

Tutorial: Calculation of paired angular contact bearings

A pair of angular contact ball bearings mounted back-to-back should be calculated for a load case radial load only, and a second load case tilting moment only. The bearings have a build in pretension which is further increased by mounting and temperature.



Bearing geometry

The bearing geometry for an angular contact bearing 7010C is provided as given in following table:

	Parameter	Value	Unit
Innerdiameter	d	50	mm
Outerdiameter	D	80	mm
Width	В	16	mm
Nominal contact angle	α	15	0
Dynamic load capacity	Cr	28.2	kN
Static load capacity	COr	20.2	kN
Fatigue limit	Cu	1.1	kN
Pretension	Fpre	4.2	kN
Tolerance		P4	
Tolerance shaft		k5	
Tolerance housing		H6	
Cage frequency at 60rpm	fc	0.435	Hz
Damage frequency inner	fip	10.733	Hz
ring at 60rpm			
Damage frequency outer	fep	8.267	Hz
ring at 60 rpm			
Damage frequency rolling element at 60 rpm	frp	7.319	Hz

This data is usually available for bearings and can be easily extracted from some manufacturers. To calculate the life of the bearing you should ask the manufacturer for additional data of inner geometry.

By selecting the tab corresponding to the page "Bearing geometry", a first geometrical input will be set. Now click on the drop-down list on the left in order to choose the desired type of bearing, for this case "Axial angular contact ball bearing". To proceed with the required input data, "Enter inner geometry" must be selected from the drop-down list on the upper right side of the page.

After introducing d, D und B, the user can automatically obtain the Pitch diameter, Dpw (Dpw = (50+80)/2 = 65mm), when clicking the button \bigstar .

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General	Bearing geometry	Bea	aring configuration			Mate	rial and Lubrication	Load	ing	Tra	ck rolle	r		
Angular c	Angular contact ball bearing					÷	Enter inner geometr	Enter inner geometry 🔹						
Inner diam	eter		d	50		mm	Dynamic load number	r			Cr	0		kN
Outer dian	neter		D	80		mm	Static load number				C0r	0		kN
Width			в	16		mm	Fatigue load limit				Cur	0		kN
Number of	rolling elements		Z	0			Bearing clearance	(User ir	nput	as ope	rating d	learan	ce 🔻
Diameter o	of rolling elements	Dw	0		mm		Axial clearance		F	Ра	0		mm	
Pitch diam	eter	Dpw	65		mm	*]							
Contact ar	ngle	ao	15		•	÷								
Conformity	y inner ring	fi	0.52]									
Conformity	y outer ring	fe	0.53]									
Shoulder d	liameter inner ring	dSi	0		mm	+								
Shoulder d	liameter outer ring	dSe	0		mm	+								

Since the conformity is not provided we use the values according to ISO/TS 16281 with fi = 0.52 and fe = 0.53

Now, the number of rolling elements Z = 19 and the ball diameter Dw = 8.731 will be figured out as the result of a backwards calculation by using the damage frequencies, which must be given to the software. To do so, a pop-up window is opened when pressing the button located next to the "Dw" input, and then "Calculate" once the input data is filled out, and also OK to close the window.

Calculate Z, Dw from frequencies			x
Speed of inner ring	ni	60	rpm
Speed of outer ring	ne	0	rpm
Pitch diameter	Dpw	65	mm
Damage frequency for inner race	fip	10.733	1/s
Damage frequency for outer race	fep	-8.267	1/s
Damage frequency for rolling element	frp	-7.319	1/s
Number of rolling elements	Z	19	
Roller diameter	Dw	8.73139	mm
Nominal contact angle	٥	14.938	•
ОК	Calculate	Can	icel

Note that Dw and α must be manually rounded off on the page "Bearing geometry" so that they match standard values (The calculated Dw is practically equal to an usual one with 11/32 inch = 8.731mm, and the contact angle to 15°).



