Gear and Gear Unit Design: Theory and Practice
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Lecture – 17
Bearing Load Calculation- Intermediate Shaft

In module 4, this is the second lecture and we shall continue with the bearing selection for inputs shaft.

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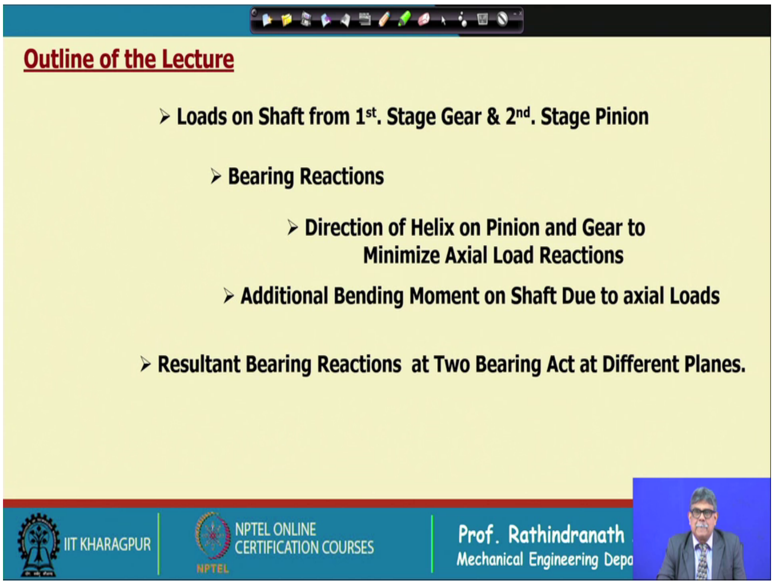

In this lecture I shall cover loads on shaft from hostage gear and second stage pinion. We have considered the intermediate shaft on intermediate shaft there are gear of first stage and pinion of second stage.

Now, then we shall calculate the bearing reactions the direction of helix on pinion and gear to minimize axial load reaction; this is an important issue. I shall discuss about that and additional bending moments on shaft due to axial load resultant bearing reactions at two bearings act at a different planes.

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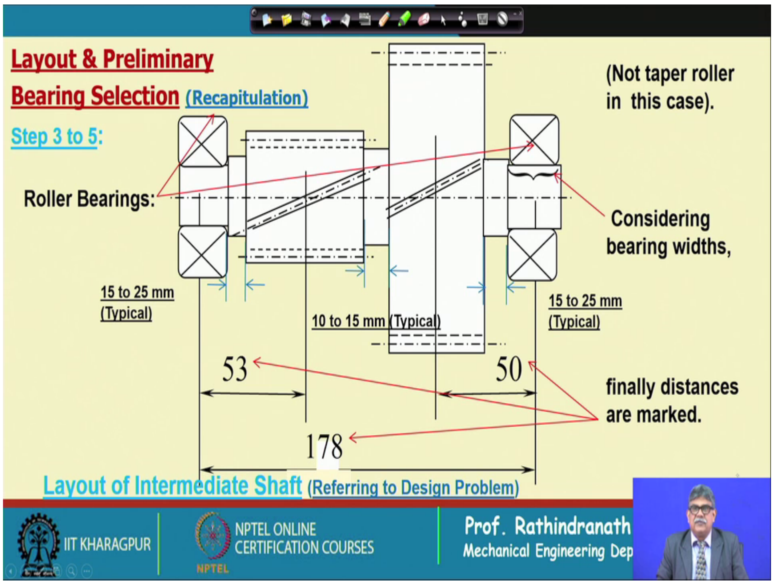

And now coming to this intermediate shaft, we have the pinion here we have taken the midpoint of the pinion; this is we have taken 5 millimetre more than the active width what we have calculated, but this is not coming into picture.

Because, we have considered the proper gaps here, and then we have taken a bearing of with something between 20 to 25 millimetre and midpoint of that is the reaction points bearing supports. We have calculated from the drawing this is 178 millimetres; this side it is 53 millimetres this side it is 50 millimetre this is the input gear and input side gear this is the output side pinion.

These two are the bearings not the taper roller bearing. We shall go for some other bearing and typical gap is 10 to 15 millimetre in between gears and pinion and at the bearing this gap is taken 15 to 25 millimetre. Then we have considered the width of the bearing and final discussion distances are given.

