Design of a Gear Box

Part-III & IV

Calculation of Loads on Shaft,

Bearing Selection & Shaft Design

A Typical Helical Gear Box Design Problem (Example)

Recapitulation

A helical gear reduction unit has to transmit 31 Nm input torque at 1500 rpm with a total reduction of about 37 to 40.

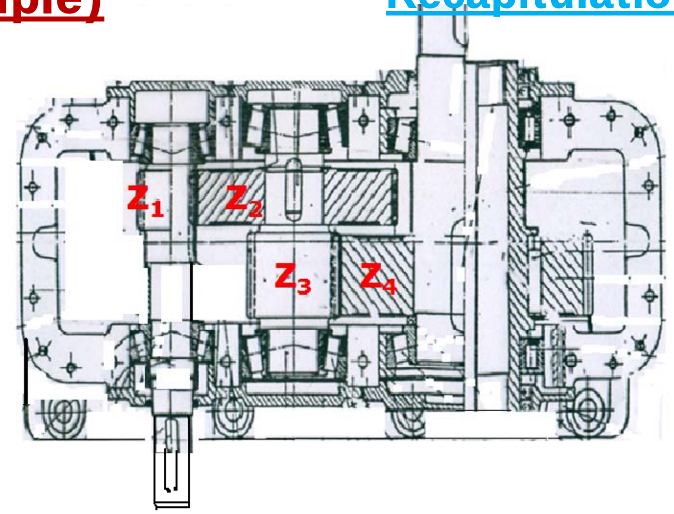
At starting the torque may go as high as 200 % and also there is medium shock loads during operation.

The material for pinion is EN 19A and for gear wheel it is EN 18A.

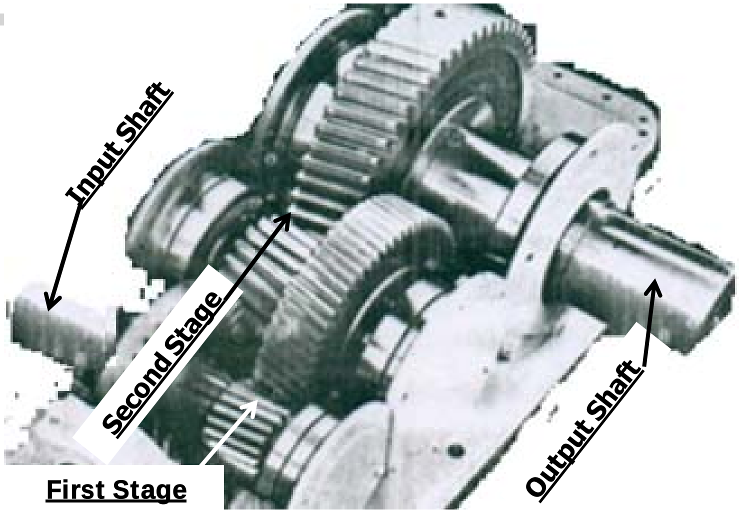
The gear box may be an ordinary industrial class unit preferably with uncorrected gears.

It is continuous duty with medium shock and overhauling time is Two years.

(Alternatively -the bearing life should not be below 10,000 hours).



Assembled plan view is of 2-stage gear box.



Photographic plan view is of 2-stage gear box.

A Typical Helical Gear Box Design Problem

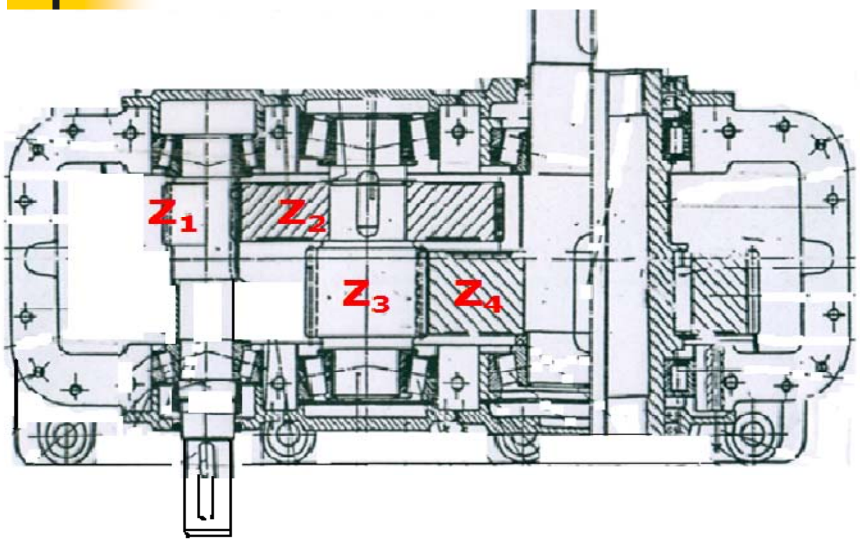
1st. Step. ➢**Selection of number of stages with respect to Total Transmission Ratio.**

In the present problem Total Transmission Ratio, i_t = 37 to 40.

Considering not more than ratio 6 in a stage (particularly in 1st. Stage) a total ratio above 6 and below 36 can be managed in two stages.

For a Ratio above 36, usually three stage reduction is preferred.

However, allowing a ratio little more than 6 in second stage (which is done very often to reduce cost) a total ratio of 37 to 40 is done in two stages.



Assembled plan view is of 2-stage gear box.

Now, the ratios are to be selected in a way that the size of the gear box becomes optimum.

Optimization technique to be adopted in this regard.

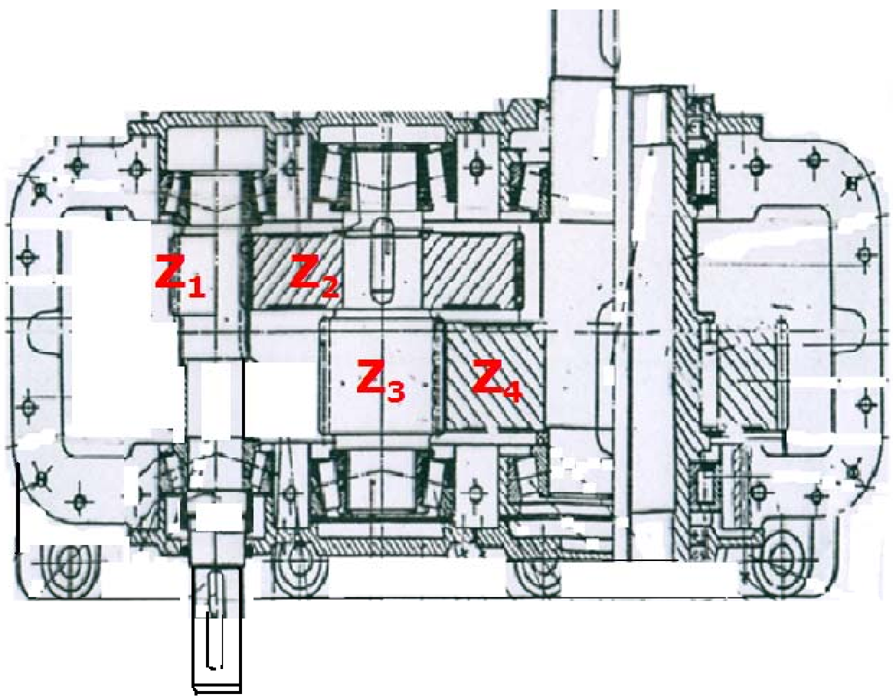
The process is tedious. However, experienced designer can do it with a little manipulation and trial and error on the selection of the stage reductions.

Recapitulation

1st. Step (Contd).

➢ **Selection of number of stages for a Total Transmission Ratio $\dot{i}_t$ = 37 to 40.**

Considering two stage reduction the numbers of teeth of pinions and gears were selected as follows:



Assembled plan view is of 2-stage gear box.

1st. Stage:

$$\dot{i}_1 = \frac{Z_2}{Z_1} = \frac{81}{17} = 4.76$$

2nd. Stage:

$$\dot{i}_2 = \frac{Z_4}{Z_3} = \frac{131}{16} = 8.19$$

Therefore, total ratio becomes:

$$\dot{i}_t = \dot{i}_1 \times \dot{i}_2 = \frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} = \frac{81}{17} \times \frac{131}{16}$$

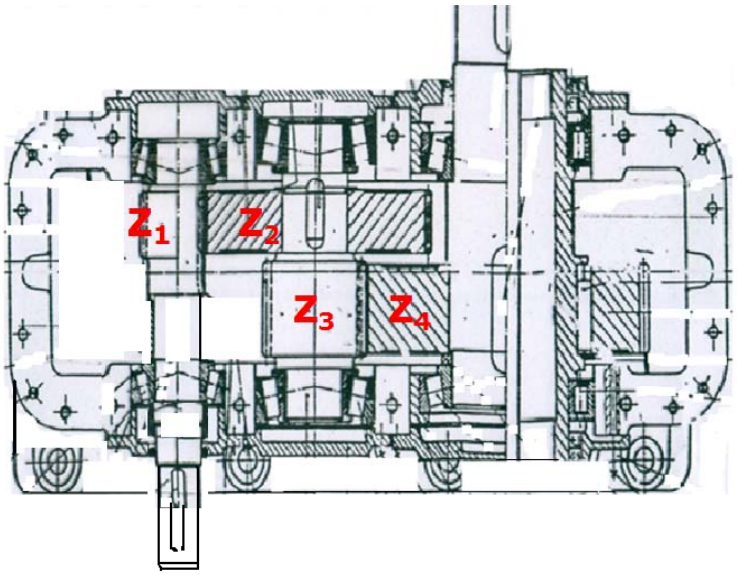
$$= 4.76 \times 8.19 = 39.01$$

This is acceptable.

A Typical Helical Gear Box Design Problem

1st. Step (Contd).

➢**Selection of number of stages for a Total Transmission Ratio** $\dot{i}_t$ **= 37 to 40.**



Assembled plan view is of 2-stage gear box.

In choosing the numbers of teeth and stage ratios, not only the size optimization is considered but also the roundness in centre distances with uncorrected gears is taken care* of:

2nd. Step.

In next step gears are designed as described in earlier lectures.

Estimated 1st. Stage module is $m_{n1} = 3\,mm$

and 2nd. Stage module is $m_{n2} = 4\,mm$

With a suitable selection of helix angle, $\beta_1 = \beta_2 = 11^o 26' 52''$ **, for which** $\cos\beta_1 = \cos\beta_2 = 0.98$ **and centre distances become:**

$$A_1 = \frac{(Z_1 + Z_2)\times m_{n1}}{2\times\cos\beta_1} = \frac{(17+81)\times 3}{2\times 0.98} = \frac{98\times 3}{2\times 0.98} = 150\ mm^*$$

and

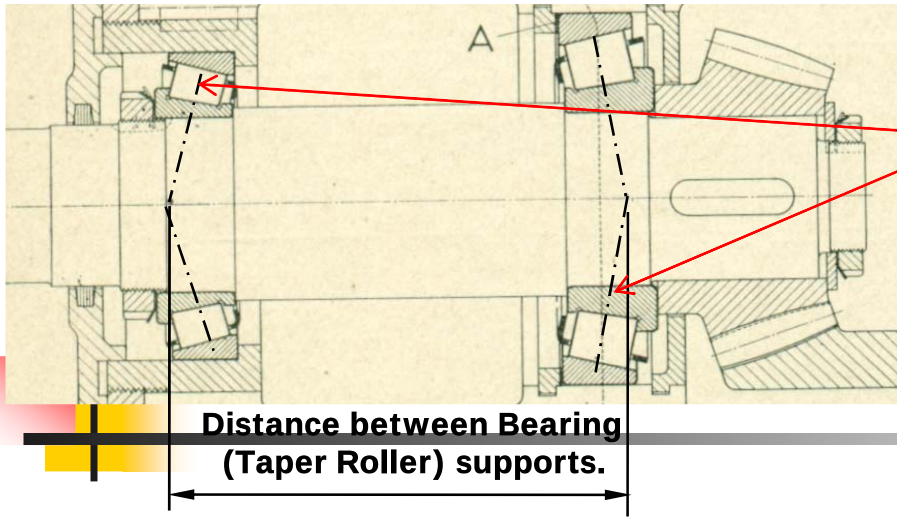
$$A_2 = \frac{(Z_3 + Z_4)\times m_{n2}}{2\times\cos\beta_2} = \frac{(16+131)\times 4}{2\times 0.98} = \frac{147\times 4}{2\times 0.98} = 300\ mm^*$$

Gear Data

Sl. No.	Description	First Stage		Second Stage	
		Pinion	Gear	Pinion	Gear
1.	Z ,, Number of Teeth	17	81	16	131
2.	Profile	20^o Involute Full Depth, Un corrected			
3.	m_n , Normal module	3 mm		4 mm	
4.	β , Helix Angle	$11^o 26' 52''$		$11^o 26' 52''$	
		RH	LH	LH	RH
5.	Addendum Height (mm) $f_a \times m_n$ = $1.0 \times m_n$	3.0		4.0	
6.	Dedendum Height (mm) $f_d \times m_n$ $1.25 \times m_n$	3. 75		5.0	
7.	d_p , Pitch Circle Diameter (PCD) (mm)	52.04	247.96	65.306	534.69
8.	d_a , Addendum or Tip Diameter (mm)	58.04	253.96	73.30	542.70
9.	d_d Dedendum or Root Diameter (mm)	44.54	240.46	55.30	524.70
10.	b , Face width. (mm)	63	58	68	63
11.	Material	EN 19A	EN 18A	EN 19A	EN 18A
12.	Surface Hardness (BHN) (Through Hardened)	350	300	350	300
p and g may be added to subscript of Nomenclature to indicate pinion and gear respectively. Similarly 1 and 2 can be added to indicate stage of Gear.					

3rd. Step. Layout & Bearing Selection

Layout of pinion and gears is made in next step. Shafts are automatically shaped.



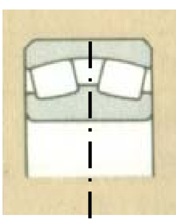
Distance between Bearing (Taper Roller) supports.

Then Bearing *types* are chosen taking into account service severity and life.

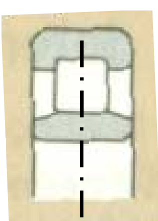
Taper Roller Bearing to be used in pair.

