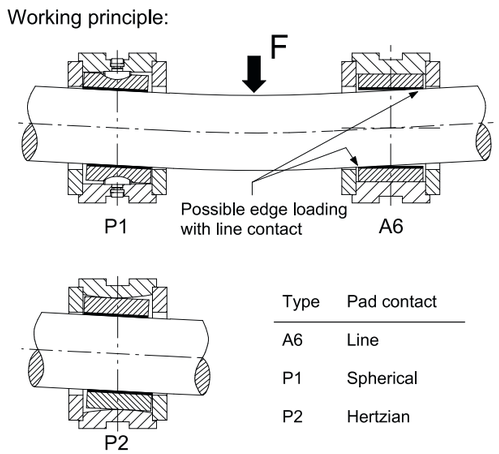
Flooded lubrication (throttle rings)

Pivot Design

Miba bearings are available with different pivot designs:

Line contact:
The line contact is the most frequently chosen design, suitable for the majority of applications.

Spherical contact:
Spherical contact (e.g. Ball & Socket) allows pad tilting also in axial direction, to cope with misalignment and thereby avoid edge contact.



Type	Pad contact
A6	Line
P1	Spherical
P2	Hertzian

Pivot design comparison

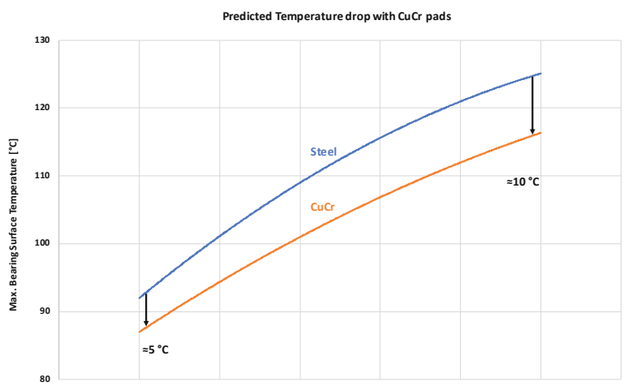
Materials

Steel – White metal
16MnCr5 steel with a high-quality white metal is the standard material combination for the tilting pads.

The material combination offers a high bonding strength (according to ISO 4386-2 / Chalmers Test) and mechanical properties which clearly exceed the demand of even highly loaded bearings.

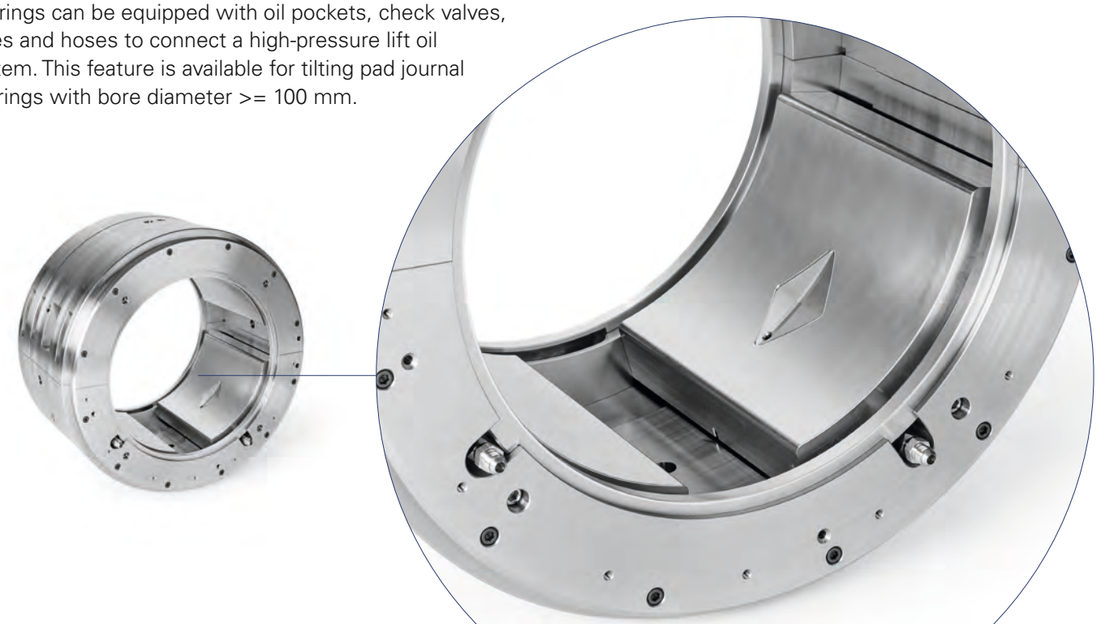
Steel – Bronze
The higher temperature limit of bronze allows increased pad temperatures for special applications. A hardened shaft is recommended (HB > 160).

CuCr – White metal
For the reduction of maximum bearing temperatures under extreme conditions, Miba Industrial Bearings offer CuCr pad base material with a 6x higher thermal conductivity than steel. The effect is depicted in the chart.



Hydrostatic Jacking

For start-up loads above 1,5 – 2,0 MPa or continuous slow-roll / turning gear operation. Miba Industrial Bearings can be equipped with oil pockets, check valves, pipes and hoses to connect a high-pressure lift oil system. This feature is available for tilting pad journal bearings with bore diameter >= 100 mm.

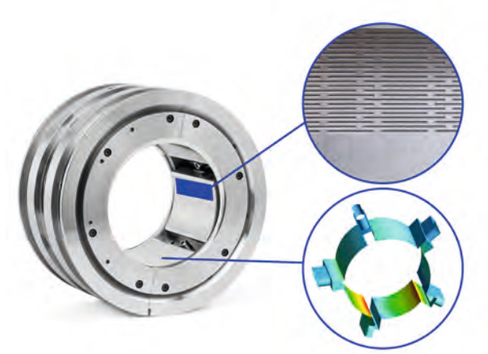


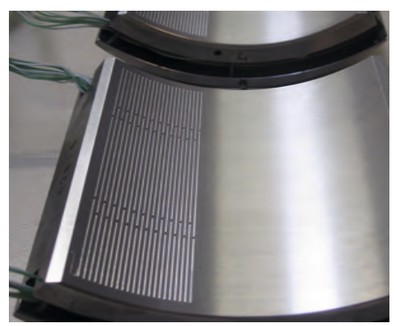
Eddy Grooves

For reducing maximum bearing temperatures, Miba developed the patent pending eddy grooves. The grooves create radial flow components in the fluid film at the high load area of the bearing, where normally full laminar flow exists.

