Gear and Gear Unit Design: Theory and Practice
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Lecture - 11
Gear Unit Design - Selection of Stage Ratios, Pinion and Gear Teeth Numbers

In module 3, we shall start with the designing design of a general purpose industrial helical gear reduction unit and in module 3 is the part 1 and our first lecture will be on gear unit design selection of stage ratios, pinion and gear tooth numbers.

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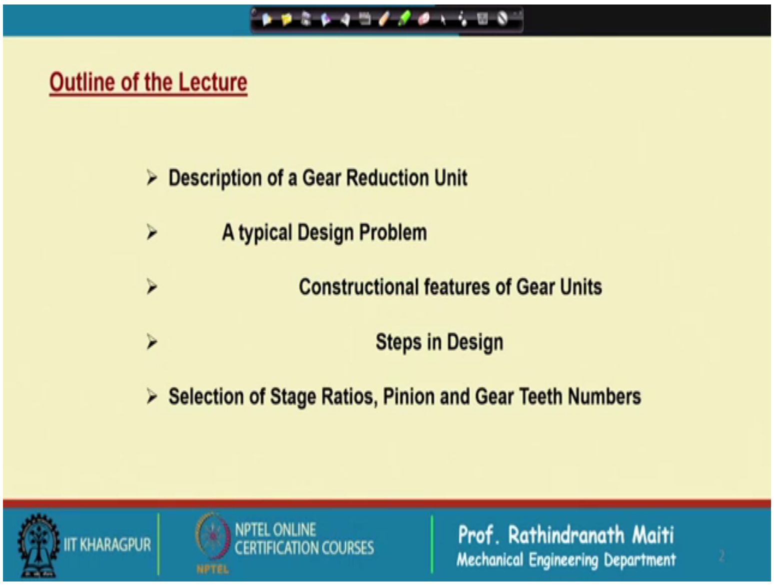

So, in this lecture first of all we shall learn about what is a gear reduction unit? Next a; we shall consider a typical design problem, next the constructional feature of gear units steps in design will come next and then finally selection of stage ratios pinion and gear teeth numbers.

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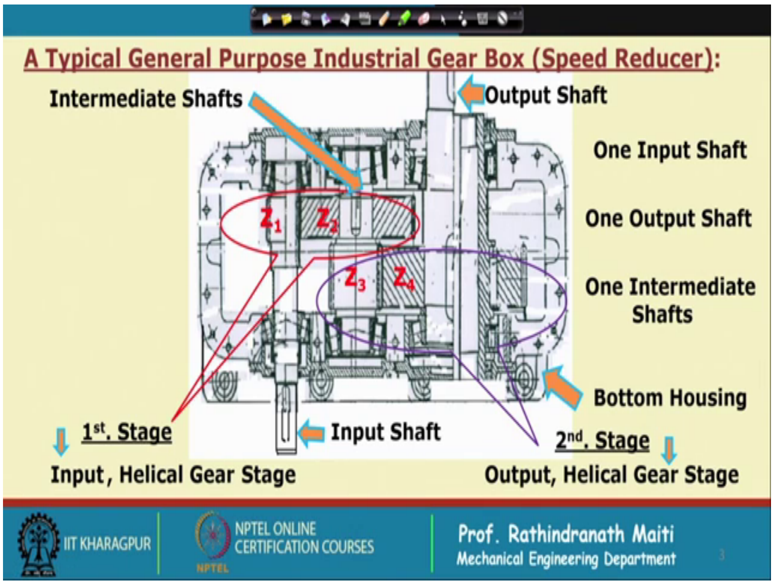

Now, what I have shown here a typical general purpose industrial gear box it is a speed reducer what we find here? See this is a shaft and then here is a pinion and it is meeting with a gears and then in the same shaft there is another pinion which is meeting with a another gears. If we consider their base circle and then we can imagine that cross bell drive definitely these will have the reduction here; that means, there will be reduction in speed and increase in torque and that will be further the torque will be further increase by this one. Now, for this gear box so this is input first stage and which is helical gears this we shall we are going to consider the helical gears so this is helical gear first stage and next we shall design the second stage also which is also in this case helical gear.

