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Course
on
Spur and helical Gear Cutting

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Lecture 02: Simple Gear Calculations

Welcome viewers to the second lecture of our open online lecture series on spur and helical gear cutting, so last time we were discussing the speed ratio of old gear train which means that if we have number of gears forming a train from the you know input side to the output side, how they are numbers of teeth extra and their configuration that means the way in which they are connected how it be affecting the speed ratio and solved a small numerical problem and obtain an answer.

Now when we are dealing with you know gear cutting through say milling gear hobbling gear shaping some methods like these we will in variably come across some calculations which will be involving either gear train like these or there will some mechanisms like screw nut mechanisms, worm and worm gear mechanisms then the well gears extra, extra which I think I should introduce at this point.

So that in the introduction itself you will quite confident the gears I understand about the basic mechanisms which are used in case of gear cutting and therefore I can follow when it is being discussed in you know in more advanced form.

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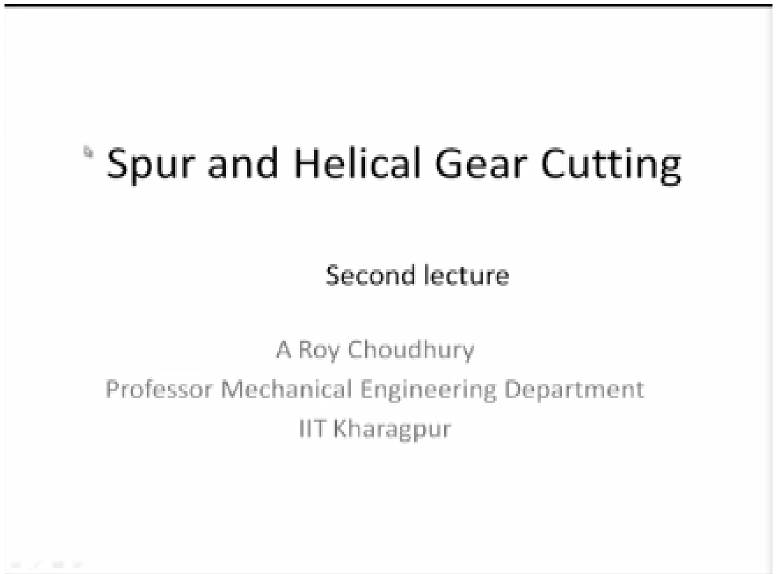

So let us have so in the second lecture let us start with some of these mechanisms.

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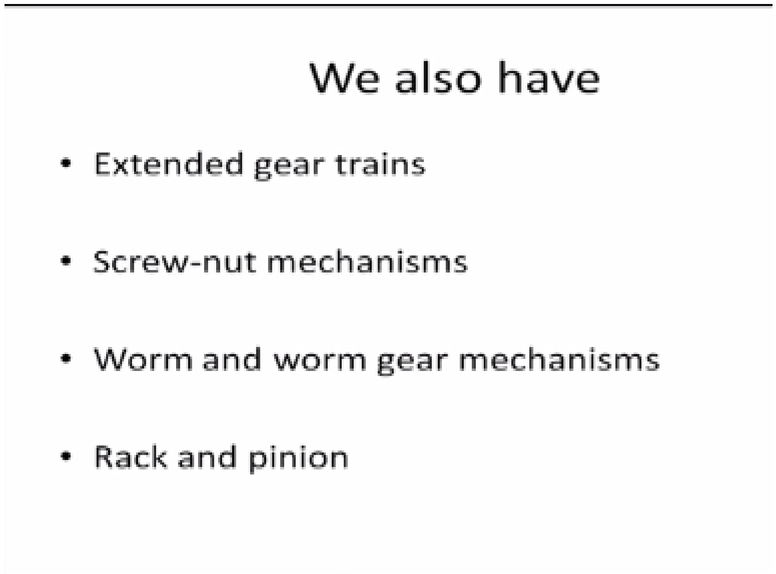

We also have apart from gear trains, extended gear trains, screw nut mechanisms, worm and worm mechanisms, worm and worm gear mechanisms and rack and pinion. So first of all let us have a quick look at what is this screw nut mechanism let us see.

