SUMMARY

ASSEMBLY MANUAL

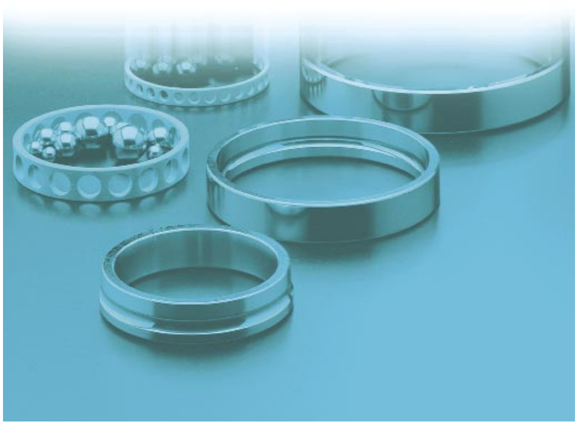
BEARING DAMAGE ANALYSIS

SNFA angular contact, super precision ball bearings are recognised for their high performance capabilities, especially where the demands of precision and speed are at their greatest.

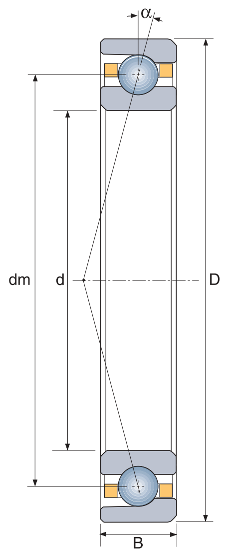
SNFA bearings satisfy ISO dimensional requirements (18, 19, 10, 02) as well as AFBMA international regulations (Std. 20), These tolerances are listed in the general SNFA catalogue.

The content of this publication shall be viewed as a supplement of, and complimentary to, the data that is contained in the "SNFA General Catalogue" and it is intended for SNFA bearing users.

It provides a useful set of assembly instructions, but does not presume to provide specific instructions as each application has its own particular requirements.



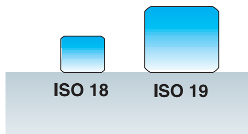
Symbols and units of measurement

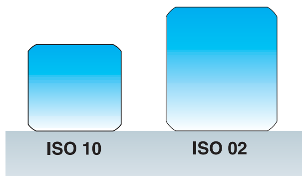


d	: Bearing bore diameter	mm
D	: External bearing diameter	mm
B	: Bearing width	mm
α	: Contact angle	degrees
dm	: Average bearing diameter	mm
C33	: Dynamic load capacity	daN
Co	: Static load capacity	daN
Ra	: Axial rigidity	daN/μm
Vh	: Maximum speed of a single, spring preloaded, oil lubricated bearing, $\alpha = 15°$ (Series BS200 and BS $\alpha = 62°$)	revs /min
Cr	: Low speed bearing assembly rolling torque	daN • mm
M	: Mass	Kg
n	: Rotational speed	rpm
ndm	: Speed factor	rpm • mm

Other symbols appearing within the text are described in the section in which they are found.

SNFA series	ISO	Characteristics
SEA	**18**	Average load capacity Speed up to 1,500,000 ndm (oil)
SEB	**19**	Good load capacity Speed up to 1,500,000 ndm (oil)
VEB	**19**	Good load capacity Speed in excess of 2,000,000 ndm (oil)
HB	**19**	Speed > 2,000,000 ndm, complete with oil lubrication via the outer race and integral O-rings (... / GH) Grease lubrication complete with seals (... / S)
EX	**10**	High load capacity Speed up to 1,500,000 ndm (oil)
VEX	**10**	Good load capacity Speed in excess of 2,000,000 ndm complete with oil lubrication via the outer race and integral O-rings (... / GH) Speed up to 1,600,000 ndm complete with grease lubrication and seals (... / S)
HX	**10**	Speed > 2,000,000 ndm, complete with oil via the outer race and integral O-rings (... / GH) Grease lubrication complete with seals (... / S)
E 200	**02**	High load capacity Speed up to 1,500,000 ndm (oil)
BS 200	**02**	Mainly axial load High rigidity and axial load capacity
BS (Special)	**-**	As per BS 200



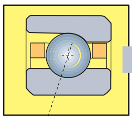


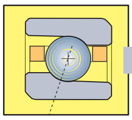
Comparison Table of SNFA Bearings with other makes

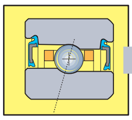
This table is provided for purely indicative purposes and is not binding as regards the technical characteristics and performance.

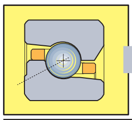
SERIES	SNFA	FAG BARDEN		FAFNIR	GMN	NSK	RHP	SKF	SNR
ISO 18	**SEA**	B 71800						71800	71800
ISO 19	**SEB**	B 71900	1900 H	9300 WI	S 61900	7900	7900	71900	71900
ISO 19	**HB..VEB**	HS 71900		99300 WN		BNC 19	XS 7900	71900 CE	
ISO 19	**HB../S**	HSS 71900						S71900 B	
ISO 10	**EX**	B 7000	100 H	9100 WI	S 6000	7000	7000	7000	7000
ISO 10	**HX - VEX**	HS 7000		99100 WN	SH 6000	BNC 10	X-T 7000	7000 CC 7000 CE	
ISO 10	**HX../S VEX../S**	HSS 7000						S 7000 B S 7000 C	
ISO 02	**E 200**	B 7200	200 H	200 WI	S 6200	7200	7200	7200	7200
ISO 02	**BS 200**	76020						BSA 2	

ISO series and SNFA production









ISO 18

- SEA Ø 10 ÷ 150

ISO 19

- SEB Ø 17 ÷ 280
- VEB Ø 8 ÷ 120
- HB Ø 30 ÷ 120

ISO 10

- EX Ø 6 ÷ 240
- VEX... Ø 6 ÷ 120
- VEX/S Ø 20 ÷ 120
- HX Ø 30 ÷ 70

ISO 02

- E 200 Ø 7 ÷ 140
- BS 200 Ø 12 ÷ 75

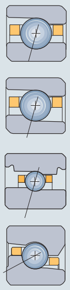
Ø BORE	ISO 18 Series	D	B	ISO 19 Series	D	B	ISO 10 Series	D	B	ISO 02 Series	D	B
6		13	3.5		15	5	EX, VEX	17	6		19	6
7		14	3.5		17	5	EX, VEX	19	6	E 200	22	7
8		16	4	VEB	19	6	EX, VEX	22	7	E 200	24	8
9		17	4		20	6	EX, VEX	24	7	E 200	26	8
10	SEA	19	5	VEB	22	6	EX, VEX	26	8	E 200	30	9
12	SEA	21	5	VEB	24	6	EX, VEX	28	8	E 200, BS 200	32	10
15	SEA	24	5	VEB	28	7	EX, VEX	32	9	E 200, BS 200	35	11
17	SEA	26	5	SEB, VEB	30	7	EX, VEX	35	10	E 200, BS 200	40	12
20	SEA	32	7	SEB, VEB	37	9	EX, VEX, VEX/S	42	12	E 200, BS 200	47	14
25	SEA	37	7	SEB, VEB	42	9	EX, VEX, VEX/S	47	12	E 200, BS 200	52	15
30	SEA	42	7	SEB, VEB, HB	47	9	EX, VEX, VEX/S, HX	55	13	E 200, BS 200	62	16
35	SEA	47	7	SEB, VEB, HB	55	10	EX, VEX, VEX/S, HX	62	14	E 200, BS 200	72	17
40	SEA	52	7	SEB, VEB, HB	62	12	EX, VEX, VEX/S, HX	68	15	E 200, BS 200	80	18
45	SEA	58	7	SEB, VEB, HB	68	12	EX, VEX, VEX/S, HX	75	16	E 200, BS 200	85	19
50	SEA	65	7	SEB, VEB, HB	72	12	EX, VEX, VEX/S, HX	80	16	E 200, BS 200	90	20
55	SEA	72	9	SEB, VEB, HB	80	13	EX, VEX, VEX/S, HX	90	18	E 200	100	21
60	SEA	78	10	SEB, VEB, HB	85	13	EX, VEX, VEX/S, HX	95	18	E 200, BS 200	110	22
65	SEA	85	10	SEB, VEB, HB	90	13	EX, VEX, VEX/S, HX	100	18	E 200	120	23
70	SEA	90	10	SEB, VEB, HB	100	16	EX, VEX, VEX/S, HX	110	20	E 200	125	24
75	SEA	95	10	SEB, VEB, HB	105	16	EX, VEX, VEX/S	115	20	E 200, BS 200	130	25
80	SEA	100	10	SEB, VEB, HB	110	16	EX, VEX, VEX/S	125	22	E 200	140	26
85	SEA	110	13	SEB, VEB, HB	120	18	EX, VEX, VEX/S	130	22	E 200	150	28
90	SEA	115	13	SEB, VEB, HB	125	18	EX, VEX, VEX/S	140	24	E 200	160	30
95	SEA	120	13	SEB, VEB, HB	130	18	EX, VEX, VEX/S	145	24	E 200	170	32
100	SEA	125	13	SEB, VEB, HB	140	20	EX, VEX, VEX/S	150	24	E 200	180	34
105	SEA	130	13		145	20	EX	160	26	E 200	190	36
110	SEA	140	16	SEB, VEB, HB	150	20	EX, VEX, VEX/S	170	28	E 200	200	38
120	SEA	150	16	SEB, VEB, HB	165	22	EX, VEX, VEX/S	180	28	E 200	215	40
130	SEA	165	18	SEB	180	24	EX	200	33	E 200	230	40
140	SEA	175	18	SEB	190	24	EX	210	33	E 200	250	42
150	SEA	190	20	SEB	210	28	EX	225	35		270	45
160		200	20	SEB	220	28	EX	240	38		290	48
170		215	22	SEB	230	28	EX	260	42		310	52
180		225	22	SEB	250	33	EX	280	46		320	52
190		240	24	SEB	260	33	EX	290	46		340	55
200		250	24	SEB	280	38	EX	310	51		360	58
220		270	24	SEB	300	38	EX	340	56		400	65
240		300	28	SEB	320	38	EX	360	56		440	72
260		320	28	SEB	360	46		400	65		480	80
280		350	33	SEB	380	46		420	65		500	80

Bearing identification code

E | X | 50 | /NS | /S | 7 | CE | 1 | DD | L

FORM

E SE	
VE	
H	
BS	



DIMENSIONAL SERIES

A	ISO 18
B	ISO 19
X	ISO 10
2	ISO 02

BORE DIAMETER (mm)

FOLLOWED BY:

-	STANDARD BEARINGS
R...	SPECIAL BEARINGS

STANDARD VARIATIONS

/NS	CERAMIC BALLS
/H1	LUBRICATION HOLE THROUGH THE OUTER RACE
/S	COMPLETE WITH SEALS
/GH	LUBRICATION HOLE THROUGH THE OUTER RACE AND O-RINGS/GROOVES
/G1	H1 LUBRICATION HOLE THROUGH THE OUTER RACE AND O-RINGS/GROOVES
/XN	**CHROMEX® 40** RACEWAYS AND CERAMIC BALLS

CONTACT ANGLE

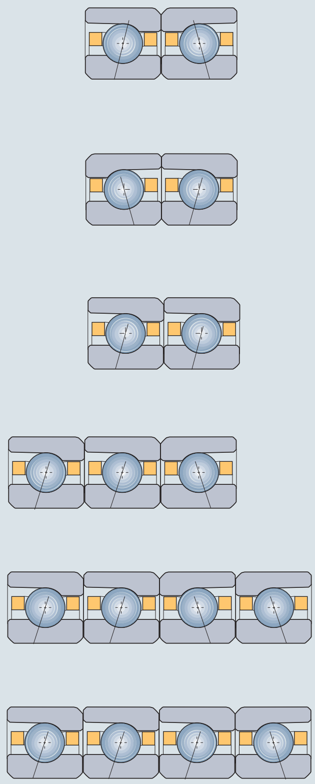
0	12°
1	15°
2	18°
3	25°
62	62°

PRELOAD

L	LIGHT
M	MEDIUM
F	HIGH
.....daN	Special preload in daN
.....µm	Axial play in µm

SET PAIRING

U	Universal
DU	Universal Duplex
TU	Universal Triplex
DD	
FF	
T	
TD	
TDT	
3TD	



PRECISION

5	ABEC 5
7	ABEC 7
9	ABEC 9
.....	SPECIAL

CAGE MATERIAL

C	PHENOLIC RESIN
P	POLYAMMIDE 6.6
L	BRASS
B	BRONZE
X	SPECIAL MATERIAL

CAGE LOCATION

E	EXTERNAL
I	INTERNAL

Bearing precision

Dimensional and functional tolerances for ABEC 5, ABEC 7, ABEC 9 (AFBMA STD 20) bearings

Internal ring

(Values in microns)