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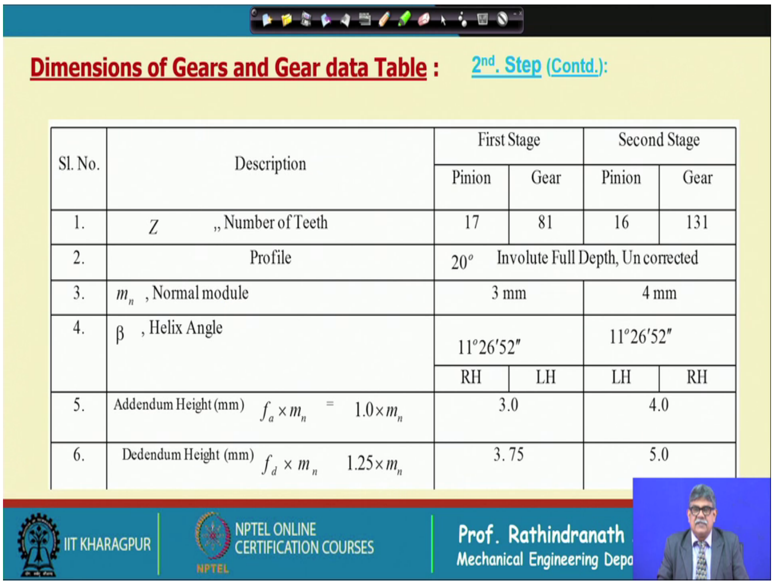

Sl. No.	Description		First Stage		Second Stage	
			Pinion	Gear	Pinion	Gear
1.	Z ,, Number of Teeth		17	81	16	131
2.	Profile		20^o Involute Full Depth, Uncorrected			
3.	m_n , Normal module		3 mm		4 mm	
4.	β , Helix Angle		$11^o26'52''$		$11^o26'52''$	
			RH	LH	LH	RH
5.	Addendum Height (mm) $f_a \times m_n$	$= 1.0 \times m_n$	3.0		4.0	
6.	Dedendum Height (mm) $f_d \times m_n$	$1.25 \times m_n$	3. 75		5.0	

Also this gear dimensions that is necessary while we are calculating the bearing loads.

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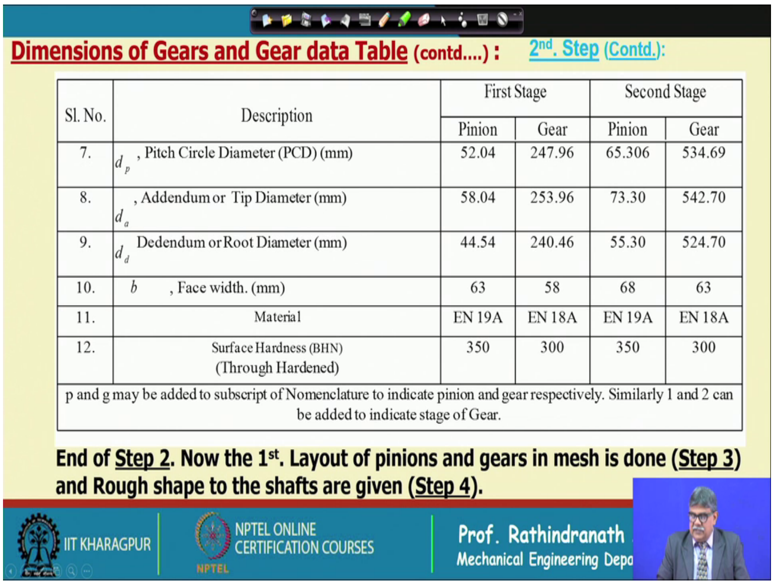

Sl. No.	Description	First Stage		Second Stage	
		Pinion	Gear	Pinion	Gear
7.	d_p , Pitch Circle Diameter (PCD) (mm)	52.04	247.96	65.306	534.69
8.	d_a , Addendum or Tip Diameter (mm)	58.04	253.96	73.30	542.70
9.	d_d Dedendum or Root Diameter (mm)	44.54	240.46	55.30	524.70
10.	b , Face width. (mm)	63	58	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.					

