Gear and Gear Unit Design: Theory and Practice

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Lecture - 16
Bearing Selection and Shaping Shafts

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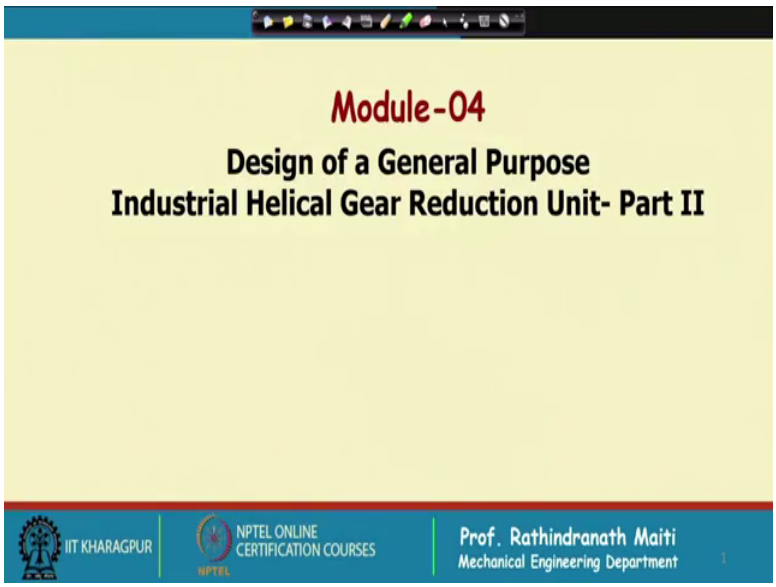

We are continuing with design of general purpose industrial helical gear reduction unit. Now, in this module; module 4, this is part 2, we shall consider the mainly the bearing selections and shaping the shafts in earlier module we have designed the gears for first stage and second stage, we have selected what will be the module, we have finalized the gear data and we have made the preliminary layout. Now in this lecture, we shall look into the bearing arrangement, how the bearing arrangement is done or in this case in with respect to this problem we shall learn how the bearings are arranged and selected for the gear units.

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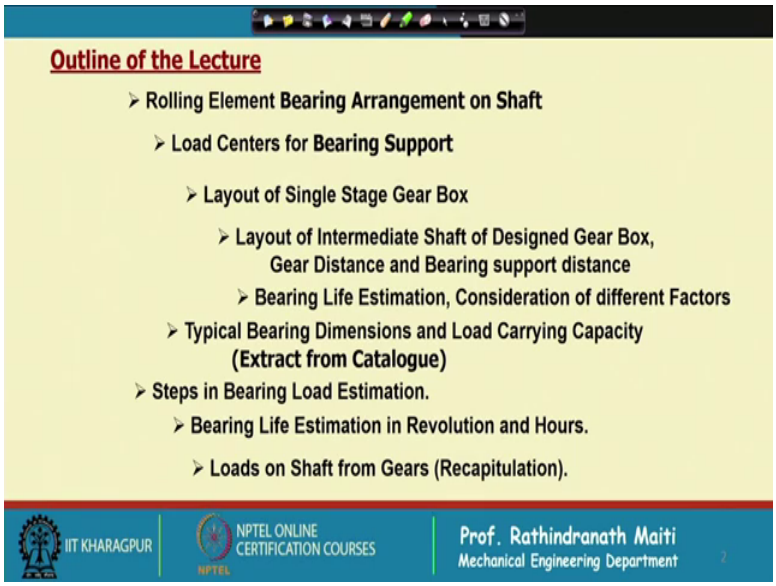

Now, in this lecture, I shall cover rolling element bearing arrangement on shaft, load centres for bearing supports; that means, once the bearing is selected we have already made a layout of the gears and then we will put the bearing without knowing whether, it will give the life or not, but we have to select on experience some bearing and from there, we will find out the load centre where the load is acting on the supports, unless, we select that we will not be able to find out; what is the load on the bearing support. We will not be able to calculate; what will be the life of the bearing, we will not be able to calculate; what will be the bending moment on the shafts and how the shaft design will be satisfactory or not. So, that is essential.

