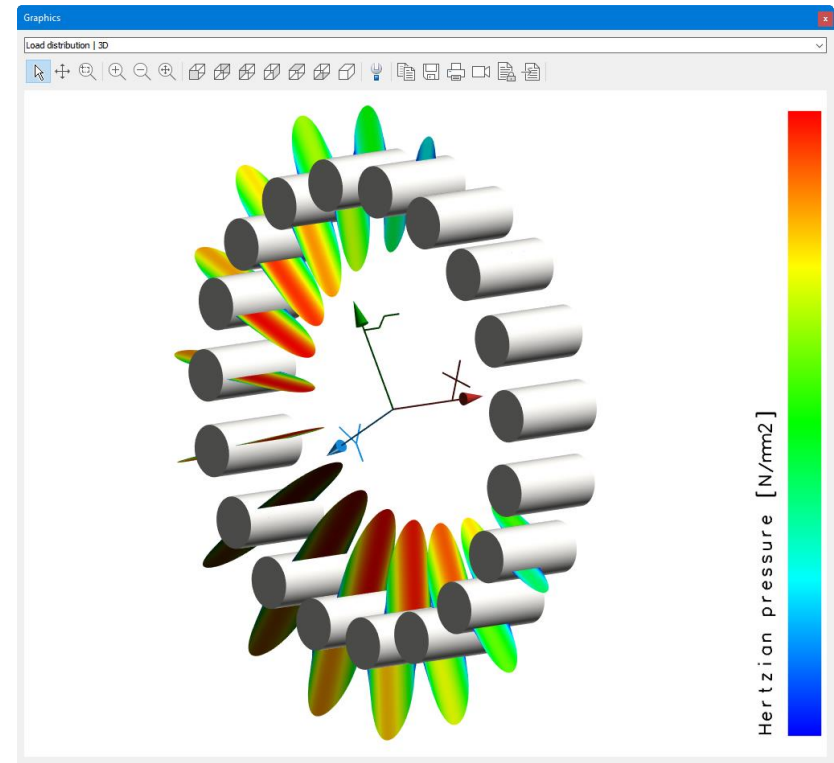


Bearing calculations in KISSsoft

Part 1: Concepts, theory, terminology

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Document change record

Version	Date	Owner / Autor(s)	Comments	File
earlier		HD / HD	Several previous versions of document	
v2201	17.5.22	HD / HD, RP		"G:\00-KISSOFT\00-09-USE\02-THEORY\71-ROLLBRG\Theory-Rollbrg-00-Part_1_concpets_theory_terminology-en-v2201-hd-draft.pptx"

Content

Bearing database

Concepts

Effect of bearing clearance

Bearing stiffness

Calculation reports

Graphics

SKF cloud calculations

TIMKEN cloud calculations

Further topics

KISSsoft usage

Selected references

Bearing database

Bearing database

Database tool

Lists several databases, many for bearings, one database per bearing type

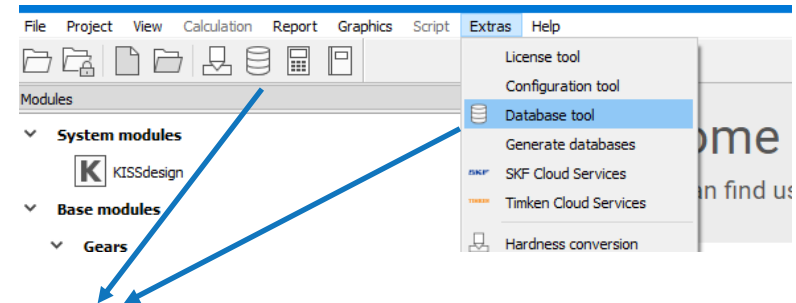
Contains catalogue data from supplied by e.g., SKF, Timken, Schaeffler, RKB, Koyo, ...

Typically, does not contain bearing inner geometry data

May contain some bearing inner geometry data supplied by some bearing, e.g., by SKF

Correctness, actuality and completeness of data is defined through the bearing supplier supplying the data to KISSsoft AG

KISSsoft AG does not guarantee for correctness, actuality or completeness of data



The 'Database tool' window displays a table with the following columns: Group, Label, Database, and Table. The table lists various bearing types and their associated databases and tables. The row for 'Cylindrical roller thrust bearing' is highlighted in blue.

Group	Label	Database	Table
Materials	Spring calculation	KMAT	F000
Materials	Disc spring calculation	KMAT	F040
Materials	Plain bearing calculation	KMAT	W070
Materials	Basic material Glued and Soldered joints	M000	M090MAT
Rolling bearings	Taper roller thrust bearings	W000	W05WNORM54
Rolling bearings	Thrust needle cages	W000	W05WNORM46
Rolling bearings	Spherical roller thrust bearings	W000	W05WNORM62
Rolling bearings	Deep groove thrust ball bearing (one-sided)	W000	W05WNORM22
Rolling bearings	Deep groove thrust ball bearing (two-sided)	W000	W05WNORM23
Rolling bearings	Angular contact thrust ball bearing (one-sided)	W000	W05WNORM20
Rolling bearings	Angular contact thrust ball bearing (two-sided)	W000	W05WNORM21
Rolling bearings	Axial angular contact roller bearing	W000	W05WNORM38
Rolling bearings	Cylindrical roller thrust bearing	W000	W05WNORM36
Rolling bearings	Taper roller bearing (single row)	W000	W05WNORM50
Rolling bearings	Taper roller bearing (paired) (X,TDI)	W000	W05WNORM51
Rolling bearings	Taper roller bearing (paired) (O, TDO)	W000	W05WNORM52
Rolling bearings	Needle cages	W000	W05WNORM41
Rolling bearings	Needle roller bearing with/without inner ring	W000	W05WNORM40
Rolling bearings	Self-aligning ball bearings	W000	W05WNORM13
Rolling bearings	Spherical roller bearings	W000	W05WNORM61
Rolling bearings	Deep groove ball bearing (single row)	W000	W05WNORM10
Rolling bearings	Deep groove ball bearing (double row)	W000	W05WNORM12
Rolling bearings	Angular contact ball bearing (single row)	W000	W05WNORM15
Rolling bearings	Angular contact ball bearing (double row) (O/X)	W000	W05WNORM16
Rolling bearings	Barrel-shaped and toroidal roller bearings	W000	W05WNORM60
Rolling bearings	Four-point contact bearing	W000	W05WNORM18
Rolling bearings	Cylindrical roller bearing (single row)	W000	W05WNORM30
Rolling bearings	Cylindrical roller bearing (single row, full complement)	W000	W05WNORM33
Rolling bearings	Cylindrical roller bearing (double row)	W000	W05WNORM31
Rolling bearings	Cylindrical roller bearing (double row, full complement)	W000	W05WNORM34
Rolling bearings	Tolerance classes	W000	W0STOL
Rolling bearings	Bearing clearance, deep groove ball bearing (single row)	W000	W05CLEARANCE10
Rolling bearings	Bearing clearance, deep groove ball bearing (double row)	W000	W05CLEARANCE12

Bearing database

Database

Each database lists bearing data per bearing type

- 1) Move column / order ascending / order descending
- 2) Show / hide hidden data sets
- 3) Search database
- 4) Move items up / to top or down / to bottom
- 5) Add new item
- 6) Hide item
- 7) Export / import data set / lists
- 8) Save database
- 9) Edit selected dataset
- 10) Close database

The screenshot shows the 'Database tool' window with the following details:

- Database: W000
- Table: W05WNORM10
- Filter: Display only active

ID	Order	Manufacturer	Bearing label	d [mm]	D [mm]	Without inner ring	Without outer ring
8794	1	SKF	W 618/1	1.0000	3.0000	No	No
14100	2	SKF	W 618/1 R	1.0000	3.0000	No	No
13598	3	SKF	W 638/1	1.0000	3.0000	No	No
13601	4	SKF	W 619/1	1.0000	4.0000	No	No
14106	5	SKF	W 619/1 R	1.0000	4.0000	No	No
13595	6	SKF	D/W R09	1.0160	3.1750	No	No
14101	7	SKF	D/W R09 R	1.0160	3.1750	No	No
13599	8	SKF	D/W R0	1.1910	3.9670	No	No
14104	9	SKF	D/W R0 R	1.1910	3.9670	No	No
13616	10	SKF	D/W R0-2Z	1.1910	3.9670	No	No
14120	11	SKF	D/W R0 R-2Z	1.1910	3.9670	No	No
13602	12	SKF	WBB1-8700	1.2000	4.0000	No	No
13622	13	SKF	WBB1-8700-2Z	1.2000	4.0000	No	No
13604	14	SKF	D/W R1	1.3970	4.7620	No	No
14109	15	SKF	D/W R1 R	1.3970	4.7620	No	No
13642	16	SKF	D/W R1-2Z	1.3970	4.7620	No	No
14146	17	SKF	D/W R1 R-2Z	1.3970	4.7620	No	No
13596	18	SKF	W 618/1.5	1.5000	4.0000	No	No
14102	19	SKF	W 618/1.5 R	1.5000	4.0000	No	No
13605	20	SKF	W 638/1.5-2Z	1.5000	4.0000	No	No
14110	21	SKF	W 638/1.5 R-2Z	1.5000	4.0000	No	No
13607	22	SKF	W 619/1.5	1.5000	5.0000	No	No
14111	23	SKF	W 619/1.5 R	1.5000	5.0000	No	No

Numbered callouts in the image:

- 1: Points to the 'Order' column header.
- 2: Points to the 'Display only active' filter dropdown.
- 3: Points to the search bar at the bottom.
- 4: Points to the 'Move up' icon.
- 5: Points to the 'Move down' icon.
- 6: Points to the 'Sort ascending' icon.
- 7: Points to the 'Sort descending' icon.
- 8: Points to the 'Save' button.
- 9: Points to the 'Edit' button.
- 10: Points to the 'Close' button.

Dataset

Each dataset contains three tabs of data

- 1) Basic data, catalogue data
- 2) Additional data
- 3) Inner geometry data
- 4) Status information

The screenshot shows the 'Display entry' window for bearing ID 14577. The window is divided into three tabs: 'Basic data', 'Additional data', and 'Internal geometry'. The 'Basic data' tab is active, showing various fields for geometry, operating data, and factors. The 'Additional data' and 'Internal geometry' tabs are also visible. Four blue callout boxes with numbers 1, 2, 3, and 4 point to specific fields: 1 points to the ID field, 2 points to the 'Additional data' tab, 3 points to the 'Internal geometry' tab, and 4 points to the 'Created by' field.

Geometry	
Manufacturer	SKF
Bearing label	315933
Comment	
Inner diameter	d 630.000000 mm
External diameter	D 780.000000 mm
Bearing type series	
Note	
Nominal width of bearing	B 56.000000 mm
Minimum corner radius	r _{s min} 0.000000 mm

Operating data	
Basic dynamic load rating	C 605.000000 kN
Basic static load rating	C ₀ 1290.000000 kN
Hybrid bearings	No
Speed limit grease lubrication	n _{Gmax} 0.000000 1/min
Speed limit using oil lubrication	n _{Omax} 0.000000 1/min
Weight	m 55.000000 kg
Contact angle	α ₀ 0.000000 °

Factors	
Factor e, e ₀	0.200000 0.000000
Factor X ₁ , X ₂	1.000000 0.920000
Factor X ₀₁ , X ₀₂	1.000000 1.000000
Factor Y ₁ , Y ₂	0.000000 0.600000
Factor Y ₀₁ , Y ₀₂	0.000000 0.000000
Factor for the calculation of e, X and Y	f ₀ 0.000000

Dataset

Tab “Basic data”

- 1) Load ratings, X, Y factors, ...
- 2) “Hybrid bearings”: for information only, does not affect any results

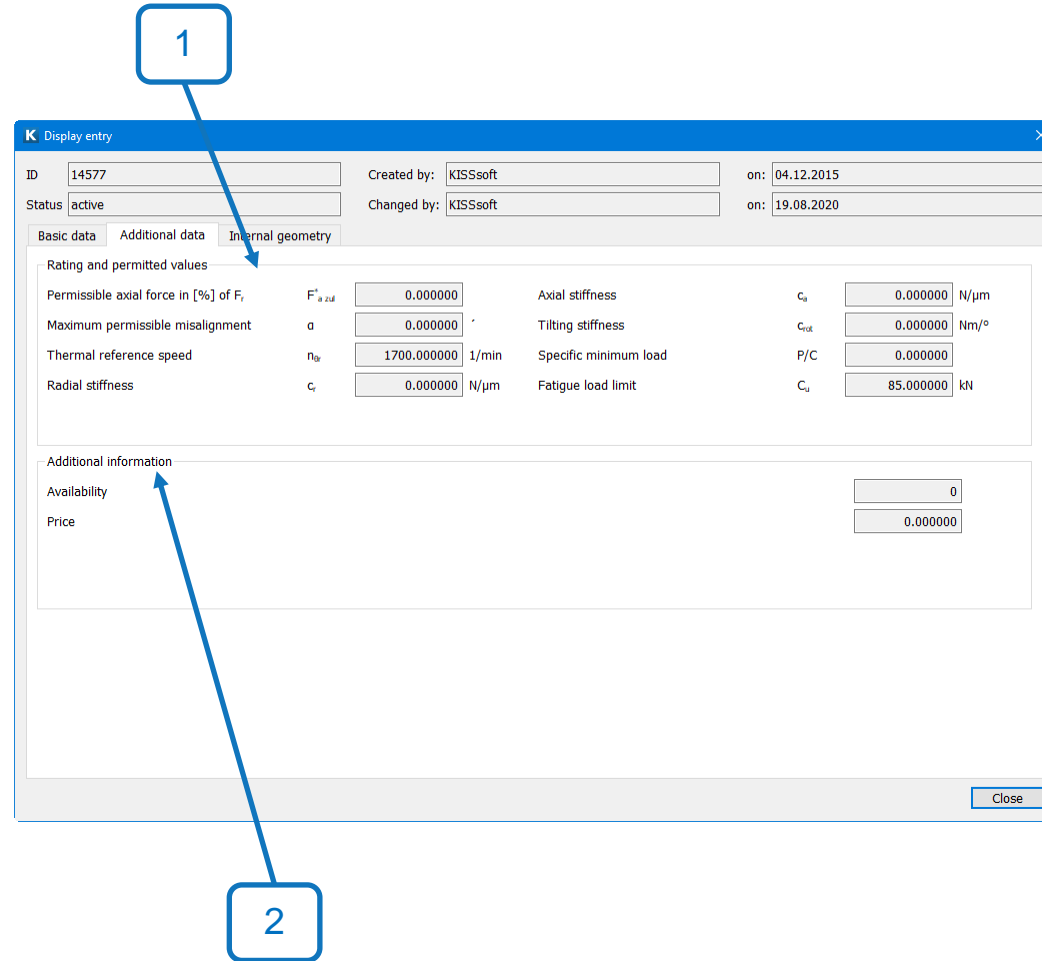
The screenshot shows the 'Display entry' window for a bearing with ID 14577. The 'Basic data' tab is active. The 'Hybrid bearings' field is set to 'No'. The 'Factors' section contains several input fields for load ratings and factors.

Field	Value	Unit
ID	14577	
Status	active	
Created by	KISSsoft	
Created on	04.12.2015	
Changed by	KISSsoft	
Changed on	19.08.2020	
Manufacturer	SKF	
Bearing label	315933	
Inner diameter (d)	630.000000	mm
External diameter (D)	780.000000	mm
Nominal width of bearing (B)	56.000000	mm
Minimum corner radius (r _{s min})	0.000000	mm
Basic dynamic load rating (C)	605.000000	kN
Basic static load rating (C ₀)	1290.000000	kN
Speed limit grease lubrication (n _{Gmax})	0.000000	1/min
Speed limit using oil lubrication (n _{Omax})	0.000000	1/min
Weight (m)	55.000000	kg
Contact angle (α ₀)	0.000000	°
Factor e ₁ , e ₀	0.200000	0.000000
Factor X ₁ , X ₂	1.000000	0.920000
Factor X ₀₁ , X ₀₂	1.000000	1.000000
Factor Y ₁ , Y ₂	0.000000	0.600000
Factor Y ₀₁ , Y ₀₂	0.000000	0.000000
Factor for the calculation of e, X and Y (f ₀)	0.000000	

Dataset

Tab “Additional data”

- 1) Additional values used for calculations. If no data is available, calculation or warning messages associated are ignored.
- 2) Additional values used for information. These values are currently not used in calculations but for documentation only.



Bearing database, rolling bearing fatigue load limit C_u

- Bearing fatigue load limit C_u is used to calculate factor a_{ISO} , which is needed to calculate modified rating life. If C_u is not in the database, it is calculated.
- For modified **basin** rating life (L_{nm}) acc. to
 - simplified** method given in ISO 281:2008 **B.3.3**.
- For **reference** rating life (L_{nmr}) acc. to:
 - advanced** method given in ISO 281:2008 **B.3.2** for **ball** bearings,
 - simplified** method given in ISO 281:2008 **B.3.3** for **roller** bearings.
- Each section in the bearing report prints the value used at that section.

3 Shaft 'Shaft' Rolling bearing 'Roller bearing 1 - DGBB'		
Deep groove ball bearing (single row) (TIMKEN 62208-2RS)		
Inner diameter	[d]	40.000 mm
Outer diameter	[D]	80.000 mm
Width	[B]	23.000 mm
Dynamic load rating	[C]	29.100 kN
Static load rating	[C ₀]	17.900 kN
Fatigue load limit	[C _u]	0.000 kN

3.2 Results according to ISO 281		
Load ratio	[C/P]	2.989
Operating viscosity	[v]	425.092 mm ² /s
Reference viscosity	[v ₁]	19.117 mm ² /s
Viscosity ratio	[k]	22.236
Contamination factor	[e _c]	0.410
Fatigue load limit	[C _u]	0.814 kN

3.3 Calculation with estimated bearing internal geometry (ISO/TS 16281:2008)		
Number of rolling elements	[Z]	9
Diameter of rolling element	[D _w]	11.660 mm
Reference diameter	[D _{ref}]	60.000 mm
Diameter of inner ring	[d _i]	48.334 mm
Diameter of outer ring	[d _e]	71.666 mm
Radius of curvature inner ring	[r _i]	6.063 mm
Radius of curvature outer ring	[r _e]	6.180 mm
Nominal contact angle	[α]	0.000 °
Initial contact angle	[α ₀]	8.564 °
Dynamic load rating	[C ₁]	29.100 kN
Fatigue load limit	[C _u]	0.873 kN

Bearing database

Dataset

Tab “Internal geometry”

- 1) Correction factors
- 2) Axial clearance
- 3) Contains internal geometry data
- 4) Definition of rolling element modification
- 5) Influences graphics in shaft editor

The screenshot shows the 'Display entry' window for a bearing dataset. The 'Internal geometry' tab is active. The window contains the following fields and callouts:

- Callout 1: Correction factor (dynamic rating) f_c = 1.0000
- Callout 2: Axial displacement possibility non-locating bearing v_1 = 0.0000 mm and Axial displacement possibility fixed bearing v_2 = 0.0000 mm
- Callout 3: Number of rollers Z = 11
- Callout 4: Inner raceway modification $r_{mod,i}$ = 0.0000 mm
- Callout 5: Without inner ring = No

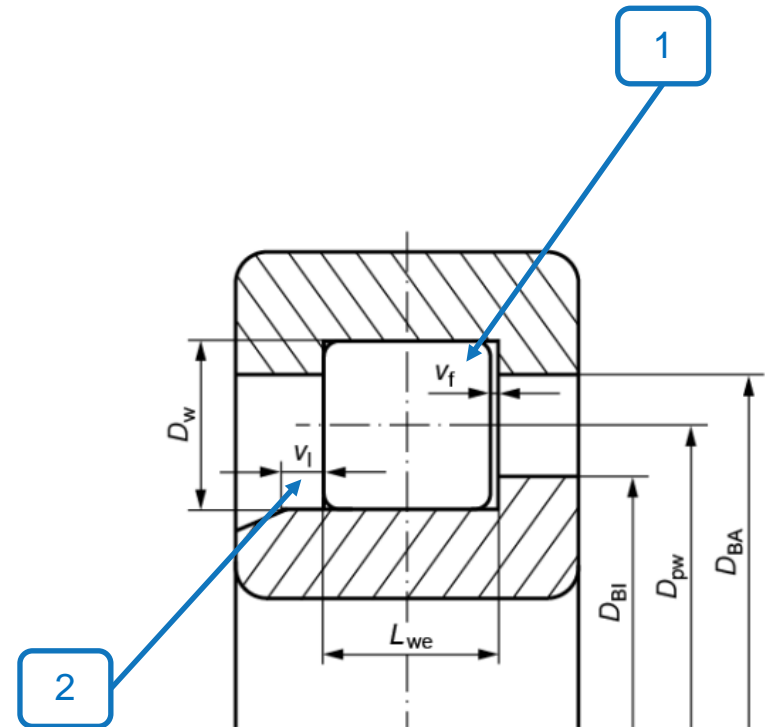
Parameter	Value	Unit
ID	8003	
Status	active	
Created by	KISSsoft	
Created on	24.11.2006	
Changed by	KISSsoft	
Changed on	19.08.2020	
Correction factor (dynamic rating) f_c	1.0000	
Correction factor (static rating) f_{c0}	1.0000	
Number of rollers Z	11	
Diameter of roller D_w	6.5000	mm
Rolling body pitch circle diameter D_{pw}	28.6000	mm
Inside diameter of the rim, pressure side D_{BI}	0.0000	mm
Outside diameter of the rim, pressure side D_{BA}	0.0000	mm
Effective roller length L_{we}	0.0000	mm
Axial displacement possibility non-locating bearing v_1	0.0000	mm
Axial displacement possibility fixed bearing v_2	0.0000	mm
Inner raceway modification $r_{mod,i}$	0.0000	mm
Outer raceway modification $r_{mod,o}$	0.0000	mm
Without inner ring	No	
Without outer ring	No	

Tab “Internal geometry”

Axial displacement possibility

- 1) V_f : For a locating bearing, one ring is free to move with respect to the other by amount V_f in axial direction.
- 2) V_l : For a non-locating bearing, one ring is free to move with respect to the other by amount V_l in axial direction.

Note the setting “Axial clearance” in module specific settings.

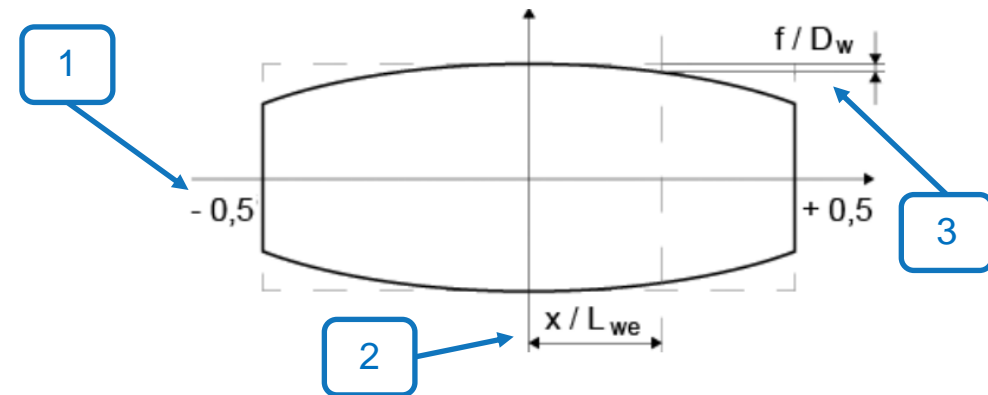


Bearing database

Tab “Internal geometry”

Roller and raceways modifications

- 1) Effective roller length is normalized
- 2) Length coordinate is normalized with effective roller length
- 3) Modification is normalized with nominal roller diameter (positive value removes material from cylinder)
- 4) Modification is defined in a text (*.dat) file
- 5) First column is a counter
- 6) Second column defines normalized, lengthwise coordinate
- 7) Third column defines normalized modification value
- 8) Example file



The screenshot shows a text file named 'rollerProfile-original.dat' with the following content:

```
rollerProfile-original.dat x
-- index          position      roller length (mm / mm)      profile / roller diameter (mm / mm)
-- this line is a comment
DATA
0          0.45      0.001581256
1          -0.43      0.000970938
2          -0.41      0.000390587
3          -0.39      0.00032813
4          -0.37      0.000277616
5          -0.35      0.000235671
6          -0.33      0.000200197
7          -0.31      0.000169805
8          -0.29      0.000143527
...
```

Blue boxes labeled 4, 5, 6, and 7 point to the first, second, and third columns of the data table respectively.

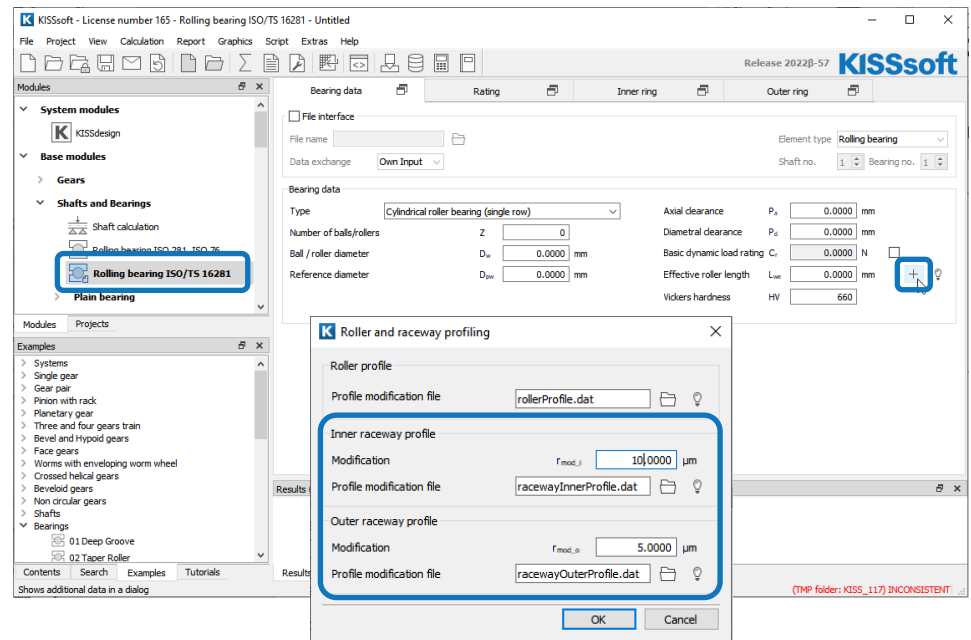
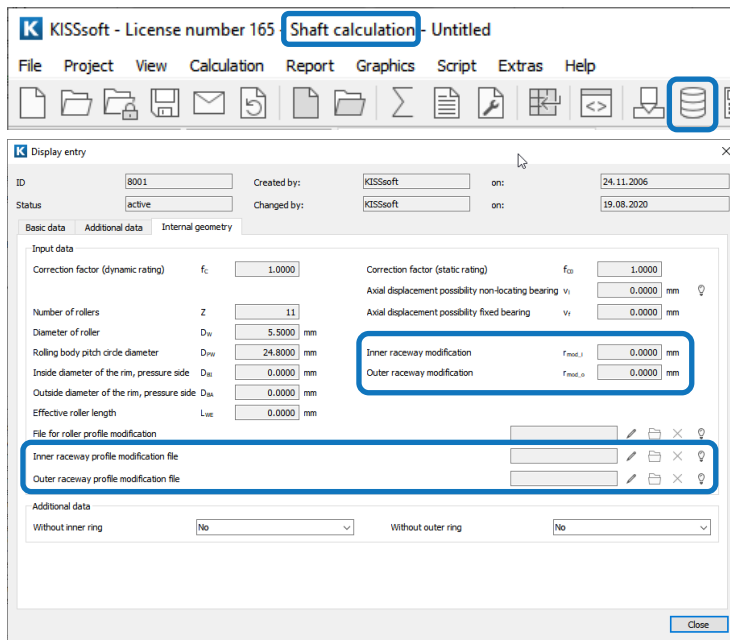
The screenshot shows a file explorer window with the following files:

Name	Änderungsdatum
ringDeformation.dat	17.08.2020 07:54
ringDeformationAndTilting.dat	17.08.2020 07:54
rollerProfile.dat	17.08.2020 07:54

A blue box labeled '8' points to the 'rollerProfile.dat' file.

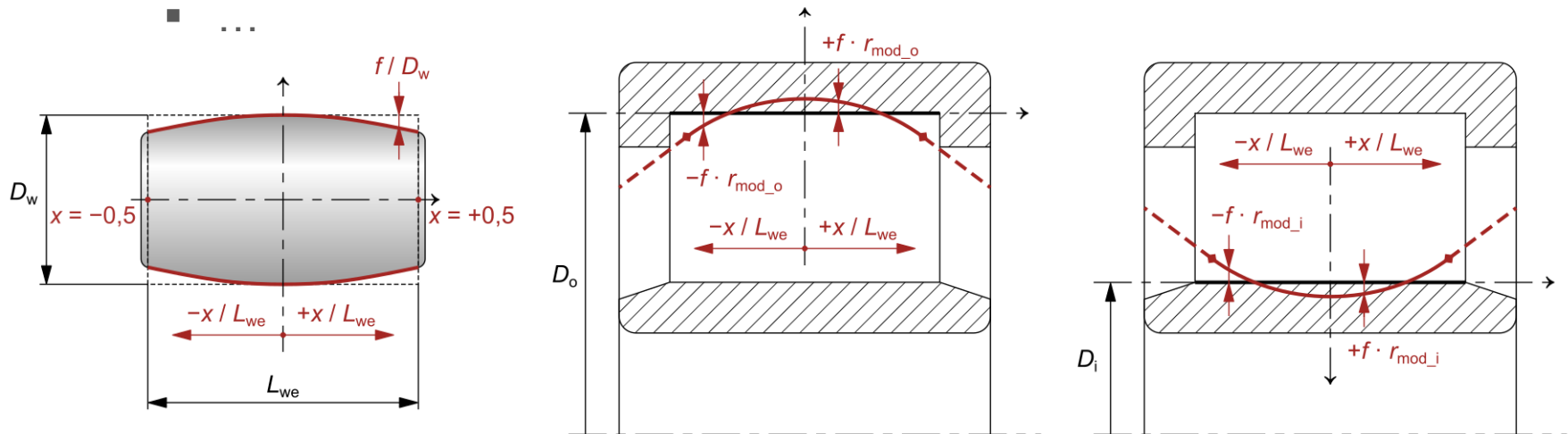
Bearing database: Custom raceway profile for cylindrical roller bearings

- Define custom raceway profile for cylindrical roller bearing by providing raceway profile modification file.
- Raceway profile modification $\Delta(x)$ is defined as a multiplication of a constant modification value r_{mod} and a modification ratio for a given relative position along the roller effective length $f(x)$: $\Delta(x) = f(x) \cdot r_{mod}$



Bearing database: Custom raceway profile for cylindrical roller bearings

- **Cylindrical roller bearings** usually have profiled rollers and flat raceways
- Similarly, as one can already define custom profile of rollers, now it can also define custom profiles of inner and outer raceways.
- Why would one like to do that?
 - To simulate production errors.
 - For custom designed bearings.

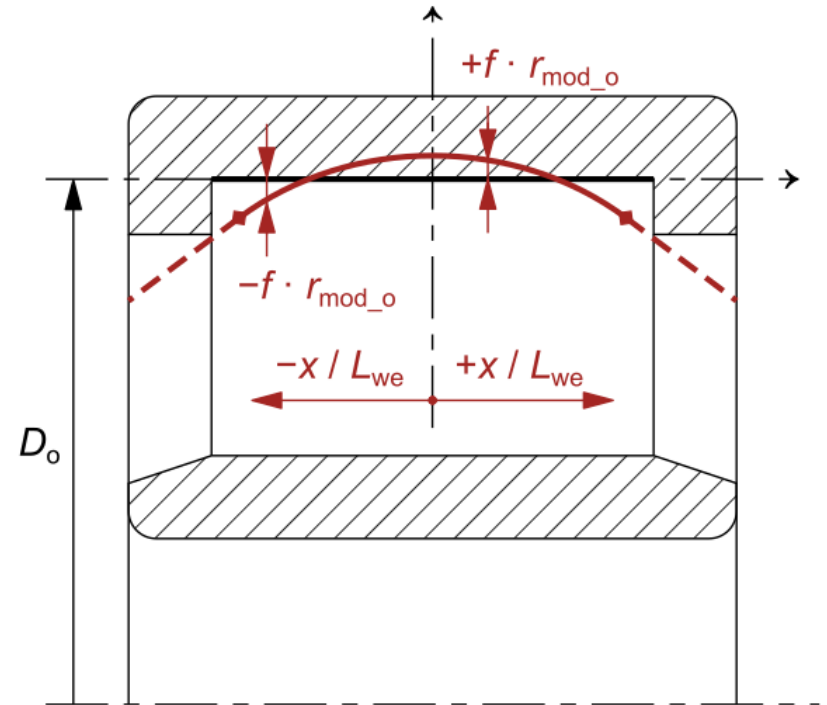


Bearing database: Custom raceway profile for cylindrical roller bearings

- Raceway profile modification $\Delta(x)$ is defined as a multiplication of a constant modification value r_{mod} and a modification ratio $f(x)$ for a given relative position along the roller effective length:

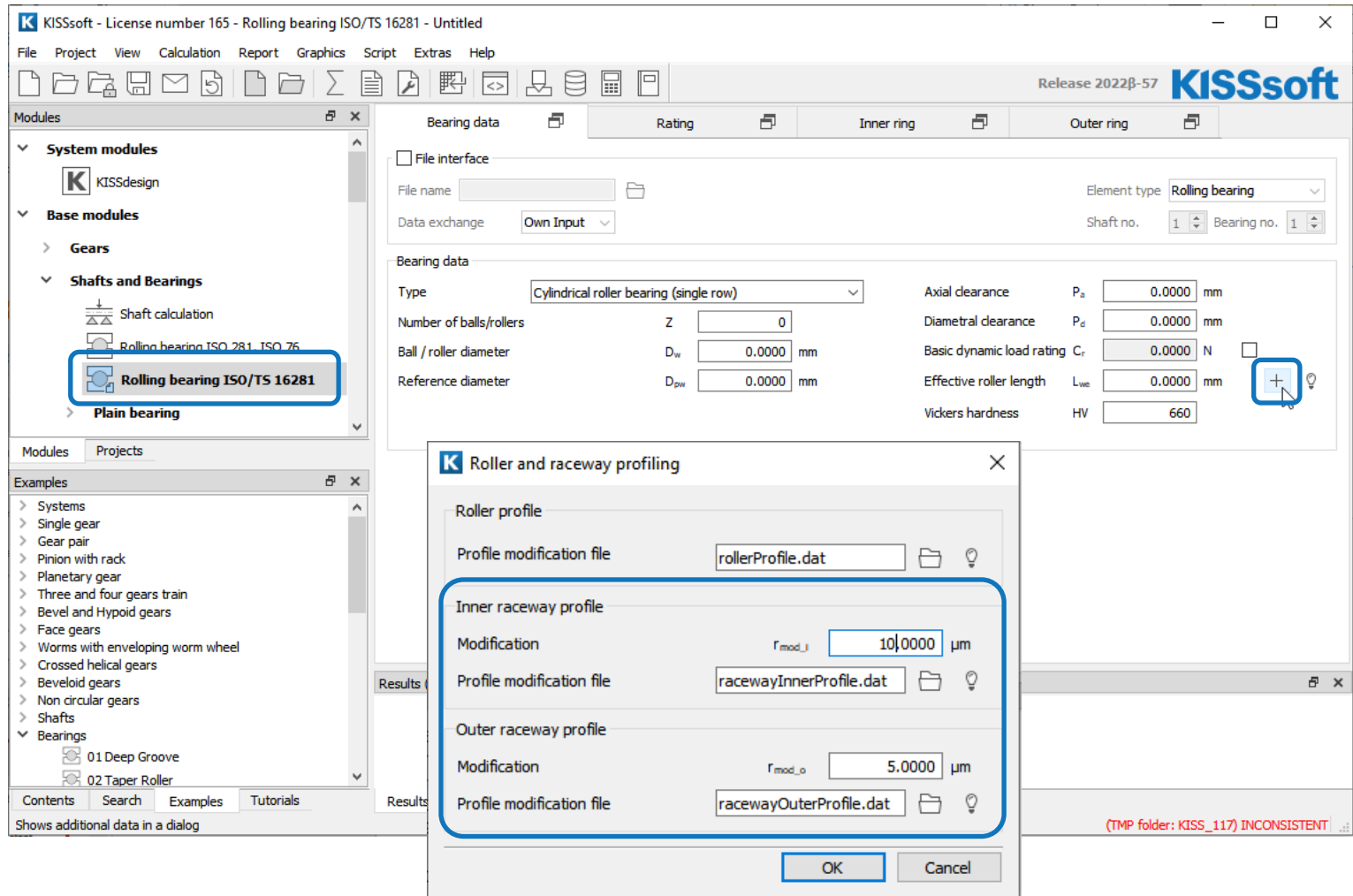
$$\Delta(x) = f(x) \cdot r_{mod}$$

- Profile modification can be defined for each raceway separately.
- Modification ratio $f(x)$ is defined in a DAT file.
- Constant modification value r_{mod} is defined in user interface.