This already I have shown these are the bearing data.

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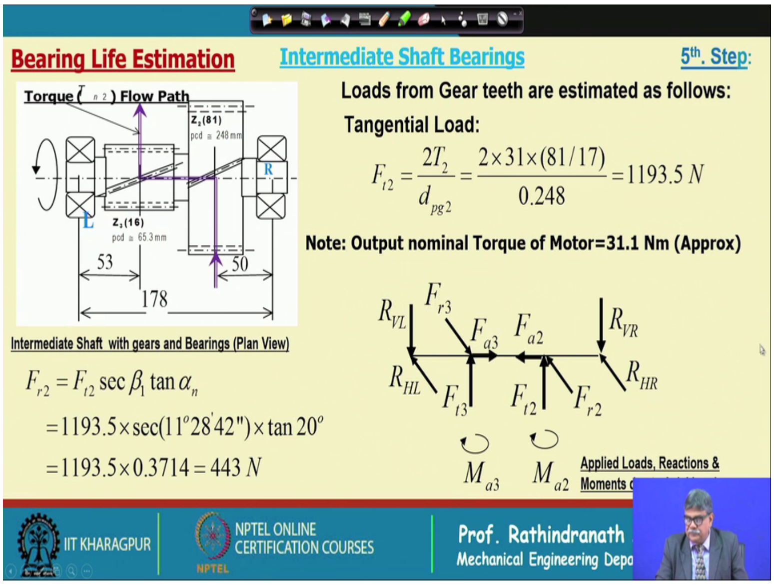

And we are now calculating the; what are the reaction load coming on the shaft? Now first of all the; we are considering the torque this shaft torque is the input torque multiplied by the fastest gear ratio. Now here one important issue is that the output nominal torque of motor is around 31.1 Newton meter. So, here this torque we have considered 31 Newton; instead of 30 we have considered the 31 Newton meter, because after if we know the torque; what is the torque input?.

Torque is required; then gears may be calculated on that basis and finally, we can calculate what might be the power of the motor and then motor or prime over; and then we can consider that output of that motor is the nominal torque in this case as the 200 percent starting torque, the prime mover is taken such that it can give the nominal torque most of the time whereas, at starting it is able to take 200 percent torque also.

Now here we can see this; how the torque is moving from input side to output side? And then the force tangential force on the this pinion, which is this is pitch circle diameter of the pinion no pitch circle diameter of the gear this is the circle diameter of the gear and two is stand for the gear two in drawing; I have shown this is gear two this is pinion three this is and then there gear four.

So, that is why this designation has been taken and the diameter of; that is, 0.247, 0.96. we have taken a square value 2.248 and the torque is 31, we have not multiplied any factor of safety at this stage, because we have need to calculate the nominal loads and from there. When we consider the bearing design consider the shaft design; in that case we will multiply with the factors there and this torque is coming 1193.5 Newton, if there might be some round of value maybe it is 93.45 or something like that, but that that is considered that can be considered.

Now, next we are considering the loads on this shaft ok. Now here if we consider this pinion this is pinion 3, this is geared number is taken as 3. So, radial load we are considering that this is the gear in the other side the below this and pinion is top of this here; if we consider the pinion is top of this and gear is below this. So, the directions of load will be like this if we consider this point if you consider this point this F r is acting from this side and as the direction of rotation is like this direction of rotation is clockwise from this side. Then this must be pushing the gear sorry this gear is in this plane in this plane. So, it is being pushed downwards for this rotation. So, tangential load is coming in this directions here ok.

And if we consider this point, then this is coming upwards sorry this first we I told the pinion is gear is below this no gear is in this plane pinion is in this plane. So, in this case also this point is going off. So, tangential load is like this and radial load is from this side it is going in this directions ok. Now what about the axial load? Axial load if we consider this direction of helix this direction of helix is right hand or left hand, this is if we consider the screw rule this is left hand.