Now, this is a simple gear box we have consider reduction gear unit we have consider, but there might have more stages; that means, in this case there will be another pinion then another gear here and that may be connected to output or further reduction will be there a commonly you will find that depending on the transmission ratio. Of course, there is usually 2 stage reduction unit there also one stage reduction unit is also used, now this is the input shaft so power is this is connected to prime over through which the power is coming to this pinion and then it is modulated to the haft or with this gear and finally this is the output shaft.

So, we have one input shaft one output shaft now this shaft is called intermediate shaft. So, in process of designing this gear unit we shall learn how to design the gears? Then we will consider that shaft in fact the shaft is not cannot be rigorously designed rather the size of the shaft will be dictated depending on that what will be the bearing this is supported by bearings and then so selection of the bearings and then say we have to put the keyways and finally housing. So, this is the bottom housing it is shown the top housing is open for this gear box top housing is removed and if we consider this output may be a solid shaft or even it might be hollow shaft as well as input might be also hollow shaft, but which is usually not but in some cases the output shaft is made hollow.

In some cases also that output is by reductional in the shaft output is here as well as in this direction also in case of hollow shaft also it is possible. So, this is a very basic idea about the gear box and in this housing on which this is half of the gear box on which it is put this is usually cast or even it can be made of fabrication made by fabrication; that means, welding.

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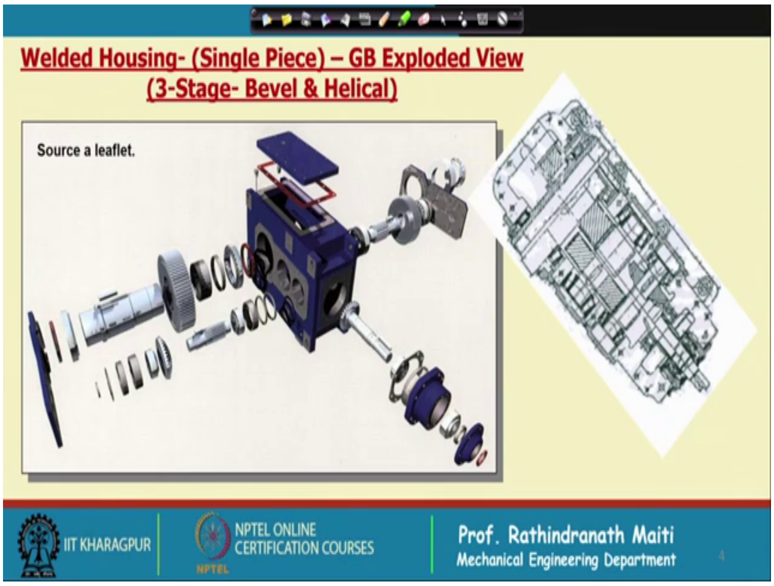

Now, in this picture it is shown a gear box having the welded structure of housing this is the welded structure of housing and in this case it is not a split one this is a not a split one. This is a single gear box and it is possible that all the gears can be assembled from the side and top of end this is the top cover.

Now, say for example; if we consider this is the input, now in case of input what is done that first the gear is put inside this that blue cover along with the bearings and the whole thing is put here next so this is the input. Now, next comes this gear so this is an intermediate shaft sorry, now in this case you can see this is the shaft and this is the a pinion integral with this shaft and these 2 are bearings and bearing covers etcetera. So, gear is put here and it is not possible that you can put this gear here and you can assemble.

So, this shaft partially is put inside then this gear is put from that side and then this is assembled from this side so this is the first intermediate shaft. Next this intermediate shaft comes bearings have put then this shaft with pinion comes and this gear can be put from this side and then this side cover is put there is another cover finally; this is the output shaft this is put here. So, this is a little complicated and not an easy task to assemble it, but this is a shown that what are the gear boxes? What is the reduction unit and what are the components there and design of such gear box involves? the design of helical gear, the design of shaft, design of bevel gear, design a selection of the bearings, then calculation of the how much lubricant is required? All such things for refine calculation you need to consider also this how much the heat generation etcetera.