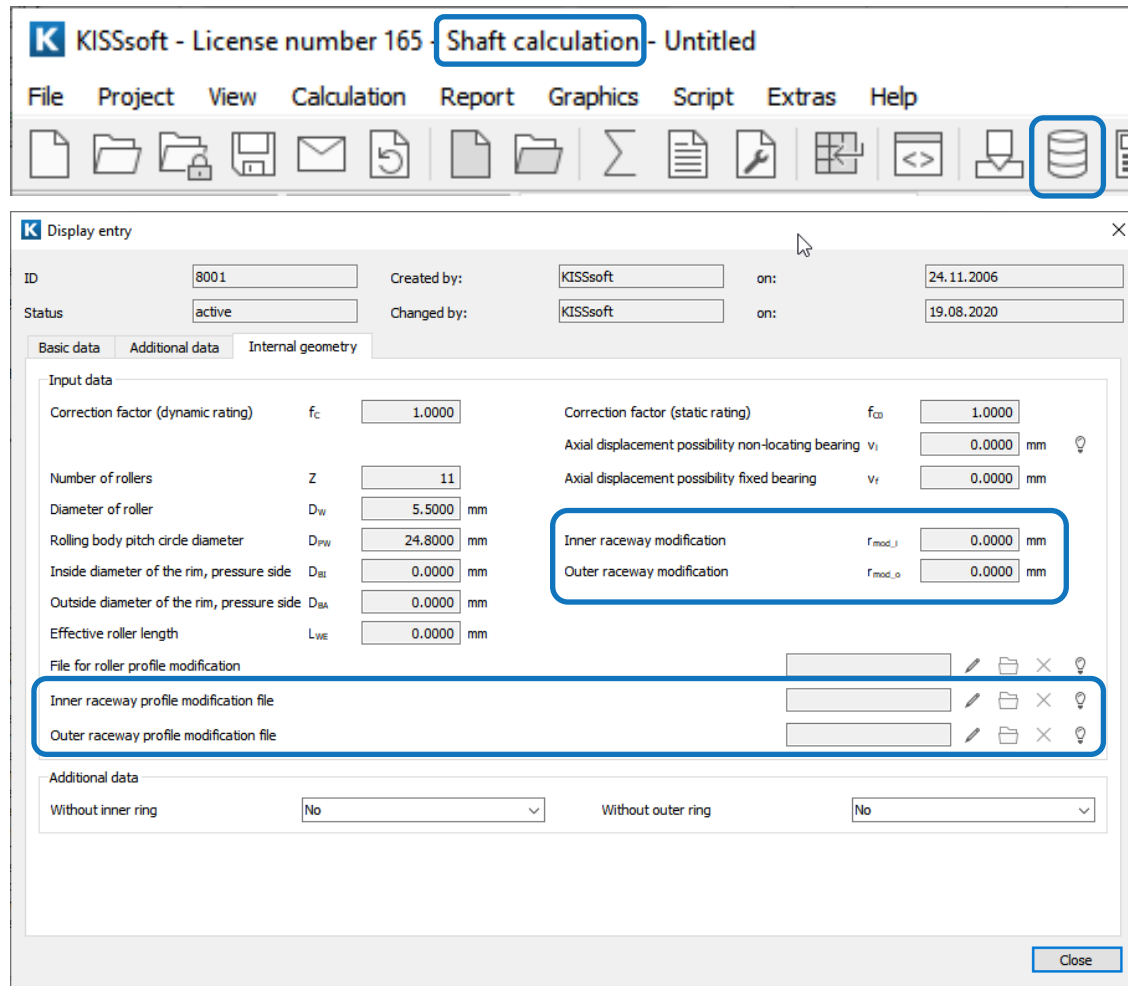
Bearing database: Custom raceway profile for cylindrical roller bearings

- It can be used from module **Rolling bearing ISO/TS 16281**



W010 & W051, RP: Custom raceway profile for cylindrical roller bearings

- It can be used from module **Shaft calculation** by defining custom bearing



Bearing database: Custom raceway profile for cylindrical roller bearings

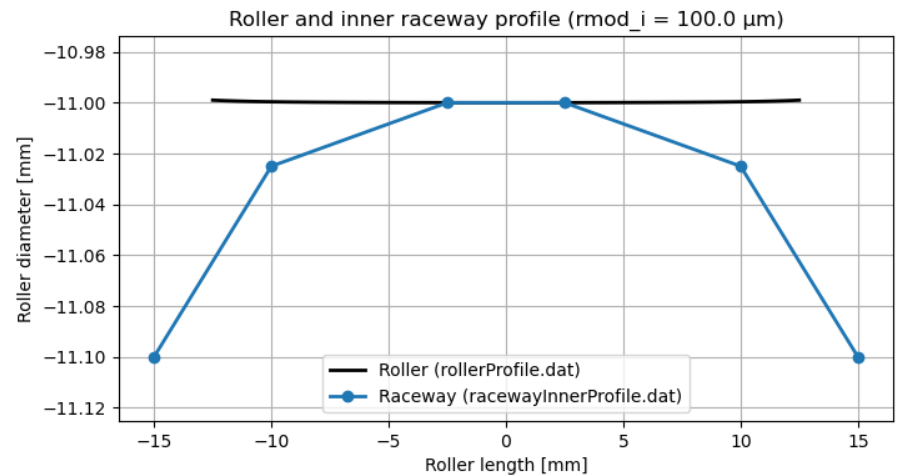
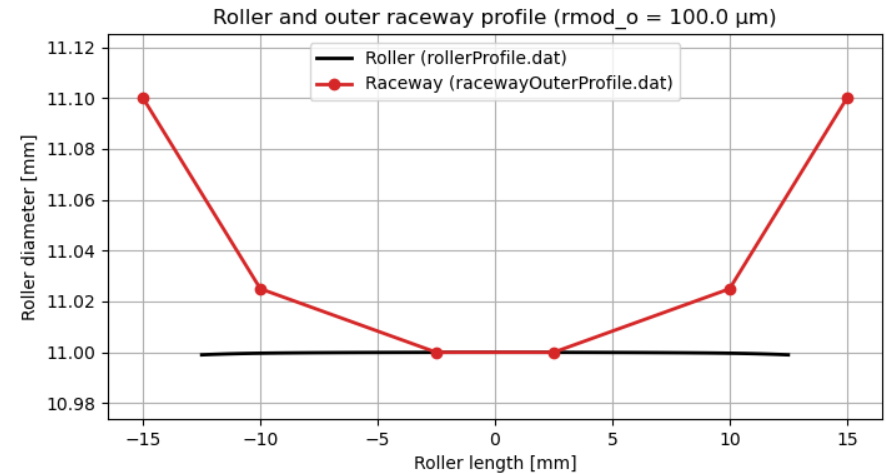
Example of raceway profile modification files

File Explorer path: This PC > OS (C:) > Program Files > KISSsoft AG > KISSsoft 2022 > dat

Name	Date modified	Type
racewayInnerProfile.dat	02/03/2022 13:37	DAT File
racewayOuterProfile.dat	02/03/2022 13:37	DAT File

```
racewayOuterProfile.dat
1  -- This is a comment
2  -- Positive modification ratio increases clearance
3  -- Negative modification ratio reduces clearance at
4  -- At least 1 value of modification ratio must be
5  -- index | relative position | modification ratio
6  DATA
7  .1 . . . . . -0.60 . . . . . 1.00
8  .2 . . . . . -0.40 . . . . . 0.25
9  .3 . . . . . -0.10 . . . . . 0.00
10 .4 . . . . . 0.10 . . . . . 0.00
11 .5 . . . . . 0.40 . . . . . 0.25
12 .6 . . . . . 0.60 . . . . . 1.00
13 END
```

```
racewayInnerProfile.dat
1  -- This is a comment
2  -- Positive modification ratio increases clearance
3  -- Negative modification ratio reduces clearance at
4  -- At least 1 value of modification ratio must be
5  -- index | relative position | modification ratio
6  DATA
7  .1 . . . . . -0.60 . . . . . 1.00
8  .2 . . . . . -0.40 . . . . . 0.25
9  .3 . . . . . -0.10 . . . . . 0.00
10 .4 . . . . . 0.10 . . . . . 0.00
11 .5 . . . . . 0.40 . . . . . 0.25
12 .6 . . . . . 0.60 . . . . . 1.00
13 END
```



Bearing database: Custom raceway profile for cylindrical roller bearings

- Module W051: example 5 with changed load, **without raceway modification**

The screenshot displays the KISSsoft software interface for bearing calculation. The main window is divided into several sections:

- Bearing data / Rating:** Shows input parameters for the bearing. Under "Rating", "Displacement" is selected. "Tilting around z-axis" is set to 1.0000 mrad. Other parameters include axial displacement (0.0000 mm), radial displacement in y and z directions (0.0000 mm), rotation speed of inner and outer rings (1000.0000 and 0.0000 1/min), and lubricant (Oil: ISO-VG 220).
- Results (basic calculation):** A table showing calculated values:

Cr	166.184 kN		
L10r		17.55	
Lnrh		292.441 h	
pmax_i	3522.068 N/mm ²		inside
pmax_o	2086.963 N/mm ²		outside
ux	0.000 μm	Fx	-0.000 kN
uy	0.000 μm	Fy	0.000 kN
uz	0.000 μm	Fz	-0.059 kN
ry	0.000 mrad	My	0.000 Nm
rz	1.000 mrad	Mz	-2141.078 Nm
- Graphics:** A 3D visualization of the bearing's load distribution. The rollers are shown in a circular arrangement, with a color scale on the right indicating Hertzian pressure in N/mm². The scale ranges from 0.000 (blue) to 3522.068 (red).
- Roller and raceway profiling:** A dialog box showing the roller profile and raceway profiles. The "Inner raceway profile" and "Outer raceway profile" modification fields are both set to 0.0000 mm.

Bearing database: Custom raceway profile for cylindrical roller bearings

- Module W051: example 5 with changed load, with raceway modification

The screenshot displays the KISSsoft software interface for bearing calculation. The main window is divided into several panels:

- Bearing data:** Contains input fields for Rating (Force/Displacement), Tilting moment/Tilting, and Rotation/Vibration. The 'Tilting around z-axis' r_z is set to 1.0000 mrad.
- Results (basic calculation):** A table showing calculated values. The 'Reference rating life' section is highlighted with a blue box.
- Roller and raceway profiling:** A dialog box for defining custom profiles. The 'Modification' fields for both inner and outer raceways are set to 0.1 mm.
- Graphics:** A 3D visualization of the bearing's load distribution, showing rollers and raceways with a color-coded Hertzian pressure map. A vertical color scale on the right indicates pressure values from 0.000 to 1658.139 N/mm².

Parameter	Value
Cr	166.184 kN
L10r	1909.59
Reference rating life	
Lnrh	31826.428 h
pmax_i	1658.139 N/mm ² (inside)
pmax_o	841.209 N/mm ² (outside)

Parameter	Value
ux	0.000 μm
uy	0.000 μm
uz	0.000 μm
ry	0.000 mrad
rz	1.000 mrad
Fx	-0.000 kN
Fy	-0.000 kN
Fz	0.005 kN
My	0.000 Nm
Mz	-592.459 Nm

Bearing database: Custom raceway profile for cylindrical roller bearings

Results

KISSsoft

Roller profile file [P(k)]: rollerProfile.dat
 Raceway profiling file - inner ring [RPI(k)]: racewayInnerProfile.dat
 Raceway profiling file - outer ring [RPO(k)]: racewayOuterProfile.dat

Section k	Position (mm)	Profiling			a _{ISO} (-)	P _{ks} (N)
		P(k) (μm)	RPI(k) (μm)	RPO(k) (μm)		
1	-12.20	13.084	0.000	0.000	0.38	155036.13
2	-11.59	10.093	0.000	0.000	0.58	82544.59
3	-10.98	7.811	0.000	0.000	0.60	78663.96
4	-10.37	6.138	0.000	0.000	0.61	76208.99
5	-9.76	4.933	0.000	0.000	0.63	73174.45
6	-9.15	4.034	0.000	0.000	0.66	69556.51
7	-8.54	3.308	0.000	0.000	0.69	65607.57
8	-7.93	2.708	0.000	0.000	0.74	61398.78
9	-7.32	2.206	0.000	0.000	0.79	56985.29
10	-6.71	1.784	0.000	0.000	0.85	52398.72
11	-6.10	1.430	0.000	0.000	0.93	47673.59
12	-5.49	1.128	0.000	0.000	1.04	42860.06
13	-4.88	0.870	0.000	0.000	1.19	37981.34
14	-4.27	0.651	0.000	0.000	1.41	33059.05
15	-3.66	0.472	0.000	0.000	1.73	28101.52
16	-3.05	0.324	0.000	0.000	2.28	23143.73
17	-2.44	0.206	0.000	0.000	3.34	18213.56
18	-1.83	0.115	0.000	0.000	5.99	13343.64
19	-1.22	0.051	0.000	0.000	17.18	8580.14
20	-0.61	0.014	0.000	0.000	50.00	4012.76
21	0.00	0.002	0.000	0.000	50.00	18.79
22	0.61	0.014	0.000	0.000	50.00	4012.76
23	1.22	0.051	0.000	0.000	17.18	8580.14
24	1.83	0.115	0.000	0.000	5.99	13343.64
25	2.44	0.206	0.000	0.000	3.34	18213.56

KISSsoft

Roller profile file [P(k)]: rollerProfile.dat
 Raceway profiling file - inner ring [RPI(k)]: racewayInnerProfile.dat
 Raceway profiling file - outer ring [RPO(k)]: racewayOuterProfile.dat

Section k	Position (mm)	Profiling			a _{ISO} (-)	P _{ks} (N)
		P(k) (μm)	RPI(k) (μm)	RPO(k) (μm)		
1	-12.20	13.084	57.927	57.927	1.00	0.00
2	-11.59	10.093	48.780	48.780	50.00	3791.86
3	-10.98	7.811	39.634	39.634	4.68	15107.93
4	-10.37	6.138	30.488	30.488	1.87	26589.66
5	-9.76	4.933	24.187	24.187	1.38	33500.61
6	-9.15	4.034	22.154	22.154	1.39	33430.15
7	-8.54	3.308	20.122	20.122	1.41	32957.52
8	-7.93	2.708	18.089	18.089	1.45	32184.21
9	-7.32	2.206	16.057	16.057	1.51	31176.75
10	-6.71	1.784	14.024	14.024	1.59	29971.53
11	-6.10	1.430	11.992	11.992	1.69	28602.51
12	-5.49	1.128	9.959	9.959	1.82	27115.13
13	-4.88	0.870	7.927	7.927	1.98	25529.57
14	-4.27	0.651	5.894	5.894	2.18	23863.63
15	-3.66	0.472	3.862	3.862	2.44	22121.94
16	-3.05	0.324	1.829	1.829	2.78	20333.70
17	-2.44	0.206	0.000	0.000	3.34	18213.56
18	-1.83	0.115	0.000	0.000	5.99	13343.64
19	-1.22	0.051	0.000	0.000	17.18	8580.14
20	-0.61	0.014	0.000	0.000	50.00	4012.76
21	0.00	0.002	0.000	0.000	50.00	18.79
22	0.61	0.014	0.000	0.000	50.00	4012.76
23	1.22	0.051	0.000	0.000	17.18	8580.14
24	1.83	0.115	0.000	0.000	5.99	13343.64
25	2.44	0.206	0.000	0.000	3.34	18213.56

- Limitations:
 - Currently it works only for cylindrical roller bearings
 - Important note for roller edge stresses – ISO/TS 16281

5.3.3 Concentration of edge stress

In cases where the rolling elements are only lightly profiled or severely misaligned, edge stresses can arise which need to be taken into account in the rating life calculation. The distribution of contact stress over the length of the rolling elements can be calculated by means of References [5], [6] or [7]. From the calculated distribution of the contact stress over the roller length, an approximated function of the stress concentration at the inner ring raceway, $f_i[j,k]$, can be obtained from Equation (58) and at the outer ring raceway, $f_e[j,k]$, from Equation (59).

$$f_i[j,k] = \left[\left(\frac{P_{Hi,j,k}}{271} \right)^2 D_{we} (1 - \gamma) \frac{L_{we}}{n_s} \right] / q_{j,k} \quad (58)$$

$$f_e[j,k] = \left(\frac{P_{He,j,k}}{271} \right)^2 D_{we} (1 + \gamma) \frac{L_{we}}{n_s} / q_{j,k} \quad (59)$$

As a first approximation, a stress riser function, $f[k]$, determined from contact stress calculations, can be used for the lamina k

$$f_i[k] = f_e[k] = 1 - \left[0,01 / \ln \left(1,985 \left| \frac{2k - n_s - 1}{2n_s - 2} \right| \right) \right] \quad (60)$$

This approximation function is only valid for an approximated profile obtained with the aid of the Equations (42), (43) and (44), and providing the conditions of medium load and a total misalignment of the bearing of less than 4' are fulfilled. For a general calculation, the use of the methods described in References [5], [6] or [7] is recommended.

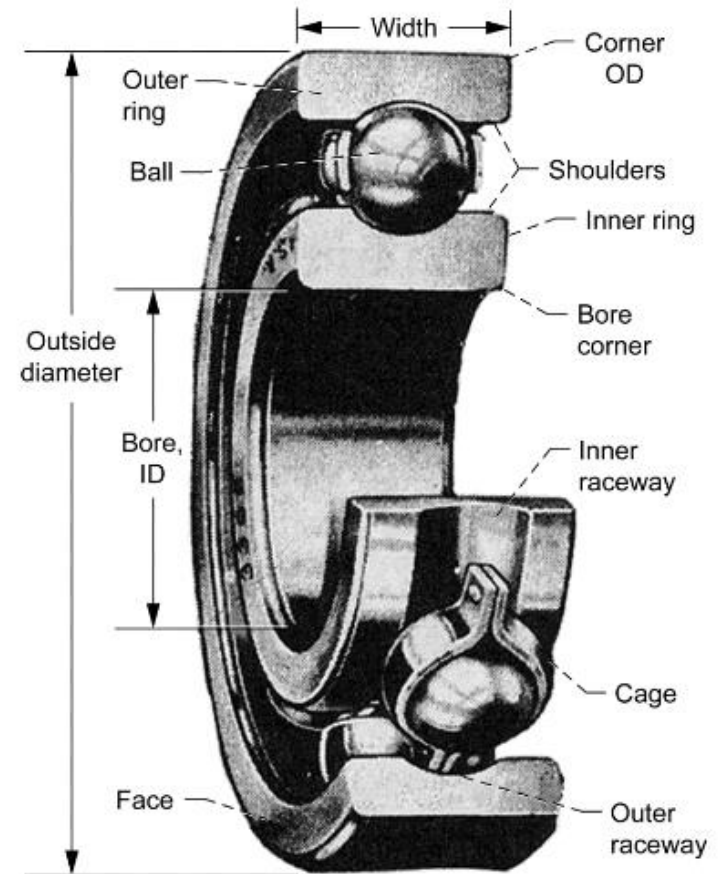
Concepts

Nomenclature

Rolling elements may be balls or rollers.


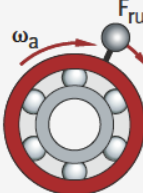

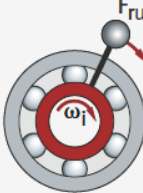
In case of rollers, different roller types, e.g., cylindrical rollers may be used.

While cages are most important for proper working of bearings and may be a cause of failure, they are not covered here as calculation methods including or aiming at cages are not included in the calculation methods implemented in KISSsoft.



Inner and/or outer ring rotation

- Calculation of basic **reference** rating life L_{nr} acc. to ISO/TS 16281 basically takes into account “number of load passages over a point on the bearing ring”.
- It is important to know whether the bearing ring is **stationary** or **rotating** relative to the bearing load → point load or circumferential load.

Conditions of rotation	Example	Schematic	Load case	Fit
Rotating inner ring Stationary outer ring Constant load direction	Shaft with weight load		Circumferential load on inner ring and Point load on outer ring	Inner ring: tight fit necessary and Outer ring: loose fit permissible
Stationary inner ring Rotating outer ring Load direction rotates with outer ring	Hub bearing arrangement with significant imbalance			
Stationary inner ring Rotating outer ring Constant load direction	Passenger car front wheel, track roller, (hub bearing arrangement)		Point load on inner ring and Circumferential load on outer ring	Inner ring: loose fit permissible and Outer ring: tight fit necessary
Rotating inner ring Stationary outer ring Load direction rotates with inner ring	Centrifuge, vibrating screen			

Source: Schaeffler Technical Pocket Guide, 2021

Inner and/or outer ring rotation

- Basic **reference** rating life L_{nr} acc. to ISO/TS 16281 for ball bearings

$$L_{10r} = \left[\begin{array}{c} Q_{ci} \\ Q_{ei} \end{array} \right]^{-10/3} + \left[\begin{array}{c} Q_{ce} \\ Q_{ee} \end{array} \right]^{-10/3} \Bigg]^{-9/10}$$

→ Rolling element load for the basic dynamic load rating C
→ Dynamic equivalent rolling element load for the bearing load

4.3.2 Dynamic equivalent rolling element load

The dynamic equivalent rolling element load for an inner ring or a shaft washer, Q_{ei} , which is rotating relative to the bearing load is

$$Q_{ei} = \left(\frac{1}{Z} \sum_{j=1}^Z Q_j^3 \right)^{1/3} \quad (25)$$

and for an inner ring or a shaft washer which is stationary relative to the bearing load is

$$Q_{ei} = \left(\frac{1}{Z} \sum_{j=1}^Z Q_j^{10/3} \right)^{3/10} \quad (26)$$

The dynamic equivalent rolling element load for an outer ring or a housing washer, Q_{ee} , which is stationary relative to the bearing load is

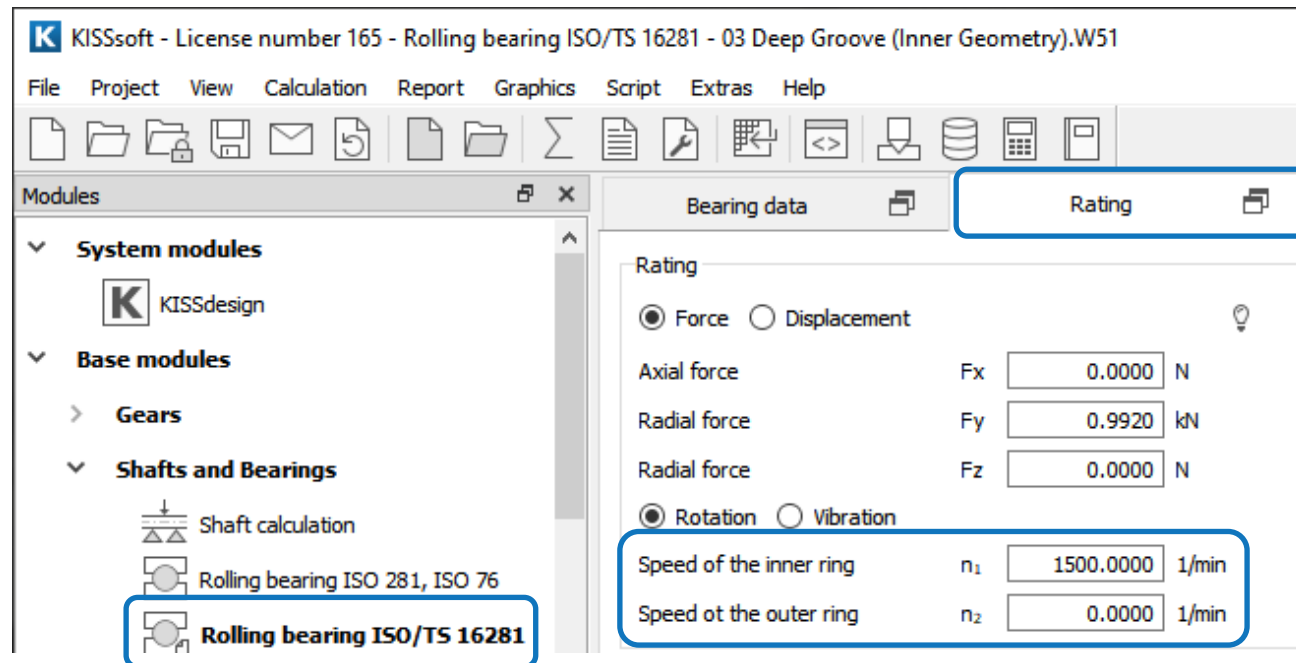
$$Q_{ee} = \left(\frac{1}{Z} \sum_{j=1}^Z Q_j^{10/3} \right)^{3/10} \quad (27)$$

and for an outer ring or a housing washer which is rotating relative to the bearing load is

$$Q_{ee} = \left(\frac{1}{Z} \sum_{j=1}^Z Q_j^3 \right)^{1/3} \quad (28)$$

Inner and/or outer ring rotation

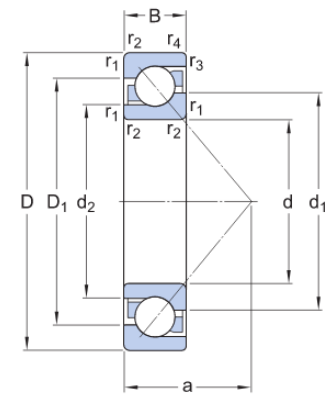
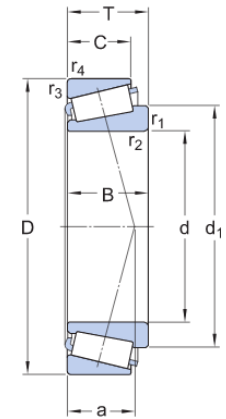
- Module W10: automatically taken into account by rotating speed(s) of the shaft(s).
- Module W051: two separate fields to enter inner/outer ring rotating speeds.



Inner and/or outer ring rotation

- Comparison of results

	A	B	C	D	E	F	G	H	I	J
2		Test file:	W010-Test SKF interface with different speeds.W10							
3										
4		Bearing 1	2021-SP2			2022-DEBUG-20211110			Delta 2021 vs 2022 [%]	
5		SKF 32052 X	KISSsoft	SKF	Delta [%]	KISSsoft	SKF	Delta [%]	KISSsoft	SKF
6	Lnrh	n1 = 50 rpm n2 = 0 rpm	58853	56087	-4,70	58853	56087	-4,70	0,00	0,00
7		n1 = 0 rpm n2 = 50 rpm	58853	56087	-4,70	54063	51970	-3,87	-8,14	-7,34
8		n1 = 15 rpm n2 = +75 rpm	49044	46739	-4,70	50954	48979	-3,88	3,89	4,79
9		n1 = +75 rpm n2 = 15 rpm	49044	46739	-4,70	50955	48979	-3,88	3,90	4,79
10		n1 = 15 rpm n2 = -75 rpm	32696	31159	-4,70	33970	32653	-3,88	3,90	4,79
11		n1 = -75 rpm n2 = 15 rpm	32696	31159	-4,70	33970	32654	-3,87	3,90	4,80
12										
13		Bearing 2	2021-SP2			2022-DEBUG-20211110			Delta 2021 vs 2022 [%]	
14		SKF 7052	KISSsoft	SKF	Delta [%]	KISSsoft	SKF	Delta [%]	KISSsoft	SKF
15	Lnrh	n1 = 50 rpm n2 = 0 rpm	2534	2818	11,21	2534	2818	11,21	0,00	0,00
16		n1 = 0 rpm n2 = 50 rpm	2534	2818	11,21	2454	2758	12,39	-3,16	-2,13
17		n1 = 15 rpm n2 = +75 rpm	2111	2348	11,23	2193	2445	11,49	3,88	4,13
18		n1 = +75 rpm n2 = 15 rpm	2111	2348	11,23	2193	2445	11,49	3,88	4,13
19		n1 = 15 rpm n2 = -75 rpm	1408	1565	11,15	1462	1630	11,49	3,84	4,15
20		n1 = -75 rpm n2 = 15 rpm	1408	1565	11,15	1462	1630	11,49	3,84	4,15



Load distribution

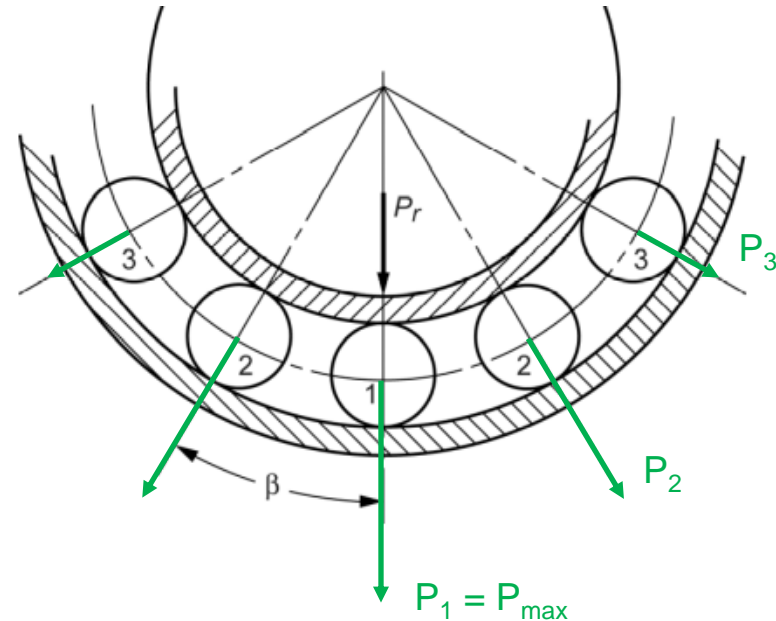
Stribeck number

- 1) Load P_r is applied to a bearing.
- 2) The rolling element loads for an undeformed, clearance free bearing may be determined.
- 3) Load P_r is equal to the sum of the pair forces P_i , component in direction of P_r

$$P_r = P_1 + 2P_2 \cos \beta + 2P_3 \cos 2\beta + \dots + 2P_{n+1} \cos n\beta$$

$$n = \text{INT} \left(\frac{z-1}{4} \right) \quad \beta = \frac{2\pi}{z} \quad P_{\max} = \frac{P_r}{Q} = \frac{S_t P_r}{z} \quad S_t = \frac{z}{Q} = \frac{P_{\max}}{P_r / z}$$

P_r	radial load
z	number of rolling elements
n	number of pairs of rolling elements under load
S_t	Stribeck number, ≈ 5
P_{\max}	Highest load on a rolling element
Q	$= z / S_t$
β	Pitch angle

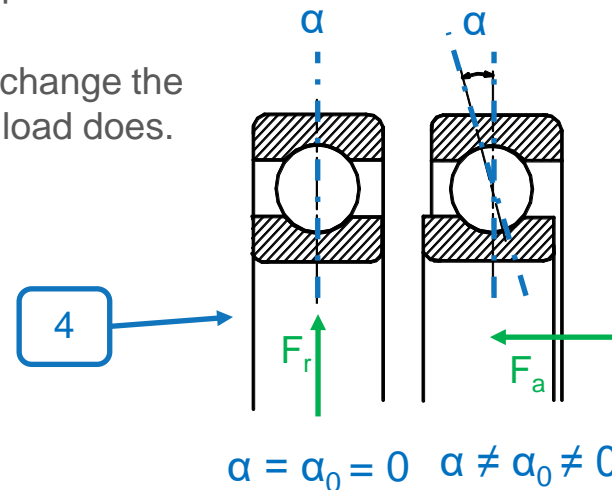
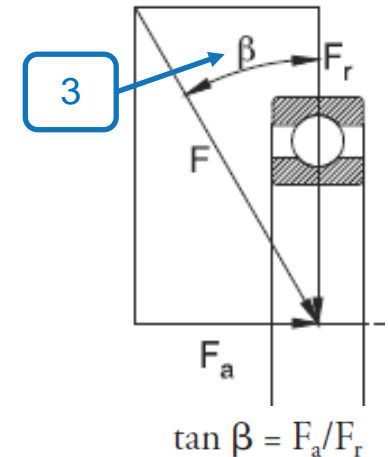
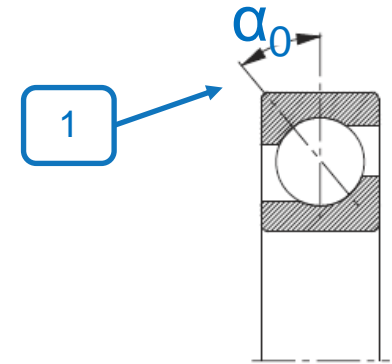


$S_t = 4.37$ according to Stribeck, 4.08 according to Palmer, use 5.00 to account for some uneven load distribution

Contact angle

Nominal vs. operating contact angle vs. load angle

- 1) Nominal contact angle (pressure angle) α_0 : Angle between the line connecting the contact points and the plane perpendicular to bearing axis, no load condition. Same value for all rolling elements applies.
- 2) Operating contact angle (pressure angle) α : Angle between the line connecting the contact points and the plane perpendicular to bearing axis, under operating load condition. Different values for each rolling element.
- 3) Load angle β : Angle between resultant applied load F and plane perpendicular to bearing axis.
- 4) Example for DGBB: Radial load does not change the operating contact angle per ball, but axial load does.

