Gear and Gear Unit Design: Theory and Practice
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Lecture - 20
Development (Layout) of Intermediate Shaft

This is the last lecture of module 4, that is week four design of General Purpose Industrial Helical Gear reduction unit and this is part two. We have already learned how to calculate the gears and bearings? How to select the bearings? And how to make the assess? The size of the different shafts; now in this lecture, I shall cover the development of intermediate shaft.

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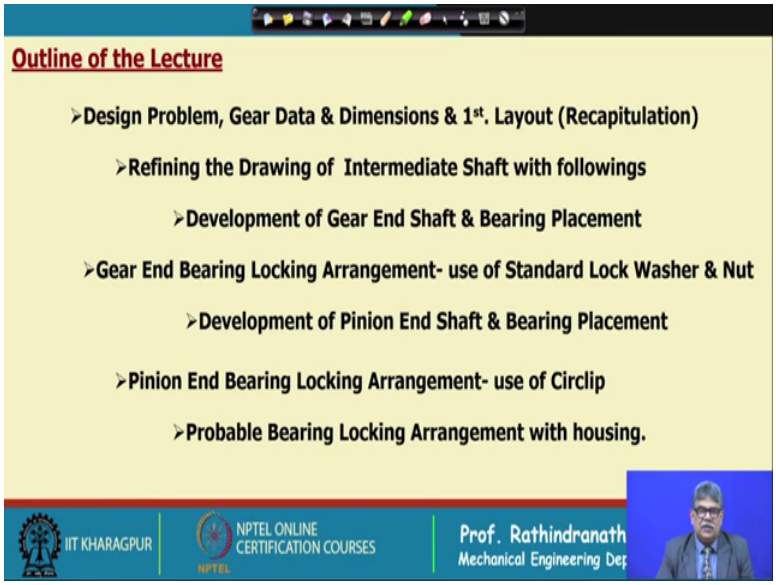

Now, in this lecture first, I will discuss design problem gear data dimension and first layout; that it that we recapitulate and refining the drawing of intermediate shaft with followings development of gear end shaft and bearing. And bearing placement next gear end bearing locking arrangement use of standard lock washer and nut development opinion in shaft and placement of bearing and then pinion end bearing locking arrangement use of circlip and finally, I will show the possible bearing locking arrangement with housing.

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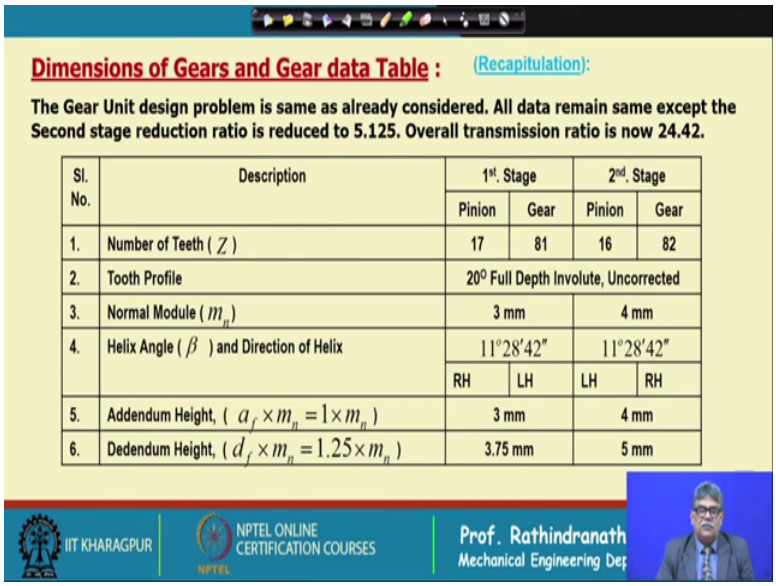

Now if we remember that the lectures are delivered on a gearbox having the transmission ratio close to 39, this detailed drawing will be done on the basis of a total reduction ratio. Total transmission ratio 29.42 and only change in the last stage reduction ratio last stage we had the final stage output stage gear was 131 teeth, but now we have taken 82 teeth 82 teeth. So, transmission ratio has that stage has reduced to 5.125 and for that there is not change up to intermediate shaft only the centre distance. In second stage will be reduced and size of the gear will be reduced which we have not yet a calculated the shaft for output.

So, there is no problem and these are the dimensions and.

