**Gear and Gear Unit Design: Theory and Practice**
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**Lecture - 28**
**Development of Plan and Elevation of Gear Reduction Unit – I**

Welcome to module 6 lectures, that is week 6 lectures we are still continuing with design of general purpose industrial helical gear reduction unit; this is part 4 and here mainly we will complete the design and drawing.

Now, this is second lecture of week 6 and in this lecture I shall start the development of line and elevation of gear reduction unit and this will be the part 1 it will be completed in the next lecture.

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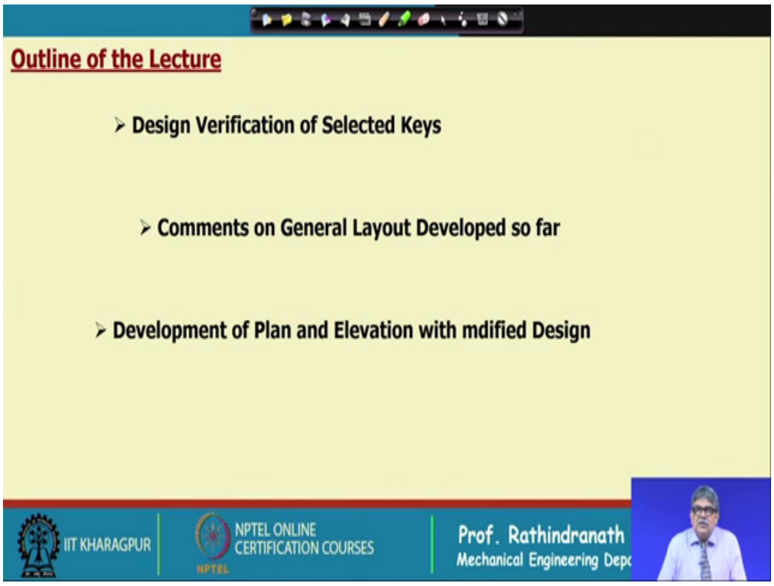


Now, outline of the lecture is that design verification of selected keys; that means, we have already started verifying the design of the keys, unless we complete these design of the keys or we check the strength of the keys we cannot finalize the shaft size and therefore, if we would like to alter the bearings which already we have selected ah, it might be difficulties. So, it is essential that we should verify the design of the keys first and after completing that I will make a general comment on the layout what we are going to do and then next development of line and elevation with modified design.

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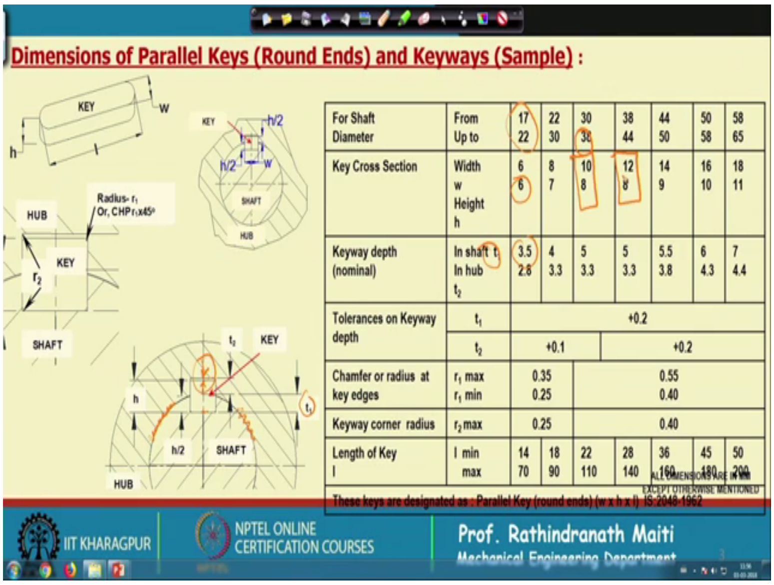


Now, this in this slide I have shown that what is the key fittings I have already discussed, but still let me discuss a little bit, the type of key what we have chosen all are it is called parallel keys and it is rectangular not square, parallel rectangular key with round head. It is half circular head and as specified the length is the total length which is designated by l height of the key is designated by h and width of the key is designated by W.

Now, if you look into that how they are put inside the shaft and half then as I told that this key way groove is made on the shaft and how in such a way half of the key height is inside the shaft and half of the key is inside the half. However, importantly if we look into this that there is a clearance between the hub and the key, this is just to avoid the interference with the bottom of the key with the shaft and top of the key with the hub. If by mistake it is done then there will be additional stress and elongation at the joining of this shaft and hub that is to be avoided.