Now, next I would show that layout of a single stage gearbox although in detail drawing will be shown later, but here some idea will be given that how the layout is made and then layout of intermediates shaft of design gearbox; what we have designed gear distance bearing support distance, etcetera, then bearing life estimation consideration of different factors, how the life is estimated and then typical bearing dimensions, we will look into that load carrying capacity of bearings that is extract from catalogue and steps in bearing load estimations and bearing life estimation in revelation and hours and finally, load on shafts from gears that we will capitulate in this lecture.

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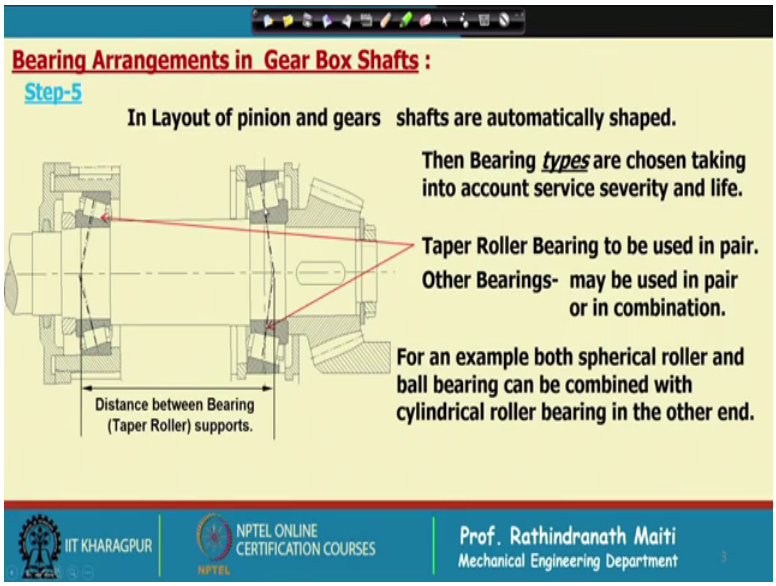

Now, here a shaft along with the pinion of course, it is a butyl pinion it is making with a bevel gear bevel pinion is making with a bevel gear. Now this shaft as you see this is supported by two bearing; one two. Now, this bearing is larger than that this bearing because as the load adducting here. So, loads on this these bearings will be more than this bearing that is why the small bearing has been taken there are recommendations, what should be the distance between two bearings because this is mounted in cantilever way. Now these bearings, if you have the idea about the rolling element bearing, these are taper roller bearing bearings may be others also which I am coming, then barring types are chosen taking into account service severity and life.

Now, if there is light load, probably, we can go for light bearing which is small bearing is light bearing than the cylindrical or taper roller bearing or spherical roller bearing, but if there is more load, we have to go for taper roller bearing or spherical roller bearing as well, as we need to go cylindrical roller bearing also. Now this is taper roller bearing other bearings may be used in pair or in combination.

Now taper roller must be used in pairs because in one side if is a taper roller other side also should be taper roller reason is that in case of taper roller bearing, this part along with the roller and the inner surface with cage this is cage they are assembled whereas, this part is separate and that can be brought in to miss. So, if we put other side other bearing then there is no guarantee that this will miss ok. So, this bearing either this is in

these directions or it may be put in two opposite directions and these are tightened by a thread. So, that by a knot on the shaft so, that these two under a initial pressure initial load. So, you should remember that if we go for taper roller bearing, then we have to use in paper pair where is for other bearings it is not we are coming next to that.

For an example, both spherical roller and ball bearing can be combined with cylindrical roller bearing in the other end now to find out the load centre we have to how to find out the load centre, it is available in the catalogue that this point distance of this point from one side, but the procedure is that take the midpoint of this taper roller along the axis central axis and draw this line perpendicular to the central axis. We will get this point; these points are the load centre or the taper roller bearing. So, in shaft calculations or bearing support calculation, we will take, this is the span between the two bearings.

