Gear and Gear Unit Design: Theory and Practice
Prof. Rathindranath Maiti
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 26
Design Verification of Input Shaft (including Bearing Life Estimation)

Welcome to the last lecture of module 5, which is Design of General Purpose Industrial Helical Gear Reduction Unit part III. And this is lecture number 26, where I will show how the input shaft design verification is done. It is also included in this lecture the bearing life estimation. This means that what we did for output shaft in last two lecture that will be for the input shaft in a single lecture, because procedure is more or less same, only we have to careful about the loads, moments etcetera, etcetera.

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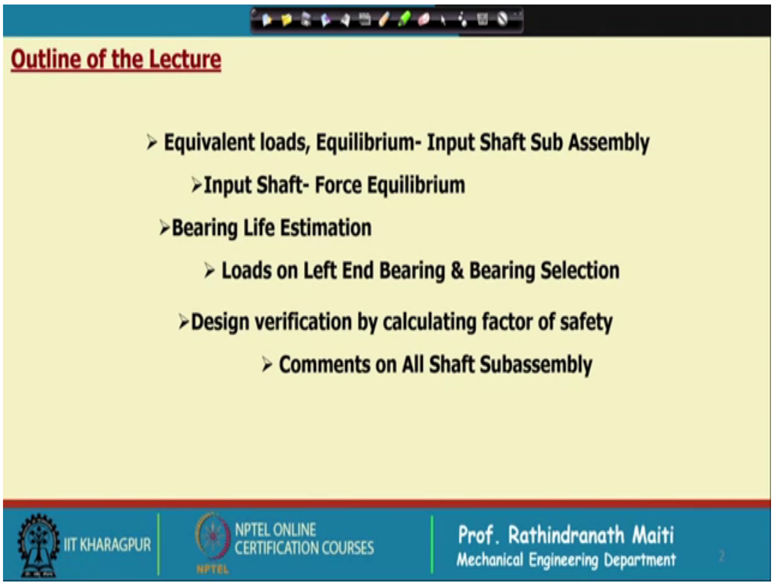

Now in this lecture; therefore, first of all we will look into equivalent loads, equilibrium inputs shaft sub assembly, and then input shaft force equilibrium we will consider, and from there we will find the reaction force and then bearing life estimation, loads on left end bearing and bearing selections, design verification by calculating factor of safety.

Also we will consider the right bearing which is not written here; that means, we will consider calculate the load in the right end bearing also. Now, finally, I will I shall make a comment on the this sub assembly, and maybe overall comment on this week 5 lecture.

And this is already explained that we have considered the, modified the design a little bit to have to have the parity with the week 4 lectures and for easy understanding.

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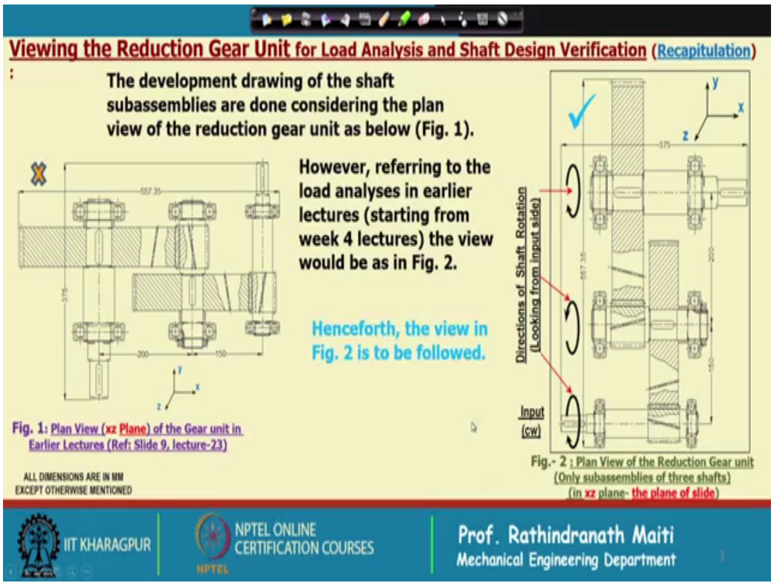

So, we are considering this figure only and the same thing it is written here, already it is debated in earlier lecture.