Now, the view of these this is output the cast housing bottom housing edge shown in this case this is the not cast one this is the fabricated one, but a functionally this will have the first reduction here bevel reduction next there next there is a helical reduction. So, this is one first intermediate shaft, this is second intermediate shaft and this is the final stage where the helical gear and pinion shaft is there. So, this is just to give an idea what is a gear box?

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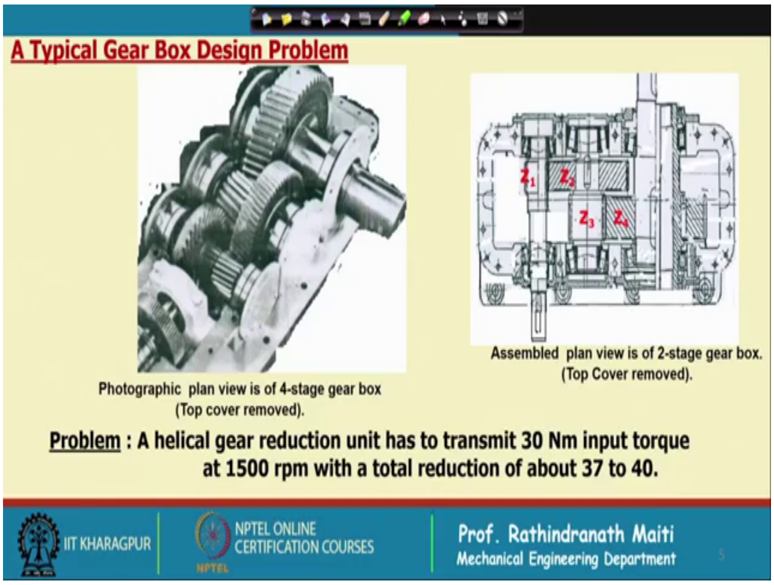

Now in our case we shall learn the design of gears selection of gearings finalizing the shaft dimension etcetera based on a problem, now here I have shown as if we are designing a 2 stage gear box, but the stage depend on what is the transmission ratio? So, this is a pictorial view of the gearbox already I have discussed this is a 4 stage gear box, first stage, second stage, third stage and in front of that there is another stage is there here is another stage is there ok.

So, this is a 4 stage gear box if you take a picture it looks something like this, but what we are going to design that is a 2 stage gear box and with helical gears so it will looks something like this, in the process of in the progress of this lectures I will show how this gear box have design and finally, we will also draw a gear box of our design. Now the problem is that; which we are going to solve a helical gear reduction unit has to transmit 30 Newton meter input torque at 1500 rpm with a total reduction of about 37 to 40.

Now, first of all we have given a specified torque which is 30 Newton meters now that depends on at the end how much at the output how much torque we need and what is the prime over we have? Or depending on the output and their load spectrum we have to select the, what should be the input torque input power of this prime over and very often what is the nominal torque and what is the torque and power at stable condition? That is simply a base data and our motor is of our prime over is of higher size, because we may need high starting torque, we may need additional torque during the power transmission during the operations, so that is why we the prime over may be of higher part then nominally what is required? The question is that for designing the gears shall we considered the nominal torque or shall we consider the higher torque depending on the; what is coming from the prime over?

Now, that is decided depending on the load cycles and that is usually specified by the manufacturer or sometimes it is the designer experience, at in this case we have specified that we are going to design we are considering the nominal torque is 30 Newton meter, now for designing the gears we may multiply the torque with a value depending on what is the amount of shock or starting torque is there now here it is specified that input rpm will be 1500, now reduction ratio instead of taking a fixed reduction ratio we have given 37 to 40 why it is given like that?

In normal cases industrial operations plus minus 5 percent variation for exact what value we need this variation is acceptable reason is that in any case this prime over also may give plus minus 5 percent variation or the whole purpose will be, even if we take plus minus 5 percent variation. However, we can always specify here that the reduction ratio should be such, but the reduction ratio is the ratio of teeth number and it may not be possible that always we arrived into exact number anyway let us look into the other part of the problem.

