Manufacturing Processes II
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Lecture No. 32
Gear Manufacturing

Welcome to the subject Manufacturing Processes – II. Now our module going on is seventh screw threads and gear manufacturing methods and today's lecture will cover Manufacture of Gears.

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Now what are the contents?

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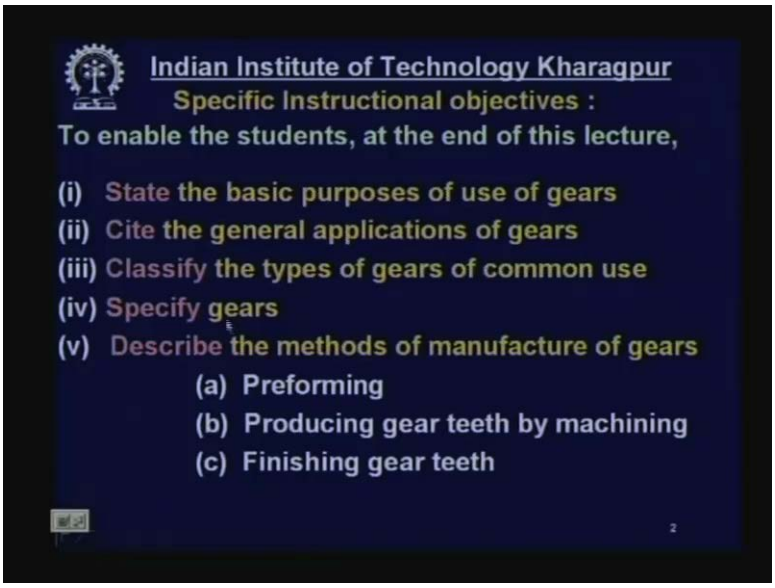

Specific instructional objectives: Today the basic purposes of use of gears. The general applications of gears; now before that let me tell you that in the history of science and technologies especially engineering like screws or threads, gears invention have been a break through. So gears are very very important in engineering. So today we are discussing about Manufacture of gears. The types of gears of common use that we shall discuss the classification of gears, then how to specify gears and last the methods of manufacture of gears by preforming producing of gear teeth by machining and finishing gear teeth by various methods.

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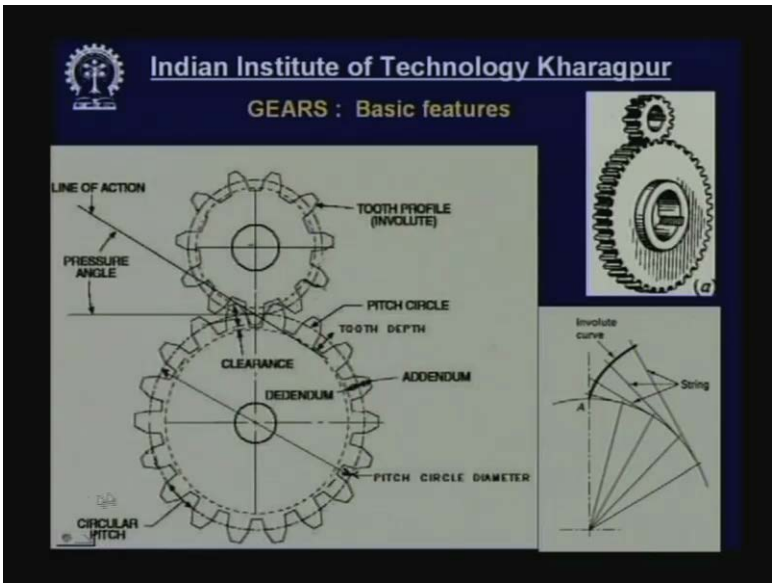

Before we are going to manufacture, we have to understand what is gear? What does it do? How does it work? What is the shape, size or configuration? Here, you can see that gear is basically a cylinder or a disc having equi spaced teeth or serrations around the surface. Around the surface, here you see the teeth and here also and these teeth enable positive transmission of motion and power a torque from one shaft from here. This is the one shaft to another shaft. So this is the gear. This is basically disc having uniformly distributed teeth in the both the gears to transmit positively without slip the motion and torque between two shafts.