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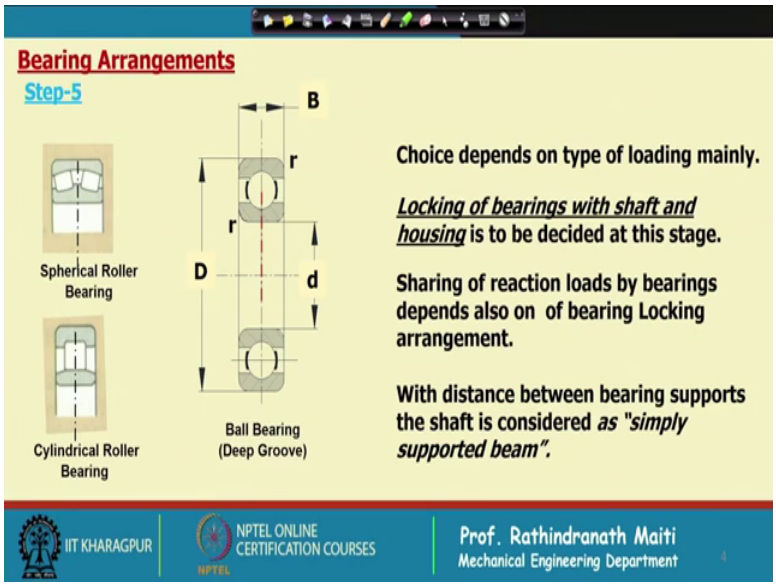

Now, here a spherical roller bearing is shown and bottom is that cylindrical roller bearing the cylindrical roller bearing usually that inner is kept to be free; that means, this can move this way on that way. It cannot take any axial load taper roller bearing can take axial load radial load spherical roller bearing also can take axial load and radial load, but it cylindrical roller bearing cannot take the axial load all these three bearings having very high capacity of radial load carrying capacity may be the taper roller bearing is the highest or cylindrical roller maybe the maximum; however, the taper roller bearing can take also high axial load whereas, spherical roller cannot take that much axial load on the

other hand spherical roller bearing is having the facility that this race, this can move this way and that way.

Therefore, in true sense, if we put the spherical roller bearing both side that might be considered as the simply supported beam whereas, if you put cylindrical roller bearing taper roller bearing or even ball bearing these are actually the rigid support; however, the all the bearings having a little bit flexibility in taking the rotation also taper roller bearing maybe the less highest maybe the ball bearing, but with all such bearings for practical purposes we consider the shaft supported with the bearings whether it is ball bearing in pair whether it is spherical roller in pair spherical roller with cylindrical roller ball bearing with cylindrical roller these are all simply supported bearing.

So, this is a ball bearing with dime dimension on normal pressure is given the dimension we need that d small d is the id of the bearing internal diameter capital d is the outsider od of the bearing b is the width of the bearing r is the corner radius. So, these informations are required and when we are choosing such bearing we have to think of also how we are locking the bearings suppose if we use the taper roller bearing it is fully locked it cannot move right way or left way what happens if there is a increase in the shaft size due to the heat.

So, tapered roller bearing will be loaded more in case of ball bearing in pair what we can do we can lock the bearing with the shaft fully and on the housing only one side bearing is locked; that means, positionally, it cannot move then in that case if there is some extension or contraction of shaft due to temperature change. So, other side bearing will move on the other hand that side bearing will not be able to take any axial load. So, as for spherical roller bearing, but best way is that if we use one side ball bearing and other side spherical roller bearing, sorry, cylindrical roller bearing then we need to lock only the ball bearing or spherical roller bearing and cylindrical roller bearing may be outer race is or both the races are locked with housing outer race with housing inner race with the shaft, but that can move. So, because it is not capable of taking axial load and this can move.

So, that is that will be the best solution, but cylindrical roller bearing if we take a pair with ball bearing cylindrical roller bearing will be slightly expensive and also the inventory will increase. So, usually it is the practice is that if possible both the bearings

would be same as well as they are of equal size, the shafts sharing the reaction loads by bearing depends also on bearing locking arrangement which I have discussed with distance between bearing supports this shaft is considered as simply supported beam in all cases as we have discussed and in case of cylindrical spherical and ball bearings we can simply find out their load centre is the middle of along the width of those bearings.

Apart from these, there are other bearings thrust bearing conical bearing which we are not discussing.

