

Module-05

Design of a General Purpose Industrial Helical Gear Reduction Unit- Part III

Lecture-21

Development (Layout) of Input Shaft & Integral Pinion

Outline of the Lecture

- **Design Problem, Gear Data & Dimensions**
 - **1st. Layout (Recapitulation)**
 - **Development Drawing of Input Pinion (Integral with Shaft)**
- **Bearing Dimensions for Initial Choice of Bearing**
 - **Development of Pinion End Side Shaft & Bearing Placement**
- **Pinion End Bearing Locking Arrangement- use of Circlip**
 - **Development of Input Side Shaft & Bearing Placement**
 - **Step of Input Side Shaft for Oil Seal**
 - **Development of Input End of Shaft**
- **Probable Bearing Locking Arrangement with housing**
 - **Load Centers on Input Shaft.**

Dimensions of Gears and Gear Data Table : (Recapitulation):

The Gear Unit design problem is same as already considered. All data remain same except the Second stage reduction ratio is reduced to 5.125. Overall transmission ratio is now 24.42.

Sl. No.	Description	1 st . Stage		2 nd . Stage	
		Pinion	Gear	Pinion	Gear
1.	Number of Teeth (Z)	17	81	16	82
2.	Tooth Profile	20° Full Depth Involute, Uncorrected			
3.	Normal Module (m_n)	3 mm		4 mm	
4.	Helix Angle (β) and Direction of Helix	11°28'42"		11°28'42"	
		RH	LH	LH	RH
5.	Addendum Height, ($a_f \times m_n = 1 \times m_n$)	3 mm		4 mm	
6.	Dedendum Height, ($d_f \times m_n = 1.25 \times m_n$)	3.75 mm		5 mm	

Dimensions of Gears and Gear data Table : (Recapitulation):

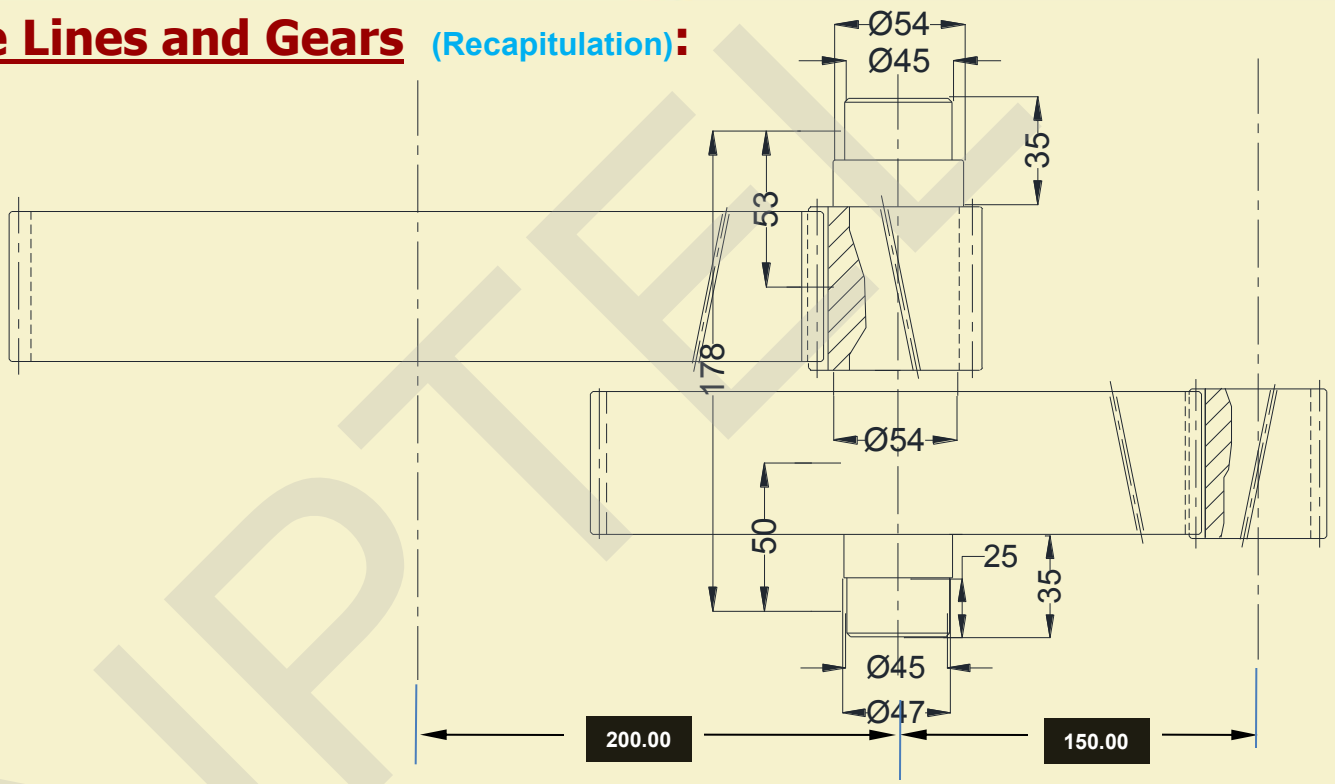
Sl. No.	Description	1 st . Stage		2 nd . Stage	
		Pinion	Gear	Pinion	Gear
7.	Pitch Circle Diameter (mm)	52.04	247.96	65.306	334.694
8.	Centre Distance (mm)	150		200	
9.	Addendum or Tip Circle Diameter (mm)	58.04	253.96	73.306	342.694
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694
11.	Face width (b)	63 mm	58 mm	68 mm	63 mm
12.	Material	EN 19A	EN 18A	EN 19A	EN 18A
13.	Hardness , Through Hardened (BHN)	350	300	350	300

1st. Layout- Centre Lines and Gears (Recapitulation):

**Centre Lines &
All pinion & Gears
Intermediate shaft
Between Pinion
and Gear**

1st. Stage Gear End

2nd. Stage Pinion End



Sl. No.	Description	1 st . Stage		2 nd . Stage	
		Pinion	Gear	Pinion	Gear
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

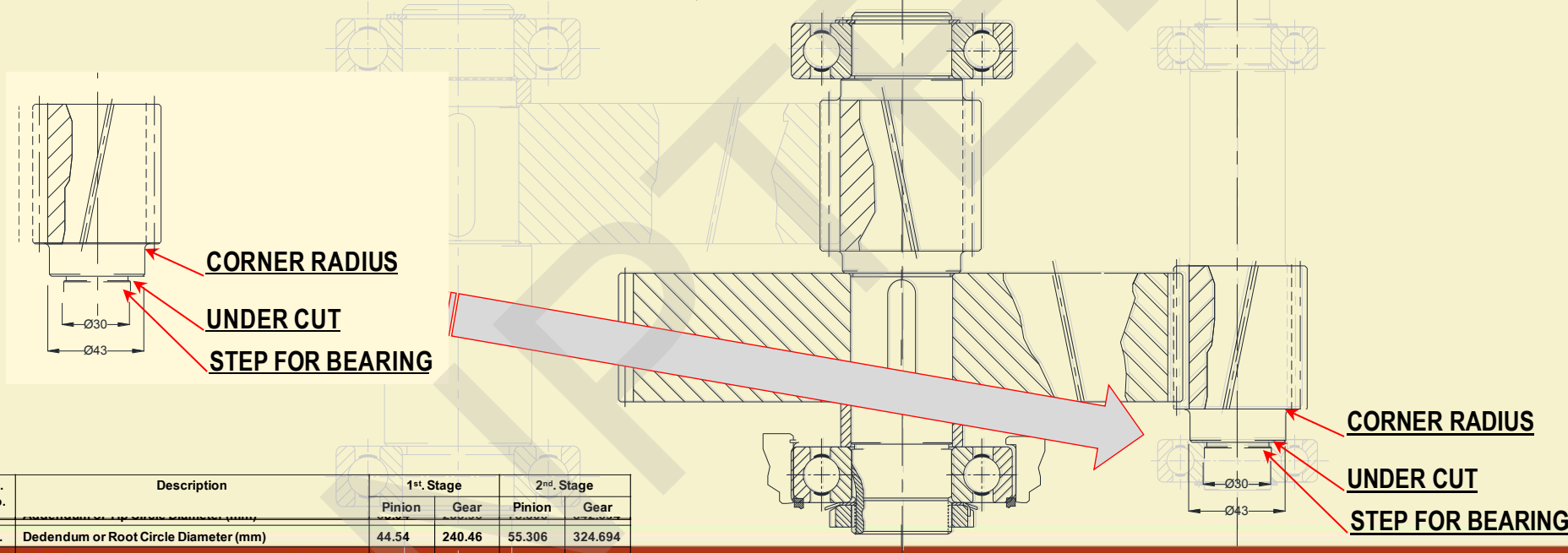
Development of Input Shaft :

Details of Integral Pinion End :

Step Adjacent to Pinion

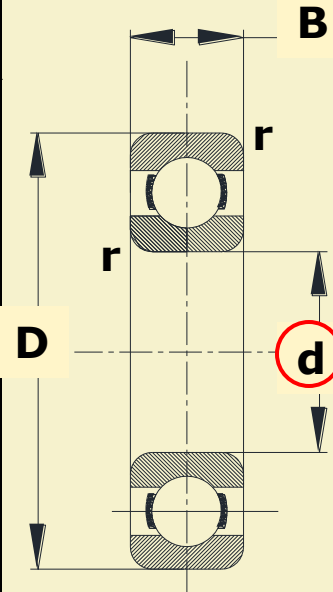
Input Shaft Material - EN 19 (40Cr4Mo3) having $S_u = 940MPa$ and $S_y = 600MPa$ (at BHN 350).

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED



Ball Bearing Data (SKF) & BEARING Choice :

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	1.3870	11	0.4331	1	1430	800
01	12	0.4724	37	1.4567	12	0.4724	1.5	1760	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	2.5346	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

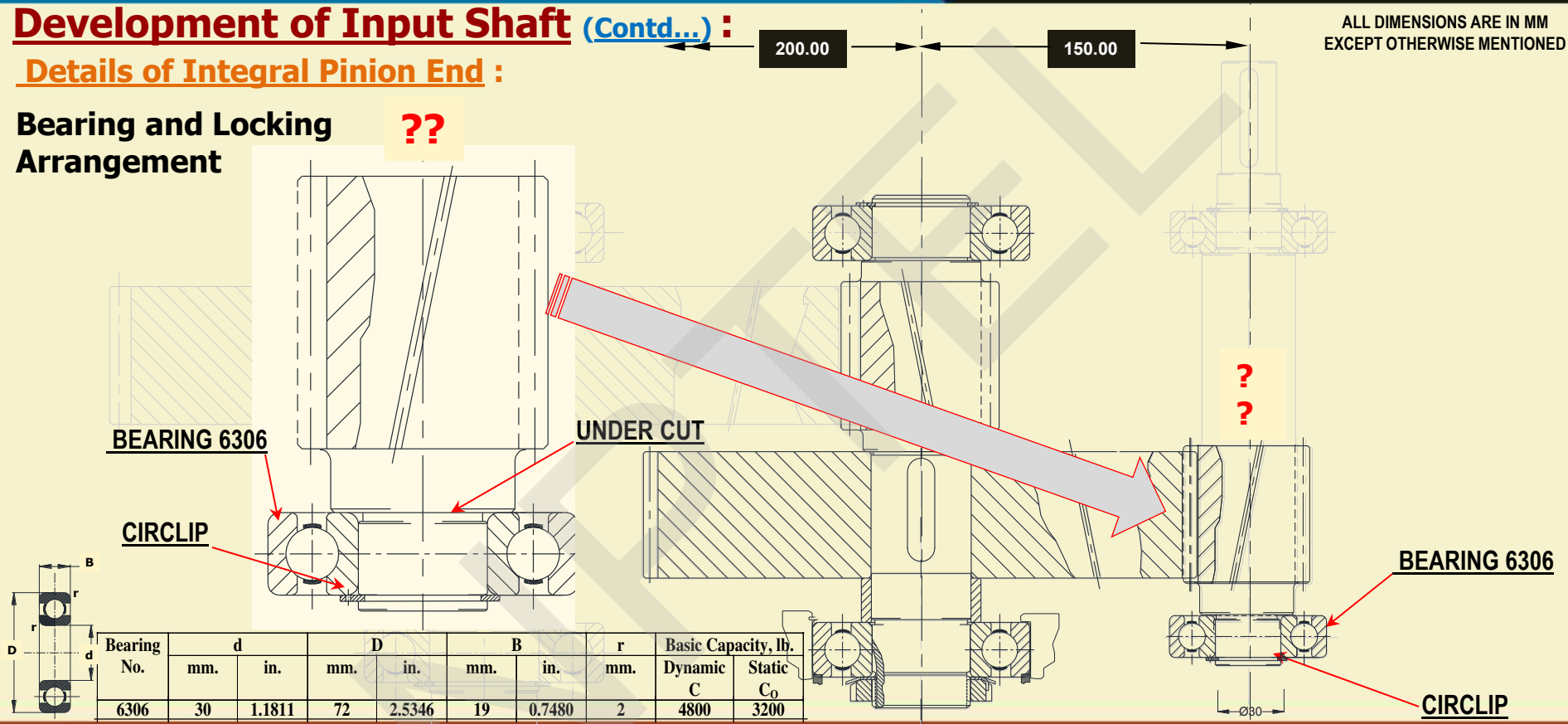


Development of Input Shaft (Contd...) :

Details of Integral Pinion End :

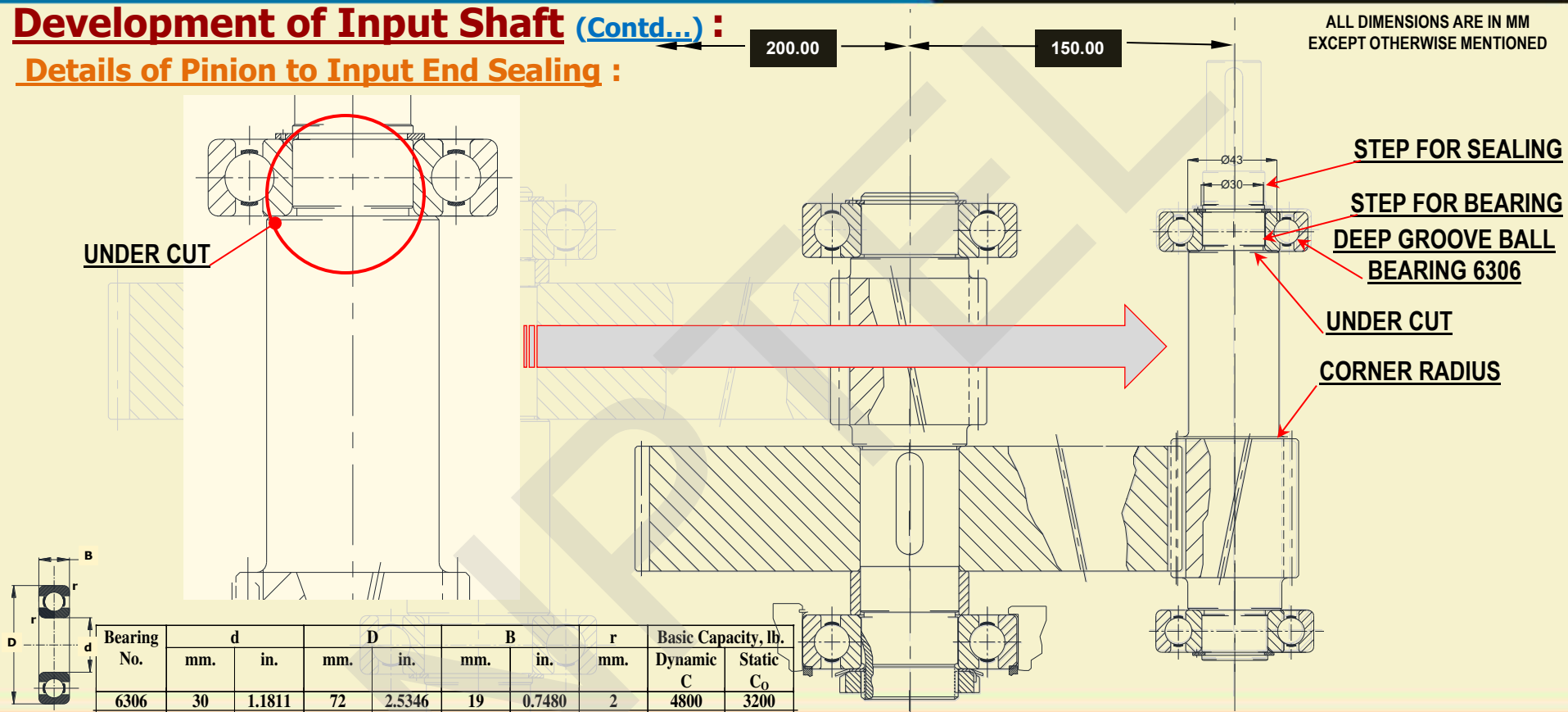
Bearing and Locking Arrangement ??

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EXCEPT OTHERWISE MENTIONED

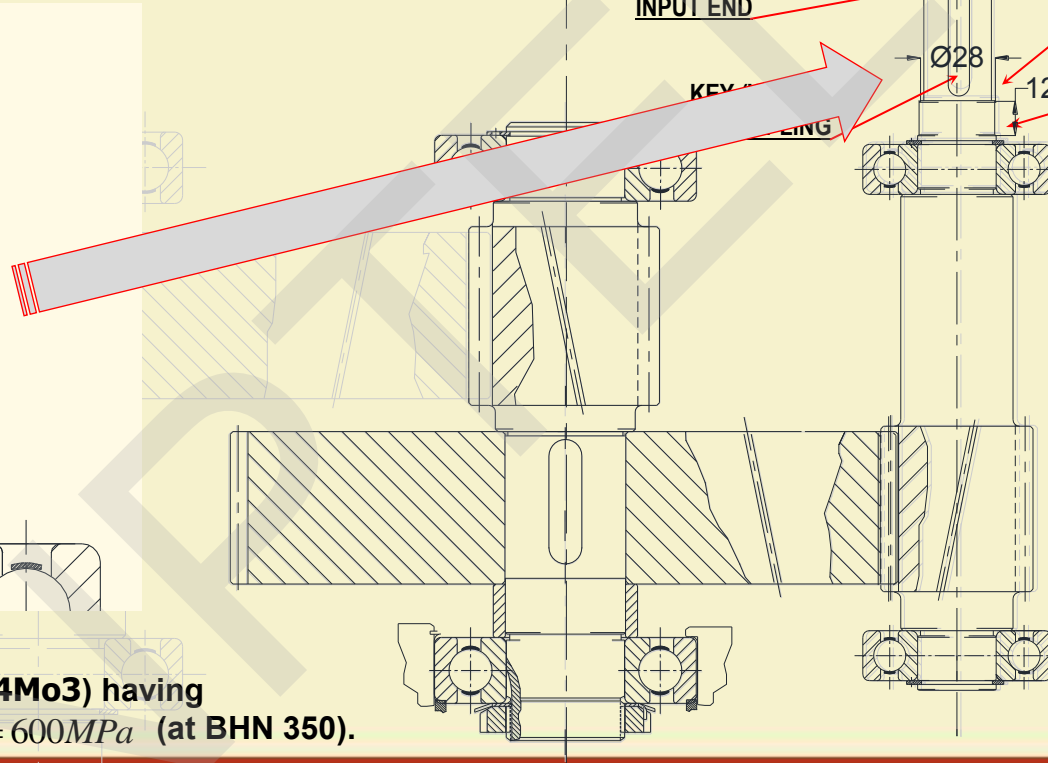


Development of Input Shaft (Contd...) :

Details of Pinion to Input End Sealing :



Details of Input End :



**ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED**

INPUT END

STEP FOR OIL SEAL

CIRCLIP

12.50

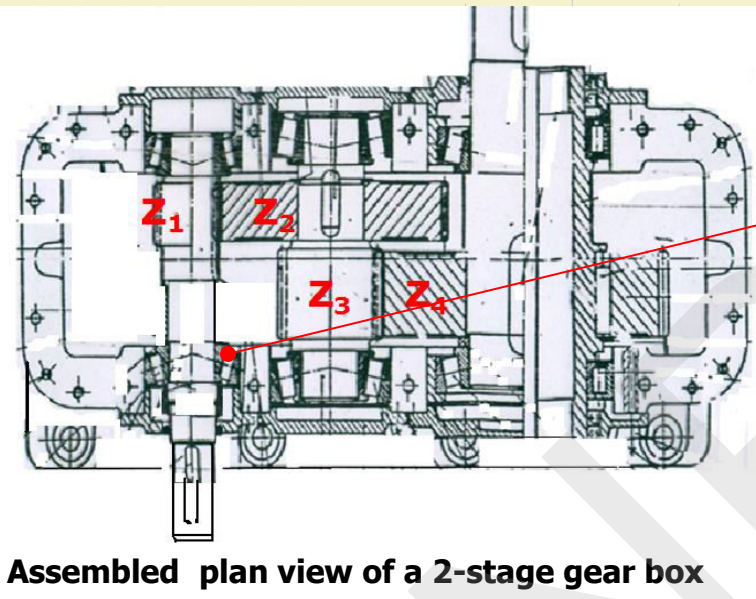
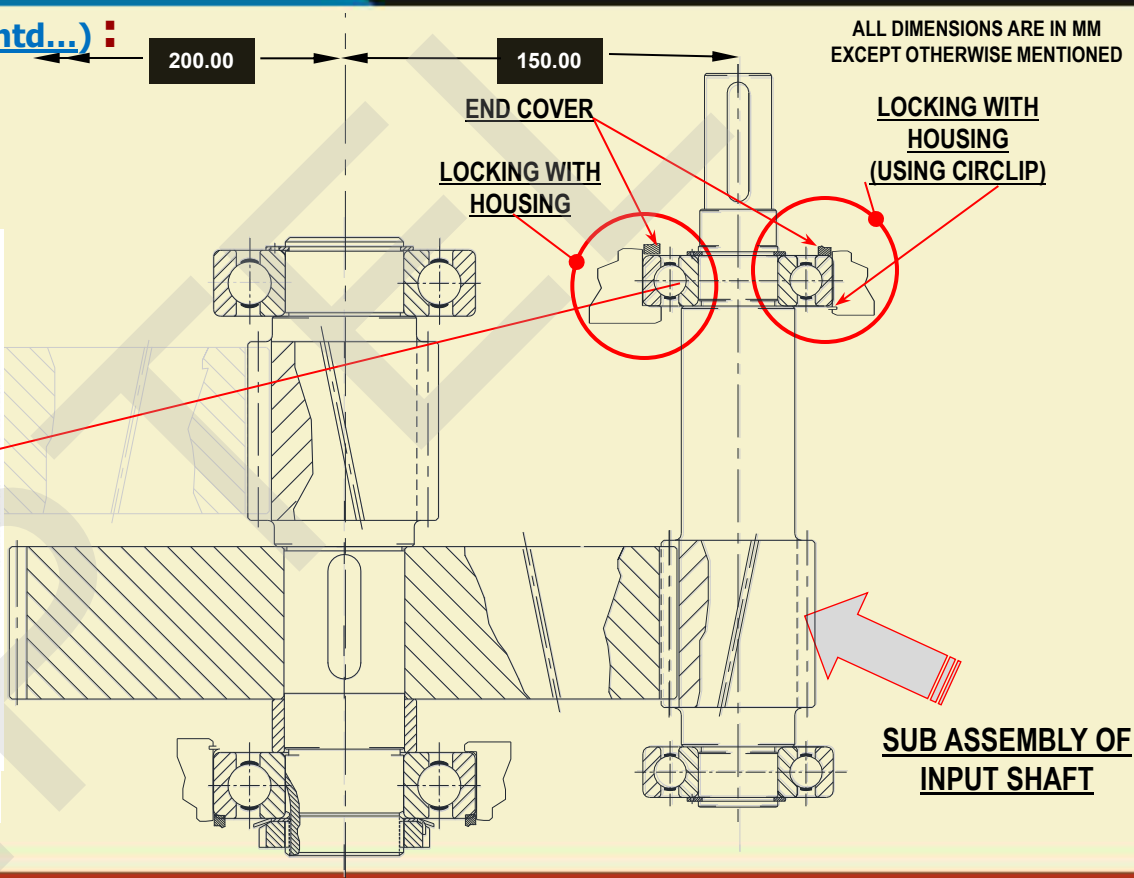
KEY

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Development of Input Shaft (Contd...) :

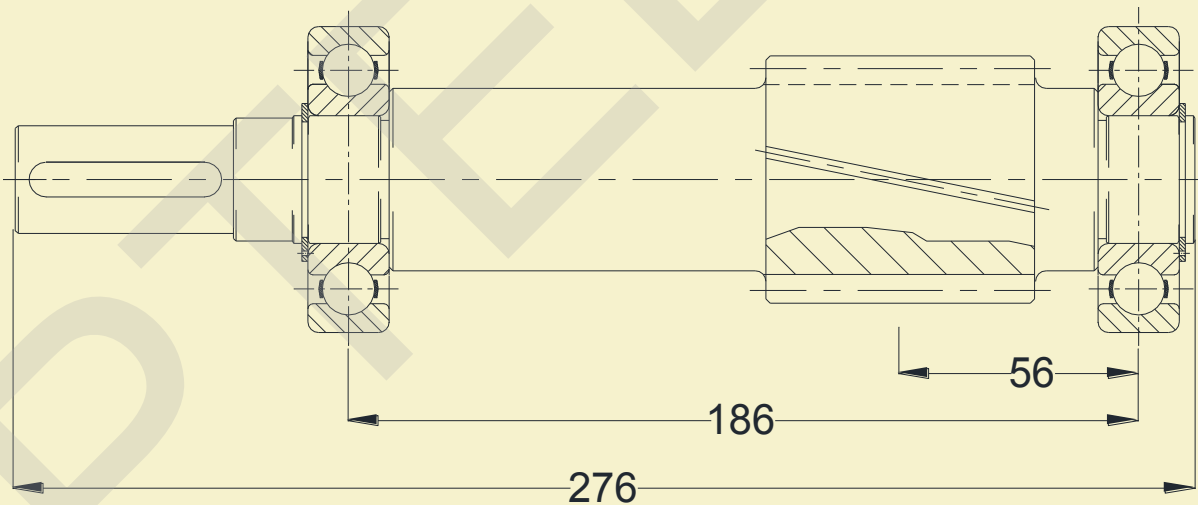
Bearing Locking with Housing :

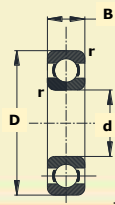


Development of Input Shaft (Contd...) :

Load Centres on Input Shaft :

Sl. No.	Description	1 st . Stage	
		Pinion	Gear
1.	Number of Teeth (Z)	17	81
2.	Tooth Profile	20° Full Depth Inv	
3.	Normal Module (m_n)	3 mm	
4.	Helix Angle (β) and Direction of Helix	11°28'42"	
		RH	LH
5.	Addendum Height, ($a_f \times m_n = 1 \times m_n$)	3 mm	
6.	Dedendum Height, ($d_f \times m_n = 1.25 \times m_n$)	3.75 mm	
7.	Pitch Circle Diameter (mm)	52.04	247.96
8.	Centre Distance (mm)	150	
9.	Addendum or Tip Circle Diameter (mm)	58.04	253.96
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46
11.	Face width (b)	63 mm	58 mm
12.	Material	EN 19A	EN 18A
13.	Hardness , Through Hardened (BHN)	350	300



	Bearing No.	d		D		B		r	Basic Capacity, lb.	
		mm.	in.	mm.	in.	mm.	in.	mm.	Dynamic C	Static C ₀
	6306	30	1.1811	72	2.5346	19	0.7480	2	4800	3200

SUB ASSEMBLY OF INPUT SHAFT

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Thank You



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Module-05

Design of a General Purpose Industrial Helical Gear Reduction Unit- Part III

Lecture-22

Development (Layout) of Output Shaft and 2nd. Stage (Output) Gear



Outline of the Lecture

- **Design Problem, Gear Data & Dimensions**
 - **1st. Layout (Recapitulation)**
- **Input Pinion, Integral with Shaft & Intermediate Shaft Layout (Recapitulation)**
 - **Output Shaft Material & Size Estimation**
 - **Development of Gear Side (Output) Shaft**
 - **Choice of Bearing**
 - **Placement of Key, Output Gear & Spacer**
 - **Gear End Bearing, Locking Arrangement- use of Circlip**

Dimensions of Gears and Gear Data Table :

(Recapitulation):

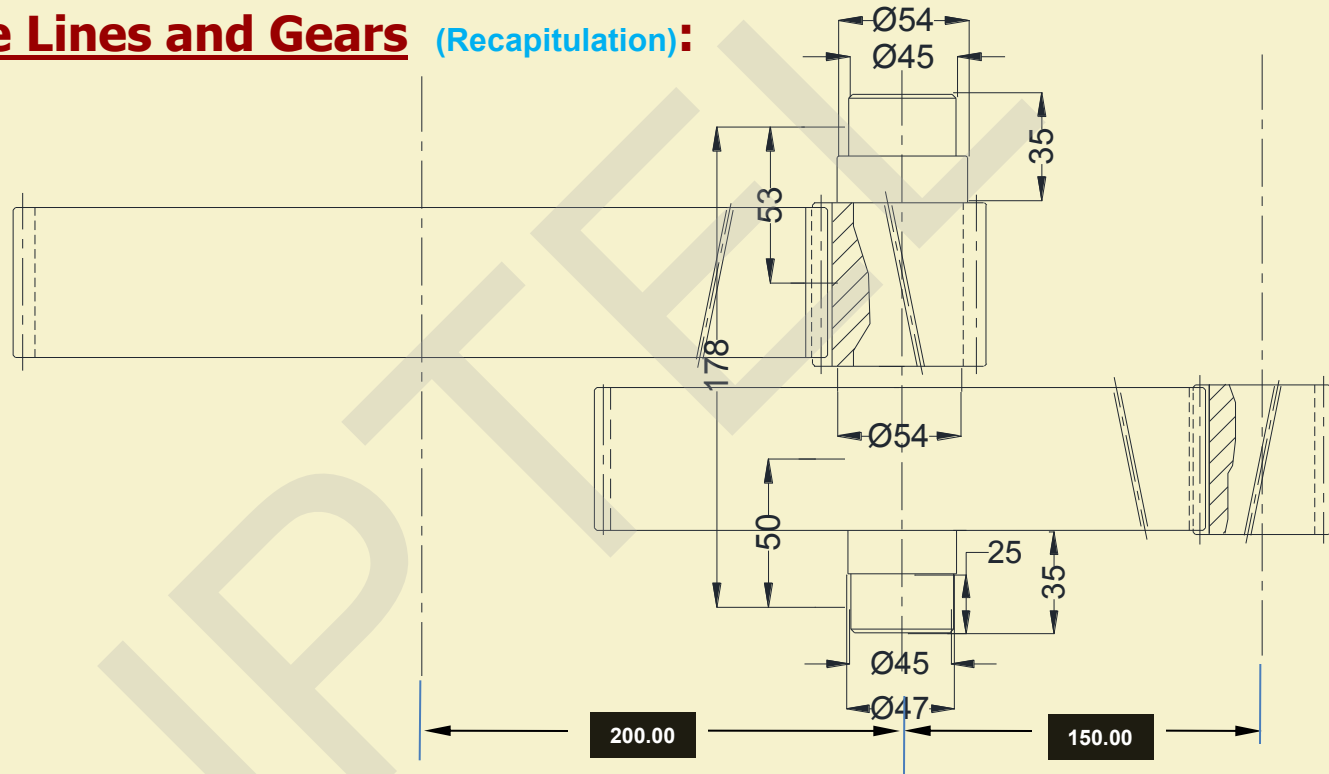
Sl. No.	Description	1 st . Stage		2 nd . Stage	
		Pinion	Gear	Pinion	Gear
1.	Number of Teeth (Z)	17	81	16	82
2.	Tooth Profile	20° Full Depth Involute, Uncorrected			
3.	Normal Module (m_n)	3 mm		4 mm	
4.	Helix Angle (β) and Direction of Helix	11°28'42"		11°28'42"	
		RH	LH	LH	RH
5.	Addendum Height, ($a_f \times m_n = 1 \times m_n$)	3 mm		4 mm	
6.	Dedendum Height, ($d_f \times m_n = 1.25 \times m_n$)	3.75 mm		5 mm	

Dimensions of Gears and Gear data Table : (Recapitulation):

Sl. No.	Description	1 st . Stage		2 nd . Stage	
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9.	Addendum or Tip Circle Diameter (mm)	58.04	253.96	73.306	342.694
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694
11.	Face width (b)	63 mm	58 mm	68 mm	63 mm
12.	Material	EN 19A	EN 18A	EN 19A	EN 18A
13.	Hardness , Through Hardened (BHN)	350	300	350	300

(Recapitulation)

2nd. Stage Pinion End



Sl. No.	Description	1 st . Stage		2 nd . Stage	
		Pinion	Gear	Pinion	Gear
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694

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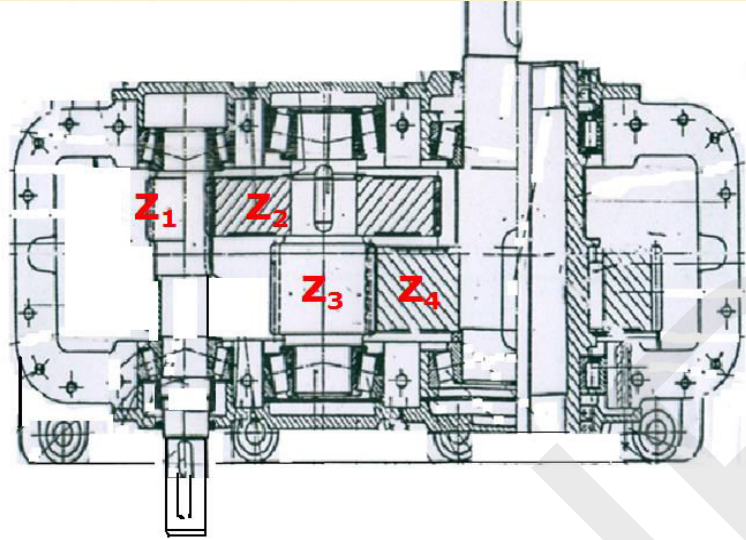
Developed Input and Intermediate Shafts (Recapitulation) :

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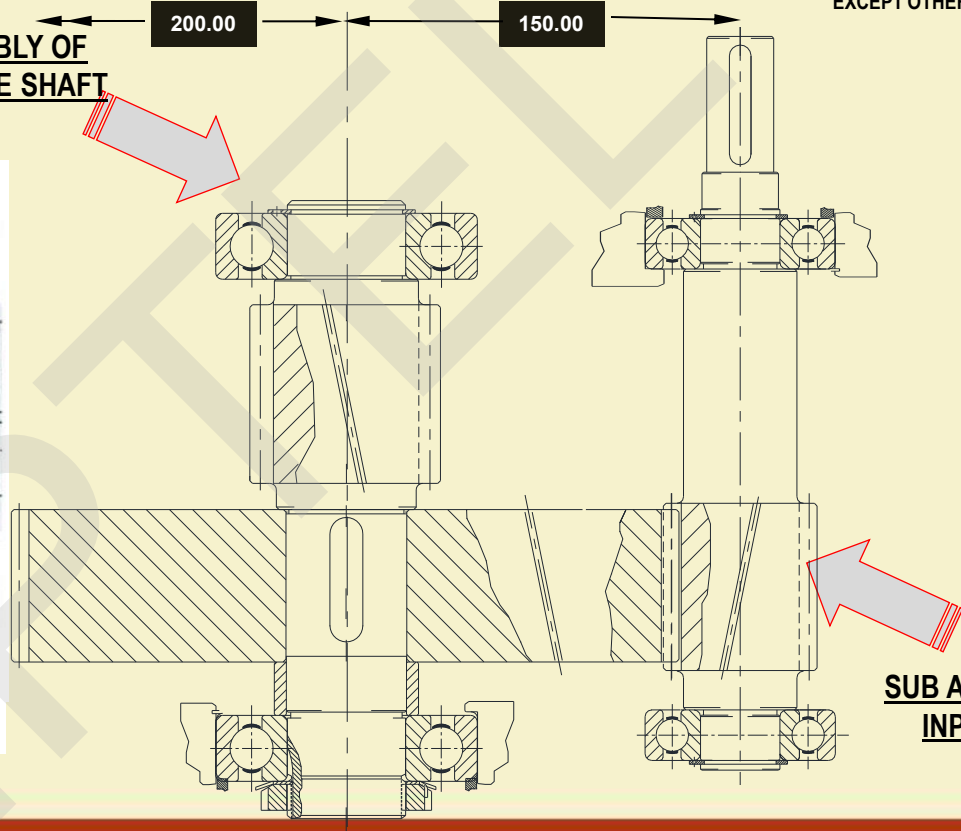
SUB ASSEMBLY OF
INTERMEDIATE SHAFT

200.00

150.00



Assembled plan view of a 2-stage gear box



SUB ASSEMBLY OF
INPUT SHAFT

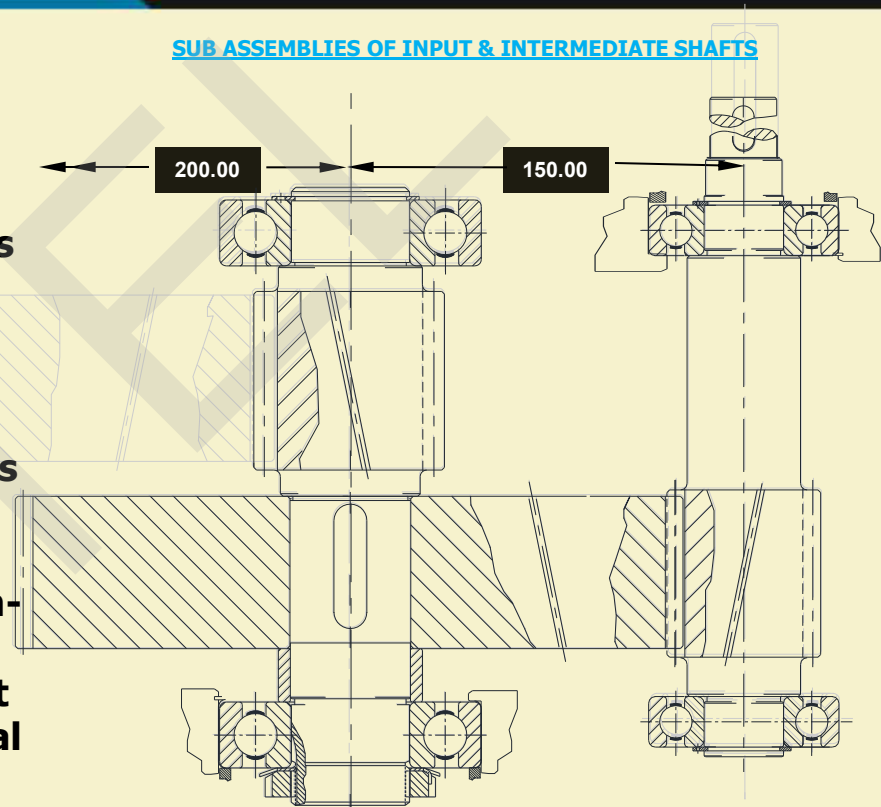
Development of Output Shaft & Gear :

Output Shaft Size Estimation:

The 1st. Stage Pinion (Input) is integral with the Input Shaft and the 2nd. Stage Pinion is integral with the Intermediate Shaft, as the root diameters are low .

This is mainly because, if they are made non-integral then the shaft sizes will be low and will not be able to withstand with bending moments as well as accommodating bearings will be difficult.

The output gear size is big and it can be made non-integral with the output shaft. Therefore, the Output shaft is made as a separate item. Usually it is made of 'medium carbon steel' in case of general purpose gear units.



Output Shaft Material - EN 8 (C40/C45) having $S_u = 570 \text{ MPa}$ and $S_y = 280 \text{ MPa}$.

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Development of Output Shaft & Gear (Contd....) :

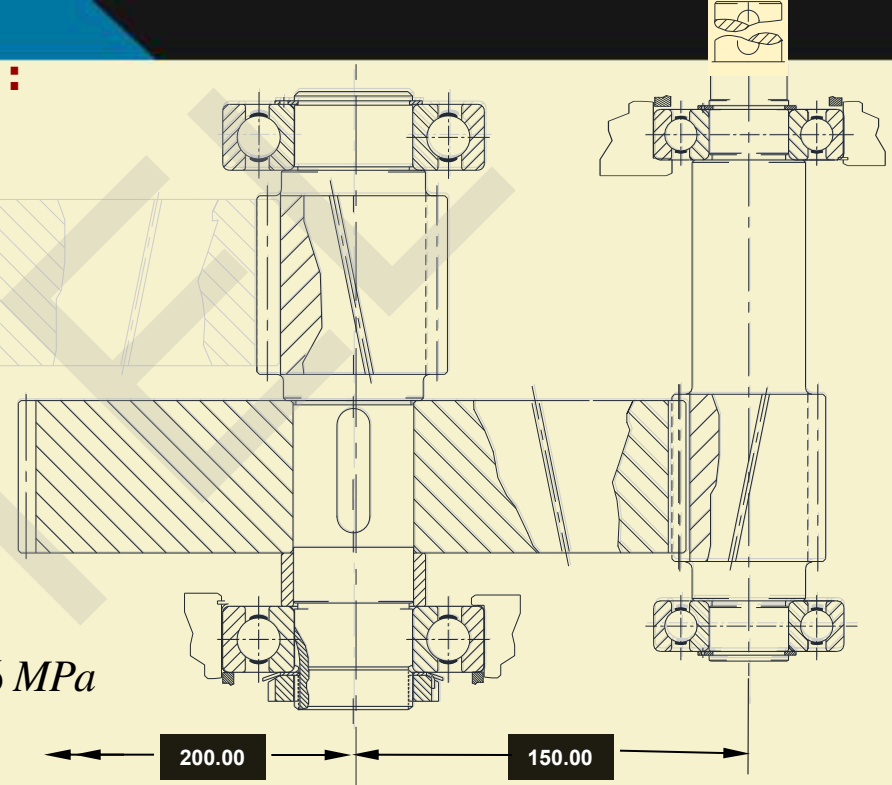
Output Shaft Size Estimation (Contd....) :

The bearings (6309) in Intermediate shafts have ID of 45 mm.
The estimated lives were nearly double the specified required value.
Therefore, in the output shaft bearing lives may be satisfied with 6310 i.e., for bearing mounting the shaft diameter may be initially taken as 50 mm. At the output end the diameter may be taken as 40 mm. For torque only the nominal shear stress estimated as:

$$\tau = \frac{16T}{\pi d^3} = \frac{16 \times (2 \times 30 \times 24.42)}{\pi \times (0.040)^3} = 116 \times 10^6 \text{ Pas} = 116 \text{ MPa}$$

This is in higher side. However, if necessary shaft size may be altered.