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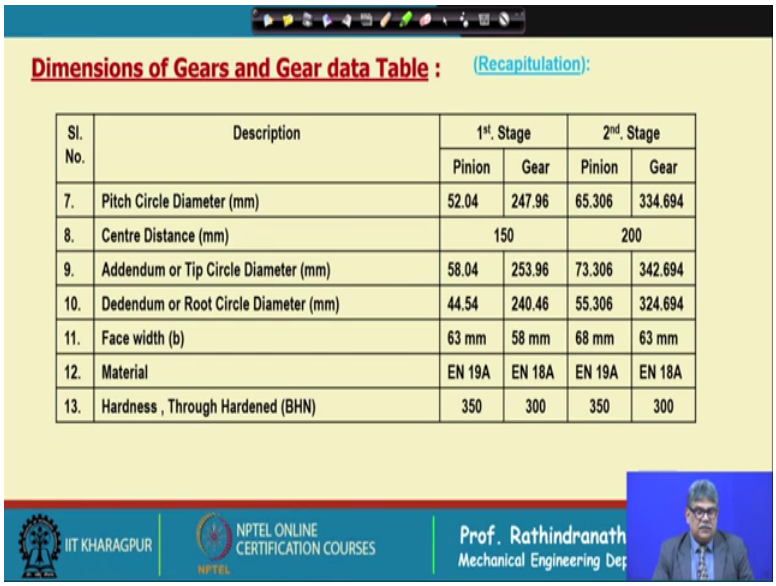

Sl. No.	Description	1st. Stage		2nd. Stage	
		Pinion	Gear	Pinion	Gear
7.	Pitch Circle Diameter (mm)	52.04	247.96	65.306	334.694
8.	Centre Distance (mm)	150		200	
9.	Addendum or Tip Circle Diameter (mm)	58.04	253.96	73.306	342.694
10.	Dedendum or Root Circle Diameter (mm)	44.54	240.46	55.306	324.694
11.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

We have calculated all the dimensions of the gears and centre distance in first stage, 150 and second stage earlier it was 300. Now it is 200 as well as the size of the output gears also reduced as you see from this chart.

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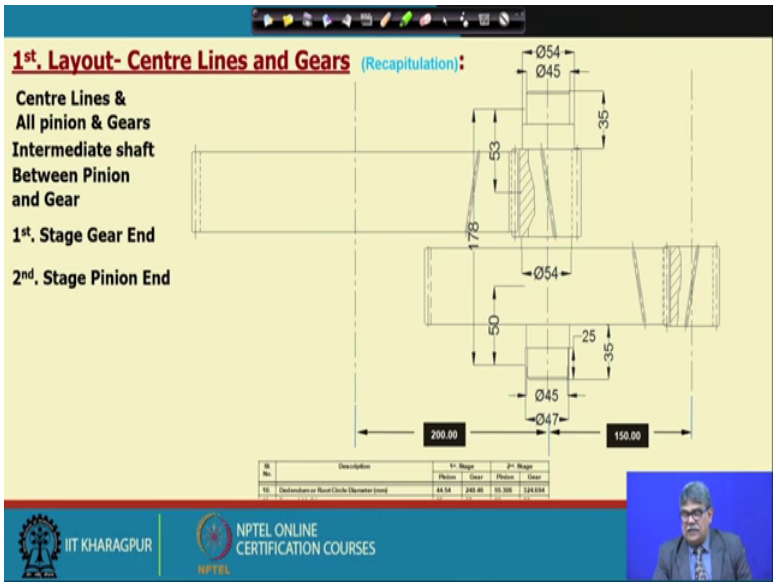

Now, already we have made the layout and we have given a shape a preliminary shape to the intermediate shaft, if you look into this drawing which is done using autocad intermediate shaft between pinion and gear. So, first we have find out, what will be the what may be the diameter? There it is as we find here the second stage pinion. This one

is the second stage pinion on the intermediate shaft it has root diameter is equal to 55.306.

So, we have taken 54 and next in the first stage gear we have drawn and after that; we have also the end after the gear that we have developed, this is a preliminary development to find out the position of the bearing, and from there we finalized the bearing selection and as well as mainly the varying selections and loads on the shafts.

. So, second stage pinion end also the dimensions are we have chosen like this, but in this present lecture I will show you more details. So, these are the dimensions came last time last time these were the dimensions, but there is a change.

