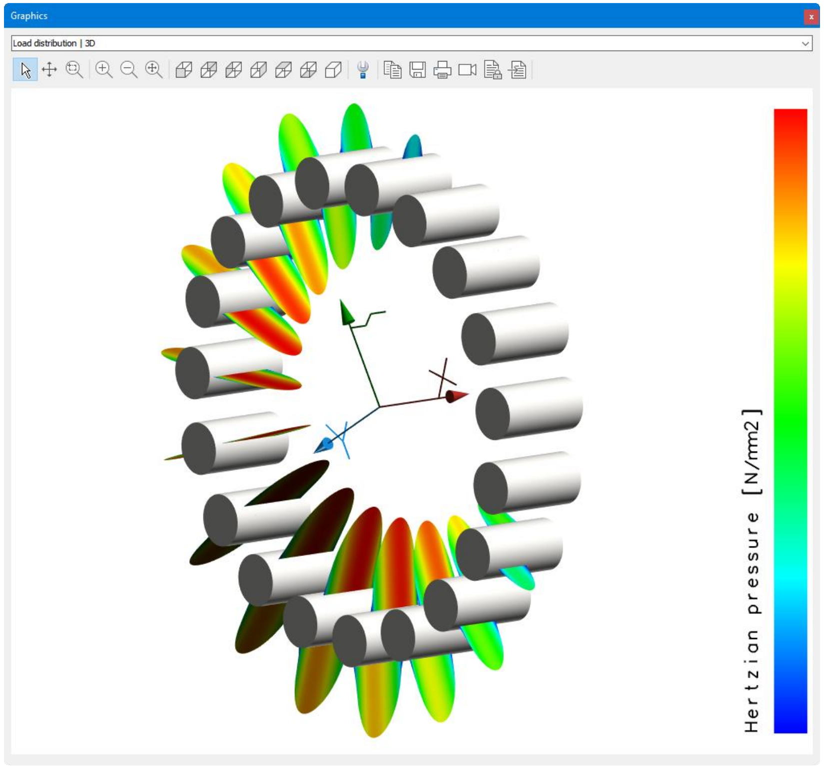
Bearing calculations in KISSsoft



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-KISSSOFT\00-09-USE\02-THEORY\71-ROLLBRG\Theory-Rollbrg-00-Part_1_concpets_theory_terminology-en-v2201-hd-draft.pptx"

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Content

Content

Bearing database

Bearing database

Database tool

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

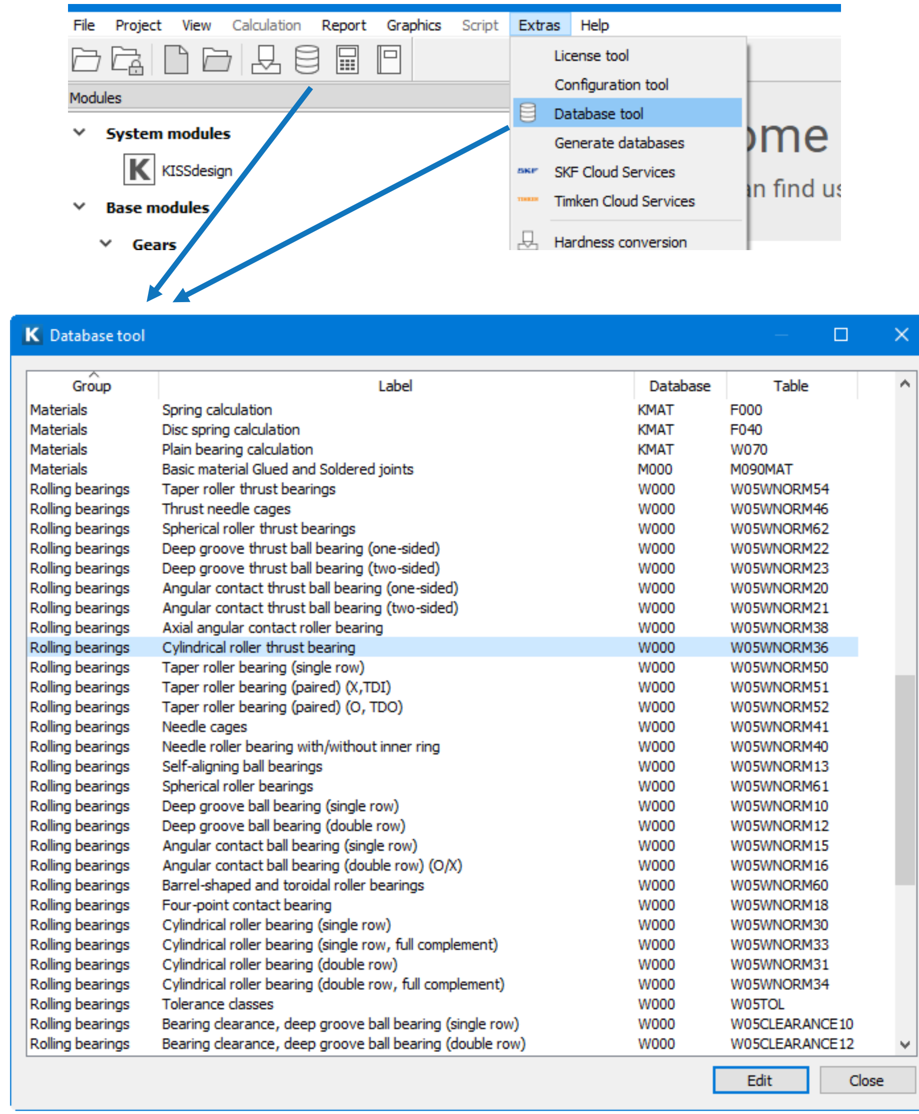
Contains catalogue data from supplied by e.g., SKF, Timken, Schaeffler, RKB, Koyo, …

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



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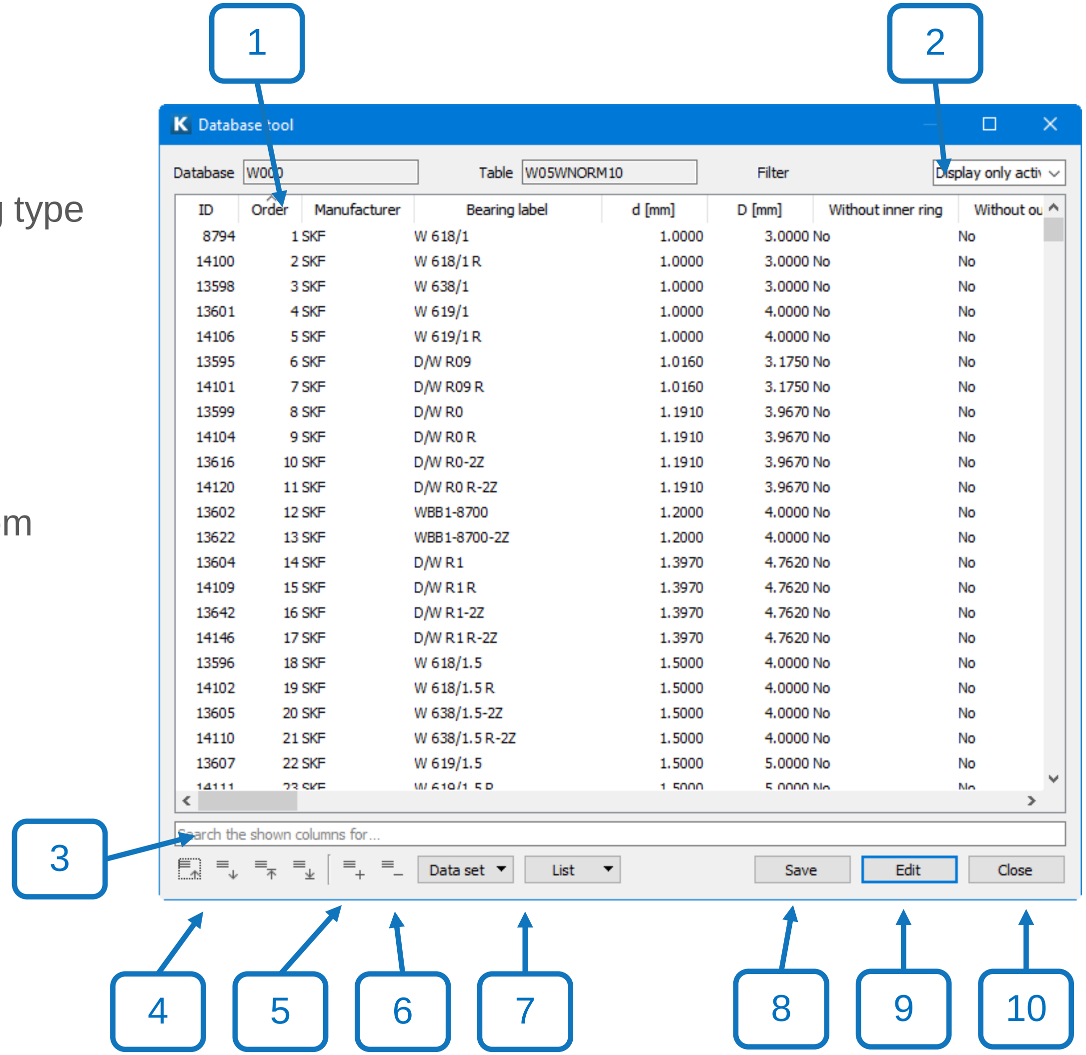
Database

Each database lists bearing data per bearing type

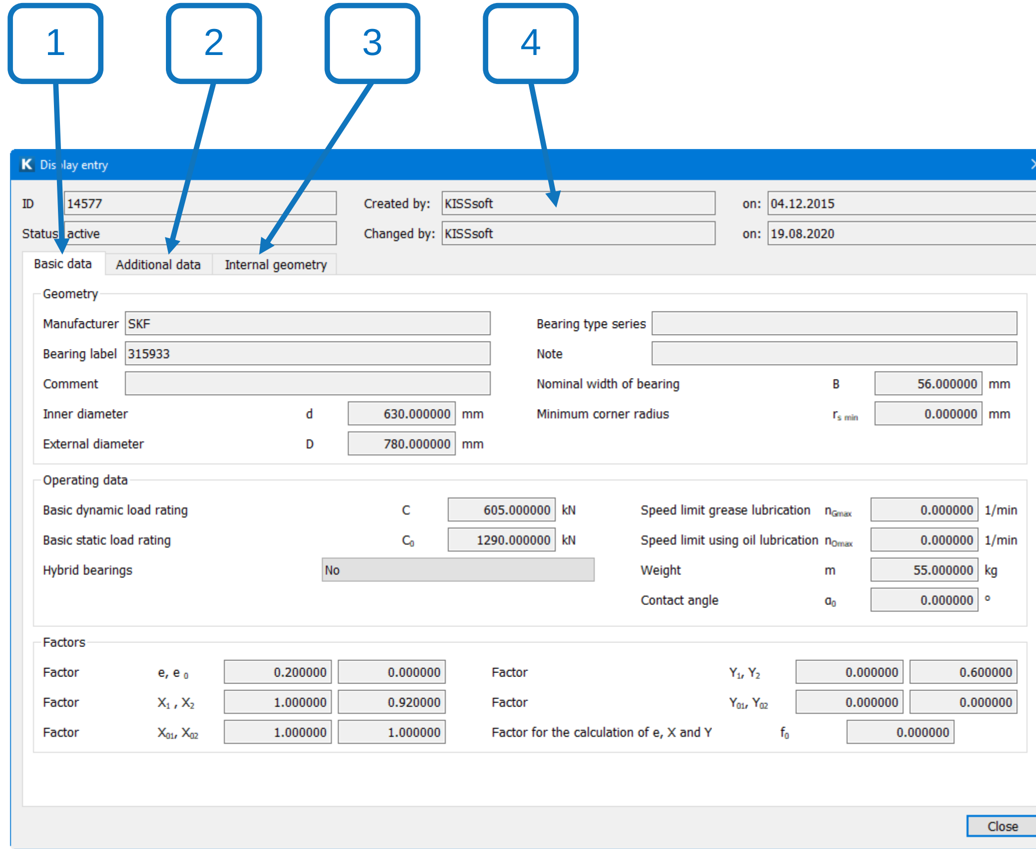
1) Move column / order ascending / order descending
2) Show / hide hidden data sets
3) Search database
4) Move items up / to top or down / to bottom
5) Add new item
6) Hide item
7) Export / import data set / lists
8) Save database
9) Edit selected dataset
10) Close database



Dataset

Each dataset contains three tabs of data

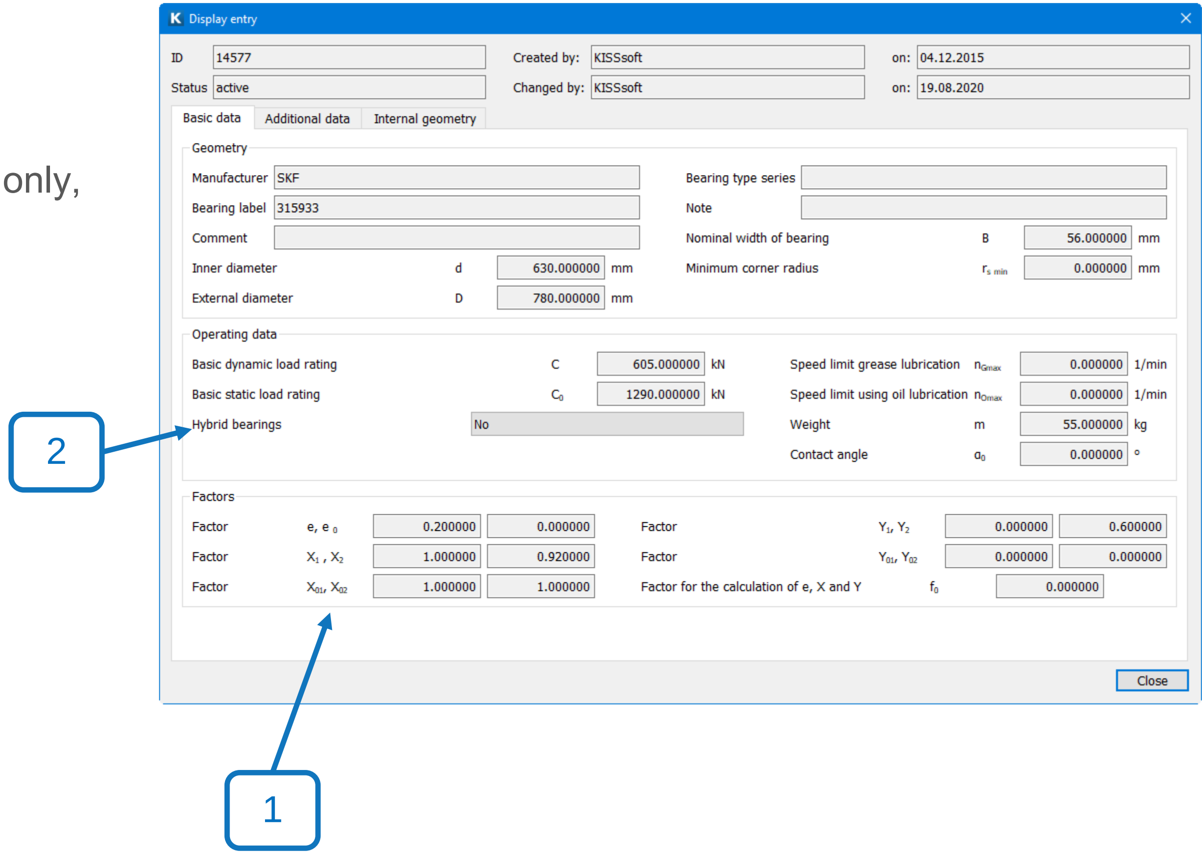
1) Basic data, catalogue data
2) Additional data
3) Inner geometry data
4) Status information



Dataset

Tab “Basic data”

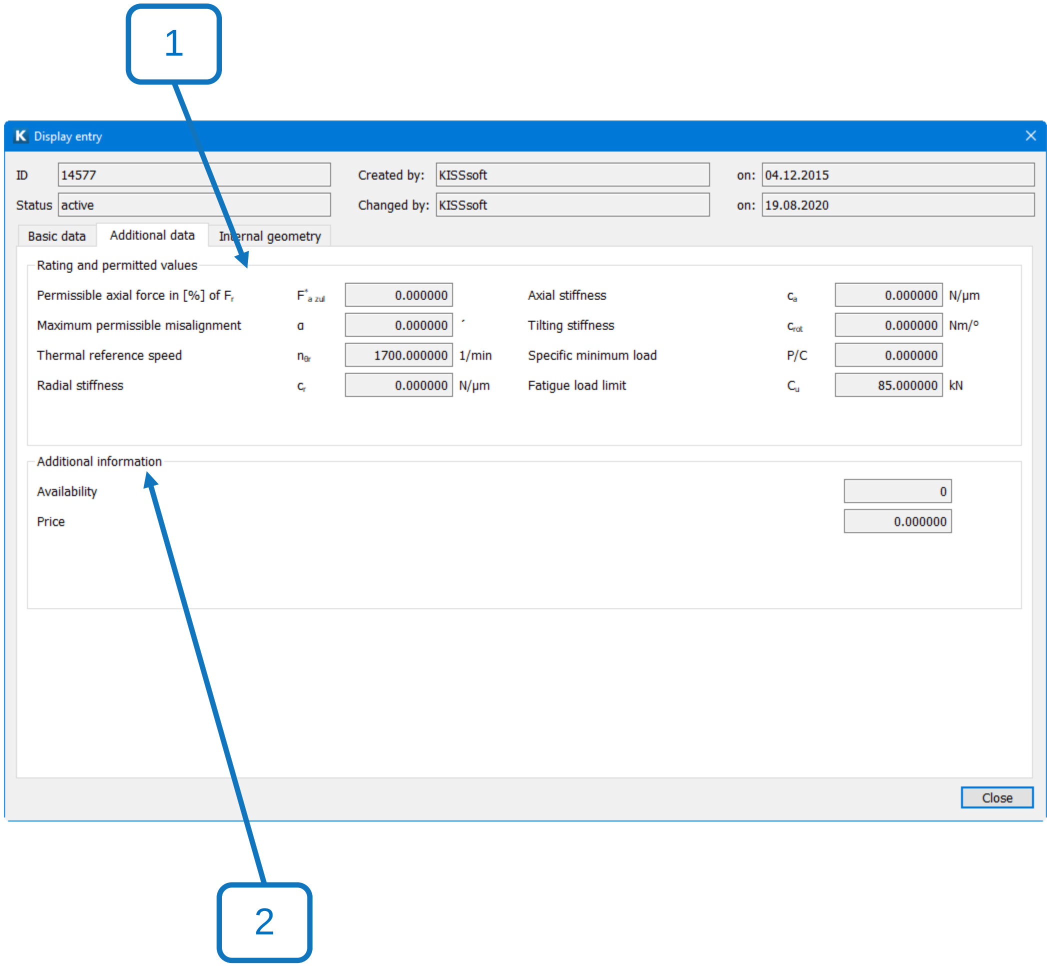
1) Load ratings, X, Y factors, …
2) “Hybrid bearings”: for information only, does not affect any results



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.



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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 calculated modified rating life. If C_u is not in the database, it is calculated.

- For modified basing 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	[ν]	425.092	mm²/s
Reference viscosity	[ν_1]	19.117	mm²/s
Viscosity ratio	[κ]	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_{pw}]	60.000	mm
Diameter of inner ring	[d_i]	48.334	mm
Diameter of outer ring	[d_o]	71.666	mm
Radius of curvature inner ring	[r_i]	6.063	mm
Radius of curvature outer ring	[r_o]	6.180	mm
Nominal contact angle	[α]	0.000	°
Initial contact angle	[α_0]	8.564	°
Dynamic load rating	[C_r]	29.100	kN
Fatigue load limit	[C_u]	0.873	kN

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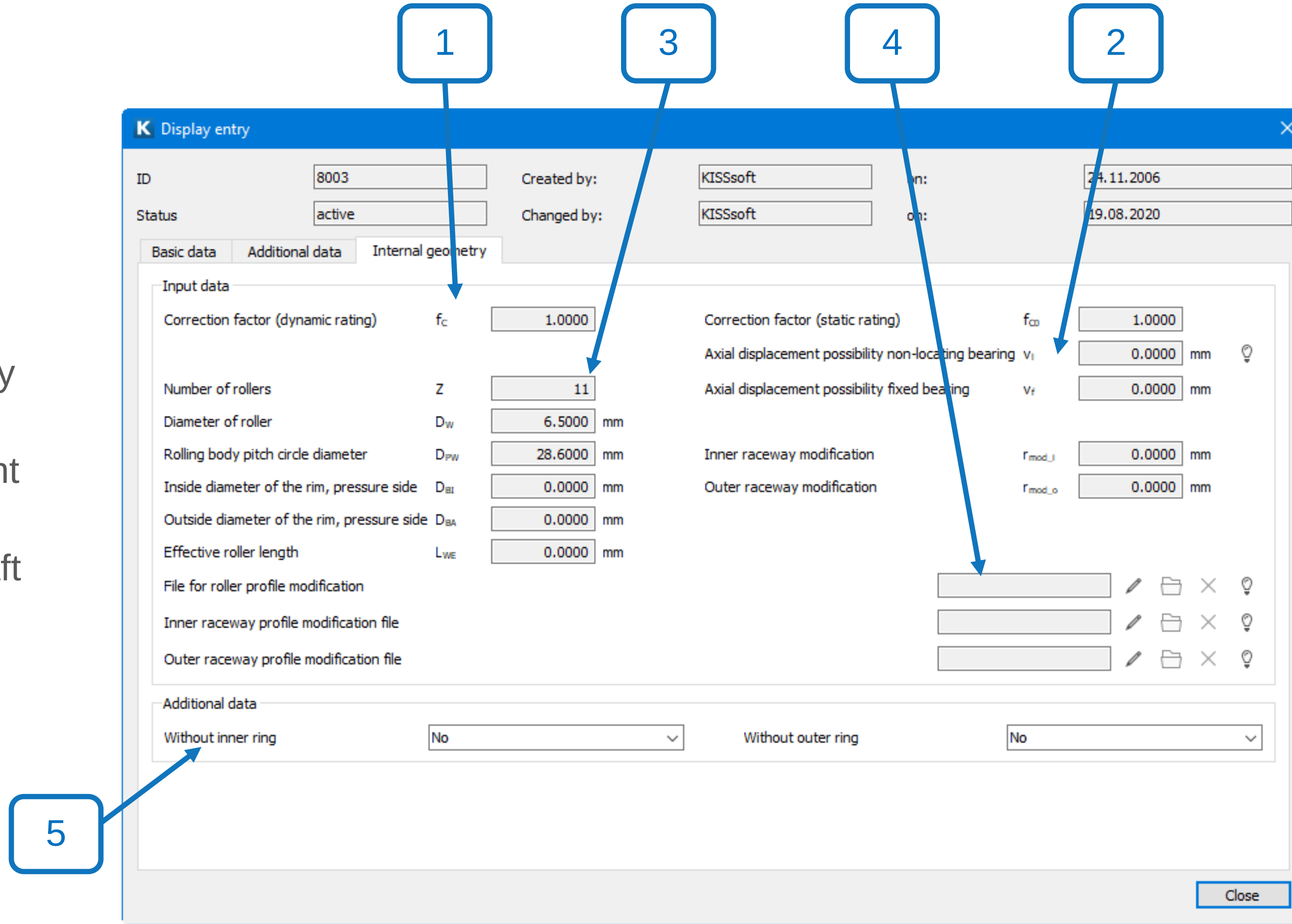
Dataset

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

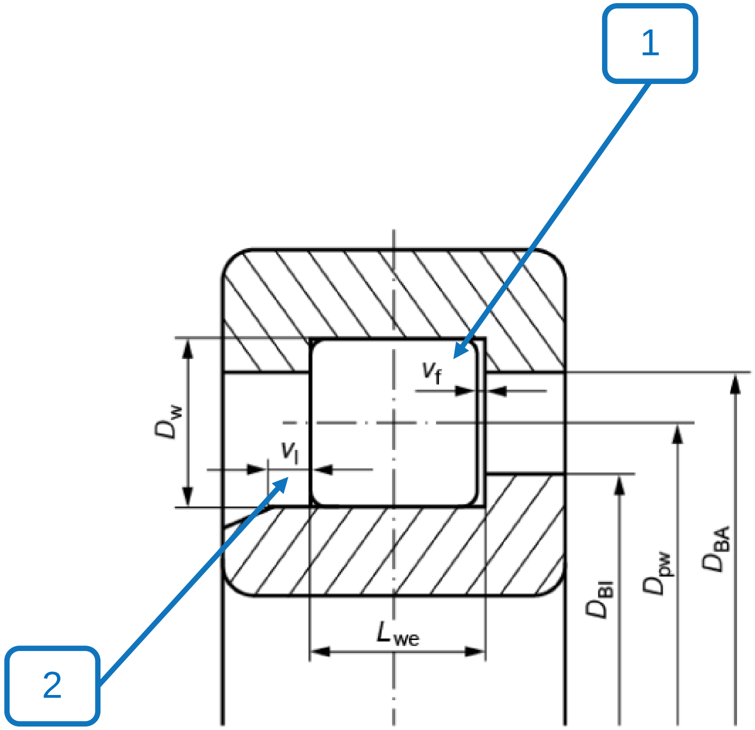


Tab “Internal geometry”

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.

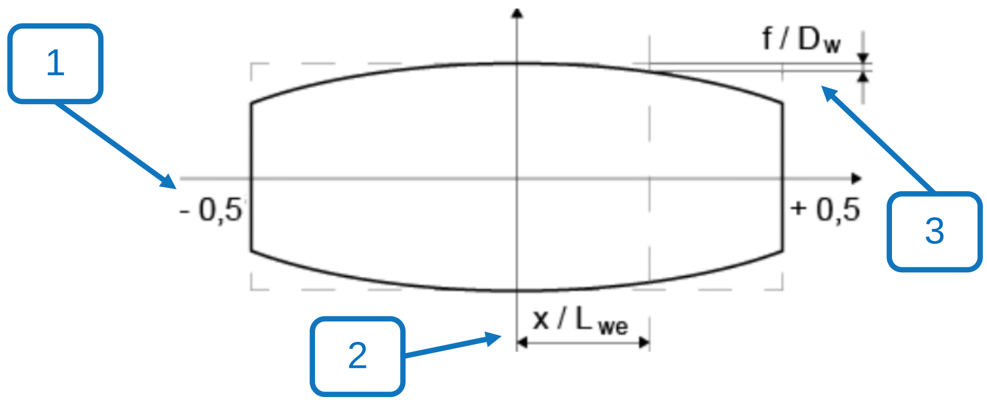
Note the setting “Axial clearance” in module specific settings.

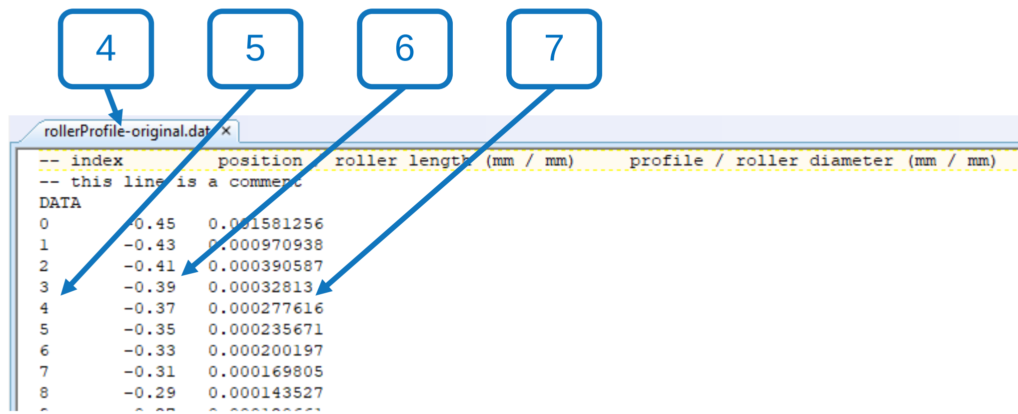


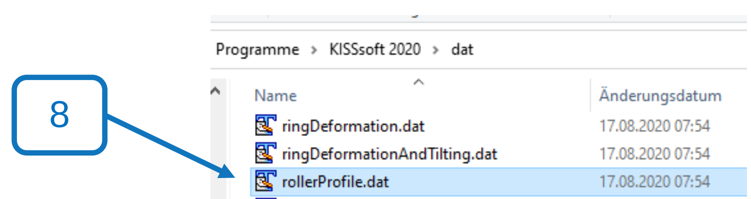
Tab “Internal geometry”

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







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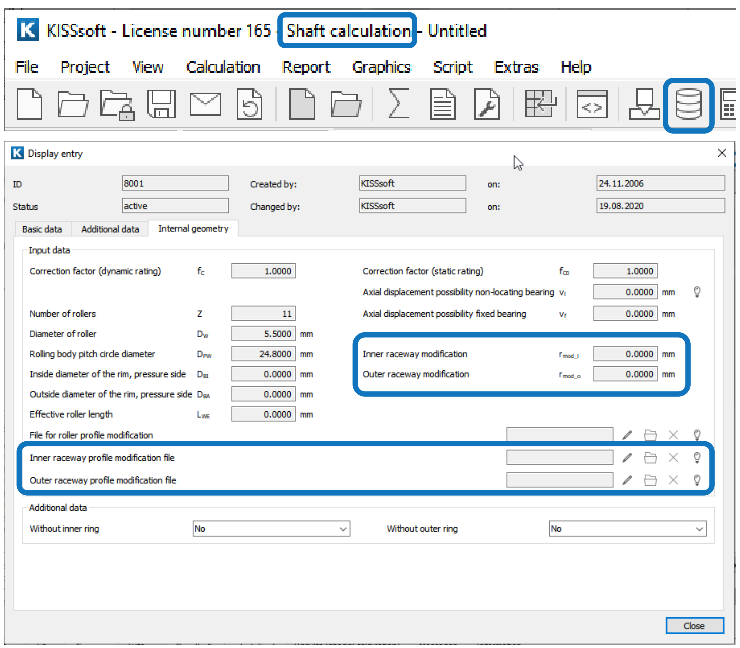
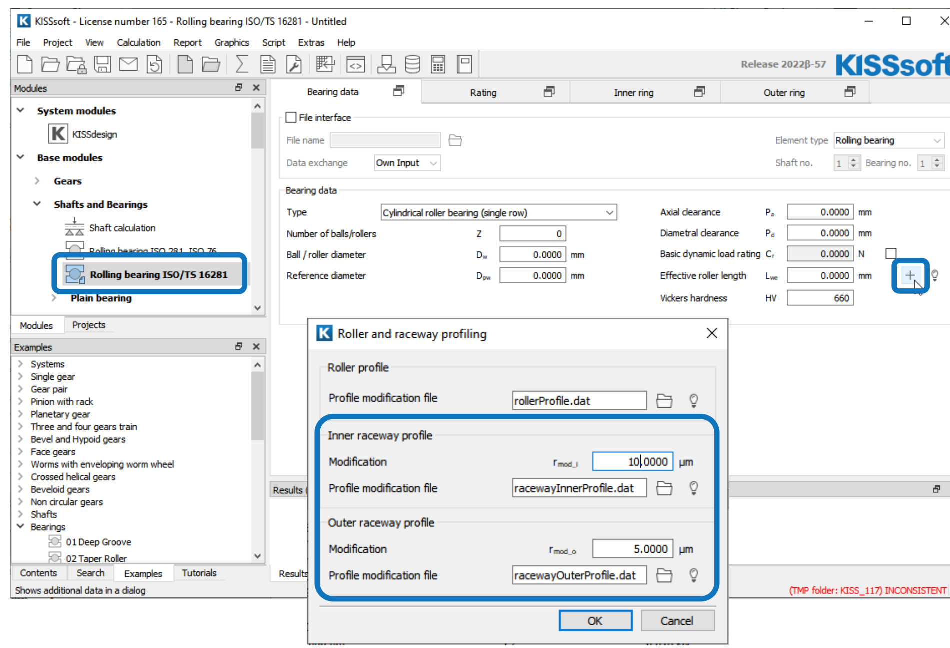
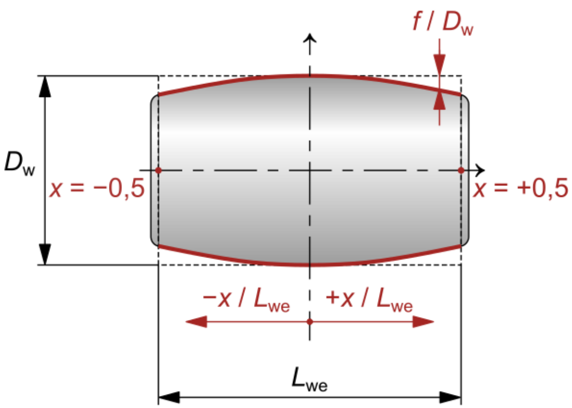
Bearing database: Custom raceway profile for cylindrical roller bearings