However the key first is put on the shaft it is tight fit, it can be a drive inside it may be wooden or plastic hammer with the help of hammer it can be put in there normally it will not go out, normally it may not be go out, but sometimes this key is also screwed to the shaft ok. Now, if we consider the groove in the hub which is made by the slotting machine, the width is just fitting it is a very light drive fit it is very light drive fit, if it is a very tight fit in that case again their stress will be developed and elongation will be developed at that point.

So, to avoid that it is just fitting ok. So, this is the fittings of the key and now if you look into the geometry then to make the groove. So, that half of the height goes inside the shaft will find from the top of this on this axis this depth of cut a little more than half of the key height which is designated by t 1 and as you see here you will find that t 1. For example, in the first case t 1 is 3.5 where the half of the h will be 6, 3 half of the h will be 3 in case of half it is 2.8, but still with the 2.8 there will be the clearance will be there in that way all grooves and other dimension are found.

Now, again another issue is there on say for example, if our shaft diameter it say 38, then we can go for either this key or even we can go for this key, say last time when I was showing this outputs shaft the stress was being high. So, probably we have to go for higher sized teeth in that case because our shaft size is 40 or even we can yeah shaft size is 40 in any case we have to we can go for 12 into 8 ok. So, we will we will see that.

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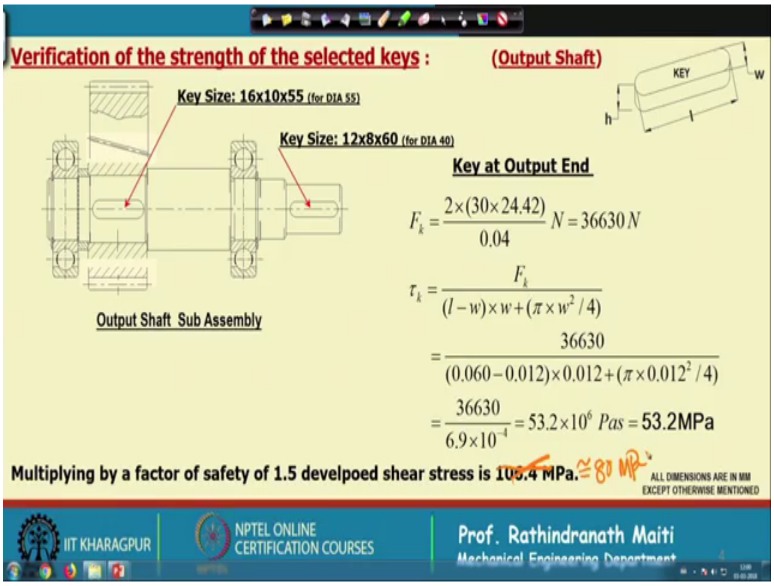


The verification of the strength of the selected key output shaft if we consider key at output shaft, now here as it is shown that on 40 diameter we have chosen 40 diameter. So, there it will be 12 into 8 into 60 we have taken this 60, it is possible that we can make this length a little higher also we can may go up to 75 no harm because the hub length of the coupling can be made bigger if necessary. However, where the gear is sitting there the shaft diameter is 55 and recommended key dimension is that width is 16 and height is 10.

So, there somewhat this length is 55 we cannot go more than that of course, it can be for example, here say this key length here can be extended up to like this, so that the full length here get into contact there. Similarly for other site also we can extend a little bit, but which have to be careful about the length because here is the spacer is there. So, by no means the key length should exceed the shaft ok; that means, here the gear width is about 63 millimeter at the most we can have 60 or maybe 65 millimeter in contact, 60 may be a good dimensions. This I am talking because we found that stresses in this on the key in this shaft is higher.

Now, very quickly I will show the calculation, now if we would like to calculate the forces on this teeth here ok; that means, at this point here or here ok. So, first of all we will calculate how much is the torque, torque is 30 into the total transmission ratio 24.42 this is nominal torque that divided by the diameter here we have taken the 40 millimeter diameter into here 2 t by diameter that is directly giving the force that is nominal force.

Now, on that basis if we calculate the what is the shears stress that is 53.2 mega Pascal and it is slightly in the higher side by no means that mild steel or C 20 k can be taken moreover if we consider the severity of the operation which is we have considered the medium shock load probably we should multiply with 1.5 at least we will multiply by 1.5, say.