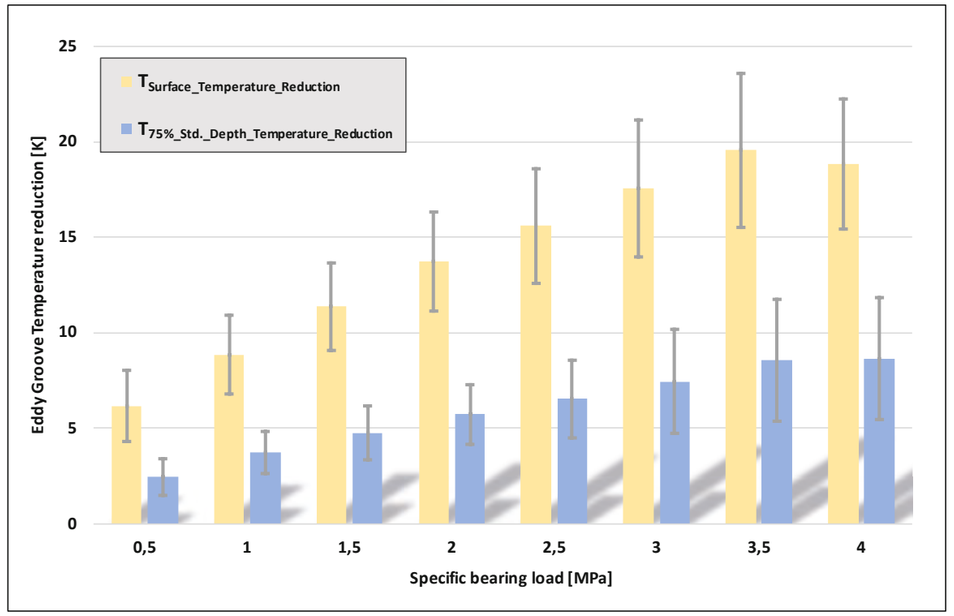
These flow components act as an increase of the lubricants' thermal conductivity and thereby improve the heat exchange between cooler lubricant near the shaft and warmer lubricant near the bearing surface.

Experimental results show a considerable reduction of the maximum bearing temperatures, depending on the bearing load.





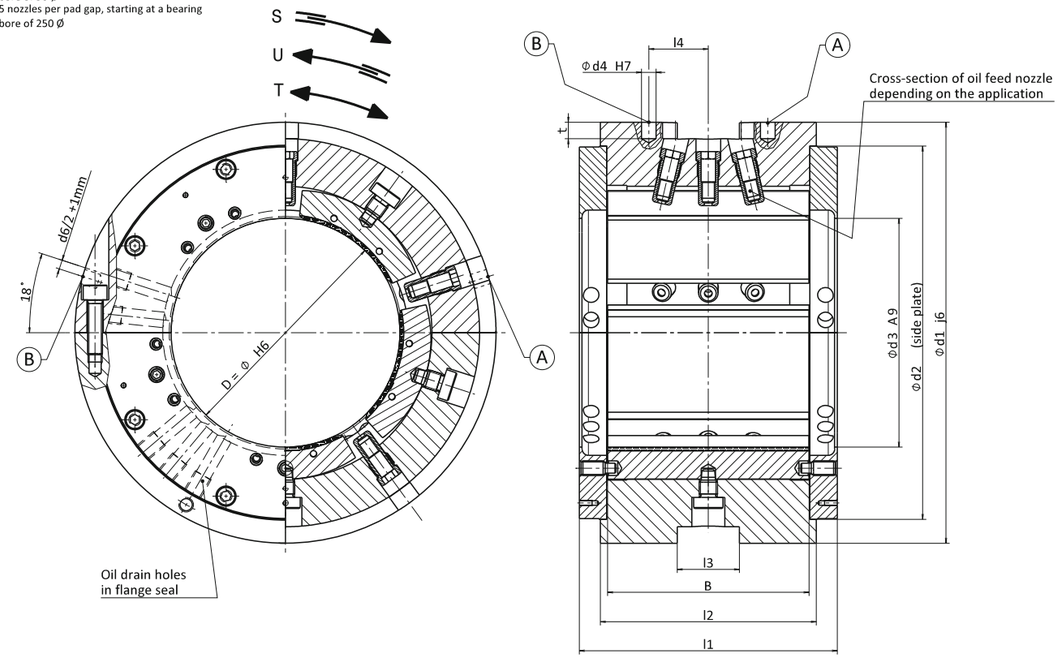
Tilting pad equipped with eddy grooves



Measured reduction of maximum bearing surface temperature (yellow) and for the standard 75% temperature sensor, 1 mm below the white metal (blue), including the standard deviation (grey).

Dimension Tables:
L/D 0.6 (Design Example Germany)

Standard A6 B/D 0,6
3 nozzles per pad gap, starting at a bearing bore of 90 Ø
5 nozzles per pad gap, starting at a bearing bore of 250 Ø