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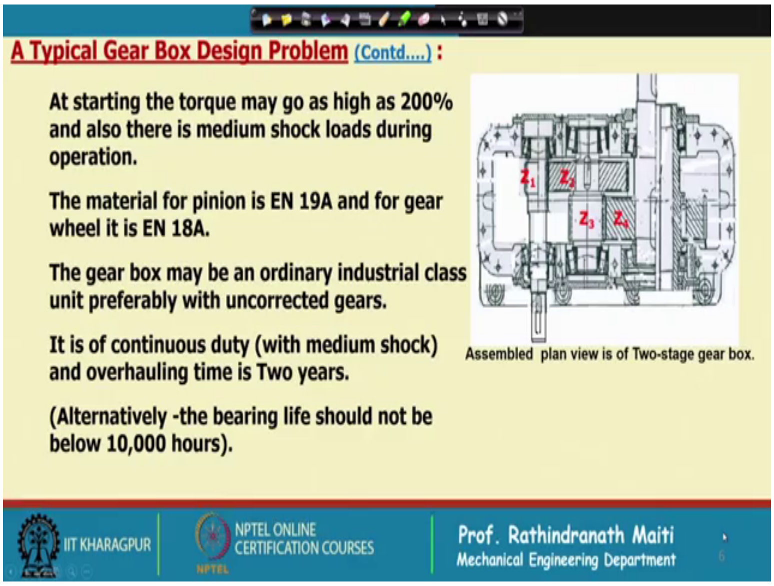

At starting the torque may go as high as 200 percent and also there is medium shock loads during operation this means that what are the nominal torque we have considered that must be multiplied with some factors. So, that design the design gear that can sustain at 200 percent starting torque and whenever some shock is coming.

The material for pinion is EN 19A and for gear wheel it is EN 18A now I would like to mention that EN there that is the British standard emergency national in our country still we follow this numbers, but it has the Indian equivalent when will you come to the design I shall give you the exact equivalent of this material, EN 19A this is a 4 steel with allow steel and it is very good for gears and EN 18A that also can be forced, but that also can be used for casting. The gear box may be an ordinary industrial class unit preferably with uncorrected gears, so we are going to design a uncorrected gear sets. It is a continuous duty with medium shock has already mentioned and overhauling time is 2 years what does it mean overhauling times?

Now, 2 words are associated; one is maintenance, another is overhauling maintenance of gears means you have to look into the gear box whether oil is properly filled or is there anything something is going wrong in the gear box whether bolt is properly tighten even in after operations in case of say for example; ruling wheel you will find the gear box the foundation bolt almost every day it is tightened, in case of general purpose it may not be required for inspecting the lubricant. You need to check the check through the window that whether lubrication is there or there is a leakage sometimes if necessary you can also one can observe whether any (Refer Time: 17:13) has come inside the lubricant.

Also these are the part of maintenance, but overhauling means after certain time you need to change some components of any machines in case of gear box usually all bearings are replaced and scenes are replaced and if necessary that some other own out components are which is highly stressed or damaged that should also be replaced, but mainly main things are there bearing and sills will be replaced after certain time and this is required to have the better life of the any machines, this means also that what should be the life of the bearing while we are designing?

Now 2 years means what it is? From this we have to know that in a day how long this machine will run and in 2 years what will be the total running time? That is again from the application of the machine that is why in some cases we can say the bearing life should not be should not be below 10000 hours. So, bearing should last 10000 hours and what is the life of the bearing? Life of the bearing is that; it on the process it will be own out so at some point it gradually it will become loose and which the as it owns out the dynamics of the gear box will in increase, now a days there is a process is called for liveliness by which we can say that how much vibration is coming and from there we can identity that what should be whether we should replace the bearing or not, but in normal cases it is specified after say 10000 hours or 5000 hours you can replace the bearing; that means, beyond that point the dynamic condition will be more watts uh. So, we must replace that.