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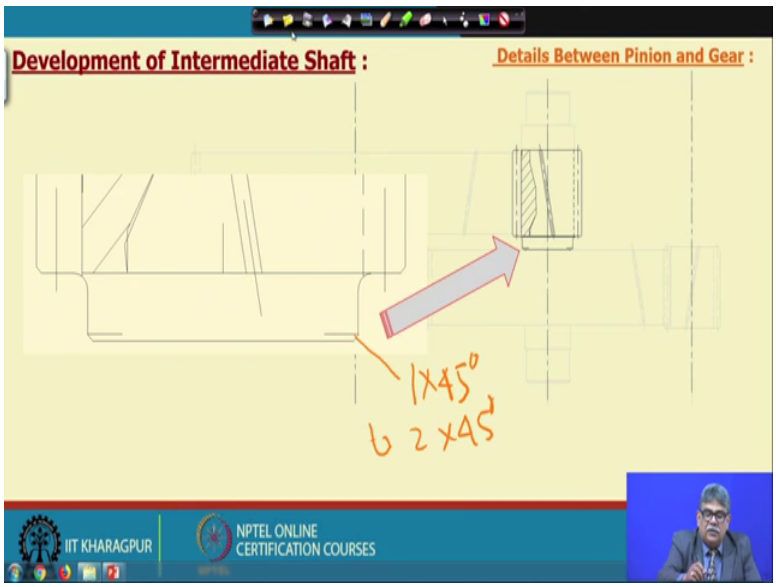

While we started developing the intermediate shaft drawing; we found that for locking another arrangement, we had to change a design a little bit and there is a little change in the shaft dimensions also.

Now, first of all this is the second stage pinion that; what is there? We have put it there then, we have already mentioned that the shaft portion in between the pinion and gear. And, if we look into the details this is as you see that after the gear teeth this is the this one; this is the root or the duodenum diameter. So, we have reduced a little bit this diameter ok, now as you see this is somewhat 55 something. So, this we have taken phi 54 just 1 millimetre down.

But at the as you see the pinion and the shaft here at this corner instead of making a just cut like this; we have provided a circular arc and for which this as you see the teeth will be slightly extended at these portions. And, if you observe the gears in industry it looks like that and here we have provided a chamber this chamber is standardized in company. So, usually here perhaps it is 1.5 into 45 degree sorry 1.5 this chamber is a 1 into 45 degree to may be 2 into 45 degree some chamber this is general chamber this is given by a ordinary turning tool.

So, these are automatically given, but while we were designing you need to mention that now this portion shown after that.

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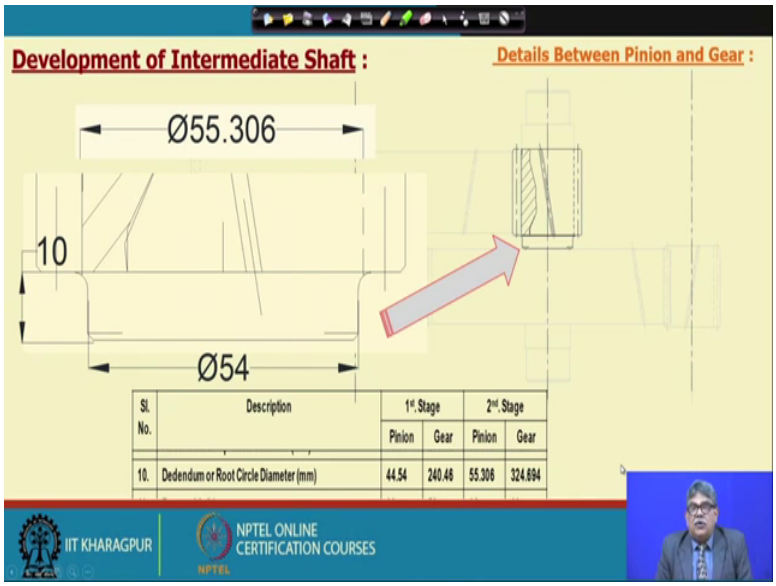

. So, here it is already discussed that second stage Dedendum was 55.3. We have taken 54 here this dimension, we have taken 54 and it is about 10 millimetre gap we have kept and after that.