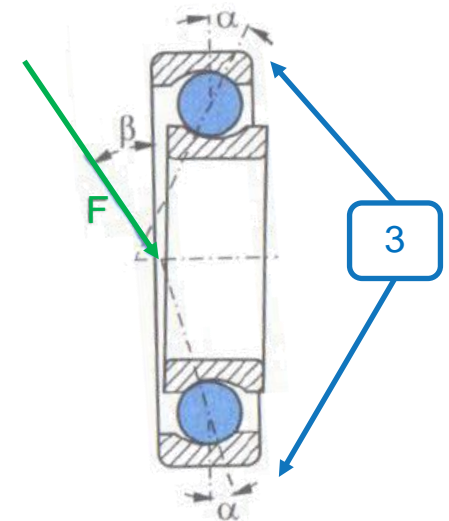
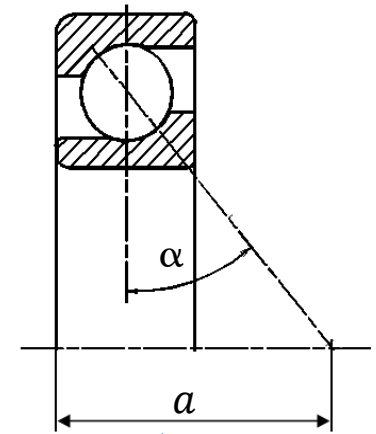


Contact angle

Typical values

- 1) Typically, the nominal contact angle α_0 is defined through the distance a of the pressure point from the backside of the bearing
- 2) The higher the contact angle, the higher the axial load capacity of a bearing.
- 3) Under general load condition, each rolling element may have different operating contact angle α .
- 4) Typical values apply:

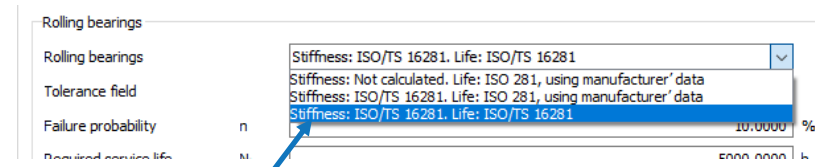
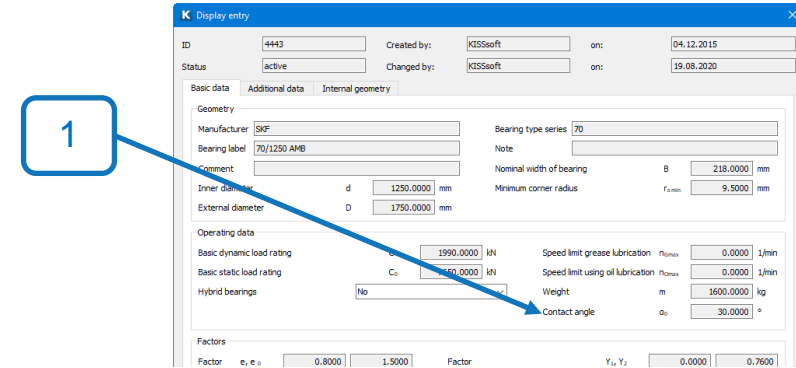
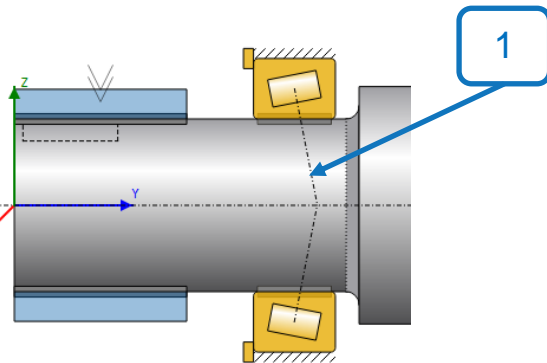
Bearing type	Nominal contact angle α_0
Deep groove ball bearings	0°
Above, axial offset	5° ... 15°
Angular ball bearings, single row	15° ... 40°
Angular ball bearings, double row	25° ... 45°
Spherical ball bearings	5° ... 20°
Cylindrical roller bearings	0°
Needle bearings	0°
Taper roller bearing	9° ... 30°
Spherical roller bearings	4° ... 18°
Axial deep groove ball bearings	90°
Axial angular ball bearings	60°
Axial spherical roller bearings	50°
Axial cylindrical roller bearings	90°



Contact angle

KISSsoft usage

- 1) Nominal contact angle α_0 is shown in shaft editor, value from database
- 2) Operating contact angle α is calculated and shown in report
- 3) For this, calculation option must consider ISO/TS 16281 calculation in tab «Basic data»
- 4) Calculation does not consider centrifugal effects

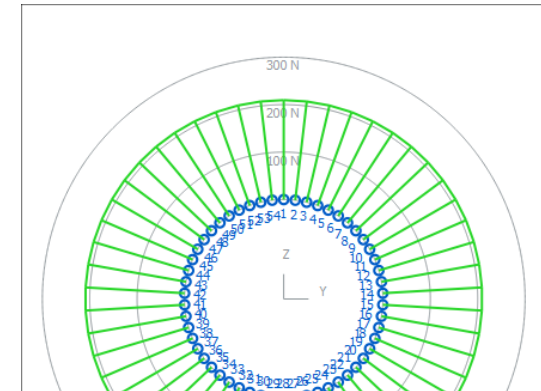
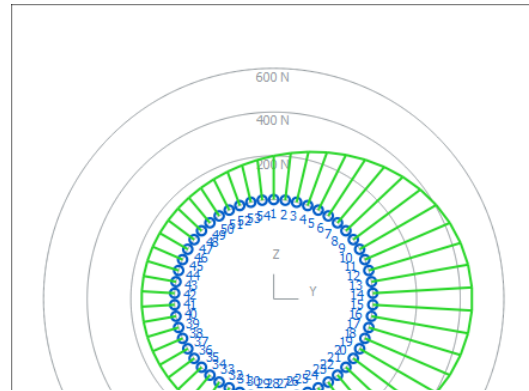
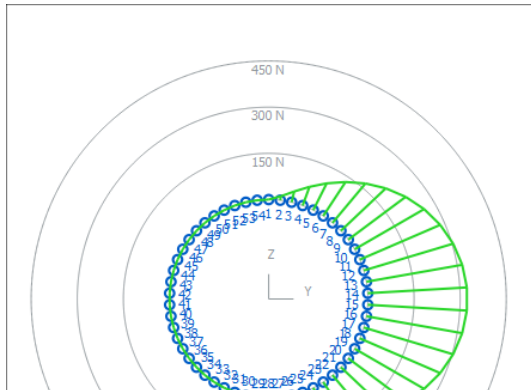


#	F (kN)	F _r (kN)	F _y (kN)	F _z (kN)	M _x (Nm)	M _y (Nm)	α (°)	p _{max} (N/mm ²)	a _i (mm)	b (mm)	a ₀ (mm)	b _i (mm)
1	0.441	-0.405	0.173	-0.000	-0.000	4.678	23.15	2599.552	0.83	0.10	0.70	0.11
2	0.198	-0.177	0.080	-0.044	-0.514	2.088	23.64	1982.354	0.64	0.07	0.54	0.09
3	0.024	-0.019	0.010	-0.010	-0.123	0.234	24.25	983.327	0.32	0.04	0.26	0.04
4	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.00	0.00	0.00	0.00
5	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.00	0.00	0.00	0.00

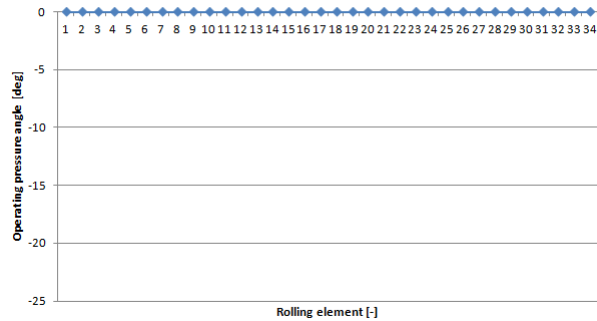
Contact angle

Operating contact angle

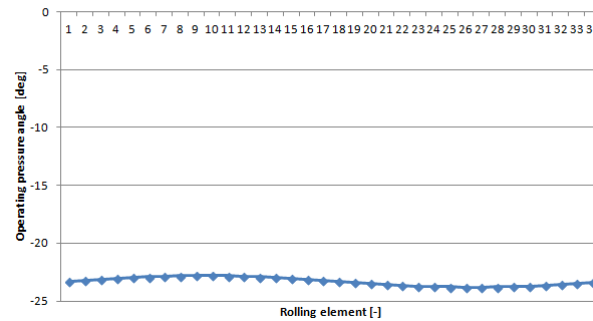
Pure radial load vs. combined load vs. pure axial load, for a deep groove ball bearing with nominal contact angle $\alpha_0 = 0$, load distribution and operating pressure angle α .



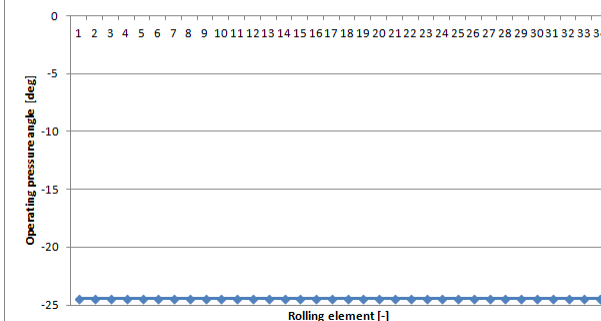
Operating pressure angle for all rolling elements, bearing under pure radial load



Operating pressure angle for all rolling elements bearing under mixed load

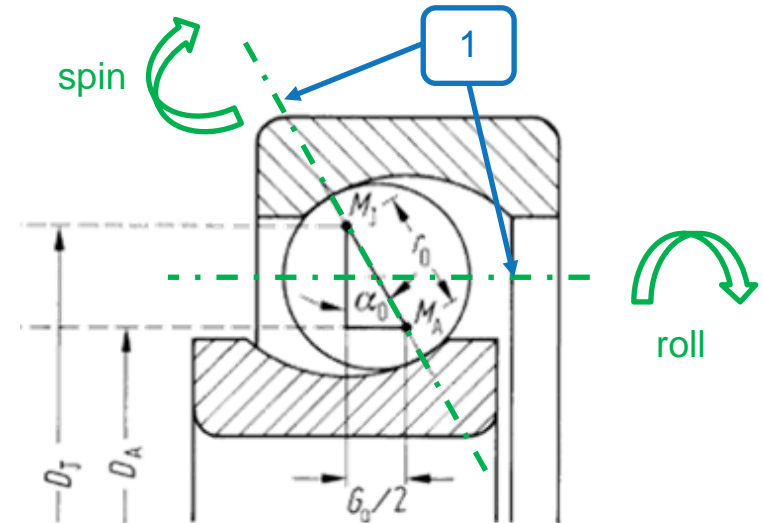


Operating pressure angle for all rolling elements bearing under pure axial load



Spin to roll ratio

- 1) For ball bearings with $\alpha \neq 0$, ball rotation consists of “roll” (axis parallel to bearing axis) and “spin” (axis is the line connecting the contact points).
- 2) The ‘spin to roll ratio’ is based on the assumption of “outer raceway control”, meaning that no spin of the ball is present on the outer raceway.
- 3) High values increase heat generation and wear, and decrease efficiency.
- 4) Spin to roll ratio is listed in the reports.



3 Shaft 'Shaft' Rolling bearing 'Roller bearing 1'

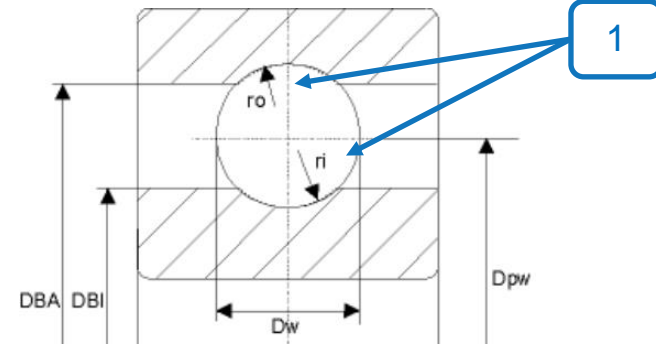
Angular contact ball bearing (single row) (SKF 7008 ACB/HCP4A)

Inner diameter	[d]	40.000	mm
Outer diameter	[D]	68.000	mm
Width	[B]	15.000	mm
Dynamic load rating	[C]	6.900	kN
Static load rating	[C ₀]	5.300	kN
Fatigue load limit	[C _u]	0.163	kN
Life modification factor for reliability	[a ₁]	1.000	
Correction factor (dynamic rating)	[f _c]	1.000	
Correction factor (static rating)	[f _{c0}]	1.000	
Minimum EHL lubricant film thickness	[h _{min}]	0.428	µm
Spin to roll ratio	[-]	0.070	

4

Conformity

- 1) Outer ring conformity $f_o = r_o / d$, inner ring conformity $f_i = r_i / d$. Where r_o, r_i = raceway radii on inner race and outer race, d = ball diameter. Perfect conformity $2 * r = d \rightarrow f_{max} = 0.50$
- 2) Higher conformity \rightarrow more friction / lower contact stress. Typically: $0.51 \leq f \leq 0.54$, typical values are $f_i = 0.52$, $f_o = 0.53$. These values are used in single bearing KISSsoft module sizing function).
- 3) Inner geometry definition though dataset (if no data given, value of 0.52 on inner race and 0.53 on outer race is used) and conformity is calculated.



Bearing data

Type:

Number of balls/rollers: Z

Ball / roller diameter: D_w mm

Reference diameter: D_{pw} mm

Radius of curvature, inner ring: r_i mm ←

Radius of curvature, outer ring: r_o mm ←



Basic data | Additional data | Internal geometry

Input data

Correction factor (dynamic rating) f_c Correction factor (static rating) f_{c0}

Number of balls: Z Radius of curvature, outside r_o mm

Ball diameter: D_w mm

Rolling body pitch circle diameter: D_{pw} mm

Inside diameter of the rim, pressure side: D_{BI} mm

Outside diameter of the rim, pressure side: D_{BA} mm

Radius of curvature, inside: r_i mm

Conformity

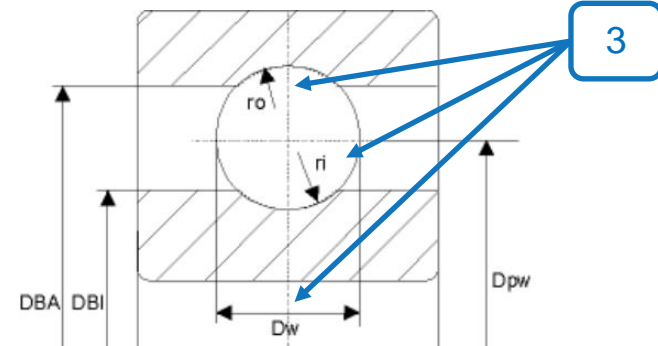
- 1) Conformity may also be expressed as (for inner race) κ_i
- 2) Conformity may also be expressed as (for outer race) κ_o
- 3) Where:

r_i = Radius of curvature, inner race

r_o = Radius of curvature, outer race

r_w = Radius of ball

D_w = Diameter of ball, $D_w = 2 * r_w$



1

$$\kappa_i = \frac{r_i - r_w}{r_w} = \frac{2 * r_i - 2 * r_w}{2 * r_w} = \frac{2 * r_i}{D_w} - 1$$

2

$$\kappa_o = \frac{r_o - r_w}{r_w} = \frac{2 * r_o - 2 * r_w}{2 * r_w} = \frac{2 * r_o}{D_w} - 1$$

Conformity vs contact stress

- 1) Lower radius of curvature on raceways → higher conformity → lower stress
- 2) Typical radii of curvature on raceways → typical conformity → typical stress
- 3) Higher radii of curvature on raceways → lower conformity → higher stress

Bearing data (Case 1)

Type	Deep groove ball bearing (single row)	
Number of balls/rollers	Z	34
Ball / roller diameter	D _w	10.0000 mm
Reference diameter	D _{pw}	120.0000 mm
Radius of curvature, inner ring	r _i	5.1000 mm
Radius of curvature, outer ring	r _o	5.2000 mm

Results (basic calculation) (Case 1)

Cr	45.883 kN		
L10r	11342.98		
pmax_i	1150.910 N/mm ²	inside	
pmax_o	1226.618 N/mm ²	outside	
ux	0.000 μm	Fx	0.000 kN
uy	7.752 μm	Fy	-2.000 kN
uz	-0.000 μm	Fz	0.000 kN
ry	0.000 mrad	My	0.000 Nm
rz	0.000 mrad	Mz	0.000 Nm

Bearing data (Case 2)

Type	Deep groove ball bearing (single row)	
Number of balls/rollers	Z	34
Ball / roller diameter	D _w	10.0000 mm
Reference diameter	D _{pw}	120.0000 mm
Radius of curvature, inner ring	r _i	5.2000 mm
Radius of curvature, outer ring	r _o	5.3000 mm

Results (basic calculation) (Case 2)

Cr	45.883 kN		
L10r	11194.42		
pmax_i	1323.237 N/mm ²	inside	
pmax_o	1334.192 N/mm ²	outside	
ux	0.000 μm	Fx	0.000 kN
uy	8.792 μm	Fy	-2.000 kN
uz	0.000 μm	Fz	-0.000 kN
ry	0.000 mrad	My	0.000 Nm
rz	0.000 mrad	Mz	0.000 Nm

Bearing data (Case 3)

Type	Deep groove ball bearing (single row)	
Number of balls/rollers	Z	34
Ball / roller diameter	D _w	10.0000 mm
Reference diameter	D _{pw}	120.0000 mm
Radius of curvature, inner ring	r _i	5.3000 mm
Radius of curvature, outer ring	r _o	5.4000 mm

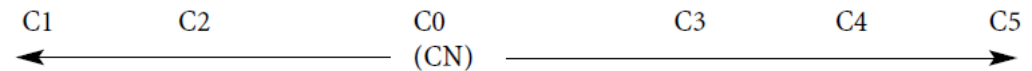
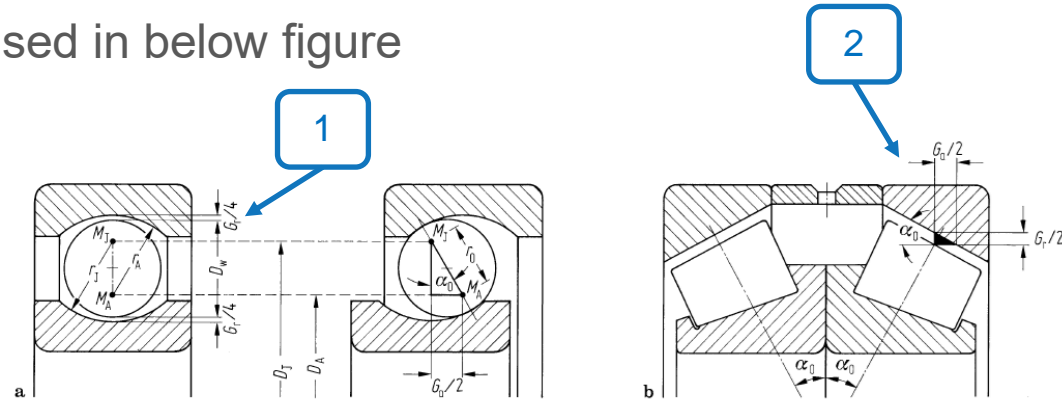
Results (basic calculation) (Case 3)

Cr	45.883 kN		
L10r	11136.56		
pmax_i	1437.660 N/mm ²	inside	
pmax_o	1417.062 N/mm ²	outside	
ux	0.000 μm	Fx	0.000 kN
uy	9.490 μm	Fy	-2.000 kN
uz	-0.000 μm	Fz	-0.000 kN
ry	0.000 mrad	My	0.000 Nm
rz	0.000 mrad	Mz	0.000 Nm

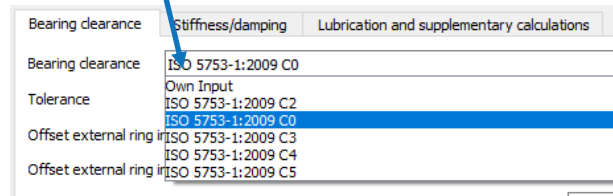
Clearance, definitions

Radial and axial clearance “G” is used in below figure

- 1) Radial clearance is defined amount of radial movement inner ring can move to outer ring at no load
- 2) For angular bearings, radial and axial clearance are related
- 3) C0 or CN = normal clearance, lower numbers = lower clearance, higher numbers = higher clearance
- 4) Clearance is selected in bearing element editor
- 5) From clearance, assembly clearance and operating clearance is calculated



Internal clearance group	Description	Standard	Application
CN	Normal radial internal clearance CN is not included in bearing designations	DIN 620-4 ISO 5 753	For normal operating conditions with shaft and housing tolerances, see section Operating clearance and Design of bearing arrangements
C2	Internal clearance < CN		For heavy alternating loads combined with oscillating motion
C3	Internal clearance > CN		For bearing rings with press fits and large temperature differential between inner and outer ring
C4	Internal clearance > C3		
C5	Internal clearance > C4	ISO 5 753	



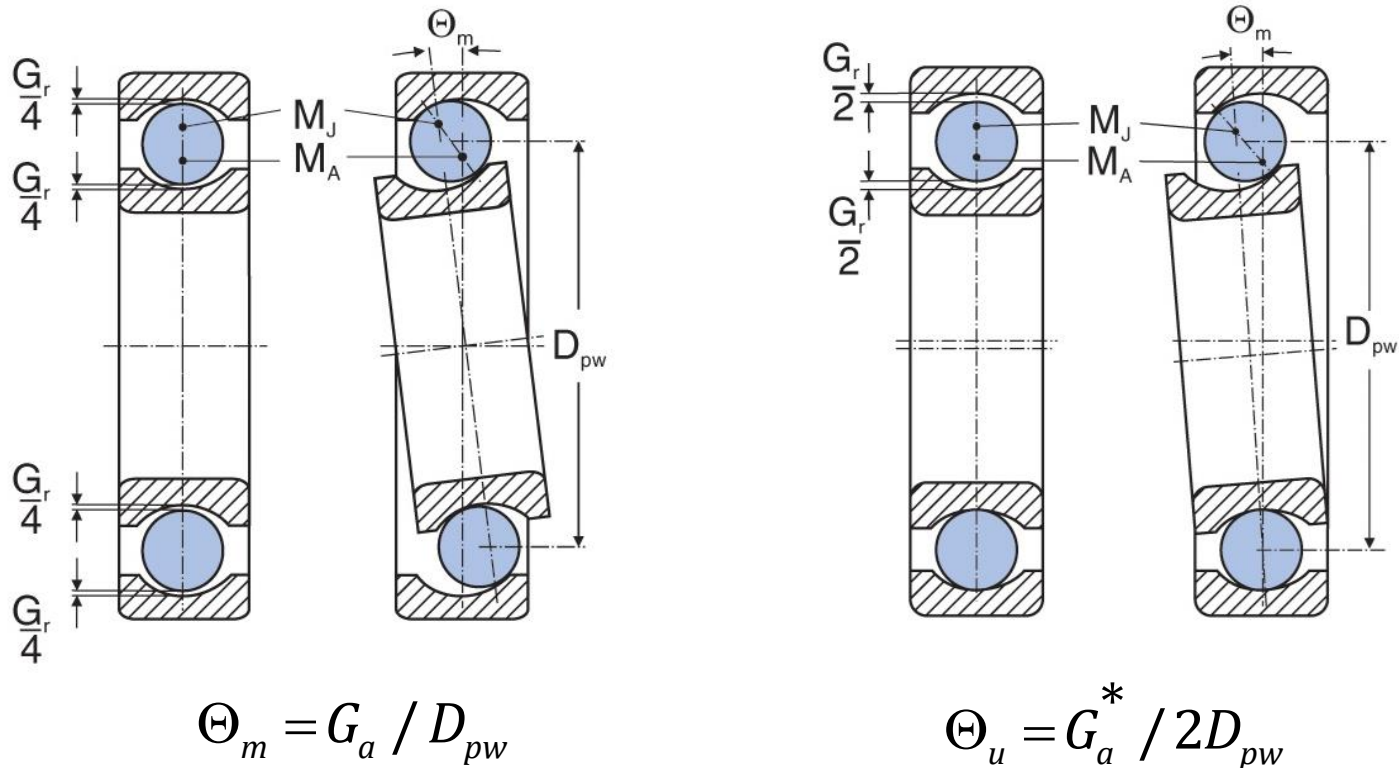
Axial clearance P_a

The axial clearance P_a is the clearance before assembly in axial direction. It is defined as the amount by which the inner ring can be moved with respect to the outer ring from one extreme position to the other in the direction of the bearing axis. It is a function of the radial clearance for many bearing types as shown here:

Bearing type		Ratio between axial and radial internal clearance s_a/s_r	
Self-aligning ball bearings		$2,3 \cdot Y_0^{1)}$	
Spherical roller bearings		$2,3 \cdot Y_0^{1)}$	
Tapered roller bearings	Single row, arranged in pairs	$4,6 \cdot Y_0^{1)}$	
	Matched pairs (N11CA)	$2,3 \cdot Y_0^{1)}$	
Angular contact ball bearings	Double row	Series 32 and 33	1,4
		Series 32...-B and 33...-B	2
	Single row	Series 72...-B and 73...-B, arranged in pairs	1,2
Four point contact bearings		1,4	

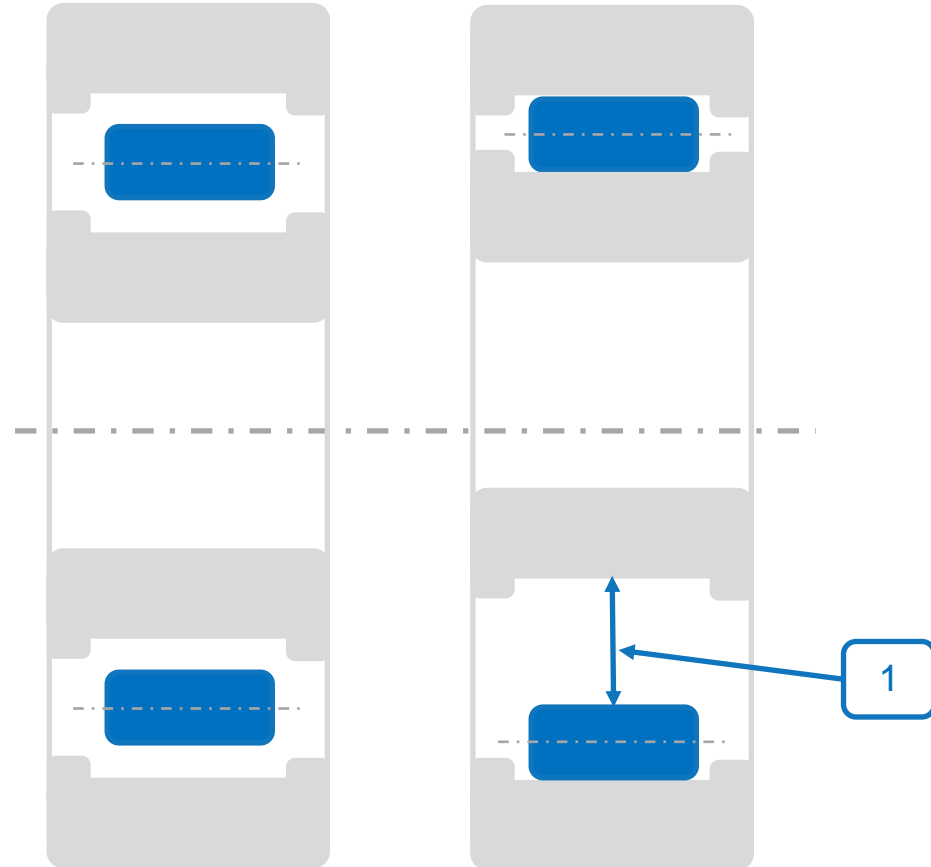
Axial clearance Pa

Axial clearance allows for tilting of e.g. ball bearings around the centre or around the lowest ball. For the left case, a higher tilting is possible. Permissible values typically 2...10 minutes.



Bearing clearance, assembly clearance, operating clearance

- 1) Radial clearance is defined amount of radial movement inner ring can move to outer ring at no load
- 2) Bearing clearance is a bearing (part) property
- 3) Assembly clearance considers shaft and housing seat and stiffness, surface roughness, bearing tolerances
- 4) Operating clearance considers temperature and centrifugal effects
- 5) Sometimes, the terms „measured clearance“ or „apparent clearance“ is used as opposed to „theoretical clearance“. For the clearance measurement, a certain radial load needs to be applied which results in a deformation (for ball bearings, for roller bearings, this deformation may be neglected). The theoretical clearance is the internal clearance as measured minus the deformation (which can e.g. be calculated).



Clearance, definitions

Bearing clearance, assembly clearance, operating clearance

- 1) Select bearing clearance class or use "Own input". If "Own input" is used, then, enter bearing clearance and operating clearance is calculated.
- 2) For tolerances, the position in the tolerance field used for calculations can be selected in tab "Basic data". Default is the use of mean value in all tolerance fields.
- 3) Bearing parts temperatures may be defined per bearing or for all bearings in model (through shaft and housing temperature).

Element Editor

Designation: Roller bearing 2

Position on shaft: y 225.0000 mm

Position in global system: Y 225.0000 mm

Type of bearing: Fixed bearing adjusted on right side ->

Type: Cylindrical roller bearing (single row)

Number: SKF NU 1007 ECP (d=35.000 mm, D=62.000 mm, B=14.000 mm)*

Comment: SKF Popular Item

Inner diameter: d 35.000 mm

External diameter: D 62.000 mm

Nominal width: B 14.000 mm

Bearing clearance: Stiffness/damping Lubrication and supplementary calculations

Bearing clearance: ISO 5753-1:2009 C3

Tolerance: DIN 620:1988 PN

Input shaft: Tolerance

Tolerance Shaft: p5

Input hub: Tolerance

Tolerance hub: H6

Define housing bore

Internal diameter of housing bore: D_{hi} 62 mm

External diameter of housing bore: D_{ho} 110 mm

Rolling bearing temperature: Own input

Inner ring temperature: T_i 33 °C

Outer ring temperature: T_o 55 °C

Rolling body temperature: T_w 44 °C

Offset external ring in X-direction: δ_x 0.0000 mm

Offset external ring in Y-direction: δ_y 0.0000 mm

Offset external ring in Z-direction: δ_z 0.0000 mm

Outer ring tilting around X-axis: δ_{rx} 0.0000 °

Outer ring tilting around Z-axis: δ_{rz} 0.0000 °

Rolling bearings

Rolling bearings: Stiffness: ISO/TS 16281. Life: ISO/TS 16281

Tolerance field: Mean value

Failure probability: n

Required service life: N_i

Clearance, definitions

Bearing clearance, assembly clearance, operating clearance

- 1) Select bearing clearance class or use "Own input". If "Own input" is used, then, enter bearing clearance and operating clearance is calculated.
- 2) If additionally "Tolerance = not considered" is selected, then, bearing operating clearance is equal to bearing clearance.

Element Editor

Designation: Roller bearing 2

Position on shaft: y 225.0000 mm

Position in global system: Y 225.0000 mm

Type of bearing: Fixed bearing adjusted on right side ->

Type: Cylindrical roller bearing (single row)

Number: SKF NU 1007 ECP (d=35.000 mm, D=62.000 mm, B=14.000 mm)*

Comment: SKF Popular Item

Inner diameter: d 35.0000 mm

External diameter: D 62.0000 mm

Nominal width: B 14.0000 mm

Bearing clearance: Stiffness/damping | Lubrication and supplementary calculations

Bearing clearance: Own Input

Diametral bearing clearance: Δ 9.9900 μm

Tolerance: not considered

Offset external ring in X-direction: δ_x 0.0000 mm

Offset external ring in Y-direction: δ_y 0.0000 mm

Offset external ring in Z-direction: δ_z 0.0000 mm

Outer ring tilting around X-axis: δ_{rx} 0.0000 $^\circ$

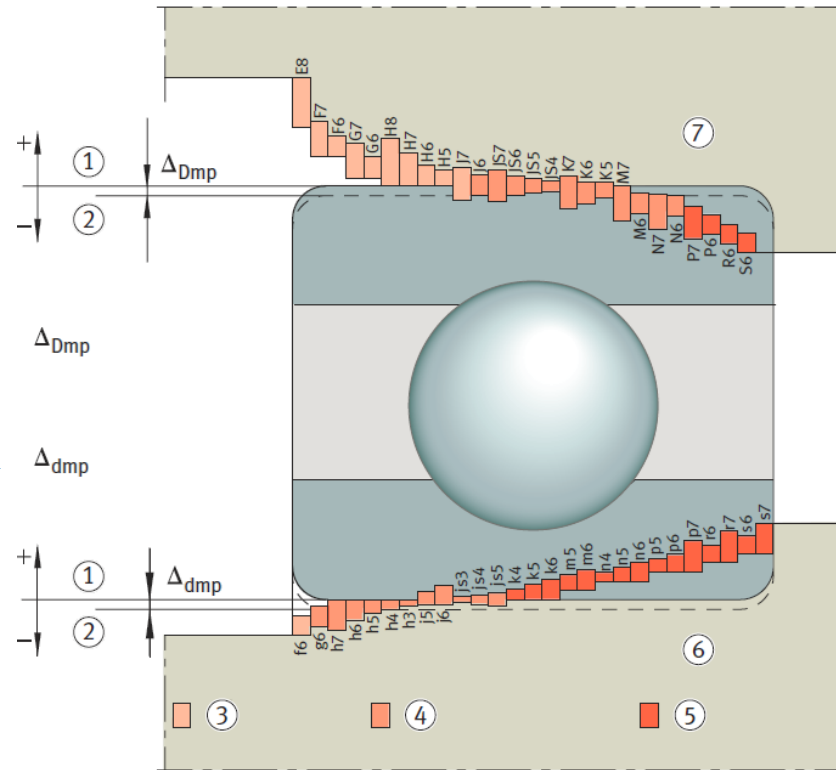
Outer ring tilting around Z-axis: δ_{rz} 0.0000 $^\circ$

Bearing clearance, assembly clearance, operating clearance

1) Shaft and housing tolerances can either be given as tolerance fields or as absolute values in KISSsoft element editor

2) Definitions of shaft and hub tolerances

- (1) Reference line
- (2) Nominal diameter
- (3) Loose fit
- (4) Transition fit
- (5) Press fit
- (6) Shaft diameter
- (7) Housing diameter



Tolerance	DIN 620:1988 PN
Input shaft	Tolerance
Tolerance Shaft	p5
Input hub	Tolerance
Tolerance hub	H6

Bearing ring with rotating load → should be press fit

Bearing ring with spot load → transition or loose fit

Fit required is a function of load applied. Ring deformation due to load applied should not result in fit becoming loose; $d_f > \Delta d_F$. The change in fit / reduction in interference Δd_F may be estimated:

$$\Delta d_F = \frac{0.08}{1000} * \sqrt{\frac{d}{B} * F_r}$$

Where F_r is the radial bearing force in [N], d is the inner ring bore diameter [mm] and B is the inner ring width [mm].