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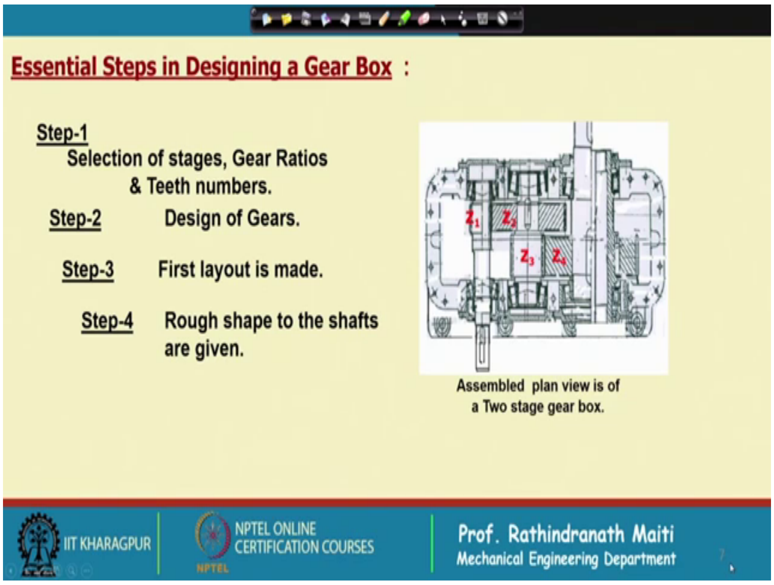

Now, with this given data now what are the design steps? What we should do now? In first step we should the selection of stage gear ratio and teeth numbers. In first stage we will consider this, next in step 2 we will consider we will design the gears and then third step we will make a first layout in that layout the gears will be drawn and the centre distance will be finalized and a shape of the shaft will come next.

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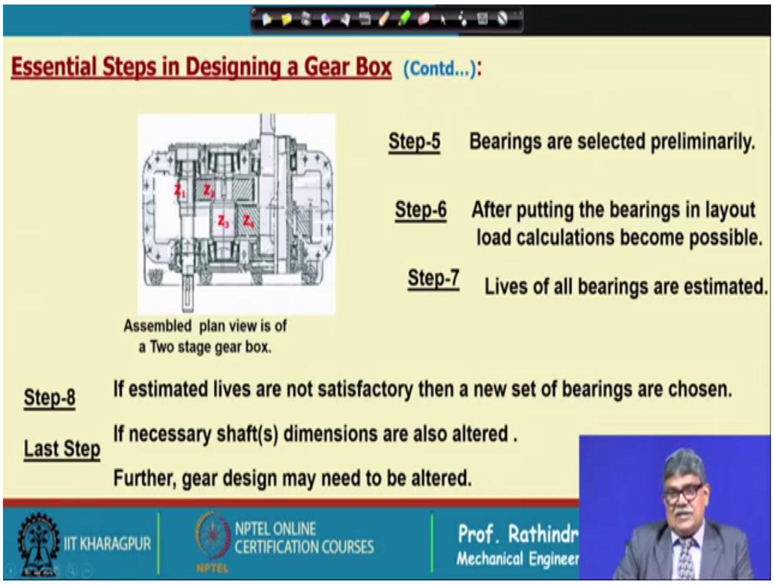

So, rough shape of the shaft is given in the fourth stage then fifth step is the bearings are selected preliminarily and then after putting the bearing in layout load calculations become possible. Now, unless we do not put the bearing here we do not know how much load will come on the shaft what will be the bending movement and what will be the load on the bearing? So, first of all we have to select 2 bearing from the experience and that we have to put at two ends and then from there we know what is the where is support and where is the loading point?

We will calculate the bending movement of the shaft load on the bearing and then we will in step 7 we will do lives of the bearing that will be estimated and finally, we will then we will check if the estimated lives are not satisfactory then a new set of bearings are chosen selecting a new set of bearings means; either we have to go for higher series of bearing, if it is a ruling eliminate bearing and in that case higher series means; the inner diameter of the bearings will remain same.

