Hydrodynamic plain journal bearings

i **Calculation without errors.**

ii **Project information**

? **Calculations section**

1.0 Calculation Units, Units Conversion

1.1 Calculation units: SI Units (N, mm, kW...)

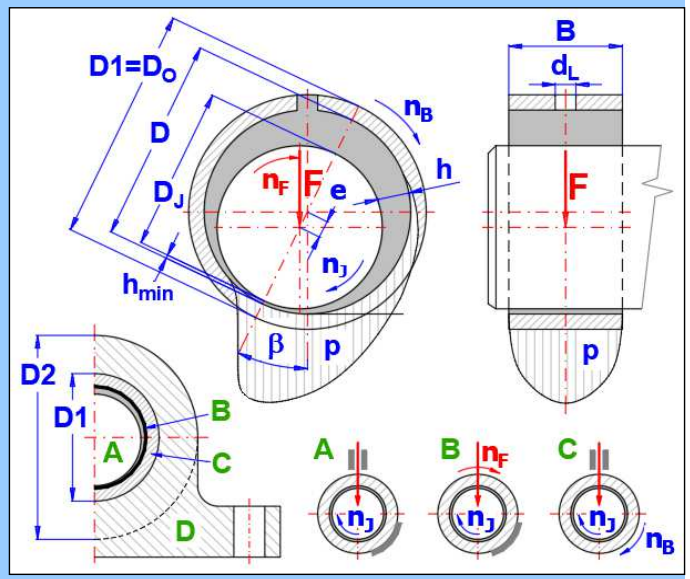
1.2 **Units conversion**

Length	1	µm	3.93701E-05	inch	Speed	1	m/s	3.280839895	ft/s
Area	1	m²	1550.0031	inch²	Acceleration	1	m/s²	3.280839895	ft/s²
Density	1	kg/m³	0.062427961	lb/ft³	Revolutions	1	/min	0.016666667	/s
Mass	1	kg	2.204624	lb	Force	1	N	0.224809	lbf
Kin.viscosity	1	mm²/s	1	cSt	Moment	1	Nm	0.737561	lbf·ft
Dyn.viscosity	1	µrein	6.89475729	cPoise	Power	1	HP	2545.819362	Btu/h
Temperature	20	°C	68	°F	Energy	1	kWh	3599997.12	J
Specific heat capacity	1	J/kg/°K	0.000238846	BTU/lb/°F	Pressure	1	MPa	145.037	psi
Flow rate	1	m³/s	35.31	ft³/s	Roughness	1	Ra [µm]	4 (3.8-14.5)	Rz [µm]

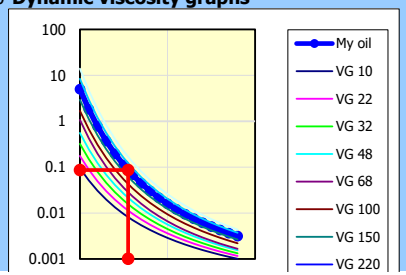
2.0 Radial plain bearing design / check (ISO 7902, DIN 31562...)

2.1 **Basic input data**

2.2	Bearing force (nominal load)	F	36000		[N]
2.3	Rotational speed of the shaft, Angular velocity	nJ, ωJ	300	31.42	[/min],[rad/s]
2.4	Rotational speed of the bearing, Angular velocity	nB, ωB	0	0.00	[/min],[rad/s]
2.5	Rotational speed of the force vector, Angular velocity	nF, ωF	0	0.00	[/min],[rad/s]
2.6	Rotational speed, Hydrodynamic angular velocity	n, ωH	300	31.42	[/min],[rad/s]
2.7	Bearing width ratio, relative bearing width	B/D	0.5	0.2-1.5	[~]
2.8	Level of accuracy, manufacturing, stiffness...		High level		
2.9	**Material selection (shaft, bearing, housing)**				
2.10	***A. Shaft material***		1. Low carbon steel C<0.4%		
2.11	Linear heat expansion coefficient	αLJ	11.7		[10^{-6} K]
2.12	Poisson number	νJ	0.3		[~]
2.13	Modulus of elasticity in tension (Young modulus)	EJ	210000		[MPa]
2.14	***B. Material of the bearing sliding layer***		Cu-Sn alloys (7 MPa) *		
2.15	Maximum permissible specific bearing load	plim', plim'.max	7	23 (25)	[MPa]
2.16	***C. Bearing material***		1. Low carbon steel C<0.4%		
2.17	Linear heat expansion coefficient	αLB	11.7		[10^{-6} K]
2.18	Poisson number	νB	0.3		[~]
2.19	Modulus of elasticity in tension (Young modulus)	EB	210000		[MPa]
2.20	***D. Housing (machine) material***		2. Grey cast iron		
2.21	Linear heat expansion coefficient	αLH	10.5		[10^{-6} K]
2.22	Poisson number	νH	0.25		[~]
2.23	Modulus of elasticity in tension (Young modulus)	EH	110000		[MPa]
2.24	**Automatic design**				
2.25	Start the "Automatic design"				
2.26	**Lubricant selection (definition)**				
2.27	ISO VG (Viscosity grade)		VG 220 (SAE 50, AGMA 5		
2.28	ISO VI (Viscosity index)		03. ISO VI = 95		
2.29	Temperature at point 1,2	T1,T2	20.0	50.0	[°C]
2.30	Dynamic viscosity at point 1,2	η1, η2	0.77625	0.111443	[Pa.s]
2.31	Density for T=20C	Rho20	900		[kg/m³]



