Plain thrust pad bearings and Plain tilting pad thrust bearings (ISO12131, ISO12130)

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	39.37007874	µinch	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	1	J/kg/°K	Pressure	1	MPa	0.145037	kpsi
Flow rate	1	litre/min	0.016666667	litre/s	Roughness	3.2	Rz [µm]	128	Rz [µin]

2.0 Axial plain bearing design / check (ISO 12131, ISO 12130, DIN 31654...)

2.1 **Basic input data**

2.2 **Selection of the bearing type**: B. Plain tilting pad thrust bearings

2.3	Bearing force (load) at nominal rotational frequency	F	20000		[N]
2.4	Bearing force (load) at standstill	Fst	0	= 0	[N]
2.5	Speed of thrust collar, Angular velocity	n, ωN	400	41.89	[/min],[rad/s]
2.6	Material of the bearing sliding layer		Cu-Pb alloys (7 MPa) *		
2.7	Maximum permissible specific bearing load	plim', plim'.max	7	13 (20)	[MPa]
2.8	Diameter ratio (Di / Do)	DR	0.6	0.4-0.8	[~]
2.9	Bearing pad ratio (B / L)	BL	1	0.8-1.5	[~]
2.10	Level of accuracy		Medium level		

2.11 **Automatic design**

2.12 Start the "Automatic design"

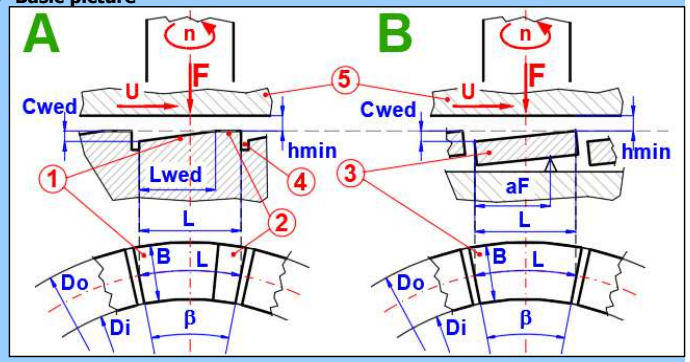
2.13 **Lubricant selection (definition)**

2.14	ISO VG (Viscosity grade)		VG 220 (SAE 50, AGMA 5		
2.15	ISO VI (Viscosity index)		03. ISO VI = 95		
2.16	Temperature at point 1,2	T1,T2	20.0	50.0	[°C]
2.17	Dynamic viscosity at point 1,2	η1, η2	0.77625	0.111443	[Pa.s]
2.18	Density for T=20C	Rho20	900		[kg/m³]
2.19	Thermal expansion coefficient	βL	0.72	0.72	[10^{-3} K]
2.20	Specific heat capacity of the lubricant	cp1, cp2	1806.174	1943.814	[J/kg/°K]

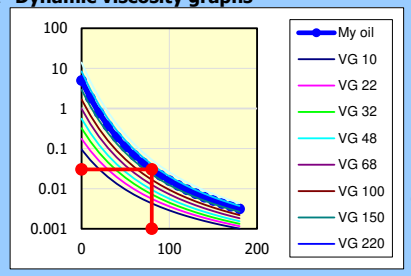
2.21 **Design of dimensions**

2.22	Inside diameter of friction segments - proposal	Diprop	108.25		[mm]
2.23	Inside diameter of friction segments	Di	110	110	[mm]
2.24	Outside diameter of friction segments	Do	190	190	[mm]
2.25	Length of segment in circumferential direction	L	40	40	[mm]
2.26	Number of segments	Z	9	9 (11)	[~]
2.27	Mean sliding diameter	D	150		[mm]
2.28	Width of one segment	B	40		[mm]

2.80 **Basic picture**



2.81 **Dynamic viscosity graphs**



2.82 **User values**

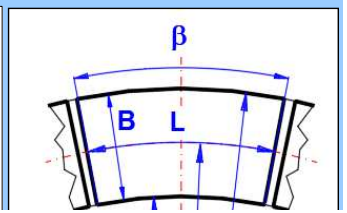
Tx	80	[°C]
Rhox	862.7301	[kg/m³]
ηx	0.030269	[Pa.s]
vx	3.51E-05	[mm²/s]
VI	94	[~]

Graph

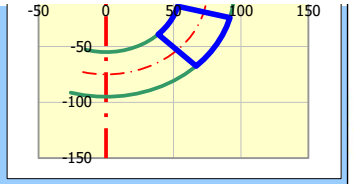
►x...T [°C]