After finishing the tutorial such a data can be checked at the report:

Damage Frequencies		
Speed of inner ring	ni	1.000 1/s
Speed of outer ring	ne	0.0000 1/s
Rotation speed of cage	fc	0.4351 1/s
Damage frequency for inner race	fip	10.73 1/s
Damage frequency for outer race	fep	-8.2674 1/s
Damage frequency for rolling element	frp	-7.3194 1/s

A further unknown is the axial clearance of the bearing, since a pretension is given as a force. To

calculate the axial clearance click on the conversion button located by its side and calculate the axial clearance:

Calculation of	axial c	learance Pa	22
Pretension force	Fp	4200	N
_			
	OK	Ca	ncel

To get a pretension of 4.2kN we need an axial clearance Pa = -0.0525mm.

Bearing dearance	User input	as operating cl	earan	.e 🔻
Axial clearance	Pa	-0.0525011	mm	

Now all the geometry of the bearing is given and both the tolerances and load capacities can be entered, so "Enter inner geometry and load capacity" and "User input" must be selected from the drop-down lists, as well as the desired Bearing tolerance. Both "Shoulder diameter inner ring" and "Shoulder diameter inner ring" will be shown after running the software.

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General	Bearing geometry	Bea	Bearing configuration			Mate	erial and Lubrication Lo	ading	Tra	ck roller	r		
Angular c	ontact ball bearing				•	+	Enter inner geometry and load capacity						•
Inner diam	leter		d	50		mm	Dynamic load number			Cr	28.2		kN
Outer dian	neter		D	80		mm	Static load number			C0r	20.2		kN
Width			в	B 16		mm	Fatigue load limit			Cur	1.1		kN
Number of	rolling elements		z	Z 19			Bearing clearance	er input 🔹 🔻				-	
Diameter o	of rolling elements	Dw	8.731	8.731 mm			Axial clearance	_	Pa	-0.052	25011	mm	
Pitch diam	eter	Dpw	65		mm	*	Bearing tolerance		ISO 49			94	•
Contact ar	ngle	ao	15		•	÷	Fit to shaft	[k6				÷
Conformity	v inner ring	fi	0.52		1		Surface roughness shaft			Rz	4		μm
					1		Shaft inner diameter			dsi	0		mm
Conformity	y outer ring	re	0.53				Fit to housing	ſ	H6				~
Shoulder d	liameter inner ring	dSi	61.50	61.5076 mm		÷	Surface roughness housing			Rz	4		μm
Shoulder d	liameter outer ring	dSe	68.49	68.4924 mm		+	Housing outer diameter		dhe	0		mm	

The dynamic load capacity of the bearing given by the manufacturer is slightly larger than according ISO 281. Often manufacturers provide higher values than the standard to consider better material and quality. Therefore it is also possible to enter the values manually in addition to the calculation according to ISO 281.



Bearing configuration



Ge	eneral Bearing	geometry Bearin	g configuration Mater	al and Lubrication	Loading	Track roller	
V	Consider group o	fbearings					
	Position [mm]	Axial Offset [mm]	Center of contact con	ie			
1	-8	0	left				
2	8	0	right				
		1	P	uuud			

An axial offset between the outer races can be defined additionally, if some additional pretension is introduced in the assembly. In this case we have no modification.

Running a calculation with zero load and opening the report, by pressing on the 🤣 and 退 buttons, we will see the pressure between shaft an inner ring because of the interference fit and an increased pretension of the bearing of 5.79kN (also because of the interference fit. We already get a pressure of 2181MPa in the contact between balls and races:

Number	Fx [kN]	ux [mm]	Fy [kN]	uy [mm]	Fz [kN]	uz [mm]	My [Nm]	ry [mrad]	Mz [Nm]	rz [mrad]	pmax [MPa]	SF
1	5.79494	0.0000	0	0.0000	0	0.0000	0.00	0.00	0.00	0.00	2181.52	7.14
2	-5.79494	0.0000	0	0.0000	0	0.0000	0.00	0.00	0.00	0.00	2181.52	7.14



Loading

We want to consider two load cases. The first one is a radial load of Fy = 15kN, the second a moment load of My = 300Nm. The speed of the inner ring should be ni = 2200rpm. The temperature of the shaft should be 50°C, the temperature of the housing 40°C.

Results for no loading

First we have a look at the results for zero loading. So press now on the tab "Loading" and enter just the aforementioned temperatures and inner ring speed.