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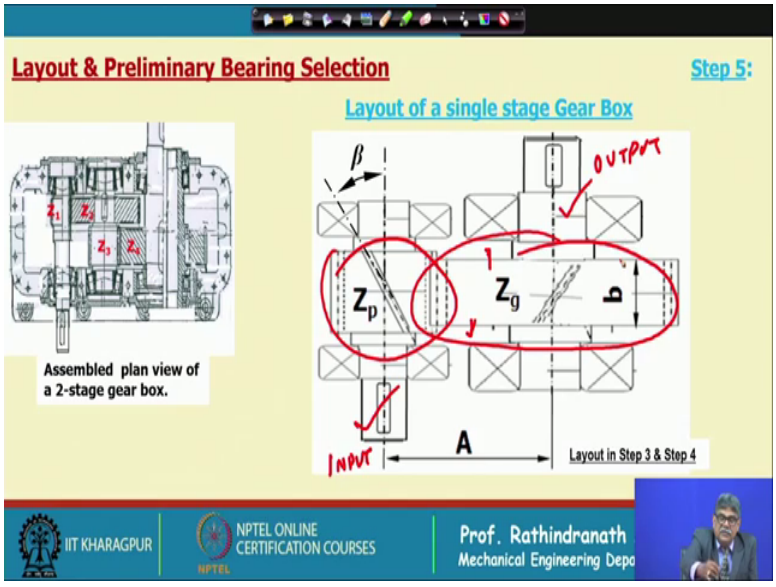

Those bearings are special purpose , now we should make a layout and then preliminary bearing selection to be done layout of single stage gearbox now here it might be only a single stage gearbox in that case only pinion and. So, this is the pinion and this is the gear and this is the shaft output shaft this is the input shaft. So, this is input and this is output and. So, after the gears are selected we have taken the five millimetre bore width of the, for the pinion because there might have some misalignment this means this may go in this directions or it might be in this directions. So, with the mismatch if we take the exact width then active width will be less than the width of the pinion or gear if they are same.

So, one should be greater than other to take care of that misalignment in the axial directions now why opinion, if we take the width of the gear is more than the pinion in that case unnecessarily there will be increase in weight. So, that is why as the size of the

pinion is small we take the width of the pinion is higher ok, then we consider with a recommended gap we consider, what will be the width of the sorry what will be the bearing we can select.

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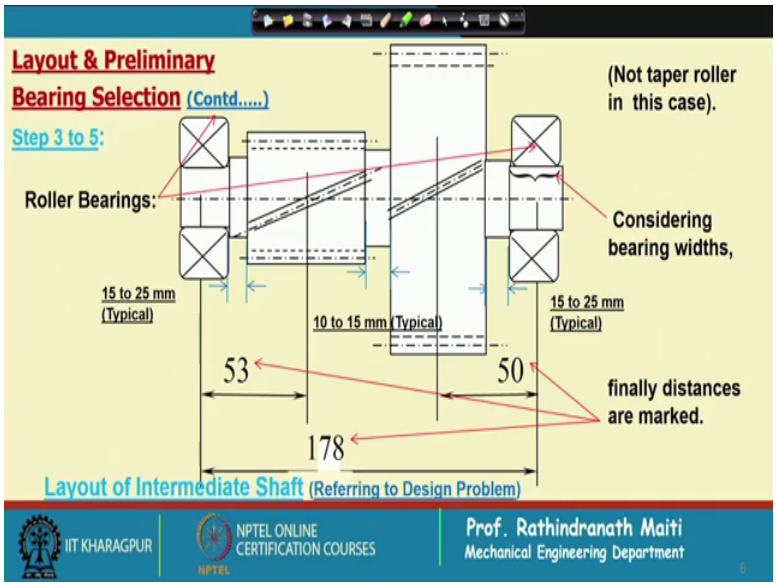

Now, this is the intermediate shaft of our gearbox what we have designed we have taken the module in first stage 3 millimetre and in second stage, it is 4 millimetre. So, this is this is the fastest gear and this is the second stage pinion. Now, we will see that this is the layout is made and from there we have considered this shaft.

Now, these are the roller bearings this may not be a taper roller bearing, in this case, we are not going for the taper roller bearing. So, these are not taper roller bearing and this gap may be kept even less than 10 millimetre, but in common practice usually it is kept 10 to 15 millimetre, we have to keep in mind that here the another gear is missing with that pinion. So, this gear and this gear will have a relative motions.