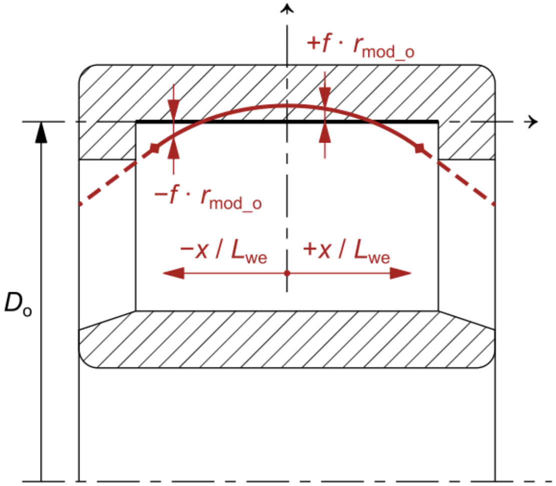
- Define custom raceway profile for cylindrical roller bearing by providing raceway profile modification file.
- Raceway profile modification $\Delta(x)$ is defined as a multiplication of a constant modification value r_{mod} and a modification ratio for a given relative position along the roller effective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

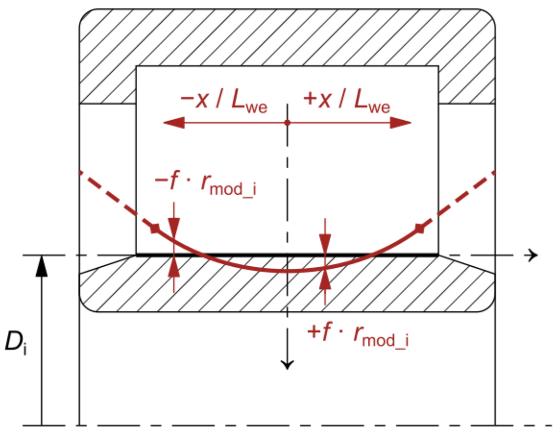




- Cylindrical roller bearings usually have profiled rollers and flat raceways
- Similarly, as one can already define custom profile of rollers, now it can also define custom profiles of inner and outer raceways.
- Why would one like to do that?
  - To simulate production errors.
  - For custom designed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



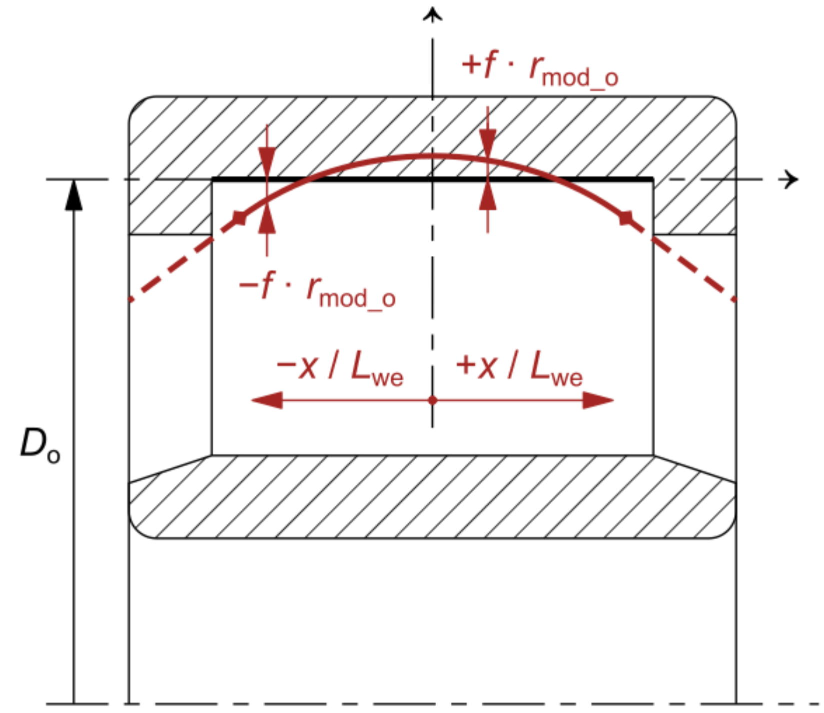




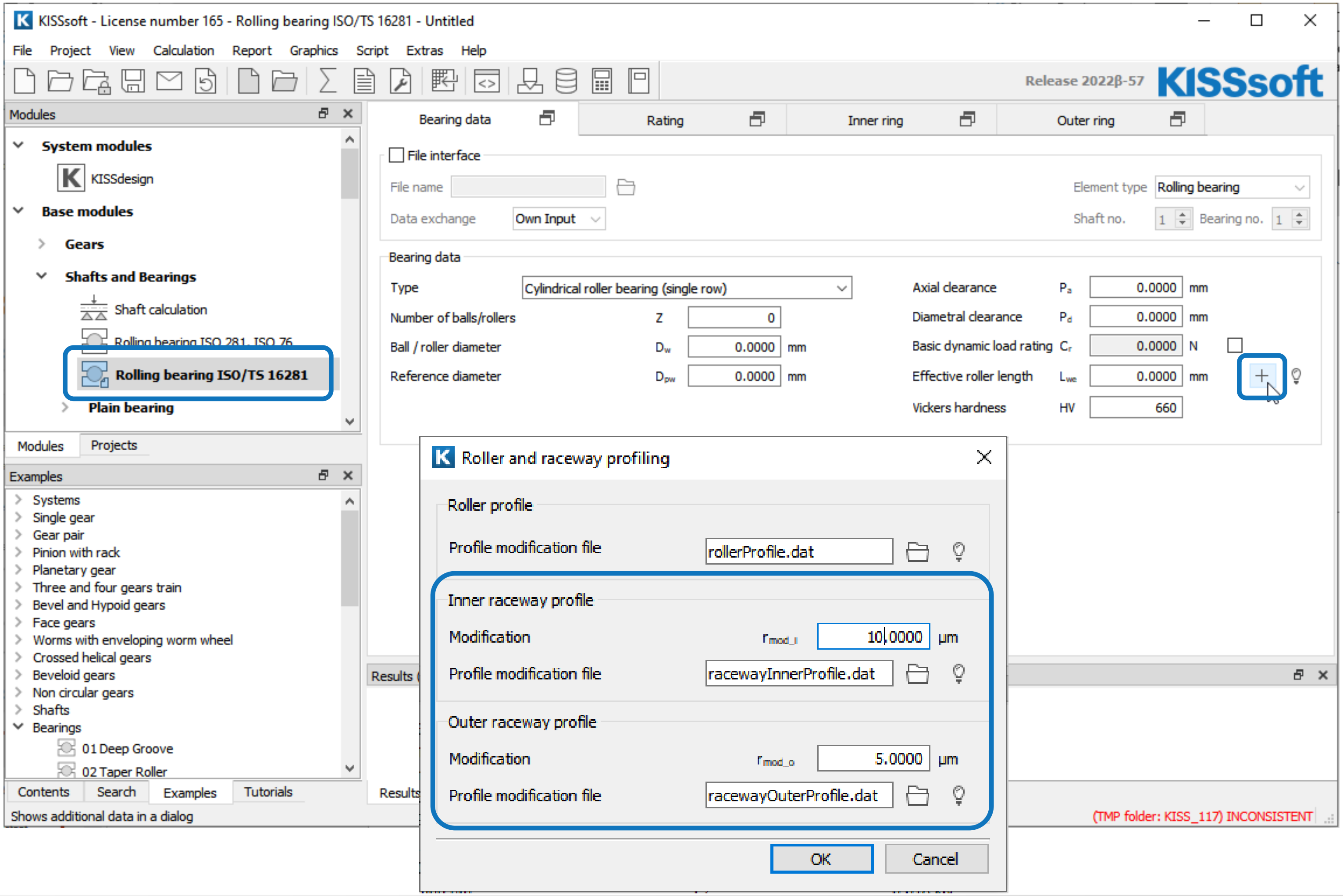
- Raceway profile modification $\Delta(x)$ is defined as a multiplication of a constant modification value r_{mod} and a modification ratio $f(x)$ for a given relative position along the roller effective length:

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

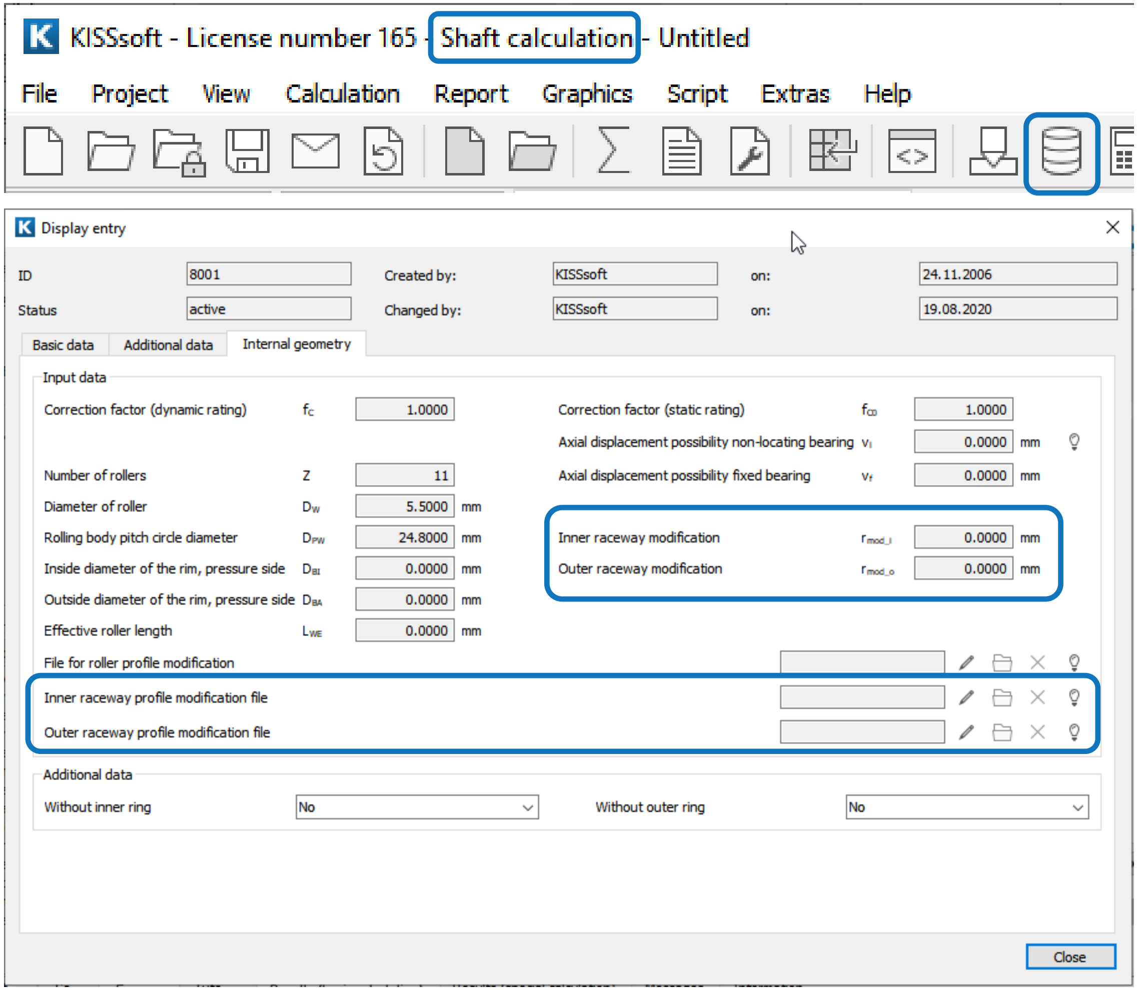
- Profile modification can be defined for each raceway separately.
- Modification ratio $f(x)$ is defined in a DAT file.
- Constant modification value r_{mod} is defined in user interface.



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



- 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

This PC › OS (C:) › Program Files › KISSsoft AG › KISSsoft 2022 › dat

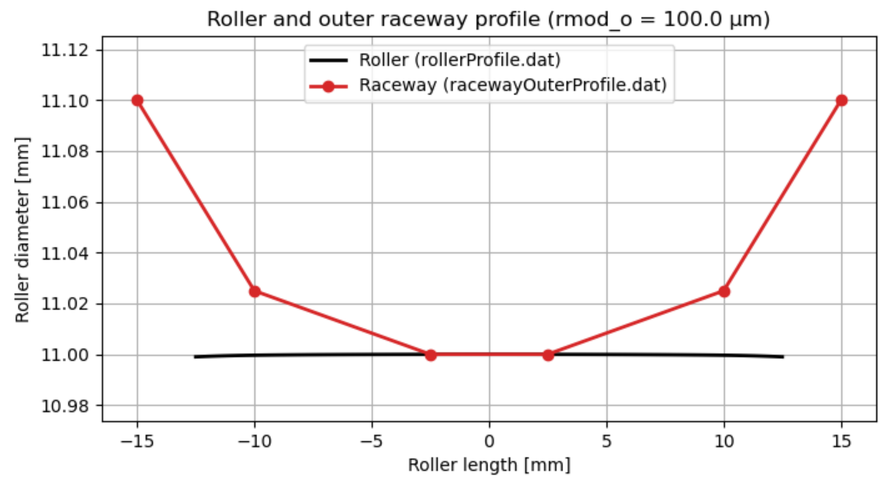
Name	Date modified	Type
racewayInnerProfile.dat	02/03/2022 13:37	DAT File
racewayOuterProfile.dat	02/03/2022 13:37	DAT File

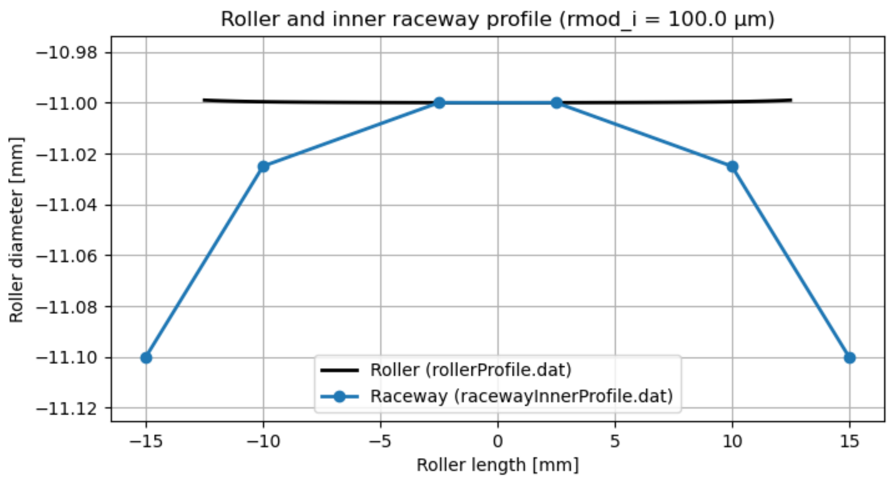
racewayOuterProfile.dat

```
-- This is a comment
-- Positive modification ratio increases clearance
-- Negative modification ratio reduces clearance a
-- At least 1 value of modification ratio must be
-- index | relative position | modification ratio
DATA
  1      -0.60       1.00
  2      -0.40       0.25
  3      -0.10       0.00
  4       0.10       0.00
  5       0.40       0.25
  6       0.60       1.00
END
```

racewayInnerProfile.dat

```
-- This is a comment
-- Positive modification ratio increases clearance
-- Negative modification ratio reduces clearance a
-- At least 1 value of modification ratio must be
-- index | relative position | modification ratio
DATA
  1      -0.60       1.00
  2      -0.40       0.25
  3      -0.10       0.00
  4       0.10       0.00
  5       0.40       0.25
  6       0.60       1.00
END
```





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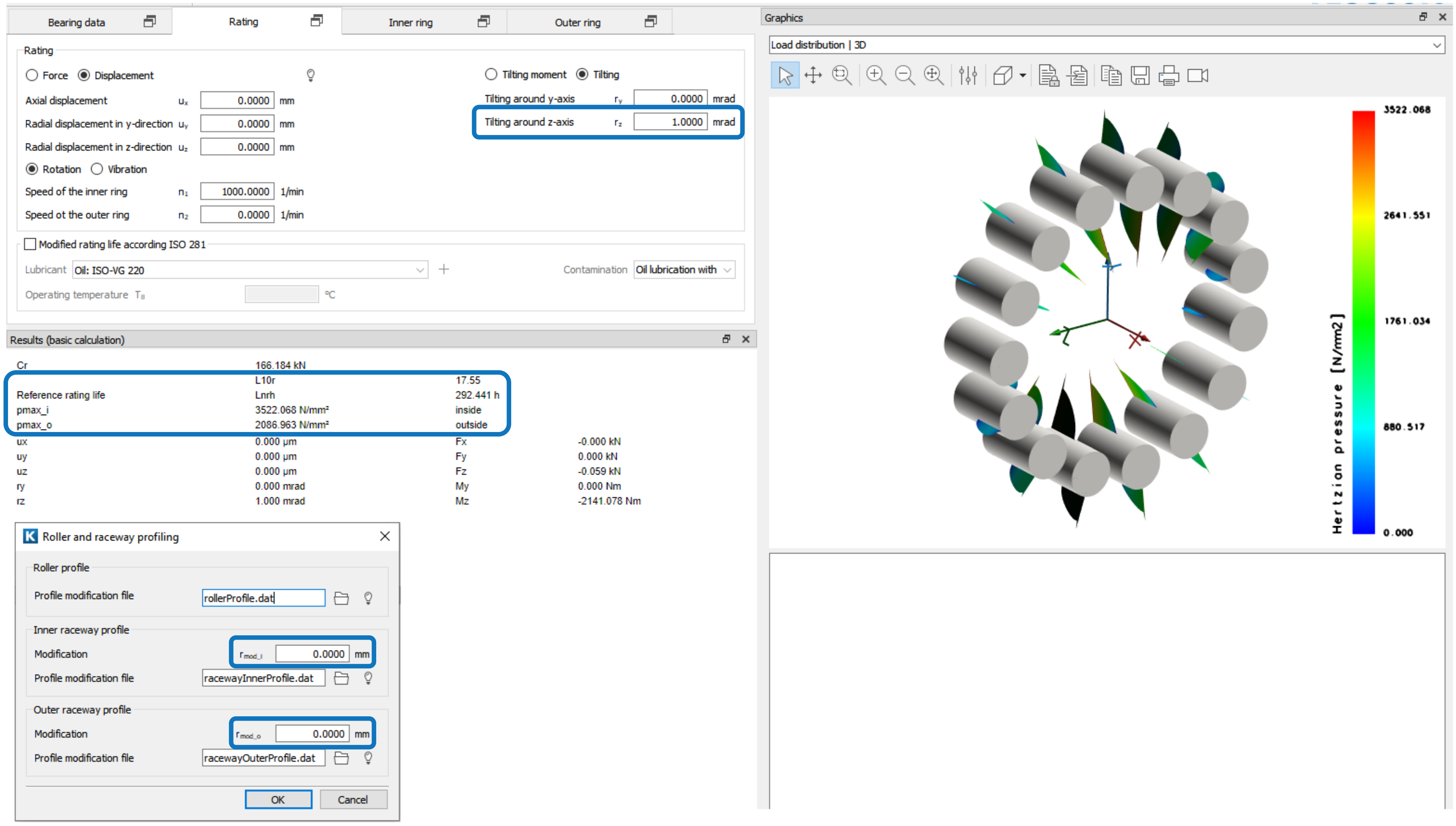
Bearing database: Custom raceway profile for cylindrical roller bearings

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



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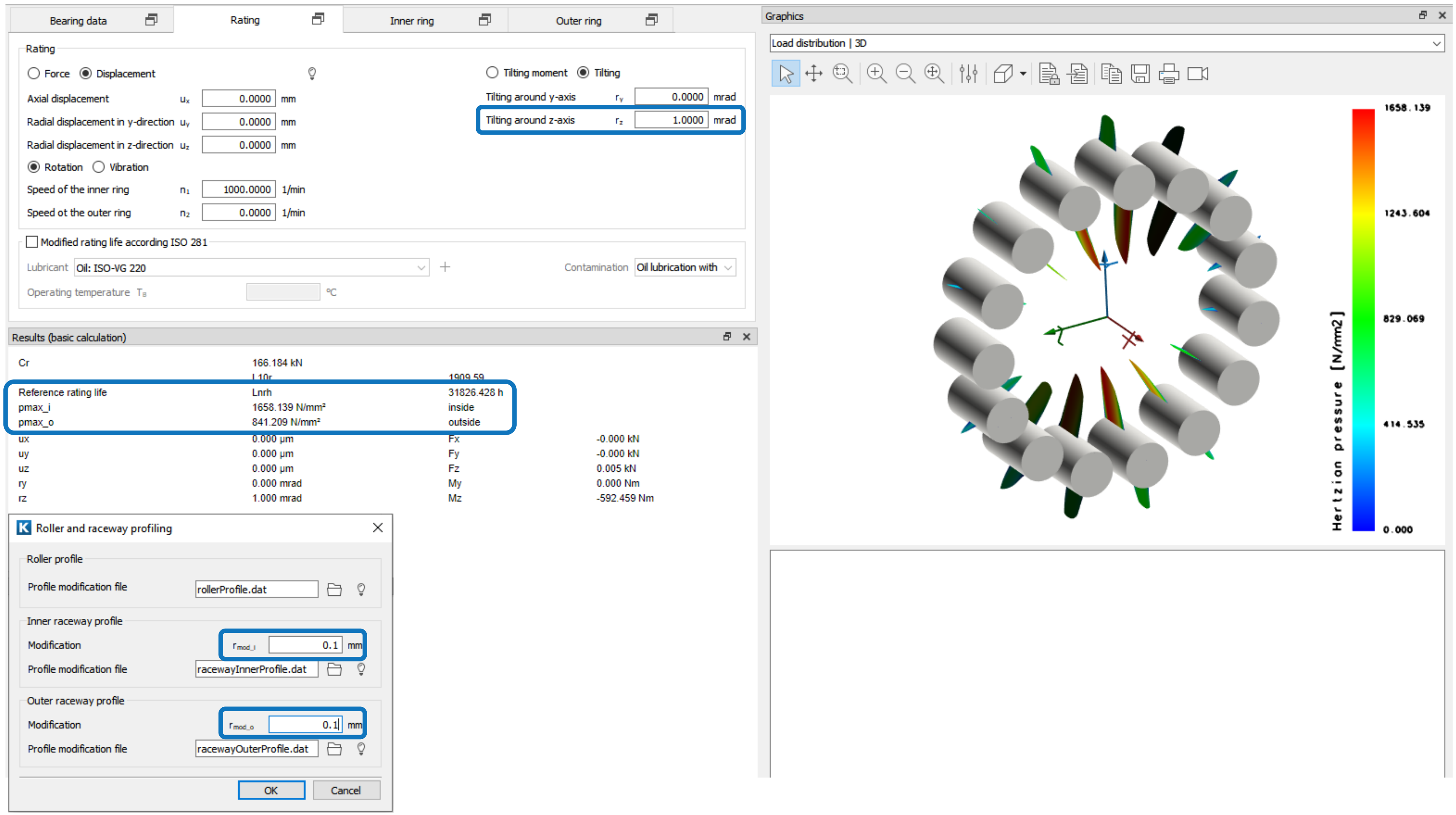
- Module W051: example 5 with changed load, with raceway modification



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Bearing database: Custom raceway profile for cylindrical roller bearings

- Results

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

		Profiling				
Section k	Position (mm)	P(k) (µm)	RPI(k) (µm)	RPO(k) (µm)	a_{ISO} (-)	P_{ks} (N)
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

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

		Profiling				
Section k	Position (mm)	P(k) (µm)	RPI(k) (µm)	RPO(k) (µm)	a_{ISO} (-)	P_{ks} (N)
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).

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

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

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

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

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.

Content

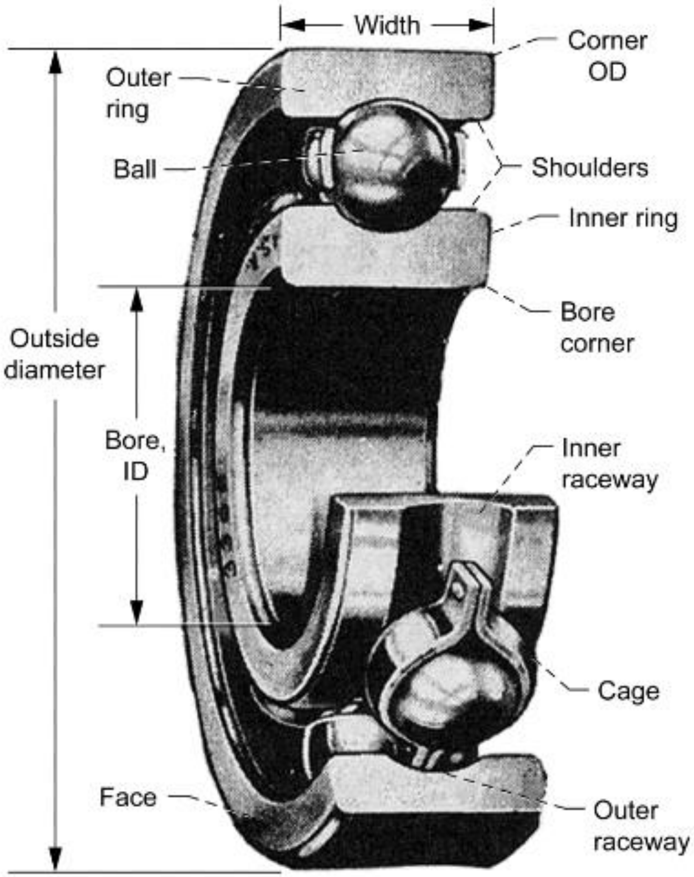
Concepts

Nomenclature

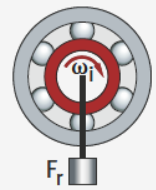
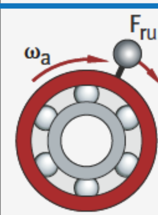
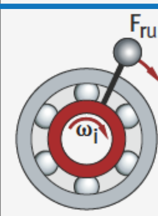
Rolling elements may be balls or rollers.

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.



- 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

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

$$L_{10r} = \left[\left(\frac{Q_{ci}}{Q_{ei}} \right)^{-10/3} + \left(\frac{Q_{ce}}{Q_{ee}} \right)^{-10/3} \right]^{-9/10}$$

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

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

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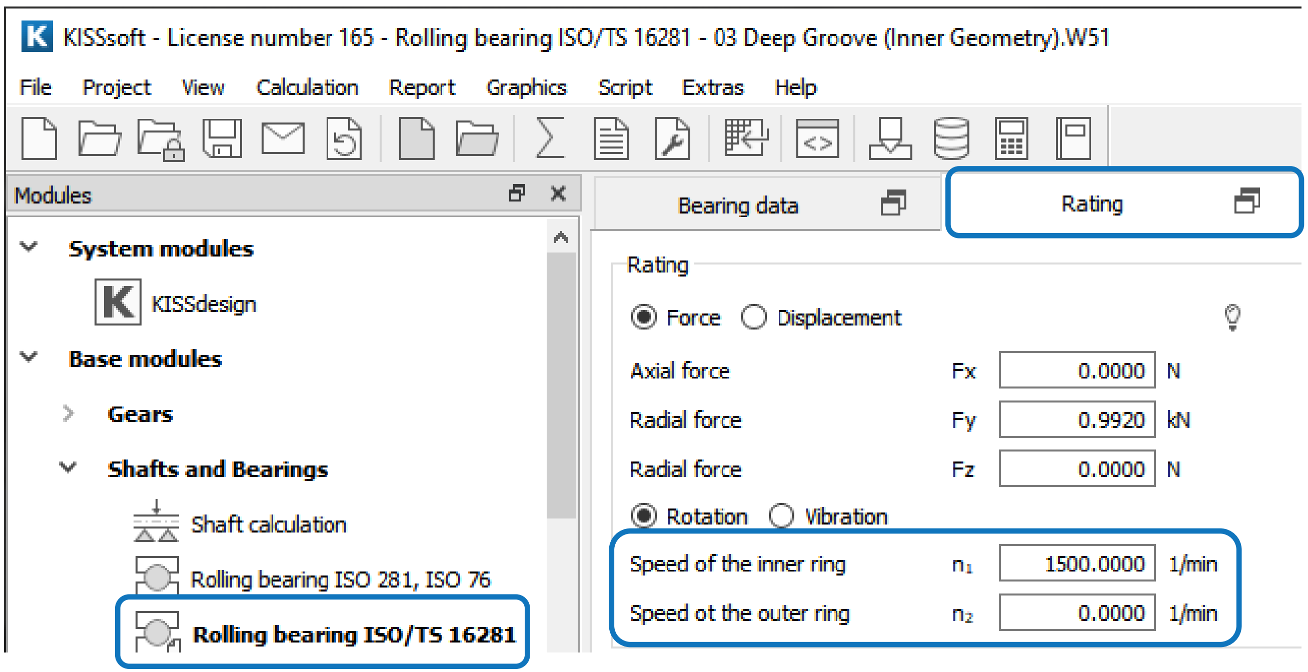
- Module W10: automatically taken into account by rotating speed(s) of the shaft(s).
- Module W051: two separate fields to enter inner/outer ring rotating speeds.

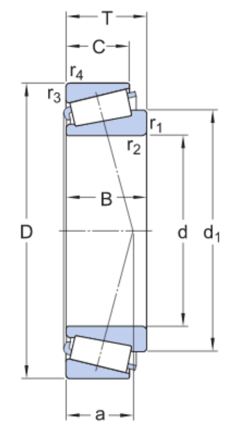


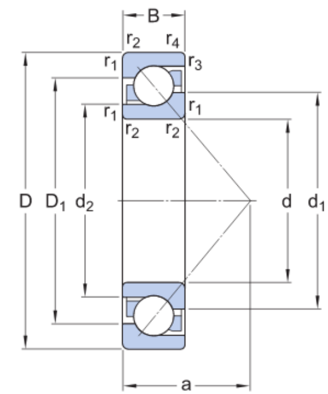
- Comparison of results

Test file: **W010-Test SKF interface with different speeds.W10**

	Bearing 1 SKF 32052 X	**2021-SP2**			**2022-DEBUG-20211110**			**Delta 2021 vs 2022 [%]**	
		KISSsoft	**SKF**	**Delta [%]**	**KISSsoft**	**SKF**	**Delta [%]**	**KISSsoft**	**SKF**
Lnrh	n1 = 50 rpm n2 = 0 rpm	58853	56087	-4,70	58853	56087	-4,70	0,00	0,00
	n1 = 0 rpm n2 = 50 rpm	58853	56087	-4,70	54063	51970	-3,87	-8,14	-7,34
	n1 = 15 rpm n2 = +75 rpm	49044	46739	-4,70	50954	48979	-3,88	3,89	4,79
	n1 = +75 rpm n2 = 15 rpm	49044	46739	-4,70	50955	48979	-3,88	3,90	4,79
	n1 = 15 rpm n2 = -75 rpm	32696	31159	-4,70	33970	32653	-3,88	3,90	4,79
	n1 = -75 rpm n2 = 15 rpm	32696	31159	-4,70	33970	32654	-3,87	3,90	4,80

	Bearing 2 SKF 7052	**2021-SP2**			**2022-DEBUG-20211110**			**Delta 2021 vs 2022 [%]**	
		KISSsoft	**SKF**	**Delta [%]**	**KISSsoft**	**SKF**	**Delta [%]**	**KISSsoft**	**SKF**
Lnrh	n1 = 50 rpm n2 = 0 rpm	2534	2818	11,21	2534	2818	11,21	0,00	0,00
	n1 = 0 rpm n2 = 50 rpm	2534	2818	11,21	2454	2758	12,39	-3,16	-2,13
	n1 = 15 rpm n2 = +75 rpm	2111	2348	11,23	2193	2445	11,49	3,88	4,13
	n1 = +75 rpm n2 = 15 rpm	2111	2348	11,23	2193	2445	11,49	3,88	4,13
	n1 = 15 rpm n2 = -75 rpm	1408	1565	11,15	1462	1630	11,49	3,84	4,15
	n1 = -75 rpm n2 = 15 rpm	1408	1565	11,15	1462	1630	11,49	3,84	4,15



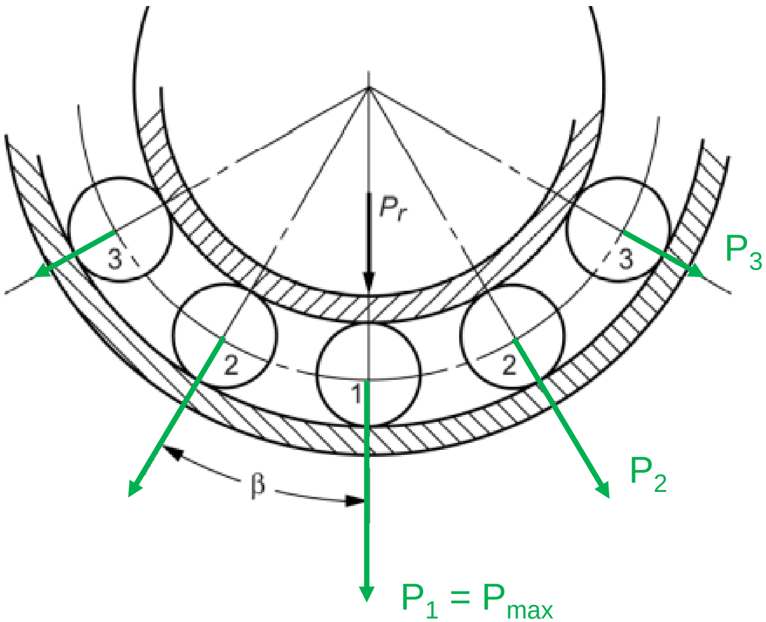


Stribeck number

1) Load Pr 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

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

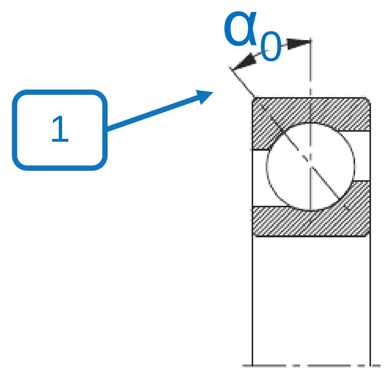
$$n = INT\left(\frac{z-1}{4}\right) \quad \beta = \frac{2\pi}{z} \quad P_{max} = \frac{P_r}{Q} = \frac{S_t P_r}{z} \quad S_t = \frac{z}{Q} = \frac{P_{max}}{P_r / z}$$



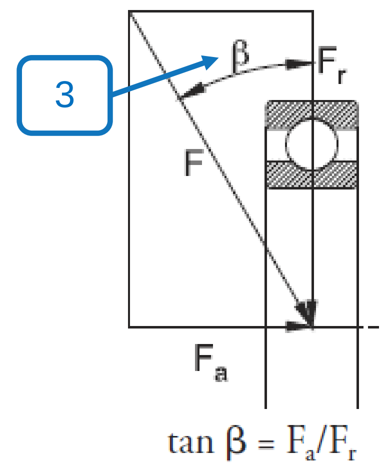
P_r	radial load
z	number of rolling elements
n	number of pairs of rolling elements under load
S_t	Stribeck number, ≈ 5
P_{max}	Highest load on a rolling element
Q	$= z / S_t$
β	Pitch angle

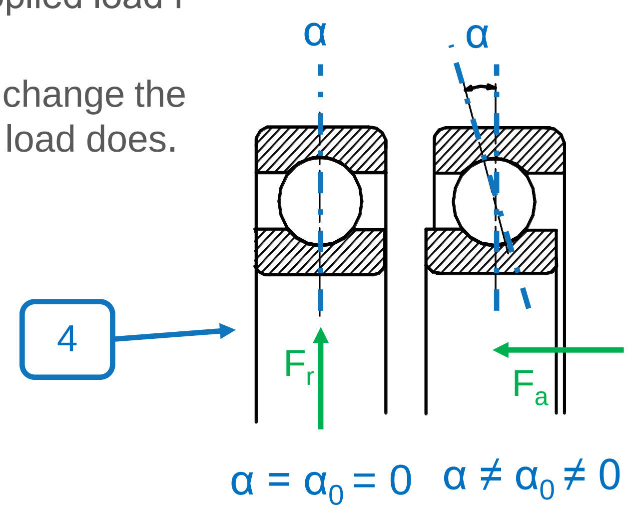
S_t = 4.37 according to Stribeck, 4.08 according to Palmer, use 5.00 to account for some uneven load distribution

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.