2.120 **Dynamic viscosity graphs**



2.121 **User values**

Tx	55	[°C]
Rhox	877.8775	[kg/m³]
ηx	0.086547	[Pa.s]
νx	9.86E-05	[mm²/s]
VI	94	[~]

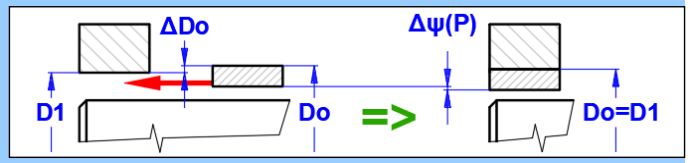
Graph

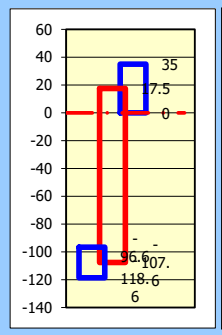
►x...T [°C]

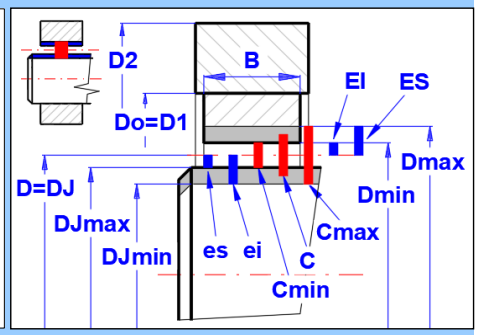
2.32	Thermal expansion coefficient	βL	0.72	0.72	[10^{-3} K]
2.33	Specific heat capacity of the lubricant	cp1, cp2	1806.174	1943.814	[J/kg/°K]
2.34	**Design of dimensions**				
2.35	Nominal bearing diameter proposal	Dprop	101.4		[mm]
2.36	Nominal bearing diameter (inside diameter)	D	105	105	[mm]
2.37	Bearing outside diameter	Do (=D1)	110	110	[mm]
2.38	Housing outside diameter	D2	195	195	[mm]
2.39	Nominal bearing width	B	60	60	[mm]
2.40	Bearing width ratio, relative bearing width	B/D	0.571	0.2-1.7	[~]
2.41	Bearing weight	m	0.3977		[kg]
2.42	**Bearing seating in the bearing housing by press fitting**				
2.43	Using a press-fit coupling for a bearing		Not used		
2.44	Selection of fit		ISO: H7 / r6 *		
2.45	Mean value of the interference	ΔDo	0.0475	0.0475	[mm]
2.46	Pres fitt change of the relative bearing clearence	Δψ'(P)	-0.000383		[~]
2.47	**Relative bearing clearence ψ' and tolerances selection**				
2.48	What procedure is used to determine ψ'		B. ψ' = f (v , D)		
2.49	***A. ψ' proposal - ISO 7902-3, Tolerances ISO 12129 (25<D<1250 mm)***				
2.50	Relative bearing clearence	ψ'	0.00132	0.00132	[~]
2.51	Tolerance zone Bearing / Shaft	ES-EI, es-ei	35.00	22.00	[µm]
2.52	***B. ψ' proposal - formula, Tolerances ISO 286***				
2.53	Relative bearing clearence	ψ'	0.001192	0.001192	[~]
2.54	Tolerance grade Bearing / Shaft	ITB, ITJ	IT7	IT6	
2.55	Selection of fit		Not selected		
2.56	Tolerance zone Bearing / Shaft	ES-EI, es-ei	35.00	22.00	[µm]
2.57	**Bore and shaft dimensions**				
2.58	Bore of the bearing Dmin, Dmax	Dmin, Dmax	105	105.035	[mm]
2.59	Diameter of the shaft DJmin, Djmax	DJmin, DJmax	104.8814	104.9034	[mm]
2.60	Mean relative bearing clearance	ψ'	0.00119		[~]
2.61	Mean relative bearing clearance	ψmin, ψmax	0.00092	0.00146	[~]
2.62	Nominal bearing clearance	C	0.125124999		[mm]
2.63	Nominal bearing clearance	Cmin, Cmax	0.096625	0.153625	[mm]
2.64	**Bearing mounting and bearing geometry selection**				
2.65	Bearing mounting method		A. Cylindrical housing		
2.66	Area of heat-emitting surface (bearing housing)	A	0.086519	0.086519	[m²]
2.67	Outer heat transmission coeff, Air velocity	kA	20	1.2 [m/s]	[W/m²/K]
2.68	Angular span of bearing segment	Ω	360		[°]
2.69	Include friction in the unloaded part of the bearing?		Yes		
2.70	Lubricant hole type, dimensions and location		A		
2.71	Lubrication hole diameter	dL	7	7	[mm]
2.72	Angles of leading edge and trailing edge	φA,φE	0	60	[°]
2.73	Lubricant feed pressure	pen	0.15	~0.05-0.2	[MPa]
2.74	**Permissible operational parameters**				
2.75	Maximum permissible lubricant film pressure	plim'	7		[MPa]
2.76	Minimum permissible lubricant film thickness	hlim	0.0052	Table	[mm]
2.77	Maximum permissible bearing temperature (convection)	TlimC	90	90 (110)	[°C]
2.78	Maximum permissible bearing temperature (pressure)	TlimP	100	100 (115)	[°C]
2.79	**Limit operating conditions**				
2.80	Sliding speed	v	1.649		[m/s]