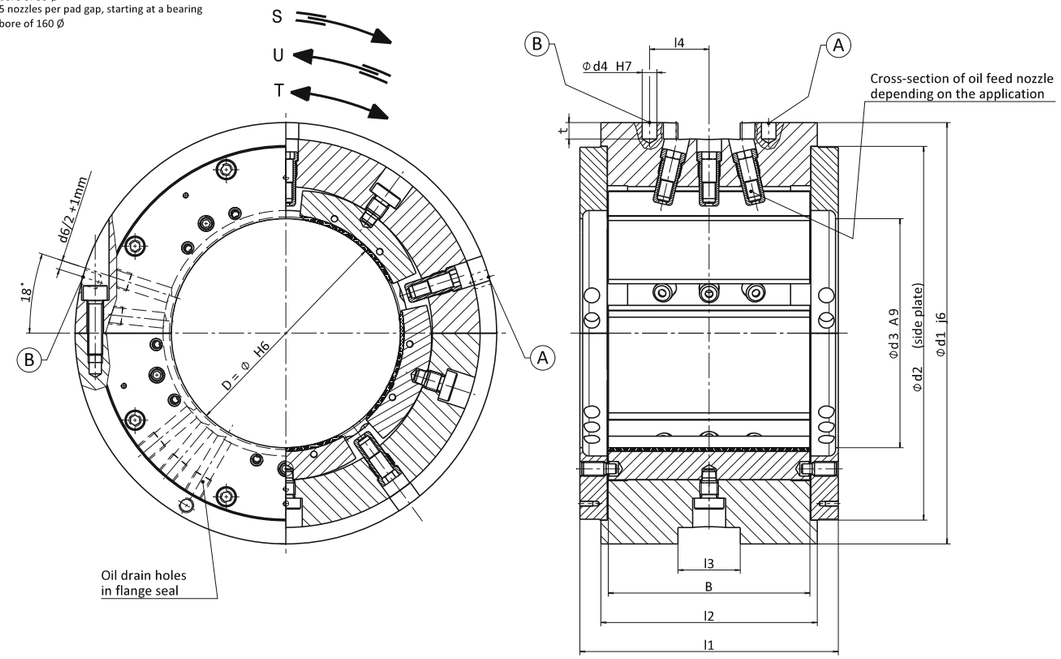
L/D 0.6 Example Germany											
D	B	d1*	d1**	d2*	d3	d4	l1	l2	l3	l4	t
30	18	85	69	64	30	4	36.2	40	8	11.0	5
35	22	85	76	64	35	4	40.2	40	8	11.0	5
40	25	110	82	88	40	5	47.2	50	10	14.0	6
45	25	110	89	88	45	5	47.2	50	10	14.0	6
50	30	110	95	88	50	5	52.2	50	10	14.0	6
55	30	110	111	95	55	5	52.2	50	10	14.0	6
60	35	110	120	95	60	5	57.2	50	10	14.0	6
65	40	160	-	133	65	6	64.2	60	16	21.0	7
70	40	160	130	133	70	6	64.2	70	16	21.0	7
75	45	160	-	133	75	6	69.2	70	16	21.0	7
80	45	160	139	133	80	6	69.2	70	16	21.0	7
85	50	160	-	133	85	6	69.2	70	16	21.0	7
90	55	160	165	133	90	6	79.2	70	30	21.0	7
95	55	200	-	175	95	6	85.2	80	32	28.0	7
100	60	200	177	175	100	6	90.2	90	32	28.0	7
105	60	200	-	175	105	6	90.2	90	32	28.0	7
110	65	200	190	175	110	6	95.2	90	34	28.0	7
115	70	200	-	175	115	6	100.2	95	34	28.0	7

L/D 0.6 Example Germany											
D	B	d1*	d1**	d2*	d3	d4	l1	l2	l3	l4	t
120	75	230	-	204	120	8	105.2	105	34	32.5	9
125	80	230	215	204	125	8	110.2	105	34	32.5	9
130	85	230	-	204	130	8	113.2	105	35	32.5	9
140	90	230	228	204	140	8	123.2	105	35	32.5	9
150	95	280	-	240	150	8	129.2	110	35	37.5	9
160	100	280	266	240	160	8	134.2	115	42	37.5	9
170	115	315	-	265	170	8	145.2	125	42	37.5	9
180	115	315	298	265	180	8	145.2	125	42	37.5	9
200	120	350	336	285	200	8	160.2	130	42	37.5	9
225	135	425	374	320	225	10	180.3	145	45	42.5	11
250	150	475	406	355	250	10	200.3	160	50	45.0	11
280	165	500	450	400	280	12	221.3	175	60	54.0	13
300	180	515	482	425	300	12	240.3	190	65	56.5	13
315	190	580	-	450	315	12	253.3	200	65	56.5	13

*Design: line and spherical contact
**Design: line contact; alternative OD

Dimension Tables:
L/D 0.9 (Design Example Germany)

Standard A6 B/D 0,9
3 nozzles per pad gap, starting at a bearing bore of 55 Ø
5 nozzles per pad gap, starting at a bearing bore of 160 Ø



L/D 0.9 Example Germany											
D	B	d1*	d1**	d2*	d3	d4	l1	l2	l3	l4	t
30	28	85	69	64	30	4	46.2	40	8	11.0	5
35	32	85	76	64	35	4	50.2	40	8	11.0	5
40	36	110	82	88	40	5	58.2	50	10	14.0	6
45	40	110	89	88	45	5	62.2	50	10	14.0	6
50	45	110	95	88	50	5	67.2	52	10	14.0	6
55	50	110	111	95	55	5	72.2	57	20	14.0	6
60	56	110	120	95	60	5	78.2	63	20	14.0	6
65	60	160	-	133	65	6	84.2	68	25	21.0	7
70	63	160	130	133	70	6	87.2	71	31	21.0	7
75	67	160	-	133	75	6	91.2	75	30	21.0	7
80	71	160	139	133	80	6	95.2	79	30	21.0	7
85	77	160	-	133	85	6	101.2	85	30	21.0	7
90	80	160	165	133	90	6	104.2	88	30	21.0	7
95	85	200	-	175	95	6	115.2	93	32	28.0	7
100	90	200	177	175	100	6	120.2	98	32	28.0	7
105	95	200	-	175	105	6	125.2	103	32	28.0	7
110	100	200	190	175	110	6	130.2	108	34	28.0	7
115	105	200	-	175	115	6	136.2	113	34	28.0	7

