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

Lecture – 15
Gear Unit Design – 1st. Layout
(After Gear Design)

We are continuing with design of general purpose industrial helical gear reduction unit. And this is module three and part one of the design and lecture number is 15, where we will make a first layout of the gear unit after gear design.

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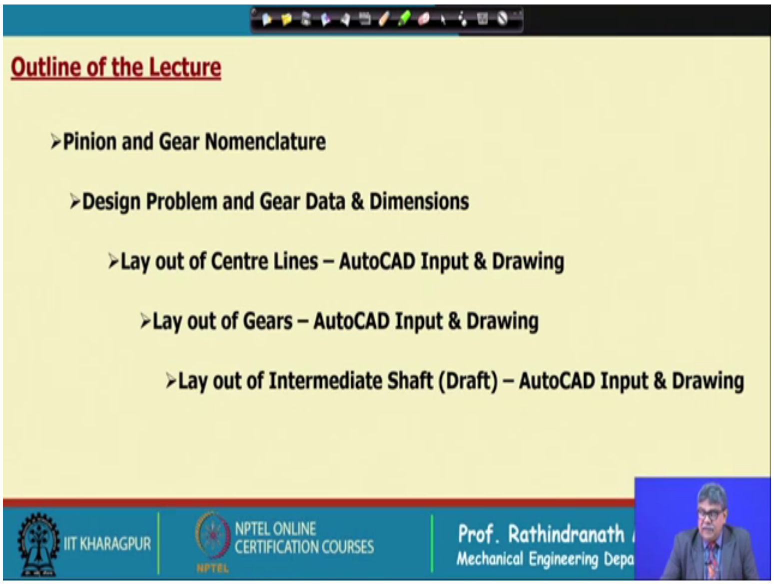

Now outline of this lecture is that pinion and gear nomenclature that we will learn a little bit, this is required for the drawing. Design problem and gear data and dimensions. Layout of a of centre lines, I will show that how to keep input in AutoCAD, and what is the output that is the drawing. And layout of gears AutoCAD input and drawing. Layout of intermediate shaft this will be draft means it may be final it will be finalized later after selecting gears etcetera. And here also AutoCAD how the AutoCAD is given that is also discussed.

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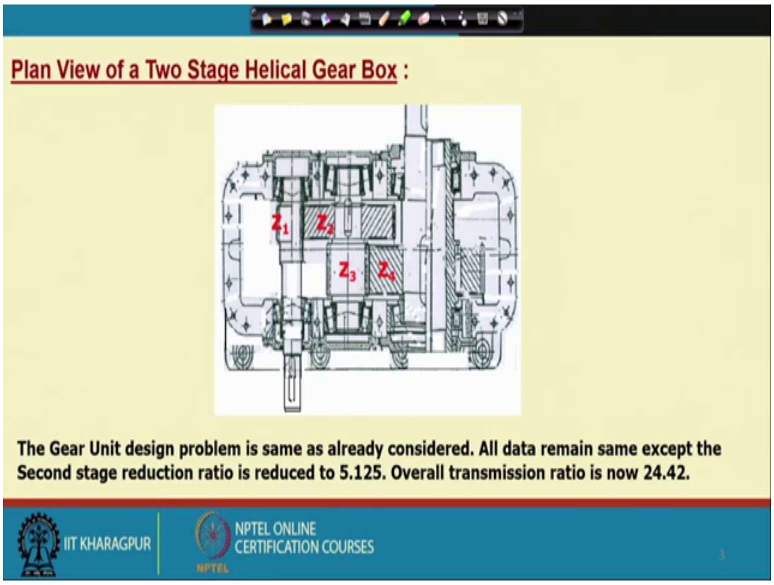

Now, the what the problem we have taken we are going to design a two stage helical gear box which looks like this what is shown. This is the plan view, top open plan view of the gearbox. And z 1, z 2, z 3, z 4 are the teeth numbers. In first stage pinion teeth number is z 1, and gear is meeting gear is teeth number is z 2. And thus in second stage pinion teeth number is z 3 and final output through the meeting gears z 4.

And the problem is same as already considered and discussed as we are solving. And in this lecture all data remains same except the second stage reduction ratio which is reduced to 5 5.125 overall transmission ratio is now 24.42 instead of which was close to 40, thirty nine point something which was there. And in this case only we have changed the teeth number of z 4, we have reduced the teeth number of output stage gear; others remain same. Therefore, torque up to the intermediate shaft will remain same, and the design of get z 1, z 2 and z 3 will remain same, and thereby z 4 module will remain same only the size will change. So, this problem we have taken for the drawing the region I shall explain when we will come to the drawing.

