Gear and Gear Unit Design: Theory and Practice
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Lecture – 01
Introduction Motivation and Theme of the Course

Welcome to the course gear and gear unit design theory and practice. Now this is the first lecture of module one.

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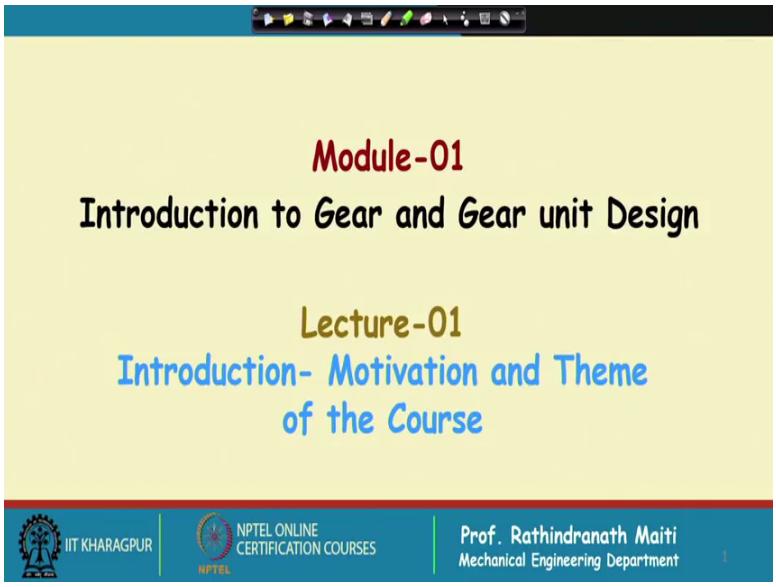

And this means the first lecture of the first week this module one is on introduction to gear and gear unit design and the first lecture is on introduction motivation and theme of the course.

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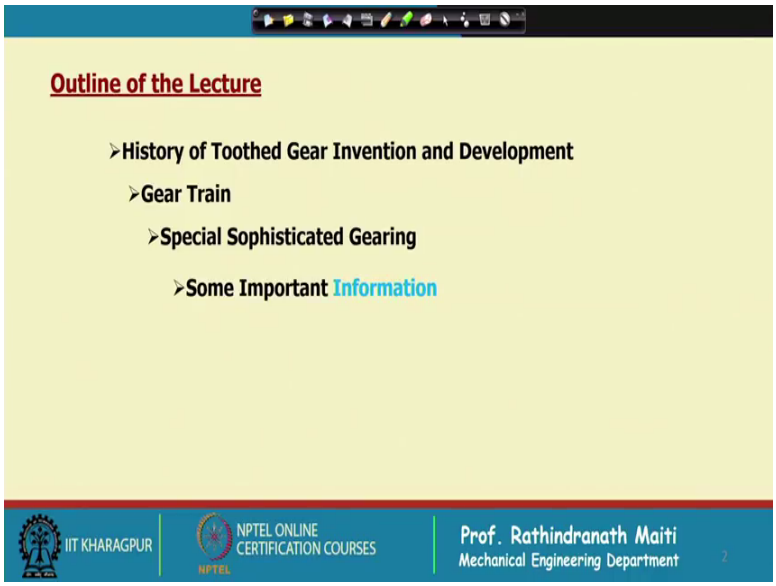

In this lecture, I shall give a brief history of toothed gear invention and development and next something about the gear train, then special sophisticated gearing some important information.

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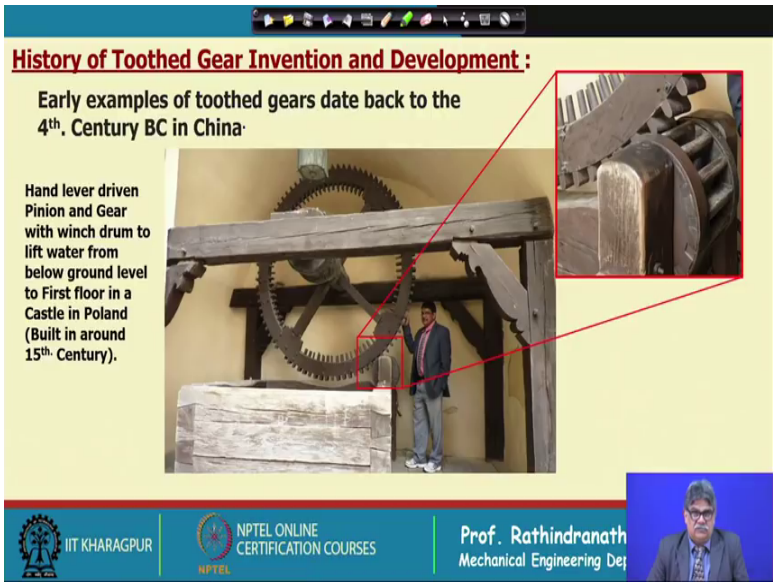

Now, coming to the history of toothed gear invention and development now to transmit the torque who to magnify torque and to reduce the speed from the very beginning of the human civilization people who have started thinking, how it can be done and there are they used various methods lever, then rope tackle etcetera and in that way also toothed

gear came in the way before that of course, the friction drive was there and some sort of well drive was also there.

However early example of toothed gears get back to the fourth century and fourth century BC; Before Christ and it is in china. Now first toothed gear was somewhat; what I am showing here of course, this is not the first toothed gear that was introduced in long back and probably that was used for mechanism, but this one is an example where it is transmitting also the torque. Now, this is hand lever driven pinion and gear with winch drum to lift water from below ground level to first floor in a castle in Poland and based of the information it is built in 15th century.