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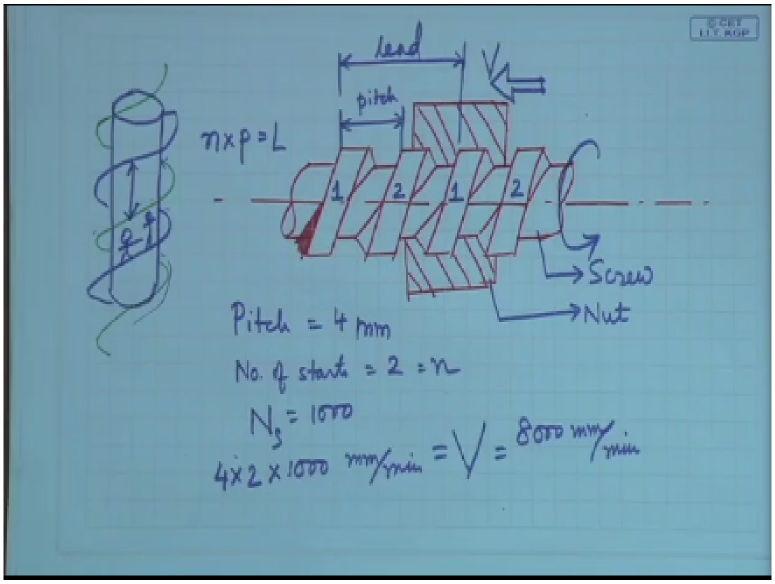

First of all if you kindly have a look here I draw an axis line to mean that whatever I am drawing it has you know it is axes symmetric and this is basically a screw, okay that is it. So we have sorry, we have a screw to start with so it is basically a helix okay, wrapped around a cylinder screwing this so when here such a member sorry this one should be like this, when we have a member like this it has a corresponding body called a nut which can be fit on top of this sorry, if I fit it here now we can depicted this way and an engineering drawing.

So this particular member we name as the screw and this member we call the nut and what is the specification that we give here pitch equal to say let us put a numerical value so that we can correspondingly solve a problem as well. So you 4 mm, number of starts=2, what is number of starts, number of start is you know this looks like a helix and what is the helix to give you a very, very simple you know everyday example you might have seen against round object a spiral stairway.

What is the idea of the spiral stairway, you can move up the spiral stairway up or down so this is what is this spiral all around this particular cylinder. Now the question is if someone said just like you have two way highways that is it is a divider on one way you go say forward and on one way you go not backward but you go the other way, so in the same way in order to have better traffic control on the spiral stairway build another one parallely, okay.

So think of the you know advantage you will have on the spiral phase, spiral stairways are you know very much constructed in space, constrained in space so that if you have someone moving down you have a problem you have to shift and give him or her some space to move and already you the space is constrained so it will be a problem so someone says why did not we have a parallel spiral here, why do not we have it, we generally do not have it at all.

We could have had it is there going to be any clash in space, no they are all moving in the same direction then can you really come down yes, why not you can go down and along this will you have a clash no, never, so do not we have it, because of possibly this head space. If you put another spiral stairway you would have to move with you know bend down, so you do not have it here.

But on the screw side there is no constrained of accommodating someone here in between, no. So we many times have two or three or even more such spirals moving parallely, so it may be spiral 1 moving all around and coming up spiral 1 and this is a completely different one spiral 2 moving around like this and coming back again spiral. In this case if these you know helixes are belonging to separate, you know separate threads these threads are belonging to separate helixes and there are two such helixes we will say number of starts 2.

Then how does the definition of pitch still remain relevant it remains relevant this way, you know this distance is the pitch and the nut now if there is you know number of starts higher than 1 the nut movement will be correspondingly higher. So the nut will be moving actually twice of pitch and it is called the lead and we have the equation number of starts x pitch = lead, okay. So if I say N=1000, N_s=1000 and the nut is made to move, the screw is rotating and not allow to translate, no and the nut is allow to translate but not allow to rotate in that case what will be the movement of the nut, say what will be the velocity of the nut in mm/min.

So we can say per rotation of the screw the movement of the nut will be one lead, so this will be 4x2, 4x2 per rotation and if there are 1000 rotations per minute it will be these many mm/min=V, so that comes out to be 8 meters okay, 8000 mm/min of the nut. So this way we understand the screw works we have to see, we have to keep a look out for the pitch, we have to keep a look out for the number of starts n sometimes it is referred to as K and we have to keep remain alter for the number of rotations suffered by the screw and that combine will give us ultimately the movement of the nut.