So, when the load is acting tangential load is acting like this then here considering this direction the axial load acting in this directions, now if we consider the pinion then pinion teeth is pushing downwards the gears. So, for that this axial load must be acting in this directions; this means that only if we take the direction of helix same, if the gear is left hand then pinions would also be left hand if gear is right hand and pinion also to be right hand. And then this axial load will act in the opposite direction; if we rotate in the opposite directions; that means, if the direction of rotation instead of that if it is in the anti clockwise directions. Then the axial load will act in these directions, and in this case it will act in these directions for the same direction of helix this means that this will try to cancel each other. So, resultant axial force will be less and that is why you will find that in gearboxes in intermediate shaft direction of helix of the gears are same.

It is shown here ok. Now access this barring reaction is concerned in that case for the radial loads. So, radial loads is acting like this and acting like this. So, for that one reaction must be here and other reaction. On the other end this reaction is HR this is right hand reaction and R HR is the right hand reactions on the bearing R HL is the left hand reaction on the bearing due to radial load it is interesting that we have not taken the normal load we have resolved into the components at gears and pinions. And then we are finding out their reactions and then we will find finally, find the; what is the resultant load at the bearings?

Next due to this tangential load at the gears there will be two reactions one in left hand and other is right hand and then finally, these are calculated load R calculated F r 2 is equal to F 2 to F dt. This formula we have used and from there we have calculated what is the load if r 2; that means, the radial load on gears due to gears is 443 Newton.

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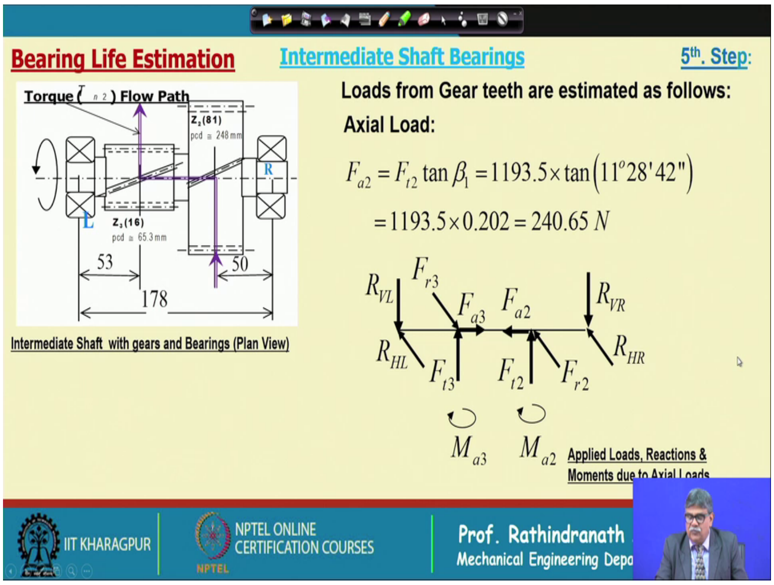

And then axial load is coming over 240.65 N.

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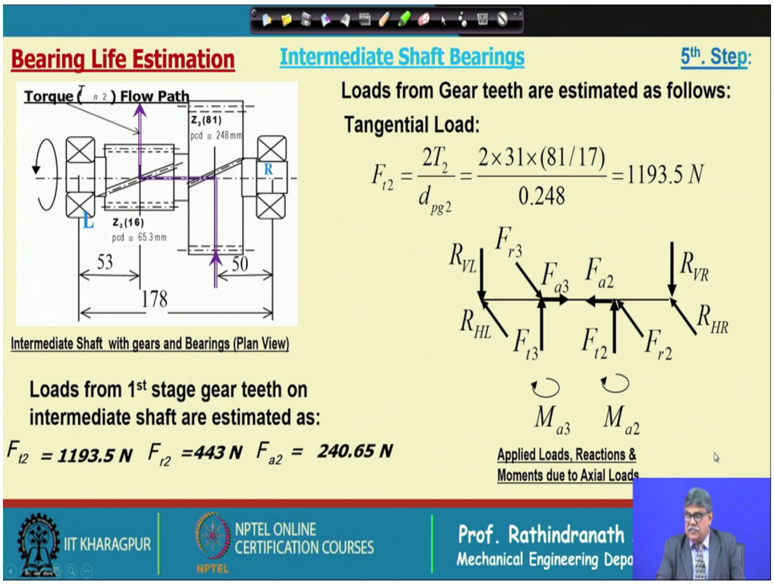

And if we again consider the ultimately final load is coming that tangential load at gear first is gear is 1193.5 Newton. Radial load is 443 Newton and axial load is 240.65 Newton and direction for the clockwise direction of rotation is shown here.