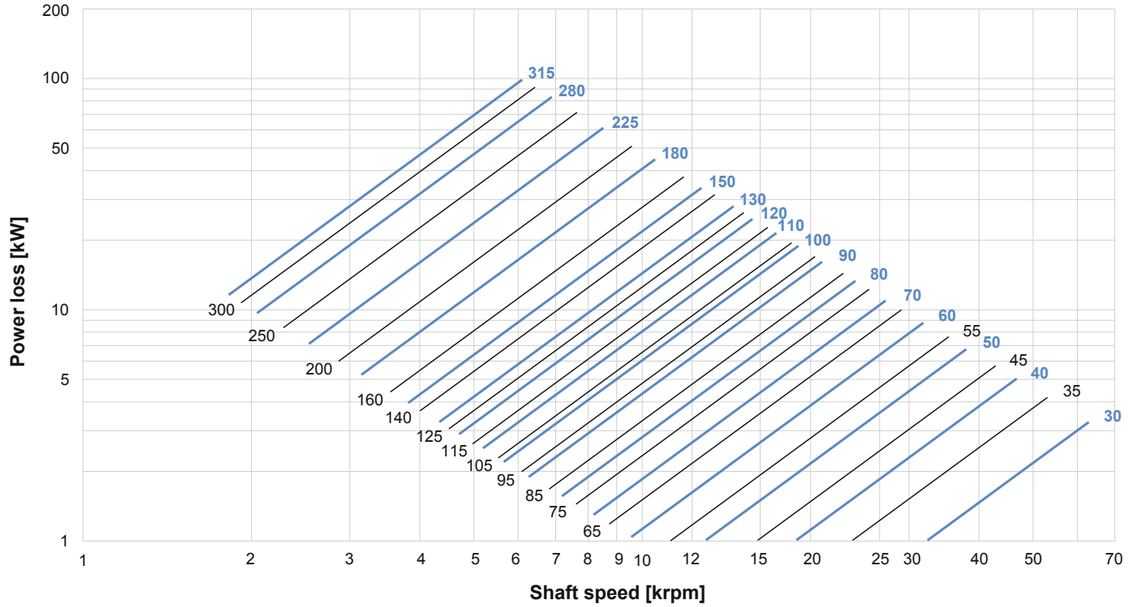
L/D 0.9 Example Germany											
D	B	d1*	d1**	d2*	d3	d4	l1	l2	l3	l4	t
120	110	230	-	204	120	8	140.2	118	34	32.5	9
125	110	230	215	204	125	8	140.2	118	34	32.5	9
130	117	230	-	204	130	8	147.2	125	35	32.5	9
140	125	230	228	204	140	8	158.2	133	35	32.5	9
150	135	280	-	240	130	8	169.2	143	35	37.5	9
160	140	280	266	240	160	8	174.2	148	42	37.5	9
170	160	315	-	265	170	8	190.2	168	42	37.5	9
180	160	315	298	265	180	8	190.2	168	42	37.5	9
200	180	350	336	285	200	8	220.2	190	42	37.5	9
225	200	425	374	320	225	10	245.3	212	45	42.5	11
250	225	475	406	355	250	10	275.3	237	50	45.0	11
280	250	500	450	400	280	12	306.3	262	60	54.0	13
300	270	515	482	425	300	12	330.3	282	65	56.5	13
315	280	580	-	450	315	12	343.3	292	65	56.5	13

*Design: line and spherical contact
**Design: line contact; alternative OD

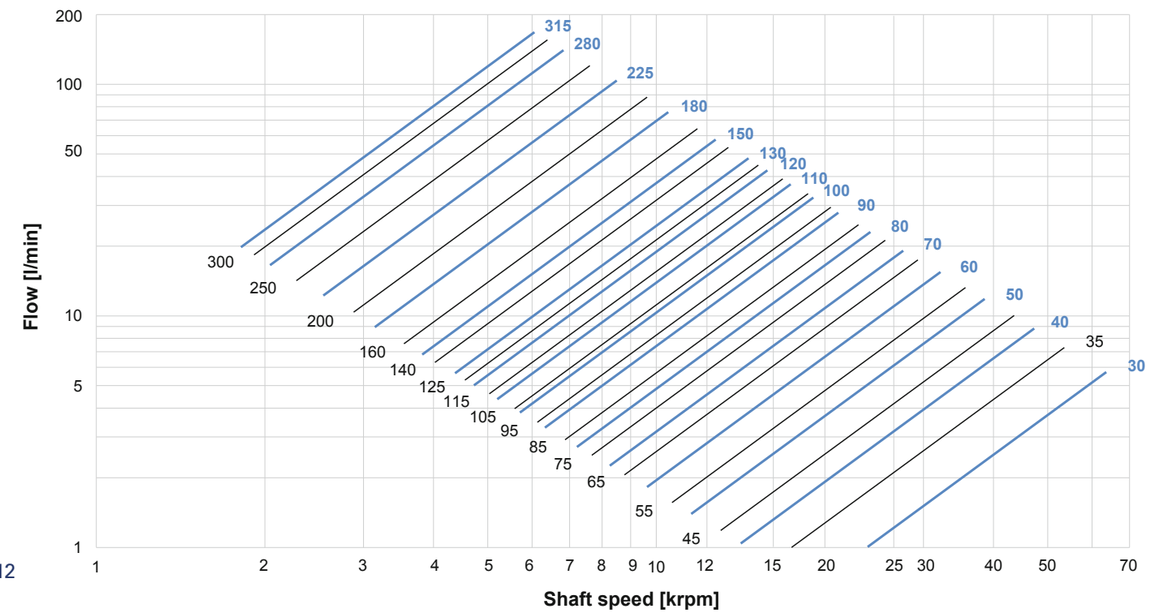
Performance Charts L/D = 0.6

Power loss / Oil supply charts:
- Calculation based on DIN 31657; Oil type: VG32 @ 50 °C; directed lubrication; Center pivot; ΔT ≈ 21 K.
- Offset pivot pads show reduced temperatures with an approximately 15% increased rate of oil flow.
- For ISO VG 46 power loss and oil flow are approximately 20% higher.
- Calculations for divergent parameters on request.