Other Bearings- may be used in pair or in combination.

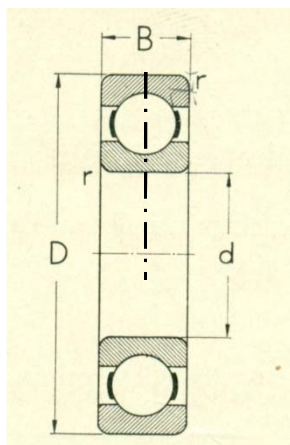
For an example both spherical roller and ball bearing can be combined with cylindrical roller bearing in the other end.



Spherical Roller Bearing



Cylindrical Roller Bearing



Ball Bearing (Deep Groove)

Choice depends on type of loading mainly.

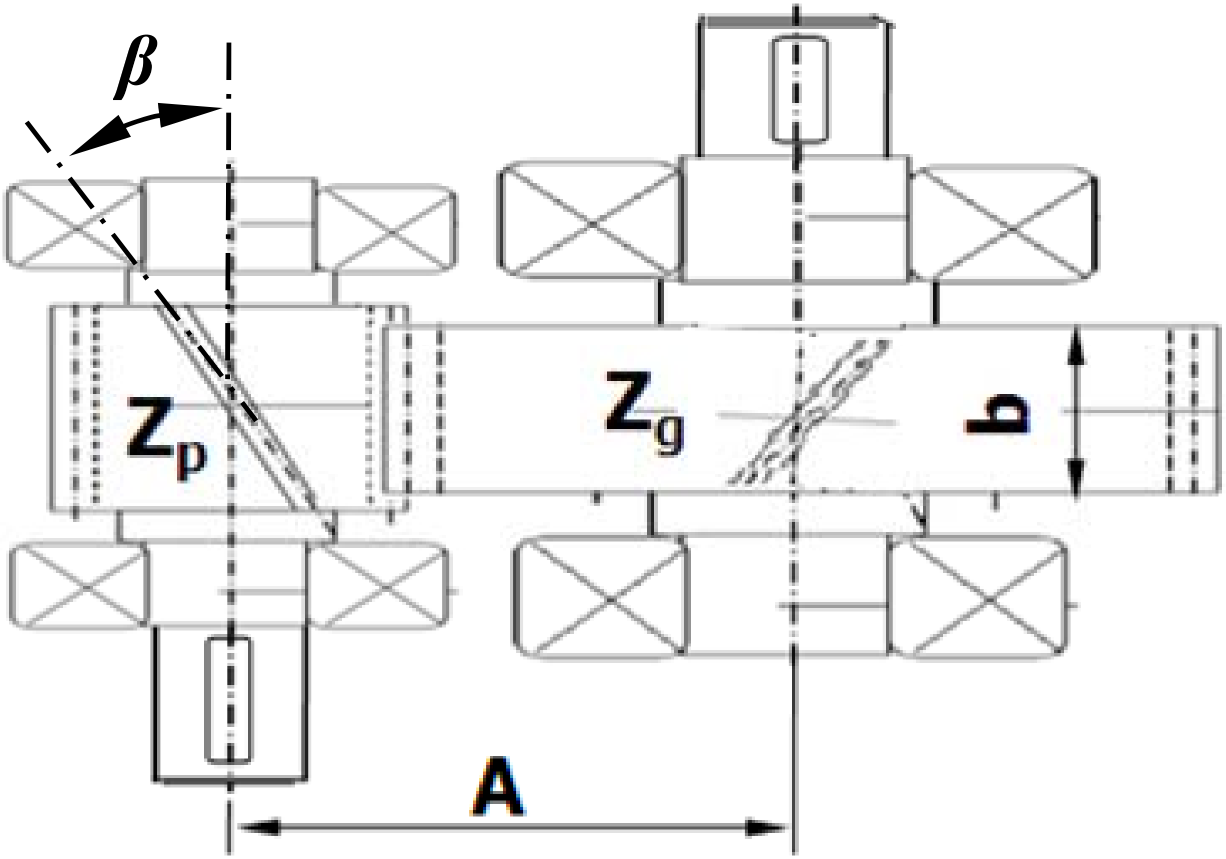
***Locking of bearings with shaft and housing* is to be decided at this stage.**

Sharing of reaction loads by bearings depends also on of bearing Locking arrangement.

With distance between bearing supports the shaft is considered *as "simply supported beam".*

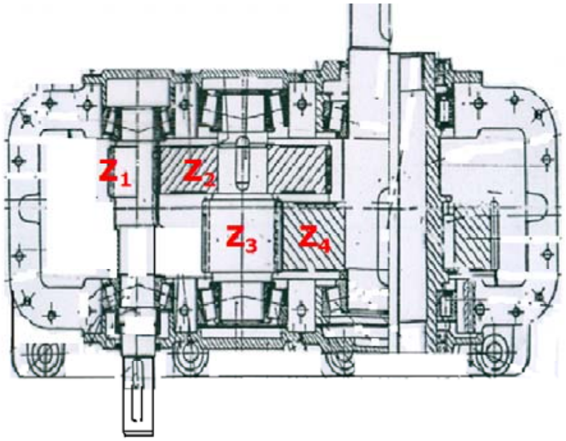
3rd. Step: Layout & Bearing Selection (Contd.....)

Layout of a single stage Gear Box

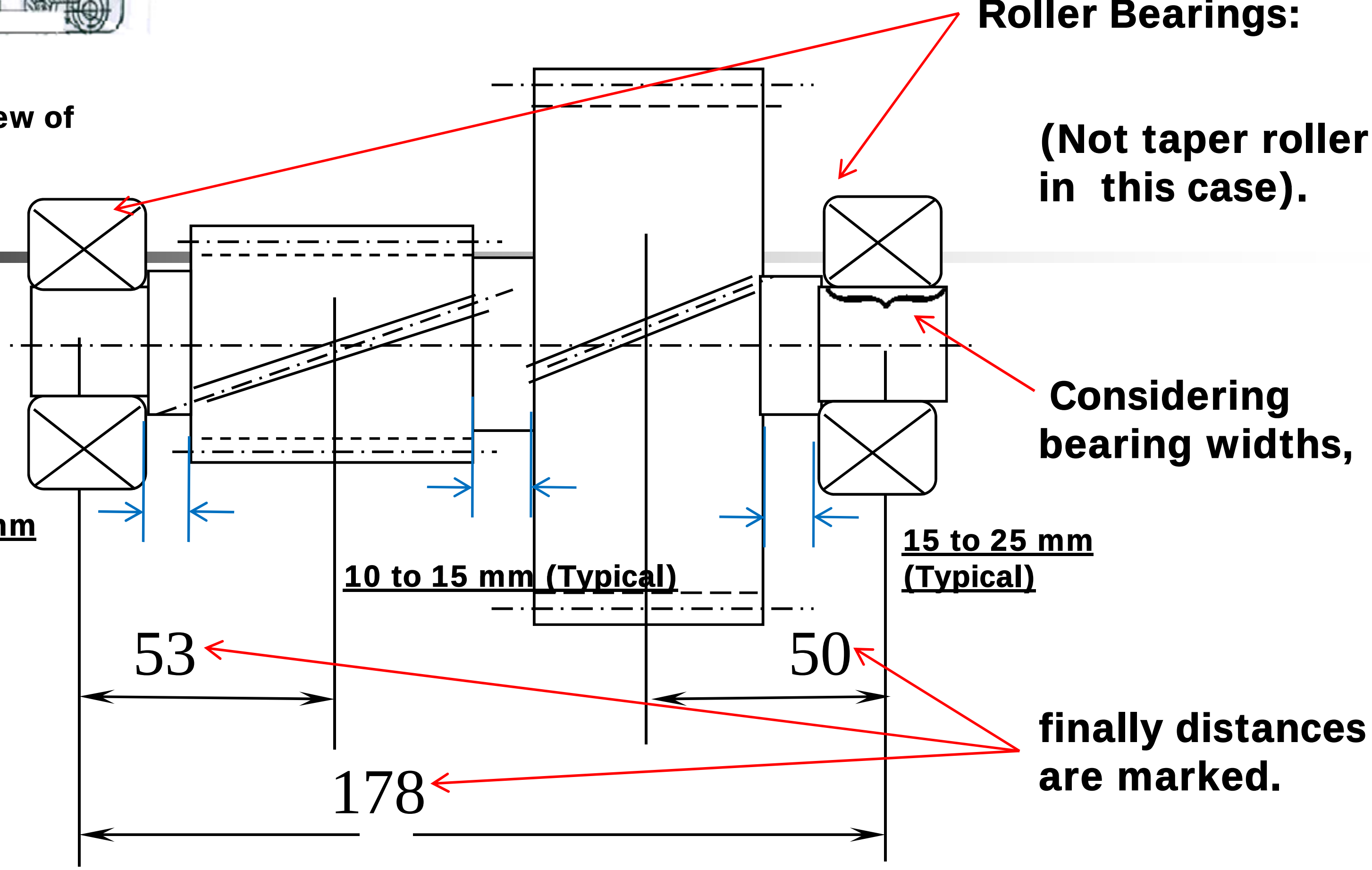


Plan View -Schematic

3rd. Step: Layout & Bearing Selection (Contd.....)

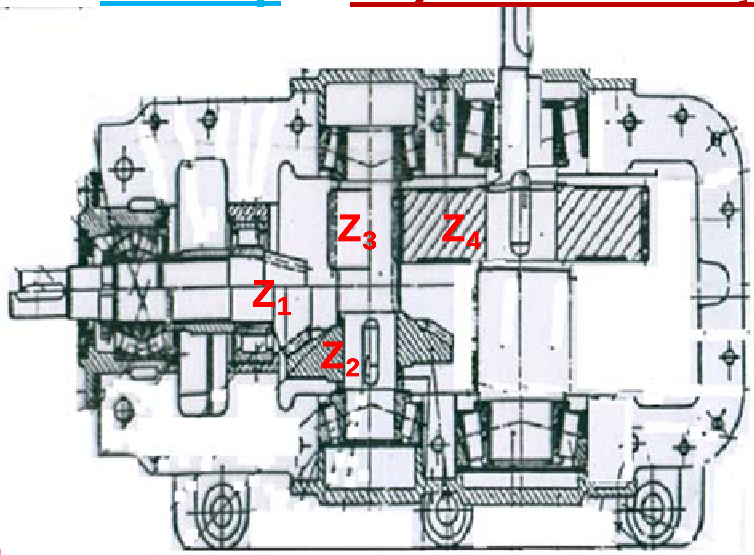


Assembled plan view of a 2-stage gear box.

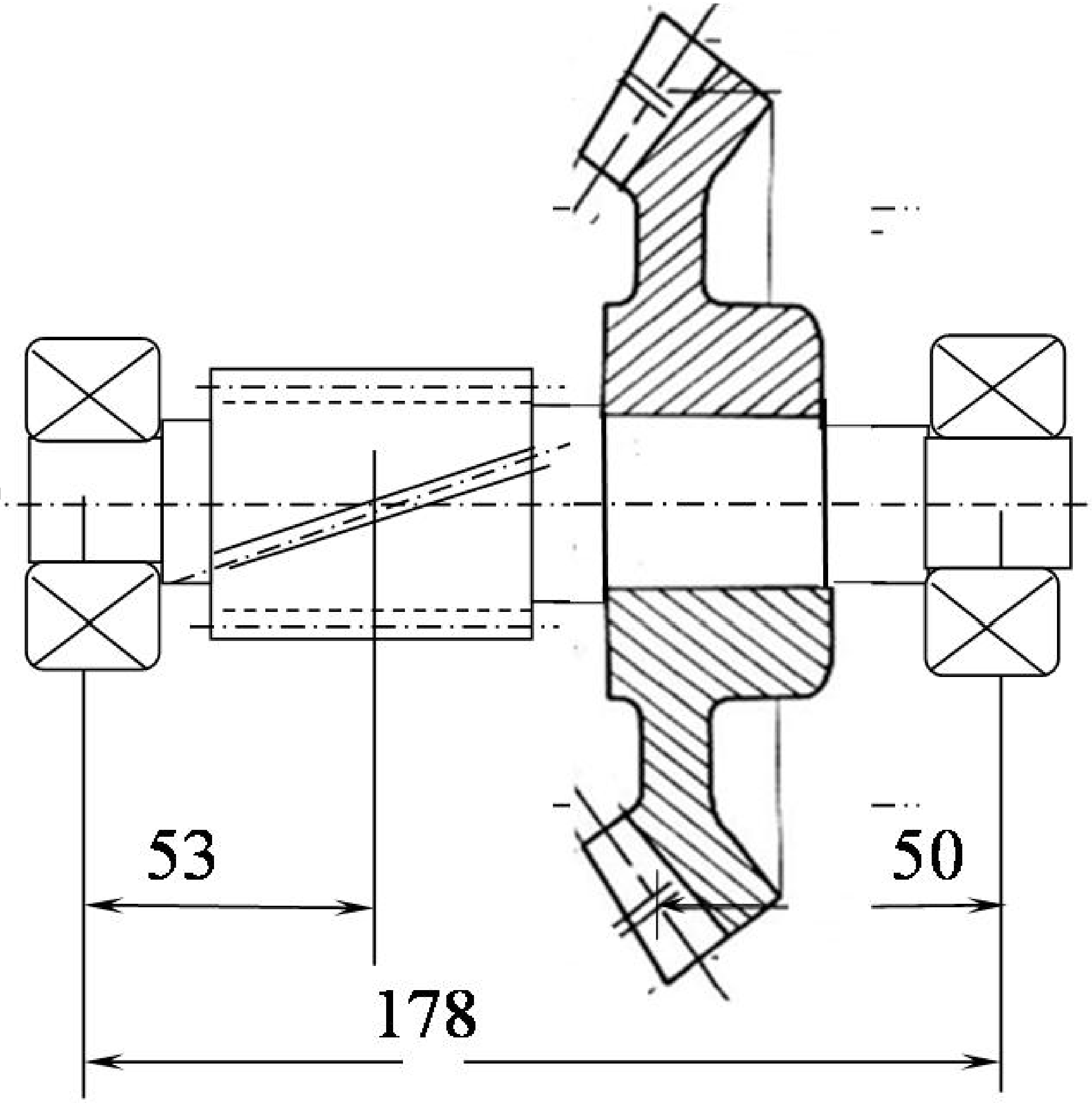


Layout of Intermediate Shaft (Referring to Example Problem)

3rd. Step: Layout & Bearing Selection (Contd.....)