For very highly loaded bearings ($F_r > 0.2 * C_{0r}$), use

$$\Delta d \geq \frac{0.02}{1000} * \frac{F_r}{B}$$

Recommended fits, SKF book

Bearing type	Shaft tolerances (for solid steel shafts and rotating inner ring load)								Housing tolerances (for steel, spheroidal graphite or grey cast iron and stationary outer ring load)			
	Shaft diameter (mm) ≤18 to 40	(18) to 100	(40) to 140	(100) to 200	(140) to 280	(200) to 500	(280) to 500	>500	Housing bore diameter (mm) ≤300 to 300	(300) to 500	>500	Bearing arrangement
Deep groove ball bearings (for light loads $P \leq 0,06 C$)	j5	k5	k5	k6	k6	m6	m6	m6	J6 G6	J6 G7	H7 F7	Locating Non-locating
Angular contact ball bearings												
single row (adjusted via the outer ring)	j6	k6	k6	m6	m6	n6	p6	p6	J6	J6	H7	Cross located
double row, paired single row (series 32, 33, 70 BG, 72 BG, 73 BG)	j5	k5	k5	m5	m5	m5	–	–	J6	J6	H7	Locating
double row (series 33 D)	k5	k5	m5	m5	–	–	–	–	J6	J6	H7	Locating
Four-point contact ball bearings	k5	k5	m5	m5	n6	–	–	–	approx. 1 mm radial clearance (locate to prevent turning)		Thrust bearing	
Cylindrical roller bearings (N, NU, NJ designs)	k5	k5	m5	m5	n6	p6	p6	r6	J6	J6	H7	–
Spherical roller bearings	k5	k5	m5	m5	n6	p6	p6	r6	J6 G6	J6 G7	H7 F7	Locating Non-locating
Taper roller bearings												
single row (adjusted via the outer ring)	k6	k6	m6	m6	n6	p6	p6	–	J6	J6	H7	Cross located
double row, paired single row	k5	k5	m5	m5	n6	p6	p6	r6	J6	J6	H7	Locating
Thrust ball bearings	h6	h6	h6	h6	h6	g6	g6	g6	G7	G7	F7	Thrust bearing
Spherical roller thrust bearings	j6 (for all diameters)								approx. 1 mm radial clearance		Thrust bearing	
Form and position tolerances, surface roughness												
Cylindricity	IT5/2 (for all diameters)											
Rectangularity	IT5 (for all diameters)											
Permissible surface roughness R_z (µm)	4	4	4	6,3	6,3	6,3	6,3	10	8	10	16	

When shaft tolerances p6 and r6 are used, use of the oil injection method will ease dismounting

Recommended fits, SKF book

Case	Housing tolerance Housing bore diameter (mm)		
	< 300	(300) to 500	> 500
Deep groove ball bearings and spherical roller bearings as non-locating bearings with rotating inner ring load and stationary outer ring load and a temperature differential > 10 °C from outer ring to housing (e.g. when heating via the shaft, high speed operation, very solid housings, low environmental temperatures)	G7	F7	E8
Deep groove ball bearings and spherical roller bearings, cross located, with rotating inner ring load and stationary outer ring load			
a) axial displacement of outer ring in housing required, e.g. with thermal expansion of shaft and axially stiff housing	G6	G7	F7
b) axial displacement of outer ring not required, e.g. when thermal expansion of shaft is compensated by elastic deformation of housing without overloading bearings	J6	J6	H7
Cylindrical roller bearings of NUP design with rotating inner ring load and stationary outer ring load			
a) locating bearing	G6	G7	F7
b) non-locating bearing	J6	J6	H7
Locating bearings and cylindrical roller bearings under oscillating outer ring load, e.g. when weight and tooth force act in different directions. Special steps have to be taken when mounting in one-piece (non-split) housings (e.g. heating the housing)	JS6	JS6	JS7

Recommended fits, SKF book

Tolerances for bearings mounted in gear hubs

Table 3

Bearing type	Bearing arrangement	Shaft tolerance Shaft diameter (mm)			Housing tolerance Housing bore diameter (mm)		
		< 120 to 250	(120) to 250	(250) to 315	< 120 to 250	(120) to 250	> 250
Deep groove ball bearings	Shifting gear (inner and outer rings rotate at same speed)	j5	js6	k6	M6 ¹⁾	M6 ¹⁾	N6 ¹⁾
	Planetary gear, intermediate gear (outer ring rotates, inner ring stationary)	h5	h6	h6	M6 ¹⁾	M6 ¹⁾	M6 ¹⁾
Spherical roller bearings Cylindrical roller bearings	Planetary gear, intermediate gear (outer ring rotates, inner ring stationary)	h5	h6	h6	N6	P6 ¹⁾	R6 ¹⁾
Cylindrical roller bearings	Planetary gear, intermediate gear (rotating inner and outer ring load)	see Table 1			N6 ¹⁾	P6 ¹⁾	R6 ¹⁾
Cylindrical roller bearings without outer ring	Planetary gear, intermediate gear (planetary gear rotates, inner ring stationary)	h5	h6	h6	G6 ²⁾	F6 ²⁾	F6 ²⁾
Cylindrical roller bearings without inner ring	Planetary gear, intermediate gear (outer ring rotates)	f6 ²⁾	e6 ²⁾	e6 ²⁾	N6	P6	R6
Needle roller and cage assemblies	Planetary gear, intermediate gear	g5 ²⁾	g5 ²⁾	–	G6 ²⁾	G6 ²⁾	–

¹⁾ C3 internal clearance required

²⁾ For raceways on the planetary pins and in gear hubs,

the deviation from circularity should be < 25 % of actual diameter tolerance;

the deviation from cylindricity should be < 50 % of actual diameter tolerance;

the surface roughness should be $R_a \leq 0,2 \mu\text{m}$ and $R_z \leq 1 \mu\text{m}$;

hardness should be 58 to 64 HRC

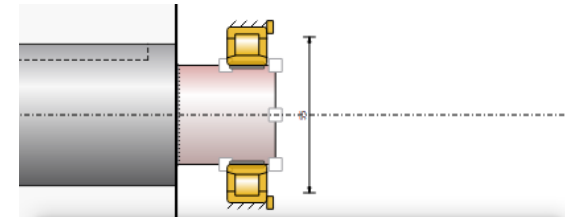
and the case depth when finish machined should be $E_{\text{Ht}} = 0,5 \sqrt{D_w} - 0,5 \geq 0,3 \text{ mm}$, with D_w = rolling element diameter in mm

Roughness influence

- 1) During assembly, housing, shaft and bearing surface roughness is reduced, influencing fits, influencing assembly clearance. As per DIN7190, the embedding is estimated as follows (U_w = interference U considering the roughness reduction):

$$U_w = U - 0,8 (R_{zA} + R_{zI})$$

- 2) Other sources („Wälzlagerpraxis“) propose a value of 0.7 instead of 0.8.
- 3) Input shaft surface roughness, per shaft element.
- 4) Input housing surface roughness, in module specific settings.



Element Editor

Label: Cylinder 4

Position on shaft: y 200.0000 mm

Position in global system: Y 200.0000 mm

Length: l 35.0000 mm

Diameter: d 35.0000 mm

Surface roughness: N6 Rz=4.8 (Grinding)

3

4

K Module specific settings

Calculations | Rolling bearings | Reliability | Shaft editor and 3D view

General

Display critical bearing

Display rating life in scientific notation

Save user defined bearings in calculation file

Read user-defined rolling bearings from calculation file

Define lubrication for each bearing individually

Axial clearance (classical calculation) u_A 0.0100 mm

Maximum life modification factor $a_{ISO,max}$ 50.0000

Surface roughness of housing: N7 Rz=8.0 (Turned with diamond)

Timken Cloud Services: Use proprietary internal geometry data (used for calculation only, not available for reports and similar)

Clearance calculation report

- 1) Input lists user selections. Temperatures of bearing elements entered by user are listed in results section.
- 2) Outer ring and inner ring speed influences operating clearance due to centrifugal effect.
- 3) Roughness of shaft and housing influences assembly clearance due to setting effects.
- 4) Embedding due to parts roughness.

3

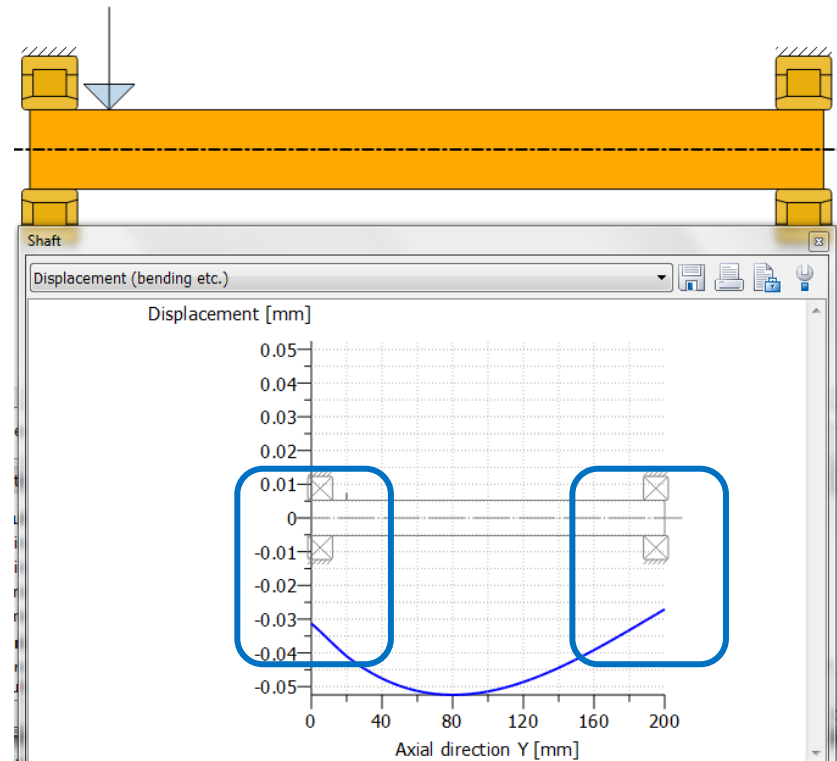
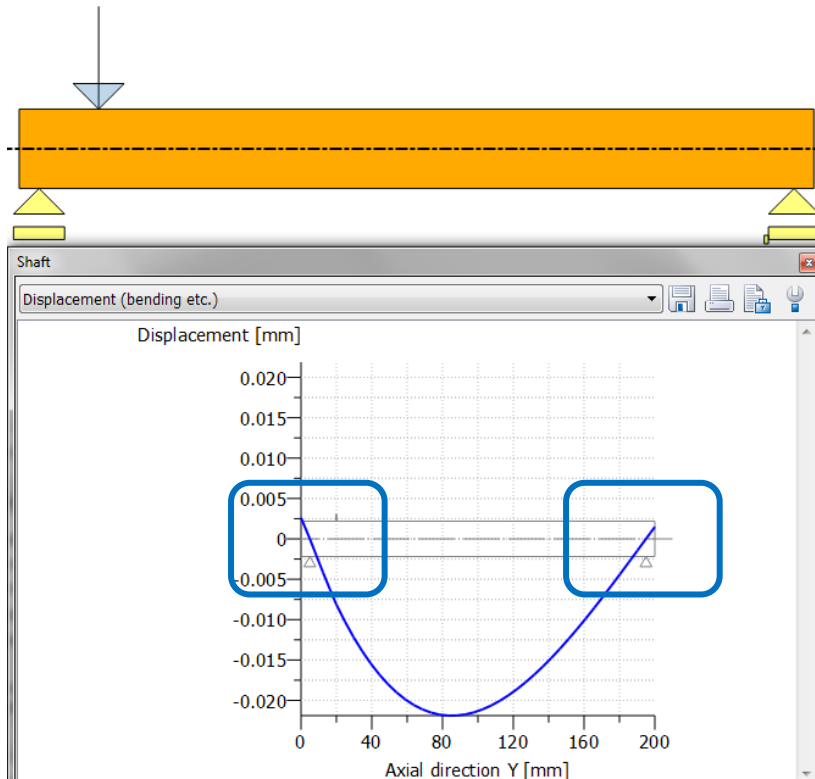
2

4

KISSsoft			
4.1 Operating bearing clearance			
4.1.1 Inputs			
Nominal bearing clearance	[-]	ISO 5753-1:2009 C3	
Nominal diametral clearance	[Pd0]		57.500 μm
Tolerance	[-]	DIN 620:1988 FN	
Inner diameter	[dBi]		34.988/ 34.994/ 35.000 mm
Diameter of inner ring	[dIr]		41.971 mm
Diameter of outer ring	[Dro]		57.029 mm
Outer diameter	[DBo]		61.987/ 61.993/ 62.000 mm
Tolerance shaft	[-]	p5	
Shaft inside diameter	[dSi]		0.000 mm
Shaft external diameter	[dSo]		35.026/ 35.032/ 35.037 mm
Shaft roughness	[Rzi]		4.800 μm
Tolerance hub	[-]	H6	
Hub inside diameter	[DHi]		62.000/ 62.010/ 62.019 mm
Hub external diameter	[DHo]		110.000 mm
Hub roughness	[Rzo]		8.000 μm
4.1.2 Results			
Tolerance field	[-]	Mean value	
Press fit, shaft internal ring			
Shaft speed	[ni]		980.000 1/min
Shaft temperature	[Ts]		20.0 °C
Temperature of inner ring	[Ti]		33.0 °C
Diameter	[dsoT]		35.032 mm
Diameter	[dBiT]		34.999 mm
Interference	[Uwi]		32.268 μm
Embedding	[si]		1.920 μm
Hertzian pressure	[p _i]		27.868 N/mm ²
Effective interference (20.0 (°C))	[Uwi_eff]		30.348 μm
Diametral clearance change	[ΔPdI]		-31.525 μm
Press fit, hub external ring			
Hub speed	[no]		0.000 1/min
Hub temperature	[Tn]		20.0 °C
Temperature of outer ring	[To]		55.0 °C
Diameter	[DBoT]		62.018 mm
Diameter	[DHiT]		62.010 mm
Interference	[Uwo]		8.952 μm
Embedding	[so]		3.200 μm
Hertzian pressure	[p _e]		1.393 N/mm ²
Effective interference (20.0 (°C))	[Uwo_eff]		5.752 μm
Diametral clearance change	[ΔPdo]		18.031 μm
Rolling body temperature			
Rolling body expansion	[ΔDw]		44.0 μm
Total diametral clearance change	[ΔPd]		2.070 μm
Operating diametral clearance	[P _e]		-17.834 μm (ΔPdI + ΔPdo - 2 * ΔDw)
			39.866 μm (Pd0 + ΔPd)

Clearance in KISSsoft

The clearance / operating clearance is considered in the bearing calculation and influences the shaft deformation:



Effect of bearing clearance

Clearance, influencing max. roller load

Roller load and bearing life

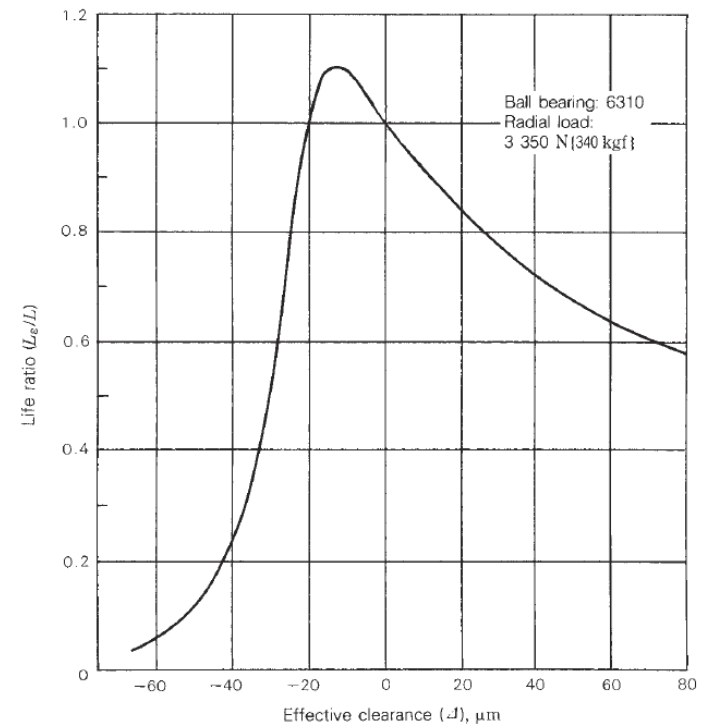
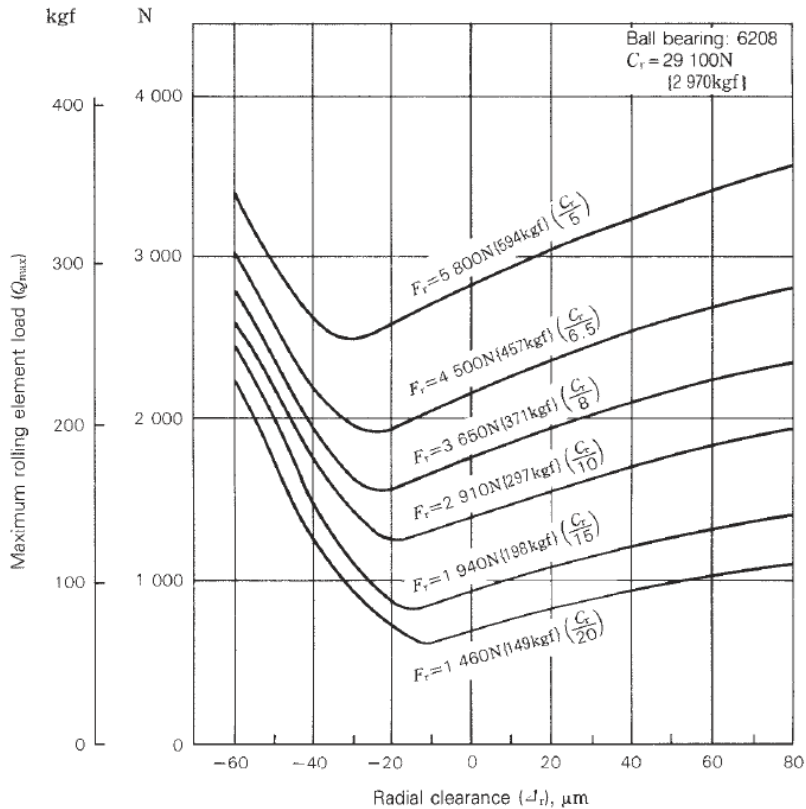


Fig. 1 Relation between effective clearance and bearing life for 6310 ball bearing

The maximum roller load is minimized for a slight pre-tension of the bearing

The bearing life is maximized for a slight pre-tension

Summary

Key statements

A small pre-tension / negative clearance in operation typically results in highest life rating

Clearance below the optimum leads to rapid reduction of rating life. Clearance above the optimum leads to gradual reduction of rating life.

Typically, most highly loaded ball in a deep groove ball with zero clearance bearing is loaded about 4.37 (found by Stribeck) or 4.08 (found by Palmgren) or 5 times (recommendation, rounded, accounting for other effects) higher than the average ball load.

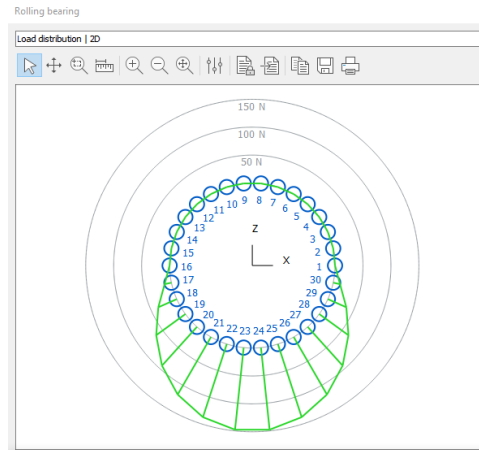
Bearing clearances, five groups, 2, N, 3, 4, 5 (N = normal), ISO 5753 or ANSI/ABMA 20

Basic rating life is assuming load distribution for zero clearance

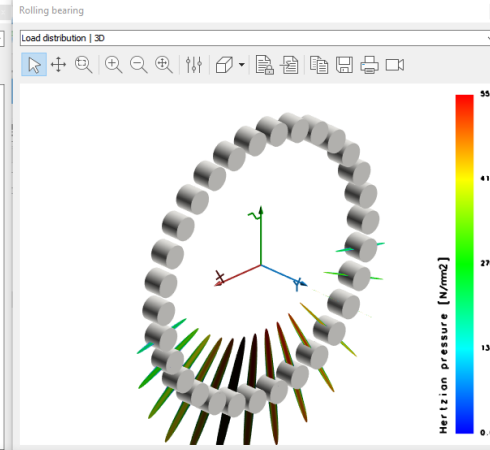
Influence on stress distribution

Bearing operating clearance $Pd = 0.00 \mu\text{m}$ and $Fr = -Fz$ and pure radial load

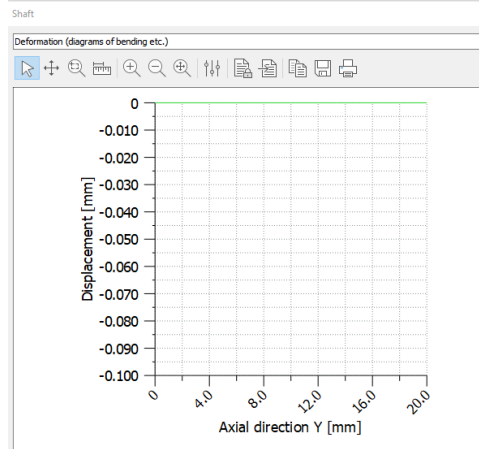
Rolling element forces



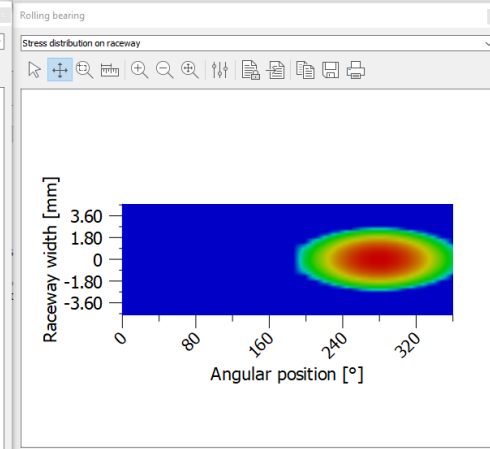
Contact stresses on rolling elements



Inner ring displacement



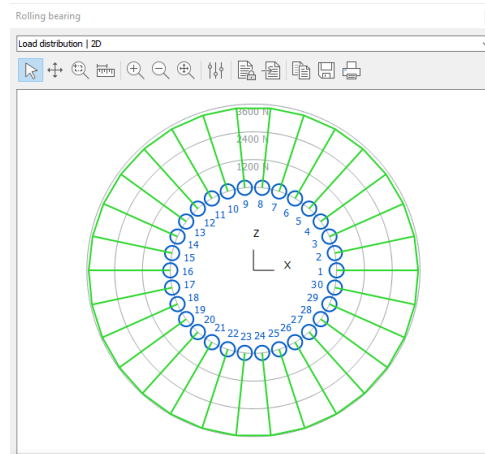
Stress distribution projected onto inner raceway



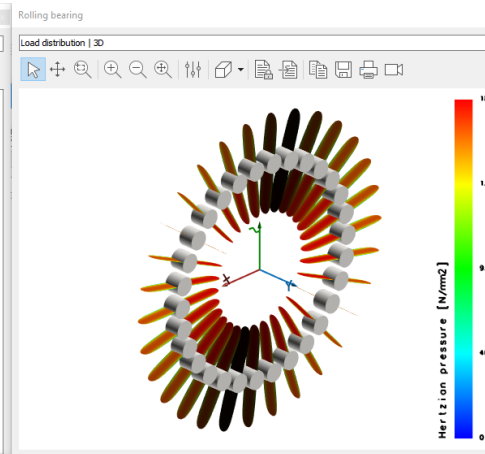
Influence on stress distribution

Bearing operating clearance $Pd = -50.00 \mu\text{m}$ and $Fr = -Fz$ and pure radial load

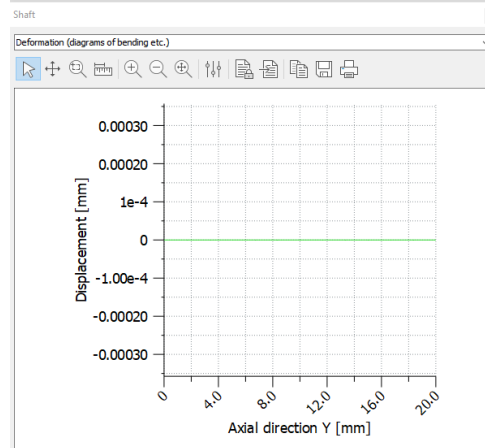
Rolling element forces



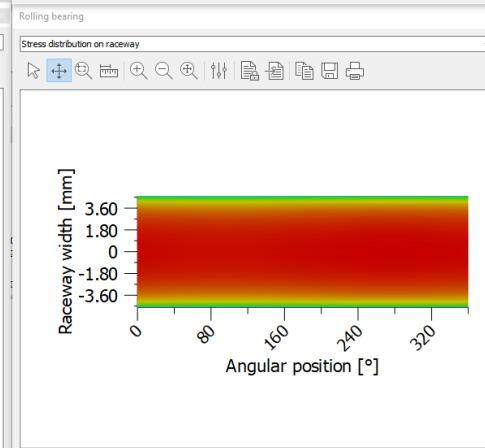
Contact stresses on rolling elements



Inner ring displacement



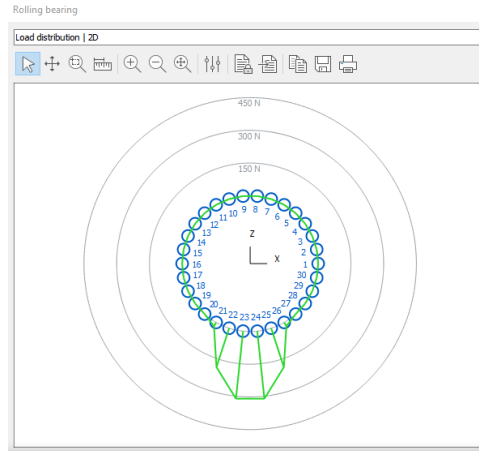
Stress distribution projected onto inner raceway



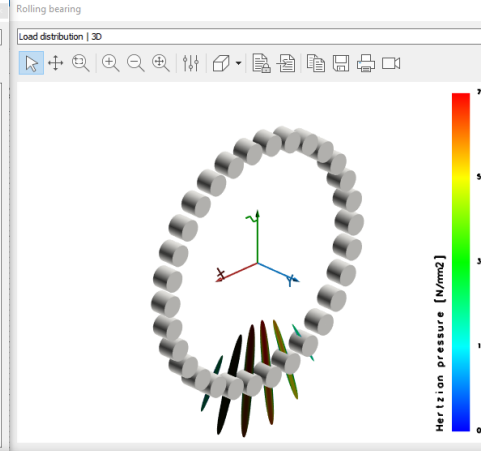
Influence on stress distribution

Bearing operating clearance $Pd = +50.00 \mu\text{m}$ and $Fr = -Fz$ and pure radial load

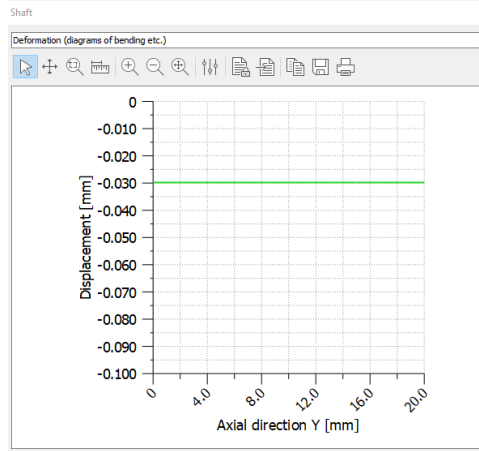
Rolling element forces



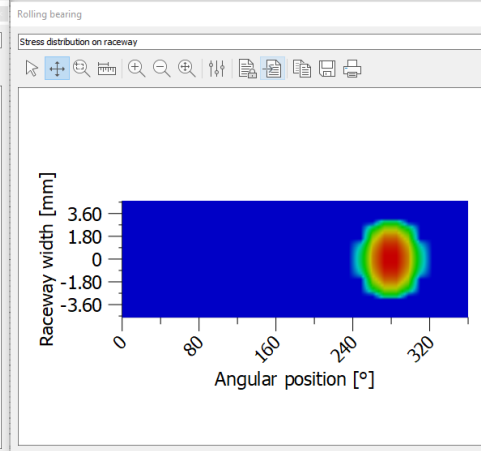
Contact stresses on rolling elements



Inner ring displacement



Stress distribution projected onto inner raceway



Clearance

Positive clearance → less than half of the circumference is loaded. Load distribution is determined

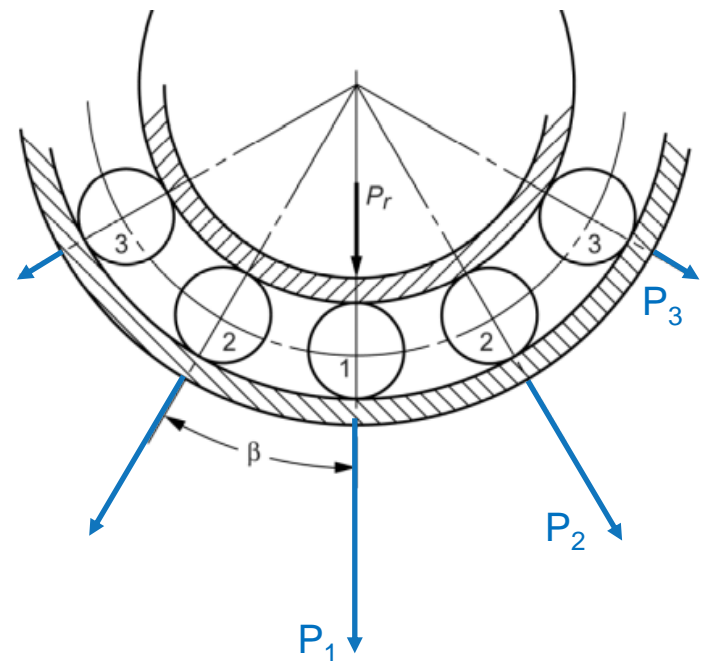
$$P_r = P_1 + 2P_2 \cos \beta + 2P_3 \cos 2\beta + \dots + 2P_{n+1} \cos n\beta$$

Where n is the number of pairs of rolling bodies under load. n may be estimated from the number of rolling bodies in the bearing, z (INT = integer part of resulting number). The pitch angle β is as shown below.

$$n = \text{INT} \left(\frac{z-1}{4} \right) \quad \beta = \frac{2\pi}{z}$$

The highest load $P_{\max} = P_1$ may be estimated as a function of the Stribeck number St , use $St \approx 5$ to account for some uneven load distribution.

$$P_{\max} = \frac{P_r}{Q} = \frac{S_t P_r}{z} \quad S_t = \frac{z}{Q} = \frac{P_{\max}}{P_r / z}$$

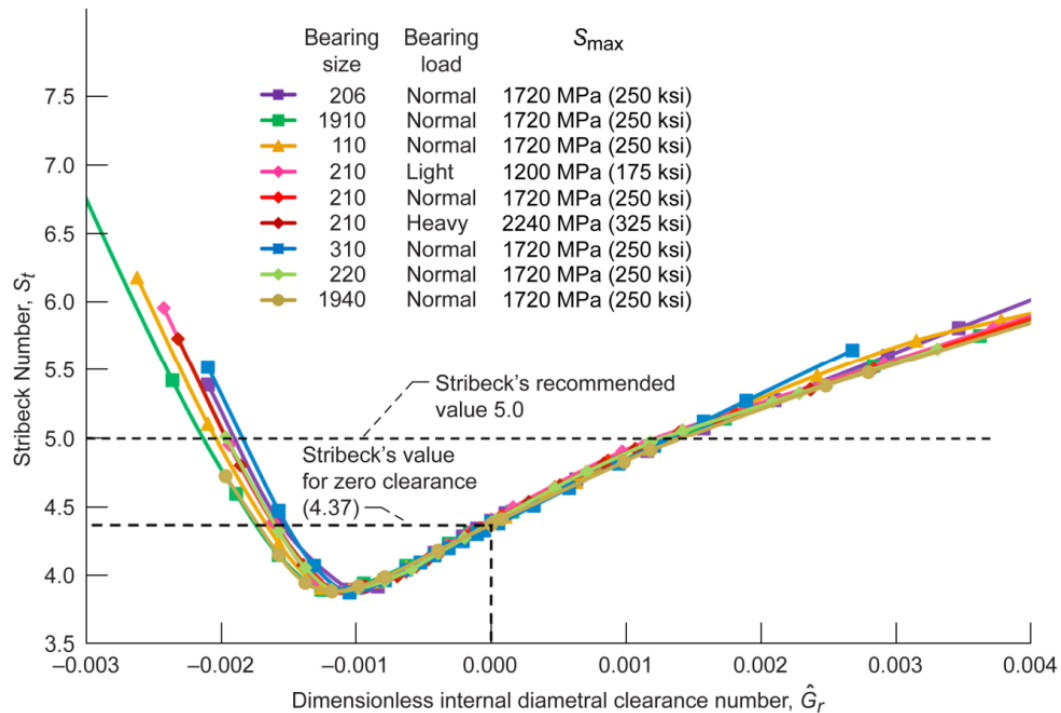


Effect of clearance

Stribeck number

For deep groove ball bearings, Stribeck found $S_t = 4.37$ (4.08 for CRB) for a bearing of zero clearance and recommends $S_t = 5.00$. If a suitable pre-tension is applied, S_t drops to below $S_t = 4.00$

$$S_t = \frac{z}{Q} = \frac{P_{\max}}{P_r / z}$$

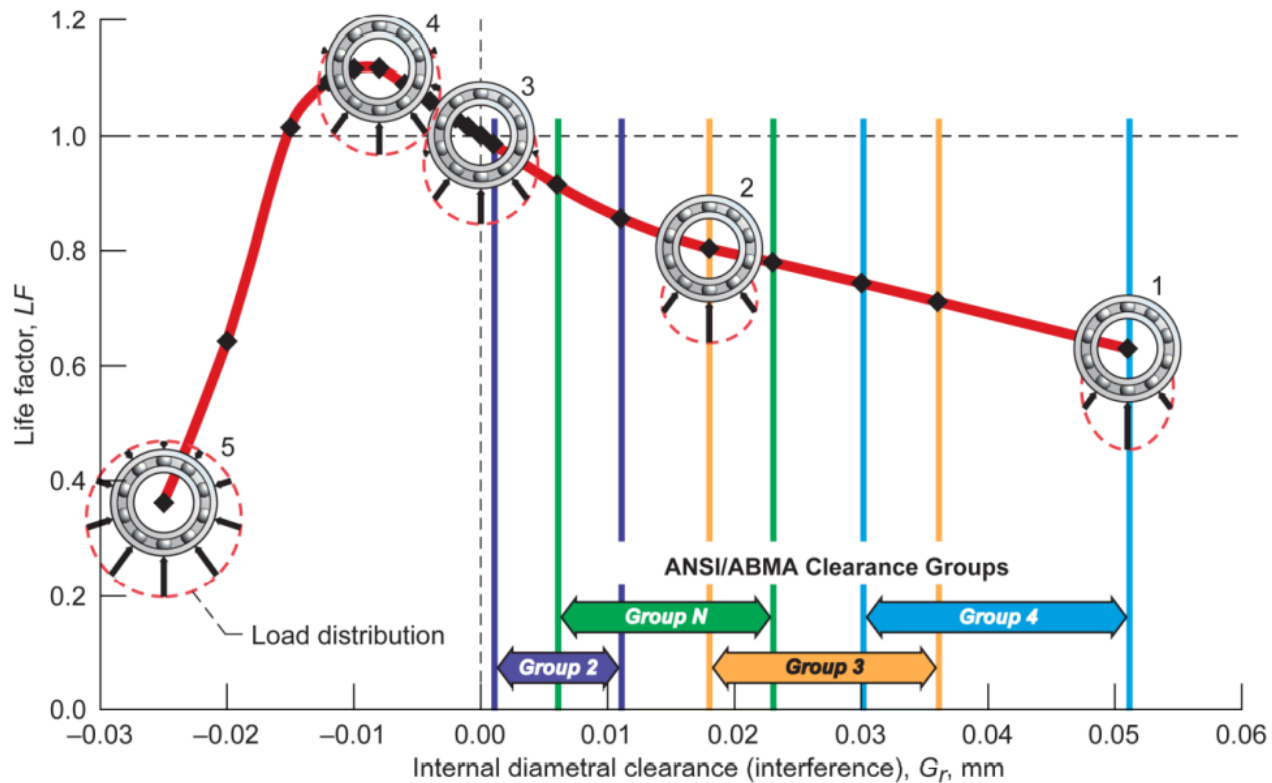


© Joseph Poplawski, from: Oswald et al., Effect of internal clearance on load distribution and life of radially loaded ball and roller bearings, March 2012, Tribology Transactions, 55(2):245-265

