Fundamentals of Industrial Oil Hydraulics and Pneumatics
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Lecture 29
Module 08
Design Analysis of ORBIT Motor - I

Welcome to today's lecture Design Analysis of ORBIT Motor, this is lecture 1 on orbit motor when we should discuss about basic design and feature. And this is under the module 8 which will cover some special topics on hydrostatic transmission unit and system.

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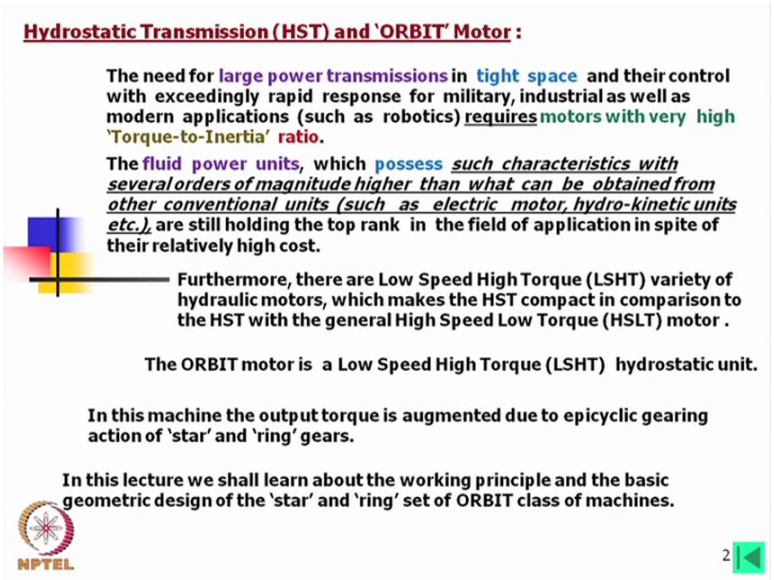

Now already we have discussed that large power transmission in tight space and their control with exceedingly rapid response for military, industrial as well as modern applications such as robotics requires motors with very high Torque to inertia ratio. The fluid power units in general, which possess such characteristics with several orders of magnitude higher than what can be obtained from other conventional units such as electrical motor, hydro kinetic units, et cetera. And these are still holding the top rank in the field of application in spite of their relatively high cost.

Furthermore, there are low speed high torque variety of hydraulic motors, which makes the HST compact very compact in comparison to the HST with the general high-speed load torque HSLT motor. The orbit motor is a low speed high torque hydrostatic unit. In this lecture we shall learn

about the working principle and the basic geometry design of the ‘star’ and ‘ring’ set of ORBIT class of machines. In this machine the output torque is augmented due to epicyclic gearing action of ‘star’ and ‘ring gears.

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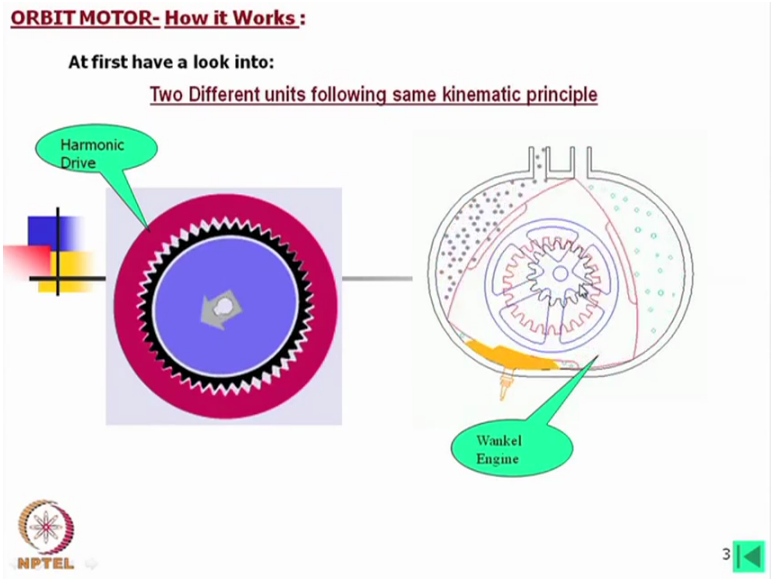

Now at first, look into 2 different units following same kinematic principle, this is to understand how the orbit motor works, Now this is harmonic drive where what we find the outer member is fixed, inner member which is a flex gear, it is rotated by a camp and if we very slowly observe very closely observe then what we will find that this flex gear is rotating at a very slow speed, in turn it is transmitting very high torque. The ratio is nothing but the teeth number in the flex gear divided by the difference of the teeth, in this case which is true and suppose there is a 100 teeth of flex point then in a single stage we will get reduction of (())(4:19).

Now another machine which is Wankel Engine, here we observed that more or less similar pattern of motion. In this case what we find that inside like a triangle which we can call 3 lobes or 3 teeth is rotating inside another somewhat oval and if we observe it is having 2 lobes the identical if we draw a vertical line, the right-hand side will be identical with the left hand side that means this is the 2 teeth, here inside 3 teeth outside 2 teeth, this is also a gearing option, the inside gear for the transmission, forget about this part.

But what we find that this space is increasing and decreasing, it is expanding and compression mode and you can imagine that in in one chamber the fuel is being injected then this is being the

ignition and then the combustion and it is going out, in that way the Wankel engine motion is available.

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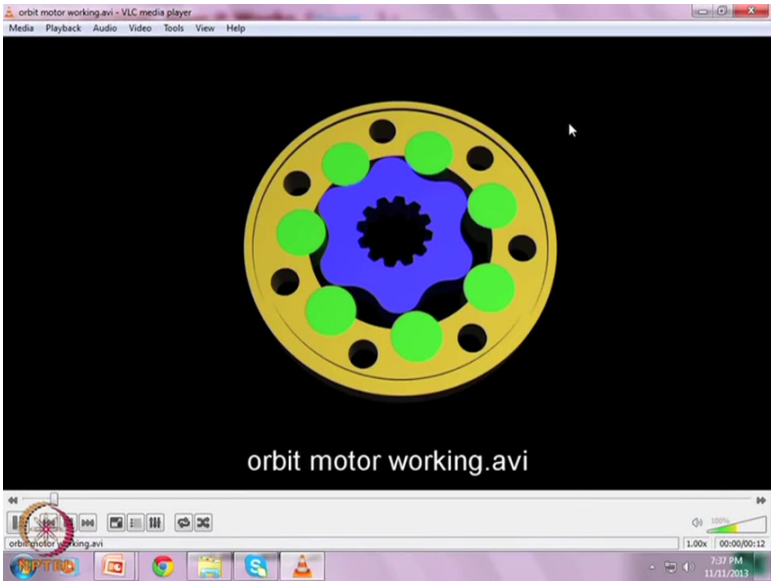

Now with this Wankel engine if we compare, we can think of the machine which I shall discuss today that is orbit motor. But here what I have shown that there is an inside member and there is an outside member, the inside member is called star and outside member is called ring. Now in comparison to this Wankel engine if you compare with this Wankel engine, here is also the similar motion is possible and we will find that the chamber between these 2 contacts and this space is going compression and expansion so this also can be used as an engine or maybe motor.

Also if it is in this case what we find the outer member is fixed, inner one is rotating okay. In this case also if we do it like that then we will find the similar action but the difference is that, in this case outside 2 lobes inside 3 lobe, in this case what we find outside 7 lobes, inside 6, 1 less, in this case 1 more, I shall come later why it is like that but let us see what is happening there.

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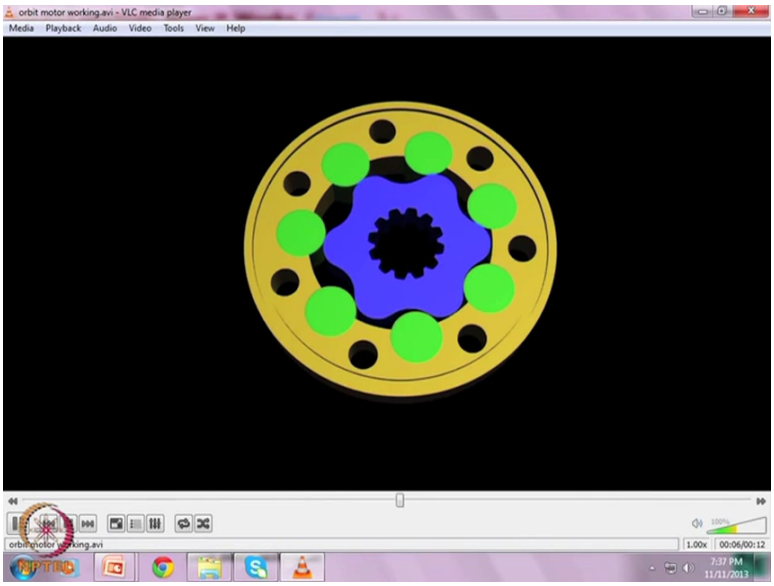

Now look at this, this is in the same fashion it is rotating what is in Wankel engine or what even in the harmonic Drive also and we find that this space is going under compression and expansion. So we can think of that we can pump out the oil but later I shall explain that using this as a pump unit is not beneficial, rather if we allow the high-pressure oil to come in like an engine and then if this is rotated we will get both motor action and as well as gearing action and which will give us the high torque low speed machine or low speed high torque machines, which is called orbit motor .

