Gear and Gear Unit Design: Theory and Practice
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Lecture - 23
Development (Layout) of Output Shaft (Contd.), Loads on Shaft & Bearing

We are continuing with design of a general purpose industrial Gear Unit. This is module 5 part 3 of that lecture and today's lecture number 23 development; that is layout of output shaft, which is being continued from the previous lecture and loads on shaft and bearings.

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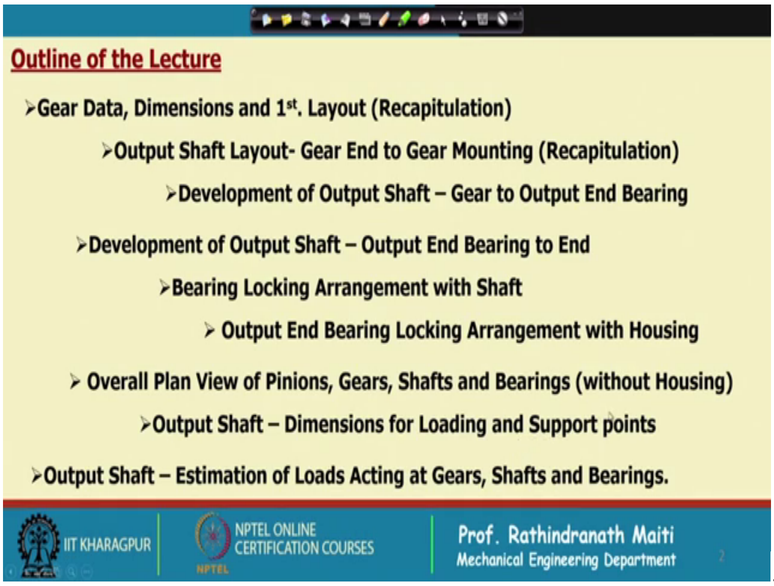

Now, in this lecture first of all I will show the gear data, because we need every time the gear data and another data for drawing. And then output shaft layout gear end to gear mounting, development of output shaft gear to a output end bearing, then development of output shaft output in bearings to end, bearing locking arrangement with shaft output end bearings locking arrangement with housing, overall plan view of pinions gears shafts and bearings without housing.

And outputs have dimensions what is the overall dimension that I will show and finally, the output shaft estimation of loads acting on gears shafts and bearings.

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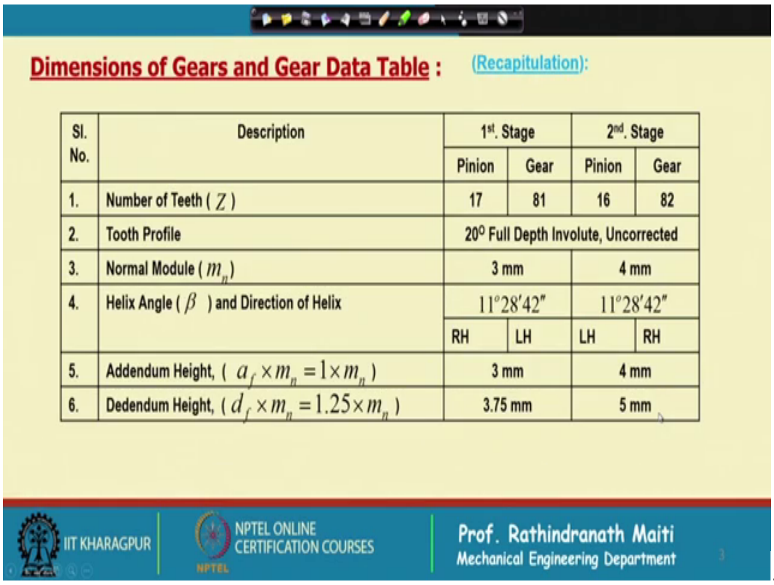

Sl. No.	Description	1st. Stage		2nd. Stage	
		Pinion	Gear	Pinion	Gear
1.	Number of Teeth (Z)	17	81	16	82
2.	Tooth Profile	20⁰ Full Depth Involute, Uncorrected			
3.	Normal Module (m_n)	3 mm		4 mm	
4.	Helix Angle (β) and Direction of Helix	$11°28'42''$		$11°28'42''$	
		RH	LH	LH	RH
5.	Addendum Height, ($a_f \times m_n = 1 \times m_n$)	3 mm		4 mm	
6.	Dedendum Height, ($d_f \times m_n = 1.25 \times m_n$)	3.75 mm		5 mm	

Now, this is the gear data it is already shown several times.

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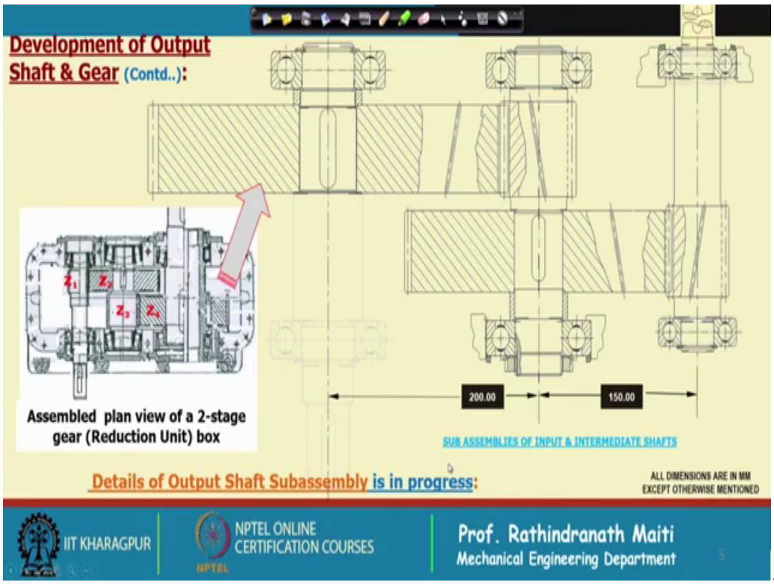