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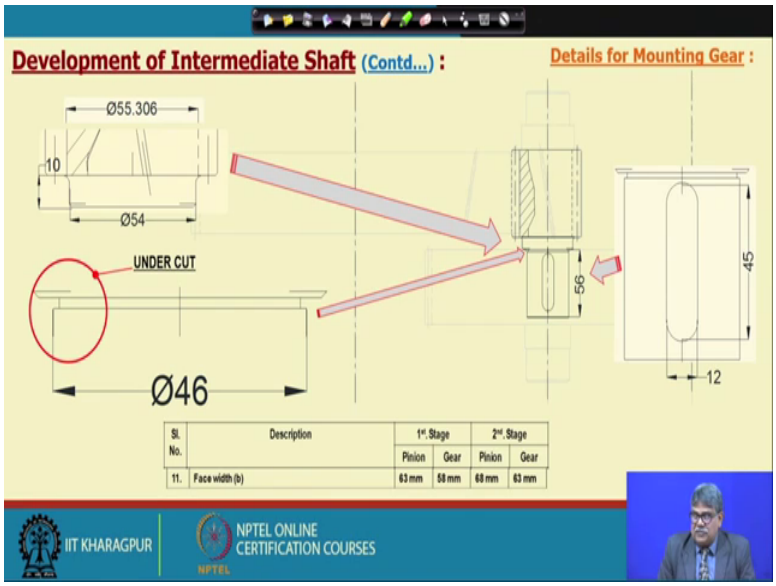

This is shown here further and then we think of the shaft extended for the gears for mounting the gears.

Now, the gear face width as you see it this is first stage gear we have to keep in mind, that is; first stage gear will be here this is input side. So, first stage gear will be here and that width is 58 millimetre and this tape here we have all diameter is 54 say may be we can reduce the diameter to 54, 50 even less 51, 52 and or we can we then we will get a solder and we can put the gear there itself say this is the solder ok. So, so that gear can rest there.

Now, adjust the length of the shaft on which the gear will be mind mounted that must be less than the width of the gear width of the gear is 58. So, we have taken 56. So, I think this part is clear then we will go into the further details and if we look into this portion that corner this corner.

What we find some cart is given. So, this is this is this is under cut. So, we have given some undercut and diameter. We have reduced to 46 millimetres keeping in mind that bearing might be of 45 millimetres. We have just reduced up to 46 millimetre diameter there from the this key is available that is rectangular key is available in market with a standard dimensions and for the shaft size around it might be from 40 to 50 we can accommodate either 12 millimetre width or might be ten millimetre width also.

We have chosen 12 millimetre width keyway and the length we have taken 45 millimetre, it is multiple usually multiple of 5 millimetres and details about the key and key way we shall discuss when we make the detail drawing of the shaft now.

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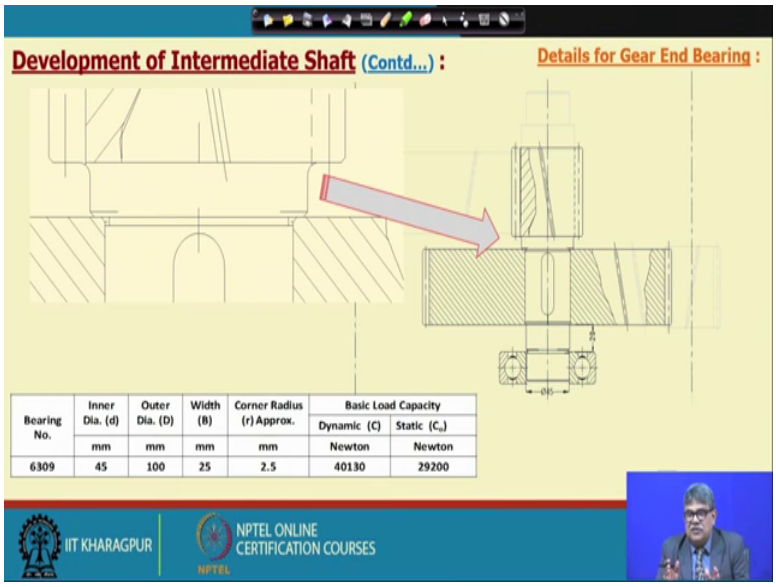

Bearing No.	Inner Dia. (d)	Outer Dia. (D)	Width (B)	Corner Radius (r) Approx.	Basic Load Capacity	
					Dynamic (C)	Static (C_o)
	mm	mm	mm	mm	Newton	Newton
6309	45	100	25	2.5	40130	29200

. So, what we do we assemble the gear there? And as you look into this is the assembled gear is assembled, and again I will mention that this under cut is given. So, that this gear touches the solder clearly.