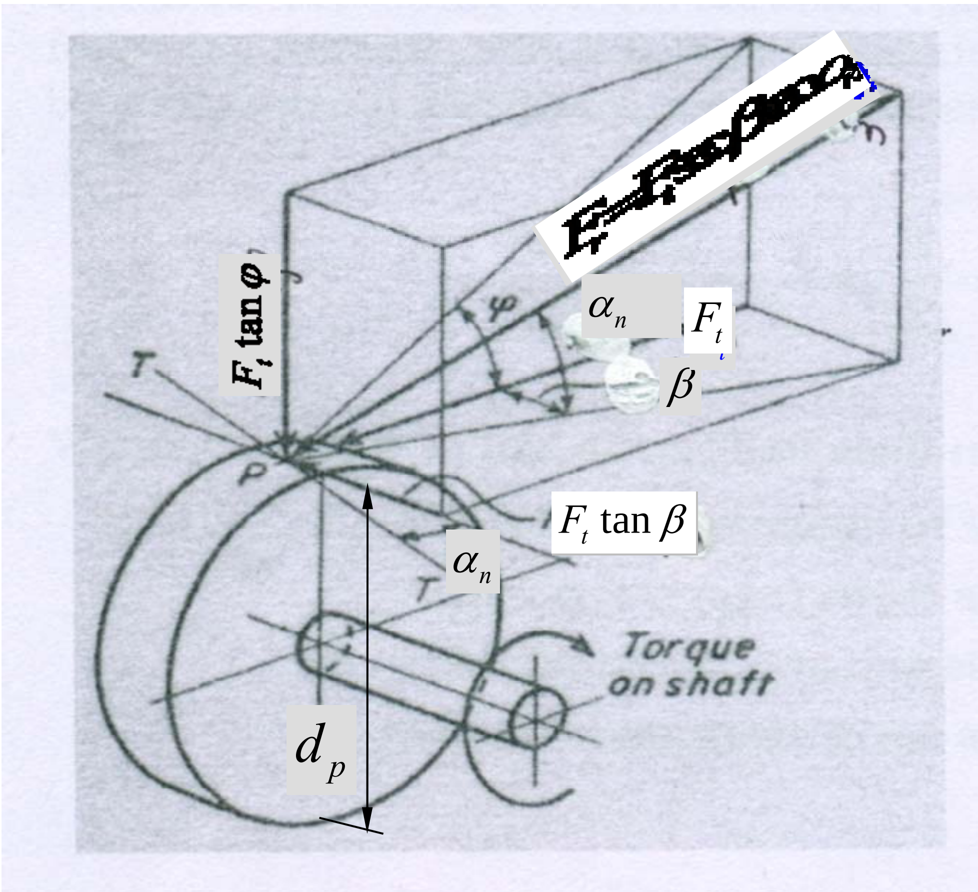


Assembled plan view (Top cover removed)



Layout of Intermediate Shaft (Referring to Design Problem)

4th. Step. Loads on Gear, Pinion Teeth (Helical Gear).



Forces on Helical Spur Gear Tooth.

Tangential Load: $F_t = \dfrac{2T}{d_p}$

$$\left(d_p = \frac{Z \times m_n}{\cos\beta} \right)$$

Normal Load: $F_{tn} = \dfrac{F_t}{\cos\beta}$

$$F_n = \frac{F_{tn}}{\cos\alpha_n} = F_t \sec\beta . \sec\alpha_n$$

Radial Load:

$$F_r = F_n . sin\alpha_n$$

$$= F_t sec\beta . sec\alpha_n . sin\alpha_n$$

$$F_r = F_t \sec\beta . \tan\alpha_n$$

$$(= F_t \tan\varphi)$$

Axial Load:

$$F_a = F_n \sin\beta = F_t \tan\beta$$

$$F_n = F_t \sec\beta . \sec\alpha_n$$

Straight Bevel Gear Design:

Module (m, in meter) can be estimated as:

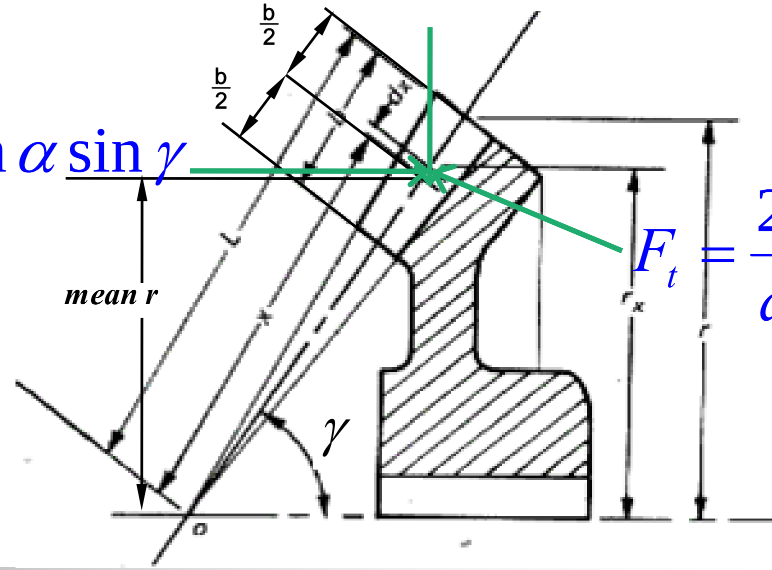
For straight tooth bevel gear:

$$m_{bevel} = \sqrt[3]{\frac{2T}{\frac{S_d}{c_v c_w} ZY\psi(1-\psi_o)}}$$

$$F_r = F_t \tan\alpha \cos\gamma$$

$$F_a = F_t \tan\alpha \sin\gamma$$

$$F_t = \frac{2T}{d_p}$$



Straight Tooth Bevel Gear.

Mean PCD (Straight Bevel)

$$= 2 \times mean\ r = Z \times m_{bevel}$$

Other relations.

$$\gamma_p + \gamma_g = 90^o$$

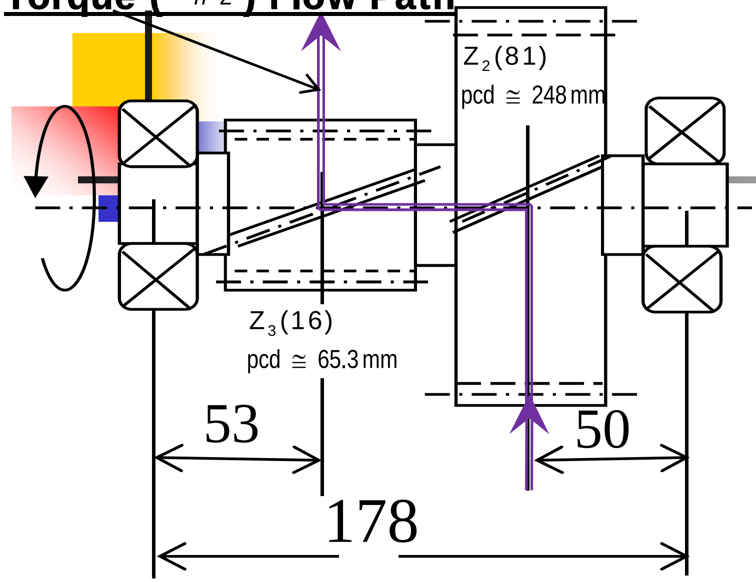
And,

$$\sin\gamma_p / \sin\gamma_g = \tan\gamma_p = Z_p / Z_g$$

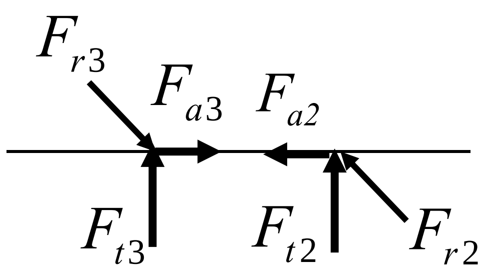
4th. Step (Contd...): *Calculation of Loads and Reactions on Shaft & Bearing*

For Intermediate Shaft (Referring to Design Problem)

Torque (T_{n2}) Flow Path



Intermediate Shaft with gears and Bearings



Applied Loads, Reactions & Moments due to Axial Loads

Nominal Torque = Input Torque x Ratio

$$T_{n2} = T_{n1} \times \frac{Z_2}{Z_1} = 31 \times 4.76 = 148\ Nm$$

$$\boldsymbol{F_{t2}} = 2 \times T_{n2} \ / \ 0.248\ \ N = \mathbf{1193.5\ \ N}$$

$$\boldsymbol{F_{r2}} = F_{t2} sec\beta_1 . tan\alpha_n$$

$$= 1193.5 \times sec(11^o 26'52'') \times tan(20^o)$$

$$= 1193.5 \times 1.02 \times 0.364 = \mathbf{443\ N}$$

$$\boldsymbol{F_{a2}} = F_{t2} tan\beta_1$$

$$= 1193.5 \times tan(11^o 26'52'')$$

$$= \mathbf{240.65\ \ N}$$

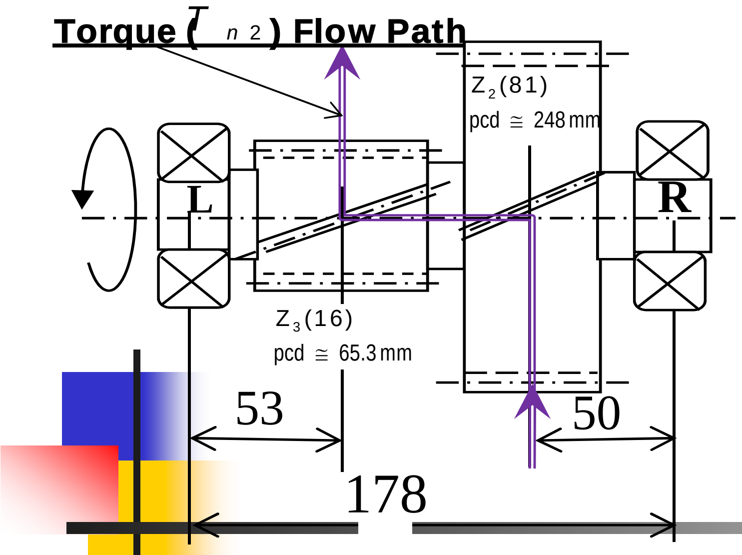
Similarly forces (rounded of) at pinion (Z_3) of 2nd. Stage:

F_{t3} = 4533 N $\qquad$ F_{r3} =1683 N

F_{a3} = 914 N

4th. Step (Contd...): *Calculation of Loads and Reactions on Shaft & Bearing*

For Intermediate Shaft (Referring to Design Problem)



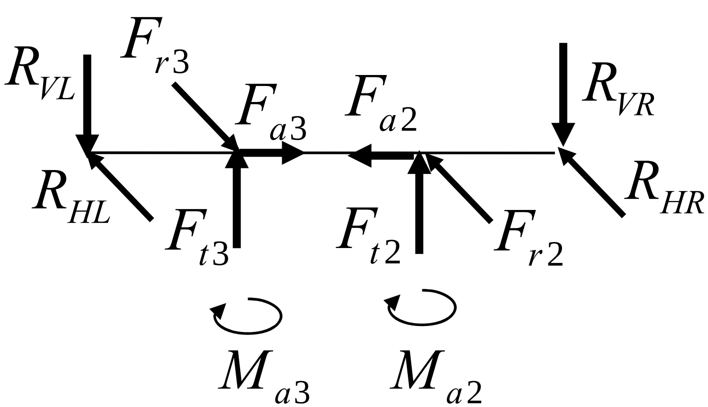
Intermediate Shaft with gears and Bearings

Loads and reactions are calculated on the basis of Nominal Torque & approximate bearing width = 25 mm.

Bending Moment due to Axial Load:

$$M_{a2} = F_{a2} \times \frac{d_{p2}}{2} = \frac{240.65 \times 0.2479}{2} = 30\ Nm$$

$$M_{a3} = F_{a3} \times \frac{d_{p3}}{2} = \frac{914 \times 0.0653}{2} = 30\ Nm$$



F_{t3} = 4533 N F_{r3} =1683 N F_{a3} = 914 N

F_{t2} = 1193.5 N F_{r2} =443 N F_{a2} = 240.65 N

Applied Loads, Reactions & Moments due to Axial Loads

For moment equilibrium (horizontal plane) about *R*

$$R_{HL} = \frac{1683 \times 0.125}{0.178} - \frac{443 \times 0.05}{0.178} - \frac{30}{0.178} - \frac{30}{0.178}$$
$$= 1182 - 124.4 - 168.5 - 168.5 = 720.6\ \mathrm{N}$$

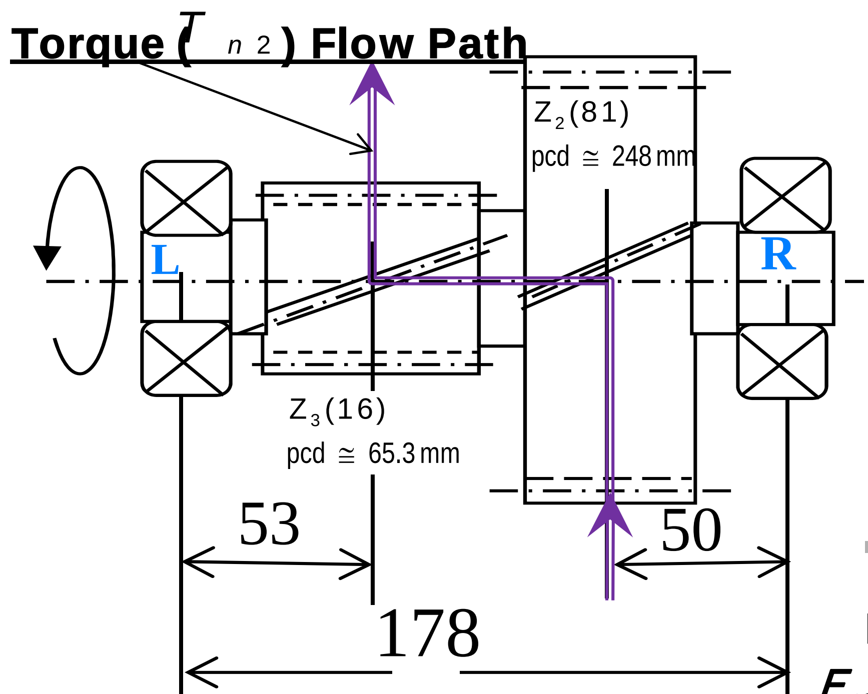
From force equilibrium- R_{HR} ***= 520 N***

