Bearing Technical Calculation Tool Usage Method

Contents

1-1. Overview of Bearing Technical Calculations

There are five technical calculations that can be performed within the **NTN** Bearing Technical Calculation Tool.

1. Basic rating life

(calculation function)
- Can be input/output in SI units
- Input/output either grease lubrication or oil lubrication
- Bearing basic rating life based on JIS (L_{10h}) or modified rating life that takes into account a_{ISO} (L_{10mh})

(input item)
- Can be selected by entering the boundary dimensions (inner dia., outer dia., width) and searching for the bearing, or entering the bearing product name
- Selection of the calculated bearing life, lubrication (oil, grease)
- Up to 10 steps can be entered for the load placed on the bearing (radial load, axial load) and rot. speed
- Required life
- 【For modified rating life】 In addition to the above, the contamination level or contamination factor, lubricating oil kinematic viscosity (40°C, 100°C), and operating temperature

(output item)
- Basic rating life (L_{10h}), basic dynamic load ratings, basic static load ratings, fatigue limit load, equivalent load, limiting speed (catalog, adjusted)
- 【For modified rating life】 In addition to the above, the modified rating life (L_{10mh}), contamination level or contamination factor, operating temperature, lubricating oil viscosity during operation, reference kinematic viscosity, viscosity ratio and life modification factor

2. Gear load and basic rating life

(calculation function)
- Can be input/output in SI units
- Input/output either grease lubrication or oil lubrication
- Applies to 2 shafts
- Bearing supported at two points on the shaft
- Up to five gear meshing conditions
- Bearing basic rating life based on JIS (L_{10h}) or modified rating life that takes into account a_{ISO} (L_{10mh})

(input item)
- Can be selected by entering the boundary dimensions (inner dia., outer dia., width) and searching for the bearing, or entering the bearing product name
- Distance bet. bearings
- Selection of the calculated bearing life, lubrication (oil, grease)
- Gear specifications
- Input shaft tor.
- Input shaft rot.
- 【For modified rating life】 In addition to the above, the contamination level or contamination factor, lubricating oil kinematic viscosity (40°C, 100°C), and operating temperature

(output item)
- Gear torque of the input shaft and output shaft, rot. speed, and gear load (tangent dir. load, radial dir. load, axial dir. load) under each condition
- Total life (L_{10h}), brg. system life, basic dynamic load ratings, and fatigue limit load of each bearing
- Bearing load (radial dir. load, axial dir. load), limiting speed (adjusted), rot. speed, equivalent load, basic rating life (L_{10h}), and frequency of each bearing, under each condition
- 【For modified rating life】 In addition to the above, the modified rating life (L_{10mh}), contamination level or contamination factor, operating temperature, lubricating oil viscosity during operation, reference kinematic viscosity, viscosity ratio and life modification factor

3. Bearing load and basic rating life

(calculation function)
- Can be input/output in SI units
- Input/output either grease lubrication or oil lubrication
- Selection of the calculated bearing life, lubrication (oil, grease)

- Bearing basic rating life based on JIS (L_{10h}) or modified rating life that takes into account a_{ISO} (L_{10mh})
- Two bearing rows
- Up to three load centers

(input item)
- Can be selected by entering the boundary dimensions (inner dia., outer dia., width) and searching for the bearing, or entering the bearing product name
- Distance bet. bearings
- Load conditions (radial load, axial load, moment load, load center position)
- Rot. speed
- 【For modified rating life】 In addition to the above, the contamination level or contamination factor, lubricating oil kinematic viscosity (40°C, 100°C), and operating temperature

(output item)
- Bearing basic rating life (L_{10h}), brg. system life
- Bearing load (radial load, axial load), equivalent load, basic dynamic load ratings, basic static load ratings
- Limiting speed (catalog, adjusted)
- 【For modified rating life】 In addition to the above, the modified rating life (L_{10mh}), contamination level or contamination factor, operating temperature, lubricating oil viscosity during operation, reference kinematic viscosity, viscosity ratio and life modification factor

4. Operating clearance calculation

(calculation function)
- Can be input/output in SI units
- Radial internal clearance taking into account the fit with the shaft and bearing, bearing and housing, and shaft and housing material and temperature
- Fitting pressure and fitting stress calculation taking into account the fit with the shaft and bearing, bearing and housing, and shaft and housing material and temperature

(input item)
- Can be selected by entering the boundary dimensions (inner dia., outer dia., width) and searching for the bearing, or entering the bearing product name
- Bearing tolerances
- Radial internal clearance
- Shaft bore diameter, housing outer diameter
- Fit with shaft and housing
- Material of shaft and housing
- Shaft, housing temperature under operating condition

(output item)
- Minimum and maximum values of the residual clearance, fitting pressure and fitting stress after fitting (not taking into account the temperature of the shaft and housing)
- Minimum and maximum values of the operating clearance, fitting pressure and fitting stress under operating condition (taking into account the temperature of the shaft and housing)

5. Bearing vibration frequency

(calculation function)
- Calculate the bearing vibration frequency generated form within the bearing due to rotation of the bearing

(input item)
- Can be selected by entering the boundary dimensions (inner dia., outer dia., width) and searching for the bearing, or entering the bearing product name
- Rot. speed

(output item)
- Rotational speed of cage
- Rotational speed of cage relative to inner ring
- Number of load cycles of inner ring per second
- Number of load cycles of outer ring per second
- Rotational speed of rolling element

1-2. Screen flowchart

On-screen processing for each window is displayed in **Fig. 1**.

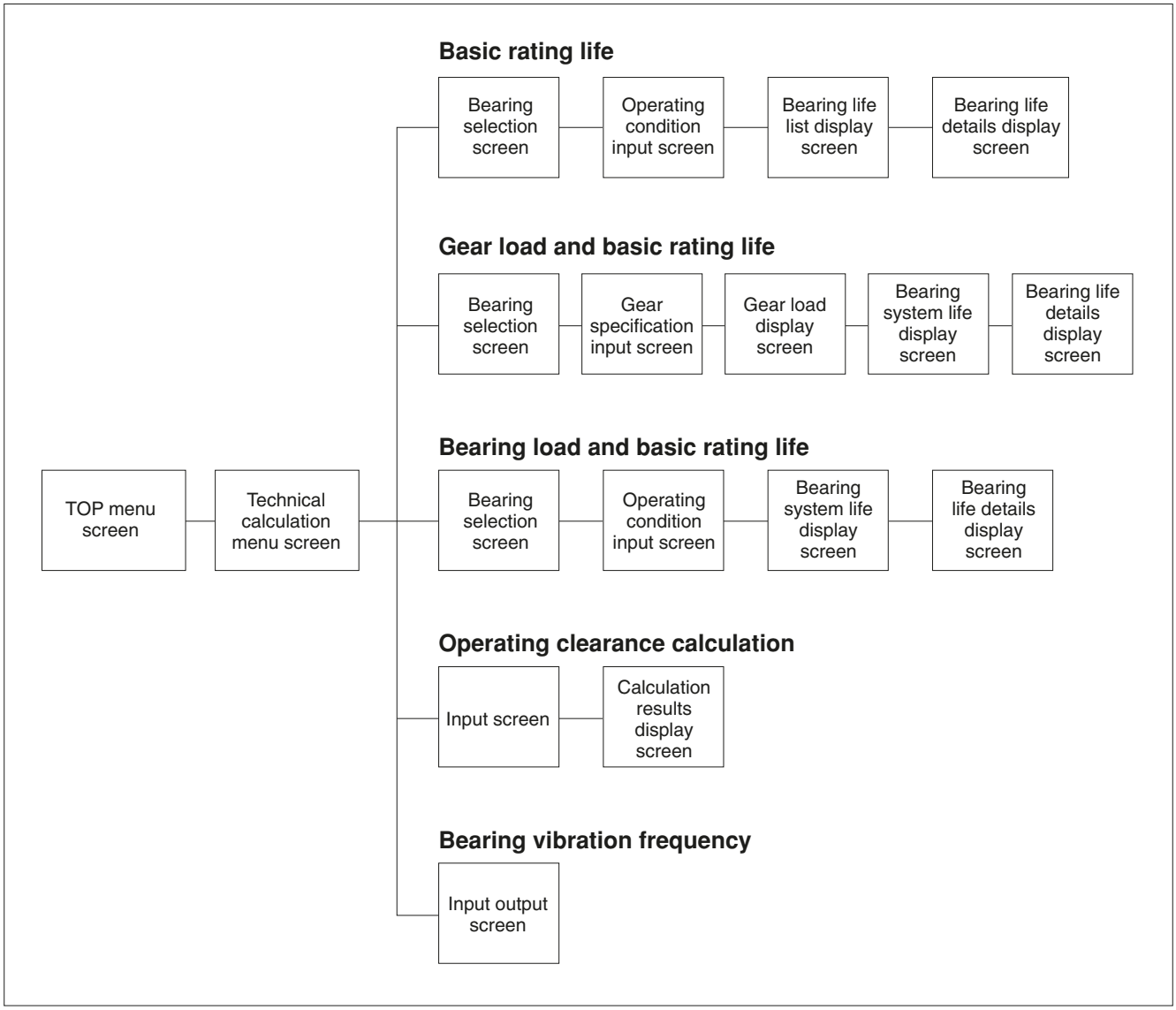


Fig. 1. Screen transition between each window

1-3. Bearing technical calculation screen operation

1-3-1. Description of on-screen buttons

Print ·····Prints the displayed screen on a printer or similar device.

OK·····If there is no error, proceed to the next screen. If there is an error, a warning screen is displayed.

Calculate·····If there is no error, the calculation results screen is displayed. If there is an error, a warning screen is displayed.

Search ·····Search for bearings from the inner dia., outer dia. and width. (see 1-3-12. Bearing search window)

Bearing A (B, C, D) ···The basic rating life (L_{10h}) and the modified rating life (L_{10mh}) are displayed for each condition of the selected bearing.

Bearing life·····If there is no problem with use under the operating conditions of the bearing, the total life of the bearing system and bearing is displayed. If there is a problem with use under the operating conditions of the bearing, an error message is displayed.

Detail of Brg. life ·····The basic rating life (L_{10h}) for each condition of each bearing and the modified rating life (L_{10mh}) depending on the selection are displayed.

Condition 1 (2, 3, 4, 5) ···For 1-3-8. Gear load and basic rating life, the screen switches to one where the gear specifications of meshing conditions for the selected gear are input.

Detailed display ·····The results of the detailed operating life for the selected bearing are displayed.

Main menu ·····Changes to the main menu.

Return ·····Changes to the previous screen.

1-3-2. Description of selection items

Axial load ·····For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, when a bearing other than the following bearings is selected, click whether or not to apply an axial load with the mouse. (the load is applied by default)

Angular contact ball brgs., tapered roller brgs. (metric series), tapered roller brgs. (inch series)

Bearing type ·····For 1-3-7. Basic rating life, click the appropriate bearing from the following displayed bearing types with the mouse.

Deep groove ball brgs., expansion compensating brgs., miniature ball brgs., (metric series), angular contact ball brgs. (30˚, 40˚), four-point contact ball brgs., double row angular contact ball brgs., self-aligning ball brgs., cylindrical roller brgs., double row cylindrical roller brgs., tapered roller brgs. (metric series), tapered roller brgs. (inch series), double row tapered roller brgs. (outward facing), double row tapered roller brgs. (inward facing), spherical roller brgs., thrust ball brgs., thrust self-aligning roller brgs.

For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, click the appropriate bearing from the following displayed bearing types with the mouse.
Deep groove ball brgs., expansion compensating brgs., miniature ball brgs. (metric series), angular contact ball brgs. (30˚, 40˚), double row angular contact ball brgs., self-aligning ball brgs., cylindrical roller brgs., double row cylindrical roller brgs., tapered roller brgs. (metric series),

tapered roller brgs. (inch series), double row tapered roller brgs. (outward facing), double row tapered roller brgs. (inward facing), spherical roller brgs.

For 1-3-10. Operating clearance calculation, click the appropriate bearing from the following displayed bearing types with the mouse.

Deep groove ball brgs., cylindrical roller brgs. spherical roller brgs.

For 1-3-11. Bearing vibration frequency, click the appropriate bearing from the following displayed bearing types with the mouse.

Deep groove ball brgs., angular contact ball brgs. (30˚, 40˚), self-aligning ball brgs. cylindrical roller brgs., tapered roller brgs. (metric series), tapered roller brgs. (inch series), spherical roller brgs.

Bearing tolerances ···For 1-3-10. Operating clearance calculation, click the bearing precision to use from JIS Class 0, JIS Class 6, JIS Class 5, JIS Class 4 and JIS Class 2 with the mouse. (see 1-7. attached tables **1** and **2**)

Bearing selection ·····For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, select the bearing by entering the bearing type and **NTN** product name.

Shaft material ·····For 1-3-10. Operating clearance calculation, click the shaft material to use with the mouse. The materials that can be selected are as displayed below. (see 1-7. attached tables **14**)
Bearing steels, carbon steels, gray iron castings, spheroidal graphite iron castings, aluminium, martensitic stainless steels, austenitic stainless steels, copper

Fit with shaft ·····For 1-3-10. Operating clearance calculation, click the fit symbol of the bearing and shaft to use with the mouse.

The fit symbols that can be selected are as displayed below. (see 1-7. attached tables **6** to 9)

			g5	h5	j5	js5	k5	m5			
d6	e6	f6	g6	h6	j6	js6	k6	m6	n6	p6	r6
				h7	j7		k7				r7
				h8							
				h9							
				h10							

Housing material ·····For 1-3-10. Operating clearance calculation, click the housing material to use with the mouse. The materials that can be selected are as displayed below. (see 1-7. attached tables **14**)
Bearing steels, carbon steels, gray iron castings, spheroidal graphite iron castings, aluminium, martensitic stainless steels, austenitic stainless steels, copper

Fit with housing ·····For 1-3-10. Operating clearance calculation, click the fit with bearing and housing symbol to use with the mouse.
The fit symbols that can be selected are as displayed below. (see 1-7. attached tables **10** to **13**)

						K5	M5	N5	
E6	F6	G6	H6	J6	JS6	K6	M6	N6	P6
	F7	G7	H7	J7	JS7	K7	M7	N7	P7
			H8						

Lubrication ·····Click either oil or grease to use with the mouse.
(grease is selected by default)

Contact ang. ort. ·····For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, when a bearing other than the following bearings are selected, click the direction of the contact ang. with the mouse.

Angular contact ball brgs., tapered roller brgs. (metric series), tapered roller brgs. (inch series)

I/O Param. Unit ·····I/O param. unit for load, etc., is SI only.

Input shaft rotation direction ·····For 1-3-8. Gear load and basic rating life, click either clockwise or counterclockwise to use with the mouse. (clockwise is selected by default)

Gear shape A (gear shape B) ·····For 1-3-8. Gear load and basic rating life, click the gear to use from spur, helical-right or helical-left with the mouse.
(spur is selected by default)

Radial internal clearance ·····For 1-3-10. Operating clearance calculation, click the bearing radial internal clearance to use from C2, CN, C3, C4 or C5 with the mouse. (see 1-7. attached tables **3** to **5**)

1-3-3. Description of input items

Axial load ·····For 1-3-7. Basic rating life, enter the axial load to be applied to the bearing. (kgf)
For 1-3-9. Bearing load and basic rating life, enter the axial load to be applied to the bearing. (N)

Pres. angle ·····For 1-3-8. Gear load and basic rating life, enter the pres. angle of the gear. (˚)

Operating temperature ·····For 1-3-7. Basic rating life, 1-3-8. Gear load and basic rating life, and 1-3-9. Bearing load and basic rating life, enter the assumed operating temperature when the modified rating life $L_{10\mathrm{mh}}$ (taking into account α_{ISO}) was selected for the calculated operating life selection in each of these. If this is not entered, it will automatically be set to 20°C. (°C)

Shaft temperature under operating condition ·····For 1-3-10. Operating clearance calculation, enter the temperature of the shaft under operating condition If this is not entered, it will automatically be set to 20˚. (˚C)

Housing temperature under operating condition ·····For 1-3-10. Operating clearance calculation, enter the temperature of the housing under operating condition If this is not entered, it will automatically be set to 20˚. (˚C)

NTN product name ···Enter the **NTN** bearing number
(for calculations other than 1-3-7. Basic rating life, click the "Search" button if the **NTN** product name is unknown, and use the 1-3-12 Bearing search window)

Contamination factor e_c ·····For 1-3-7. Basic rating life, 1-3-8. Gear load and basic rating life, and 1-3-9. Bearing load and basic rating life, select the contamination level or directly enter the value was selected for the calculated operating life selection in each of these.

Rot. speed ·····For 1-3-7. Basic rating life, enter the rot. speed of the bearing.
For 1-3-9. Bearing load and basic rating life and 1-3-11. Bearing vibration frequency, enter the rot. speed of the shaft (inner ring). (min^{-1})

Calculated operating life selection ···For 1-3-7. Basic rating life, 1-3-8. Gear load and basic rating life, and 1-3-9. Bearing load and basic rating life, select basic rating life (L_{10h}) or modified rating life (L_{10mh}) for each of these.
(Basic rating life (L_{10h}) is selected by default.)

Distance bet. effective load·····For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, if bearing A and bearing B (bearing C and bearing D) are the bearings displayed below, enter the distance between the effective load of one bearing and the effective load of the other bearing. (mm)

Angular contact ball brgs., tapered roller brgs. (metric series), tapered roller brgs. (inch series)

Distance between bearing A and bearing B (distance between bearing C and bearing D) ·····For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and bearing basic distance rating life, enter the distance between the bearing centers of bearing A and bearing B (bearing C and bearing D). (mm)

Shaft bore diameter ···For 1-3-10. Operating clearance calculation, enter the inner dia. of the shaft. If this is not entered, the calculation will be made as a solid shaft. (mm)

Housing outer diameter···For 1-3-10. Operating clearance calculation, enter the outer dia. of the housing. If this is not entered, it will automatically be set to a size 1.3 times the shaft outer dia. (mm)

Lubrication·····For 1-3-7. Basic rating life, 1-3-8. Gear load and basic rating life, and 1-3-9. Bearing load and basic rating life, select the contamination level or enter the contamination factor directly.

Lubricating oil kinematic viscosity ···For 1-3-7. Basic rating life, 1-3-8. Gear load and basic rating life, and 1-3-9. Bearing load and basic rating life, enter the lubricating oil kinematic viscosity at 40°C and 100°C for each of these. It is also possible to click and enter any item from the ISO dynamic viscosity grade table or the grease characteristics table depending on the lubrication. (mm^2/s)

Use rate ·····For 1-3-7. Basic rating life, enter the hours or the ratio for performing each step. If there is only one step, there is no need to enter this. (hours or %)

Frequency ·····For 1-3-8. Gear load and basic rating life, enter the frequency of the gear meshing conditions. (%)

Steps ·····For 1-3-7. Basic rating life, enter the number of ways the load conditions and rot. speed change.

Inner dia., outer dia., width ·····For 1-3-7. Basic rating life, if the **NTN** product name is unknown, enter the min or max of at least the bearing inner dia., bearing outer dia. or bearing width, and search for the bearing. (mm)
In the 1-3-12. Bearing search window, enter the min or max of at least the bearing inner dia., bearing outer dia. or bearing width, and search for the bearing. (mm)

Input shaft rot. ·····For 1-3-8. Gear load and basic rating life, enter the rot. speed to be applied to the input shaft. (min^{-1})

Input tor. ·····For 1-3-8. Gear load and basic rating life, enter the torque to be applied to the input shaft. (N-mm)

Twisting angle ·····For 1-3-8. Gear load and basic rating life, when selecting the helical gear, enter the twisting angle of the gear. (˚)

Gear pos. ·····For 1-3-8. Gear load and basic rating life, enter the distance from the reference bearing to the gear. (mm)

Teeth ·····For 1-3-8. Gear load and basic rating life, enter the number of gear teeth.

Notes ·····Enter comments related to the calculations. The calculation is not affected even if this is left empty.

Module·····For 1-3-8. Gear load and basic rating life, enter the module of gear.

Moment load ·····For 1-3-9. Bearing load and basic rating life, enter the moment load to be applied to the shaft. (N-mm)

Required life ·····For 1-3-7. Basic rating life, enter the minimum life required of the bearing. (hours)

Radial load ·····For 1-3-7. Basic rating life, enter the radial load to be applied to the bearing. (N)
For 1-3-9. Bearing load and basic rating life, enter the radial load to be applied to the bearing. (N)

1-3-4. Description of output items

Axial load ·····Axial load placed on the bearing (Fa) (N)

Axial dir. load ·····For 1-3-8. Gear load and basic rating life, the load generated in the gear axial direction is displayed. (N)

Operating clearance ···For 1-3-10. Operating clearance calculation, fit the bearing on to the shaft and housing, and the radial internal clearance under operating conditions is displayed. (mm)
The min and max operating clearance is displayed as there are tolerances with the initial radial internal clearance, fit with shaft and fit with housing.

NTN product name ···Bearing number

Contamination factor···For 1-3-7. Basic rating life, 1-3-8. Gear load and basic rating life, and 1-3-9. Bearing load and basic rating life, the contamination level and contamination factor are displayed.

Outer dia. ·····Bearing outer dia. (D) (mm)

Rot. speed ·····For 1-3-7. Basic rating life and 1-3-11. Bearing vibration frequency, the rot. speed of the bearing is displayed. (min^{-1})
For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, the rot. speed of the bearing is displayed. (min^{-1})

Number of load cycles of outer ring per second ·····For 1-3-11. Bearing vibration frequency, the number of rolling elements that pass through a single point on the outer track surface per second. (Hz)

Reference kinematic viscosity ·····Depends on rotation speed n and size (D_{pw}) of the bearing. (mm^2/s)

Basic static load ratings ·····Static radial load (static central axial load) (C_{or} or C_{oa}) (N) corresponding to the calculated contact stress displayed below at the contact center with the rolling element and track being subjected to maximum load

Self-aligning ball brgs.: 4600 MPa
Other ball brgs.: 4200 MPa
Roller brgs.: 4000 MPa

The total permanent deformation of the rolling element and track under these contract stresses is approximately 0.0001 times the diameter of the rolling element.

Basic rating life ·····When individual bearings within the same group are rotated under the same conditions, this is the actual total number of rotations that is possible when 90% (90% reliability) of those bearings rotate without any flaking caused by rolling fatigue is generated. When the bearing is rotated at a fixed rpm, the total number of hours is used. (hours)

Basic dynamic load ratings ·····A certain static radial load (central axial load) (Cr or Ca) (N) that the bearing should theoretically be able to withstand a basic rating life of 1 million rotations.