So this is about screw and nut mechanisms, so we have learnt now about gears, we have learnt about gear trains, we have learnt about screw and nut mechanisms.

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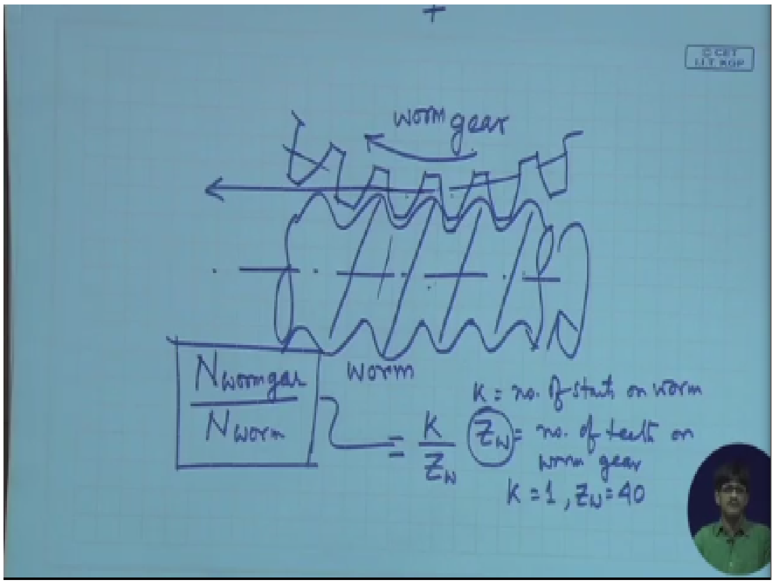

And now are going to have combination of the 2 let us have a quick look at what we mean by that, let us represent the screw once again, let this be our screw and some innovative person say things that okay, let me combine gear and the screw and he puts it here, he or she puts it here. But you will say what just this going to give you, the screw which is rotating here that is simply going to carry out rotation, the screw is rotating and have there being a nut it would have been pushed to one side.

So it will do that only all these teeth which I have got engaged in these you know thread roots they will get pushed to one side, but however you constraining this particular gear so we call this the gear and this screw is given a specific name the worm why, because worms you know those earthworms they have and they are annelids so this is roughly looking like annelid, okay that means rings one after the other as if there are rings really not so but anyway, so this called a worm.

Now in this gear what is the way in which we are constraining this gear we are simply having a pivot at the center of sorry, it cannot be seen here this is the pivot point, that means it is able to rotate so if you give it a push here this way it is going to suffer rotation due to that, so the gear suffers rotation. So if the worm rotates this is now we getting a name of itself worm gear, the worm gear will rotate to one side and therefore we have a mechanism in which can transfer motion from rotating screw thread to a gear this is a big achievement.

Previously, we were you know transferring motion from worm, from one gear to another gear we were transmitting motion from screw threads to nut extra. But we were not able to in anyway move from a screw thread to a gear directly this is being done here this is a very important function which is serve by this worm and worm gear mechanism. Incidentally the speed ratio that means N worm gear/ N worm this is the speed ratio that means the worm gear is being rotated and worm is the driving member, this one can be shown to be equal to K/Z_w where K is the number of starts on worm and Z_w= number of teeth on worm gear.

So from this we understand that very useful purpose will be serve by this mechanism, what is that generally the number of starts=1,2,3 like that and the number of teeth of the worm gear can be typically say 80, 40 like that. So let us take an example in which K=1 and Z_w=40 what is the speed ratio we get, the speed ratio will be a thumbing for 1/40 so you just imagine rotation on a shaft can be reduced to 40 times its original value, why is this so important and why is this so you know useful let us have a look here.