However, it is also possible if we keep these 2 axis fix and allow the outer member to also rotate when the inner member is rotating, in that case this expansion will be also expansion and compression will be also be there, but the output will be at higher speed which is termed as Gerotor unit or Geroler unit and in that case this will act as a high-speed load torque hydrostatic unit which is motor or pump.

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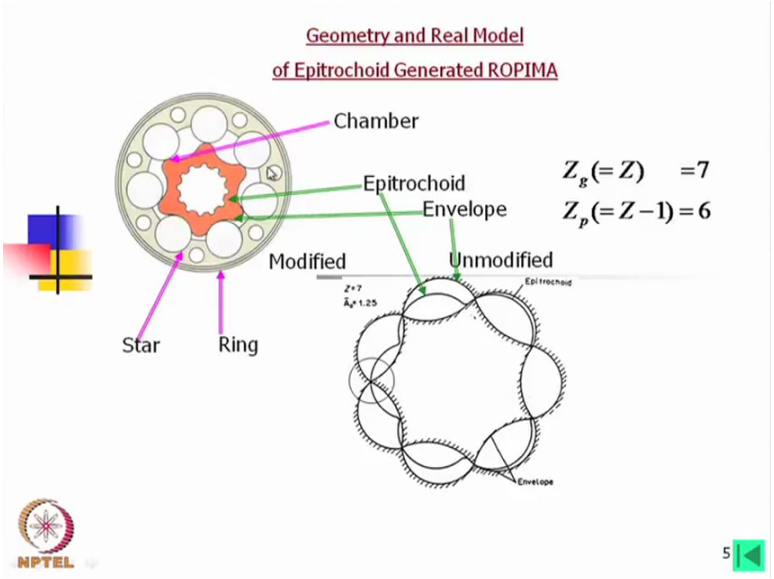

Now here I have explained that these are the chambers, this is between these 2 contacts which are active contacts and this roller and this space is an area, variation of area multiplied by the constant width will give the variation of volume. Now this profile is called Epitrochoid, it is modified Epitrochoid whereas this profile the outer profile is called Envelope and this is ring and this is this one is Star, perhaps this is slightly displaced but you can understand easily. However, this Star which is in Epitrochoid, the ring will be Envelope of this. Now here what is shown if this is the Epitrochoid which is not modified, this is this we should consider as modified and this one is not modified?

Now if this same motion is generated of this profile, then we will find that this will generate a profile either like this or like this, how? If we make this one as a solid cutter then we will find it will make a profile like this which is actually Envelope, motion is same as like this what you have seen just. Or if we make this is a hollow cutter, hollow cutter do you understand? Say let us consider a cylindrical body and inside shape is like that this portion is hollow, in that case this will generate a profile like this. Now what is there, if these points are called chronobed, in that point if we fix a circle then what will happen fixing the circle and taking shape either outer one or inner one anything only.

Let us consider the circle, the circle is we allow to rotate give the reverse motion then we will find a profile which is parallel to this just like this I mean parallel to this, inwardly shift profile

okay. So this profile is the star profile, whereas this roller becomes the envelope of this so it is not easy to grasp just from a single lecture, if you read then you will be able to understand, you have to visualise this. Anyway, in that way these profiles are generated and this is a very simple machine but very effective to give high torque at low speed.

Now in this case we have named Z g is the lobe number or say teeth number of the ring gear and Z p is the lobe number of the star gear, we can call it gear, this is outer one gear and this is pinion. What we find in this case inner one is 6, outer one is 7, now these 2 numbers should be consecutive numbers always, if this is 7 then 8 but making this is 8 and this is 7 means number of Chambers will be 8 so even number which is not benefited. So always you will find that ring gear lobe number is 7, 9 or 5, something like this, whereas this is even number 1 less than the outer member number okay.

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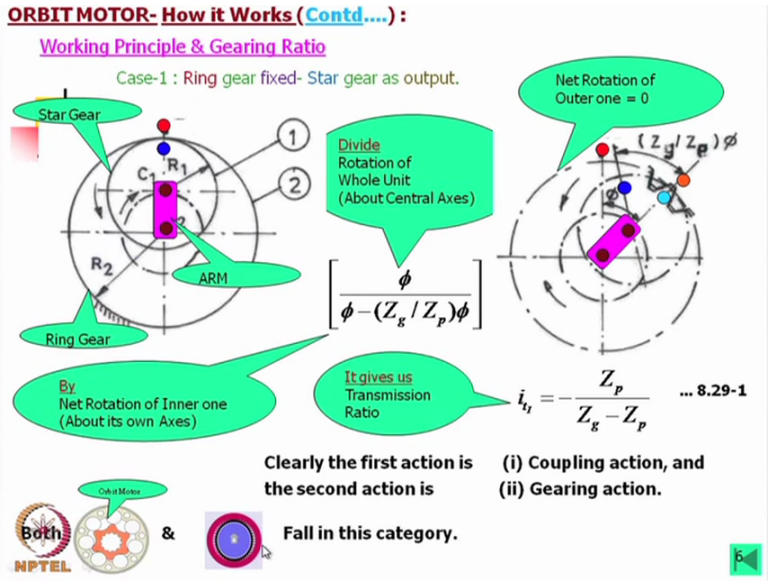

Now let us see the working principle, the 1st case we shall study the Ring gear fixed-Star gear as input. Now these 2 circles, these are we should call base circle if it is in terms of involute teeth in, if it is of other teeth usually this is called describing circle say cycloidal teeth, in that case it is called describic circle. What I have mentioned, the teeth are here, the Epitrochoidol teeth which is from the family of cycloidal teeth and this motion is called Cycloidal motion. In that case the outer one is the describing circle of the outer member that is in this case envelope ring gear, and inner one is the describing circle of the inner member that is Star member.

Or if we compare with the harmonic drives then this is the base circle or the describing circle of the Flex gear, the outer one is the base circle or describing circle of the outer gear the ring gear. Now we have taken this, 2 describing circles which you can consider the drum equivalent drum, even if this you may consider the pitch circle, pitch drum of these 2 gears. So this means that whatever motion we have observed, whatever motion we achieve from these gears that can be shown by 2 friction discs; one is the hollow one and one is the solid one. And if we consider the sliplel motion, it will show the same motion as in case of orbit motor or harmonic drives.

Now this is the ring gear representing ring gear and what we have in the we have taken this case the outer gear is fixed, ring gear is fixed, inner gear will rotate. Now this outer one is the star gear, now next imagine the arm okay so this arm means on a single plate you can say that this is pivoted, this gear is pivoted here and this pivot is gear is pivoted here. Now what we do, we consider 2 points on these 2 gears, now in next phase what we do, we give the whole unit a angle Phi this angle motion okay. So what will happen, these 2 points are here, these 2 points are here and next moment what we do, we bring back these points to here keeping this arm fixed what we do, we just simply rotate back this point to here.

Now this means that this gear again is rotating in the opposite direction anticlockwise direction by the same angle, what will happen the inner one has to rotate by this much angle. What is that? This is Z g by Z p, which is equivalent to their radius R 2 and R 1 we can put R 2 = R g, R 1 = R p so that ratio is this one. What we can see from here, while this is rotating in the opposite direction, this has to rotate also in this direction and this arc length and this arc length has to be same and if we equate, we will find this gear has rotated by this much okay. So as we have taken back this point to its original position we can say the net rotation of outer one is equal to 0 okay.

Then what we find that the 1st action which we have given is the coupling action and the 2nd action is gearing action that means what we have done in this phase that is the gearing action. In case of all such machine you will find that gearing action is actually happening in the opposite direction and it is happening simultaneously, so we have to consider while we are going for the gearing analyses for the gearing portion which one is driving and which one is driven and where is the contact, to analyse we must understand these 2 actions. These 2 actions simultaneously giving the action of harmonic drives or gearing action in orbit motors okay.

Now to find out the what is the transmission ratio what we do, divide rotation of whole unit about central axis by the net rotation of inner one and equation wise what what we will find, we have first given this rotation so this we can consider the input and this is the net rotation of this unit inner one by its own axis, First it has rotated in this direction by this angle and next it rotation by this angle in the opposite direction, so difference of that is the net rotation of this one.

So this is definitely giving the speed ratio, if we equate further we will get the transmission ratio which is equal to Z p by Z g – Z p, so this is the difference of the teeth number and this is the teeth number of the star, and '–' sign is coming to the fact that while the input in clockwise direction, the output will be in the anticlockwise direction so this is the total transmission ratio what we will get out of this pinion the Star member which is the output of the harmonic drive which I have shown and the output of the orbit motor which I have I have shown okay. There is another okay this what I have shown here these 2 these 2 falls in the same category okay both the orbit motor this harmonic Drive falls in the same category.