Nominal dimension of bore in mm		> 0 ≤ 10	> 10 ≤ 18	> 18 ≤ 30	> 30 ≤ 50	> 50 ≤ 80	> 80 ≤ 120	> 120 ≤ 150	> 150 ≤ 180	> 180 ≤ 250	> 250 ≤ 315	> 315 ≤ 400	> 400 ≤ 500
Δ_{dmp}	ABEC 5	-5	-5	-6	-8	-9	-10	-13	-13	-15	-18	-23	
	ABEC 7	-4	-4	-5	-6	-7	-8	-10	-10	-12			
	ABEC 9	-2.5	-2.5	-2.5	-2.5	-4	-5	-7	-7	-8			
K_{ia}	ABEC 5	4	4	4	5	5	6	8	8	10	13	15	
	ABEC 7	2.5	2.5	3	4	4	5	6	6	8			
	ABEC 9	1.5	1.5	2.5	2.5	2.5	2.5	2.5	5	5			
S_{ia}	ABEC 5	7	7	8	8	8	9	10	10	13	15	20	
	ABEC 7	3	3	4	4	5	5	7	7	8			
	ABEC 9	1.5	1.5	2.5	2.5	2.5	2.5	2.5	5	5			
S_d	ABEC 5	7	7	8	8	8	9	10	10	11	13	15	
	ABEC 7	3	3	4	4	5	5	6	6	7			
	ABEC 9	1.5	1.5	1.5	1.5	1.5	2.5	2.5	4	5			
V_{Bs}	ABEC 5	5	5	5	5	6	7	8	8	10	13	15	
	ABEC 7	2.5	2.5	2.5	3	4	4	5	5	6			
	ABEC 9	1.5	1.5	1.5	1.5	1.5	2.5	2.5	4	5			
Δ_{Bs}	ABEC 5	-40	-80	-120	-120	-150	-200	-250	-250	-300	-350	-400	
	ABEC 7	-40	-80	-120	-120	-150	-200	-250	-250	-300			
	ABEC 9	-40	-80	-120	-120	-150	-200	-250	-300	-350			
Δ_{B1s}	ABEC 5	-250	-250	-250	-250	-250	-380	-380	-380	-500	-500	-630	
	ABEC 7	-250	-250	-250	-250	-250	-380	-380	-380	-500			
	ABEC 9												

Outer ring

(Values in microns)

Nominal dimension outer Ø in mm		> 0 ≤ 6	> 6 ≤ 18	> 18 ≤ 30	> 30 ≤ 50	> 50 ≤ 80	> 80 ≤ 120	> 120 ≤ 150	> 150 ≤ 180	> 180 ≤ 250	> 250 ≤ 315	> 315 ≤ 400	> 400 ≤ 500
Δ_{Dmp}	ABEC 5	-5	-5	-6	-7	-9	-10	-11	-13	-15	-18	-20	-23
	ABEC 7	-4	-4	-5	-6	-7	-8	-9	-10	-11	-13	-15	
	ABEC 9	-2.5	-2.5	-4	-4	-4	-5	-5	-7	-8	-8	-10	
K_{ea}	ABEC 5	5	5	6	7	8	10	11	13	15	18	20	23
	ABEC 7	3	3	4	5	5	6	7	8	10	11	13	
	ABEC 9	1.5	1.5	2.5	2.5	4	5	5	5	7	7	8	
S_{ea}	ABEC 5	8	8	8	8	10	11	13	14	15	18	20	23
	ABEC 7	5	5	5	5	5	6	7	8	10	10	13	
	ABEC 9	1.5	1.5	2.5	2.5	4	5	5	5	7	7	8	
S_D	ABEC 5	8	8	8	8	8	9	10	10	11	13	13	15
	ABEC 7	4	4	4	4	4	5	5	5	7	8	10	
	ABEC 9	1.5	1.5	1.5	1.5	1.5	2.5	2.5	2.5	4	5	7	
V_{Cs}	ABEC 5	5	5	5	5	6	8	8	8	10	11	13	15
	ABEC 7	2.5	2.5	2.5	2.5	3	4	5	5	7	7	8	
	ABEC 9	1.5	1.5	1.5	1.5	1.5	2.5	2.5	2.5	4	5	7	
Δ_{Cs} Δ_{C1s}	ABEC 5	Values identical to those of the corresponding inner ring of the same bearing											
	ABEC 7												
	ABEC 9												

N.B.: Bearings with special tolerance limits can be supplied on request.

Δdmp = Deviation of the mean bore diameter from the nominal ($\Delta_{dmp} = d_{mp} - d$).

ΔDmp = Deviation of the mean outside diameter from the nominal ($\Delta_{Dmp} = D_{mp} - D$).

K_{ia}, Kea = Radial runout of the assembled bearing inner ring and the assembled bearing outer ring respectively.

S_{ia}, Sea = Side face runout of the assembled bearing inner ring and the assembled bearing outer ring respectively.

Sd = Side face runout with reference to the bore (of the inner race).

S_D = Taper of the outer race external diameter cylindrical surface relative to the outer ring side face.

V_{Bs}, VCs = Ring width variation: the difference between the largest and Smallest measurements of the inner race width and outer race width measurements respectively.

Δ_{Bs}, ΔCs = Deviation from the nominal value of a single inner race or a single outer race width ($\Delta_{Bs} = B_s - B$ ecc.).

Δ_{B1s}, $\Delta C1s$ =Deviation the nominal value of a single inner race width or a single outer race width of a set manufactured for paired mounting or a universal bearings ($\Delta_{B1s} = B_s - B$ ecc.).

Assembly tolerances

Bearing assembly and fitting tolerances are extremely important for both assembly and bearing operation.

The values shown in the following table are a guideline for the design of the shaft, housing and bearing location.

Given that precision angular contact ball bearings are widely used in machine tools, the tolerances shown are mainly for this field of application where the shaft rotates whilst the outer race is stationary. If the application is reversed, i.e. the inner race stationary and the housing/outer race rotating, then the fit between outer race and housing will need to have increased interference to prevent creep during operation.

The same applies to any shafts that are subjected to high rotational loads (e.g. winding shafts).

The values given in the following table are valid for steel shafts and housings.

Critical situations may occur where there is a high temperature gradient between shaft/housing and the bearing raceways and these will require special consideration. Thermal effects need to be carefully analysed and assembly tolerances adjusted to prevent either excess bearing preload or loss of preload and subsequent failure.

Shafts and Housings for precision ABEC 7 and ABEC 9 bearings

STEEL SHAFTS (rotating)

Nominal shaft Diameter in mm		≥ <	**6** **10**	**10** **18**	**18** **30**	**30** **50**	**50** **80**	**80** **120**	**120** **180**	**180** **250**	**250** **315**
	Shaft diameter tolerance in µm		0 -4	0 -4	0 -4	0 -5	0 -5	+2 -4	+3 -5	+4 -6	+5 -7
	ISO		-	-	h3	-	h3	-	-	-	-

STEEL HOUSINGS

Nominal seat diameter in mm		≥ <	**10** **18**	**18** **30**	**30** **50**	**50** **80**	**80** **120**	**120** **180**	**180** **250**	**250** **315**	**315** **400**
Support locked axially	Tolerance in µm		+5 0	+6 0	+7 0	+8 0	+7 -3	+9 -3	+11 -3	+13 -3	+15 -3
	ISO		H4	H4	H4	H4	-	-	-	-	-
Support axially free	Tolerance in µm		+7 +2	+8 +2	+9 +2	+10 +2	+10 0	+12 0	+14 0	+16 0	+18 0
	ISO		-	-	-	-	H4	H4	H4	H4	H4

N.B.: Please refer to our Technical Office for special applications

Shafts and seats for precision ABEC 5 bearings

STEEL SHAFTS (rotating)

Nominal shaft Diameter in mm		≥ <	**6** **10**	**10** **18**	**18** **30**	**30** **50**	**50** **80**	**80** **120**	**120** **180**	**180** **250**	**250** **315**
	Shaft diameter tolerance in µm		0 -5	0 -5	0 -6	0 -7	0 -8	+3 -7	+4 -8	+5 -9	+6 -10
	ISO		-	h4	h4	h4	h4	-	-	-	-

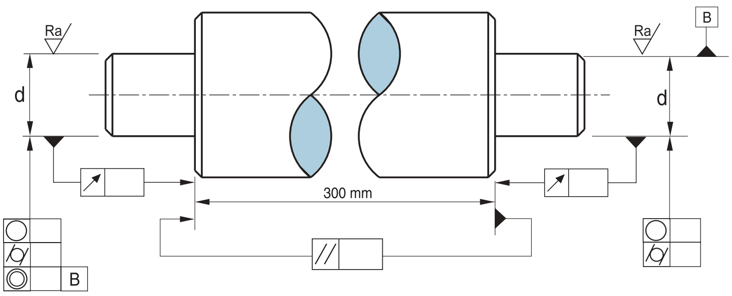
STEEL HOUSINGS

Nominal seat diameter in mm		≥ <	**10** **18**	**18** **30**	**30** **50**	**50** **80**	**80** **120**	**120** **180**	**180** **250**	**250** **315**	**315** **400**
Support locked axially	Tolerance in µm		+8 0	+9 0	+11 0	+13 0	+12 -3	+14 -4	+16 -4	+19 -4	+21 -4
	ISO		H5	H5	H5	H5	-	-	-	-	-
Support axially free	Tolerance in µm		+10 +2	+11 +2	+13 +2	+15 +2	+15 0	+18 0	+20 0	+23 0	+25 0
	ISO		-	-	-	-	H5	H5	H5	H5	H5

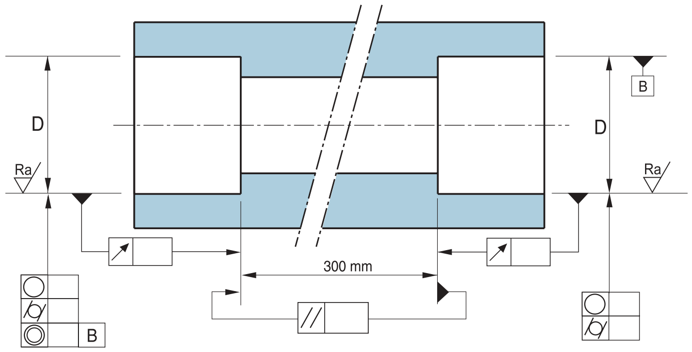
N.B.: Please refer to our Technical Office for special applications

SNFA

Errors of form and squareness
(Maximum permissible theoretical tolerance)



ISO 1101		ABEC 5	ABEC 7	ABEC 9
○	Roundness	$\frac{IT\ 3}{2}$	$\frac{IT\ 2}{2}$	$\frac{IT\ 1}{2}$
⌭	Cylindricity	$\frac{IT\ 3}{2}$	$\frac{IT\ 2}{2}$	$\frac{IT\ 1}{2}$
↗	Runout	IT 3	IT 2	IT 1
//	Parallelism	IT 3	IT 2	IT 1
◎	Concentricity	IT 4	IT 3	IT 2
Ra	Roughness	0,4 µm	0,4 µm	0,2 µm

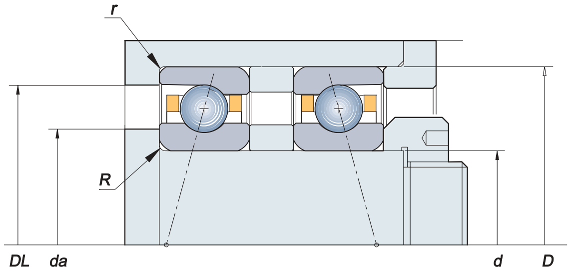


ISO 1101		ABEC 5	ABEC 7	ABEC 9
○	Roundness	$\frac{IT\ 3}{2}$	$\frac{IT\ 2}{2}$	$\frac{IT\ 1}{2}$
⌭	Cylindricity	$\frac{IT\ 3}{2}$	$\frac{IT\ 2}{2}$	$\frac{IT\ 1}{2}$
↗	Runout	IT 3	IT 2	IT 1
//	Parallelism	IT 3	IT 2	IT 1
◎	Concentricity	IT 4	IT 3	IT 2
Ra	Roughness	0,8 µm	0,4 µm	0,4 µm

Nominal diameter in mm	≥ <	6 10	10 18	18 30	30 50	50 80	80 120	120 180	180 250	250 315	315 400
Tolerance of form and squareness in microns	IT 0	0,6	0,8	1	1	1,2	1,5	2	3	-	-
	IT 1	1	1,2	1,5	1,5	2	2,5	3,5	4,5	6	7
	IT 2	1,5	2	2,5	2,5	3	4	5	7	8	9
	IT 3	2,5	3	4	4	5	6	8	10	12	13
	IT 4	4	5	6	7	8	10	12	14	16	18

Diameters of shoulders and corner radii of seatings

(The maximum radii of seatings shall correspond to the relevant bearing rmin and Rmin)