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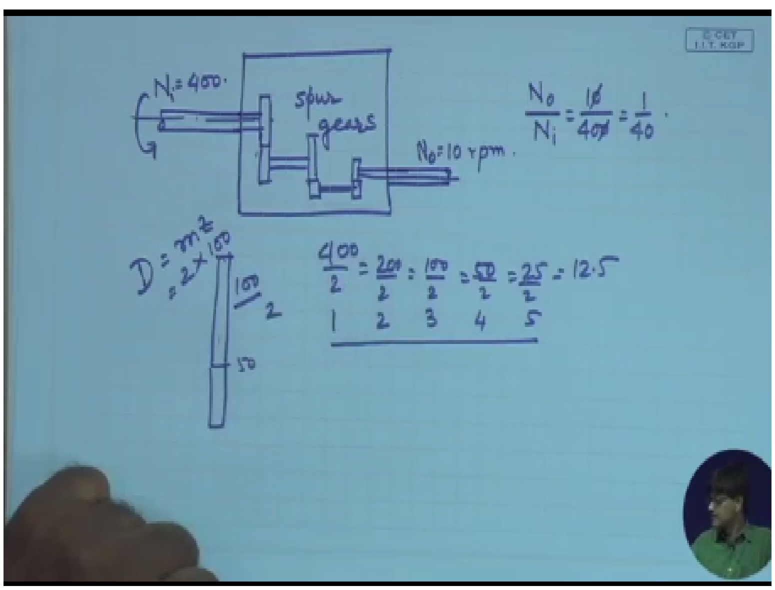

If I am having say an input shaft with rotational speed=400 and if I tell you that make a gear box into which it is moving in put whatever you know ordinary gears that we have discussed up till now spur gears I will come to this terms per gears put whatever gears that you can put in and get me a speed of how much 10 rpm.

So you immediately find out what is the speed ratio required N output, N input. N_O/N_I = 10/400 = 1/40. So if I can put gears of this type may be, my drawing is not very good but you can gears of this type and we can reach 1/40. Let see how difficult it is, whenever we think of gears which I having, say 100 teeth, 50 teeth okay. What sort of speed ratio is possible here? 2, so if you are going on putting gears of this type, as an example.

So 40/ 2 in one stage you can get 20 rpm, in the second stage you can get sorry in one stage you can get 200 rpm, 2^{nd} stage you can get 100 rpm, another stage 50 rpm, another stage 25 rpm, another stage how much 12.5 rpm. This is more like that 10 rpm that we were requiring, so you would have to use stage1, stage 2, stage 3, stage 4, stage 5. Just imagine 5 steps in here, here I have drawn 3 steps and that to you know when you are accommodating 100 numbers of teeth in the module say 2.

Therefore the diameter which you have to accommodate it would have been 100 D if you remember D=mz, m=2 and number of teeth is 100, so it would have been 200mm just imagine. This way you would have covered 200mm, this would have minimized 100 mm, there are 300mm in every stage, 5 steps such stage. So in most general space it would have been when you have huge space a gear box requiring a huge space.

Now who would be interested in such a gear box if just to get reduction of 400 to 10, you would be requiring say 2m/2 spaces no one will be interested. Here comes the worm and worm gear the application of worm gear, you can notice here by the worm that we have just discuss just now.

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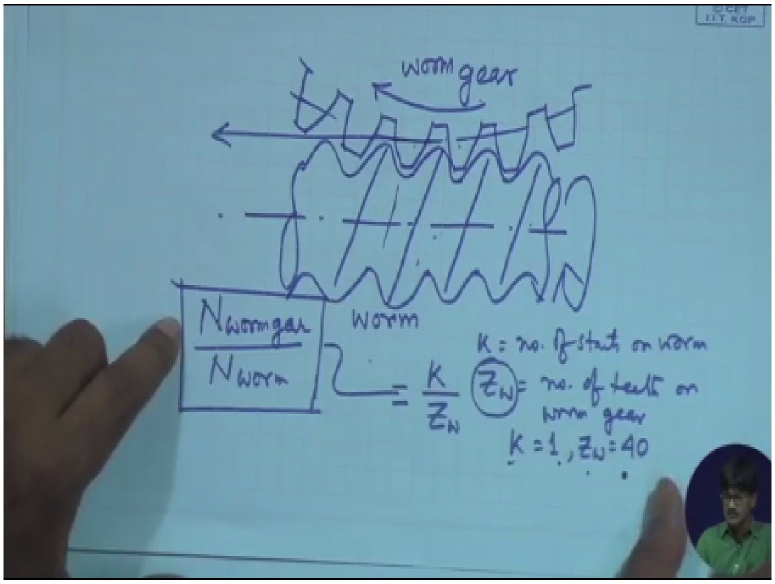

Just now from the first step itself if you can reduce the speed from 400 to 10 by employing k=1, zw=40. As simple as that okay, this is the advantage of the worm and worm gear. This drastic speed reduction in a single stage, there are problem associated to worm gears and sometimes those problems are made use of. For example you know specific helix angles and coefficient of friction, this is self locking.