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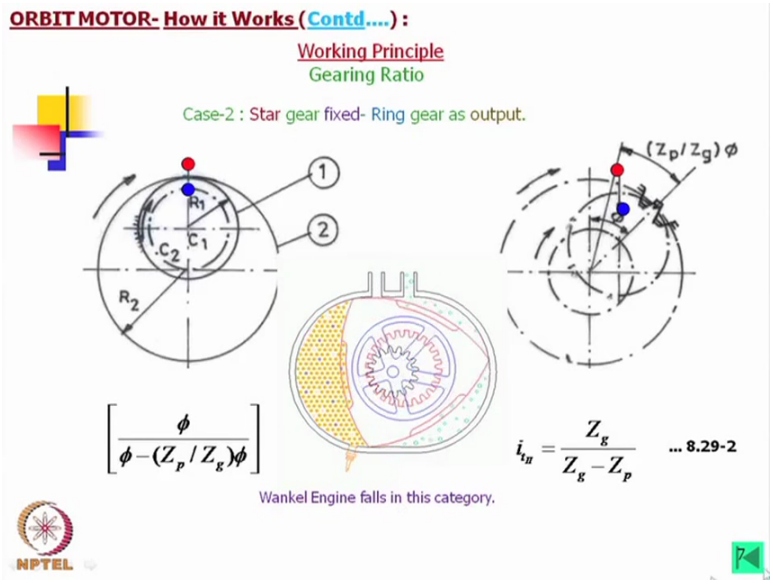

Now another possibility is there that we can keep the inner member fixed and output is taken through the outer member. Now the arm is as you have seen so we have to definitely this will be central axis, in that case what we should consider the rotation of the inner member Star member about its own axis is restricted that means it is not allowed to rotate about its own axis whereas this can able like this. This is possible because imagine a the current shaft or universal joint, now

holding the universal joint you can rotate the other member like this, which is not allowed to rotate about its axis, so this motion is possible.

Now here is what we have done like earlier case, we have again taken these 2 points, in this case what we have done the inner member we have bought it back to this position so outer member has rotated by this much angle Z p – Z g by into Phi this means that R 1 by R 2 by Phi okay. So definitely this angle must be less than this angle because this arc length when it will cover on this larger circle, it will rotate by smaller angle. This is as you see this almost in a line, it is not that this will rotate slightly in this direction, but ultimately this motion of the outer body will be in the clockwise direction, we can consider this is fixed, fixed pin rotation about its own axis is arrested okay.

So this is rotating in the same direction and the transmission ratio if you derive it will come as like this, so this is the transmission ratio of this one. In this case what we find, at the numerator the number of lobes or number of teeth of the outer ring is there and at the denominator the difference is there. And in case of orbit motor you find that the difference is always one so if this is 7, this transmission ratio will be directly 7 okay. And in case of harmonic drives you will find this difference is true normally so if it is 100 then this will be 50, so as in 1st example I told that this Z p is hundred so this is hundred too so this will be 51 okay.

Now Wankel engine falls in this category, this means that actually this here what is the inner member what we are looking here that is basically the outer member or I would say that base circle of this is larger than the base circle of this one the outer member. How it is possible? This is possible if we cut the material by the opposite cutter, I have told you that while we are generating envelope once we are using that cutter as a hollow and solid. If we make this cutter as a hollow then inner member will be the envelope and envelope will have 1 lobe more than the outer member, Wankel engine is generated in this way. However it is not complicated but just combustion to grasp in a single lecture, but you just remember this thing that is why I have shown here, this Wankel engine falls in this type 2 category okay.

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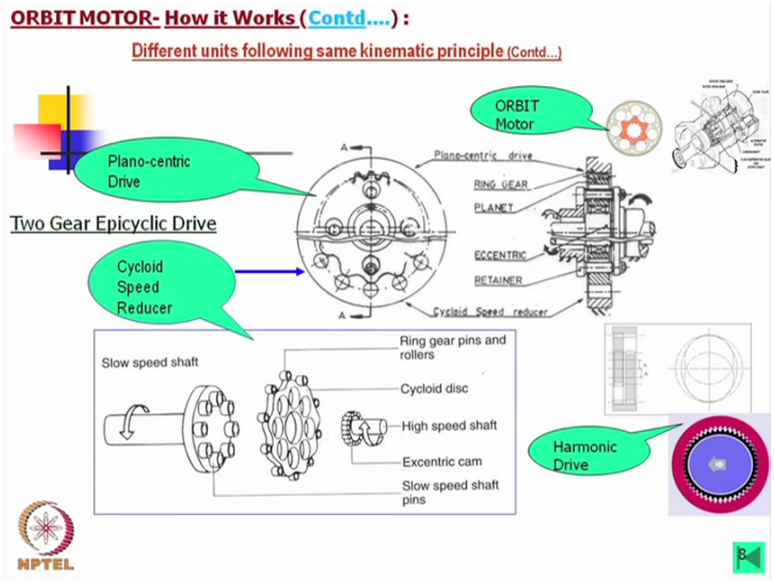

Now before going to the orbit motor, what we see this what is the working principle kinematic I have shown in that category the harmonic drives is there, orbit motor that is also falling in the same category then there is another machine which is called cycloid speed reducer that also falls in the same category. Basically this cycloid speed reducer and the orbit motor principle and tooth generation are more or less same, only this here the planet carrier is different because the torque is transmitted through the planet carrier. Also with the solid gears not harmonic drive with the solid gears we can have another gear drive which is called Planocentric drive.

This looks like, here what I have shown that bottom portion I have shown the cycloidal and the top portion I have shown the planocentric drive. And this planocentric drive and this drive is same, only thing is in this case we are using fix gear because making the gear fix we can go for 2 teeth difference whereas in this case we cannot go for 2 teeth difference minimum 4-5 tooth difference will be there. Anyway that is different issue we are not going into that but the kinematics which I have explained that all such machines fall in the same category okay.

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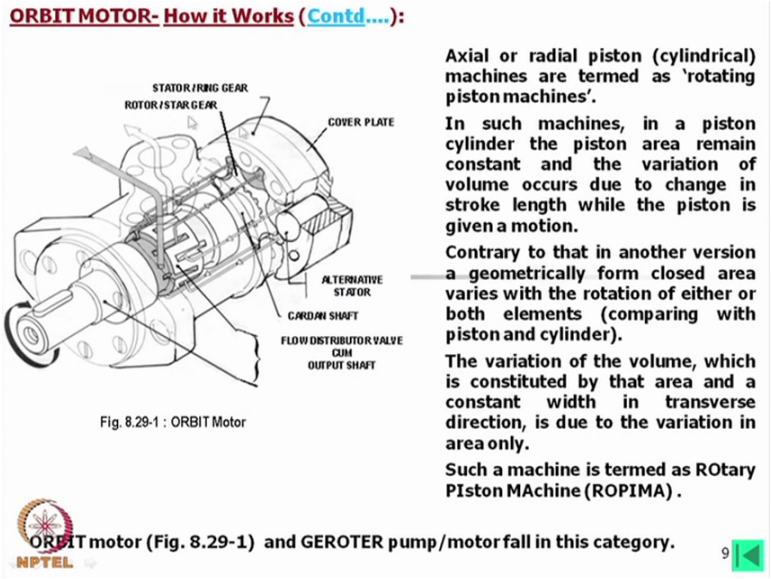

Now axial or radial piston cylindrical machines are termed as rotating piston machines rotating piston machines okay. Just this term is not very common, we are not it is not very popular term but still we can say rotating piston machine say engine is a rotating piston machine. In such machines, in a piston cylinder the piston area remain constant and the variation of volume occurs due to change in stroke length while the piston is given a motion. Contrary to that in another version a geometrically form closed area, where is with the rotation of either or both elements comparing with piston and cylinders.

The variation of the volume which is constituted by that area and a constant width in transverse direction is due to the variation in area only. This means that what the machine we have new machine in comparison to that we are talking about that variation of volume is equal to the variation of area into the constant width. So if we equate the time variation of the area that will give the volume displacement of the machines for a unit area sorry unit width. Such machine is termed as ROtary PIston MAchine which is called as ROPIMA.

Now this ROPIMA term is not normally known to people but Wankel engine I think Wankel he himself put this name Rotary Piston machine, contrary to the Rotating Piston machine this is called Rotary Piston machine. Now Wankel sorry the Wankel like Wankel engine, orbit motor also falls in this category okay. So this is the view of an orbit motor which I am going to explain now. Now in this orbit motor what we find that let us look again what is happening.