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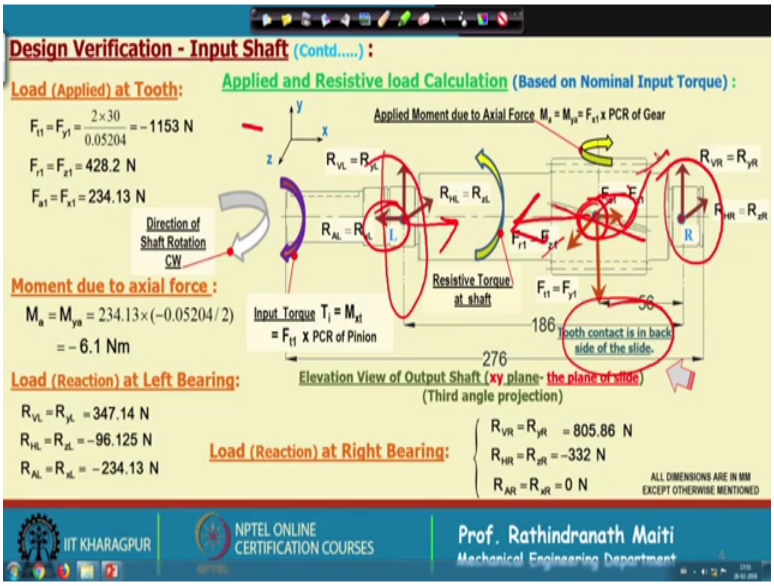

Now directly we are coming into the input shaft. On the input shaft as we find input is from the left hand side, direction of rotation is given, torque is given and then the loads on that shaft what are coming over there that are also shown here. So, at this stage what we have shown that, that this is the. I think the all total loads has shown here, so better it is, we should go for this.

So we have considered the all loads on the shaft right. The pinion, it is rotating in the clockwise directions, if we consider the. This is the plan view. No this is we are considering the elevation and that is in the plane of slide, x y is that plane. Now here if we consider this contact point, this contact point. This contact point if we if we consider the tooth mace; that is in the back side of this slide; that means, this is below the slides you can say, because the contact was there and it was rotating like this ok. So, due to that you can say that when these teeth is coming like this, it was pushing the gear in the upper directions, pushing the gear of the intermediate shaft in the upper directions and that is why due to this helix angle axial force has to be come in this direction. This is the axial force

Now as this load on the right hand side, right hand bearing due to the tangential load and the radial load will be more, than the left hand side. So, we have locked this left hand bearing. If you remember the drawing when developed we locked the left hand bearing, it has fully constant; that means, fully means, it was able to rotate, but it cannot move in x y directions. It is locked to the shaft as well as to the housing. So, this means that this, if we consider the bearing reaction, it is here, it is acting in this directions.

Now the question is that, it is somewhat sometimes it is a little confusing. Actually if we consider that bearing at this end, it is fixed ok, end the applied load is pulling. So, bearing what the load offering to the shaft this is in the opposite directions; that mean, bearing is pulling the shaft in the left directions; that is why the sign has become like this. Students used to ask sir why it is on the bearing it is like this. You have to visualize at this point.

Now suppose if we change the direction of rotation. In that case if we change the direction of rotation this axial load direction will change. Here at this point it will be in these directions and here it will be in the opposite direction. Or else if we change the direction of helix angle also, then for the clockwise directions the load will be like this. So, that I think this is not very difficult to understand one can put some time to understand this, and then he can go for the right diagram.

Now, also in this section what we have shown. We have shown all reactions that moment due to the axial force everything has shown here, except the bending moment, bending moment it will not come in this picture. So, we have not shown right. So, while you are reading this you can spend more time on these slides to understand how it is acting. Now we have considered the right bearing right end bearing.