Power loss
5-tilting pad journal bearing - Directed Lubrication Design, L/D = 0.6



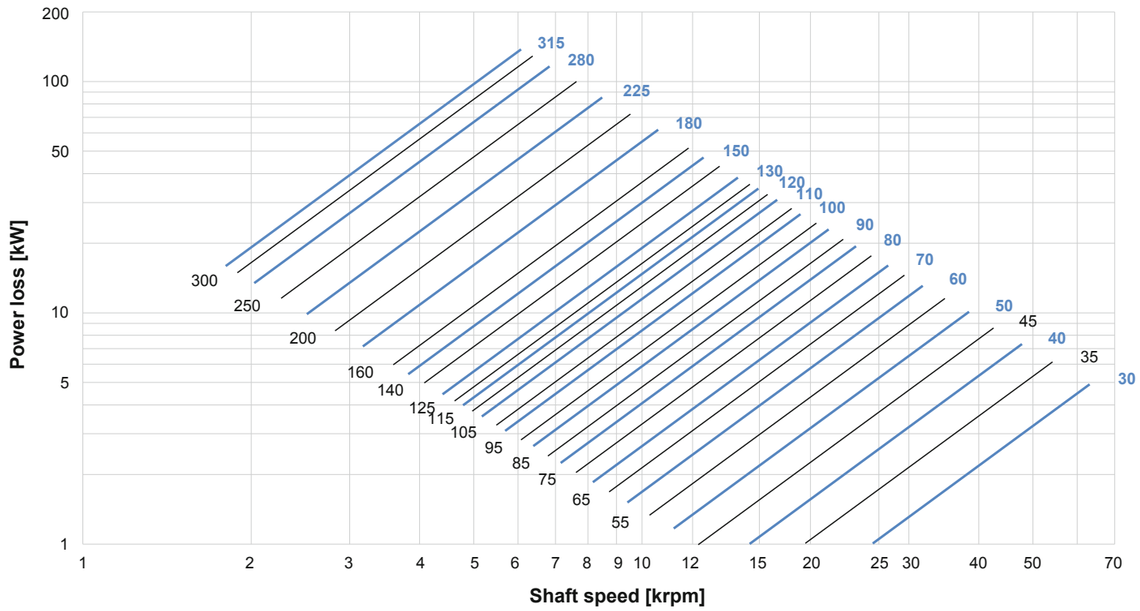
Oil supply
5-tilting pad journal bearing - Directed Lubrication Design, L/D = 0.6



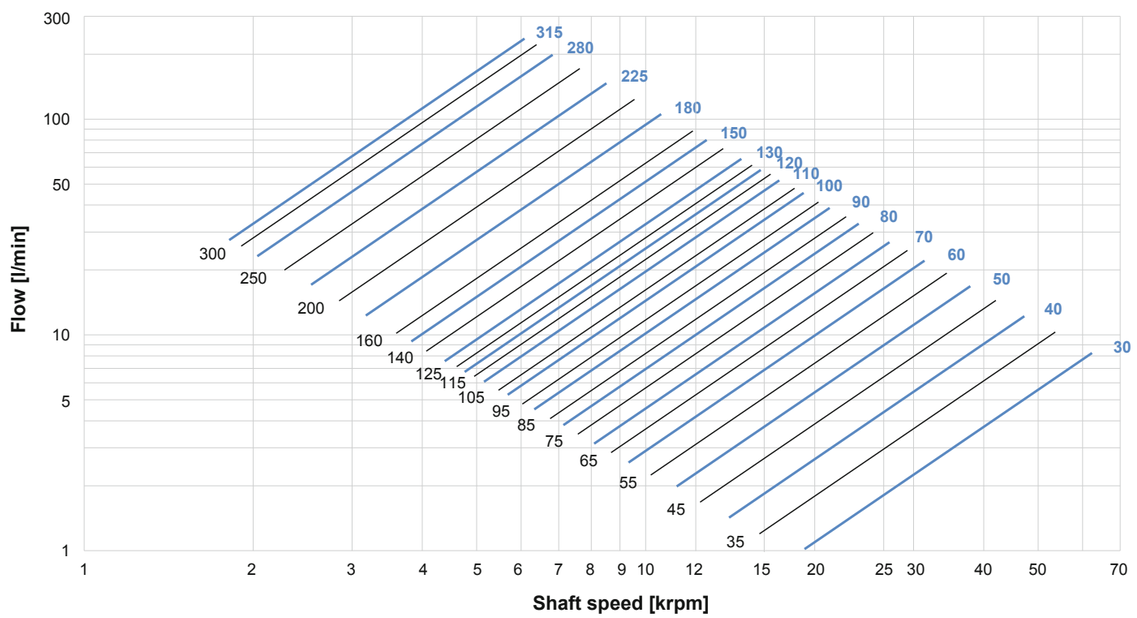
Performance Charts L/D = 0.9

Power loss / Oil supply charts:
- Calculation based on DIN 31657; Oil type: VG32 @ 50 °C; directed lubrication; Center pivot; ΔT ≈ 21 K.
- Offset pivot pads show reduced temperatures with an approximately 15% increased rate of oil flow.
- For ISO VG 46 power loss and oil flow are approximately 20% higher.
- Calculations for divergent parameters on request.

Power loss
5-tilting pad journal bearing - Directed Lubrication Design L/D = 0.9



Oil supply
5-tilting pad journal bearing - Directed Lubrication Design, L/D = 0.9