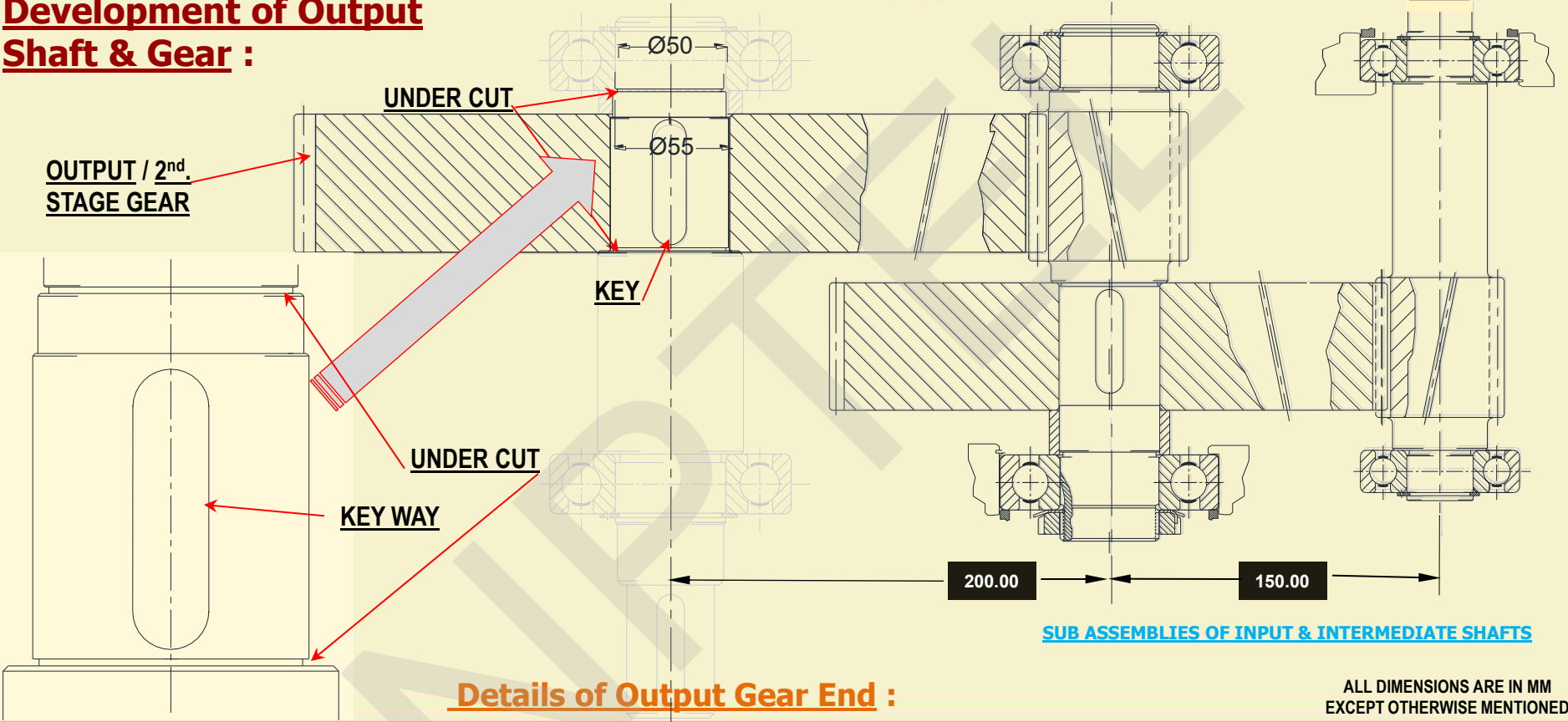
Output Shaft Material - EN 8 (C40/C45) having $S_u = 570 \text{ MPa}$ and $S_y = 280 \text{ MPa}$.



SUB ASSEMBLIES OF INPUT & INTERMEDIATE SHAFTS

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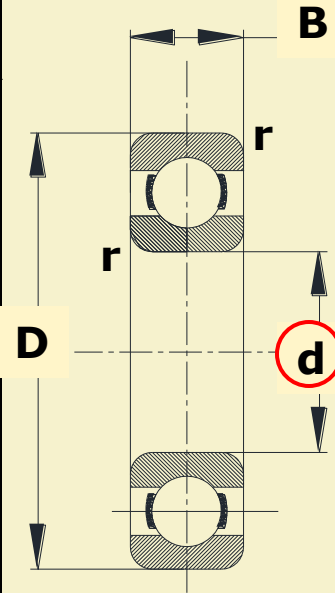
Development of Output Shaft & Gear :



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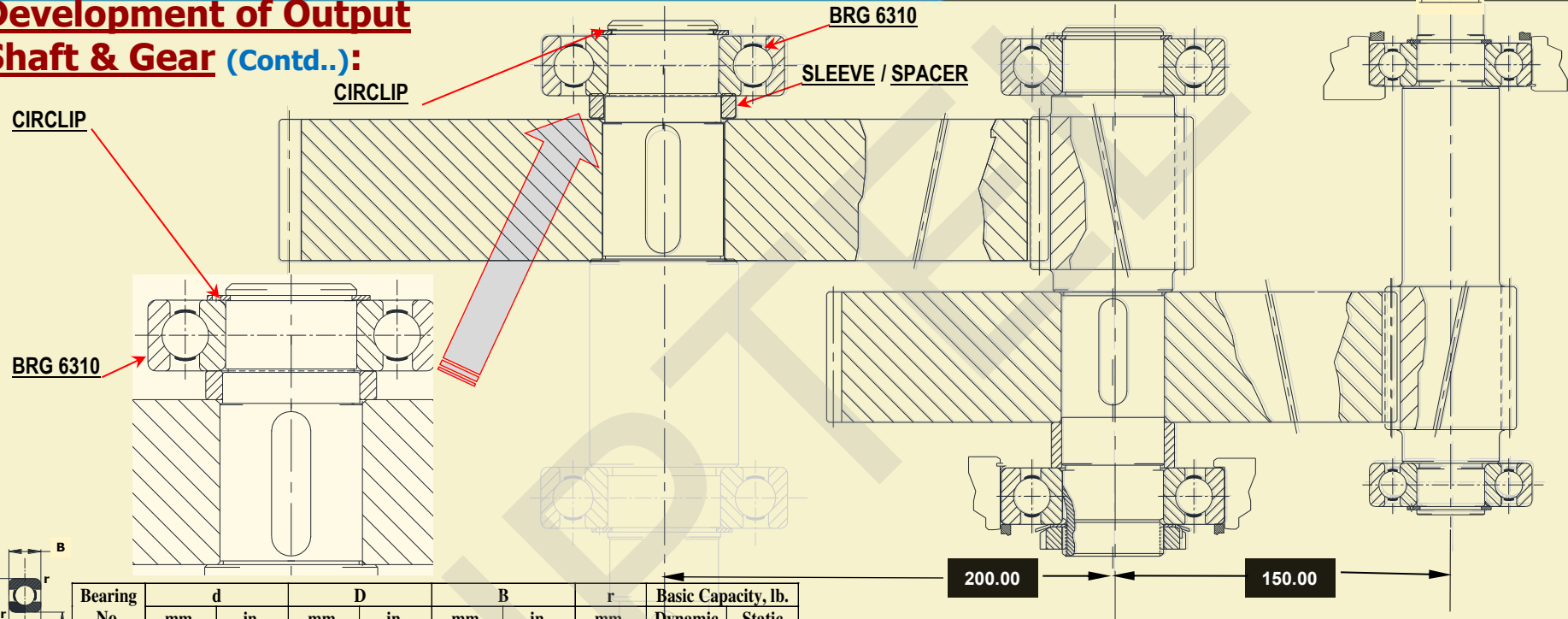
Ball Bearing Data (SKF) & BEARING Choice :

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	1.3870	11	0.4331	1	1430	800
01	12	0.4724	37	1.4567	12	0.4724	1.5	1760	950
02	15	0.5906	42	1.6535	13	0.5118	1.5	1930	1140
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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

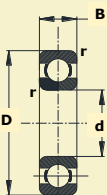




Development of Output Shaft & Gear (Contd.):



SUB ASSEMBLIES OF INPUT & INTERMEDIATE SHAFTS



Bearing No.	d		D		B		r	Basic Capacity, lb.	
	mm.	in.	mm.	in.	mm.	in.		Dynamic C	Static C ₀
6306	30	1.1811	72	2.5346	19	0.7480	2	4800	3200
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

Details of Output Gear End (Contd.):

ALL DIMENSIONS ARE IN MM EXCEPT OTHERWISE MENTIONED

To be continued in Next Lecture

Thank You



Module-05

Design of a General Purpose Industrial Helical Gear Reduction Unit- Part III

Lecture-23

Development (Layout) of Output Shaft (contd...), Loads on Shaft & Bearings



Outline of the Lecture

- **Gear Data, Dimensions and 1st. Layout (Recapitulation)**
 - **Output Shaft Layout- Gear End to Gear Mounting (Recapitulation)**
 - **Development of Output Shaft – Gear to Output End Bearing**
 - **Development of Output Shaft – Output End Bearing to End**
 - **Bearing Locking Arrangement with Shaft**
 - **Output End Bearing Locking Arrangement with Housing**
- **Overall Plan View of Pinions, Gears, Shafts and Bearings (without Housing)**
 - **Output Shaft – Dimensions for Loading and Support points**
- **Output Shaft – Estimation of Loads Acting at Gears, Shafts and Bearings.**

Dimensions of Gears and Gear Data Table :

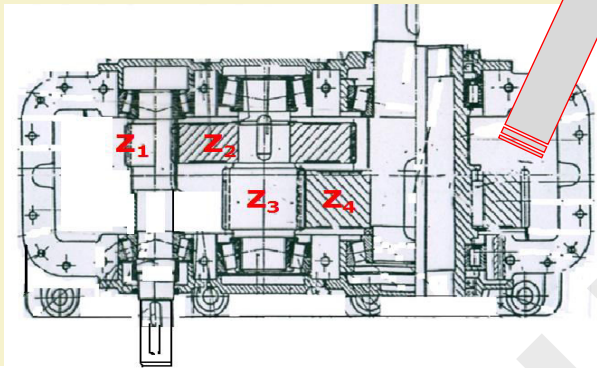
(Recapitulation):

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		Pinion	Gear	Pinion	Gear
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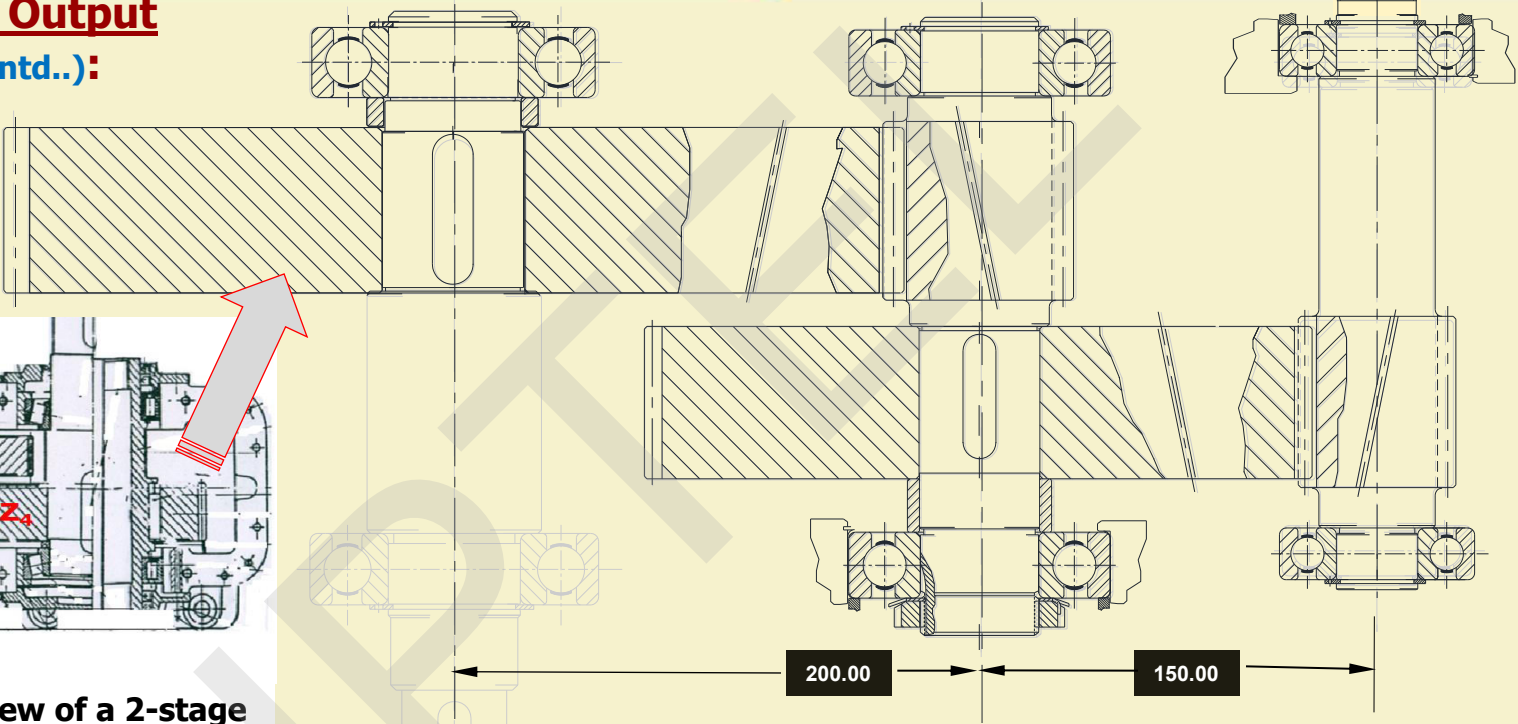
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10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694
11.	Face width (b)	63 mm	58 mm	68 mm	63 mm
12.	Material	EN 19A	EN 18A	EN 19A	EN 18A
13.	Hardness , Through Hardened (BHN)	350	300	350	300

**Development of Output
Shaft & Gear (Contd..):**



**Assembled plan view of a 2-stage
gear (Reduction Unit) box**



SUB ASSEMBLIES OF INPUT & INTERMEDIATE SHAFTS

Details of Output Shaft Subassembly is in progress:

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED



Development of Output Shaft & Gear (Contd.):

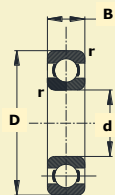
CIRCLIP

CIRCLIP

BRG 6310

SLEEVE / SPACER

BRG 6310



Bearing No.	d		D		B		r	Basic Capacity, lb.	
	mm.	in.	mm.	in.	mm.	in.		Dynamic C	Static C ₀
6306	30	1.1811	72	2.5346	19	0.7480	2	4800	3200
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

200.00

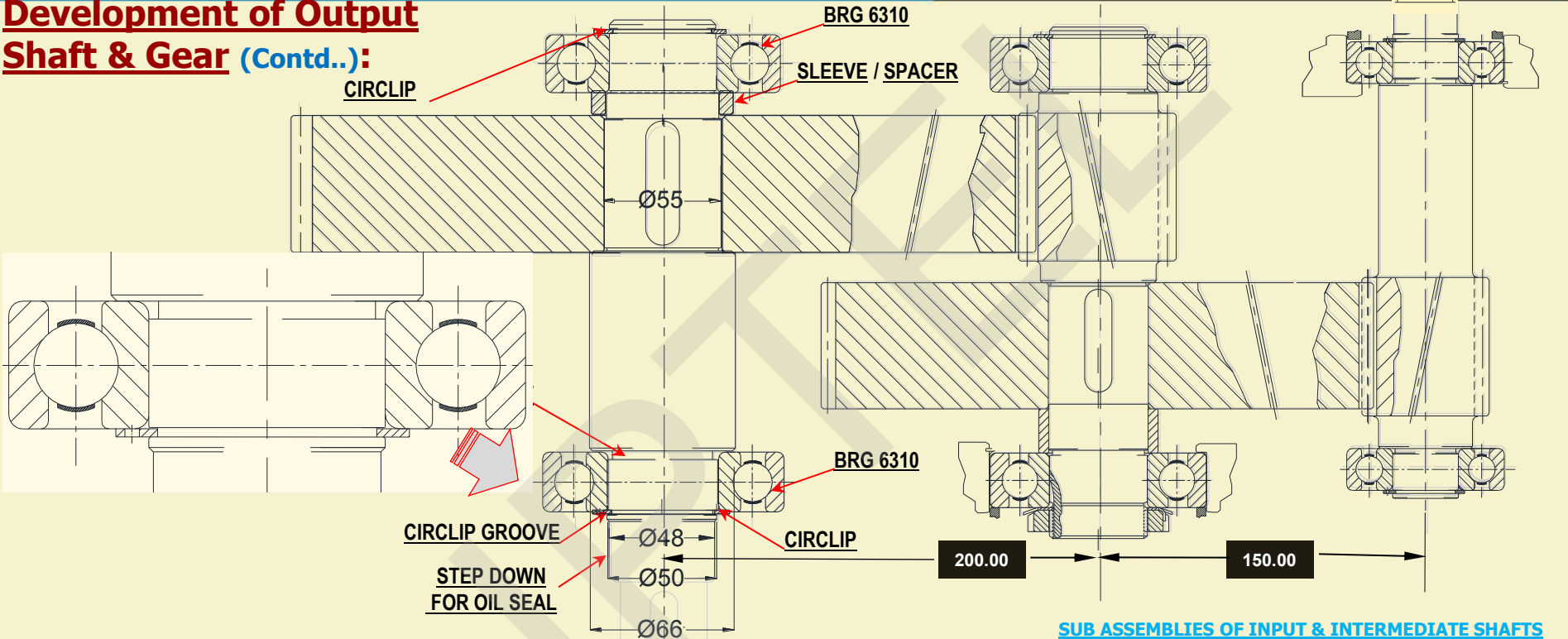
150.00

SUB ASSEMBLIES OF INPUT & INTERMEDIATE SHAFTS

Details of Output Gear Assembly and Shaft End are Completed:

ALL DIMENSIONS ARE IN MM EXCEPT OTHERWISE MENTIONED

Development of Output Shaft & Gear (Contd.):



Details of Output Shaft from Gear to Output Shaft End :

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Development of Output Shaft & Gear (Contd.):

Locking of Output Shaft Bearing with Housing using Circlip and End Cover

Locking of Output Shaft Bearing with Housing using Step in Housing Wall & End Cover