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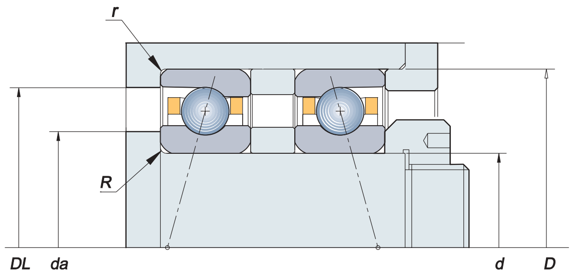
d	SEA SERIES					SEB SERIES					EX SERIES					E 200 SERIES				
	D	damin	DLmax	rmax	Rmax	D	damin	DLmax	rmax	Rmax	D	damin	DLmax	rmax	Rmax	D	damin	DLmax	rmax	Rmax
6											17	8.5	14.5	0.15	0.3					
7											19	9.5	16.5	0.15	0.3	22	11.0	19.0	0.15	0.3
8											22	11.0	19.0	0.15	0.3	24	11.0	21.0	0.15	0.3
9											24	12.5	20.5	0.15	0.3	26	13.0	23.0	0.15	0.3
10	19	12.0	17.0	0.1	0.3						26	13.5	22.5	0.3	0.3	30	14.5	25.5	0.3	0.6
12	21	14.0	19.0	0.1	0.3						28	15.0	25.0	0.15	0.3	32	16.5	27.5	0.3	0.6
15	24	17.0	22.0	0.1	0.3						32	19.0	28.5	0.15	0.3	35	18.5	31.5	0.3	0.6
17	26	19.0	24.0	0.1	0.3	30	19.5	27.5	0.15	0.3	35	20.5	31.5	0.15	0.3	40	21.5	35.5	0.3	0.6
20	32	23.0	29.0	0.1	0.3	37	24.0	33.5	0.15	0.3	42	24.5	37.5	0.3	0.6	47	26.5	40.5	0.6	1.0
25	37	28.0	34.0	0.1	0.3	42	29.0	38.5	0.15	0.3	47	29.0	43.0	0.3	0.6	52	30.5	46.5	0.6	1.0
30	42	33.0	39.0	0.1	0.3	47	34.0	43.5	0.15	0.3	55	34.5	50.5	0.3	1.0	62	36.5	55.5	0.6	1.0
35	47	38.0	44.0	0.1	0.3	55	39.5	50.5	0.3	0.6	62	40.5	56.5	0.3	1.0	72	44.0	63.0	0.6	1.1
40	52	43.0	49.0	0.1	0.3	62	44.5	57.5	0.3	0.6	68	46.0	62.0	0.3	1.0	80	49.0	71.0	0.6	1.1
45	58	48.5	54.5	0.1	0.3	68	50.0	63.0	0.3	0.6	75	50.5	69.5	0.3	1.0	85	54.0	76.0	0.6	1.1
50	65	53.5	61.5	0.1	0.3	72	54.0	68.0	0.3	0.6	80	55.5	74.5	0.3	1.0	90	57.5	83.0	0.6	1.1
55	72	58.5	68.5	0.1	0.3	80	59.5	75.5	0.3	1.0	90	61.5	83.5	0.6	1.1	100	63.0	92.0	1.0	1.5
60	78	63.5	74.5	0.1	0.3	85	64.5	80.5	0.3	1.0	95	66.5	88.5	0.6	1.1	110	71.5	100.5	1.0	1.5
65	85	69.5	80.5	0.3	0.6	90	69.5	85.5	0.3	1.0	100	71.5	93.5	0.6	1.1	120	76.5	108.5	1.0	1.5
70	90	74.5	85.5	0.3	0.6	100	75.5	94.5	0.3	1.0	110	77.5	103.0	0.6	1.1	125	81.5	113.5	1.0	1.5
75	95	79.5	90.5	0.3	0.6	105	80.5	99.5	0.3	1.0	115	82.5	108.0	0.6	1.1	130	86.5	118.5	1.0	1.5
80	100	84.5	95.5	0.3	0.6	110	85.5	104.5	0.3	1.0	125	88.0	117.0	0.6	1.1	140	92.5	128.0	1.0	2.0
85	110	90.5	104.5	0.3	1.0	120	91.5	113.5	0.6	1.1	130	93.0	122.0	0.6	1.1	150	98.5	137.0	1.0	2.0
90	115	95.5	109.5	0.3	1.0	125	96.5	118.5	0.6	1.1	140	100.5	130.0	1.0	1.5	160	103.0	147.0	1.0	2.0
95	120	100.5	114.5	0.3	1.0	130	101.5	123.5	0.6	1.1	145	104.0	136.0	1.0	1.5	170	112.0	153.0	1.1	2.1
100	125	105.5	119.5	0.3	1.0	140	107.5	133.0	0.6	1.1	150	109.0	141.0	1.0	1.5	180	116.0	164.0	1.1	2.1
105	130	110.5	124.5	0.3	1.0						160	115.0	150.0	1.0	2.0	190	122.0	173.0	1.1	2.1
110	140	116.5	134.0	0.3	1.0	150	117.5	143.0	0.6	1.1	170	121.0	159.0	1.0	2.0	200	130.0	181.0	1.1	2.1
120	150	126.5	144.0	0.3	1.0	165	128.0	157.0	0.6	1.1	180	131.0	169.0	1.0	2.0	215	143.0	192.0	1.1	2.1
130	165	138.0	157.0	0.6	1.1	180	140.0	170.0	0.6	1.5	200	143.0	188.0	1.0	2.0	230	152.0	209.0	1.5	3.0
140	175	148.0	167.0	0.6	1.1	190	151.0	180.0	0.6	1.5	210	153.0	198.0	1.0	2.0	250	165.0	225.0	1.5	3.0
150	190	159.0	181.0	0.6	1.1	210	161.0	199.0	1.0	2.0	225	164.0	212.0	1.0	2.1					
160						220	171.0	209.0	1.0	2.0	240	175.0	226.0	1.0	2.1					
170						230	181.0	219.0	1.0	2.0	260	188.0	242.0	1.0	2.1					
180						250	192.0	238.0	1.0	2.0	280	201.0	259.0	1.0	2.1					
190						260	202.0	248.0	1.0	2.0	290	211.0	269.0	1.0	2.1					
200						280	215.0	266.0	1.0	2.1	310	220.0	290.0	1.0	2.1					
220						300	234.0	286.0	1.0	2.1	340	242.0	319.0	1.5	3.0					
240						320	254.5	305.5	1.0	2.1	360	262.0	339.0	1.5	3.0					
260						360	278.5	342.0	1.0	2.1										
280						380	299	361	1.0	2.1										

Values in mm

Diameters of shoulders and corner radii of seatings

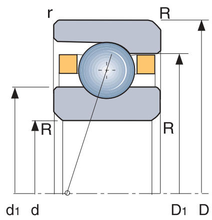
(The maximum radii of seatings shall correspond to the relevant bearing rmin and Rmin)



d	VEB - HB SERIES					VEX - HX SERIES					BS 200 SERIES					BS (special) SERIES				
	D	damin	DLmax	rmax	Rmax	D	damin	DLmax	rmax	Rmax	D	damin	DLmax	rmax	Rmax	D	damin	DLmax	rmax	Rmax
6						17	8.5	14.5	0.15	0.3										
7						19	9.5	16.5	0.15	0.3										
8	19	10.5	16.5	0.15	0.3	22	11.0	19.0	0.15	0.3										
9						24	12.5	20.5	0.15	0.3										
10	22	13.0	19.0	0.15	0.3	26	13.5	22.5	0.3	0.3										
12	24	15.0	21.0	0.15	0.3	28	15.0	25.0	0.15	0.3	32	17.0	26.5	0.6	0.6					
15	28	17.5	25.5	0.15	0.3	32	19.0	28.5	0.15	0.3	35	20.0	30.0	0.6	0.6					
17	30	19.5	27.5	0.15	0.3	35	20.5	31.5	0.15	0.3	40	23.0	34.0	0.6	0.6	47	23.5	40.0	1.0	1.0
20	37	24.0	33.5	0.15	0.3	42	24.5	37.5	0.3	0.6	47	27.0	40.0	0.6	1.0	47	27.0	40.0	1.0	1.0
25	42	29.0	38.5	0.15	0.3	47	29.5	42.0	0.3	0.6	52	32.0	45.0	0.6	1.0	62	34.0	53.5	1.0	1.0
30	47	34.0	43.5	0.15	0.3	55	36.5	48.5	0.6	1.0	62	39.0	53.5	0.6	1.0	62	39.0	53.5	1.0	1.0
35	55	39.5	50.5	0.3	0.6	62	41.5	55.5	0.6	1.0	72	45.0	61.5	0.6	1.1	72	45.0	61.5	1.1	1.1
40	62	44.5	57.5	0.3	0.6	68	47.0	61.0	0.6	1.0	80	51.0	69.0	0.6	1.1					
45	68	50.0	63.0	0.3	0.6	75	53.0	67.0	0.6	1.0	85	56.0	74.0	0.6	1.1					
50	72	54.0	68.0	0.3	0.6	80	57.5	72.5	0.6	1.0	90	61.0	79.0	0.6	1.1					
55	80	59.5	75.5	0.3	1.0	90	64.5	80.5	0.6	1.1										
60	85	64.5	80.5	0.3	1.0	95	69.5	85.5	0.6	1.1	110	74.0	96.0	0.6	1.5					
65	90	69.5	85.5	0.3	1.0	100	74.0	91.0	0.6	1.1										
70	100	75.5	94.5	0.3	1.0	110	80.5	99.5	0.6	1.1										
75	105	80.5	99.5	0.3	1.0	115	85.5	104.5	0.6	1.1	130	91.0	114.0	0.6	1.5					
80	110	85.5	104.5	0.3	1.0	125	91.5	113.5	0.6	1.1										
85	120	91.5	113.5	0.6	1.1	130	96.5	118.5	0.6	1.1										
90	125	96.5	118.5	0.6	1.1	140	104.0	126.0	1.0	1.5										
95	130	101.5	123.5	0.6	1.1	145	107.3	132.5	1.0	1.5										
100	140	107.5	133.0	0.6	1.1	150	112.5	137.5	1.0	1.5										
105																				
110	150	117.5	143	0.6	1.1	170	127.5	152.5	1.0	2.0										
120	165	128	157	0.6	1.1	180	135.5	164.0	1.0	2.0										
130																				
140																				
150																				
160																				
170																				
180																				
190																				
200																				
220																				
240																				
260																				
280																				

Values in mm

Shoulder diameter and corner radii of bearings

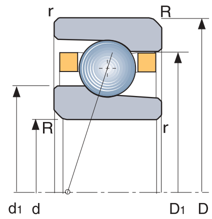


SE - E SERIES

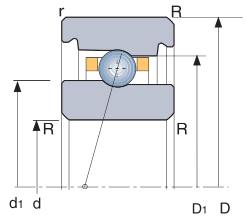
d	SEA SERIES					SEB SERIES					EX SERIES					E 200 SERIES				
	D	d1	D1	r_{min}	R_{min}	D	d1	D1	r_{min}	R_{min}	D	d1	D1	r_{min}	R_{min}	D	d1	D1	r_{min}	R_{min}
6											17	9.2	14.0	0.15	0.3					
7											19	10.3	15.7	0.15	0.3	22	12.1	17.9	0.15	0.3
8											22	12.1	17.9	0.15	0.3	24	13.1	18.8	0.15	0.3
9											24	13.6	19.4	0.15	0.3	26	14.8	21.3	0.15	0.3
10	19	13.1	16.1	0.1	0.3						26	15.6	20.4	0.3	0.3	30	16.3	23.7	0.3	0.6
12	21	15.1	18.1	0.1	0.3						28	17.0	23.3	0.15	0.3	32	18.0	26.0	0.3	0.6
15	24	18.1	21.1	0.1	0.3						32	20.7	26.9	0.15	0.3	35	20.8	29.1	0.3	0.6
17	26	20.1	23.0	0.1	0.3	30	21.1	25.9	0.15	0.3	35	22.7	29.3	0.15	0.3	40	24.2	32.8	0.3	0.6
20	32	24.1	28.1	0.1	0.3	37	25.7	32.0	0.15	0.3	42	27.2	34.8	0.3	0.6	47	29.0	38.0	0.6	1.0
25	37	29.1	33.1	0.1	0.3	42	30.7	36.4	0.15	0.3	47	31.7	40.3	0.3	0.6	52	33.8	43.2	0.6	1.0
30	42	34.1	38.1	0.1	0.3	47	35.8	41.4	0.15	0.3	55	37.9	47.2	0.3	1.0	62	40.3	51.7	0.6	1.0
35	47	39.1	43.1	0.1	0.3	55	41.7	48.3	0.3	0.6	62	43.9	53.2	0.3	1.0	72	47.8	59.2	0.6	1.1
40	52	44.1	48.1	0.1	0.3	62	47.2	54.8	0.3	0.6	68	49.2	58.8	0.3	1.0	80	53.3	66.8	0.6	1.1
45	58	49.6	53.6	0.1	0.3	68	52.7	60.3	0.3	0.6	75	54.3	65.7	0.3	1.0	85	58.8	71.5	0.6	1.1
50	65	55.1	60.0	0.1	0.3	72	56.7	65.3	0.3	0.6	80	59.3	70.8	0.3	1.0	90	62.4	77.7	0.6	1.1
55	72	60.7	66.5	0.1	0.3	80	62.8	72.3	0.3	1.0	90	65.8	79.2	0.6	1.1	100	69.0	86.1	1.0	1.5
60	78	65.7	72.5	0.1	0.3	85	67.8	77.3	0.3	1.0	95	70.8	84.2	0.6	1.1	110	77.4	94.6	1.0	1.5
65	85	71.7	78.5	0.3	0.6	90	72.8	82.3	0.3	1.0	100	75.8	89.2	0.6	1.1	120	83.0	102.0	1.0	1.5
70	90	76.7	83.5	0.3	0.6	100	79.3	90.5	0.3	1.0	110	82.4	97.6	0.6	1.1	125	88.0	107.0	1.0	1.5
75	95	81.7	88.5	0.3	0.6	105	84.3	95.5	0.3	1.0	115	87.4	102.6	0.6	1.1	130	93.0	112.0	1.0	1.5
80	100	86.7	93.5	0.3	0.6	110	89.3	100.5	0.3	1.0	125	94.0	111.0	0.6	1.1	140	99.4	120.6	1.0	2.0
85	110	93.2	102.1	0.3	1.0	120	96.0	109.2	0.6	1.1	130	99.0	116.0	0.6	1.1	150	106.0	129.0	1.0	2.0
90	115	98.2	107.1	0.3	1.0	125	101.0	114.2	0.6	1.1	140	106.4	123.6	1.0	1.5	160	113.9	136.4	1.0	2.0
95	120	103.2	112.1	0.3	1.0	130	106.0	119.2	0.6	1.1	145	110.5	129.5	1.0	1.5	170	120.1	144.9	1.1	2.1
100	125	108.2	117.0	0.3	1.0	140	112.4	127.5	0.6	1.1	150	115.5	134.5	1.0	1.5	180	126.5	153.5	1.1	2.1
105	130	113.2	122.0	0.3	1.0						160	122.0	143.6	1.0	2.0	190	132.3	162.7	1.1	2.1
110	140	119.8	130.6	0.3	1.0	150	122.4	137.5	0.6	1.1	170	128.5	151.5	1.0	2.0	200	139.7	170.3	1.1	2.1
120	150	129.8	140.6	0.3	1.0	165	134.0	151.0	0.6	1.1	180	138.5	161.5	1.0	2.0	215	152.3	182.7	1.1	2.1
130	165	141.8	153.2	0.6	1.1	180	146.4	163.6	0.6	1.5	200	151.7	178.3	1.0	2.0	230	162.8	197.1	1.5	3.0
140	175	151.3	163.7	0.6	1.1	190	156.4	173.6	0.6	1.5	210	161.7	188.3	1.0	2.0	250	177.0	213.0	1.5	3.0
150	190	163.3	176.7	0.6	1.1	210	168.6	191.5	1.0	2.0	225	173.2	201.8	1.0	2.1					
160						220	178.6	201.5	1.0	2.0	240	185.0	215.0	1.0	2.1					
170						230	188.6	211.5	1.0	2.0	260	199.0	231.0	1.0	2.1					
180						250	201.7	228.4	1.0	2.0	280	212.9	247.2	1.0	2.1					
190						260	211.7	238.4	1.0	2.0	290	222.9	257.2	1.0	2.1					
200						280	224.8	255.2	1.0	2.1	310	234.1	275.9	1.0	2.1					
220						300	244.8	275.2	1.0	2.1	340	257.2	302.8	1.5	3.0					
240						320	264.8	295.2	1.0	2.1	360	277.2	322.8	1.5	3.0					
260						360	291.0	329.1	1.0	2.1										
280						380	311.0	349.0	1.0	2.1										