Now, this is we are going to complete a plan view fast this is the housing plan view top open of a general view of a 2 stage gearbox. And we have so, far completed in development of the intermediate shaft first, then input shaft and then output shaft we have so, far developed the gear end bearings shafts, keyway, and we have also put the gear there. Next we shall complete these bearings.

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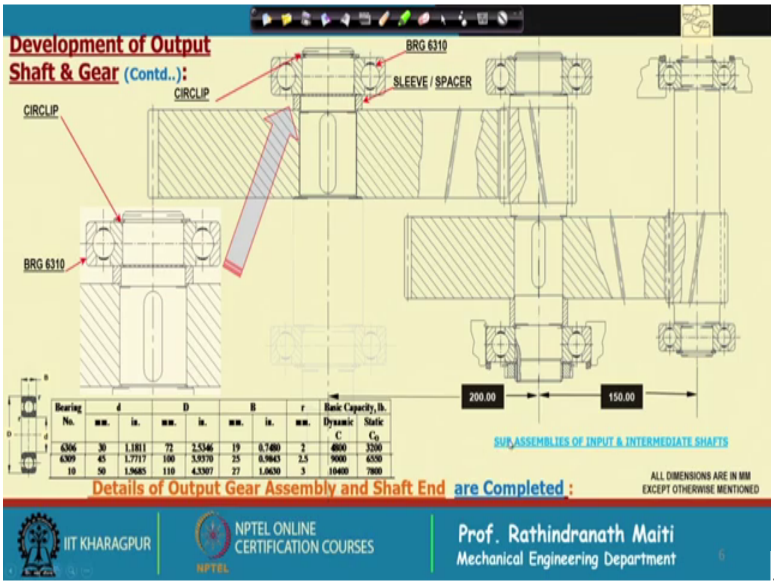

The bearing which we have selected that is also shown and then this part has been completed, and now we shall take the next part.

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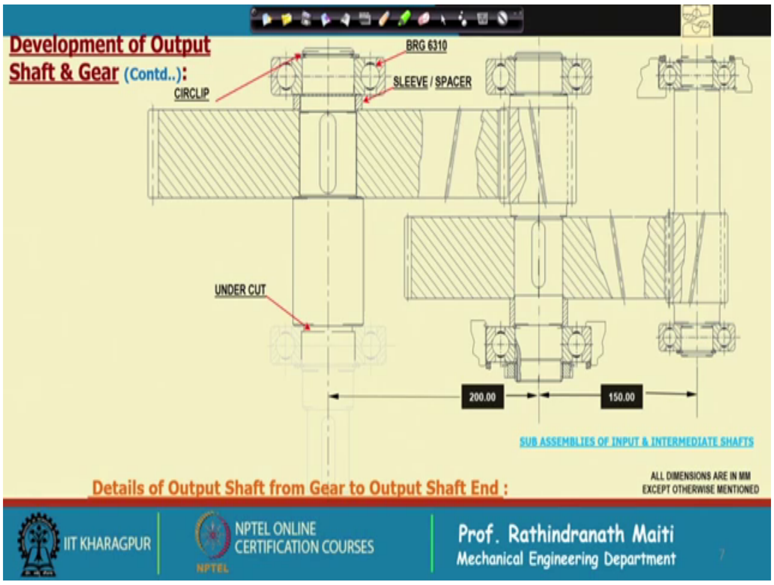

Now, what is done that this is this drawing is being developed in the AutoCAD and from the AutoCAD the step wise it is being shown how it is being developed. After completing the gear side including the bearings, then we have taken off the next part where we have shown. That from gear into the next end bearing that is the output side end bearing the shaft is first drawn and there it is also shown that what is the probable diameter can be taken from the bearing. We are going to take the same bearing as we have taken in the other side that is bearing 6 3 1 0. So, essentially we consider that bearing this means this bearing here we will mount the bearing. So, barring mounting dimension we have take a diameter is equal to 50.

And the we have taken this dimension between the gear and the bearing 66 millimetres. Now here I would like to mention if it is a few give we are going to make only few or 1 gearbox the Taylor made gearbox, in that case we should look into the what is the bar side available in the market; 60 see exactly not will be available, but we will consider the 70 millimetre bar, which can be machined to 66 millimetre ok.

There is another bar 63 millimetre, but for after machining probably we have to we may not get the stay for this bearing here a gear here which is 55 and step for the bearing here in that case of course, it can be managed with even 60 millimetre bar we have to put then a spatial in between the gear and the bearing what we are going to install now. Anyway we have in this case we have taken 66 millimetre diameter after the gear to be any and then we have considered the bearing diameter 50, because we are going to take the same bearing.

Now next part is that next here it is a undercut; under cut is shown this under-cut already although I have mentioned, I will mention again this under-cut helps in first of all helps in grinding if this under cut is given, then grinding will need not move up to the shaft shoulder on which the bearing will rest.