Effect of clearance

Bearing life vs. bearing operating clearance

Highest calculated life is reached for a small amount of pre-tension

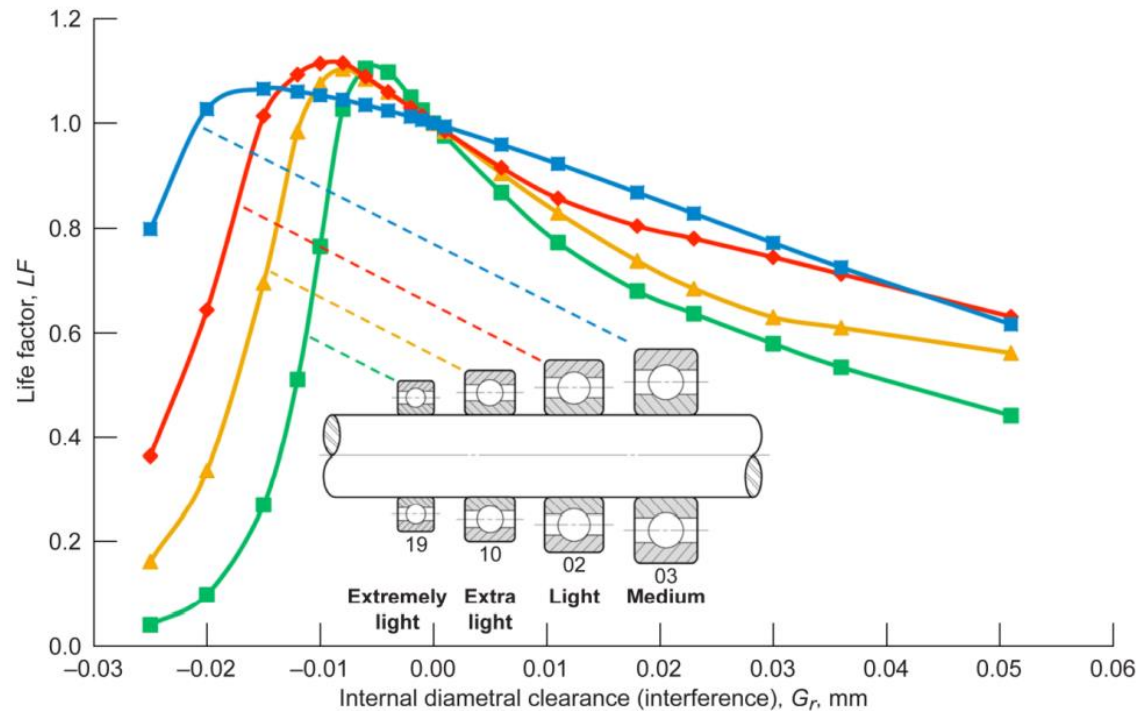


© Joseph Poplawski, from: Oswald et al., Effect of internal clearance on load distribution and life of radially loaded ball and roller bearings, March 2012, Tribology Transactions, 55(2):245-265

Effect of clearance

Effect of bearing size

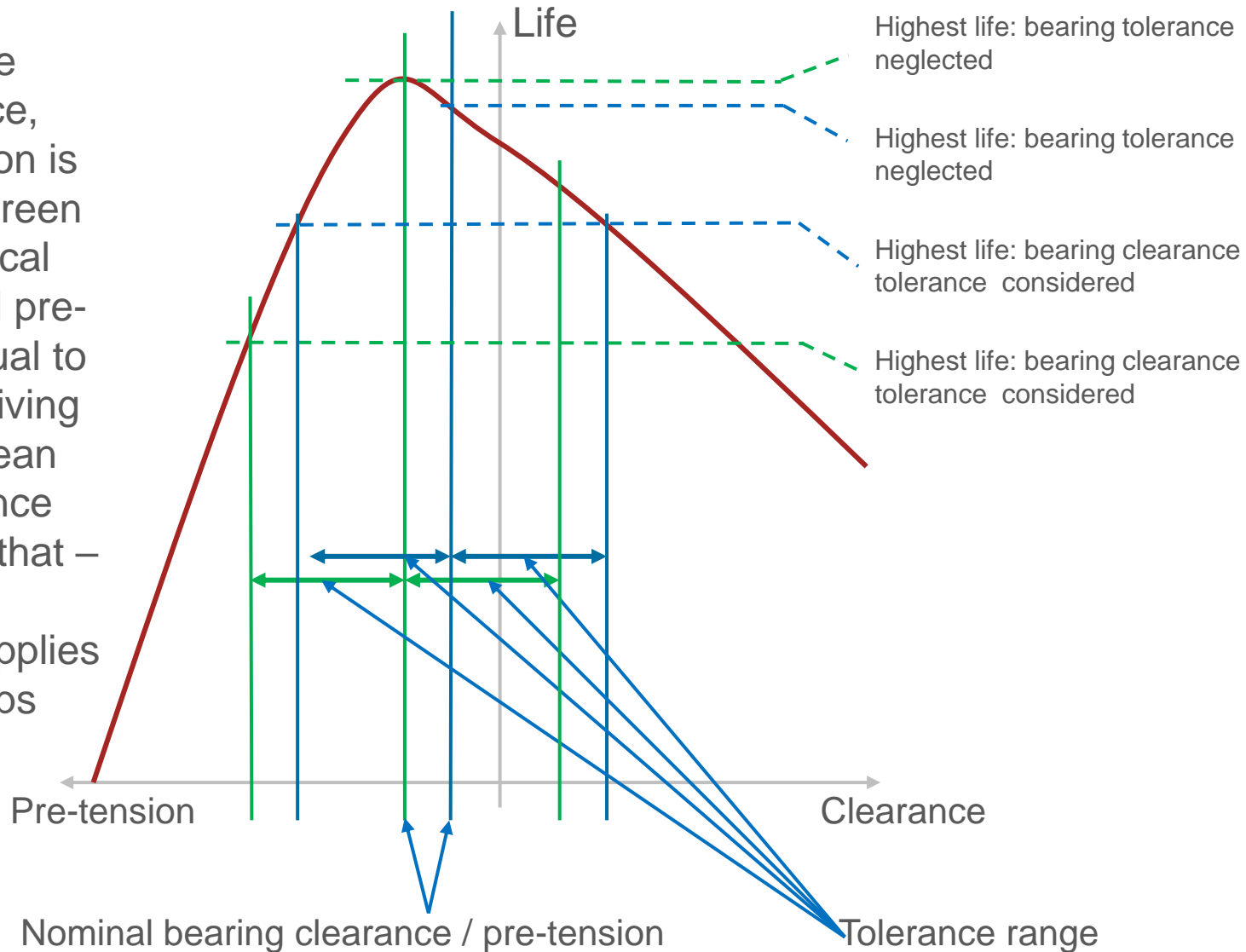
The shape of the life vs. clearance curve depends on the bearing size envelope:



© Joseph Poplawski, from: Oswald et al., Effect of internal clearance on load distribution and life of radially loaded ball and roller bearings, March 2012, Tribology Transactions, 55(2):245-265

Effect of clearance

Assume tolerance band for clearance, optimal pre-tension is in the middle of green band (green vertical line). The optimal pre-tension is not equal to the pre-tension giving highest life for mean position in tolerance band. Reason is that – if lower end in tolerance band applies – bearing life drops drastically.

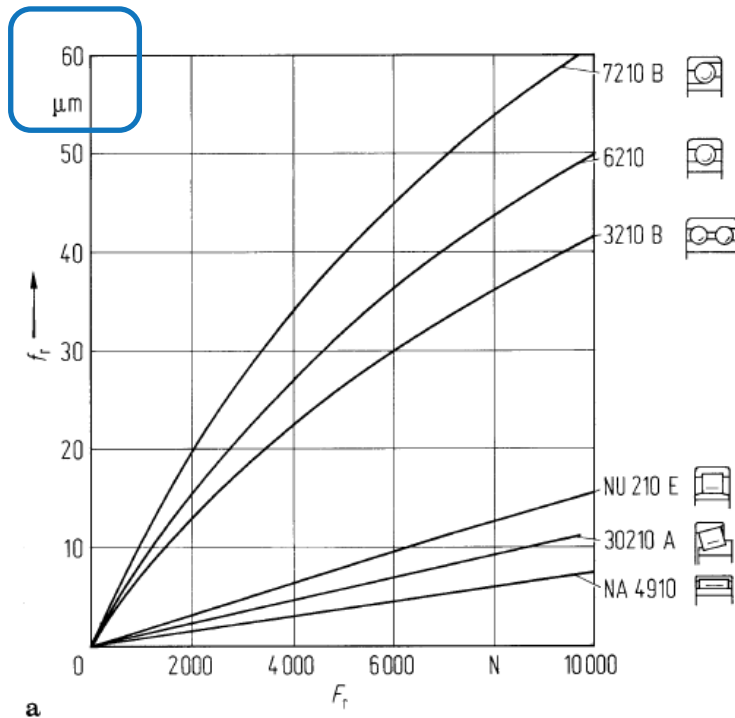


Bearing stiffness

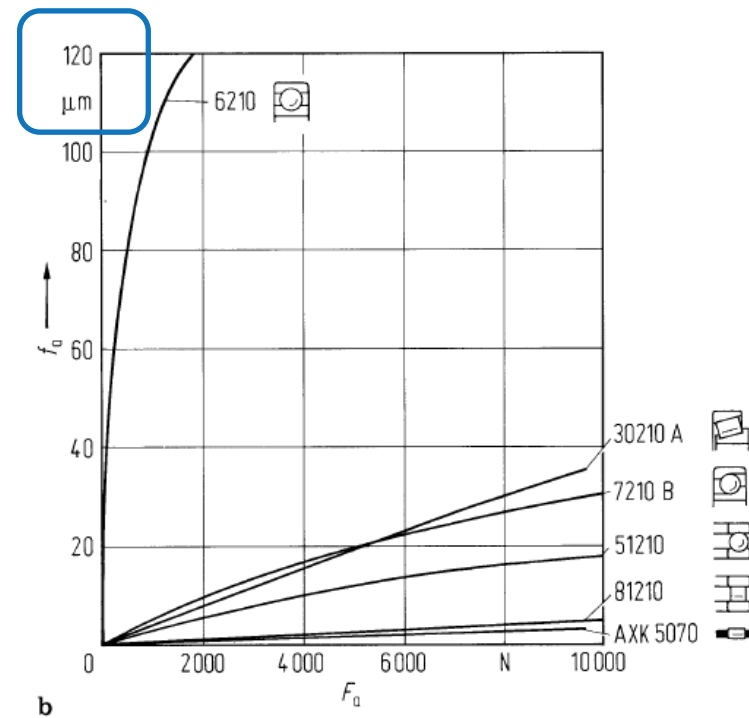
Bearing stiffness

Bearing stiffness is a function of the roller types and bearing series. Below, stiffness curves for purely radial / purely axial loads, $d=50\text{mm}$. Note the scale!

For radial loads



For axial loads



Bearing stiffness

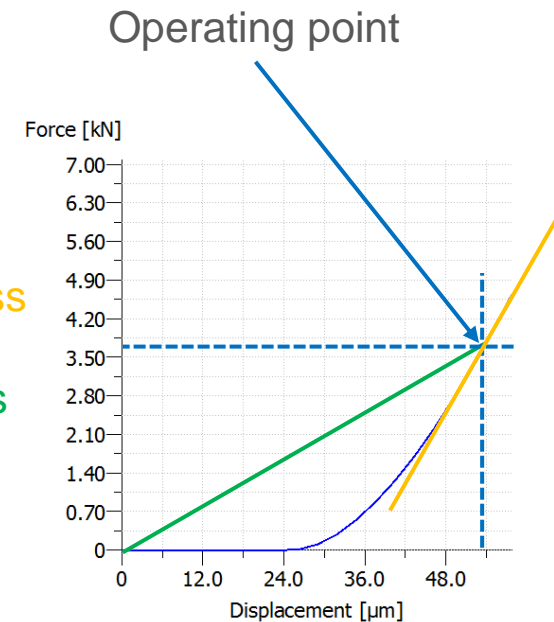
Bearing stiffness calculation based on inner geometry results in a 6x6 matrix for the operating point (note that the bearing stiffness is not linear). Obviously, the stiffness c_y (bearing rotation around the shaft axis) is very small in practice and assumed to be zero in calculations.

Note that stiffness may be given as stiffness in the operating point / tangent stiffness dF/du or a secant stiffness F/u .

$$\mathbf{K} = \begin{matrix} & \begin{matrix} u_x & u_y & u_z & r_x & r_y & r_z \end{matrix} \\ \begin{matrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{matrix} & \begin{bmatrix} \dots & \dots & \dots & \dots & 0 & \dots \\ \dots & \dots & \dots & \dots & 0 & \dots \\ \dots & \dots & \dots & \dots & 0 & \dots \\ \dots & \dots & \dots & \dots & 0 & \dots \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \dots & \dots & \dots & \dots & 0 & \dots \end{bmatrix} \end{matrix}$$

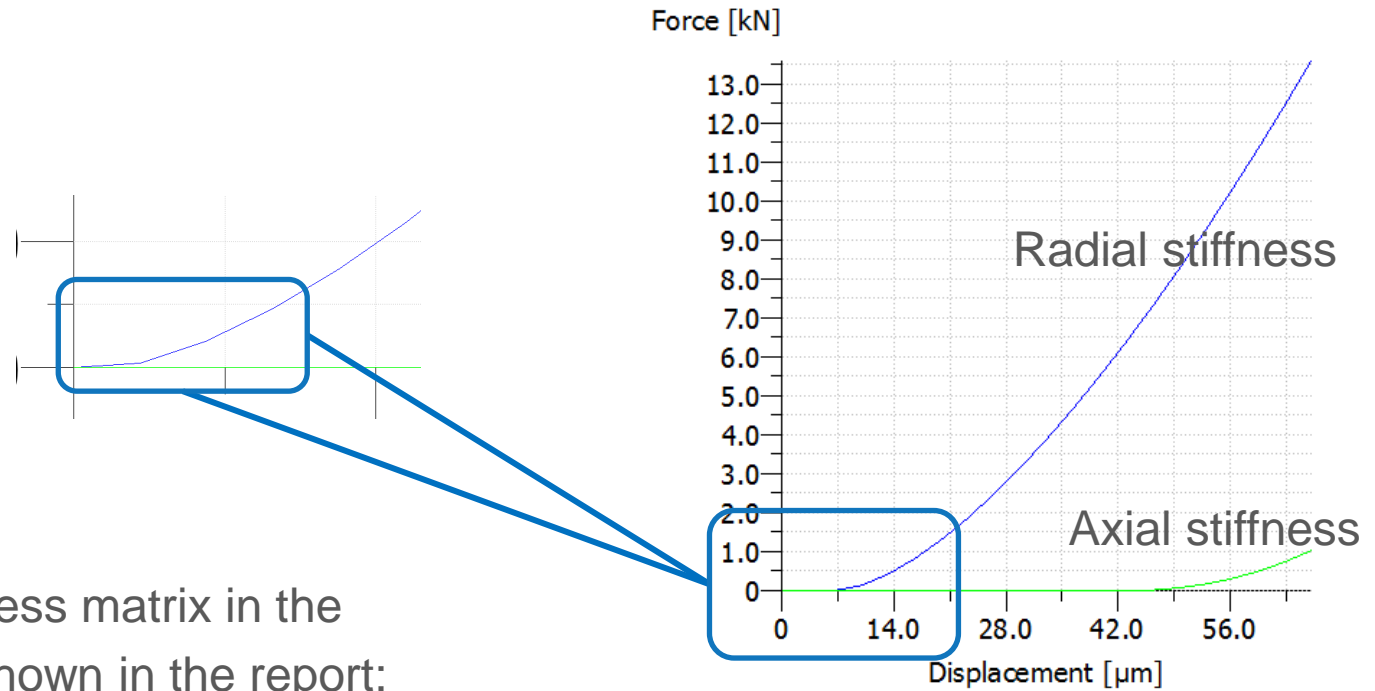
Tangent stiffness

Secant stiffness



Bearing stiffness

The bearing stiffness is non-linear and considers the operating clearance. With increasing load, as more and more rolling elements get into contact, the stiffness increases in steps:



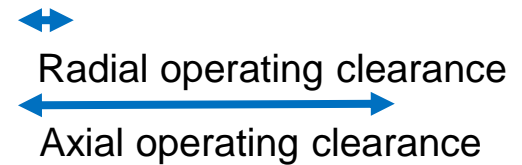
The complete stiffness matrix in the operating point is shown in the report:

Bearing stiffness in operation point

$dFr/dur = 1607.860 \text{ N}/\mu\text{m}$, $(dFr/dur)_{\text{eff}} = (Fr/ur) = 221.054 \text{ N}/\mu\text{m}$

$dMr/drr = 41.488 \text{ Nm}/\text{mrad}$ (724.098 Nm^2), $(dMr/drr)_{\text{eff}} = (Mr/r) = 1048.148 \text{ Nm}/\text{mrad}$ (18293.635 Nm^2)

	$[u_x]$	$[u_y]$	$[u_z]$	$[r_x]$	$[r_z]$
$[F_x]$	-229.702 N/ μm	52.437 N/ μm	9.348 N/ μm	-45.307 N/mrad	1999.280 N/mrad
$[F_y]$	52.177 N/ μm	-118.186 N/ μm	-87.168 N/ μm	-1494.234 N/mrad	-885.224 N/mrad
$[F_z]$	9.283 N/ μm	-87.477 N/ μm	-237.711 N/ μm	-1974.145 N/mrad	44.847 N/mrad
$[M_x]$	-0.046 Nm/ μm	-1.486 Nm/ μm	-1.960 Nm/ μm	-32.267 Nm/mrad	-1.718 Nm/mrad
$[M_z]$	1.986 Nm/ μm	-0.880 Nm/ μm	0.045 Nm/ μm	-1.715 Nm/mrad	-30.080 Nm/mrad



Bearing stiffness, Influence of different settings and calculation methods

Timoshenko or Euler beam model

Influences shaft bending stiffness and therefore bearing loads. Select in tab "Basic data":

Consider deformation due to shearing (Timoshenko beam, not Euler-Bernoulli beam)

Timoshenko beam

Calculation according to ISO 76, ISO 281, ISO/TS 16281

Results

Left (SKF N 1010 KPHA/HC5SP)
Between (SKF N 1010 KPHA/HC5SP)
Right (SKF N 1010 KPHA/HC5SP)

S0	L10h	Lnrh	pmax_i
11.72	23979 h	10589 h	1836 N/mm ²
3.04	267 h	694 h	2312 N/mm ²
17.46	90498 h	289371 h	1155 N/mm ²

Bearing reaction force

Left (SKF N 1010 KPHA/HC5SP)
Between (SKF N 1010 KPHA/HC5SP)
Right (SKF N 1010 KPHA/HC5SP)

Component	X	Y	Z	Rxz
F	0.000 kN	-0.000 kN	-2.859 kN	2.859 kN
M	50.877 Nm	0.000 Nm	0.000 Nm	50.877 Nm
F	-0.000 kN	0.000 kN	11.014 kN	11.014 kN
M	1.240 Nm	0.000 Nm	0.000 Nm	1.240 Nm
F	0.000 kN	0.000 kN	1.919 kN	1.919 kN
M	-0.625 Nm	0.000 Nm	0.000 Nm	0.000 Nm

Euler beam

Calculation according to ISO 76, ISO 281, ISO/TS 16281

Results

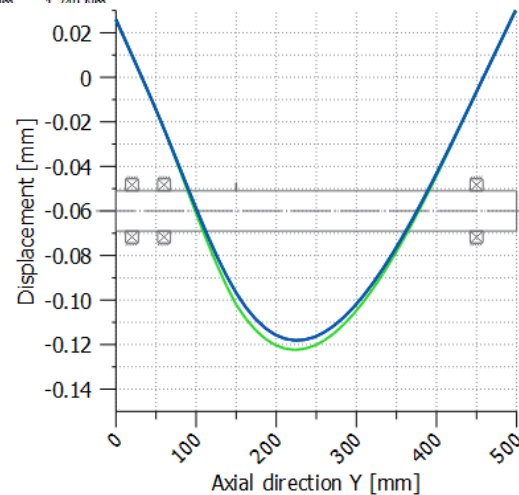
Left (SKF N 1010 KPHA/HC5SP)
Between (SKF N 1010 KPHA/HC5SP)
Right (SKF N 1010 KPHA/HC5SP)

S0	L10h	Lnrh	pmax_i
11.14	20229 h	10578 h	1836 N/mm ²
3.00	255 h	658 h	2326 N/mm ²
17.56	92276 h	295311 h	1152 N/mm ²

Bearing reaction force

Left (SKF N 1010 KPHA/HC5SP)
Between (SKF N 1010 KPHA/HC5SP)

Component	X	Y	Z	Rxz
F	-0.000 kN	-0.000 kN	-3.008 kN	3.008 kN
M	49.256 Nm	0.000 Nm	-0.000 Nm	49.256 Nm
F	0.000 kN	0.000 kN	11.175 kN	11.175 kN
M	1.227 Nm	0.000 Nm	0.000 Nm	1.227 Nm
F	-0.000 kN	0.000 kN	1.908 kN	1.908 kN
M	-0.618 Nm	0.000 Nm	0.000 Nm	0.618 Nm



Bearing stiffness, Influence of different settings and calculation methods

Linear or non-linear calculation

Influences equilibrium and therefore bearing loads. Select in module specific settings:

Non-linear shaft

Linear calculation

Calculation according to ISO 76, ISO 281, ISO/TS 16281

Results

Left (SKF 32004 X)
Right (SKF 32004 X)

Bearing reaction force
Left (SKF 32004 X)

Right (SKF 32004 X)

Component	X	Z	Rxz
F	-0.000 kN	-1.469 kN	0.506 kN
M	12.673 Nm	0.000 Nm	0.000 Nm
F	0.000 kN	1.469 kN	0.506 kN
M	-12.673 Nm	0.000 Nm	-0.000 Nm

S0	L10h	Lnrh	pmax_i
17.15	39681 h	3103 h	2975 N/mm ²
17.15	39681 h	3103 h	2975 N/mm ²

Non-linear calculation

Calculation according to ISO 76, ISO 281, ISO/TS 16281

Results

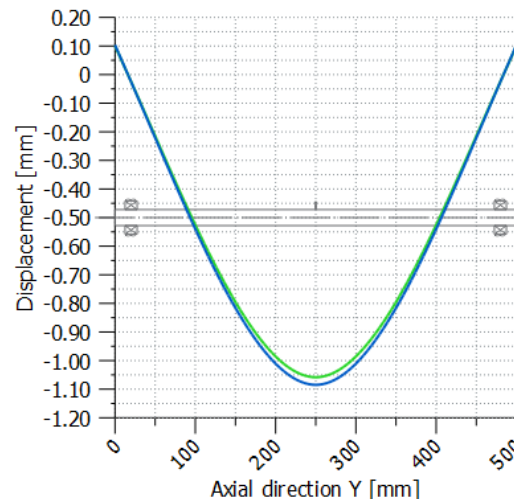
Left (SKF 32004 X)
Right (SKF 32004 X)

Bearing reaction force
Left (SKF 32004 X)

Right (SKF 32004 X)

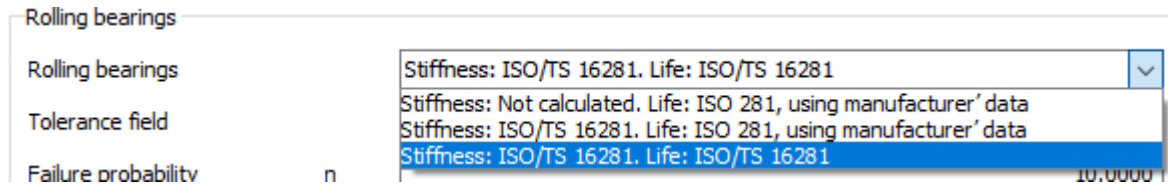
Component	X	Z	Rxz
F	-0.000 kN	-1.536 kN	0.506 kN
M	12.987 Nm	0.000 Nm	0.000 Nm
F	0.000 kN	1.536 kN	0.506 kN
M	-12.988 Nm	-0.000 Nm	-0.000 Nm

S0	L10h	Lnrh	pmax_i
16.51	34539 h	3151 h	2949 N/mm ²
16.51	34539 h	3150 h	2949 N/mm ²



Bearing stiffness, Influence of different settings and calculation methods

Calculation settings in tab “Basic data”



	Operating clearance	Stiffness	Life rating	Static rating	Contact stress
Selection 1	Nominal bearing clearance	Infinite or as defined in database or as given as user input	Basic rating L10h, Modified rating Lnmh	S0 calculated along ISO 76 based on C0	No contact stress calculation
Selection 2	Calculated from nominal bearing clearance, fits, temperatures, ...	Calculated along ISO / TS 16281	Basic rating L10h, Modified rating Lnmh	S0 calculated along ISO 76 based on C0	No contact stress calculation
Selection 3	Calculated from nominal bearing clearance, fits, temperatures, ...	Calculated along ISO / TS 16281	Basic rating L10h, Modified rating Lnmh, Reference rating Lnrh, Modified reference rating Lnmrh	S0 calculated along ISO 76 based on C0	Calculated along ISO / TS 16281

Bearing stiffness, Influence of different settings and calculation methods

Selection 1, stiffness not calculated

- 1) By default, stiffness is infinite
- 2) User may define stiffness values in element editor, in tab «Stiffness/damping»
- 3) Stiffness values are entered for radial and axial direction and for tilting separately
- 4) Stiffness values may be read from a file

2

3

4

The screenshot shows the 'Element Editor' window for a bearing. The 'Stiffness/damping' tab is active, showing the following settings:

- Enter stiffness
- Set damping
- Radial stiffness: c_r = 12.0000 N/μm
- Read data from file: [empty field]
- Axial stiffness: c_a = 23.0000 N/μm
- Read data from file: [empty field]
- Tilting stiffness: c_{rot} = 34.0000 Nm/°
- Read data from file: [empty field]

Other visible parameters include: Designation: Right; Position on shaft: y = 480.0000 mm; Position in global system: Y = 480.0000 mm; Type of bearing: Fixed bearing adjusted on left side <-; Type: Cylindrical roller bearing (single row); Number: SKF N 204 ECP (d=20.000 mm, D=47.000 mm, B=14.000 mm)*; Comment: SKF Explorer - SKF Popular Item; Inner diameter: d = 20.000 mm; External diameter: D = 47.000 mm; Nominal width: B = 14.0000 mm.

Bearing stiffness, Influence of different settings and calculation methods

Input of stiffness values in database

- 1) Stiffness values may be associated with a rolling element bearing by entering stiffness values in the bearing data base.
- 2) If stiffness value is present in database and also in bearing model (direct input), then, stiffness values are taken from direct input and value in database are ignored.

The screenshot shows the 'Create a new entry' dialog box with the following data:

Field	Value
ID	20002
Created by:	hdinner
on:	18.05.2022 11:13:48
Status	aktiv
Changed by:	
on:	

Basic data | Additional data | Internal geometry

Rating and permitted values

Parameter	Value	Unit
Permissible axial force in [%] of F_r	0.0000	
Maximum permissible misalignment	0.0000	
Thermal reference speed	20000.0000	1/min
Radial stiffness	123	N/ μ m
Axial stiffness	456	N/ μ m
Tilting stiffness	789	Nm/ $^\circ$
Specific minimum load	0.0000	
Fatigue load limit	2.6000	kN

Additional information

Availability	1
Price	0.0000

Bearing stiffness, Influence of different settings and calculation methods

Input of stiffness values from file

- 1) The file uses the force/torque information on the bearing to give displacement/tilting values.
- 2) Force (tilting moment) vs. displacement information is encoded in three separate sections in the file. One for radial force and displacement, one for axial force and displacement and one for tilting moment and tilting.
- 3) Note the units and definitions

3

1

4

```
Example-Userdefined-Bearing-Stiff... x
-----
-- example file for user-defined rolling bearing stiffness
--
-- Units
-- =====
-- F: radial force in N
-- Fy: axial force in N
-- u: radial displacement in mm
-- uy: axial displacement in mm
-- M: tilting moment in Nm
-- r: tilting of outer bearing ring in mrad
--
-- (c) by KISSsoft AG, CH-8608 Bubikon
--
-- 18.09.2015   ik   Initial version
-- 06.07.2017   ik   Added axial stiffness

:TABLE LIST forceDisplacement
INPUT index TREAT NEXT_BIGGER
OUTPUT F, u
DATA
1      0      0.000
2     16     0.001
3     46     0.002
4     84     0.003
5    130     0.004
6    182     0.005
7    514     0.010
8    943     0.015
9   1452     0.020
10  2030     0.025
11  2668     0.030
12  4108     0.040
13  5741     0.050
14  7547     0.060
15  9511     0.070
16 11620     0.080
17 13865     0.090
18 16239     0.100
END

:TABLE LIST axialForceDisplacement
INPUT index TREAT NEXT_BIGGER
OUTPUT Fy, uy
DATA
1      0      0.000
2     12     0.001
3     35     0.002
4     65     0.002
5    101     0.003
```



D6CFA2FD.dat

Calculation reports

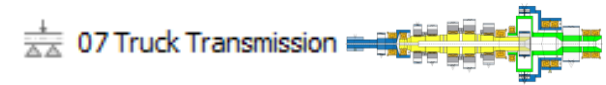
Main report, based on example

Lists bearing properties

Lists relationship between bearings and shaft(s)

Lists results, including

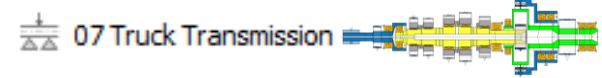
- 1) Equivalent load, static and dynamic
- 2) Minimum EHL film thickness
- 3) Reliability factor a_1 for modified rating
- 4) Results based on ISO 281 calculations
- 5) Results based on ISO/TS 16281 calculations
- 6) Operating clearance calculation details see report "Rolling bearing"



15.15 Rolling bearing 'bz6'			
Position (Y-coordinate)	[y]	385.00	mm
Dynamic equivalent load	[P]	0.02	kN
Static equivalent load	[P _s]	0.02	kN
Minimum EHL lubricant film thickness	[h _{min}]	0.598	µm
Life modification factor for reliability	[a]	1.000	
15.15.1 Results according to ISO 281			
Lubricant		ISO-VG 220	
Lubricant with additive, effect on bearing lifetime confirmed in tests.			
Lubricant - service temperature	[T _a]	30.00	°C
Oil lubrication, on-line filtration, ISO 4406 -/19/16			
Contamination factor	[e _c]	0.283	
Load ratio	[C/P]	3106.397	
Operating viscosity	[ν]	425.092	mm ² /s
Reference viscosity	[ν _r]	52.514	mm ² /s
Viscosity ratio	[k]	8.095	
Life modification factor	[a _{ISO}]	50.000	
Fatigue load limit	[C _r]	21.200	kN
Basic bearing rating life	[L ₁₀]	> 1000000	h
Modified bearing rating life	[L _{10m}]	> 1000000	h
Static safety factor	[S ₀]	7059.99	
15.15.2 Calculation with proprietary bearing internal geometry data (ISO/TS 16281)			
Operating diametral clearance	[Pd]	57.500	µm
Contamination factor	[e _c]	0.283	
Fatigue load limit	[C _r]	21.200	kN
Reference rating life	[L _{10r}]	> 1000000	h
Modified reference rating life	[L _{10mr}]	> 1000000	h
Effective static safety factor	[S _{0e}]	732.24	
Static safety factor	[S _{0m}]	9999.99	
Static equivalent load	[P _{0m}]	0.00	kN
Bearing reaction force	[F _r]	-0.000	kN
Bearing reaction force	[F _t]	0.000	kN
Bearing reaction force	[F _x]	-0.024	kN
Bearing reaction force	[F _y]	0.024	kN
Inclination angle	[α _{in}]	-90.000	°
Bearing reaction moment	[M _r]	-0.062	Nm
Bearing reaction moment	[M _t]	0.000	Nm
Bearing reaction moment	[M _x]	-0.000	Nm
Bearing reaction moment	[M _y]	0.062	Nm
Inclination angle	[α _{out}]	-180.000	°
Displacement of bearing	[u _r]	-0.000	µm
Displacement of bearing	[u _t]	0.202	µm
Displacement of bearing	[u _x]	28.992	µm
Displacement of bearing	[u _y]	28.992	µm
Inclination angle	[α _u]	90.000	°
Misalignment of bearing	[r _{r,1}]	0.009	mrad
Moment of friction, seals	[M _{loss}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M _{loss2}]	0.000	Nm
Torque of friction	[M _{loss1}]	0.461	Nm
Power loss	[P _{loss}]	11.762	W
The moment of friction is calculated according to the details in SKF Catalog 2018.			
The calculation is always performed with a coefficient for additives in the lubricant $\mu_{bl}=0.15$.			
The factors used to calculate the torque loss have been assumed for this bearing.			