Now, if we look a close look to the gear and pinion as you find this pinion is pure cylindrical rod cylindrical wooden rod connected by two piece of circular wooden blank and that is pivoted on two wooden column and that is driving the teeth which is also made of wood and this is also put on a rim wooden rim this can be splitted somewhere it can be splitted and bolted ok. So, these are simply precipitated over there and that teeth looks somewhat like involute, and this is the drum and this is a hole on the top floor and the water well is just below this and it is in the ground floor and in a well.

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Next, if we look into this gear this is probably the first set of gear unit. Now it is cutted to drive the cable car in Lucerne, Switzerland. This toothed looks like involute; however, this hitch apparently looks the involved like toothed, but with slight an undercut; here, if

we notice this part, see, it is looking slightly undercut, but later we will learn for this number of teeth undercut was not necessary and probably to give more clearances this tooth safe looks like that, but it is very close to involute and these gears was initially cast this with this toothed form and then probably this was also melt to get the shape.

Next toothed profile particularly of gear looks like close to involute and this is has already told Cast and milled gear in after introducing the toothed gear.

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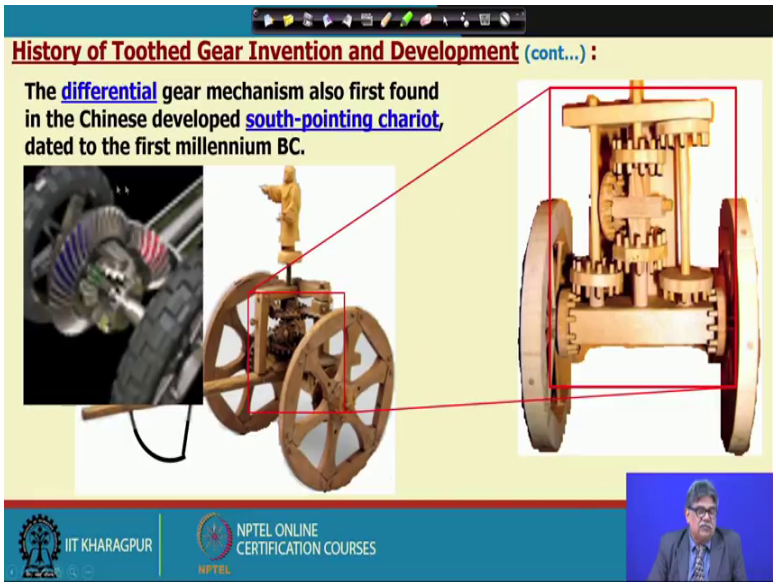

There is lot of development on the gears in china and they also introduced the differential gear mechanism also, it is found in china for a device what is which is called south pointing chariot and this was also around, it is Before Christ, but after the development of the toothed gear.

Now, as you see in this figure that a man is pointing his hand and he is standing on a chariot. Now if this hitch put pointing south and then if this wheeler rotated or dragged pulled in some direction this finger will always point to the south and it became possible with the hairy gear arrangement which is the first differential gearing arrangement of course, one thing we should consider that this wheel; this it should not sleep on the ground they should firmly attached on the ground and this would roll.

Now, if we look details of this gearing as you find that when the wheel is rotating these wheels are rotating these gears; two gears and then here as you find this gear is rotating

this one and in turns it is rotating this column and on that column this man is standing. So, whatever may be the rotations, this will always point towards the initial point in this case, it is they are; it is always pointing towards the south; that means, whole device, we have to keep directing this finger toward the south and then it would work.

Now, here if we look into these gears this is again on the simply on cylindrical bar put on cylindrical wooden disc. Now, this is by no means the present gear toothed form involute or cycloidal it is simply pin type gears, but close observation will give us that this is perhaps the first idea not only of the differential, but also of the bevel gear, say, if we look into this manner particularly this gearing. So, this is the concept of bevel gear.

Next if we come to the bevel gear as you see here this is a different cell unit which is used in automobiles these are hypoid gears here and this is the differential pinions and then this it is driving the two wheels, but when it is turning then one will be with high torque and it will be almost off another one will rotate in a angular directions.

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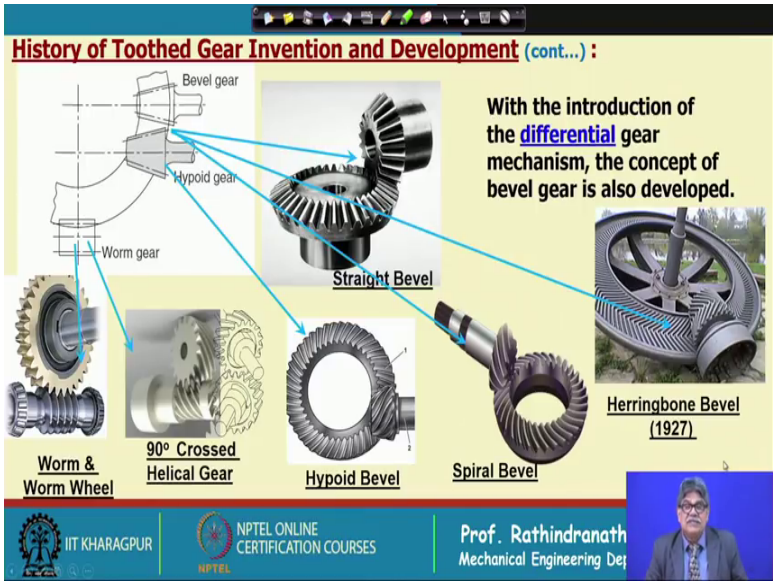

Now, coming to the bevel gear this bevel gear developed eventually with other gears, but there are different type of bevel gears and it is first it was needed to drive in intersecting sets somewhat in the 90 degree.