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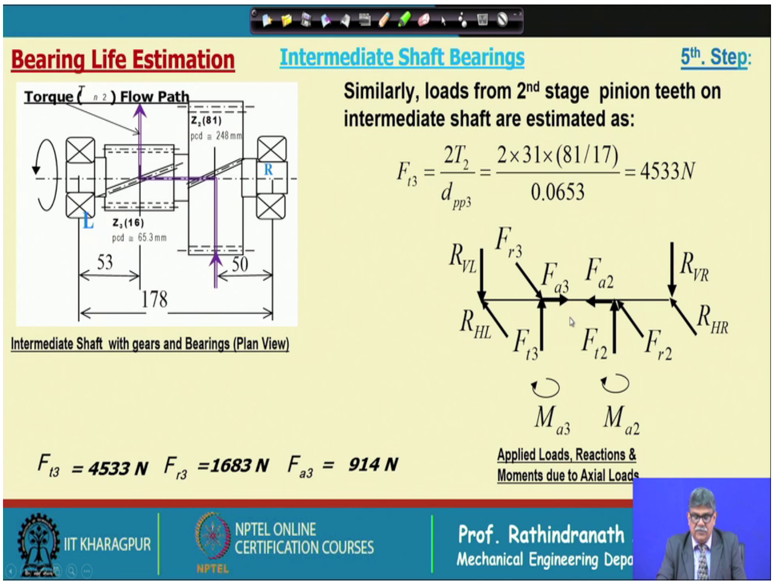

Now, if we come to the pinion then torque remains same, but diameter of the pinion is much less. So, therefore, this force tangential force is much higher F t 3 is 4533 Newton this one and then here also due to that again this different loads will be there and we can calculate the radial load is coming as 1683; that means, this load is coming 1683 Newton and axial load is coming 914 Newton.

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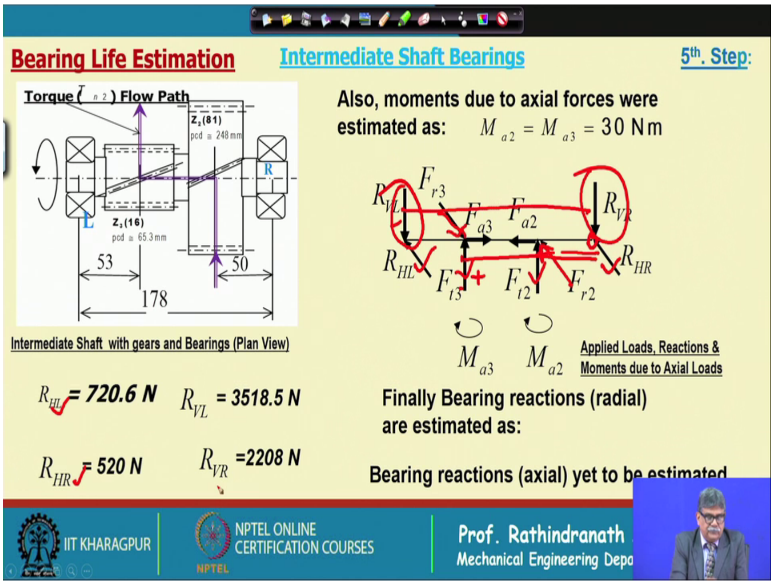

Again due to this axial load which is acting? Axial load is actually acting at this point this is the direction. So, it is acting over here and this is the direction of load it is acting over here. Now, these directions due to this load in this direction due to this load in this direction, which is shown here sometimes this moment is neglected, because this amount of this moment is not much, but for rigorous calculation one would consider this moment along with the bending moment coming on the shaft this is only 30 Newton meter.

Finally, bearing reactions radial are estimated. Now, it is perhaps known how to calculate this load and the bearing say we would like to calculate RVL, then what we will consider? We will consider the moment about this point, we will consider this load is known this load into this distance will give one moment and this load into this distance this will give one moment that summation of this divided by this distance will give these reactions ok.