Now, there is two things are there one is that; although, there will be a chamber on the gears will be given there, but if we give this corner without giving this undercut; then it might be that chamber portion will touch we may not touch properly on this solder. So, it will not be able to take the load this is first thing second thing is that if; we think of the grinding. Then grinding wheel although this is the grinding wheel, although there is a corner radius that corner radius is very small, but we wish that this surface of these grinder should not surface this touch otherwise dimensional will be lost. So, this will move very close to that, but it will not touch, but if we do not give the under cart then there will be some portion with a circular arc which again give the problem that gear will not touch the solder.

Anyway we can discuss much more in the little drawing here, I would like to mention such under cut is given by a special tool, which is available which is kept aside and it is put on the multiple tooth directive tool stand and then this can be given this is a simple

maybe 2 millimetre thick and it will be just depend there this is apart from that this also says; suppose without this undercut your I show go stress curve make way go like this hm, but when we give this under cut it is surprising that this same curve will improve here a little bit ok. So, that is why this undercut is given and it has different purpose here I have shown that this undercut has been introduced there.

. So, after that we will think of the rest of the portion; that means, the gear end bearing side. Now we think of the here it is already taken 46, then it might be after that this shaft maybe; as I told it might be on the gears maybe 46 or may even 47 still we will have to 3 millimetre solder each side for supporting the gear alternatively we can put we can put.

Another, sleeve here just to pass the load anyway; then this side if we think of the 45 millimetre bearing, so we reduced the shaft diameter after the gear mounting a little bit and then rest of the part we make 45. Now the question is that why we have taken this must 20 millimetre length, because as in the calculation we have shown that we need to lock this side bearing we are going for deep groove ball bearing and we will lock this side bearing. So, that this side bearing can take the axial load whatever may be the direction of rotation? So, that is why we have kept a little more place. So, that bearing can be locked with the shaft; as well as housing and that we will understand a little later.

So, and this is we have taken 45 and the bearing we have chosen 6309 ball bearing for which internal diameter is 45 and width is 25 millimetre. So, we have made the shaft. Accordingly, now we put that bearing there, but here a one question as you can see from this figure that this bearing, if we would like to lock with the gear we must put something in between that is called slave or others. Otherwise we cannot this load cannot be transferred there.

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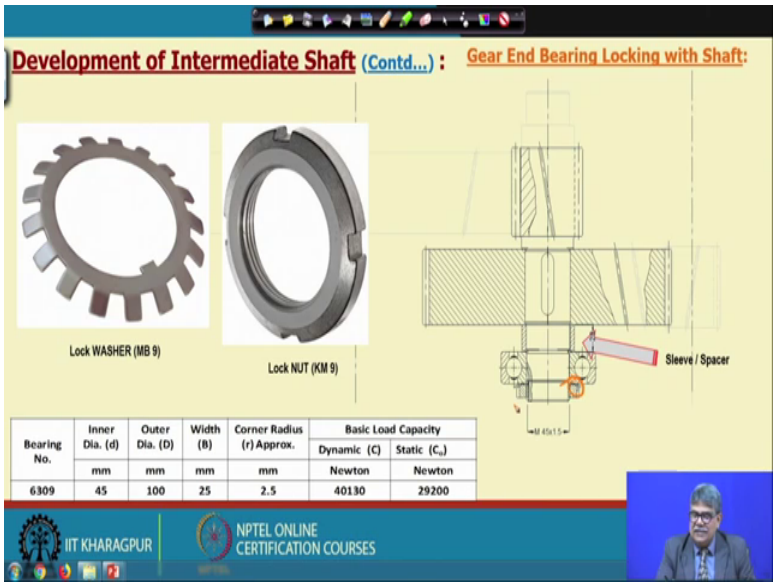

So, in next page what we are doing first we put the sleeve this sleeve is nothing, but you can say this hollow cylindrical body and this length we have taken 20 millimetre, and if you if you think of the step up to this groove, there is also under cut if we look at this portion there is under cut and this portion it is less than 20 we have taken and the sleeve we have taken 20 length 20. So, that bearing; solder touches there.