If we multiply by 1.5, sorry this value has not correct, this will be it will be some 1.5 means approximately 80 MPa and if we consider the C 20 that is the mild steel, hardly the yield strength will be in the level of 240 or so, mega Pascal yield strength maximum. And if we divide if we consider the shear stress is approximately with safety approximately 4 times less than the yield strength. So, it will be around 60 mega Pascal at the most. So, therefore, definitely this MS will not do, ok.

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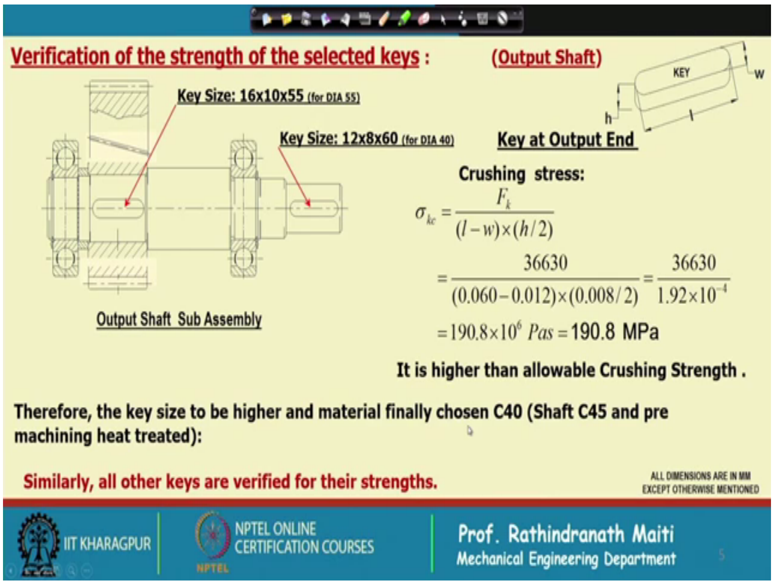


Next we shall go for or even see 30 what we consider may not do. Now still we are continuing with that the; we are now verifying the crushing strength and what we find on the nominal force the crushing strength is really very high 190.8 and that we are checking at the output end ok, so 190.8. If we multiply with 1.5 considering severity. So, it will become around 300 mega Pascal and by no means we can go for C 20 or C 30.

So, one decision can be taken that at least at this stage, the key would be of better material and we can then go for C 40 and this shaft strictly we shall go for C 45 with and this is pre heat treated before machining; that means, whatever hardness can be increased up to for the turning. So, turning we shall not go for grinding we will not go for grinding because as we have decided this is general purpose industrial gearbox we will try to avoid the grinding.

So, C 45 with preheat treatment can be taken for the shaft and whereas, C 40 would be taken for the key material as well as we will increase the length, this little bit instead of 12 8 into 60 probably we can go for 12 8 into 75 material C 45 and here, but at this point even if we do not increase the key length still it will be possible to accommodate. However, we can easily go for 60 or we can go for 65 this side a little more cut without cutting this side, so that key is not going out because if we think of the groove in half that hub is through slots. So, we can utilize the full length there.

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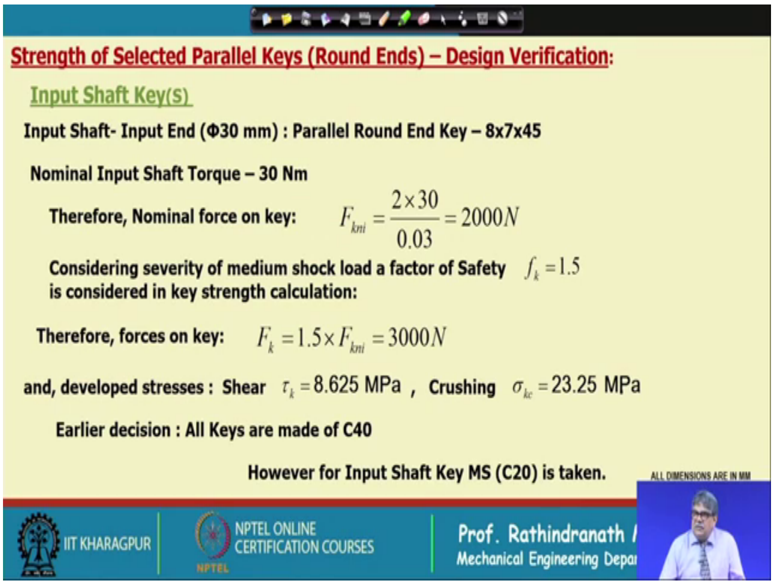


Similarly, other keys are verified for their strength. So, without you showing the calculations very quickly I will show the calculations for the other key inputs shaft key, at input end we have taken 8 into 7 into 45 and their input shaft diameter we have taken 30 millimeter. But as you as you remember, if you remember or look into the chart then you will find that this is also for shaft diameter 25 we can use the same key.