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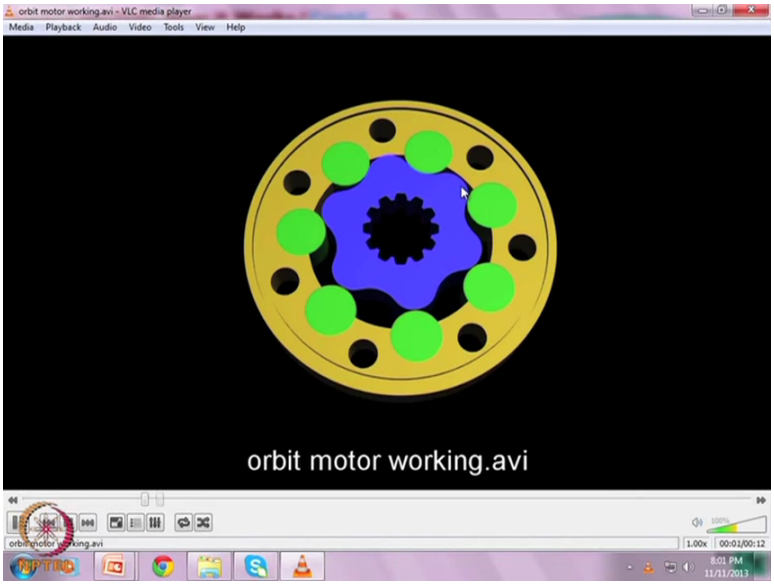

So this is the rotary motion which we are taking as an output, but this is being rotated by allowing the oil high-pressure oil to come in okay. Now with respect to that if we look into this machines say this is the star member and this is the envelope the lobe member, this member can be integral part or we can use separate roller.

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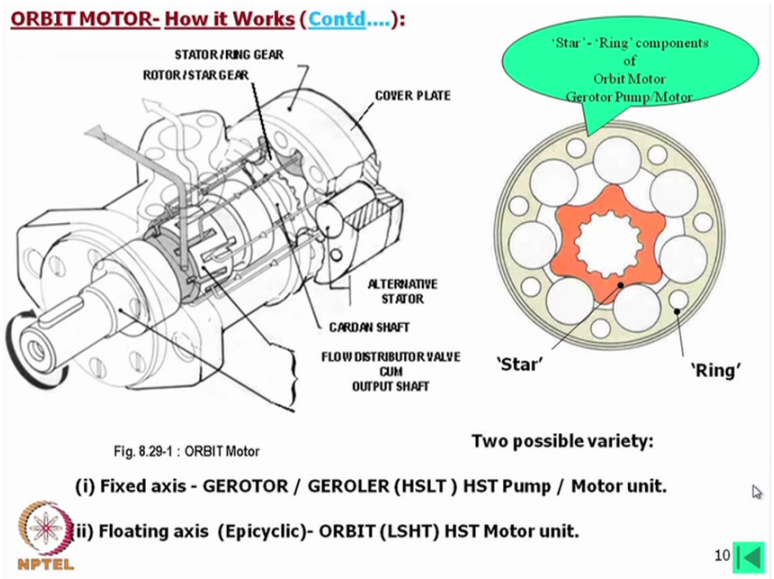

Now what is there, this torque is connected to a shaft by a joint which is called current joint current shaft, this is principle wise it is same as the universal joint. Only in this case this is 2 gear coupling at 2 sides, one is inside this shaft, another is on this star okay. Now this shaft is integral

with the flow distributor valve, in that valve what we find I shall describe the valve function later a little bit but at this moment just look at this, the oil is coming through the outer body to this pocket, then there are few slots on the shaft on this valve and through this slot it is going inside the chamber, the passage is allowed to oil go into this chamber and this oil will go only when this is in the expansion mode and when it is in compression mode, the oil will come out through this passage and it will go out so in this this way here this motor functions okay.

Here what I have shown that this is a cylindrical lobe which also can be made integral one. Two possible variety out of this star and ring; one is that fixed axis Gerotor or Geroler high-speed low torque hydrostatic transmission unit which is pump or motor. In this case this axis is fixed, at this is also fixed, usually what is done say a shaft is connected here, a shaft is being rotated and this is also allowed to rotate about its another body and then you will find these chambers are varying, we need not (())(34:19) shaft in that case okay. Usually you will find out a member in that case Gerotor or Geroler are even fixed and then this can be used as a comparable motor because motor action is just reverse action of the pump.

And if we ask the orbit motor why it is not used as a pump? This is basically high torque low speed machine, now if you would like to use this as a pump work for the same pumping action we have to transmit very high torque at low speed say using an engine means that engine we have to maybe we have to use a reduction gearbox to run this as a pump which is not benefited so usually this version this epicyclic motion version is always used as a motor. It can be used as a pump action but the different applications say for example, when this unit used as an orbital steering unit then a pumping action of this is also used there but that is different issue, in normal case this always as a motor.

So this version this 2nd version is the floating axis, actually this is an epicyclic gearing action is there epicyclic motion is there. This axis why we call this is floating because this is not in true sense not rigidly connected to any shaft because this is this motion of this guided by these contacts which is firmed close, this is called firmed closed. Always theoretically these points are with full contact, no gap in between neither it is a interference fit it is an interference fit okay, so 2 possible machines are possible with this arrangement.

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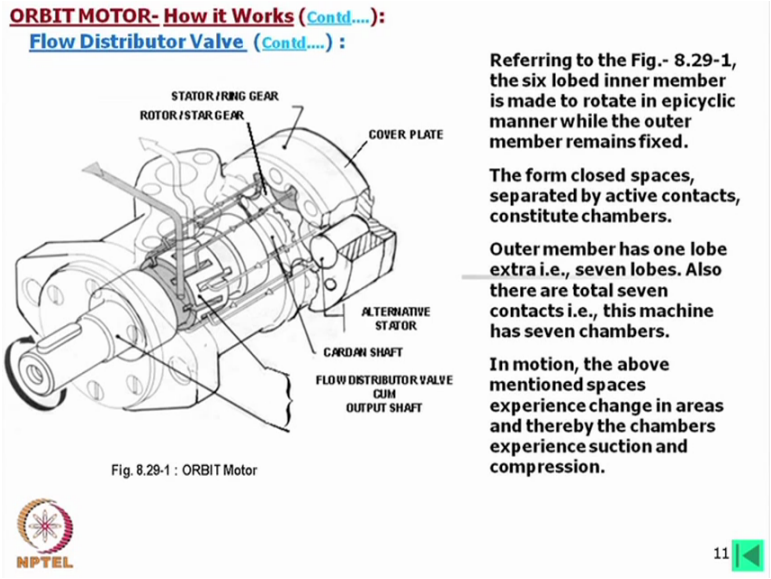

Now with this figure the in this case it is a 6 lobed inner member, so this is described the 6 lobe inner member is made to rotate in epicyclic manner while the outer member remains fixed. The form closed spaces the term is formed closed the spaces, separated by active contacts these contacts are called active contacts, constitute chambers. Outer member has one lobe extra in this case 7 lobes are also there are total 7 contacts 1, 2, 3, 4 you will find that there are 7 contacts and this machine has 7 Chambers. In motion, the above-mentioned spaces experiences change in areas and thereby the chamber experiences suction and compression.

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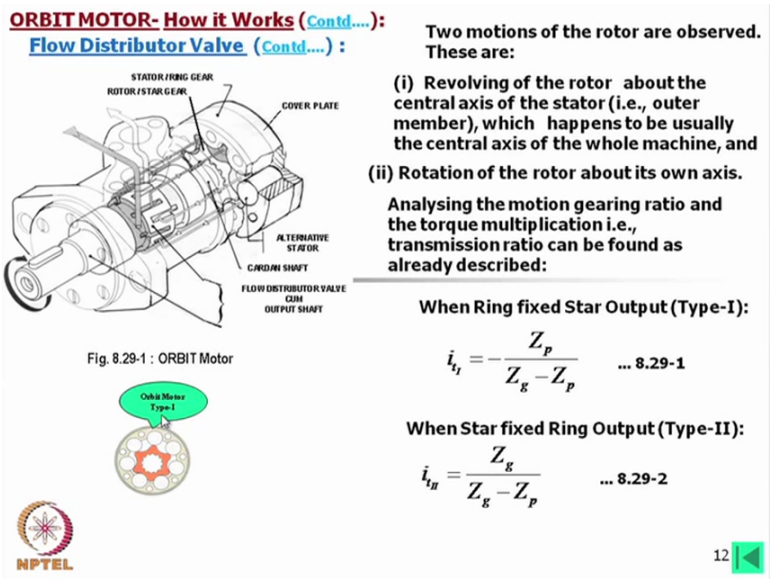

Two motions of the rotor are observed; these are revolving of the rotor, rotor means in this case star about the central axis of the stator, state means in this case ring gear here, which happens to be usually the central axis of the whole machine that means the axis central axis of the outer member is the central axis of the whole machine. Rotation of the rotor about its own axis, this member is having a revolving motion around the central axis and it has a motion about its own axis.

Analysing this motion gearing ratio and the torque multiplication that is transmission ratio can be found as already described that when the ring fixed star output the type one, the transmission ratio is the number of star member divided by the difference and when the star fixed and the ring is output, then the number of lobe of the ring divided by the difference. Only here this is a '–' sign that means these 2 motions; one is the revolving action and the output motion is in the opposite direction where this is a '+' sign means the evolving action and the rotation is in the same direction, so this is the orbit motor type one which we have we have seen already but still let us observe one second.