So, they would not fall or if a particles come in between this should not rub that is why this gap is taken sufficiently large 10 millimetre is sufficient, but one can go for 15 millimetre also now similarly these two sides to be in safe side that we have to lock we may need to lock this bearing or this bearing or both therefore, we should keep sufficient space because when will consider the housing sometimes the housing is body is made like this. So, that this is kept locked from this side because there will be if we do not

keep a space will not be able to provide these steps or as well as we will not be able to arrange anything.

So, this is essential t and left side 53 and we have considered also the width of the bearing is we may consider something between 20 to 25 in the first item. So, suppose if we take a bearing of 22 millimetre and later we find 25 millimetre, still we can give the span 178 and this gap will be slightly reduced, if it is more also the same way we can give maintain the dimensions and bearing weeds as I have already told and final distances are marked as 53 and 178.

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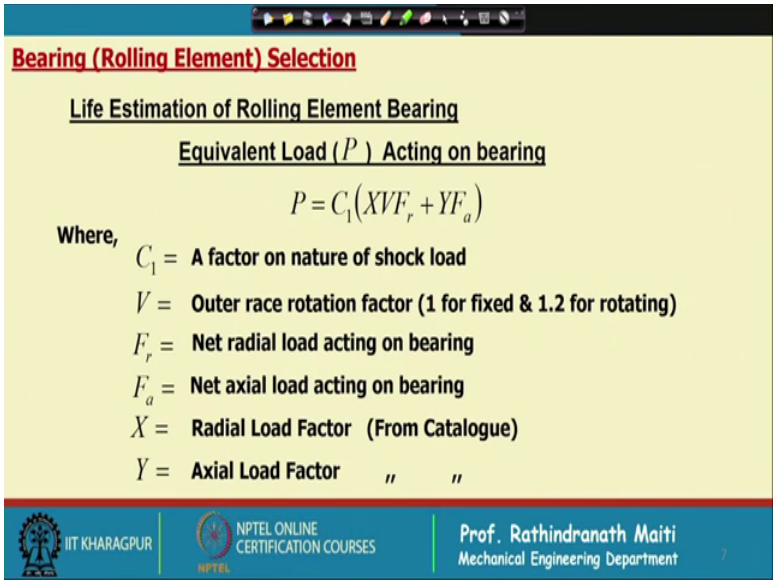

Now, we shall consider what is the life of the bearing life first of all equivalent load on the bearing which is acting on the bearing can be expressed P is equal to C 1 within parenthesis X V F r plus Y into F a, what are these C 1 is a factor of nature of shock load if this C 1 can be taken one, if there is no shock load may be for a heavy shock load, it can be taken 2 and we can choose any value in between that that that is usually recommended by the manufacturers of the bearing as well as depending on the load sometimes over this the manufacturer of care units also, they consider this value, they choose this value accordingly.

Now, V is outer race rotating factor which is one for if the outer race is fixed in normal case normal gearbox is outer race remain fixed. So, it is one and in case of epicyclic gearing in case of planetary gearing or in special cases also outer race rotates a relative to

inner race may be fixed all or it might also be rotating in that case it is better to take this value is 1.2 Fr is the net radial load acting on the bearing whatever load is coming on the gears through the shaft, it is being transferred to the bearing for the load support and calculating those we can calculate what are the net radial load F a is the net axial load acting on bearing and X is the radial load factor from catalogue and Y is the axial load factor this is also from catalogue.

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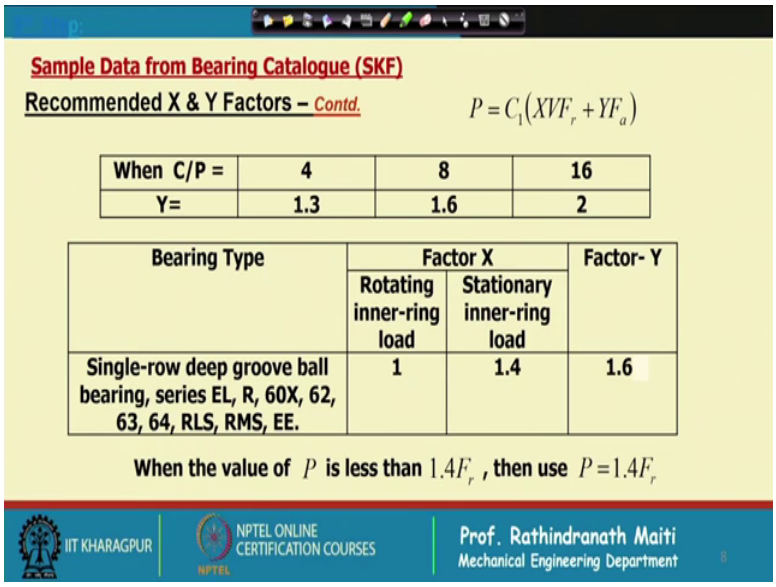