Calculation reports

Report «Rolling bearing», based on example



For each bearing in the shaft model, a section with four sub section is created

- 5 Shaft 'Output shaft' Rolling bearing 'b8' _____ 25
- 5.1 Operating bearing clearance _____ 25
- 5.2 Results according to ISO 281 _____ 26
- 5.3 Calculation with proprietary bearing internal geometry data (ISO/TS 16281) _____ 26
- 5.4 Results according to ISO/TS 16281 _____ 27

Additional details compared to main report are included.

5 Shaft 'Output shaft' Rolling bearing 'b8'

Cylindrical roller bearing (single row) (SKF NU 1016)
SKF Popular Item

Inner diameter	[d]	80.000	mm
Outer diameter	[D]	125.000	mm
Width	[B]	22.000	mm
Dynamic load rating	[C]	64.400	kN
Static load rating	[C ₀]	78.000	kN
Fatigue load limit	[C ₁₀]	9.800	kN
Life modification factor for reliability	[a]	1.000	
Correction factor (dynamic rating)	[f]	1.000	
Correction factor (static rating)	[f ₀]	1.000	
Minimum EHL lubricant film thickness	[h _{min}]	1.063	µm
Dynamic equivalent load	[P]	14.450	kN
Static equivalent load	[P ₀]	14.450	kN
Effective speed	[n]	975.610	1/min (ck)

5.1 Operating bearing clearance

5.1.1 Inputs

Nominal bearing clearance	[]	ISO 5753-1:2009 C2
Nominal diametral clearance	[P _{d0}]	27.500 µm
Tolerance	[]	DIN 620:1988 PN
Inner diameter	[dbi]	79.985/ 79.993/ 80.000 mm
Diameter of inner ring	[dri]	91.486 mm
Diameter of outer ring	[dro]	113.514 mm
Outer diameter	[Dbo]	124.982/124.991/125.000 mm
Tolerance shaft	[]	h7
Shaft inside diameter	[dsi]	60.000 mm
Shaft external diameter	[dso]	79.970/ 79.985/ 80.000 mm
Shaft roughness	[Rz]	8.000 µm
Tolerance hub	[]	H7
Hub inside diameter	[Dhi]	125.000/125.020/125.040 mm
Hub external diameter	[Dho]	250.000 mm
Hub roughness	[Rzo]	8.000 µm

5.1.2 Results

Tolerance field	[]	Mean value
Press fit, shaft internal ring		
Shaft speed	[n]	975.610 1/min
Shaft temperature	[T _s]	20.0 °C
Temperature of inner ring	[T _i]	20.0 °C
Diameter	[dsoT]	79.985 mm
Diameter	[dbiT]	79.993 mm
Interference	[U _w]	0.000 µm
Embedding	[s]	0.000 µm
Hertzian pressure	[p]	0.000 N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000 µm
Diametral clearance change	[ΔP _d]	-0.000 µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
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Diametral clearance change	[ΔP _d]	-0.000	µm

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Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

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Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
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Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
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Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

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Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
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Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
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Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

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Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

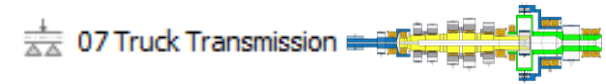
Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
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Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
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Diametral clearance change	[ΔP _d]	-0.000	µm

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Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure	[p]	0.000	N/m ²
Effective interference (20.0 (°C))	[U _{w_e} ff]	0.000	µm
Diametral clearance change	[ΔP _d]	-0.000	µm

Shaft speed	[n]	975.610	1/min
Shaft temperature	[T _s]	20.0	°C
Temperature of inner ring	[T _i]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[U _w]	0.000	µm
Embedding	[s]	0.000	µm
Hertzian pressure			

Report «Rolling bearing clearance, load spectrum»



The operating clearance is calculated for each bin in the load spectrum

- 1) The bin number for which the results are documented is included in the section title
- 2) For each bearing, for each bin, a section is added in the report
- 3) These are containing the usual sub-sections.



KISSsoft			
9 Shaft 'Shaft' Rolling bearing 'Roller bearing 1': Bearing clearance change - Load spectrum [8]			
9.1 Operating bearing clearance			
9.1.1 Inputs			
Nominal bearing clearance	[-]	ISO 5753-1:2009 C0	
Nominal bearing clearance - Radial	[Pd0]		37.500 μm
Tolerance	[-]	DIN 620:1988 P6	
Inner diameter	[di]		39.980/39.995/40.000 mm
Diameter of inner ring	[di]		61.026 mm
Diameter of outer ring	[Dro]		81.205 mm
Outer diameter	[Dbo]		89.987/89.993/90.000 mm
Tolerance shaft	[-]	p6	
Shaft inside diameter	[dsi]		0.000 mm
Shaft external diameter	[dso]		40.026/40.034/40.042 mm
Shaft roughness	[Rzi]		4.800 μm
Tolerance hub	[-]	H7	
Hub inside diameter	[Dhi]		90.000/90.017/90.035 mm
Hub external diameter	[Dho]		180.000 mm
Hub roughness	[Rzo]		8.000 μm
9.1.2 Results			
Tolerance field	[-]	Mean value	
Press fit shaft internal ring			
Shaft speed	[ni]		980.000 1/min
Shaft temperature	[Ti]		20.0 °C
Temperature of inner ring	[Ti]		69.0 °C
Diameter	[dsoT]		40.034 mm
Diameter	[dsoT]		40.018 mm
Interference	[Uwi]		16.463 μm
Embedding	[s i]		1.920 μm
Hertzian pressure	[p]		21.664 N/m ²
Effective interference (20.0 (°C))	[Uwi_eff]		14.543 μm
Bearing clearance change	[ΔPd1]		-43.898 μm
Press fit hub external ring			
Hub speed	[no]		0.000 1/min
Hub temperature	[Tn]		20.0 °C
Temperature of outer ring	[To]		49.0 °C
Diameter	[DboT]		90.024 mm
Diameter	[DhoT]		90.017 mm
Interference	[Uwo]		6.013 μm
Embedding	[s o]		3.200 μm
Hertzian pressure	[p]		0.572 N/m ²
Effective interference (20.0 (°C))	[Uwo_eff]		2.813 μm
Bearing clearance change	[ΔPdo]		24.700 μm
Rolling body temperature	[Tw]		59.0 °C
Rolling body expansion	[ΔDw]		4.575 μm
Total bearing clearance change	[ΔPd]		-28.336 μm (ΔPd1 + ΔPdo - 2 * ΔDw)
Operating bearing clearance - Radial	[Pd]		8.164 μm (Pd0 + ΔPd)

Report «Service life factor (classic)»

Data for life rating along ISO 281 and static rating along ISO 76 are listed.

- 1) For single load case including complete description.
- 2) For load spectrum, compressed style.

1

$F_r/F_r(0.553 \text{ N}) > e_0(0 \text{ N}): X_0 = 1.000, Y_0 = 2.80, P_0 = 8465 \text{ N}$ ($F_r = 3320 \text{ N}, F_a = 1837 \text{ N}$)
 $P_0 = 8465 \text{ N}, S_0 = 12.8$
 $F_a/F_r(0.553 \text{ N}) > e(0.240 \text{ N}): X = 0.670, Y = 4.20, P = 9942 \text{ N}$ ($F_r = 3320 \text{ N}, F_a = 1837 \text{ N}$)
 $v = 425, v_1 = 17.6, K = 24.2, K_{calc} = 4.00$
 $C_u = 12 \text{ kN}, e_c = 0.500, a_{ISO} = 6.00$
 $P = 9942 \text{ N}, P/C = 0.0929, P/C_{min} = 0.0200$
 $L_{10h} = 46810 \text{ h}, a_{ISO} = 6.00, L_{nmh} = 280824 \text{ h}$

2

-- LS [7]
 $F_r/F_r(0.554 \text{ N}) > e_0(0 \text{ N}): X_0 = 1.000, Y_0 = 2.80, P_0 = 9588 \text{ N}$ ($F_r = 3758 \text{ N}, F_a = 2082 \text{ N}$)
 $P_0 = 9588 \text{ N}, S_0 = 11.3$
 $F_a/F_r(0.554 \text{ N}) > e(0.240 \text{ N}): X = 0.670, Y = 4.20, P = 11263 \text{ N}$ ($F_r = 3758 \text{ N}, F_a = 2082 \text{ N}$)
 $v = 425, v_1 = 17.6, K = 24.2, K_{calc} = 4.00$
 $C_u = 12 \text{ kN}, e_c = 0.500, a_{ISO} = 4.68$
 $P = 11263 \text{ N}, P/C = 0.105, P/C_{min} = 0.0200$
 $L_{10h} = 30883 \text{ h}, a_{ISO} = 4.68, L_{nmh} = 144612 \text{ h}$

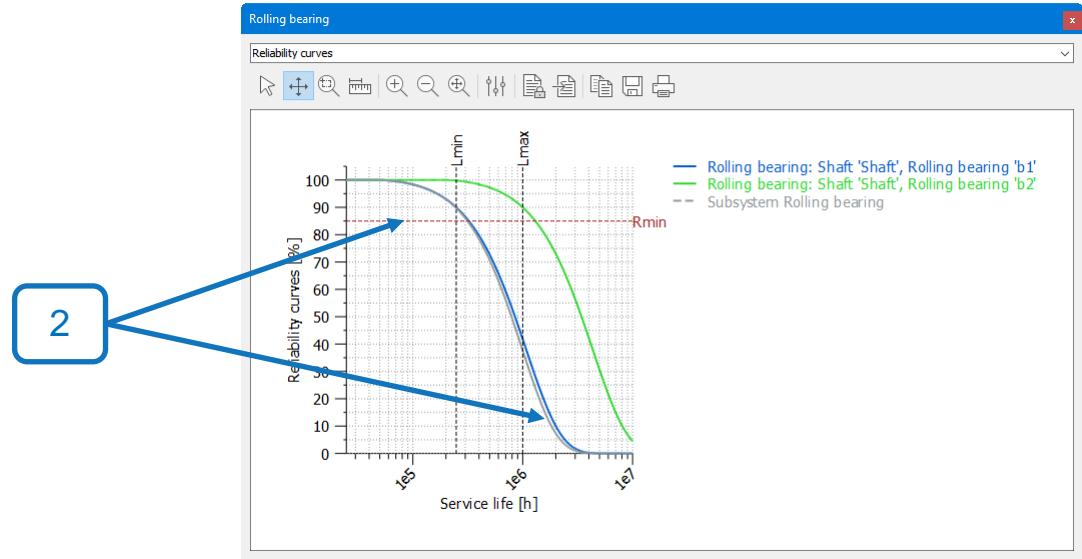
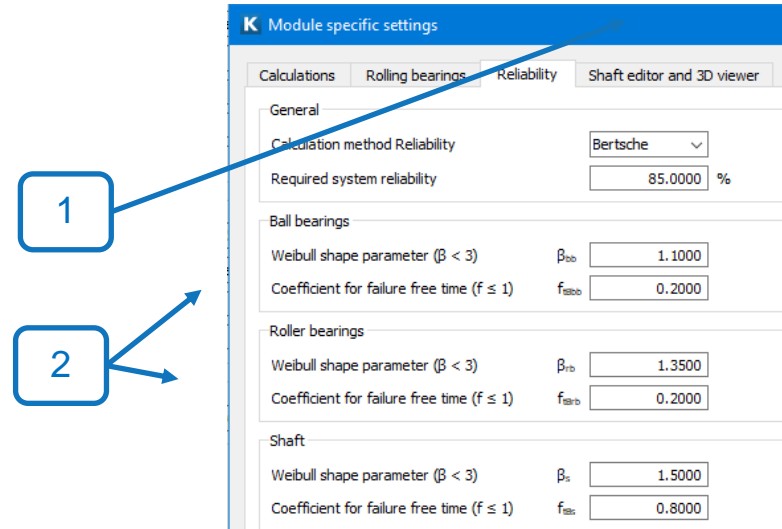
-- LS [6]
 $F_r/F_r(0.555 \text{ N}) > e_0(0 \text{ N}): X_0 = 1.000, Y_0 = 2.80, P_0 = 10711 \text{ N}$ ($F_r = 4195 \text{ N}, F_a = 2327 \text{ N}$)
 $P_0 = 10711 \text{ N}, S_0 = 10.1$
 $F_a/F_r(0.555 \text{ N}) > e(0.240 \text{ N}): X = 0.670, Y = 4.20, P = 12584 \text{ N}$ ($F_r = 4195 \text{ N}, F_a = 2327 \text{ N}$)
 $v = 425, v_1 = 17.6, K = 24.2, K_{calc} = 4.00$
 $C_u = 12 \text{ kN}, e_c = 0.500, a_{ISO} = 3.81$

2 Rolling bearing analysis			
2.1 Shaft 'Shaft', Rolling bearing 'Roller bearing 1': SKF 21308 E			
Speed	[n]	980.0	1/min
Radial force	[F _r]	5869.5	N
Axial force	[F _a]	3263.6	N
Load ratio	[F _a /F _r]	0.556	
Limiting value (F _a /F _r > e ₀)	[e ₀]	0.000	
Static radial load factor	[X ₀]	1.000	
Static axial load factor	[Y ₀]	2.800	
Static equivalent load	[P ₀]	15007.6	N
Static load rating	[C ₀]	108.000	kN
Limiting value (F _a /F _r > e)	[e]	0.240	
Dynamic radial load factor	[X]	0.670	
Dynamic axial load factor	[Y]	4.200	
Dynamic equivalent load	[P]	17639.7	N
Dynamic load rating	[C]	107.000	kN
Fatigue load limit	[C _L]	11.800	kN
Minimum required dynamic load ratio	[P/C _{min}]	0.020	
Actual dynamic load ratio	[P/C]	0.165	
Contamination factor	[e _c]	0.500	
Operating viscosity	[v]	425.1	mm ² /s
	[v ₁]	17.6	mm ² /s
	[k]	24.205	
	[K _{calc}]	4.000	
	[a ₁]	1.000	
	[a _{ISO}]	2.205	
	[a ₁ * a _{ISO}]	2.205	
	[S ₀]	7.20	
	[L ₁₀]	407	10 ⁶
	[L _{10h}]	6922	h
	[L _{min}]	898	10 ⁶
	[L _{nmh}]	15266	h

Graphics

Reliability curves

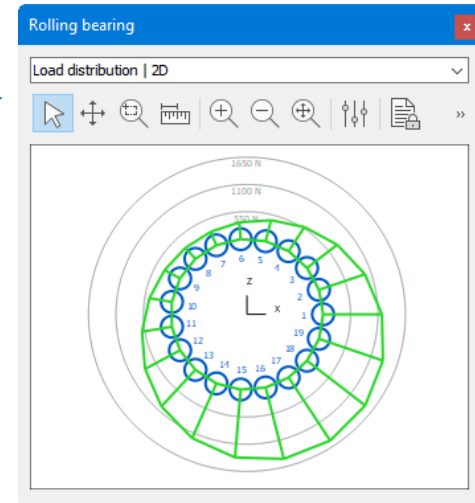
- 1) Calculation method and required reliability level is defined in module specific settings, tab «Reliability».
- 2) Weibull distribution shape parameter and coefficient for failure free time are defined separately for ball and roller bearings.
- 3) Graphic shows reliability curve for each bearing and for bearing sub-system. Required reliability level is in graph.



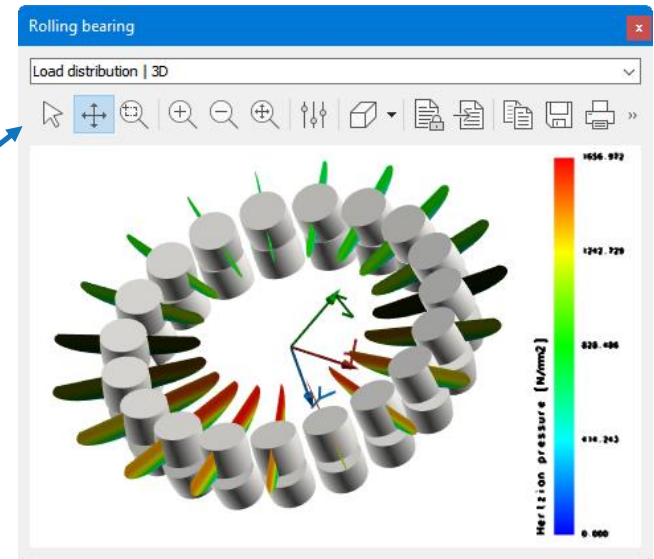
Load distribution

- 1) 2D graphic shows contact force per rolling element, in case of double row bearings, for both rows. Select bearing in properties.
- 2) 3D graphic shows contact stress per rolling element, in contact to inner and to outer ring. Select bearing in properties.
- 3) In case of load spectrum calculation, results for nominal load are shown.

1



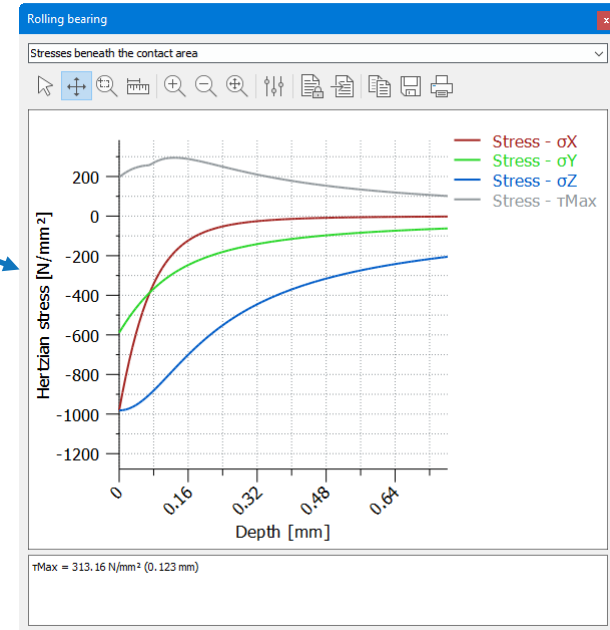
2



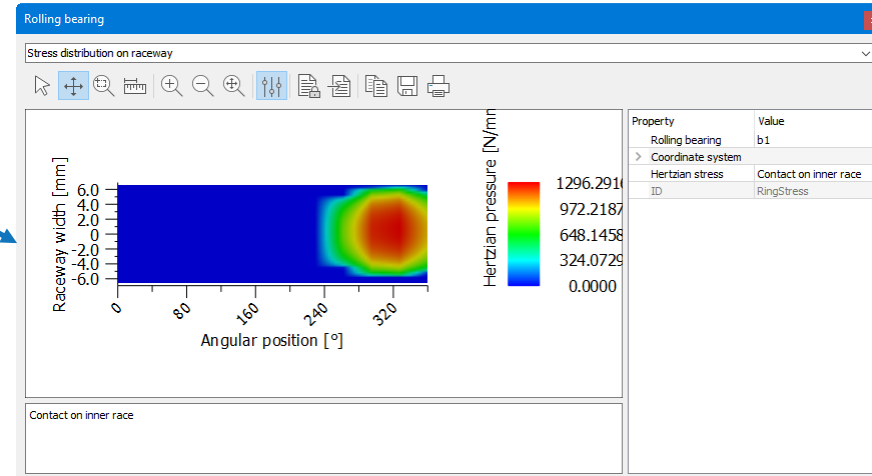
Raceway stress

- 1) Subsurface stresses calculated as per Hertzian theory, for each bearing, for each row of rolling elements, for each rolling element and for each slice (in case of roller bearings).
- 2) Contact stress distribution on inner and outer raceway.

1

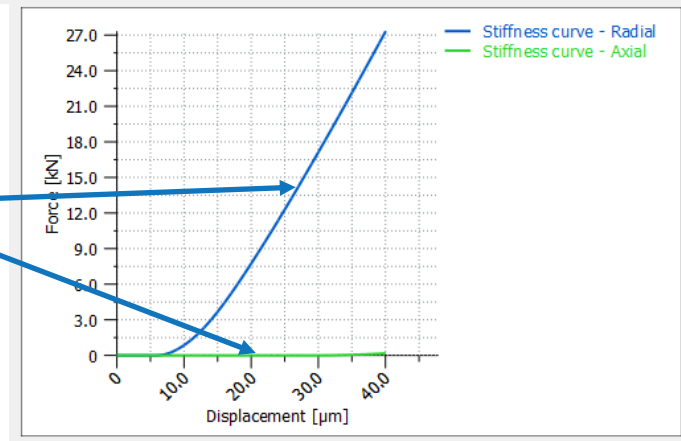
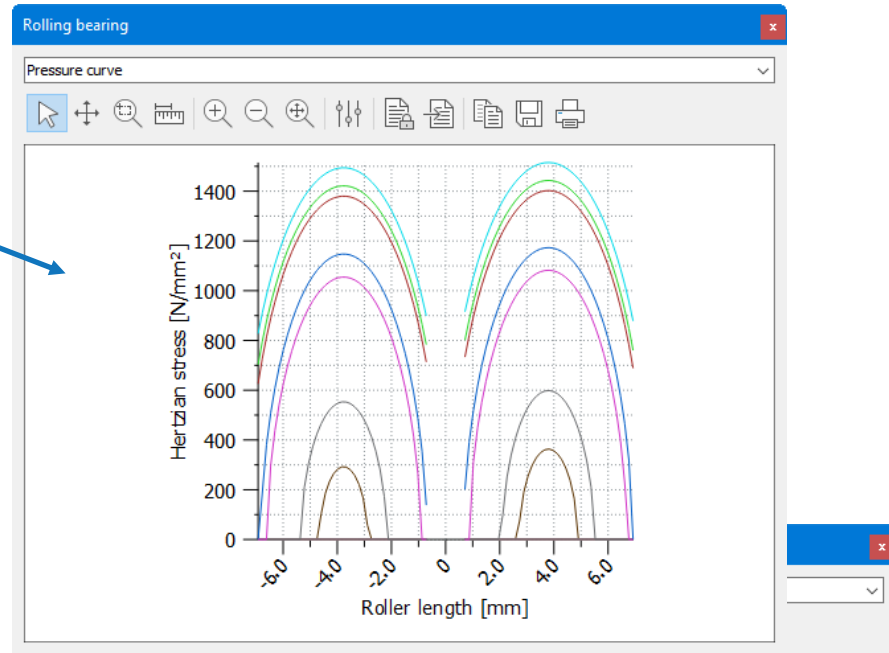


2



Raceway stress and stiffness

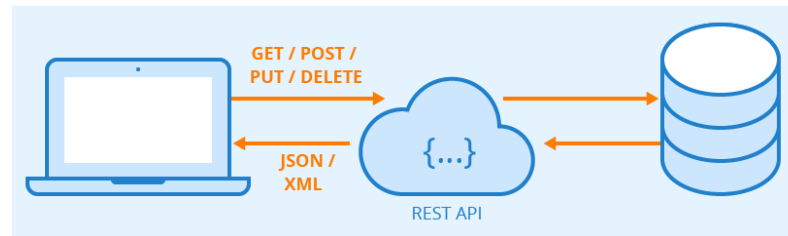
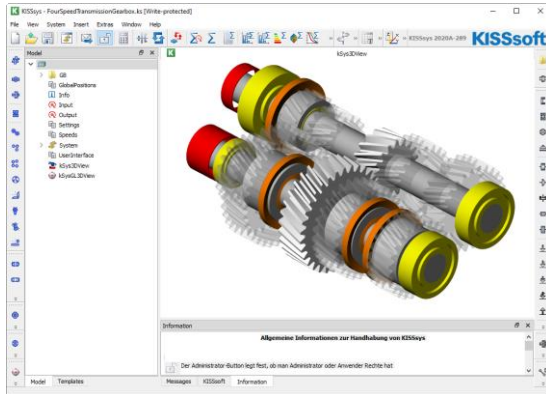
- 1) Contact stress course along each rolling element, for contact to inner or outer raceway.
- 2) Stiffness in radial and axial direction for purely radial and purely axial load.



SKF cloud calculations

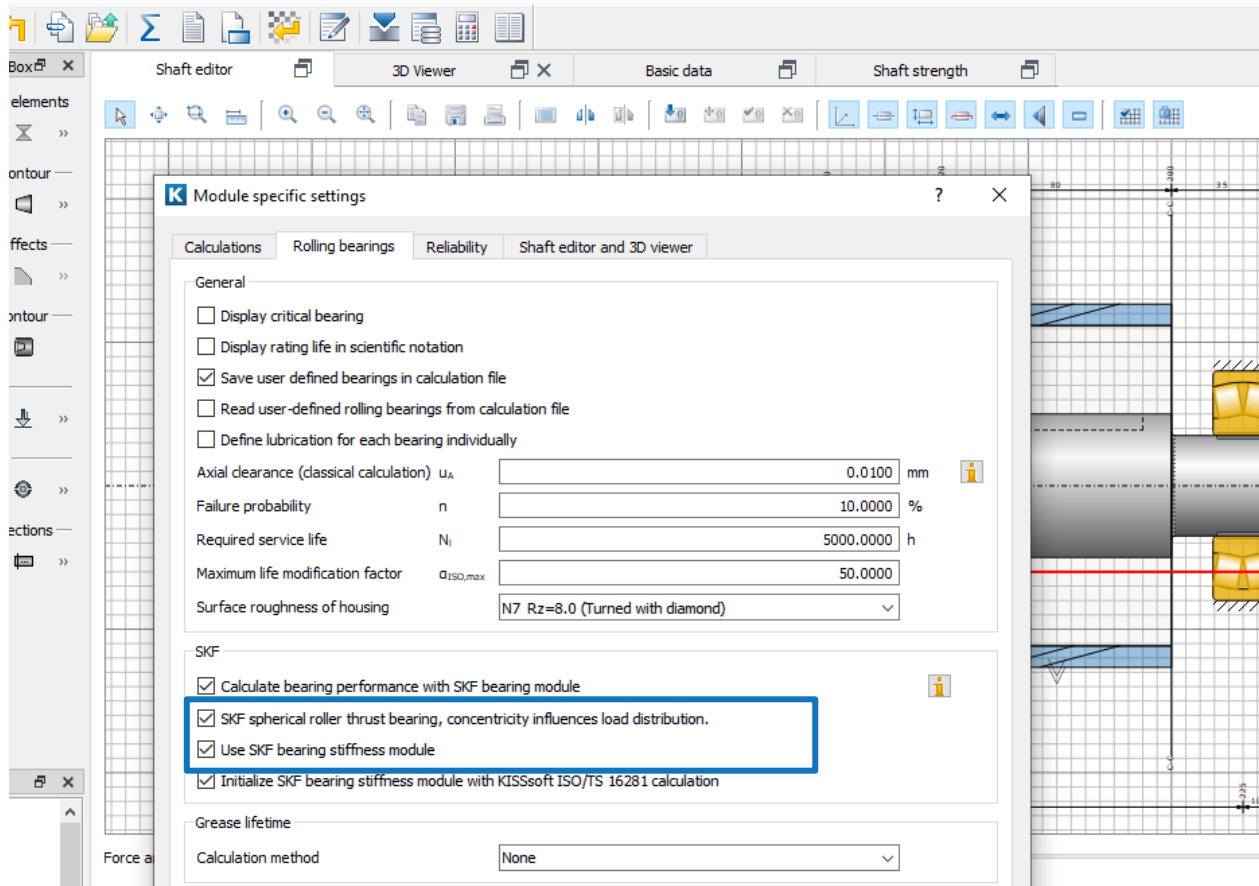
SKF cloud calculations

Provide accurate, inner geometry based and SKF specific bearing calculation results



SKF cloud calculations


This option can be activated in the module specific settings.



SKF bearings

- SKF Spherical roller thrust bearings, concentricity influences load distribution
This flag is in the module specific settings, which you can set, if the runout affecting load distribution of SKF spherical thrust roller bearings or not. If the flag isn't set the dynamic equivalent load will be multiplied with a factor of 0.88.

SKF

Calculate bearing performance with SKF bearing module 

SKF spherical roller thrust bearing, concentricity influences load distribution.

Use SKF bearing stiffness module

SKF cloud calculations

SKF Calculation Tool

Additional calculations were added

Available Calculation Services	External Tools	
	KISSsoft 2019	KISSsoft 2020
Minimum load	YES	YES
Minimum radial load	*	✓
Equivalent dynamic load	YES	YES
Load ratio	✓	✓
Grease life and relubrication interval	NO	YES
Grease life	*	✓
Relubrication interval	*	✓
Grease quantity	*	✓
Bearing rating life	YES	YES
Basic rating life	✓	✓
SKF rating life	✓	✓
Contamination factor	✓	✓
Life modification factor	✓	✓
Static safety factor	NO	YES
Static safety factor	*	✓
Viscosity	YES	YES
Operating viscosity	✓	✓
Reference viscosity	✓	✓
Viscosity ratio	✓	✓
Bearing frequencies	NO	YES
Rotational frequency inner ring	*	✓
Rotational frequency outer ring	*	✓
Rotational frequency cage	*	✓
Rotational frequency rolling element	*	✓
Over-rolling frequency inner ring	*	✓
Over-rolling frequency outer ring	*	✓
Over-rolling frequency rolling element	*	✓
Friction and power loss	NO	YES
Total frictional moment	*	✓
Rolling frictional moment	*	✓
Sliding frictional moment	*	✓
Frictional moment drag losses	*	✓
Frictional moment seals	*	✓
Starting frictional moment	*	✓
Bearing frictional power loss	*	✓
Adjusted reference speed	NO	YES
Adjusted reference speed	*	✓
Adjustment factors for bearing load P	*	✓
Adjustment factors for Oil viscosity	*	✓

KISSsoft Release 2019

Results of the calculation with the SKF Bearing Module			
Load ratio	[C/P]	6.070	
Operating viscosity	[v]	424.000	mm ² /s
Reference viscosity	[v _i]	14.100	mm ² /s
Viscosity ratio	[k]	29.900	
Contamination characteristic quantity	[e _c]	0.470	
Life modification factor	[a _{SKF}]	4.360	
Basic rating life	[L _{nh}]	6930.00	h
SKF rating life	[L _{nmh}]	30200.00	h

KISSsoft Release 2020

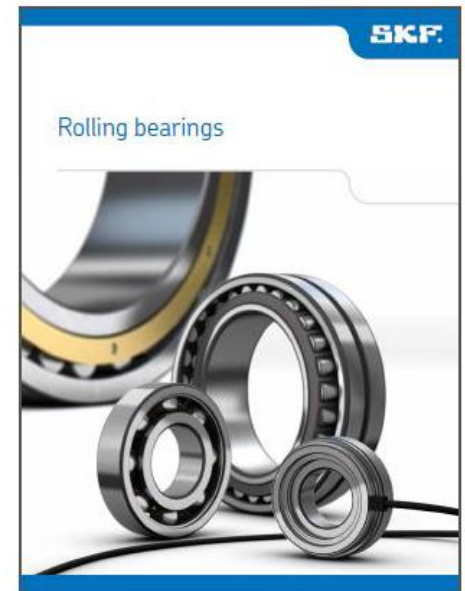
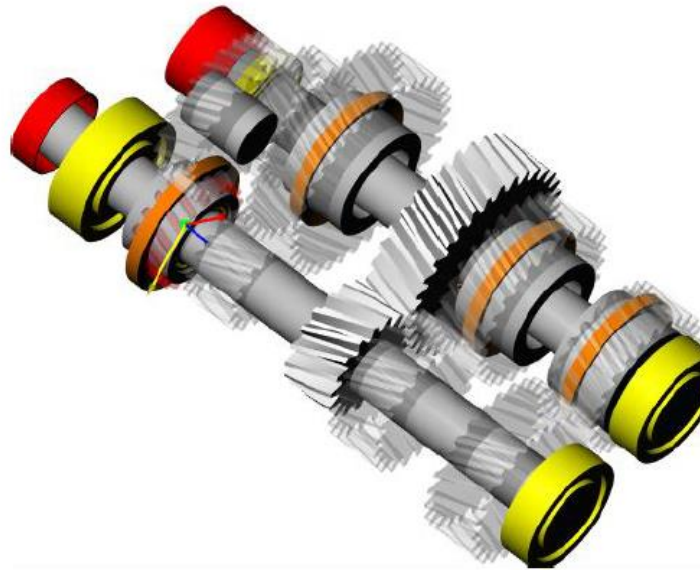
Results of the calculation with the SKF Bearing Module			
Minimum equivalent load	[F _i]	324.000	N
Take weight into account	[-]	yes	
Rotational frequency of inner ring	[f]	16.300	Hz
Rotational frequency of outer ring	[f _o]	0.000	Hz
Rotational frequency of cage	[f _c]	7.000	Hz
Rotational frequency of rolling element	[f _r]	55.700	Hz
Over-rolling frequency of inner ring	[f _{oi}]	177.000	Hz
Over-rolling frequency of outer ring	[f _{oo}]	133.000	Hz
Over-rolling frequency of rolling element	[f _{or}]	111.000	Hz
Total frictional moment	[M]	2060.000	Nmm
Rolling frictional moment	[M _r]	1780.000	Nmm
Sliding frictional moment	[M _{sl}]	199.000	Nmm
Frictional moment drag losses	[M _{drag}]	74.400	Nmm
Frictional moment seals	[M _{seal}]	0.000	Nmm
Starting frictional moment	[M _{start}]	599.000	Nmm
Frictional power loss	[P _{loss}]	212.000	W
Application reference speed	[n _{ar}]	3620.000	1/min
Adjusted factor for load	[f _l]	0.610	
Adjusted factor for viscosity	[f _v]	0.840	
Load ratio	[C/P]	6.070	
Operating viscosity	[v]	424.000	mm ² /s
Reference viscosity	[v _i]	14.100	mm ² /s
Viscosity ratio	[k]	29.900	
Contamination characteristic quantity	[e _c]	0.470	
Life modification factor	[a _{SKF}]	4.360	
Basic rating life	[L _{nh}]	6930.00	h
SKF rating life	[L _{nmh}]	30200.00	h
Static safety factor	[S ₀]	7.200	

SKF & KISSsoft get connected

Hedzer Tillema, Product Line Manager Engineering Tools
SKF B.V., Houten, The Netherlands

KISSsoft
Drivetrain Design Solutions

SKF



SKF

Content

- SKF Bearing Module
- New rating life model for hybrid bearings (GBLM)
- Model exchange via REXS



SKF company profile



Quick Facts

 <p>Customers and distribution: 130 countries</p>	 <p>Employees: 44,428</p>
 <p>We do: Reliable Rotation</p>	 <p>Manufacturing sites: 94 in 24 countries</p>
 <p>Years in business: 112</p>	 <p>Technical centres: 15 around the world</p>




Vision

A world of reliable rotation

Mission

The undisputed leader in the bearing business

Half-year results 2019

 22,488	 2,539	 11.3
Net sales, MSEK	Operating profit, MSEK	Operating margin, %



SKF Bearing Module



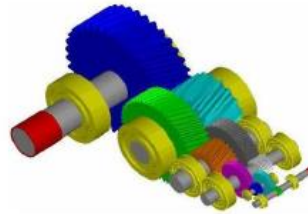
SKF bearing module in KISSsoft

In short:

KISSsoft
Drivetrain Design Solutions



1. Enable SKF calculation by one-time registration



2. Perform modelling & analysis as usual



3. SKF results are displayed for SKF bearings

Results of bearing calculation with the SKF bearing module

Load conditions	[C _R]	14.003
Operating viscosity (mm ² /s)	[ν]	51.794
Viscosity ratio	[ν]	3.589
Impurity characteristic quantity	[α ₀]	0.500
Life modification factor	[aSKF]	18.310
Life modification factor for reliability	[β1]	1.000
Basic rating life (h)	[L ₁₀]	48600.800
SKF rating life (h)	[L _{10h}]	354000.800

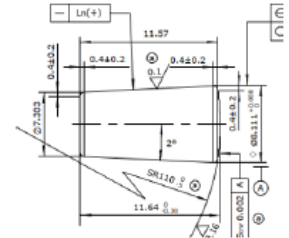
Available in KISSsoft 2019 bearing and shaft module

SKF

SKF bearing module in KISSsoft



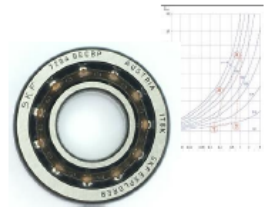
- Only bearing supplier owns bearing (internal) geometry data
- ISO rating life calculations do not accurately predict performance of all bearings (e.g. SKF Explorer or hybrid)



- Embedded calculation of SKF bearing performance

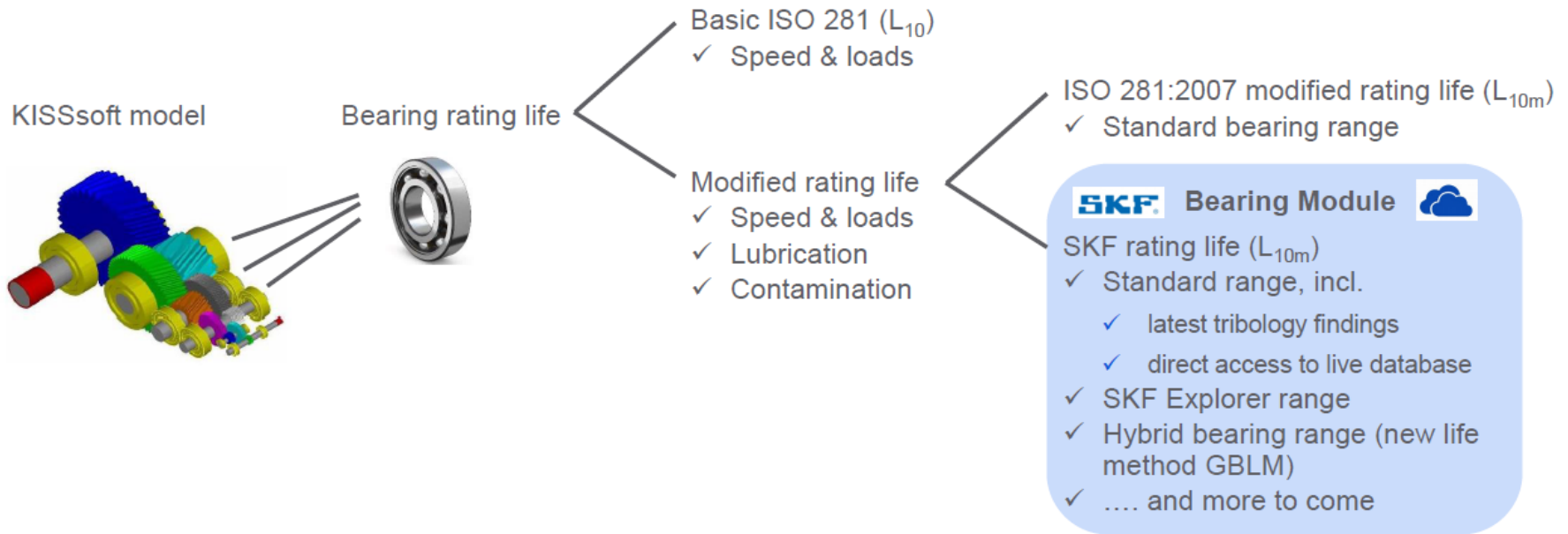


- Accurate & consistent: shows 'true' SKF bearing performance
- Live connection to bearing supplier
- Warnings & info regarding model validity and limitations
- Prepared for the future



SKF

SKF bearing module in KISSsoft



SKF bearing module in KISSsoft

User feedback

“In KISSsoft 2019, the connection with the SKF cloud to calculate bearings is a great function, especially because it gives KISSsoft access to important information and the results are “certified by SKF”.”