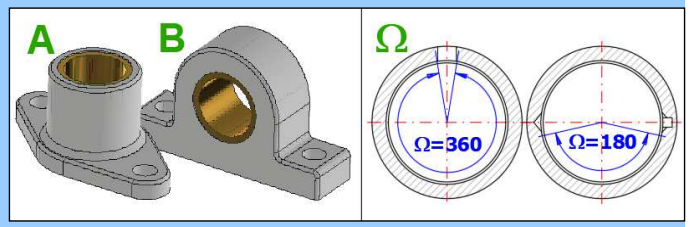
2.122 **Table of diameters and widths**

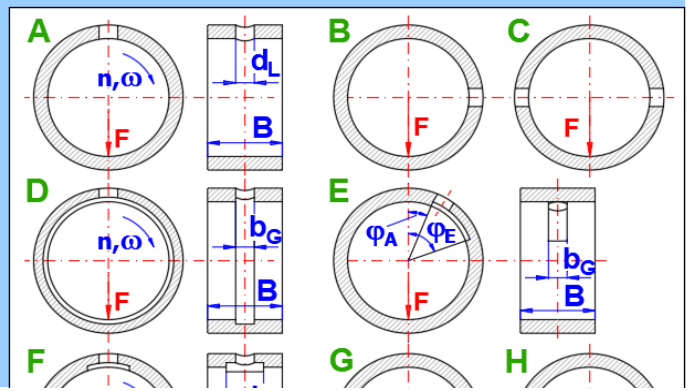
D=2	Do=3	(B=3, 5)
D=3	Do=4	(B=3, 5, 6)
D=4	Do=5	(B=3, 4, 6)
D=5	Do=6	(B=5, 8, 10)
D=6	Do=7	(B=4, 6, 8, 10)
D=8	Do=9	(B=6, 8, 10, 12)
D=10	Do=11	(B=8, 10, 12)
D=2	Do=3.5	(B=3, 5)
D=3	Do=4.5	(B=3, 5, 6)
D=4	Do=5.5	(B=3, 4, 6, 10)
D=3	Do=5	(B=3, 4, 5, 6)