Now, this X and Y factors there is little recommendations of X and Y factors in the catalogue. So, once we select the beheading of a particular manufacturer should it be fags who did we escape should it be national bearing company of India, we should follow their catalogue and we should follow this values, but these values are more or less standardized and you will find more or less same in all bo; however, this is only an extract which I have given depending on C C by P where C is the dynamic load carrying capacity of the bearing dynamic load carrying capacity of the bearing which is not given here not written here we will come to that.

So, y may be taken as one point three one point six to two and similarly X factor here we have followed the SKF catalogue and there they have different series of bearing EL, R, 60 X, 62, 63, these are ball bearing, RLS, roller bearings, etcetera for which factor X can be considered like this rotating in a ring load stationary in a ring load and factor y is one point six this is nominal value what we can consider.

However in calculation if P is found to be less than 1.4 times F r we can consider P is equal to 1.4 into a radial load.

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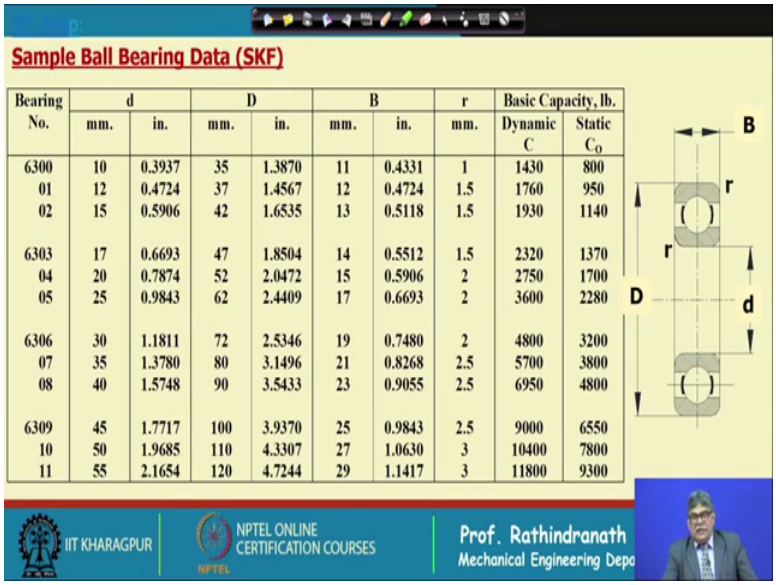

Now, this is a typical extract from a catalogue escape catalogue of the ball bearing what we find this is series of the bearing is 63. Now 6300 means it is 10 millimetre dia point 1 is 12 point sorry 0 2 is 15; that means, 63 zero two whether it is SKF, fag or any company inside diameter id will be 15 would you will be 4 2 millimetre in millimetre and width will be thirteen millimetre and corner radius will be 1.5, these are standard for all bearings all bearing company, it will be same and dynamic load carrying capacity see is 1930 pound whereas, static load capacity 1140 that it is C 0 1140 pound.

So, in no case that a radial component of load should be more than static load carrying capacity and with the dynamic load we will find out what will be the life another thing I would like to mention up to 6303, the shaft diameter 10, 12, 15, 17, but from 6304, it is multiple of 5; that means, directly if you multiply five with the last two digit you will get the id in millimetre.

So, 04 into 5 is 20. So, it will become id is 20 millimetre and if you go for 11, then in that case 11 into 555 millimetre. Now if we go for other series 64 which will have more load carrying capacity, but with the number 63, 64, 11, it will have internal diameter 55, but we will find external diameter will be more than 120 millimetre as well as width

maybe more corner radius may be a little more you will find node carrying capacities both dynamic and static will be more.