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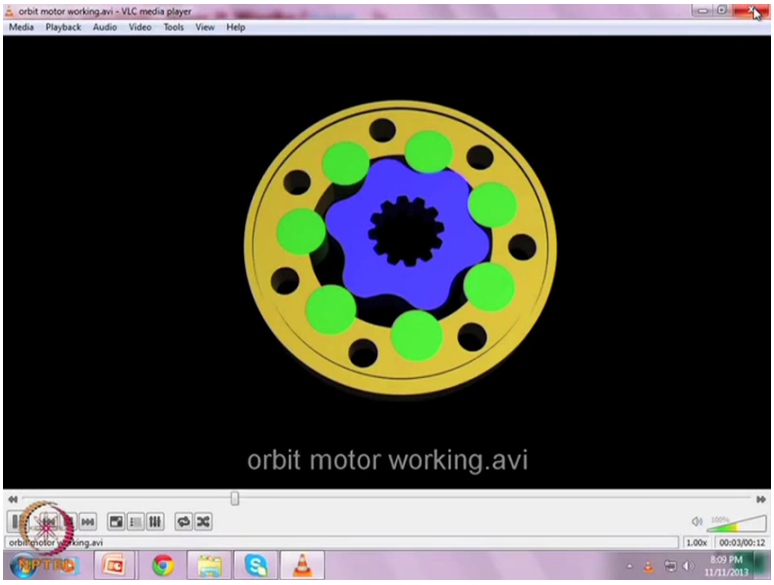

So this is the motion already which you have seen and this is normal case orbit motor. The outer member is rotated by holding the shaft, if you held the shaft in this case only thing you have to think of the oil connections and you will find outer member rotation you can use, that type of

machine is also used where the rotation of the outer member is used say for example, big merry-go-round in that case it is used okay.

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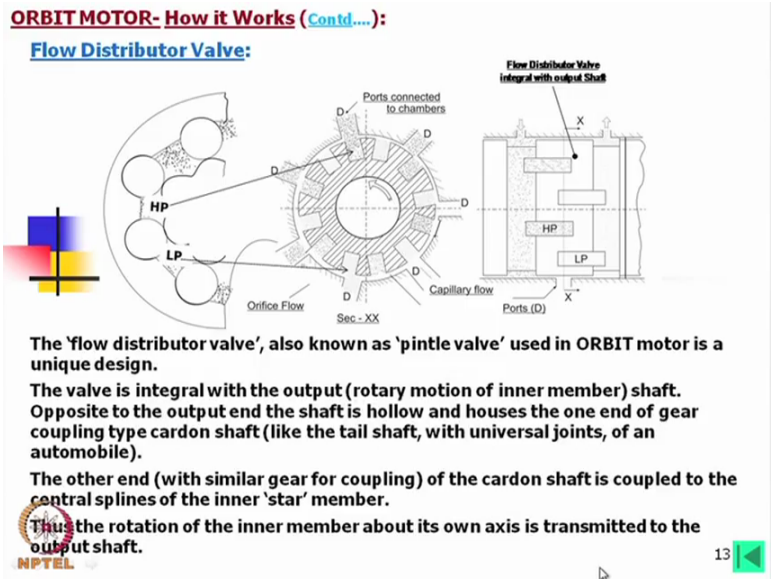

Now let us consider the flow distributor valve how it is working. What we find that this we have taken 6 number of lobes for this star member, 7 number of lobes of the ring member and what we find say this is the distributor valve, this is the valve cum the output shaft, which you have seen in the machine. And then if you observe that these grooves or these grooves, we have taken this section and these grooves, so alternative grooves are connected to these 2 slots if one is under high pressure other is in low pressure. Now what we find that this through one the oil is coming in, through another one this groove oil is going out.

And then there is on the body there is also connection through which the oil can either come in or come out, or in other words these grooves are connected to this passage, this passage are this one so these are finally connected to these chambers okay. Now if we count that these channels there are 7; 1, 2, 3, 4, 5, 6, 7 okay, whereas these slots are 12 so 6 in this direction, 6 in other direction. Now at a time if you observe, so this is completely blocked high-pressure connected to high pressure whereas this is open but this is connected to low pressure. Next if we come that high-pressure must be connected to one chamber, then next one is also connected to another chamber whereas this is blocked that means this slot is blocked.

Next this is also blocked whereas this is connected to another chamber and next this is block and this is also connected to a high-pressure chamber. What we find in this case, 4 slots of this out of 6 are connected to high-pressure chambers that must be in expansion mode and in between 3 slots are blocked which is in connected to low pressure chambers. Next you come here what we find that this slot is a low pressure slot is connected to one chamber then one high-pressure slot is blocked then another low-pressure chamber is connected to low pressure slot is connected to another chamber whereas another high-pressure chamber is blocked.

So what we find, 2 are blocked, 4 are open, 2 high-pressure are blocked whereas, 3 low-pressure slots are open to 3 chambers, there must be in compression mode oil is going out, so this is the beauty of this valve I do not know who invented this but very unique design. This flow distributor valve also known as “pintle valve” it is also called as “pintle valve” used in orbit motor is a unique design. The valve is integral with the output (rotary motion of inner member) shaft. Opposite to the output end, that means suppose this is the output end output end the shaft is hollow and the houses the one and of the gear coupling type cordon shaft, the cordon shaft is connected.

Actually if we consider say suppose this is the output side, just when the distributor valve is beginning that is at the junction, there is a coupling gear coupling and through the hollow side it is connected to the star so this is described here. The other end of the cordon shaft is coupled to the Central splines of the inner “star” member. Thus the rotation of the inner member about its own axis is transmitted to the output shaft.

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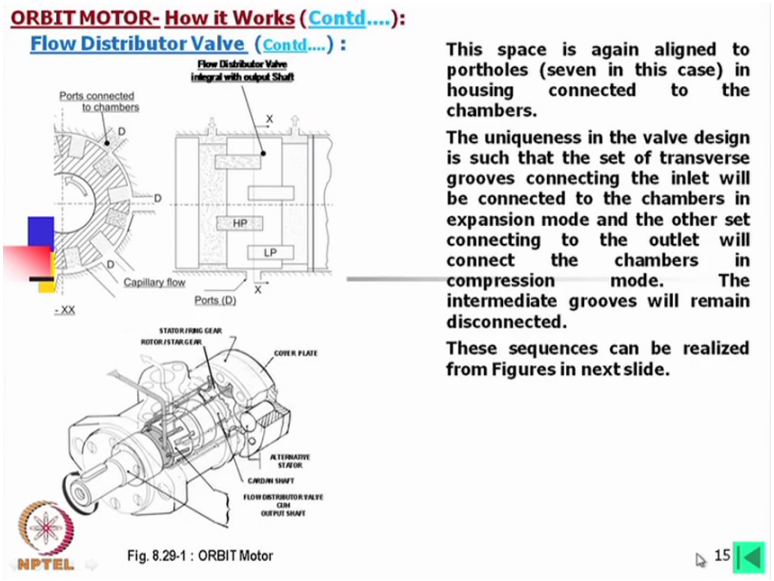

Now if we look into this valve, you can see you can compare this how this oil is going. Say these long slots through the body is these grooves okay, I will show also assembly of this machine where you will be able to understand. On the valve body there are 2 circumferential grooves which are aligned to 2 port holes which I have already described so if you read it you will be able to understand what I have just described about this valve how it is working. The uniqueness in the valve design is such that the set of transverse grooves connecting the inlet will be connected to the chambers in expansion mode and the other said connecting to the outlet will connect the chambers in compression mode, the immediate grooves will remain disconnected.

This means that there will be a sequence when one of the chambers is in neutral position then you will find in case of in this case where the 6 slots are there; 3 are connected to high-pressure, 3 are in low-pressure, 1 is in neutral okay. That neutral if it is first from the high-pressure force then 1 neutral, 3 high-pressure, 3 low-pressure, next phase it will come that 4 in low-pressure and then 3 in high-pressure then 1 chamber will be neutral but that is momentarily.

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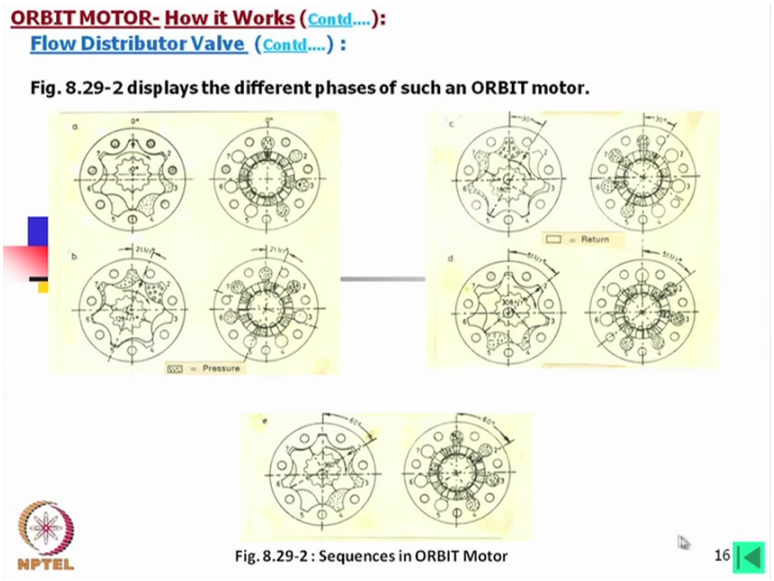

Now here I have shown the different phases okay, so you can say this what is connected to which groove through this, here is the star and gear and here is the valve and their connecting ports. So if you study this very closely the sequences will be understood okay. Here is also the angle is given that what angle this works, this this is, you can say this top dead at Centre of chamber. And the bottom dead say this is the bottom dead position of the chamber this the same chamber, here it is bottom dead centre, here it is the top dead centre, here is also at the bottom dead centre okay.