And the nominal force there is 2000 Newton, and if we consider here we are multiplying at the beginning a factor of safety for the medium shock 1.5 then it is coming 3000 Newton and if we calculate the shear strain and crushing strength this is very nominal. Shear strength is coming 8.625 mega Pascal and crushing strength is coming 23.25 mega Pascal’s and for such fittings of keys we need not go for verifying the bearing strength, bearing strength it is not required it will be always higher than, I mean it will be always in the safe side.

And therefore, possibly we can go for the MS key for this. Now there one, one question that for output shaft we are going for C 40 whereas, for in the input shaft we are mild steel. But definitely inventory can be get separated because this is input, shaft size key and output shaft size key are other. So, there is no harm we can go for some other material as well.

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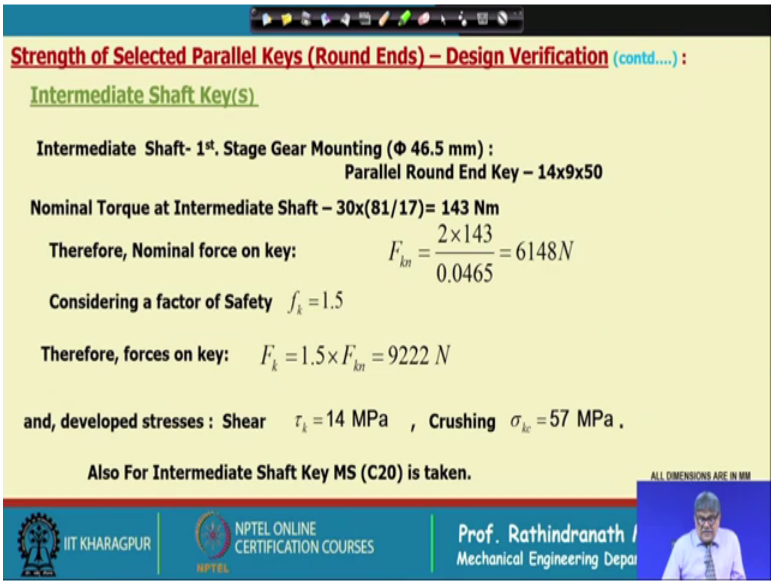


And next if you check the intermediate shaft in that case the, what was the input torque that has been multiplied by the first stage ratio and it has become 143 Newton meter. On that basis if you calculate the force is coming 6148 nominal force and the same way if we calculate if we consider the load may as high as 1.5 times considering the medium shock it is coming 9222 and for which if we calculate the shear strength on the key, shear stress is 14 mega Pascal and crushing stress is 57 mega Pascal's and still in this case also we can go for MS key, ok.

But here one thing I would like to discuss that for gear design we have multiplied with 2, multiplied with 2 as the 200 percents starting torque and mediums shock is there. Now, this is to take care that key the failure is more severe than such key failure sorry, here tooth failure will be more severe than this key failure because gear tooth is something like a cantilever beam over its rim therefore, more gear should be taken there.

So, far I would like to say that considering the key gear etcetera and design is satisfactory and we can go for general purpose gearbox with hobbeying, darling etcetera, we did not go for heat treatment further heat treatment after machining and grinding ok.