▲y...η [Pa.s]

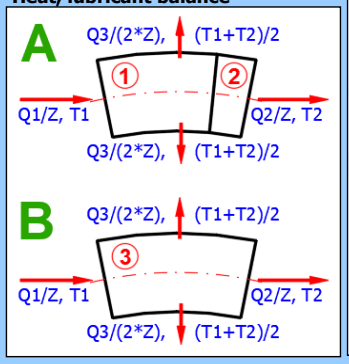
2.83 **Inside and outside diameters**

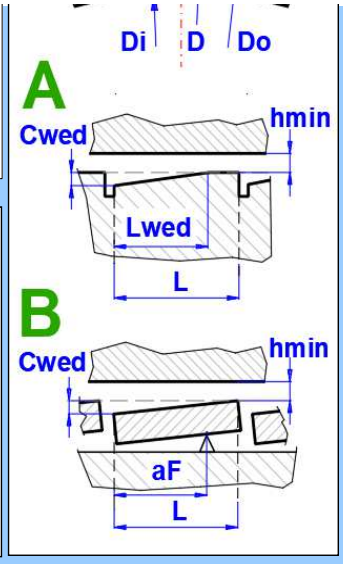


2.29	Angle of one segment	β	30.56		[°]
2.30	Diameter ratio DR = Di / Do	DR	0.58		[~]
2.31	Segment dimensions ratio BL = B / L	BL	1.00		[~]
2.32	**Friction segment parameters**				
2.33	Wedge depth	Cwed	0.035	0.035	[mm]
2.34	Wedge length	Lwed	30	30.000	[mm]
2.35	Relative distance of supporting point aF*=aF/L	aF*	0.64	0.64	[~]
2.36	**Bearing mounting**				
2.37	Bearing mounting method		A. Cylindrical housing		
2.38	Area of heat-emitting surface (bearing housing)	A	0.1575	0.1575	[m²]
2.39	Outer heat transmission coeff, Air velocity	kA	20	1.2 [m/s]	[W/m²/K]
2.40	**Permissible operational parameters**				
2.41	Roughness of thrust collar	Rz	3.2	3.2	[µm]
2.42	Minimum permissible lubricant film thickness	hlim,tr	0.00632		[mm]
2.43	Minimum permissible lubricant film thickness	hlim	0.00791	0.00791	[mm]
2.44	Maximum permissible bearing temperature (convection)	TlimC	90	90 (110)	[°C]
2.45	Maximum permissible bearing temperature (pressure)	TlimP	100	100 (115)	[°C]
2.46	Sliding velocity relative to mean diameter of bearing ring	U	3.142		[m/s]
2.47	Specific bearing load	p'	1.39	<7(20)	[MPa]



2.84 **Heat, lubricant balance**



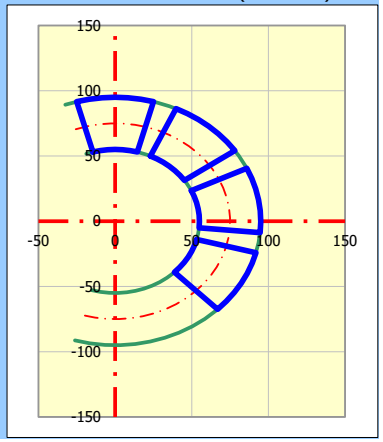


2.48 **Calculation of thermal and functional characteristics** — **Plain tilting pad thrust bearings**