Gear torque ·····For 1-3-8. Gear load and basic rating life, the torque applied to the gear is displayed. (N-mm)

Limiting speed ·····As the rot. speed of the bearing increases, the temperature of the bearing increases due to friction heat generated within the bearing, which causes burning and other damage, preventing reliable operation of the bearing from continuing. This limiting rotational speed is called the limiting speed. (min^{-1})
The "Catalog" is the limiting speed value listed in the "**NTN** Bll and Roller Bearing Catalog" (CAT.NO.2203/E).
The "Adjusted value" is the value acquired when the adjusted coefficient is applied by applying a load to the "Catalog" value.

Count of result ·····For 1-3-7. Basic rating life, this is the number of bearings when (basic rating life) ≥ (required life) is met.

Residual clearance ···For 1-3-10. Operating clearance calculation, the radial internal clearance is displayed with the bearing fit to the shaft and housing. (mm)
The min and max residual clearance is displayed as there are tolerances with the initial radial internal clearance, fit with shaft and fit with housing.

Corrected rating life···The life corrected using the a_{ISO} factor that was calculated from the contamination factor, lubricating oil kinematic viscosity, operating temperature, etc., against the basic rating life $L_{10\mathrm{h}}$. (hours)

Bearing life·····For 1-3-8. Gear load and basic rating life, the total life of each bearing takes into account the frequency of gear meshing conditions. (hours)
For 1-3-9. Bearing load and basic rating life, this is the basic rating life ($L_{10\mathrm{h}}$) of each bearing calculated from the bearing load placed on each bearing. (hours)

Brg. system life·····For 1-3-8. Gear load and basic rating life and 1-3-9. Bearing load and basic rating life, this is the life for bearing systems that are supported by two bearings until either bearing becomes damaged due to rolling fatigue. (hours)

Modified rating life ···Obtained with the following formula from the basic rating life using the life modification factor

$$L_{\mathrm{nm}} = a_1 \cdot a_{\mathrm{ISO}} \cdot L_{\mathrm{n}}$$

Life ·····For 1-3-8. Gear load and basic rating life, this is the basic rating life ($L_{10\mathrm{h}}$) for each meshing condition of the gear in the Detail of Brg. life window. (hours)
For 1-3-9. Bearing load and basic rating life, this is the basic rating life ($L_{10\mathrm{h}}$) for each bearing in the Detail of Brg. life window. The value is the same as "Bearing life." (hours)

Life modification factor ···Obtained by integrating material characteristics and lubrication conditions. It is given as a function like the following formula in ISO 281:2007.

$$a_{\mathrm{ISO}} = f\left(\frac{e_c\, C_{\mathrm{u}}}{p}\, k\right)$$

Lubrication·····The selected lubrication conditions are displayed. (oil lubrication or grease lubrication)

Use rate ····· For 1-3-7. Basic rating life, the hours or the ratio for performing each step is displayed. If the number of steps is "1" and no use rate is entered, the use rate in the output is displayed as "1." (hours or %)

Frequency ····· For 1-3-8. Gear load and basic rating life, the frequency of the gear meshing conditions is displayed. (%)

Tangent dir. load ····· For 1-3-8. Gear load and basic rating life, the load generated in the gear Tangent dir. is displayed. (N)

Total life ····· For 1-3-8. Gear load and basic rating life, this is the total life of each bearing taking into account the frequency of the meshing condition of the gear in the Detail of Brg. life window. (hours)
For 1-3-9. Bearing load and basic rating life, this is the basic rating life (L_{10h}) for each bearing in the Detail of Brg. life window. The value is the same as "Bearing life" and "Life." (hours)

Units ····· The selected units are displayed. (SI unit or Gravit. unit)

Rotational speed of rolling element ··· For 1-3-11. Bearing vibration frequency, the rot. speed of the rolling element per second is displayed when viewed from the center of the bearing. (Hz)

Equivalent load ····· A certain static radial load (central axial load) placed on the bearing so that the same life as the life of bearings achieved under actual load conditions is attained. (Pr or Pa) (N)

Inner dia. ····· Bearing inner dia. (d) (mm)

Number of load cycles of inner ring per second ··· For 1-3-11. Bearing vibration frequency, the number of rolling elements that pass through a single point on the inner track surface per second. (Hz)

Rotational speed of cage relative to inner ring ··· For 1-3-11. Bearing vibration frequency, this is the rotational speed of the cage per second relative to the standard rotating inner ring. (Hz)

Width ····· Bearing width (B) (mm)

Fitting stress (inner ring) ····· For 1-3-10. Operating clearance calculation, the stress generated when fitting the shaft and bearing is displayed. (MPa)

The min and max fitting stress is displayed as there are tolerances in fitting with the shaft.

Fitting stress (outer ring) ····· For 1-3-10. Operating clearance calculation, the stress generated when fitting the bearing and housing is displayed. (MPa)

The min and max fitting stress is displayed as there are tolerances in fitting with the housing.

Fitting pressure (bearing and housing) ····· For 1-3-10. Operating clearance calculation, the pressure generated when fitting the bearing and housing is displayed. (MPa)

The min and max fitting pressure is displayed as there are tolerances in fitting with the housing.

Fitting pressure (shaft and bearing) ····· For 1-3-10. Operating clearance calculation, the pressure generated when fitting the shaft and bearing is displayed. (MPa)

The min and max fitting pressure is displayed as there are tolerances in fitting with the shaft.

Fatigue limit load ····· Load applied on bearings that becomes the fatigue limit stress at the maximum load contact part of the raceway. This depends on the bearing internal specifications, quality, and material strength. The fatigue limit load values with respect to the **NTN** bearing numbers are specified in each specification table. (N)

Rotational speed of cage ····· For 1-3-11. Bearing vibration frequency, this is the rot. speed of the cage per second. (Hz)

Notes ·····Details entered into the notes are displayed as they are.

Required life ·····For 1-3-7. Basic rating life, the required life that was entered is displayed. (hours)

Radial load ·····Radial load placed on the bearing (Fr) (N)

Radial dir. load ·····For 1-3-8. Gear load and basic rating life, the load generated in the gear radial direction is displayed. (N)

1-3-5. Description of quantity symbols

B ·····Bearing width (mm)

C ·····Basic dynamic load ratings (N)

Ca ·····Basic dynamic axial load ratings (N)
If the bearing type is four-point contact ball brgs., thrust ball brgs., thrust spherical roller brgs. $C=Ca$

Cr ·····Basic dynamic radial load ratings (N)
If the bearing type is a bearing other than four-point contact ball brgs., thrust ball brgs., thrust spherical roller brgs. $C=Cr$

Co ·····Basic static load ratings (N)

Coa ·····Basic static axial load ratings (N)
If the bearing type is four-point contact ball brgs., thrust ball brgs., thrust spherical roller brgs. $Co=Coa$

Cor·····Basic static radial load ratings (N)
If the bearing type is a bearing other than four-point contact ball brgs., thrust ball brgs., thrust spherical roller brgs. $Co=Cor$

d·····Bearing inner dia. (mm)

D ·····Bearing outer dia. (mm)

dp ·····As determined by $dp=\frac{d+D}{2}$ (mm)

Fa ·····Axial load (N)

Fr ·····Radial load (N)

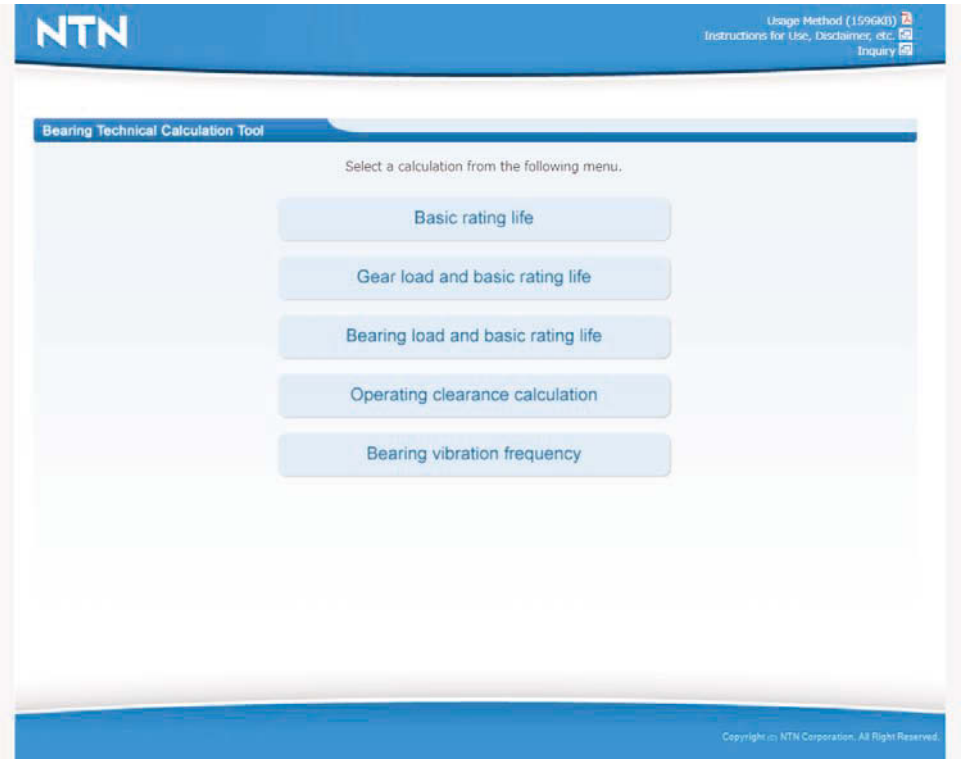
n ·····Rot. speed (min^{-1})

P ·····Equivalent load (N)

Pa ·····Equivalent axial load (N)
If the bearing type is four-point contact ball brgs., thrust ball brgs., thrust spherical roller brgs. $P=Pa$

Pr ·····Equivalent radial load (N)
If the bearing type is a bearing other than four-point contact ball brgs., thrust ball brgs., thrust spherical roller brgs. $P=Pr$

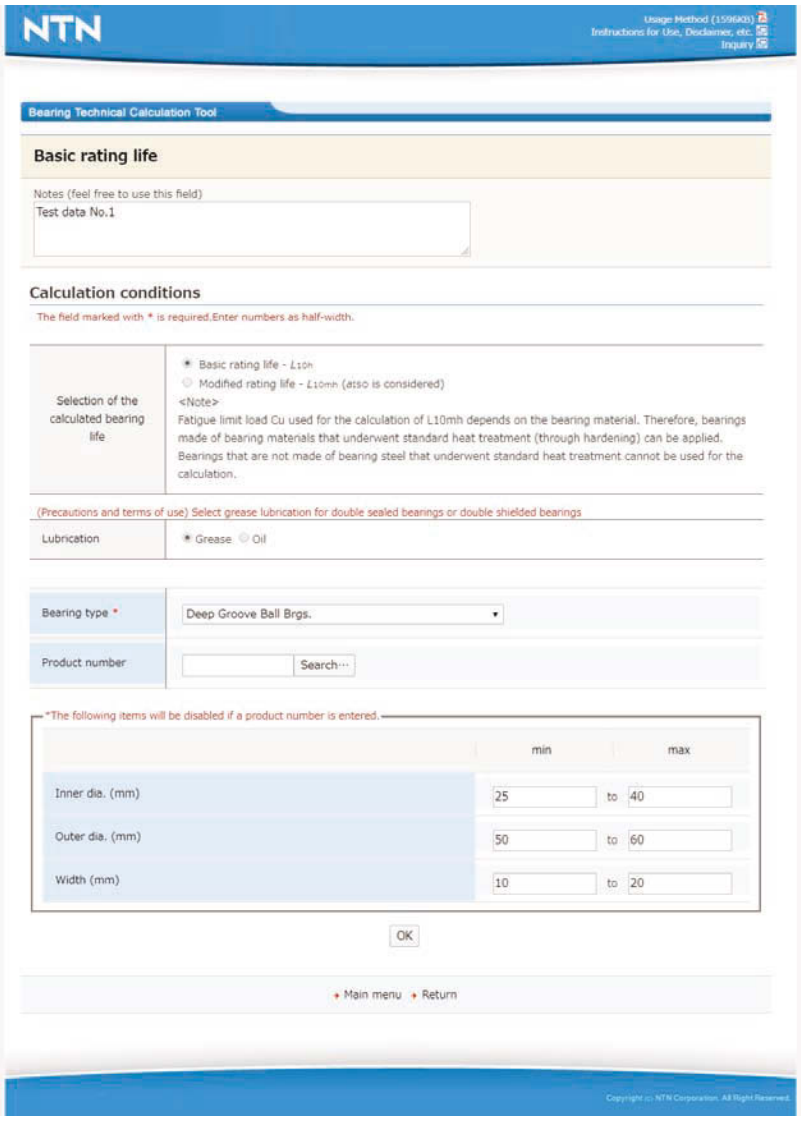
1-3-6. Technical calculation menu screen



Screen No. 1 Technical calculation menu window

1-3-7. Basic rating life

1. Bearing selection



Screen No. 2 Bearing selection window

(selection item) (see 1-3-2 Description of selection items)

Life selection, bearing type, lubrication

(input item) (see 1-3-3 Description of input items)

Enter the calculation details into the notes if necessary.

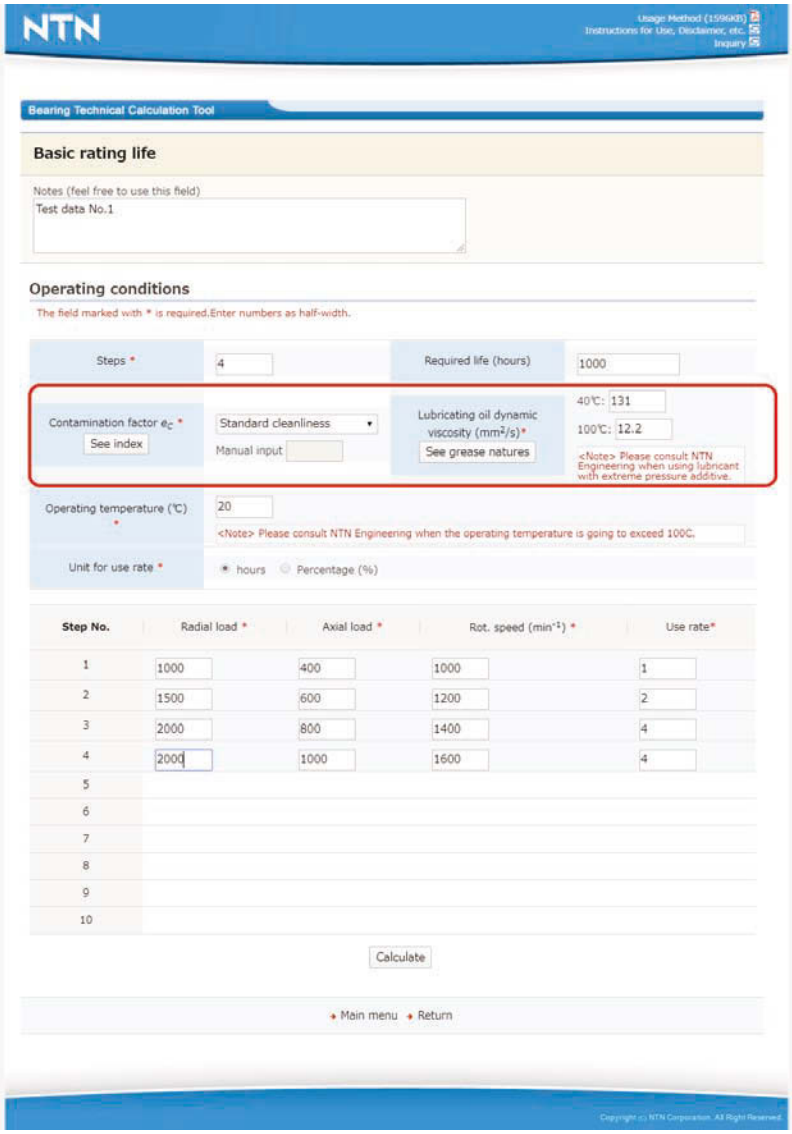
If the **NTN** product name is known

Enter the **NTN** product name.

If the **NTN** product name is unknown

Enter at least one of inner dia. (min and max), outer dia. (min and max), and width (min and max).

2. Enter operating conditions



Screen No. 3 Enter operating conditions
(The section in the red box is only for the modified rating life)

(input item) (see 1-3-3 Description of input items)

Always enter the number of steps.

Enter the required life if necessary.

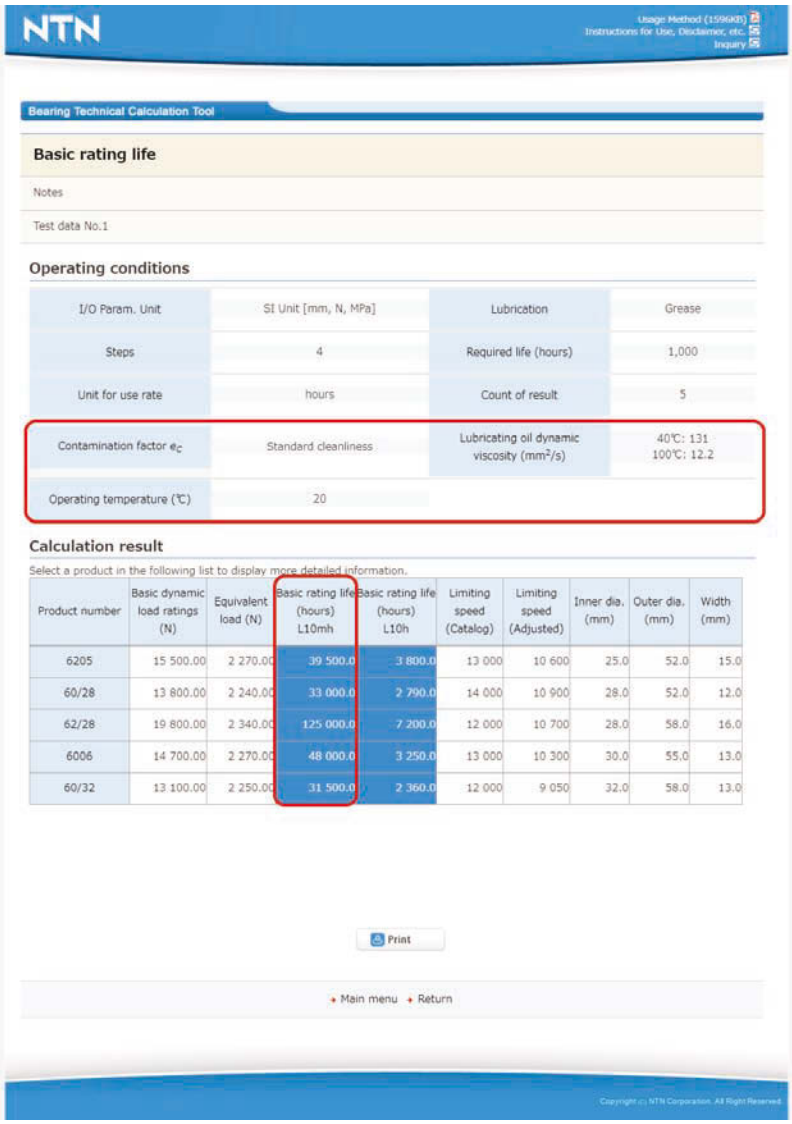
Always enter the rot. speed and use rate for each step. For a single step, the use rate does not need to be entered.

Enter the required item for each step for the radial load and axial load.

(When modified rating life was selected) Select the contamination level or select “Direct input” and then directly enter the contamination factor value. Always enter the lubricating oil kinematic viscosity for 40°C and 100°C. Always enter the operating temperature. Click the “See index” button to open the “Contamination factor ec index” and confirm the content of each contamination level. Also, click the “See ISO grade table” button (for oil lubrication) and the “See grease characteristics table” button (for grease lubrication) to open a table with typical base oil viscosity for each lubricant. Click the row in the table to enter the corresponding base oil viscosity value in the column for 40°C and 100°C of the lubricating oil kinematic viscosity.

3. Life calculation results display

<List display of life>



Screen No. 4 List display of life
(The section in the red box is only for the modified rating life)

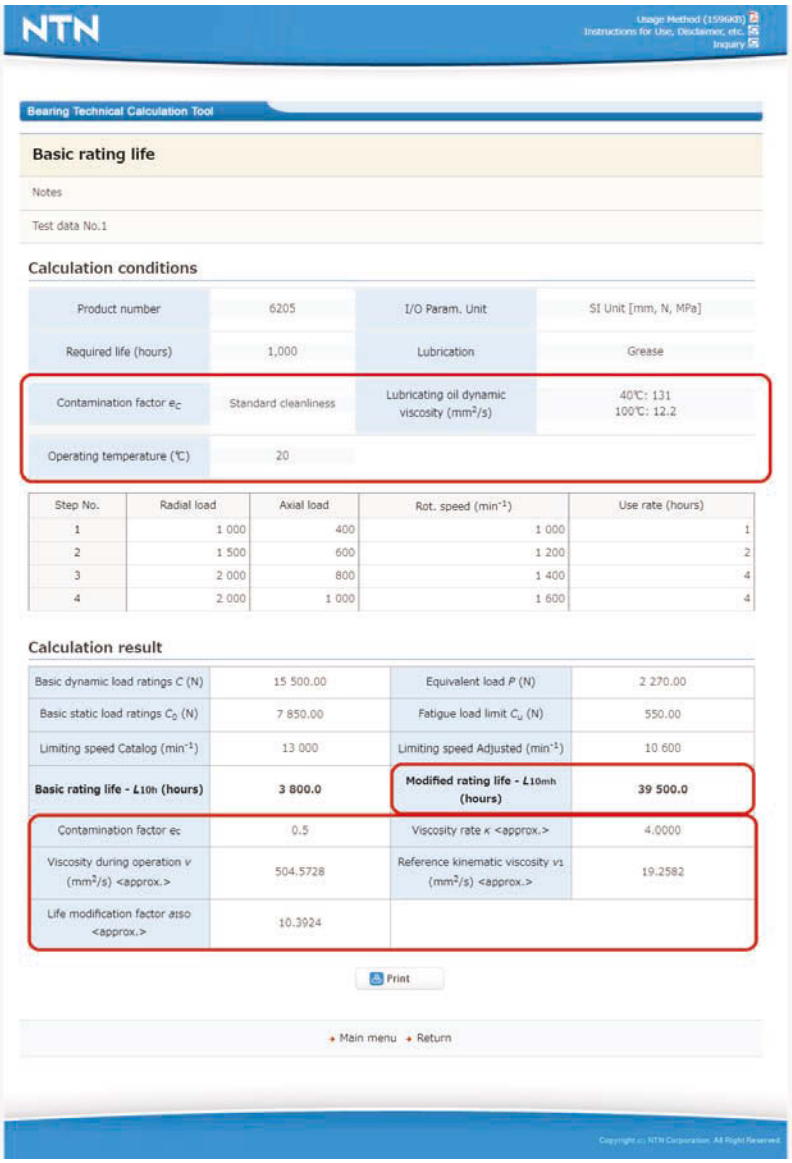
(output item) (see 1-3-4 Description of output items)

Notes, required life, count of result, units, lubrication, **NTN** product name, basic dynamic load ratings, equivalent load, basic rating life (L_{10h}), limiting speed (catalog, adjusted), inner dia., outer dia., width

Note 1) The basic rating life (L_{10h}) is displayed as "9999999.9" if it exceeds 10 million hours.
Note 2) If the count of results exceeds 24, a scroll bar is displayed on the right edge of the screen and the screen can be moved up and down.
Click "△" with the mouse: move the screen up
Click "▽" with the mouse: move the screen down

(When modified rating life was selected) The contamination factor, lubricating oil kinematic viscosity (40°C, 100°C), operating temperature, and modified rating life (L_{10mh}).