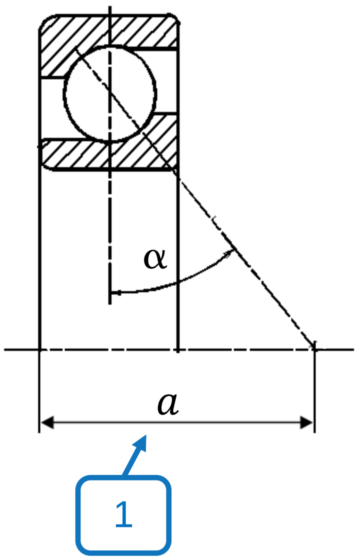


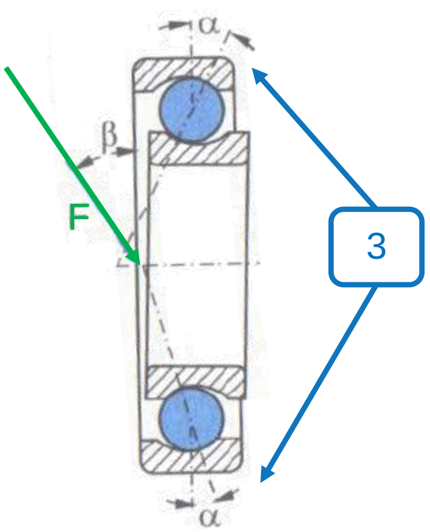


Typical values

1) Typically, the nominal contact angle α_0 is defined through the distance a of the pressure point form 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°

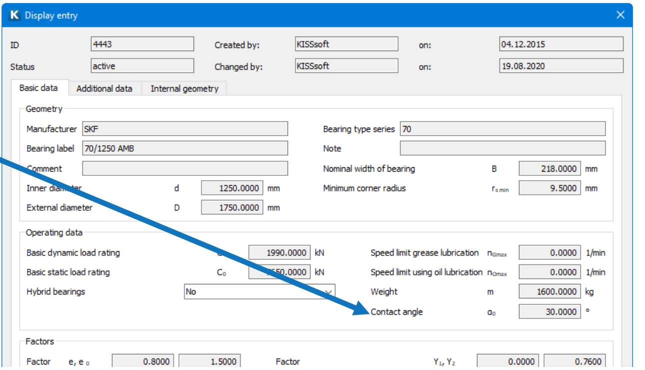


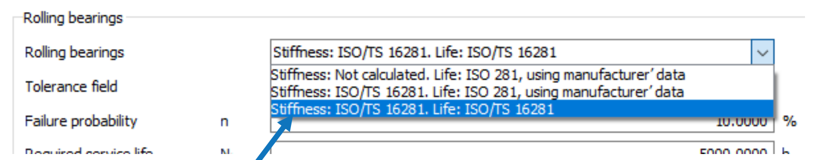


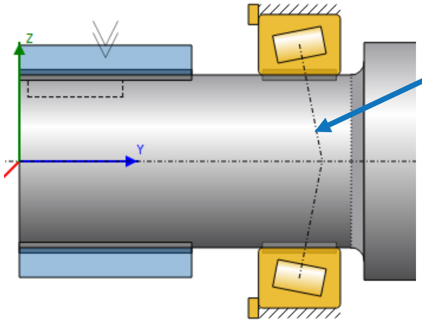
KISSsoft

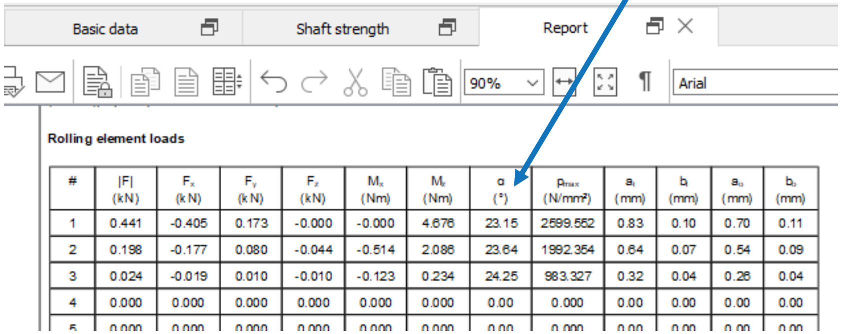
KISSsoft usage

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





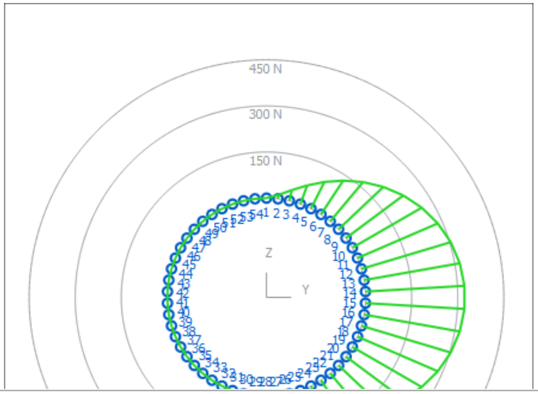


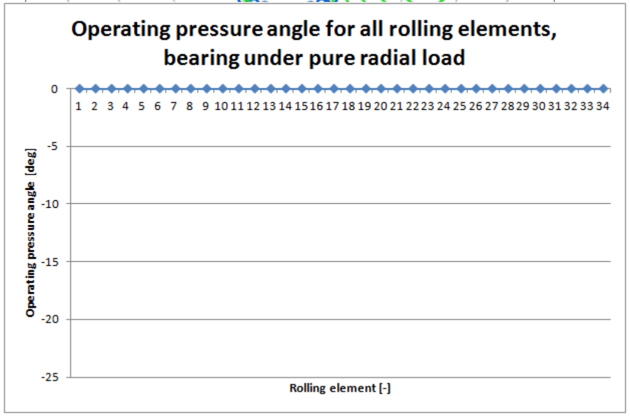


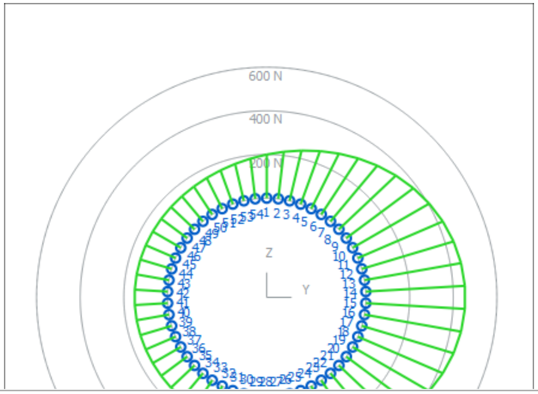
#	|F| (kN)	F_x (kN)	F_y (kN)	F_z (kN)	M_x (Nm)	M_z (Nm)	α (°)	p_{max} (N/mm²)	a_i (mm)	b_i (mm)	a_o (mm)	b_o (mm)
1	0.441	-0.405	0.173	-0.000	-0.000	4.676	23.15	2599.552	0.83	0.10	0.70	0.11
2	0.198	-0.177	0.080	-0.044	-0.514	2.086	23.64	1992.354	0.64	0.07	0.54	0.09
3	0.024	-0.019	0.010	-0.010	-0.123	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

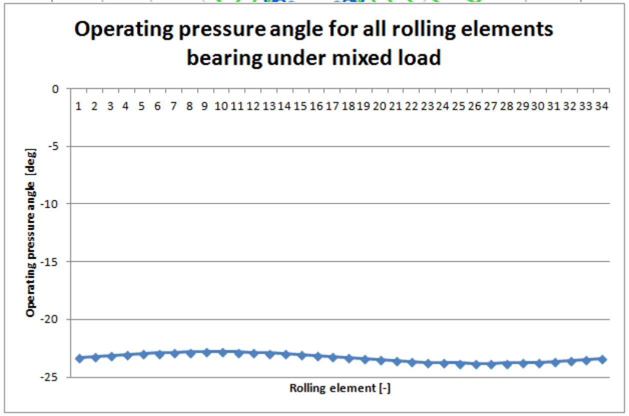
Operating contact angle

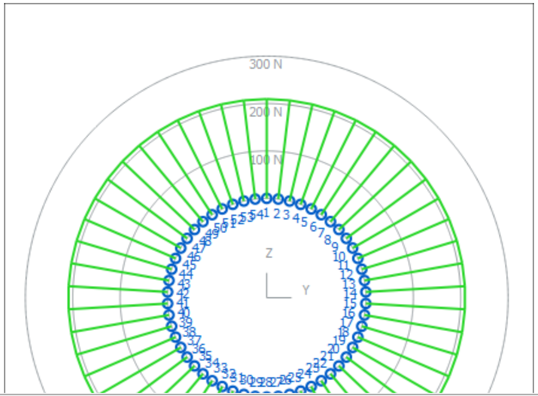
Pure radial load vs. combined load vs. pure axial load, for a deep groove ball bearing with nominal contact angle α_0 = 0, load distribution and operating pressure angle α.

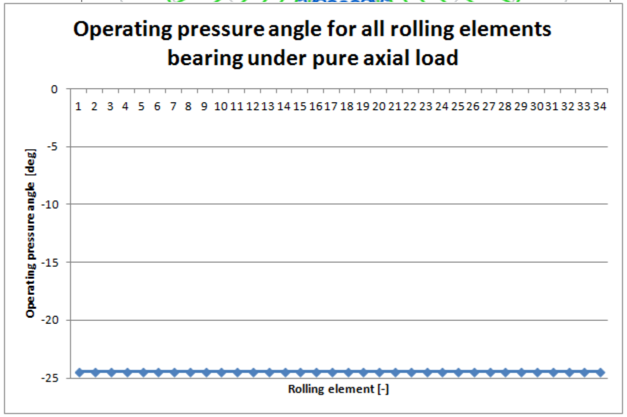




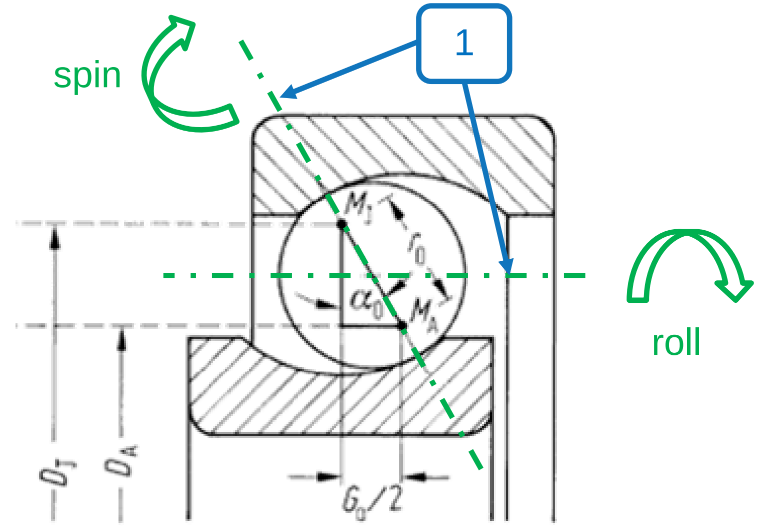








Spin to roll ratio



1) For ball bearings with α ≠ 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.

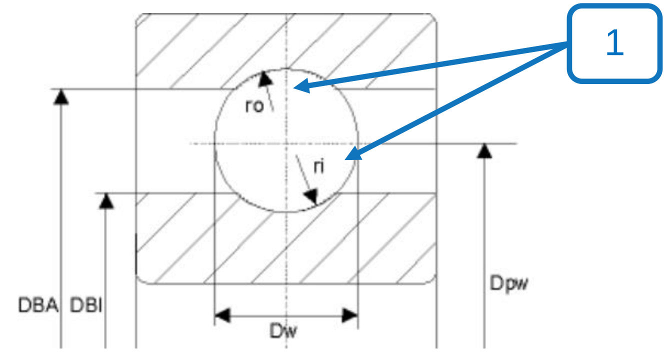
3 Shaft 'Shaft' Rolling bearing 'Roller bearing 1'

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

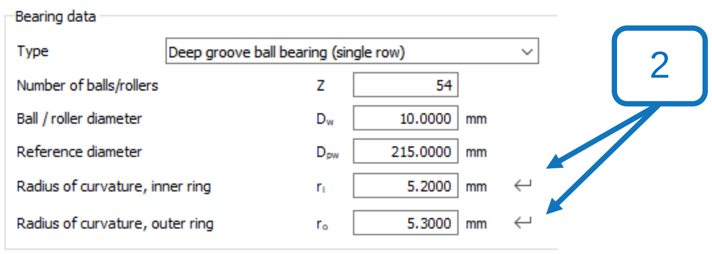
Inner diameter	[d]	40.000	mm
Outer diameter	[D]	68.000	mm
Width	[B]	15.000	mm
Dynamic load rating	[C]	6.900	kN
Static load rating	[C_0]	5.300	kN
Fatigue load limit	[C_u]	0.163	kN
Life modification factor for reliability	[a_1]	1.000	
Correction factor (dynamic rating)	[f_C]	1.000	
Correction factor (static rating)	[f_{C0}]	1.000	
Minimum EHL lubricant film thickness	[h_{min}]	0.428	µm
Spin to roll ratio	[-]	0.070	

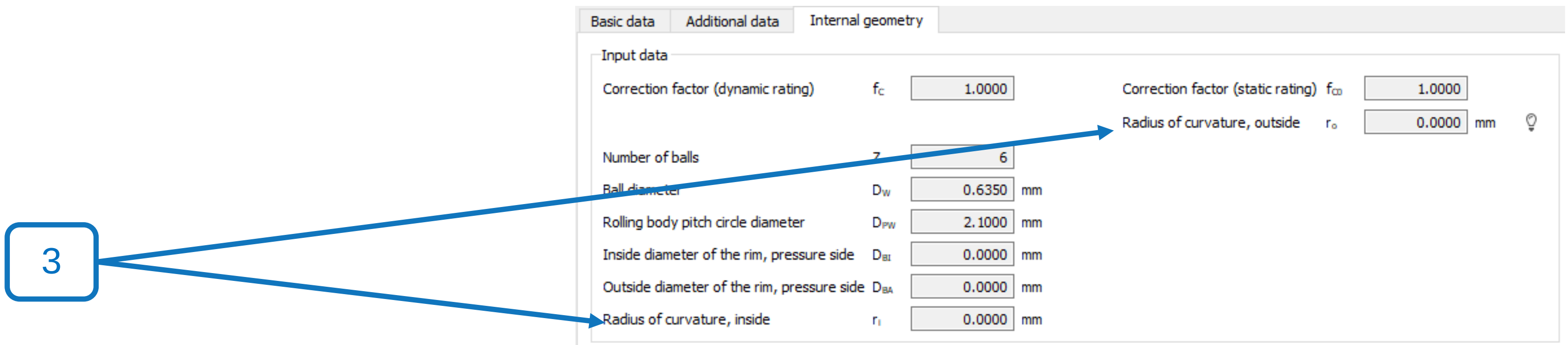
4

Conformity

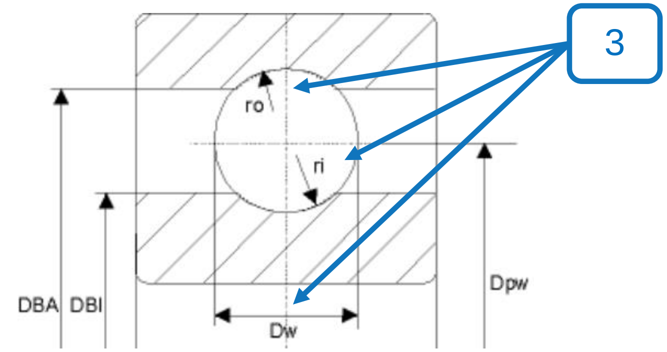


1) Outer ring conformity fo = ro / d, inner ring conformity fi =ri / d. Where ro, ri = raceway radii on inner race and outer race, d = ball diameter. Perfect conformity 2*r = d → f_{max} = 0.50
2) Higher conformity → more friction / lower contact stress. Typically: 0.51 ≤ f ≤ 0.54, typical values are fi = 0.52, fo = 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.





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

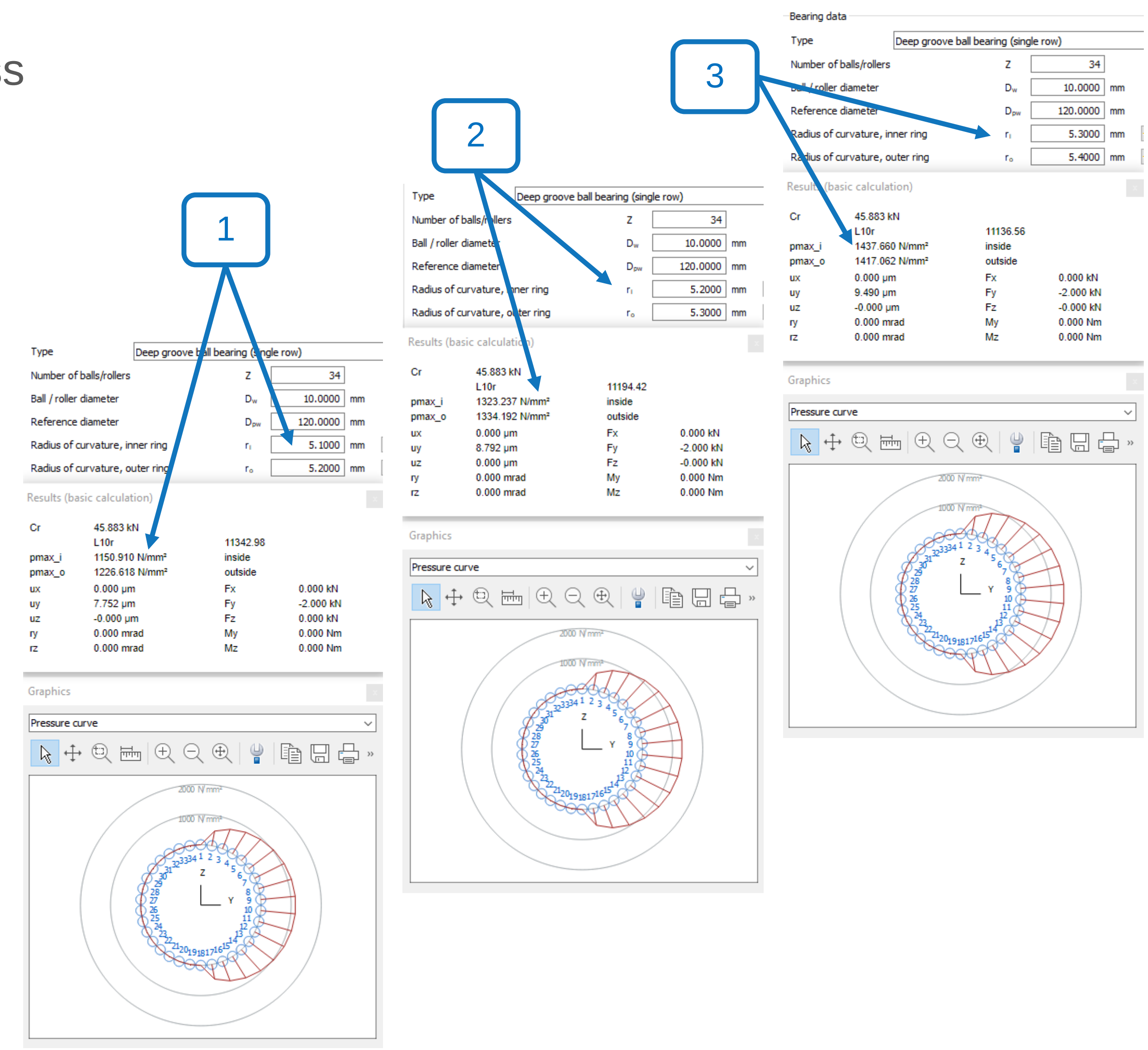
$$\kappa_i = \frac{r_i - r_w}{r_w} = \frac{2*r_i - 2*r_w}{2*r_w} = \frac{2*r_i}{D_w} - 1$$

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

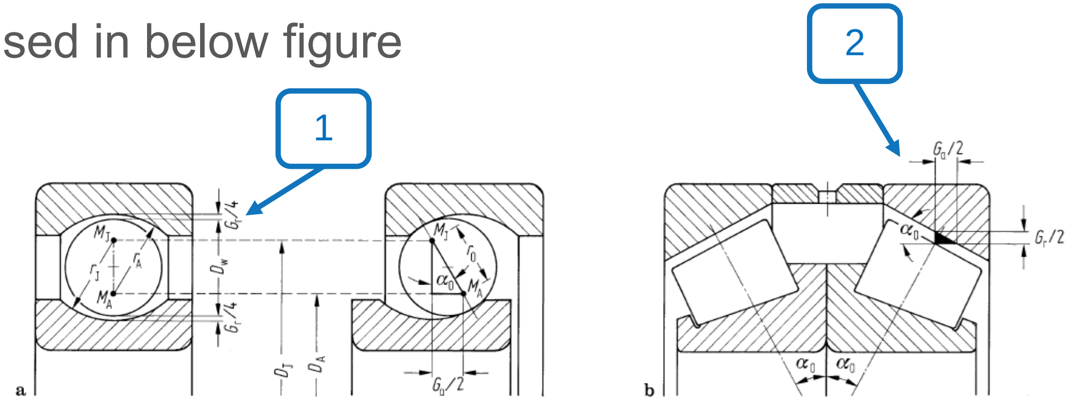


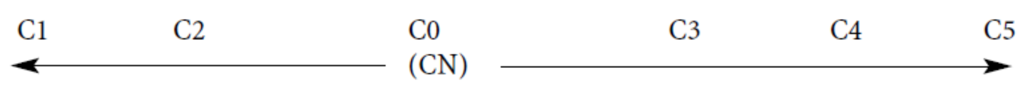
 / 17.5.2022, v2201 / Bearing calculation in KISSsoft /

KISSsoft

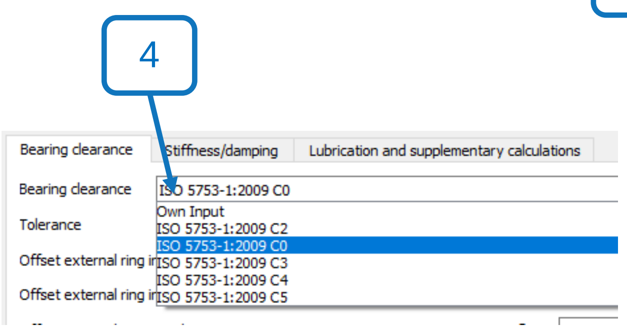
Radial and axial clearance “G” is used in below figure

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	



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Axial clearance Pa

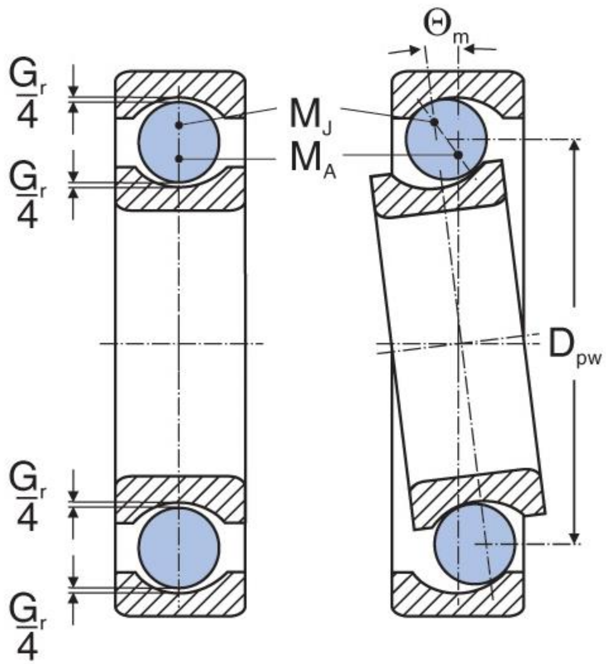
The axial clearance Pa is the clearance before assembly in axial direction. It is defined as the amount by which the inner ring can be moved with respect to the outer ring from one extreme position to the other in the direction of the bearing axis. It is a function of the radial clearance for many bearing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

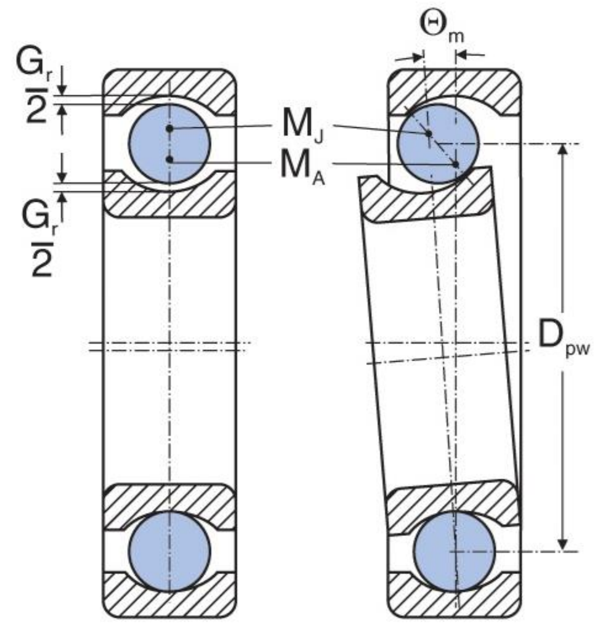
Clearance, definitions

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.



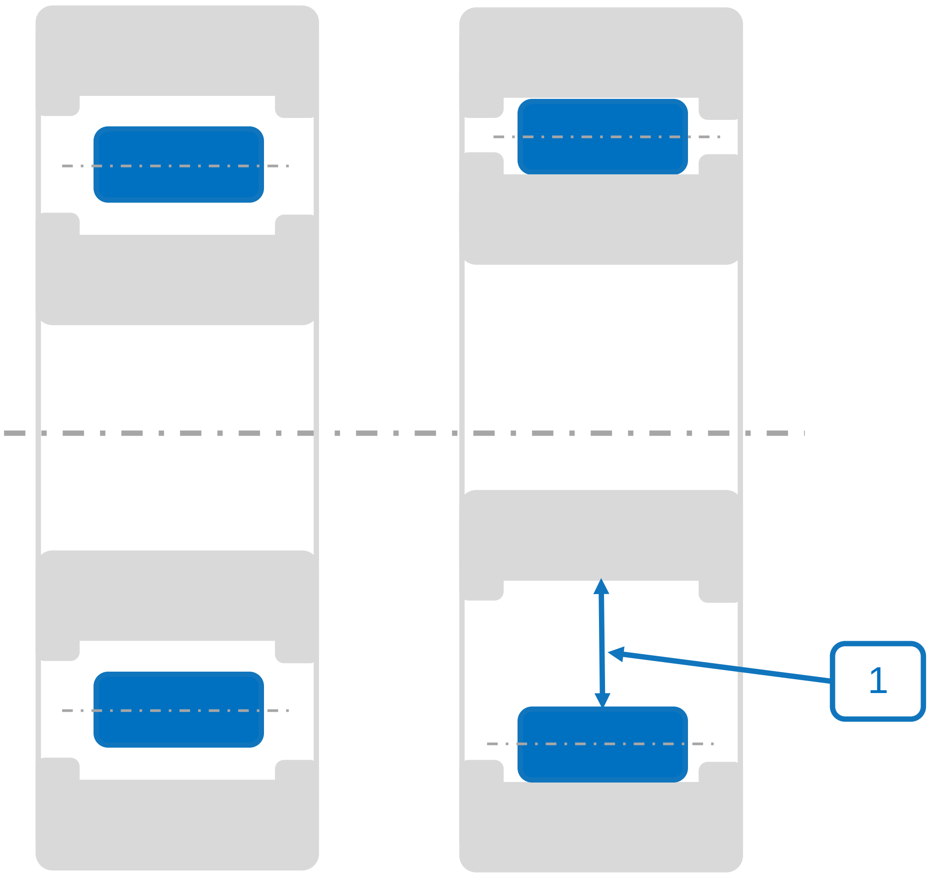
$$\Theta_m = G_a / D_{pw}$$



$$\Theta_u = G_a^* / 2D_{pw}$$

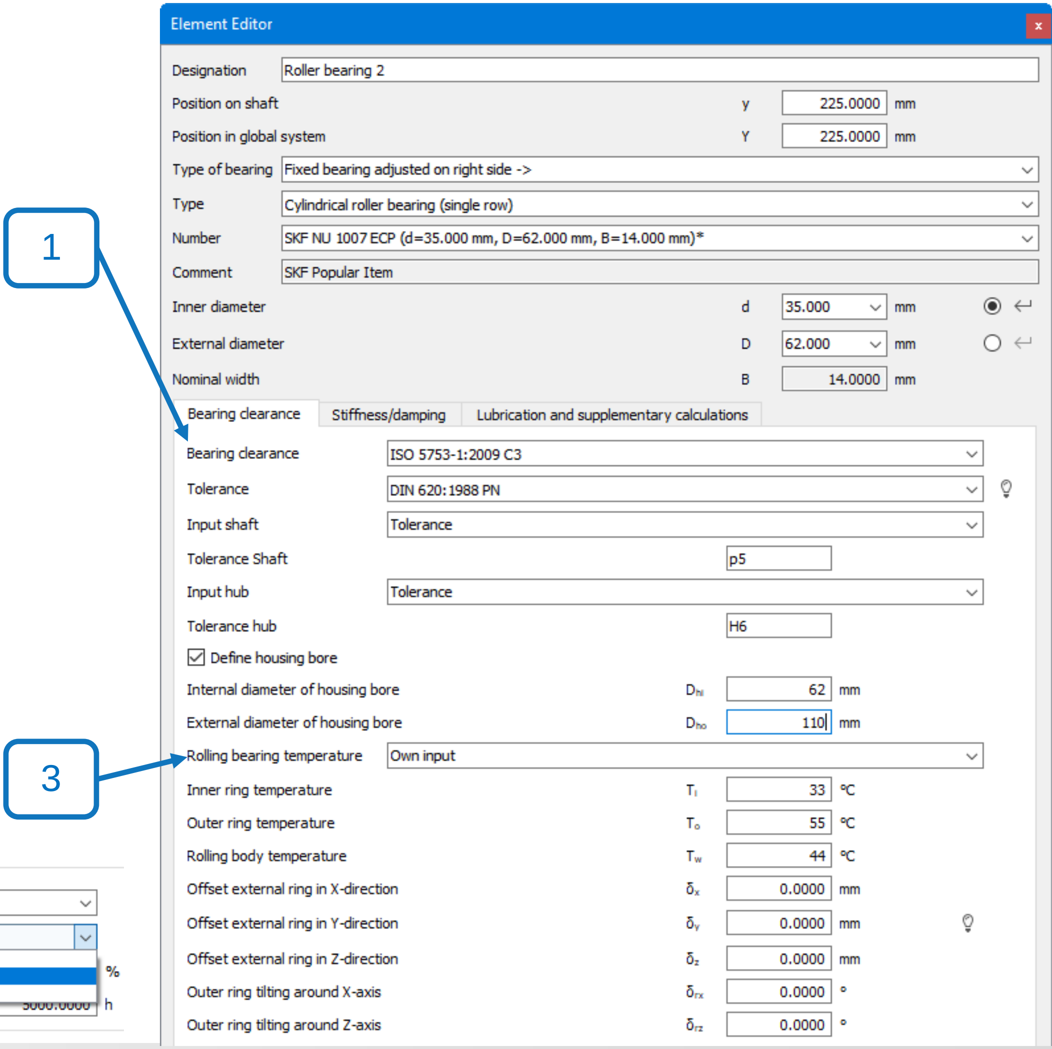
Bearing clearance, assembly clearance, operating clearance

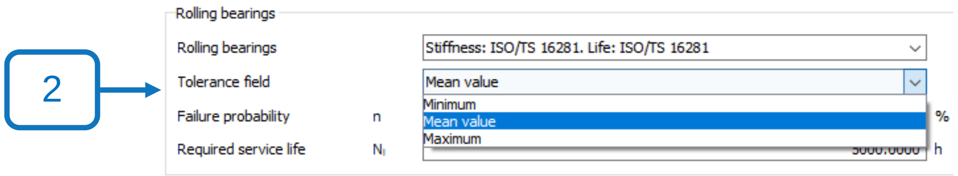
1) Radial clearance is defined amount of radial movement inner ring can move to outer ring at no load
2) Bearing clearance is a bearing (part) property
3) Assembly clearance considers shaft and housing seat and stiffness, surface roughness, bearing tolerances
4) Operating clearance considers temperature 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).