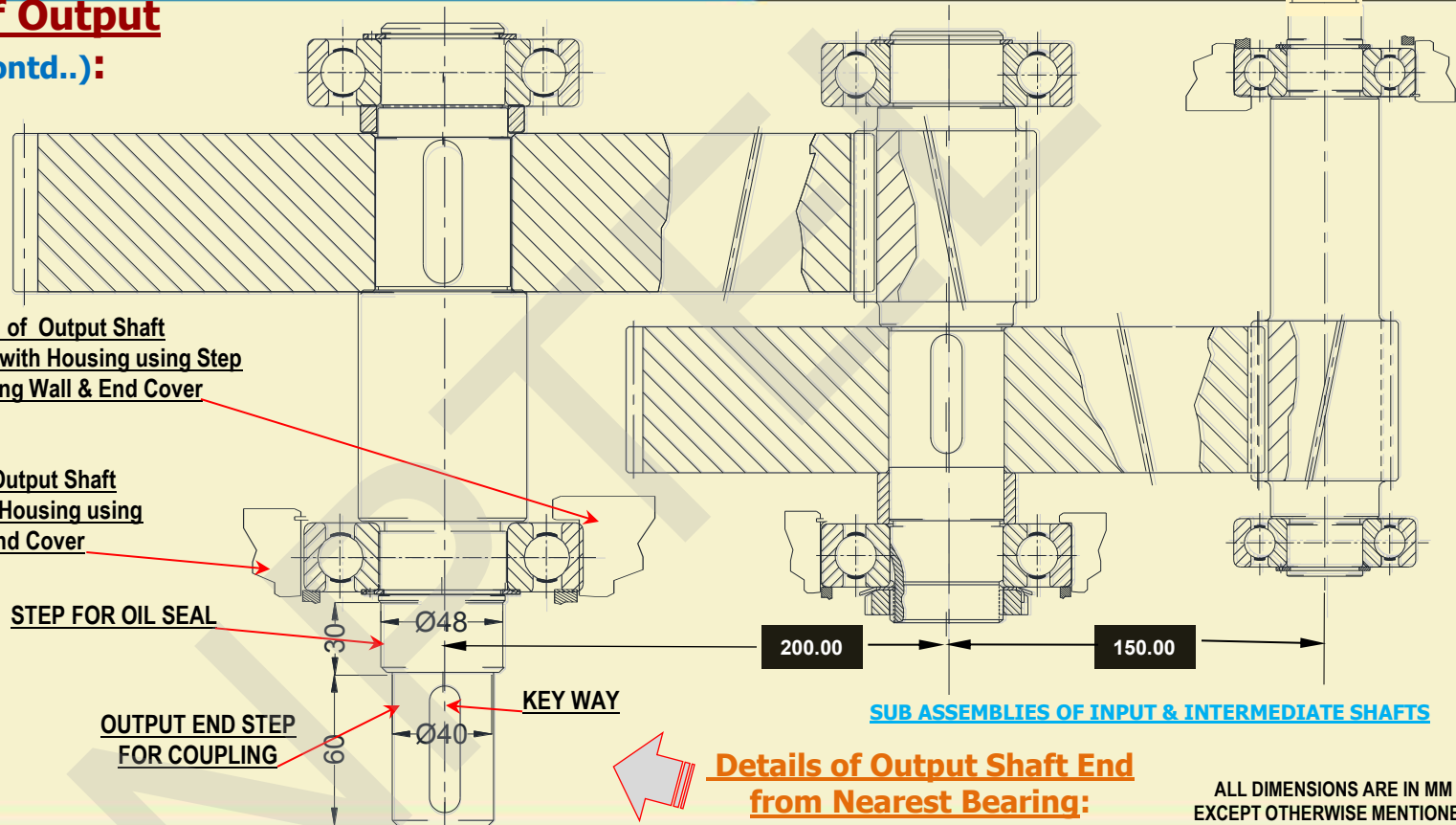
STEP FOR OIL SEAL

OUTPUT END STEP FOR COUPLING

KEY WAY

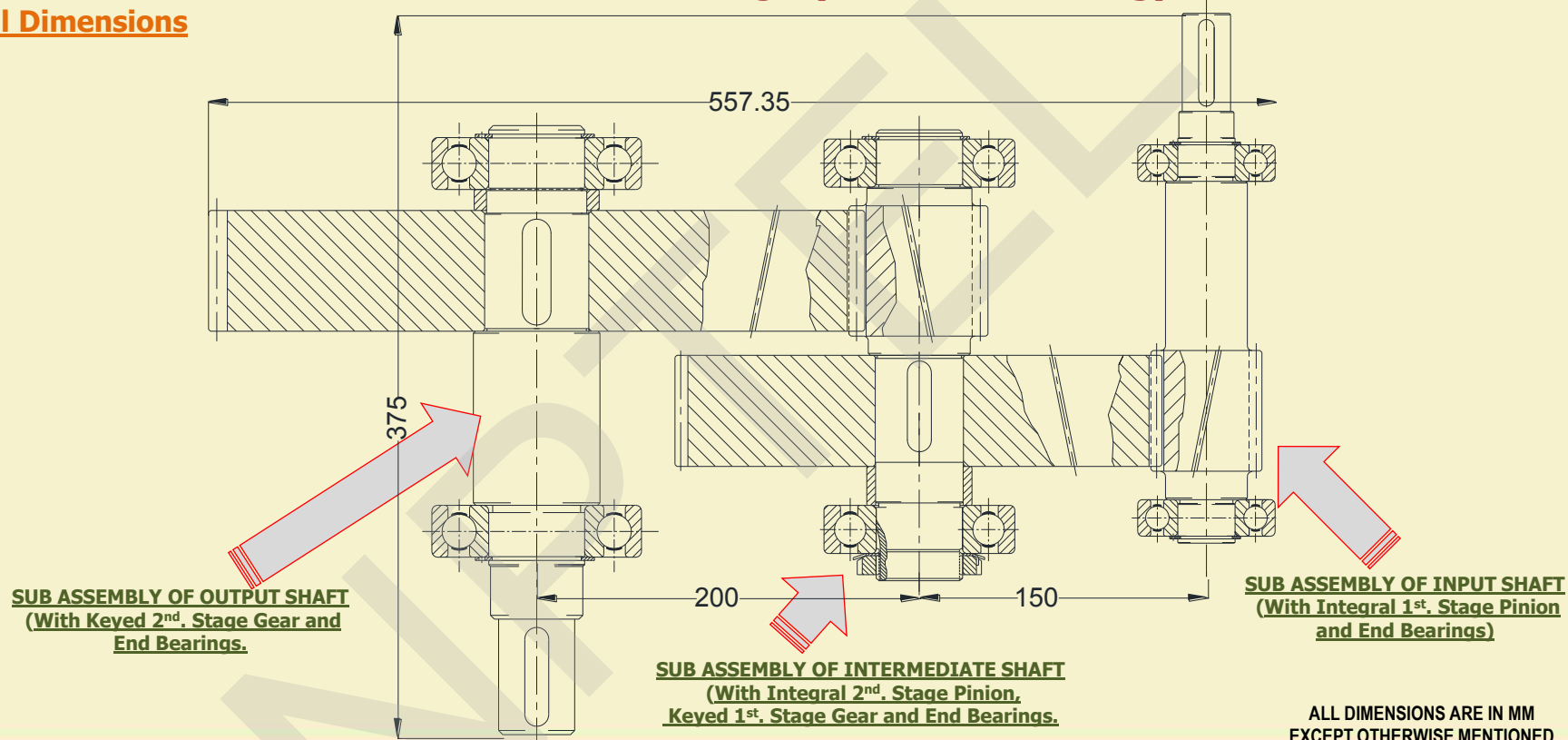
Details of Output Shaft End from Nearest Bearing:

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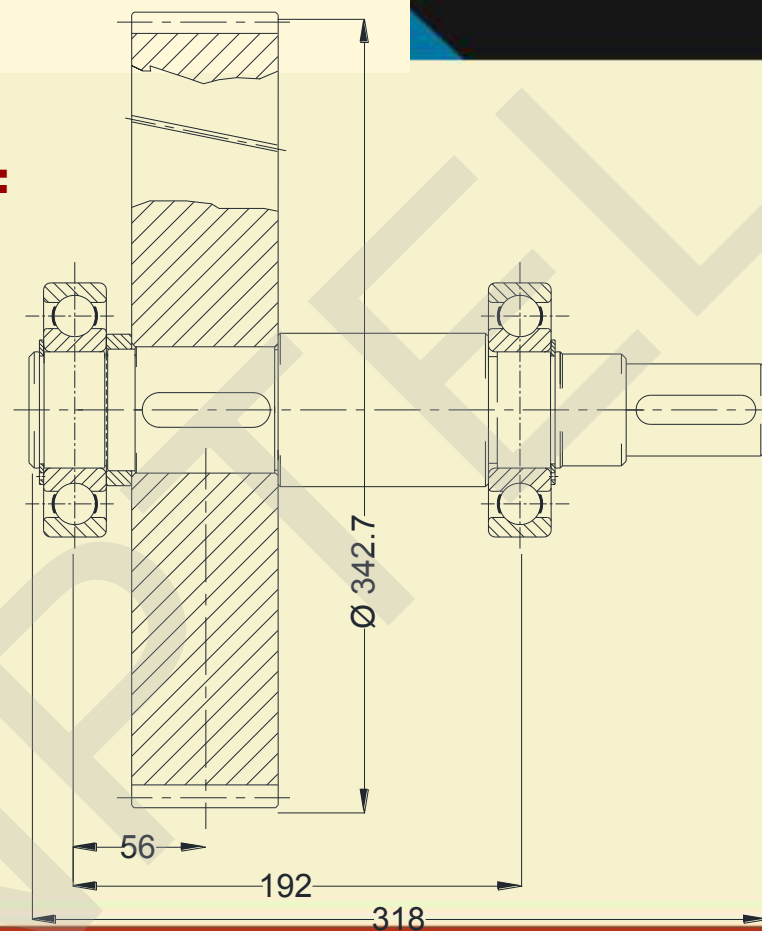
Plan View of Pinions, Gears, Shafts and Bearings (Without Housing) :

Overall Dimensions



Subassembly of Output Shaft with Keyed Gear and End Bearings :

Overall Dimensions
and Dimensions for Load
Calculations



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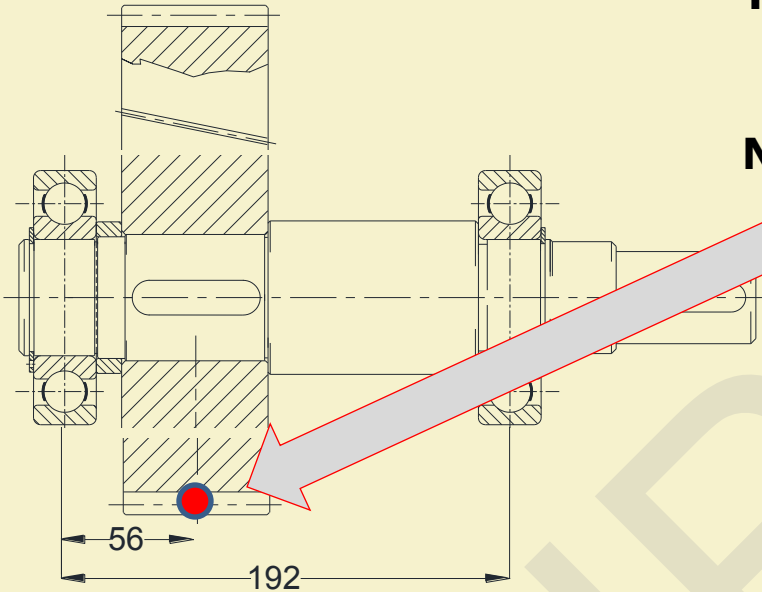
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Loads on Output Gear Tooth, Shaft and End Bearings :



SUB ASSEMBLY OF OUTPUT SHAFT
(With Keyed 2nd. Stage Gear and
End Bearings.

ALL DIMENSIONS ARE IN MM
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Tangential Load:

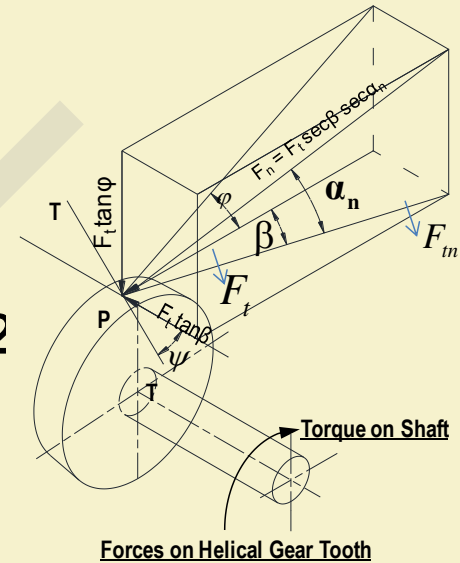
$$F_t = \frac{2T}{d_p}$$

Now, Nominal Torque*:

$$T_o = T_i \times i_2 = 30 \times 24.42 \\ = 732.6 \text{ Nm}$$

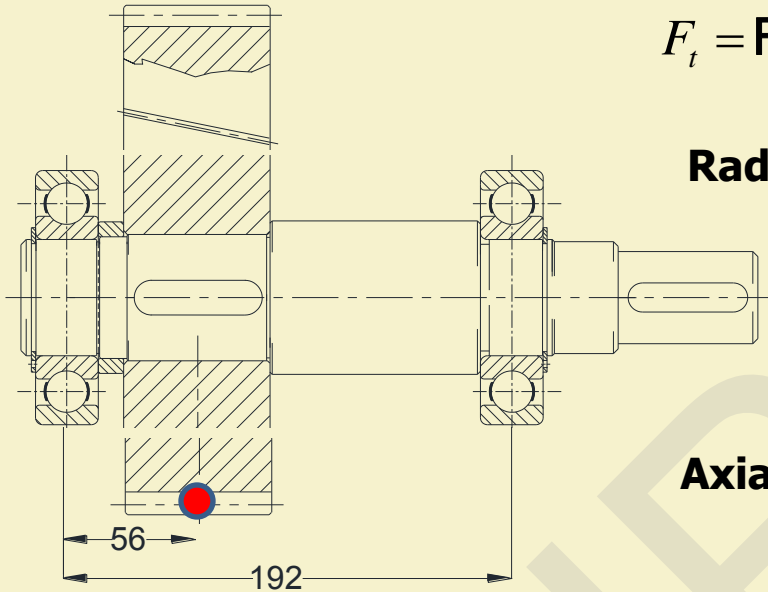
PCD of Output Gear:

$$d_p = d_{pg} = 334.7 \text{ mm}$$



* In week four lectures Nominal Torque has been taken as 31 Nm by mistake. However, those and other minor calculation errors have been rectified through assignments.

Loads on Output Gear Tooth, Shaft and End Bearings (contd...):



SUB ASSEMBLY OF OUTPUT SHAFT
(With Keyed 2nd. Stage Gear and
End Bearings.

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EXCEPT OTHERWISE MENTIONED

Substituting, the Tangential Load:

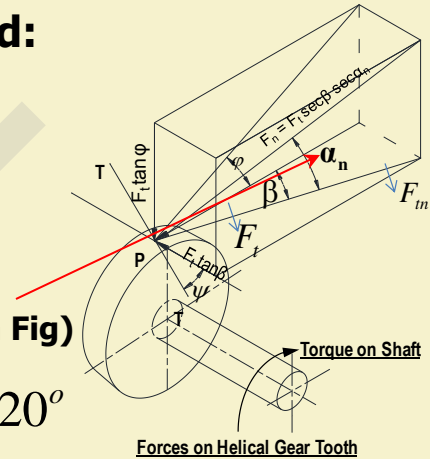
$$F_t = F_{t4} = \frac{2 \times 732.6}{0.3347} = 4377.65 \text{ N}$$

Radial Load:

$$\begin{aligned} F_{r4} &= F_{t4} \sec \beta \tan \alpha \quad (\alpha = \alpha_n \text{ in Fig}) \\ &= 4377.65 \times \sec 11.48^\circ \times \tan 20^\circ \\ &= 1625.85 \text{ N} \end{aligned}$$

Axial Load: $F_{a4} = F_{t4} \tan \beta$

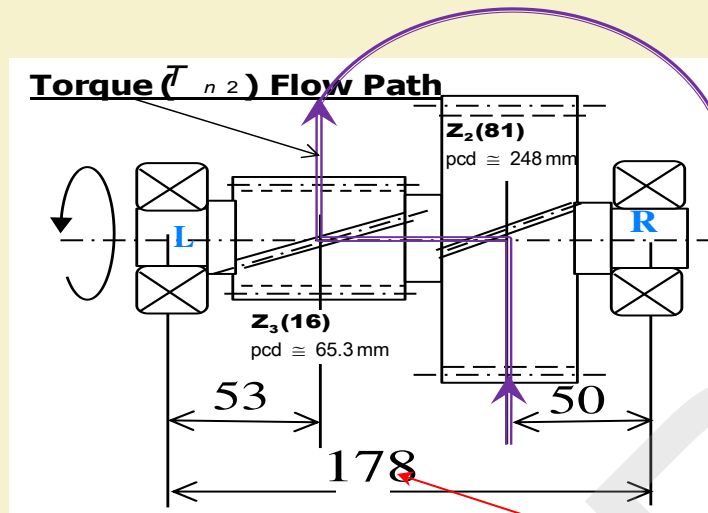
$$= 4377.65 \times \tan 11.48^\circ = 889 \text{ N}$$



In earlier (week -4 lectures) erroneous calculation loads on 2nd. Stage Pinion were:

$$F_{t3} = 4533 \text{ N} \quad F_{r3} = 1683 \text{ N} \quad F_{a3} = 914 \text{ N}$$

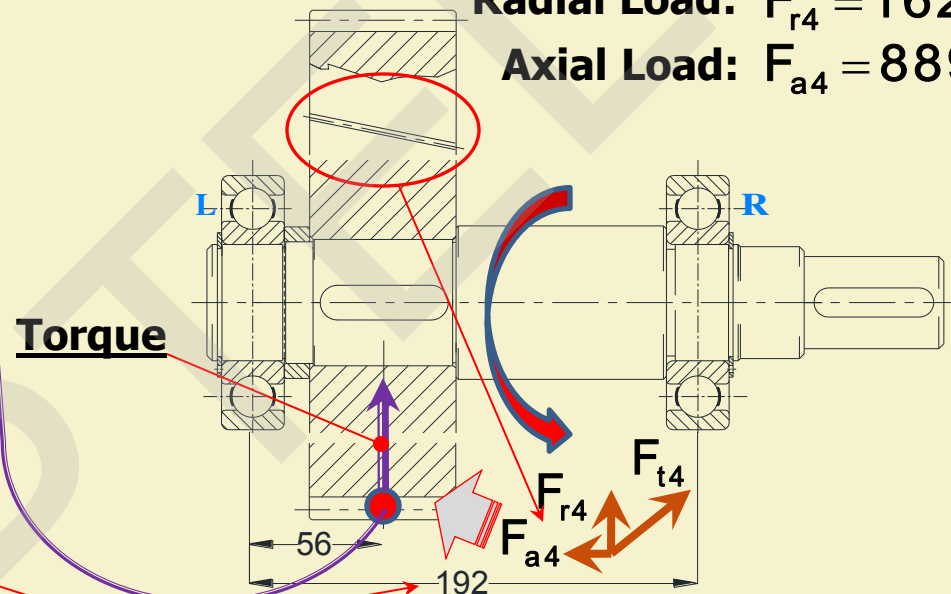
Loads on Output Gear Tooth, Shaft and End Bearings (contd...) :



Intermediate Shaft with gears and Bearings (Plan View)

Note: Bearing span and gear (& pinion) load centers are different in the unit finally consider for drawing.

Tangential Load: $F_{t4} = 4377.65\text{ N}$
Radial Load: $F_{r4} = 1625.85\text{ N}$
Axial Load: $F_{a4} = 889\text{ N}$



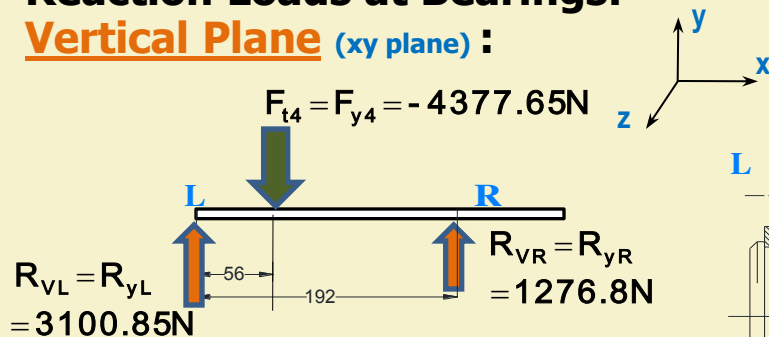
SUB ASSEMBLY OF OUTPUT SHAFT
(With Keyed 2nd. Stage Gear and
End Bearings.