Now, if we look into the bevel gear performance operation then we will see that from bevel gear with angular change features change it will come into one gear now here what

it is shown that is a straight bevel gear, but it is of course, the intersecting, if we consider the axis through the pinion and axis through the gear they will intersect, but looking into this photographic view this is of course, not 90 degree this angle will be slightly more than 90 degree, but that can be achieved by straight bevel it is called straight bevel when you learn about more about the bevel gears, then we will see this what is straight and what is helical etcetera.

Now, next of when on the bevel gear if we look into this, this is spiral bevel the spiral bevel means the same it might be the same intersecting shafts same teeth number, but toothed are spiral and if we consider the center of curvature that is somewhere outside this gear teeth ok, but still the shafts are intersecting maybe 90 degree or maybe more than 90 degree. So, this is spiral wiggle it is close to the helical gear.

Now, if we consider this, this here also teeth are some sort of this spiral, but this is you can say that it is somewhat eloquent and in this case we can shift the shaft also and that this means that the axis is not intersecting. Now, this is example of herringbone bevel or you can say double bevel double teeth bevel and in this case as you see that this pinion will experience or vice versa, the gear will experience the force both in this direction and in in this directions therefore, this you can say the axial force towards the shaft is neutralized, but this is expensive and also this is not normally used.

Now, next if we come to this somewhat non parallel shafts then the first example is the crossed helical gear the gears what we normally if we saying here it is spur gears it might be straight tooth or helical here, what it is shown this is a crossed helical gear; that means, shaft you can cross and then it is shown that here this in the photographic view it is 90 degree crossed helical and when this rotates then this will also rotate ok.

Now, the further if we develop this one the that is the crossed helical gear then we shall arrive into worm gear now in case of crossed helical gear the teeth number of this one and teeth number of this I mean particularly teeth number of pinion may be three four five etcetera whereas, in case of worm gear a self-locking worm gear, we will have only single start spiral teeth this is as you see that this is like a thread even if it might be three teeth that within three start, but this will be always in spiral form whereas, in this case these are not fully spiral it is something like helix gear.

So, this is you can say a transformation from bevel to worm and this is all are un non parallel sets it might be intersecting or might not be intersecting.

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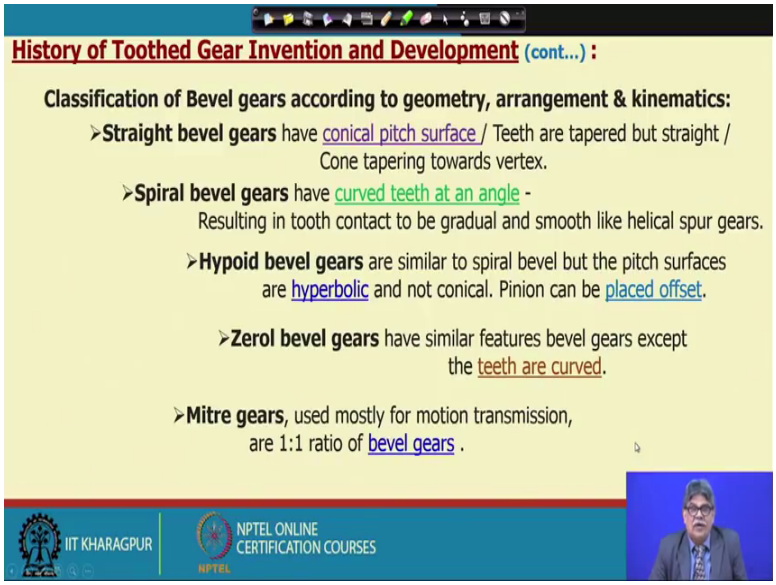

Now, here it is perhaps we should know particularly bevel gears they are of various type the street bevel gear which I have shown in earlier slide, it has the conical pitch surface teeth are tapered, but straight and cone tapered tapering towards vertex.

Spiral bevel gears have curve teeth at an angle resulting in tooth contact to be gradual and smooth like helical spur gear hypoid will gears are similar to spiral bevel gear, but the pitch surfaces are hyperbolic and not conical pinion can be placed or upset and hypoid gear bevel gears have the highest tooth carrying capacity of same size in comparison to spiral bevel gears and bevel geart state bevel gears.

Now, apart from that there is another class of gears which is zerol bevel gears it is something like a straight bevel gears, but tooth are curved like spiral bevel gears, but that curvature not in the not an angle this is thus the center of curvature or maybe the center only will be somewhat straight on the teeth now apart from that usually for bevel gear another term is used which it is called mitre gears this is used mostly for motion transmission and this is of ratio one is to one.

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Now, the one gear was invented in the Indian subcontinent for use in cotton gins sometime during thirteenth and fourteenth centuries this is a picture from encyclopedia Britannica and where it is shown that this is the cotton gins cotton gins means the raw cotton will be put one side and this will pass through this and while it is passing then the seeds will be out of the cotton which is shown, here the seeds are coming out now this is a as we see this is a spiral one, this all projected pointer can be considered as if the circular toothed teeth of circular gear and when the cotton passes through this the seeds comes out.

Now, this is the first example of worm gear and if we look into the worm gear this is of course, from a internet and this is swing that how the worm gear operates.