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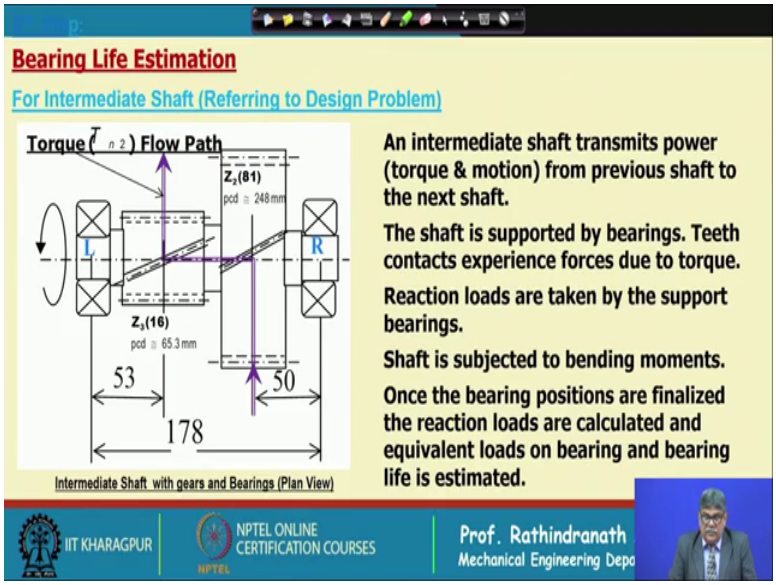

So, this is a little idea about what are the bearings.

Now, we will go to go for bearing life estimation and intermediate shaft transmits power from previous steps to the next step. So, if we look into this then torque is coming like this and torque is going out. So, load is being transferred in that way and the shaft is supported by bearings teeth contacts experience forces do to torque we need to calculate reaction loads are taken by these support bearings and shaft is subjected to bending moments we should consider all such things here we have given the dimensions of the bearings also PCD and we have mentioned also with not mentions, but we have kept the gap R capital R in blue stands for the right hand capital L stands for the left hand.

So, once the bearing positions are finalized the reaction loads are calculated and equivalent loads on bearings and bearing life is estimated.

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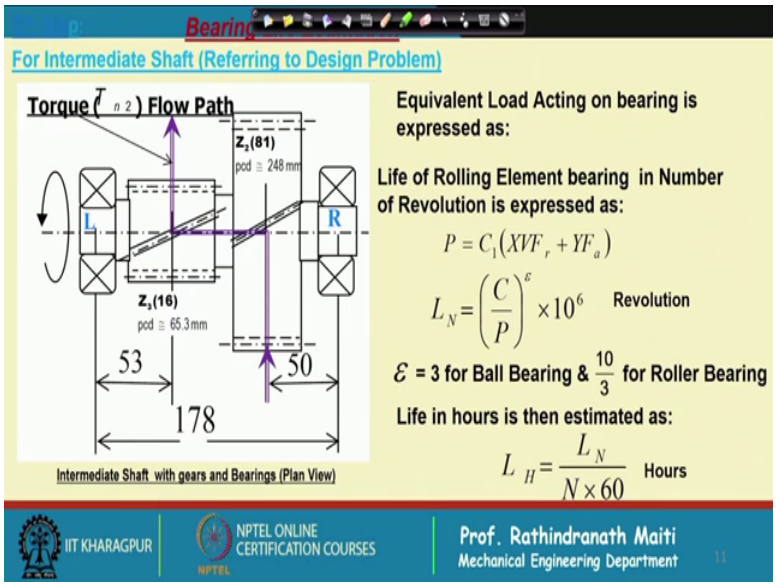

So, again we consider the P is the equivalent load on the bearing which is given by C 1 Xb F r plus YF a in this the design we have considered X will be one because here the outer race is fixed and now we can estimate the life of the bearing in revolution C by P to the power epsilon into 10 to the power 6 revolution where C is the dynamic load capacity of the bearing selected bearing and P is the equivalent load from the reaction loads; that means, whatever load is radial load and axial load and X and Y factors who when factors we choose from the catalogue.