<Details of life calculation results>



Screen No. 5 Detailed display of life calculation results
(The section in the red box is only for the modified rating life)

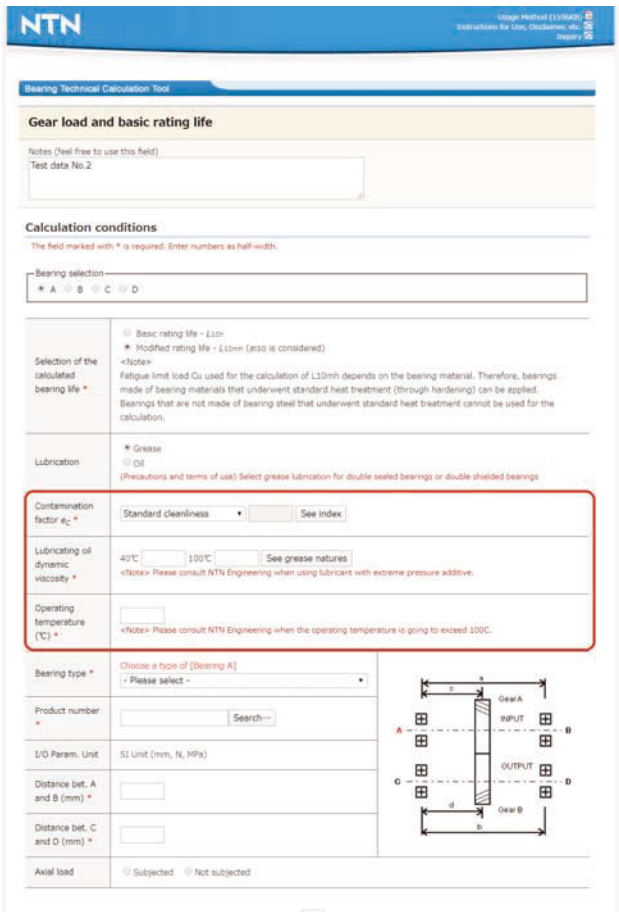
(output item) (see 1-3-4 Description of output items)

Notes, **NTN** product name, required life, count of result, units, lubrication, step No., radial load, axial load, rot. speed, use rate, basic dynamic load ratings, basic static load ratings, equivalent load, limiting speed (catalog, adjusted), basic rating life (L_{10h}).

Note 1) The basic rating life is displayed as "9999999.9" if it exceeds 10 million hours.
(When modified rating life was selected) The modified rating life (L_{10mh}), contamination factor, viscosity ratio, kinematic viscosity, reference kinematic viscosity, life correction factor.

1-3-8. Gear load and basic rating life

1. Bearing setting



Screen No. 6 Bearing setting window
(The section in the red box is only for the modified rating life)

(selection item) (see 1-3-2 Description of selection items)

When the bearing type is angular contact ball brgs. (30˚, 40˚), tapered roller brgs. (metric series), tapered roller brgs. (inch series)

Bearing selection, bearing type, lubrication, contact ang. ort. and for other bearing types

Bearing selection, bearing type, lubrication, axial load

(input item) (see 1-3-3 Description of input items)

Enter the calculation details into the notes if necessary.

If the **NTN** product name is known

Enter the **NTN** product name.

If the **NTN** product name is unknown

Click the "Search" button and search for the relevant bearing. (see 1-3-12. Bearing search window)

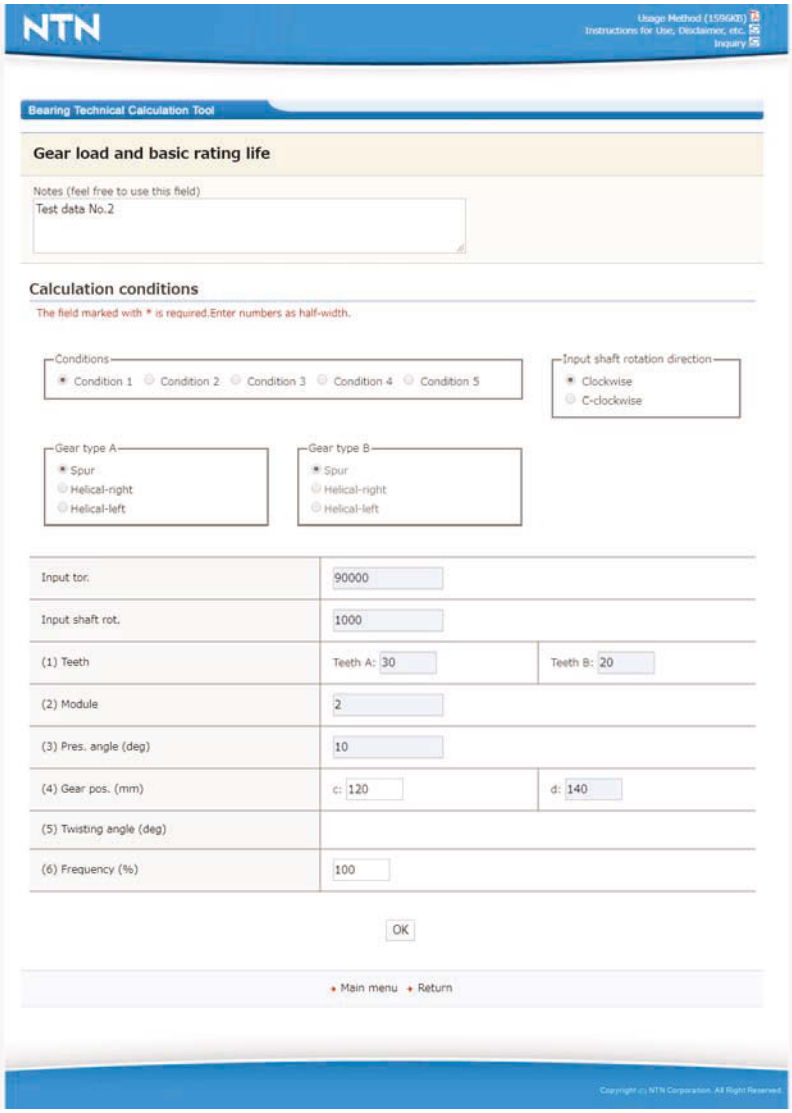
When the bearing type is angular contact ball brgs. (30˚, 40˚), tapered roller brgs. (metric series), tapered roller brgs. (inch series), enter the distance bet. effective load (bearing A and bearing B, bearing C and bearing D).

For other bearing types,

enter the distance between bearing A and bearing B, and the distance between bearing C and bearing D.

(When modified rating life was selected) Select the contamination level or select “Direct input” and then directly enter the contamination factor value. Always enter the lubricating oil kinematic viscosity for 40°C and 100°C. Always enter the operating temperature. Click the “See index” button to open the “Contamination factor ec index” and confirm the content of each contamination level. Also, click the “See ISO grade table” button (for oil lubrication) and the “See grease characteristics table” button (for grease lubrication) to open a table with typical base oil viscosity for each lubricant. Click the row in the table to enter the corresponding base oil viscosity value in the column for 40°C and 100°C of the lubricating oil kinematic viscosity.

2. Enter gear specifications



Screen No. 7 Gear specification input window

(button items) (see 1-3-1 Description of on-screen buttons)

Condition 1 (condition 2, condition 3, condition 4, condition 5)

(selection item) (see 1-3-2 Description of selection items)

Input shaft rotation direction, gear type A, gear type B

(input item) (see 1-3-3 Description of input items)

Input tor., input shaft rot. speed, number of teeth, module, pressure angle

gear position: gear A is the distance from bearing A, gear B is the distance from bearing C

(If gear A (B) is to the right of bearing A (C): enter pos.

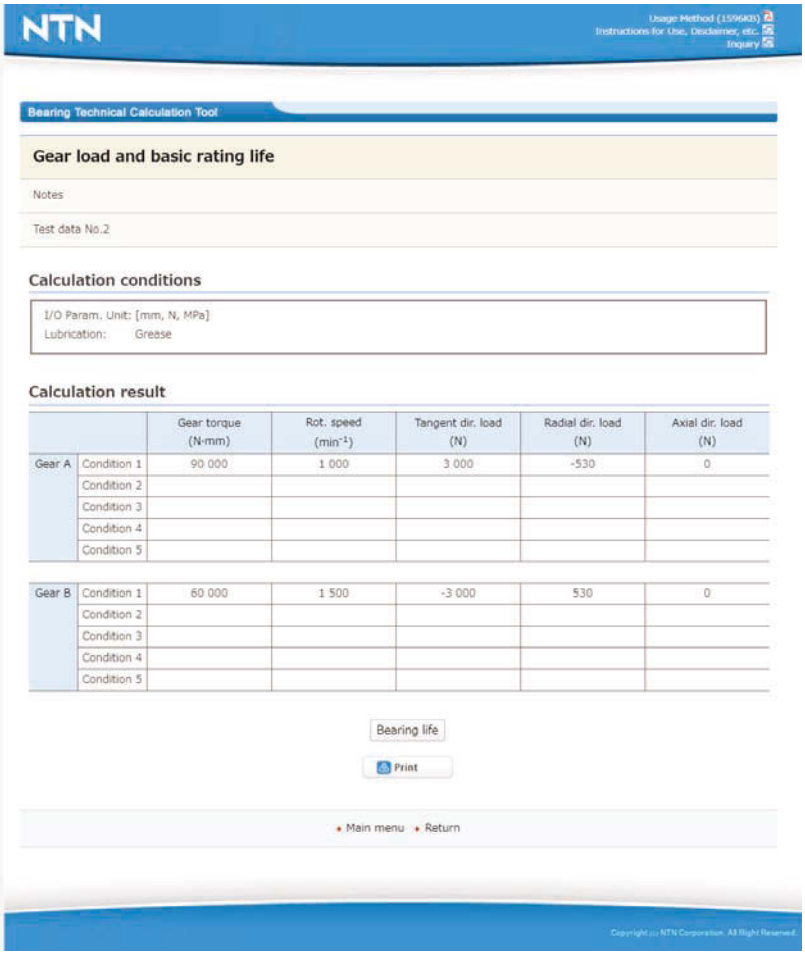
If gear A (B) is to the left of bearing A (C): enter neg.)

Twisting angle (helical gear only)

The frequency is up to five conditions, and the total of all conditions must be 100%.

3. Calculation results display

<Gear load>

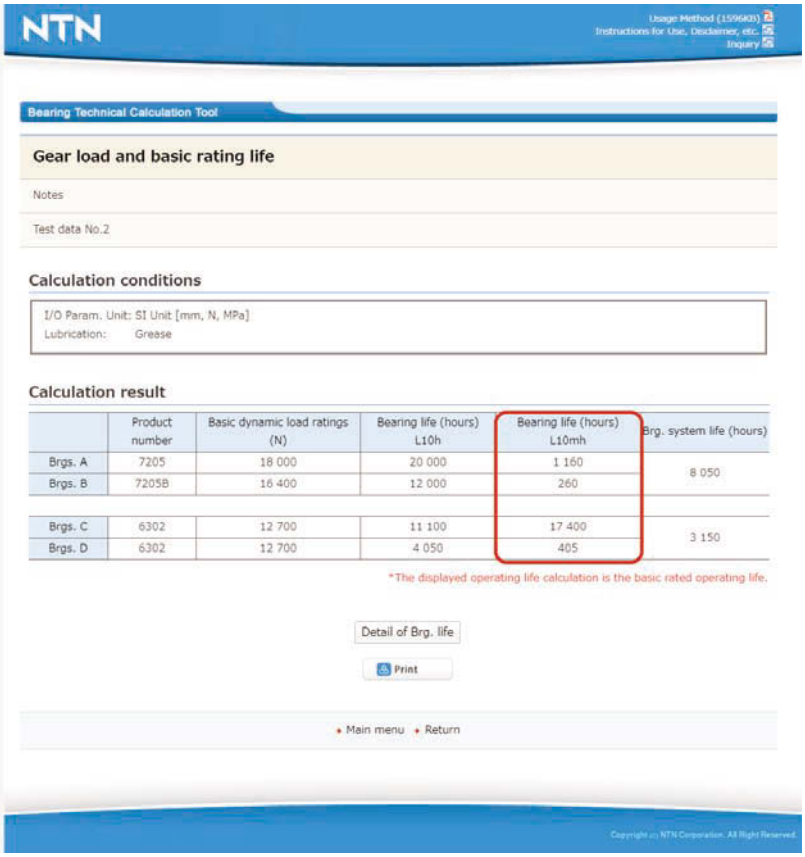


Screen No. 8 Gear load display

(output item) (see 1-3-4 Description of output items)

Notes, units, lubrication, gear torque, rot. speed, tangent dir. load, radial dir. load, axial dir. load

<Total life of bearing system and bearings>



Screen No. 9 Display of total life of bearing system and bearings
(The section in the red box is only for the modified rating life)

(output item) (see 1-3-4 Description of output items)

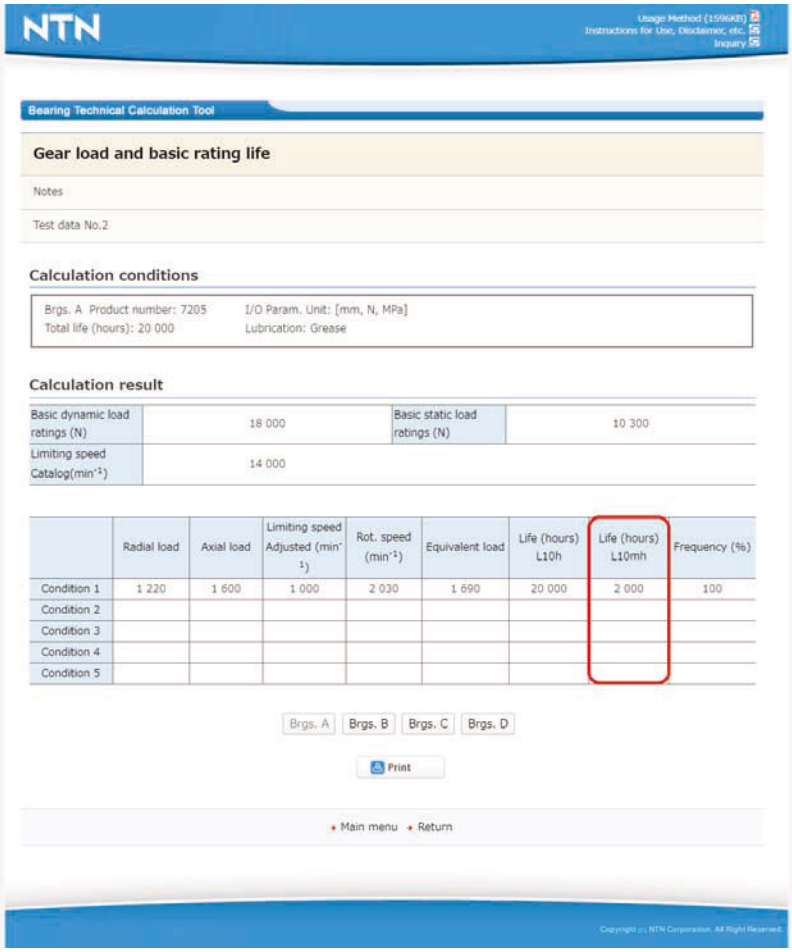
Notes, units, lubrication, NTN product name, basic dynamic load ratings, bearing life (L_{10h}): Total life of each bearing (hours)

Brg. system life: total life of combination of bearing A and bearing B, and bearing C and bearing D (hours)

Note 1) The life is displayed as "9999999.9" if it exceeds 10 million hours.

(When modified rating life was selected) Modified rating life (L_{10mh}): Total life of each bearing (hours)

<Detail of Brg. life>



Screen No. 10 Display of details of bearing life
(The section in the red box is only for the modified rating life)

(output item) (see 1-3-4 Description of output items)

Notes, **NTN** product name, units, lubrication, basic dynamic load ratings, basic static load ratings, limiting speed catalog value

Total life: total life taking into account the frequency of each bearing (hours)

The output items below are displayed for each condition.

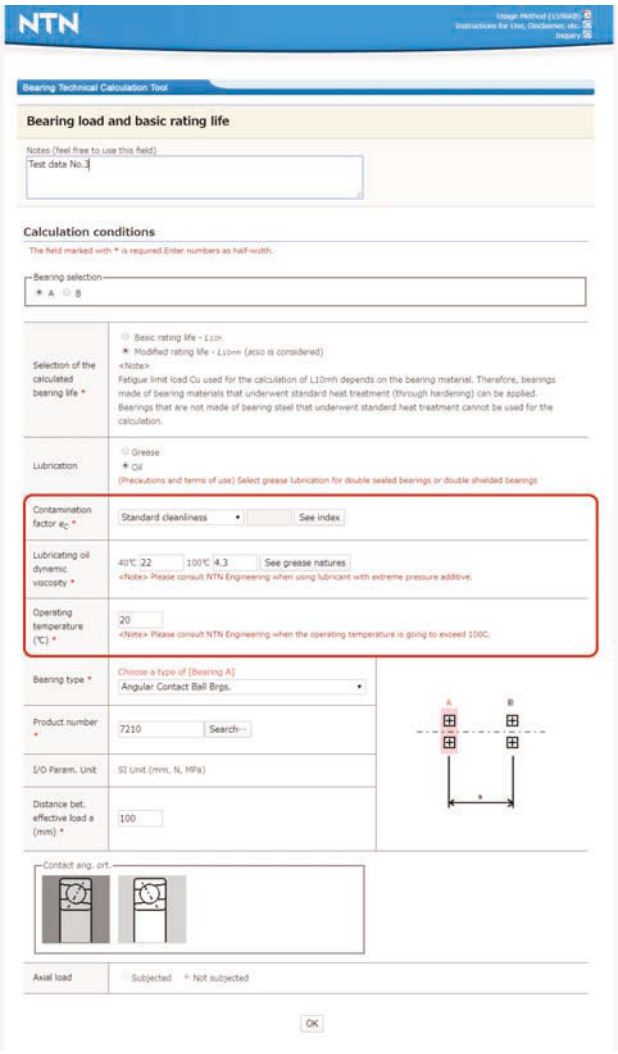
Radial load, axial load, limiting speed adjusted value, rot. speed, equivalent load, life (L_{10h}), frequency.

Note 1) The life is displayed as "9999999.9" if it exceeds 10 million hours.

(When modified rating life was selected) Life (L_{10mh})

1-3-9. Bearing load and basic rating life

1. Bearing setting



Screen No. 11 Bearing setting window
(The section in the red box is only for the modified rating life)

(selection item) (see 1-3-2 Description of selection items)

When the bearing type is angular contact ball brgs. (30˚, 40˚), tapered roller brgs. (metric series), tapered roller brgs. (inch series), bearing selection, bearing type, lubrication, I/O param. unit, contact ang. ort.

Bearing selection, bearing type, lubrication, contact ang. ort. and for other bearing types

Bearing selection, bearing type, lubrication, axial load

(input item) (see 1-3-3 Description of input items)

Enter the calculation details into the notes if necessary.

If the **NTN** product name is known

Enter the **NTN** product name.

If the **NTN** product name is unknown

Click the "Search" button and search for the relevant bearing. (see 1-3-12. Bearing search window)

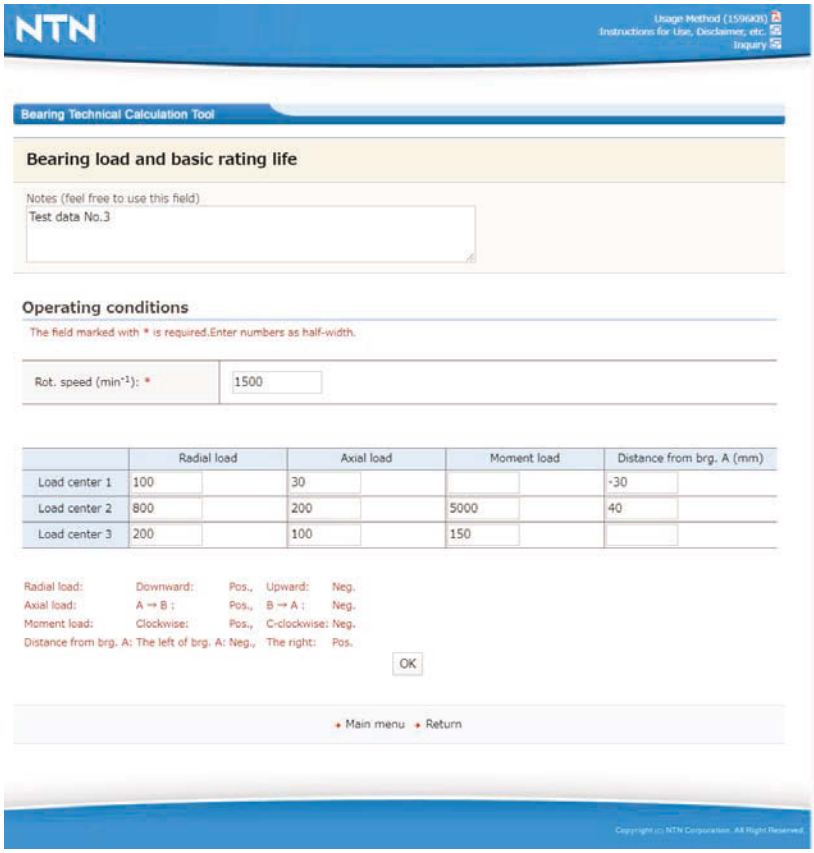
When the bearing type is angular contact ball brgs. (30˚, 40˚), tapered roller brgs. (metric series), tapered roller brgs. (inch series),

Enter the distance bet. effective load a.