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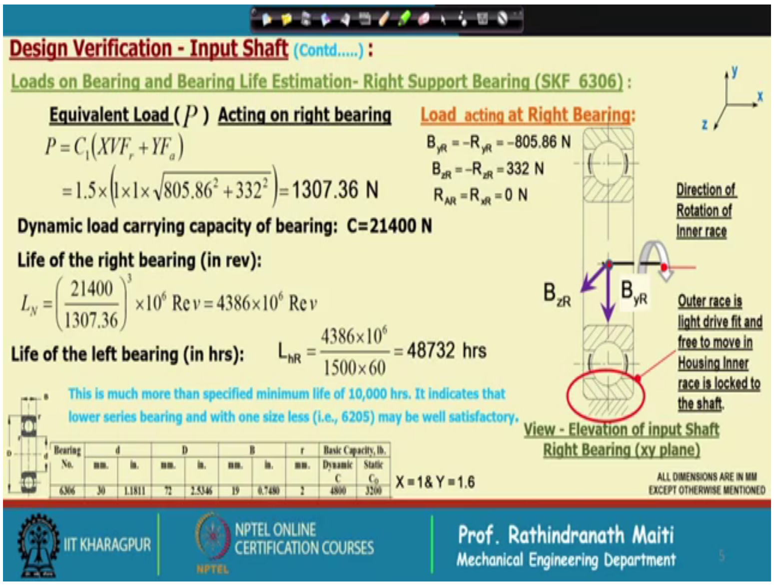

Now, in this right bearing as you know that no axial force is acting, as there is a radial loads are more. So, in the same way what we calculated in case of output shaft, we have calculated the load here, and bearing loads we have designated as by B, B means load acting on bearing. Then next comes Y or Z; that means, in that is the directions and then comes R as a subscript, which means it is right bearing. Now if we observe this bearing very carefully what we have shown here, it is fixed.

This actually means it is with the housing, this outer race is held, it cannot rotate, but if the question comes, whether it can move X directions or Y direction, the answer is that this cannot move also in the X Y direction, this can move in the X Y directions as this bearing is not locked with the shaft and what are the load coming over there; that is why we find that there is the component of tangential load, component of radial load and they are acting in y and z directions, the magnitude etcetera are given there itself, and then we shall go for bearing life calculations. This is the direction of rotation is shown also here.

Now this is locking arrangement we have shown. Now we are calculating the you equivalent load acting on the bearing. Now clearly in the equation of equivalent node P is equal to C 1 X B F r plus Y F a, that 1.5 the factor we have taken for it is a medium shaft load, but X factor is for that series of bearing it is 1, and the race rotation factor is also 1, because the outer wrist is fixed which is shown here and there is no axial load, so the Y F a component vanishes. And ultimately from the load shown here we calculate that equivalent load is 1307.36 Newton.

Then life of the right bearing in revolution is L N is equal to that is 2104. Sorry 21400, which is the dynamic load capacity of the bearing, this is bearing I think I have shown at the last process, this is in pound, it is given as 4800 which becomes 2000 100 400 Newton 2000 100 400 Newton. So, life in number of revolution is nothing, but that C by P to the power a factor epsilon, in this case it is 3 as it is a ball bearing multiplied by million of revolutions. So, that becomes for this case 4386 into 10 to the power 6 revolutions, and if we calculate the life in hours this input shaft is rotating at 1500 r p m.

So, in hour it is 1500 into 60 r p m, and that we, that we divide the number of life in number of revolution by that amount which is very large. The value is coming 4840 8732 hours, whereas, we are expecting on only the life of minimum life of 10,000 hours. Now here we shall check the other bearing and then we make some comment on this issue. Oh Here itself this is much more than specified minimum life of 10,000 hours, and it naked that lower seed is bearing and with one size less, maybe will satisfactory. We have chosen 6306, probably 6205 also satisfy the life.