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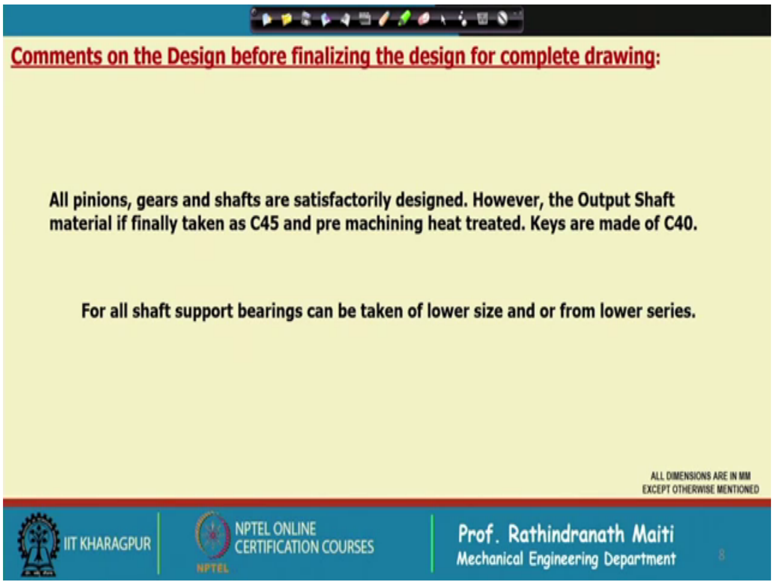


After selecting such keys next as I already mentioned all pinions and gear shafts are satisfactorily designed; however, the output shaft material is finally, taken as C 45 because of the reason we cannot reduce the diameter of the shaft from, because it is just being satisfied with C 40, and again what we find the key are not being satisfactory. So, what we have done material will be C 45 and the keys will be C 40 for output shaft. And input and intermediate shaft they are made of alloy steel because the pinion is integral there e n nineteen chromium molybdenum steel, but the key is MS as the key length each satisfactory now.

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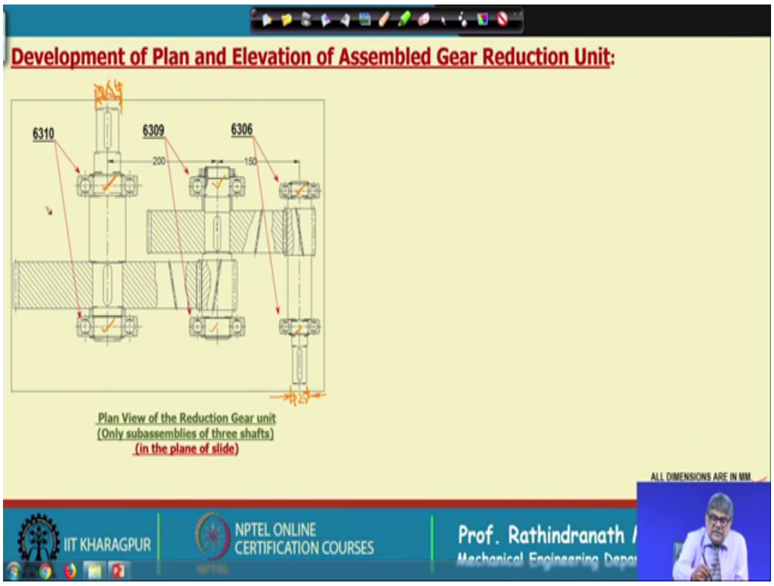

So; however, what we have found there earlier, probably we can reduce the size of the shaft in intermediate and as well as input and we can go for bearing of a 1 size lower. If we remember that intermediate shaft we have taken the bearing is 6309 means it is 45 millimeter the bearing from 60 series and there what we found that the bearing life was more than 200 percents what we are expecting of 10000 hours. Live was coming 22000, 23000 of course, if the direction of rotation is changed it will may reduce in one side a little bit less, but still we can take a bearing for which the allowable dynamic load may be half of that 6309, let us see what can be done next.

Now, here what view I have shown that is the view we what we have developed that is the layout of 3 shafts sub assemblies including bearing, their locking system that I have shown here and the I have also mentioned what the bearing we have taken the in inputs shaft the inside diameter of the bearing was 30 millimeter. So, that we could go for the input end 25 millimeter, here if we consider here we take taken 25 millimeter all dimensional in millimeter and output what we have taken this is 40 millimeter, y is equal to 40. So, that we decided and here the at bearing it is 50, here is also 50, here 45 here also 45 and here 30 and here 30.

Now, as we have found out that even in intermediate shaft perhaps we can go for 6208, 6208 means it is 45 millimeter, inside diameter 40 millimeter inside diameter 08 and also lower series. So, definitely dynamic load capacity is less, but if we look into the catalog dynamic load capacity will be slightly higher than what the dynamic load capacity 6309 slightly higher than half of the what is the dynamic load capacity of the 6309 and as life was coming there more than 200 percents.