Now, I will show that one. So, now, what we do after putting the sleeve we put the bearing; and as well as we have also put the; locking the extension of the shaft there for locking the bearing. Using lock nuts I am coming to coming to that next. So, in this slides what we find that the a sleeve is put. So, that the axial load is transferred from this side to the gear side it can rest on that and now we will lock the outside of this bearing. So, that it becomes fully locked the bearing is fully locked axially with the shaft.

. So, this for locking what we have used what we are going to do we will use the lock nuts and for that we have made a thread of m 45 into 1.5; 1.5 is the pitch m 45 means (Refer Time: 19:10) 45 and that we have made it there these details will be shown further in the proceedings of this drawing as well as in the little drawing. Now, what is this lock? This is a lock washer this lock washer is put fast that mean on the shaft not only thread a groove is made and this key this key portion of this lock washer will go here it will remove up to this point ok. And this groove is shown it is usually card by side and phase

cutter. So, it is go slightly inside, but this can go up to a little bit more than the end of this bearing ok.

Then we consider the lock nut this lock nut; it looks like this is this is the inside this would go inside and that is the outside interestedly; what we find here? We have four slots. Now if we count here 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 we have 17, this is even this is odd number and due to that; what happens if you tight a little bit if you need to tight this not a little bit you will find maybe this one is matching with one and if you tight a little further, then not the next one here, but another one will come over this slot. So, due to this is the outside number is made as many as possible and it is made or numbered ok.

Now, we shall use this one for locking this let us see. So, we have put this one this lock nut lock washer and lock nut there and fully tighten and after that we have folded, if you look into this is folded here we got one there and we have folded it there. So, this will never open. Now, what we find that on this shaft after the pinion the gear key the key is put then gear is put, then asleep is put then bearing is put and then it is locked. So, this portion is completely locked and it cannot actually now this gear or bearing they cannot move on the shaft.

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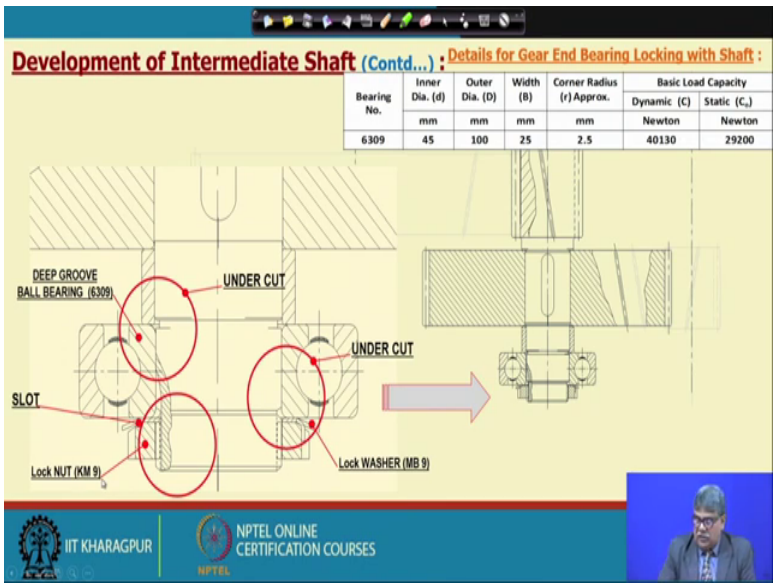

Now, again if we come to this side then we will see that; what is the arrangement still little this you have to decide while you are making this drawing, but may not be such

details such undercut details may not be here on the assembly drawing, but a good designer he always considered that how he is assembling and he all provide all these things.

As you see that the length on shaft is kept a less. So, that sleep comes to the; this gear face end and it touches the gears and next to that here we have also put an under cut. So, that this grinding can be done properly and as well as this bearing end also touches the sleeve. And, if we look observe this side also there we will find that we have also a under cutter of things after the thread. So, that this touches properly and it can be tightened fully and this slot it is for the; this washer to go inside. So, that it does not rotate and then we get after tightening. We get one twofold and which we have folded here.

Now this under cut as we have already mentioned and this is also there is an under cut and this slot is for accommodating the notch sorry the projected portion of the washer. So, that it does not rotate this is the locking arrangement and also this deep groove ball bearing we have put 6309. And then this part is completed. So, this is the lock washer and this is the lock nut these are the lock washer number clock nut number ok.