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).





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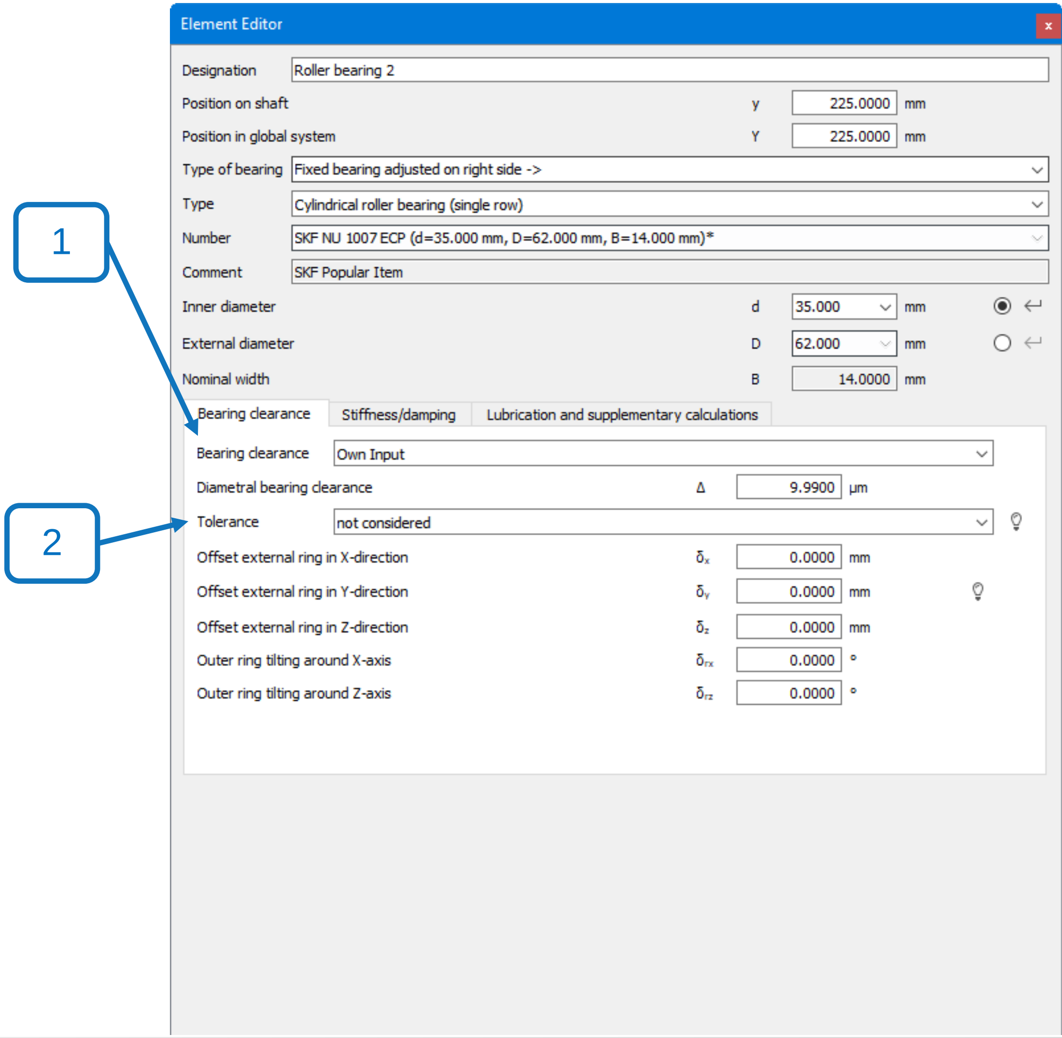
Bearing clearance, assembly clearance, operating clearance

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.



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

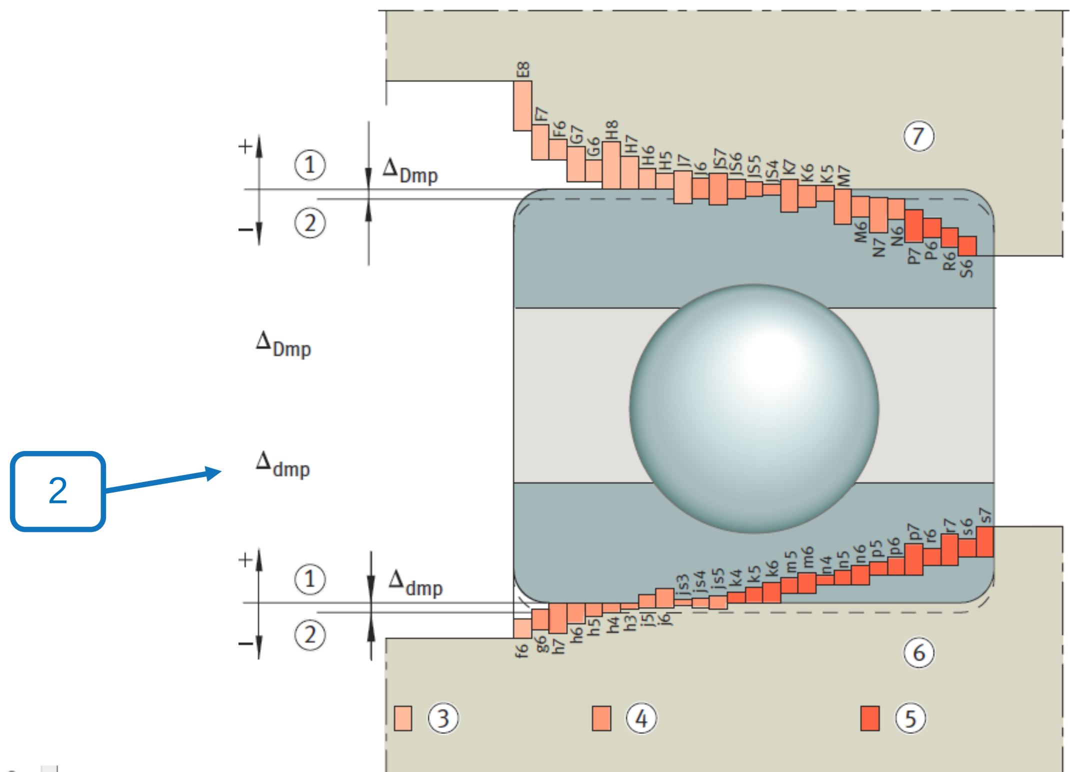
(3) Loose fit

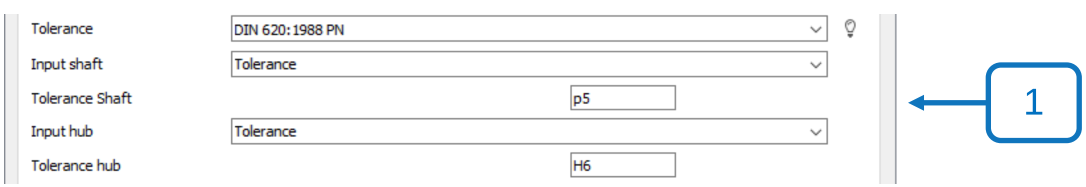
(4) Transition fit

(5) Press fit

(6) Shaft diameter

(7) Housing diameter





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Fits

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; df> ΔdF. The change in fit / reduction in interference ΔdF may be estimated:

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

Where Fr 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 (Fr>0.2*C0r), use

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

KISSsoft

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)								Housing bore diameter (mm)			Bearing arrangement
	≤18	(18) to 40	(40) to 100	(100) to 140	(140) to 200	(200) to 280	(280) to 500	>500	≤300	(300) to 500	>500	
Deep groove ball bearings (for light loads $P \le 0{,}06\ C$)	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

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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	(120) to 250	(250) to 315	< 120	(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;

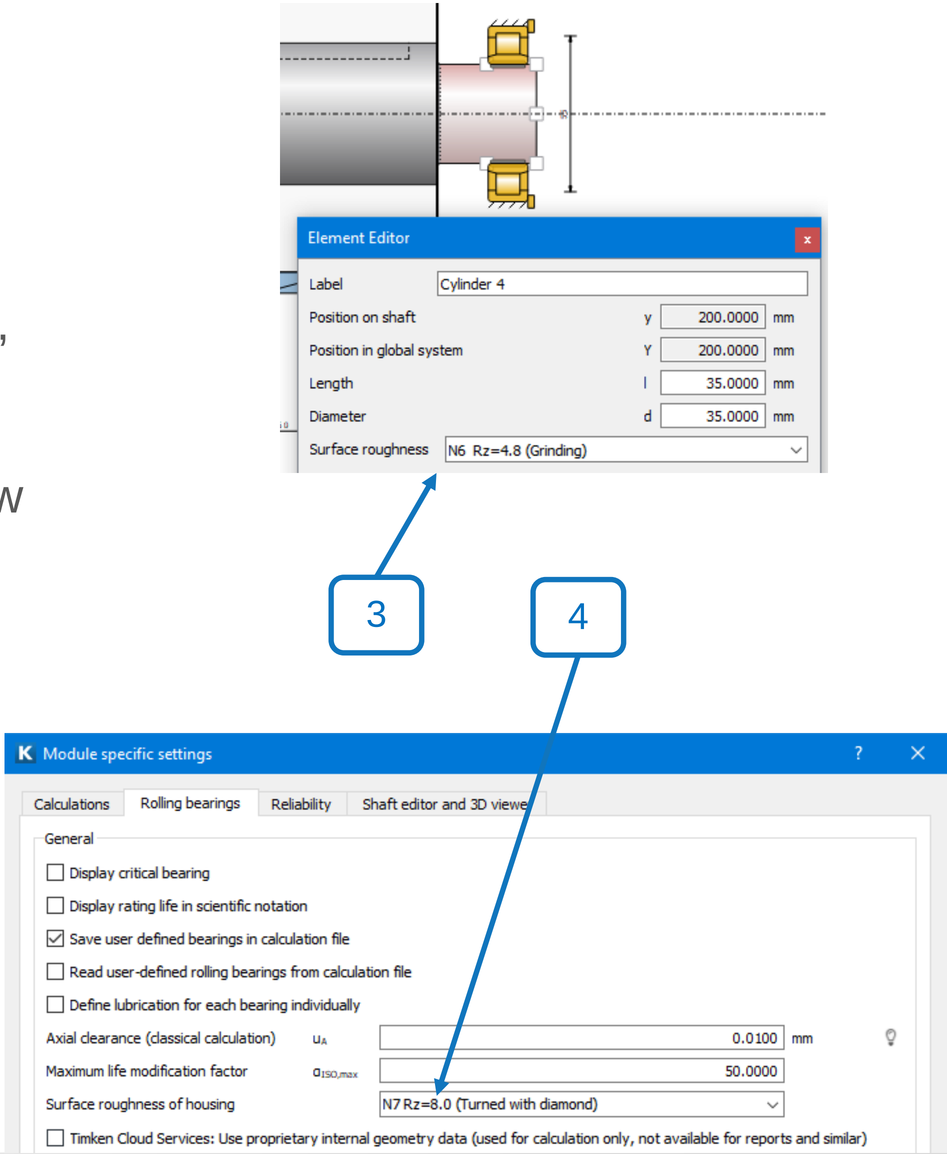
the surface roughness should be $R_a \leq 0{,}2$ µm and $R_z \leq 1$ µm;

hardness should be 58 to 64 HRC

and the case depth when finish machined should be $E_{ht} = 0{,}5\,\sqrt{D_w} - 0{,}5 \geq 0{,}3$ 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 (Uw = 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.



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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.

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4.1 Operating bearing clearance

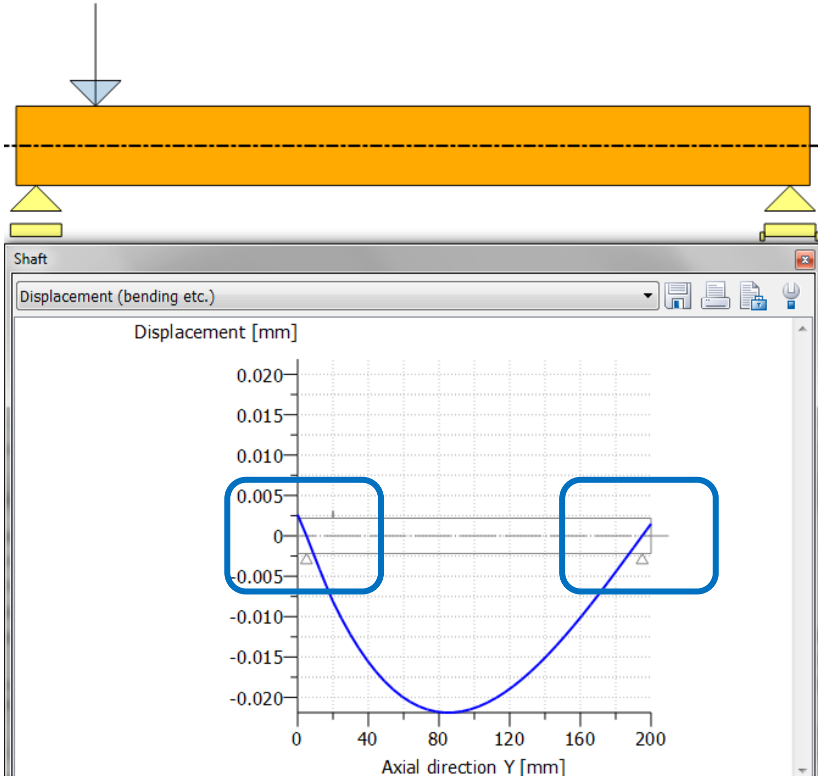
4.1.1 Inputs

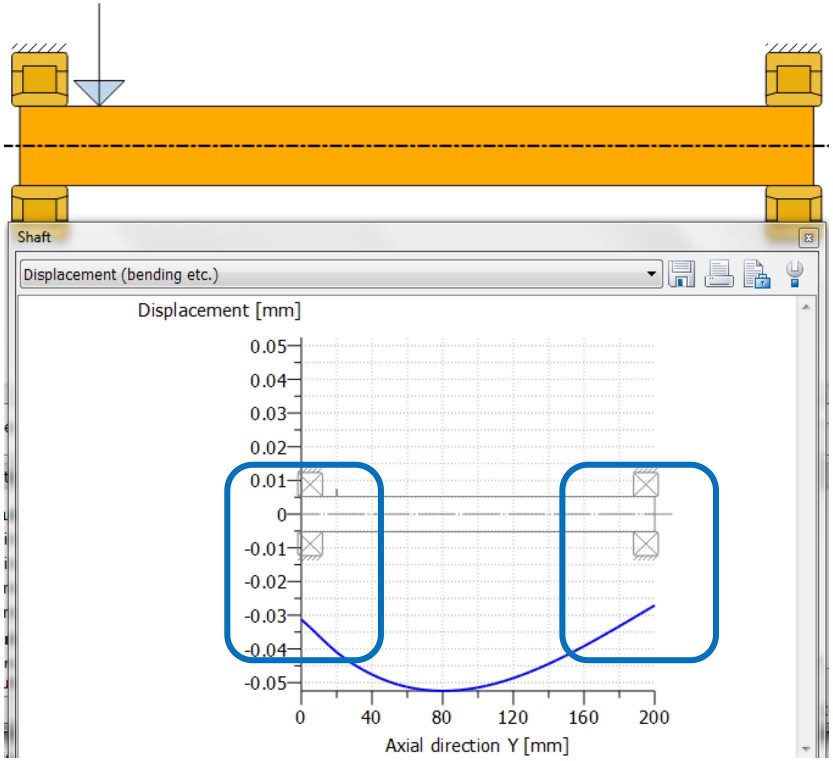
Nominal bearing clearance	[-]	ISO 5753-1:2009 C3		
Nominal diametral clearance	[Pd0]		57.500	µm
Tolerance	[-]	DIN 620:1988 PN		
Inner diameter	[dbi]		34.988/ 34.994/ 35.000	mm
Diameter of inner ring	[dri]		41.971	mm
Diameter of outer ring	[Dro]		57.029	mm
Outer diameter	[Dbo]		61.987/ 61.993/ 62.000	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]	27.686	N/m²	
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_o]	1.393	N/m²	
Effective interference (20.0 (°C))	[Uwo_eff]	5.752	µm	
Diametral clearance change	[ΔPdo]	18.031	µm	
Rolling body temperature	[Tw]	44.0	°C	
Rolling body expansion	[ΔDw]	2.070	µm	
Total diametral clearance change	[ΔPd]	-17.634	µm	(ΔPdi + ΔPdo - 2 * ΔDw)
Operating diametral clearance	[P_d]	39.866	µm	(Pd0 + ΔPd)

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





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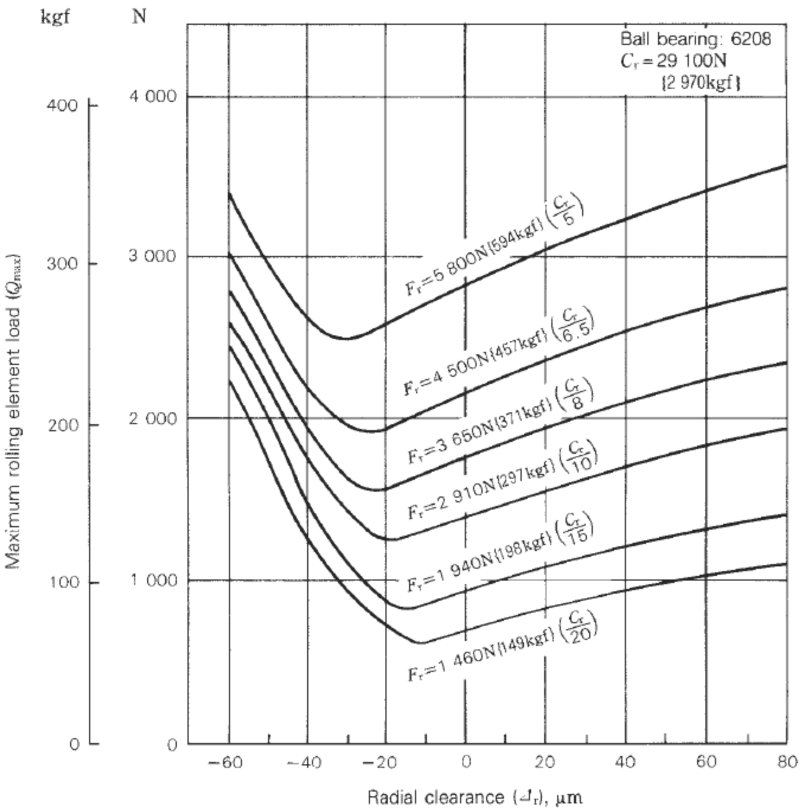
Content

Effect of bearing clearance

Roller load and bearing life



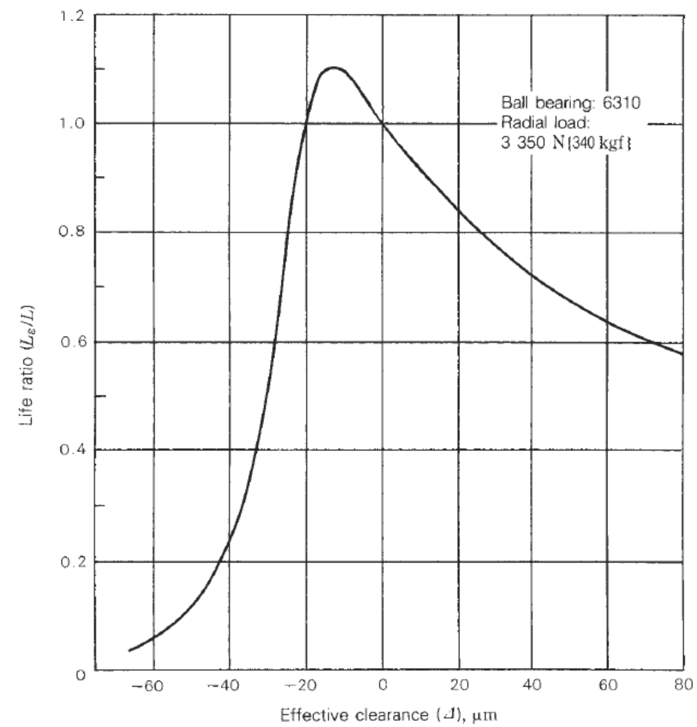


Fig. 1 Relation between effective clearance and bearing life for 6310 ball bearing

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

The bearing life is maximized for a slight pre-tension

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.

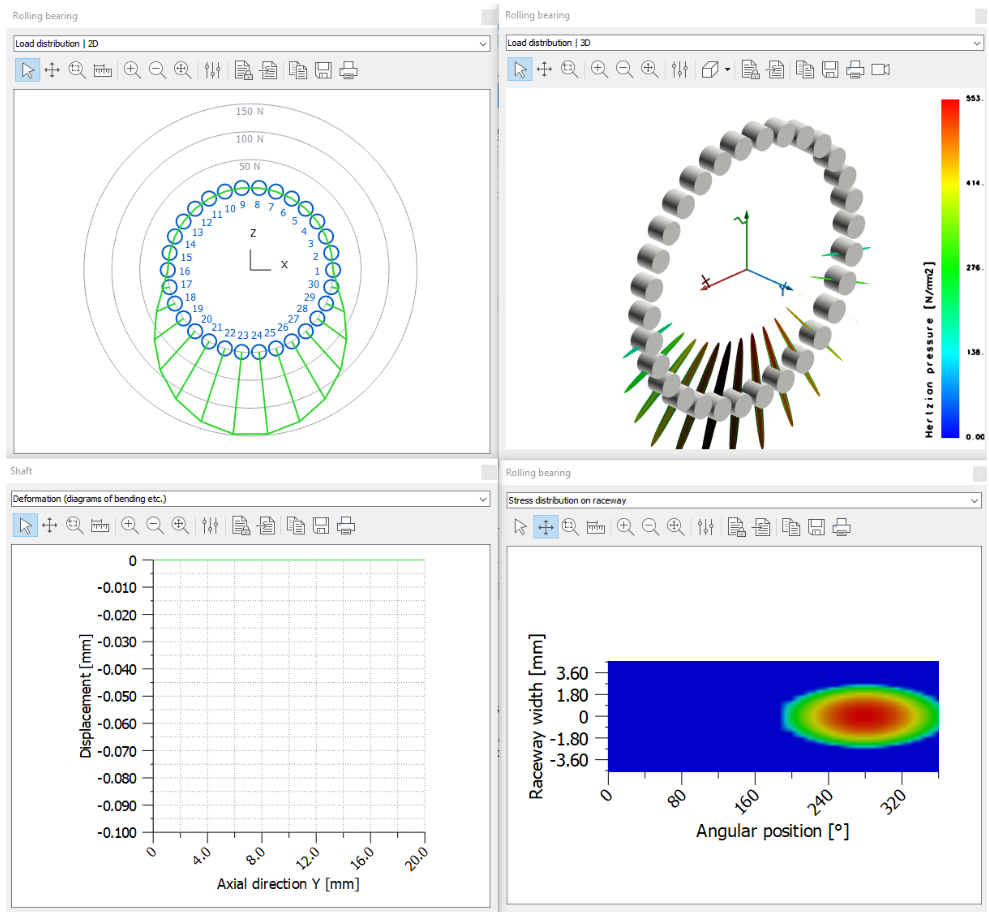
Bearing clearances, five groups, 2, N, 3, 4, 5 (N = normal), ISO 5753 or ANSI/ABMA 20

Basic rating life is assuming load distribution for zero clearance

Bearing operating clearance Pd = 0.00 µm and Fr = - Fz and pure radial load

Rolling element forces

Contact stresses on rolling elements



Inner ring displacement

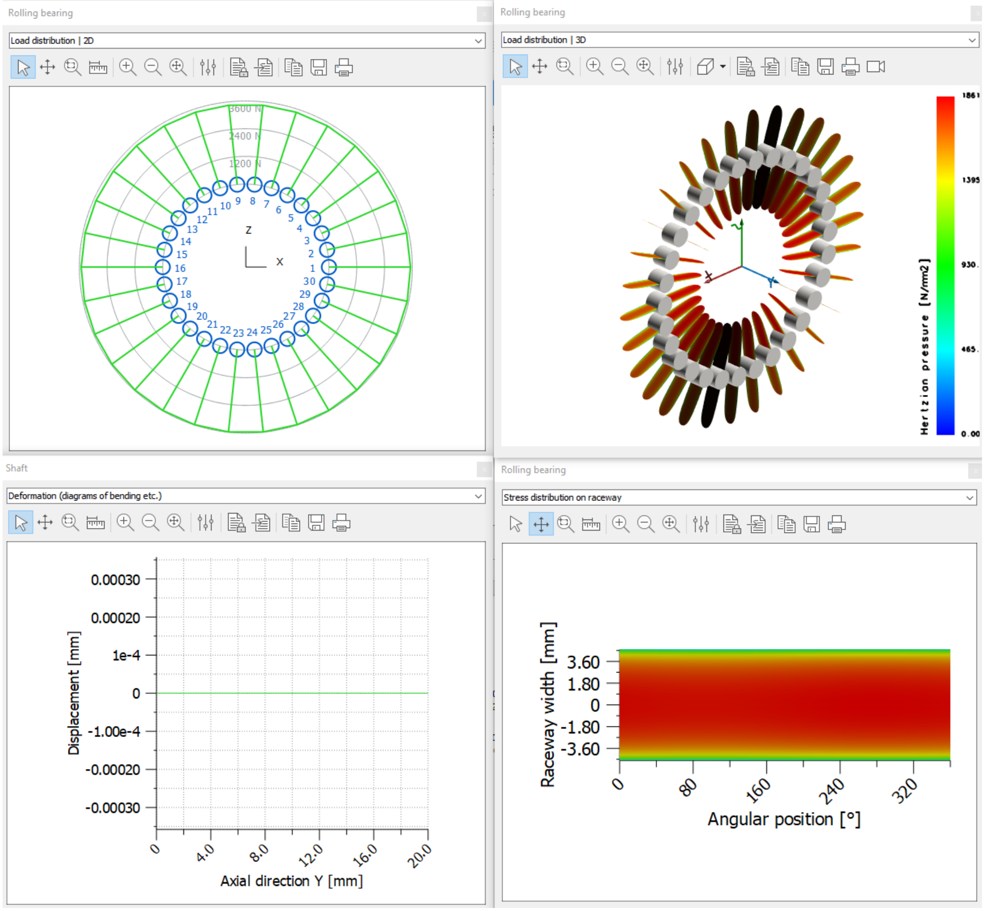
Stress distribution projected onto inner raceway

Influence on stress distribution

Bearing operating clearance Pd = -50.00 µm and Fr = - Fz and pure radial load

Rolling element forces

Contact stresses on rolling elements



Inner ring displacement

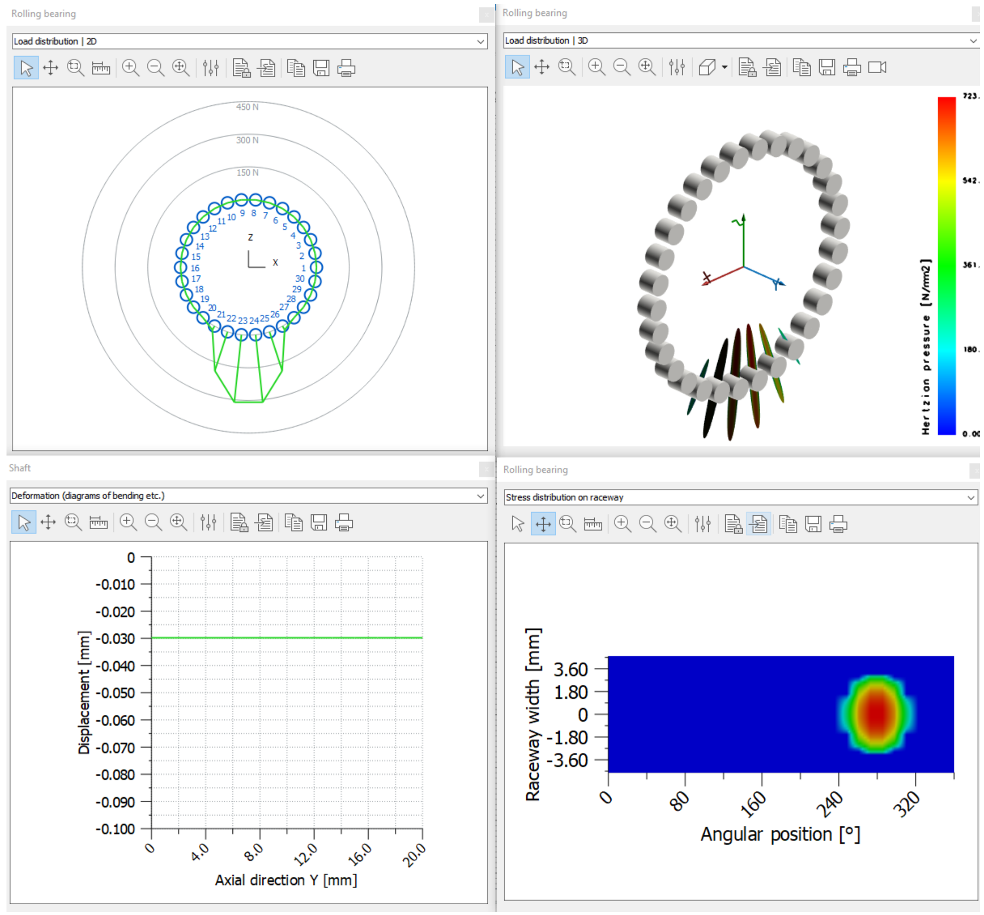
Stress distribution projected onto inner raceway

Influence on stress distribution

Bearing operating clearance Pd = +50.00 µm and Fr = - Fz and pure radial load

Rolling element forces

Contact stresses on rolling elements



Inner ring displacement

Stress distribution projected onto inner raceway

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Clearance

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

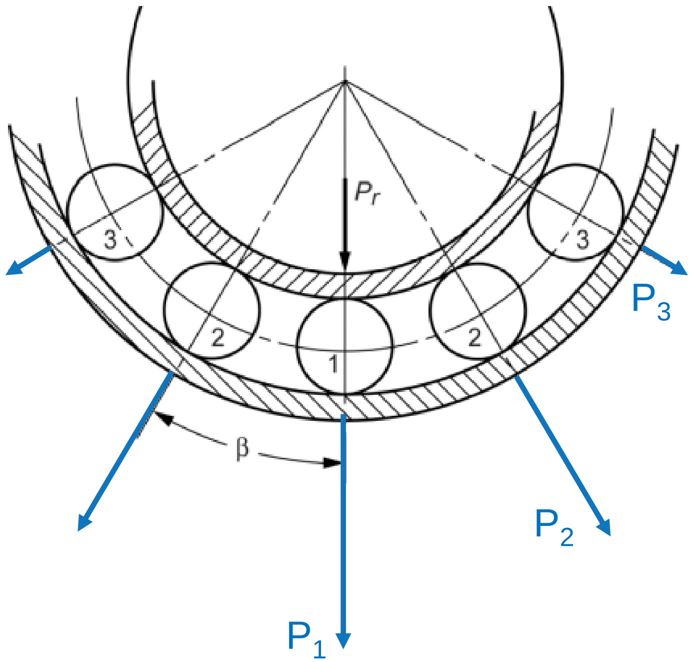
$$P_r = P_1 + 2P_2\cos\beta + 2P_3\cos 2\beta + \ldots + 2P_{n+1}\cos n\beta$$

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.