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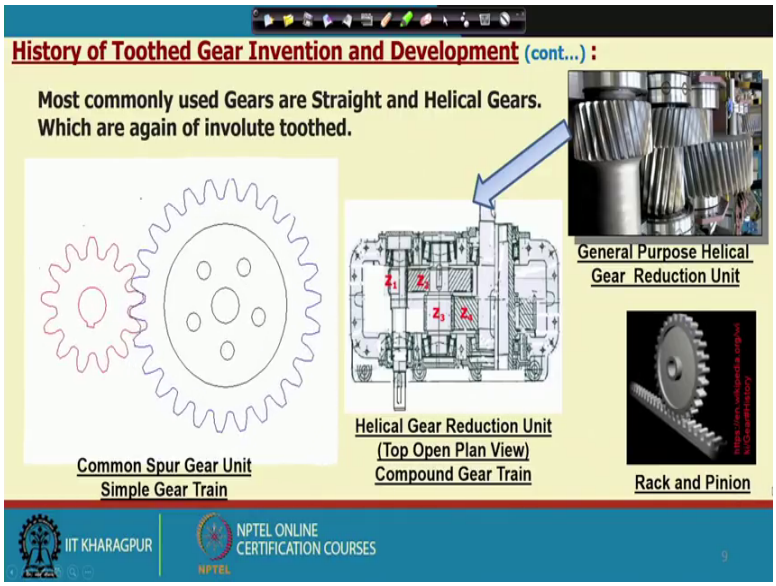

Now; however, in this course we shall we shall learn little bit about bevel gear worm wear etcetera design of that, but our design method etcetera mainly we will concentrate on spur gear helical bevel gear sorry helical spur or straight tooth spur gear ok.

Now, this is a figure it is saying that a common spur gear unit of simple gear chain now if we look into the industrial gear boxes it looks somewhat like here which I have shown in a photographic view, this is general general purpose helical gear reader reaction gear unit here we have shown it is two stage and when the power is transmitted in the first stage, then through the pinion to the next stage this is called compound gearing. So, we have the comparing gearing if the reduction is more than single stage then it is compound gearing and if we look into the top open assembled view in drawing form it will look somewhat like this which is shown at the middle.

Now, we shall in this course a major portion of this course is devoted on designing sachi gear unit finally, we will see a rack and pinion the rack is nothing, but a gear which is having in finite radius and in involute in case of involute here teeth profiles are a straight line inclined at an angle of the pressure angle of the gear.

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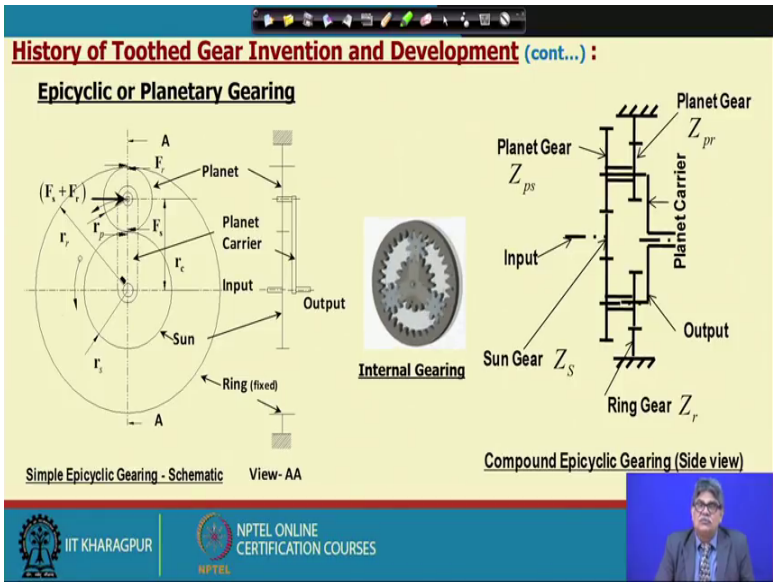

Now, internal gearing the tooth also can be generated inside the ring here if you look into here and then power can be transmitted, either the pinion can directly engaged with the internal gear or through an idler, we can have the simple gear train, we can have also compound gear train.

Now, it will be epicyclic gear drive epicyclic gear drive or planetary gear drive these are the planets these three pinions are called planets. So, planetary term is due to the following the motion of the planets. So, it rotates about its own axis as well as rotates about another central axis and it is also called epicyclic gearing and in that case for reduction speed reduction usually we will find the internal gear that is the ring gear will remain fixed sun will be input and a planet carrier that will be the output.

Now, if we look into this view here the internal gear ring gear is fixed and then this is the planet carrier which is the output and the sun is the input. So, we will get some extra reduction than the simple gear ratio that will come later now this is of course, the sintel; the simple gear train and here this planet is and you can say some sort of idler it is not transmitting the torque the gear itself is not transmitting the torque to the shaft, it is transmitting torque from the sun to ring gear ok.

Now, it can also be made this epicyclic, gearing can also be made compound in that case, what we find this sun gear is connected to a somewhat larger planet gear and this planet gear or pinion is integral with another small pinion and that is connected to the ring gear

the ring gear is kept fixed and planet carrier it is passing through this this planet gear set ok.

So, here these are by no means the idler because this is transmitting torque from here to its adjacent pinion. So, this is compound recycling gear this is simple gear train epicyclic gear with internal gearing the same epicyclic gearing can also be done with external tooth in due course we shall learn a little bit about that also.