So, probably we can go for 6208, if we come to the inputs shaft their life was so high easily we can go for 6205. 6205 this means that at bearing the diameter will be 25 millimeter, but once the bearing at the bearing diameter is 25 5 millimeter output shafts should be less than that. Even if we can keep 24.5 millimeter, but still it should be less than that by no means we can go for 25 millimeter, but still this design will be possible because the shaft is not failing as it is a alloy steel material and intermediate shaft also alloy steel material.

And coming to the output shaft is it possible we can go for 6209; that means, 45 millimeters shaft add the bearing, answer is yes because the at the sitting of the bearings on the outputs shaft the bending moment is 0 at the middle bending moment is 0, only torque in output side there will be torque, ok. So, but still it will be possible that we can go for the 45 millimeter dia and as we have seen the, if we verify or if you verify that 6209 dynamic capacity of that bearing it such that the output shaft we can it will be able to take output shaft load with sufficient bearing life.

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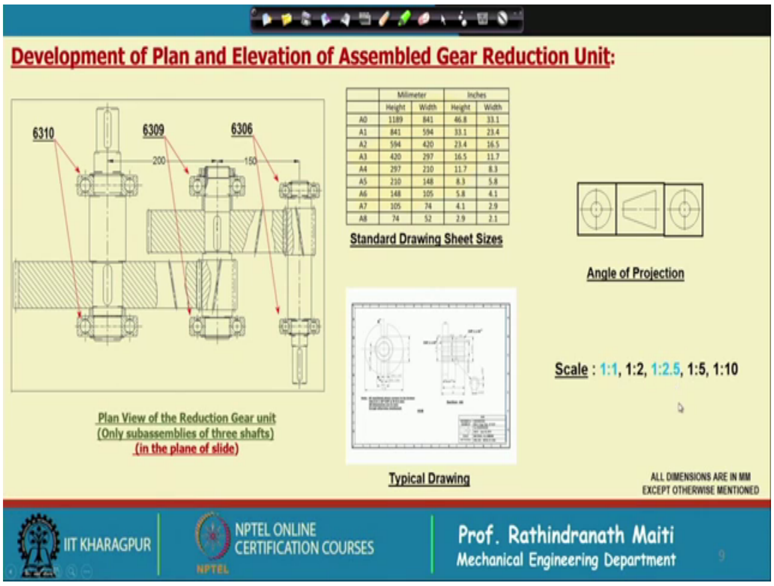


So, on such analysis we have developed the land view of the drawing, but before that I would like to discuss in plan view of the drawing normal in practice nowadays everything is done in autocad and we restrictly we may not follow the drawing seat size. But still if we look into the drawings seat size from the point of view they are preservations and etcetera for long time and we can say that for standardizations, here is the chart is given it is available anywhere it in a internet.

So, a 0 size 11 89 841 rarely used normal the size used a 1 is used, a 0 is used in industry where you need to go for big drawings. So, then we have to select we would like to draw in a single seat the plan elevation side view and if necessary small views. So, first of all we will select that what should be the size for this gearbox. We have seen the overall size and if we prefer to be 1 is to 1 scale I am coming to that point.

Now, first of all we have to look into this what projection we would like to go, the this is it is something like that. This is a truncated cone if we look into this side then we are looking from this side and we were drawing it here which is clearly third angle projections and this is we are looking from this side and this view of this truncated cone presented here so that is the first angle projections. Now if we would like to go for third angle projection then plan view, suppose this is a drawing seat plan view will be somewhere here, here and here we have to put into elevation and side view the paper rules place for side view is here. So, this means that here if we put a nameplate and then we would have enough space to place these 3 views here and this space can be utilized for note etcetera if it is required, ok.

Now, let us see a typical drawing seat it will be something like that here whatever the size is given in this chart above that is the outside that outside of this and then about 20 millimeter in all side we can have a further a line and here it is each compartment 1, 2, 3, 4, 5, 6 is written and in this side a, b, c, d; that means, in vertical column it is written a b c d and horizontal top and bottom it is written 1, 2, 3, 4.

So, why it is like that suppose there we find some mistake say after this drawing is done that will go to the manufacturing unit they will verify and they want to know about this dimension then they will specify C 4. C 4 means somewhere here this dimension is wrong ok, that is why it is given like that; that means, whatever drawing size we are selecting we have to for the border and etcetera we have to keep around 25 millimeter all sides then the available space and on that you have to put the drawing. So, essentially first of all you have to select the, what should be the size.