Values in mm

Shoulder diameter and corner radii of bearings



VE SERIES

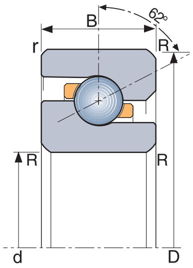


H SERIES

d	VEB SERIES					HB SERIES					VEX SERIES					HX SERIES				
	D	d1	D1	r_{min}	R_{min}	D	d1	D1	r_{min}	R_{min}	D	d1	D1	r_{min}	R_{min}	D	d1	D1	r_{min}	R_{min}
6											17	9.2	14.0	0.15	0.3					
7											19	10.3	15.7	0.15	0.3					
8	19	11.3	15.7	0.15	0.3						22	12.1	17.9	0.15	0.3					
9											24	13.6	19.4	0.15	0.3					
10	22	14.0	17.9	0.15	0.3						26	15.6	20.4	0.3	0.3					
12	24	16.0	19.9	0.15	0.3						28	17.0	23.3	0.15	0.3					
15	28	19.1	23.9	0.15	0.3						32	20.7	26.9	0.15	0.3					
17	30	21.1	25.9	0.15	0.3						35	22.7	29.3	0.15	0.3					
20	37	25.7	32.0	0.15	0.3						42	27.2	34.8	0.3	0.6					
25	42	30.7	36.4	0.15	0.3						47	32.2	39.8	0.3	0.6					
30	47	35.8	41.4	0.15	0.3	47	36	41.2	0.15	0.3	55	38.7	46.3	0.6	1.0	55	39.5	45.5	0.6	1.0
35	55	41.7	48.3	0.3	0.6	55	42.5	47.7	0.3	0.6	62	44.2	52.8	0.6	1.0	62	45.5	51.7	0.6	1.0
40	62	47.2	54.8	0.3	0.6	62	48.5	53.7	0.3	0.6	68	49.7	58.2	0.6	1.0	68	51	57.2	0.6	1.0
45	68	52.7	60.3	0.3	0.6	68	53.5	59.7	0.3	0.6	75	55.7	64.2	0.6	1.0	75	56.4	63.8	0.6	1.0
50	72	56.7	65.3	0.3	0.6	72	58	64.2	0.3	0.6	80	60.2	69.8	0.6	1.0	80	61.4	68.4	0.6	1.0
55	80	62.8	72.3	0.3	1.0	80	63.9	71.3	0.3	1.0	90	67.7	77.3	0.6	1.1	90	68.2	77.1	0.6	1.1
60	85	67.8	77.3	0.3	1.0	85	68.9	76.3	0.3	1.0	95	72.7	82.3	0.6	1.1	95	73.2	82.1	0.6	1.1
65	90	72.8	82.3	0.3	1.0	90	73.9	81.3	0.3	1.0	100	77.3	87.7	0.6	1.1	95	78.2	87.1	0.6	1.1
70	100	79.3	90.5	0.3	1.0	100	80.9	89.3	0.3	1.0	110	84.3	95.3	0.6	1.1	100	84.9	95.4	0.6	1.1
75	105	84.3	95.5	0.3	1.0	105	85.9	94.3	0.6	1.0	115	89.3	100.7	0.6	1.1					
80	110	89.3	100.5	0.3	1.0	110	90.7	99.6	0.6	1.0	125	95.8	109.2	0.6	1.1					
85	120	96.0	109.2	0.6	1.1	120	98.2	107	0.6	1.1	130	100.8	114.2	0.6	1.1					
90	125	101.0	114.2	0.6	1.1	125	102.9	112.3	0.6	1.1	140	108.3	121.7	1.0	1.5					
95	130	106.0	119.2	0.6	1.1	130	107.9	117.3	0.6	1.1	145	112.4	127.6	1.0	1.5					
100	140	112.4	127.5	0.6	1.1	140	114.9	125.3	0.6	1.1	150	117.4	132.6	1.0	1.5					
105																				
110	150	122.4	137.5	0.6	1.1	150	124.4	135.9	0.6	1.1	170	132.4	147.6	1.0	2.0					
120	165	134	151	0.6	1.1	165	136.9	148.4	0.6	1.1	180	141.4	158.6	1.0	2.0					
130																				
140																				
150																				
160																				
170																				
180																				
190																				
200																				
220																				
240																				
260																				
280																				

Values in mm

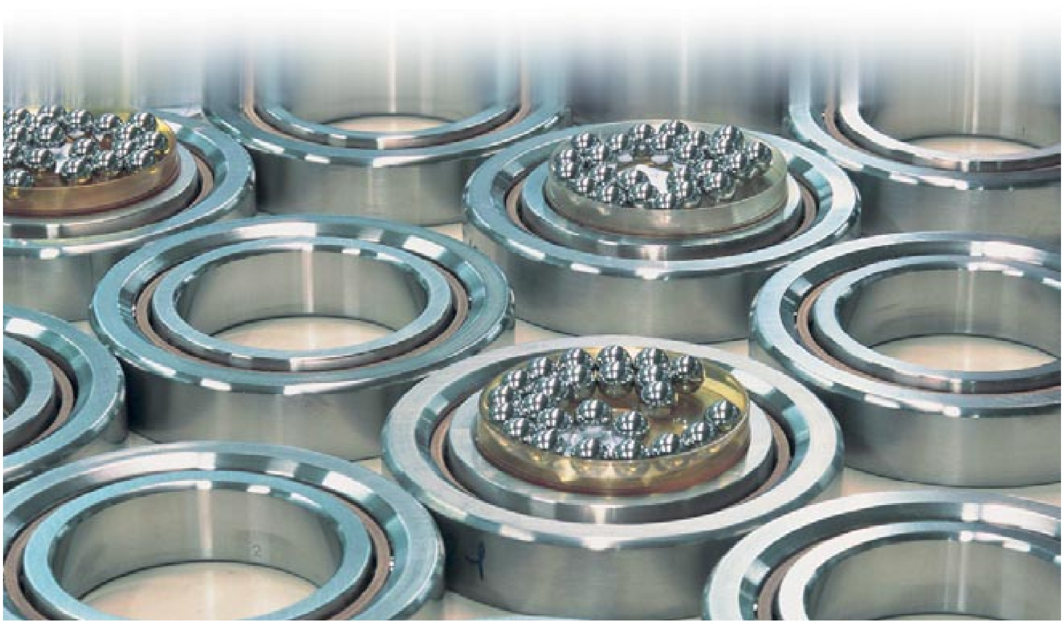
Shoulder diameter
and corner radii of bearings



BS (SPECIAL) - BS 200 SERIES

d	BS 200 SERIES					BS (SPECIAL) SERIES				
	D	d1	D1	rmin	Rmin	D	d1	D1	rmin	Rmin
6										
7										
8										
9										
10										
12	32	22.0	22.1	0.6	0.6					
15	35	25.0	25.1	0.6	0.6					
17	40	28.5	28.6	0.6	0.6	47	33.5	33.6	1.0	1.0
20	47	33.5	33.6	0.6	1.0	47	33.5	33.6	1.0	1.0
25	52	38.5	38.6	0.6	1.0	62	46.0	46.1	1.0	1.0
30	62	46.0	46.1	0.6	1.0	62	46.0	46.1	1.0	1.0
35	72	53.5	53.6	0.6	1.1	72	53.5	53.6	1.1	1.1
40	80	60.0	60.1	0.6	1.1					
45	85	65.0	65.1	0.6	1.1					
50	90	70.0	70.1	0.6	1.1					
55										
60	110	85.0	85.1	0.6	1.5					
65										
70										
75	130	102.5	102.7	0.6	1.5					

Values in mm

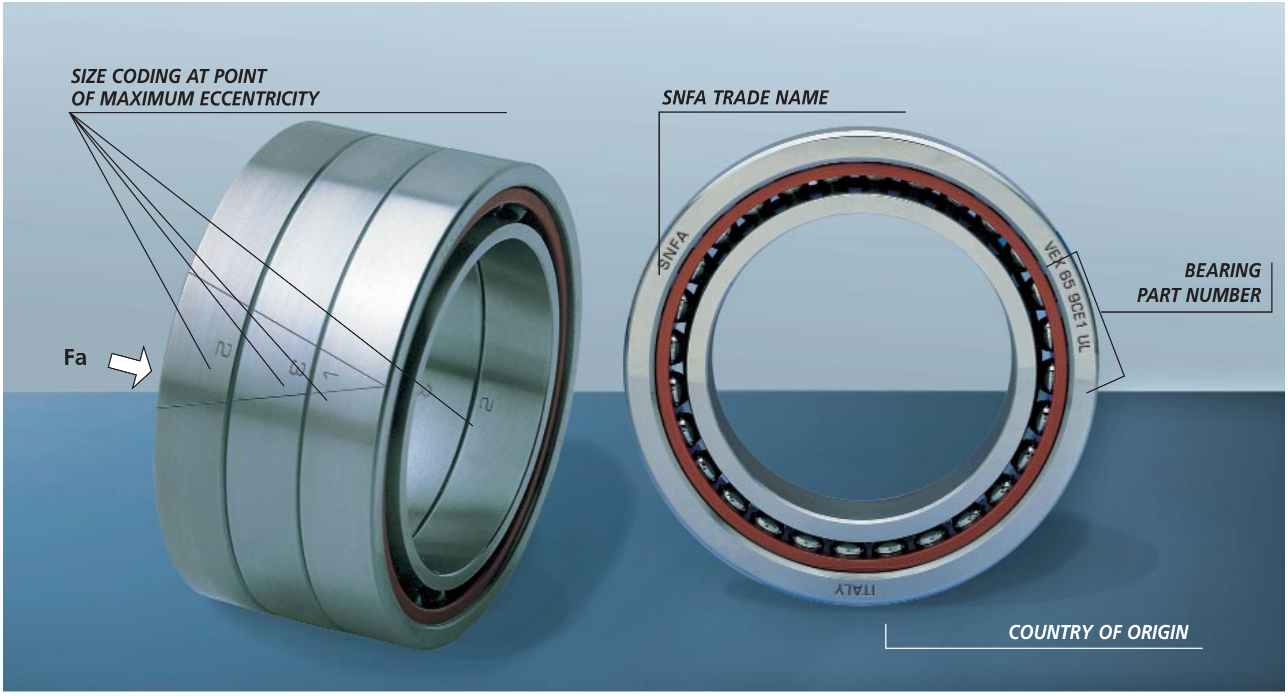


Marking

In assemblies of large and medium diameter bearings, a complete description including variant codes (contact angle, level of precision, coupling type, etc.) is applied to each bearing in the set. For smaller bearings full marking may be applied to one bearing only and the others partially marked with base type, trademark and country of origin (e.g. SNFA, Italy).

The deviation in microns from the nominal value, for both the bore and outside diameter of each bearing, is marked at the highest point of eccentricity for that ring.
By positioning that point diametrically opposite the point of maximum eccentricity of the shaft, optimum assembly concentricity will be achieved.

Other symbols that might also appear on the ring faces include manufacturing references: e.g. date of manufacture, set number, etc.



The **"V"** marking applied to the outer diameter of the bearing indicates the direction of the thrust applicable to the inner rings of the bearing set.

The arrow is located at the point of maximum eccentricity (maximum radial thickness) of the outer rings.

Greasing of bearings

To reduce the risk of contamination during spindle assembly and to ensure correct lubrication it is recommended for customers to have bearings greased by SNFA.

This operation is preformed in a clean room using specialist equipment immediately after the bearings have been washed. In this way the cleanliness of the bearing, the correct amount of grease and its uniform distribution are ensured.

Lubrication

Lubrication reduces friction and hence heat generation inside the bearing by separating the rolling and sliding surfaces and works even under high contact stress. Lubricants will also protect the metal surfaces against corrosion.

Grease

This is the most common form of lubrication as it is simple and easy to use.

When operating conditions (speed, temperature and cleanliness) are within the limits stipulated by the grease manufacturers, bearings require no special maintenance or subsequent topping up. This is often called life-long lubrication.

Selection of grease type is critical for bearing operation and depends on:

- operating temperature,
- life,
- protection,
- noise level.

A wide range of commercially available high quality synthetic greases is now available. Products satisfying the limits in the table below are most frequently used.

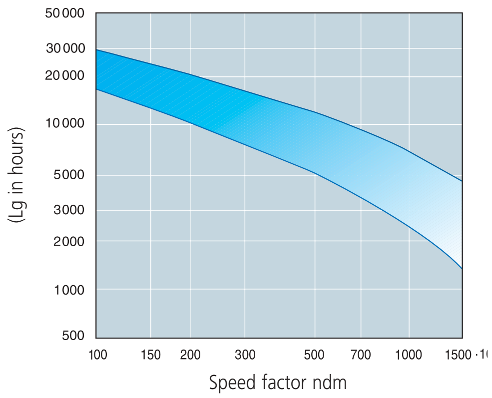
Bearings operating at high temperatures, such as electrospindles, must be lubricated with long-life grease that has an adequate base oil viscosity and high wear resistance.