Similarly computing for vertical plane:

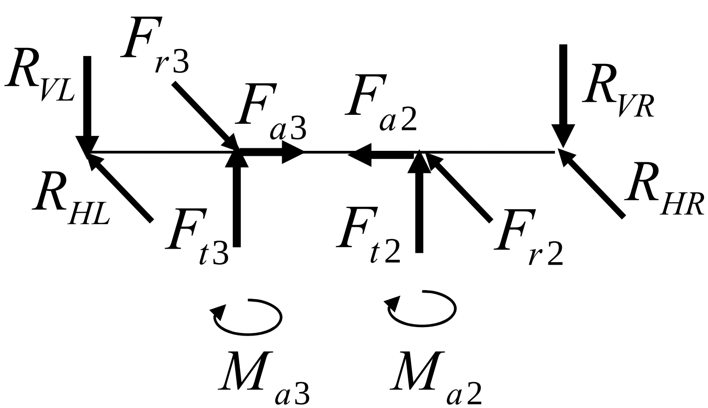
R_{VL} ***= 3518.5 N*** R_{VR} ***=2208 N***

5th. Step: ***Bearing Life Estimation***

For Intermediate Shaft (Referring to Design Problem)



Intermediate Shaft with gears and Bearings (Plan View)



Applied Loads, Reactions & Moments due to Axial Loads

Equivalent Load Acting on bearing is expressed as: $P = C_1\left(XVF_r + YF_a\right)$

Life of Rolling Element bearing in Number of Revolution is expressed as:

$$L_N = \left(\frac{C}{P}\right)^{\varepsilon} \times 10^6 \quad \textbf{Revolution}$$

Life in hours is then estimated as:

$$L_H = \frac{L_N}{N \times 60} \quad \textbf{Hours}$$

Loads from Gear teeth were estimated as:

F_{t3} = 4533 N F_{r3} =1683 N F_{a3} = 914 N

F_{t2} = 1193.5 N F_{r2} =443 N F_{a2} = 240.65 N

Also, moments due to axial forces were estimated as: $M_{a2} = M_{a3} = 30\ \text{Nm}$

Finally Bearing reactions (radial) were estimated as:

R_{HL} = 720.6 N R_{VL} = 3518.5 N

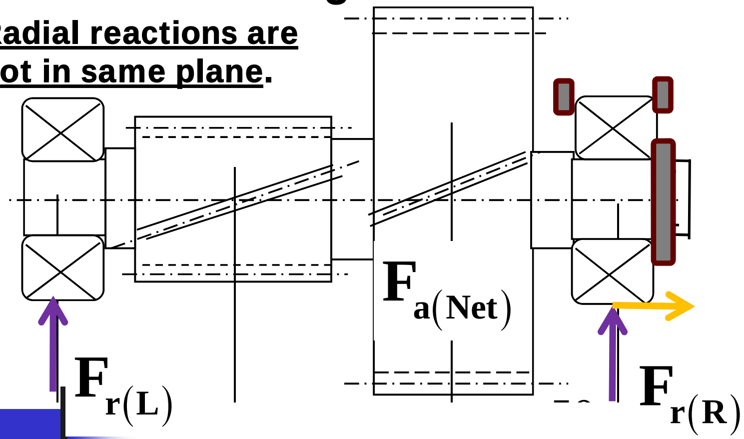
R_{HR} = 520 N R_{VR} =2208 N

Bearing reactions (axial) yet to be estimated.

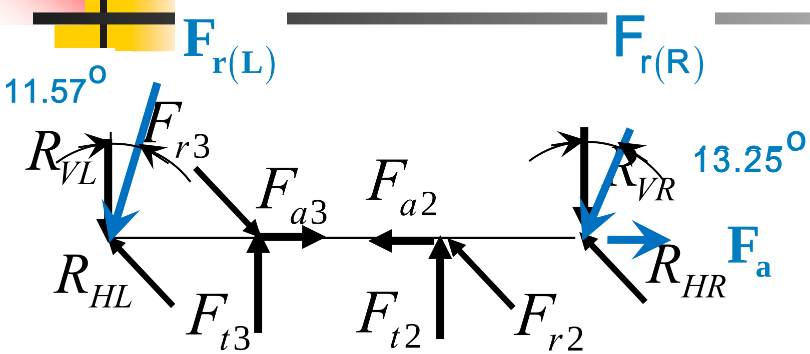
5th. Step (Contd...): *Bearing Life Estimation*

The Final bearing reactions:

Radial reactions are not in same plane.



Bearing Reactions (& Locking)



F_{t3} = 4533 N F_{r3} = 1683 N F_{a3} = 914 N

F_{t2} = 1193.5 N F_{r2} = 443 N F_{a2} = 240.65 N

R_{HL} = 720.6 N R_{VL} = 3518.5 N

R_{HR} = 520 N R_{VR} = 2208 N

Details of loading & Resultant bearing Reactions.

From details of loading resultant right bearing (radial) reaction is calculated as:

$$\mathbf{F}_{\mathbf{r(R)}} = \sqrt{R_{VR}^2 + R_{HR}^2} = \sqrt{2208^2 + 520^2}$$

$$= \mathbf{2268.4\,N}$$

It is acting at an angle θ_R with vertical plane,

derived as $\theta_R = \tan^{-1}\left(R_{HR}/R_{VR}\right) = 13.25°$ **.**

Similarly, $\mathbf{F}_{\mathbf{r(L)}} = \sqrt{R_{VL}^2 + R_{HL}^2} = \sqrt{3518.5^2 + 720.6^2}$

$$= \mathbf{3591.5\,N}$$

and, $\theta_L = \tan^{-1}\left(R_{HL}/R_{VL}\right) = 11.57°$

Resultant axial load may act only on one bearing irrespective of its direction (i.e., direction of shaft rotation).

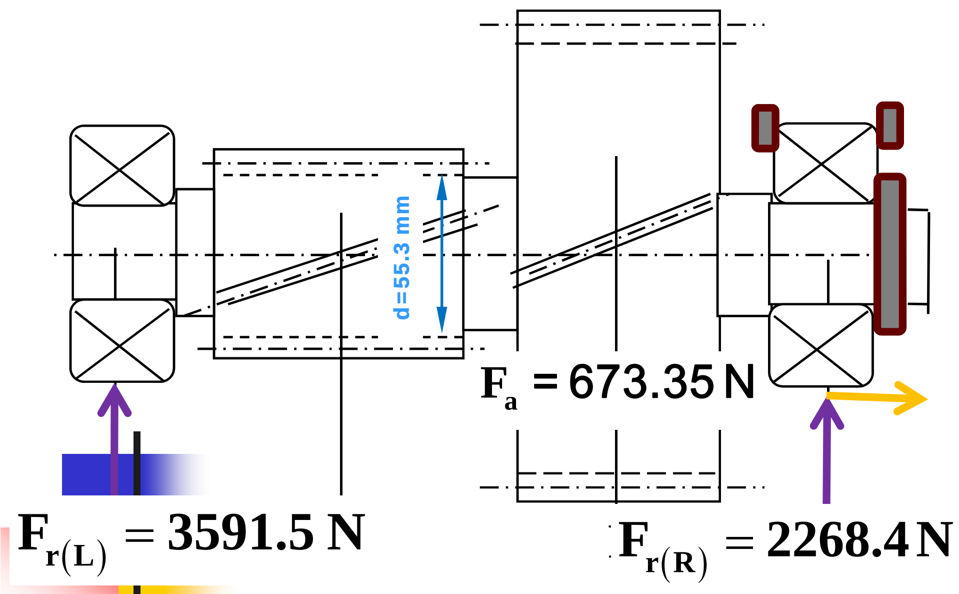
It depends on bearing locking arrangement.

In this case it is on right bearing which is with less radial load.

Net axial load $\mathbf{F}_{\mathbf{a(Net)}} = \mathbf{F}_{\mathbf{a}} = F_{a3} - F_{a2}$

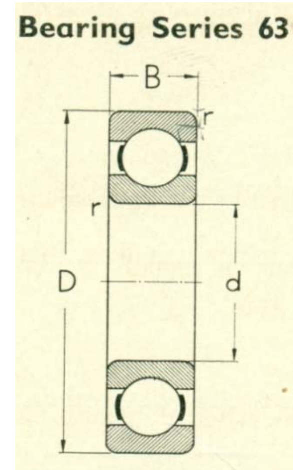
$$= 673.35\,\text{N}$$

5th. Step (Contd...): *Bearing Life Estimation*



Consider deep groove ball bearing SKF 6309 as both end supports of intermediate shaft:

Equivalent load on left bearing:



X = 1 & Y = 1.6

$$P_L = C_1\left(XVF_{r(L)} + YF_{a(L)}\right)$$
$$= 1.5\times(1.0\times1\times3591.5 + Y\times0)$$
$$= 5387.25\ \text{N}$$

Bearing No.	Inner Dia. (d)	Outer Dia. (D)	Width (B)	Corner Radius (r) Approx.	Basic Load Capacity	
					Dynamic C	Static C_o
	mm	mm	mm	mm	Newton	Newton
6309	45	100	25	2.5	40130	29200

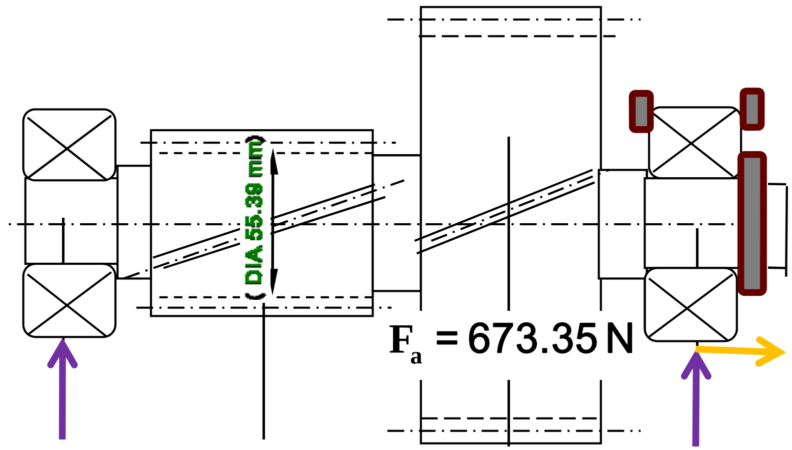
[Note: C_1 is taken as 1.5 considering medium shock load (given) on the estimated load on bearings based on nominal torque.]

Life (in hrs) of left bearing:

$$L_{H(L)} = \frac{L_{N(L)}}{N\times60} = \frac{(40130/5387.5)^3\times10^6}{(1500\times17/81)\times60}$$
$$= 0.021880\times10^6\ \text{hrs} = 21,880\ \text{hrs}$$

5th. Step (Contd...): *Bearing Life Estimation*

Ball bearing SKF 6309 is selected for both end supports of intermediate shaft:



$F_{r(L)} = 3591.5\ N$ $\qquad$ $F_{r(R)} = 2268.4\,N$

($L_{H\ (L)} = 21{,}880$ hrs.) $\qquad$ ($L_{H\ (R)} = 27{,}067$ hrs.)

Similarly, estimated equivalent load and life of right bearing:

$$P_R = 1.5\times(1.0\times1\times2268.4+1.6\times673.35) = 5018.64\ N,$$

$$L_{H\ (R)} = \frac{(40130/5018.64)^3\times10^6}{(1500\times17/81)\times60}$$

$$= 0.027067\times10^6\,hrs\ = 27{,}067\ hrs$$

Note: Estimated lives of both bearings are more or less same & above the required specified life (10,000 hrs).

Now it can be examined the life with bearing of lower load capacity:

Bearing No.	Inner Dia. (d)	Outer Dia. (D)	Width (B)	Corner Radius (r) Approx.	Basic Load Capacity	
					Dynamic C	Static C_o
	mm	mm	mm	mm	Newton	Newton
6309	45	100	25	2.5	40130	29200
6308	40	90	23	2.5	31000	21400
6211	55	100	21	2.5	32100	25415

As the root diameter of pinion is 55.39 mm then a bearing of id 55 mm (maximum) may be selected.

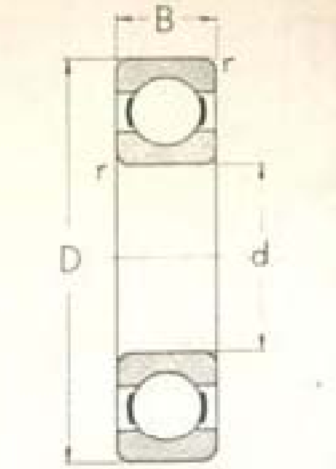
If SKF 6308 or 6211 is selected then life will be *reduced* by $(C_{6309}/C_{6308\ or\ 6211})^3$ i.e., 2.17 or 1.95 times respectively, which is acceptable.

However, design with SKF 6309 will perhaps be preferred.