For other bearing types,

Enter the distance between bearing A and bearing B.

2. Enter operating conditions



Screen No. 12 Operating conditions input window

(input item) (see 1-3-3 Description of input items)

Always enter the rot. speed.

Enter the radial load (downward: pos., upward: neg.), the axial load (A→B: pos., B→A: neg.), moment load (clockwise: pos., counterclockwise: neg.) placed on each load center into the required items.

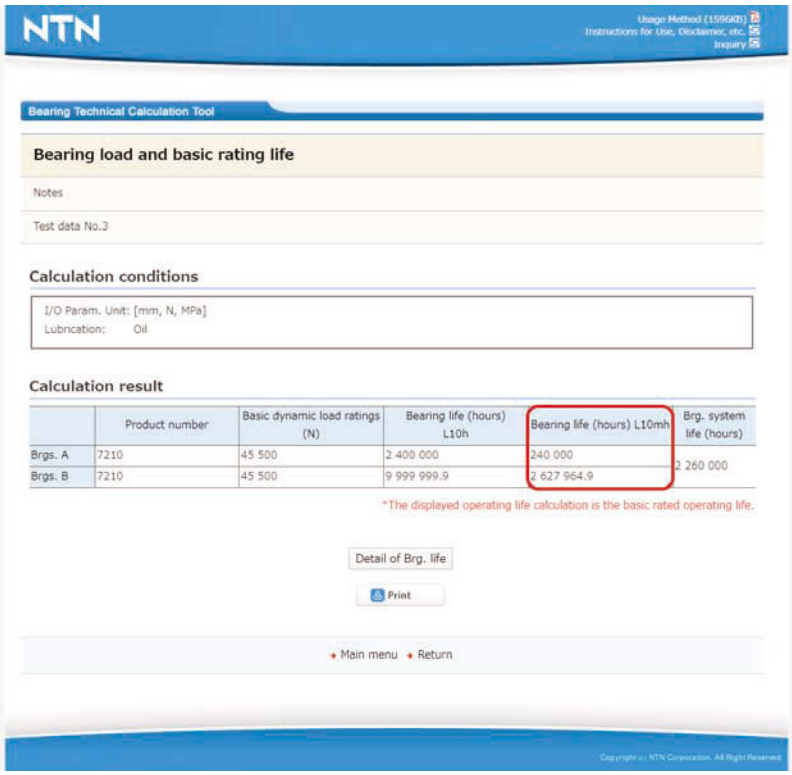
Distance from bearing A: distance from bearing A of each load center (mm)

(if bearing A is on the left of the load center: neg., if bearing A is on the right of the load center: pos.)

Enter the distance from bearing A only for load centers where a load is placed.

3. Calculation results display

<Brg. system life>



Screen No. 13 Display of brg. system life
(The section in the red box is only for the modified rating life)

(output item) (see 1-3-4 Description of output items)

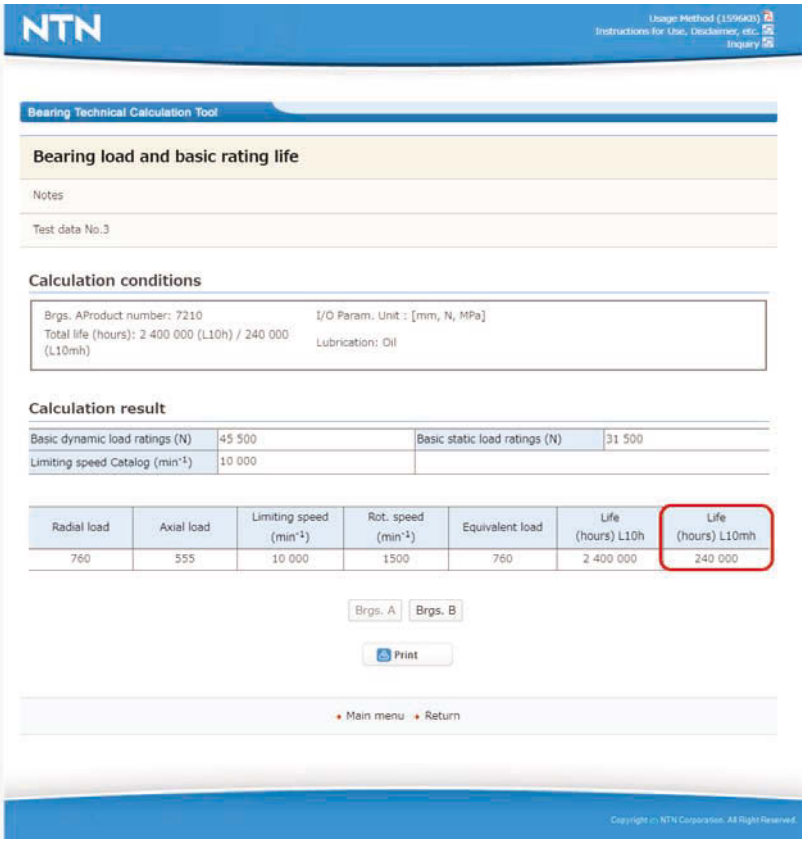
Notes, units, lubrication, **NTN** product name, basic dynamic load rating bearing life: Basic rating life (L_{10h}) of each bearing (hours)

Brg. system life: life of combination of bearing A and bearing B (hours)

Note 1) The life is displayed as "9999999.9" if it exceeds 10 million hours.

(When modified rating life was selected) Modified rating life (L_{10mh}) of each bearing (hours).

<Detail of Brg. life>



Screen No. 14 Display of details of bearing life
(The section in the red box is only for the modified rating life)

(output item) (see 1-3-4 Description of output items)

Notes, units, lubrication, **NTN** product name, basic dynamic load ratings, basic static load ratings, limiting speed (catalog value, adjusted value), radial load, axial load, rot. speed, equivalent load

Total life: basic rating life of the bearing (hours)

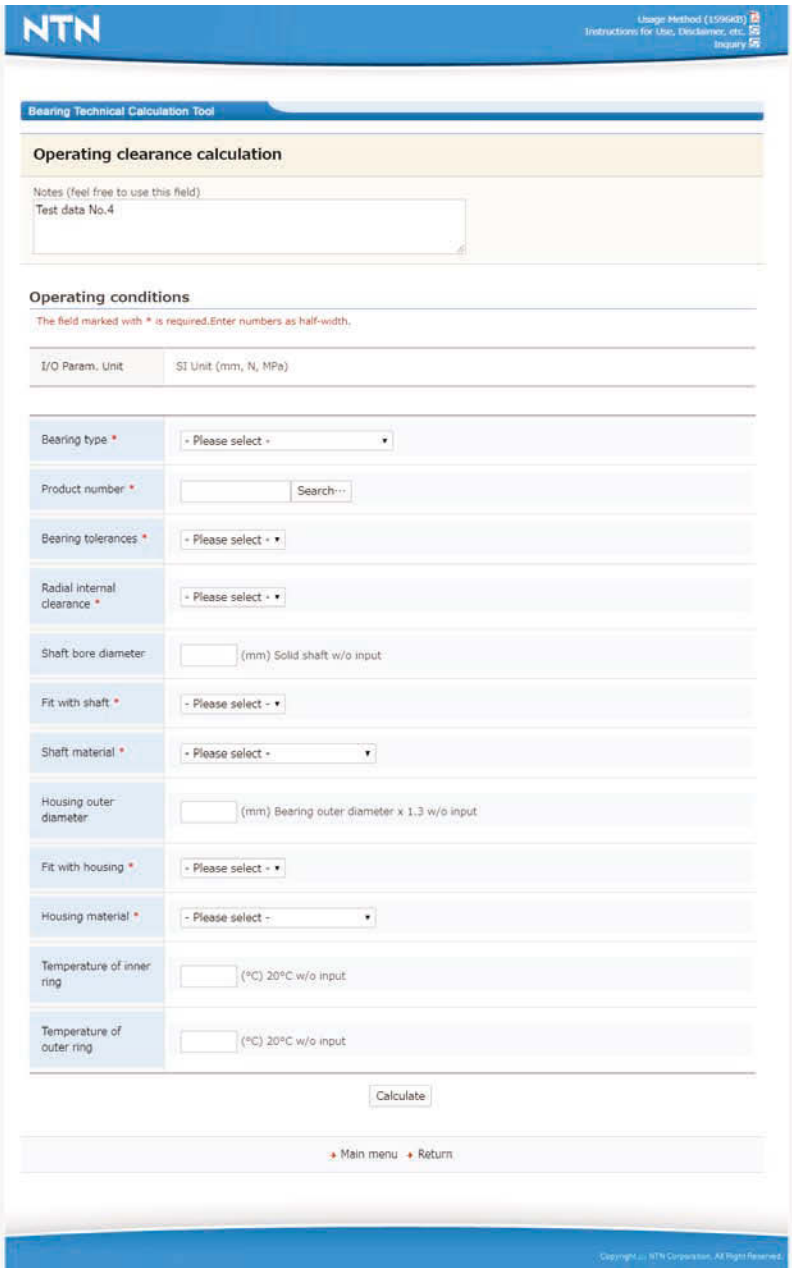
Life: Basic rating life of the bearing (hours) L_{10h} (= total life)

(When modified rating life was selected) Life: Modified rating life of the bearing (hours) L_{10mh}

Note 1) The life is displayed as "9999999.9" if it exceeds 10 million hours.

1-3-10. Operating clearance calculation

1. Enter calculation conditions



Screen No. 15 Bearing setting window

(selection item) (see 1-3-2 Description of selection items)

Bearing type, bearing tolerances, radial internal clearance, fit with shaft, shaft material, fit with housing, housing material.

(input item) (see 1-3-3 Description of input items)

Enter the calculation details into the notes if necessary.

If the **NTN** product name is known

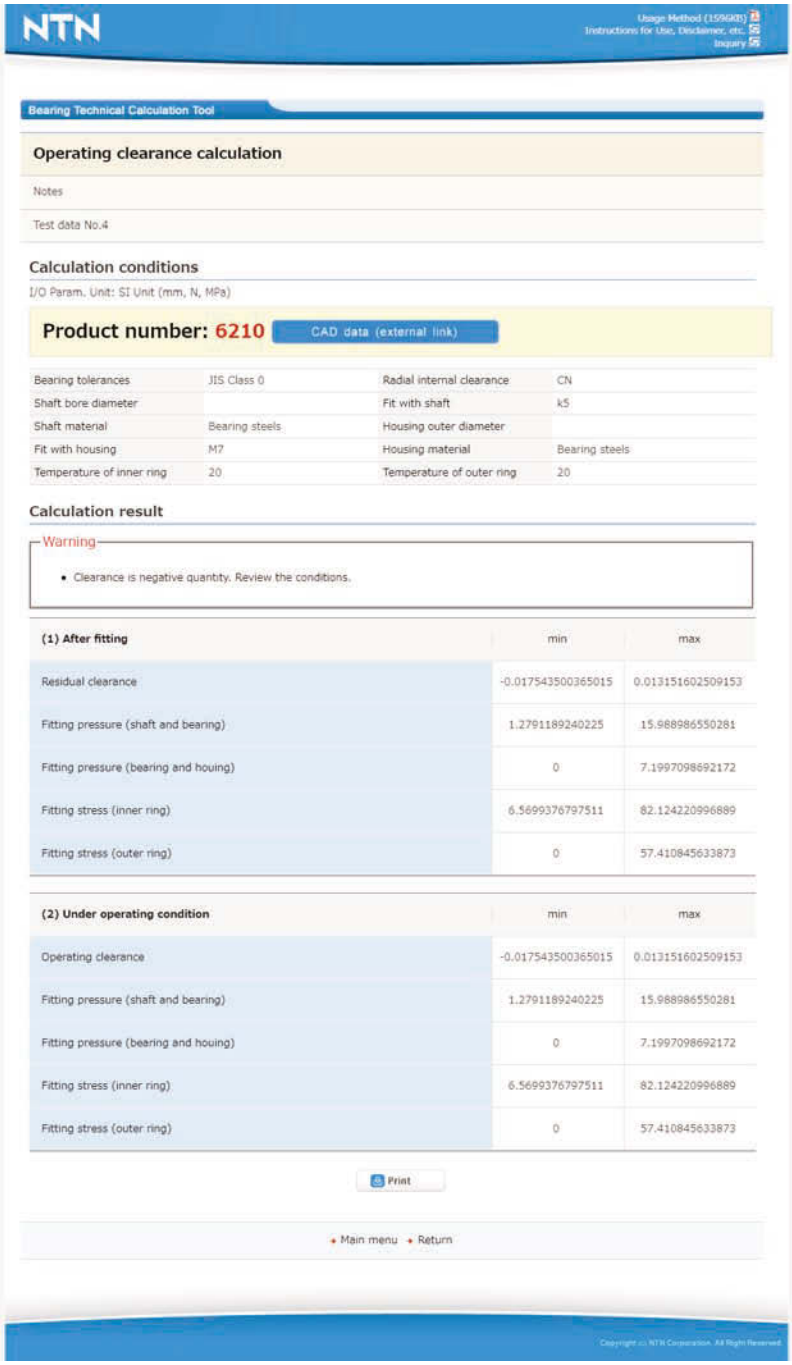
Enter the **NTN** product name.

If the **NTN** product name is unknown

Click the "Search" button and search for the relevant bearing. (see 1-3-12. Bearing search window)

Enter the required items for shaft bore diameter, housing outer diameter, shaft temperature and housing temperature under operating condition.

2. Calculation results display



Screen No. 16 Display of calculation result

(output item) (see 1-3-4 Description of output items)

Notes, units, **NTN** product name

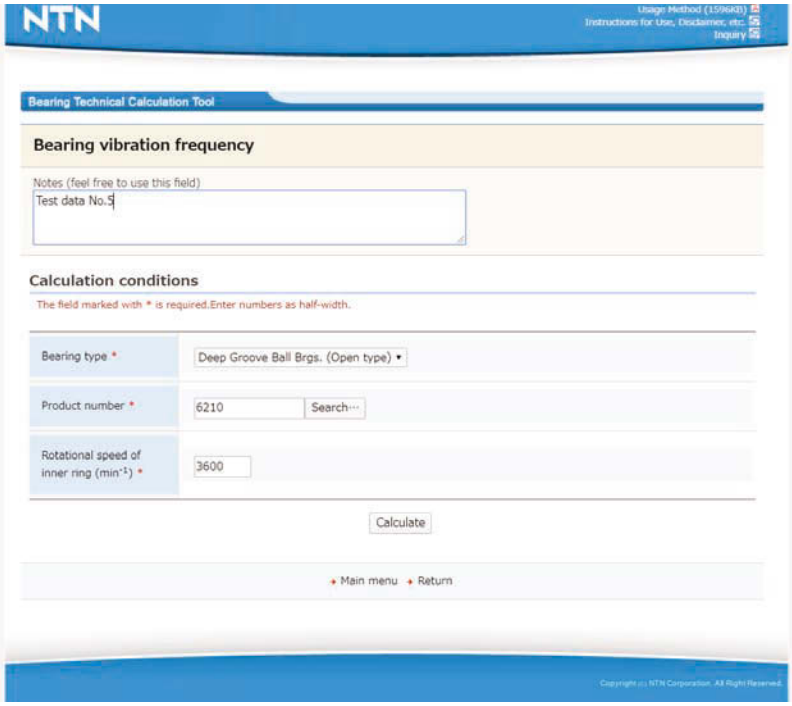
The min and max of each of the following items is displayed.

After fitting: residual clearance, fitting pressure (shaft and bearing), fitting pressure (bearing and housing), fitting stress (inner ring), fitting stress (outer ring)

Under operating condition: operating clearance, fitting pressure (shaft and bearing), fitting pressure (bearing and housing), fitting stress (inner ring), fitting stress (outer ring)

1-3-11. Bearing vibration frequency

1. Enter calculation conditions



Screen No. 17 Calculation conditions input window

(selection item) (see 1-3-2 Description of selection items)

Bearing type

(input item) (see 1-3-3 Description of input items)

Enter the calculation details into the notes if necessary.

If the **NTN** product name is known

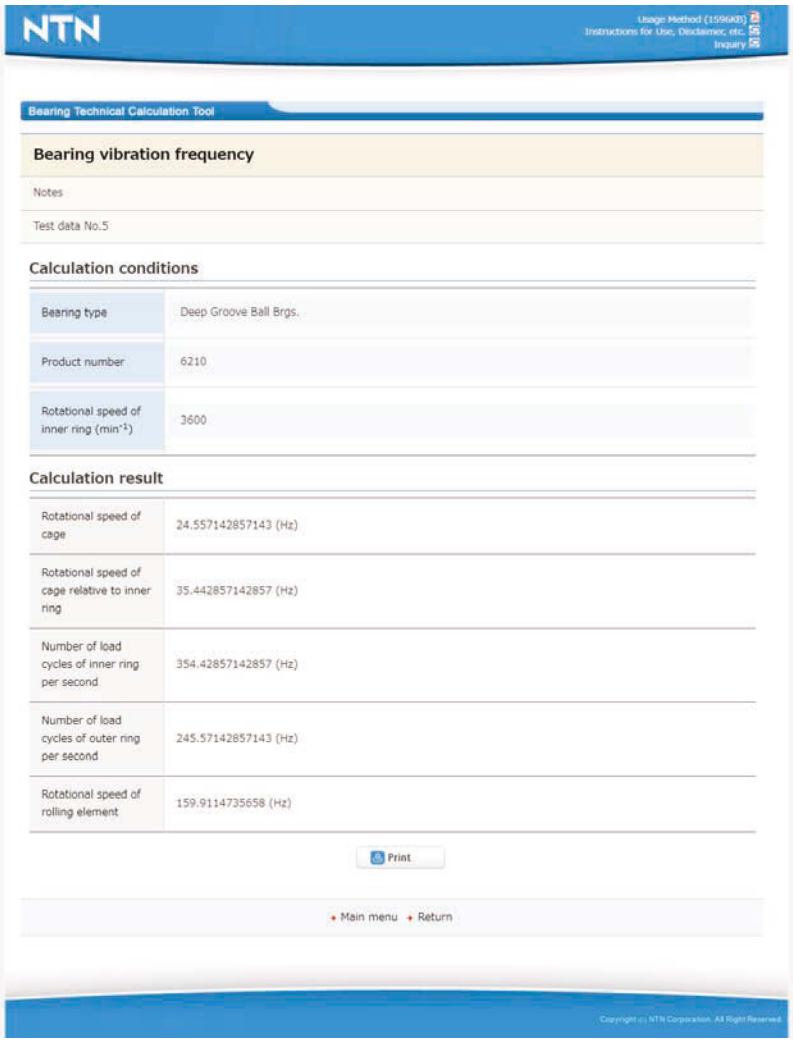
Enter the **NTN** product name.

If the **NTN** product name is unknown

Click the "Search" button and search for the relevant bearing. (see 1-3-12. Bearing search window)

Always enter the rot. speed.

2. Display of calculation result



Screen No. 18 Display of calculation result

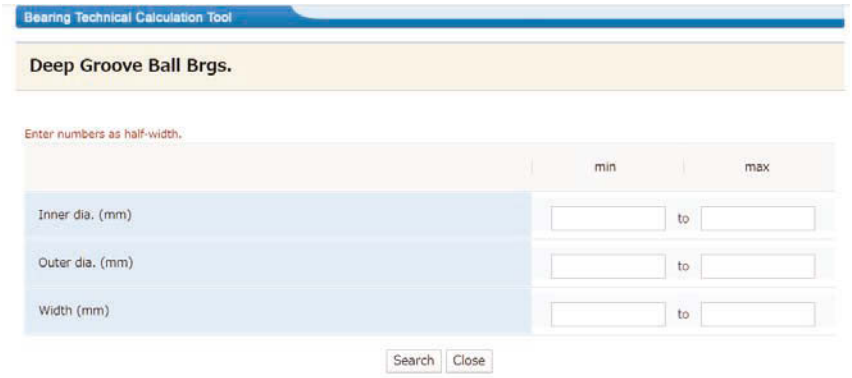
(output item) (see 1-3-4 Description of output items)

Notes, bearing type, **NTN** product name, rot. speed, rotational speed of cage, rotational speed of cage relative to inner ring, number of load cycles of inner ring per second, number of load cycles of outer ring per second, rotational speed of rolling element

1-3-12. Bearing search window

For bearing setting screens other than calculations for "Basic rating life," if the **NTN** product name is unknown, clicking the "Search" button displays the following window.

1. Bearing search window 1



Screen No. 19 Bearing search window 1

(input item)

Enter at least one of inner dia., outer dia. or width.

Inner dia. :

Inner dimensions of bearing (min and max) (mm)

(Input example) If the inner dia. of the required bearing is 25mm or more and 30mm or less

Inner dia. (mm): enter [25] to [30].

Outer dia. :

Outer dimensions of bearing (min and max) (mm)

(Input example) If the outer dia. of the required bearing is 50mm or more and 60mm or less

Outer dia. (mm): enter [50] to [60].

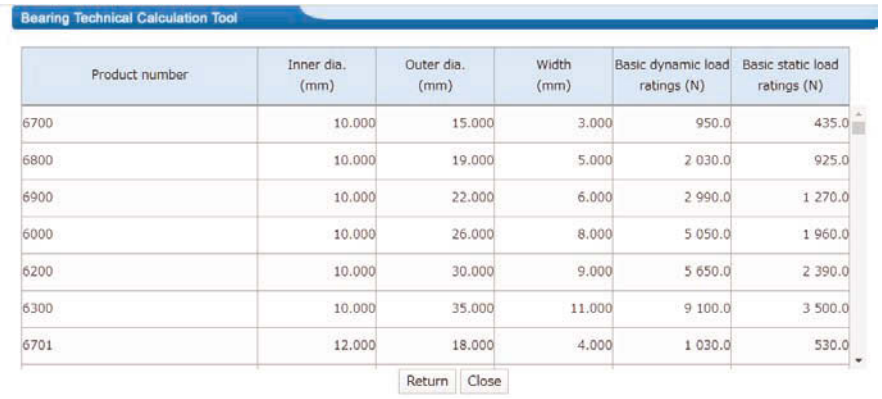
Width :

Width dimensions of bearing (min and max) (mm)

(Input example) If the width of the required bearing is 10mm or more and 20mm or less

Width (mm): enter [10] to [20].