Now here, if you see from closely into the gears, this is the configuration. This is the configuration of the gears. Suppose there are two gears mounted on two shaft. This is one shaft and this is another shaft and suppose this is the driving shaft. This is rotating in this direction by power. This will cause rotation of this gear. As a result, rotation of this shaft on which it is mounted, so rotation and torque are transmitted from this shaft to this shaft through this pair of gears. Now this gear and this gear have got the serrations or teeth over the surface all right and there the gears in contact. Now when there is action, the tooth flanks or the faces push the teeth of the other gear tooth of one gear pushes the tooth of the other gear and this continues.

Now the shape of the tooth or profile of the tooth flanks should be done taken very carefully it should be such that the motion and torque and forces be transmitted positively that is without slip smoothly uniformly without fluctuation in speed and force with constraint transmission ratio with minimum possible wear at the contact zone through the working action contact between teeth will be mostly in the rolling mode which will give lesser friction and longer life. Now so what are the major features that the pitch circle this is called pitch circle. They cannot pass through the contact point, pitch circle and this is the pitch circle diameter which is the major then this is the tooth. These are called tooth profile. This is say sub addendum. What is addendum? Addendum is the distance between the pitch circle and the outer circle at the upper half of the tooth dedendum will be the lower portion. This portion will be called dedendum.

Now this is the line of action of the teeth that means the contact point between the teeth conjugate teeth will follow this path in a straight line. So that the forces will not fluctuate and the angle between these two, the line of action and the common tangent will constitute the angle very important called pressure angle and this is called circular pitch that is distance between two conjugative teeth of the gear at a given point. Now this tooth profile: now all the conditions mentioned can be fulfilled by one tooth profile curve called involute. This has been found to work excellent to fulfill all the points mentioned.

Now what is involute? Involute is suppose on a cylinder, a rod is rolling like this gradually rod is rolling from here to there or here to here and the locus of the tip of the rod or any point on the rod which is rolling over the cylinder will produce a path. This path will be involute. In another way, if you take a string or thread strongly or tightly wound over the cylinder, now you gradually un-wind the thread in stress condition, then the tip of the thread will produce a path and that will be involute. Of course other type of curves likes say cycloid are often used but if cycloid is used all conditions will be

fulfilled excepting the pressure angle which will keep on fluctuating and make all vibration or say oscillation. These are undesirable. So in all respects, involute profile is ideal for gear teeth, most of the gear teeth. Now come to basic purposes of use of gears:

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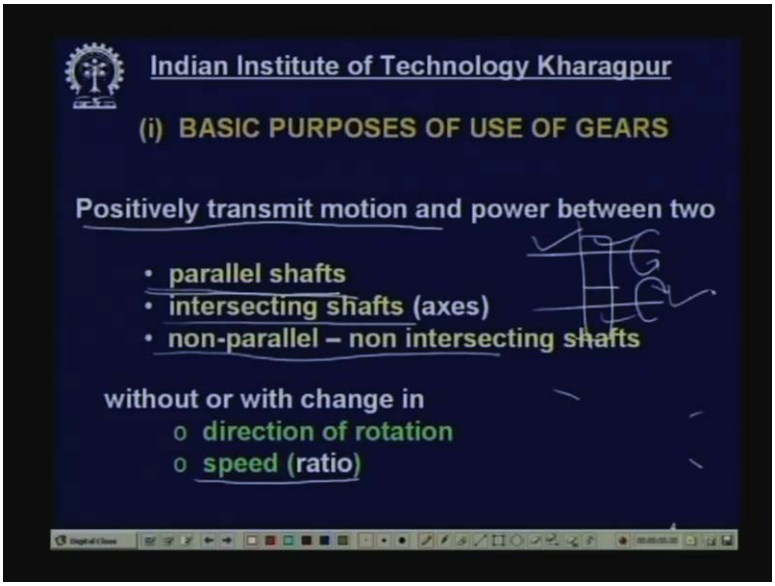

What are the basic purposes? Positively transmit positively transmit motion and power rather torque as well as power between two parallel shaft. Suppose, there are two parallel shafts and the motion has to be transmitted from this shaft to this shaft. So you mount two gears on them in contact. So when this will rotate? This will rotate in the opposite direction. So the motion torque and power will be transmitted. This is between parallel shafts. Now it may not be that the shafts will be parallel. It means in the two shafts which have got axis inclined like this, but there will be intersecting if extended. How the motion has been transmitted from this shaft by this gear and put another gear here by bevel gear and so intersecting shafts were the axis of the shafts, if extended will intersect at the point. Non-parallel - non intersecting shaft.