Now, if we look into this hour gear unit what we have done. So, in this side again we may consider another 200 and here 100. So, this is 350 plus 200 550, around 600 to 650 is in the length of this gear box or at least bit space required for 650 and if you look into this length here the dimension is not given earlier we have given we will need around 300. So, 300 to 650 and if you would like to maintain in 1 is to 1 scale probably this one we have to go for this one, a 0 seat ok.

So, and for drawing 1 is to 1 is preferred, next is 1 is to 2 also preferred, but I like due to some reason that 1 is to 1 or 1 is to 2.5, 2.5 means all dimensions you multiply by 0.4 at then you will get the exact dimensions, sorry 1.25 yeah it is 1 4 multiplying this you will give the dimensions. So, where this 1 is to no 1 is not fitting then instead of 1 is to 2 sometimes I suggest that 1 is to 2.5 is good.

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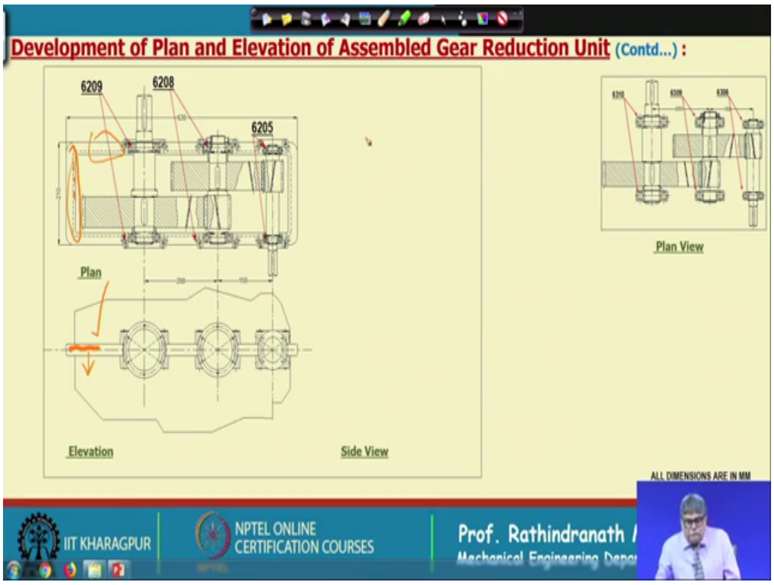


Anyway for this drawing we have taken 1 is to 1, a 0 side seat and 1 is to 1 and then you can see that we have placed our plan view here and this is only in the partial side elevation that will be shown later full view, but what we have done we have put the gear, sub assemblies and then here whatever the bearing sitting arrangement on the housing that we have shown. And as shown here all we have taken the 62 size bearing and input shaft diameter has been reduced and at the bearing end diameter has been reduced and this bearing has been taken.

And then simply on the layout of the gears what we have done first we have draw a rectangular box keeping around 15 millimeter minimum space, in all sides and then we have taken another line all parallel and of equal thickness if you look into this dotted line here. Look into the dotted lines, here also dotted lines that is the wall thickness. Now, if we go for casting then that wall thickness should not be less than 6 preferably 7 millimeter because casting thickness would be around 7 millimeter and there will be slightly draft maybes at some places there will be deeper.

So, at you can find that is maybe 6.75 to 7 millimeter 6.75 to 7 millimeter is the wall thickness after casting that we have drawn and then as we there will be upper half this is the upper half and this is the lower half and. So, there we will need to put the bolt that bolt holes are not yet shown yet.

So, that weeds we have taken around 25 millimeter for such as gearbox maybe only 5 millimeter, m 5 or m 6 bolt will do. So, 25 minus 7 this means 18 millimeter from the wall to the edge will do. So, we have drawn this boarder lines fast circle and then we have.

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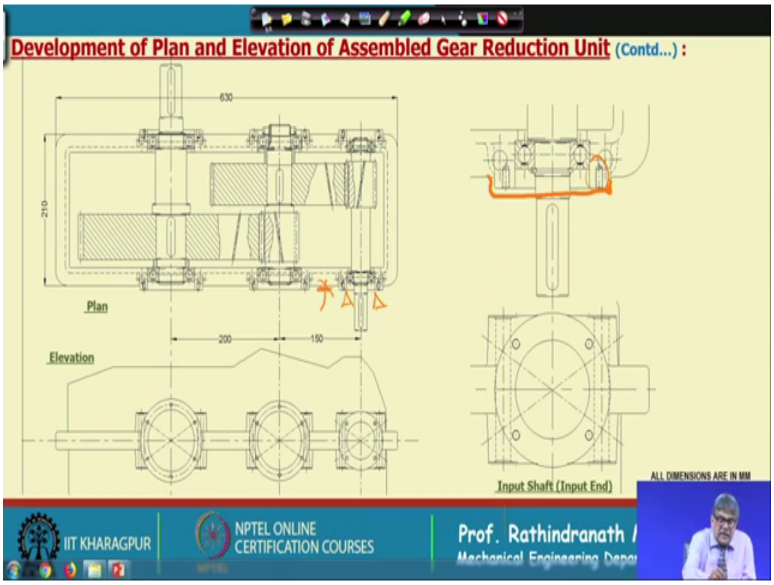