			Convection cooling				Pressure oil cooling		
2.49	Bearing cooling method								
2.50	Lubricant temperature at bearing entrance					Ten	40.00		[°C]
2.51	Assumed lubricant temperature at bearing exit					Tex	60.00	~50-70	[°C]
2.52	Ambient temperature	Tamb	20.00	20-40	[°C]	ΔT	20		[°C]
2.53	Assumed initial bearing temperature (TB,0=Teff)	TB,0	81.57	< 90	[°C]				
2.54	Effective lubricant film temperature					Teff,0	56.15		[°C]
2.55	Reynolds number	Re	1.219078	< 600	[~]	Re	0.733859	< 600	[~]
2.56	Density of lubricant	Rho(T)	861.7987		[kg/m³]	Rho(T)	877.167		[kg/m³]
2.57	Dynamic viscosity of the lubricant	η(T)	0.028624	>0.0129	[Pa.s]	η(T)	0.081833	>0.0132	[Pa.s]
2.58	Characteristic value of load carrying capacity	F*	0.064142		[~]	F*	0.064142		[~]
2.59	Relative minimum lubricant film thickness	hmin/Cwed	0.426275	0.2-2	[~]	ımin/Cwed	0.426275	0.2<2	[~]
2.60	Minimum lubricant film thickness	hmin	0.012889	>0.0079	[mm]	hmin	0.021793	>0.0079	[mm]
2.61	Characteristic value of friction	f*	0.614418		[~]	f*	0.614418		[~]
2.62	Heat transfer coefficient related to the product B * L * Z	k	218.75		[W/m²/K]	k	218.75		[W/m²/K]
2.63	Heat flow rate arising from the friction power	Pth,f	193.9324		[W]	Pth,f	327.9033		[W]
2.64	Frictional moment	Mf	4.630135		[Nm]	Mf	7.82869		[Nm]
2.65	Calculated bearing temperature	TB,1	**81.57**	< 90	[°C]				
2.66	Improved assumption of the bearing temperature	TB,2	**81.57**		[°C]				
2.67	Relative lubricant flow rate Q0 = B * hmin * U * Z					Q0	1.478806	litre/min	
2.68	Lubricant flow rate at the inlet of the clearance gap (circumferential direction)					Q1	1.883926	[litre/min]	
2.69	Lubricant flow rate at the outlet of the clearance gap (circumferential direction)					Q2	1.095506	[litre/min]	
2.70	Lubricant flow rate at the sides (perpendicular to circumferential direction)					Q3	0.78842	[litre/min]	
2.71	Total amount of lubricant to be fed to the bearing					Q	0.56868	[litre/min]	
2.72	Mixing factor		**Iteration**			M	0.5	0.4 - 0.6	[~]
2.73	Lubricant temperature at the inlet of the clearance gap					T1	52.33		[°C]
2.74	Lubricant temperature at the outlet of the clearance gap					TB=T2	**59.96**	< 100	[°C]
2.75	Effective lubricant film temperature					Teff,1	**56.14**		[°C]
2.76	Improved assumption of the effective lubricant film temperature					Teff,2	**56.15**		[°C]

2.85 **Optimization**

2.86	Viscosity	
2.87	VG 220 (SAE 50, AGMA 5)	
2.88	Ratio Di / Do	
2.89	DR = 0.58	(DRInp=0.6)
2.90	Ratio B / L	
2.91	BL = 1.00	(L=40 mm)
2.92	Diameter Di	
2.93	Di = 110 mm	
2.94	Diameter Do	
2.95	Do = 190 mm	
2.96	Number of segments Z	
2.97	Z = 9	(Zmax=11)



? **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

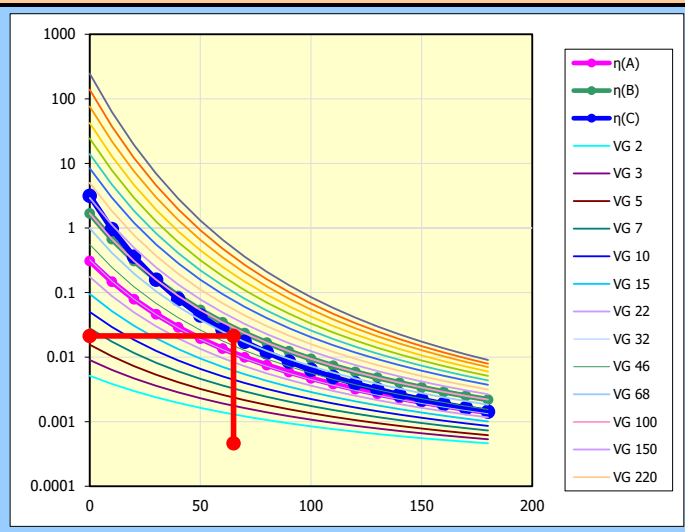
3.4	ISO VG (Viscosity grade)	VG	11. ISO VG 100	[VG]
3.5	ISO VI (Viscosity index)	VI	03. ISO VI = 95	[VI]
3.6	ISO VR (Position in range)	VR	0.5 (0 - 1)	[~]

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	400	50	[mm²/s]
3.16	Dynamic viscosity at point 1,2	η1, η2	0.36	0.044049	[Pa.s]
3.17	Viscosity index		0		[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**