2. Bearing search window 2



Screen No. 20 Bearing search window 2

(Bearing search method)

(1) For "Bearing search window 2," click the **NTN** product name to be used with the mouse. (the clicked bearing is displayed as white text on a black background to distinguish it from the others)

(2) Click the "OK" button.

(3) For the bearing setting screen for each calculation, enter the searched **NTN** product name into the **NTN** product name field.

Note 1) If the count of results exceeds 14, a scroll bar is displayed on the right edge of the screen and the screen can be moved up and down.

Click "△" with the mouse: move the screen up

Click "▽" with the mouse: move the screen down

1-4. Warning screens

1-4-1. Basic rating life

(1) "The entered load is too large. Contact NTN for more information."
The equivalent load calculated from the entered load conditions is a larger value than either "Basic dynamic load ratings ÷2" or "Basic static load ratings" for all bearings corresponding to the bearing selection conditions.
For expansion compensating brgs., this is also displayed when the equivalent load exceeds the limiting load.

(2) "The entered rotational speed exceeds the limiting speed. Contact NTN for more information."
The entered rot. speed is a value larger than the adjusted limiting speed of all bearings that correspond to the bearing selection conditions.

(3) "The entered load is too large and the limiting speed cannot be adjusted. Contact NTN for more information."
If C/P < 5, the above warning is displayed.

(4) The axial load is too large for the radial load to adjust the limiting speed. Contact NTN for more information."
For deep groove ball brgs., expansion compensating brgs., miniature ball brgs. (metric series), angular contact ball brgs. (30˚, 40˚), tapered roller brgs. (metric series), tapered roller brgs. (inch series), when Fa/Fr > 2.0, the above warning is displayed. For spherical roller brgs., when either Fa/Fr > 2.0 or Fa/Fr > $2 \cdot e$, the above warning is displayed.

(5) "$dp \cdot n$ < 10000. (see manual for quantity symbols) Contact NTN for more information."
If $dp \cdot n$ < 10000 from the entered rot. speed and bearing inner dia. and outer dia., the above warning is displayed.

(6) "Axial loads cannot be taken into account for life calculations with cylindrical roller brgs. For cylindrical roller brgs. (NJ, NUP, NF type) with an axial load placed on them, a separate limiting axial load must be considered."
If an axial load is entered to calculate the life of cylindrical roller brgs. and double row cylindrical roller brgs., the above warning is displayed.

1-4-2. Gear load and basic rating life, bearing load and basic rating life

(1) "The load placed on bearing A is too large. Contact NTN for more information."
If there is even one bearing with the equivalent load calculated from the load placed on each bearing that exceeds "basic dynamic load ratings) ÷2" or "(basic static load ratings)" of each bearing, the above warning is displayed. An example of the above example is when the load placed on bearing A exceeds either "basic dynamic load ratings) ÷2" or "(basic static load ratings)."
For expansion compensating brgs., this is also displayed when the equivalent load exceeds the limiting load.

(2) "The input rotational speed of bearing A exceeds the limiting speed. Contact NTN for more information."
If there is even one bearing with the rot. speed acting on each bearing that exceeds the adjusted limiting speed of each bearing, the above warning is displayed.
An example of the above example is when the rot. speed acting on bearing A exceeds the adjusted limiting speed.

(3) "The load placed on bearing A is too large and the limiting speed cannot be adjusted. Contact NTN for more information."
If either bearing is C/P <5, the above warning is displayed. An example of the above is when the load placed on bearing A is C/P < 5.

(4) "For bearing A, the axial load is too large for the radial load. Contact NTN for more information."
For deep groove ball brgs., expansion compensating brgs., miniature ball brgs. (metric series), angular contact ball brgs. (30˚, 40˚), tapered roller brgs. (metric series), tapered roller brgs. (inch series), when Fa/Fr > 2.0, the above warning is displayed. An example of the above is when the load placed on bearing A is Fa/Fr > 2.0.

(5) "For bearing A, the axial load is too large for the radial load to adjust the limiting speed. Contact NTN for more information."
For spherical roller brgs., when either $Fa/Fr > 2.0$ or $Fa/Fr > 2 \cdot e$, the above warning is displayed.

(6) "For bearing A, $dp \cdot n$ < 10000. (see manual for quantity symbols) Contact NTN for more information."
For either bearing, if $dp \cdot n$ < 10000 from the entered rot. speed and bearing inner dia. and outer dia., the above warning is displayed.

(7) "Axial loads cannot be taken into account for life calculations with cylindrical roller brgs. For cylindrical roller brgs. (NJ, NUP, NF type) with an axial load placed on them, a separate limiting axial load must be considered."
For either bearing, if an axial load is entered to calculate the life of cylindrical roller brgs. and double row cylindrical roller brgs., the above warning is displayed.

(8) "Is it OK to place an axial load on two bearings?"
For "Bearing load and basic rating life," if an axial load is placed on two bearings other than angular contact ball brgs. or tapered roller brgs., the above warning is displayed. If YES, proceed to the next step. If NO, return to the bearing selection screen and reselect the axial load.

1-4-3. Operating clearance calculation

(1) "The clearance is negative. Check the values again."
If the min residual clearance or the min operating clearance is negative, the above warning is displayed. A calculation result is output.

(2) "Interference is out of the standard of safety. Review the fit."
- Max fitting stress after fitting (inner ring)
- Max fitting stress under operating condition (inner ring)

If either of these exceeds 127 MPa, the above warning is displayed. A calculation result is output.

(3) "The conditions to use the bearing are not suitable because of high temperature."
If a temperature that exceeds 150˚C has been entered for the shaft temperature under operating condition or the housing temperature under operating condition, the above warning is displayed. A calculation result is output.

1-5. Error messages

1-5-1. Basic rating life

(1) "Select a bearing type"
In the 1-3-7-1. Bearing selection window, clicking the "OK" button without selecting a bearing type displays the above error message.

(2) "The NTN product name is incorrect"
In the 1-3-7-1. Bearing selection window, clicking the "OK" button after entering an incorrect **NTN** product name displays the above error message.

(3) "The inner dia. (MIN > MAX) is incorrect"
In the 1-3-7-1. Bearing selection window, clicking the "OK" button with the (min) > (max) for the entered dimensions (inner dia., outer dia., width) displays the above error message.

(4) "Fa/Co > 0.5. Life calculation is not possible (see manual for quantity symbols) Contact NTN for more information."
If an **NTN** product name has been entered, if the entered axial load (Fa) is not within the $0 \leq Fa/Co \leq 0.5$ range for deep groove ball brgs., the above error message is displayed.

(5) "Fa/Co > 0.3. Life calculation is not possible (see manual for quantity symbols) Contact NTN for more information."
If an **NTN** product name has been entered, if the entered axial load (Fa) is not within the $0 \leq Fa/Co \leq 0.3$ range for miniature ball brgs., the above error message is displayed.

(6) "The calculation is not possible because the equivalent load (P) = 0."
If an **NTN** product name has been entered, when both the radial load and axial load have not been entered in the 1-3-7-2. Operating conditions input window, the above error message is displayed.

(7) "Equivalent load 0 division"
If an **NTN** product name has been entered, when the rot. speed has not been entered in the 1-3-7-2. Operating conditions input window, the above error message is displayed.

(8) Enter a number of 10 or less for the number of steps"
If nothing has been entered, or a value of 11 or more has been entered as the number of steps in the 1-3-7-2. Operating conditions input window and the "Calculate" button is clicked, the above error message is displayed.

(9) "No applicable data could be found"
When selecting "deep groove ball brgs." or "expansion compensating brgs." as the bearing type in the 1-3-7-1. bearing selection window and entering the dimensions to search for bearings, if it is not within the $0 \leq Fa/Co \leq 0.5$ range from the entered operating conditions, the above error message is displayed. Also, when selecting "miniature ball brgs." as the bearing type and entering the dimensions to search for bearings, if it is not within the $0 \leq Fa/Co \leq 0.3$ range from the entered operating conditions, the above error message is displayed.
When entering dimensions and searching for bearings in the 1-3-7-1. Bearing selection window, if both the radial load and axial load have not been entered in the 1-3-7-2. Operating conditions input window, the above error message is displayed.
When entering dimensions and searching for bearings in the 1-3-7-1. Bearing selection window, if the rot. speed has not been entered in the 1-3-7-2. Operating conditions input window, the above error message is displayed.

(10) "No bearings meet the required life with these operating conditions"

If there are no bearings that meet the required life when entering the operating conditions and clicking the "Calculate" button, the above error message is displayed.

1-5-2. Gear load and basic rating life, bearing load and basic rating life

(1) "Select a bearing type"

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, clicking the "OK" button without selecting at least one bearing type displays the above error message.

(2) "Enter the NTN product name"

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, clicking the "OK" button without selecting entering the **NTN** product name displays the above error message.

(3) "The NTN product name is incorrect"

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, clicking the "OK" button after entering an incorrect **NTN** product name displays the above error message.

(4) "The inner dia. (MIN > MAX) is incorrect"

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, when clicking the "Search" button and searching for bearings, clicking the "Search" button with the (min) > (max) for the entered dimensions (inner dia., outer dia., width) displays the above error message.

(5) "Enter the correct value for distance bet. bearings"

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, clicking the "OK" button without entering the distance between bearing A and bearing B, or the distance between bearing C and bearing D (or the distance bet. effective load for angular contact ball brgs. and tapered roller brgs.) displays the above error message.

(6) "Wrong combination of the contact ang. ort."

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, when angular contact ball brgs., tapered roller brgs. (metric series) or tapered roller brgs. (inch series) are selected, if the contact ang. ort. has been selected but the same angle has been selected for both contact angles, the above error message is displayed.

(7) "Bearing type not applicable."

In the 1-3-8-1. Bearing setting and 1-3-9-1. Bearing setting window, if bearing A and bearing B, or bearing C and bearing D is set as angular contact ball brgs. or tapered roller brgs., and the other is set as bearings other than angular contact ball brgs. or tapered roller brgs., the above error message is displayed.

(8) "The total frequency is not 100%"

In the 1-3-8-2. Gear specification input window, if the total frequency is not 100%, completely entering the gear specifications and clicking the "Calculate" button displays the above error message.

(9) "Calculation error"

In the 1-3-8-2. Gear specification input window, clicking the "Calculate" button without entering any frequency at all displays the above error message.

(10) "The calculation not possible because the equivalent load (P) = 0 [Bearing A (condition 1)]"

In the 1-3-8-2. Gear specification input window, if only the input tor. of the gear specifications are not entered but other items are entered, clicking the "Calculate" button clears all gear loads (tangent dir., radial dir., axial dir.) in <Gear loads> in the 1-3-8-3 Calculation results display window. Clicking the "Bearing life" button here displays the above error message.

(11) "The calculation not possible because the rot. speed (n) = 0 [Bearing A (condition 1)]"

In the 1-3-8-2. Gear specification input window, if only the rot. speed of the gear specifications are not entered but other items are entered, clicking the "Calculate" button clears all rot. speeds for gear A and gear B in <Gear loads> in the 1-3-8-3 Calculation results display window. Clicking the "Bearing life" button here displays the above error message.

(12) "Enter the correct value for gear specifications"

In the 1-3-8-2. Gear specification input window, if at least one of the number of teeth and module of gear A and gear B have not been entered, clicking the "Calculate" button displays the above error message.

(13) "Enter the correct value for rot. speed"

In the 1-3-9-2. Load conditions input window, clicking the "OK" button without entering the rot. speed displays the above error message.

(14) "The calculation not possible because the equivalent load (P) = 0 [Bearing A]"

In the 1-3-9-2. Load conditions input window, clicking the "OK" button without entering any loads at all displays the above error message.

(15) "Fa/Co > 0.5 for bearing A. Life calculation is not possible (see manual for quantity symbols) Contact NTN for more information."

If any of the bearings include deep groove ball brgs., and the axial load placed on those bearings is not within the $0 \leq Fa/Co \leq 0.5$ range, the above error message is displayed.

(16) "Fa/Co> 0.3 for bearing A. Life calculation is not possible (see manual for quantity symbols) Contact NTN for more information."

If any of the bearings include miniature ball brgs., and the axial load placed on those bearings is not within the $0 \leq Fa/Co \leq 0.3$ range, the above error message is displayed.

1-5-3. Operating clearance calculation

(1) "Required items have not been entered"

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with no selection items selected at all, or not entering the **NTN** product name, the above error message is displayed.

(2) "Select a bearing type"

In the 1-3-10-1. Operating conditions input window, clicking the "Search" button of the **NTN** product name without selecting a bearing type displays the above error message.

(3) "The NTN product name is incorrect"

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with an incorrect **NTN** product name entered, or if the bearing type and the **NTN** product name do not match, the above error message is displayed.

(4) "Bearing inner diameter ≤ Shaft bore diameter. Impossible to calculate."

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with the entered shaft bore diameter exceeding the bearing inner dia. displays the above error message.

(5) "The value of inner dia. (housing outer diameter) is inappropriate"

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with the entered shaft bore diameter (housing outer diameter) value negative or a character other than a number displays the above error message.

(6) "Housing outer diameter ≤ Bearing outer diameter. Impossible to calculate."

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with the entered housing outer diameter less than the bearing outer dia. value displays the above error message.

(7) "The value of the shaft (housing) temperature under operating condition is inappropriate."

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with the entered shaft (housing) temperature under operating conditions other than a number displays the above error message.

(8) "MIN inner dia. is incorrect"

In the 1-3-10-1 Operating conditions input window, when clicking the **NTN** product name "Search" button and searching for bearings, clicking the "Search" button with the entered dimensions (inner dia., outer dia., width) other than a number, the above error message is displayed.

(9) "The inner dia. (MIN > MAX) is incorrect"

In the 1-3-10-1 Operating conditions input window, when clicking the **NTN** product name "Search" button and searching for bearings, and

(1) The "Search" button is clicked with (min) entered for dimensions (inner dia., outer dia., width) > (max),

(2) The "Search" button is clicked without entering a min value for dimensions (inner dia., outer dia., width) and a negative value entered of max, the above error message is displayed.

(10) "No applicable data could be found"

In the 1-3-10-1 Operating conditions input window, clicking the **NTN** product name "Search" button and searching for bearings, and there are bearings that meet the conditions for dimensions (inner dia., outer dia., width), the above error message is displayed.

(11) "Precision symbols are not defined for large diameter bearings"

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with both an **NTN** product name with a large inner dia. and outer dia., and precision symbols that have not been defined with JIS have been entered for those inner dia. and outer dia., the above error message is displayed.

(12) "Fit symbols are not defined for large diameter bearings"

In the 1-3-10-1. Operating conditions input window, clicking the "Calculate" button with both an **NTN** product name with a large inner dia. and outer dia., and fitting symbols that have not been defined with JIS have been entered for those inner dia. and outer dia., the above error message is displayed.

1-5-4. Bearing vibration frequency

(1) "Required items have not been entered"

In the 1-3-11-1. Calculation conditions input window, clicking the "Calculate" button without either the bearing type, **NTN** product name or rot. speed entered, the above error message is displayed.

(2) "The corresponding bearing type does not exist"

In the 1-3-11-1. Calculation conditions input window, clicking the "Search" button of the **NTN** product name without selecting a bearing type displays the above error message.

(3) "The NTN product name is incorrect"

In the 1-3-11-1. Calculation conditions input window, clicking the "Calculate" button with an incorrect **NTN** product name entered, or if the bearing type and the **NTN** product name do not match, the above error message is displayed.

(4) "The value of rot. speed is inappropriate"

In the 1-3-11-1. Calculation conditions input window, clicking the "Calculate" button with the entered rot. speed value negative or a character other than a number displays the above error message.

(5) "MIN inner dia. is incorrect"

In the 1-3-11-1 Calculation conditions input window, when clicking the **NTN** product name "Search" button and searching for bearings, clicking the "Search" button with the entered dimensions (inner dia., outer dia., width) other than a number, the above error message is displayed.

(6) "The inner dia. (MIN > MAX) is incorrect"

In the 1-3-11-1 Calculation conditions input window, when clicking the **NTN** product name "Search" button and searching for bearings, and

(1) The "Search" button is clicked with (min) entered for dimensions (inner dia., outer dia., width) > (max),

(2) The "Search" button is clicked without entering a min value for dimensions (inner dia., outer dia., width) and a negative value entered of max, the above error message is displayed.

(7) "No applicable data could be found"

In the 1-3-11-1 Calculation conditions input window, clicking the **NTN** product name "Search" button and searching for bearings, and there are bearings that meet the conditions for dimensions (inner dia., outer dia., width), the above error message is displayed.

1-6. Calculation formula

1-6-1. Description of quantity symbols

K_t ····· : Tangent dir. load of gear (N)
K_s ····· : Radial dir. load of gear (N)
K_a ····· : Axial dir. load of gear (N)
M ····· : Torque applied to gear (N·mm)
z ····· : Teeth of gear
m ····· : Module of gear

D_p : Pitch diameter of gear $\left(=\frac{z \cdot m}{\cos\beta}\right)$ (mm)

α ····· : Pres. angle of gear
β ····· : Twisting angle of gear (helical gear only)
SB_1 ····· : Distance between bearing A and bearing B (mm)
SG_1 ····· : Distance between bearing A and gear A (mm)
SB_2 ····· : Distance between bearing C and bearing D (mm)
SG_2 ····· : Distance between bearing C and gear B (mm)
D_{pA} ····· : Pitch diameter of gear A (mm)
D_{pB} ····· : Pitch diameter of gear B (mm)
F_r ····· : Radial load placed on bearing (N)
F_a ····· : Axial load placed on bearing (N)
F_{rA} ····· : Radial load placed on bearing A (N)
F_{rB} ····· : Radial load placed on bearing B (N)
F_{rC} ····· : Radial load placed on bearing C (N)
F_{rD} ····· : Radial load placed on bearing D (N)
F_{aA} ····· : Axial load placed on bearing A (N)
F_{aB} ····· : Axial load placed on bearing B (N)
P ····· : Equivalent load (N)
P_r ····· : Equivalent radial load (N)
P_a ····· : Equivalent axial load (N)
P_m ····· : Average value of equivalent load (N)
P_i ····· : Equivalent load placed on each step (N)
P_{min} ····· : Min value of equivalent load (N)
P_{max} ····· : Max value of equivalent load (N)
p ····· : Life calculation formula index
Ball bearings P = 3
Roller bearings P = 10/3
n ····· : Rot. speed (min^{-1})
n_i ····· : Rot. speed of each step (min^{-1})
n_m ····· : Average value of rot. speed (min^{-1})
$n_1, n_2, \cdots n_n$ ····· : Rot. speed of each step (min^{-1})
t_i ····· : Use rate of each step (hours or %)
$t_1, t_2, \cdots t_n$ ····· : Use rate of each step (hours or %)
X ····· : Radial load coefficient
Y ····· : Axial load coefficient
Y_A ····· : Axial load coefficient of bearing A
Y_B ····· : Axial load coefficient of bearing B

F_{ri}	:	Radial load placed on shaft load center	(N)
F_{mi}	:	Moment load placed on shaft load center	(N·mm)
L_1	:	Distance from bearing A to load center	(mm)
L_B	:	Distance from bearing A to bearing B	(mm)
L_{10h}	:	Basic rating life	(hours)
L_T	:	Total life of bearing system	(hours)
L_t	:	Total life of bearing unit	(hours)
L_A	:	Basic rating life of bearing A	(hours)
L_B	:	Basic rating life of bearing B	(hours)
L_{10hi}	:	Basic rating life under each meshing condition	(hours)
C	:	Basic dynamic load ratings	(N)
e	:	When both are ball bearings e=10/9	
		When both are tapered roller bearings e=9/8	
		When one is a ball bearing, and the other is a tapered roller bearing e=(10/9+9/8)/2	
q_i	:	Frequency of gear meshing conditions	(%)
S	:	Shaft bore diameter	(mm)
H	:	Housing outer diameter	(mm)
T_S	:	Shaft temperature under operating condition	(˚C)
T_H	:	Housing temperature under operating condition	(˚C)
d	:	Bearing inner dia.: (nominal dimensions)	(mm)
D	:	Bearing outer dia.: (nominal dimensions)	(mm)
dd_{min}	:	Min value of bearing inner dia. tolerance	(mm)
dd_{max}	:	Max value of bearing inner dia. tolerance	(mm)
DD_{min}	:	Min value of bearing outer dia. tolerance	(mm)
DD_{max}	:	Max value of bearing outer dia. tolerance	(mm)
SS_{min}	:	Min value of shaft outer dia. tolerance	(mm)
SS_{max}	:	Max value of shaft outer dia. tolerance	(mm)
HH_{min}	:	Min value of housing outer dia. tolerance	(mm)
HH_{max}	:	Max value of housing outer dia. tolerance	(mm)
$C_{r\,min}$	:	Min value of radial internal clearance	(mm)
$C_{r\,max}$	:	Max value of radial internal clearance	(mm)
E_S	:	Young's modulus of shaft	(MPa)
ν_S	:	Poisson's ratio of shaft	
α_S	:	Coefficient of linear thermal expansion of shaft	(1/˚C)
E_H	:	Young's modulus of housing	(MPa)
ν_H	:	Poisson's ratio of housing	
α_H	:	Coefficient of linear thermal expansion of housing	(1/˚C)
E_B	:	Young's modulus of bearing inner ring, outer ring	(= 208000 MPa)
d_m	:	Average inner ring groove diameter	(mm)
D_m	:	Average outer ring groove diameter	(mm)
D_r	:	Outer ring groove diameter	(mm)
S_o	:	Expansion of shaft outer dia. nominal dimensions taking into account temperature	(mm)
d_o	:	Expansion of bearing inner dia. nominal dimensions taking into account temperature	(mm)
D_o	:	Expansion of bearing outer dia. nominal dimensions taking into account temperature	(mm)
H_o	:	Expansion of housing inner dia. nominal dimensions taking into account temperature	(mm)
m_i	:	Average value of interference of shaft and inner ring	(mm)
σ_i	:	Standard deviation of interference of shaft and inner ring	(mm)
m_o	:	Average value of interference of outer ring and housing	(mm)
σ_o	:	Standard deviation of interference of outer ring and housing	(mm)

λ_i	: Average inner ring groove diameter coefficient of expansion	
λ_o	: Average outer ring groove diameter coefficient of expansion	
M_i	: Average value of clearance reduction due to fitting with inner ring and shaft	(mm)
Σ_i	: Standard deviation of clearance reduction due to fitting with inner ring and shaft	(mm)
M_o	: Average value of clearance reduction due to fitting with outer ring and housing	(mm)
Σ_o	: Standard deviation of clearance reduction due to fitting with outer ring and housing	(mm)
Δ_t	: Clearance reduction due to temperature difference of shaft and housing	(mm)
U_m	: Average value of operating clearance	(mm)
U_σ	: Standard deviation of operating clearance	(mm)
Q_S, Q_i, Q_O, Q_H, m_f, σ_f, t_O, μ_t, σ_t	: values used during calculations	
U_{min}	: Min value of operating clearance	(mm)
U_{max}	: Max value of operating clearance	(mm)
P_{imin}	: Min value of fitting pressure (shaft and bearing)	(MPa)
P_{imax}	: Max value of fitting pressure (shaft and bearing)	(MPa)
σ_{imin}	: Min value of fitting stress (inner ring)	(MPa)
σ_{imax}	: Max value of fitting stress (inner ring)	(MPa)
P_{omin}	: Min value of fitting pressure (bearing and housing)	(MPa)
P_{omax}	: Max value of fitting pressure (bearing and housing)	(MPa)
σ_{omin}	: Min value of fitting stress (outer ring)	(MPa)
σ_{omax}	: Max value of fitting stress (outer ring)	(MPa)
n_i	: Rot. speed of inner ring	(min^{-1})
α_0	: Contact ang.	(°)
Z	: Number of rolling elements	(No.)
D_w	: Rolling element diameter	(mm)
d_{pw}	: Rolling element pitch diameter	(mm)
n_c	: Rotational speed of cage	(Hz)
n_{ci}	: Rotational speed of cage relative to inner ring	(Hz)
f_c	: Number of load cycles of inner ring per second	(Hz)
f_{ce}	: Number of load cycles of outer ring per second	(Hz)
n_a	: Rotational speed of rolling element	(Hz)
L_{10mh}	: Modified rating life	(hours)
a_{ISO}	: Modified rating life factor	
e_c	: Contamination factor	
C_u	: Fatigue limit load	(N)
ν	: Viscosity during operation	(mm^2/s)
ν_1	: Reference kinematic viscosity	(mm^2/s)
κ	: Viscosity ratio	

1-6-2. Gear load

$$K_t = \frac{2 \cdot M}{D_p}$$

$$K_s = K_t \cdot \tan\alpha \quad \text{(spur)}$$

$$= K_t \cdot \frac{\tan\alpha}{\cos\beta} \quad \text{(helical gear)}$$

$$K_a = K_t \cdot \tan\beta \quad \text{(helical gear only)}$$

Each positive and negative gear load in this catalog has been set from the rotation direction of the input shaft when viewing bearing A from bearing B, and the twisting direction of each gear as in **Table 1**.