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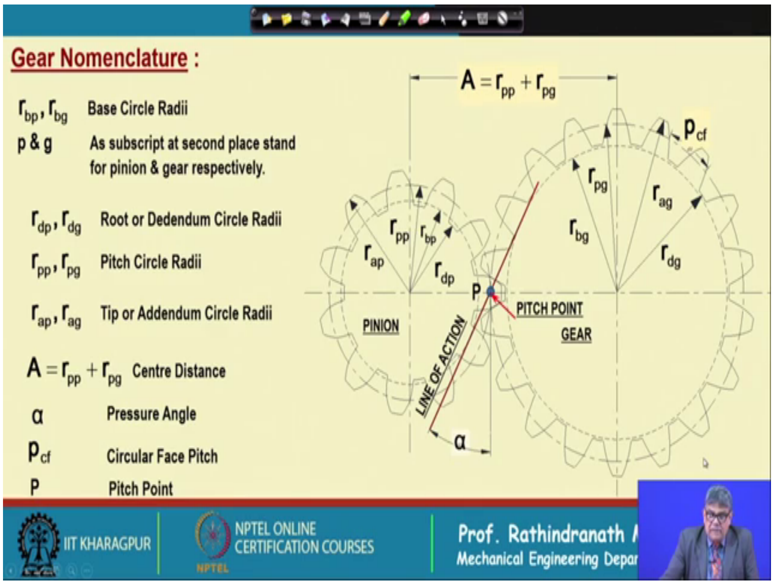

Now, at such the nomenclature of gear which earlier shown, the here it is a meeting gears is shown. Pinion and gear both are shown; and line of action also shown with a pitch point. And most of the dimension will repair for the drawing. However, the base circle which is designated by r b, r b, e pp and r bg, where p stands for pinion, g stands for gear.

The base circle radius that actually will not be needed for the gear drawing but if we look very quickly to the dimensions root and dedendum circle radii that will be required pitch circle radius that will be also required. Tip circle will also be required. Center distance definitely, and the pressure angle is not required. Circular face pitch as such will not be required for the drawing, but this is just to give an idea what are the dimensions of the gears.

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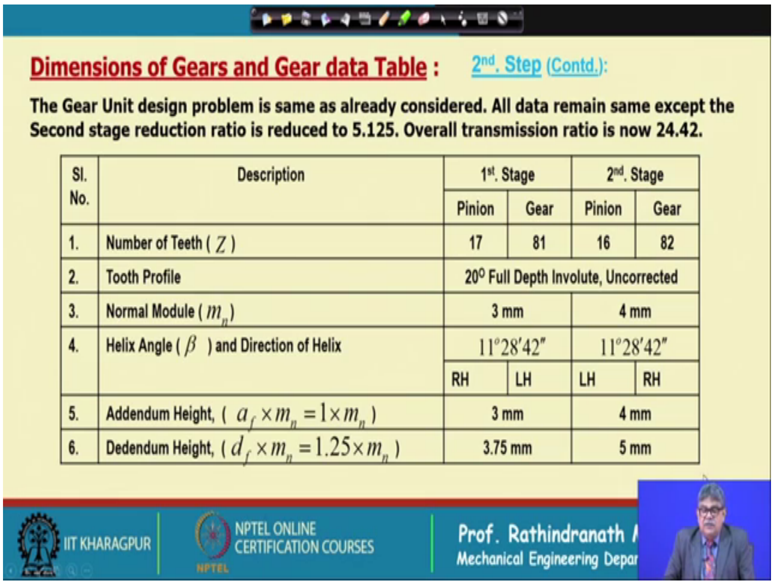

Now, next we have already designed the gear as I told that input torque remains same and fastest deduction remains same. So, second stage torque, torque in the intermediate shaft that remains same. And thereby the module of the that pinion the dimensions of the pinion for the second stage input also remains same. And if we look into this the what are the teeth number the z 1 is 17, z 2 is 81, z 3 is 16 and z 4 is 82, which was 131 in the problem which we have solved.

Now, z 1 means the input pinion, and gear is the z 2 is the first stage gear. Now, the tooth profile as mentioned it is 20 degree full depth involute, uncorrected. Full depth means addendum factor will be 1. Now, model as we have calculated and with from different considerations we have ultimately taken at first stage, it will be 3 millimeter; and second stage, it will be 4 millimeter. Helix angle what we have taken that is 11 degree, 28 minute 42 seconds, cos of this will be 0.98 and for which we will get a the centre distance sum square value that I will discuss.

Now, addendum height as told this is 1. So, addendum height of first stage tooth addendum height is 3 millimeter, and second stage it is 4 millimeter. And dedendum height is 1.25 that is 3.75 millimeter and 5 millimeter for the second stage. This means that tooth height at first stage will be 6.75 millimeter and second stage it will be 9 millimeter that will we have to enter into the drawing, we have to show into the drawing..

Now, another point I forgot to mention that direction of helix angle input pinion is right hand. So, therefore, gear, meeting gear has to be left hand. And also it is important then intermediate shaft the direction of helix angle for the adjacent pinion also to be same to reduce axial reaction load that also comes into the next page of calculation. And if that pinion is left hand, second stage, then definitely the gear will be right hand.

Now, next we calculate the pitch circle diameter of the pinion input pinion which is fifty two point not four, and for gear 247.96. Second stage pinion is 65.306, and gear is 334.694 that is against the 82 number of teeth. And as we have taken the cos value is equal to 0.98, cos value of helix angle 0.98 that becomes 17 plus 51 sorry 17 plus 81 divided by 0.98 which gives 100 that multiplied by 3. And it divided by 2 gives 150.