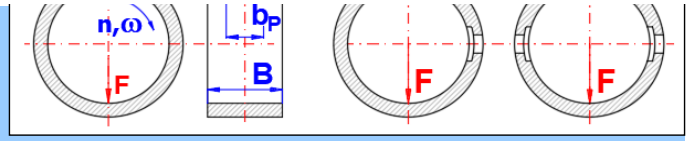








2.81	Specific bearing load	p'	5.7143	<7(25)	[MPa]
2.82	Limit speed - Mixed-film lubrication	nmA,nmB	175	63	[/min]
2.83	Limit speed - formation of turbulence	ntA,ntB	2590	7128	[/min]
2.84	Maximum bearing force	Fmax	62664.46	172485.2	[N]



2.85 Calculation of bearing thermal and functional characteristics

2.86 Bearing clearance used for calculation: Nominal C (0.12512 mm)

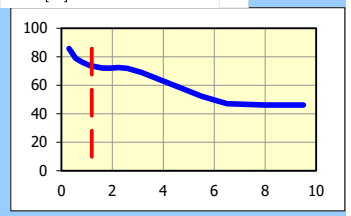
2.87 Bearing cooling method

		Convection cooling			Pressure oil cooling			
2.88	Lubricant temperature at bearing entrance				Ten	40		[°C]
2.89	Assumed initial lubricant temperature at bearing exit				Tex,0	61.11		[°C]
2.90	Ambient temperature	Tamb	20	20-40				[°C]
2.91	Assumed initial bearing temperature (TB,0=Teff)	TB,0	73.42	< 90	Teff	50.55257	< 100	[°C]
2.92	Reynolds number	Re	2.309859	<1196.4	Re	0.839179	<1196.4	[~]
2.93	Density of lubricant	Rho(T)	866.6632		Rho(T)	880.6281		[kg/m³]
2.94	Dynamic viscosity of the lubricant	η(T)	0.038716	>0.013	η(T)	0.108283	>0.0132	[Pa.s]
2.95	Thermal change of the relative bearing clearence	Δψ(T)	0		Δψ(T)	0		[~]
2.96	Pres fitt change of the relative bearing clearence	Δψ(P)	0		Δψ(P)	0		[~]
2.97	Effective bearing clearance (relative / nominal)	ψeff/C	0.001192	0.125125	ψeff/C	0.001192	0.125125	[~]/[mm]
2.98	Sommerfeld number	So	6.671653	1-15	So	2.385397	1-15	[~]
2.99	Relative eccentricity [ε = 2e/(D — DJ)]	ε	0.909871	0.7-0.96	ε	0.81521	0.7-0.96	[~]
2.100	Minimum lubricant film thickness	hmin	0.005639	>0.0052	hmin	0.011561	>0.0052	[mm]
2.101	Attitude angle	β	22.6376		β	32.0271		[°]
2.102	Specific coefficient of friction	f '/ψeff	1.306526	(L + U)	f '/ψeff	2.538453	(L + U)	[~]
2.103	Coefficient of friction	f '	0.001557		f '	0.003025		[~]
2.104	Heat flow rate due to frictional power	Pth,f	92.44524		Pth,f	179.6121		[W]
2.105	Frictional moment	Mf	2.942623		Mf	5.71723		[Nm]
2.106	Calculated bearing temperature	TB,1	**73.42**	< 90				[°C]
2.107	Improved assumption of the bearing temperature	TB,2	**73.42**					[°C]
2.108	Lubricant flow rate parameter due to hydrodynamic pressure				Q3*	0.105335		[~]
2.109	Lubricant flow rate parameter due to feed pressure				Qp*	0.147444		[~]
2.110	Lubricant flow rate due to hydrodynamic pressure				Q3	0.273903	litre/min	
2.111	Lubricant flow rate due to feed pressure				Qp	0.024007	[litre/min]	
2.112	Lubricant flow rate				Q	0.29791	[litre/min]	
2.113	Specific heat capacity of the lubricant				cp	1946.349		[J/kg/°K)]
2.114	Heat flow rate in the lubricant				Pth,L	179.6121		[W]
2.115	Calculated lubricant temperature at bearing exit				Tex,1	**61.11**	< ~111	[°C]
2.116	Improved assumption of the lubricant temperature at bearing exit				Tex,2	**61.11**		[°C]