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

The highest load Pmax = P1 may be estimated as a function of the Stribeck number St, use St≈5 to account for some uneven load distribution.

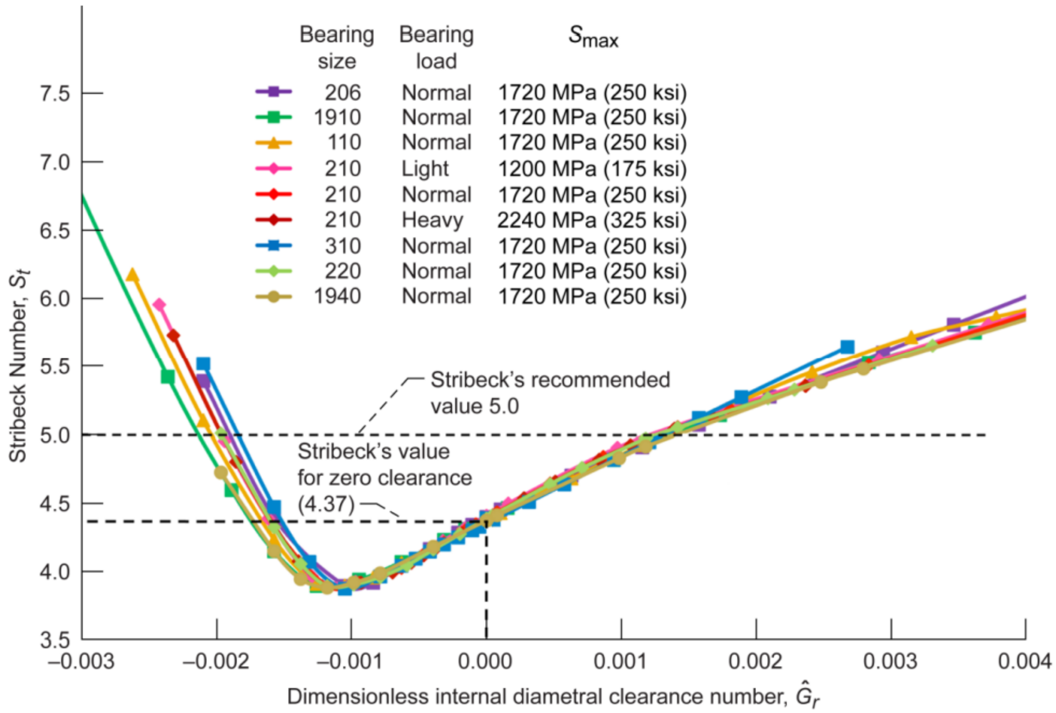
$$P_{max} = \frac{P_r}{Q} = \frac{S_t P_r}{z} \qquad S_t = \frac{z}{Q} = \frac{P_{max}}{P_r / z}$$



Stribeck number

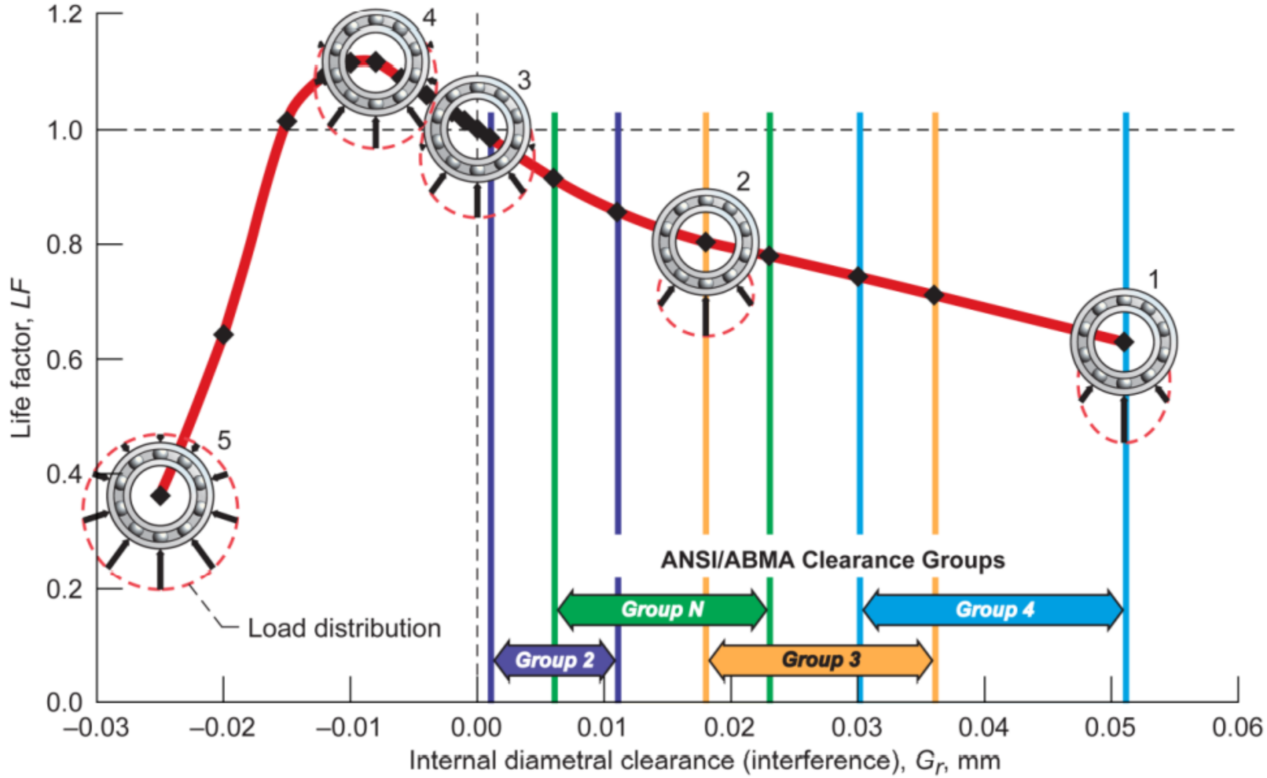
For deep groove ball bearings, Stribeck found S_t = 4.37 (4.08 for CRB) for a bearing of zero clearance and recommends S_t = 5.00. If a suitable pre-tension is applied, S_t drops to below S_t = 4.00

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



Bearing life vs. bearing operating clearance

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



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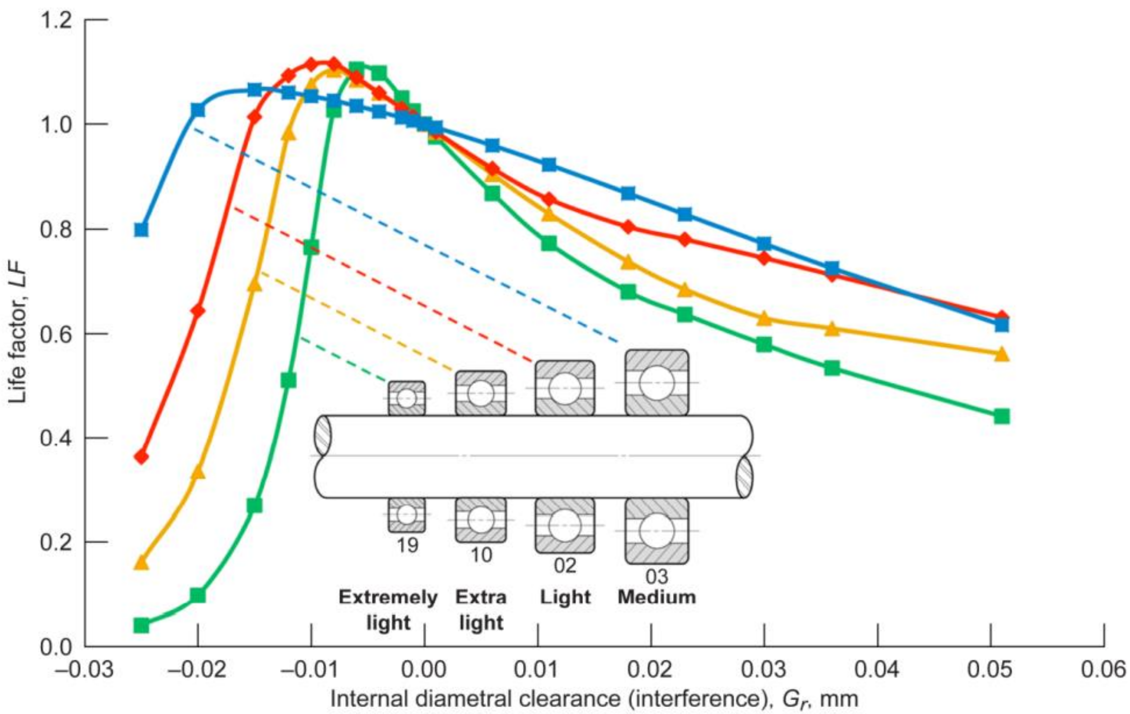
Effect of bearing size

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



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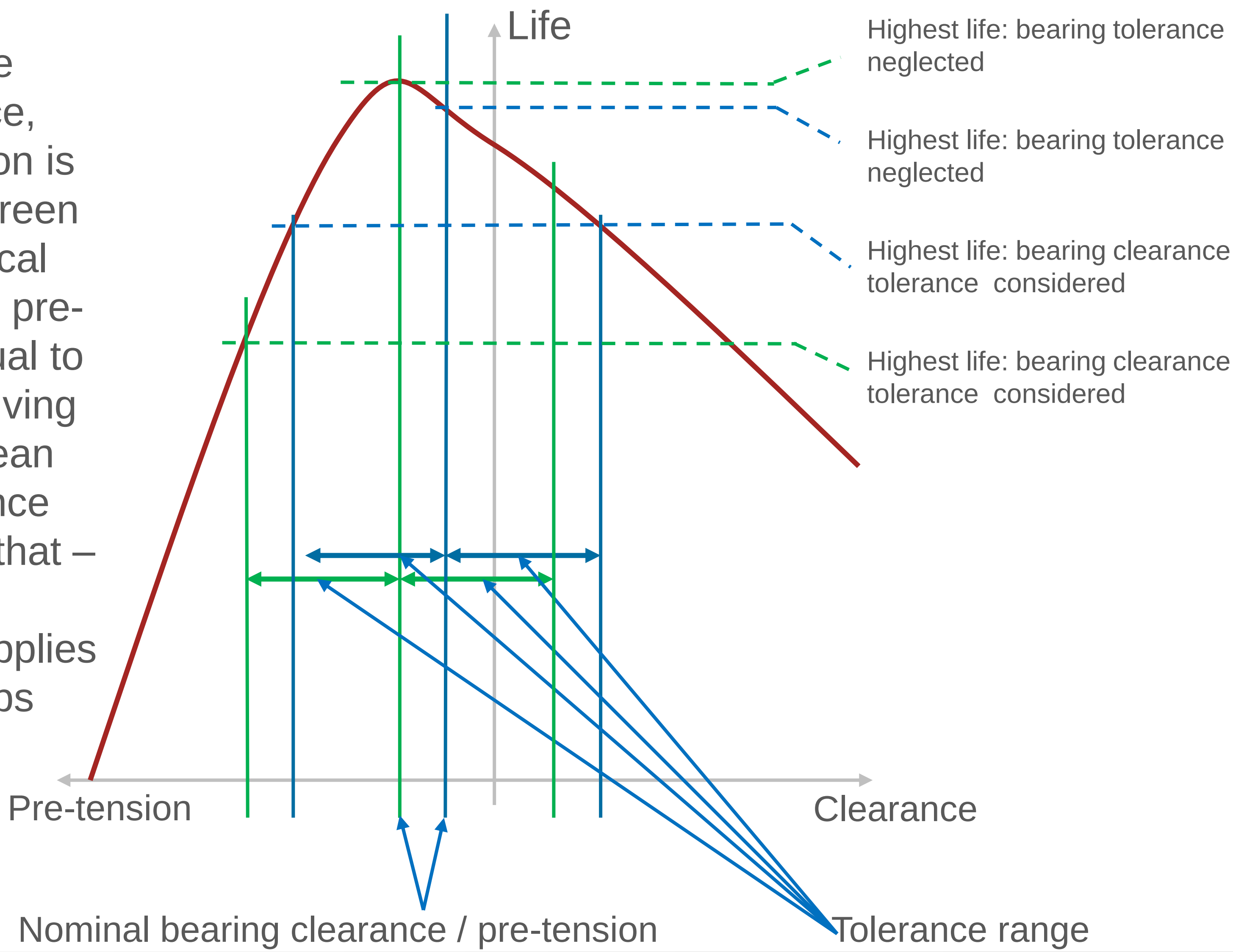
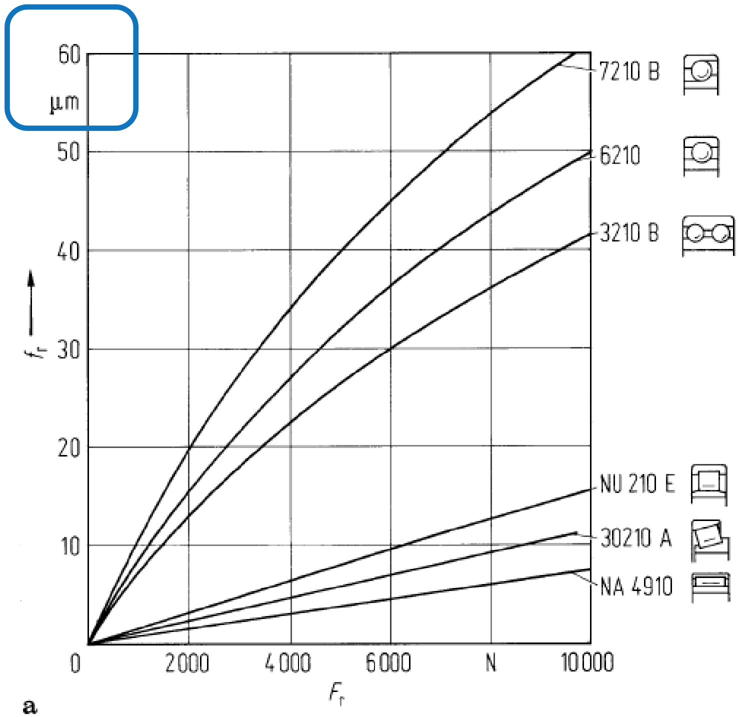
Assume tolerance band for clearance, optimal pre-tension is in the middle of green band (green vertical line). The optimal pre-tension is not equal to the pre-tension giving highest life for mean position in tolerance band. Reason is that – if lower end in tolerance band applies – bearing life drops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



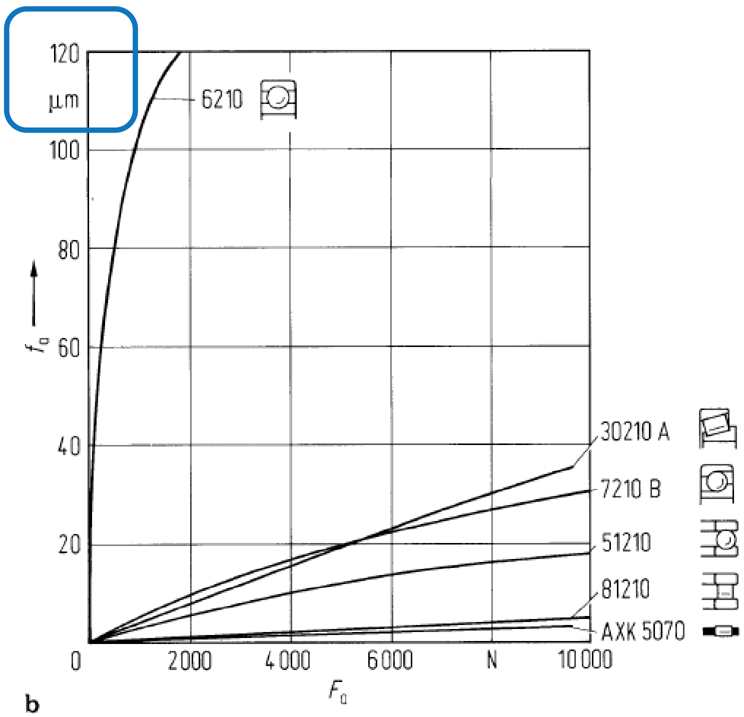
Bearing stiffness

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

For radial loads



For axial loads

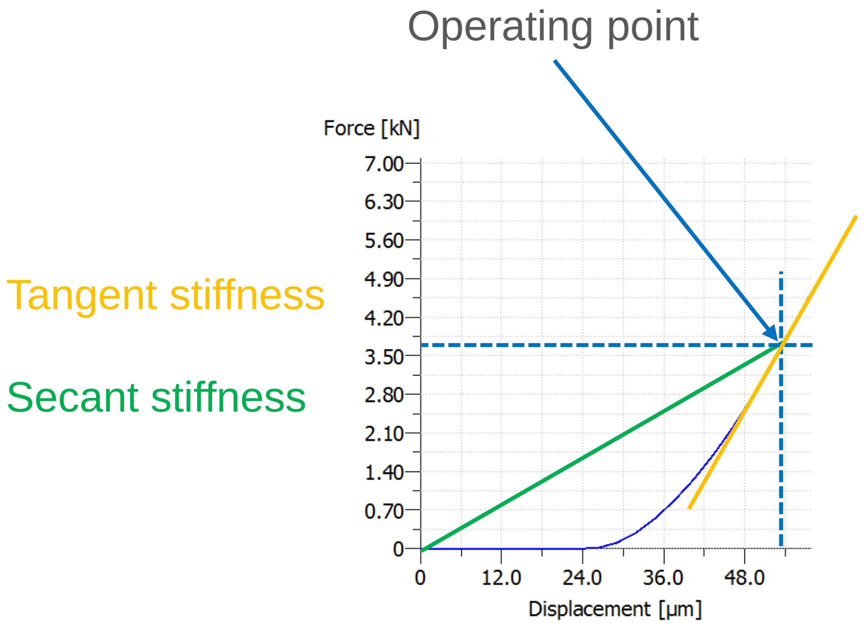


 / 17.5.2022, v2201 / Bearing calculation in KISSsoft /

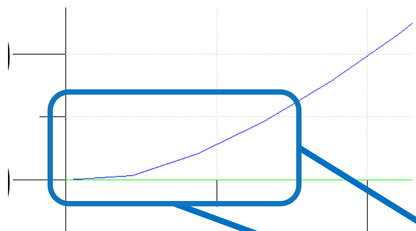
Bearing stiffness calculation based on inner geometry results in a 6x6 matrix for the operating point (note that the bearing stiffness is not linear). Obviously, the stiffness cy (bearing rotation around the shaft axis) is very small in practice and assumed to be zero in calculations.

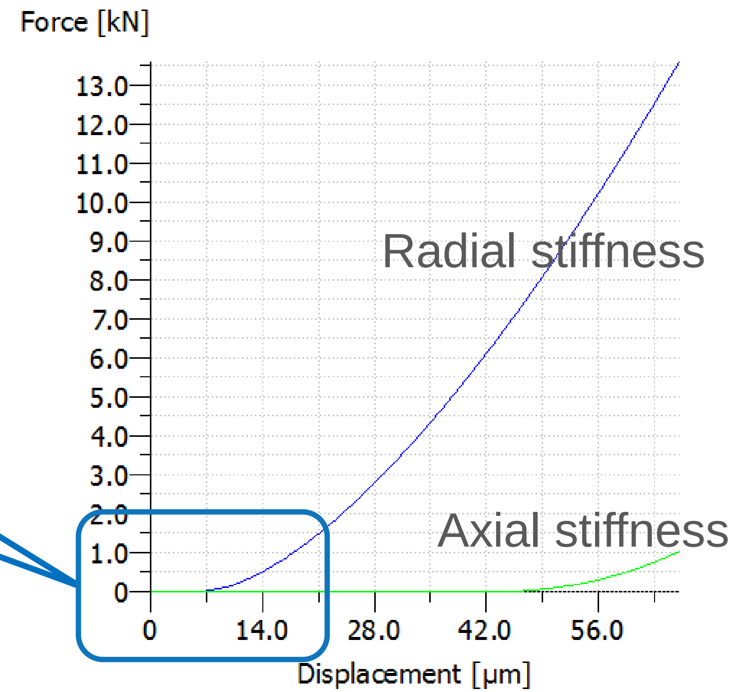
Note that stiffness may be given as stiffness in the operating point / tangent stiffness dF/du or a secant stiffness F/u.

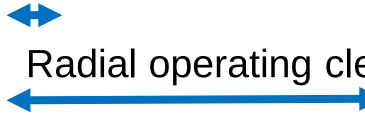
$$
\begin{array}{c|c}
 & \begin{array}{cccccc} u_x & u_y & u_z & r_x & r_y & r_z \end{array} \\
\begin{array}{c} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{array} &
\mathbf{K} = \begin{bmatrix}
\cdots & \cdots & \cdots & \cdots & 0 & \cdots \\
\cdots & \cdots & \cdots & \cdots & 0 & \cdots \\
\cdots & \cdots & \cdots & \cdots & 0 & \cdots \\
\cdots & \cdots & \cdots & \cdots & 0 & \cdots \\
0 & 0 & 0 & 0 & 0 & 0 \\
\cdots & \cdots & \cdots & \cdots & 0 & \cdots
\end{bmatrix}
\end{array}
$$



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 N/µm ,(dFr/dur)_eff = (Fr/ur) = 221.054 N/µm

dMr/drr = 41.488 Nm/mrad (724.098 Nm/°) ,(dMr/drr)_eff = (Mr/rr) = 1048.148 Nm/mrad (18293.635 Nm/°)

	[ux]	[uy]	[uz]	[rx]	[rz]
[Fx]	-229.702 N/µm	52.437 N/µm	9.348 N/µm	-45.307 N/mrad	1999.280 N/mrad
[Fy]	52.177 N/µm	-118.186 N/µm	-87.168 N/µm	-1494.234 N/mrad	-885.224 N/mrad
[Fz]	9.283 N/µm	-87.477 N/µm	-237.711 N/µm	-1974.145 N/mrad	44.847 N/mrad
[Mx]	-0.046 Nm/µm	-1.486 Nm/µm	-1.960 Nm/µm	-32.267 Nm/mrad	-1.718 Nm/mrad
[Mz]	1.986 Nm/µm	-0.880 Nm/µm	0.045 Nm/µm	-1.715 Nm/mrad	-30.080 Nm/mrad

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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	S0	L10h	Lnrh	pmax_i
Left (SKF N 1010 KPHA/HC5SP)	11.72	23979 h	10589 h	1836 N/mm^2
Between (SKF N 1010 KPHA/HC5SP)	3.04	267 h	694 h	2312 N/mm^2
Right (SKF N 1010 KPHA/HC5SP)	17.46	90498 h	289371 h	1155 N/mm^2

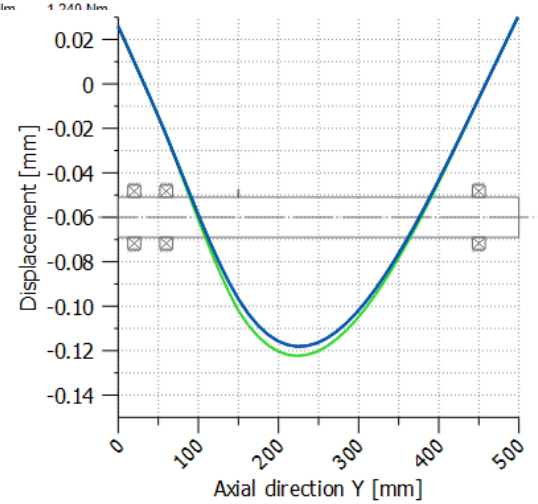
Bearing reaction force	Component	X	Y	Z	Rxz
Left (SKF N 1010 KPHA/HC5SP)	F	0.000 kN	-0.000 kN	-2.859 kN	2.859 kN
	M	50.877 Nm	0.000 Nm	0.000 Nm	50.877 Nm
Between (SKF N 1010 KPHA/HC5SP)	F	-0.000 kN	0.000 kN	11.014 kN	11.014 kN
	M	1.240 Nm	0.000 Nm	0.000 Nm	1.240 Nm
Right (SKF N 1010 KPHA/HC5SP)	F	0.000 kN	0.000 kN	1.919	
	M	-0.625 Nm	0.000 Nm	0.000	

Euler beam

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

Results	S0	L10h	Lnrh	pmax_i
Left (SKF N 1010 KPHA/HC5SP)	11.14	20229 h	10578 h	1836 N/mm^2
Between (SKF N 1010 KPHA/HC5SP)	3.00	255 h	658 h	2326 N/mm^2
Right (SKF N 1010 KPHA/HC5SP)	17.56	92276 h	295311 h	1152 N/mm^2

Bearing reaction force	Component	X	Y	Z	Rxz
Left (SKF N 1010 KPHA/HC5SP)	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
Between (SKF N 1010 KPHA/HC5SP)	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



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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	S0	L10h	Lnrh	pmax_i
Left (SKF 32004 X)	17.15	39681 h	3103 h	2975 N/mm²
Right (SKF 32004 X)	17.15	39681 h	3103 h	2975 N/mm²

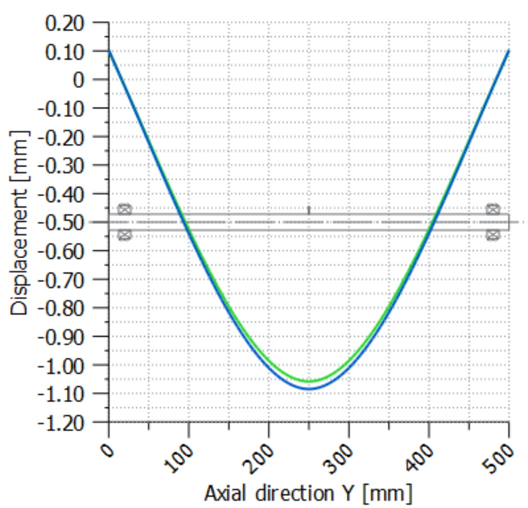
Bearing reaction force	Component	X	Y	Z	Rxz
Left (SKF 32004 X)	F	-0.000 kN	-1.469 kN	0.506 kN	0.506 kN
	M	12.673 Nm	0.000 Nm	0.000 Nm	12.673 Nm
Right (SKF 32004 X)	F	0.000 kN	1.469 kN	0.506 kN	0.506 kN
	M	-12.673 Nm	0.000 Nm	-0.000 Nm	12.673 Nm

Non-linear calculation

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

Results	S0	L10h	Lnrh	pmax_i
Left (SKF 32004 X)	16.51	34539 h	3151 h	2949 N/mm²
Right (SKF 32004 X)	16.51	34539 h	3150 h	2949 N/mm²

Bearing reaction force	Component	X	Y	Z	Rxz
Left (SKF 32004 X)	F	-0.000 kN	-1.536 kN	0.506 kN	0.506 kN
	M	12.987 Nm	0.000 Nm	0.000 Nm	12.987 Nm
Right (SKF 32004 X)	F	0.000 kN	1.536 kN	0.506 kN	0.506 kN
	M	-12.988 Nm	0.000 Nm	-0.000 Nm	12.988 Nm



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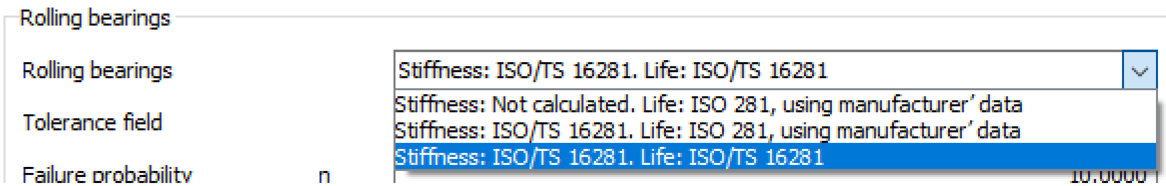
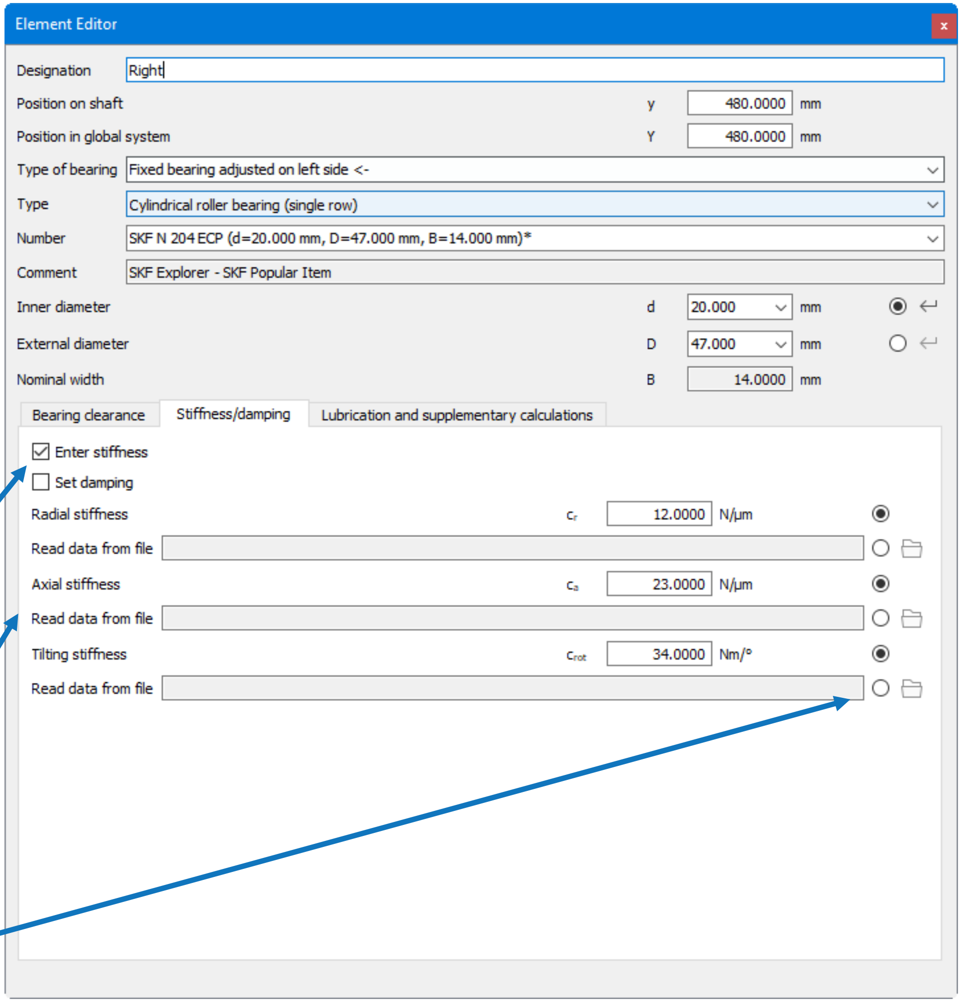
Calculation settings in tab “Basic data”



	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

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



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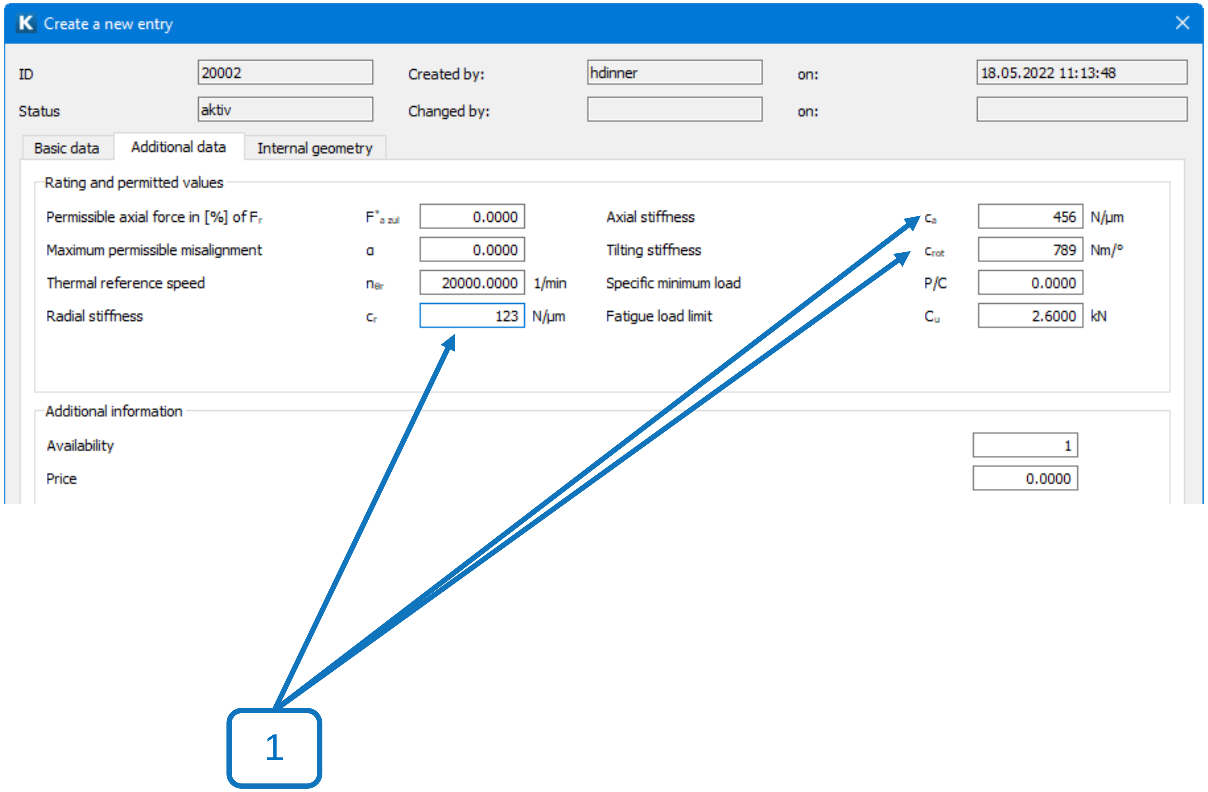
Input of stiffness values in database

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.