Miba Services

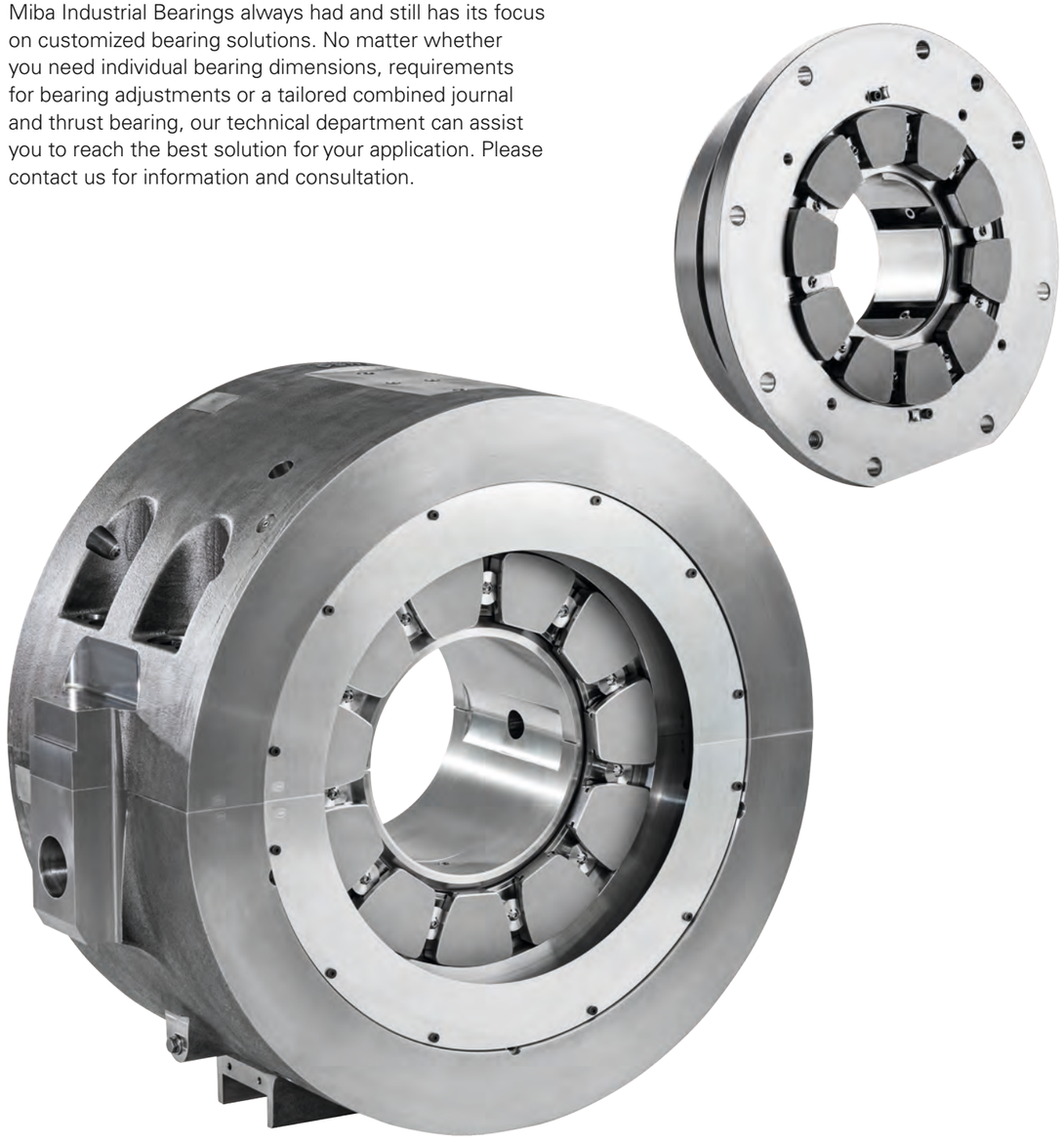
Miba’s technical support provides customer consultation, bearing calculations and engineering assistance. Providing excellent customer support and quick help when our customers need us most. A Miba bearing calculation contains comprehensive information and indicates the operational safety of the bearing under the given conditions.

```
KSR-DIN - PROGRAMM DER MIBA INDUSTRIAL BEARINGS GERMANY GmbH
© Uwe Klein 2019 - Programm-Version 2.4
Berechnungsverfahren in Anlehnung an DIN 31657

T I L T I N G  P A D  J O U R N A L  B E A R I N G  C A L C U L A T
I O N

Kunde/Customer:                                Miba Industrial
Bearings
Abteilung/Department:                          Engineering
Referenz/Reference:                            Example
Anfrage-Datum/Date of enquiry:                 23.09.2020
MIBA-Info:                                     Case 1
Berechnungs-Nr./Calculation-No.:               LC9999a1
Zeichnungs-Nr./Drawing-No.:                    A6-Standard
Lagertyp/Bearing type:                         _K_T A6 60/110x78.2
Rechnungsdatum/Date of Calculation:            23-Sep-20 /08:44:22
Bearbeiter/Author:                             Miba Technical Support
-------------------------------------------------------------------------
----
Bore type/Load direction                       5 x 52. deg/ between
pads
Tilting point                                  center
Bearing diameter                    [mm]        60.000 H6
Width of pads                       [mm]        56.000
Shaft diameter                      [mm]        59.860 h5
Mean bearing clearance (cold/warm)  [mm]     0.156 / 0.133
Mean relative clearance (cold/warm) [â]      2.600 / 2.218
Pad diameter                        [mm]        60.080
Preload value                       [-]          0.311
-------------------------------------------------------------------------
----
Speed                               [RPM]         28650.0
Sliding-speed                       [m/s]            90.0
Load                                [N]           6720.0
Specific load                       [MPa]            2.00

Oil type                                        ISO VG 32
Rate of oil flow                    [l/min]          21.2
Oil pressure                        [bar]            1.50
Oil supply temperature              [∞C]             45.0
Oil temperature raise               [∞C]             21.0
Max. oil film temperature (DIN31657)[∞C]             93.1

Power loss                          [kW]            12.30
Minimum/Permissible film thickness  [mm]        0.028 / 0.023

Stiffness and damping coefficients:
∑ Cxx                               [N/mm]         195123
∑ Cxy                               [N/mm]              0
∑ Cyx                               [N/mm]              0
∑ Cyy                               [N/mm]         352722
∑ Dxx                               [Ns/mm]          63.4
∑ Dxy                               [Ns/mm]             0
```