That means by rotating the worm you can rotate the worm gear, but by rotating the worm gear we cannot rotate the worm okay. Some particular properties like that are associated with the worm and worm gears. But this is the big thing; you can get drastic speed reduction in 1 stage okay. Now let us take the case of

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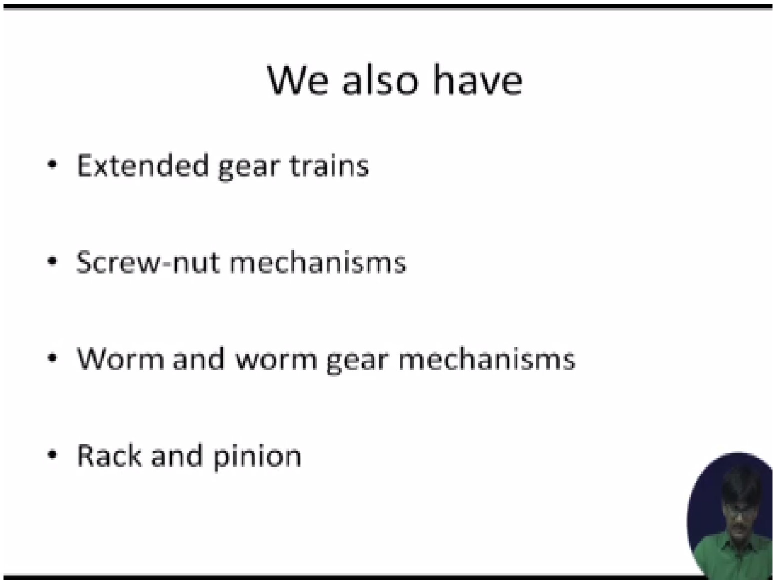

Rack and pinion let us take a simple problem also,

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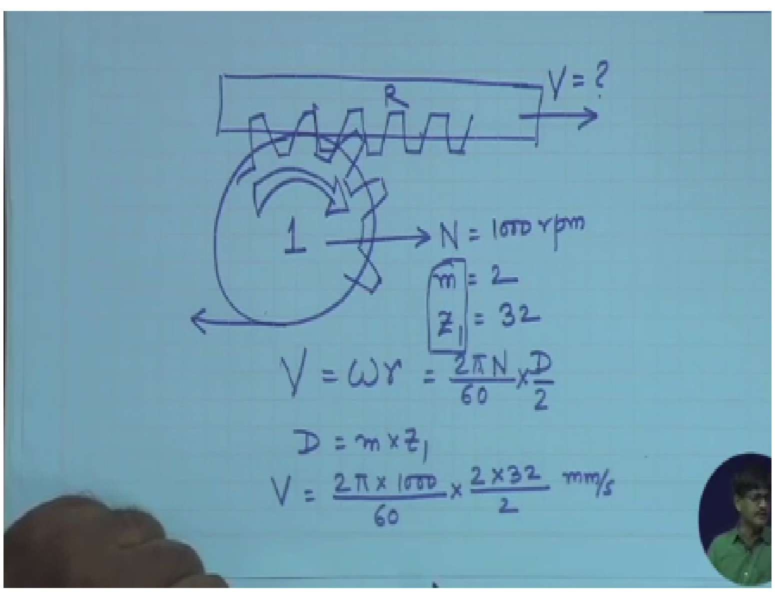

Say I have this has a gear depiction of a gear and this as a rack. Suppose I give this formation this one is root heating, this one is called 1 and this is called R. For R I am interested to find out the velocity it will develop, and here I am having N = 100 rpm, m= 2, number of heat = 32. What will be the speed developed by the rack? So in this case what do we do?

In this case we can say that I can easily find out the preferable speed of this gear and the pitch circumference. Once I find out the preferable speed of the gear, I can incubate to the rack speed and that will be my answer. How do I find out the preferable speed? If you move from first principle you can say, velocity has to be found out it can be $=\omega r = 2\pi N/60 \times r$ let say D/2 okay. Now this N is it is rotation is this given? Yes it is given.