A value which is multiple of 10 millimeter which is preferred in standard gearbox design now, it is not essential that we have to make that cos value is such that it will be adjusted. Actually, in actual case a gear tooth correction is given to make the center distance multiple of 10 millimeter or 5 millimeter, 10 milli multiple of 10 millimeter is very common.

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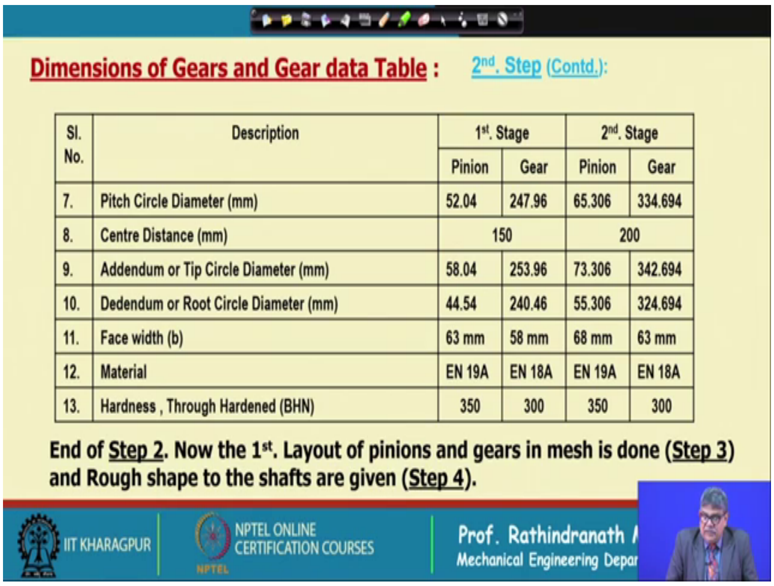

Sl. No.	Description	1st. Stage		2nd. Stage	
		Pinion	Gear	Pinion	Gear
7.	Pitch Circle Diameter (mm)	52.04	247.96	65.306	334.694
8.	Centre Distance (mm)	150		200	
9.	Addendum or Tip Circle Diameter (mm)	58.04	253.96	73.306	342.694
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694
11.	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

In this case, we are getting the center distance 150 millimeter in first stage and second stage 200 millimeter. Then we have also shown calculated the addendum or tip circle diameter and also root circle diameter. Then face width, face width when we have calculated then after finalizing the module we have multiplied the width factor which is given by psi with the module, calculated module. What the value is we get that directly that width is directly given to the gear. And pinion meeting pinion is made 5 millimeter more, usually 5 millimeter more. The reason is that due to misalignment axial misalignment always the contact active contact will remain what value we have taken.

Now, question is that why not why the pinion is made shorter and gear is not made wider. If we make the gear wider, it will need much more material weight will increase that is why always the additional width is given to the pinion. Similarly, the second stage pinion is 68 millimeter, whereas active width given to the gear is 63 millimeter what we have calculated. Now, material has already mentioned EN 19A for the pinion; and EN 18A for the gear. And to give the appropriate life wear life or the wear load capacity point of view, we have kept the Brinell hardness number of pinion is 350; and for gear it is 300, in both stage we have kept it.

And it can be mentioned that with this value we can cut the gear simply by hop cutting; grinding is not essential grinding is not essential with this hardness. So, perhaps for that only we had to increase the module a little bit in the first stage its itself and then as well as in second stage also. If we increase with the same material same teeth number, if we increase the hardness probably we can go for a lower size that means, module can be taken 2.5 in the first stage like that. Anyway we have already decided something and we are going we going with that.

Now, with this with this data which was the end of step two already mentioned now the first layout of pinions and gear in mesh is done that is the step three, and rough shape to the shaft are given, so that will be shown.

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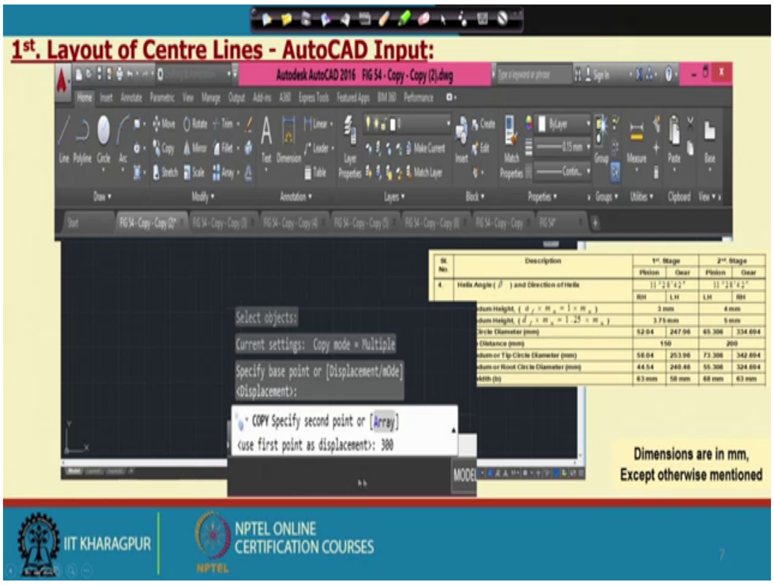

Now, drawing such drawing can be done in drawing seat, there is no problem. One can measure on the scale and start drawing. However, nowadays almost everywhere AutoCAD our similar powerful software is used for engineering drawing. And advantage of this using this that a there are many modules say for example, bearings that is already drawn and many sub assemblies also kept as a subroutine that directly can be imported into the AutoCAD and the drawing can be completed. Apart from that advantage is that anytime we can alter the drawing, we can simply delete one line we can add one line.