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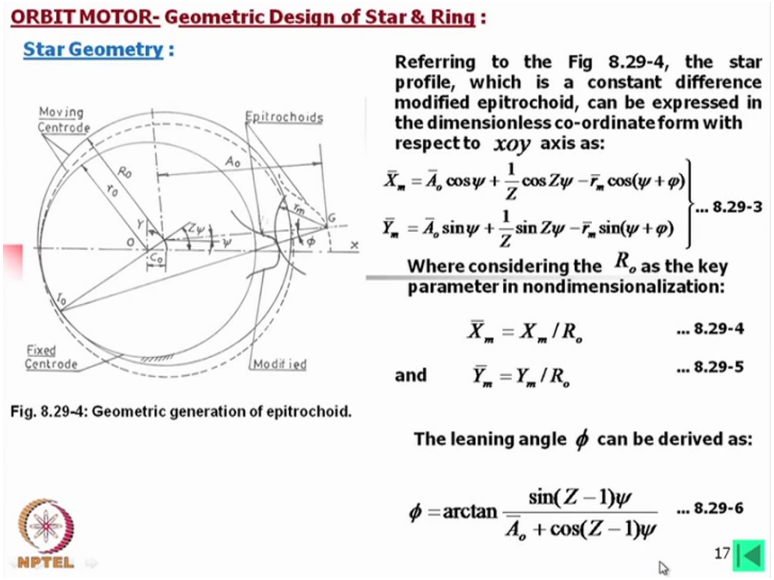

Now, how to design such a star and ring. In that case again we consider that this is the describing circle of the outer member, this is the describing circle of the inner member. What we are trying to do, we are trying to generate the lobes or the profile gear profile, what we should do? We shall keep the inner member we are trying to generate the lobe on this, this is the star member okay. So what we will do, we will consider this member as fixed and then this member is rotated about this axis that means this is just sliding over this, no slip and we have taken a point outside this rotating circle.

Say let us consider this is a hollow body that means a plate is like this and this side hole is made, then we have taken the generating point here. If the point is taken on this circle then we should call this is a epicycloid, the generating point if it is on the circle we should call epicycloid, we have taken this point outside, it is called Epitrochoid. Now this curve will generate a curve like this I mean this point will generate a curve like this as we allow it to rotate. So therefore we can have this equation of this curve by only forget about this portion, first 2 terms will give this equation of this curve where A 0 is the length of this arm.

Now we have used a bar, this bar has been used to make this formula dimension less, what we have done actually, we have divided these terms by R 0 which is the radius of the outer describing circle capital R 0 we have divided by that and we have made it dimensionless. This is A 0 by R 0 and this is r small r 0 by capital R 0 sorry this R 0 – small r 0 by this capital R 0. This you can easily this is geometrically easily you can find out, so we have not considered this part. Now, so this is to show this dimensionless form, now what we have done we have as I told that we can fix a curve between 2 nodes and then what they will find, that we will find another profile which is parallel to this that means inwardly shifted parallely shifted this profile and which will give the active profile the effective profile of the star gears.

And this is this is a constant then this this profile will be a circular arc. Now this profile you will find in that generating point will move that means when you are generating this curve, this can move in this this will move in this direction by maximum of this angle which is called leaning angle, it will move this side also it will move this side. Now to find out the equation of this point what we do, simply we take this radius and this is in this direction inward direction so '–' sign is there and this is the angle this angle + this angle, geometrically you can easily find out.

Now only thing this angle is the input angle of this rotation that easily we can find out but for each and every point we have to calculate this angle that is which is called leaning angle and this leaning angle can be derived by this equation so this is the all known values so you can easily calculate what will be the angle this angle

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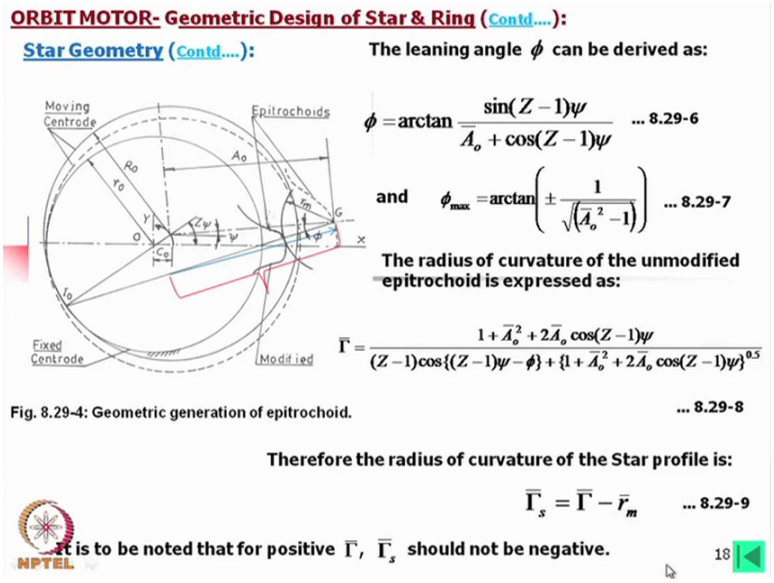

And the maximum of this angle leaning angle this already I have shown there so maximum of this angle is given by this one, so this will vary in this direction and move in this direction, also in this direction. Now for this each and every moment we have to find out the radius of curvature of this one because this r m should not be greater than this value, if this is greater than this value than this curve feasible curve will not be available. So each and every moment we have to calculate this radius of curvature which is given by this one.

Okay, so here it is specified therefore, the radius of curvature of Star profile is R s = that this is capital R – r m this is the radius of curvature, so this is the radius of curvature of these points this should be always positive. It is to be noted that this value should not be negative, the effective radius of curvature of this new profile should never become negative if it becomes negative then this curve will not be possible.

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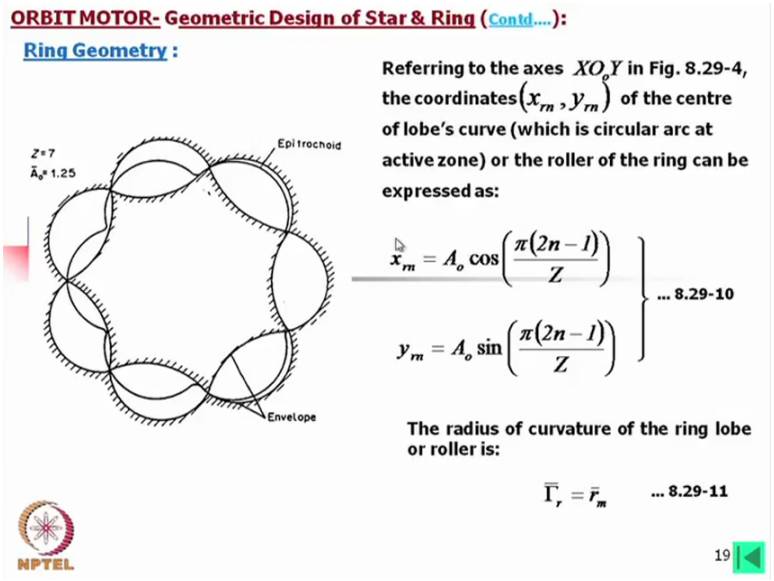

Now to design the envelope already I have described how this can be designed, now actually in actual machines we need not bother about these curves because these curves we are not using, we are using the modified curve which is nothing but an circular arc and the Centre is known, this centre can be easily calculated by using this formula. In actual design we are using the earlier formula to find this modified star profile and we are using these coordinates to find out these points where we can put the circular arc. Only thing between these 2 circular arc whatever the portion that we need to design, in case of the separate roller even we need not bother about that, we can take a circular arc, in that case we can make a groove and we can put the pin.

In case of integral one we have to see that tip of the star should not form the inner chamber otherwise it has no value, we can increase that space also like in (())(56:09) gears okay. So the radius of curvature of the ring lobe is equal to r m so this is known, if we go for test analysis, always we should take this at the contact the radius of curvature of outer member the ring gear is r m whereas, radius of curvature at the contact point is r s which we have to calculate, so now kinematic of active contacts, if we would like to observe this let us see.