Is the diameter provided? No I do not know the diameter. So how would you proceed? Here you will find if m and z are provided you can use $D= m \times z1$, either put it here, so $2\pi \times 1000/60$ it gives you the number of what you call it? Here we have put ω therefore Nrps, $2\pi \times 1000/60 \times m \times z$ that is 2 x 32. Let us write it down therefore $V = 2\pi \times 1000 /60 \times 2 \times 32/ 2$, as this is rotation per second and this is in mm you have mm/s.

This is the answer, so the calculations are required I have shown it and solved the problem. So now we have covered gear trains, screw nut mechanism, worm and worm gear mechanism and rack and pinion and therefore we can carry out all the calculations which are required on the stand, on how the machine in cutting of gears express now coming back to our original discussion.

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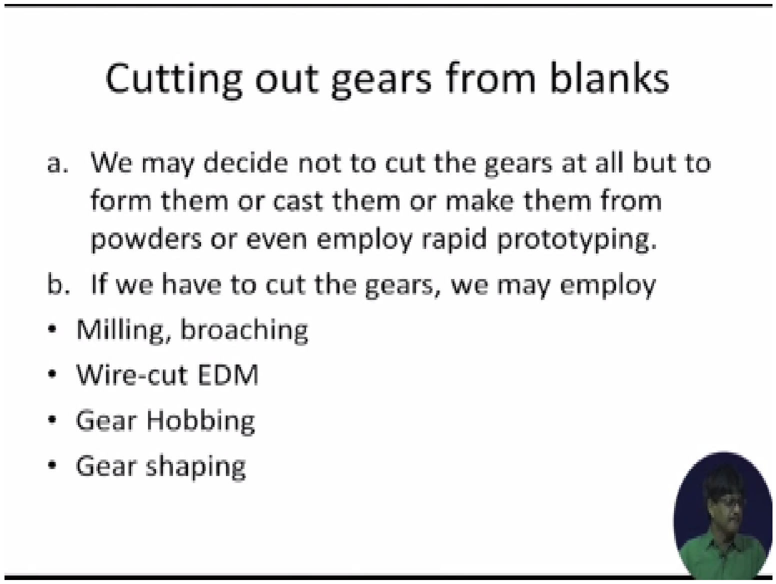

Let us now take the methods by which the gears are cut out but before that we should notice gears are not produced only for cutting or machining. Machining basically means cutting with the removal of unwanted material form of chips, form of largest size blank. We might not always cut gears out of blanks; we might get gears for completely you know we can go for forming them disgusting, stamping etc, or even blanking.

So we might them also cast them okay, or we might be getting the means of powder meteorology or even employee rapid prototyping. All these methods are involving, either thickness manufacturing or they are the primary methods of manufacturing. So they are completely different from cutting of gears but old family of methods cutting out of gears has evolved over time and they have their own areas of specialization.

Like there will be some cases in the bridge they are very much essential to be used okay, and we will be studying about those things. So what are the typical methods of gear we might of milling, we might of broaching, we can also have wire – cut electrical machining, we can have gear hobbing, we can have gear shaping and we can have yet other different methods, but these are the most generalized process and they have their respective area of applications.

For example milling, what do we exactly mean by milling? I can out the gear by, say for example rotary 2/3rd cutting tool, so what do we exactly mean by this? Rotary factor okay, this is basically a form cutter and let us have a look at that.

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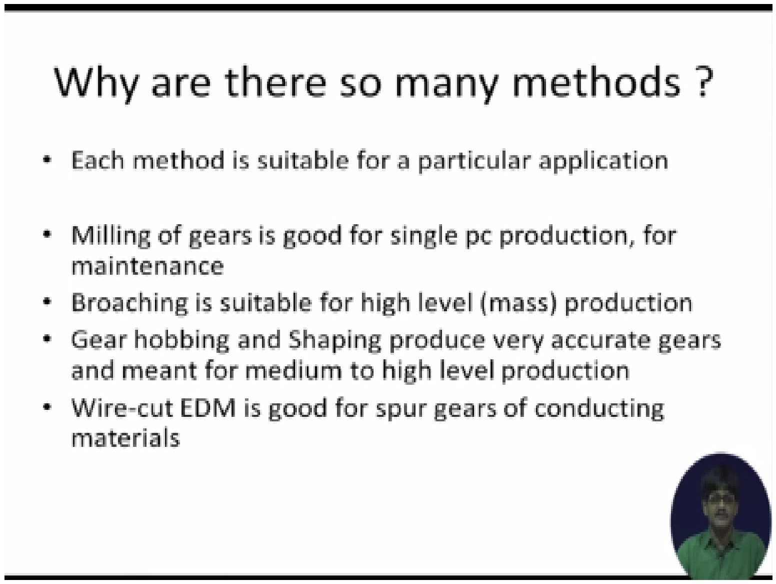