Now, if we look into the shaft then what we have done, we have reduced the shaft size up to 30 millimetre to have the output, sorry input end of 25 millimetre, but if we go for 25 millimetre bearing, then probably that shaft input size will be reduced to 22 and 23 millimetre, but that is possible, because after, in between that there will be one seal that seal is available almost every 2 millimetre. So; that means, if we take a bearing of 25 millimetre inside the probably we can make the same diameter at, therefore, the oil seal 24 millimetre and shaft diameter probably 22 millimetre or even 22 and half millimetre. So, that is acceptable, and they are also different type of locking arrangement is possible. In fact, after the bearing we can put a boost there and after that we can sorry asleep there and then we can put a coupling. So that we when will make the little drawing or plan view of the heisting, we shall discuss again about this matter, but next that

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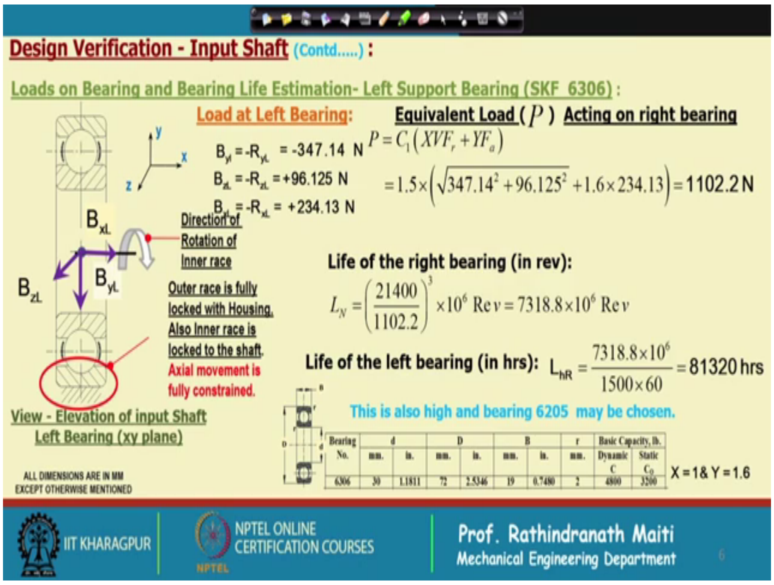

We considered the left end bearing the same way we have calculated, but in this case we have the axial load. So, for that axial load what we find. Here we have written this is fully locked with housing, also inner race is locked to the shaft, axial movement is fully constrained. So, in that case again what we find the load still including the effect of.

Here if you look into this factor 1.6 into this axial load that we have considered, because Y is 1.6, but still including that it is less than the other bearing. However, the life becomes at May 1320 hours. So, it is 8 times than what we are expecting, and the comment is same, probably we can compromise with 60 05 ok. We will look into this matter after this.

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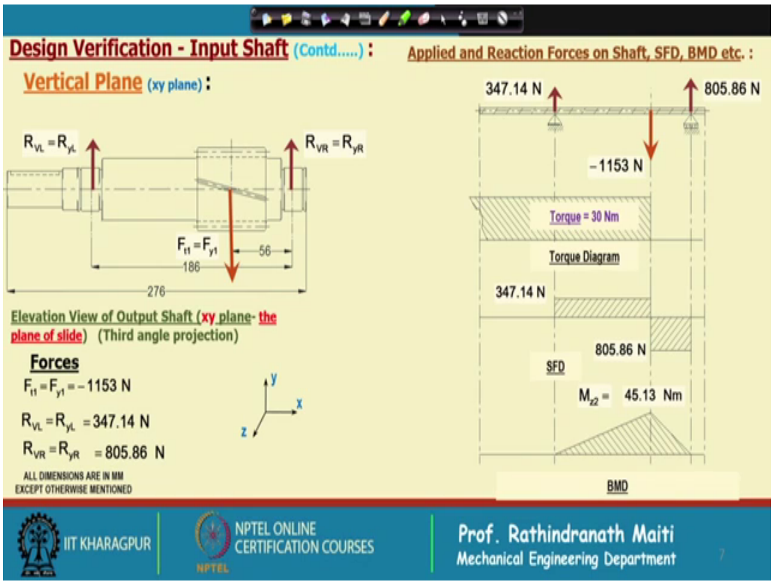

Now we shall go for calculating the bending moment in the vertical plane. The same way what we did for output shaft, we shall also analyze the input shaft. I would like to mention here, if you look into the direction for two stage gearbox, direction of rotation of the both shaft in the same directions, and direction helix is also same.