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Loads on Output Gear Tooth, Shaft and End Bearings (contd...):

Reaction Loads at Bearings:

Vertical Plane (xy plane):

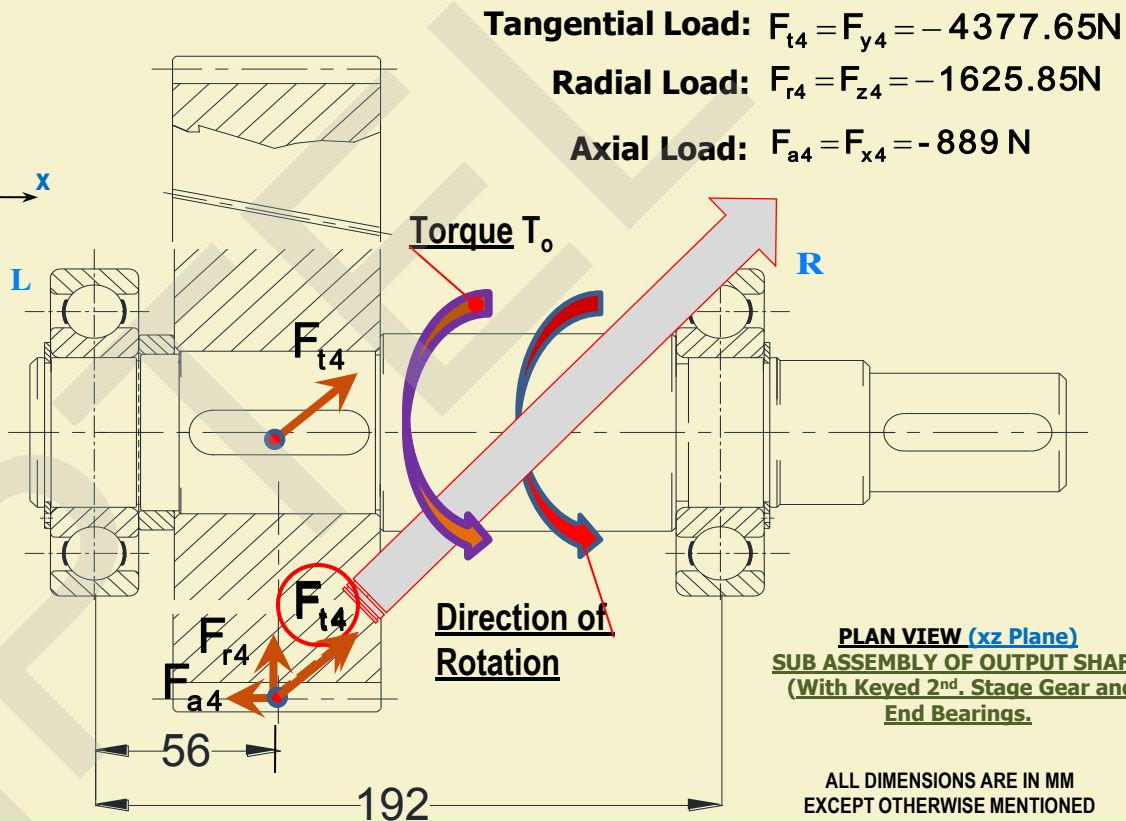


Taking moment about L
support point:

$$R_{yR} = \frac{4377.65 \times 56}{192} = 1276.8 \text{ N}$$

and therefore,

$$R_{yL} = 4377.65 - 1276.8 = 3100.85 \text{ N}$$

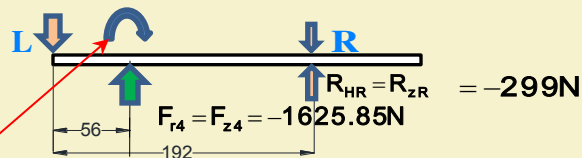


Loads on Output Gear Tooth, Shaft and End Bearings (contd...):

Reaction Loads at Bearings:

Horizontal Plane (xz plane):

$$R_{HL} = R_{zL} = 1924.85\text{N}$$



Moment due to axial force

$$M_a = 889 \times 0.167 = 148.46\text{Nm}$$

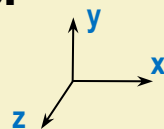
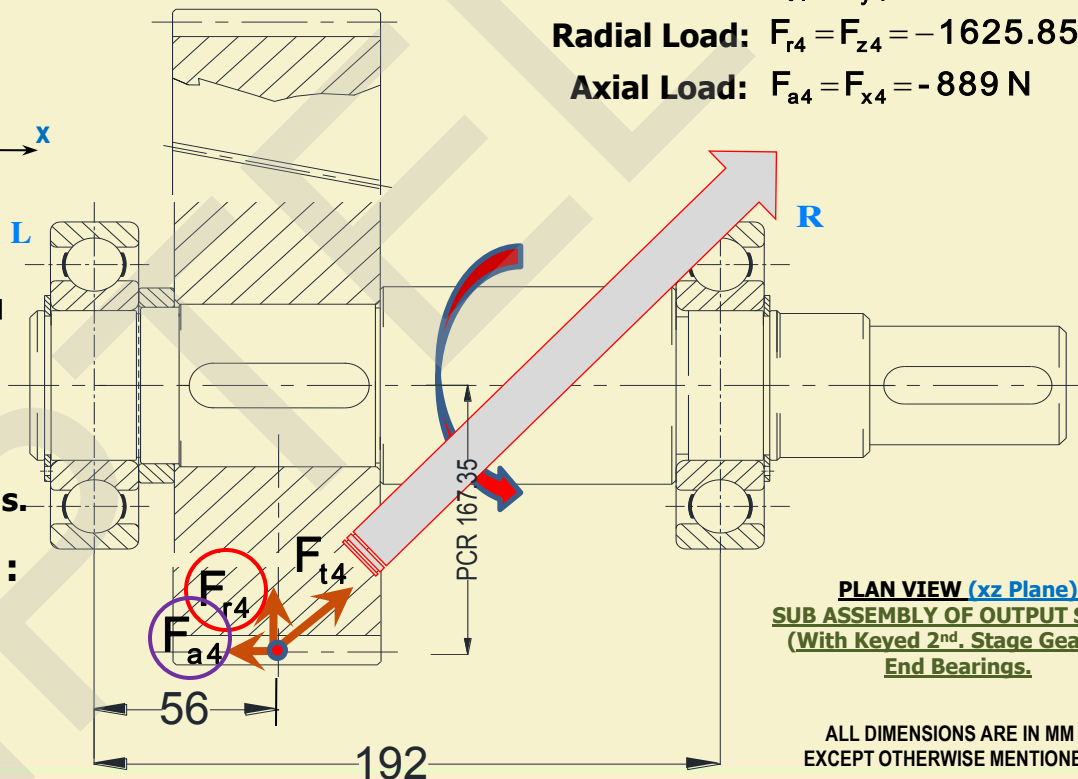
This Moment is balance by a Couple at bearings.

Taking moment about L support point :

$$R_{zR} = \frac{1625.85 \times 0.056 - 148.46}{0.192} = -299\text{N}$$

and therefore,

$$R_{zL} = 1625.85 - (-299) = 1924.85\text{N}$$



$$\text{Tangential Load: } F_{t4} = F_{y4} = -4377.65\text{N}$$

$$\text{Radial Load: } F_{r4} = F_{z4} = -1625.85\text{N}$$

$$\text{Axial Load: } F_{a4} = F_{x4} = -889\text{N}$$

PLAN VIEW (xz Plane)
SUB ASSEMBLY OF OUTPUT SHAFT
(With Keyed 2nd. Stage Gear and
End Bearings.

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Loads on Output Gear Tooth, Shaft and End Bearings (contd...):

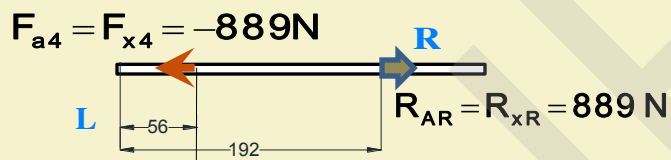
Reaction Loads at Bearings:

Due to axial Load (Along x axis):

Right Bearing if fully Locked with Shaft & Housing.

Therefore, axial load F_{a4} is taken by that bearing.

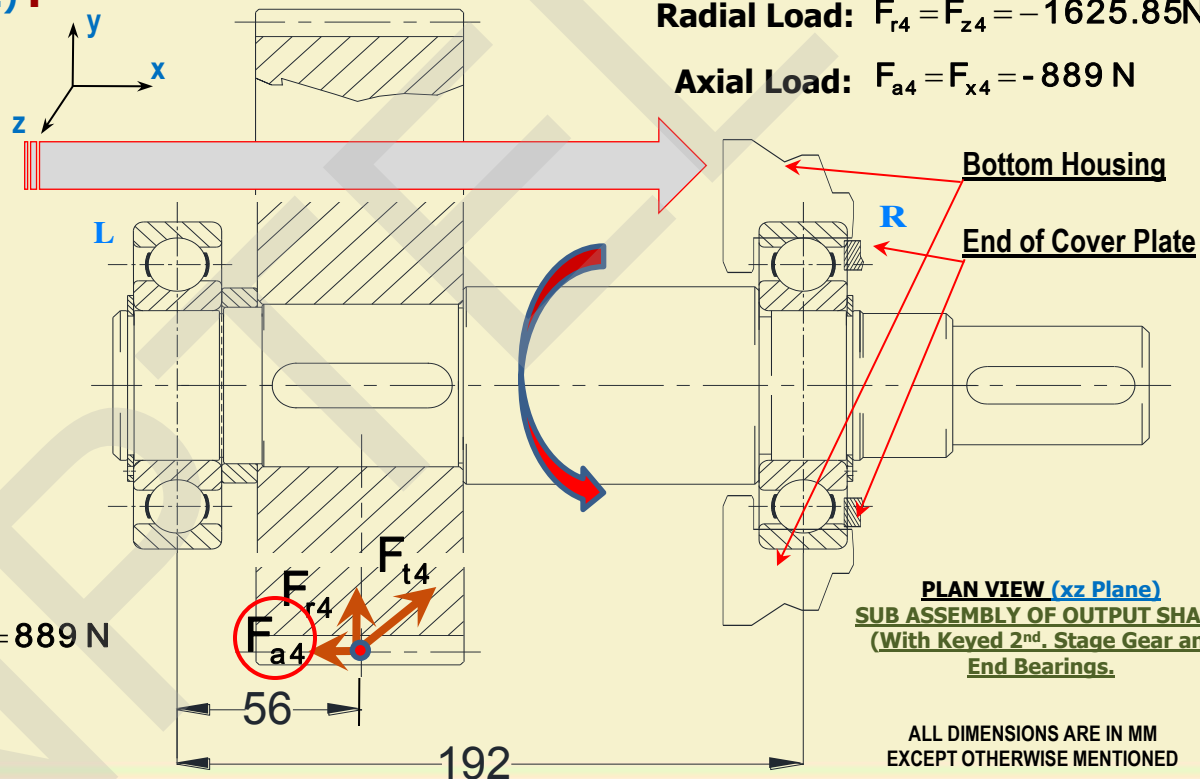
It is irrespective of the direction of rotation.



Tangential Load: $F_{t4} = F_{y4} = -4377.65 \text{ N}$

Radial Load: $F_{r4} = F_{z4} = -1625.85 \text{ N}$

Axial Load: $F_{a4} = F_{x4} = -889 \text{ N}$



Loads on Output Gear Tooth, Shaft and End Bearings (contd...):

Reaction Loads at Bearings:

Load (Applied) at Tooth:

Tangential Load: $F_{t4} = F_{y4} = -4377.65\text{N}$

Radial Load: $F_{r4} = F_{z4} = -1625.85\text{N}$

Axial Load: $F_{a4} = F_{x4} = -889\text{N}$

Load (Reaction) at Left Bearing:

$R_{VL} = R_{yL} = 3100.85\text{N}$ Vertical Plane

$R_{HL} = R_{zL} = 1151.64\text{N}$ Horizontal Plane

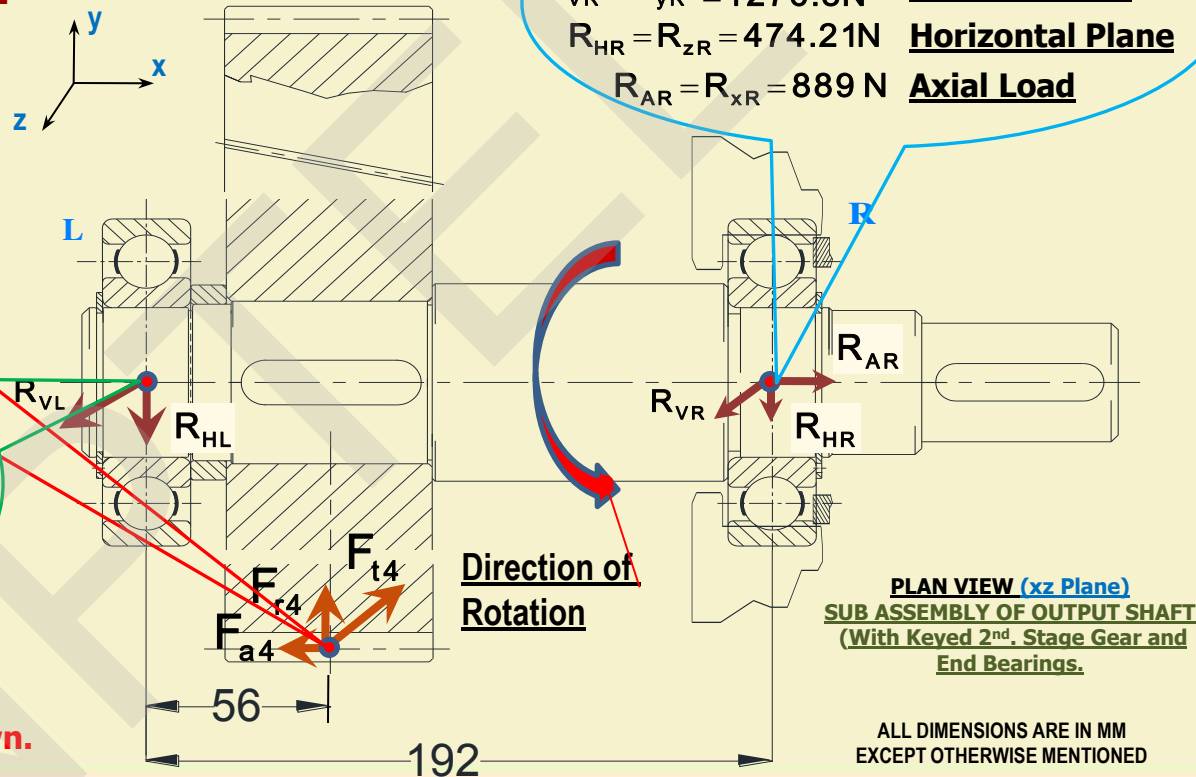
$R_{AL} = R_{xL} = 0$ Axial Load

Load (Reaction) at Right Bearing:

$R_{VR} = R_{yR} = 1276.8\text{N}$ Vertical Plane

$R_{HR} = R_{zR} = 474.21\text{N}$ Horizontal Plane

$R_{AR} = R_{xR} = 889\text{N}$ Axial Load



Note: Moments due to Loads are not shown.

Thank You



Module-05

Design of a General Purpose Industrial Helical Gear Reduction Unit- Part III

Lecture-24

Output Shaft-Bearing Lives



Outline of the Lecture

- **Output Shaft Subassembly with loads (Recapitulation)**
 - **Equivalent loads, Equilibrium- Output Shaft Sub Assembly**
- **Output Shaft- Force Equilibrium**
 - **Bearing Life Estimation- Equivalent Load Formula (Recapitulation)**
 - **Loads on Left End Bearing & Bearing Selection**
- **Life Estimation of Left End Bearing**
 - **Life Estimation of Right End Bearing**
 - **Comments on Output Shaft Subassembly**
 - **Applied and Resistive loads on Output Shaft and Equilibrium.**

Loads on Output Gear Tooth, Shaft and End Bearings :

Reaction Loads at Bearings:

Load (Applied) at Tooth:

Tangential Load: $F_{t4} = F_{y4} = -4377.65 \text{ N}$

Radial Load: $F_{r4} = F_{z4} = -1625.85 \text{ N}$

Axial Load: $F_{a4} = F_{x4} = -889 \text{ N}$

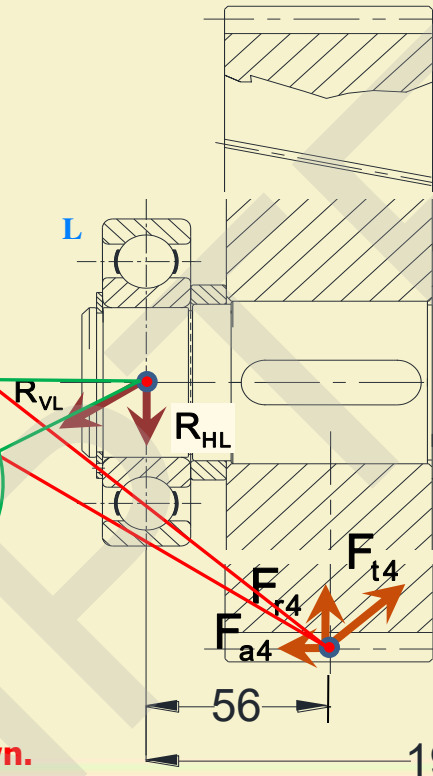
Load (Reaction) at Left Bearing:

$R_{VL} = R_{yL} = 3100.85 \text{ N}$ Vertical Plane

$R_{HL} = R_{zL} = 1924.85 \text{ N}$ Horizontal Plane

$R_{AL} = R_{xL} = 0$ Axial Load

Recapitulation



Load (Reaction) at Right Bearing:

$R_{VR} = R_{yR} = 1276.8 \text{ N}$

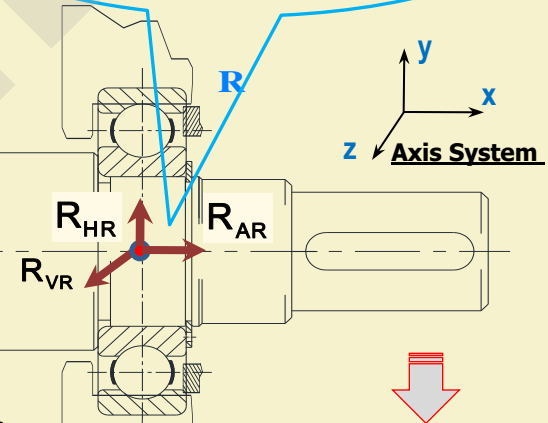
Vertical Plane

$R_{HR} = R_{zR} = -299 \text{ N}$

Horizontal Plane

$R_{AR} = R_{xR} = 889 \text{ N}$

Axial Load



Direction of Rotation

PLAN VIEW (xz Plane)
SUB ASSEMBLY OF OUTPUT SHAFT
(With Keyed 2nd. Stage Gear and
End Bearings.

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Note: Moments due to Loads are not shown.

Loads on Output Shaft and End Bearings : Equivalent Loading & Equilibrium:

Load (Applied) at Tooth:

$$F_{t4} = F_{y4} = -4377.65 \text{ N}$$

$$F_{r4} = F_{z4} = -1625.85 \text{ N}$$

$$F_{a4} = F_{x4} = -889 \text{ N}$$

Load (Reaction) at Left Bearing:

$$R_{VL} = R_{yL} = 3100.85 \text{ N}$$

$$R_{HL} = R_{zL} = 1924.85 \text{ N}$$

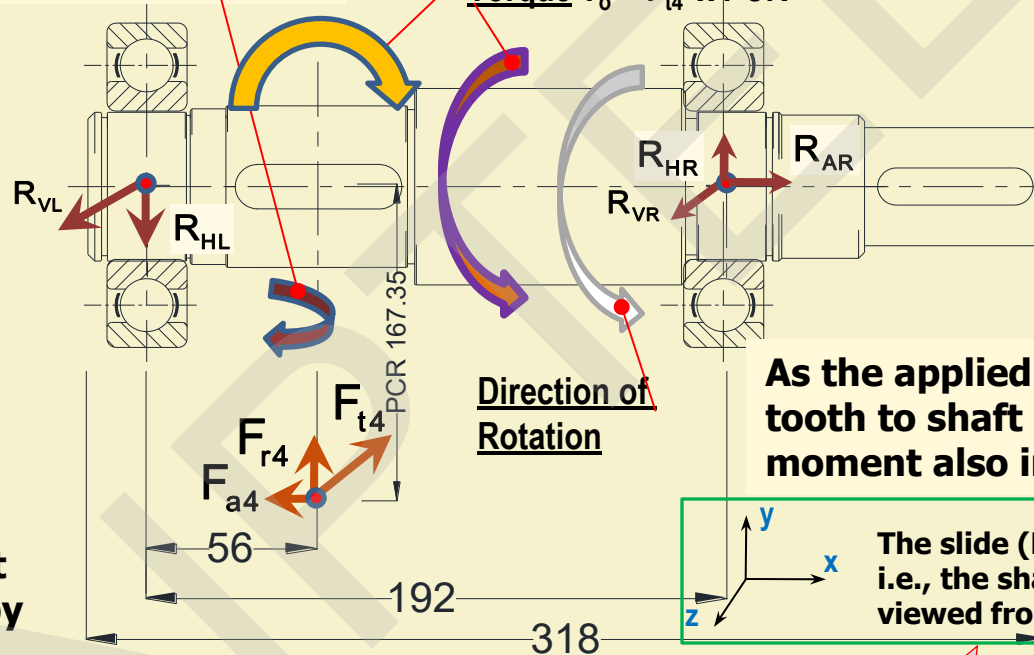
$$R_{AL} = R_{xL} = 0$$

Reaction Loads at shaft
means Loads offered by
bearings to shaft.

Bending Moment due to F_{t4}

Bending Moment due to
 F_{a4} and F_{r4} in same plane

$$\text{Torque } T_o = F_{t4} \times \text{PCR}$$



Direction of
Rotation

As the applied load shifted from
tooth to shaft axis, there will be
moment also in equivalent system.

The slide (Plan view) is in xz plane ,
i.e., the shaft sub assembly is being
viewed from top.