So, that surface will be saved as well as on which the bearing is sitting that will be properly ground. Also as I mentioned earlier that due to this under-cut instead of the corner finish here, the stress concentration is improved. And it helps in setting the bearing with the corner radius, in this case the corner radius is 2.5 and we are now put the bearing there.

Then after the bearing we consider the next part; first of all we would like to lock this bearing with the shaft. Therefore, there is some locking arrangement to be done here, what we find that we have taken a groove and after that this shaft is reduced.

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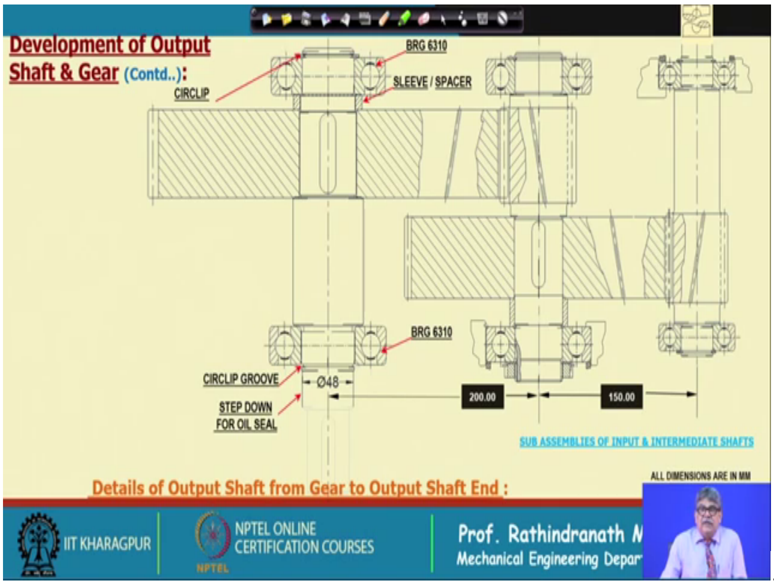

And this groove is for Circlip where we will put the circlip now. This step down is for oil seal we need to provide a oil seal, because otherwise if the dust will come from outside and oil will go outside. So, oil seal will be used here. And this diameter we have taken 48 millimetre, if the bearing is available say 50 45 in between that at least 2 3 bearing the seal sizes will be there; that means, 48 may be available, 45 will be available and maybe 43 will be available. That we will see when we will develop the little drawing we see the catalog and I will see and the present moment we have taken it 48 then we put the circlip.

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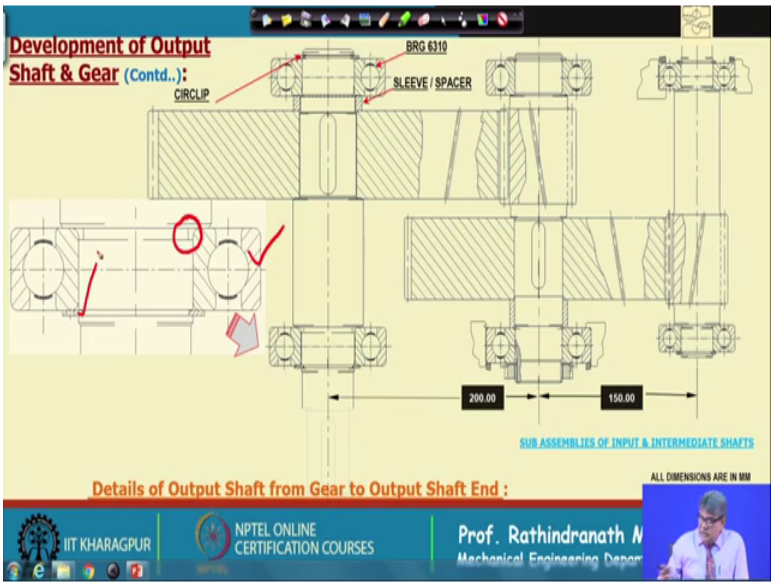

And this view if we enlarge as you can see the bearing is here this is the bearing and then this is the groove and then this is the circlip here is the circlip ok.

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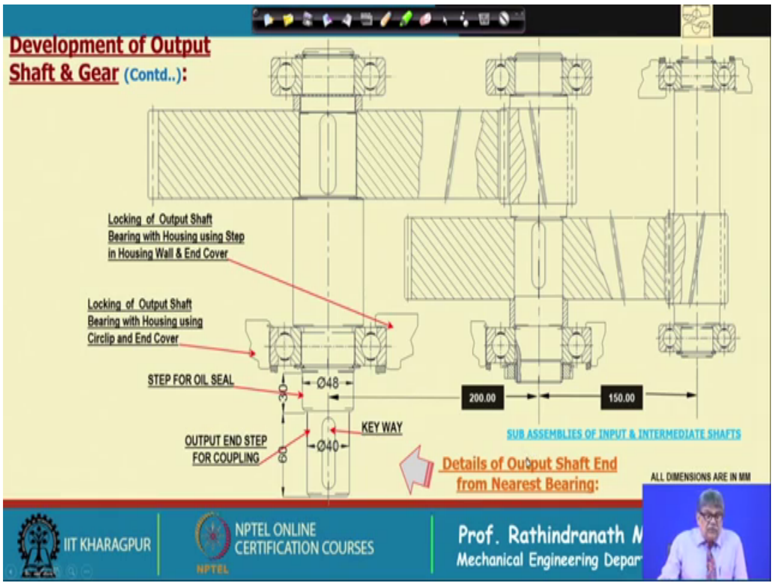

So, now next part the output shaft ends from nearest bearing ok. So, stiff for oil seal that already seen and then the end part of this shaft, which is the output part is further stave reduction is there and this is kept forty millimetre diameter and length for this portion is taken 60 millimetre whereas, for oil seal portion it has been kept 30 millimetre.