APPLICATION		GREASE	
Speed (ndm)	Load	NLGI Consistency	Soap
Up to 600.000	Light / medium	2	Lithium
Up to 600.000	High	2	Calcium / lithium
Up to 900.000	Medium	2	Calcium / barium / lithium
Over 900.000	Light	2	Calcium / barium / lithium

Grease life

The effectiveness of the grease reduces in time due to operating conditions such as temperature, stress and contamination levels and its chemical and physical characteristics.

Grease life (Lg in hours) Fig.1



However, these parameters are hard to estimate, so the grease life hours **"Lg"** are calculated using statistical data.

Figure 1 the elements needed for assessing the life of good quality synthetic greases in optimum operating conditions. The upper part of the life curve relates to operating conditions at moderate temperatures (e.g. spindles fitted with a belt transmission). The lower part of the life curve, on the other hand, relates to applications where there is another heat source (e.g. electro-spindles) that significantly increases the temperature of the bearing with negative effects on the lubricant.
From the diagram it is clear that, in applications that feature high operating temperatures, bearing life is more significantly dependent upon the grease life than it is on material fatigue properties.

Running-in

This activity is extremely important if spindle operation is to be guaranteed and especially so if the lubricant is grease.
Running-in ensures that all spindle components "settle down" after assembly and, if grease lubrication is being used, that is uniformly distributed.

Bearing and lubricant life and performance are directly linked to the correct running in of a spindle and the procedures used. In the case of grease based lubrication it is important to adhere to the following guidelines:

1 - Start off with a reduced rotation speed

$$n_1 \leq n_{max} \cdot 0{,}1$$

2 - Gradually increase the speed, in steps that are approximately 15% of the maximum speed:

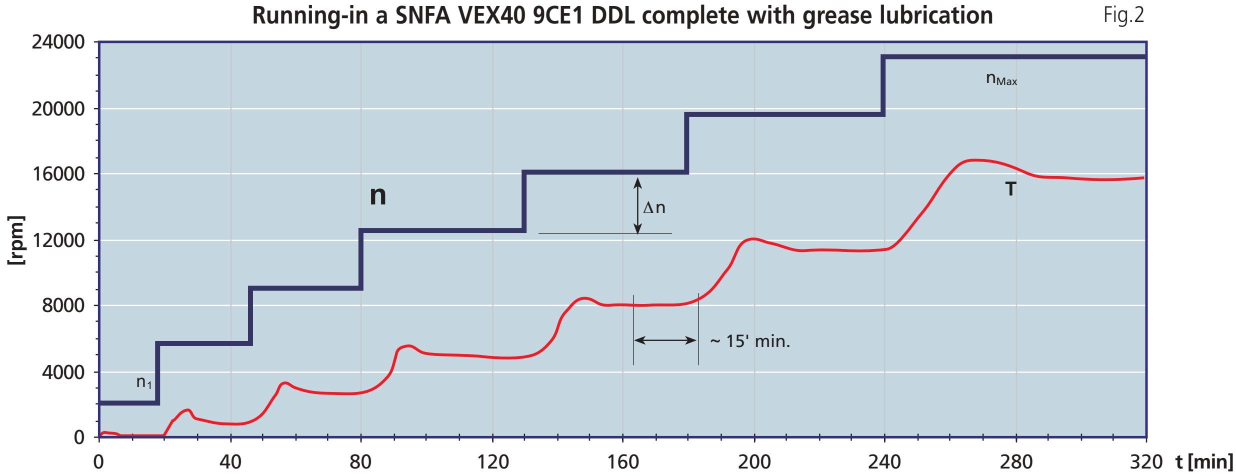
$$\Delta n \cong n_{max} \cdot 0{,}15$$

Wait at least 15 minutes after the bearing operating temperature has stabilised before increasing the speed.

During the run-in period it is essential to monitor the bearing temperature, using a probe that is in contact with the bearings (figure 2).
If at any time the temperature should rise to 55oC then the running in should be stopped, the spindle allowed to cool and the process restarted from the pervious stage, with the rotation speed being increased in half steps.

The temperature of 55°C is precautionary in nature.
The bearing is in fact capable of handling uniform temperatures up to approximately 100°C, but it is a good idea not to exceed this limit as the temperature might reach a far higher level for a short time within the body of the bearing itself.

Running-in a SNFA VEX40 9CE1 DDL complete with grease lubrication Fig.2



Grease Quantity

The quantity of grease used varies according to the type of bearing and operating speed. As such, the quantity is calculated by multiplying the factor **K** (a function of the maximum anticipated rotation speed, expressed in **"ndm"** - figure 3) by the value of the **"reference quantity"** highlighted in table 4.

Factor K

Fig. 3

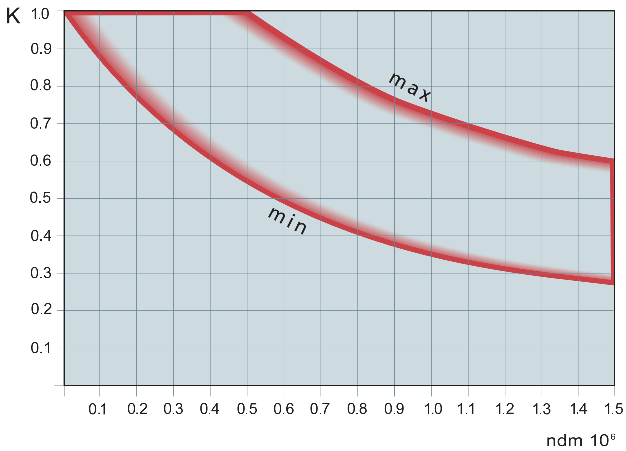
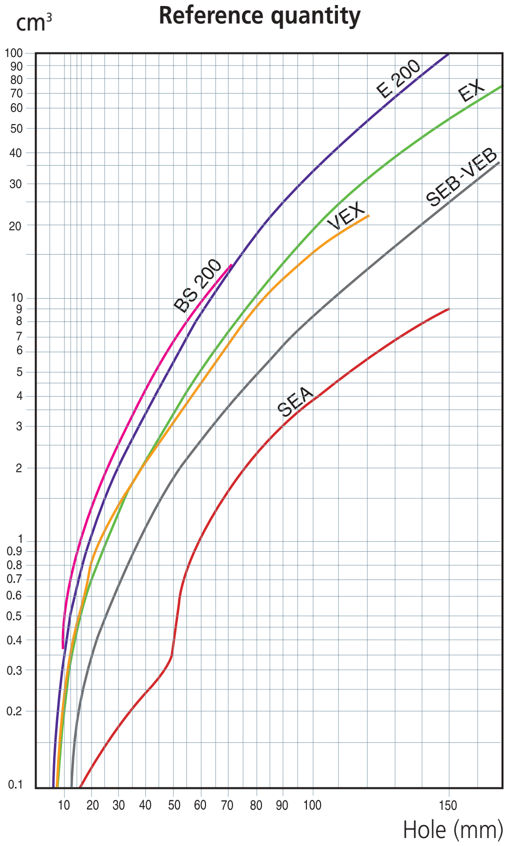


Table 4 - Basic quantity of grease

In the case of smaller bearings, where the amount of grease used is small, it is recommended first to immerse the bearing in a mixture of solvent and grease (3 - 5%), then to dry it by evaporation in the open air, before finally adding the lubricant that is needed.
This will guarantee that the lubricant spreads uniformly across all bearing surfaces.

Reference quantity



Factory Greased Bearings

Very often, SNFA bearings are supplied with the type and quantity of grease requested by the customer.

This solution offers operating and economic advantages for the customer as the bearing is greased during the manufacturing route with greater control over the cleanness, quantity and distribution.

Oil lubrication

Oil lubrication is mandatory when greasing limits are exceeded. A number of different oil based lubrication systems are available and for the machine tool sector, the best known are:

- **Oil injection**
- **Oil mist**
- **Air-Oil.**

Oil injection

Oil injection is preferred for bearings having to operate at very high speed, high load and where conditions do not allow "oil mist" lubrication owing to the need to cool the bearings.

Oil is injected into the bearings through nozzles placed so as to lubricate the ball/race contacts with minimum churning. Drainage channels must be provided to prevent oil from stagnating and/or churning and hence generating heat.

Besides ensuring proper lubrication the oil crossing the bearing also removes the heat generated by the bearing operation and by entering from external sources and will maintain temperatures at an acceptable level.

The assembly should also include oil filtering, a heat exchanger to dissipate heat removed from the bearings and an adequate oil reserve. A suitably sized reservoir facilitates heat dispersion and the settling out of any debris, it also avoids early lubricant ageing.

This type of lubrication system requires accurate and proper analysis. Precise rules for calculating oil flow take account of the bearing type and the assembly. The oil viscosity range for an oil injection system is usually **ISO VG10** or **VG15.**

Viscosity grade ISO	Average kinematic viscosity at 40°C mm²/s (cSt)	Limits of kinematic viscosity 40°C mm²/s (cSt)	
		Minimum	Maximum
VG 2	2.2	1.98	2.42
VG 3	3.2	2.88	3.52
VG 5	4.6	4.14	5.06
VG 7	6.8	6.12	7.48
VG 10	10.0	9.00	11.00
VG 15	15.0	13.50	16.50
VG 22	22.0	19.80	24.20
VG 32	32.0	28.80	35.20
VG 46	46.0	41.40	50.60
VG 68	68.0	61.20	74.80
VG 100	100.0	90.00	110.00
VG 150	150.0	135.00	165.00

Quantity of oil for lubrication with cooling

Bore (mm)				
	>		50	120
	≤	50	120	280
Quantity of oil (l/h)		2 ... 24	15 ...120	60 ... 300

Oil mist

Oil mist lubrication is widely used, especially in high-speed applications as it provides the following advantages:

- A reasonable level of efficiency, even with a complex bearing arrangement.
- Low temperatures, reduced power absorption.
- Low cost assembly.
- Simple construction (channels, spacers, etc.)
- Good protection for the bearing against outside contamination (pressurised environment).

Oil mist lubrication equipment also needs to be designed in accordance with precise standards that take into account the design features and speed of the bearings being lubricated.

Oil Mist control unit manufacturers can provide the specific data that is needed.

The recommended oil viscosity for oil mist lubrication is **ISO VG32.**

Air / oil

A significant characteristic of this system is the use of high viscosity synthetic oil (generally **ISO VG68**) that, even in small quantities, ensures the presence of a resistant oil film between the rolling elements and the bearing raceways.

This provides both reduced ball rolling resistance and, simultaneously, good bearing behaviour even under high stress.

The system is only moderately polluting as it has:

- A low level of oil consumption,
- A controlled atomisation effect.

Indeed, in this system, the air (the carrier) and the oil are supplied to the bearing via side **nozzles (figure 5) or via holes in the external ring of the bearing itself** (please refer to the following page for "H1" and "G1" bearings), without any mixing en route.

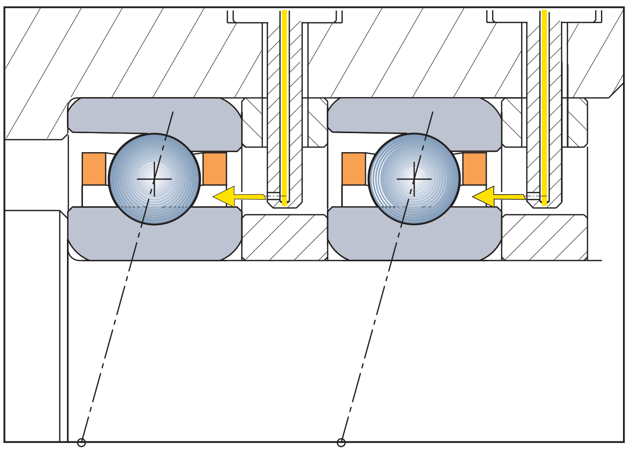


Fig. 5

Notable results have been achieved in the high frequency and high power electro-spindle sector using air / oil lubrication.

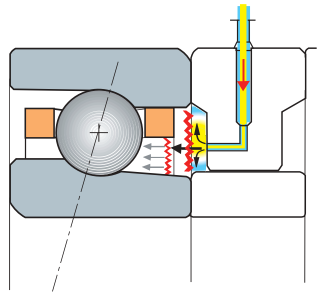
High speed VEB and VEX bearings with the NS/H1 or NS/G1 designation (ceramic material balls and outer ring with radial lubrication holes), and air / oil lubrication are capable of achieving high rotation speeds in excess of 2,500,000 ndm.

An approximate calculation of the quantity of oil (Q) that is needed is obtained using the following formula:

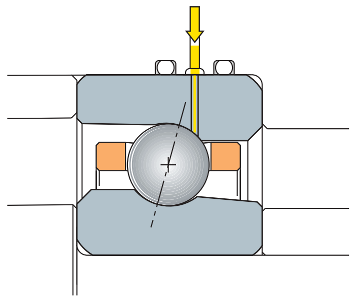
$Q = 1.2 \cdot dm$ mm3/h **for each bearing**
where **dm** is the bearing mean diameter (in mm).

The air / oil flow to the bearings must be homogeneous and without any losses along the way. It is therefore strongly recommended that each bearing be supplied individually even if, at times, a more complex delivery system is required.

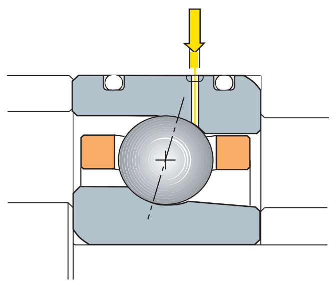
CONVENTIONAL



H1



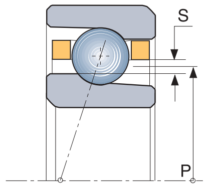
G1



Minimum oil

Any system capable of sending the quantity of oil to a bearing that is strictly needed in order for it to operate correctly is considered to be "minimum" in nature.
This type of lubrication can also be used in high-speed bearings, by injecting small quantities of oil directly into the bearing itself.
A control unit and circuit that guarantees continuity of pressure and flow controls the type and dose of oil used.