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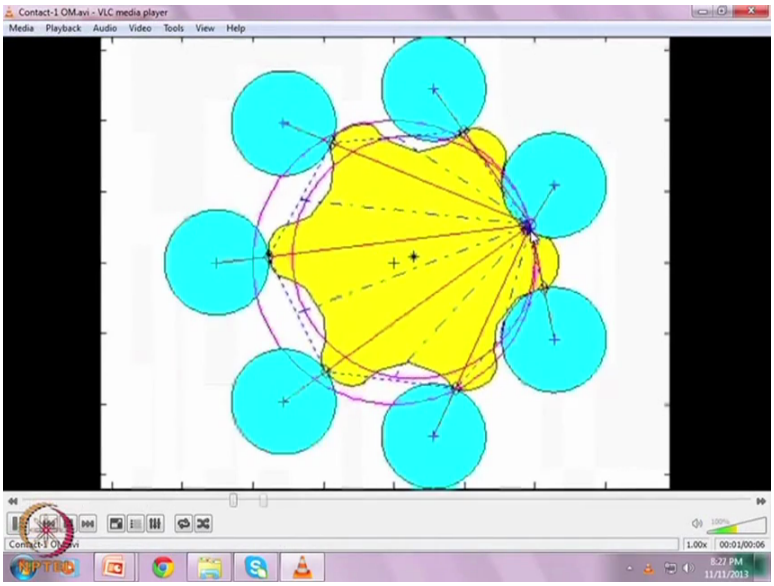

So as you can see that each and every contact point you can find out that this is the instantaneous center of rotation of this, you join this point to the Centre of this circular arc, you will find you will find this contact point so next day we shall learn how to calculate the contact point and what is the variation of this chamber. Simply you can calculate these 2 contact points, variation of this length will give you the variation of chamber volume okay.

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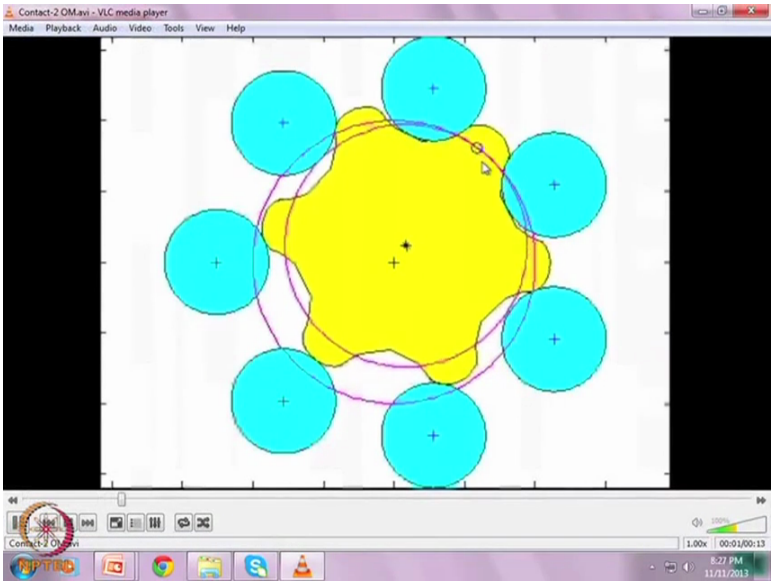

Now also we can observe the other as you see, this is the variation, you can see this is rotating in one direction whereas this point is rotating in the opposite direction and the instantaneous contact

point is rotating like this, so this will be required for the further analysis, volume displacement, stress analysis, et cetera. Now the last thing I would like to show you that assembly on the functional features.

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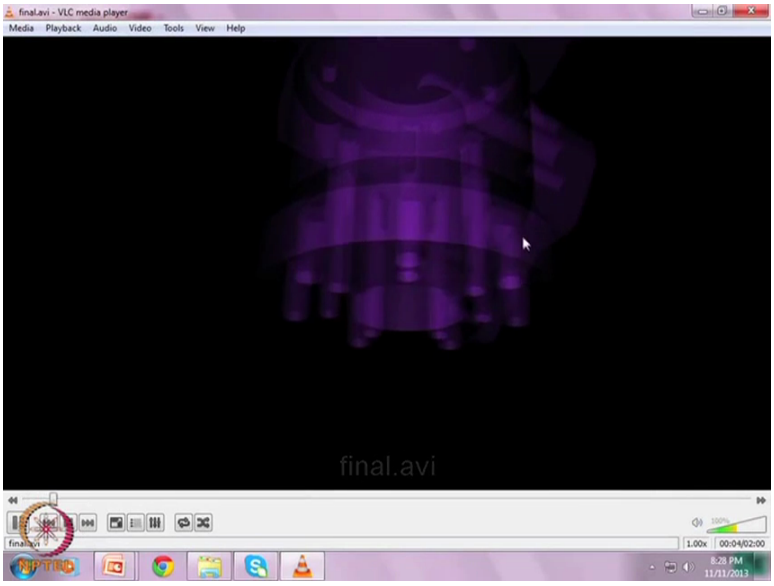

Now if you look into this, this is the body of the orbit motor, in that case this long hole that is the passage to each chamber and you can look into a key short type grooves through which the oil from the distributor valve comes into chamber and it goes back in the same way, you will find 7 such long holes as well you will find the 7 such short holes for fixing the star ring, etc.

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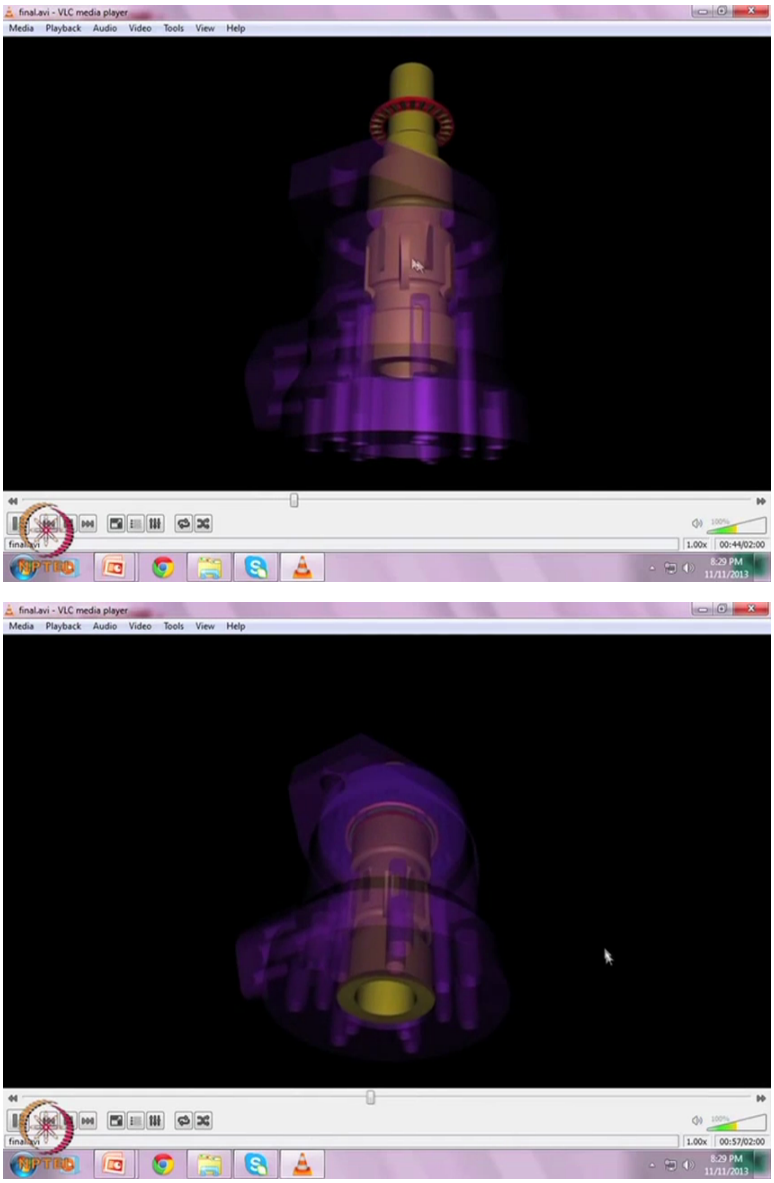

Now look at the distributor valve which is coming in, you can see these slots grooves are like this and these grooves mid position this common portion will match with these grooves, if you look into this this is matching.

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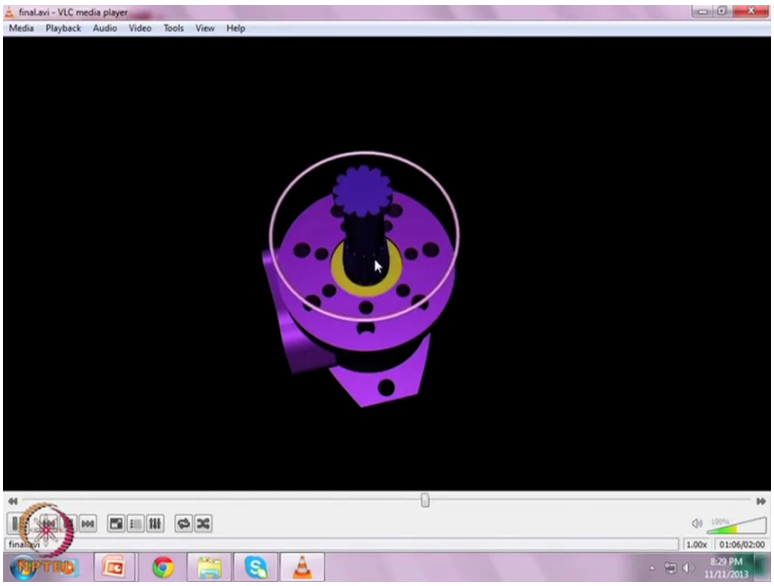

Now this is this side covers plate with a bearing, et cetera, then this is the cordon shaft, the other end side of the shaft there is a gear coupling so this is being engaged to this gear coupling and this portion will be engaged to the star gear and this is a groove where the oil seal is put to make it leak proof.