Actually at this part we have not thought much about this what will be the cover size and other things. So, better to keep sufficient space for that it is depends on also experience how much we should give for the length for the oil seal?

We will see later if necessary will improve this drain a little bit also the length. And finally, we have put a keyway looking into this view of keyway this key way is made with the end mill cutters and this key also available in market standard key. So, we take this dimension from the standard catalog manufacturer catalog.

So, the output shaft along with the gear and bearing that is sub assembly of the output shaft is also completely developed. So, in this view what we find sub assembly of input intermediate shaft and output shaft and then we think of the locking arrangement. Now it is already we are experienced that in the shaft in the gear end only if it is one gear or pinion at that end the radial load will be very high. So, one possible arrangement as in case of earlier that we lock the other end bearing. So, that it can take radial load and the resultant axial load.

And as in other cases one possibility is that the housing is boring on the housing is made in such a way there will be step on which the outer race will rest say it is like that. And other end it will be locked by using a cover ok. Alternatively we can use also circlip inside; that means, circlip inside and the cover on the outside ok. So, this is with circlip and the other side is with. So, my left hand side is the with a locking with circlip and cover plate and right side is the raised portion of the housing and in the cover plate, but you should remember any one of that will be followed not both together.

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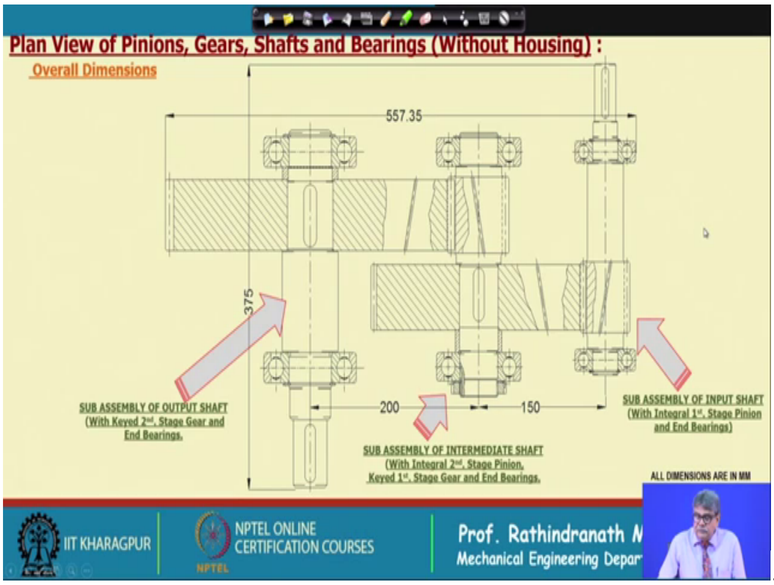

So, next phase I have shown here, the complete land view of the gear and shaft sub-assemblies 3 shafts are there and this is shown without locking arrangement, but here we may look into the what are the dimensions has come, this is have an assembly of input shaft and this is the sub assembly of intermediate shaft we have developed first this one and then input shaft and finally, now we have developed the sub assembly of output shaft.

Next if you look into the dimension then it is the dimension of which this the centre distance have 150 and the total overall width including the input shaft and output shaft it is around 3 7 5 millimetre and whereas, including the bearing and input pinion to the end of the output gear it is 557.3 5 millimetre.

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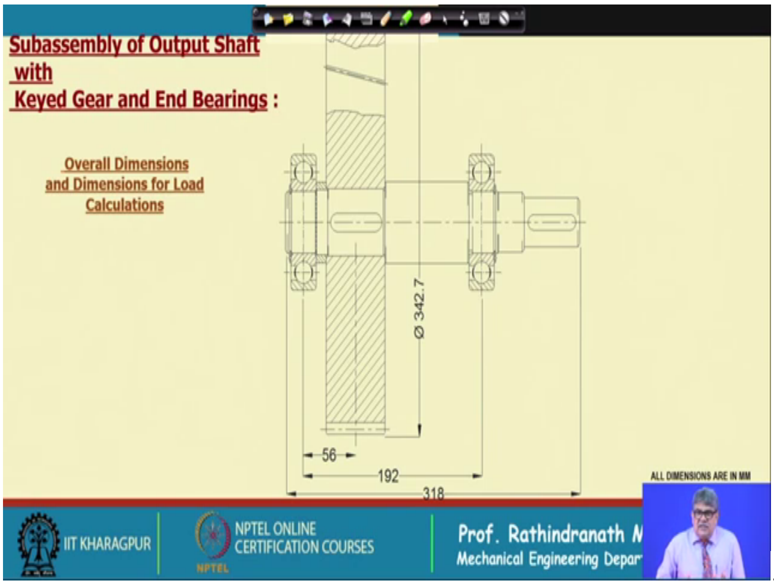

Now, we considering the only the output shaft sub assembly and first we will check the dimension this, we have put in such a way this shaft as you can understand that the shaft has been put in such a way that too match with the figure for the intermediate shaft when we calculated the load and estimated the bearing life ok.