So, we will calculate this load R VL we change due to the tangential load, it is coming 3518.5 and R VR must be equal to plus this this plus this minus this 1 minus this one will give this out here which is coming 2208 Newton. In the same way we will calculate also R HL and R HR which are this and this and this is due to this forces we will calculate these two also. So, now, on the bearing we have calculated load at different two planes.

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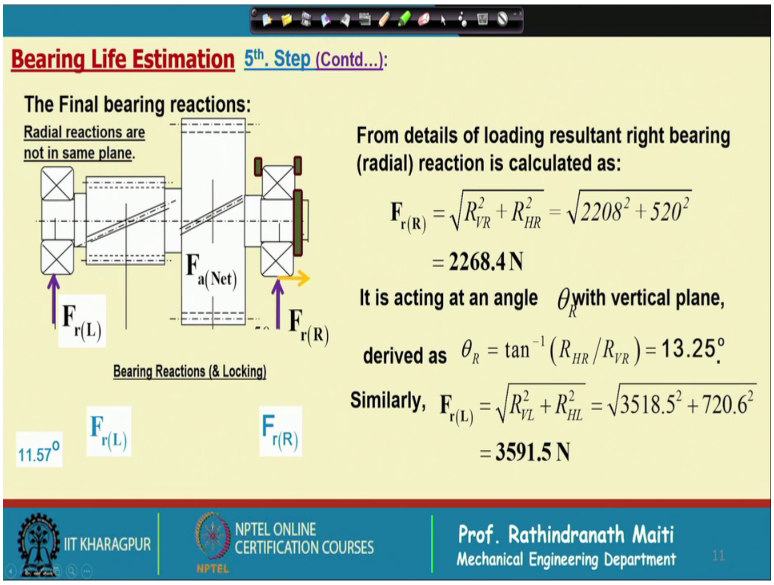

Now, finally, what we calculate the on right hand bearing resultant radial load is 2268.4 which is nothing, but from this value you can see it and it is 2268.4 similarly. So, this is radial load, now sorry resultant load in right hand bearing a radial load resultant radial load and right hand bearing is 2268.4 Newton. And if we calculate what is the direction of this is with vertical plane it is 13.25 degree.

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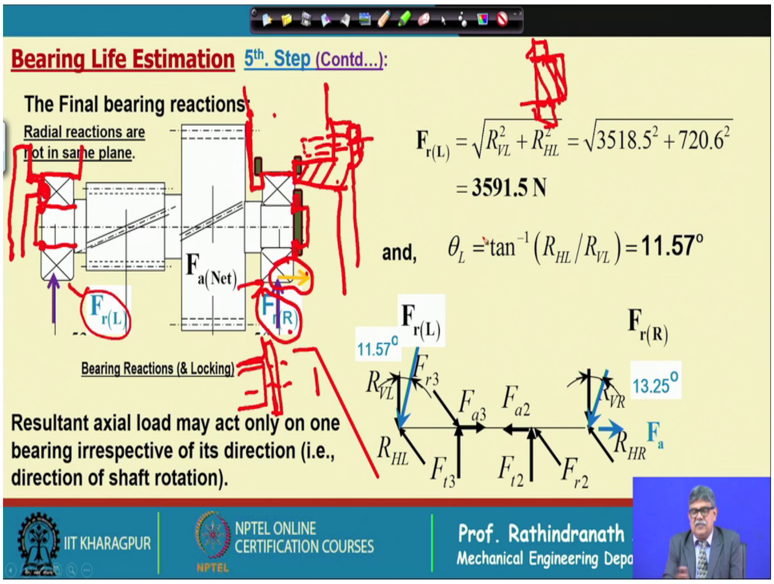

So, we can calculate sorry this is 13.2. Finally, two it will be shown and similarly we calculate the radial load resultant radial load on left hand bearing, which is 3591.5

Newton and that is acting at 11.57 degree. So, as you see these loads are acting at different plane. Now if we consider the normal load F n and then this calculation become more difficult then resolving this force and calculating this force at two planes ok.

So, that is why loads are resolved, then bearing erection calculated then finally, it is found out. So, we have at this stage resultant load F r at both the bearing and now we shall discuss about the bearing locking in this intermediate shaft what is done the bearings are right hand side bearing is locked whereas, left hand side bearing has been kept free.