Nozzle position.



Maximum performance is achieved for all oil lubrication systems when the lubricant flow reaches the bearing contact areas with minimum turbulence.

Nozzle positioning, as indicated in the table below, is therefore strongly recommended.

"P" and "S" values for nozzle position

Diameter d	SERIES									
	SEA		SEB - VEB		EX		VEX		E 200	
	P	S	P	S	P	S	P	S	P	S
6					10.10	0.90	10.10	0.90		
7					11.30	1.00	11.30	1.00	13.10	1.00
8			12.10	0.85	13.30	1.20	13.30	1.20	13.80	0.70
9					14.80	1.20	14.80	1.20	16.10	1.30
10	13.40	0.30	14.80	0.75	16.50	0.90	16.50	0.90	17.90	1.55
12	15.40	0.30	16.80	0.75	18.20	1.20	18.20	1.20	19.60	1.60
15	18.40	0.30	19.80	1.15	21.90	1.20	21.90	1.20	22.30	1.45
17	20.40	0.30	22.00	0.90	24.10	1.35	24.10	1.35	25.70	1.55
20	24.50	0.35	26.70	1.05	28.70	1.50	28.70	1.50	30.80	1.75
25	29.50	0.35	31.80	1.05	33.50	1.75	33.80	1.65	35.50	1.65
30	34.50	0.35	36.80	1.00	39.70	1.90	40.30	1.65	42.40	2.05
35	39.50	0.35	43.00	1.25	45.70	1.90	46.10	1.90	49.90	2.05
40	44.50	0.35	48.70	1.45	51.10	1.90	51.60	1.85	55.80	2.50
45	50.00	0.35	54.20	1.45	56.60	2.30	57.60	1.85	60.90	2.10
50	55.60	0.45	58.40	1.65	61.60	2.30	62.30	2.10	65.20	2.75
55	61.30	0.55	64.60	1.85	68.10	2.30	69.60	1.90	72.20	3.15
60	66.40	0.65	69.60	1.85	73.10	2.30	74.60	1.85	80.20	2.80
65	72.40	0.65	74.50	1.75	78.10	2.30	79.30	2.05	86.00	3.00
70	77.40	0.65	81.50	2.20	85.20	2.80	86.50	2.15	91.00	3.00
75	82.40	0.65	86.50	2.15	90.20	2.80	91.50	2.25	95.80	2.75
80	87.40	0.65	91.50	2.15	97.00	3.00	98.50	2.70	102.70	3.30
85	94.10	0.90	98.60	2.55	102.00	3.00	103.50	2.70	110.00	4.00
90	99.10	0.90	103.50	2.50	109.50	3.10	111.00	2.65	116.00	2.05
95	104.10	0.90	108.50	2.50	113.60	3.10	115.40	3.05	123.80	3.70
100	109.10	0.90	115.40	3.00	118.80	3.25	120.40	3.05	130.30	3.75
105	114.60	1.40			126.00	4.00			137.20	4.85
110	120.90	1.10	125.40	2.95	132.80	4.25	135.40	3.05	144.40	4.65
120	130.90	1.10	137.40	3.40	142.80	4.25	144.90	3.50	157.20	4.85
130	144.00	2.20	149.80	3.40	157.10	5.40			168.60	5.70
140	153.20	1.85	159.80	3.35	167.10	5.40			182.50	5.50
150	165.60	2.20	173.30	4.65	178.90	5.65				
160			183.30	4.65	190.80	5.75				
170			193.30	4.65	204.50	5.50				
180			207.40	5.65	219.50	6.55				
190			217.30	5.60	229.00	6.05				
200			231.10	6.30	240.30	6.20				
220			251.10	6.30	264.10	6.90				
240			271.00	6.20	283.60	6.40				
260			298.90	7.95						
280			318.3	7.30						

"P" and "S" dimensions in mm

Influence of the amount of lubricant contamination on bearing behaviour and life.

The level of bearing cleanliness affects both bearing life and efficiency. It is therefore extremely important to achieve an application where the bearings operate free of external contamination.

With **grease lubrication** it is essential that all precautions are taken to prevent the ingress of contaminants both during the greasing process, assembly and operation. Spindle sealing has a significant role to play in keeping the bearing system free from debris during normal operation. The new range of SNFA sealed bearings can also offer designers new options in ensuring longer life.

In the case of **oil lubrication** the basic demands for cleanness also apply but there is the added requirement of ensuring that the oil remains adequately free from contaminating particles. **The contamination level will need monitoring.** The frequency of monitoring will be governed by; the rate of contamination, the effectiveness of the sealing and the standard of the filtration and filter size.

ISO 4406 CONTAMINATION LEVEL

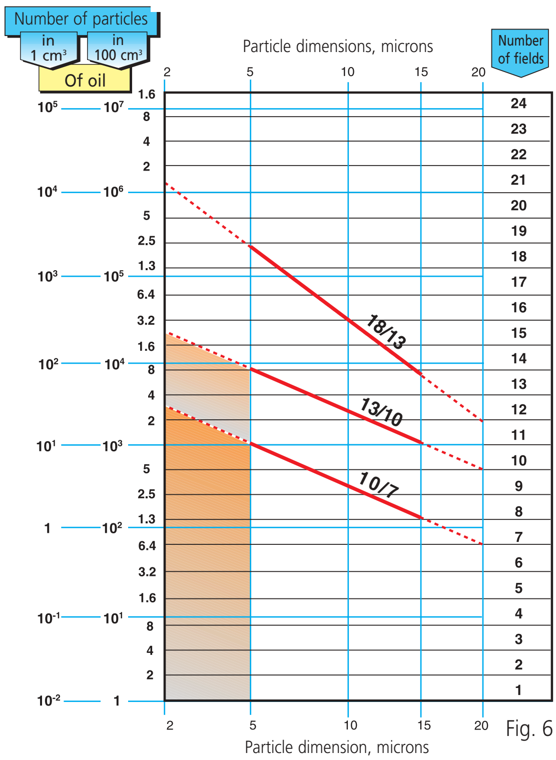


Fig. 6

Apart from particulates, oils are also contaminated by the ingress of cutting oils and coolants etc. The oil properties are reduced so adversely affecting bearing life. This problem should be minimised by good sealing of the spindle.

Contaminating particle classifications are available that specify size limits and amounts per 100cm³ of oil.

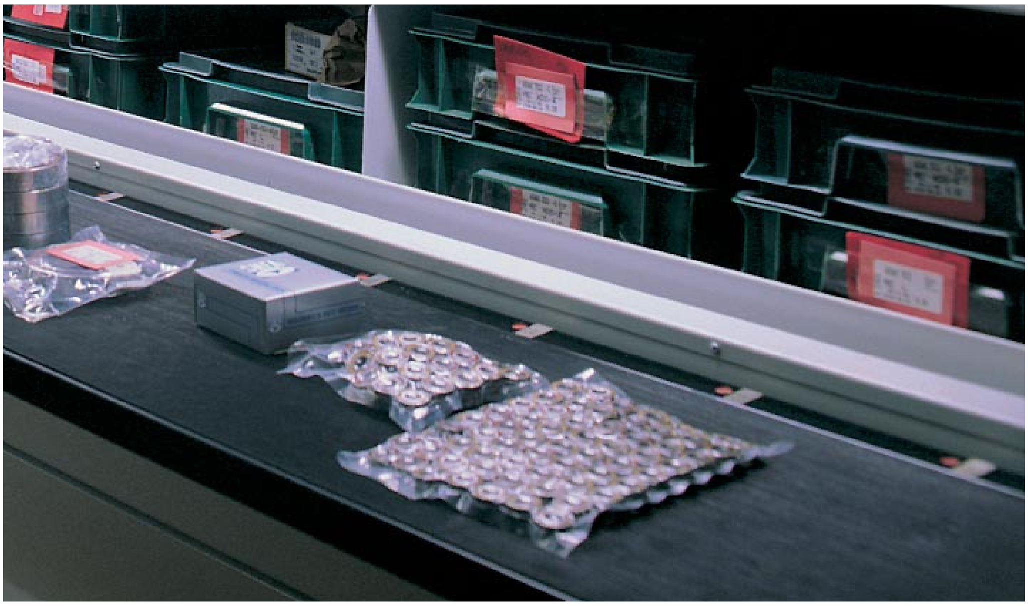
With reference to classification **ISO 4406** and **ISO 4572** (figure 6) and the high precision sector, especially the high performance electro-spindle sector, it is advisable not to exceed a **maximum contamination level of 11/8 and a filtering efficiency of B3 ≥ 200.**

Bearing handling

Angular contact super precision SNFA ball bearings are manufactured and packaged under strictly controlled environmental conditions.

The end user can only take full advantage of bearing performance by using them properly and observing the following advice very carefully:

- **Store the bearings in the original packing and in a dry environment.**
- **Plan the assembly sequences carefully.**
- **Operate in a suitable environment.**
- **Inspect components close to the bearings and check their cleanness.**
- **Check on the drawing that the bearing designation on the box is correct.**
- **Open the package only when the bearings are required for installation**
- **In the case of grease lubrication, introduce the correct amount of grease and distribute it evenly.** In the case of synthetic grease, issues might arise relating to incompatibility with the protective oil. Whenever possible wash the bearing in well filtered products compatible with the environment and bearing materials and dry it immediately using dry and filtered compressed air.
  On no account should the bearing be spun using the air jet.
- **Assemble the bearing in accordance with the instructions enclosed in the packaging (excessive force must be avoided).**
- **If necessary preheat the bearing bore or outer housing to ease assembly.**



Fitting and clamping of bearing rings.

Bearings are tightened axially on journals or into housings with either ring nuts or end caps. These must be designed and manufactured to have:

- High geometrical precision.
- Good mechanical strength.
- Reliable locking (to avoid loosening during operation).

The clamping force, P_a, which is obtained either by tightening the ring nuts or end caps, is of significant importance and shall be able to:

- Prevent any relative movements of the components and so avoid any fretting corrosion during operation.
- Guarantee correct bearing location without resulting in any kind of deformation.
- Minimise material fatigue.

Correct assessment of the force P_a is difficult given the uncertainty of the parameters that are in play. However, as a general guide, the tightening force $\mathbf{P_a}$ and the resultant value of the tightening torque **C** for the ring nuts and end caps can be calculated using the following rules:

Calculation of the axial tightening force, P_a

The value for P_a can be obtained from:

$$P_a = F_s + (N_{cp} \cdot F_c) + P_r$$

Where:

P_a	Axial clamping force (daN)
F_s	Minimum axial clamping force (daN)
F_c	Axial fitting force (daN)
P_r	Bearing preload (daN)
N_{cp}	Number of preload bearings

Values for F_s and F_c are listed on the following page by bearing series and bore diameter.
The preload value P_r, is specified in the bearing data table or, when dealing with a special preload, in the bearing designation.
For a more accurate calculation please contact the SNFA Technical Office.

Tightening torque calculation

With values for P_a the value of the tightening torque C (daN mm) can be calculated:

$$C = K \cdot P_a \quad \text{for the locking nut}$$

$$C = K \cdot P_a / N_b \quad \text{for bolts in the end cap.}$$

K is a based on the screw thread (see the table on page 26) and N_b is the number of screws on the end cap.
Details and recommendations on the tightening procedures are included in the "SNFA bearings assembly" manual.

N.B.: *The tightening torque value C calculated using the above method is only valid for:*

- *Locking bearing sets that comply with the tolerances that are recommended in this catalogue.*
- *Locking bearings and spacers only and not other components (e.g. gearwheels).*
- *A maximum axial workload of less than 2 • P_a.*
- *Good quality ring nuts or end caps where the thread is lightly oiled.*

The SNFA technical department can provide the requisite advice if the above conditions cannot met.

Calculation of the axial tightening force

d	SEA SERIES		SEB - VEB - HB SERIES		VEX - EX - HX SERIES		E 200 SERIES		BS 200 - BS (SPECIAL) SERIES	
	Fs	Fc	Fs	Fc	Fs	Fc	Fs	Fc	Fs	Fc
6					26	43				
7					31	41	49	55		
8			33	28	45	49	49	60		
9					60	49	65	60		
10	37	24	50	28	65	55	85	70		
12	43	21	60	28	70	47	100	70	120	75
15	55	18	65	28	100	49	95	60	140	75
17	60	16	75	28	100	49	130	70	190	80
20	95	25	130	40	160	65	230	85	260	95
25	120	21	160	34	180	50	240	75	320	95
30	140	18	190	30	250	55	340	80	480	95
35	160	21	260	44	330	75	550	120	650	130
40	180	18	310	50	410	75	600	120	800	140
45	240	19	380	48	450	75	700	120	900	130
50	290	18	310	38	500	65	600	100	1000	130
55	330	23	410	43	600	80	750	110		
60	330	24	450	40	650	75	1100	130	1500	150
65	470	26	480	37	700	70	1300	130		
70	500	24	650	50	850	80	1400	130		
75	550	23	650	48	900	75	1500	130	2100	210
80	550	30	700	65	1100	120	1700	190		
85	750	55	900	90	1100	140	1900	250		
90	800	50	950	85	1600	170	1900	250		
95	800	48	1000	85	1400	150	2700	300		
100	850	46	1200	100	1500	140	2700	310		
105	900	45					3100	330		
110	1100	60	1300	90	2000	180	3700	360		
120	1200	60	1600	120	2200	190	4500	430		
130	1700	90	2300	160	2700	270	4800	450		
140	1600	80	2400	150	2900	250	5900	500		
150	2100	100	2700	180	3400	270				
160			2800	170	3800	290				
170			3000	160	5100	350				
180			3700	220	6400	450				
190			3900	260	6800	500				
200			4800	320	6600	550				
220			5200	290	7900	600				
240			5700	270	8600	550				
260			7700	400						
280			8300	400						

Tightening procedure

Closure using ring nuts

- Use a torque spanner initially to tighten the ring nut to a level that is approximately three times greater than C (this operation is important).
- Loosen off the ring nut.
- Retighten the ring nut to a torque of C.
- Close the anti-locking device according to the manufacturer's instructions.