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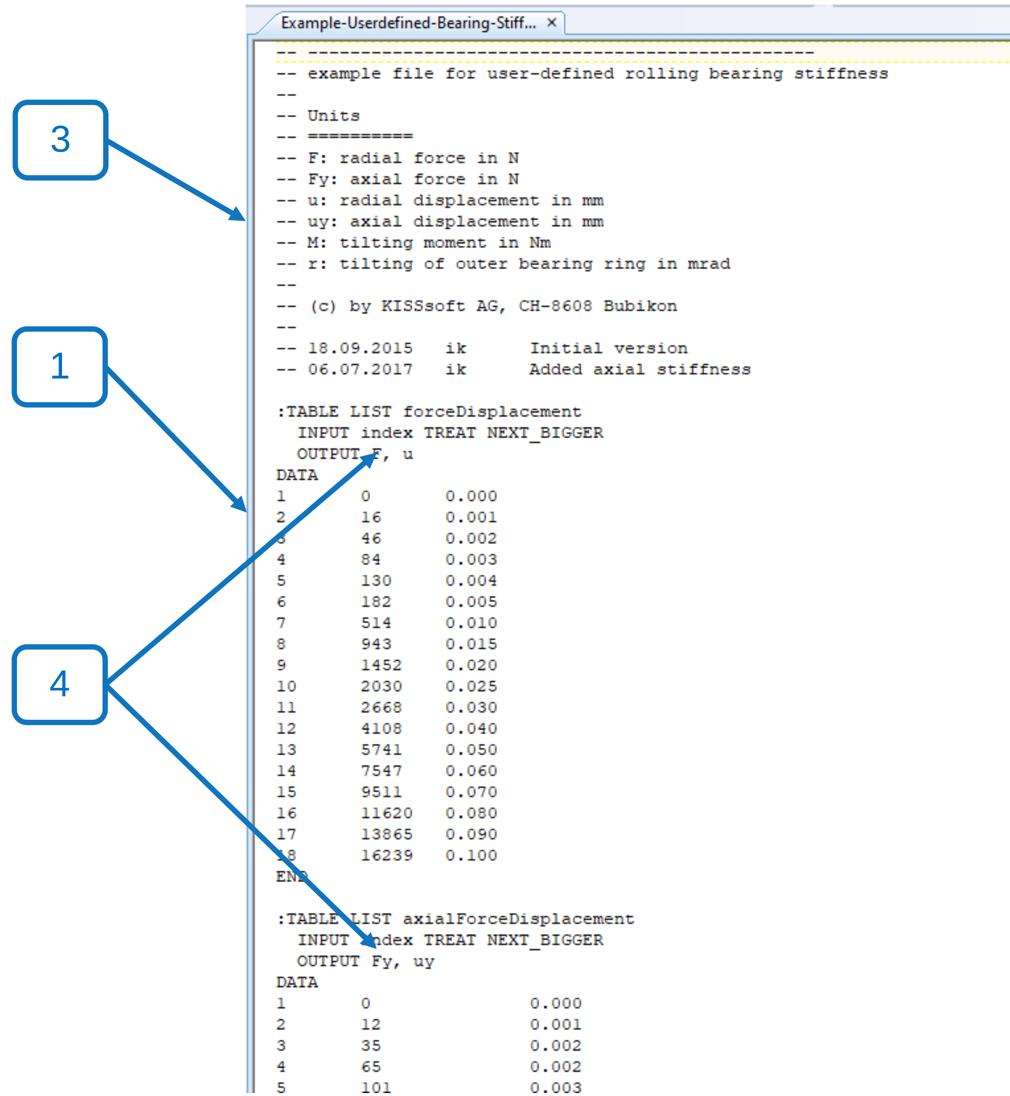
Input of stiffness values from file

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




```
-- ---------------------------------------------------
-- 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
```

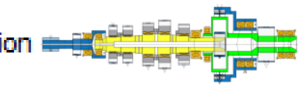
D6CFA2FD.dat

Content

Calculation reports

Main report, based on example

07 Truck Transmission



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 a1 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”

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15.15 Rolling bearing 'bz6'

Position (Y-coordinate)	[y]	385.00	mm
Dynamic equivalent load	[P]	0.02	kN
Static equivalent load	[P_0]	0.02	kN
Minimum EHL lubricant film thickness	[h_{min}]	0.598	µm
Life modification factor for reliability	[a_1]	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_B]	30.00	°C
Oil lubrication, on-line filtration, ISO4406 -/19/16			
Contamination factor	[e_C]	0.283	
Load ratio	[C/P]	3106.397	
Operating viscosity	[ν]	425.092	mm²/s
Reference viscosity	[$ν_1$]	52.514	mm²/s
Viscosity ratio	[κ]	8.095	
Life modification factor	[a_{ISO}]	50.000	
Fatigue load limit	[C_u]	21.200	kN
Basic bearing rating life	[L_{nh}]	> 1000000	h
Modified bearing rating life	[L_{nmh}]	> 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_u]	21.200	kN
Reference rating life	[L_{nrh}]	> 1000000	h
Modified reference rating life	[L_{nrmh}]	> 1000000	h
Effective static safety factor	[S_{0w}]	732.24	
Static safety factor	[S_{0ref}]	9999.99	
Static equivalent load	[P_{0ref}]	0.00	kN
Bearing reaction force	[F_x]	-0.000	kN
Bearing reaction force	[F_y]	0.000	kN
Bearing reaction force	[F_z]	-0.024	kN
Bearing reaction force	[F_r]	0.024	kN
Inclination angle	[$α_{Fr}$]	-90.000	°
Bearing reaction moment	[M_x]	-0.062	Nm
Bearing reaction moment	[M_y]	0.000	Nm
Bearing reaction moment	[M_z]	-0.000	Nm
Bearing reaction moment	[M_r]	0.062	Nm
Inclination angle	[$α_{Mr}$]	-180.000	°
Displacement of bearing	[u_x]	-0.000	µm
Displacement of bearing	[u_y]	0.202	µm
Displacement of bearing	[u_z]	28.992	µm
Displacement of bearing	[u_r]	28.992	µm
Inclination angle	[$α_{ur}$]	90.000	°
Misalignment of bearing	[r_x]	0.009	mrad
		-3.321	mrad
		0.000	mrad
		0.009	mrad
		0.000	mm
		0.452	Nm
		0.009	Nm

Moment of friction, seals	[M_{seal}]	0.000	Nm
Moment of friction for seals determined according to SKF main catalog 17000/1 EN:2018			
Moment of friction flow losses	[M_{drag}]	0.000	Nm
Torque of friction	[M_{loss}]	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 µbl=0.15.
The factors used to calculate the torque loss have been assumed for this bearing.

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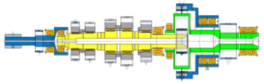
Report «Rolling bearing», based on example



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

Additional details compared to main report are included.

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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_u]	9.800	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}]	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 (clc

5.1 Operating bearing clearance

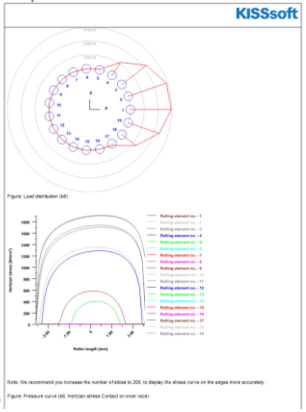
5.1.1 Inputs

Nominal bearing clearance	[-]	ISO 5753-1:2009 C2	
Nominal diametral clearance	[Pd0]	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	[Rzi]	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	[ni]	975.610	1/min
Shaft temperature	[Ts]	20.0	°C
Temperature of inner ring	[Ti]	20.0	°C
Diameter	[dsoT]	79.985	mm
Diameter	[dbiT]	79.993	mm
Interference	[Uwi]	0.000	µm
Embedding	[si]	0.000	µm
Hertzian pressure	[pi]	0.000	N/m²
Effective interference (20.0 (°C))	[Uwi_eff]	0.000	µm
Diametral clearance change	[ΔPdi]	-0.000	µm

. . .



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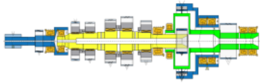
Report «Rolling bearing clearance, load spectrum»

07 Truck Transmission



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.

1

2

3

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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	[dbi]		39.990/ 39.995/ 40.000	mm
Diameter of inner ring	[dri]		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	[Ts]		20.0	°C	
Temperature of inner ring	[Ti]		69.0	°C	
Diameter	[dsoT]		40.034	mm	
Diameter	[dbiT]		40.018	mm	
Interference	[Uwi]		16.463	µm	
Embedding	[si]		1.920	µm	
Hertzian pressure	[p_i]		21.664	N/m²	
Effective interference (20.0 (°C))	[Uwi_eff]		14.543	µm	
Bearing clearance change	[ΔPdi]		-43.886	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	[DhiT]		90.017	mm	
Interference	[Uwo]		6.013	µm	
Embedding	[so]		3.200	µm	
Hertzian pressure	[p_o]		0.572	N/m²	
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	(ΔPdi + ΔPdo - 2 * ΔDw)
Operating bearing clearance - Radial	[P_d]		9.164	µm	(Pd0 + ΔPd)

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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

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_u]	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	[ν]	425.1	mm²/s
	[ν_1]	17.6	mm²/s
	[κ]	24.205	
	[κ_{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_{nm}]	898	10^6
	[L_{nmh}]	15266	h

2

$F_a/F_r(0.553\ N) > e_0(0\ N)$: $X_0 = 1.000$, $Y_0 = 2.80$, $P_0 = 8465$ N ($F_r = 3320$ N, $F_a = 1837$ N)
$P_0 = 8465$ N, $S_0 = 12.8$
$F_a/F_r(0.553\ N) > e(0.240\ N)$: $X = 0.670$, $Y = 4.20$, $P = 9942$ N ($F_r = 3320$ N, $F_a = 1837$ N)
$\nu = 425$, $\nu_1 = 17.6$, $\kappa = 24.2$, $\kappa_{calc} = 4.00$
$C_u = 12$ kN, $e_c = 0.500$, $a_{ISO} = 6.00$
$P = 9942$ N, $P/C = 0.0929$, $P/C_{min} = 0.0200$
$L_{10h} = 46810$ h, $a_{ISO} = 6.00$, $L_{nmh} = 280824$ h

-- LS [7]
$F_a/F_r(0.554\ N) > e_0(0\ N)$: $X_0 = 1.000$, $Y_0 = 2.80$, $P_0 = 9588$ N ($F_r = 3758$ N, $F_a = 2082$ N)
$P_0 = 9588$ N, $S_0 = 11.3$
$F_a/F_r(0.554\ N) > e(0.240\ N)$: $X = 0.670$, $Y = 4.20$, $P = 11263$ N ($F_r = 3758$ N, $F_a = 2082$ N)
$\nu = 425$, $\nu_1 = 17.6$, $\kappa = 24.2$, $\kappa_{calc} = 4.00$
$C_u = 12$ kN, $e_c = 0.500$, $a_{ISO} = 4.68$
$P = 11263$ N, $P/C = 0.105$, $P/C_{min} = 0.0200$
$L_{10h} = 30883$ h, $a_{ISO} = 4.68$, $L_{nmh} = 144612$ h

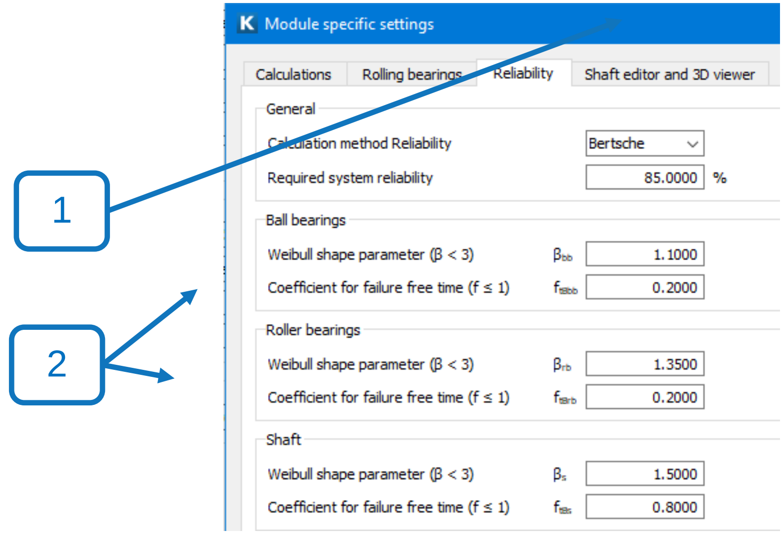
-- LS [6]
$F_a/F_r(0.555\ N) > e_0(0\ N)$: $X_0 = 1.000$, $Y_0 = 2.80$, $P_0 = 10711$ N ($F_r = 4195$ N, $F_a = 2327$ N)
$P_0 = 10711$ N, $S_0 = 10.1$
$F_a/F_r(0.555\ N) > e(0.240\ N)$: $X = 0.670$, $Y = 4.20$, $P = 12584$ N ($F_r = 4195$ N, $F_a = 2327$ N)
$\nu = 425$, $\nu_1 = 17.6$, $\kappa = 24.2$, $\kappa_{calc} = 4.00$
$C_u = 12$ kN, $e_c = 0.500$, $a_{ISO} = 3.81$

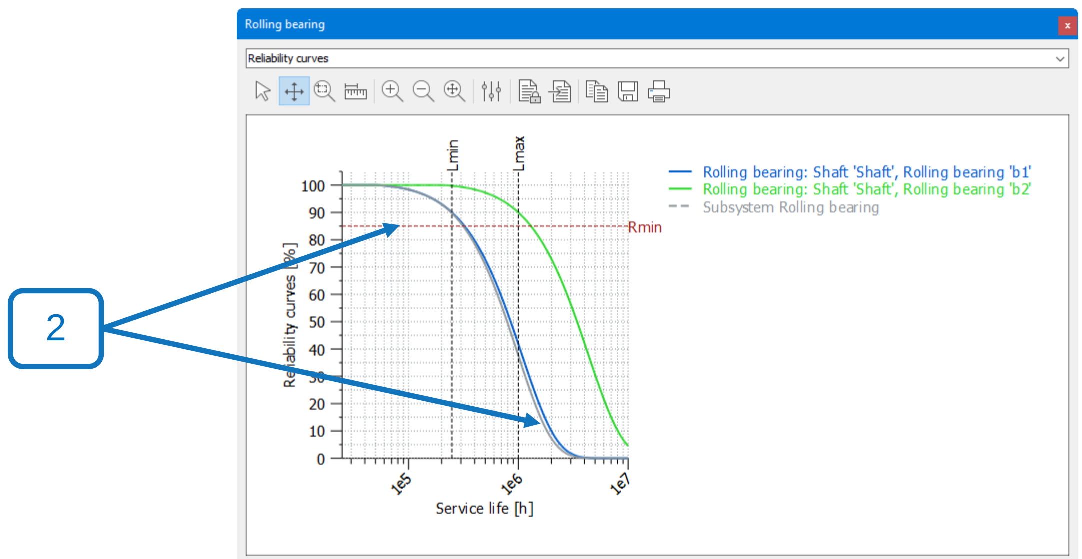
Content

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.





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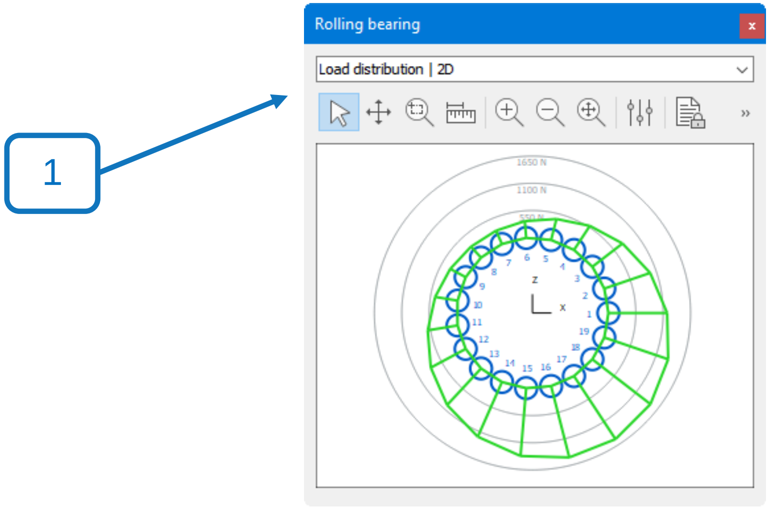
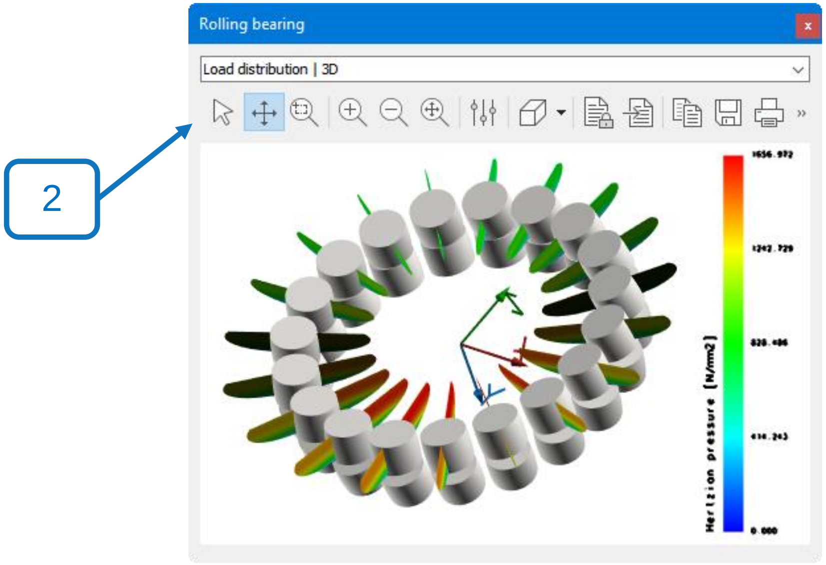
Load distribution

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.

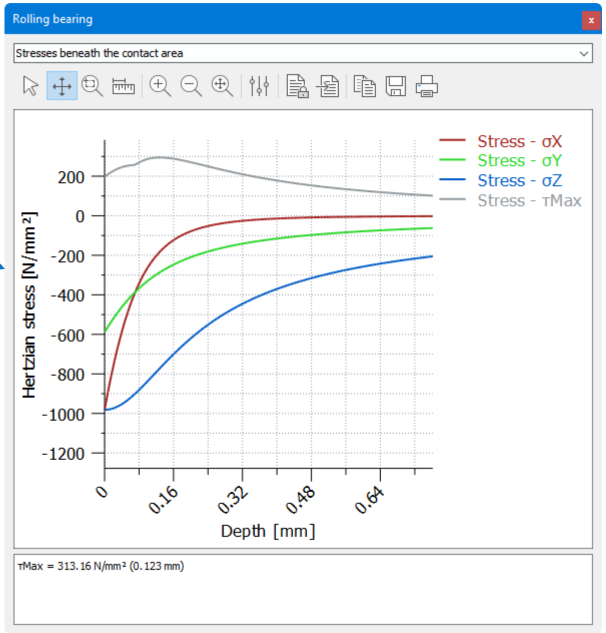




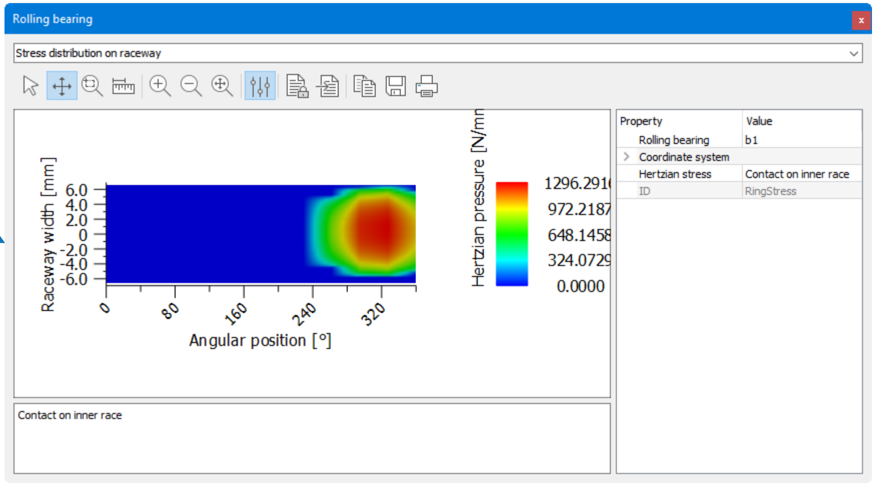
Raceway stress

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



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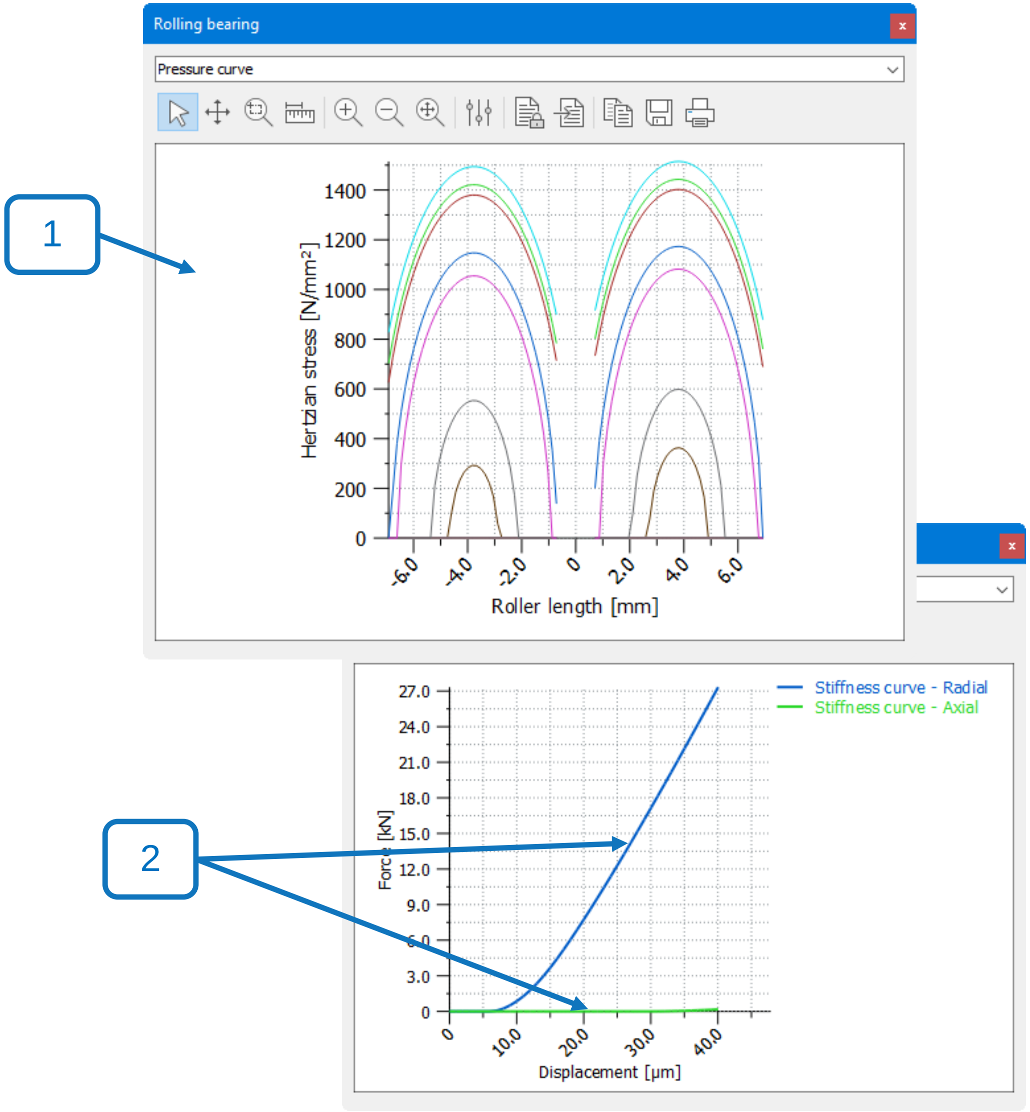
Raceway stress and stiffness

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.

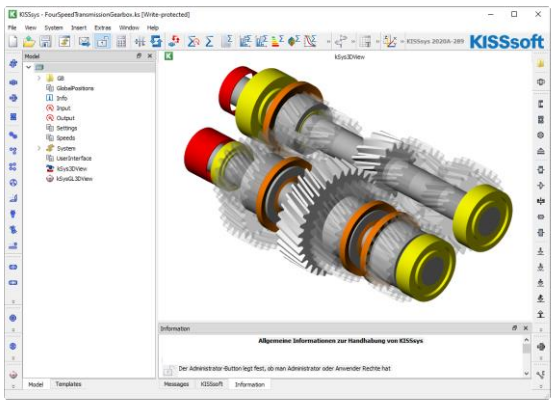


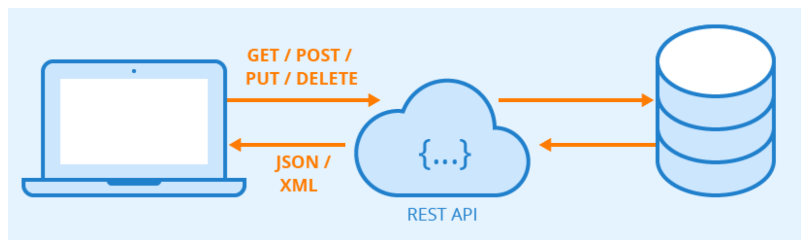
Content

SKF cloud calculations

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

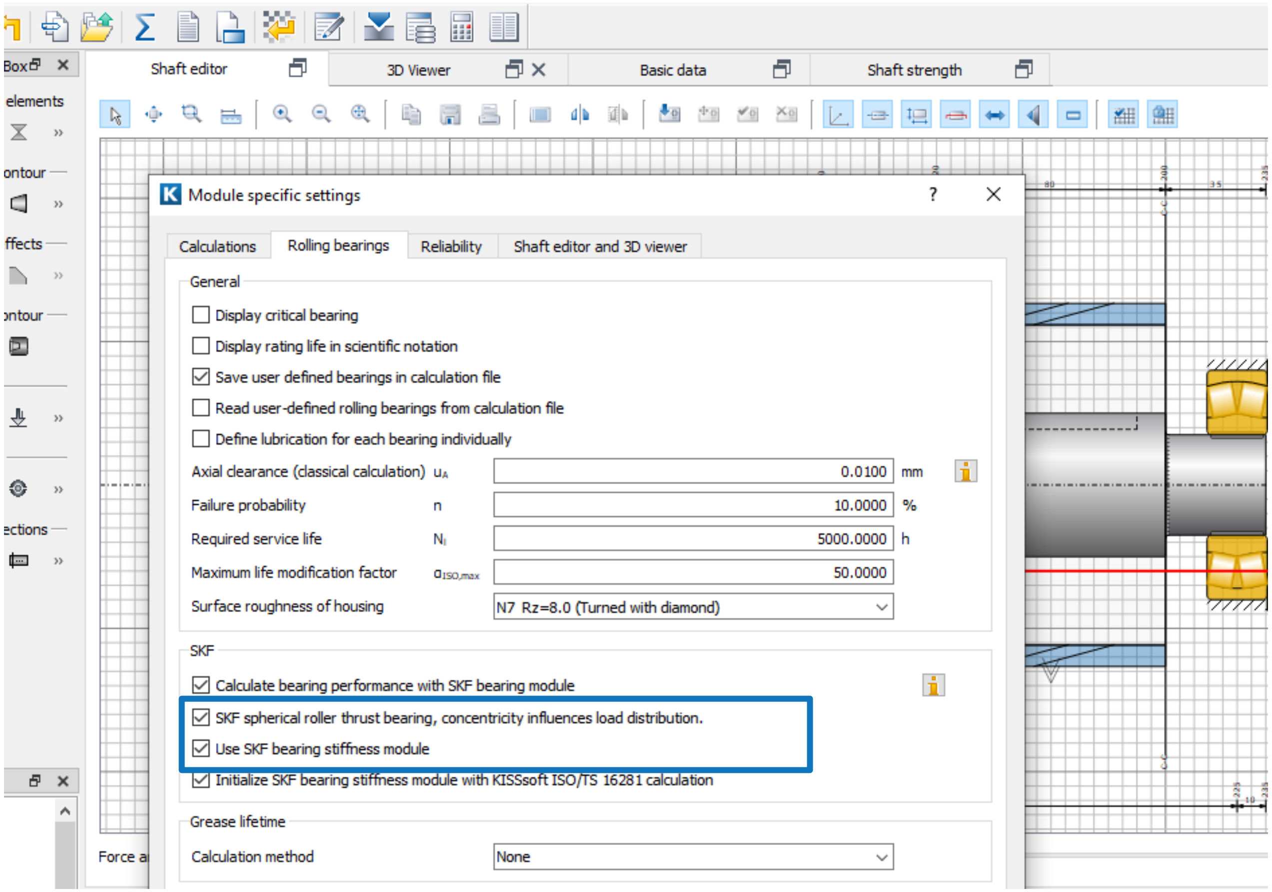
Bearing specs | Clearance, … | ux, uy, uz, rx, rz





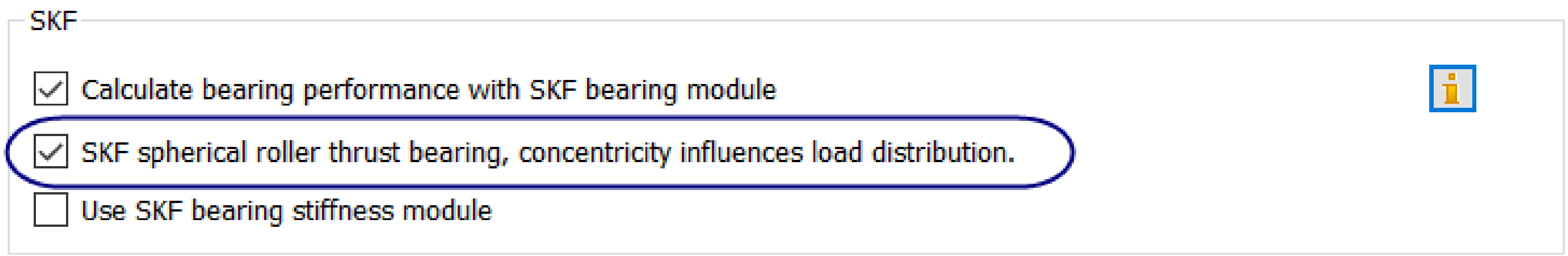
Stiffness matrix | Fx, Fy, Fz, Mx, Mz | Lnrh, Lmnrh, …

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 multiplicated with a factor of 0.88.