Specification of Deep Groove Ball Bearing

Bearing No.	d		D		B		r ≈	Basic capacity, lb.	
	mm.	in.	mm.	in.	mm.	in.	mm.	Dynamic C	Static C_0
6300	10	0.3937	35	1.3780	11	0.4331	1	1430	800
01	12	0.4724	37	1.4567	12	0.4724	1.5	1700	950
02	15	0.5906	42	1.6535	13	0.5118	1.5	1930	1140
6303	17	0.6693	47	1.8504	14	0.5512	1.5	2320	1370
04	20	0.7874	52	2.0472	15	0.5906	2	2750	1700
05	25	0.9843	62	2.4409	17	0.6693	2	3600	2280
6306	30	1.1811	72	2.8346	19	0.7480	2	4800	3200
07	35	1.3780	80	3.1496	21	0.8268	2.5	5700	3800
08	40	1.5748	90	3.5433	23	0.9055	2.5	6950	4800
6309	45	1.7717	100	3.9370	25	0.9843	2.5	9000	6550
10	50	1.9685	110	4.3307	27	1.0630	3	10400	7800
11	55	2.1654	120	4.7244	29	1.1417	3	11800	9300
6312	60	2.3622	130	5.1181	31	1.2205	3.5	13200	10600
13	65	2.5591	140	5.5118	33	1.2992	3.5	15300	12000
14	70	2.7559	150	5.9055	35	1.3780	3.5	17300	13700
6315	75	2.9528	160	6.2992	37	1.4567	3.5	18600	16000
16	80	3.1496	170	6.6929	39	1.5354	3.5	20400	17600
17	85	3.3465	180	7.0866	41	1.6142	4	22400	19300
6318	90	3.5433	190	7.4803	43	1.6929	4	24000	21600
19	95	3.7402	200	7.8740	45	1.7717	4	26500	24500
20	100	3.9370	215	8.4646	47	1.8504	4	30500	29000
6321	105	4.1339	225	8.8583	49	1.9291	4	32000	31500
22	110	4.3307	240	9.4488	50	1.9685	4	36000	36000
6324	120	4.7244	260	10.2362	55	2.1654	4	36000	36500
26	130	5.1181	280	11.0236	58	2.2835	5	40500	43000
28	140	5.5118	300	11.8110	62	2.4409	5	45500	49000
30	150	5.9055	320	12.5984	65	2.5591	5	49000	56000

Bearing Series 63



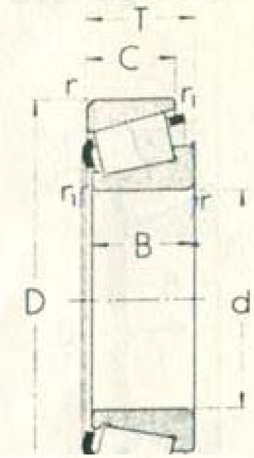
Specification of Taper Roller Bearing

TAPER ROLLER BEARINGS

Metric Dimension Series 22

Bearing No.	d		D		T max.		T min.	B	C	r ≈	r_1 ≈
	mm.	in.	mm.	in.	mm.	in.	Millimetres				
32206	30	1.1811	62	2.4409	21.5	0.846	21	20	17	1.5	0.5
07	35	1.3780	72	2.8346	24.5	0.965	21	23	19	2	0.8
08	40	1.5748	80	3.1496	25	0.984	24.5	23	19	2	0.8
32209	45	1.7717	85	3.3465	25	0.984	24.5	23	19	2	0.8
10	50	1.9685	90	3.5433	25	0.984	24.5	23	19	2	0.8
11	55	2.1654	100	3.9370	27	1.063	26.5	25	21	2.5	0.8
32212	60	2.3622	110	4.3307	30	1.181	29.5	28	24	2.5	0.8
13	65	2.5591	120	4.7244	33	1.299	32.5	31	27	2.5	0.8
14	70	2.7559	125	4.9213	33.5	1.319	33	31	27	2.5	0.8
32215	75	2.9528	130	5.1181	33.5	1.319	33	31	27	2.5	0.8
16	80	3.1496	140	5.5118	35.5	1.398	35	33	28	3	1
17	85	3.3465	150	5.9055	39	1.535	38	36	30	3	1
32218	90	3.5433	160	6.2992	43	1.693	42	40	34	3	1
19	95	3.7402	170	6.6929	46	1.811	45	43	37	3.5	1.2
20	100	3.9370	180	7.0866	49.5	1.949	48.5	46	39	3.5	1.2
32221	105	4.1339	190	7.4803	53.5	2.106	52.5	50	43	3.5	1.2
22	110	4.3307	200	7.8740	56.5	2.224	55.5	53	46	3.	
24	120	4.7244	215	8.4646	62	2.441	61	58	50	3.	

Bearing Series 3



Follow the directions on pp. 13—24 when determining the bearing

Bearing No.	Basic capacity, lb.		Revolutions per minu							
	Dynamic C	Static C_0	40	63	100	160	250	400	630	1000
			Relative radial capacity							
32206	7200	6100	6800	5850	5000	4300	3650	3150	2700	2320
07	9500	8150	9000	7650	6550	5600	4800	4150	3550	3050
08	10600	9000	10000	8650	7350	6300	5400	4650	4000	3400
32209	11400	10200	10800	9300	8000	6800	5850	5000	4300	3650
10	11600	10600	11000	9500	8150	6950	6000	5100	4400	3750
11	15300	13700	14300	12200	10600	9150	7800	6700	5700	4900
32212	18300	17000	17300	14600	12500	10800	9300	8000	6800	5850
13	22000	20400	20800	18000	15300	12900	11200	9650	8300	7100
14	22400	20400	21200	18300	15600	13200	11400	9800	8500	7200
32215	23600	22400	22400	19300	16600	14000	12000	10400	9000	7650
16	27500	25500	26000	22400	19300	16600	14000	12000	10400	9000
17	31500	30500	30000	25500	22000	19000	16300	13700	11800	10200
32218	37500	36000	35500	30500	26000	22400	19300	16600	14000	12000
19	43000	40500	40500	34500	30000	25500	22000	19000	16300	13700
20	48000	46500	45500	39000	33500	28500	24500	21200	18300	15600
32221	56000	54000	53000	45500	39000	33500	28500	24500	21200	18300
22	63000	61000	60000	51000	44000	37500	32000	27500	23000	20400
24	75000	75000	71000	61000	52000	45000	38000	32500	28000	24000

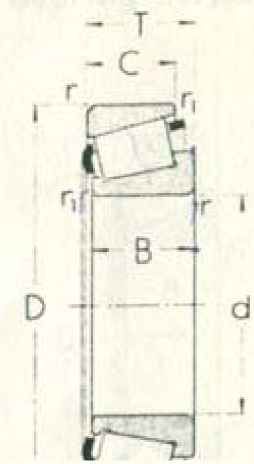
Specification of Taper Roller Bearing

TAPER ROLLER BEARINGS

Metric Dimension Series 22

Bearing No.	d mm.	d in.	D mm.	D in.	T max. mm.	T max. in.	T min.	B	C	r ≈	r_1 ≈
							Millimetres				
32206	30	1.1811	62	2.4409	21.5	0.846	21	20	17	1.5	0.5
07	35	1.3780	72	2.8346	24.5	0.965	21	23	19	2	0.8
08	40	1.5748	80	3.1496	25	0.984	24.5	23	19	2	0.8
32209	45	1.7717	85	3.3465	25	0.984	24.5	23	19	2	0.8
10	50	1.9685	90	3.5433	25	0.984	24.5	23	19	2	0.8
11	55	2.1654	100	3.9370	27	1.063	26.5	25	21	2.5	0.8
32212	60	2.3622	110	4.3307	30	1.181	29.5	28	24	2.5	0.8
13	65	2.5591	120	4.7244	33	1.299	32.5	31	27	2.5	0.8
14	70	2.7559	125	4.9213	33.5	1.319	33	31	27	2.5	0.8
32215	75	2.9528	130	5.1181	33.5	1.319	33	31	27	2.5	0.8
16	80	3.1496	140	5.5118	35.5	1.398	35	33	28	3	1
17	85	3.3465	150	5.9055	39	1.535	38	36	30	3	1
32218	90	3.5433	160	6.2992	43	1.693	42	40	34	3	1
19	95	3.7402	170	6.6929	46	1.811	45	43	37	3.5	1.2
20	100	3.9370	180	7.0866	49.5	1.949	48.5	46	39	3.5	1.2
32221	105	4.1339	190	7.4803	53.5	2.106	52.5	50	43	3.5	1.2
22	110	4.3307	200	7.8740	56.5	2.224	55.5	53	46	3	[illegible]
24	120	4.7244	215	8.4646	62	2.441	61	58	50	3	[illegible]

Bearing Series 3



Follow the directions on pp. 13—24 when determining the bearing

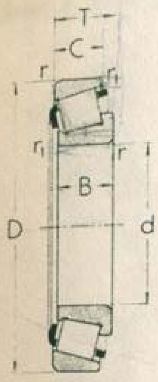
Bearing No.	Basic capacity, lb. Dynamic C	Static C_0	Revolutions per minu[te] 40	63	100	160	250	400	630	1000
			Relative radial capacity							
32206	7200	6100	6800	5850	5000	4300	3650	3150	2700	2320
07	9500	8150	9000	7650	6550	5600	4800	4150	3550	3050
08	10600	9000	10000	8650	7350	6300	5400	4650	4000	3400
32209	11400	10200	10800	9300	8000	6800	5850	5000	4300	3650
10	11600	10600	11000	9500	8150	6950	6000	5100	4400	3750
11	15300	13700	14300	12200	10600	9150	7800	6700	5700	4900
32212	18300	17000	17300	14600	12500	10800	9300	8000	6800	5850
13	22000	20400	20800	18000	15300	12900	11200	9650	8300	7100
14	22400	20400	21200	18300	15600	13200	11400	9800	8500	7200
32215	23600	22400	22400	19300	16600	14000	12000	10400	9000	7650
16	27500	25500	26000	22400	19300	16600	14000	12000	10400	9000
17	31500	30500	30000	25500	22000	19000	16300	13700	11800	10200
32218	37500	36000	35500	30500	26000	22400	19300	16600	14000	12000
19	43000	40500	40500	34500	30000	25500	22000	19000	16300	13700
20	48000	46500	45500	39000	33500	28500	24500	21200	18300	15600
32221	56000	54000	53000	45500	39000	33500	28500	24500	21200	18300
22	63000	61000	60000	51000	44000	37500	32000	27500	23600	20400
24	75000	75000	71000	61000	52000	45000	38000	32500	28000	24000

Specification of Taper Roller Bearing

TAPER ROLLER BEARINGS

Metric Dimension Series 02

Bearing Series 302

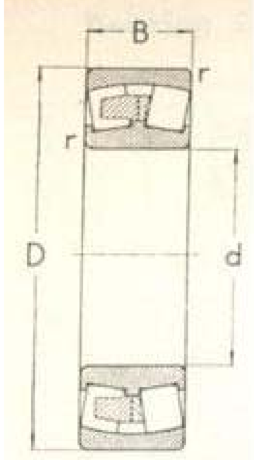


Bearing No.	d mm.	d in.	D mm.	D in.	T max. mm.	T max. in.	T min.	B	C	r ≈	r_1 ≈
							Millimetres				
30203	17	0.6693	40	1.5748	13.5	0.531	13	12	11	1.5	0.5
04	20	0.7874	47	1.8504	15.5	0.610	15	14	12	1.5	0.5
05	25	0.9843	52	2.0472	16.5	0.650	16	15	13	1.5	0.5
30206	30	1.1811	62	2.4409	17.5	0.689	17	16	14	1.5	0.5
07	35	1.3780	72	2.8346	18.5	0.728	18	17	15	2	0.8
08	40	1.5748	80	3.1496	20	0.787	19.5	18	16	2	0.8
30209	45	1.7717	85	3.3465	21	0.827	20.5	19	16	2	0.8
10	50	1.9685	90	3.5433	22	0.866	21.5	20	17	2	0.8
11	55	2.1654	100	3.9370	23	0.906	22.5	21	18	2.5	0.8
30212	60	2.3622	110	4.3307	24	0.945	23.5	22	19	2.5	0.8
13	65	2.5591	120	4.7244	25	0.984	24.5	23	20	2.5	0.8
14	70	2.7559	125	4.9213	26.5	1.043	26	24	21	2.5	0.8
30215	75	2.9528	130	5.1181	27.5	1.083	27	25	22	2.5	0.8
16	80	3.1496	140	5.5118	28.5	1.122	28	26	22	3	1
17	85	3.3465	150	5.9055	31	1.220	30	28	24	3	1
30218	90	3.5433	160	6.2992	33	1.299	32	30	26	3	1
19	95	3.7402	170	6.6929	35	1.378	34	32	27	3.5	1.2
20	100	3.9370	180	7.0866	37.5	1.476	36.5	34	29	3.5	1.2
30221	105	4.1339	190	7.4803	39.5	1.555	38.5	36	30	3.5	1.2
22	110	4.3307	200	7.8740	41.5	1.634	40.5	38	32	3.5	1.2
24	120	4.7244	215	8.4646	44	1.732	43	40	34	3.5	1.2
30226	130	5.1181	230	9.0551	44.5	1.752	43	40	34	4	1.5
28	140	5.5118	250	9.8425	46.5	1.831	45	42	36	4	1.5
30	150	5.9055	270	10.6299	50	1.969	48	45	38	4	1.5

Bearing No.	Basic capacity, lb. Dynamic C	Basic capacity, lb. Static C_0	Revolutions per minute 40	63	100	160	250	400	630	1000	1600
			Relative radial capacity, lb.								
30203	2280	1860	2160	1860	1600	1340	1160	1000	865	735	630
04	3450	2850	3250	2800	2400	2080	1800	1530	1290	1120	965
05	3800	3400	3600	3100	2650	2280	1960	1700	1430	1220	1060
30206	5300	4550	5000	4300	3650	3150	2700	2320	2000	1730	1460
07	6800	5850	6400	5500	4750	4050	3450	3000	2550	2200	1900
08	8000	6800	7500	6400	5500	4750	4050	3450	3000	2550	2200
30209	9150	8000	8650	7350	6300	5400	4650	4000	3400	2900	2500
10	10000	9000	9500	8150	6950	6000	5100	4400	3750	3200	2750
11	12200	11400	11600	10000	8650	7350	6300	5400	4650	4000	3400
30212	13200	12200	12500	10800	9300	8000	6800	5850	5000	4300	3650
13	16000	14300	15000	12700	11000	9500	8150	6950	6000	5100	4400
14	17300	15600	16300	13700	11800	10200	8800	7500	6400	5500	4750
30215	19000	18000	18000	15300	12900	11200	9650	8300	7100	6100	5200
16	21200	19300	20000	17300	14600	12500	10800	9300	8000	6800	5850
17	25000	23200	23600	20400	17600	15000	12700	11000	9500	8150	6950
30218	28000	26500	26500	22800	19600	17000	14300	12200	10600	9150	7800
19	31000	29000	29000	25000	21600	18600	16000	13400	11600	10000	8650
20	35500	34000	33500	28500	24500	21200	18300	15600	13200	11400	9800
30221	40000	36500	37500	32000	27500	23600	20400	17600	15000	12700	11000
22	45000	43000	42500	36000	31000	26500	22800	19600	17000	14300	12200
24	50000	47500	47500	40500	34500	30000	25500	22000	19000	16300	13700
30226	54000	51000	51000	44000	37500	32000	27500	23600	20400	17600	15000
28	63000	62000	60000	51000	44000	37500	32000	27500	23600	20400	17600
30	[illegible]										