	General	Bearing geometry	Bearing configuration			Mate	rial and Lubrication	Loading	Trac	k rolle	er			
	Axial load Radial loa Radial loa	d ad ad	Fx Fy Fz	0 0 0		N N N	0	Displacement Displacement Displacement	-	ux uy uz	0 0 0		mm mm mm	0
	Moment		My Mz	0		Nm Nm	0	Rotation angle Rotation angle		ry rz	0		mrad mrad	•
	Speed in	ner ring	n	i	2200		rpm	Inner ring rotates	s to load					
	Speed ou	uter ring	n	ne 0			rpm	Outer ring rotate	s to load					
	Tempera	Temperature of shaft Ti 50			°C	Temperature of hous	ing		Te	40		°C		
R	esult overvie	w												
	Basic referen	ice rating life	L10)r	26.3095		E	asic reference rating	life	L	10rh	199.314		h
	Modified refe	erence rating life	Lnm	nr [88.5518		N	lodified reference rat	ing life	Lr	nmrh	670.847		h
	Maximal pres	sure	pma	x	2343.89	N	/Pa S	tatic safety factor			SF	5.75357		

We already have a pressure of 2343MPa and a life of L10rh = 199h only because of pretension.



Radial loading

Entering the radial load of Fy = 15kN we get the following results:

	General Bearing geometry	Bearin	g co	nfiguration		Mate	rial and Lubrication Loading	Trac	k rolle	er		
	Axial load	Fx	0		N	۲	Displacement	ux	0		mm	0
	Radial load	Fy	15	000	Ν	۲	Displacement	uy	0.01	137175	mm	0
	Radial load	Fz	0		Ν	0	Displacement	uz	0		mm	\bigcirc
	Moment	Му	0		Nm	\bigcirc	Rotation angle	ry	0		mrad	۲
	Moment	Mz	0		Nm	0	Rotation angle	rz	0		mrad	۲
	Speed inner ring	п	ni	2200		rpm	Inner ring rotates to load					
	Speed outer ring	п	ne	0		rpm	Outer ring rotates to load					
	Temperature of shaft	т	Ti -	50		°C	Temperature of housing	ī	Te	40	•	°C
F	Result overview											
	Basic reference rating life	L10	Or [11.5345		E	asic reference rating life	L	10rh	87.3827		h
	Modified reference rating life	Lnn	nr 🗄	26.9023		N	Nodified reference rating life	Lr	hmrh	203.805		h
	Maximal pressure	pma	ax :	2912.08	N	1Pa S	Static safety factor		SF	3.0001		

The graphic contact stress shows that all balls are still loaded. To plot these charts, click on "Graphics" at the menu bar and select "Contact stress" and "Load distribution".





When performing the calculation according ISO 281 without pretension, we get a result of L10h = $16666/2200 * (28.2*2^{0.7}/15)^{3} = 215h$ instead of the L10rh = 87h with pretension by the software.

For the single bearings, we can see in the report that we have an axial (Fx), a radial (Fy) and a moment (Mz) load:

Number	Fx [kN]	ux [mm]	Fy [kN]	uy [mm]	Fz [kN]	uz [mm]	My [Nm]	ry [mrad]	Mz [Nm]	rz [mrad]	pmax [MPa]	SF
1	7.42436	-0.0009	7.5	0.0137	0	0.0000	0.00	0.00	-89.25	0.00	2912.08	3.00
2	-7.42436	0.0009	7.5	0.0137	0	0.0000	0.00	0.00	89.25	0.00	2912.08	3.00

Note that at "Bearing configuration" page, these kind of results can be also shown in additional cells by clicking the right mouse button and selecting them from the context menu:

Ge	eneral Bearing geometry		aring configuration	Material a	and Lubrication	Loading	Track rolle
1	Consider group o	fbearings					
	Position [mm]	Axial Offset [m	m] Center of cor	ntact cone	Fx [N]	pma	x [MPa]
1	-8	0	left		7424.36	2912.08	
2	8	0	right		-7424.36	2912.08	

If we do a calculation with operating clearance of zero for comparison (go to the "Bearing geometry" page and proceed as explained before, but now enter Pa =0 mm; Fp =0 N), we get a life of L10rh = 218h, which is close to the ISO 281 result. Now, as we can check in the graph of load distribution, the pretension is missing.