Suppose there is one shaft here, another shaft here and now this is neither parallel and there will be non - intersect. This will go over the other and if you want to transmit power in between them, you have to take a special kind of gear. Now while transmitting power while transmitting power from one shaft to another, what may happen that suppose you are transmitting power between two parallel shafts to a pair of gears okay. Now, this is one gear and this is another gear. Now, when transmission may take place without or without change in direction rotation, it is possible to keep the direction of rotation same or opposite. It is also possible to change the speed ration. This may rotate fast, this may rotate slowly and there may be change in the speed ratio, say increase or decreasing speed is also possible. So, these are the various purposes of use of gears. Now general applications of gears:

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Now keeping that particular use of gears, transmission positively transmit positive transmission of power motion and torque between two shafts may be parallel may be non-intersection may be intersecting. They have got lot of applications in engineering. For example; speed and feed gear boxes in machine tools to transmit motion, rotation from motor to the job, to the tool at different speeds gear boxes of automobiles, cars speed drives in textile engineering, jute industry or similar machineries were lot of transmission of motion are required through gears. Speed and feed drives of various material forming machines like say wire driving machine and extrusion machine.

There also some time to reduce or control the speeds, that gears are used. Machineries for mining tea industries, tea processing industries and also lot of gears are used. Large and heavy duty gear boxes comprising lot of gears are used for cement and sugar industries, cranes, conveyors, wind mills for accomplishing lot of rotary motions from the source of power like motors, precision equipments like clocks, watches, meters, microscopes also use some gears industrial robots and toys also use lot of gears of different type and capacity. Next is broad classification of gears:

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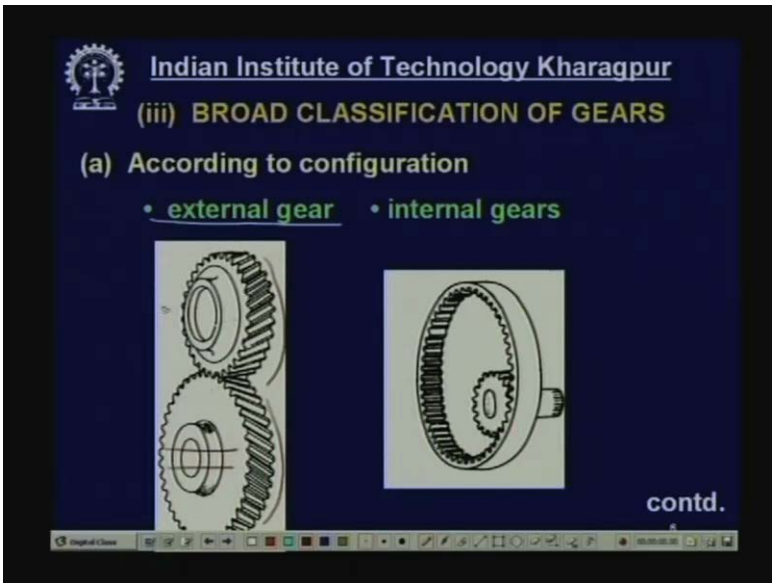

There are different types of gears. Now when we classify gears or anything, we must take a consideration with what respect we are classifying them. Now say the gears can be classified according to several aspects. First aspect according to configuration, that means external gear. This is external gear. External gear means the teeth of the gear. These are the teeth. The teeth of gears are provided on the periphery, outer surface of the wheel and here is one shaft and there is another shaft. So rotation will be transmitted from this gear to that gear but in such case, the speed of rotation will be direction of rotation will be opposite. If this rotates clockwise, this will rotate anticlockwise. It is an external gear in contact, but sometime we need use of internal gears having teeth inside a ring and this is used for keeping the direction of rotation identical. Suppose, this is one gear which is rotating in this direction and then clockwise this big gear will also rotate in the same direction. So there are few applications in machine tools of these internal gears but mostly these external gears are more commonly used according to axes of transmission.