Now here also we have considered the overall dimensions the overall dimensions of the gear is that is the tip circle diameter is 342.7 millimetre and the length of the shaft has become 318 millimetre, but in the final development maybe it will be reduced or increased adjusting the bearing positions, may be kept same or a slight alteration may be done also.

And the what we find that from the left bearing the distance midpoint of the gear where, which is which may be considered as the loading point is 56 millimetre and a distance between the bearings that is the span 192 and here also we have kept the same distance for other bearings maybe it was 190. So, it is very close 191 92 we have kept in that order, if necessary it is also possible that all bearing centres; left side and right side they are put in the same line. Otherwise a one or 2 millimetre this way that way may not be much problem.

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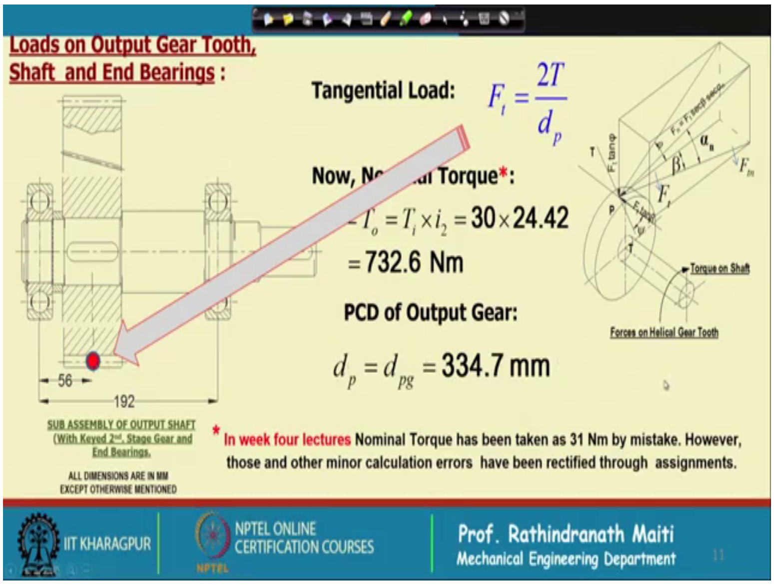

And then we will find the load on the gears first we have to calculate this load. Now this output torque nominal this is we are considering the nominal here I would like to mention for always first we should consider the nominal load on that basis we you should calculate the load at bearing or other places.

And then we should multiply with some factors considering the how much shaft load is coming what are the severity of the bearing life and load cycle etcetera etcetera, that needs experience as well as some data. Usually when you are going to consider such cases the their unit manufacturers. They are having their own data, but in this case what we have taken that I will show later already we have considered the intermediate shaft.

However, in the intermediate shaft calculation in lecture 4 by mistaken we took the nominal tour 31, but in this case again we have taken the 30 for our original design problem. And therefore, the torque here this is again for the first lecture we considered that the total reduction will be 39, but for the development of drawing we have taken all that the same, but overall reduction ratio is 20 for 4.4 2. Therefore, nominal torque that is output shaft torque becomes 732.6 Newton meter.

Now, pitch circle diameter of output gear is 334.7 millimetre. Therefore, we calculate the F t using twice T by d p this formula. So, in this d p the value will be 334.7 and load will consider the concentrated load instead of the distributed load over the teeth this is there is no harm we can consider for other purposes. Only if we would like to calculate the stresses on tipped rigorously we have to consider the distributed load, which is usually done in a f p m techniques, but here we will consider the constant load which will act at this point.

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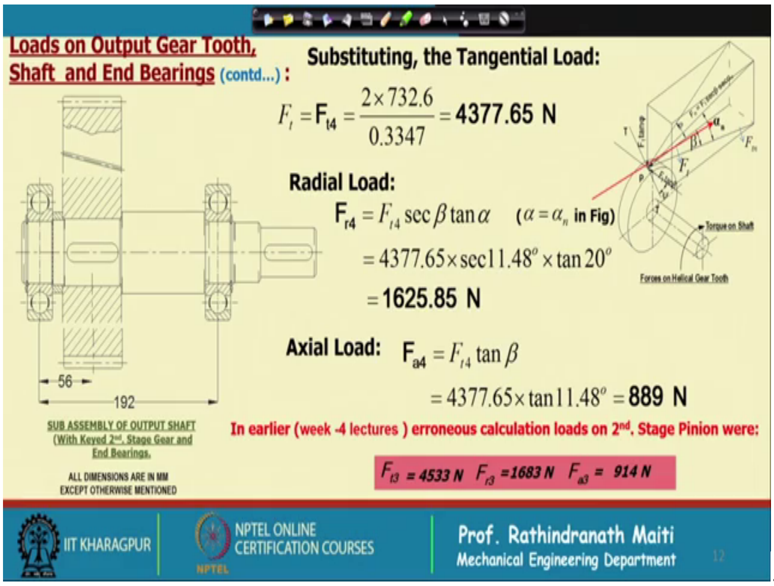

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Now, F t is clearly coming 4 3 7 7.6 5 Newton, because they we have consider the pitch circle diameter is 0.3 3 4 7 meter and the torque is 732.6 Newton meter.