But the load capacity will be more or we may need to increase the diameter of the inner diameter of the bearing; that means, diameter of this shaft also; that means, we have to alter the design that amounts that the gear design may need to be altered; that means, suppose we have taken 17 teeth with 2.5 module, but we may find for that gear that pinion is usually will be integral with the shaft and we may find that whatever the diameter we are getting at the bearing end that is not sufficient for the bearing life. So, we increase the module, we increase the shaft diameter and we go for a new set of bearing.

It is not possible that by a single calculation starting for step 1 to step 8 we will reach into a good design we may need to change the gear design after the first calculation

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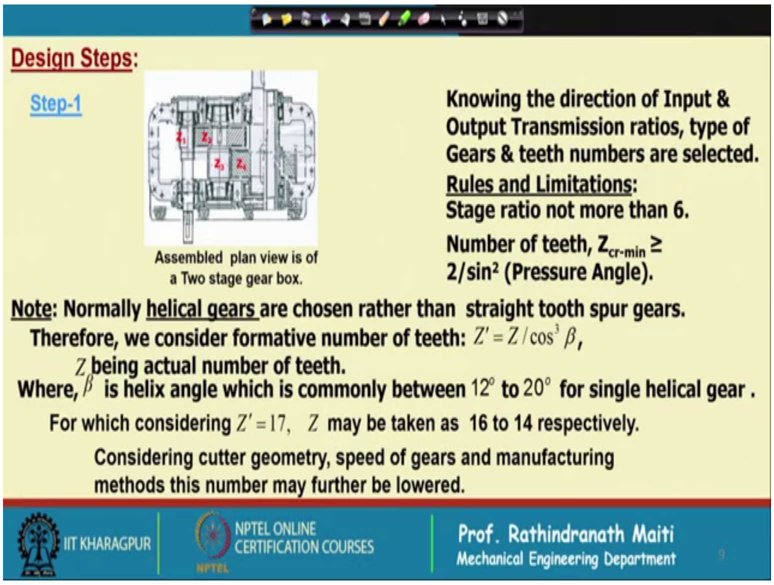

Ok in step 1: knowing the direction of input and output transmission ratios type of gears tooth numbers are selected ok, rules and limitations is that: stage ratio not more than 6 usually particularly in the first stage by no means ratio should be more than 6, now number of teeth should be again among the critical number then a normally say if it is a it is if can be managed by the spur gears say for example; this type of gear box. We can manage with the spur gears, but normally straight tooth spur gears are not chosen because the helical gears have better performance with more or less same sizes.

The two difficulties, one is the complexity a little bit complexity in calculations that is not difficult with the modern techniques as well as for the designers it absolutely there should not have any problems access the manufacturing is concerns this is also not difficult. So, helical gears are chosen instead of straight tooth spur gear and we consider the formative number of teeth is equal to Z dash by Z by cos cube beta the actual number of teeth by cos cube theta and Z being the actual number of teeth and beta is the helix angle which is normally taken 12 to 20 degree for single helical gear and as with 20 degree involved Z minimum number of teeth that is Z dash is 17..

So, we consider the formative number of teeth in case of bevel gear should be 17; that means, if we consider 12 degree to 20 degree means 16 to 14 teeth we can take easily ok. Where as in case of step 2 spur gear if we consider 14 there will undercut, considering cutter geometry speed of gears and manufacturing methods this number may further be lowered.

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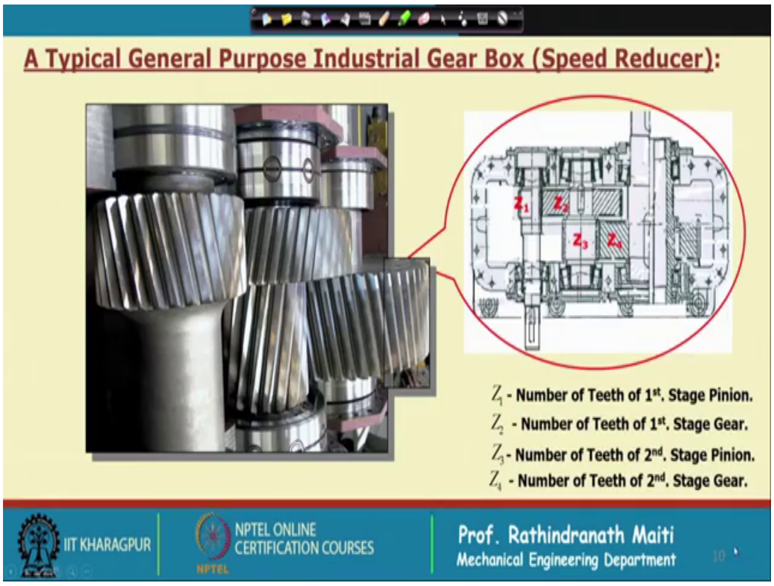