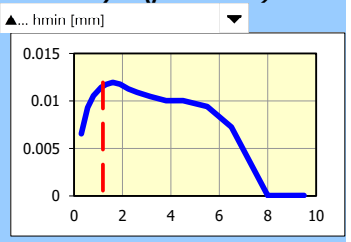
Iteration

2.123 Parameter analysis

2.124 ***Analysis (convection)***



2.125 ***Analysis (pressure oil)***



2.126 Optimization

2.127 Viscosity

2.128 VG 220 (SAE 50, AGMA 5)

2.129 Bearing clearance

2.130 ψ' = 0.001192

2.131 Diameter D

2.132 D = 105 [mm]

2.133 Bearing width B

2.134 B = 60 [mm] (B/D=0.571)

? Additions section

3.0 Lubricant selection, comparsion and specification

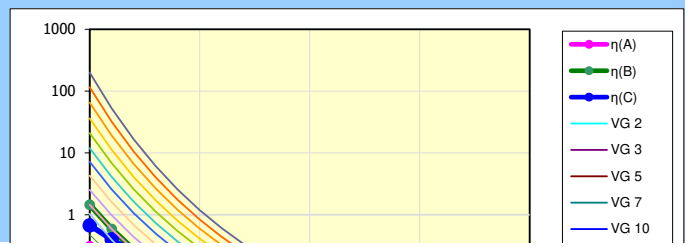
3.1 **A. Lubricant selection from lubricants table**

3.2 01. Bearing Oil SAE 10; 10-W (ISO VG--32, VI--166)

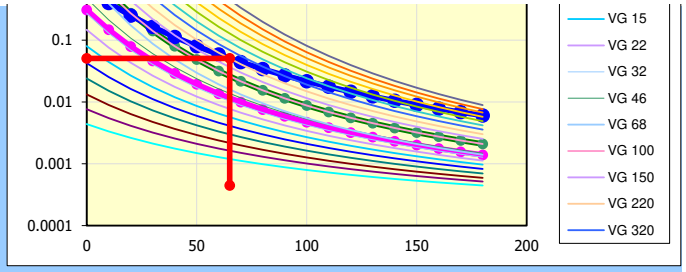
3.3 **B. Lubricant selection from ISO 3448 table**

3.4	ISO VG (Viscosity grade)	VG	11. ISO VG 100	[VG]
3.5	ISO VI (Viscosity index)	VI	03. ISO VI = 95	[VI]
3.6	ISO VR (Position in range)	VR	0 (0 - 1)	[~]

3.7 **C. Lubricant definition**



3.8	Temperature for density definition	T	20.0		[°C]
3.9	Lubricant density at T	Rho	900.00		[kg/m³]
3.10	Thermal expansion coefficient	βL	0.720	0.720	[10^{-3}/°K]
3.11	Specific thermal capacity	cp	1806.174		[J/kg/°K]
3.12	Specific heat by volume of the lubricant	Rho*cp	1625556.6		[J/m³/°K]
3.13	***Lubricant Viscosity definition***				
3.14	Temperature at point 1,2	T1,T2	20.0	50.0	[°C]
3.15	Kinematic viscosity at point 1,2	v1, v2	277.7778	90.80889	[mm²/s]
3.16	Dynamic viscosity at point 1,2	η1, η2	0.25	0.08	[Pa.s]
3.17	Viscosity index		147		[VI]
3.18	Transfer definition into paragraph [2.0]				



Graph: ►x...T [°C] ; ▲y...η [Pa.s]

3.19 **Comparison table**

ISO 3348	AGMA 9005-D94	SAE J300	SAE J306
Industrial oils	Gear oils	Engine oils	Industrial oils
680	8		140
460	7		
320	6	60	90
220	5	50	
150	4	40	
			85W
100	3	30	80W
68	2	20	
			75W
46	1		
32	0	15W	
22		10W	
15		5W, 10W	