Closure using end caps and bolts

A residual gap must remain between the end cap and the housing face *(figure 7)* once the force Pa has been applied and the tightening procedure is complete.

- Use a torque spanner to tighten the bolts to a torque that is 2- 3 times greater than the recommended value of C. The operation should be carried out gradually moving across the diameter for the next bolt.
- Loosen off the bolts.
- Re-tighten the bolts to the specified torque C (in the same manner as before)
- Measure the residual gap "L" between the end cap and the front face of the housing *(see figure 7).*
- Reduce the spigot depth by an amount that is equal to the residual gap "L" or compensate for the gap using spacers.
- Tighten the screws gradually to the MAXIMUM torque as recommended by manufacturers of the components.

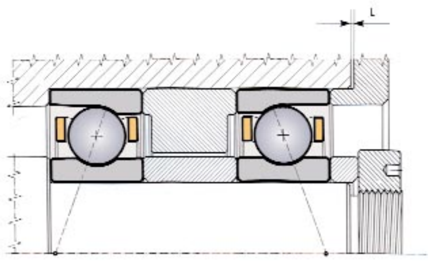


Fig. 7

It is important to remember that the spigot depth obtained using the above technique is valid for that set of bearings only. It is important to always repeat the spigot depth measurement procedure when assembling new/replacement bearings.

Spacers

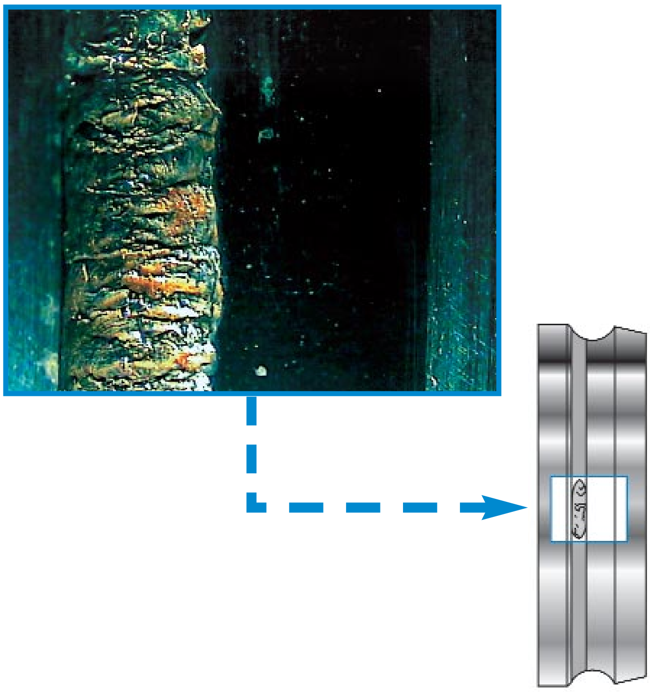
The spacer configuration that is given in the above figure is recommended in any case where the spindles operate out of the horizontal when it is important to guarantee that the grease remains close to the bearings.

Coefficient "K" used to calculate the tightening torque

THREAD	FACTOR "K"		THREAD	FACTOR "K"
	NUTS	BOLTS		NUTS
M 4		0.8	M 70	9.0
M 5		1.0	M 75	9.6
M 6		1.2	M 80	10.0
M 8		1.6	M 85	11.0
M 10	1.4	2.0	M 90	11.0
M 12	1.6	2.4	M 95	12.0
M 14	1.9	2.7	M 100	12.0
M 15	2.0	2.9	M 105	13.0
M 16	2.1	3.1	M 110	14.0
M 17	2.2		M 120	15.0
M 20	2.6		M 130	16.0
M 25	3.2		M 140	17.0
M 30	3.9		M 150	18.0
M 35	4.5		M 160	19.0
M 40	5.1		M 170	21.0
M 45	5.8		M 180	22.0
M 50	6.4		M 190	23.0
M 55	7.0		M 200	24.0
M 60	7.6		M 220	26.0
M 65	8.1		M 240	27.0
			M 260	29.0
			M 280	32.0

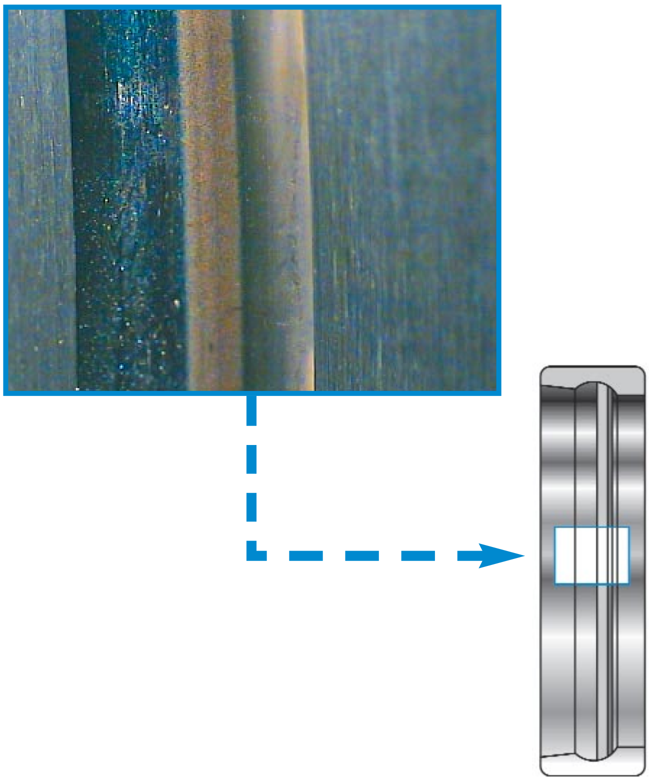
N.B.: The "K" values in the table are for fine pitch threads only.

BEARING DAMAGE ANALYSIS



EXCESSIVE LOADS

Excessive loading of the bearings demonstrates itself in many ways. The first is for a wide contact tracking band that may be discoloured by the heat generated, the second is fatigue spalling developing around microscopic pits and scratches in the raceway and the third is spalling starting from inclusions within the material body.
The first will generate in to the second and the resultant spalling will develop as shown on the ring. Spalling originating from inclusions will also develop around the ring and they could also appear as shown. Whatever the beginning, the life of the bearing will be short.
The problem can be resolved by reducing the external loads or by using bearings with a higher load capacity.



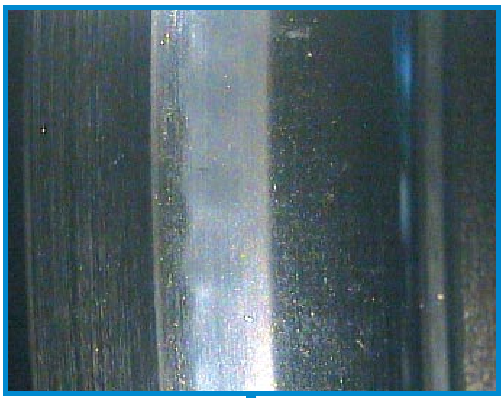
OVERHEATING

Overheated rings and balls display colouring that varies from golden yellow through to blue.
Overheating occurs because there is an application problem, because the bearing is overloaded, because the lubrication is not good enough or because there is no way the heat developed within the bearing can escape.
If the bearing runs at temperatures in excess of the tempering temperature for any period of time not only will they begin to discolour they will begin to soften and eventually become misshapen. Bearing fatigue life will be reduced.
The most common cause for this problem is related to lubrication. As shown, the ball tracks are discoloured brown indicating that the track surface has been in excess of 200°C. At this temperature the lubrication will be poor if not destroyed. This leads to more heat generation and eventual premature failure.
To control this problem, confirm that the lubrication is adequate for the operating conditions (loads, rotational speeds and temperature) and try to ensure a good heat path away from the bearing.

SNFA®

BRINNELLING

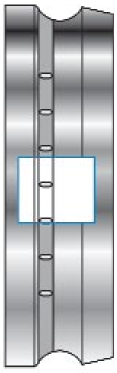
When a bearing is subjected to very high loads (it is not important if they are applied gradually or are impact loads) and the contact stresses are in excess of the elastic limit, indentations are formed. This is Brinnelling.
Brinnelling can appear as discrete indents if the bearing has not rotated or as high wear if the bearing has been running during the time of the high loading.
Brinnelling of a bearing is often first noted by high noise levels.



The most common causes of Brinnelling are:

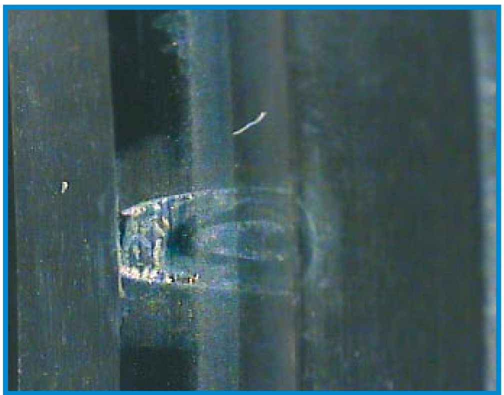
- Assembly and / or disassembly using inappropriate tools (e.g. hammer).
- Accidentally dropping previously assembled components.
- Incorrect assembly and / or disassembly procedures.

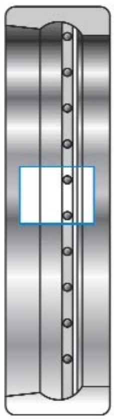
Never assemble bearings onto the shaft by applying pressure to the external ring, but rather ensure that pressure is applied directly to the internal ring. This prevents the balls and the rings from being subjected to excessive static loads.

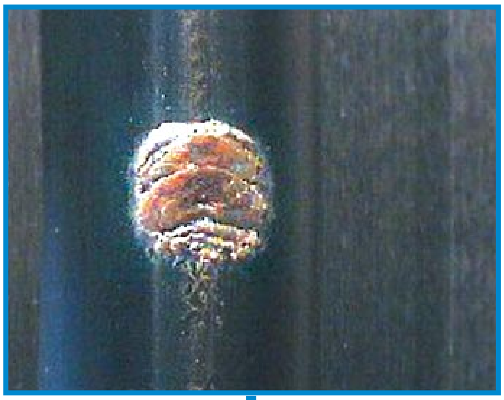


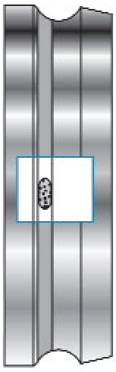
FALSE BRINNELLING

False Brinnelling resembles brinnelling but it is generated differently. When the static bearing is vibrated the ball/track contacts begin to suffer fretting corrosion. The products of this mechanism are abrasive so they tend to accelerate the process. As the bearing is static any lubricant present is ineffective.
To stop this happening there is a need to lock together the shaft and housing to prevent relative movement or fully isolate the part from the vibration source.



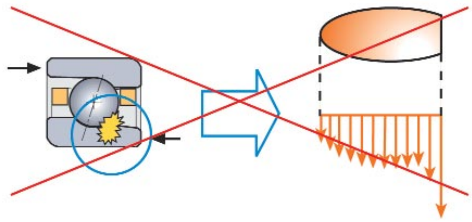




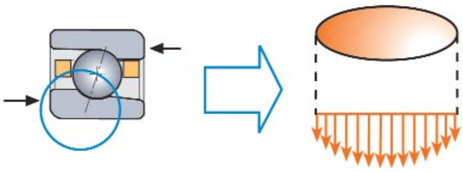


FATIGUE

Fatigue-related failure takes the form of spalling of the raceway surface. It generates either from the surface where there are high contact stresses around microscopic pits or scratches or from below the surface where stress concentrations occur around inclusions, leading to crack propagation. Fatigue spalling usually propagates gradually during operation and is evident on both the inner and outer rings as well as the balls. The problem is usually detected through increased vibration and noise levels.



Contact stress



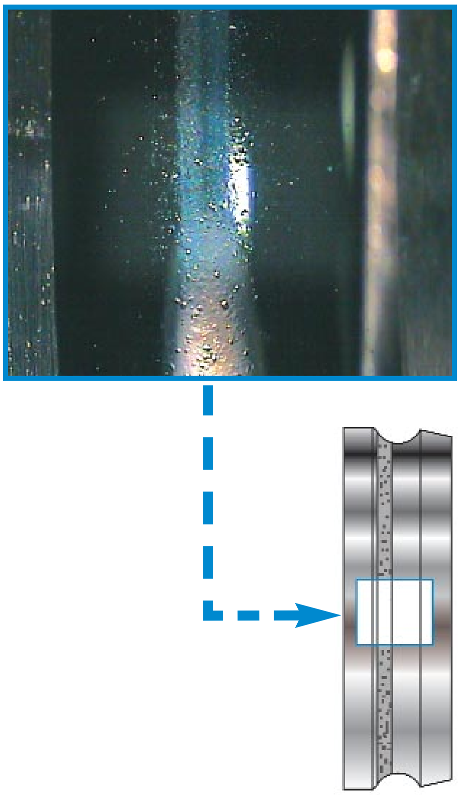
REVERSE LOADING

Angular ball bearings are designed to support axial loads that act in one direction only. If a reverse load is applied the contact area between the ball and the outer ring moves towards the non-thrust side which has a lower shoulder height. The result is that the ball/raceway contact ellipse becomes truncated resulting in high contact stresses and rapid failure.

Not all reverse load situations result in the bearing actually attempting to take thrust in the wrong direction. Most often the reverse load is sufficient to overcome the preload. This is termed off-loading. When this occurs the balls are allowed to spin and take up another preferred axis of rotation and hence develop another tracking pattern.