Specification of Spherical Roller Bearing

Bearing with cylindrical bore No.	Bearing with taper bore No.	d		D		B		r ≈	Basic capacity, lb.	
		mm.	in.	mm.	in.	mm.	in.	mm.	Dynamic C	Static C_0
22205		25	0.9843	52	2.0472	18	0.7087	1.5	4150	4550
06		30	1.1811	62	2.4409	20	0.7874	1.5	6000	6550
07		35	1.3780	72	2.8346	23	0.9055	2	8150	9000
22208	22208 K	40	1.5748	80	3.1496	23	0.9055	2	8800	9800
09	09 K	45	1.7717	85	3.3465	23	0.9055	2	9500	11000
10	10 K	50	1.9685	90	3.5433	23	0.9055	2	9800	11800
22211	22211 K	55	2.1654	100	3.9370	25	0.9843	2.5	11800	14000
12	12 K	60	2.3622	110	4.3307	28	1.1024	2.5	15000	18300
13	13 K	65	2.5501	120	4.7244	31	1.2205	2.5	18600	22400
22214	22214 K	70	2.7559	125	4.9213	31	1.2205	2.5	19300	23200
15	15 K	75	2.9528	130	5.1181	31	1.2205	2.5	19600	24500
22216	22216 K	80	3.1496	140	5.5118	33	1.2992	3	20800	22400
17	17 K	85	3.3465	150	5.9055	36	1.4173	3	27000	29000
18	18 K	90	3.5433	160	6.2992	40	1.5748	3	34000	34500
22219	22219 K	95	3.7402	170	6.6929	43	1.6929	3.5	40000	41500
20	20 K	100	3.9370	180	7.0866	46	1.8110	3.5	46500	46500
22	22 K	110	4.3307	200	7.8740	53	2.0866	3.5	61000	57000
22224	22224 K	120	4.7244	215	8.4646	58	2.2835	3.5	75000	73500
26	26 K	130	5.1181	230	9.0551	64	2.5197	4	93000	91500
28	28 K	140	5.5118	250	9.8425	68	2.6772	4	106000	104000
22230	22230 K	150	5.9055	270	10.6299	73	2.8740	4	118000	116000
32	32 K	160	6.2992	290	11.4173	80	3.1496	4	143000	143000
34	34 K	170	6.6929	310	12.2047	86	3.3858	5	163000	156000
22236	22236 K	180	7.0866	320	12.5984	86	3.3858	5	166000	170000
38	38 K	190	7.4803	340	13.3858	92	3.6220	5	183000	186000
40	40 K	200	7.8740	360	14.1732	98	3.8583	5	204000	208000
22244										

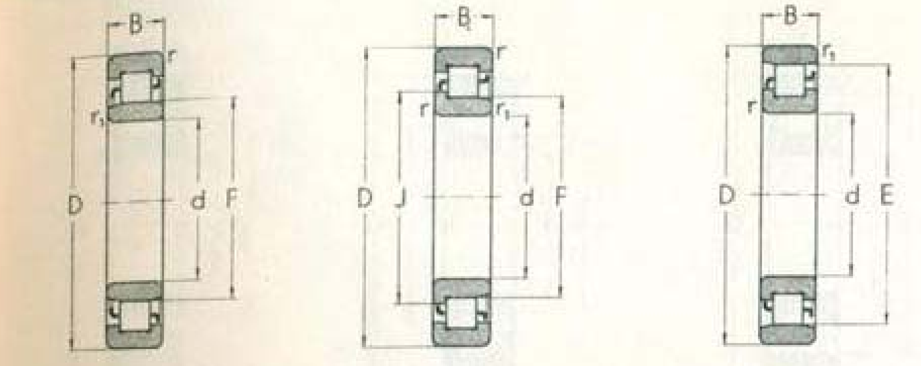


Specification of Cylindrical Roller Bearing

CYLINDRICAL ROLLER BEARINGS

Metric Dimension Series 02

Bearing Series NU 2 | **Bearing Series NJ 2** | **Bearing Series N 2**



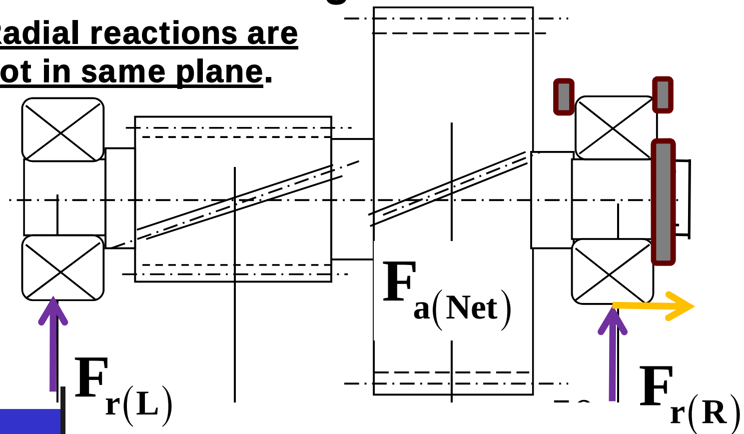
Bearing series NU 2	NJ 2	N 2	d mm.	d in.	D mm.	D in.	B mm.	B in.	E	F	J	r ≈	r_1 ≈
Bearing No.									Millimetres				
NU 204	NJ 204	N 204	20	0.7874	47	1.8504	14	0.5512	40	27	30	1.5	1
205	205	205	25	0.9843	52	2.0472	15	0.5906	45	32	35	1.5	1
206	206	206	30	1.1811	62	2.4409	16	0.6299	53.5	38.5	41.8	1.5	1
NU 207	NJ 207	N 207	35	1.3780	72	2.8346	17	0.6693	61.8	43.8	47.6	2	1
208	208	208	40	1.5748	80	3.1496	18	0.7087	70	50	54.2	2	2
209	209	209	45	1.7717	85	3.3465	19	0.7480	75	55	59	2	2
NU 210	NJ 210	N 210	50	1.9685	90	3.5433	20	0.7874	80.4	60.4	64.6	2	2
211	211	211	55	2.1654	100	3.9370	21	0.8268	88.5	66.5	70.8	2.5	2
212	212	212	60	2.3622	110	4.3307	22	0.8661	97.5	73.5	78.4	2.5	2.5
NU 213	NJ 213	N 213	65	2.5591	120	4.7244	23	0.9055	105.6	79.6	84.8	2.5	2.5
214	214	214	70	2.7559	125	4.9213	24	0.9449	110.5	84.5	89.6	2.5	2.5
215	215	215	75	2.9528	130	5.1181	25	0.9843	116.5	88.5	94	2.5	2.5
NU 216	NJ 216	N 216	80	3.1496	140	5.5118	26	1.0236	125.3	95.3	101.2	3	3
217	217	217	85	3.3465	150	5.9055	28	1.1024	133.8	101.8	108.2	3	3
218	218	218	90	3.5433	160	6.2992	30	1.1811	143	107	114.2	3	3
NU 219	NJ 219	N 219	95	3.7402	170	6.6929	32	1.2598	151.5	113.5	121	3.5	3.5
220	220	220	100	3.9370	180	7.0866	34	1.3386	160	120	128	3.5	3.5
221	221	221	105	4.1339	190	7.4803	36	1.4173	168.8	126.8	135	3.5	3.5
NU 222	NJ 222	N 222	110	4.3307	200	7.8740	38	1.4961	178.5	132.5	141.5	3.5	3.5
224	224	224	120	4.7244	215	8.4646	40	1.5748	191.5	143.5	153	3.5	3.5
226	226	N 226	130	5.1181	230	9.0551	40	1.5748	204	156	165.5	4	4
NU 228													

Bearing No. NU NJ N	Basic capacity, lb. Dynamic C	Basic capacity, lb. Static C_0	Revolutions 100	160	250	400	630	1000
			Relative radial					
204	2160	1530	1500	1270	1100	950	815	695
205	2400	1860	1700	1430	1220	1060	915	780
206	3200	2550	2240	1930	1660	1400	1200	1040
207	4650	3650	3200	2750	2360	2040	1760	1500
208	6100	5100	4250	3600	3100	2650	2280	1960
209	6400	5500	4500	3800	3250	2800	2400	2080
210	6700	6000	4650	4000	3400	2900	2500	2160
211	8150	7200	5600	4800	4150	3550	3050	2600
212	9650	8800	6700	5700	4900	4250	3600	3100
213	11200	10400	7800	6700	5700	4900	4250	3600
214	11600	11000	8150	6950	6000	5100	4400	3750
215	13400	12700	9500	8150	6950	6000	5100	4400
216	15600	15000	10800	9300	8000	6800	5850	5000
217	18000	17300	12200	10600	9150	7800	6700	5700
218	21600	20400	15000	12700	11000	9500	8150	6950
219	25000	24000	17600	15000	12700	11000	9500	8150
220	28000	27000	19600	17000	14300	12200	10600	9150
221	31000	30500	21600	18600	16000	13400	11600	10000
222	35500	33500	24500	21200	18300	15600	13200	11400
224	40000	39000	27500	23600	20400	17600	15000	12700
226	41500	41500	28500	24500	21200	18300	15600	13200
228	49000	49000	34000	29000	25000	21600	18600	16000
230	60000	68000	41500	35500	30500	26000	22400	19300
232	69000	71000	47500	40500	34500	30000	25500	22000
234	78000	81500	54000	46500	40000	34000	29000	25000

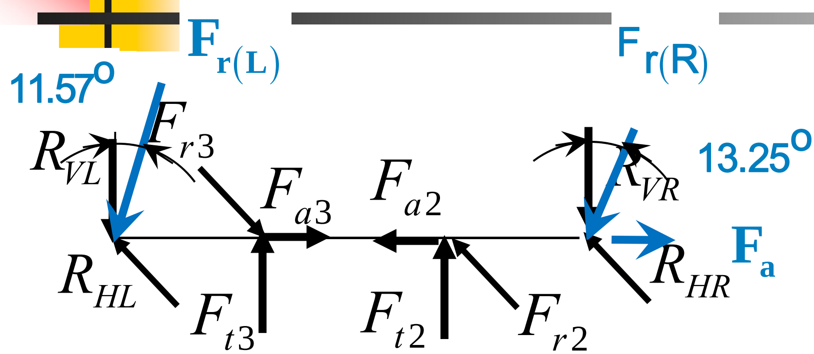
Bearing Life Estimation (Contd...)

The Final bearing reactions:

Radial reactions are not in same plane.



Bearing Reactions (& Locking)



F_{t3} = 4533 N F_{r3} =1683 N F_{a3} = 914 N

F_{t2} = 1193.5 N F_{r2} =443 N F_{a2} = 240.65 N

R_{HL} = 720.6 N R_{VL} = 3518.5 N

R_{HR} = 520 N R_{VR} =2208 N

Details of loading & Resultant bearing Reactions.

From details of loading resultant right bearing (radial) reaction is calculated as:

$$\mathbf{F}_{\mathbf{r(R)}} = \sqrt{R_{VR}^2 + R_{HR}^2} = \sqrt{2208^2 + 520^2}$$

$$= 2268.4\,\mathrm{N}$$

It is acting at an angle θ_R with vertical plane, derived as $\theta_R = \tan^{-1}\left(R_{HR}/R_{VR}\right) = 13.25^{\circ}$.

Similarly, $\mathbf{F}_{\mathbf{r(L)}} = \sqrt{R_{VL}^2 + R_{HL}^2} = \sqrt{3518.5^2 + 720.6^2}$

$$= 3591.5\,\mathrm{N}$$

and, $\theta_L = \tan^{-1}\left(R_{HL}/R_{VL}\right) = 11.57^{\circ}$

Resultant axial load may act only on one bearing irrespective of its direction (i.e., direction of shaft rotation).

It depends on bearing locking arrangement.

In this case it is on right bearing which is with less radial load.

Net axial load $\mathbf{F}_{\mathbf{a(Net)}} = \mathbf{F}_{\mathbf{a}} = F_{a3} - F_{a2}$

$$= 673.35\ \mathrm{N}$$

6th. Step Shaft Design

Bending moment on Intermediate Shaft due to Tangential Forces (Vertical Plane)

In case of gear box the diameters of a shaft is dominated by the size (root diameter) of the integral pinion and optimum bearing size mainly.

The length is determined by the placement of gear, pinion, bearings, coupling, key size, seals etc. and the optimum gap required between two consecutive elements.

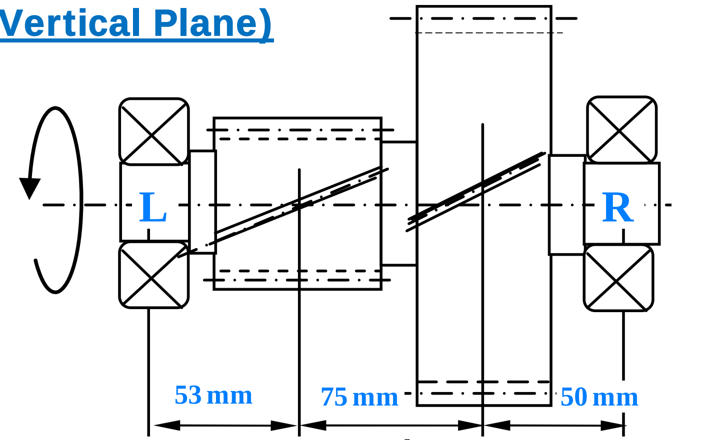
The a shaft is automatically shaped during first layout and bearing selection, as shown earlier.

Therefore, instead of designing the shaft the critical sections are verified for developed stresses.