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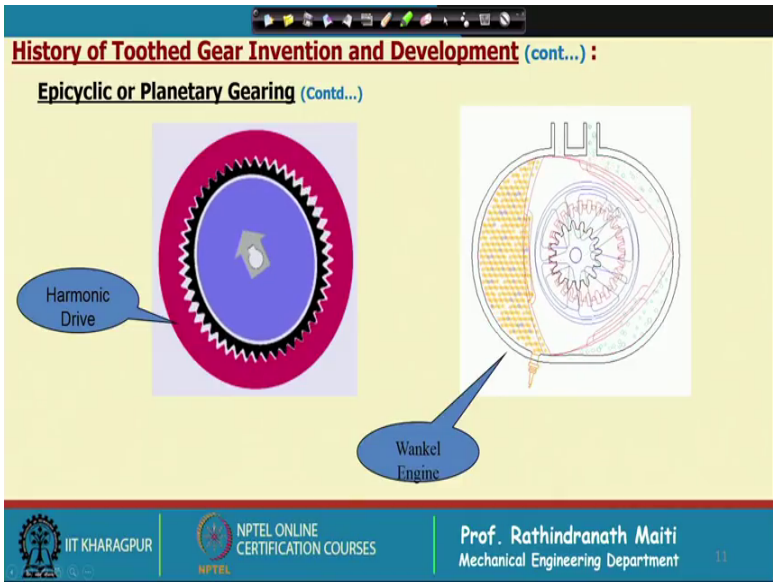

Now, then we I shall discuss about some very special gear, in this special gear, what we find? The outer ring gear is fixed and a in pinion, it is moving apparently, it is flexible, yes, it is a flexible gear and hear the tooth difference is only true and we get the reduction in the order of the tooth number of the ring gear divided by two or tooth number of the pinion divided by two depending on which one is fixed; fixed mean rotation of it is about it own axis is restricted ok.

So, depending on that and this is called harmonic drive with more or less similar motion, we will also find the Wankel engine in case of Wankel engine of course, the tooth are not like involute which is possible with in harmonic drive this is called cycloidal teeth and this is, but this is also a gearing action.

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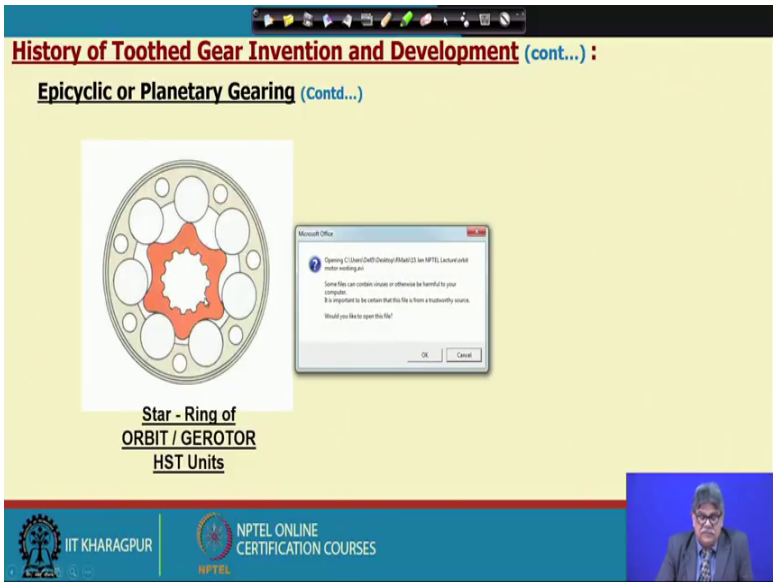

And if we come next to another machines where we have distinct teeth in this case we have seven theme outside and six lobes profile inside the inner one is called star outer one is called ring.

Now, this also can be brand at in epicyclic manner particular the unit which are showing that is used in used as hydraulic motor very high torque low speed or low torque low speed high torque machine if we look into this.

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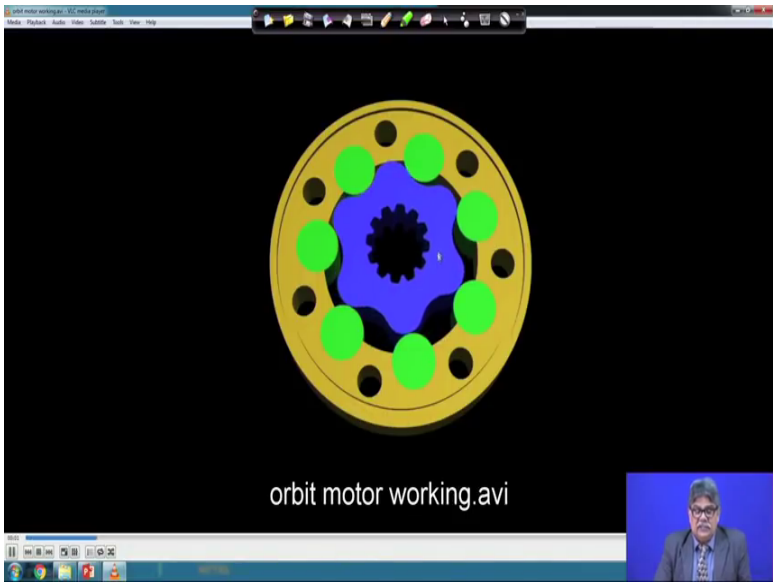

Their motion, then it moves something in this manner the star is moving in this manner now particular this machine is that the oil is the oil is pumped into the chambers which is formed by this contact and then this started rotating the output is taken through a cardan shaft from the star ok, but if we consider these are also the teeth gear teeth this is a class of c ycloidal teeth which is called a epitrochoidal this profile is modified epitrochoidal and these pins are envelope of that envelop means it is conjugate to this one.