Where complete reverse loading occurs the signs of damage will be excessive bearing noise and poor spindle operation. This may be confused with other failure causes, however, on disassembly and inspection of the balls, a deep line will be witnessed in the tracking band (caused by running over the shoulder) and the track/smaller shoulder corner radius of the bearing ring will be damaged.

CONTAMINATION

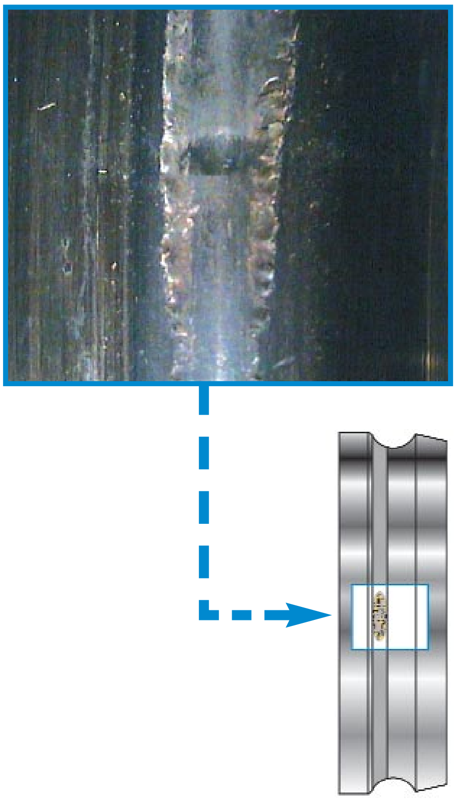


Contamination can be one of the main reasons for bearing rejection. The presence of particles in the bearing leads to indentations in the raceway as the balls roll over them. These indentations then increase the general noise level of the bearing. The indentations also act as stress raisers from which fatigue spalls can generate. Wear rates, and all that that brings with it, are enhanced.
Contaminants may include:

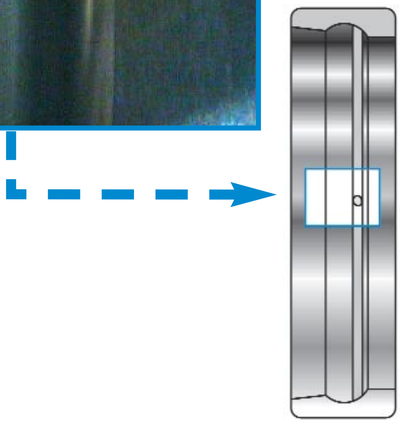
- Dust that is blown in by the air supply,
- Machining debris left behind after spindle or housing manufacture,
- Abrasive particles from grinding wheels etc normally found in a workshop.

Typically, bearings may be contaminated if the person handling them has dirty hands or uses dirty tools, or if they are located in dirty surroundings, or indeed if contaminated lubricants and washing liquids are used.
It is good practice to provide assembly areas away from any machines and preferably in an area that is enclosed with a controlled atmosphere. Bearings should be stored in their original packaging until they are needed. Should bearings need to be washed prior to fitting or greasing, then well filtered liquids must be used.
Seals play a significant role in preventing bearing contamination, and should always be damage free and hence effective.

LUBRICATION

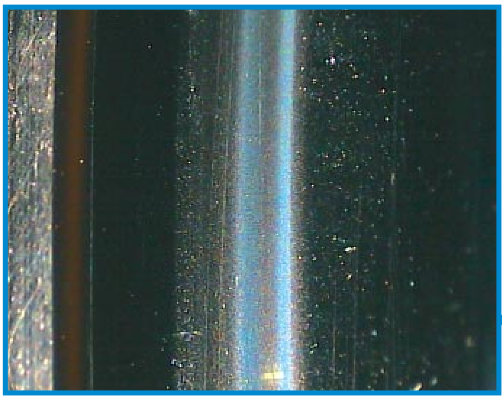


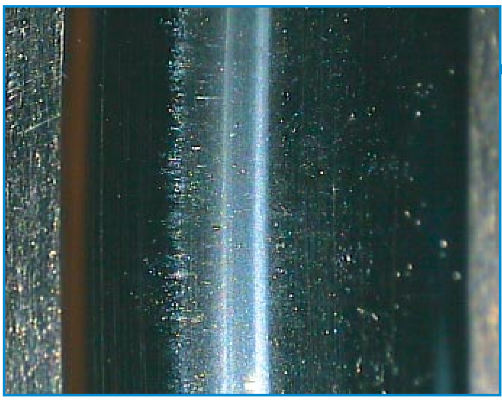
Tracking bands on rings and balls that are discoloured blue or brown are a good sign of lubrication problems. This happens because the lubricant film has been unable to maintain sufficient thickness to prevent surface to surface contact. Lubrication failure could mean that it is wrong for the application or that the supply is marginal and hence a full film can not develop. It is necessary to always ensure that the specified lubricant, delivery system and quantity is correct for the application.
A matt tracking band indicates that wear is taking place but there is no significant heating. This will progress very slowly to rejection. If the tracking bands are discoloured then the heat build up is more significant and the rejection will happen earlier. Diagnosis may be difficult as only a small part of the machine's duty cycle may cause the problem. It is therefore necessary to look at the worst case and decide if it is significant.
Bearing failure caused by lubrication problems can be dramatic. The cage can burn or melt and the track becomes red hot and material deformed and pushed out of the way by the passing balls. When rotation stops, the balls which are likely to be completely misshapen, become welded to the raceway.
Lubrication issues can be resolved by selecting the optimum lubricant that is suited to the specific application and also by eliminating any causes that could lead to an abnormal increase in the operating temperature.

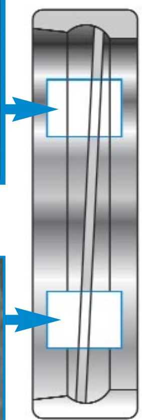


CORROSION

Corrosion displays itself in the form of red-brown marks on the ball and the rings. This happens when the bearing is exposed to environmental or chemical corrosive agents The result is a significant increase in wear and vibration levels which together act to reduce the pre-load. In some cases, corrosion can actually give rise to fatigue-related failure. Keeping the bearing dry and avoiding contact with corrosive agents is the best prevention.







MISALIGNMENT

A tracking band that does not run parallel to the stationary ring shoulder is the result of misalignment. The tracking band on the rotating ring will be wider than normal.

Misalignment is a problem associated with poor manufacturing or assembly. Abutment shoulders must always be square to the bearing seat and seats in housings or on shafts must always be concentric. If burrs or machining debris are not removed from the assembly they can become trapped between the parts and also lead to misalignment.

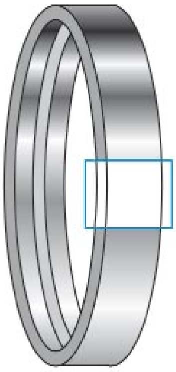
The maximum acceptable misalignment depends greatly on the bearing, the type of application and will certainly need to minimised as speeds increase.

As is shown here with the tracking band being wider on one part of the ring than on another, misalignment can develop over time as parts move or during operation as parts deflect under load.

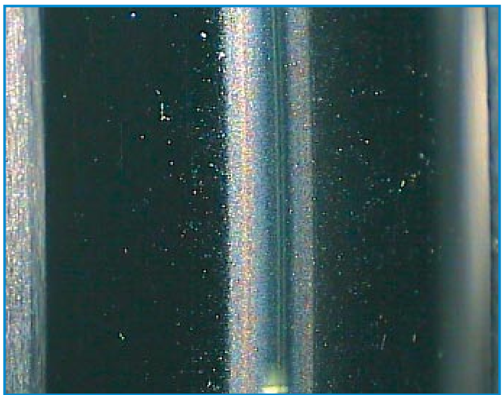
EXCESSIVE RADIAL CLEARANCE

Incorrect selection of the fit between the bearing outer ring and the housing or the inner ring and shaft can result in relative vibratory movement between the surfaces leading to fretting corrosion. Fretting corrosion generates small metallic oxide particles that are brown in colour.
These particles are abrasive and wear the surfaces. This increases the play even further and an ever rapidly increasing problem occurs.

Wear of the bearing side faces and wear of the raceway by intruding debris causes a loss of preload. Couple this with a loss of bearing fit and subsequent ring rotation and the result is poor spindle performance and spindle rejection.



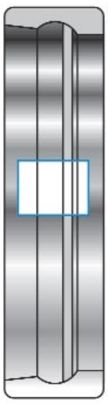
EXCESSIVE RING FIT

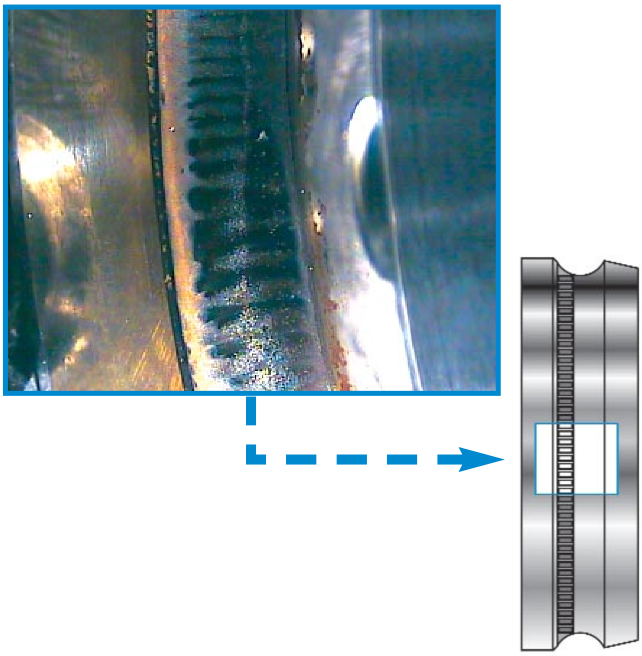


When fits on bearing rings are excessive, the radial play of the bearing may be reduced to the point where there has been a significant change in contact angle. Reducing the contact angle in a predominantly axially loaded bearing means that the contact load is increased and that, in turn, means a wide and often discoloured tracking band.

High interference also means high hoop stresses that, when added to the contact stress, effectively reduces bearing fatigue life.

Always ensure that the fits are adequate at operating conditions and take account of any thermal gradients as well as any speed effects.





ELECTRIC ARC DAMAGE

When an electrical current passes through a bearing, it tends to arc between non-contacting balls and raceways leaving visual patterns that range from random pitting to fluted patterns. Bearings that have suffered this sort of damage produce vibrations and noise and may have a short fatigue life.

Natural Frequencies

The vibrations produced by a bearing are significant indications of its' condition and, more generally of the condition of the machine in which it is fitted.
Indeed, damaged bearings or failing machinery often first present as increased vibration levels.
Using vibration analysis equipment and comparing the spectrum the equipment produces with the bearing natural frequencies, it is possible to work out if the vibrations are the result of damage to the bearing or to other machine components.

The bearing natural frequencies are functions of their geometry and are determined using the following formulae:

Outer ring ball pass frequency:

$$BPFO = \frac{n}{60} \cdot \frac{Z}{2} \left(1 - \frac{\Phi}{d_m} \cdot \cos\alpha\right) \quad [Hz]$$

Inner ring ball pass frequency:

$$BPFI = \frac{n}{60} \cdot \frac{Z}{2} \left(1 + \frac{\Phi}{d_m} \cdot \cos\alpha\right) \quad [Hz]$$

Ball Spin Frequency:

$$BSF = 0.5 \cdot \frac{n}{60} \left(\frac{d_m}{\Phi} - \frac{\Phi}{d_m} \cdot \cos^2\alpha\right) \quad [Hz]$$

Cage Rotation Frequency (Fundamental Train Frequency):

$$FTF = 0.5 \cdot \frac{n}{60} \left(1 - \frac{\Phi}{d_m} \cdot \cos\alpha\right) \quad [Hz]$$

n: Internal ring rotation velocity [revs / minute]
α: Contact angle [degrees] - **Z:** Number of balls - **Φ:** Ball diameter [mm]

The table below provides an initial analysis of the reasons that give rise to anomalous vibrations:

Fault	Dominant frequency	Vibration measurement direction	Comments
Demaged rolling element	BSF	Radial	Faults on rolling elements generate vibration peaks at the spin rotation frequency and subsequent harmonics (BSF, 2xBSF, 3xBSF, etc). In addition, the cage rotation frequency (FTF) often modulates the frequencies in question, creating smaller peaks corresponding to BSF±FTF, 2xBSF±FTF etc.
Damage cage	BSF - FTF	Radial - Axial	The frequency of vibration varies continuously. In addition, cage guided rolling elements generate vibrations that deviate from BSF.
Damaged rings	BPFO -BPFI	Radial	When a defect is present on the rolling track, the balls generate a vibration that corresponds to their pass frequency, BPFI and BPFO respectively, if the damage is to the inner or outer ring. In general, the phenomenon develops with time and also damages the rolling element that in turn begins to generate signals at BSF and its harmonics (see above)
Lubrication	Variable	Radial - Axial	In any situation in which insufficient lubrication is provided, peaks can be created in the field of a few kHz of frequency. This is due to contact between the micro-unevenness of the surfaces.
Unbalanced rotor	n/60	Radial	The most common cause of rotor vibration is the presence of an unbalanced rotating mass. This is when the rotor axis of rotation does not coincide with the geometric axis, thereby creating major vibrations at the rotation frequency.
Misalignment	n/60	Radial - Axial	Another common cause of vibration is the imperfect axial alignment of the rotor supports. Rotor supports that are not perfectly coaxial in nature generate vibrations that increase in magnitude according to the degree to which the supports are misaligned and as the speed increases. The generated vibrations reflect the rotor rotation frequency and its subsequent harmonics.
Excessive play	0.5 x n/60	Radial - Axial	When there is excessive movement between two components (e.g. a bearing and its journal) major vibrations will be generated at the shaft rotation frequency and sub-harmonics (0.5 x n/60).