Now, why it is done like this if we consider the loads at pinion side this will be more if you remember this value if our left is 3591, where if our right is less than that now intentionally this has been done in such a way whatever may be the direction of rotation resultant axial load always act on this bearing the resultant axial load will never come to this bearing. So, that is the; that is why we have locked the bearing in this way.

It is shown here that at this point resultant radial load is acting and resultant axial load is acting whereas, on this bearing only the resultant radial load is acting. So, therefore, now to calculate the life of these bearings for this bearing we will consider this radial load. And this is the axial load and for this bearing we would consider only the resultant left hand sorry resultant radial load; there is no axial load and if we would like to discuss about the locking of the bearing there are several methods.

Now, here as if in this case we consider that bearing housing is sorry projected like this bearing housing is product projected like this and. So, we are getting this locking and at this point we can consider this bearing cover it is coming like this it will be it is coming on the body. So, this is the housing body this is the cover and this cover is catching on the bearing. So, this bearing outer race cannot move.

Now, what is this one this might be simply a circle if. So, a circle can be put to lock the inner bearing and. So, this bearing will be completely locked it cannot move on the other hand if it is very tight fit we did not put anything here or else we can put also a circle here which is just to ensure that bearing will never be out of the shaft whereas, the housing in other side may go simply like this and the cover which is coming from the other side here there is a gap at this point there will be gap. So, that it can play this happens due to the thermal contraction or thermal expansion this shaft may increase to take care of that and this is one method is shown.

If we think of the locking of this bearing in some cases on the shaft end shaft end and this is the bearing is coming like this a plate is put and that is bolted with the shaft there is another arrangement. In that case if this is the shaft this is threaded and there is it is called lock nut a lock nut can be used did this knot is manufactured by the bearing manufacturer and this is supplied with the bearing if necessary.

So, there are several methods of locking, but we should only remember at this stage it is possible to lock the bearing arrangement, such that there the only one bearing will take the axial load and other bearing can be kept free and this is the direction of the axial load will be irrespective of the direction of rotations is in one case it will be this bearing is being pulled due to the axial load. In other case bearing is being pushed right right words due to this axial load.

So, this is the arrangement of bearings and it should be kept the; how the load will be distributed? Usually from this force has an intermediate shaft or even if in input shaft the bearing close to the pinion will have more loads. So, it should not take the axial load and in the other side bearing where the radial load is less it would take the axial load and in that way it might be possible that both side bearings will be of same size life of one may be slightly more than the other, but in that way inventory will be less.

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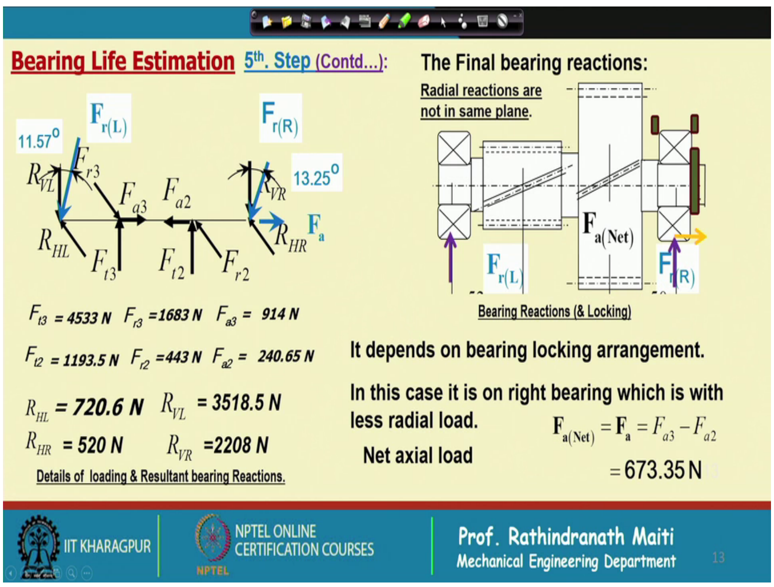

So, finally, in bearing life estimations what we have calculated all loads which is shown in the left hand side and from there we have found out the bearing reactions and locking, which we have already discussed and the net axial load which we have shown and now the data whatever the data available we are in a position to calculate the life of the bearing which I shall show you in the next lecture.

Thank you