Plan View of Output Shaft (xz plane)

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Note: These two
Bending Moments are
in transverse planes

Load (Reaction) at Right Bearing:

$$R_{VR} = R_{yR} = 1276.8 \text{ N}$$

$$R_{HR} = R_{zR} = -299 \text{ N}$$

$$R_{AR} = R_{xR} = 889 \text{ N}$$

Loads on Output Shaft and End Bearings :

Output Shaft- Force Equilibrium

Load (Applied)

at Tooth:

$$F_{t4} = F_{y4} = -4377.65 \text{ N}$$

$$F_{r4} = F_{z4} = -1625.85 \text{ N}$$

$$F_{a4} = F_{x4} = -889 \text{ N}$$

Load (Reaction)

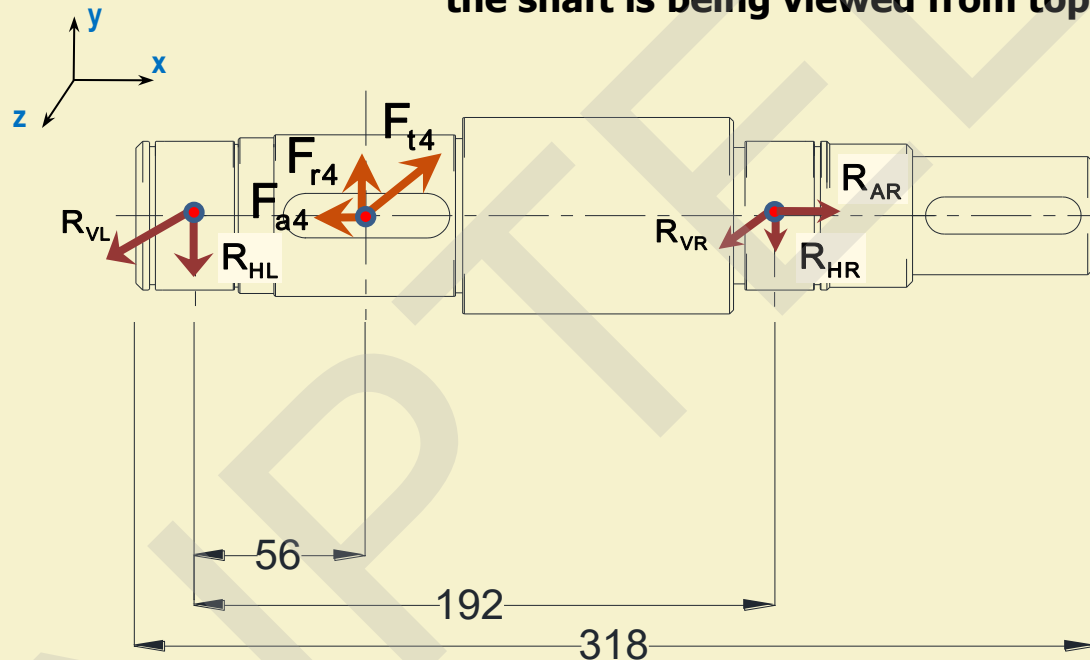
at Left Bearing:

$$R_{VL} = R_{yL} = 3100.85 \text{ N}$$

$$R_{HL} = R_{zL} = 1924.85 \text{ N}$$

$$R_{AL} = R_{xL} = 0$$

The plane of the slide is in xz plane and the shaft is being viewed from top.



Load (Reaction) at Right Bearing:

$$R_{VR} = R_{yR} = 1276.8 \text{ N}$$

$$R_{HR} = R_{zR} = -299 \text{ N}$$

$$R_{AR} = R_{xR} = 889 \text{ N}$$



Plan View of Output Shaft (zx plane)

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Bearing (Rolling Element) Selection (Recapitulation) :

Life Estimation of Rolling Element Bearing

Equivalent Load (P) Acting on bearing

$$P = C_1 (XVF_r + YF_a)$$

Where,

C_1 = A factor on nature of shock load

V = Outer race rotation factor (1 for fixed & 1.2 for rotating)

F_r = Net radial load acting on bearing

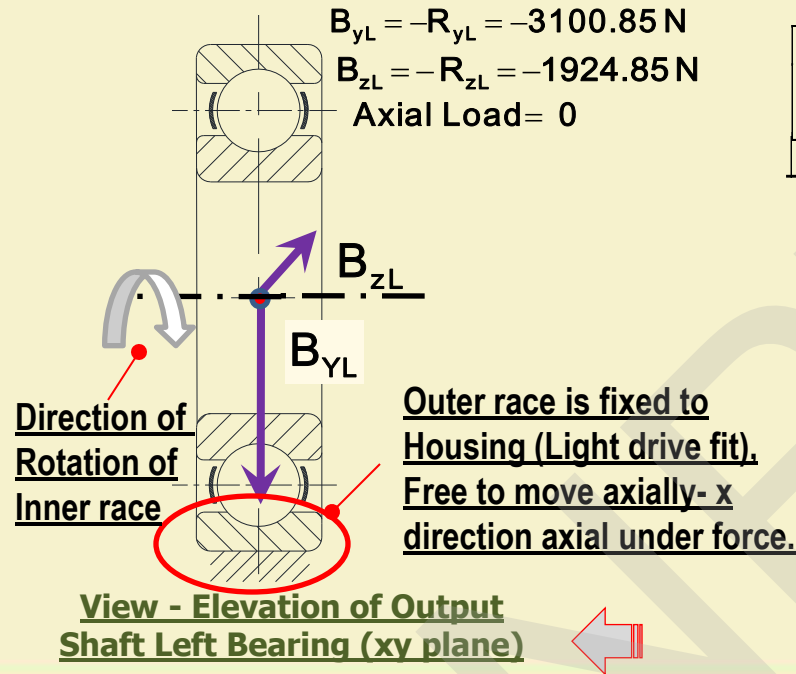
F_a = Net axial load acting on bearing

X = Radial Load Factor (From Catalogue)

Y = Axial Load Factor " "

Loads on (Output Shaft) Bearing and Life Estimation :

Load on Left Bearing:



Deep groove ball bearing **SKF 6310** are chosen for both end supports of output shaft:

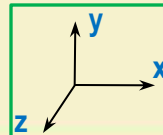
Bearing No.	d		D		B		r	Basic Capacity, lb.	
	mm.	in.	mm.	in.	mm.	in.	mm.	Dynamic C	Static C ₀
6310	50	1.9685	110	4.3307	27	1.0630	3	10400	7800

$$X = 1 \text{ \& } Y = 1.6$$

Equivalent Load (P) Acting on left bearing

$$\begin{aligned}
 P &= C_1 (XVF_r + YF_a) \\
 &= 1.5 \times \left(1 \times 1 \times \sqrt{3100.85^2 + 1924.85^2} + 0 \right) \\
 &= 1.5 \times 3649.7 = 5474.5 \text{ N}
 \end{aligned}$$

Resultant Radial Load on bearing

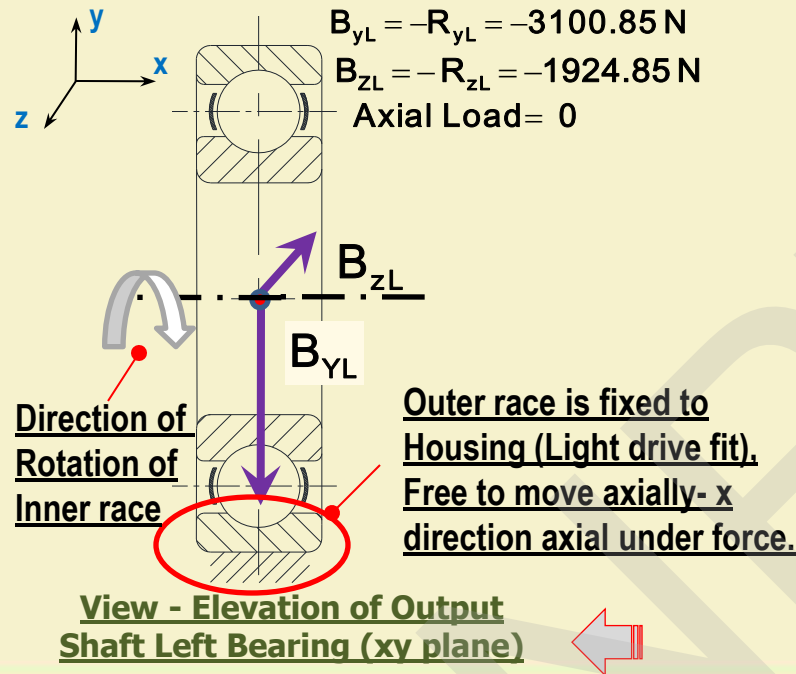


The slide is in xy plane and the bearing is being viewed straight.

ALL DIMENSIONS ARE IN MM EXCEPT OTHERWISE MENTIONED

Loads on (Output Shaft) Bearing and Life Estimation (contd...) :

Load on Left Bearing:



Life of the left bearing (in rev):

$$L_N = \left(\frac{C}{P} \right)^3 \times 10^6 \text{ Rev} = \left(\frac{46375}{5474.5} \right)^3 \times 10^6 \text{ Rev} = 607.88 \times 10^6 \text{ Rev}$$

Note: Dynamic Load Capacity of Bearing 6310 is 10400 lbs $\cong$ 46375 N

Life of the left bearing (in hrs):

$$L_{hL} = \frac{L_N}{N \times 60} = \frac{607.88 \times 10^6}{(1500/24.42) \times 60} = 164938 \text{ hrs}$$

This is much more than specified minimum life of 10,000 hrs. It indicates that lower series bearing and with one size less (i.e., 6209) may be well satisfactory.

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Loads on (Output Shaft) Bearing and Life Estimation (contd...) :

Equivalent Load (P) Acting on right bearing

Note: $X=1$ & $Y=1.6$

$$\begin{aligned} P &= C_1 (XVF_r + YF_a) \\ &= 1.5 \times \left(1 \times 1 \times \sqrt{1276.8^2 + 299^2} + 1.6 \times 889 \right) \\ &= 1.5 \times (1311.34 + 1422.4) = 4100.6 \text{ N} \end{aligned}$$

Life of the right bearing (in rev):

$$L_N = \left(\frac{46375}{4100.6} \right)^3 \times 10^6 \text{ Rev} = 1446.47 \times 10^6 \text{ Rev}$$

Life of the right bearing (in hrs):

$$L_{hR} = \frac{1446.47 \times 10^6}{(1500/24.42) \times 60} = 392475 \text{ hrs}$$

This is also high and 6209 may be chosen.

Load on Right Bearing (6310) :

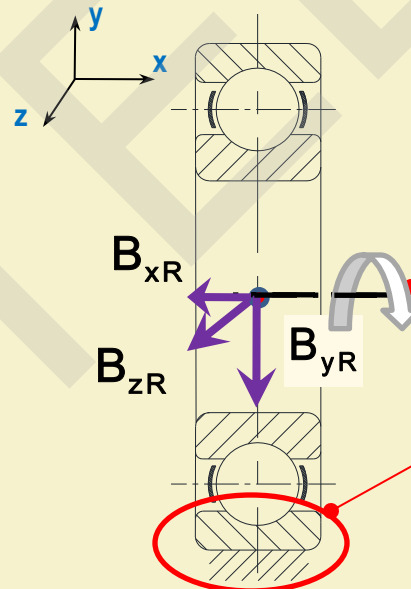
$$R_{VR} = R_{yR} = -1276.8 \text{ N}$$

$$R_{HR} = R_{zR} = 299 \text{ N}$$

$$R_{AR} = R_{xR} = -889 \text{ N}$$

Direction of
Rotation of
Inner race

Outer race is fixed to
Housing and Constrained
Fully to move axially under
force. Inner race is also
locked to the shaft.



**View - Elevation of Output
Shaft Right Bearing (xy plane)**

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Comments on Output Shaft Bearing Loads and Bearing Lives :

- **It is to be noted that if the direction of rotation or the direction of helix angle are reversed then resultant load on bearings will be different although axial load taking bearings will have comparatively less load than the respective other end bearings.**
- **It is apparent that lower size bearings or lower series bearing can be selected for both intermediate and output shafts.**
- **However, the output shaft design verification to be done before altering bearings.**

Verification of Output Shaft Design :

Applied and Resistive loads on Shaft

Load (Applied) at Tooth:

$$F_{t4} = F_{y4} = -4377.65 \text{ N}$$

$$F_{r4} = F_{z4} = -1625.85 \text{ N}$$

$$F_{a4} = F_{x4} = -889 \text{ N}$$

$$R_{VL} = R_{yL}$$

$$R_{HL} = R_{zL}$$

$$F_{a4} = F_{x4}$$

$$F_{r4} = F_{z4}$$

$$F_{t4} = F_{y4}$$

$$R_{VR} = R_{yR}$$

$$R_{HR} = R_{zR}$$

$$R_{AR} = R_{xR}$$

Load (Reaction) at Left Bearing:

$$R_{VL} = R_{yL} = 3100.85 \text{ N}$$

$$R_{HL} = R_{zL} = 1924.85 \text{ N}$$

$$R_{AL} = R_{xL} = 0$$

Load (Reaction) at Right Bearing:

$$R_{VR} = R_{yR} = 1276.8 \text{ N}$$

$$R_{HR} = R_{zR} = -299 \text{ N}$$

$$R_{AR} = R_{xR} = 889 \text{ N}$$

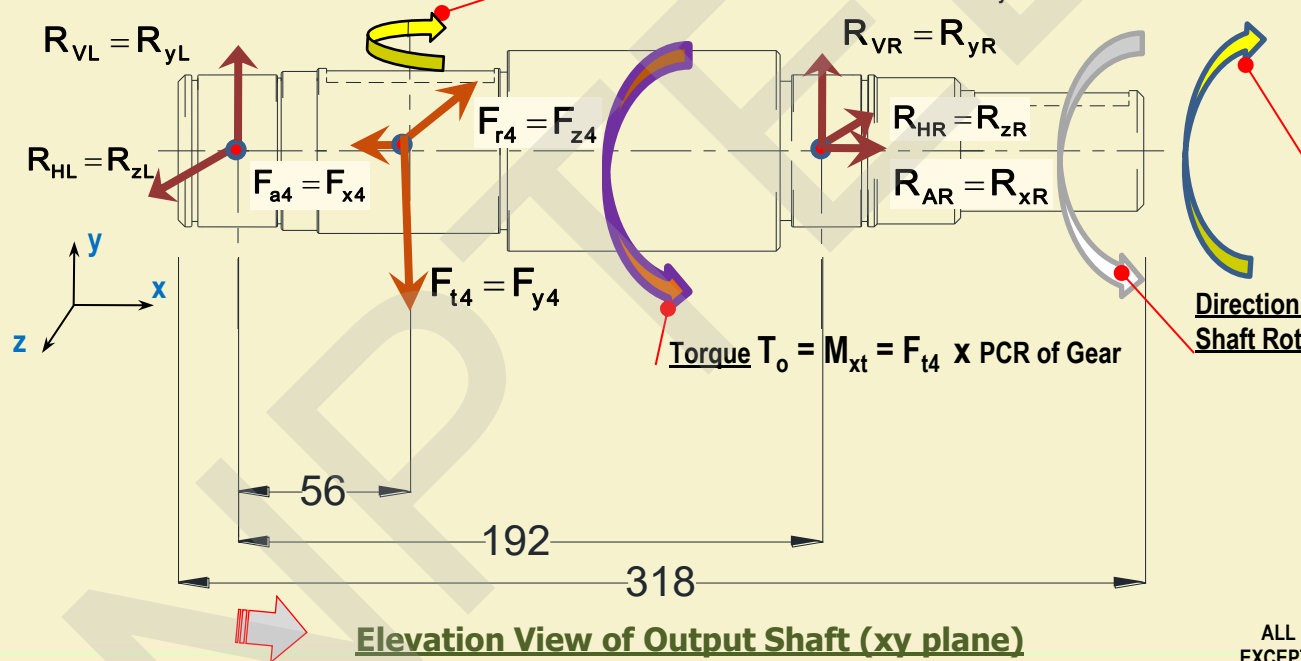
The out shaft is now being viewed as elevation. (i.e., let it has been rotated by 270° in the direction of rotation from the earlier view. The plane of the slide is now in xy plane.)

Applied Moment due to Axial Force $M_a = M_{ya} = F_{x4} \times \text{PCR of Gear}$

Torque $T_o = M_{xt} = F_{t4} \times \text{PCR of Gear}$

Resistive Torque Through coupling

Direction of Shaft Rotation



Elevation View of Output Shaft (xy plane)

ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

*Output Shaft Design (size) verification- to be continued
in next lecture.....*

Thank You



Module-05

Design of a General Purpose Industrial Helical Gear Reduction Unit- Part III

Lecture-25

Design Verification of Output Shaft



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Prof. Rathindranath Maiti
Mechanical Engineering Department

Outline of the Lecture

- **Applied and Reaction loads on Output Shaft and Equilibrium (Recapitulation) .**
 - **Finalizing Output Shaft Design comprising of following steps**
 - **Applied and Reaction loads and moments in details**
 - **Bending Moment in vertical plane- Torque diagram, SFD, BMD**
 - **Bending Moment in horizontal plane- SFD, BMD**
 - **Assessing critical section(s)**
 - **Estimation of bending, shear and direct stresses at critical section (s)**
 - **Shaft Design verification by calculating factor of safety**



Viewing the Reduction Gear Unit for Load Analysis and Shaft Design Verification :

The development drawing of the shaft subassemblies are done considering the plan view of the reduction gear unit as below (Fig. 1).

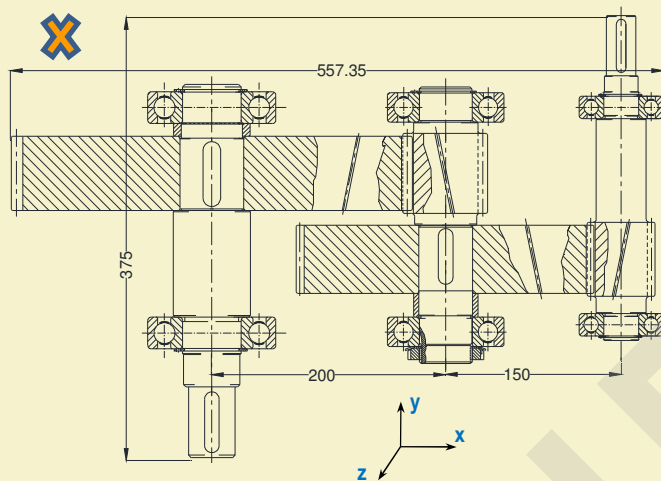


Fig. 1: Plan View (xz Plane) of the Gear unit in Earlier Lectures (Ref: Slide 9, lecture-23)

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EXCEPT OTHERWISE MENTIONED

However, referring to the load analyses in earlier lectures (starting from week 4 lectures) the view would be as in Fig. 2.

Henceforth, the view in Fig. 2 is to be followed.

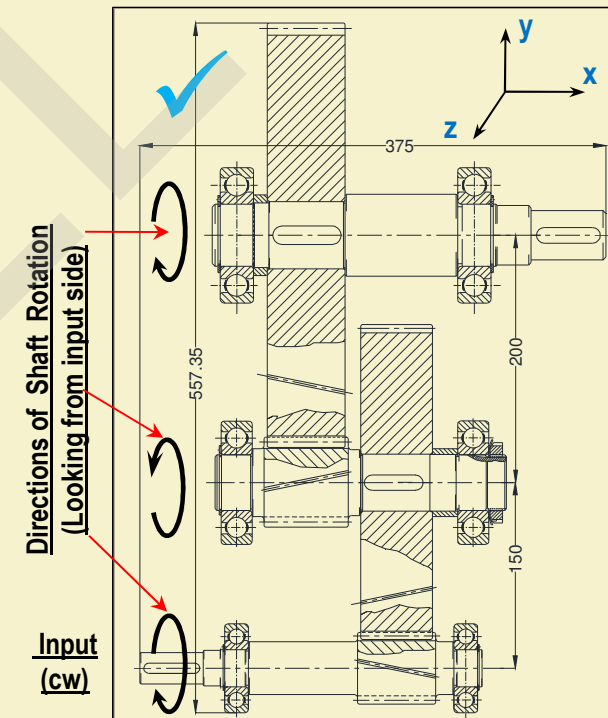


Fig.- 2 : Plan View of the Reduction Gear unit (Only subassemblies of three shafts) (in xz plane- the plane of slide)

Verification of Output Shaft Design :

Applied and Reaction loads on Shaft

Load (Applied) at Tooth:

$$F_{t4} = F_{y4} = -4377.65 \text{ N}$$

$$F_{r4} = F_{z4} = -1625.85 \text{ N} \quad R_{VL} = R_{yL}$$

$$F_{a4} = F_{x4} = -889 \text{ N}$$

Load (Reaction) at Left Bearing:

$$R_{VL} = R_{yL} = 3100.85 \text{ N}$$

$$R_{HL} = R_{zL} = 1924.85 \text{ N}$$

$$R_{AL} = R_{xL} = 0$$

Load (Reaction) at Right Bearing:

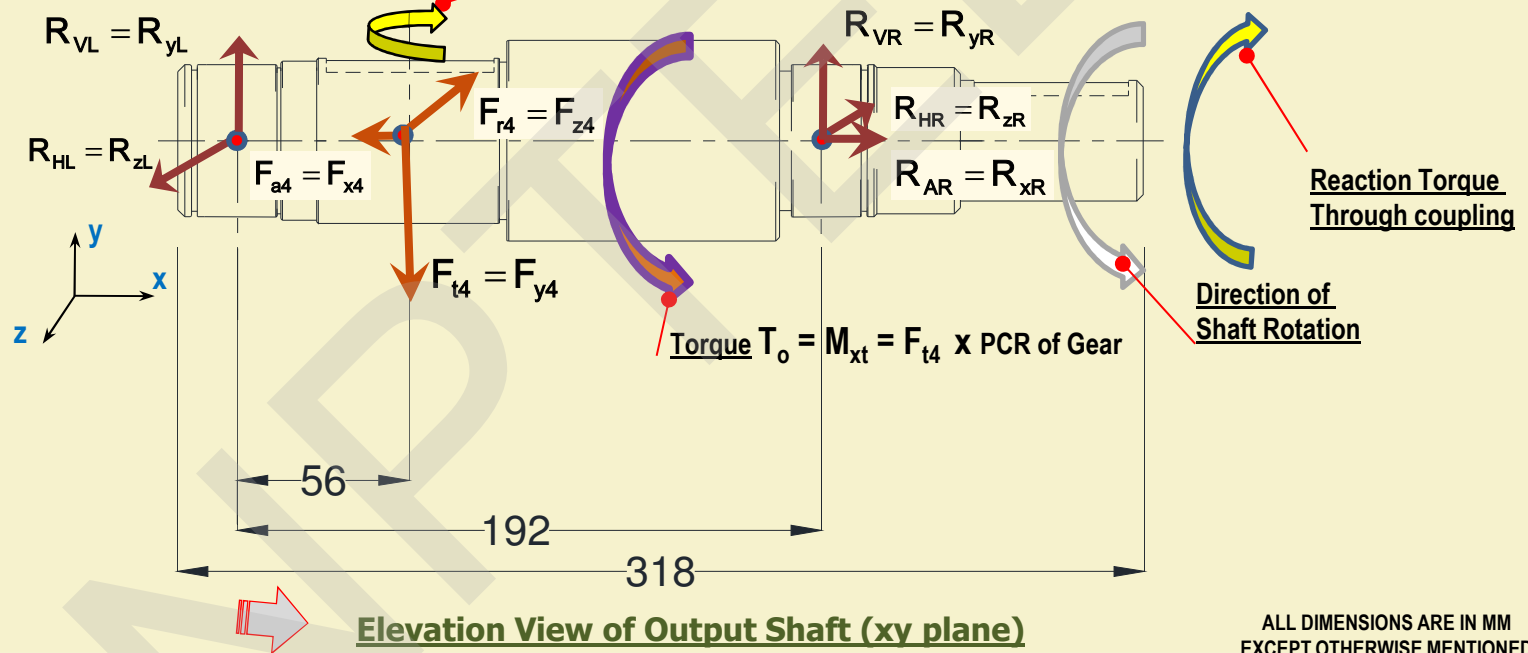
$$R_{VR} = R_{yR} = 1276.8 \text{ N}$$

$$R_{HR} = R_{zR} = -299 \text{ N}$$

$$R_{AR} = R_{xR} = 889 \text{ N}$$

The out shaft is now being viewed as elevation. (i.e., let it has been rotated by 270° in the direction of rotation from the earlier view. The plane of the slide is now in xy plane.)