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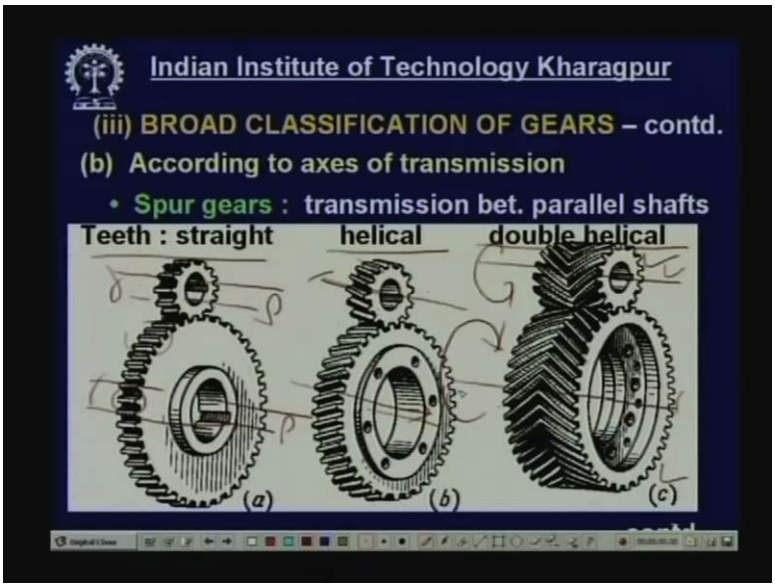

As I told you that, the axes of the shafts between which power rotation etcetera transmitted by gears may be parallel, may be intersecting, may be non-parallel, non-intersecting various possibilities are there. Now let us see spur gears. What spur gear mean? Those gears which transmit power rotation etcetera between parallel shafts between two parallel shafts. Say here, here you can see this is one gear with a shaft like this, this is another gear, parallel shaft like this. So long shafts are parallel, they will be called spur gears but this is straight tooth. Here you can see the teeth of the gear. All the teeth of the gear are straight, parallel to the axes of the shaft or axes of the gear. This is helical.

Now here the teeth are slightly inclined with respective axes of the gear why because then you get better contact, wider contact between the teeth which enable smooth running of the gears as well as transmit more torque, heavier torque unlike straight tooth. So these are used for heavy power transmission and smooth work, but these are more difficult to manufacture slightly. So, they are little costly. Now this is double helical. Here you can see double helical. This is the one shaft, this is another shaft. Both are parallel. So this rotates in this direction. This will also rotate but in opposite direction and the speed ratio will depend upon the size of the tool.

This gear is small, this gear is big. So if these gears rotate at certain speed, this will rotate at lower speed. Now here you can see the teeth have got double helical, that means it is stronger than single helical. The one limitation of single helix is there can be an axial force. There can be an axial force relative to that that may cause a tendency of separation of the gears axially. So this double helical will prevent that and this kind of double helical or herringbone gears are used for heavy duty work at high torque transmission for heavy power transmission at moderate speed or even high speed. Now, according to axes of transmission continued.

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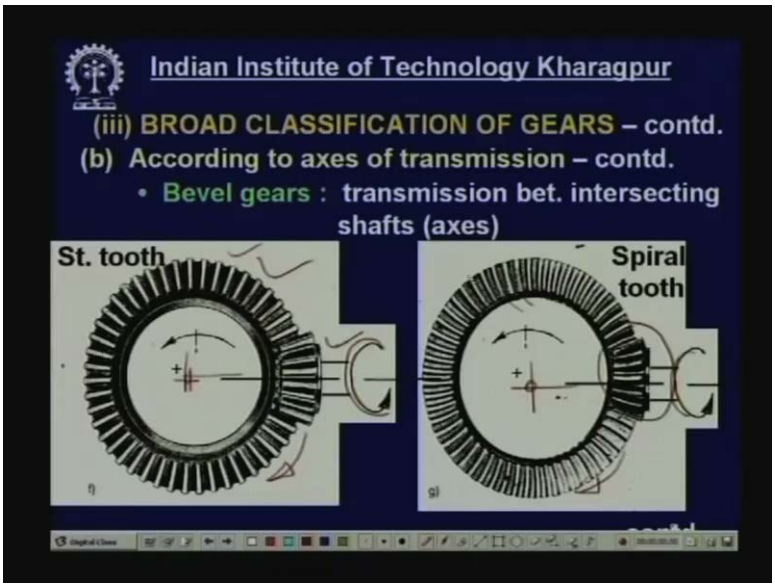