Then radial load we calculate using this formula and here we have considered the F t and then the helix angle 11.4 8 degree, it is slightly after 4 8 some values might be there, but we have rounded up when there is no harm and the pressure angle is 20 degree. So, on the basis we get 1 6 2 5.8 5 Newton is the radial load and then axial load it comes the using this formula considering the helix angle 11.4 8 degree 8 8 9; Newton 8 8 9 Newton again I mentions in case of straight spur gear that beta is 0 and load will become 8 a no axle load will come over there.

And here it is mentioned that week 4 lectures in generously we calculated these are the forces. We considered the nominal input torque was 31 Newton meter as well as also there are some; small error in angle anyway this has been rectified through the assignments problems.

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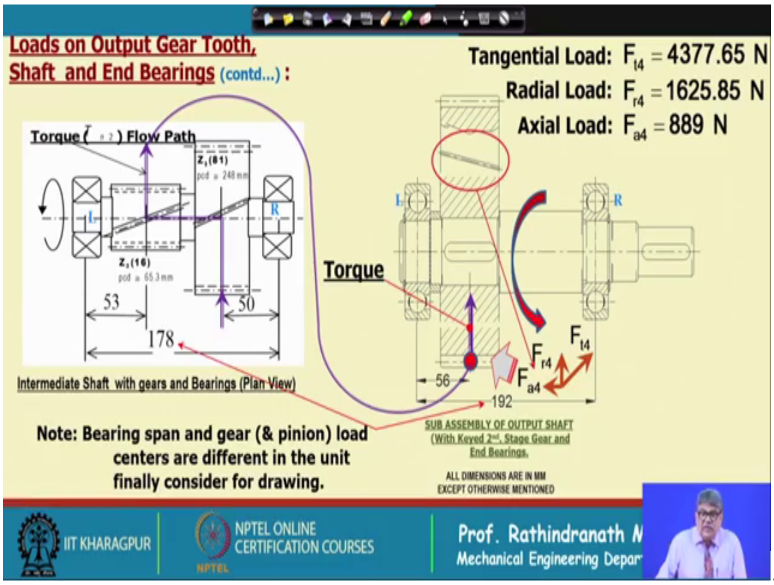

Now, next we will consider the torque is acting on the shaft and this has the ideal load and this is the axial load, which is acting over there. And then axial load is acting in the leftward direction at the point of application, this is because the direction of Hellix as shown here this is right end this is also given in the chart. So, this is right end and these due to this direction of rotation. So, it will act in this directions and F t 4 is acting downward on this.

And this is we have considered right hand bearing and that we have considered left hand bearing, if we consider the earlier considered the intermediate shaft of course, there is a difference, because this when we first considered the calculation of this intermediate shaft we considered the bearing span was 178 later that has been 190 perhaps.

And, however just if we consider the figure there and if we think of the torque flow, then torque is from this point it is coming to this point. So, it was clockwise intermediate shaft rotation was clockwise from the right hand side. And therefore, from the right hand side the direction of rotation of this will be in anti-clockwise directions; that means, if we consider the pinion, intermediate shaft pinion, connected to the output shaft gear. It is pushing the gear towards the backside of the slides backside of the slides.

And; however, the radial load is always toward the axis that is shown here and will later consider the axis system and there it will be shown in better way. This change you going with please note that change.

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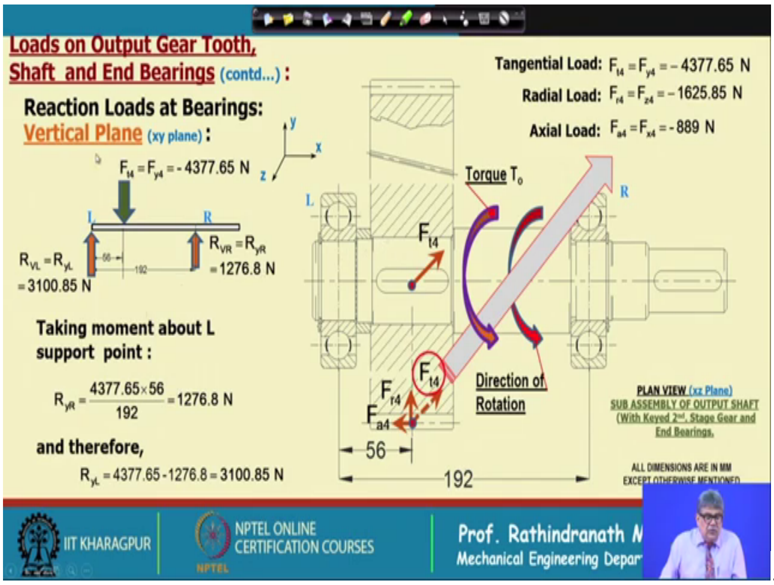

Now, reacts and loads at bearing that we are going to calculate. Here as you see that we have considered a axis system x y is the vertical plane and z x z is the horizontal plane right. Now this plan view which is drawn here this is in the x z plane and therefore, this load the tangential load which we are now considering, that we are shifting, that to the axis. This is done to this is the equivalent system to find out the bearing loads and as we shift this load on the shaft there will be a moment also. That moment if you consider the right direction it will act in the anti-clockwise direction and this is nothing, but the moment about x axis.

And which is nothing, but the torque output torque for which this gearbox is being designed. And then we consider a shaft this white bar with black boundary is the shaft the period representation of this shaft. Now on that the load on the vertical plane is acting downwards load means the tangential load of the gears tangential force on the gear, that is acting at a distance 56 millimetre from the left bearing and the bearing span is 192 millimetre.