Applied Moment due to Axial Force $M_a = M_{ya} = F_{x4} \times \text{PCR of Gear}$



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Design Verification of a Shaft of Reduction Gear Unit (Recapitulation) :

Verification of Overall factor of safety at the Critical most Section is done.

The **factor of safety** f_s can be estimated using the following formula, which is based 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.

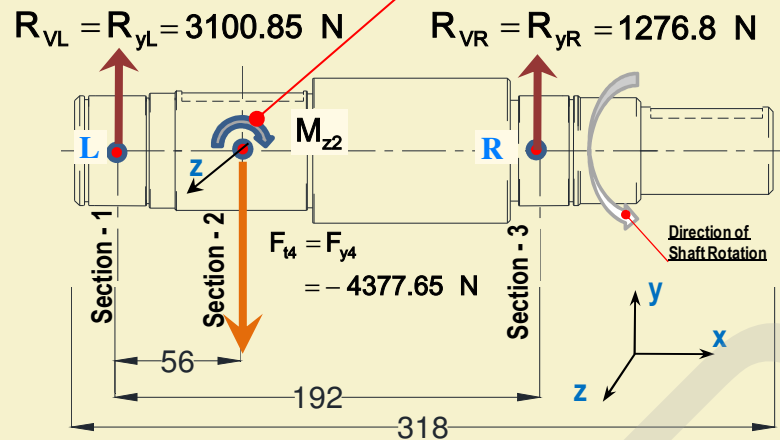
It is chosen considering on what basis section modulus has been calculated in estimating σ_a .



Verification of Output Shaft Design (Contd.....) : Applied and Reaction Forces on Shaft, SFD, BMD etc. :

Vertical Plane (xy plane) :

Bending Moment (Not to be shown in load Equilibrium Diagram)



Note: It is considered that rolling element bearing can not resist Moment

Bending Moment at section 2:

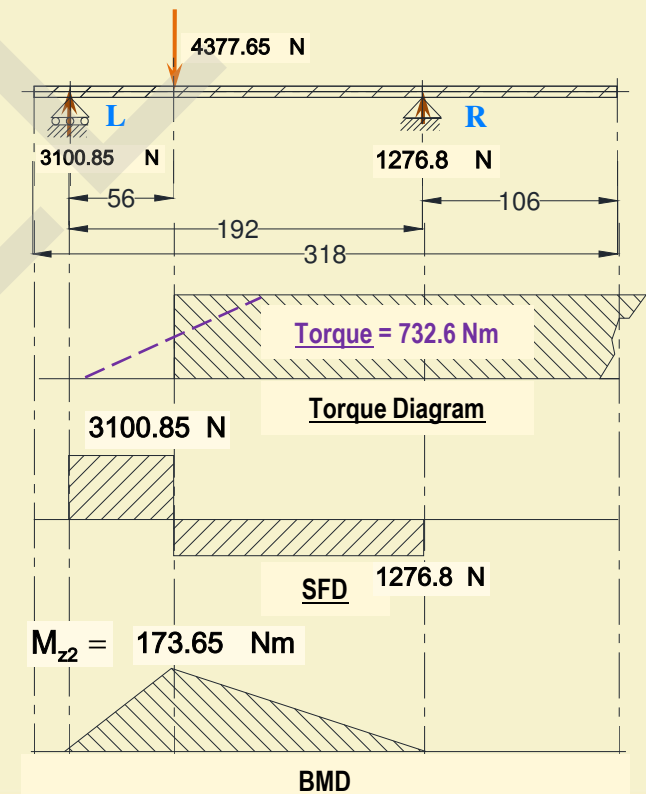
$$M_{z2} = 3100.85 \times 0.056 = 173.65 \text{ Nm}$$

Elevation View of Output Shaft (xy plane- the plane of slide)



ALL DIMENSIONS ARE IN MM
EXCEPT OTHERWISE MENTIONED

Note: For better understanding the view (the axis of the shaft), forces and moments are in the plane of slide



Verification of Output Shaft Design (Contd.....) : Applied and Reaction Forces on Shaft, SFD, BMD etc. :

Horizontal Plane (xz plane) :

Reaction Load at Bearings (In details) :

For radial components of tooth load $F_{r4} = F_{z4}$:

Taking moment about L support point :

$$R_{zRr} = \frac{-1625.85 \times 0.056}{-0.192} = 474.2 \text{ N}$$

Moment due to axial force $M_{ya} = -889 \times 0.167 = -148.46 \text{ Nm}$

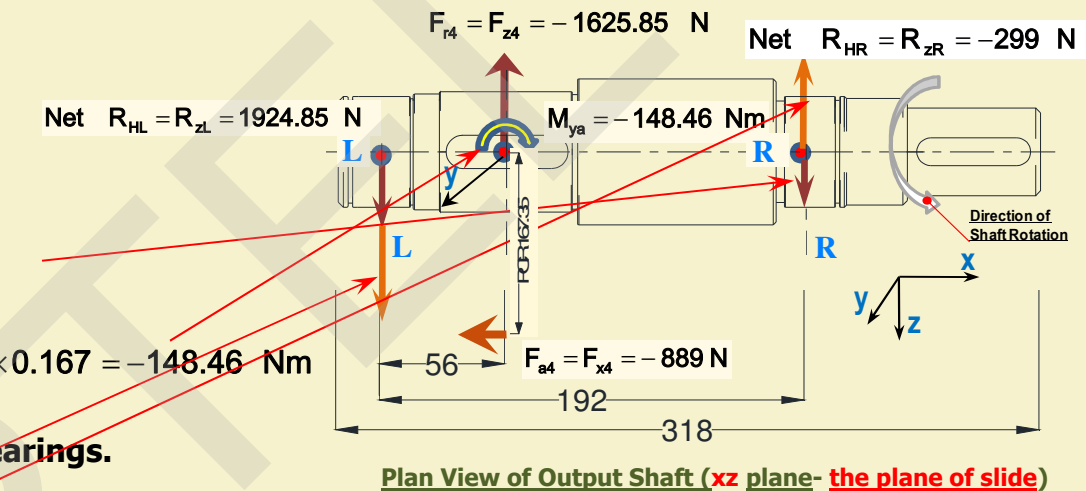
This Moment is balance by a Couple at bearings.

The Couple force $R_{zaL} = -R_{zaR} = \frac{148.46}{0.192} = 773.2 \text{ N}$

Therefore, net reaction at left support: $R_{zL} = (1625.85 - 474.2) + 773.2 = 1924.85 \text{ N}$

and , at right support:

$$R_{zR} = 474.2 - 773.2 = -299 \text{ N}$$



Note: For better understanding the view (the axis of the shaft), forces and moments are in the plane of slide

ALL DIMENSIONS ARE IN MM EXCEPT OTHERWISE MENTIONED



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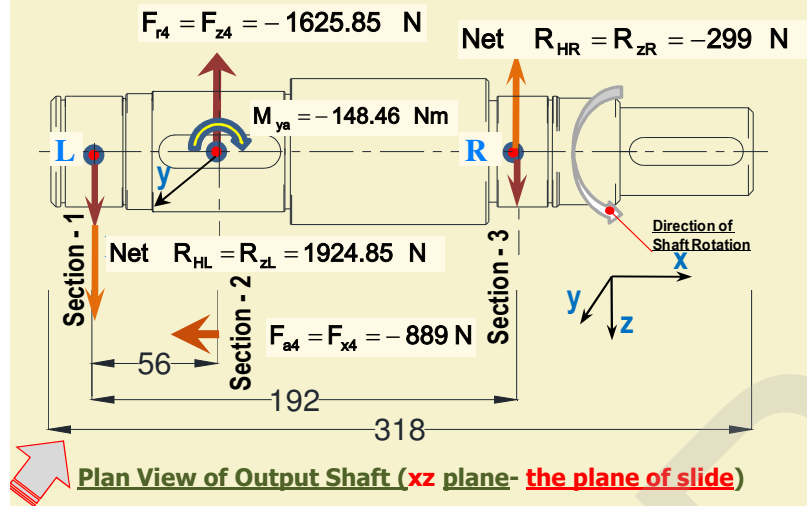


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Verification of Output Shaft Design (Contd.....) :

Horizontal Plane (xz plane) :



Check: Bending Moment at section 3 :

$$M_{y3} = 1924.85 \times 0.192 - 148.46 - 1625.85 \times (0.192 - 0.056) = 0 \text{ Nm}$$

Bending Moment at just left of section 2:

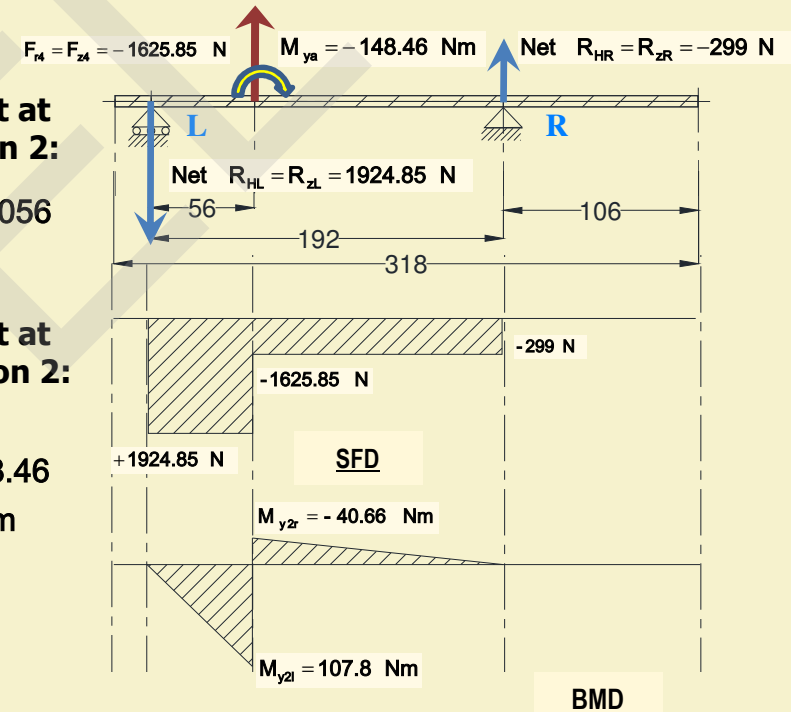
$$M_{y2l} = 1924.85 \times 0.056 = 107.8 \text{ Nm}$$

Bending Moment at just right of section 2:

$$M_{y2r} = M_{y2l} + M_{ya} = 107.8 - 148.46 = -40.66 \text{ Nm}$$

Note: For better understanding the view (the axis of the shaft), forces and moments are in the plane of slide

Applied and Reaction Forces on Shaft, SFD, BMD etc. : (Torque diagram is not shown)



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Verification of Output Shaft Design (Contd.....) :

The sections are critical where there is stress concentration with substantial torque and bending moment with less section modulus. Sections with 'steps and undercuts', 'key ways' are more vulnerable.

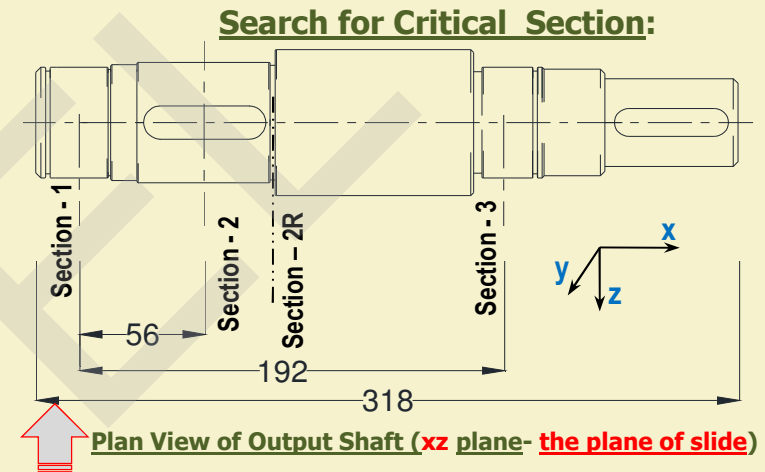
Looking into the feature of output shaft and resultant bending moment the section 2 will be most critical.

Resultant bending moment just at the left of section- 2:

$$M_{2_{res}} = \sqrt{M_{y2l}^2 + M_{z2}^2} = \sqrt{107.8^2 + 173.65^2} = 204.4 \text{ Nm}$$

Torque at section- 2:

$$T_o = 732.6 \text{ Nm}$$



Note: Section 2R could be critical as there will be more stress concentration. However, BM is less. With the change in direction of rotation or helix angle BM will increase. Therefore, f_s also needs to be verified.

Note: For better understanding the view (the axis of the shaft), forces and moments are in the plane of slide

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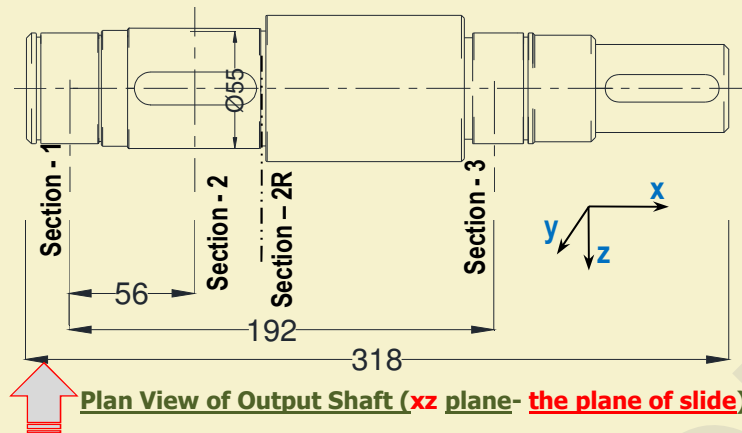
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Verification of Output Shaft Design (Contd.....) :



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

$$\sigma_a = f_c \frac{M}{z} = f_c \frac{32M}{\pi d^3}$$

(Section modulus $z = \frac{I}{y} = \frac{\pi d^4 / 64}{d / 2}$ and f_c stress concentration factor).

Verification of factor of Safety f_s :

Maximum bending stress at section 2:

$$\sigma_{a2} = 2 \times \frac{32 \times 204.4}{\pi \times (0.055)^3} = 25 \text{ MPa}$$

f_c is taken 2 in general for milled single keyway.

Average mean stress due to axial load at section 2:

$$\sigma_{m2} = f_c \frac{4F_a}{\pi d^2} = 2 \times \frac{4 \times 889}{\pi \times (0.055)^2} = 0.748 \text{ MPa}$$

Maximum shear stress at section 2:

$$\tau_{m2} = f_c \frac{16T_o}{\pi d^3} = 2 \times \frac{16 \times 732.6}{\pi \times (0.055)^3} = 44.85 \text{ MPa}$$

Note: Effects of key way on area, area moment of inertia etc. are neglected.

Note: For better understanding the view (the axis of the shaft), forces and moments are in the plane of slide

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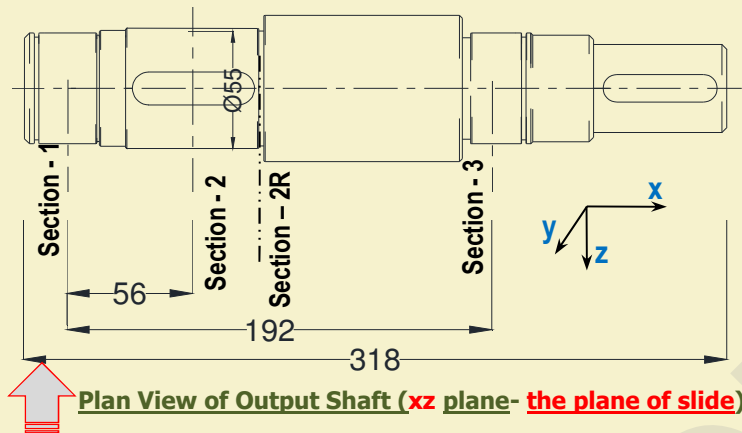
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Verification of Output Shaft Design (Contd.....) :



Plan View of Output Shaft (xz plane- the plane of slide)

Output Shaft Material - EN 8 (C40/C45) having

$$S_u = 570 \text{ MPa} \text{ and } S_y = 280 \text{ MPa}.$$

Considering $S_{en} = 256 \text{ MPa}$ (About 45% of S_u for well finished /ground shaft),

Verification of factor of Safety f_s :
and substituting the values f_c is calculated as:

$$\frac{280}{f_s} = \sqrt{\left(0.748 + 2 \times \frac{280}{256} \times 25\right)^2 + 4 \times (44.85)^2}$$

$$= \sqrt{3073.1 + 8046.1} = \sqrt{11119.2} = 105.45$$

$$\therefore f_s = \frac{280}{105.45} = 2.65$$

This is Satisfactory*.

(*Note: Shaft diameter can not be reduced at the place of Gear fitting although at bearings it may be possible).

However, as mentioned it is to be verified for 'Section – 2R' if the direction of rotation is reversed.

Note: For better understanding the view (the axis of the shaft), forces and moments are in the plane of slide

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Thank You



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12

Module-05

Design of a General Purpose Industrial Helical Gear Reduction Unit- Part III

Lecture-26

Design Verification of Input Shaft (including Bearing Life Estimation)



Outline of the Lecture

- **Equivalent loads, Equilibrium- Input Shaft Sub Assembly**
 - **Input Shaft- Force Equilibrium**
- **Bearing Life Estimation**
 - **Loads on End Bearing & Bearing Selection**
- **Design verification by calculating factor of safety**
 - **Comments on All Shaft Subassembly**

Viewing the Reduction Gear Unit for Load Analysis and Shaft Design Verification (Recapitulation)

The development drawing of the shaft subassemblies are done considering the plan view of the reduction gear unit as below (Fig. 1).

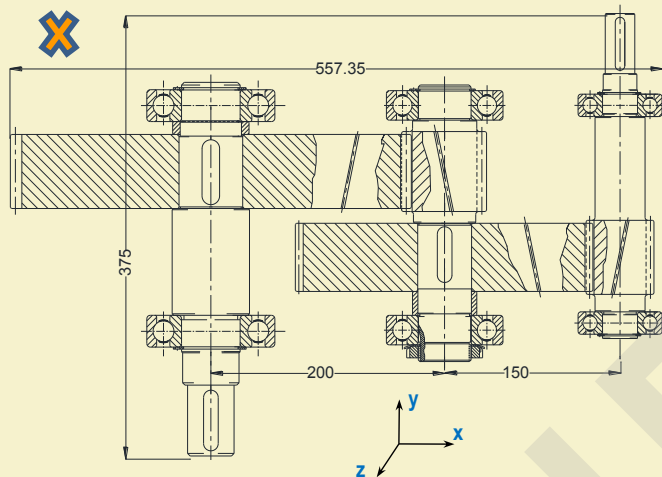


Fig. 1: Plan View (xz Plane) of the Gear unit in Earlier Lectures (Ref: Slide 9, lecture-23)

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However, referring to the load analyses in earlier lectures (starting from week 4 lectures) the view would be as in Fig. 2.