Now previously we saw parallel shafts. Now bevel gears: transmission between intersecting shafts. Now intersecting shafts; you can see that suppose this is one bevel gear, this is one shaft. So, there will be another bevel gear with another shaft. So these are the one. These are two gears. They will transmit from this shaft to this shaft if they are intersecting. Now here you can see that there this is one bevel gear. This is another bevel gear. This is a small bevel gear say pinion and we can call it big bevel gear or crown gear. If it rotates in this direction, then this will rotate in this direction in this direction but the axes of this gear and axes of this big gear which is here they will intersect at this point. Now here also the same the axes rotation of this small gear will cause rotation of this bevel gear and there axes are intersecting at a point. Here the teeth is straight. Here you can see the tooth are straight, radial. But, here the teeth are slightly curved and these are called helical or spiral tooth gear and this has got capacity of transmitting more power torque etcetera. Now non parallel non-intersecting shafts:

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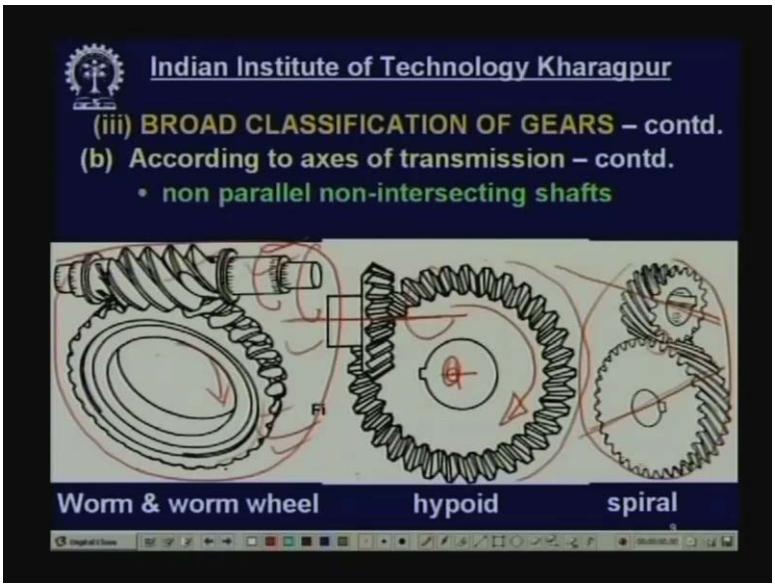

Here the two shafts will neither intersect nor parallel. So these two are parallel but those two fingers, but these two will be this cases non parallel but intersecting but it will be like this. Neither parallel not intersecting one above the other, they will not intersect. So in such situation what kind of gears will be appropriate? Now here, you can see that this is one gear, this is another gear, this is called worm and worm wheel mechanism. This is called worm. This is worm wheel. If this rotates at high speed, this will rotate at very low speed. So this can be used for speed reduction. This worm has got one or two teeth is basically this is a screw and this is a gear and another thing which is irreversible. Normally this worm rotates at high speed and causes rotation of the worm wheel big gear at low speed.

It is irreversible, that means if you rotate the worm wheel, the worm cannot be rotated unless the helix angle is very large like say very large may be thirty degree, forty degree then only it can be reversible. Normally worm and worm wheel are used for reduction and this is irreversible. Here is another example. This is one bevel gear with an axes rotation rotating about this axis perpendicular to this plane and this is another gear. So when this gear will rotate, this will called rotation of these gears but here you can see the axis of these gear and axes of gears are not intersecting.

Now this is another case, this is one shaft. This is another shaft, they are neither intersecting nor parallel. So these are called spiral gears. The teeth look like helical gears, but helical gears mean the teeth are inclined curve but they will transmit rotation between two parallel shafts. But here, the shafts are not neither parallel nor intersecting and the point of the contact is only point contact very weak and this kind of gears are used for low duty activities where torque power to be transmitted is reasonably low, then till now we have told that gears are used to transmit rotation between shafts but sometime, the gears can be used also to transmit, convert rotation to translation or vice versa.