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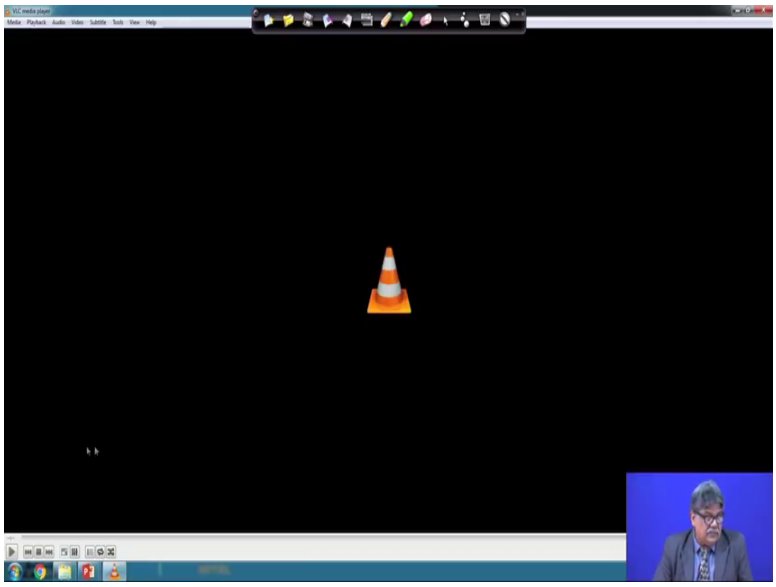

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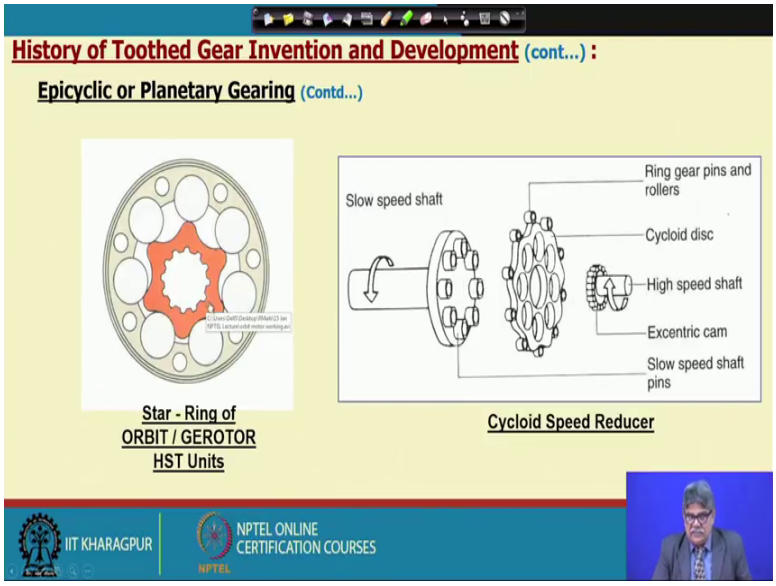

So, this gives also the gearing motion and with the same profiles that is a epitrochoidal profiles the gear unit is also available which is called cycloid speed reducer as you see here this is the epitrochoidal star and these are the loabs in the envelope which is essentially circular and the planet this is the input this is a cam sort of thing eccentric cam and the output is taken through these holes with the planet carrier.

The planet carrier is this one this is the planet carrier this is the lobe of the ring this is the planet carrier this is put inside the axis of the input shaft and axis of the output shaft will be in the same directions and these pin size and this whole sides differ by the eccentricity or which is the center distance between that. So, this will have two motion one is rotation about it on axis and another is revolving around the central axis like this one and this as I have already mentioned this is called cycloid speed reducer.

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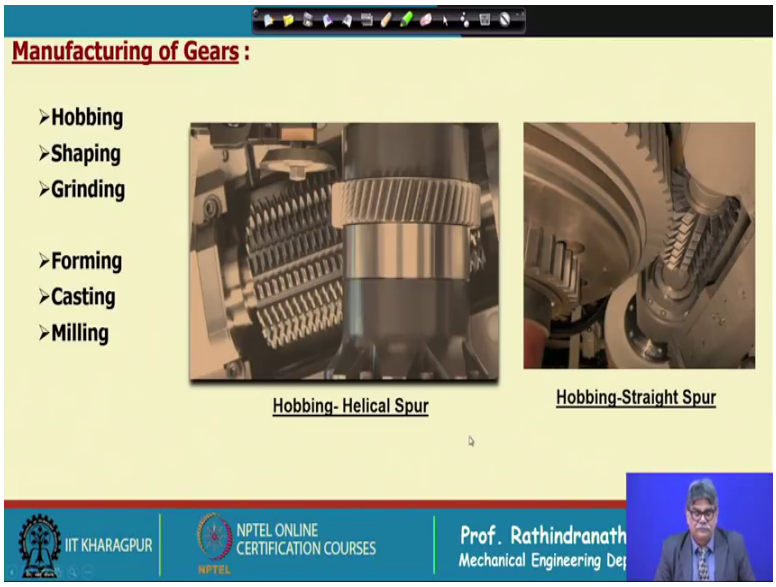

Now, if we look into the manufacturing process of processing then first of all the blanks of the gears are can be readily cut form a stalk or it can be forged it can also be cast after casting then we have to go for Hobbing and if we think of the strength of the material with respect to heat treatment Hobbing is possible up to certain hardness. So, sometimes the blank is raised to that hardness and then it is Hobbing.

So, here it is shown that Hobbing of a helical gear this is the helical gear and this is the cutter this is a helical gear and this is the cutter this cutter, cutter is like a thread sort of things and with a cut here to leave the materials and while this is set the hob cutter is set

an angle that is calculated from the angle of the helix and the lead of the or you can say yes the lead angle of the hob cutter ok.