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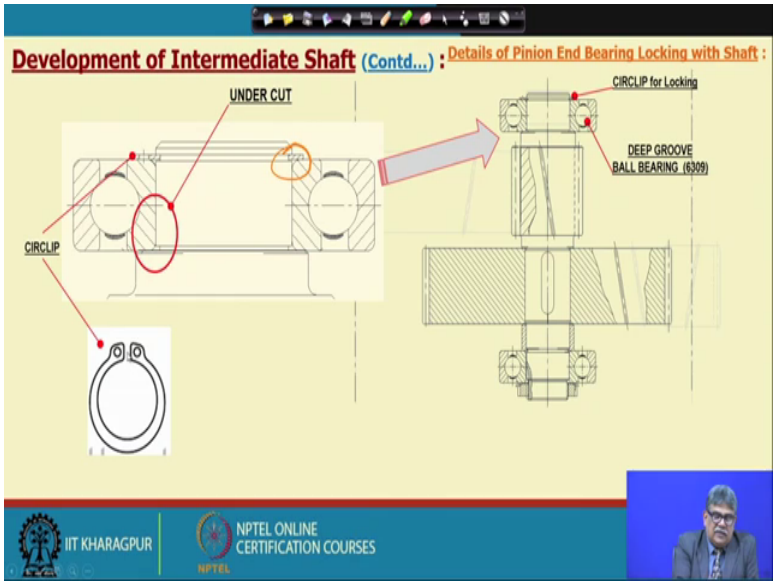

Now, the other end if we look the other end in that end also first this dimension. If we remember the root dimensions of the; second stage pinion was 55. So, after that we have taken 54, what we developed this side? We have taken the other side also same, but there after immediately after that step we can put the bearing. So, close to the bearing we have

reduced the diameter to 45, this means that from shoulder is 54 and then shaft diameter is 45, we have got put and half millimetre each side and that is good enough to give the side thrust to transfer the sides thrust to the bearing, but in any case we are not going to lock that bearing axially, that is it is it is such that that bearing is not entitled to take any axial load.

Ok, but how we have locked this one if we go further we have is a circlip there and we have used deep groove ball bearing 6309 and to make the details the details looks like in that and as you see this is called circlip. So, this under cut this side also given. So, that bearing can sit properly the grinding can be done the as we saw in the other side also we have put a circlip there and.

So, circlip look likes this it is a very thin plate sort of things inside hole is there and here it is a split here it is split ok. And then we do it is called nose pliers there is a circuit plier special pliers available you can enlarge this hole a little bit and from this side you can put it there. Once you put it you push it and then you leave this take the pliers out and automatically it will sit there. Now, this actually not necessary in a sense that we are not going to log that side, but it is better to put such a circlip. So, that bearing will never go out of the shaft ok.

So, the other side of shaft also we have completed.

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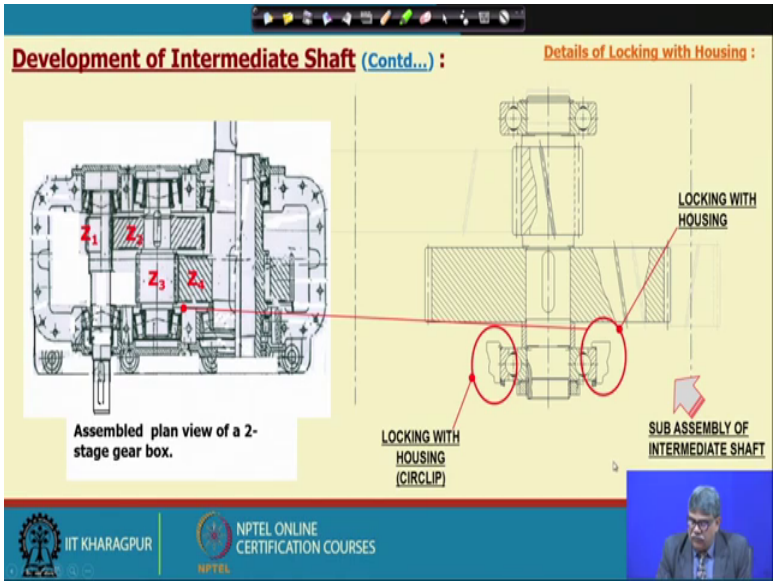

Now, if we compare with the gearbox housing, we should call this one what we have developed. So, far not only the intermediate shaft and as you have put the bearing and as you have locked whole unit can be called as sub assembly of intermediate shaft this sub assembly can be mounted separately not necessarily you have to mount on the gear in a gearbox housing and then whole thing can be this whole this unit you can bring it here and you can put on the bottom cover ok.