“Sometimes we need an SKF calculation of modified rating life. Now this calculation can be done more easily with the SKF bearing module.”

“When you are on the border with ISO you feel more safe if SKF rating life is higher. It gives us more confidence.”

“SKF rating life seems more optimistic than ISO rating life, therefore we can sometimes select a smaller size bearing.”

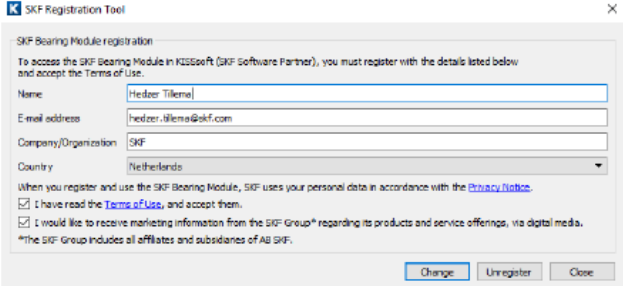
The SKF logo is displayed in white text on a blue background. The letters 'SKF' are bold and sans-serif, with a registered trademark symbol (®) to the right.

SKF bearing module in KISSsoft

Simply activate it in three steps:

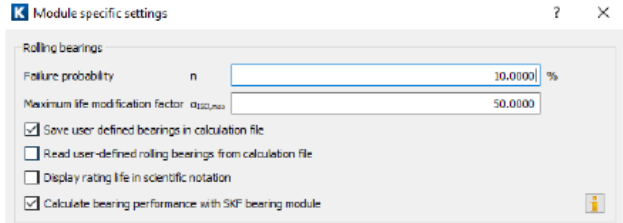
1. Go to the 'SKF Registration Tool' under Extras and register yourself
2. Enable the SKF calculation in the Calculation settings
3. Make sure to enable the calculation of modified rating life

1



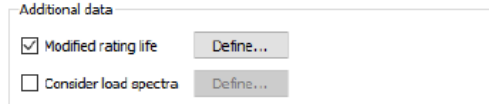
The image shows a dialog box titled "SKF Registration Tool". It contains a form for registration with the following fields: Name (Hedzer Tilerna), E-mail address (hedzer.tilerna@skf.com), Company/Organization (SKF), and Country (Netherlands). Below the form, there are two checked checkboxes: "I have read the Terms of Use, and accept them." and "I would like to receive marketing information from the SKF Group* regarding its products and service offerings, via digital media." There are three buttons at the bottom: "Change", "Unregister", and "Close".

2



The image shows a dialog box titled "Module specific settings". It contains a section for "Rolling bearings" with the following settings: Failure probability (n) set to 10.0000 %, Maximum life modification factor ($a_{20,100}$) set to 50.0000. There are three checkboxes: "Save user-defined bearings in calculation file" (checked), "Read user-defined rolling bearings from calculation file" (unchecked), and "Display rating life in scientific notation" (unchecked). There is also a checkbox for "Calculate bearing performance with SKF bearing module" (checked). An information icon is visible in the bottom right corner.

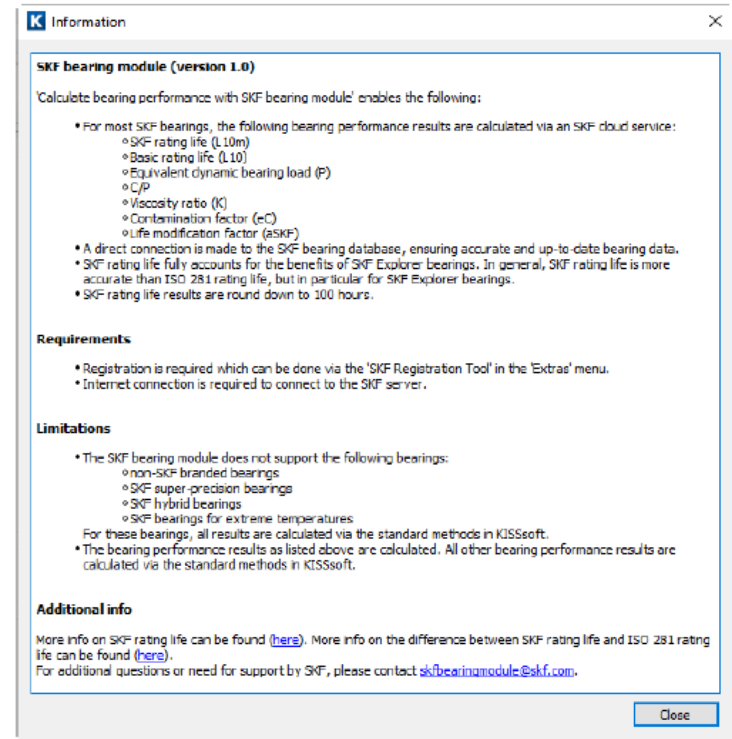
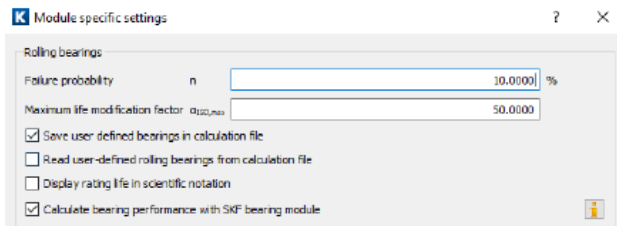
3



The image shows a dialog box titled "Additional data". It contains two checkboxes: "Modified rating life" (checked) and "Consider load spectra" (unchecked). Each checkbox has a "Define..." button next to it.

SKF bearing module in KISSsoft

More info behind  button



SKF bearing module in KISSsoft

SKF rating life and ISO 281 rating life in results overview

SKF results displayed in a separate frame in report



Calculation with the SKF Bearing Module
 Bearing rating life
 Roller bearing 1
 Roller bearing 2
 Calculation according to ISO 281
 Bearing rating life
 Roller bearing 1
 Roller bearing 2

Notice the difference!

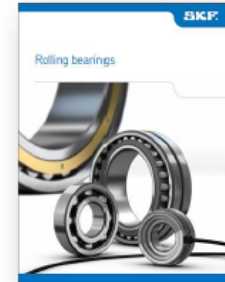
	Lnh	Lnmh	Lnrh	Lnmrh	pmax_j
	6930 h	30200 h			
	45700 h	402000 h			
S0	Lnh	Lnmh	Lnrh	Lnmrh	pmax_j
7.20	6937 h	15311 h	50499 h	365257 h	1590 N/mm ²
9.72	45759 h	198121 h	204690 h	> 1000000 h	1401 N/mm ²

Results of the calculation with the SKF Bearing Module		
Load ratio	[C/P]	6.070
Operating viscosity	[v]	424.334 mm ² /s
Reference viscosity	[v _r]	14.150 mm ² /s
Viscosity ratio	[κ]	29.988
Contamination characteristic quantity	[e _c]	0.470
Life modification factor	[a _{SKF}]	4.360
Basic rating life	[L _{nrh}]	6930.00 h
SKF rating life	[L _{nmh}]	30200.00 h

SKF bearing module in KISSsoft

What will come in the future?

- Calculation of additional 'catalogue type' bearing performance results:
 - Friction & power loss, grease life / relubrication interval, static safety, minimum load, bearing frequencies, etc.
- Access to non-published bearing performance results:
 - Rating life for hybrid bearings (GBLM)
 - More detailed bearing contact results
- Calculation of bearing stiffness

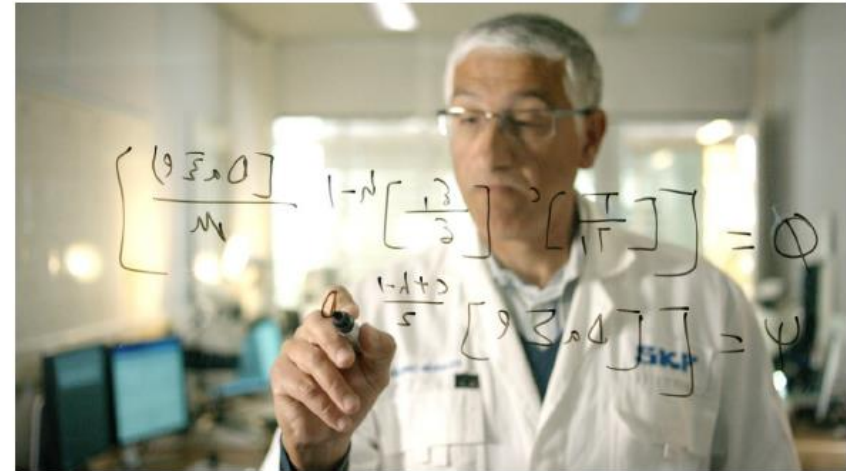


k_{11}	k_{12}	k_{13}	k_{14}	k_{15}	k_{16}
k_{21}	k_{22}	k_{23}	k_{24}	k_{25}	k_{26}
k_{31}	k_{32}	k_{33}	k_{34}	k_{35}	k_{36}
k_{41}	k_{42}	k_{43}	k_{44}	k_{45}	k_{46}
k_{51}	k_{52}	k_{53}	k_{54}	k_{55}	k_{56}
k_{61}	k_{62}	k_{63}	k_{64}	k_{65}	k_{66}

'Step by step you can get closer into the heart of the bearing supplier'



New life model for hybrid bearings (GBLM)



SKF

General benefits of hybrid bearings



Product features:

- Electrical insulation
- High wear resistance
- Performance under poor lubrication
- Low friction
- High speed capabilities
- Tolerant to vibration and oscillating applications
- Higher stiffness compared to equivalent all-steel bearings

User benefits:

- Extended service life in demanding application conditions
- Insulates and eliminates electric current damage
- Extended grease life
- Reduced maintenance cost
- Energy saving
- Environmentally friendly

Source: 14359 „Why SKF Hybrid bearings“

Hybrid bearings in current rating life models

INTERNATIONAL STANDARD **ISO 281**

Second edition
2007-02-15

Rolling bearings — Dynamic load ratings and rating life

Roulements — Charges dynamiques de base et durée nominale

1 Scope

This International Standard specifies methods of calculating the basic dynamic load rating of rolling bearings within the size ranges shown in the relevant ISO publications, manufactured from contemporary, commonly used, high quality hardened bearing steel, in accordance with good manufacturing practice and basically of conventional design as regards the shape of rolling contact surfaces.

This document also specifies methods of calculating the basic rating life, which is the life associated with 90 % reliability, with commonly used high quality material, good manufacturing quality and with conventional operating conditions. In addition, it specifies methods of calculating the modified rating life, in which various reliabilities, lubrication condition, contaminated lubricant and fatigue load of the bearing are taken into account.

This International Standard does not cover the influence of wear, corrosion and electrical erosion on bearing life.

This document is not applicable to designs where the rolling elements operate directly on a shaft or housing surface, unless that surface is equivalent in all respects to the bearing ring (or washer) raceway it replaces.

Double-row radial bearings and double-direction thrust bearings are, when referred to in this document, presumed to be symmetrical.

Further limitations concerning particular types of bearings are included in the relevant clauses.

C:\Users\S195362\AppData\Local\Temp\SNAGHTML1b24bed8.PNG

- ISO 281 is defined for „...commonly used, high quality hardened bearing steel...“
- Ceramic rolling elements? Hybrid bearings?

What's behind ISO 281 Life and Load ratings

Modified rating life

$$L_{nm} = a_1 a_{ISO} L_{10}$$

Reliability

Material
Lubricant regime
Contamination

Basic rating life

$$L_{10} = \left(\frac{C_r}{P_r} \right)^{10/3}$$

External load

Dynamic load rating C (for roller bearings)

$$C_r = b_m f_c (i L_{we} \cos \alpha)^{7/9} Z^{3/4} D_{we}^{29/27}$$

Material factor

Geometry

Life and dynamic load rating acc. to ISO 281 are mainly a function of:

- Material
- Lubricant
- Contamination
- Geometry

Limitations of current life models



What cannot yet be quantified in common life models

- **Features**
 - Material and heat treatment effects, carbonitriding, case carburization, induction, roughness and waviness of surfaces, coatings, etc.
- **Application conditions**
 - Shock loads, very high speeds, extreme temperatures, effect of grease, exotic lubricants, grease life, etc.
- **Failure modes**
 - Wear, micro-pitting, starvation, seizure, cage fatigue, electric current, etc.



Development of rating life models needed!

Concept of Generalized Bearing Life Model (GBLM)

- GBLM incorporates both **surface and sub-surface related failure modes**, but keeps them clearly separated.
- GBLM potential: more realistic quantification of
 - Product design features
 - Demanding application conditions
 - Other failure modes
- Additional output parameter: Relative Surface Fatigue (RSF)

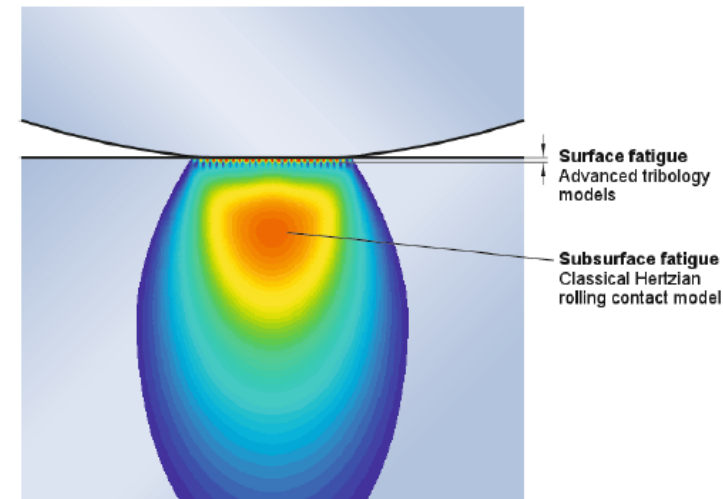
$$L_{nGM} = a_1 \left[\frac{1}{L_{n.surf}} + \frac{1}{L_{n.sub}} \right]^{-1/e}$$

L_{nGM} = SKF GM rating life (at 100 – n% reliability) [Mrev],

a_1 = life adjustment factor for reliability

$L_{n.surf}$ = SKF GM surface rating life (at 100 – n% reliability) [Mrev],

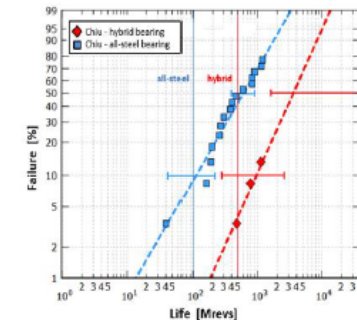
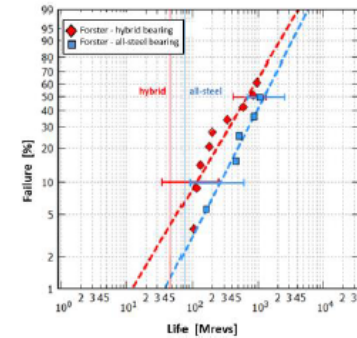
$L_{n.sub}$ = SKF GM subsurface rating life (at 100 – n% reliability) [Mrev],



Benefits of Generalized Bearing Life Model (GBLM)

- More realistic rating life calculation for hybrid bearings
- Separation of surface and subsurface effects on bearing life
- Easy to use in SKF software tools (Bearing Select, SimPro)
- Compatible with ISO 281: preselection of hybrid bearing based on ISO Basic Rating Life
- Compatible with new ISO 20056-1 and -2 (load ratings of hybrid bearings)
- Validated by endurance test data from external sources and SKF test rigs

Exclusively available through SKF bearing module in KISSsoft (work in progress)



Read more

A model for hybrid bearing life with surface and subsurface survival

<https://www.sciencedirect.com/science/article/abs/pii/S0043164818312894>

Benefits of Hybrid Bearings in severe conditions

<http://evolution.skf.com/benefits-of-hybrid-bearings-in-severe-conditions/>

The progression of surface rolling contact fatigue damage of rolling bearings

<http://evolution.skf.com/the-progression-of-surface-rolling-contact-fatigue-damage-of-rolling-bearings/>

A major step forward in life modelling

<http://evolution.skf.com/a-major-step-forward-in-life-modelling/>

A model for Rolling Bearing Life with Surface and Subsurface Survival – Tribological Effects

<https://www.tandfonline.com/doi/full/10.1080/10402004.2015.1025932>



TIMKEN cloud calculations

Further topics

Summary

- Lubrication can be defined for each bearing individually
 - Bearing friction calculation parameters can be defined for each bearing individually
 - All thermally safe operating speed parameters can be defined for each bearing separately
 - Temperature of outer ring, inner ring and rolling elements can be defined as own input
 - Added tolerance table data for axial/thrust bearings
 - Allow to consider tolerances for spherical roller thrust bearings
 - Use bearing pitch diameter D_{pw} for calculation of reference viscosity if available
 - Gear inner diameter added for better representation in 3D viewer / shaft editor
- ### COM Interface
- Added new method ``GetVarAsJson`` (experimental)
 - Added new method ``CallJsonFunc`` (experimental)



Bearing specific data

- Lubrication can be defined for each bearing individually
- Bearing friction calculation parameters can be defined for each bearing individually
- All thermally safe operating speed parameters can be defined for each bearing separately
- Temperature of outer ring, inner ring and rolling elements can be defined as own input
- Added tolerance table data for axial/thrust bearings

The image displays three overlapping screenshots of the 'Element Editor' window in KISSsoft, illustrating the configuration of bearing specific data for SKF 21308 E bearings. The background shows a 3D model of a shaft with bearings.

Top Screenshot: General and Lubrication Settings

- Position in global system: Y = 65.0000 mm
- Type of bearing: Fixed bearing adjusted on left side <-
- Type: Spherical roller bearings
- Number: SKF 21308 E (d=40.000 mm, D=90.000 mm, B=23.000 mm)*
- Comment: SKF Explorer - SKF Popular Item
- Inner diameter: d = 40.000 mm
- External diameter: D = 90.000 mm
- Nominal width: B = 23.000 mm
- Tab: Lubrication
- Lubricant: ISO-VG 220
- Lubricant temperature: T_B = 30.0000 °C
- Contamination: Oil lubrication with filtration, ISO 4406 -/17/14, β₂₅=75

Middle Screenshot: Thermally safe operating speed and Friction Settings

- Position in global system: Y = 65.0000 mm
- Type of bearing: Fixed bearing adjusted on left side <-
- Type: Spherical roller bearings
- Number: SKF 21308 E (d=40.000 mm, D=90.000 mm, B=23.000 mm)*
- Comment: SKF Explorer - SKF Popular Item
- Inner diameter: d = 40.000 mm
- External diameter: D = 90.000 mm
- Nominal width: B = 23.000 mm
- Tab: Thermally safe operating speed
- Enter values:
- Coefficient f₀: 0.0000
- Coefficient f₁: 0.0000
- Coefficient f₂: 0.0000
- Heat-transferring reference surface A_s: 0.0000 mm²
- Dynamic equivalent load P₁: 0.0000 N
- Average bearing temperature T_{em}: 70.0000 °C
- Temperature around the bearing T_a: 20.0000 °C
- Tab: Bearing friction
- Lubrication type: Oil bath lubrication - oil level to center of lowest rolling body

Bottom Screenshot: Oil Level and Friction Settings

- Position in global system: Y = 65.0000 mm
- Type of bearing: Fixed bearing adjusted on left side <-
- Type: Spherical roller bearings
- Number: SKF 21308 E (d=40.000 mm, D=90.000 mm, B=23.000 mm)*
- Comment: SKF Explorer - SKF Popular Item
- Inner diameter: d = 40.000 mm
- External diameter: D = 90.000 mm
- Nominal width: B = 23.000 mm
- Tab: Bearing friction
- Take oil level into account:
- Oil level: -30.0000 mm
- Lubrication: Oil bath lubrication

KISSsoft usage

Module specific settings

Flag 1: Bearing colored based on required life vs. calculated life.

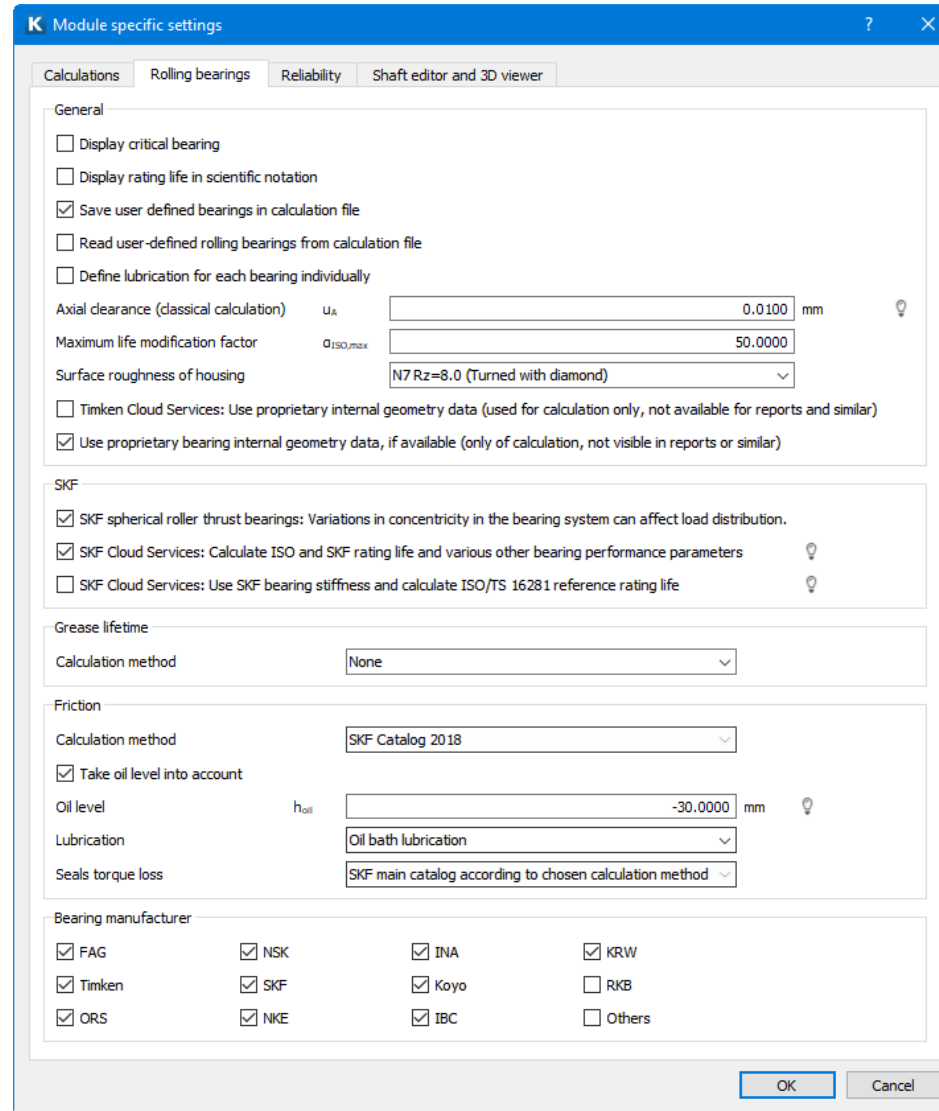
Flag 2: Change life value to scientific notation.

Flag 3: Bearing data defined by the user is saved in the file, not in the database. This ensures that when sending the file by email (without sending the bearing database), all bearing data is transmitted as well. Typically, keep this flag activated.

Flag 4: If active and if file contains user defined bearing data, then, bearing data as in the file is used. If not active and if file contains user defined bearing data (e.g., in data set 20'001), then, data in data set 20'001 in database is used.

Flag 5: By default, lubrication data is defined for the whole shaft model, for all bearings. But lubrication may also be defined per bearing differently.

Input 6: Axial clearance if bearing is not calculated along ISO/TS 16281



Module specific settings

Input 7: Define upper limit (maximum value is 50 as per ISO/TS 16281) for a_{ISO} factor used in calculations.

Input 8: Define surface of housing where bearing outer ring touches, to determine the amount of embedding, influencing the operating clearance.

Flag 9: Run calculation through TIMKEN cloud solution. Note that bearing inner geometry used by TIMKEN will not be shown.

Flag 10:

Flag 11...13: see section on SKF cloud solution.

Input 14: Calculation method for grease ageing calculation.

Input 15: Calculation method for bearing power loss.

Flag 16: Consider oil level for bearing churning losses calculation.

Input 17: Enter oil level for whole model (may also be defined separately for each bearing)

K Module specific settings

Calculations Rolling bearings Reliability Shaft editor and 3D viewer

General

- Display critical bearing
- Display rating life in scientific notation
- Save user defined bearings in calculation file
- Read user-defined rolling bearings from calculation file
- Define lubrication for each bearing individually

Axial clearance (classical calculation) u_A mm

Maximum life modification factor $a_{ISO,max}$

Surface roughness of housing

- Timken Cloud Services: Use proprietary internal geometry data (used for calculation only, not available for reports and similar)
- Use proprietary bearing internal geometry data, if available (only of calculation, not visible in reports or similar)

SKF

- SKF spherical roller thrust bearings: Variations in concentricity in the bearing system can affect load distribution.
- SKF Cloud Services: Calculate ISO and SKF rating life and various other bearing performance parameters
- SKF Cloud Services: Use SKF bearing stiffness and calculate ISO/TS 16281 reference rating life

Grease lifetime

Calculation method

Friction

Calculation method

- Take oil level into account

Oil level h_{oil} mm

Lubrication

Seals torque loss

Bearing manufacturer

<input checked="" type="checkbox"/> FAG	<input checked="" type="checkbox"/> NSK	<input checked="" type="checkbox"/> INA	<input checked="" type="checkbox"/> KRW
<input checked="" type="checkbox"/> Timken	<input checked="" type="checkbox"/> SKF	<input checked="" type="checkbox"/> Koyo	<input type="checkbox"/> RKB
<input checked="" type="checkbox"/> ORS	<input checked="" type="checkbox"/> NKE	<input checked="" type="checkbox"/> IBC	<input type="checkbox"/> Others

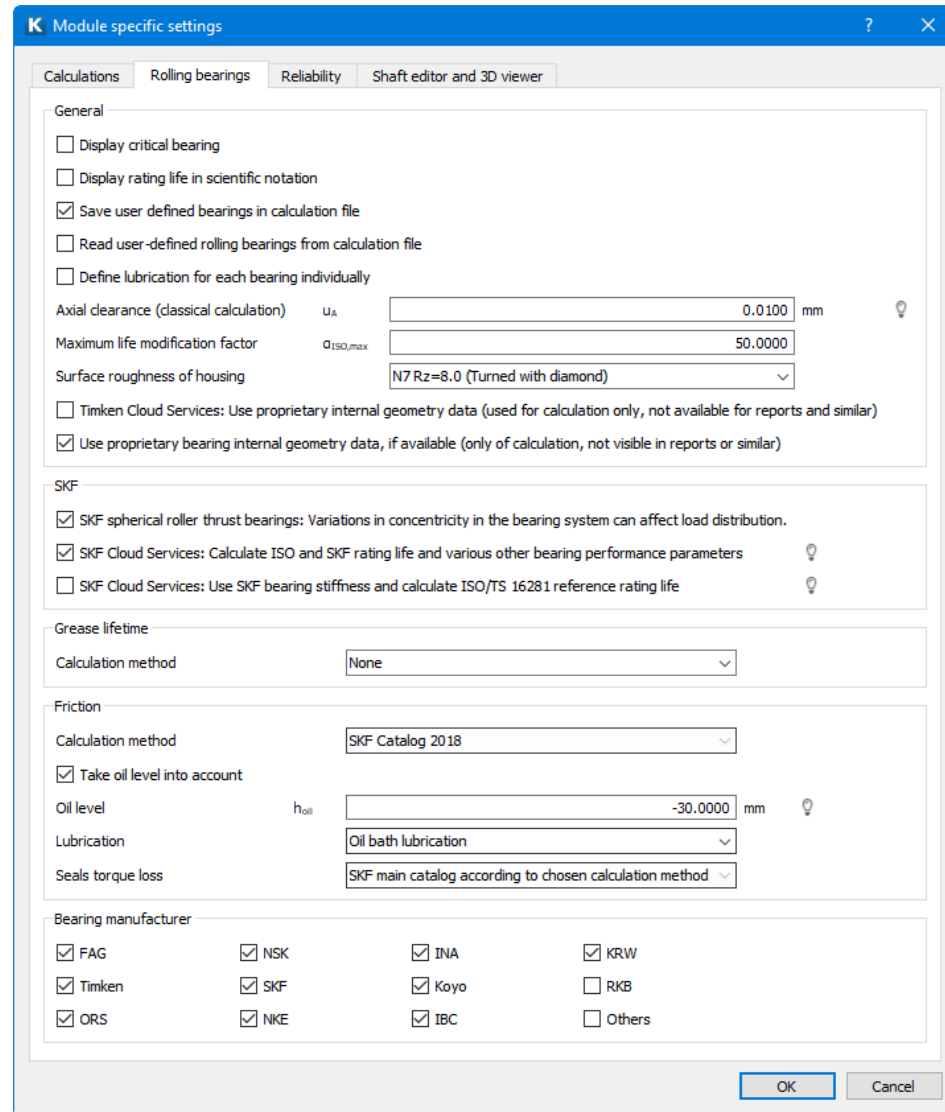
OK Cancel

Module specific settings

Input 18: Define type of lubrication, used for power loss calculation only.