Henceforth, the view in Fig. 2 is to be followed.

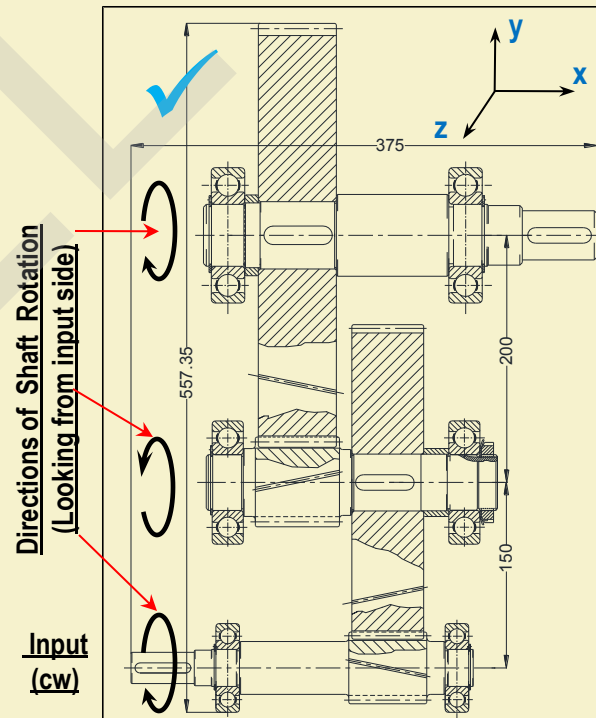


Fig. - 2 : Plan View of the Reduction Gear unit (Only subassemblies of three shafts) (in xz plane- the plane of slide)

Design Verification - Input Shaft (Contd.....) :

Load (Applied) at Tooth:

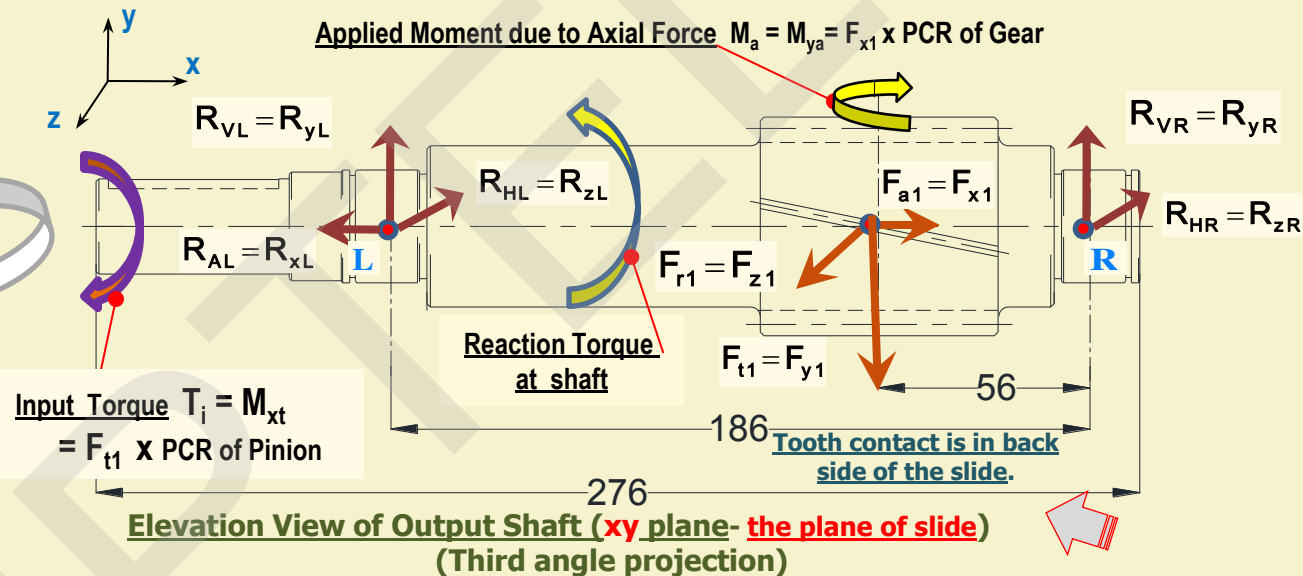
$$F_{t1} = F_{y1} = \frac{2 \times 30}{0.05204} = -1153 \text{ N}$$

$$F_{r1} = F_{z1} = 428.2 \text{ N}$$

$$F_{a1} = F_{x1} = 234.13 \text{ N}$$

Direction of
Shaft Rotation
CW

Applied and Reaction load Calculation (Based on Nominal Input Torque) :



Moment due to axial force :

$$M_a = M_{ya} = 234.13 \times (-0.05204 / 2) = -6.1 \text{ Nm}$$

Load (Reaction) at Left Bearing:

$$R_{VL} = R_{yL} = 347.14 \text{ N}$$

$$R_{HL} = R_{zL} = -96.125 \text{ N}$$

$$R_{AL} = R_{xL} = -234.13 \text{ N}$$

Load (Reaction) at Right Bearing:

$$\left\{ \begin{array}{l} R_{VR} = R_{yR} = 805.86 \text{ N} \\ R_{HR} = R_{zR} = -332 \text{ N} \\ R_{AR} = R_{xR} = 0 \text{ N} \end{array} \right.$$

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Design Verification - Input Shaft (Contd.....) :

Loads on Bearing and Bearing Life Estimation- Right Support Bearing (SKF 6306) :

Equivalent Load (P) Acting on right bearing

$$P = C_1(XVF_r + YF_a)$$

$$= 1.5 \times \left(1 \times 1 \times \sqrt{805.86^2 + 332^2}\right) = 1307.36 \text{ N}$$

Dynamic load carrying capacity of bearing: **C=21400 N**

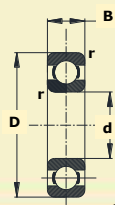
Life of the right bearing (in rev):

$$L_N = \left(\frac{21400}{1307.36}\right)^3 \times 10^6 \text{ Rev} = 4386 \times 10^6 \text{ Rev}$$

Life of the left bearing (in hrs):

$$L_{hR} = \frac{4386 \times 10^6}{1500 \times 60} = 48732 \text{ hrs}$$

This is much more than specified minimum life of 10,000 hrs. It indicates that lower series bearing and with one size less (i.e., 6205) may be well satisfactory.



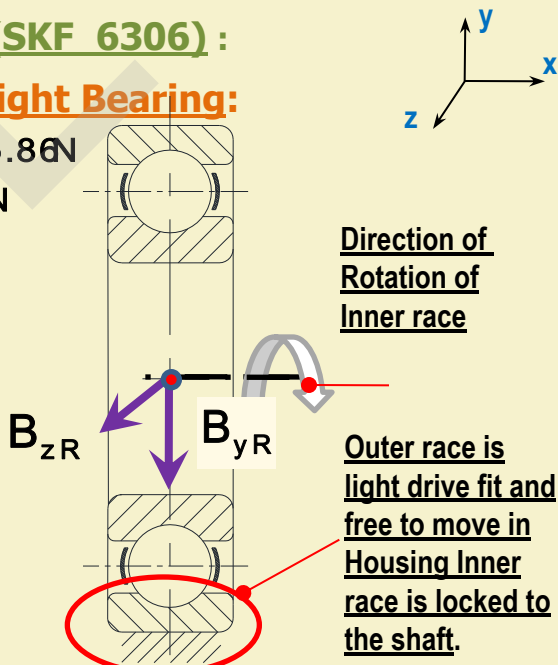
Bearing No.	d		D		B		r	Basic Capacity, lb.	
	mm.	in.	mm.	in.	mm.	in.	mm.	Dynamic C	Static C ₀
6306	30	1.1811	72	2.5346	19	0.7480	2	4800	3200

Load acting at Right Bearing:

$$B_{yR} = -R_{yR} = -805.86 \text{ N}$$

$$B_{zR} = -R_{zR} = 332 \text{ N}$$

$$R_{AR} = R_{xR} = 0 \text{ N}$$



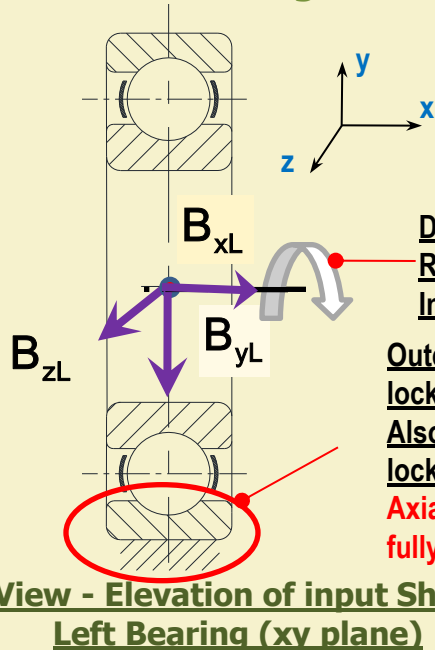
View - Elevation of input Shaft Right Bearing (xy plane)

$$X = 1 \text{ \& } Y = 1.6$$

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Design Verification - Input Shaft (Contd.....) :

Loads on Bearing and Bearing Life Estimation- Left Support Bearing (SKF 6306) :



Load at Left Bearing:

$$B_{yL} = -R_{yL} = -347.14 \text{ N}$$

$$B_{zL} = -R_{zL} = +96.125 \text{ N}$$

$$B_{xL} = -R_{xL} = +234.13 \text{ N}$$

Direction of
Rotation of
Inner race

Outer race is fully
locked with Housing.
Also Inner race is
locked to the shaft.
Axial movement is
fully constrained.

Equivalent Load (P) Acting on right bearing

$$P = C_1 (XVF_r + YF_a) = 1.5 \times \left(\sqrt{347.14^2 + 96.125^2} + 1.6 \times 234.13 \right) = 1102.2 \text{ N}$$

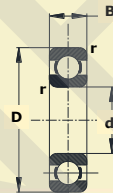
Dynamic load carrying capacity of bearing: **C=21400 N**

Life of the right bearing (in rev):

$$L_N = \left(\frac{21400}{1102.2} \right)^3 \times 10^6 \text{ Rev} = 7318.8 \times 10^6 \text{ Rev}$$

Life of the left bearing (in hrs): $L_{hR} = \frac{7318.8 \times 10^6}{1500 \times 60} = 81320 \text{ hrs}$

This is also high and bearing 6205 may be chosen.



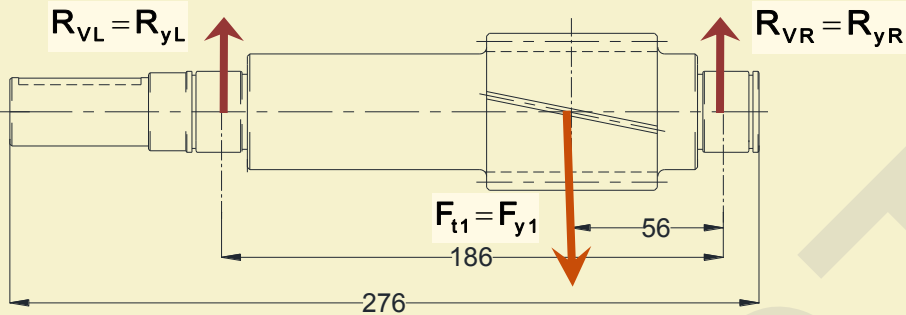
Bearing No.	d		D		B		r	Basic Capacity, lb.	
	mm.	in.	mm.	in.	mm.	in.		Dynamic C	Static C ₀
6306	30	1.1811	72	2.5346	19	0.7480	2	4800	3200

$$X = 1 \text{ \& } Y = 1.6$$

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Design Verification - Input Shaft (Contd.....) :

Vertical Plane (xy plane) :



Elevation View of Output Shaft (xy plane- the plane of slide) (Third angle projection)

Forces

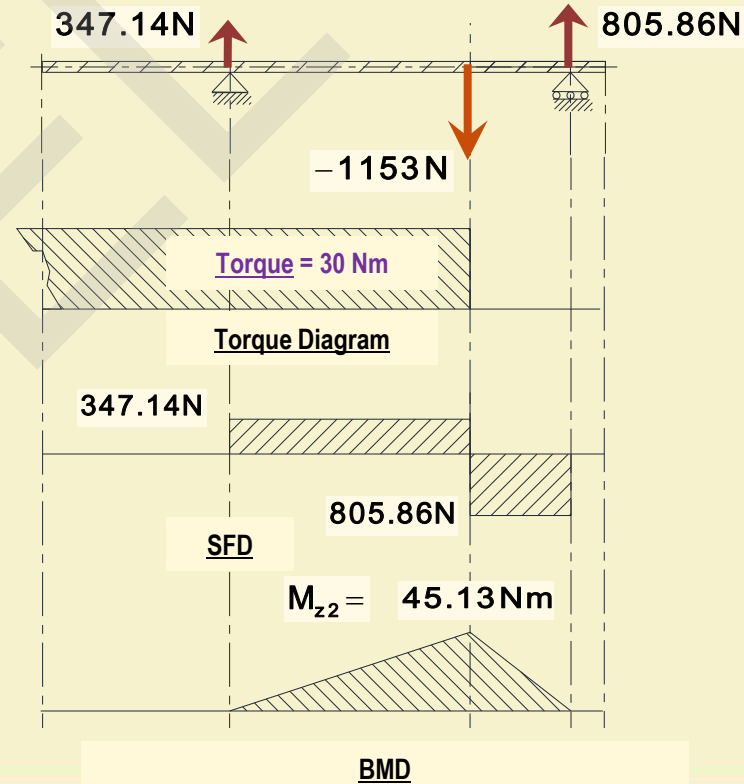
$$F_{t1} = F_{y1} = -1153 \text{ N}$$

$$R_{VL} = R_{yL} = 347.14 \text{ N}$$

$$R_{VR} = R_{yR} = 805.86 \text{ N}$$

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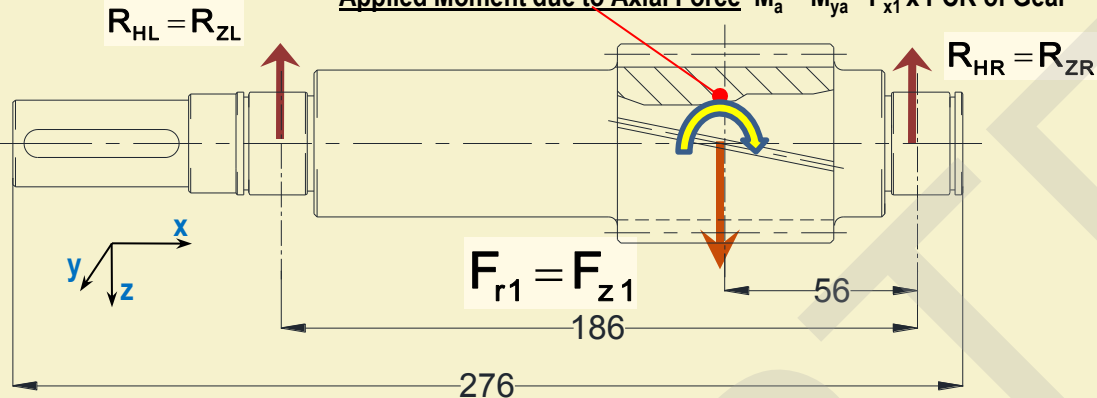
Applied and Reaction Forces on Shaft, SFD, BMD etc. :



Design Verification - Input Shaft (Contd.....) :

Horizontal Plane (xz plane) :

Applied Moment due to Axial Force $M_a = M_{ya} = F_{x1} \times \text{PCR of Gear}$



Plan View of Output Shaft (xz plane- the plane of slide)

$$M_a = M_{ya} = -6.1 \text{ Nm}$$

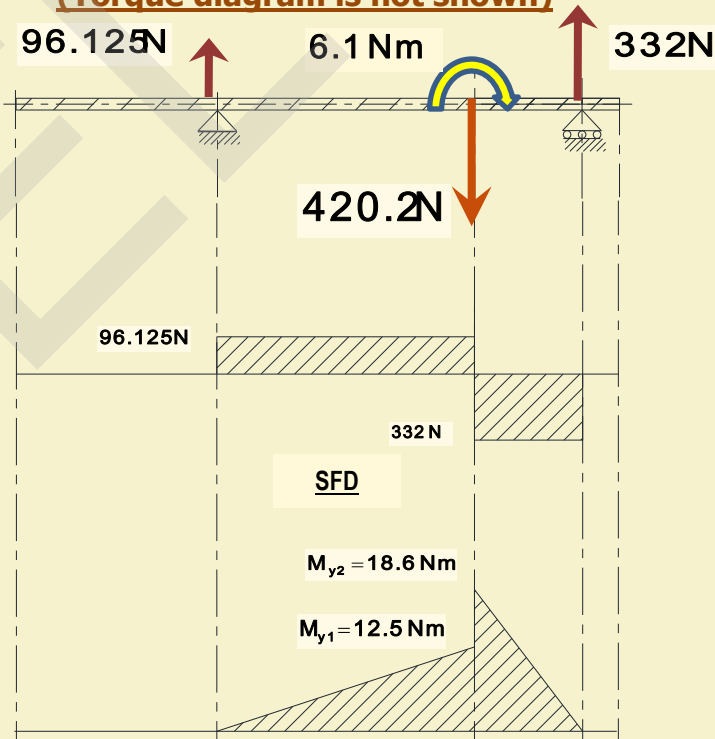
$$F_{r1} = F_{z1} = 428.2 \text{ N}$$

$$R_{HL} = R_{ZL} = -96.125 \text{ N}$$

$$R_{HR} = R_{ZR} = -332 \text{ N}$$

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Applied and Reaction Forces on Shaft, SFD, BMD etc. : (Torque diagram is not shown)



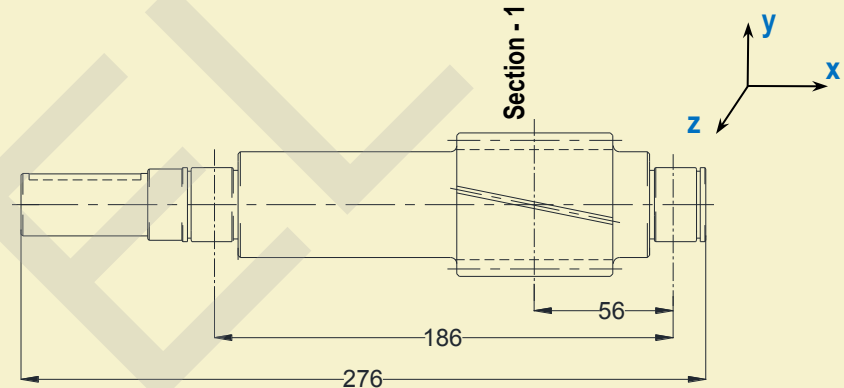
Design Verification - Input Shaft (Contd.....) :

Looking into the feature of the shaft the critical most section will be the section 1 as the resultant bending moment is maximum there with some stress concentration due to the integral pinion.

However, the material is EN 19 and the moment is not very high.

Therefore, it is apparent that 'factor of safety' f_s will be high i.e., the developed maximum stress will be well below the 'Yield Strength'.

Verification of factor of Safety f_s :



Elevation View of Output Shaft (xy plane
- the plane of slide) (Third angle projection)

Verification of the strength of the selected keys for all shafts are to be done next before finalizing the plan view.

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Thank You

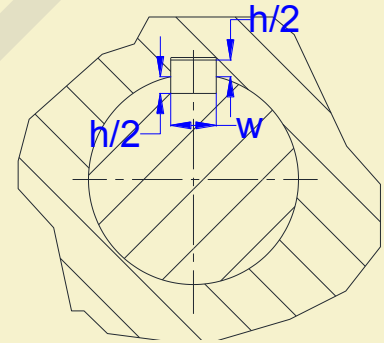


Verification of the strength of the selected keys :

For all shafts the chosen keys are standard rectangular keys. All key ways are cut by end mill key slot cutter.

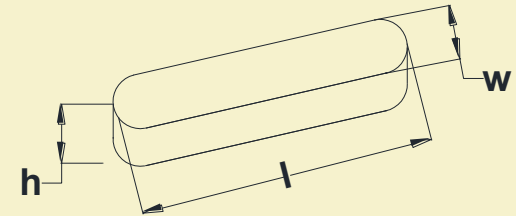
Keys are made of low to medium carbon steel (C30 – an example).
It is made weaker than shaft and mating parts material.

Keys are made of low to medium carbon steel (C30 – an example).
It is made weaker than shaft and mating parts material.



Out 55 10x16x
Out 40-55 9x14x

Input 25 7x8x
Int 50 9x14x



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