So, this can be mounted there and similarly the others shafts also will be mounted together and after that the cover will be put now here. So, on this we need to think that how we can lock the; this bearing which would supposed to take the axial load that is the gear side bearing with the housing. So, this is one option is that you can on the housing say this is the housing here if you look into this housing in that case it is controlling machines instead of that we will give some portion. So, that bearing can rest on that while we are boring and this is the; this one is the cover here we have used one cover. So, this cover will touch over there this means that if we make such arrangement then this bearing is locked with respect to the housing.

So, now whatever axial load coming on this shaft that will be taken by this bearing and other side we simply make a straight cart. And even if this cover which is shown hey little bit this will be shown a later more details, but here there will be gap. So, that if there is extension of shaft or contraction of shaft that can move this way. In that way and this is called light drive feet the housing will be made on this bearing a slight light drive fit here also it is kept a light drive feet ok.

So, I think this is now clear, but we can make also an alternative locking arrangement. So, this is locking with house as I have seen this at this point it is locking here this joint it is locking, but we can also go for instead of the range portion here instead of this range portion here we can use a circlip there as well ok. So, that is another method of locking.

There is a due to some people used to go for the raised portion some people use the circlip it is like that, but I think it is clear now that; how this sub assembly of intermediate shaft locked with the housing and as we need to lock with some material. We have kept a some gap here, because we do not know what is the actual surface of the housing? but it is not necessarily we can reduce this dimension further may be another five ten millimetre we can reduce this.

So, this is alternating arrangement of locking with housing.

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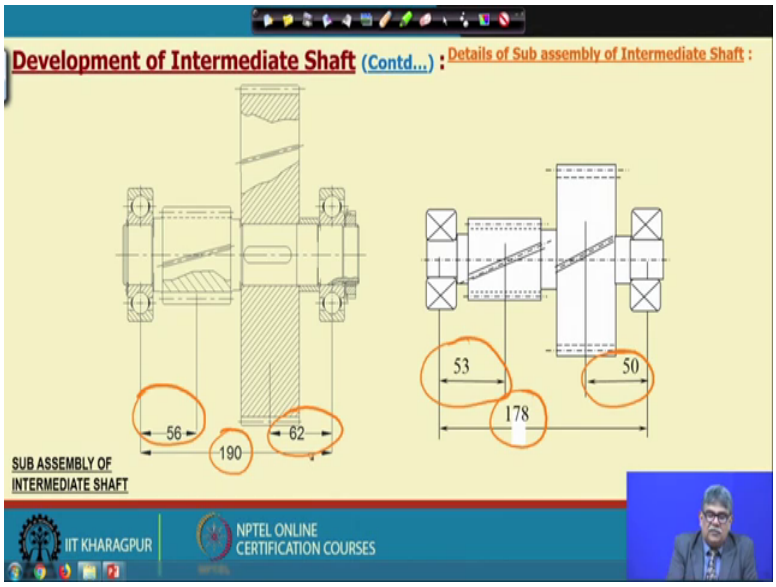

And now what we have arrived that as the shaft intermediate shaft sub assembly is completed. We have now we find these dimensions maybe this side left side it is fifty six whereas, earlier one when we can calculated; we took it 53 and this one we took 50 instead of that that has become 62, because here we have made elaborate arrangement for locking and total length of between the bearing it has increased by about 12 millimetre which was 178, but still I would say that we need not repeat the calculation of the bearing life even we need not recheck the shaft design verifications because this due to this minor change still there will be there will be change in life there will be change in stresses maximum stresses, but that may not be very serious; however, be possible then a little calculation is made on the basis of new dimensions ok.

So, this is the end of this lecture and next stage next week 5 and week 6. We shall do much more on the detail design of the gearbox hydrogen; next probably the output shaft will be made in the same way what we did it here for the intermediate shaft and then we will after there we will select a bearing and we will go for the bearing life calculations. We will see that whether it is satisfactory; otherwise we will change again the design and after that we take up the any input shaft and that will be also done in the same way detail drawing as well as the bearing selection shaft design verification etcetera.

Thank you.