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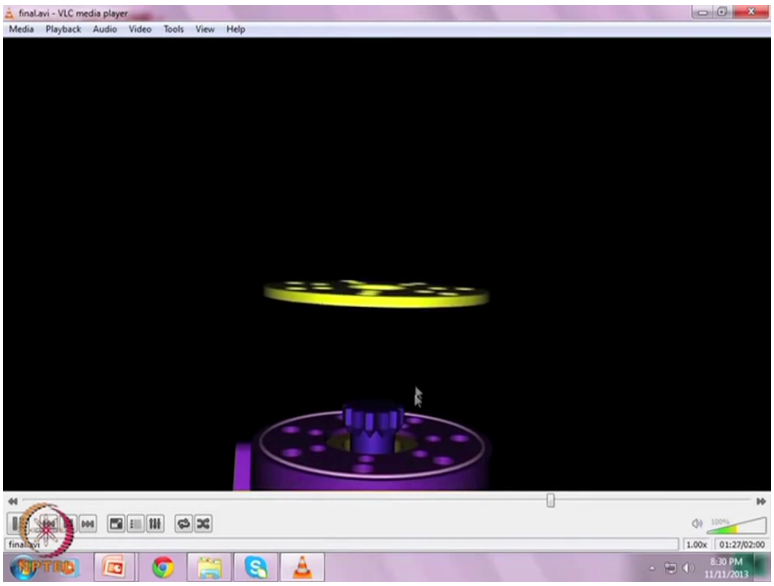

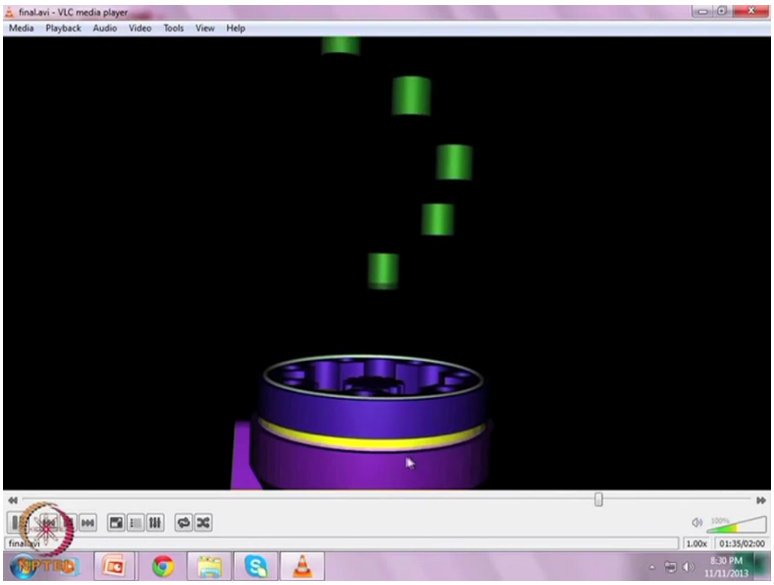

Then you will find that this plate is called valve plate, this plate is required because there is a star is rotating so there is a rubbing so the main body is not suitable for this so we need a valve plate which we can replace also easily.

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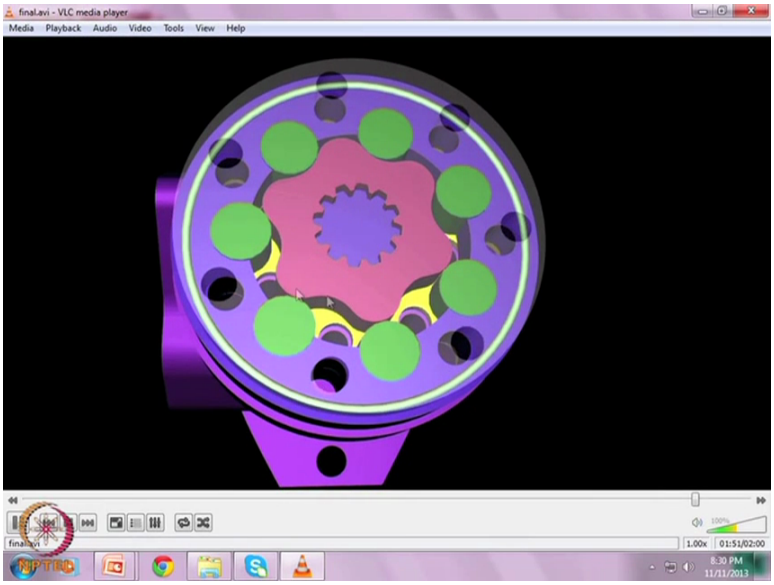

Now you can see this star is put and then this there will be another cover plate and then the final cover will be there but in this case we have shown the final cover is a transparent one to see this gear inside. We can have another look, just observe this you will be able to understand yourself how it is working. This is the input, input and output end connections, in case if we find that this body is being used as an output, we have to connect this input and output oil may be through this

shaft, it is possible, in the shaft from the front side which is will be held, we can make 2 grooves and that we can make a hole here and here so it is possible count, I mean it is not difficult.

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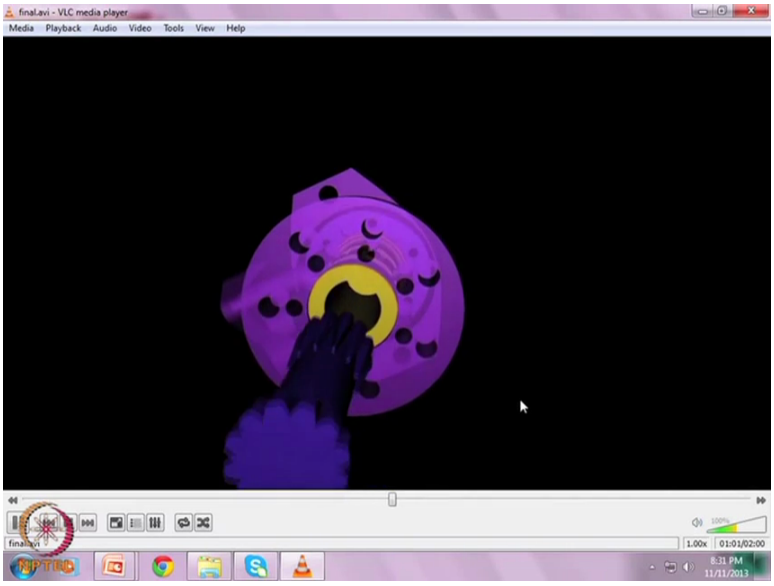

Now look at this, this current shaft will go inside, now to maintain this how these grooves and then the Inter chamber is linked, actually the cordon shaft all the teeth both sides the same phase, there is no lead-lag. And then in the star, these splines or the gears, those are made with a particular sequence that means one groove of this spline is matching with the bottom of this one. Say for example, in this case perhaps it is like that, this one is the center of this one whereas, it is this is the center of this one, this matching we should do to maintain the sequence.

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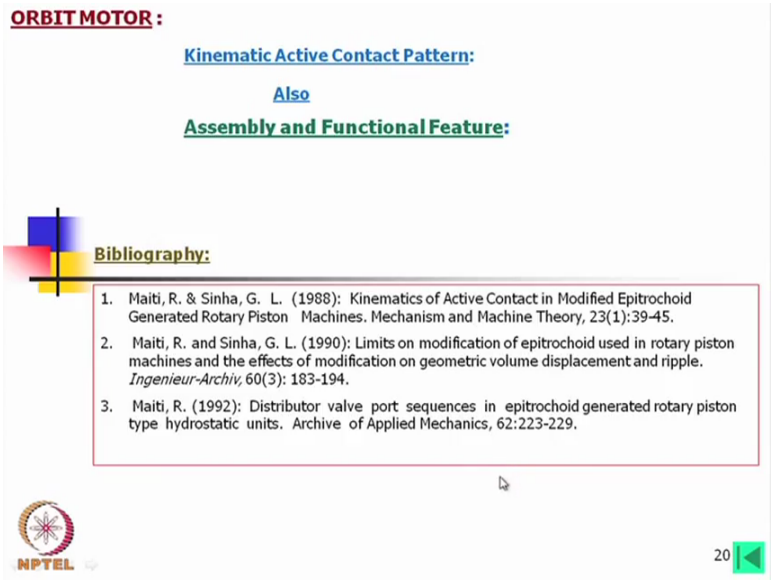

Now there is not, what I have described this is you may not find in any book but if you go through these papers you will be able to understand what I have described today, thank you.