Table 1 Positive and negative of each gear load

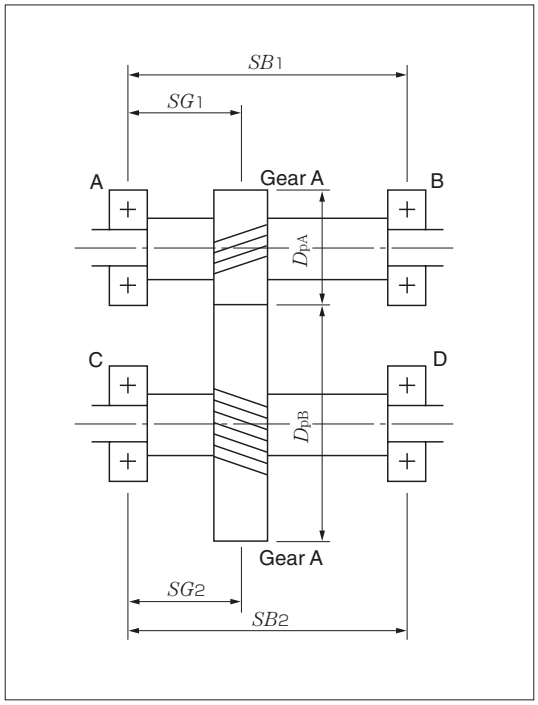
Rotation direction of input shaft	Twisting direction of gear		Tangent dir. load	Radial dir. load	Axial dir. load
Clockwise	Gear A	Right screw	Pos.	Neg.	Neg.
		Left screw	Pos.	Neg.	Pos.
	Gear B	Right screw	Neg.	Pos.	Neg.
		Left screw	Neg.	Pos.	Pos.
Counterclockwise	Gear A	Right screw	Neg.	Neg.	Pos.
		Left screw	Neg.	Neg.	Neg.
	Gear B	Right screw	Pos.	Pos.	Pos.
		Left screw	Pos.	Pos.	Neg.

Note 1) Axial dir. load not taken into account for spurs.
Note 2) Gear twisting direction not taken into account for spurs.

1-6-3. Load distribution on bearings

1. Gear load

Radial load (applies to both spurs and helical gears)



1) When the twisting direction of gear A is right and the direction of rotation is clockwise, or the twisting direction of gear A is left and the direction of rotation is counterclockwise,

$$F_{rA} = \sqrt{\left(\frac{SB_1 - SG_1}{SB_1} K_t\right)^2 + \left(\frac{SB_1 - SG_1}{SB_1} K_s + \frac{D_{pA}}{2 \cdot SB_1} K_a\right)^2}$$

$$F_{rB} = \sqrt{\left(\frac{SG_1}{SB_1} K_t\right)^2 + \left(\frac{SG_1}{SB_1} K_s - \frac{D_{pA}}{2 \cdot SB_1} K_a\right)^2}$$

$$F_{rC} = \sqrt{\left(\frac{SB_2 - SG_2}{SB_2} K_t\right)^2 + \left(\frac{SB_2 - SG_2}{SB_2} K_s - \frac{D_{pB}}{2 \cdot SB_2} K_a\right)^2}$$

$$F_{rD} = \sqrt{\left(\frac{SG_2}{SB_2} K_t\right)^2 + \left(\frac{SG_2}{SB_2} K_s + \frac{D_{pB}}{2 \cdot SB_2} K_a\right)^2}$$

2) When the twisting direction of gear A is left and the direction of rotation is clockwise, or the twisting direction of gear A is right and the direction of rotation is counterclockwise,

$$F_{rA}=\sqrt{\left(\frac{SB_1-SG_1}{SB_1}K_t\right)^2+\left(\frac{SB_1-SG_1}{SB_1}K_s-\frac{D_{pA}}{2\cdot SB_1}K_a\right)^2}$$

$$F_{rB}=\sqrt{\left(\frac{SG_1}{SB_1}K_t\right)^2+\left(\frac{SG_1}{SB_1}K_s+\frac{D_{pA}}{2\cdot SB_1}K_a\right)^2}$$

$$F_{rC}=\sqrt{\left(\frac{SB_2-SG_2}{SB_2}K_t\right)^2+\left(\frac{SB_2-SG_2}{SB_2}K_s+\frac{D_{pB}}{2\cdot SB_2}K_a\right)^2}$$

$$F_{rD}=\sqrt{\left(\frac{SG_2}{SB_2}K_t\right)^2+\left(\frac{SG_2}{SB_2}K_s-\frac{D_{pB}}{2\cdot SB_2}K_a\right)^2}$$

Note 1) For spurs, $K_a=0$

Axial load (helical gear only)

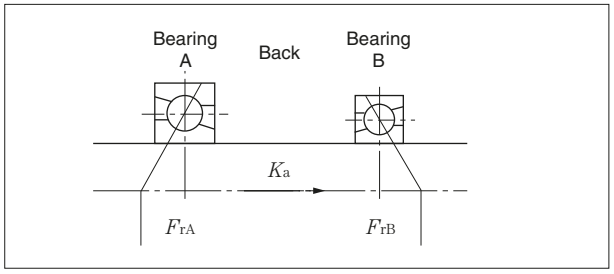
1) Angular contact ball brgs. and tapered roller brgs.

If a radial load (F_r) is placed on angular contact ball brgs. and tapered roller brgs., a component force is generated in the axial direction. This is called the induced thrust load (F_a'). The size of the induced thrust load is determined with the following formula.

$$F_a'=\frac{0.5\cdot F_r}{Y}\cdots\cdots\cdots\cdots\cdots\cdots\text{(N or kgf)}$$

The calculation of the axial load and equivalent load of each bearing when angular contact ball brgs. and tapered roller brgs. are positioned opposite each other.

(a) Back-to-back arrangement



(1) For $\frac{0.5\cdot F_{rA}}{Y_A}\leqq\frac{0.5\cdot F_{rB}}{Y_B}+K_a$

$$F_{aA}=\frac{0.5\cdot F_{rB}}{Y_B}+K_a$$

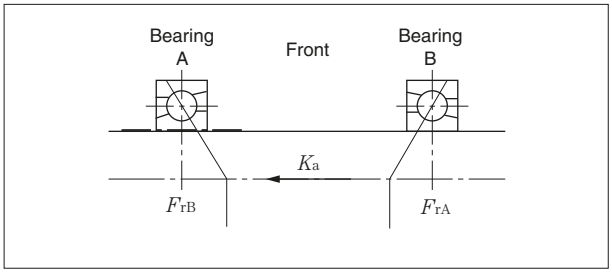
$$F_{aB}=\frac{0.5\cdot F_{rB}}{Y_B}$$

(2) For $\frac{0.5\cdot F_{rA}}{Y_A}>\frac{0.5\cdot F_{rB}}{Y_B}+K_a$

$$F_{aA}=\frac{0.5\cdot F_{rA}}{Y_A}$$

$$F_{aB}=\frac{0.5\cdot F_{rA}}{Y_A}-K_a$$

(a) Face-to-face arrangement



(1) For $\frac{0.5\cdot F_{rB}}{Y_B}\leqq\frac{0.5\cdot F_{rA}}{Y_A}+K_a$

$$F_{aA}=\frac{0.5\cdot F_{rA}}{Y_A}$$

$$F_{aB}=\frac{0.5\cdot F_{rA}}{Y_A}+K_a$$

(2) For $\frac{0.5\cdot F_{rB}}{Y_B}>\frac{0.5\cdot F_{rA}}{Y_A}+K_a$

$$F_{aA}=\frac{0.5\cdot F_{rB}}{Y_B}-K_a$$

$$F_{aB}=\frac{0.5\cdot F_{rB}}{Y_B}$$

1) Other bearings

If there is an instruction to place an axial load on the bearing setting screen, place an axial load on the bearing.

(1) If the load is placed on a single row, the entire axial load is placed on those bearings.

(2) If the load is placed on two rows, half the axial load is placed on those bearings.

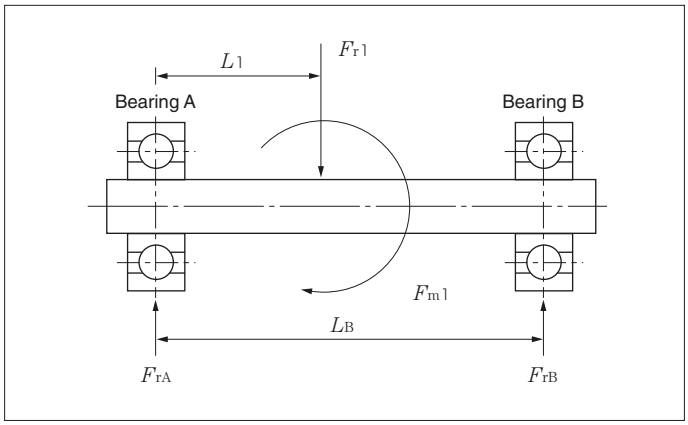
2. Load placed on shafts

Radial load

Bearing radial load calculated from the radial load and moment load placed on the shaft load center

$$F_{rA}=\frac{L_B-L_1}{L_B}F_{r1}-\frac{F_{m1}}{L_B}$$

$$F_{rB}=\frac{L_1}{L_B}F_{r1}+\frac{F_{m1}}{L_B}$$



Axial load

1) Angular contact ball brgs. and tapered roller brgs.

Replacing the axial dir. load (K_a) of the gear with the axial load (F_a) placed on the shaft means the calculation method is the same as 1-6-3-1.2 Axial load of the gear load.

2) Other bearings

If there is an instruction to place an axial load on other bearing setting screens, place an axial load on the bearing.

(1) If the load is placed on a single row, the entire axial load is placed on those bearings.

(2) If the load is placed on two rows, half the axial load is placed on those bearings.

1-6-4. Calculation of equivalent load

1. Radial bearings excluding cylindrical roller brgs.

1) Application bearings ：Deep Groove Ball Brgs.
Expansion Compensating Brgs.
Miniature Ball Brgs.
Angular Contact Ball Brgs.
Double Row Angular Contact Ball Brgs.
Self-Aligning Ball Brgs.
Tapered Roller Brgs. (Metric series)
Tapered Roller Brgs. (Inch series)
Double Row Tapered Roller Brgs. (Outward facing type)
Double Row Tapered Roller Brgs. (Inward facing type)
Spherical Roller Brgs.

2) Equivalent load formula

$$P_r = X \cdot F_r + Y \cdot F_a$$

2. Cylindrical Roller Brgs.

1) Application bearings ：Cylindrical Roller Brgs
Double Row Cylindrical Roller Brgs.

2) Equivalent load formula

$$P_r = F_r$$

3. Thrust Spherical Roller Brgs.

1) Application bearings ：Thrust Spherical Roller Brgs.

2) Equivalent load formula

$$P_a = F_a + 1.2 \cdot F_r \quad \text{(however, } F_r/F_a \leq 0.55\text{)}$$

4. Thrust Spherical Roller Brgs.

1) Application bearings ：Four-Point Contact Ball Brgs.
Thrust Ball Brgs.
Double Row Thrust Ball Brgs.
Thrust Cylindrical Roller Brgs.

2) Equivalent load formula

$$P_a = F_a$$

1-6-5. Calculation of average equivalent load when calculating bearing unit life

$$P_m = \left\{ \frac{\Sigma (P_i^p \cdot n_i \cdot t_i)}{\Sigma (n_i \cdot t_i)} \right\}^{1/p}$$

1-6-6. Calculation of basic rating life

$$L_{10h}=\frac{10^6}{60\cdot n}\left(\frac{C}{P}\right)^p$$

Note 1) For bearing unit life calculations, if there are 2 or more steps, enter the average value of the rot. speed determined with the following formula into the rot. speed of the above formula

$$n_m=\frac{n_1\cdot t_1+n_2\cdot t_2\cdots n_n\cdot t_n}{t_1+t_2\cdots t_n}$$

1-6-7. Calculation of total life of bearing system

Determine the total life of the shaft supported by bearing A and bearing B as follows.

$$L_T=\frac{1}{\left\{(1/L_A)^e+(1/L_B)^e\right\}^{1/e}}$$

1-6-8. Total life of the bearing unit calculated from the frequency of meshing conditions of the gear in 1-3-8. Gear load and basic rating life

$$L_t=\frac{100}{\Sigma\left(\frac{q_i}{L_{10hi}}\right)}$$

1-6-9. Calculation of average inner ring groove diameter, average outer ring groove diameter

The average inner ring groove diameter d_m, average outer ring groove diameter D_m and outer ring groove diameter D_r is calculated with the following formula.

Table 1 Average inner and outer ring groove diameter, outer ring groove diameter

Bearing type	d_m	D_m	D_r
Deep Groove Ball Brgs.	$1.05\cdot\frac{4d+D}{5}$	$0.95\cdot\frac{d+4D}{5}$	$\frac{d+4D}{5}$
Cylindrical Roller Brgs.	$1.05\cdot\frac{3d+D}{4}$	$0.98\cdot\frac{d+3D}{4}$	$\frac{d+3D}{4}$
Spherical Roller Brgs.	$\frac{2d+D}{3}$	$0.97\cdot\frac{d+4D}{5}$	$\frac{d+4D}{5}$

1-6-10. Expansion of each component dimension taking into account shaft and housing temperature

Calculate expansion of each component dimension taking into account shaft and housing temperature with the following formula.

$S_0=d\cdot\alpha_S\cdot(T_S-20)$
$d_0=d\cdot 12.5\cdot 10^{-6}\cdot(T_S-20)$
$D_0=D\cdot 12.5\cdot 10^{-6}\cdot(T_H-20)$
$H_0=D\cdot\alpha_H\cdot(T_H-20)$

1-6-11. Calculation of inner ring and shaft

1-6-11-1. Calculation of average value of interference of inner ring and shaft, and standard deviation of interference of inner ring and shaft

Calculate the average value of interference m_i and standard deviation of interference σ_i of the inner ring and shaft with the following.

① Calculate $(S_0+SS_1) - (d_0+dd_2)$

If $(S_0+SS_1) - (d_0+dd_2) \geqq 0$, proceed to ②,

If $(S_0+SS_1) - (d_0+dd_2) < 0$, proceed to ③.

② Interference calculation for interference fit

$$m_i = \left(\frac{2\cdot S_0+SS_1+SS_2}{2} - \frac{2\cdot d_0+dd_1+dd_2}{2}\right)\cdot\frac{d}{d+3}$$

$$\sigma_i = \sqrt{\left(\frac{SS_2-SS_1}{2\cdot 3}\right)^2+\left(\frac{dd_2-dd_1}{2\cdot 3}\right)^2}\cdot\frac{d}{d+3}$$

(end of 1-6-11-1)

③ Calculate $(S_0+SS_2) - (d_0+dd_1)$

If $(S_0+SS_2) - (d_0+dd_1) > 0$, proceed to ④,

If $(S_0+SS_2) - (d_0+dd_1) \leqq 0$, proceed to ⑤.

④ Interference calculation for transition fit

$$m_f = \left(\frac{2\cdot S_0+SS_1+SS_2}{2} - \frac{2\cdot d_0+dd_1+dd_2}{2}\right)\cdot\frac{d}{d+3}$$

$$\sigma_f = \sqrt{\left(\frac{SS_2-SS_1}{2\cdot 3}\right)^2+\left(\frac{dd_2-dd_1}{2\cdot 3}\right)^2}\cdot\frac{d}{d+3}$$

If $t_0 = -m_f/\sigma_f$, determine μ_t, σ_t from **Table 2**.

Table 2 $\mu_t \cdot \sigma_t$ calculation chart

t_0	μ_t	σ_t	t_0	μ_t	σ_t
–3.0	0.0004	0.999	0.1	0.451	0.549
–2.8	0.0008	0.998	0.2	0.509	0.515
–2.6	0.0015	0.996	0.3	0.567	0.480
–2.4	0.0027	0.993	0.4	0.630	0.446
–2.2	0.005	0.988	0.5	0.698	0.412
–2.0	0.008	0.980	0.6	0.769	0.380
–1.8	0.014	0.969	0.7	0.843	0.349
–1.6	0.023	0.953	0.8	0.920	0.318
–1.4	0.037	0.931	0.9	1.000	0.289
–1.2	0.056	0.902	1.0	1.083	0.262
–1.0	0.083	0.867	1.2	1.256	0.211
–0.9	0.100	0.846	1.4	1.437	0.168
–0.8	0.120	0.823	1.6	1.623	0.131
–0.6	0.143	0.799	1.8	1.814	0.100
–0.5	0.169	0.772	2.0	2.008	0.075
–0.4	0.198	0.744	2.2	2.205	0.056
–0.3	0.230	0.714	2.4	2.4027	0.041
–0.2	0.267	0.683	2.6	2.6015	0.029
–0.1	0.307	0.651	2.8	2.8008	0.020
0	0.351	0.618	3.0	3.0004	0.014
	0.399	0.577			

※Areas between each value are calculated with linear interpolation. If $t_0 < -3.0$ and $3.0 < t_0$, conduct the calculation using the $-3.0 \leq t_0 \leq -2.8$ and $2.8 \leq t_0 \leq 3.0$ interpolation curve.

Using μ_t and σ_t from **Table 2**,

$m_i = m_f + \mu_t \cdot \sigma_t$

$\sigma_i = \sigma_t \cdot \sigma_f$

(end of 1-6-11-1)

⑤ Interference calculation for clearance fit

$m_i = 0$, $\sigma_i = 0$

(end of 1-6-11-1)

1-6-11-2. Calculation of average inner ring groove diameter coefficient of expansion

Calculate the average inner ring groove diameter coefficient of expansion λ_i with the following.

$$Q_i = \frac{d_m^2 + d^2}{d_m^2 - d^2}$$

$$Q_s = \frac{d^2 + S^2}{d^2 - S^2}$$

$$\lambda_i = \frac{E_s \cdot (Q_i + 1)}{E_s \cdot (Q_i + 0.3) + E_B \cdot (Q_s - \upsilon_s)} \cdot \frac{d}{d_m}$$

1-6-11-3. Calculation of clearance reduction due to fitting with inner ring and shaft

Calculate the average value M_i and standard deviation Σ_i of clearance reduction due to fitting of the inner ring and shaft.

$$\Sigma_i = \sigma_i \cdot \lambda_i$$

$$M_i = m_i \cdot \lambda_i$$

1-6-12. Outer ring and housing calculation

1-6-12-1. Calculation of average value of interference of outer ring and housing, and standard deviation of interference of outer ring and housing

Calculate the average value of interference m_0 and standard deviation of interference σ_0 of the outer ring and housing with the following.

① Calculate $(D_0 + DD_1) - (H_0 + HH_2)$

If $(D_0 + DD_1) - (H_0 + HH_2) \geqq 0$, proceed to ②,

If $(D_0 + DD_1) - (H_0 + HH_2) < 0$, proceed to ③.

② Interference calculation for interference fit

$$m_0 = \left(\frac{2 \cdot D_0 + DD_1 + DD_2}{2} - \frac{2 \cdot H_0 + HH_1 + HH_2}{2} \right) \cdot \frac{D}{D+3}$$

$$\sigma_0 = \sqrt{\left(\frac{DD_2 - DD_1}{2 \cdot 3} \right)^2 + \left(\frac{HH_2 - HH_1}{2 \cdot 3} \right)^2} \cdot \frac{D}{D+3}$$

(end of 1-6-12-1)

③ Calculate $(D_0 + DD_2) - (H_0 + HH_1)$

If $(D_0 + DD_2) - (H_0 + HH_1) > 0$, proceed to ④,

If $(D_0 + DD_2) - (H_0 + HH_1) \leqq 0$, proceed to ⑤.

④ Interference calculation for transition fit

$$m_f = \left(\frac{2 \cdot D_0 + DD_1 + DD_2}{2} - \frac{2 \cdot H_0 + HH_1 + HH_2}{2} \right) \cdot \frac{D}{D+3}$$

$$\sigma_f = \sqrt{\left(\frac{DD_2 - DD_1}{2 \cdot 3} \right)^2 + \left(\frac{HH_2 - HH_1}{2 \cdot 3} \right)^2} \cdot \frac{D}{D+3}$$

If $t_0 = -m_f / \sigma_f$, determine μ_t, σ_t from **Table 2**.