Now, here it is again shown that what may be the autographic view of the gears. So, this is a typical view of a photographic view of a gear in this top open and as I have shown in the drawing it will something look like this where the; Z 1 is the number of the teeth in first stage pinion, Z 2 is the teeth number of gears in first stage, Z 3 is the teeth number of pinion in second stage, Z 4 is the number of teeth in second stage of the gear number of teeth in second stage.

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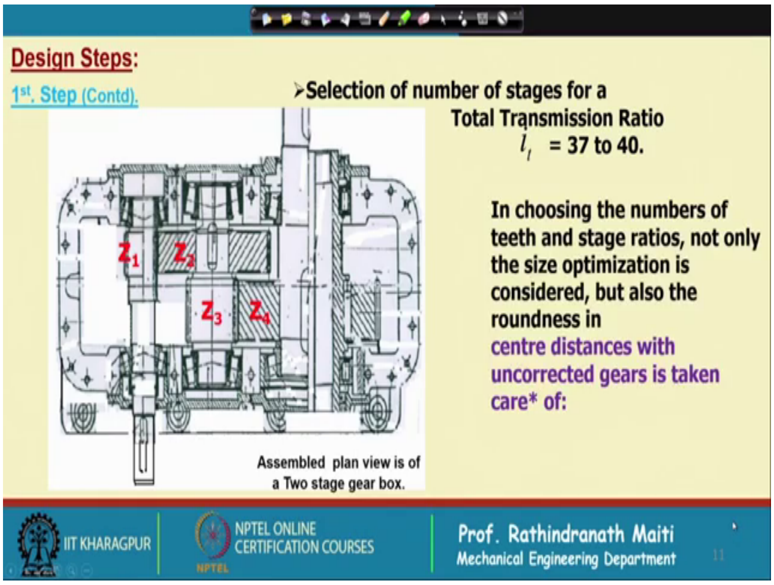

And now we will select that the transmission ratio it is 37 to 40 it is given. In choosing the numbers of teeth and stage ratios not only the size optimization is considered, but also the roundness in center distances with uncorrected gear is taken care of. Normally, I would say that when the gear box gear box manufacturer who are manufacturing standard gear box sometimes; they manufacture they offer the gear box what is available with them. In that case the center distances are specified over load size of the gear box is specified centre das distance usually multiple of 5 millimeter.

Now, with uncorrected gears to make the centre distance multiple of 5 millimeter we have to choose the helix angle number of teeth in such a way that should be within limit as well as that should satisfy the centre distance this is one part, second part while we are selecting the number of teeth then usually a stage ratio should not be a whole number say for example; Z 2 by Z 1 the first stage ratio that should not be a whole numbers, whole number means that the after say it is three; that means, every after 3 revolution same pair of teeth will come in contact for that type of contact there will be increase in dynamics because if there is a error every after 3 cycle that error will be located and it is called tooth haunting to avoid that usually the ratio is made fraction as much as possible.