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	[ν]	424.000	mm²/s
Reference viscosity	[ν_1]	14.100	mm²/s
Viscosity ratio	[κ]	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

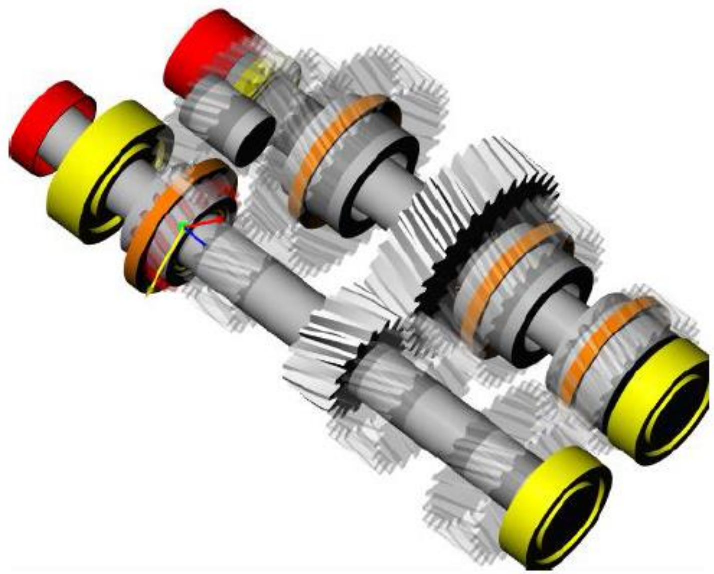
Results of the calculation with the SKF Bearing Module

Minimum equivalent load	[F_r]	324.000	N
Take weight into account	[-]	yes	
Rotational frequency of inner ring	[f_i]	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_{ip}]	177.000	Hz
Over-rolling frequency of outer ring	[f_{op}]	133.000	Hz
Over-rolling frequency of rolling element	[f_{rp}]	111.000	Hz
Total frictional moment	[M]	2060.000	Nmm
Rolling frictional moment	[M_{rr}]	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_p]	0.610	
Adjusted factor for viscosity	[f_v]	0.840	
Load ratio	[C/P]	6.070	
Operating viscosity	[ν]	424.000	mm²/s
Reference viscosity	[ν_1]	14.100	mm²/s
Viscosity ratio	[κ]	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

KISSsoft

Content

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

SKF company profile

Quick Facts

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

Vision

A world of reliable rotation

Mission

The undisputed leader in the bearing business

Half-year results 2019

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

SKF Bearing Module

SKF bearing module in KISSsoft

In short:

1. Enable SKF calculation by one-time registration

2. Perform modelling & analysis as usual

Results of bearing calculation with the SKF bearing module

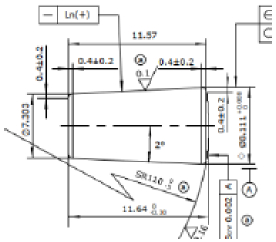
Load conditions	[C/P]	14.003
Operating viscosity (mm²/s)	[v]	51.794
Viscosity ratio	[κ]	3.589
Impurity characteristic quantity	[ec]	0.500
Life modification factor	[aSKF]	18.310
Life modification factor for reliability	[a1]	1.000
Basic rating life (h)	[Lnh]	46600.000
SKF rating life (h)	[Lnmh]	854000.000

3. SKF results are displayed for SKF bearings

Available in KISSsoft 2019 bearing and shaft module

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

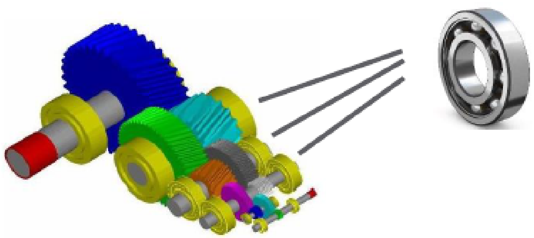
SKF

KISSsoft

SKF bearing module in KISSsoft

KISSsoft model

Bearing rating life



Basic ISO 281 (L_{10})
- ✓ Speed & loads

Modified rating life
- ✓ Speed & loads
- ✓ Lubrication
- ✓ Contamination

ISO 281:2007 modified rating life (L_{10m})
- ✓ Standard bearing range

SKF Bearing Module

SKF rating life (L_{10m})
- ✓ Standard range, incl.
  - ✓ latest tribology findings
  - ✓ direct access to live database
- ✓ SKF Explorer range
- ✓ Hybrid bearing range (new life method GBLM)
- ✓ …. and more to come

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.”

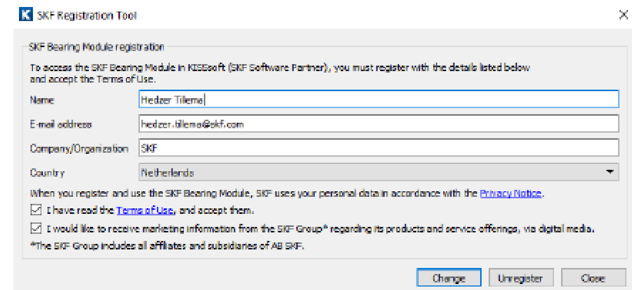
“SKF rating life seems more optimistic than ISO rating life, therefore we can sometimes select a smaller size bearing.”

SKF bearing module in KISSsoft

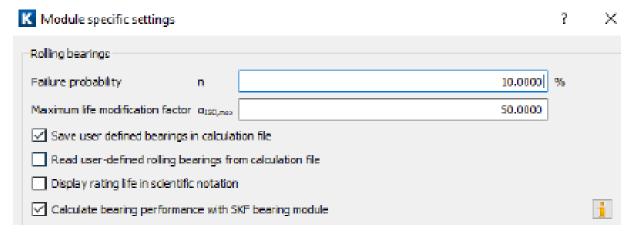
Simply activate it in three steps:

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

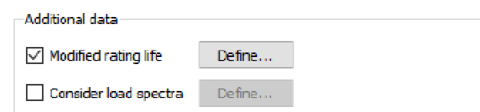
1



2

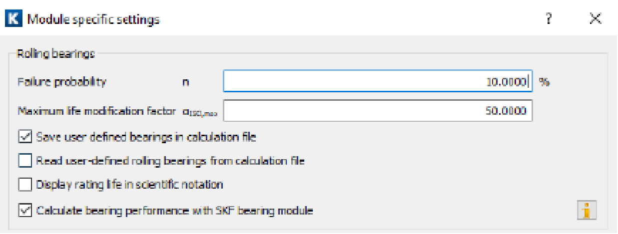


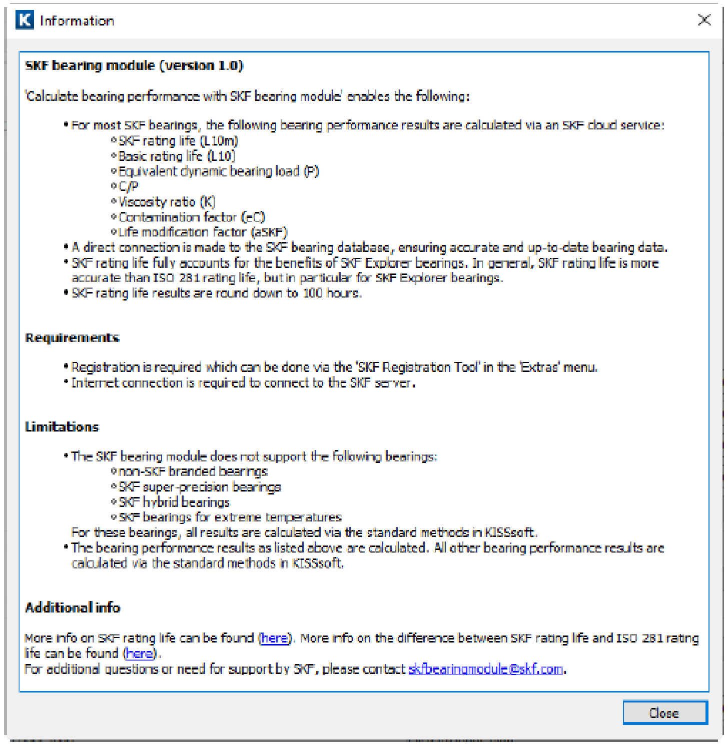
3



SKF bearing module in KISSsoft

More info behind [i] button





SKF bearing module in KISSsoft

SKF rating life and ISO 281 rating life in results overview

Notice the difference!

Calculation with the SKF Bearing Module						
Bearing rating life		Lnh	Lnmh			
Roller bearing 1		6930 h	30200 h			
Roller bearing 2		45700 h	402000 h			
Calculation according to ISO 281						
Bearing rating life	S0	Lnh	Lnmh	Lnrh	Lnmrh	pmax_i
Roller bearing 1	7.20	6937 h	15311 h	50499 h	365257 h	1590 N/mm²
Roller bearing 2	9.72	45759 h	198121 h	204690 h	> 1000000 h	1401 N/mm²

SKF results displayed in a separate frame in report

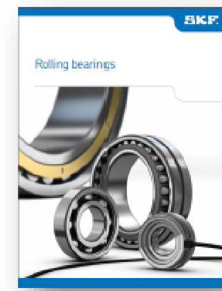
Results of the calculation with the SKF Bearing Module			
Load ratio	[C/P]	6.070	
Operating viscosity	[ν]	424.334	mm²/s
Reference viscosity	[$ν_1$]	14.150	mm²/s
Viscosity ratio	[κ]	29.988	
Contamination characteristic quantity	[e_c]	0.470	
Life modification factor	[a_{SKF}]	4.360	
Basic rating life	[L_{nh}]	6930.00	h
SKF rating life	[L_{nmh}]	30200.00	h

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

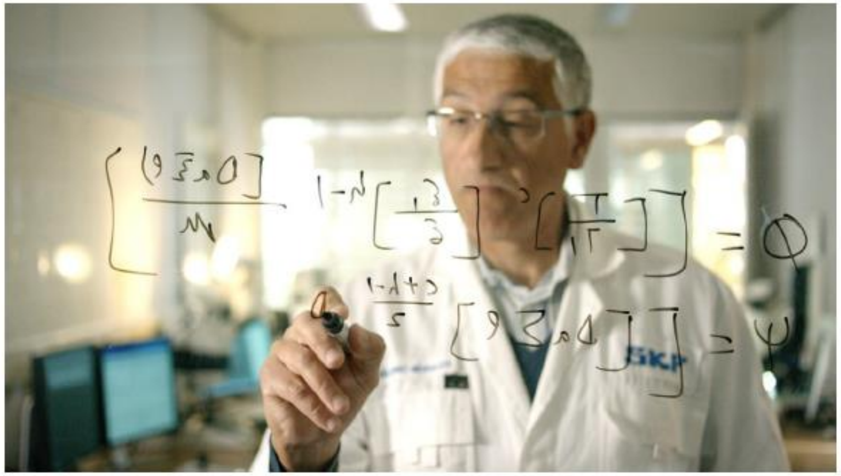
‘Step by step you can get closer into the heart of the bearing supplier’



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

SKF

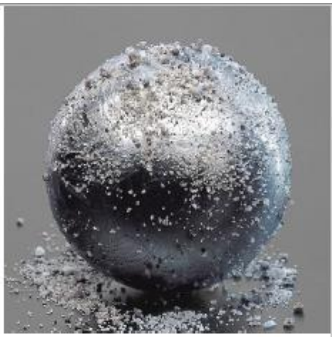
KISSsoft



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"

SKF

KISSsoft

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

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Rolling bearings — Dynamic load ratings and rating life

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.

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

SKF

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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

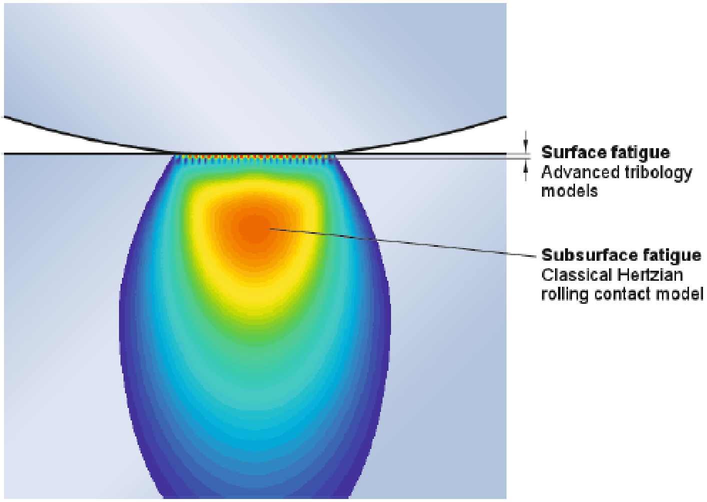
What cannot yet be quantified in common life models

- **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)



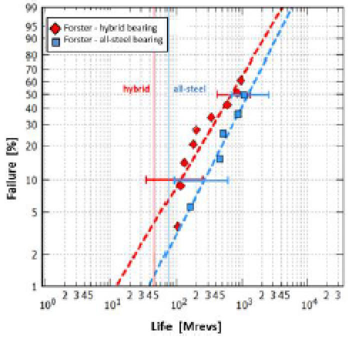
$$L_{nGM} = a_1 \left[\frac{1}{L_{n.surf}} + \frac{1}{L_{n.sub}} \right]^{-1/e}$$

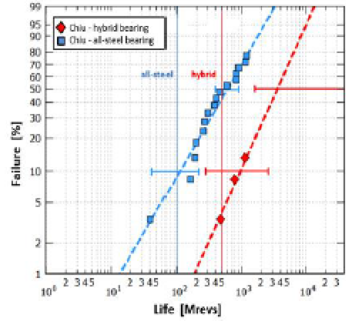
L_{nGM} = SKF GM rating life (at 100 – n% reliability) [Mrev],
a_1 = life adjustment factor for reliability
$L_{n.surf}$ = SKF GM surface rating life (at 100 – n% reliability) [Mrev],
$L_{n.sub}$ = SKF GM subsurface rating life (at 100 – n% reliability) [Mrev],

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

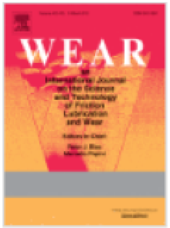
Benefits of Hybrid Bearings in severe conditions
http://evolution.skf.com/benefits-of-hybrid-bearings-in-severe-conditions/

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

ELSEVIER



EVOLUTION
BUSINESS AND TECHNOLOGY FROM SKF

SKF

KISSsoft

Content

TIMKEN cloud calculations

Content

Further topics

Summary

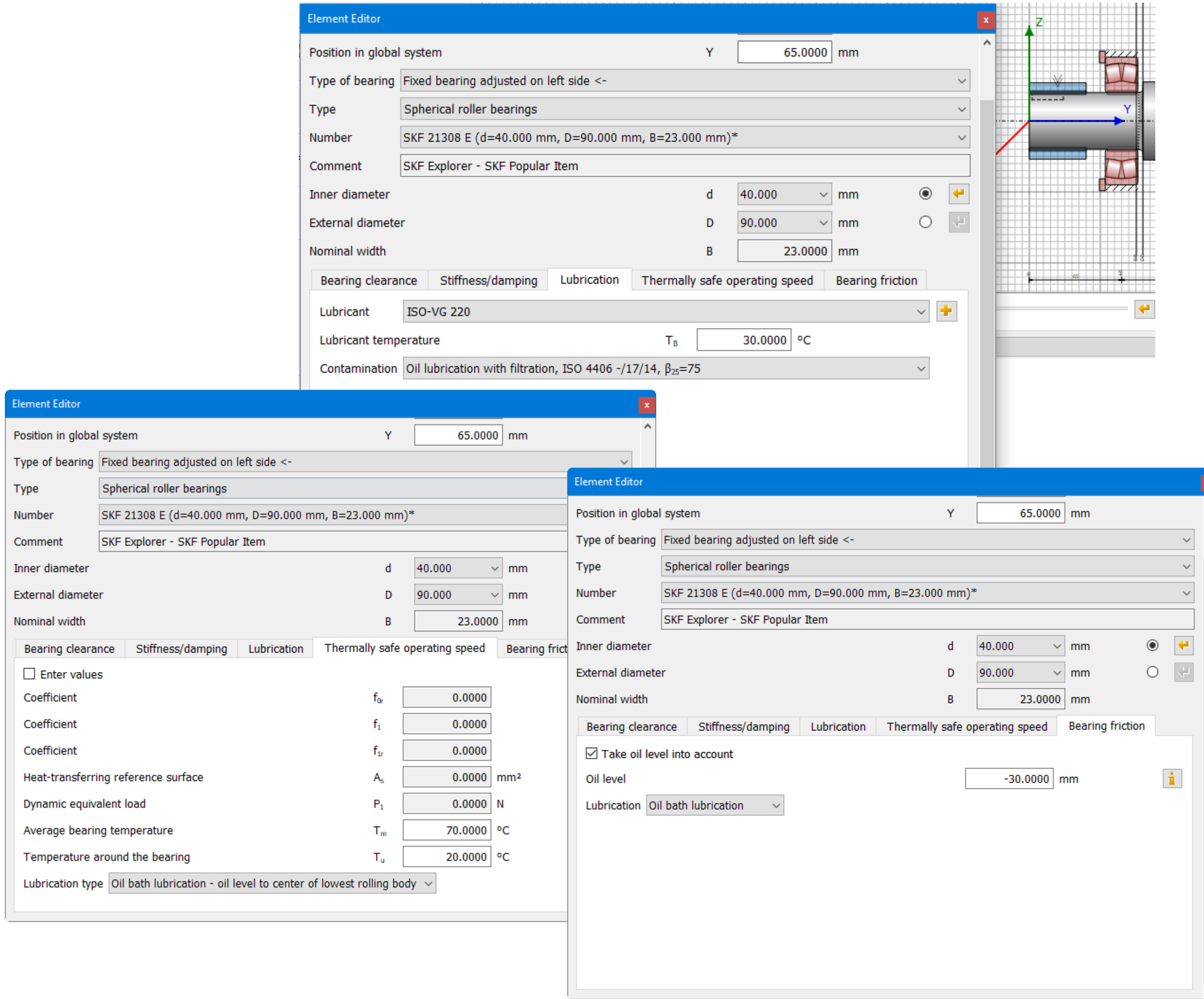
- Lubrication can be defined for each bearing individually
- Bearing friction calculation parameters can be defined for each bearing individually
- All thermally safe operating speed parameters can be defined for each bearing separately
- Temperature of outer ring, inner ring and rolling elements can be defined as own input
- Added tolerance table data for axial/thrust bearings
- Allow to consider tolerances for spherical roller thrust bearings bearings
- Use bearing pitch diameter Dpw 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



KISSsoft

Content

KISSsoft usage

Module specific settings

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

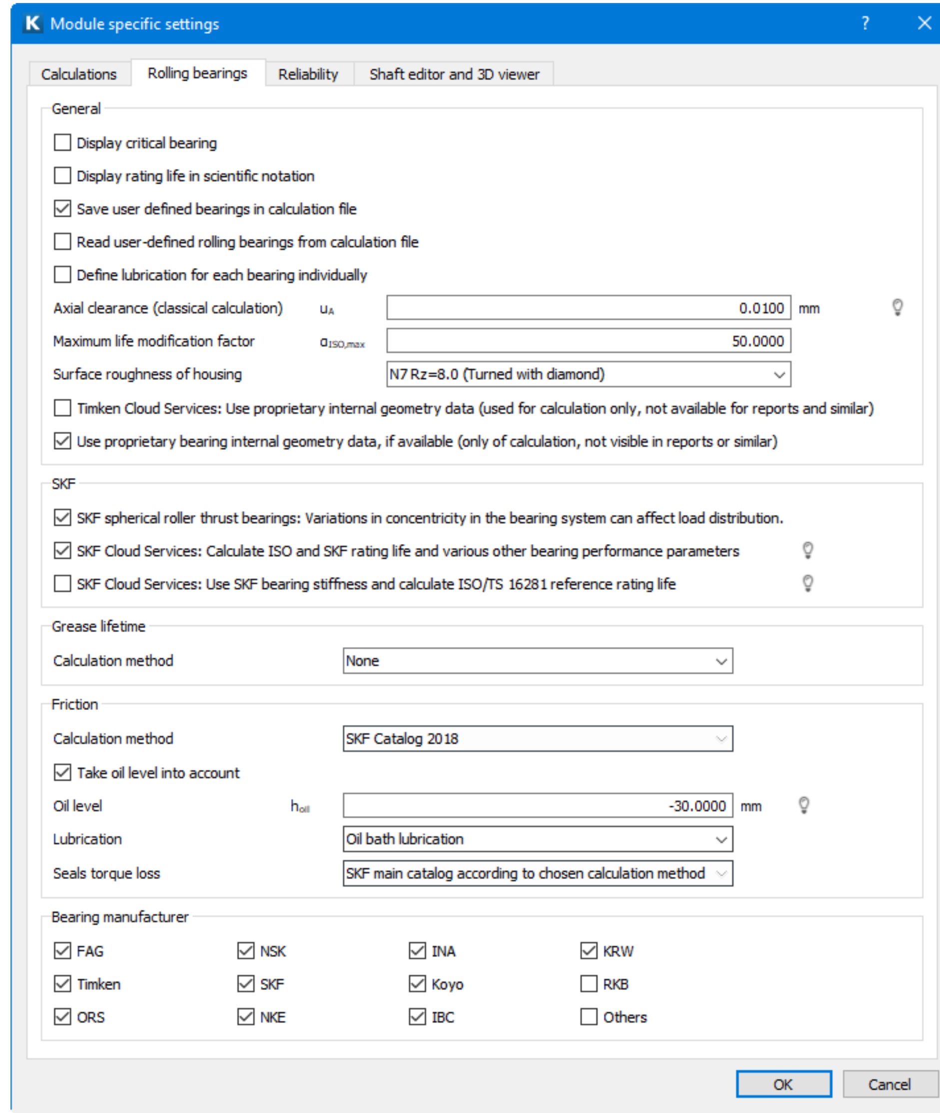
Flag 2: Change life value to scientific notation.

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:

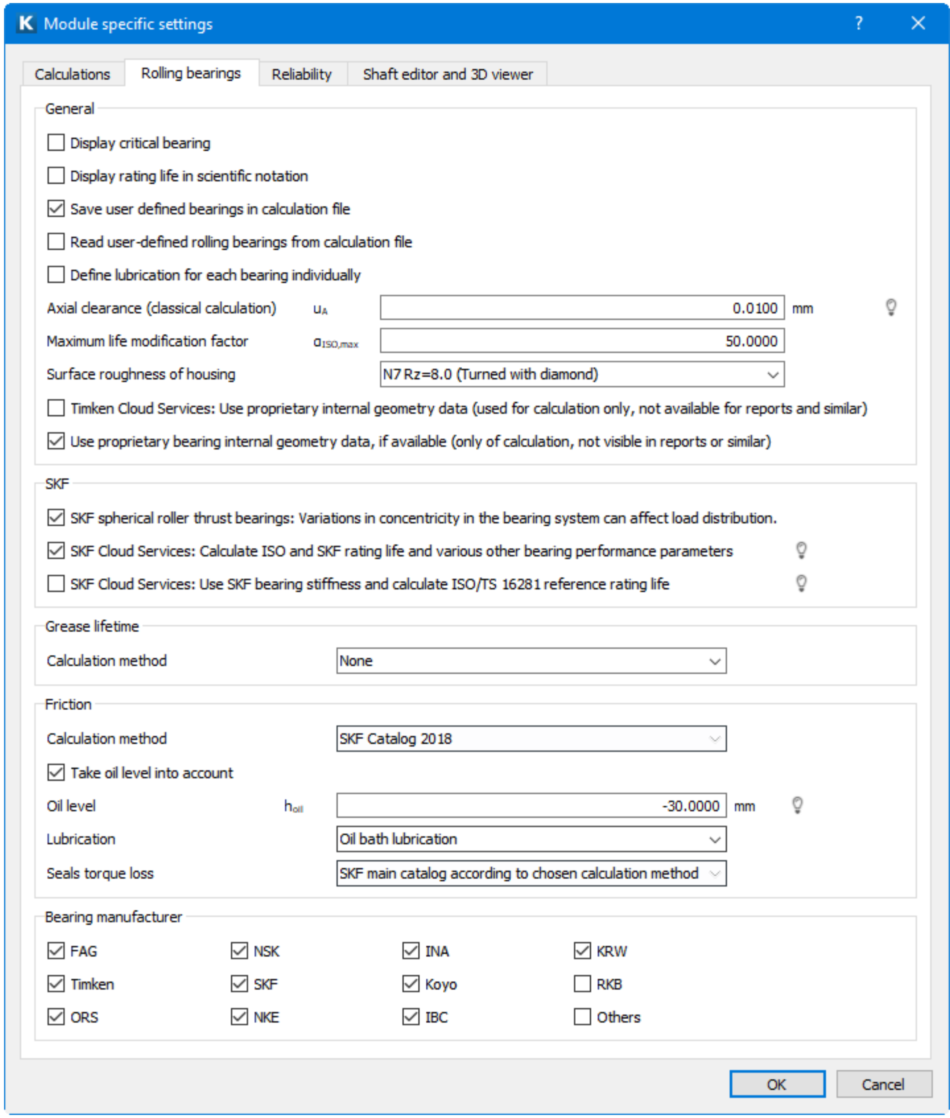
Flag 11…13: see section on SKF cloud solution.

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)

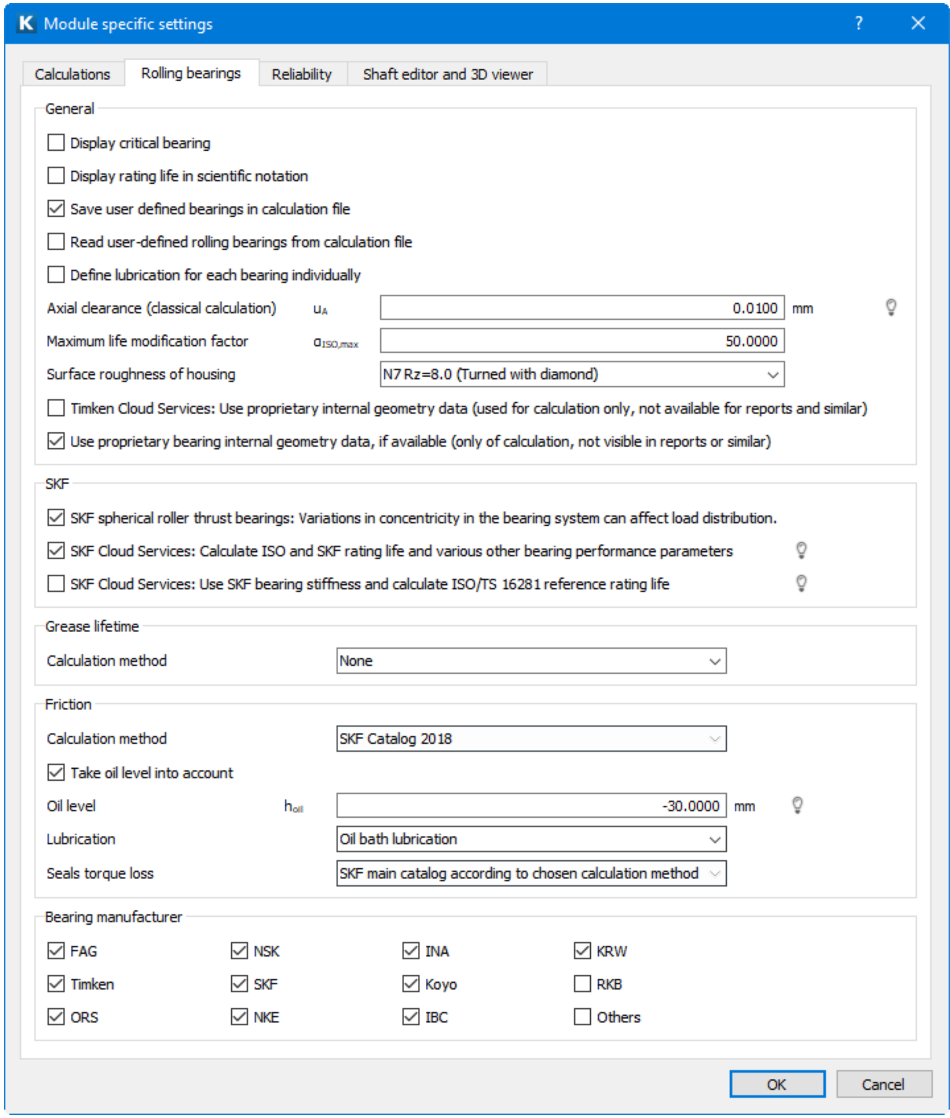


Module specific settings

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

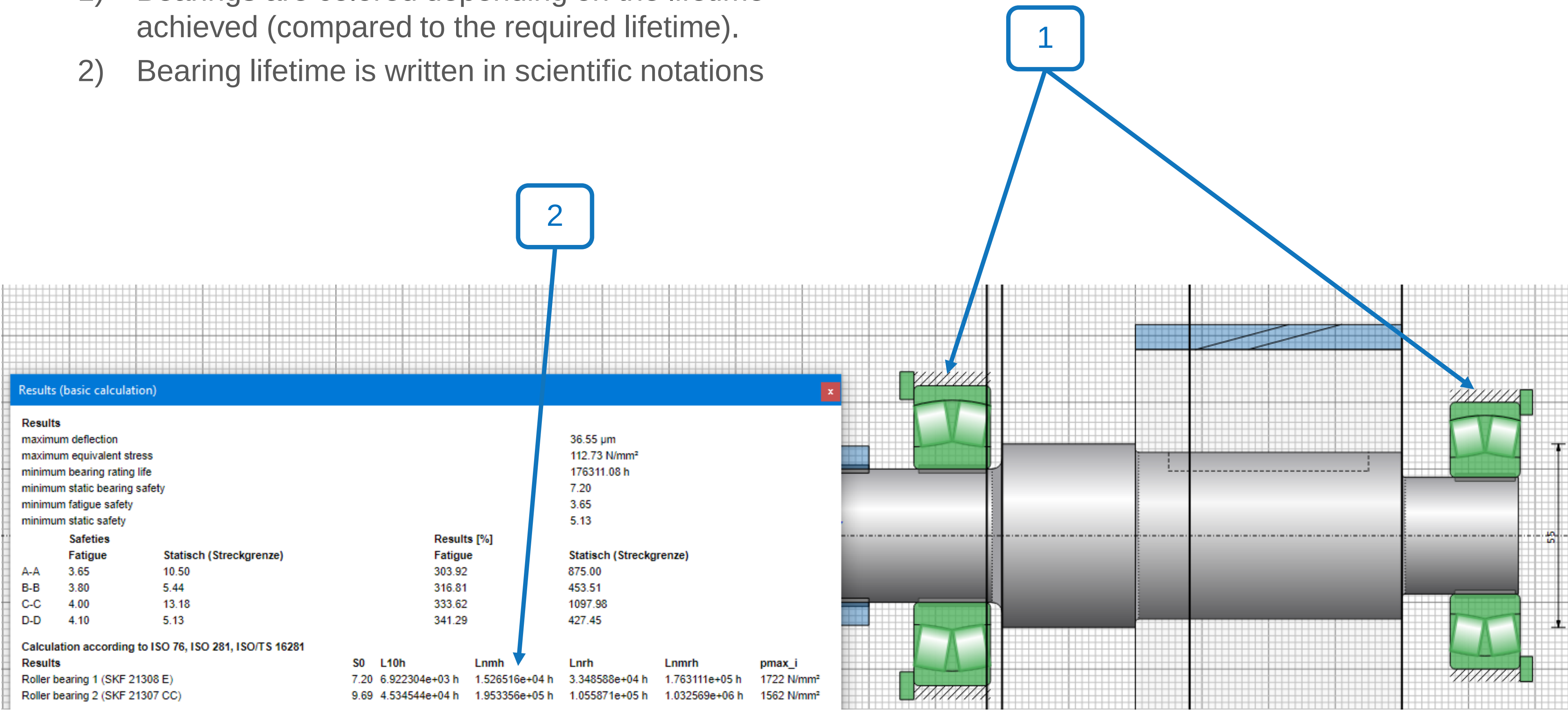
Input 19: Define calculation method for bearing seal friction calculation.