3.20 **Viscosity, density and thermal capacity table**

	T	η(A)	η(B)	η(C)	v(C)	Rho(C)	cp(C)
	[°C]	[Pa.s]	[Pa.s]	[Pa.s]	[mm²/s]	[kg/m³]	[J/kg/°K]
Ts	0	0.308278	1.451032	0.673604	737.6714	913.1494	1688.191
	10	0.147648	0.588371	0.39906	440.2075	906.527	1747.495
	20	0.078914	0.2727	0.25	277.7778	900	1806.174
	30	0.04612	0.14104	0.164334	183.9081	893.5663	1864.251
	40	0.029	0.079847	0.112608	126.9223	887.224	1921.749
	50	0.019367	0.048718	0.08	90.80889	880.971	1978.686
	60	0.013594	0.031635	0.058651	67.04408	874.8056	2035.085
	70	0.009946	0.021639	0.044199	50.87749	868.7259	2090.963
	80	0.007534	0.015463	0.034123	39.55192	862.7301	2146.339
	90	0.005877	0.011465	0.026911	31.40798	856.8165	2201.232
	100	0.0047	0.008771	0.021627	25.41396	850.9834	2255.657
	110	0.003839	0.006891	0.017673	20.90946	845.2292	2309.632
	120	0.003194	0.005539	0.014659	17.4604	839.5522	2363.172
	130	0.0027	0.004542	0.012321	14.77459	833.9511	2416.293
	140	0.002314	0.003788	0.01048	12.65104	828.4242	2469.008
	150	0.002008	0.003207	0.00901	10.94868	822.97	2521.333
	160	0.001761	0.002751	0.007822	9.566746	817.5872	2573.28
	170	0.001559	0.002388	0.006849	8.432021	812.2744	2624.863
	180	0.001392	0.002094	0.006045	7.490495	807.0301	2676.094

3.21 **User values**

Tx	65	0.011573	0.026009	0.050751	58.21673	871.7551	2063.088

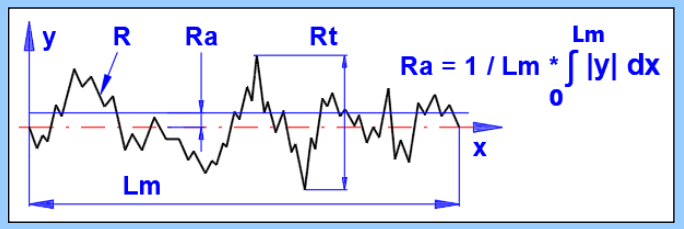
4.0 Roughness tables

Conversion chart						
ISO 468	ASA B.46.1	BS 1134	Germany	JIS		
Ra µm	AA µin	CLA µin	Rt µm	Rz µm	Ry µm	ISO 1302
0.006	0.25					N01
0.012	0.5			0.05	0.05	N0
0.025	1		0.25	0.1	0.1	N1
0.05	2		0.5	0.2	0.2	N2
0.1	4	4	0.8	0.4	0.4	N3
0.2	8	8	1.6	0.8	0.8	N4
0.4	16	16	2.5	1.6	1.6	N5
0.8	32	32	4	3.2	3.2	N6

ISO 468			
Ra µm	Rz µm	Ra µm	Rz µm
0.006	**0.025**	2.0	8.0
0.008	0.032	2.5	10.0
0.010	0.040	**3.2**	**12.5**
0.012	**0.050**	4.0	16.0
0.016	0.063	5.0	20
0.020	0.080	**6.3**	**25**
0.025	**0.100**	8.0	32
0.032	0.125	10.0	40
0.040	0.160	**12.5**	**50**

DIN 4763-60	
Ra µm	Rz µm
0.01	0.04
0.016	0.063
0.025	0.1
0.04	0.16
0.063	0.25
0.1	0.4
0.16	0.63
0.25	1
0.4	1.6

1.6	63	63	8	6.3	6.3	N7
3.2	125	125	16	12.5	12.5	N8
6.3	250	250	25	25	25	N9
12.5	500	500	50	50	50	N10
25	1000	1000	100	100	100	N11
50	2000		200	200	200	N12
100	4000			400	400	N13
200	8000					N14



0.050	**0.20**	16.0	63
0.063	0.25	20	80
0.080	0.32	**25**	**100**
0.100	**0.40**	32	125
0.125	0.50	40	160
0.160	0.63	**50**	**200**
0.20	**0.80**	63	250
0.25	1.00	80	320
0.32	1.25	**100**	**400**
0.40	**1.60**	125	500
0.50	2.0	160	630
0.63	2.5	**200**	**800**
0.80	**3.2**	250	1000
1.00	4.0	320	1250
1.25	5.0	**400**	**1600**
1.60	**6.3**		

0.63	2.5
1	4
1.6	6.3
2.5	10
4	16
6.3	25
10	40
16	63
25	100
40	160
63	250
100	400
160	630
250	1000