However, it needs a practice. Unfortunately there is no scope that I can teach the AutoCAD and neither I am an expert in that field. However, with a little knowledge of the AutoCAD, you can still develop how the drawing. Now, first of all this is the if you open the AutoCAD, it is auto disk AutoCAD 2016 that version is there. So, if you open this one, you will find that off there are many menus, and also bottom there is a splash where the data input will appear.

Now, first of all the gear data what will be required for this drawing. We are going to make a plan view of the drawing. So, we need what was the helix angle, direction of helix, addendum height, dedendum height, pitch circle diameter, center distance etcetera, etcetera that the table already geared at a table which is shown that is only essential data are shown here.

Now, if we look into the top of that you can see that here the menu this line is there, a polynomial curve is there, you can draw an arc circle you have to click there. And there is some it will ask for some data that you have to give as an input there are many possibilities. For example, if you would like to draw a circle, it is possible that you have to give a center and radius or center and three points on the circles, so that option you know which one will be better for you. And you can give such inputs and you can get the circle.

Similarly, the if you would like to write something that text is there. And there is also that you can enter the dimension, save this is for linear dimensions here. Say this is you can click on oh linear dimension, for circle that you have to click here and then a different fillet, trimming, you can rotate the view at some place. You can take the mirror image of the view and complete the other part. If it is a it has a symmetry about an axis and there are many, many options which you have to learn of your own.

Now, the a typical menu for a line will be that that you have to first of all you have to draw a line. And then you suppose if you would like to draw at a distance, then you have to give to where you have how much displacement is required. And there you can draw a line. In this case what we have shown that is the centered some distance it was given. This is just to show you that how that menu are given.

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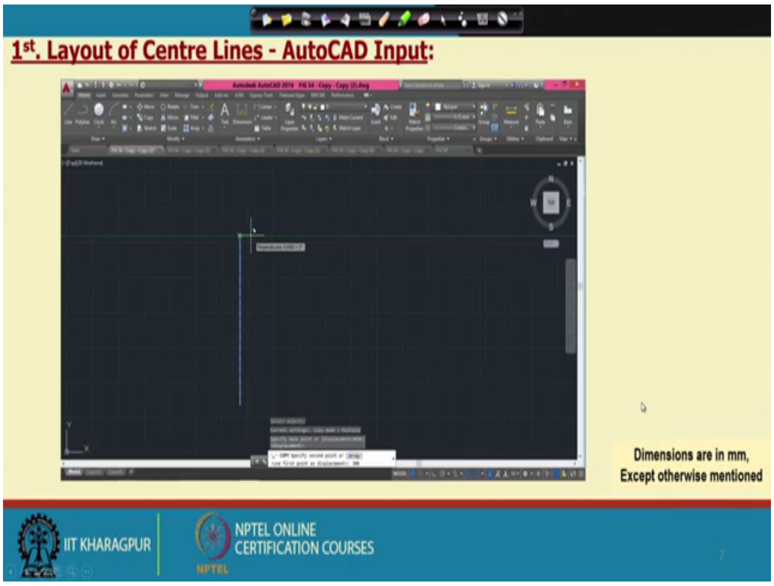

And next the this you will get a line you will get a line like this. And this is the output shaft axis line. Now, before that obviously, you should know what should be the length of the central line that is you have to I always suggests better we should think of any intermediate shaft at the width of pinion and gear which will be assembled on the intermediate shaft. Between the pinion and gear there will be 10 millimeter gap; and by the side of gear and pinion there will be another 20, 25 millimeter gap, and then bearing width will be 25 millimeter or so, each side.

So, if you add them, then you will you will get that what should be the length of this centre line.

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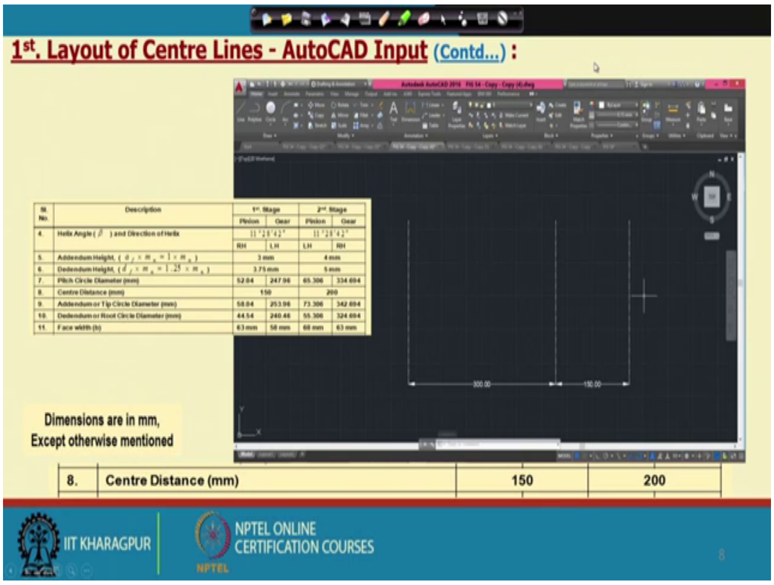