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



Results

maximum deflection	36.55 µm
maximum equivalent stress	112.73 N/mm²
minimum bearing rating life	176311.08 h
minimum static bearing safety	7.20
minimum fatigue safety	3.65
minimum static safety	5.13

	Safeties		Results [%]	
	Fatigue	Statisch (Streckgrenze)	Fatigue	Statisch (Streckgrenze)
A-A	3.65	10.50	303.92	875.00
B-B	3.80	5.44	316.81	453.51
C-C	4.00	13.18	333.62	1097.98
D-D	4.10	5.13	341.29	427.45

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

Results	S0	L10h	Lnmh	Lnrh	Lnmrh	pmax_i
Roller bearing 1 (SKF 21308 E)	7.20	6.922304e+03 h	1.526516e+04 h	3.348588e+04 h	1.763111e+05 h	1722 N/mm²
Roller bearing 2 (SKF 21307 CC)	9.69	4.534544e+04 h	1.953356e+05 h	1.055871e+05 h	1.032569e+06 h	1562 N/mm²

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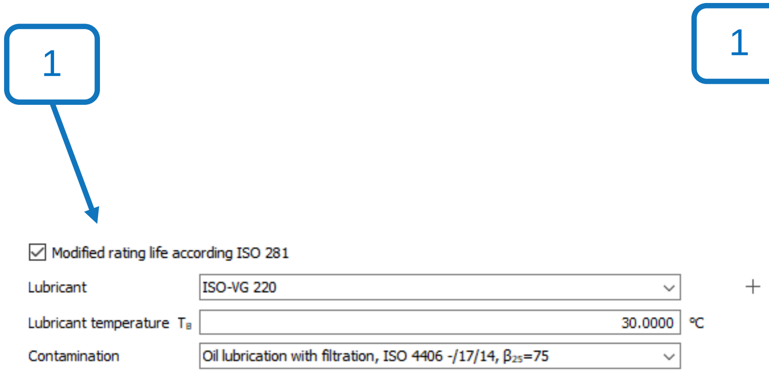
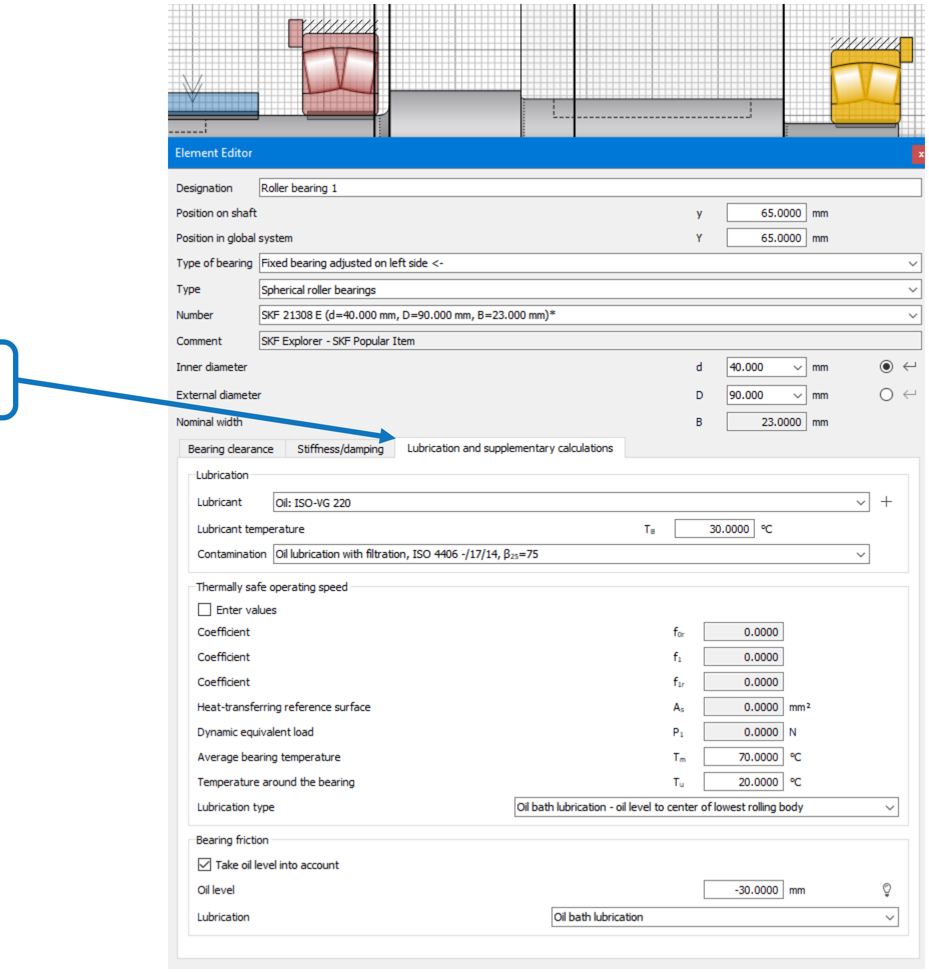
Define lubrication for each bearing individually

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.





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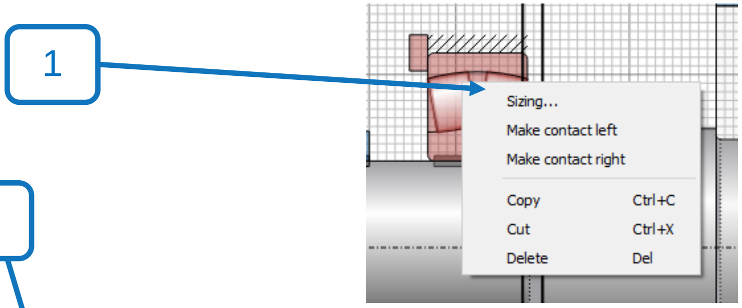
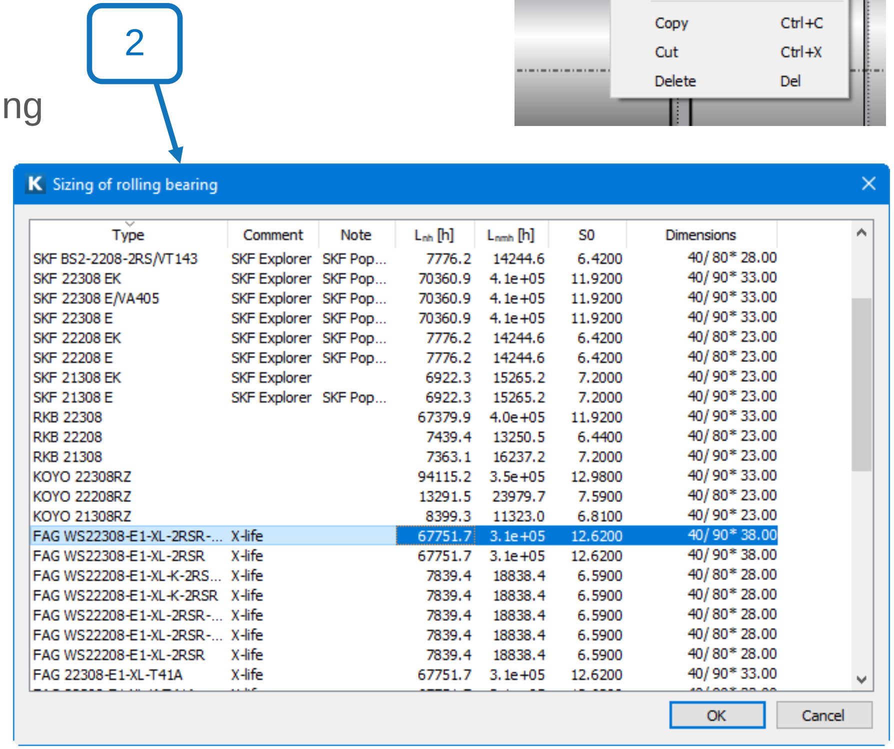
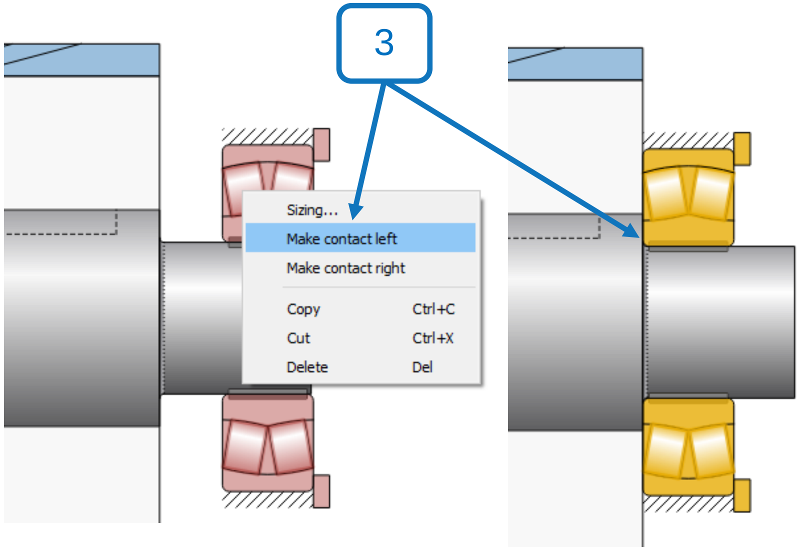
Context menu

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.





Type	Comment	Note	L_{nh} [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		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



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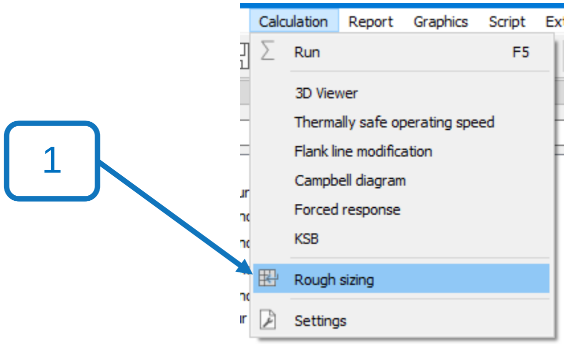
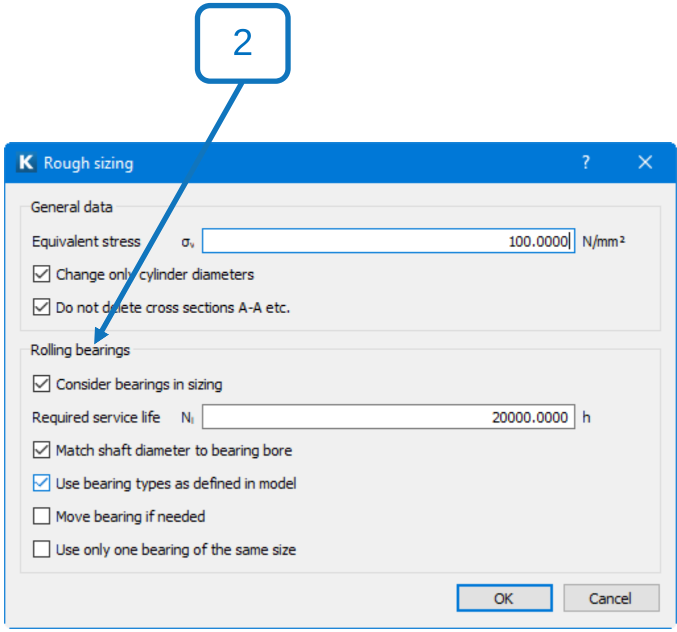
Shaft rough sizing including bearing rough sizing

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.





Content

Selected references

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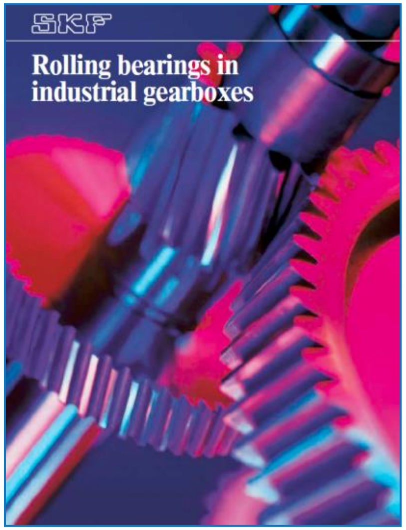

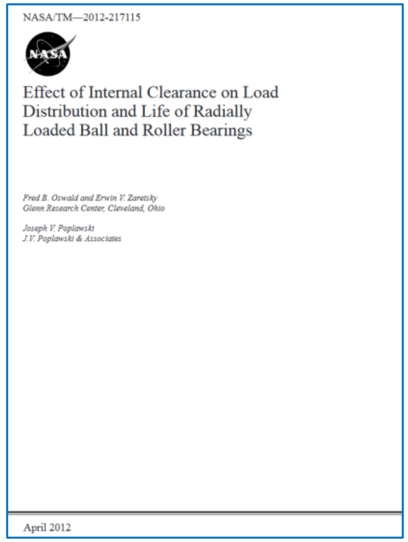

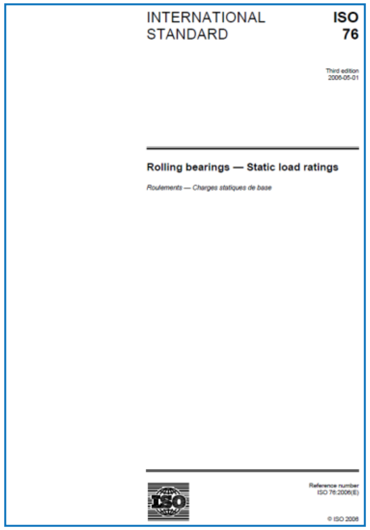

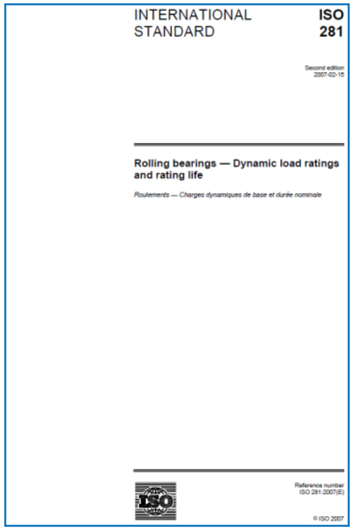

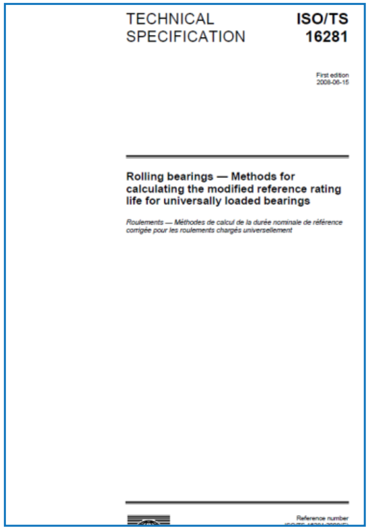

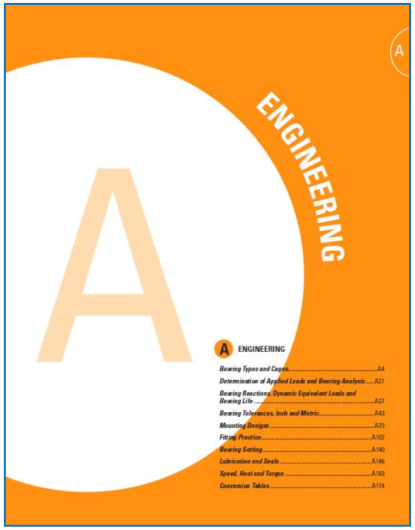

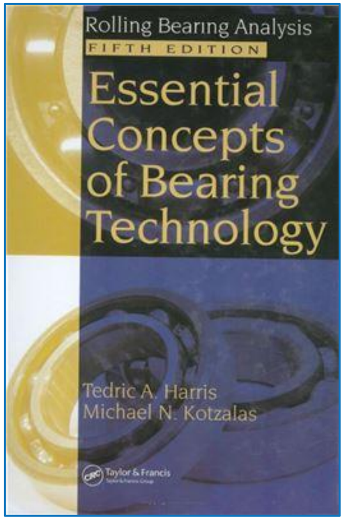

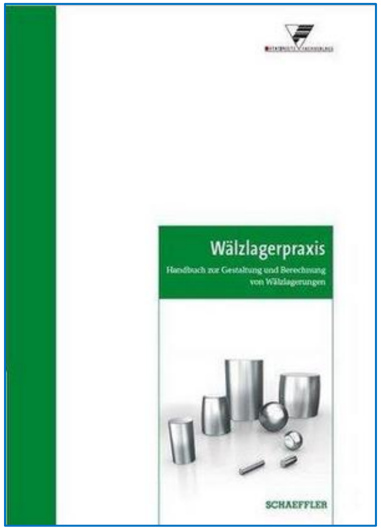

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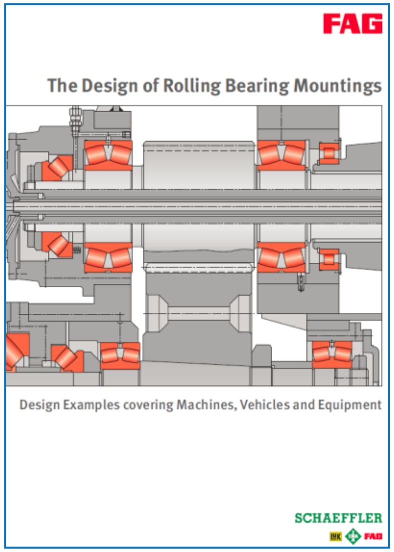

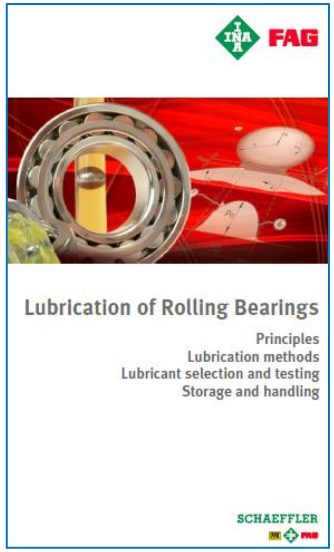

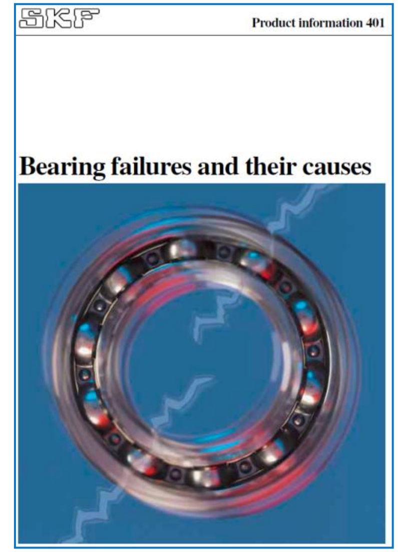


A Study on the Smearing and Slip Behaviour of Radial Cylindrical Roller Bearings

Dr. Bruno Johannes Scherb
INA WÄLZLAGER SCHAEFFLER oHG

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

Abstract

Keywords: cylindrical roller bearing, smearing, slip


American J. of Engineering and Applied Sciences 2 (2): 344-352, 2009
ISSN 1941-7020
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On the Use of Rolling Element Bearings' Models in Precision Maintenance

Ioannis S. Zotos and Theodore N. Costopoulos
Machine Elements Laboratory, School of Mechanical Engineering,
National Technical University of Athens, Iroon Polytexneiou 9, 15780 Zografou, Greece

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

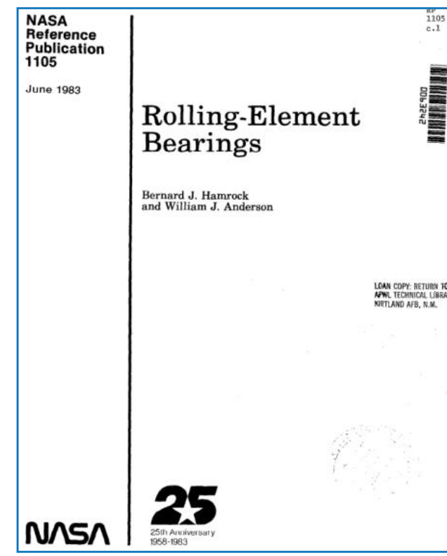
INTRODUCTION


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

TIMKEN
Where You Turn

Summary

Background



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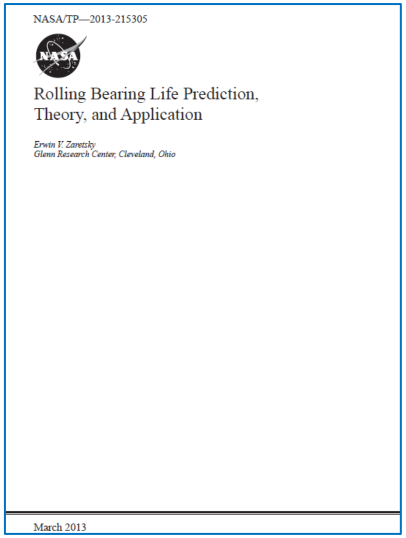
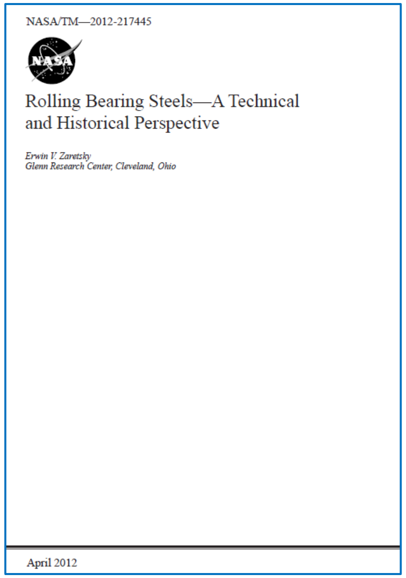

NASA/TP—2013-215305

Rolling Bearing Life Prediction, Theory, and Application

Erwin V. Zaretsky
Glenn Research Center, Cleveland, Ohio

March 2013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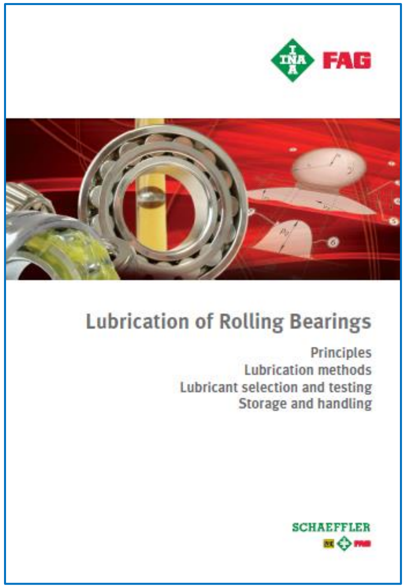
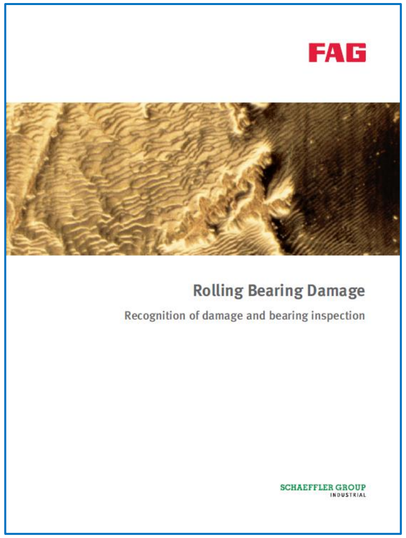
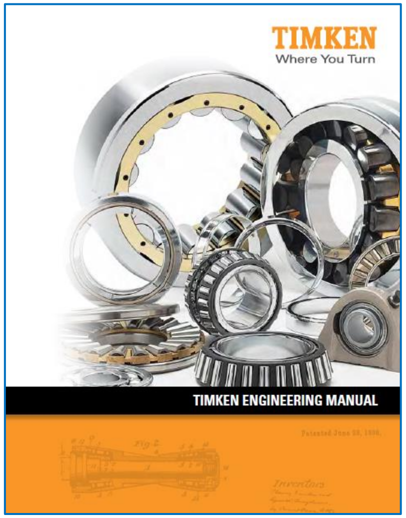
Rolling Bearing Steels—A Technical and Historical Perspective

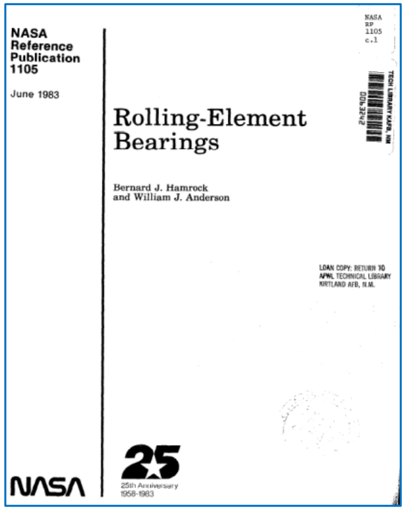
Erwin V. Zaretsky
Glenn Research Center, Cleveland, Ohio

April 2012





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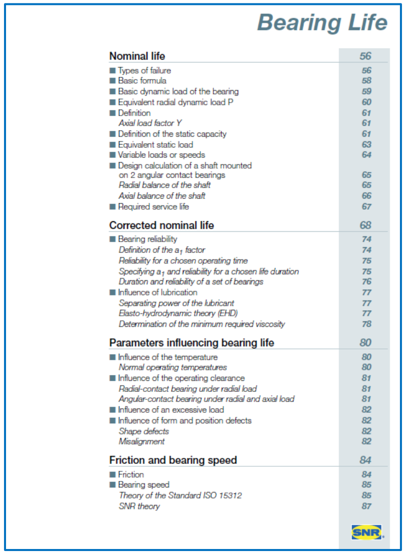
June 1983

Rolling-Element Bearings

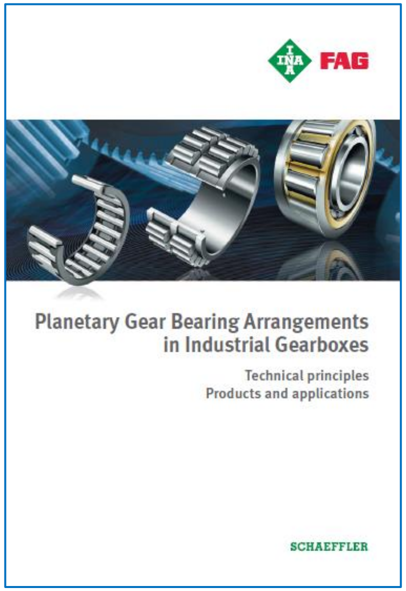
Bernard J. Hamrock
and William J. Anderson

NASA

25
25th Anniversary
1958-1983


Bearing Life

SNR



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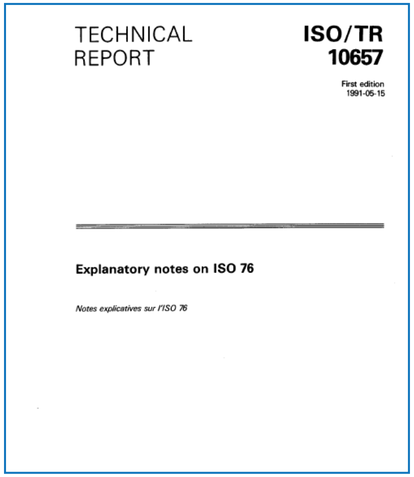
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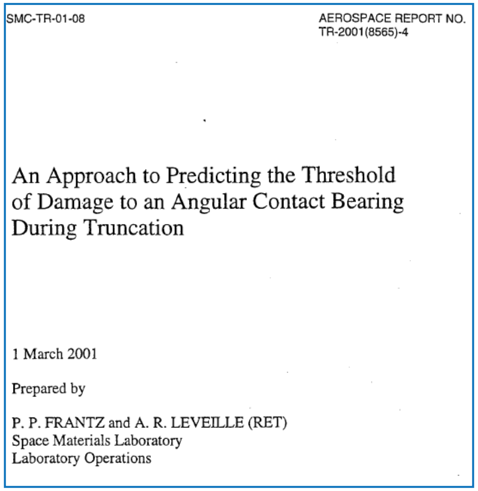
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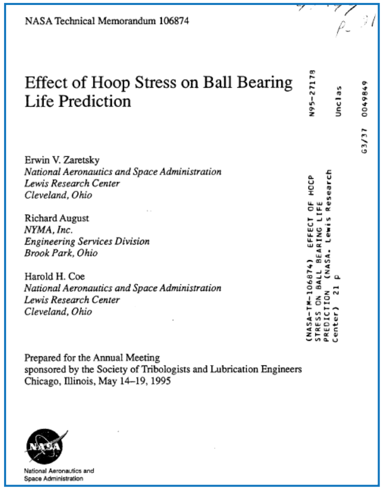
AEROSPACE REPORT NO. TR-2001(8565)-4

An Approach to Predicting the Threshold of Damage to an Angular Contact Bearing During Truncation

1 March 2001

Prepared by

P. P. FRANTZ and A. R. LEVEILLE (RET)
Space Materials Laboratory
Laboratory Operations


NASA Technical Memorandum 106874

Effect of Hoop Stress on Ball Bearing Life Prediction

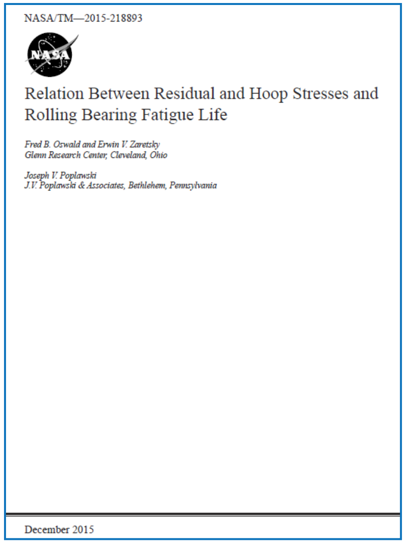
Erwin V. Zaretsky
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

Richard August
NYMA, Inc.
Engineering Services Division
Brook Park, Ohio

Harold H. Coe
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

Prepared for the Annual Meeting
sponsored by the Society of Tribologists and Lubrication Engineers
Chicago, Illinois, May 14–19, 1995

National Aeronautics and Space Administration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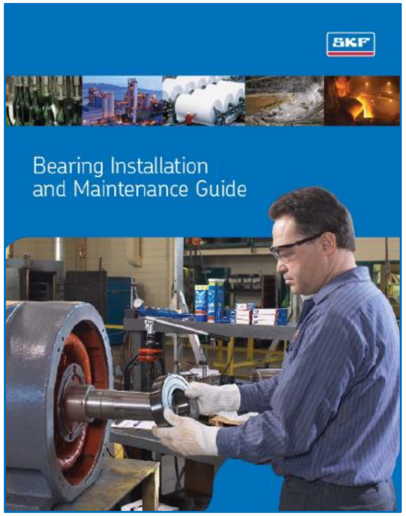
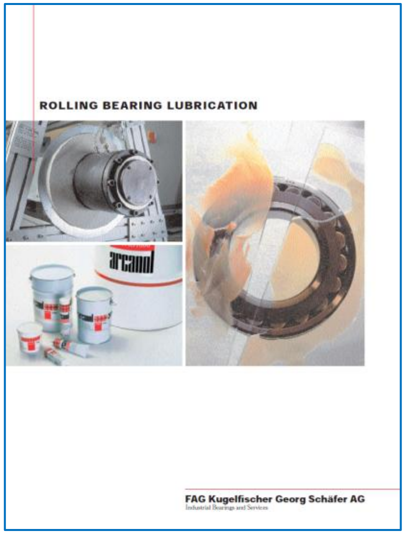
Relation Between Residual and Hoop Stresses and Rolling Bearing Fatigue Life

Fred B. Oswald and Erwin V. Zaretsky
Glenn Research Center, Cleveland, Ohio

Joseph V. Poplawski
J.V. Poplawski & Associates, Bethlehem, Pennsylvania

December 2015





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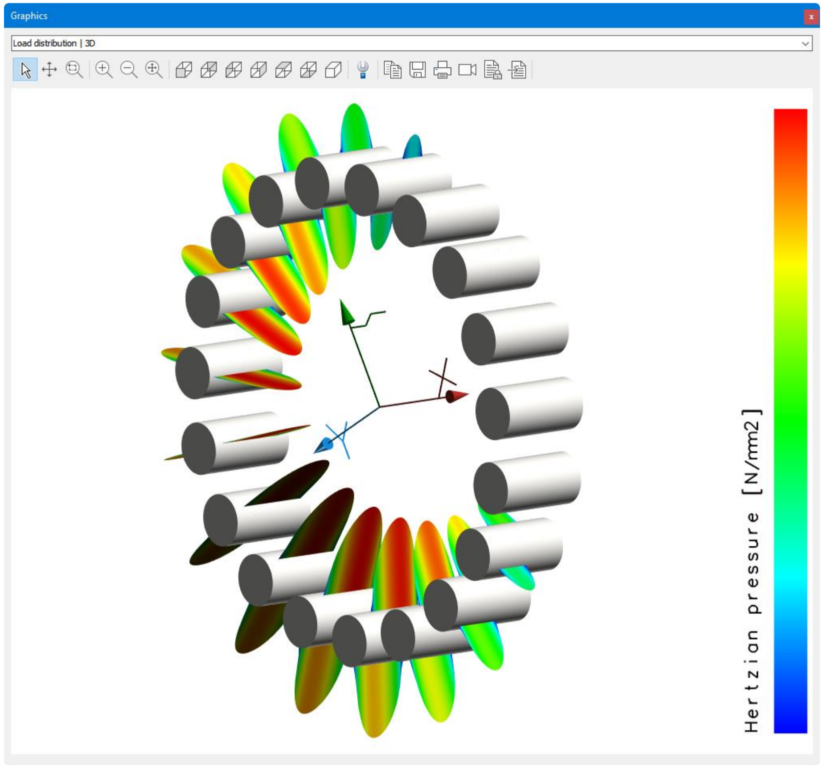

Sharing Knowledge

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