What is it area of application? Milling of gears is for good for single pc production, for maintenance, so suppose you are working in a factory in the night shift and if there is one gear which fails or gets damged, so that has to be raised immediately. So what do you do? Will you go to shop? No, because in the night time most of the shops are closed. Will you go for online shopping? You will receive through courier no. that takes a lot of time; we cannot manage to get it.

But we can have your own machine shop, we can have a milling machine which can be setup very fast and the rotary form this type of cutters, which I have referred to and mill cutters which once again they are worm factors. They can be employed there are the method of inductions, we can get easily such gear or there is example of, suppose you are having a job shop on which you are depending on orders.

Which are coming time to time but this is the order for 2 such gears etc, so for that you cannot have specialized machine, you have to have machine for that kind of production it can be manually operated and though it seems to be what you call it? Not very significant for this sort of production, it might have considerable volume okay that means you might be used number of customers who will be approaching you with orders pieces of such gear.

For which you cannot spend money to have specialized machine dedicated for that purpose. Machine in which the set up can have doing that job, and you can change the set up for some other job that you might be having in line. So milling is good for that, so milling is in such cases.

Broaching is suitable for you know high level production okay and it is single pass method so that you can very much desirable that way. We also have gear hobbing and gear shipping which can result in accurate gears because it does not have errors and in accuracy of milling etc.

Wire cut edm if you have conductive materials, and if you are having spear gears to be made then the wire cutting is quite good. But if you have helix gears it cannot be handled by wire cut. At this junction I think I should introduce the difference between spear gears and helical gears.

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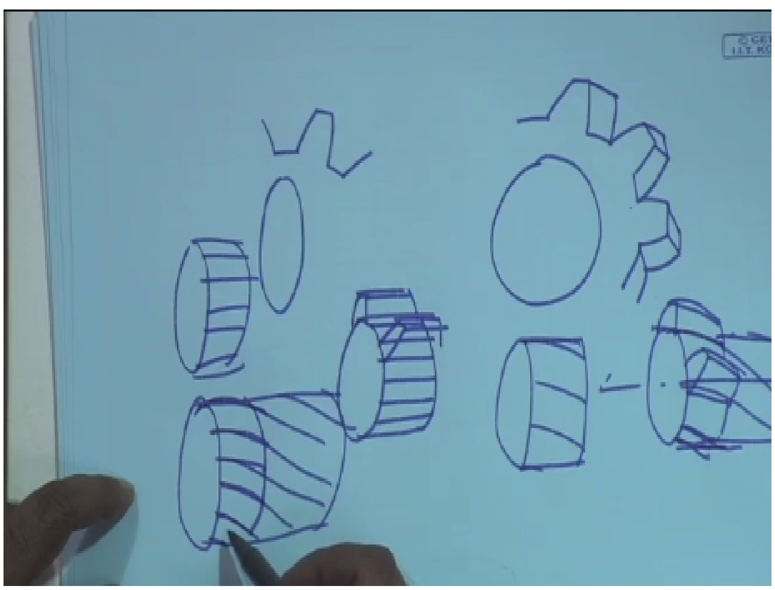

So you have quick look hear I can have the gear of this type you know, the teeth of this type as I have been drawing that means if you look along the axis of the gear the teeth are straight, so that when you draw then you can draw them in this way. But you can also have gears in which that teeth instead of being straight okay, here we are drawn gears which are having straight teeth. That means the teeth are in this way, instead of that they might have this away.

That means these two will be getting this way, this actually means that these are the basically parts of axis about this particular central axis, so this will be ultimately going this way okay. So if I have talking about helical gear, it will look like this all these axes are there and I cut it from here I get my particular helical gear. So the teeth will be like this parallel to the axes the helical gears will have the teeth in form of small portion of helices about the particular cylindrical portion okay.

So this is difference between spear and helical gears tomorrow I have plan to show you some actual helical and spear gears by bringing them here and putting them in display, so you will be convinced with and they are defiantly different. So with this one we come to an end to second lecture, we will meet for third lecture thank you very much.