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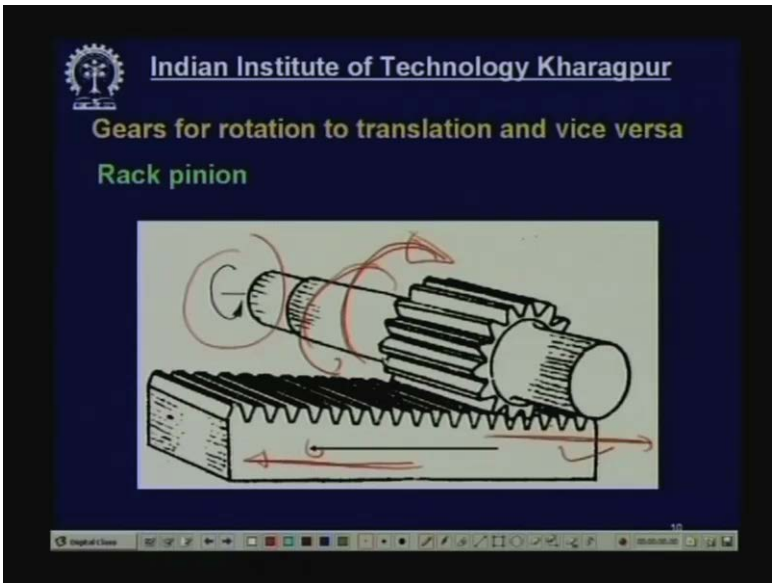

From translation to rotation, rotation to translation, say for example: rack pinion. Here this is say rack. Rack means a gear with infinite diameter. So it becomes flat and this is the pinion or a gear. Now suppose, if the gear rotates in this direction then this is wrong. This will move in this direction straight path. If you rotate in this direction, this will move in this path straight path. So, rotation is converted into linear motion from input shaft to outer rack. This is called rack. Similarly if you move it in this direction, this will rotate in this direction. This gear will rotate, if you move it in this direction this will rotate in the opposite direction, so this is reversible. So, this has got wide application in several engineering machineries or devices. Now specification of gears:

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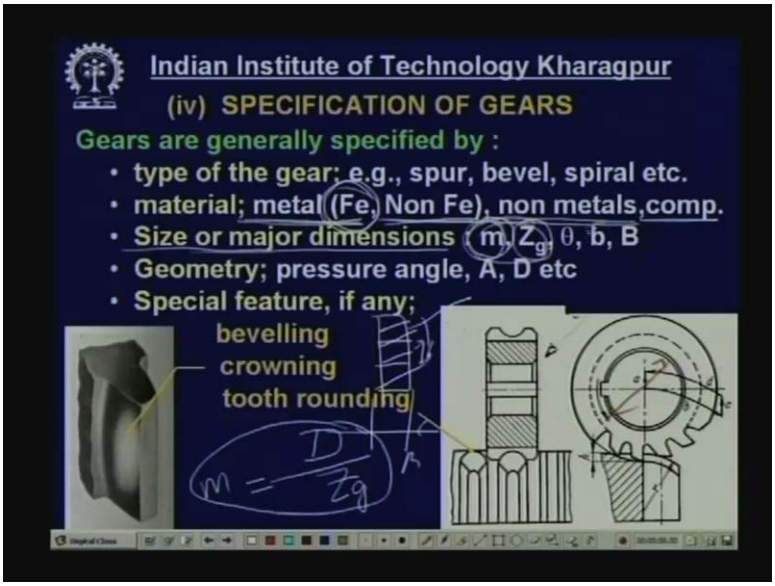

How to specify a gear? Gears are generally specified by first you have to mention type of the gear that is it spur gear, is it bevel gear, is it spiral gear, e bevel gear, is it straight tooth or helical tooth or say hypoid gear, non intersecting shafts. If it is spur is straight to spur gear or helical spur gear or herringbone gear this have to be mentioned. Next comes material which is very important because material of the gear should be such it should be strong enough. It should be tough, it should be wear resistive. It should be reasonably hard. It should be easily available, manufacturable, finishable, reasonable cost and so on. For example; the different types of materials are used for different applications. Metal; it can be metal, most of the gears used in engineering are metal. Metal means two kinds of metal. Ferrum iron base and non-iron base:

Iron-base again it can be cast iron and gray cast iron or steel both are possible. Now non-ferrous say aluminum alloy: These are little, softer aluminum aluminum alloys with say zinc, magnesium, copper and so on. It can be brass, it can be bronze like that but these iron gears particular steel gears are very strong, then cast iron and gears, then non-ferrous gears. Now non-metals: Yes, gears can be nonmetallic also like plastics thermosetting or thermoplastic type. It can be composite also. You know ceramics or metal powders are mixed with polymer and then you can make gears. Then comes size of the size or major dimensions of the gears. First is a module. What is a module? Module means size of the tooth, basically it indicates size of the tooth that is the diameter of the gear, spur gear divided number of teeth say number of teeth is Z g. This ratio is called module. So this is an indication of the size of the tooth Z g is the number of teeth of the gear, theta is a helix angle of the teeth of the gear, b is the bore diameter.

This bore diameter; Of course, this is cutter this is not gear. Anyway, this is a bore diameter of the gear and B is the width of gear. What is the width of the gear? That is suppose this is the gear, if this be a gear, then this is the bore, this is bore diameter is importance a small ‘b’ and the width is capital ‘B’. So the number of module, the size of the tooth and then number of teeth which will decide the diameter of the gear and then the helix angle of the teeth, helix angle and then the bore diameter and width. So, these are the various things to be mentioned for specifying gears. Beside that, geometry of the tooth that means you have to mention pressure angle that the angle between the line of engagement and the common tangent already described ‘A’ for addendum that is the height of the tooth from pitch circle and dedendum the height of the tooth from root circle to up to pitch circle diameter etcetera.

Now special features if any should also be mentioned but this is not compulsory for example; beveling. Now here is the tooth, gear tooth shown. Now this end may be beveled. You know this and may be instead of shoe shaft, it can be beveled. If you bevel it, then it will be slightly stronger for engagement, but it is not compulsory. Crowning; Now this you see this gear tooth is slightly crowned curve. So inside the slide is thicker. So when you engage these gears, so the gear contact is very uniform and gives longer life. Then tooth rounding. This tooth, this is the teeth of the gear which is slightly rounded that means if this is the tooth of the gear; it is rounded here and here. This is required for engagement. Suppose there is a shaft and there is one gear and there is another shaft, there is another gear. Now, these gears have to be engaged with this. Now

if this is rounded, these gears then it gives better easy contact this is called tooth rounding. Next comes manufacture of gears.

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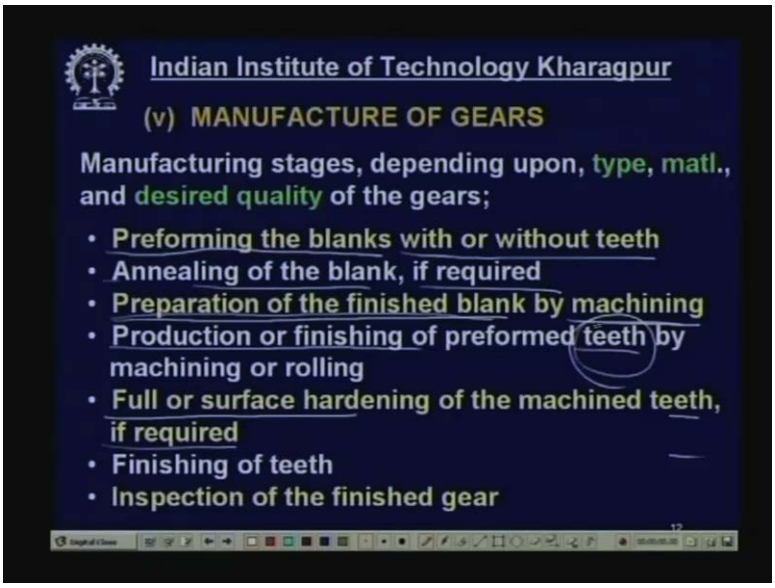

How the gears are manufactured? Now the manufacturing stages: So there are different stages of manufacturing gears. Gears can be done by one stage. Numbers of steps are there or stages. Manufacturing stage is depending upon type of the gear, material of the gear and desired qualities that is accuracy and finish of the gear. The process will be varying. What are the different procedures like say here performing the blanks with or without teeth that means first you make a disc like, a disc like by say some process like say casting, forging, hot working process and this you we can produce it by teeth also, but here the tooth will be very irregular and this will not be very accurate and such gears can be sometime used directly without finishing in some industries were the vibration is not a factor or accuracy is not a factor like jute industries such straight cut a straight preformed cust gears or force gears are used. They are cast with tooth. But, normally this is not done.