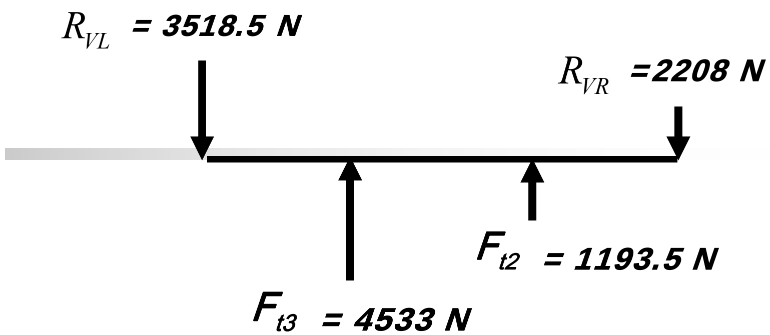
Bending Moment (respective plane) Calculation

$$BM_{P3V} = -3518.5 \times 0.053 = -186.5\ \text{Nm}$$

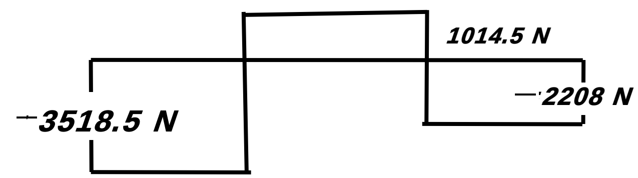
$$BM_{G2V} = -3518.5 \times 0.128 + 4533 \times 0.075 = -110.4\ \text{Nm}$$



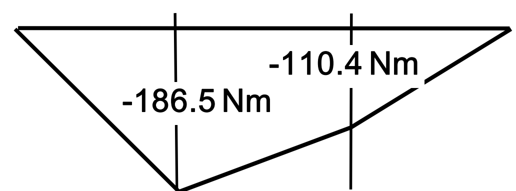
Layout



Load Diagram.



Shear Force Diagram (SFD).



Bending Moment Diagram (BMD)

Shaft Design (Contd...)

Bending moment on Intermediate Shaft due to Tangential Forces (Horizontal Plane)

Bending Moment (respective plane) Calculation (Contd...)

Considering from left support Bending Moment just left of section 3-3:

$$BM_{P3H-} = 720 \times 0.053 = 38.2 \text{ Nm}$$

And just right of section 3-3:

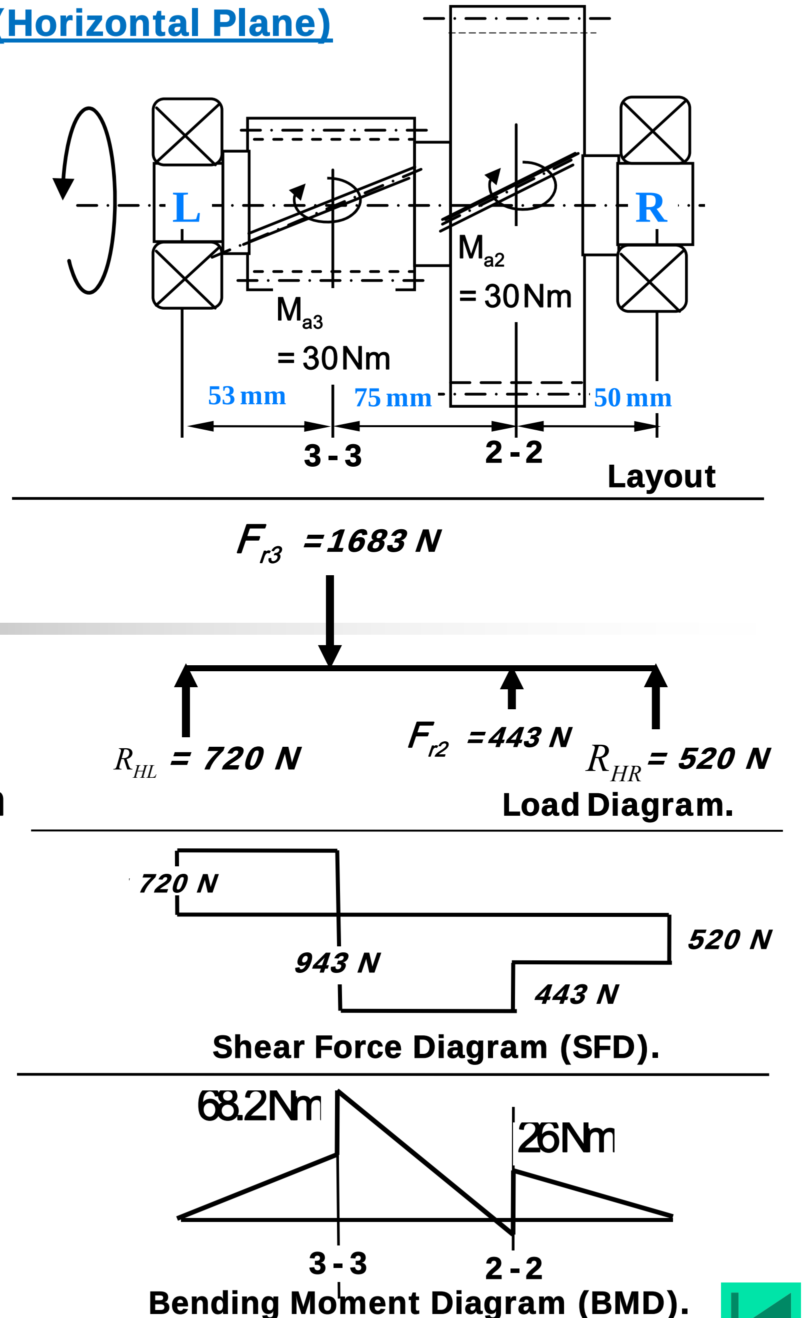
$$BM_{P3H+} = 38.2 + 30 = 68.2 \text{ Nm}$$

Similarly, BM just left of section 2-2:

$$BM_{G2H-} = 720 \times 0.128 - 1683 \times 0.075 + 30 = -4 \text{ Nm}$$

And BM just right of section 2-2:

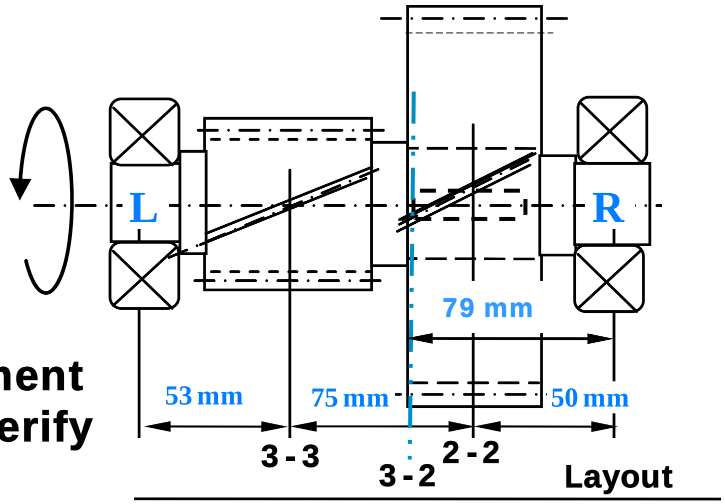
$$BM_{G2H+} = -4.1 + 30 = 26 \text{ Nm}$$



6th. Step (Contd….) Shaft Design

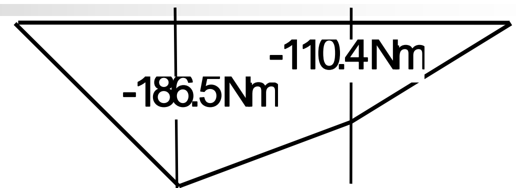
Second Step: Resultant Bending Moment and Critical Section

It is to be noted that in a rotating shaft outer layer experiences maximum flexural bending stress.

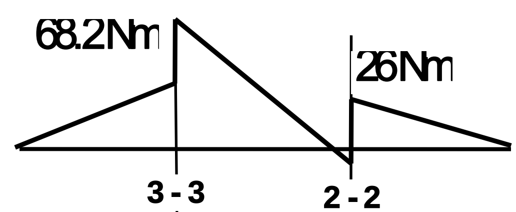


As bending stress is expressed by bending moment divided by section modulus, it is necessary to verify those for probable critical sections.

In the Intermediate shaft, any of sections 2-2, 3-2 & 3-3 may be critical i.e., experiences maximum bending stress.



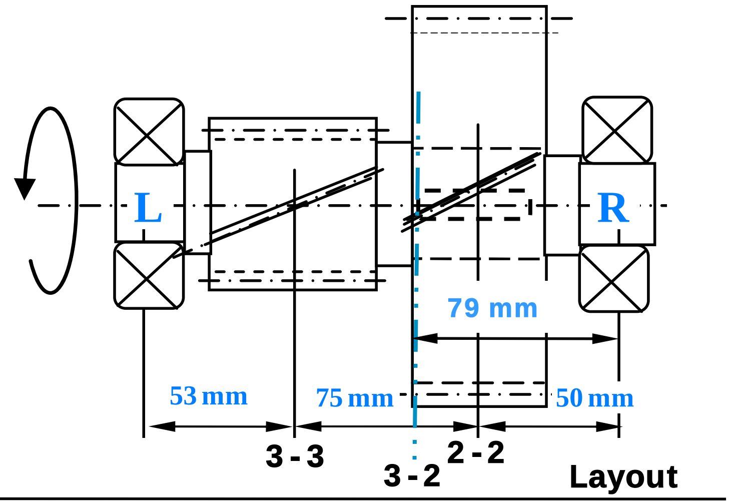
Bending Moment-Vertical Plane.



Bending Moment-Horizontal Plane.

6th. Step (Contd….) Shaft Design

Next: Resultant Bending Moment and Critical Section (Contd…)



Reasons are as follows:

Among these three sections, through which full torque transmits, section 3-3 has maximum bending moment, although it has also the maximum diameter.

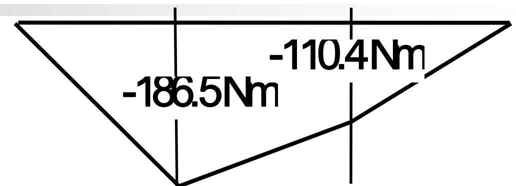
It has medium stress concentration as it is roots of teeth.

Sections 2-2 & 3-2 have equal diameters but different stress concentration factors.

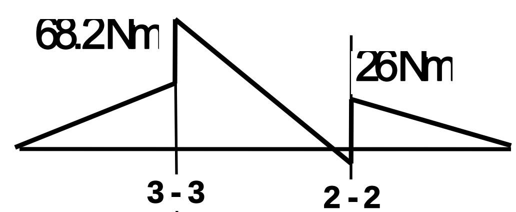
At section 3-2 there is step, where as at section 2-2 a there is keyway.

Therefore, section 2-2 may be severe than section 3-2 in stress concentration point of view.

Again 2-2 usually experiences less BM.



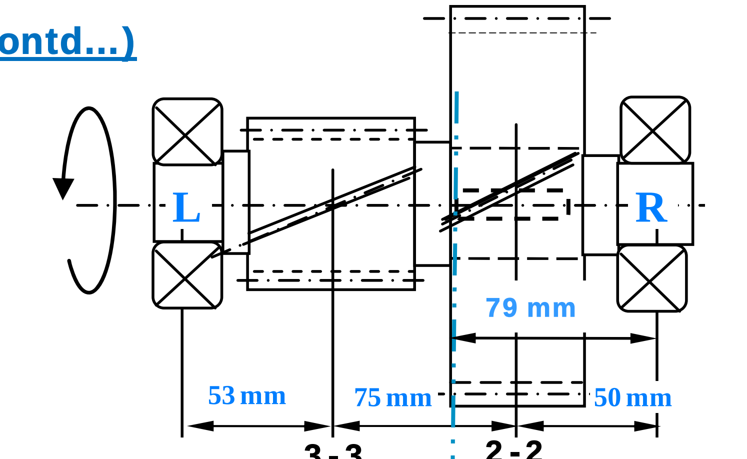
Bending Moment-Vertical Plane.



Bending Moment-Horizontal Plane.

6th. Step (Contd….) Shaft Design

Resultant Bending Moment and Critical Section (Contd...)



Layout

Resultant bending moment at 3-3:

$$BM_{R\,(3\text{-}3)} = \sqrt{68.2^2 + 186.5^2} = 198.6\ \text{Nm}$$

Resultant bending moment at 2-2:

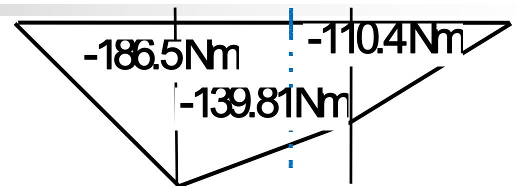
$$BM_{R\,(2\text{-}2)} = \sqrt{26^2 + 110.4^2} = 113.42\ \text{Nm}$$

Resultant bending moment at 3-2 is estimated as follows:

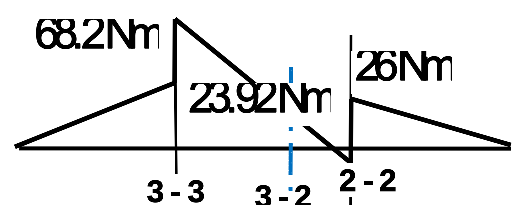
$$BM_{V\,(3\text{-}2)} = 3518.5 \times 0.099 - 4533 \times 0.046 = 139.81\ \text{Nm}$$

$$BM_{H\,(3\text{-}2)} = 720.6 \times 0.099 + 30 - 1683 \times 0.046 = 23.92\ \text{Nm}$$

$$BM_{R\,(3\text{-}2)} = \sqrt{23.92^2 + 139.81^2} = 141.84\ \text{Nm}$$



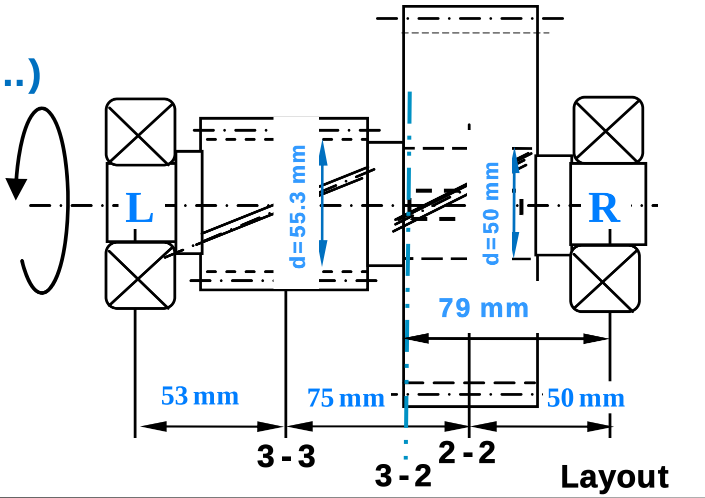
Bending Moment-Vertical Plane.