So, first central line is drawn here. And in the same way we can draw the three central line this is this lines are drawn on the basis of earlier problem, so center distance is shown here 300. But in this what we are now going to design for which our center distance will be 200, this will be 200 that means, after drawing this first line then second line will be drawn at 300 which is simply the same size only distance will be 300 millimeter. And then from there another 150 millimeter which is the first input line, center line for the input. And one point I would like to mention here if the dimensions are not mentioned then it is millimeter; otherwise it will be mentioned ok.

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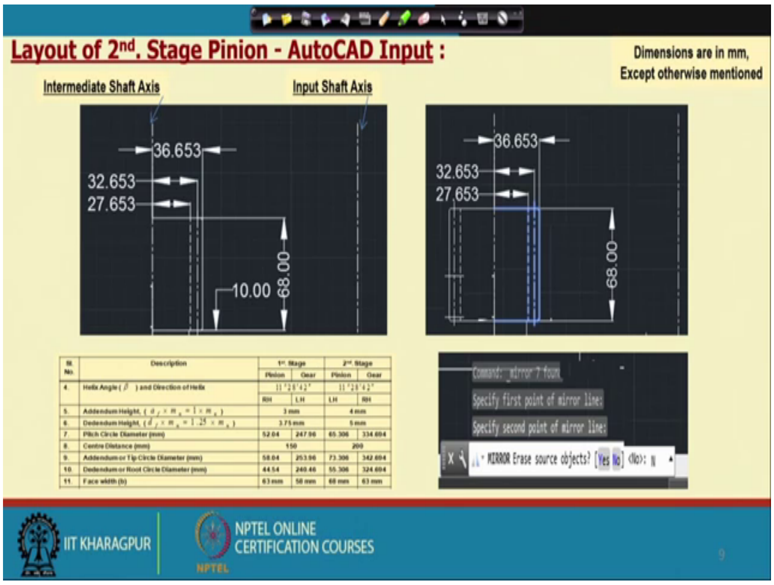

Now we will first after drawing the centerline then we will first draw the intermediate shaft gear and pinion. What the calculation we have done so far from there we can draw the centre lines only and to the envelop of the gears and pinion and their dimensions pitch circle etcetera that is a essential to determine the size of intermediate shaft, position of the bearings. Once that is decided from there we can then input we can complete then input shaft and as well as output shaft.

Now, in this in the development of this second stage pinion what we have done we have first of all we have considered that where is the pitch line. This is half of the pitch circle diameter. So, in the intermediate shaft, this is 65.306 pitch circle diameter of the pinion, we have taken half of that and we have drawn a line. Giving a space on the center lines we have kept a space for bearing etcetera after that we have say first we have drawn this centre line, and then we will draw this envelop.

And as shown that is the half of the dedendum circle and this is the half of the addendum circle of the pinion it is drawn. And then we have we have drawn this line form, and this is dot dotted because there is a this pinion is not section there. And we have given the face width which is 68 millimeter. So, we have drawn this line as well as we have given a corner chamfer. At this stage either you can finalize the sample or this is usually recommended apparently here we have given 2 into 45 degrees chamfer; that chamfer again it is available in the menu. You can shape that one you can if you click there on two lines automatically this chamfer will come there ok..

And after that what we are going to do we are making the mirror image of this one to other side to complete this pinion. So, pinion of the second stage input opinion is completed. And here the you can see this comment will be asked and you have to press one after another. Now, while we were delay selecting distance for a line, then a you have to give input point, output point. And those who are habituated with such drawing simply they can give some line and then that can be adjusted to that dimension close to that.

It is not essentials that you have to put exact dimension on that and neither it is possible. Suppose, 69 say dimension 65.306, you cannot give. So, keep it fixed 65 or 65.5 something will come over there, later while we were dimensioning there a option is there that dimension can be modified to the exact value what we need ok. So, this is done. So, what we have done so far we have drawn three center line and we have completed only the second stage pinion on the intermediate shaft.

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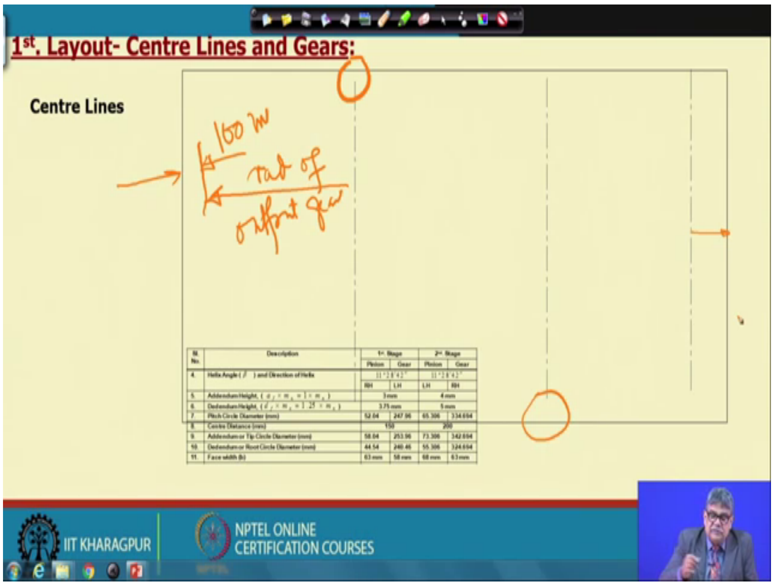