And this we have considered that F t 4 is equal to F y 4 because it is in the y directions and minus sign has come for as it is acting in the downward directions. And then if we consider this load is being supported by the bearing. Then left bearing which the force which we are going to calculate that will be R v l be for vertical l for left, which is also equivalent to R y l that is in the y axis, but in the left side.

Now first we consider the moment about the left support and then we can easily calculate, what is the force at right side? What is the course offered by the bearing to the shaft, force being offered by the bearing to the shaft? Which is R v R the vertical plane reaction and vertical plane right hand side or simply R y R, the y axis load in the right hand side. Which is which has become now 1 2 7 6.8 Newton.

And then finally, we find that total load minus this right hand side reaction, which is having 3 1 0 0 8 5 Newton that is acting on the left hand side. These force are acting in the on the vertical plane. We again I repeat we consider this forces we resolve the forces in vertical plane and horizontal plane and if necessary also. I mean it is x axis y axis and z axis directions, this is for the ease of the calculations because if we consider the resultant load. Then we will later we will find their acting in the resultant is acting in the different plane at the bearing and that might be difficult to visualize at the beginning.

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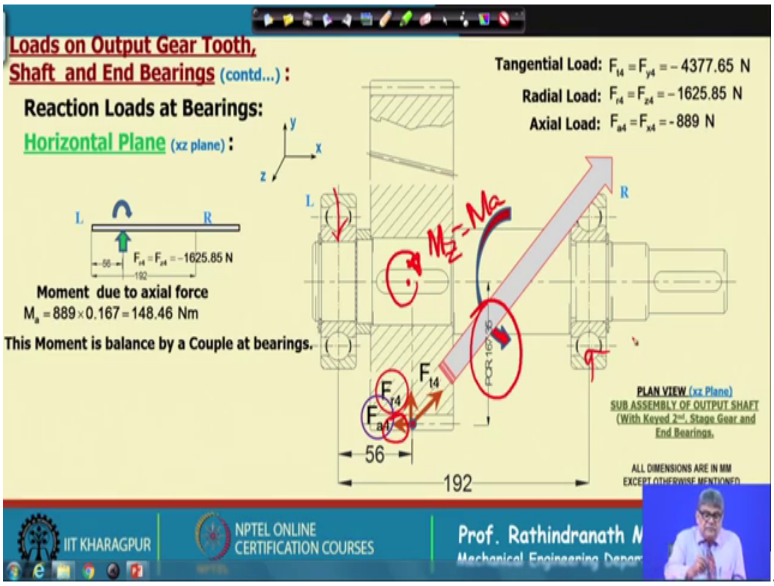

So, far we have considered this F t that is the tangential load. Now we will consider the load in horizontal plane, but it is in the this is x z plane. Now we will consider in the x z plane, but still we should remember this plan view each in the same plane exit plane, what we are now concerning.

Now clearly the radial load F R 4 it is directly acting on the axis it is passing through this force is directly passing through the axis. So, this axis will not have any moment about the axis there. However, it will definitely generate the bending moment which we will consider while we calculate the bending moment of the shaft.

However, this force will act on the shaft and also later we will find that for bearing the action that axial force has also some contribution, because this will generate a moment about the z axis, about the vertical axis z axis and to counter balance that the force will come on the bearing.

Let us see now again we have considered a equivalent of the shaft and the it is shown that where the force is acting we have considered also left and right bearing loads about point. And then this moment we have considered the moment this is nothing, but the axial force into the diameter of the pitch circle radius of the gear.

So, to show in details so, this is the axial force acting like at the gate here due to the direction of rotations and this is the pitch circle radius of the gear. So, if we consider then about this point this there will be a moment. So, this moment will be a this is in the x y plane. So, this M z this is equal to M a due to this axial force that we need to consider because to counteract this definitely there will be force like this. So, this moment is balanced by a couple at bearings ok.

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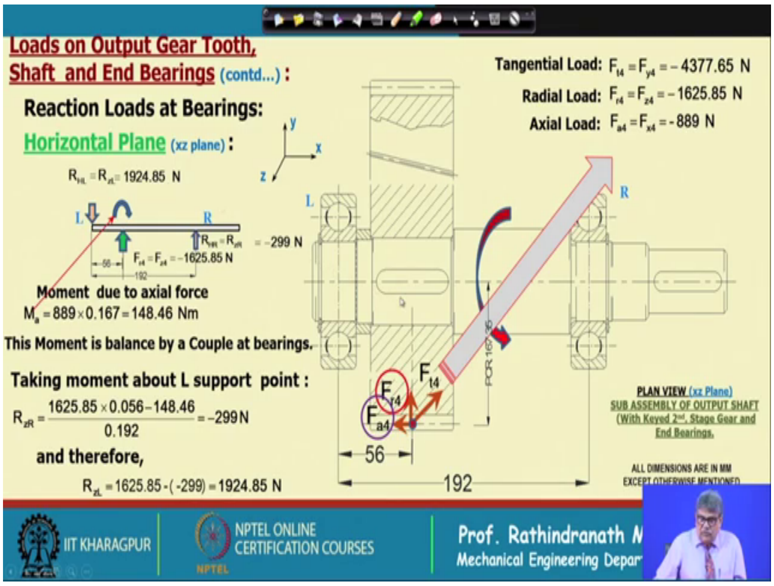

Now, we are cal we will consider them finally, or resultant we including this moment and this radial load here the reaction act left hand bearing R h l, which also can be taken as R z l, because this reaction force will act in the z direction. And in the right hand side we will consider the R h R or R z R, now one important issue is here that looking into the direction of the load the main axle load here.