So, that is a different subject manufacturing, but still I have shown here how the Hobbing is done and this Hobbing is also possible to generate or make the state spur gear this is the state spur gear. So, the hob it state in such a way considering the angle of helix is equal to 0. Next comes the shaping if we think of the shaping and Hobbing process these are called the generation of teeth it is not exactly milling it is generating in the in the teeth by cutting process here the this hob rotates as well as the blank also rotates and then hob gradually come down and goes half while it is cutting this material.

In case of shaping the process is that a tool that will move up and down as well as it will rotate and it will regenerate the gear it is we mostly use for only states power here; however, it can be used also for helical gear cutting now next the grinding this grinding is nothing, but it is like that this like a surface which is presenting the rack and then it rotates as well as the gears also rotates this motion, they are linked inside the machine by mechanism and in that way tooth are ground, but the profile is maintained.

Now, apart from that it is also possible we can form the teeth that is the hot rolling of the teeth that is can be formed in some cases it is it may be also cold rolled then; obviously, the casting where the speed is not much not much accurate gear also we can go for casting gears very slow speed gears as well as we can go for the milling in this case, we use the form cutter to generate the teeth and sometimes which is cast teeth that is also milled after casting.

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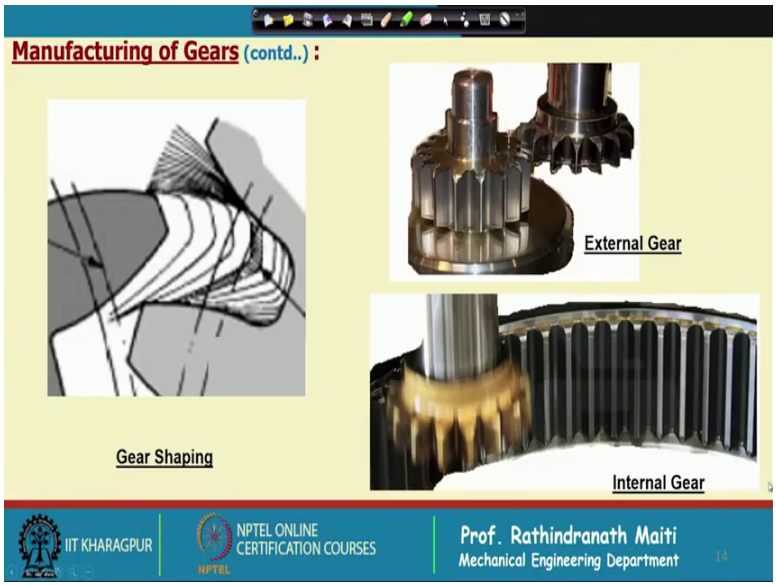

Now here it is shown that indeed why it is called general editing process because the here the cutter is moving it is rotating as well as it is going and up and down, but while it is moving the this surface is gradually moving to cut the profile which is practically generating this profile. Now, if we look into the generating process, then this is the cutter and this is the teeth is being cut this is moving up and down as well as it is rotating in a relation to this gear; that means, suppose here the cutter is having 20 teeth and it is cutting 40 teeth.

So, we can consider as if this is pinion and this is the gear we have to give this motion between the cutter and this gear blank and then this cutter move up and down and this centre distance initially it is kept the largest when the cutter is just touching the bank and gradually it can come inside to up to the root point then this is shaping of the internal gear is also done in the same way keeping this cutter and the gears in a in a relations and this cutter moves up and down, it is also possible that we can cut the internal gear by Hobbing methods, but that is a special Hobbing and we cannot go for very high helix angle for the internal gear, but it is possible.

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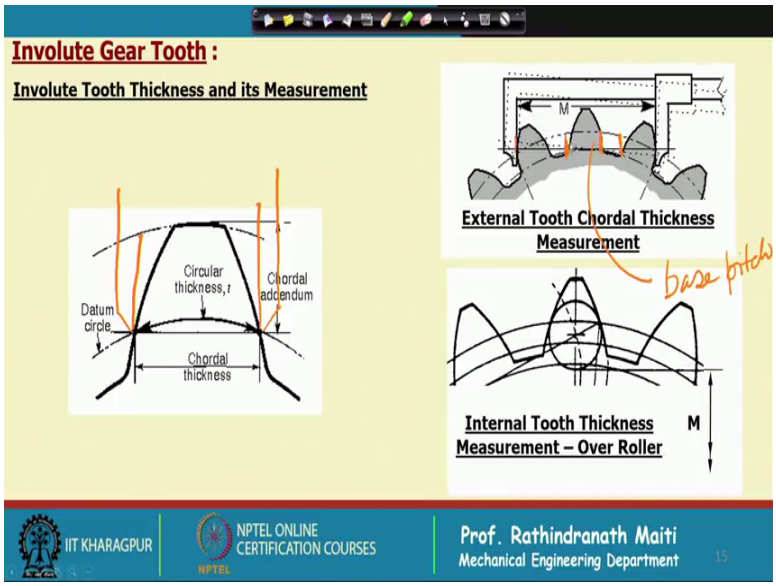

Now another issue is that measurement of the gears, gears are manufactured then how we can know that it has come to the proper shape first of all coming to that measurement we shall consider you see this is if we consider a gear teeth uncorrected in that case this arc to thickness is half of the pitch circular pitch and the chordal to thickness is that straight thickness and this height from this point to this point is called addendum this point to here the; that means, this is called addendum, but the chordal addendum will be more which is from this line to this line it can be calculated that will be shown in the tutorial how this can be calculated.