Now, a if we show at a single slides, then you can see the first this three central lines is drawn. The this box which is a rectangular box which is shown here that is given just for the space selections. Suppose, you are using a drawing sheet and let us consider you are using third angle projections. So, in that case this you have to select the place where your plan view will come. Now, plan view for usually that is made left hand top corner. Now, how much space is required normally the what the length we have taken for the centerline, length of the centerline take another 50 millimeter out of that another 50 millimeter below. So, this means that here perhaps this is the centerline already you have calculated, then we can take here 50 millimeter and this side also around 50 millimeter. And for this side we calculate the this is the radius of output gear plus say another 100 millimeter.

Similarly, this side also you can add with the radius of the pinion and input pinion and then 100 millimeter. In that way we get the a rectangular shape that we space that select for the drawing of the plan view. In case of AutoCAD, we did not do it anytime anywhere we can draw at copy, and then we can put in a final drawing sheet if that company is having such drawing sheet, otherwise the wherever it is drawn that you can directly take a printout of that. Anyway see this is this boundary line is given for to select the space.

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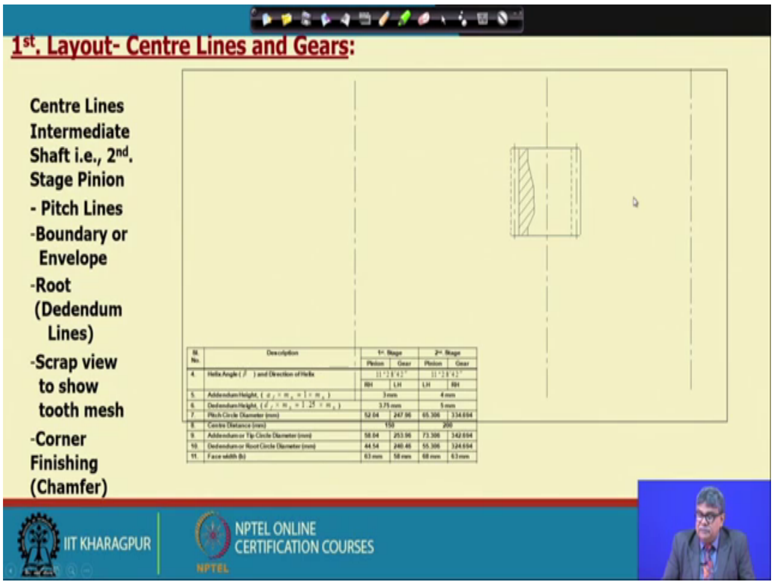

So, after drawing this three line what we do we first do draw the pitch lines of the pinion that what I have shown earlier in the AutoCAD drawing. And then we draw this boundary lines. You can see this these two lines for the width this is for addendum circle diameter and but where the pinion is meeting with the gear we have taken this line dotted. Initially even a if you do not take in dotted, you can make it dotted provided that line is invisible that you can do it, so that really does not matter, but we have we know that this will be invisible this portion that is why we have taken a dotted line there.

So, we have drawn the boundary lines envelop lines of the pinion. And then we have we have taken the addendum dedendum circles. And here we have it is called scrap view that is just to show the contact portion of the teeth with the gear. And also these corners are finished this corners are finished which hampered at the initial stage at this stage it is not required when we finalize the drawing we can do it. However, here it is done. So, this is roughly how the pinion is drawn, first it is drawn ok.

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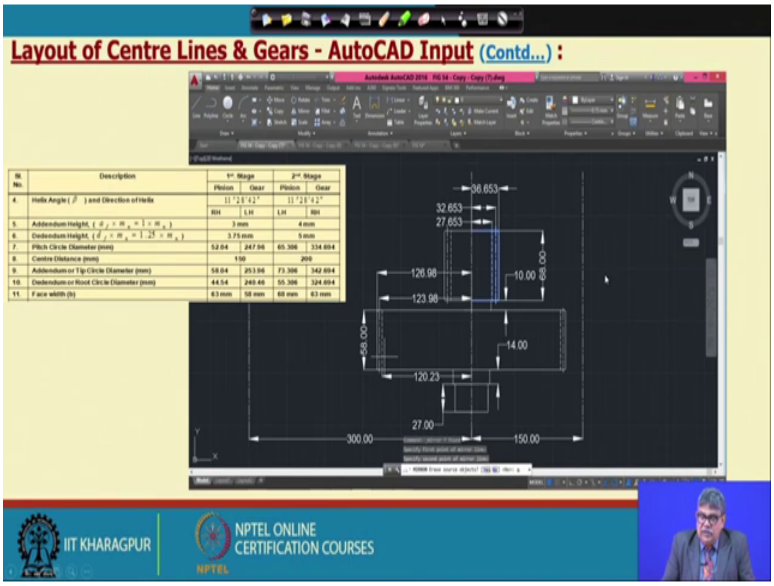