We will be we will first consider that these loads are acting towards the z directions this reaction force, but while we calculate this force taking moment about right side.

Now, if look at carefully this here we have considered the load in this directions. So, moment will be this force here, which we have calculate earlier. If our for that into this point 5 6 this force into this distance we have taken the moment we are taking the moment about this point considering the moment about this point ok.

So, this edge coming this much and that is in the anti-clockwise directions as you see whereas, our moment due to axial force in clockwise directions. So, we subtract this from this total load this can be shown separately, while we are calculating the load bearing reactions, which we will consider in details while we will consider the shaft bending moment etcetera, but at the present moment we have considered like this. And then what we find that this value has become minus 2 9 9 which means the what we have considered for the direction of the reaction load at the bearing at right bearing that will be opposite. So, issue it will be in these directions.

Now, apparently if we only look into these 3 loads direction of loads then we will find then we may have a feel that this will rotate, but it is balanced by the m a this couple and everything will be. So, this is in equilibrium and finally, we find that the load here at left bearing is 1 9 2 4.8 5 Newton.

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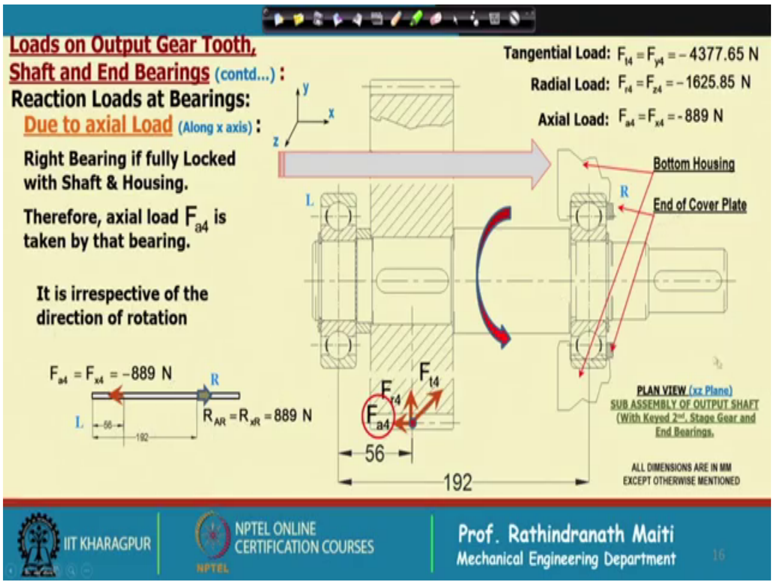

Now, only due to the axial force there will be also a action on the bearing the load will be on the bearing; however, what we have done we have fully locked this bearing the output end. So, here in this case it is right hand side bearing this means that axial load will be will be taken by the right hand bearing. And this is irrespective of the direction of rotation.

However, due to the change in direction of rotation the direction of axial load will change and that will create the moment in the opposite directions M a and due to that the horizontal plane bearing reaction will change that will see later. However, this is the view of that axial load.

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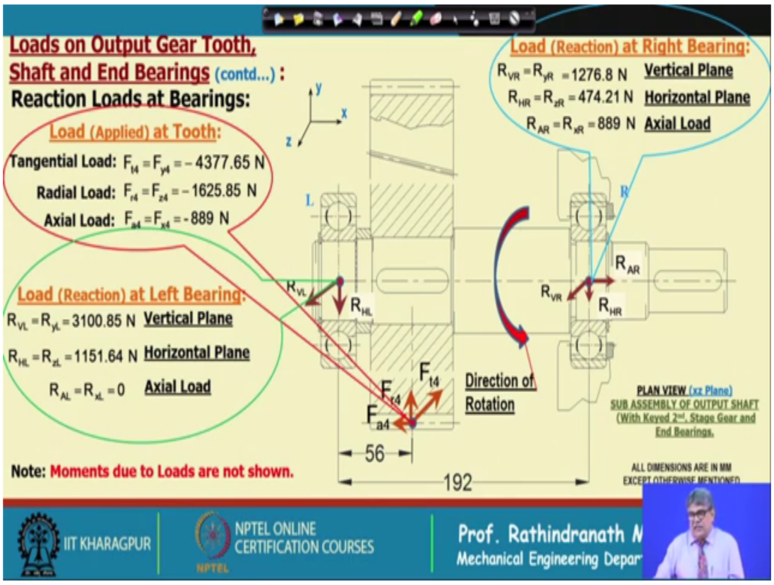

And finally, we consider. So, this is the load acting at the teeth and this is the load acting at the bearing; that means, bearing is offering this load to the shaft and this bearing is offering these loads to the shaft this their magnitude dimension directions all are shown in this so, which you can visualize by reading this.

However, the moments due to load are not shown here in this view only you have considered that what are the forces acting on the shaft. So, this is the end of this lecture and here we have shown very meticulously in details what how the shaft is developed shaft and sub-assemblies are developed by drawing wise. And then we have shown how the loads on the shafts are calculated knowing the torque acting on the shaft and also you have considered how the load acting on the bearings?