Moment loading

Now we run the same calculation with a moment loading of My = 300Nm.

General Bearing geometry	Bearing	configuration		Mate	erial and Lubrication Loading	Tra	ck rolle	er		
Axial load	Fx	0	N	۲	Displacement	ux	0		mm	0
Radial load	Fy	0	N	۲	Displacement	uy	0		mm	0
Radial load	Fz	0	N	۲	Displacement	uz	0		mm	0
Moment	Му	300	Nm	۲	Rotation angle	ry	0.61	0831	mrad	0
Moment	Mz	0	Nm	0	Rotation angle	rz	0		mrad	۲
Speed inner ring	ni	2200		rpm	Inner ring rotates to load					
Speed outer ring	ne	0		rpm	Outer ring rotates to load					
Temperature of shaft	Ti	50		°C	Temperature of housing		Te	40	•	Ċ
Result overview										
Basic reference rating life	L 10r	12.5387	7		Basic reference rating life	L	.10rh	94.9903		h
Modified reference rating life	Lnmr	30.2859		1	Modified reference rating life	L	nmrh	229.439		h
Maximal pressure	pmax	2871.54	N	IPa s	Static safety factor		SF	3.12897		

The resulting life and pressure is similar to the calculation before, but now the load distribution is mirrored between the two bearings:





The single bearings have an axial load, a radial load and a moment load:

Number	Fx [kN]	ux [mm]	Fy [kN]	uy [mm]	Fz [kN]	uz [mm]	My [Nm]	ry [mrad]	Mz [Nm]	rz [mrad]	pmax [MPa]	SF
1	7.72831	-0.0009	0	0.0000	6.68603	0.0049	96.51	0.61	0.00	0.00	2871.54	3.13
2	-7.72831	0.0009	0	0.0000	-6.68603	-0.0049	96.51	0.61	0.00	0.00	2871.54	3.13

All the calculations were done using the medium operating clearance. On the first page "General" this could be changed into minimal or maximal clearance:

Reliability	S	90	%
Calculation for medium clea	rance		•

Considering the maximal clearance it could be decided if the pretension could be decreased, to increase the overall life.

Further Analyses

Optimization of life

The maximum bearing life can be found out by identifying and optimizing those parameters with a major influence in it. For this purpose, some features of the software can be easily used, thus enabling the user to reach an optimal configuration of the bearing.

For the case of moment loading (My=300Nm), we will have a look on the nominal axial clearance, since the life has a great dependency on it. This way, we will use the parameter variation, so please select "Calculation"->"Parameter variation". Now, in the tab page "Generate List", we add a parameter on the list, so we click on the 🔂-button and a new row is created. Doing a double-click on the first cell, a drop-down list is activated, then select "Pa[mm] (Nominal axial clearance)" from it. Please fill the row as shown:

Parameter Var	iation					23
Generate List	Parameter list	Graphics 1	Graphics 2			
	Parameter		Start value	End value	Number of steps	÷
1 Pa [mm] (Nominal axial clea	arance)	-0.05	0	50	
			C	alculate	Report	Close



At the tab page "Parameter List", do a right-button click and select "L10rh" and "Pmax" from the context menu "Results".

Generate List	Parameter list	Graphics 1	Graphics 2		
	nputs Results Rearing 1 Rearing 2 Show all inputs Hide all results Hide all results	Graphics 1	Graphics 2		

Now, Pressing "Calculate", will generate a list of all parameter combinations and also run the analysis.

Pa [mm] L10rh [h] pmax [MPa] 1 -0.05 96.7973 2886.55 2 -0.049 100.786 2876.56 3 -0.048 104.905 2866.7					Farancie	erate List	Jen
1 -0.05 96.7973 2886.55 2 -0.049 100.786 2876.56 3 -0.048 104.905 2866.7	<u> </u>	*	x [MPa]	pmax	L10rh [h]	Pa [mm]	
2 -0.049 100.786 2876.56 3 -0.048 104.905 2866.7			.55	2886.5	96.7973	-0.05	1
3 -0.048 104.905 2866.7			.56	2876.5	100.786	-0.049	2
	-		.7	2866.7	104.905	-0.048	3
4 -0.047 109.152 2856.99			.99	2856.9	109.152	-0.047	4
5 -0.046 113.528 2847.43			.43	2847.4	113.528	-0.046	5
6 -0.045 118.031 2838.02			.02	2838.0	118.031	-0.045	6



Selecting the tabs "Graphics 1" and "Graphics 2" we can visualize life over clearance or pressure over clearance.