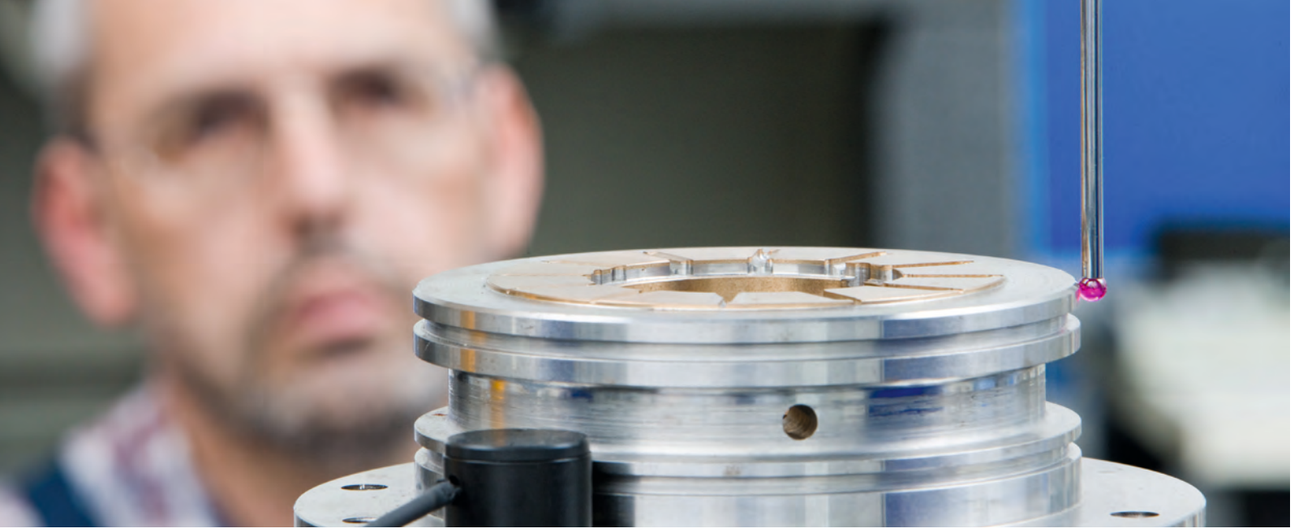
Calculation Example

Engineered Bearings

Miba Industrial Bearings always had and still has its focus on customized bearing solutions. No matter whether you need individual bearing dimensions, requirements for bearing adjustments or a tailored combined journal and thrust bearing, our technical department can assist you to reach the best solution for your application. Please contact us for information and consultation.



Examples of engineered combined journal and thrust tilting pad bearings



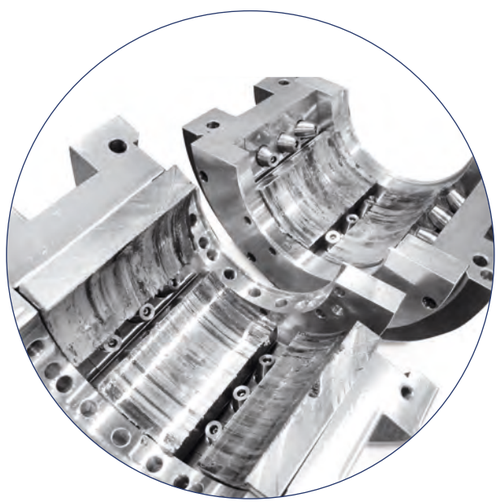
Bearing Repair, Service and Upgrade

Damage to bearings generally results in machine failure and thus in costly downtimes. This is why Miba has expanded the area of bearing repair, in addition to the specialization in the development and manufacturing of new bearings. We help customers to increase efficiency and lower costs by upgrading or reengineering old bearings.

Starting with an evaluation of the existing bearing, we can recommend the best solution and realize the repair of your bearing. Please contact us for information and consultation.

Our services:

- Bearing failure analysis
- Bearing design optimization
- Bearing repair
- Reverse engineering
- Training
- On-site service



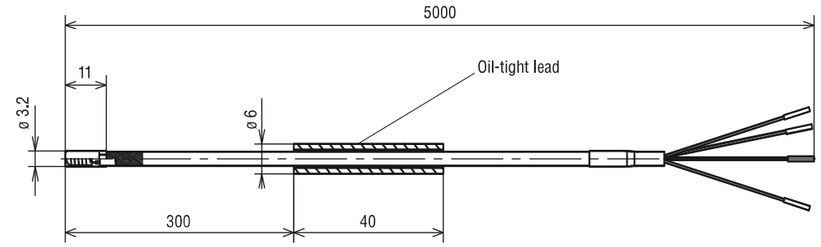
Instrumentation

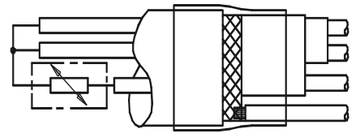
The most common bearing instrumentation is one or two single or double RTDs (PT100), according to the drawings below.

Depending on customers' needs, Miba Industrial Bearings offer a wide range of alternatives, including product offerings from several suppliers, various sensor dimensions (cable length, sensor diameter), different types of thermocouples, etc. Numerous certificates (e.g. ATEX) are available upon request.

Single resistance temperature probe
with additional mass-conductor

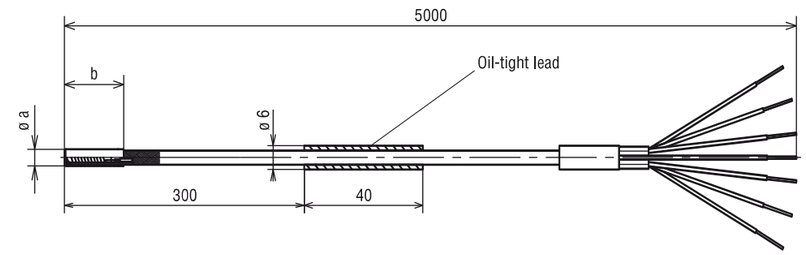
Temperature range: 0–200 °C

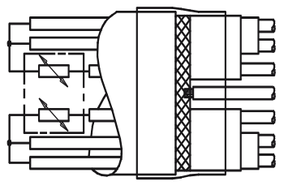




Double resistance temperature probe
with additional mass-conductor

Temperature range: 0–200 °C

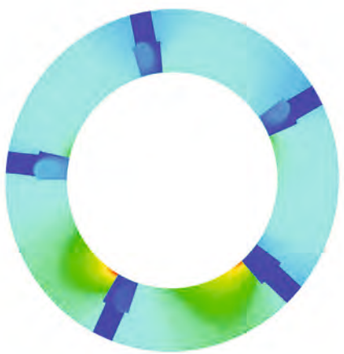




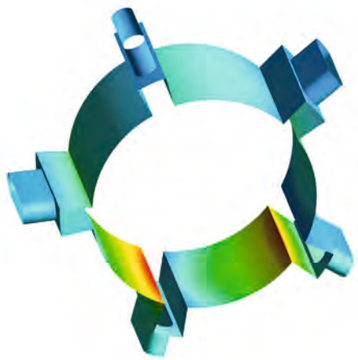
ø a	b
3.2	11
4.2	20

Simulation & Analysis

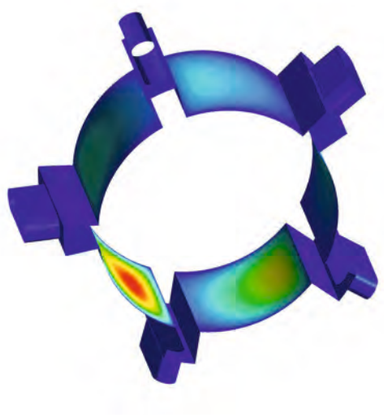
With available professional software we are able to simulate the bearing operation and visualize the flow, deformation or stress behavior. Therefore, we can analyze and further develop our product design. These tools are an indispensable addition to our test stands to guarantee you the best technical solution.