Using μ_t and σ_t from **Table 2**,

$$m_0 = m_f + \mu_t \cdot \sigma_t$$

$$\sigma_0 = \sigma_t \cdot \sigma_f$$

(end of 1-6-12-1)

⑤ Interference calculation for clearance fit

$$m_0 = 0, \quad \sigma_0 = 0$$

(end of 1-6-12-1)

1-6-12-2. Calculation of average outer ring groove diameter coefficient of contraction

Calculate the average outer ring groove diameter coefficient of contraction λ_0 with the following.

$$Q_0=\frac{D^2+D_m^2}{D^2-D_m^2}$$

$$Q_H=\frac{H^2+D^2}{H^2-D^2}$$

$$\lambda_0=\frac{E_H\cdot(Q_0+1)}{E_B\cdot(Q_H+\nu_H)+E_H\cdot(Q_0-0.3)}\cdot\frac{D_m}{D}$$

1-6-12-3. Calculation of clearance reduction due to fitting with outer ring and housing

Calculate the average value M_0 and standard deviation Σ_0 of clearance reduction due to fitting of the outer ring and housing.

$$M_0=m_0\cdot\lambda_0$$

$$\Sigma_0=\sigma_0\cdot\lambda_0$$

1-6-13. Calculation of clearance reduction due to temperature difference of shaft and housing

Calculate the clearance reduction Δ_t due to temperature difference of shaft and housing with the following formula

$$\Delta_t=D_r\cdot 12.5\cdot 10^{-6}\cdot(T_S-T_H)$$

(Δ_t can be a negative value)

1-6-14. Operating clearance calculation

Calculate the average value U_m and standard deviation U_σ of the operating clearance with the following formula.

$$U_m=\frac{C_{r\,max}+C_{r\,min}}{2}-(M_i+M_0+\Delta_t)$$

$$U_\sigma=\sqrt{\left(\frac{C_{r\,max}-C_{r\,min}}{2\cdot 3}\right)^2+\Sigma_i^2+\Sigma_0^2}$$

The min value of operating clearance U_{min} and max value of operating clearance U_{max} are the following.

$$U_{min}=U_m-3\cdot U_\sigma$$

$$U_{max}=U_m+3\cdot U_\sigma$$

1-6-15. Calculation of fitting pressure (shaft and bearing), fitting stress (shaft and bearing)

Calculate the fitting pressure (shaft and bearing) min value P_{imin}, max value P_{imax}, fitting stress (inner ring) min value σ_{imin}, max value σ_{imax} with the following formulas.

$$P_{imin}=\frac{\dfrac{\{(S_0+SS_1)-(d_0+dd_2)\}\cdot\dfrac{d}{d+3}}{2\cdot d/2}}{\left(\dfrac{1-\nu_s}{E_s}-\dfrac{1-0.3}{E_B}\right)+2\cdot\left[\dfrac{(S/2)^2}{E_s\cdot\{(d/2)^2-(S/2)^2\}}+\dfrac{(d_m/2)^2}{E_B\cdot\{(d_m/2)^2-(d/2)^2\}}\right]}$$

$$P_{imax}=\frac{\dfrac{\{(S_0+SS_2)-(d_0+dd_1)\}\cdot\dfrac{d}{d+3}}{2\cdot d/2}}{\left(\dfrac{1-\nu_s}{E_s}-\dfrac{1-0.3}{E_B}\right)+2\cdot\left[\dfrac{(S/2)^2}{E_s\cdot\{(d/2)^2-(S/2)^2\}}+\dfrac{(d_m/2)^2}{E_B\cdot\{(d_m/2)^2-(d/2)^2\}}\right]}$$

$$\sigma_{i\,min}=\frac{1+(d/d_m)^2}{1-(d/d_m)^2}\cdot P_{i\,min}$$

$$\sigma_{i\,max}=\frac{1+(d/d_m)^2}{1-(d/d_m)^2}\cdot P_{i\,max}$$

1-6-16. Calculation of fitting pressure (bearing and housing), fitting stress (outer ring)

Calculate the fitting pressure (bearing and housing) min value $P_{0\,min}$, max value $P_{0\,max}$, fitting stress (outer ring) min value $\sigma_{0\,min}$, max value $\sigma_{0\,max}$ with the following formulas.

$$P_{0\,min}=\frac{\dfrac{\{(D_0+DD_1)-(H_0+HH_2)\}\cdot\dfrac{D}{D+3}}{2\cdot D/2}}{\left(\dfrac{1-0.3}{E_B}-\dfrac{1-\nu_H}{E_H}\right)+2\cdot\left[\dfrac{(D_m/2)^2}{E_B\cdot\{(D/2)^2-(D_m/2)^2\}}+\dfrac{(H/2)^2}{E_H\cdot\{(H/2)^2-(D/2)^2\}}\right]}$$

$$P_{0\,max}=\frac{\dfrac{\{(D_0+DD_2)-(H_0+HH_1)\}\cdot\dfrac{D}{D+3}}{2\cdot D/2}}{\left(\dfrac{1-0.3}{E_B}-\dfrac{1-\nu_H}{E_H}\right)+2\cdot\left[\dfrac{(D_m/2)^2}{E_B\cdot\{(D/2)^2-(D_m/2)^2\}}+\dfrac{(H/2)^2}{E_H\cdot\{(H/2)^2-(D/2)^2\}}\right]}$$

$$\sigma_{0\,max}=\frac{1+(d/d_m)^2}{1-(d/d_m)^2}\cdot P_{0\,max}$$

$$\sigma_{0\,min}=\frac{1+(d/d_m)^2}{1-(d/d_m)^2}\cdot P_{0\,min}$$

1-6-17. Calculation of bearing vibration frequency

Calculate n_c, n_{ci}, f_{ci}, f_{ce} and n_a with the following formula.

$$n_c=\frac{n_i\cdot(d_{pw}-D_w\cdot\cos\alpha_0)}{2\cdot d_{pw}\cdot 60}$$

$$n_{ci}=\frac{n_i\cdot(d_{pw}+D_w\cdot\cos\alpha_0)}{2\cdot d_{pw}\cdot 60}$$

$$f_{ci}=n_{ci}\cdot Z$$

$$f_{ce}=n_c\cdot Z$$

$$n_a=\frac{n_i\cdot(d_{pw}{}^2-D_w^2\cdot\cos^2\alpha_0)}{2\cdot d_{pw}\cdot D_w\cdot 60}$$

1-6-18. Calculation of modified rating life

Modified rating life can be obtained with the following formula using the reliability factor, life modification factor, and basic rating life.

$$L_{nm} = a_1 \cdot a_{ISO} \cdot L_n$$

1-6-18-1 Calculation of reliability factor a_1

The value of reliability factor a_1 is provided in Appendix table 18 for reliability of 90% or greater.

* The Bearing Technical Calculation Tool uses a reliability of 90% L_{10}, that is a_1 = 1.

1-6-18-2 Calculation of modification factor a_{ISO}

Life modification factor a_{ISO} is a value obtained by integrating material characteristics and lubrication conditions, and given as a function like the following formula in ISO 281:2007. Specifically, it is obtained with the drawing or formula for each bearing type indicated in 1-16-18-7.

$$a_{ISO} = f\left(\frac{e_c C_u}{p} k\right)$$

*The Bearing Technical Calculation Tool does not support the use of a lubricant with extreme pressure additive.
Please consult **NTN** Engineering when using a lubricant with extreme pressure additive.

1-6-18-3 Calculation of viscosity ratio κ

Viscosity ratio for the lubricating material κ is represented by the following formula by the ratio of kinematic viscosity ν in use with respect to reference kinematic viscosity ν_1 of the lubricant.

$$\kappa = \frac{\nu}{\nu_1}$$

Reference kinematic viscosity ν_1 depends on bearing rotation speed n and size (D_{pw}), and can be obtained with the following formula or from **Figure A.1**.

For n < 1000 min^{-1}, $\nu_1 = 45\,000\, n^{-0.83} D_{pw}^{-0.5}$

For $n \geq$ 1000 min^{-1}, $\nu_1 = 45\,000\, n^{-0.5} D_{pw}^{-0.5}$

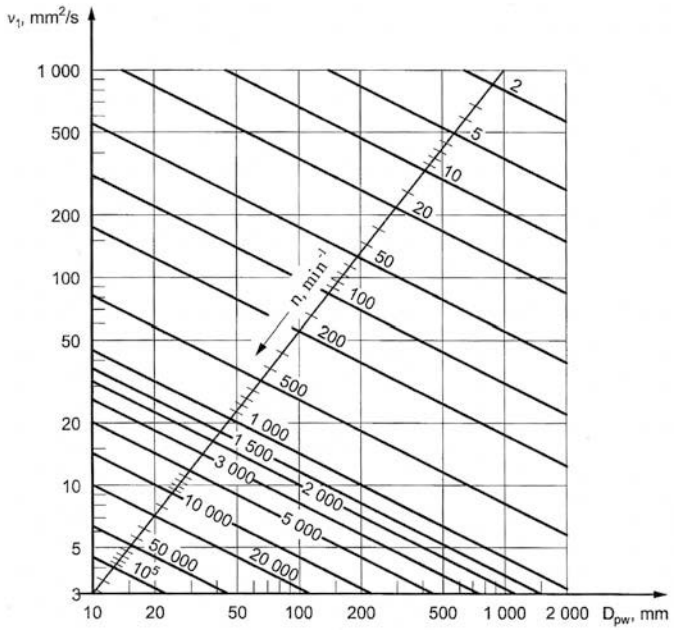


Figure A. 1 Reference kinematic viscosity $\nu 1$

1-6-18-4 Calculation of reliability factor e_c

As shown in Appendix **table 16**, approximate values are determined by the bearing size (may be substituted by rolling element pitch diameter D_{pw}, average bearing diameter (d+ D) /2), filtration and seal structures (including presence of pre-washing).

1-6-18-5 Calculation of fatigue limit load C_u

The fatigue limit load C_u is the load applied on bearings that becomes the fatigue limit stress at the maximum load contact part of the raceway. This depends on the bearing type, internal specifications, quality, and material strength, and in ISO 281:2007, 1.5 GPa is recommended as the contact stress corresponding to C_u for the bearings made of high purity bearing steel. The fatigue limit load values with respect to the **NTN** bearing numbers are specified in each specification table.

1-6-18-6 Calculation of equivalent load P

1-6-4. See calculation of equivalent load.

1-6-18-7 Calculation of life modification factor a_{ISO} for each bearing type

The value of life modification factor a_{ISO} is determined based on **Figure A.2** to **Figure A.5** or the following formula (A.5) to formula (A.16) calculation for each bearing type.

However, care should be taken concerning the following points.

① If a_{ISO} > 50, a_{ISO} = 50.

② If κ > 4, a_{ISO} is calculated with κ = 4.

③ If κ < 0.1, a_{ISO} cannot be calculated (the formula and figure do not apply)

④ If κ < 1 and $e_c \geq 0.2$, and a lubricant containing extreme pressure additive is used, the value κ =1 can be used to calculate contamination factor e_c and life modification factor a_{ISO}. However, when the value for life modification factor a_{ISO} exceeds 3 as a result of this calculation, a_{ISO} = 3.

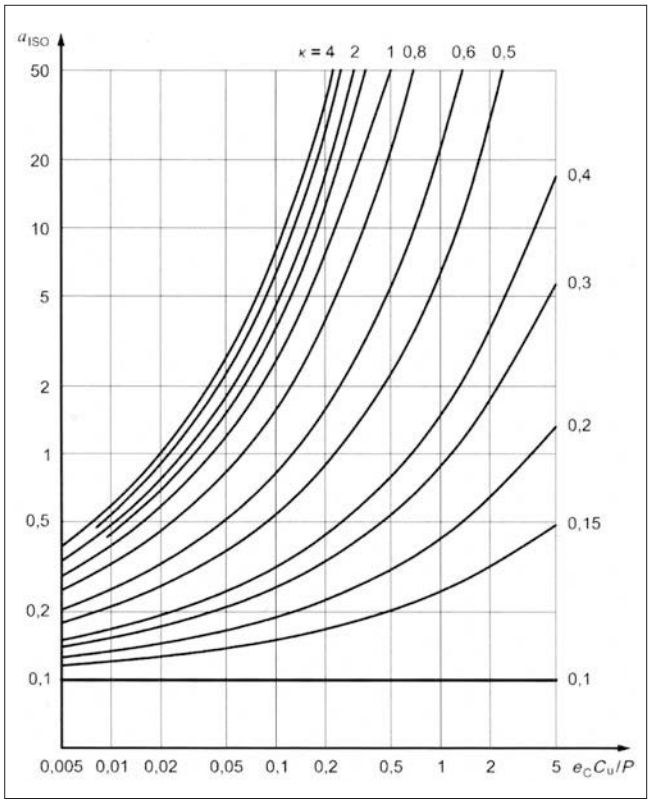


Figure A.2 Life modification factor a_{ISO} (radial ball bearing)

The curved lines shown in **Figure A.2** are based on formula (A.5) to formula (A.7).

If $0.1 \le \kappa < 0.4$,

$$a_{ISO} = 0.1\left[1-\left(2.5671-\frac{2.2649}{\kappa^{0.054381}}\right)^{0.83}\left(\frac{e_cC_u}{P}\right)^{1/3}\right]^{-9.3} \quad \text{..... (A.5)}$$

If $0.4 \le \kappa < 1$,

$$a_{ISO} = 0.1\left[1-\left(2.5671-\frac{1.9987}{\kappa^{0.19087}}\right)^{0.83}\left(\frac{e_cC_u}{P}\right)^{1/3}\right]^{-9.3} \quad \text{..... (A.6)}$$

If $1 \le \kappa \le 4$,

$$a_{ISO} = 0.1\left[1-\left(2.5671-\frac{1.9987}{\kappa^{0.071739}}\right)^{0.83}\left(\frac{e_cC_u}{P}\right)^{1/3}\right]^{-9.3} \quad \text{..... (A.7)}$$

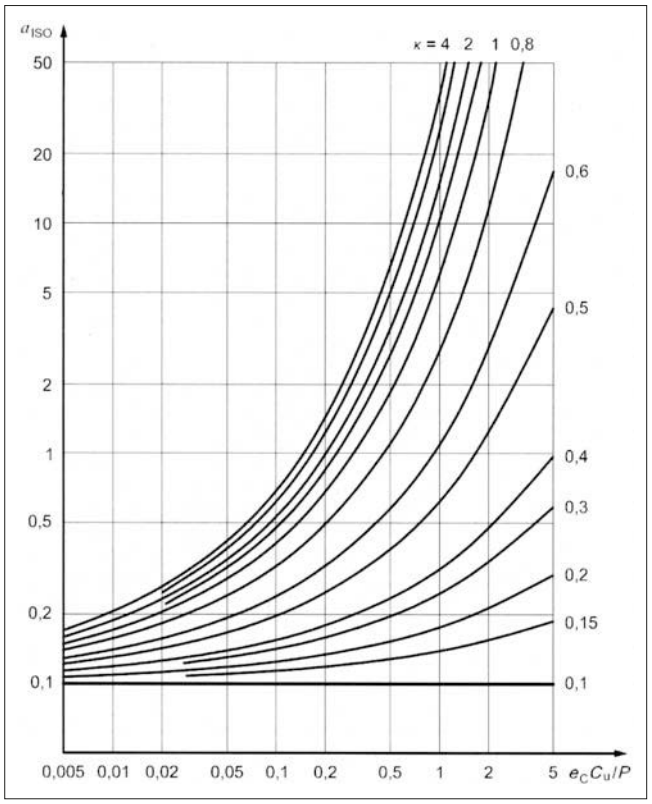


Figure A.3 Life modification factor a_{ISO} (radial roller bearing)

The curved lines shown in **Figure A.3** are based on formula (A.8) to formula (A.10).

If $0.1 \le \kappa < 0.4$,

$$a_{ISO} = 0.1\left[1-\left(1.5859-\frac{1.3993}{\kappa^{0.054381}}\right)\left(\frac{e_cC_u}{P}\right)^{0.4}\right]^{-9.185} \quad \text{..... (A.8)}$$

If $0.4 \le \kappa < 1$,

$$a_{ISO} = 0.1\left[1-\left(1.5859-\frac{1.2348}{\kappa^{0.19087}}\right)\left(\frac{e_cC_u}{P}\right)^{0.4}\right]^{-9.185} \quad \text{..... (A.9)}$$

If $1 \le \kappa \le 4$,

$$a_{ISO} = 0.1\left[1-\left(1.5859-\frac{1.2348}{\kappa^{0.071739}}\right)\left(\frac{e_cC_u}{P}\right)^{0.4}\right]^{-9.185} \quad \text{..... (A.10)}$$

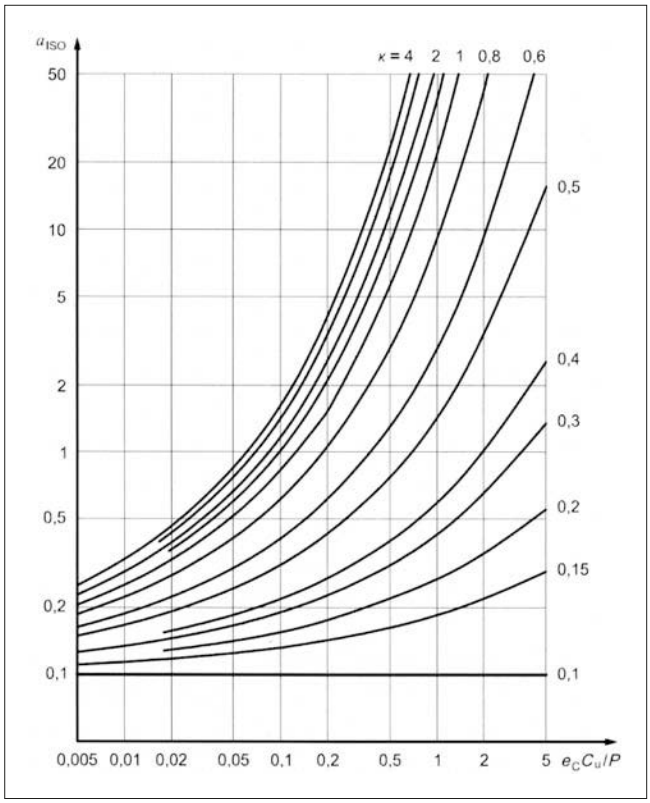


Figure A.4 Life modification factor a_{ISO} (thrust ball bearing)

The curved lines shown in **Figure A.4** are based on formula (A.11) to formula (A.13).

If $0.1 \le \kappa < 0.4$,

$$a_{ISO} = 0.1\left[1-\left(2.5671-\frac{2.2649}{\kappa^{0.054381}}\right)^{0.83}\left(\frac{e_cC_u}{3P}\right)^{1/3}\right]^{-9.3} \quad \text{...(A.11)}$$

If $0.4 \le \kappa < 1$,

$$a_{ISO} = 0.1\left[1-\left(2.5671-\frac{1.9987}{\kappa^{0.19087}}\right)^{0.83}\left(\frac{e_cC_u}{3P}\right)^{1/3}\right]^{-9.3} \quad \text{...(A.12)}$$

If $1 \le \kappa \le 4$,

$$a_{ISO} = 0.1\left[1-\left(2.5671-\frac{1.9987}{\kappa^{0.071739}}\right)^{0.83}\left(\frac{e_cC_u}{3P}\right)^{1/3}\right]^{-9.3} \quad \text{...(A.13)}$$

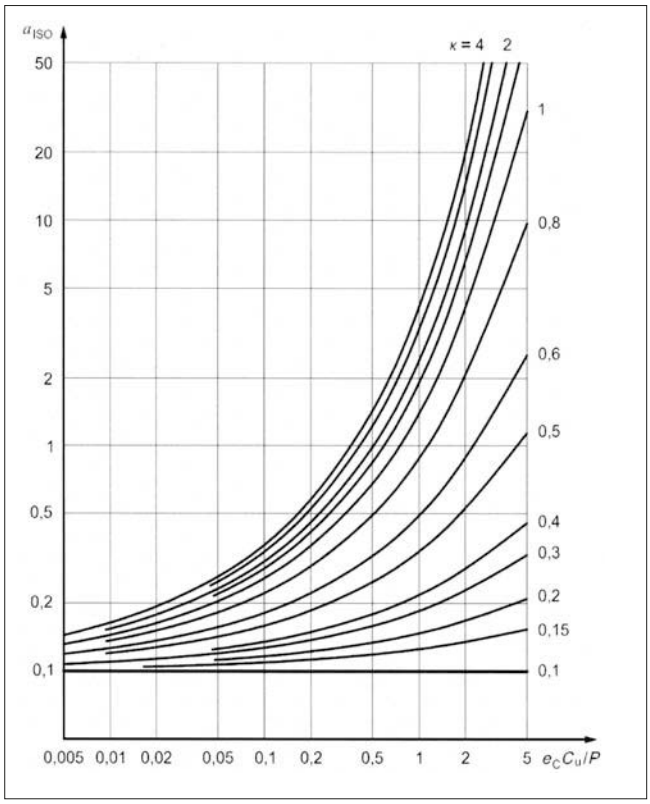


Figure A.5 Life modification factor a_{ISO} (thrust roller bearing)

The curved lines shown in **Figure A.5** are based on formula (A.14) to formula (A.16).

If $0.1 \le \kappa < 0.4$,

$$a_{ISO} = 0.1\left[1-\left(1.5859-\frac{1.3993}{\kappa^{0.054381}}\right)\left(\frac{e_cC_u}{2.5P}\right)^{0.4}\right]^{-9.185} \quad \text{...(A.14)}$$

If $0.4 \le \kappa < 1$,

$$a_{ISO} = 0.1\left[1-\left(1.5859-\frac{1.2348}{\kappa^{0.19087}}\right)\left(\frac{e_cC_u}{2.5P}\right)^{0.4}\right]^{-9.185} \quad \text{...(A.15)}$$

If $1 \le \kappa \le 4$,

$$a_{ISO} = 0.1\left[1-\left(1.5859-\frac{1.2348}{\kappa^{0.071739}}\right)\left(\frac{e_cC_u}{2.5P}\right)^{0.4}\right]^{-9.185} \quad \text{...(A.16)}$$

1-7. Appendix tables

Appendix table 1. Limiting dimensional tolerance of bearing inner dia.