For instance, in case we assume that the bearing must have a certain pretension, the user can deduce from this study, that the higher the pretension is, the shorter life the bearing has. However, if we widen the range of the possible axial clearances to the positive direction of X-Value for the bearing, we can identify a maximum over the range Pa=(-0.01, 0)mm:



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Load spectrum

A load spectrum can be used instead of a single load case. In order to activate this option in the software, go to the tab page "General" and activate the flag for "Use load spectrum".

General Bearing geome	try Bearing co	nfiguration	Material and Lubrication	Loading	Track ro	oller				
	Ϋ́S	l	Rolling Bearin	g Calc	ulati	ion				
Calculation of load d	istribution and refe	erence life for	r rolling bearings considering I	SO/TS 16281	and NREL	./TP-500-42	2362			
roject name										
alculation description										
Settings										
Limit for aISO	aISOMax	50	Reliability		S	90	%			
Friction coefficient	μ	0.1	Calculation for medi	Calculation for medium clearance Calculating bearing Cuse load spectrum Calculate modified life Use extended method for pressure distribution						
Calculate lubricant film	n thickness		Oscillating bearing							
Consider centrifugal f	orce		Use load spectru							
	dness depth		Calculate modifie							
Calculate required har										
 Calculate required har Use fatigue strength f 	for hardness depth	1	Use extended me	ethod for pres	ssure distr	ribution				

Now go to the tab page "Loading", click twice on the button in order to add two rows. By default, the column corresponding to "My [Nm]" is not activated, so do a right button click on the window and activate the flag for "enter My"; as a result of it, "ry[°]" will be hidden and "My [Nm]" will be shown in its stead. Now fill out the table as shown:

Frequency Fx [N] Fy [N] Fz [N] My [Nm] rz [°] ni [rpm] ne [rpm] T_i [°C] T_e [°C] Toil [°C] 1 0.5 0 15000 0 0 2200 0 50 40 70 2 0.5 0 0 0 300 0 2200 0 50 40 70 // enter Fx enter enter enter Fy Fy Fy Fy Fy enter Fy Fy enter Fy Fy </th <th>ne</th> <th>ral Bearin</th> <th>ig geome</th> <th>try I</th> <th>Bearing</th> <th>configuratio</th> <th>n N</th> <th>Aaterial and</th> <th>Lubrication</th> <th>Load</th> <th>ding Tr</th> <th>ack roller</th> <th></th>	ne	ral Bearin	ig geome	try I	Bearing	configuratio	n N	Aaterial and	Lubrication	Load	ding Tr	ack roller	
1 0.5 0 15000 0 0 0 2200 0 50 40 70 2 0.5 0 0 0 300 0 2200 0 50 40 70 V enter Fx V enter Fy V enter Hy enter Mz		Frequency	Fx [N]	Fy [N]	Fz [N]	My [Nm]	rz [°]	ni [rpm]	ne [rpm]	T_i [°C]	T_e [°C]	TOil [°C]	
2 0.5 0 0 0 300 0 2200 0 50 40 70 ✓ enter Fx ✓ enter Fy ✓ enter My enter Mz	1	0.5	0	15000	0	0	0	2200	0	50	40	70	
 ✓ enter Fx ✓ enter Fy ✓ enter Fz ✓ enter My enter Mz 	2	0.5	0	0	0	300	0	2200	0	50	40	70	
					[✓ entr ✓ entr ✓ entr ✓ entr 	er Fy er Fz er My er Mz						



We have set an equal distribution of load frequency for the current example, by entering "0.5" in each of the corresponding case cells.

Running the software calculation and carrying out a parameter variation study as we did before for the moment loading, it can be observed how the optimal axial clearance is now found over the range Pa=(-0.015,-0.01)mm:



Please note that for each load case, a full calculation using all factors is made. The resulting life is calculated using the life of each element.