Bending Moment-Horizontal Plane.

6th. Step (Contd....) Shaft Design

Bending Stress and search for Critical Section (Contd...)

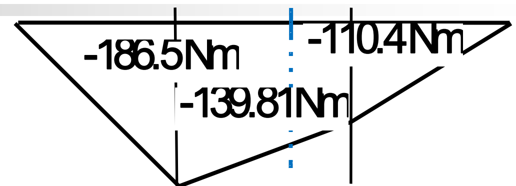


Maximum bending stress in any section of rotating shaft (solid):

$$\sigma_b = f_c \frac{My}{I} = f_c \frac{32M}{\pi d^3}$$

(Section modulus $\frac{I}{y} = \frac{\pi d^4 / 64}{d/2}$ **and**

f_c **stress concentration factor).**

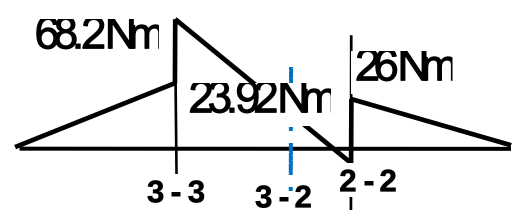


Bending Moment-Vertical Plane.

Maximum bending stress at section 3-3:

$$\sigma_{b\ (3\text{-}3)} = \frac{1.5 \times 32 \times 198.6}{\pi \times 0.0553^3} = 18 \times 10^6 \text{ Pas}$$

f_c **is taken 1.5 for hob cut gear.**



Bending Moment-Horizontal Plane.

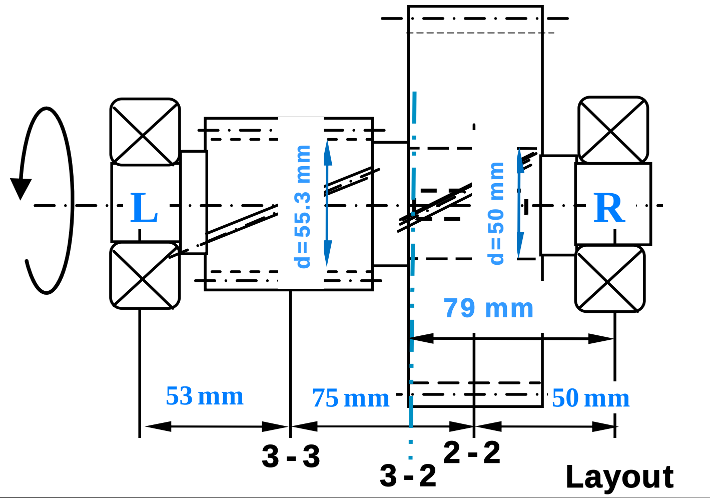
6th. Step (Contd….) Shaft Design

Bending Stress and search for Critical Section (Contd…)

Maximum bending stress at section 3-2:

$$\sigma_b(3\text{-}2) = \frac{1.5 \times 32 \times 141.84}{\pi \times 0.05^3} = 17.34 \times 10^6 \text{ Pas}$$

f_c **is taken 1.5 for well designed step.**

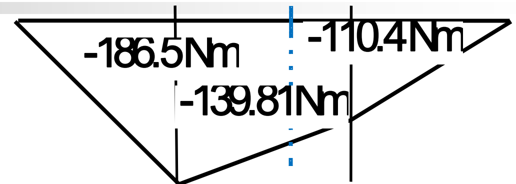


Layout

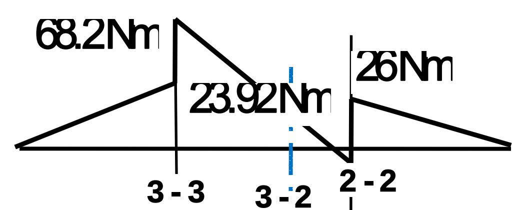
Maximum bending stress at section 2-2:

$$\sigma_b(2\text{-}2) = \frac{2 \times 32 \times 113.42}{\pi \times 0.05^3} = 18.5 \times 10^6 \text{ Pas}$$

f_c **is taken 2 for milled keyway.**



Bending Moment-Vertical Plane.



Bending Moment-Horizontal Plane.

It is apparent that section 2-2 is critical.

6th. Step (Contd….) Shaft Design

Lastly: Verification of Overall factor of safety at Critical Section

As already mentioned earlier, in gear unit design the size of the gear shaft usually biased by the sizes of gears, bearing layout and centre distances.

Particularly in case of shaft integral with the pinion there is little scope of pre-designing the shaft.

In such cases maximum stresses in the shaft are estimated identifying critical sections.

Then a *factor of safety* f_s can be estimated using the following formula, which is base on maximum shear stress theory under combined, bending, torsion and direct normal stresses.

$$\frac{S_y}{f_s} = \sqrt{\left(\sigma_m + k_f \frac{S_y}{S_{en}} \sigma_a\right)^2 + 4\tau_m^2}$$

Where,

S_y = **Yield strength of shaft material**

S_{en} = **Endurance strength of shaft material**

σ_m = **Mean (average) stress at considered section due to axial load.**

σ_a = **Maximum alternating stress at considered section due to bending.**

τ_m = **Maximum shear stress at considered section due to torsion.**

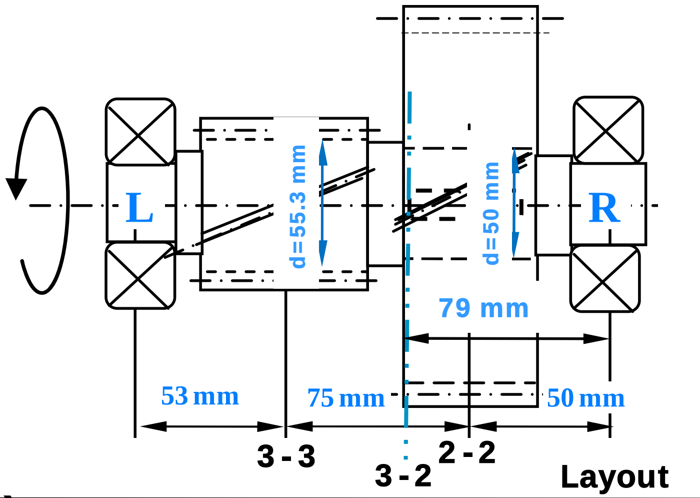
k_f = **A factor considering the feature of section and severity of service. It is chosen considering on what basis σ_a has been calculated.**

6th. Step (Contd….) Shaft Design

Verification of Overall factor of safety at Critical Section (Contd…)

In present design, the pinion is integral with shaft therefore shaft material is EN19A.

Therefore, for the critical section 2-2:

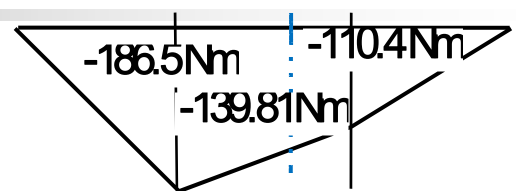


S_y **= 600 MPa,**

S_{en} **= 420 MPa (About 45% of S_u for well finished / ground shaft),**

$$\sigma_m = f_c \frac{F_a}{\pi d^2} = 2 \times \frac{673.5}{\pi \times 0.05^2}$$

$$= 0.172 \times 10^6 \text{ Pas}$$

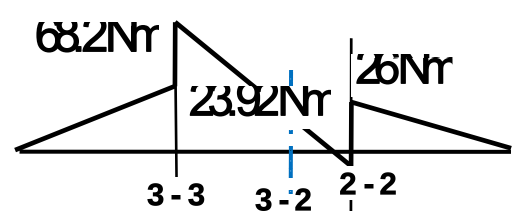


Bending Moment-Vertical Plane.

$$\sigma_a = \sigma_{b\ (3\text{-}2)} = 18.5 \times 10^6 \text{ Pas}$$

$$\tau_m = f_c \frac{16T}{\pi d^3} = 2 \times \frac{16 \times 148}{\pi \times 0.05^3}$$

$$= 12.1 \times 10^6 \text{ Pas}$$



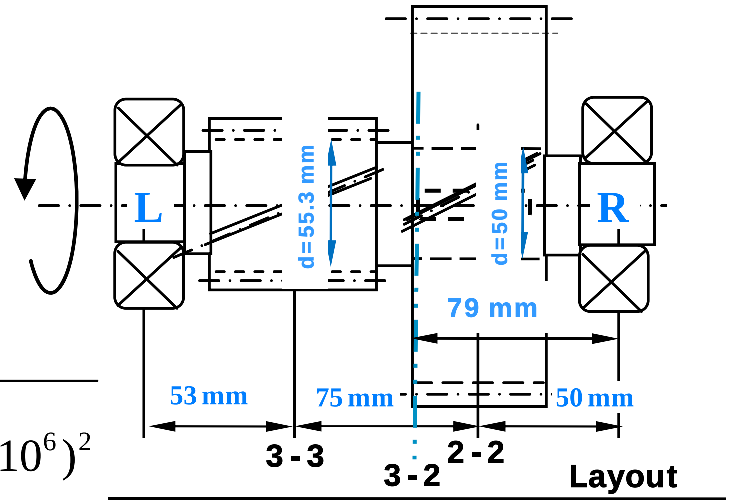
Bending Moment-Horizontal Plane.

f_c **is taken 2 in general for milled single keyway.**

6th. Step (Contd....) Shaft Design

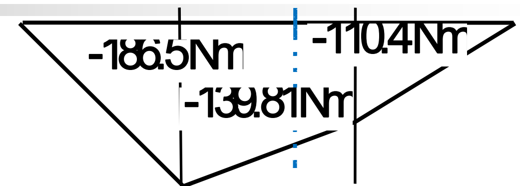
Verification of Overall factor of safety at Critical Section (Contd...)

Substituting values f_S for the critical section 2-2 is calculated as follows:



$$\frac{600\times10^6}{f_s}=\sqrt{\left[\left(0.172+1.5\times\frac{600}{420}\times18.5\right)\times10^6\right]^2+4\times(12.1\times10^6)^2}$$

$$=46.6\times10^6$$

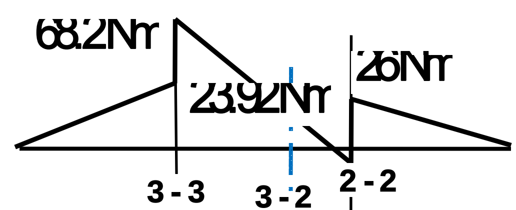


Bending Moment-Vertical Plane.

Therefore,

$$f_s=\frac{600}{46.6}=12.87$$

This is highly satisfactory.



Bending Moment-Horizontal Plane.

Usually f_s is taken as 2.5 to 3.

6th. Step (Contd....) Shaft Design

Input Shaft

The Input Shaft is also integral with the 1st. stage pinion.

Therefore, the material is EN19A.

Shaft design verification is done in same way as it is done for intermediate shaft.

Output Shaft

The Output Shaft ***not integral*** with the gear.

Therefore, medium carbon steel (C40 or C45, Equivalent to EN8), having ultimate strength- 560 MPa and yield strength- 280 Mpa, is taken as the material.

The Shaft diameter is initially estimated on transmitted torque as follows:

$$d_o = \sqrt[3]{\frac{16T_o}{\pi S_{sa}}}$$

In the present design considering a factor of 1.5 with nominal torque the Output torque:

$$T_o = 1.5 \times 31 \times 39.1 = 1818\ \text{Nm}$$

Considering allowable shear stress (S_{sa}) of material is 60 MPa.

Nominal $d_o = 53.65\ \text{mm}$

Considering the end bearings of ID 55 mm (Say SKF Ball Bearing 6311) Shaft design verification is done same way as is done for intermediate shaft.

Design of a Bevel- Helical Two Stage Gear Box:

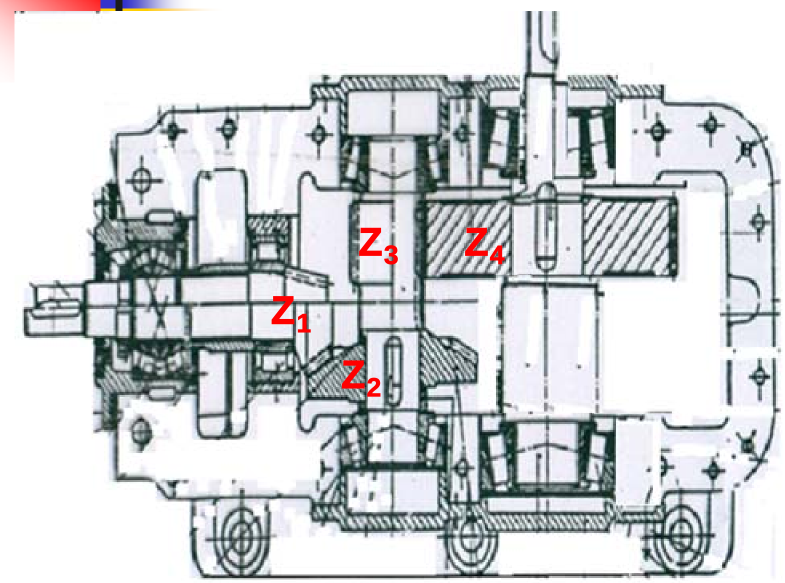
IMPORTANT:

Complete the Gear Design, Bearing Selection and Shaft design part

and

Complete the full plan view as shown below-

By 14 April, 2017



Assembled plan view
(Not of the same one as below)

IMPORTANT:

Drawing is Individual Task.

Use Full sheet.

Scale may be 1:1 or 1:2 or 1:2.5

Plan the layout to accommodate

Plan, elevation and side views in single side of the drawing sheet.

A Compensatory class will be held on 15_04_2017 (Saturday) 8:00 am to 11:00 am In MED Drawing Hall

The class test and viva will be held on

17-04-2017 (Monday)

of 2-stage (Bevel-Helical) gear box.
(Top cover open)

Thank you