5.0 System of limits and fits ISO 286 (ANSI B4.1) a ISO 12129

5.1 Transfer of diameters from paragraph 2.0

5.2 Nominal dimension — D: 105 (<3150) [mm]

5.3 **A. Calculation of tolerance sizes ISO 286 (3 < D < 3150 mm)**

5.4 ***Hole tolerance zones*** — H 7

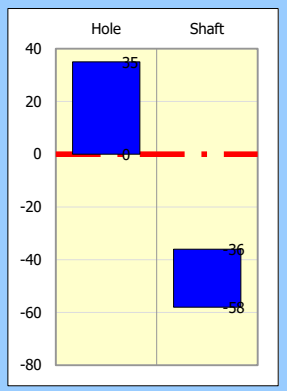
5.5	Upper deviation	ES	35	[µm]	Dmax: 105.03500	[mm]
5.6	Lower deviation	EI	0	[µm]	Dmin: 105.00000	[mm]
5.7	Tolerance zone	ES-EI	35	[µm]		

5.8 ***Shaft tolerance zones*** — f 6

5.9	Upper deviation	es	-36	[µm]	DJmax: 104.96400	[mm]
5.10	Lower deviation	ei	-58	[µm]	DJmin: 104.94200	[mm]
5.11	Tolerance zone	es-ei	22	[µm]		

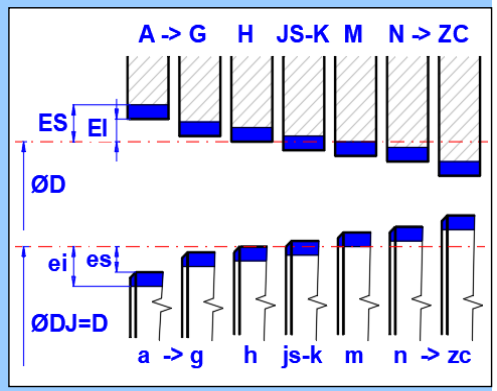
5.12 Minimum / Maximum clearance (+) / Minimum / Maximum interference (-)

5.13	Mean clearance	C: 0.06450		[mm]
5.14	Min / Max clearance	C min/max: 0.03600	0.09300	[mm]
5.15	Mean relative clearance	ψ': 0.00061		[~]
5.16	Min / Max relative clearance	ψ' min/max: 0.00034	0.00089	[~]



5.31 **System of fit, Type of fit**

5.32 ISO - øD | ISO - ød | ANSI - øD | ANSI - ød



5.17 **B. Calculation of tolerance sizes ISO 12129 (25 < D < 1250 mm)**

5.18 Mean relative clearance — ψ' 0.00132 H7\?6

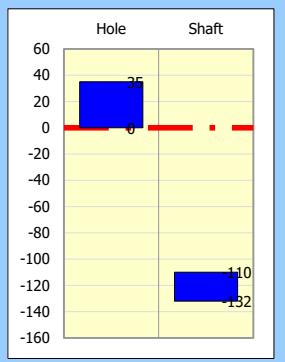
5.19	Mean relative clearance	ψ': 0.00132		[~]
5.20	Min / Max relative clearance	ψ' min/max: 0.00105	0.00159	[~]
5.21	Mean clearance	C: 0.13850		[mm]
5.22	Min / Max clearance	C min/max: 0.11000	0.16700	[mm]

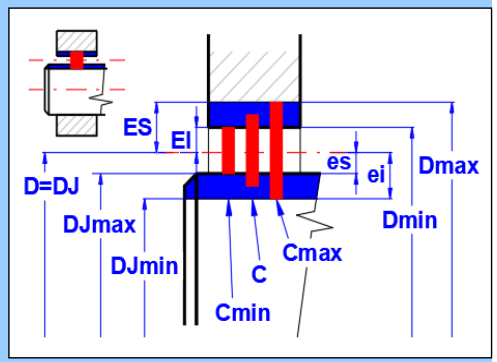
5.23 ***Hole tolerance zones***

5.24	Upper deviation	ES	35	[µm]	Dmax: 105.03500	[mm]
5.25	Lower deviation	EI	0	[µm]	Dmin: 105.00000	[mm]
5.26	Tolerance zone	ES-EI	35	[µm]		

5.27 ***Shaft tolerance zones***

5.28	Upper deviation	es	-110	[µm]	DJmax: 104.89000	[mm]
5.29	Lower deviation	ei	-132	[µm]	DJmin: 104.86800	[mm]
5.30	Tolerance zone	es-ei	22	[µm]		