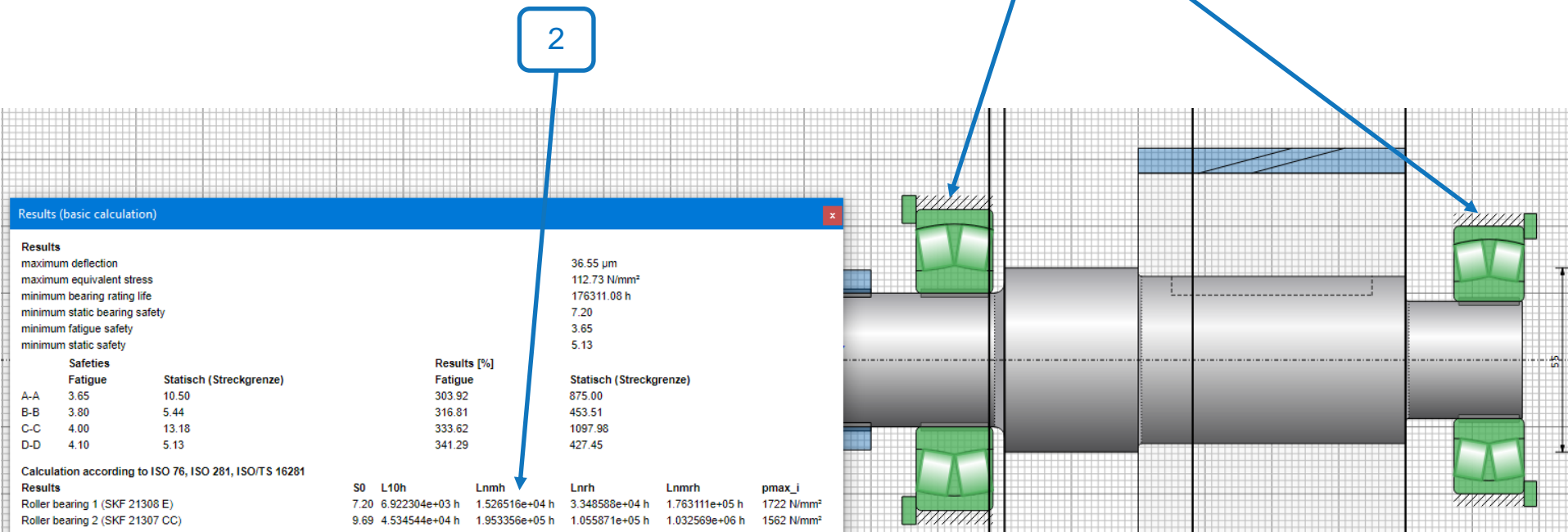
Input 19: Define calculation method for bearing seal friction calculation.

Flag(s) 20: Filter bearings available in shaft editor. Active flag means that bearing form this supplier may be selected in shaft editor. Note: If user defines his own bearings in bearing database, assigning his own names, then, activate flag for “Others”.



Display

- 1) Bearings are colored depending on the lifetime achieved (compared to the required lifetime).
- 2) Bearing lifetime is written in scientific notations



Define lubrication for each bearing individually

- 1) By default, lubrication is defined in tab “Basic data” for the whole shaft – bearing model.
- 2) Lubrication data can also be given for each bearing individually.

1

Modified rating life according ISO 281

Lubricant ISO-VG 220 +

Lubricant temperature T_{B} 30.0000 °C

Contamination Oil lubrication with filtration, ISO 4406 -/17/14, $\beta_{25}=75$

1

The screenshot shows the 'Element Editor' window for a roller bearing. The 'Basic data' tab is active, showing the following parameters:

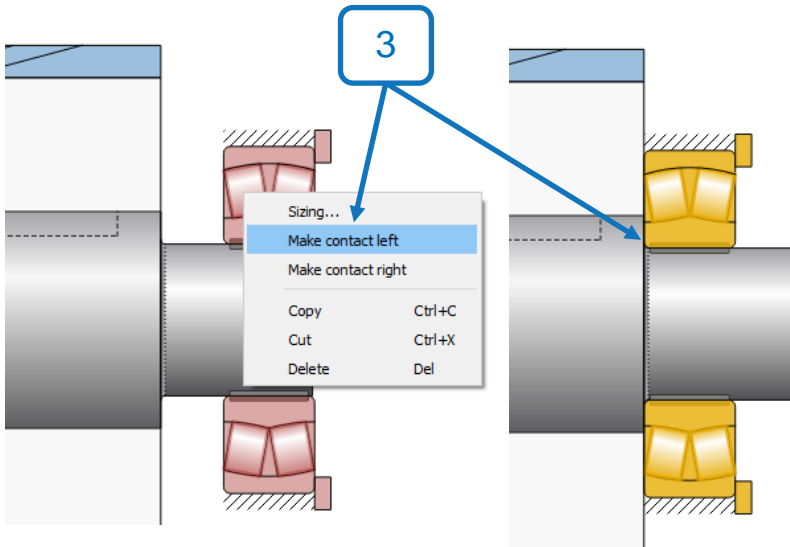
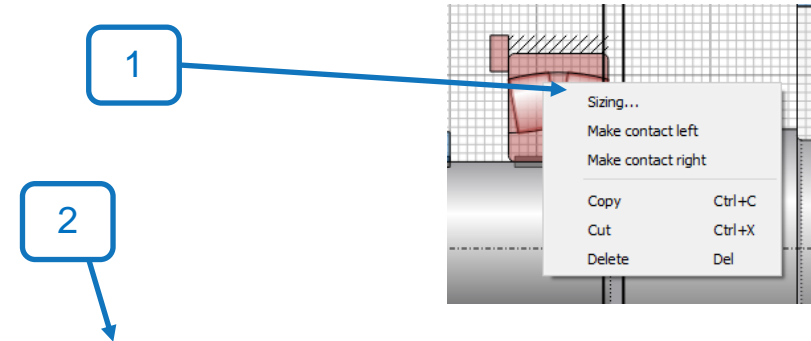
- Designation: Roller bearing 1
- Position on shaft: Y 65.0000 mm
- Position in global system: Y 65.0000 mm
- Type of bearing: Fixed bearing adjusted on left side <-
- Type: Spherical roller bearings
- Number: SKF 21308 E (d=40.000 mm, D=90.000 mm, B=23.000 mm)*
- Comment: SKF Explorer - SKF Popular Item
- Inner diameter: d 40.000 mm
- External diameter: D 90.000 mm
- Nominal width: B 23.000 mm

The 'Lubrication and supplementary calculations' tab is also visible, showing the following settings:

- Lubrication: Oil: ISO-VG 220 +
- Lubricant temperature: T_{B} 30.0000 °C
- Contamination: Oil lubrication with filtration, ISO 4406 -/17/14, $\beta_{25}=75$
- Thermally safe operating speed: Enter values
- Coefficient: f_{Dr} 0.0000
- Coefficient: f_{I} 0.0000
- Coefficient: f_{Dr} 0.0000
- Heat-transferring reference surface: A_{R} 0.0000 mm²
- Dynamic equivalent load: P_1 0.0000 N
- Average bearing temperature: T_{m} 70.0000 °C
- Temperature around the bearing: T_{O} 20.0000 °C
- Lubrication type: Oil bath lubrication - oil level to center of lowest rolling body
- Bearing friction: Take oil level into account
- Oil level: -30.0000 mm
- Lubrication: Oil bath lubrication

Context menu

- 1) Proposal for suitable bearing size
- 2) All bearings from database having same diameter and same type are calculated and results are listed. User may select e.g. low cost bearing meeting requirements.
- 3) Bearing is moved to next feature or contour or bearing on left or right side.



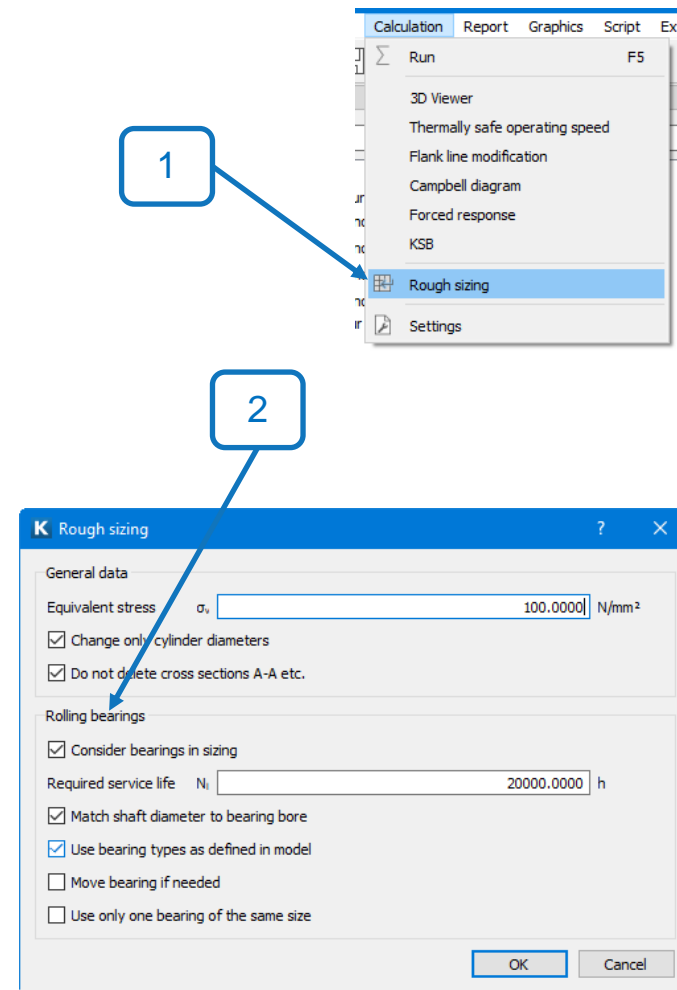
K Sizing of rolling bearing

Type	Comment	Note	L _{inh} [h]	L _{nmh} [h]	S0	Dimensions
SKF BS2-2208-2RS/VT143	SKF Explorer	SKF Pop...	7776.2	14244.6	6.4200	40/ 80* 28.00
SKF 22308 EK	SKF Explorer	SKF Pop...	70360.9	4.1e+05	11.9200	40/ 90* 33.00
SKF 22308 E/VA405	SKF Explorer	SKF Pop...	70360.9	4.1e+05	11.9200	40/ 90* 33.00
SKF 22308 E	SKF Explorer	SKF Pop...	70360.9	4.1e+05	11.9200	40/ 90* 33.00
SKF 22208 EK	SKF Explorer	SKF Pop...	7776.2	14244.6	6.4200	40/ 80* 23.00
SKF 22208 E	SKF Explorer	SKF Pop...	7776.2	14244.6	6.4200	40/ 80* 23.00
SKF 21308 EK	SKF Explorer	SKF Pop...	6922.3	15265.2	7.2000	40/ 90* 23.00
SKF 21308 E	SKF Explorer	SKF Pop...	6922.3	15265.2	7.2000	40/ 90* 23.00
RKB 22308			67379.9	4.0e+05	11.9200	40/ 90* 33.00
RKB 22208			7439.4	13250.5	6.4400	40/ 80* 23.00
RKB 21308			7363.1	16237.2	7.2000	40/ 90* 23.00
KOYO 22308RZ			94115.2	3.5e+05	12.9800	40/ 90* 33.00
KOYO 22208RZ			13291.5	23979.7	7.5900	40/ 80* 23.00
KOYO 21308RZ			8399.3	11323.0	6.8100	40/ 90* 23.00
FAG WS22308-E1-XL-2RSR...	X-life		67751.7	3.1e+05	12.6200	40/ 90* 38.00
FAG WS22308-E1-XL-2RSR	X-life		67751.7	3.1e+05	12.6200	40/ 90* 38.00
FAG WS22208-E1-XL-K-2RS...	X-life		7839.4	18838.4	6.5900	40/ 80* 28.00
FAG WS22208-E1-XL-K-2RSR	X-life		7839.4	18838.4	6.5900	40/ 80* 28.00
FAG WS22208-E1-XL-2RSR...	X-life		7839.4	18838.4	6.5900	40/ 80* 28.00
FAG WS22208-E1-XL-2RSR...	X-life		7839.4	18838.4	6.5900	40/ 80* 28.00
FAG WS22208-E1-XL-2RSR	X-life		7839.4	18838.4	6.5900	40/ 80* 28.00
FAG 22308-E1-XL-T41A	X-life		67751.7	3.1e+05	12.6200	40/ 90* 33.00

OK Cancel

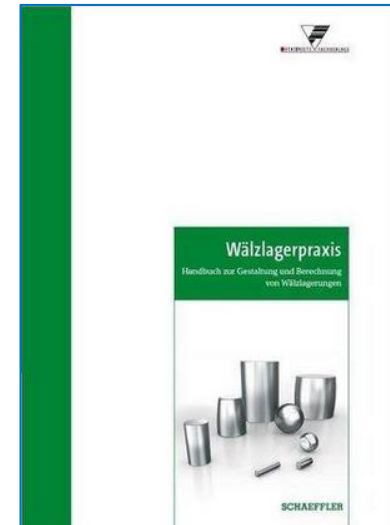
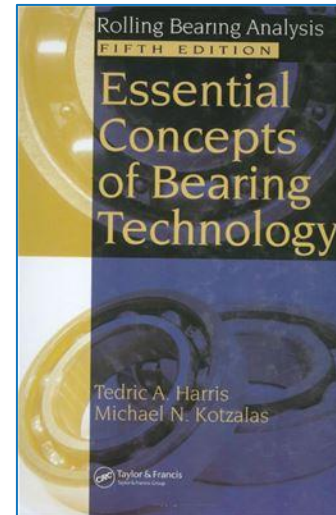
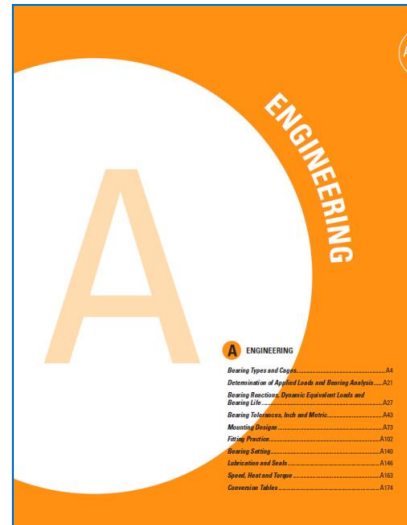
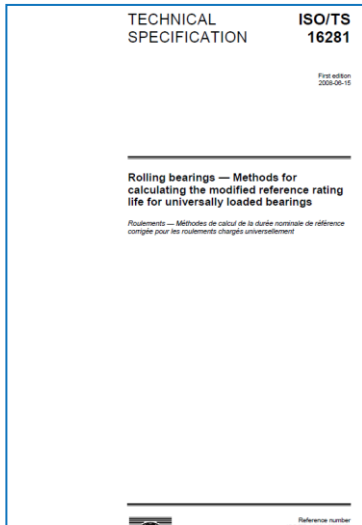
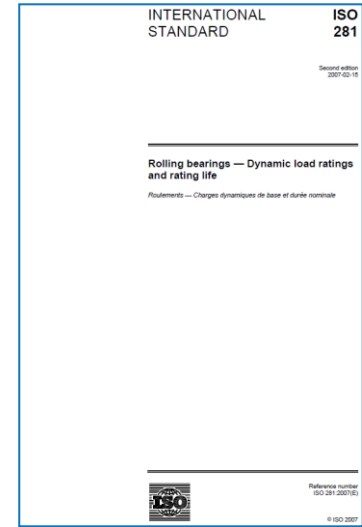
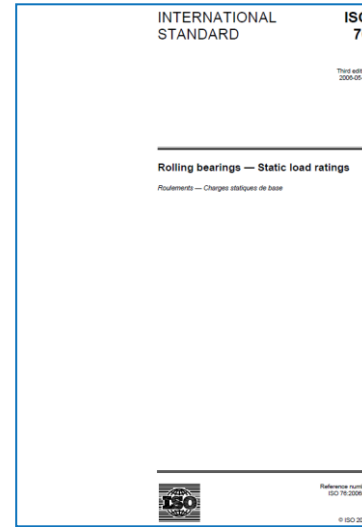
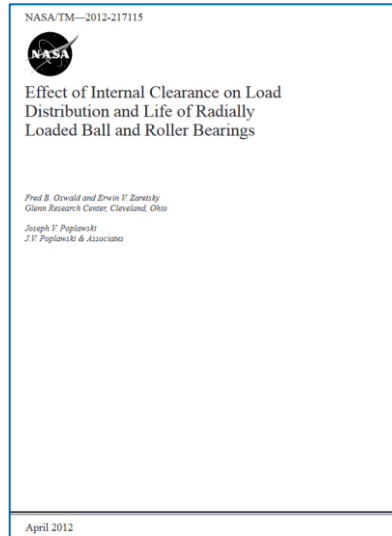
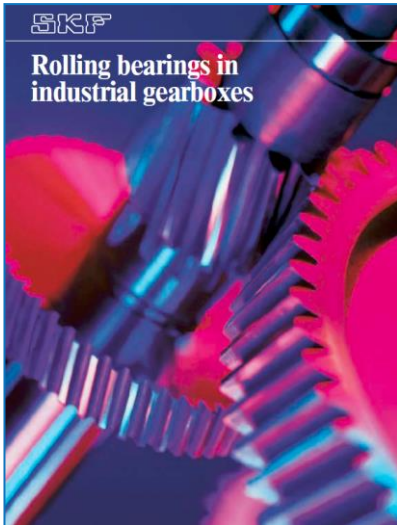
Shaft rough sizing including bearing rough sizing

- 1) Select shaft rough sizing in menu “Calculation”
- 2) Settings for bearing sizing are in group “Rolling bearings”
 - Consider bearings in sizing: If this option is selected, rolling bearings are sized according to their required service life.
 - Enter required bearing service life.
 - Match shaft diameter to bearing bore: If this option is selected, KISSsoft adjusts the cylinder diameter to match the bearing's internal diameter.
 - Take bearing type from model: If this option is selected, existing bearings are retained. Otherwise, you can replace the bearings in the model with a specific bearing type as required.
 - Move bearing if needed: When a bearing is being sized, it may happen that a larger, wider bearing is selected, and this covers the neighboring cylinder. If this option is selected, the bearing is moved so that it does not interfere with neighboring the cylinders.
 - Use only one bearing of the same size: Not all bearings in the database (having same dimensions) are calculated, but only one (the first in the list). This accelerates the sizing process.



Selected references

Selected references



Selected references

FAG

The Design of Rolling Bearing Mountings

Design Examples covering Machines, Vehicles and Equipment

SCHAEFFLER

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Lubrication of Rolling Bearings

Principles
Lubrication methods
Lubricant selection and testing
Storage and handling

Wälzlager

Kugellager
Rollenlager
Nadellager
Lauffrollen
Lager für Gewindetriebe
Spannlager/Gehäuseeinheiten
Lagergehäuse
Zubehör

SCHAEFFLER GRUPPE

SKF Product information 401

Bearing failures and their causes

A Study on the Smearing and Slip Behaviour of Radial Cylindrical Roller Bearings

Dr. Bruno Johannes Scherb
INA WÄLZLAGER SCHAEFFLER OHG

Prof. Dr. Jürgen Zech
Georg-Simon-Ohm-Fachhochschule Nürnberg

Abstract

Knowledge of the features and qualities of a machine element are essential foundations for its successful operation. High grade materials, more accurate calculation methods and modern manufacturing processes lead to continuous design and performance improvements and hence increased power within minimised spatial requirements. INA cylindrical roller bearings, series SL 1923, 251, 1923, and LSL 1923, follow this trend and due to their high performance characteristics and low physical volume they have obtained a firm place as high performance machine elements.

Essential characteristics of radial cylindrical roller bearings are their behaviour regarding kinematics, noise, vibration, dynamic frictional torque, cage speed, speed of a rolling element, slip etc. The paper gives details of the kinematic behaviour concerning the relationship between the roller set speed and the cage speed and the speed of a rolling element in connection with the occurrence of smearing.

This kind of damage occurs during the running in stage of a machine and is becoming very important because of the enormous costs which are caused by down time and lost production.

Keywords: cylindrical roller bearing, smearing, slip

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On the Use of Rolling Element Bearings' Models in Precision Maintenance

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Abstract: Problem statement: Rolling element bearings form a very important part of machinery. The increasing demands on their continuous reliable operation under diverse environments make maintenance a very important step towards the efficient use of them. To fulfil such precision maintenance is a very useful practice, since it deals not only with finding a possible fault of a machine, but also with the identification of its cause and the suggestion of possible preventive measures and corrective actions. In order to better apply precision maintenance techniques though, it is necessary to have a very good insight of the bearings' operation. Approach: This study described how the analytical models of the operation of rolling element bearings could be used for the better utilization of precision maintenance in practice. It also presented briefly these analytical models, together with a detailed description of how their results can be used in precision maintenance practice. Results: The results of a typical example were given, which showed that the proposed analysis gives an insight of the bearing operation, necessary for the better understanding of the root cause of possible failures. Conclusion: This research came to the conclusion that the knowledge of the origin of failures that could be the result of bearing's theoretical models, could be very helpful for the application of precision maintenance practices, since it could lead to the correction of the cause of each failure and thus the bearing will not fail again for the same reason.

Key words: Rolling element bearings, precision maintenance, computer models

INTRODUCTION

The development of analytical models of the operation of rolling element bearings, including loads, stresses and speeds, has been the subject of research of engineers since many years and these efforts a big number of very good scientific documents on this subject, e.g. [1].

These models have been used extensively during the initial design stages of new bearings or in demanding applications. Nevertheless, their use is still far from the better application of precision maintenance practice has not been studied in detail. Apart from that, the interconnections between the working parameters calculated by these models, although apparent and with great importance, have not been examined as much as expected, at least not in published literature or in a form a practitioners would appreciate. On the other hand, there are some very analytic investigations of models of rolling element bearings, which try to describe the phenomena up to a very big detail [2]. In such cases, although the accuracy achieved is very good, the complexity of the models is such that they cannot be easily applied in everyday maintenance practice.

Since there are many combinations of bearing types and loading conditions, it would not be practical to try and cover all of them in this paper. We decided then to include only one of the most representative cases that can give an idea of the method we describe applied in everyday maintenance practice.

The selected configuration is a radial ball bearing under

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LIFE-LIMITING WEAR OF WIND TURBINE GEARBOX BEARINGS: ORIGINS AND SOLUTIONS

G. L. Duff, M. N. Kotzalas, and F. S. King, The Timken Company, Canton, OH, USA

Summary

Microspitting and smearing are life-limiting wear modes of critical bearing positions in wind turbine gearboxes. These wear modes are caused by roller-to-roller sliding in thin lubricant conditions. Whereas bearings experiencing low load conditions at high speeds and rapid accelerations are more at risk of smearing, bearings operating for extended periods of time at low loads, slower speeds, and low boundary layer lubrication are more at risk of microspitting. Black oxide surface treatments may delay the onset but will not eliminate the risk of microspitting. Black oxide surface treatments provide no protection against smearing. On the other hand, more hydrologically advanced surface treatments applied to the rolling elements of bearings eliminate microspitting and greatly reduce the risk of smearing. Additionally, bearings with advanced engineered surfaces are about ten times more resistant to damage from lubricant starvation, have more than a 3.5 times greater load-carrying fatigue life, have about 10% less frictional torque, and are twice as resistant to damage from gearbox droplets than bearings with untreated rollers.

Background

Wind turbine gearboxes have yet to achieve their design life goals of twenty years, with most systems requiring significant repair or overhaul well before that interval is reached [1,2]. According to Muehl et al. [3], the majority of wind turbine gearbox failures appear to originate in the bearings. A general schematic of a wind turbine gearbox from Ref. 4 is shown in Fig. 1 with bearing locations identified for those exhibiting significant amounts of application failure. These three critical bearing locations are (1) the planet bearings, (2) the intermediate shaft bearings, and (3) the high speed shaft bearings.

Analysis of gearbox field failures indicates that these critical gearbox bearings are not exhibiting their full service life. In fact, inclusion related fatigue life on which bearing life is calculated, but microspitting and smearing wear. When lubricant microspitting and smearing occur on rolling element bearings, excessive sliding breaks away from the surface bearing film, compromising its protective effect of this type of wear is referred to as microspitting or gray staining. Microspitting is a micro-fatigue wear process driven by large cyclic shear stresses arising from moderate amounts of roller-to-roller sliding. Since it is a wear process involving micro crack initiation and propagation, thousands of hours of operation may be required to generate a noticeable microspitting wear on rolling element bearings.

Figure 1: Schematic of wind turbine gearbox showing bearing positions that have experienced an inordinate amount of application failure from Muehl et al.

Figure 2: In rolling element bearings, large amounts of roller-to-roller sliding can generate local temperatures in the contact zone high enough to melt the steel surfaces of the rolling elements and rollers. The large-scale plasticity and oxidation that follows generates a embrittled appearance on the respective surfaces. Fatigue cracks form in the embrittled wear paths which indicate that the local temperature in the contact zone exceeded ~500 °C. Smearing is known to occur in lightly loaded gear bearings and in bearings subjected to high accelerations or rapid speed changes, conditions that are not uncommon in wind turbine gearboxes. Smearing is usually a sudden occurrence an opposed to an accumulated wear process. Of the three critical bearing locations in wind turbine gearboxes, the high speed bearing location in Fig. 1 has the greatest risk of smearing.

Moderate amounts of sliding between rollers and ring segments can generate considerable shear stresses in the contact zone. From the viewpoint of an element of steel on the wind turbine cyclic shear stresses imparted by each passing roller will generate micro-cracks which propagate in the direction of the sliding. As these micro-cracks propagate, pieces of the respective bearing to break away from the surface bearing film, compromising its protective effect of this type of wear is referred to as microspitting or gray staining. Microspitting is a micro-fatigue wear process driven by large cyclic shear stresses arising from moderate amounts of roller-to-roller sliding. Since it is a wear process involving micro crack initiation and propagation, thousands of hours of operation may be required to generate a noticeable microspitting wear on rolling element bearings.

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Page 1 of 8

Keywords: microspitting, smearing, roller-to-roller sliding, wind turbine gearbox, bearing failure, life-limiting wear, rolling element bearings.

NASA Reference Publication 1105

June 1983

Rolling-Element Bearings

Bernard J. Hamrock and William J. Anderson

NASA

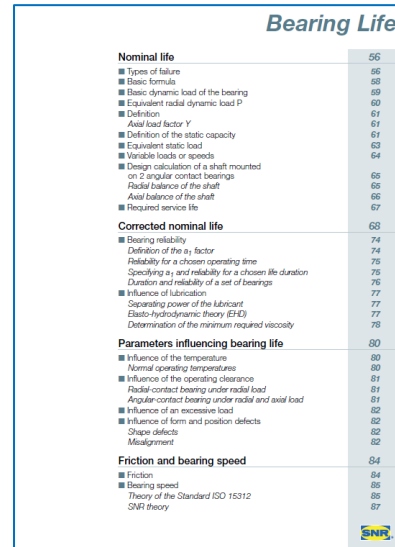
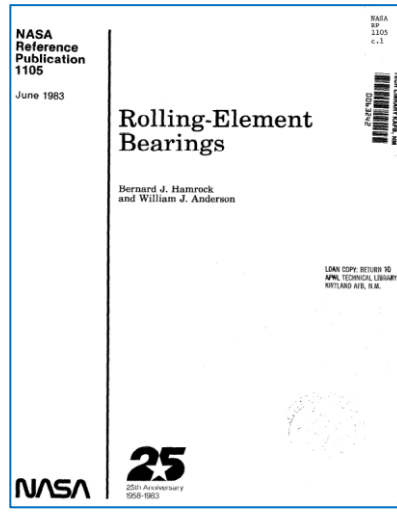
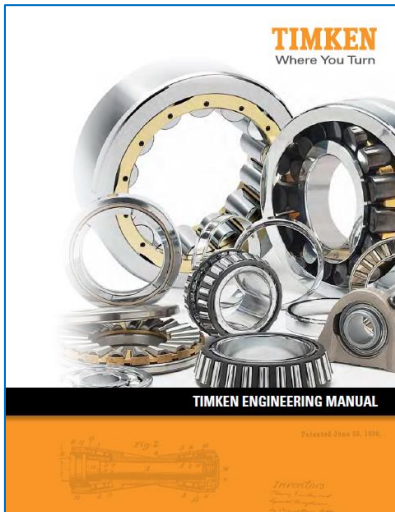
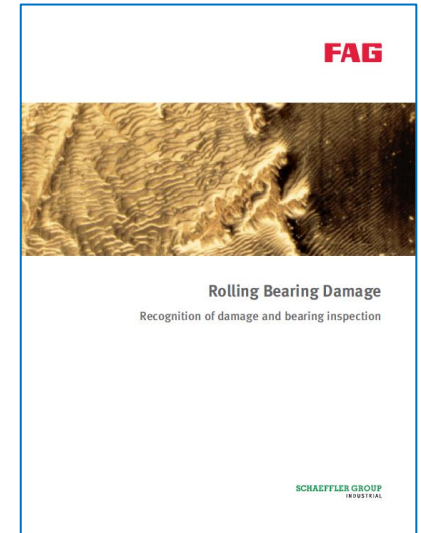
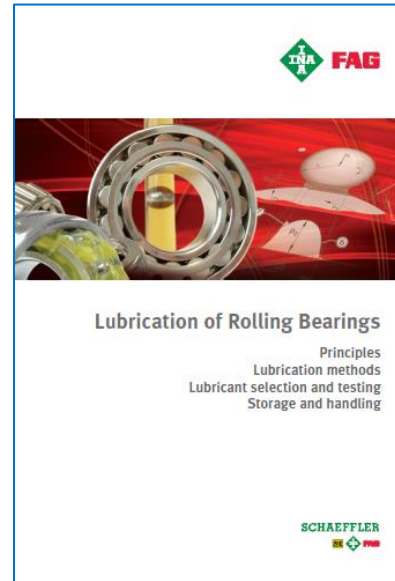
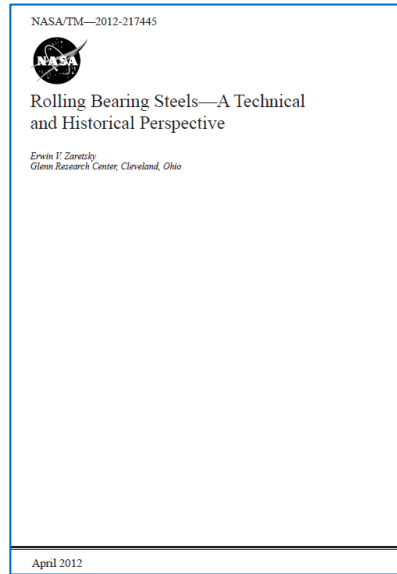
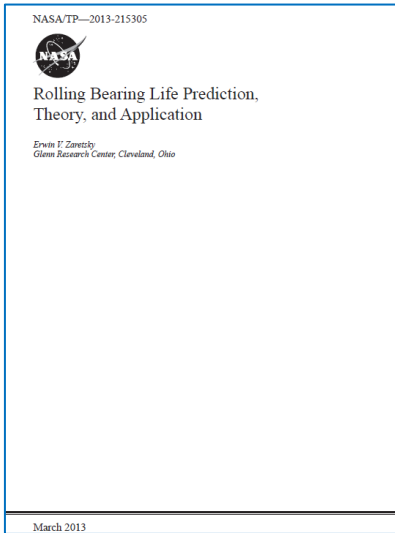
25th Anniversary 1958-1983

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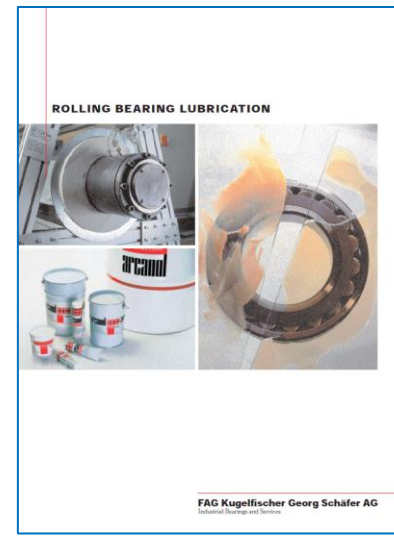
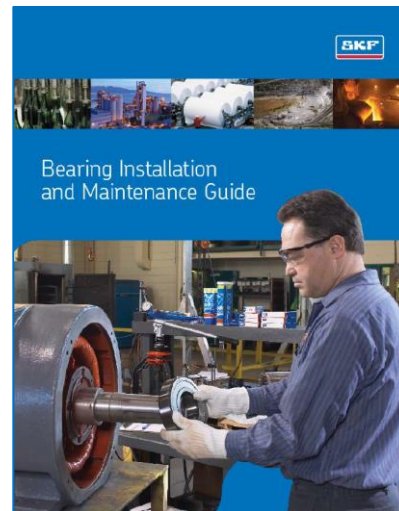
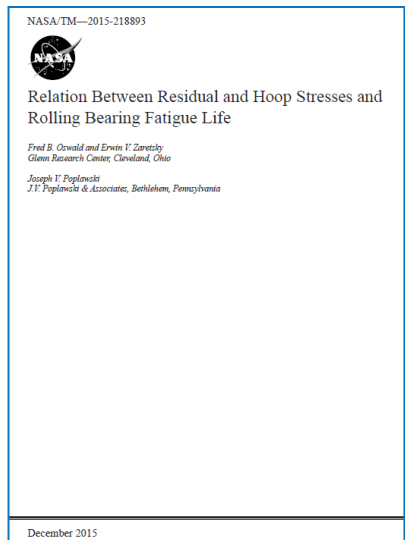
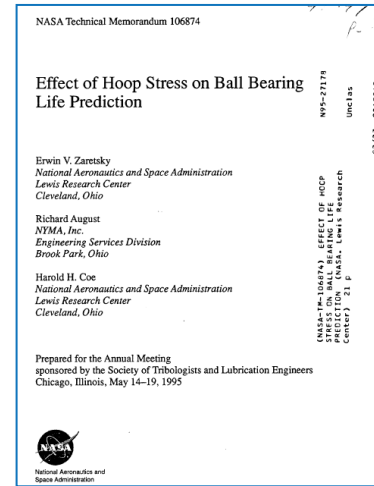
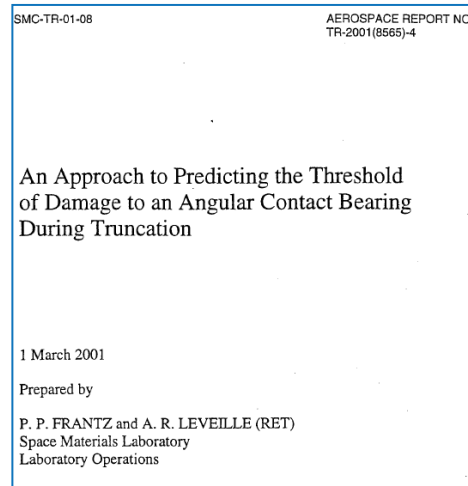
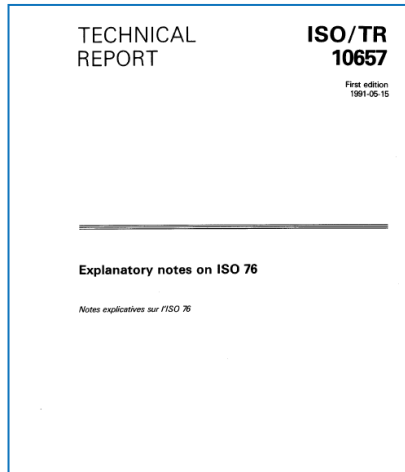
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Thank you for your attention!

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