Now, while we are measuring the tooth thickness one possibility is that we can set a calipers to this height of the teeth here say for example, on this we can set the height and then we can measure this distance, but this will not be very accurate only during the manufacturing process one can measure this distance and then can we he can assess that whether the further cut is given or not, but final measurement is done by measuring the length over teeth in this case, it is shown this is 3 teeth and it might be more depending on the if there is a gear size is more minimum three teeth is required and then if the gear size increases then the number of teeth also increases.

But interestingly if we consider say this from this point to this point this must be base speech similarly from this point to this point base speech. So, this means that if we consider to base speech minus the thickness of the tooth at base or at one thickness at

base that will be the total measuring length. So, depending on teeth and if we know the base speech this dimension should be known because this surface is touching these involute profile here ok.

So, this will not have the error like measuring at a depth next to that if we would like to measure now this is this measurement is also possible that we can put a pin here, we can we can measure also the state by measuring the pin both on the external gear, but in case of internal gear we cannot measure over the teeth what is done in case of external gear and in the in that case best method is that putting a ruler inside.

If we know the equations for the thickness of the tooth at the tangent point which can be geometrically calculated then measuring the distance between 2 pin in the opposite sides, we can calculate what will be the thickness of the tooth at a particular radius ok. So, that is the measurement techniques.

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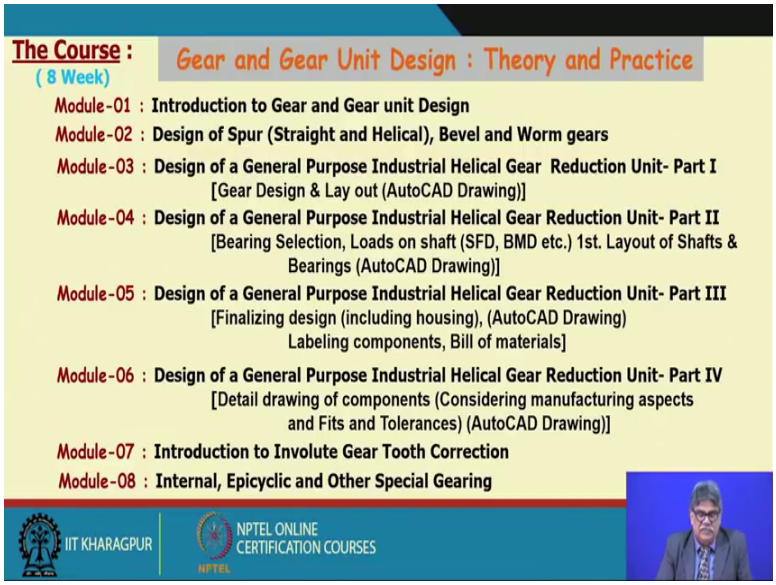

Now, with this brief introduction about the motivation, then I am coming to the course this course is 8 week course and then first week this will be on introduction to gear and gear unit design and next module or next week will be on design of spur straight and helical gears bevel and worm gears also.

Then module 3, 4, 5 and also 6, this will be devoted on design of a general purpose industrial helical gear reduction unit, first of all, we will design the gear unit and then we

will design the gears and then we will select the bearing shaft and also stage by stage it will be shown how the drawing is developed and finally, it will be shown how the detail drawings are done and is dimensioning is also done.

Next after that in module 7, we will go for a little bit about the introduction on the involute gear tooth correction and finally, there will be some special topics internal epicyclic and other special gearing.

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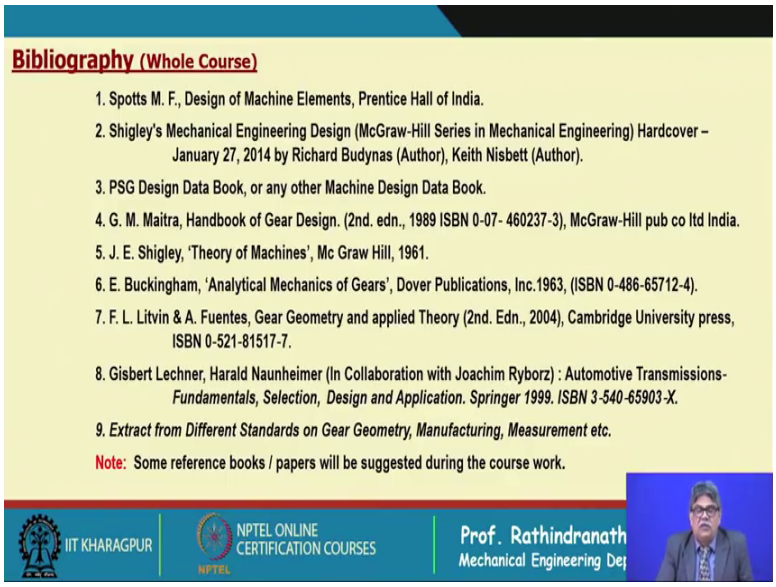

Now, as such the references and bibliography concerned to develop this course I had to consult many many books and many many references, but these few are among those which are mostly referred apart from that there are few published papers I have followed and also there will be some reference books and papers which will be given during the course there are also some standard which is on gears which has been followed to prepare this course.

Now, in the lectures; the what the calculations has shown that are sometimes; this is not cross checks there are might have some error some here I believe that it is mostly flawless, but still if it is there that can be later rectified through the discussion over the forum or from the queries from the participants.

So, with this I thank you and from the next lecture, we will go into the detail of the gears.