So, this plan view instead of that now we are doing this plan views, a plan and elevation on a 0 size we have put it there, now if we look into the development of the say input shaft end what we have done. So, this is the wall thickness was there, original wall thickness was there and from there we have first reached this portion. So, that it can sit the bearing ok. So, we have by the side of bearing we have put it like this and then edge the input side is being locked which I have discussed earlier. So, for that we have kept a slightly extra material. So, that it does not go inside and from outside there will be cover which we are going to put later ok, this will be shown in the next time.

So, this will be locked with the housing and there are also some other details which we shall discuss maybe in the next phase, but still I would like to mention that we have shown here 2 holes that by the side of the bearings we should put 2 bolts to hold this bearing firmly and in this case we have taken the m 10 bolt ok. So, this portion as you find it is raised like this and the bolts are put from here and these are tighten to hold this one and then finally, for the over we have put 4 whole here, at the 45 degree, but for the other we have put 6 bolts intermediate 7 outputs shaft and these are all m 5 or m 6 bolt.

Interestingly if you look into this figure apparently here it is fouling it is actually not that it is placed here. So, it will not foul and for example, for m 6 bolt at least depth should be 10 millimeter for m 5 also very close 9 to 10 millimeter.

So, this place to give this place we read some portion also here as you see this is the outer envelope and this surface is machined by no means this will be machined this is not machined whereas, this surface will be machined. So, input here just I have shown how what how this drawing is being developed, now if we go into the next slides perhaps that is the last, last now this is the output end.

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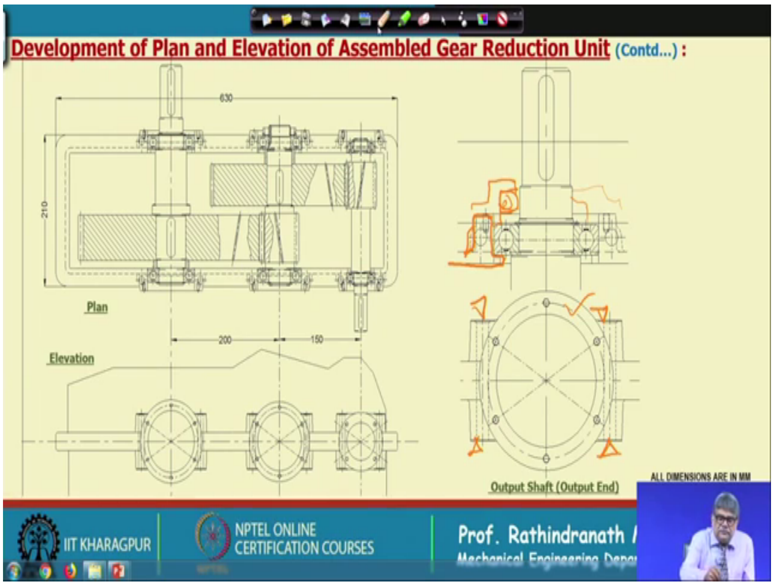


As you see in the output end so this will be also locked. So, housing will go like this and for putting the bearing it here is normally it is round like this and then for putting the tightening bolt here it is raised like this and 10 millimeter hole is made from the top and this side is machined this is also machined, this is also machined and this is also machined this surface is also machined.

So, if you look into this surface this is machined and of course, this view is not third angle projection. So, we are looking from this and next we will put the cover seal etcetera and which will be shown in the next class next lecture. So, we will put a cover something like this and here the seal will be there ok, it will be there. So, so in this lecture what I have shown this gradually after developing the 3 sub assemblies we have developed the housing and then we have also developed the bearing sitting place, we have also developed the necessary portion for bolting and next we can push it for the further details.

So, thank you, we in next lecture we shall complete the plan and elevation.