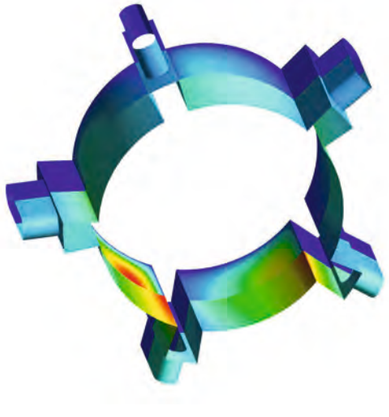
Tilting Pad Temperature



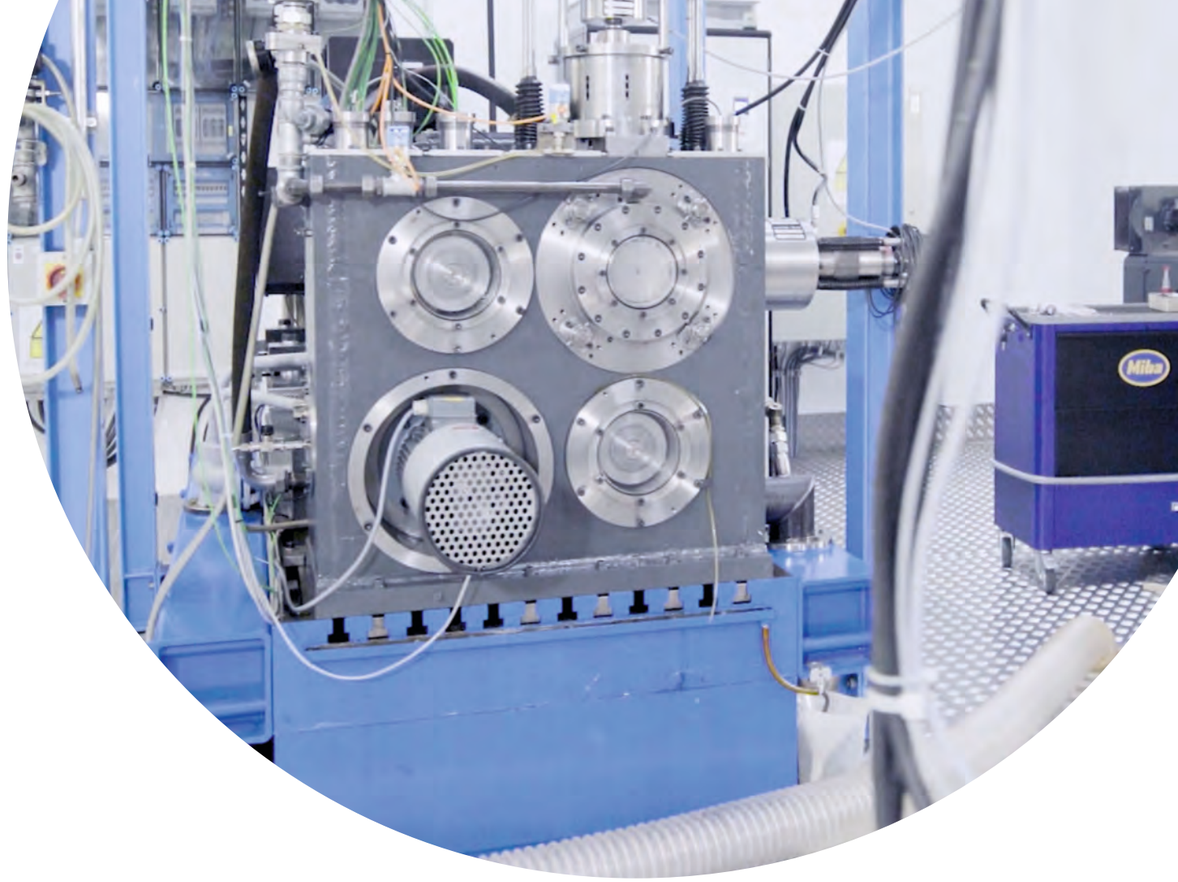
Tilting Pad Temperature



Tilting Pad Pressure



Tilting Pad Temperature Pressure



Test Stands

Since 2013, two bearing test benches for radial bearings have been in heavy use for conducting experiments and trial series to improve performance, efficiency and operational safety.

With regard to bearing performance, the test rigs allow investigations in a wide operating range at circumferential speeds between approx. 10 m/s and up to 140 m/s and specific loads between 0 MPa and approx. 10 MPa (limited by the bearings' load carrying capacity and depending, among other things, on the bearing width).

www.miba.com

Contacts:

Germany
Miba Industrial Bearings Germany
Osterode GmbH
Rolandsweg 16-20
37520 Osterode, Germany
MIBG_sales@miba.com

Germany
ADMOS Gleitlager GmbH
Wilhelminenhofstrasse 89a
12459 Berlin, Germany
info@admos-gleitlager.de

USA
Miba Industrial Bearings U.S. LLC
1111 Cedar Creek Rd,
Grafton, WI 53024, USA
MIBUSG_Sales@miba.com

USA
Miba Industrial Bearings U.S. LLC
3300 E 8th St.
Columbus, NE 68601, USA
MIBUSG_Sales@miba.com

USA
Miba Industrial Bearings U.S.
(Houston) LLC
1800 W 13th St, Deer Park,
TX 77536, USA
Houston.Sales@miba.com

Brazil
Miba Industrial Bearings Brasil Ltda
Av. Manoel Inácio Peixoto, 2147
36.771-000 Cataguases, Brazil
Vendas.MIBCAT@MIBA.COM