So you will find mostly the loads are in the same directions they are acting, and there will be not much difference in the technique of calculating the load bending moment etcetera; however, the in case of output shaft, the gear is in towards the left side and here it is in the right side, only that difference is there. The pinion is close to the right bearing. In case of gear output gear, it is close to the left bearing; however, this is the bending moment torque diagram, shear force diagram and bending movement diagram we have developed, and then we consider the horizontal plane.

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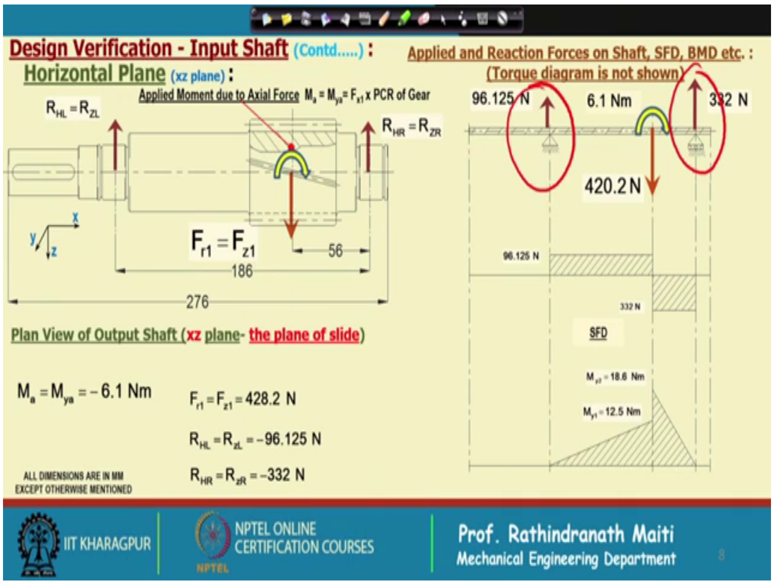

In the horizontal plane as we find that the direction of moment here in such a way, that the it has the load due to that has been the coupling, this couple force has been added to the right end bearing and it is subtracted from the left hand component, which came from the radial load. So ultimately if I say this means that this was reduced by the couple force and this will, this is increased by the couple force, but here at least directions are not confusing; like the output shaft ok.

And on the basis we have drawn the shear force diagram and then bending moment diagram. We have to be careful, if we if we remember we have to be careful that here when this moment we are taking from the left hand side, then we should remember as did this moment due to axial force is acting, by the left hand side of this shaft and the right hand side of this shaft in the moment will be different, but maximum moment, all always we should take the what the maximum magnitude, considering plus minus side of the bending moment is there, that we need to consider

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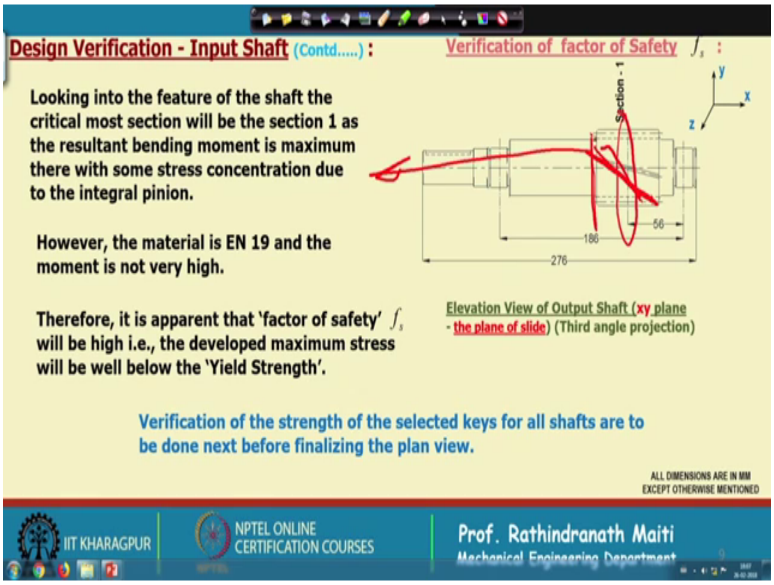