Bearing inner dia. (d) mm		JIS Class 0 μm		JIS Class 6 μm		JIS Class 5 μm		JIS Class 4 μm		JIS Class 2 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
0.6	18	0	–8	0	–7	0	–5	0	–4	0	–2.5
18	30	0	–10	0	–8	0	–6	0	–5	0	–2.5
30	50	0	–12	0	–10	0	–8	0	–6	0	–2.5
50	80	0	–15	0	–12	0	–9	0	–7	0	–4
80	120	0	–20	0	–15	0	–10	0	–8	0	–5
120	150	0	–25	0	–18	0	–13	0	–10	0	–7
150	180	0	–25	0	–18	0	–13	0	–10	0	–7
180	250	0	–30	0	–22	0	–15	0	–12	0	–8
250	315	0	–35	0	–25	0	–18	—	—	—	—
315	400	0	–40	0	–30	0	–23	—	—	—	—
400	500	0	–45	0	–35	—	—	—	—	—	—
500	630	0	–50	0	–40	—	—	—	—	—	—
630	800	0	–75	—	—	—	—	—	—	—	—
800	1000	0	–100	—	—	—	—	—	—	—	—
1000	1250	0	–125	—	—	—	—	—	—	—	—
1250	1600	0	–160	—	—	—	—	—	—	—	—
1600	2000	0	–200	—	—	—	—	—	—	—	—

Appendix table 2. Limiting dimensional tolerance of bearing outer dia.

Bearing outer dia. (D) mm		JIS Class 0 μm		JIS Class 6 μm		JIS Class 5 μm		JIS Class 4 μm		JIS Class 2 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
2.5	18	0	–8	0	–7	0	–5	0	–4	0	–2.5
18	30	0	–9	0	–8	0	–6	0	–5	0	–4
30	50	0	–11	0	–9	0	–7	0	–6	0	–4
50	80	0	–13	0	–11	0	–9	0	–7	0	–4
80	120	0	–15	0	–13	0	–10	0	–8	0	–5
120	150	0	–18	0	–15	0	–11	0	–9	0	–5
150	180	0	–25	0	–18	0	–13	0	–10	0	–7
180	250	0	–30	0	–20	0	–15	0	–11	0	–8
250	315	0	–35	0	–25	0	–18	0	–13	0	–8
315	400	0	–40	0	–28	0	–20	0	–15	0	–10
400	500	0	–45	0	–33	0	–23	—	—	—	—
500	630	0	–50	0	–38	0	–28	—	—	—	—
630	800	0	–75	0	–45	0	–35	—	—	—	—
800	1000	0	–100	0	–60	—	—	—	—	—	—
1000	1250	0	–125	—	—	—	—	—	—	—	—
1250	1600	0	–160	—	—	—	—	—	—	—	—
1600	2000	0	–200	—	—	—	—	—	—	—	—
2000	2500	0	–250	—	—	—	—	—	—	—	—

Appendix table 3. Radial internal clearance of deep groove ball brgs.

Bearing inner dia. (d) mm		C2 μm		CN μm		C3 μm		C4 μm		C5 μm	
More than	or less	min	max	min	max	min	max	min	max	min	max
6	10	0	7	2	13	8	23	14	29	20	37
10	18	0	9	3	18	11	25	18	33	25	45
18	24	0	10	5	20	13	28	20	36	28	48
24	30	1	11	5	20	13	28	23	41	30	53
30	40	1	11	6	20	15	33	28	46	40	64
40	50	1	11	6	23	18	36	30	51	45	73
50	65	1	15	8	28	23	43	38	61	55	90
65	80	1	15	10	30	25	51	46	71	65	105
80	100	1	18	12	36	30	58	53	84	75	120
100	120	2	20	15	41	36	66	61	97	90	140
120	140	2	23	18	48	41	81	71	114	105	160
140	160	2	23	18	53	46	91	81	130	120	180
160	180	2	25	20	61	53	102	91	147	135	200
180	200	2	30	25	71	63	117	107	163	150	230
200	225	2	35	25	85	75	140	125	195	175	265
225	250	2	40	30	95	85	160	145	225	205	300
250	280	2	45	35	105	90	170	155	245	225	340
280	315	2	55	40	115	100	190	175	270	245	370
315	355	3	60	45	125	110	210	195	300	275	410
355	400	3	70	55	145	130	240	225	340	315	460
400	450	3	80	60	170	150	270	250	380	350	510
450	500	3	90	70	190	170	300	280	420	390	570
500	560	10	100	80	210	190	330	310	470	440	630
560	630	10	110	90	230	210	360	340	520	490	690

Appendix table 4. Radial internal clearance of cylindrical roller brgs.

Bearing inner dia. (d) mm		C2 μm		CN μm		C3 μm		C4 μm		C5 μm	
More than	or less	min	max	min	max	min	max	min	max	min	max
10	24	0	25	20	45	35	60	50	75	65	90
24	30	0	25	20	45	35	60	50	75	70	95
30	40	5	30	25	50	45	70	60	85	80	105
40	50	5	35	30	60	50	80	70	100	95	125
50	65	10	40	40	70	60	90	80	110	110	140
65	80	10	45	40	75	65	100	90	125	130	165
80	100	15	50	50	85	75	110	105	140	155	190
100	120	15	55	50	90	85	125	125	165	180	220
120	140	15	60	60	105	100	145	145	190	200	245
140	160	20	70	70	120	115	165	165	215	225	275
160	180	25	75	75	125	120	170	170	220	250	300
180	200	35	90	90	145	140	195	195	250	275	330
200	225	45	105	105	165	160	220	220	280	305	365
225	250	45	110	110	175	170	235	235	300	330	395
250	280	55	125	125	195	190	260	260	330	370	440
280	315	55	130	130	205	200	275	275	350	410	485
315	355	65	145	145	225	225	305	305	385	455	535
355	400	100	190	190	280	280	370	370	460	510	600
400	450	110	210	210	310	310	410	410	510	565	665
450	500	110	220	220	330	330	440	440	550	625	735

Appendix table 5. Radial internal clearance of spherical roller brgs.

Bearing inner dia. (d) mm		C2 μm		CN μm		C3 μm		C4 μm		C5 μm	
More than	or less	min	max	min	max	max	max	min	max	min	max
14	24	10	20	20	35	35	45	45	60	60	75
24	30	15	25	25	40	40	55	55	75	75	95
30	40	15	30	30	45	45	60	60	80	80	100
40	50	20	35	35	55	55	75	75	100	100	125
50	65	20	40	40	65	65	90	90	120	120	150
65	80	30	50	50	80	80	110	110	145	145	180
80	100	35	60	60	100	100	135	135	180	180	225
100	120	40	75	75	120	120	160	160	210	210	260
120	140	50	95	95	145	145	190	190	240	240	300
140	160	60	110	110	170	170	220	220	280	280	350
160	180	65	120	120	180	180	240	240	310	310	390
180	200	70	130	130	200	200	260	260	340	340	430
200	225	80	140	140	220	220	290	290	380	380	470
225	250	90	150	150	240	240	320	320	420	420	520
250	280	100	170	170	260	260	350	350	460	460	570
280	315	110	190	190	280	280	370	370	500	500	630
315	355	120	200	200	310	310	410	410	550	550	690
355	400	130	220	220	340	340	450	450	600	600	750
400	450	140	240	240	370	370	500	500	660	660	820
450	500	140	260	260	410	410	550	550	720	720	900
500	560	150	280	280	440	440	600	600	780	780	1000
560	630	170	310	310	480	480	650	650	850	850	1100
630	710	190	350	350	530	530	700	700	920	920	1190
710	800	210	390	390	580	580	770	770	1010	1010	1300
800	900	230	430	430	650	650	860	860	1120	1120	1440
900	1000	260	480	480	710	710	930	930	1220	1220	1570
1000	1120	290	530	530	780	780	1020	1020	1330	1330	1720
1120	1250	320	580	580	860	860	1120	1120	1460	1460	1870
1250	1400	350	640	640	950	950	1240	1240	1620	1620	2080

Appendix table 6. Limiting dimensional tolerance of shaft (1)

Diameter classification mm		d6 m		e6 m		f6 m		g5 m		g6 m		h5 m		h6 m	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
6	10	−40	−49	−25	−34	−13	−22	−5	−11	−5	−14	0	−6	0	−9
10	18	−50	−61	−32	−43	−16	−27	−6	−14	−6	−17	0	−8	0	−11
18	30	−65	−78	−40	−53	−20	−33	−7	−16	−7	−20	0	−9	0	−13
30	50	−80	−96	−50	−66	−25	−41	−9	−20	−9	−25	0	−11	0	−16
50	80	−100	−119	−60	−79	−30	−49	−10	−23	−10	−29	0	−13	0	−19
80	120	−120	−142	−72	−94	−36	−58	−12	−27	−12	−34	0	−15	0	−22
120	180	−145	−170	−85	−110	−43	−68	−14	−32	−14	−39	0	−18	0	−25
180	250	−170	−199	−100	−129	−50	−79	−15	−35	−15	−44	0	−20	0	−29
250	315	−190	−222	−110	−142	−56	−88	−17	−40	−17	−49	0	−23	0	−32
315	400	−210	−246	−125	−161	−62	−98	−18	−43	−18	−54	0	−25	0	−36
400	500	−230	−270	−135	−175	−68	−108	−20	−47	−20	−60	0	−27	0	−40
500	630	−260	−304	−145	−189	−76	−120	—	—	−22	−66	—	—	0	−44
630	800	−290	−340	−160	−210	−80	−130	—	—	−24	−74	—	—	0	−50
800	1000	−320	−376	−170	−226	−86	−142	—	—	−26	−82	—	—	0	−56
1000	1250	−350	−416	−195	−261	−98	−164	—	—	−28	−94	—	—	0	−66
1250	1600	−390	−468	−220	−298	−110	−188	—	—	−30	−108	—	—	0	−78

Appendix table 7. Limiting dimensional tolerance of shaft (2)

Diameter classification mm		h7 μm		h8 μm		h9 μm		h10 μm		j5 μm		js5 μm		j6 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
6	10	0	–15	0	–22	0	–36	0	–58	4	–2	3	–3	7	–2
10	18	0	–18	0	–27	0	–43	0	–70	5	–3	4	–4	8	–3
18	30	0	–21	0	–33	0	–52	0	–84	5	–4	4.5	–4.5	9	–4
30	50	0	–25	0	–39	0	–62	0	–100	6	–5	5.5	–5.5	11	–5
50	80	0	–30	0	–46	0	–74	0	–120	6	–7	6.5	–6.5	12	–7
80	120	0	–35	0	–54	0	–87	0	–140	6	–9	7.5	–7.5	13	–9
120	180	0	–40	0	–63	0	–100	0	–160	7	–11	9	–9	14	–11
180	250	0	–46	0	–72	0	–115	0	–185	7	–13	10	–10	16	–13
250	315	0	–52	0	–81	0	–130	0	–210	7	–16	11.5	–11.5	16	–16
315	400	0	–57	0	–89	0	–140	0	–230	7	–18	12.5	–12.5	18	–18
400	500	0	–63	0	–97	0	–155	0	–250	7	–20	13.5	–13.5	20	–20
500	630	0	–70	0	–110	0	–175	0	–280	—	—	—	—	—	—
630	800	0	–80	0	–125	0	–200	0	–320	—	—	—	—	—	—
800	1000	0	–90	0	–140	0	–230	0	–360	—	—	—	—	—	—
1000	1250	0	–105	0	–165	0	–260	0	–420	—	—	—	—	—	—
1250	1600	0	–125	0	–195	0	–310	0	–500	—	—	—	—	—	—

Appendix table 8. Limiting dimensional tolerance of shaft (3)

Diameter classification mm		js6 μm		j7 μm		k5 μm		k6 μm		k7 μm		m5 μm		m6 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
6	10	4.5	–4.5	10	–5	7	1	10	1	16	1	12	6	15	6
10	18	5.5	–5.5	12	–6	9	1	12	1	19	1	15	7	18	7
18	30	6.5	–6.5	13	–8	11	2	15	2	23	2	17	8	21	8
30	50	8	–8	15	–10	13	2	18	2	27	2	20	9	25	9
50	80	9.5	–9.5	18	–12	15	2	21	2	32	2	24	11	30	11
80	120	11	–11	20	–15	18	3	25	3	38	3	28	13	35	13
120	180	12.5	–12.5	22	–18	21	3	28	3	43	3	33	15	40	15
180	250	14.5	–14.5	25	–21	24	4	33	4	50	4	37	17	46	17
250	315	16	–16	26	–26	27	4	36	4	56	4	43	20	52	20
315	400	18	–18	29	–28	29	4	40	4	61	4	46	21	57	21
400	500	20	–20	31	–32	32	5	45	5	68	5	50	23	63	23
500	630	22	–22	—	—	—	—	44	0	70	0	—	—	70	26
630	800	25	–25	—	—	—	—	50	0	80	0	—	—	80	30
800	1000	28	–28	—	—	—	—	56	0	90	0	—	—	90	34
1000	1250	33	–33	—	—	—	—	66	0	105	0	—	—	106	40
1250	1600	39	–39	—	—	—	—	78	0	125	0	—	—	126	48

Appendix table 9. Limiting dimensional tolerance of shaft (4)

Diameter classification mm		n6 μm		p6 μm		r6 μm		r7 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
6	10	19	10	24	15	28	19	34	19
10	18	23	12	29	18	34	23	41	23
18	30	28	15	35	22	41	28	49	28
30	50	33	17	42	26	50	34	59	34
50	65	39	20	51	32	60	41	71	41
65	80					62	43	73	43
80	100	45	23	59	37	73	51	86	51
100	120					76	54	89	54
120	140	52	27	68	43	88	63	103	63
140	160					90	65	105	65
160	180					93	68	108	68
180	200	60	31	79	50	106	77	123	77
200	225					109	80	126	80
225	250					113	84	130	84
250	280	66	34	88	56	126	94	146	94
280	315					130	98	150	98
315	355	73	37	98	62	144	108	165	108
355	400					150	114	171	114
400	450	80	40	108	68	166	126	189	126
450	500					172	132	195	132
500	560	88	44	122	78	194	150	220	150
560	630					199	155	225	155
630	710	100	50	138	88	225	175	255	175
710	800					235	185	265	185
800	900	112	56	156	100	266	210	300	210
900	1000					276	220	310	220
1000	1120	132	66	186	120	316	250	355	250
1120	1250					326	260	365	260
1250	1400	156	78	218	140	378	300	425	300
1400	1600					408	330	455	330

Appendix table 10. Limiting dimensional tolerance of housing hole (1)

Diameter classification mm		E6 μm		F6 μm		F7 μm		G6 μm		G7 μm		H6 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
10	18	43	32	27	16	34	16	17	6	24	6	11	0
18	30	53	40	33	20	41	20	20	7	28	7	13	0
30	50	66	50	41	25	50	25	25	9	34	9	16	0
50	80	79	60	49	30	60	30	29	10	40	10	19	0
80	120	94	72	58	36	71	36	34	12	47	12	22	0
120	180	110	85	68	43	83	43	39	14	54	14	25	0
180	250	129	100	79	50	96	50	44	15	61	15	29	0
250	315	142	110	88	56	108	56	49	17	69	17	32	0
315	400	161	125	98	62	119	62	54	18	75	18	36	0
400	500	175	135	108	68	131	68	60	20	83	20	40	0
500	630	189	145	120	76	146	76	66	22	92	22	44	0
630	800	210	160	130	80	160	80	74	24	104	24	50	0
800	1000	226	170	142	86	176	86	82	26	116	26	56	0
1000	1250	261	195	164	98	203	98	94	28	133	28	66	0
1250	1600	298	220	188	110	235	110	108	30	155	30	78	0
1600	2000	332	240	212	120	270	120	124	32	182	32	92	0

Appendix table 11. Limiting dimensional tolerance of housing hole (2)

Diameter classification mm		H7 μm		H8 μm		J6 μm		J7 μm		JS6 μm		JS7 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
10	18	18	0	27	0	6	–5	10	–8	5.5	–5.5	9	–9
18	30	21	0	33	0	8	–5	12	–9	6.5	–6.5	10.5	–10.5
30	50	25	0	39	0	10	–6	14	–11	8	–8	12.5	–12.5
50	80	30	0	46	0	13	–6	18	–12	9.5	–9.5	15	–15
80	120	35	0	54	0	16	–6	22	–13	11	–11	17.5	–17.5
120	180	40	0	63	0	18	–7	26	–14	12.5	–12.5	20	–20
180	250	46	0	72	0	22	–7	30	–16	14.5	–14.5	23	–23
250	315	52	0	81	0	25	–7	36	–16	16	–16	26	–26
315	400	57	0	89	0	29	–7	39	–18	18	–18	28.5	–28.5
400	500	63	0	97	0	33	–7	43	–20	20	–20	31.5	–31.5
500	630	70	0	110	0	—	—	—	—	22	–22	35	–35
630	800	80	0	125	0	—	—	—	—	25	–25	40	–40
800	1000	90	0	140	0	—	—	—	—	28	–28	45	–45
1000	1250	105	0	165	0	—	—	—	—	33	–33	52.5	–52.5
1250	1600	125	0	195	0	—	—	—	—	39	–39	62.5	–62.5
1600	2000	150	0	230	0	—	—	—	—	46	–46	75	–75

Appendix table 12. Limiting dimensional tolerance of housing hole (3)

Diameter classification mm		K5 μm		K6 μm		K7 μm		M5 μm		M6 μm		M7 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
10	18	2	–6	2	–9	6	–12	–4	–12	–4	–15	0	–18
18	30	1	–8	2	–11	6	–15	–5	–14	–4	–17	0	–21
30	50	2	–9	3	–13	7	–18	–5	–16	–4	–20	0	–25
50	80	3	–10	4	–15	9	–21	–6	–19	–5	–24	0	–30
80	120	2	–13	4	–18	10	–25	–8	–23	–6	–28	0	–35
120	180	3	–15	4	–21	12	–28	–9	–27	–8	–33	0	–40
180	250	2	–18	5	–24	13	–33	–11	–31	–8	–37	0	–46
250	315	3	–20	5	–27	16	–36	–13	–36	–9	–41	0	–52
315	400	3	–22	7	–29	17	–40	–14	–39	–10	–46	0	–57
400	500	2	–25	8	–32	18	–45	–16	–43	–10	–50	0	–63
500	630	—	—	0	–44	0	–70	—	—	–26	–70	–26	–96
630	800	—	—	0	–50	0	–80	—	—	–30	–80	–30	–100
800	1000	—	—	0	–56	0	–90	—	—	–34	–90	–34	–124
1000	1250	—	—	0	–66	0	–105	—	—	–40	–106	–40	–145
1250	1600	—	—	0	–78	0	–125	—	—	–48	–126	–48	–173
1600	2000	—	—	0	–92	0	–150	—	—	–58	–150	–58	–208

Appendix table 13. Limiting dimensional tolerance of housing hole (4)

Diameter classification mm		N5 μm		N6 μm		N7 μm		P6 μm		P7 μm	
More than	or less	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
10	18	–9	–17	–9	–20	–5	–23	–15	–26	–11	–29
18	30	–12	–21	–11	–24	–7	–28	–18	–31	–14	–35
30	50	–13	–24	–12	–28	–8	–33	–21	–37	–17	–42
50	80	–15	–28	–14	–33	–9	–39	–26	–45	–21	–51
80	120	–18	–33	–16	–38	–10	–45	–30	–52	–24	–59
120	180	–21	–39	–20	–45	–12	–52	–36	–61	–28	–68
180	250	–25	–45	–22	–51	–14	–60	–41	–70	–33	–79
250	315	–27	–50	–25	–57	–14	–66	–47	–79	–36	–88
315	400	–30	–55	–26	–62	–16	–73	–51	–87	–41	–98
400	500	–33	–60	–27	–67	–17	–80	–55	–95	–45	–108
500	630	—	—	–44	–88	–44	–114	–78	–122	–78	–148
630	800	—	—	–50	–100	–50	–130	–88	–138	–88	–168
800	1000	—	—	–56	–112	–56	–146	–100	–156	–100	–190
1000	1250	—	—	–66	–132	–66	–171	–120	–186	–120	–225
1250	1600	—	—	–78	–156	–78	–203	–140	–213	–140	–265
1600	2000	—	—	–92	–184	–92	–242	–170	–262	–170	–320

Appendix table 14. Material physical property value

Material	Young's modulus MPa {kgf/mm^2}	Poisson's ratio	Coefficient of linear thermal expansion $\times10^{-6}$ (1/°C)
Bearing steels	208000 {21200}	0.3	12.5
Carbon steels	198900 {20300}	0.3	10.23
Cast iron	100500 {10250}	0.3	10.5
Spheroidal graphite iron castings	150900 {15400}	0.3	10.0
Aluminium	68940 {7030}	0.34	21.5
Martensitic stainless steels	199900 {20400}	0.3	17.1
Austenitic stainless steels	196500 {20050}	0.3	17.1
Copper	131000 {13370}	0.35	16.5

Note) Poisson's ratio and the coefficient of linear thermal expansion are not affected by the input param. unit.

Appendix table 15. Reliability factor a_1

Reliability %	L_n	Reliability factor a_1
90	L_{10}	1
95	L_5	0.64
96	L_4	0.55
97	L_3	0.47
98	L_2	0.37
99	L_1	0.25
99.2	$L_{0.8}$	0.22
99.4	$L_{0.6}$	0.19
99.6	$L_{0.4}$	0.16
99.8	$L_{0.2}$	0.12
99.9	$L_{0.1}$	0.093
99.92	$L_{0.08}$	0.087
99.94	$L_{0.06}$	0.080
99.95	$L_{0.05}$	0.077

Appendix table 16. Value of contamination factor e_c

Contamination level	e_c	
	D_{pw} <100mm	D_{pw} ≥100mm
Extremely high cleanliness Particle size about the same as the oil film thickness of lubricant, and laboratory level environment	1	1
High cleanliness Oil filtered by an extremely fine filter, standard grease sealed bearings and seal bearings	0.8～0.6	0.9～0.8
Standard cleanliness Oil filtered by a fine filter, standard grease sealed bearings and shielded bearings	0.6～0.5	0.8～0.6
Light contamination The lubricant is slightly contaminated	0.5～0.3	0.6～0.4
Normal contamination No sealing, rough filter is used, abrasion powder, environment in which particles enter from the periphery	0.3～0.1	0.4～0.2
Heavy contamination Significantly contaminated surrounding environment, and a state in which sealing performance of bearings is insufficient	0.1～0	0.1～0
Extreme contamination	0	0