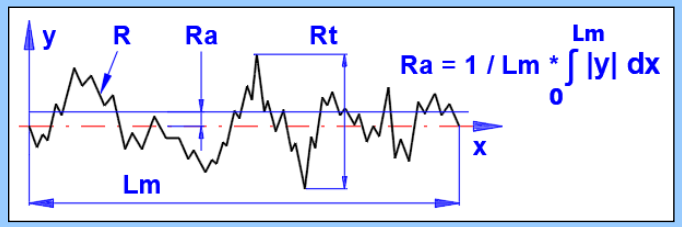
	T	η(A)	η(B)	η(C)	v(C)	Rho(C)	cp(C)
	[°C]	[Pa.s]	[Pa.s]	[Pa.s]	[mm²/s]	[kg/m³]	[J/kg/°K]
Ts	0	0.308278	1.681991	3.14682	3446.118	913.1494	1688.191
	10	0.147648	0.673535	0.962124	1061.33	906.527	1747.495
	20	0.078914	0.3087	0.36	400	900	1806.174
	30	0.04612	0.158075	0.158299	177.1543	893.5663	1864.251
	40	0.029	0.088701	0.079246	89.31894	887.224	1921.749
	50	0.019367	0.053695	0.044049	50	880.971	1978.686
	60	0.013594	0.034624	0.026652	30.46667	874.8056	2035.085
	70	0.009946	0.023538	0.017281	19.89182	868.7259	2090.963
	80	0.007534	0.016728	0.011857	13.74305	862.7301	2146.339
	90	0.005877	0.012343	0.008523	9.947707	856.8165	2201.232
	100	0.0047	0.009402	0.006369	7.48412	850.9834	2255.657
	110	0.003839	0.007358	0.004915	5.815341	845.2292	2309.632
	120	0.003194	0.005895	0.003898	4.643123	839.5522	2363.172
	130	0.0027	0.004819	0.003164	3.793669	833.9511	2416.293
	140	0.002314	0.004008	0.002619	3.161372	828.4242	2469.008
	150	0.002008	0.003385	0.002205	2.679656	822.97	2521.333
	160	0.001761	0.002897	0.001885	2.305167	817.5872	2573.28
	170	0.001559	0.002509	0.001632	2.008844	812.2744	2624.863
	180	0.001392	0.002196	0.001429	1.770704	807.0301	2676.094

3.21 **User values**

Tx	65	0.011573	0.028376	0.021294	24.42695	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
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



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**
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**		

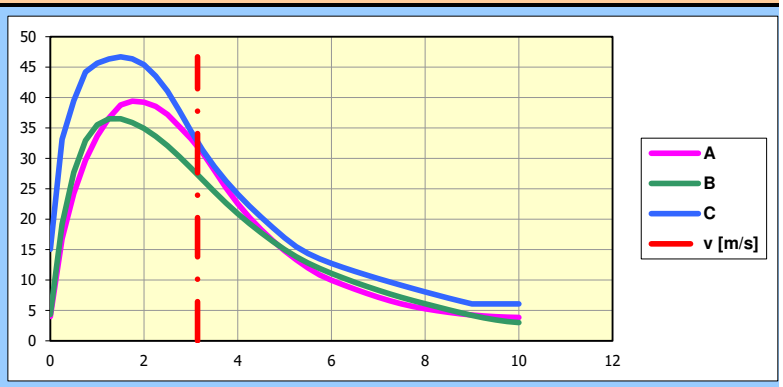
DIN 4763-60	
Ra µm	Rz µm
0.01	0.04
0.016	0.063
0.025	0.1
0.04	0.16
0.063	0.25
0.1	0.4
0.16	0.63
0.25	1
0.4	1.6
0.63	2.5
1	4
1.6	6.3
2.5	10
4	16
6.3	25
10	40
16	63
25	100
40	160
63	250
100	400
160	630
250	1000

5.0 Maximum permissible specific bearing load - graphs

5.1 **Selection of sliding layer material**

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

5.5	Sliding velocity relative to mean diameter of bearing ring	v	3.142	3.142	[m/s]
5.6	Maximum permissible specific bearing load	plim'A	31.962		[MPa]
5.7	Maximum permissible specific bearing load	plim'B	27.315		[MPa]
5.8	Maximum permissible specific bearing load	plim'C	32.663		[MPa]
5.9	Maximum sliding speed	vmaxA	>10		[m/s]
5.10	Maximum sliding speed	vmaxB	>10		[m/s]
5.11	Maximum sliding speed	vmaxC	9		[m/s]



Graph: ►x...v [m/s]; ▲y...plim [MPa]