So, this is in revolution and this value is 3 for ball, ball bearing that to the per epsilon that is taken three for ball bearing and 10 by 3 for ruling elements bearing set up are cylindrical and spherical roller bearing and life in hours is then estimated by the in a revelation divided by rpm of the shaft into 60, this in our what are the revolutions that will directly give us the life in hours ok.

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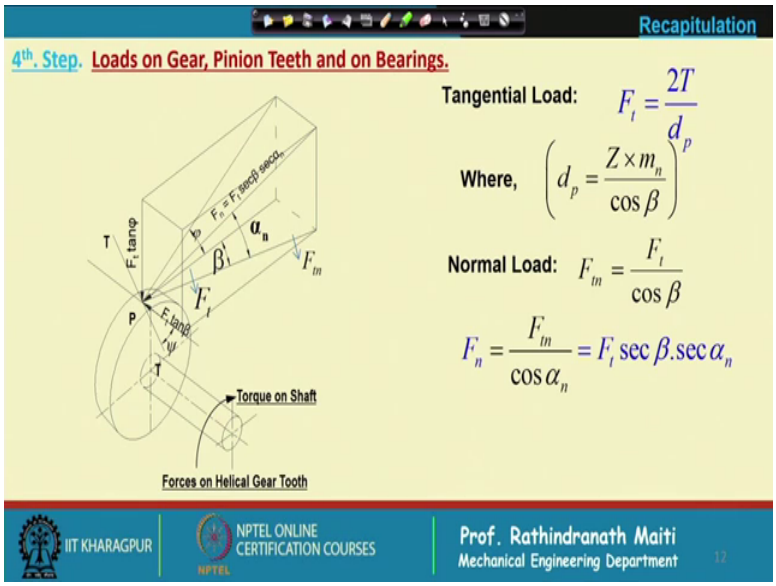

So, now we can proceed for calculating the first of all we will calculate the loads from the gear on shaft this is again we recapitulate the from torque, we can find out the tangential load and then we find the normal load and from normal load we find sorry this we this tangential direction we find out the load and then from there we can find out the normal load; that means, we are finding out this load finally, first we calculate this Ft in this directions from there we calculate this one then this one and from that value we calculate the other loads and this is given by these trigonometric relations.

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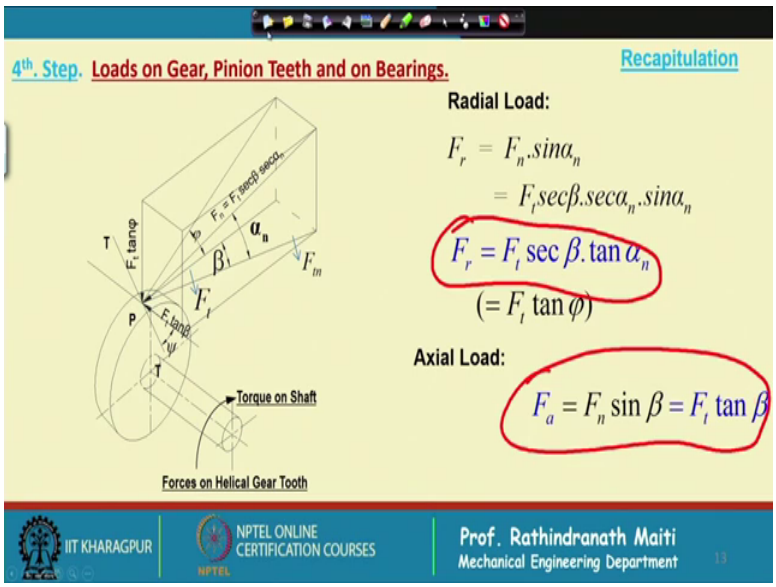

So, if r radial load on the gear finally, can be expressed as F t sec beta sec alpha n and sine alpha n or simply F n sine alpha n and sorry this actually F t 10 psi which is also can be given I, this angle is I also can be given usually better to use this formula F r is this one this is helix angle this is pressure angle whereas, for axial load we use this one it is clear that if the helix angle is 0, then axial load will be 0.

So, thank you and in next lecture we shall calculate; what are the loads coming on bearing.