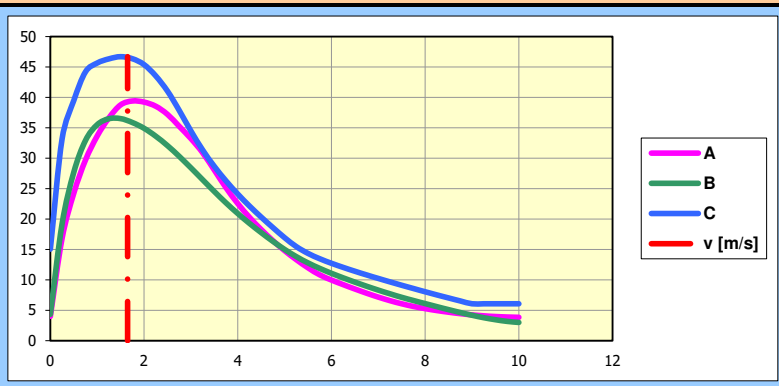


6.0 Maximum permissible specific bearing load - graphs

6.1 Selection of sliding layer material

6.2	A. Bearing sliding layer material	1. Bronze - Cu-Sn5-Pb5-Zn5
6.3	B. Bearing sliding layer material	2. Bronze - Cu-Sn10-Pb10
6.4	C. Bearing sliding layer material	3. Lead composition - Pb-Sn6-Sb6

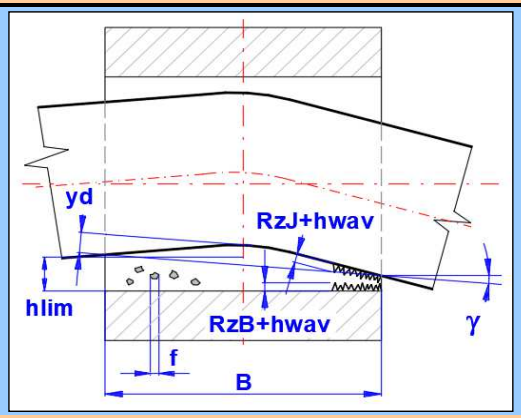
6.5	Sliding speed	v	1.649	1.649	[m/s]
6.6	Maximum permissible lubricant film pressure	plim'A	39.245		[MPa]
6.7	Maximum permissible lubricant film pressure	plim'B	36.186		[MPa]
6.8	Maximum permissible lubricant film pressure	plim'C	46.559		[MPa]
6.9	Maximum sliding speed	vmaxA	>10		[m/s]
6.10	Maximum sliding speed	vmaxB	>10		[m/s]
6.11	Maximum sliding speed	vmaxC	9		[m/s]



Graph: ►x...v [m/s]; ▲y...plim [MPa]

7.0 Minimum permissible lubricant film thickness hlim ISO 7902-3 (DIN 31652-3)

7.1	Nominal bearing diameter (inside diameter)	D	105		[mm]
7.2	Nominal bearing width	B	60		[mm]
7.3	Average peak-to-valley height of bearing sliding surface	RzB	3.20	3.20	[µm]
7.4	Average peak-to-valley height of shaft mating surface	RzJ	3.20	3.20	[µm]
7.5	Minimum particle size that will pass through the filter	fo	1.00	1.00	[µm]
7.6	Angle of misalignment of the shaft	γ	0.001	0.001	[°]
7.7	Amount of misalignment of the shaft	ya	0.52		[µm]
7.8	Amount of deflection on bearing width	yd	0.50	0.50	[µm]
7.9	Effective waviness of sliding surface	hwav,eff	0.50	0.50	[µm]
7.10	Minimum permissible lubricant film thickness	hlim	0.00867		[mm]



8.0 Calculation of bearing clearance from min/max diameters

8.1	Nominal bearing diameter (inside diameter)	D	105	105	[mm]
8.2	Bore of the bearing Dmin, Dmax	Dmin, Dmax	105	105	[mm]
8.3	Diameter of the shaft DJmin, Djmax	DJmin, DJmax	105	105	[mm]
8.4	Tolerance zone Bearing / Shaft	ES-EI, es-ei	0.00	0.00	[µm]
8.5	Mean relative bearing clearance	ψ'	0.00000		[~]
8.6	Mean relative bearing clearance	ψmin, ψmax	0.00000	0.00000	[~]
8.7	Nominal bearing clearance	C	0		[mm]
8.8	Nominal bearing clearance	Cmin, Cmax	0	0	[mm]
8.9	Transfer definition into paragraph [2.0]