Next what we do we draw the gears; in the same way we have shown we draw the gears. And as importantly this distance from the face of the pinion to face of the gear, we have kept a 10 millimeter at least 5 millimeter space should be there. There should not be very close because in that case the rotating pinion or gear or other shaft will rub on the surface mirror, so that is why this gap is essential moreover his step is required there also. Now next this is the input stage gear the dimensions and we have given here. Here it is not 300, later we will show that this will be 200, as we have taken 200 millimeter there. Anyway, this intermediate shaft pinion and gear that only we will be draw in that stage.

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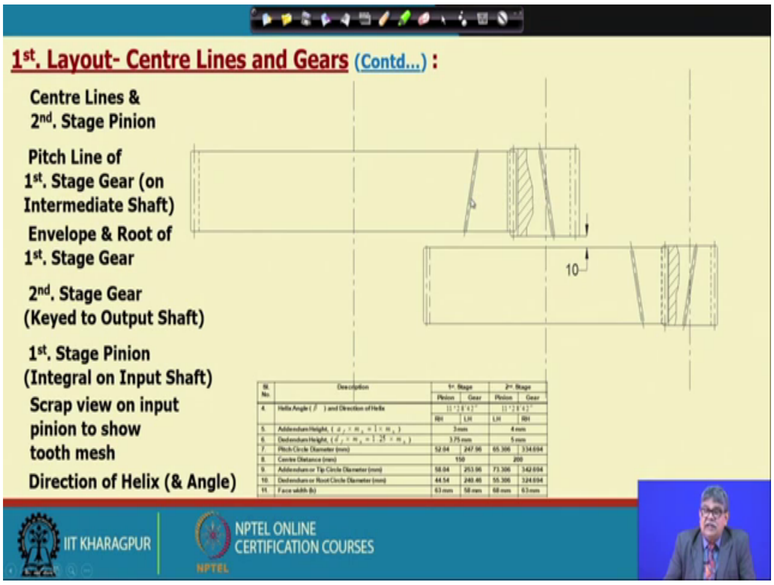

And in a slides, we are not showing the envelop of the space envelope, we are just showing the how to how this gear has been drawn. First centre lines, then gap and then the envelop we have drawn. And then the root diameter also we have shown. And second stage gear which is keyed to the output shaft that envelope is also drawn. And finally, input pinion is drawn in the same fashion. Here also a scribe view its own to see this engagement.

Looking into this view if you a look then the pinion is below the gear teeth, here also pinion is below the gear teeth ok. Here we have made it a farm line because we can add a scribe you there, here perhaps it will not be done or if required any of this line can be made farm line later only we can change it. So, at this stage, what we have done we have completed the gears. Now, shaft is not yet designed gears are designed that we have putted there.

Now we will try to give a shapes of these all the shafts, but first we will consider the intermediate shaft, no, before that what in their direction of helix, it can be mentioned by like this. The roughly we can take say this is angle is 11.28, 11.5 degree or even 12 degree draw the centre lines and two lines that indicates the direction of helix this is right hand. So, we have to be care you have to be careful about showing that which is right hand, which is left hand. So, this is right hand, this is left hand. And as this is left hand then here it is also left hand pinion on input pinion of second stage it will be left hand and here on the gear it will be right hand. So, will of the intermediate shaft.

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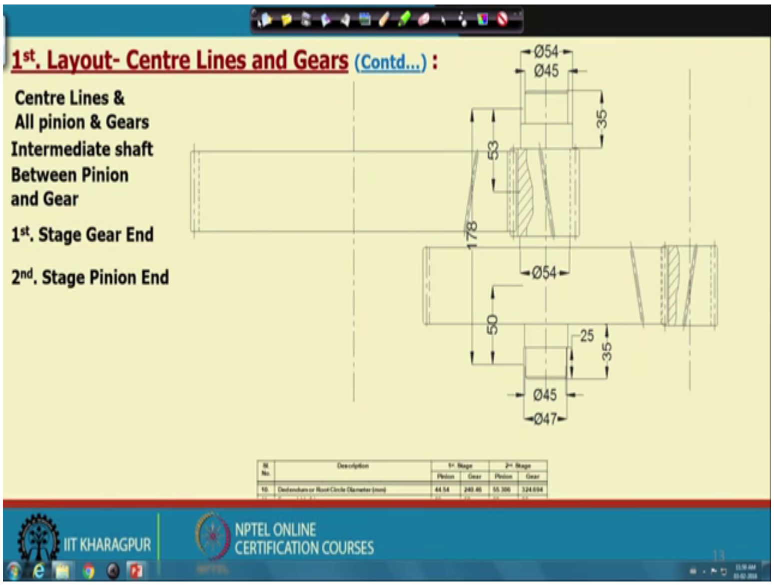

If we look the route circle or dedendum circle of the second stage pinion, the dimensions are 55.306. So, we can make the diameter just after this pinion. This pinion is integral with the shaft, which I have mentioned earlier. So, we can probably take a dimensions of 54 millimeter ok, because after that further step down will be required to accommodate this gear to assemble this gears, but that will not be shown now. So, here we take 54, and definitely here dimension will be less. Therefore while we are finalizing the shaft end for bearings heating and the space between the bearing and the gear, we will make it like this.