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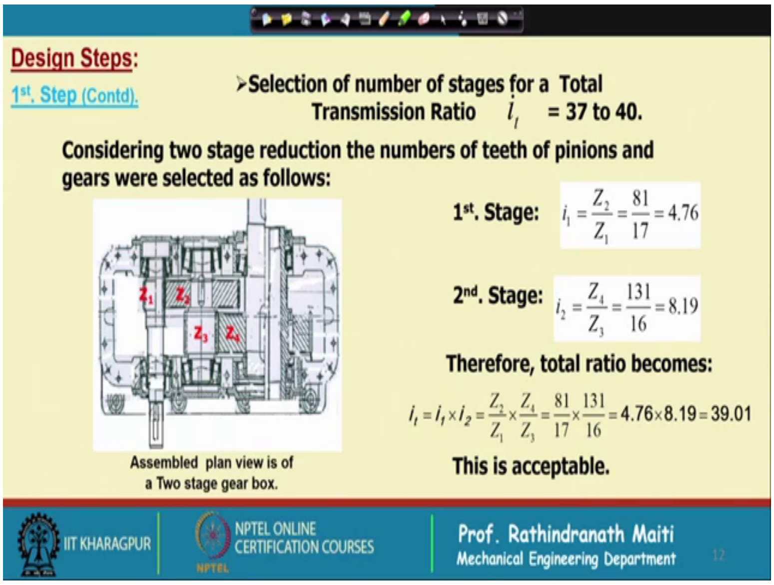

So, with this idea with this limitations we shall consider that that this will be of 2 stages, because if we cons if we if we 37 and if you would like to take the 6 is the limitations in the first stage then what we can do? 6 into 6 point something will very close to 40 so we can we can go for such a ratio, but the problem is that if you take that ratio in first stage and second stage second stage where the torque is more then you will find that gear box size will be will not be optimum this gap will be more and it will be big one.

So, we take first stage it is less and second stage is slightly higher in this case what we have taken that Z 2 by Z 1, 81 by 17 which is 4.6 it is a fraction so tooth haunting is avoided and 7 teen is a good number we did not bother about the undercut so 81 by 17 we have taken and then in second stage we have taken 131 by 16 which is more than 6, the question is that if we do not take in second stage more than more than 6 then you we have to go for this stage gear box in this stage gear box will be expensive.

So, that is why for such a ratio it is very often will manage with 2 stage and this stage is around this figure and other stage is this say 5 then 8 should be good figure for which you will find that this can be optimum, but to keep our teeth number our size within that we consider these one and then finally we find for that the transmission ratio will become 39.01 which is satisfactory.

So, we can have the teeth number may be like this. Now, next stage we shall examine for which what is the module is coming and for which whether we can manage with a centre distance which is multiple at least multiple of 5 if not 10 that we need to examine and if necessary then this teeth number again can be changed and we can go for a new ratio.

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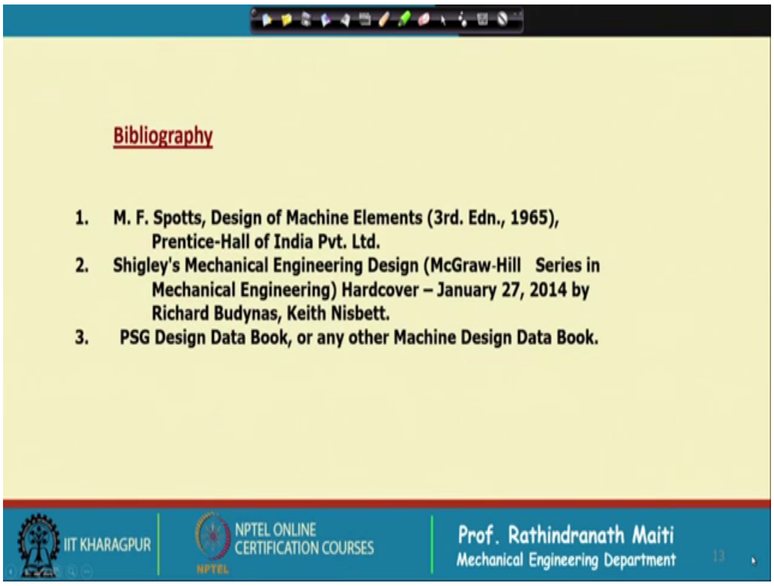

So, for this part is any machine design books will be good to understand this, but many information's are not available in standard machine design books and also if a although the bearings and others can be selected oh from the internet or catalog, but if there is a readymade design data book in hand that will be helpful ok.

Thank you.