Now, looking into the feature of this shaft, the critical moments that the, I mean the critical most section will be the section one, as the resultant bending moment is maximum there with some stress concentration due to the integral pinion. Now this means that if you consider this section, probably this will be the critical section. Say as we go towards the right hand side or towards the left hand side, the moment decreases from that value; however, this torque is somewhat like this, torque is, say it is starting from here to here, and this will going like this, so torque will be there, from this point to this point here.

Torque will be somewhat less if you want to the average load, but in that way probably the next critical section would be like this, but here the diameter is more or less same, whereas stress concentration will be more in the mid section. So, probably verifying the factor of safety for that section, section one will be good enough to verify the design of the shaft.

Now, another thing is there the material of this shaft contrary to the output shaft is E N 19 for which the strain, allowable strains are much more ok. And if we consider the bending moment and other if you remember, if you look into the 2 slides before that, we will find that amount of bending moment is not much there. So, therefore, without calculating we can say that this shaft design is highly satisfactory. And as already discussed, keeping the dimensions up to the step of bearing same for the shaft, keeping the span length also same as in the shaft, we can simply reduce the 2 diameters of the bearing seat.

Remember that if we change the direction of rotation or helix angle, then load distribution over this bearing will be different, and for due to that we do not want to use other size bearing. Of course, it can be used also, but from the inventor point of view it is better to have two same bearing in a shaft. And instead of 6306, even we can go for 6205; that means, 25 millimetre dime diameter and as already discussed we can make this shaft input end, instead of 25 millimetre we can make it 22 millimetre; however, in between if we can check these calculations, this will not be shown that, calculation will not be shown, maybe you can verify with through the assignments when the assignments will be there.

And next stage when we will develop the full drawing; that means, plan view complete the plan view, we can change the shaft diameter and we can put those bearing there. And in practical cases if it is in the industry, probably here that decision will be taken to change the shaft diameter and a design calculation will be repeated to verify and that design calculation should not take much time, because of the design procedure will be same only one has to calculate that what is that maybe week, one week not more than that and we can again arrived into the new design. And I would say this is the end of week 5 lectures, where we have gradually shown, the gradual development of the difference shaft, sub assembly, their locking arrangement, bearing selection, shaft design verification it is, it has been done

Now, straightway we can go for the plan, completing the plan view; that means, with housing, cover, seal etcetera, but there is still on a one point is left; that is we have not yet verified the design of the key. So, we need to design, we need to verify the strength of the key from the their failure point of view. In that case if necessary we have to increase the width of the gear, if necessary we have to increase the hub for the gear hub portion. So, that verification we need to do next, and then we can finalize, but from the experience I can say that while we go for the design.

I mean detailed drawings of the plan view, we have two options; one that we can straightway reduce the bearing size and we can develop or we can keep these gearbox as it is that will. Because intentionally in the intermediate shaft as I told life is around

22000 or more, still we accepted that one, because this gearbox, although it is being over designed, but that can be used for the specific problem what we have completed through this lecture or else it can be, along with that it can also be used for higher load. Say instead of the starting torque is 200 percent, but the shock is very high shock load or this gearbox everywhere we have taken the factor in such a way.

Probably it can be used for some other I mean higher value of input torque with the similar cases. This means that probably instead of 30 Newton meter with 1500 r p m, probably we will be able to go 45 Newton meter with 1500 r p m and same gearbox can be used.

So, at this moment I would like to make a comment, for that just in the process of learning what we have taken, it is slightly over designed it. This gearbox need not be makes such a everywhere the dimensions is more, even in module we have taken a little more that need not be, but anyway in the legs next week we shall complete the drawing, And then I shall make the end lecture that what really, in practical cases, what really we need to do.

Thank you once again.