What we have taken this we have taken totally 35 millimeter and here it is 25 millimeter this means that bearing width we are considering it will be close to 25 millimeter a sorry yeah width of that will be close to 25 millimeters; and after the 10 millimeter. And it is expected that within this 10 millimeter, we will be able to finish the inside wall of the housing, so that means, maybe for inside wall will go further 5 millimeter and from this gear surface there will be at least 5, 6 millimeter gap with that expectation we have considered this.

However, it can be adjusted this way and that way later and that may not required due to that it may not require that we will recalculate the bearing supports, bending moment diagram of the shafts etcetera may not require. So, this at initial stage, we will take this dimensions. And if you look into this diameter, here it was 54 and then the bearing shaft where the bearing we will see it we have taken that diameter is 45 and after that we have taken 47. This is I would say that it might be a problem that we have to put a pressure here to support the inner race of the bearing that we will see later what can be done. So, this space we have roughly taken.

And similarly we consider the other side of the if you can see this these are the dimensions on the other sides. Here it was 54 uh. So, other side also we have kep kept 54, whereas this side we have kept 47. And once this is done then what we consider as if the some here about 12 millimeter from this side, there will be the bearing center bearing center may not be bearing width may not be 25, it may be less. So, 12 millimeter from this side that means, about 22.

And in that way this adjusting this way that way we have considered, this is the center of bearing on the pinion side and this is the centre of the bearing center means along the width half of the width of the bearing that will be here. So, you may consider this is the point where the this is the point where the load will act of the bearing. So, these two point and from there the mid of the pinion is 53 millimeter and this side mid of the gear is 50 millimeter and totally it becomes 178 ok. So, totally this length has began become 178.

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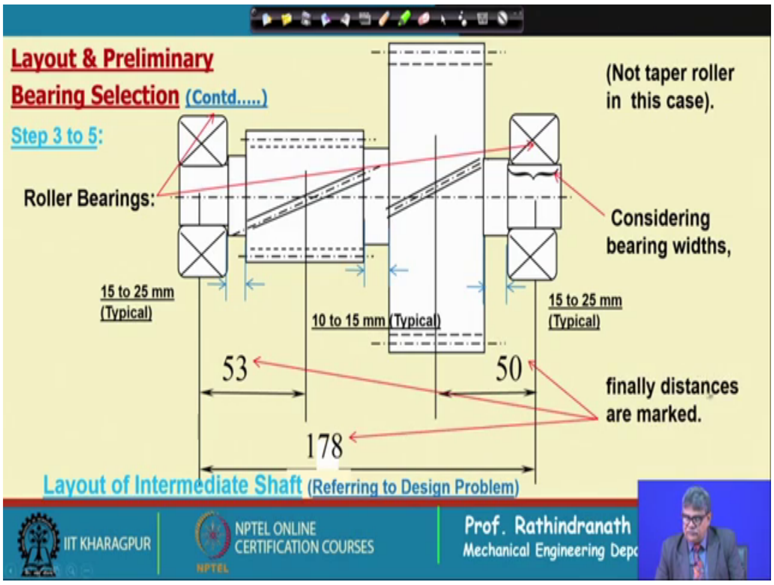

And then and then finally we from there we can take a we can consider this gears, we have it is of course, drawn in the reverse side. So, these are the dimensions for the next step calculation that means, now we can calculate what will be the load coming on the bearings and on the shafts. So, after drawing this portion, what we can do we can finalize the design of intermediate shaft, we can select the bearing that can be done In this design, we shall consider or be all bearing center will remain same, all bearing center will remain same. So, this means that length of the bearing support will remain 178 or at the most 180.

So, this is the bearings, and not taper roller bearing in this case. This is typically 10 to 15 millimeter, what we have considered 10 millimeter and this portion is 25 millimeter or so what we have also considered in between that some value. And it has the final dimensions from that drawing with what we have got it is there, but still I would say that we do not know what will is the exact width of the bearing. Only after finding out the load selecting the bearing, we will be able to know what will be the exact dimensions of the bearing. But after this stage, we have to complete other calculations before finalizing the other drawings.

So, thank you. So, in this lecture or this is the end of this module, I would like to say that what we have done we have finalized the gear design. We have made a preliminary layout where we have drawn the gear centered lines. And from there we have taken a first initial size of the shafts of the intermediate shafts. And particularly we have located where ca can be bearings can be placed. And now we are able to calculate that what are the load comings on the bearings?

And from there probably we will be able to calculate the load loads moment etcetera acting on the shaft intermediate steps. And if we consider that the distance between bearing will same for input and output shaft from there also we will be able to estimate the size of the other shafts or at least we will be able to calculate what will be the load there, and probably we will be able to finalize the bearings ok.

So, next part of wearing selection etcetera will be taught in the module four.