What is done? These discs are produced and the discs are then machined powerfully to give a perfect circle, with the perfect diameter. Annealing of the blank if required. Now, as I told say after casting or forging this will require some machining. Some machining for finishing to the appropriate dimension. Now by performing like casting and hot working like forging. This will become hard machining may be difficult. So this has to be annealed before the next step machining. So after annealing, preparation of the finished blank preparation of the finished blank by machining after annealing. Now remember all material do not require annealing because say cast iron and cast iron may not require gay cast iron may require annealing. Generally steels and steeler materials which become hard. They require annealing. plastic gears another gears do not require such thing, then production of finishing production of teeth on that teeth will be produced.

Now either this teeth already made by casting will be properly finished or new teeth will be generated on straight cylindrical body. This is a very important part of the gear manufacturing work. Next is full or surface hardening of the machine teeth if required. Now as I told you earlier that the tooth of the gear should be harden up wear resistant okay and for the purpose of machining is of machining the blanks are soften by annealing after casting or forging but it should be hard for wear resistance etcetera but it is not always done say cast and gears need not be harden plastic gears need not be harden but steel gears yes it has to be harden.

Now full or surface hardening of the machine teeth if required like steel, yes now finishing of teeth. Now if you semi finish or finish by machining and then you require hardening after hardening there will be certain amount of distortion on the profiles or damages or irregularities a scaling then after heat treatment or hardening by punching they finishing work like grinding may be required and it is done and finally inspection of the teeth have to be carried out. Now the performing of gear blanks without or with teeth.

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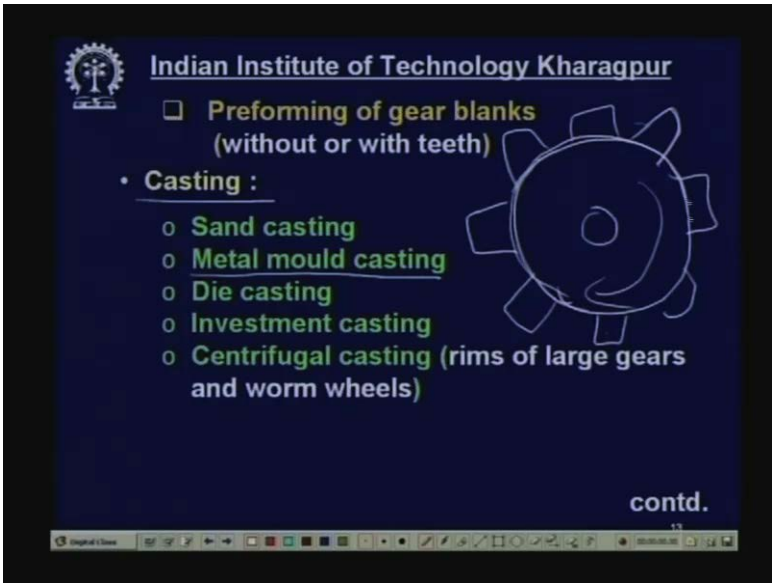

Say sand casting. What is done? The large gear blanks, large gear blanks say this type may be are produced by casting. Sand casting; so sand casting is employed for large cast iron and or may be steel gears which is not very accurate and sometimes it is produced also with tooth but these tooth are very inaccurate and they are not used precision work like machining but machine tools they can used for jute industries or say tea industries or cement industries where it can be accepted. Now metal-mold casting. Now this casting will be done in metal moulds were you get more accurate accuracy in the tooth form if required or on the diameter, width, thickness of the gear blank. Now die casting:

Die casting: now before that sand casting and metal mould sand casting are used for piece production. One or two pieces may be if required or large gears. Metal mould casting steel cast steel gears but a few number on is a batch production or piece production but

what about die casting is the mass production use volume or production of small gears. Huge production: first rapid on huge production of small gears of relatively soft materials of low melting point. For example; aluminum aluminum alloys like zinc, copper, etcetera and these are produced in die casting machine and this gears are produced with teeth always produced with teeth and these are very quiet accurate.

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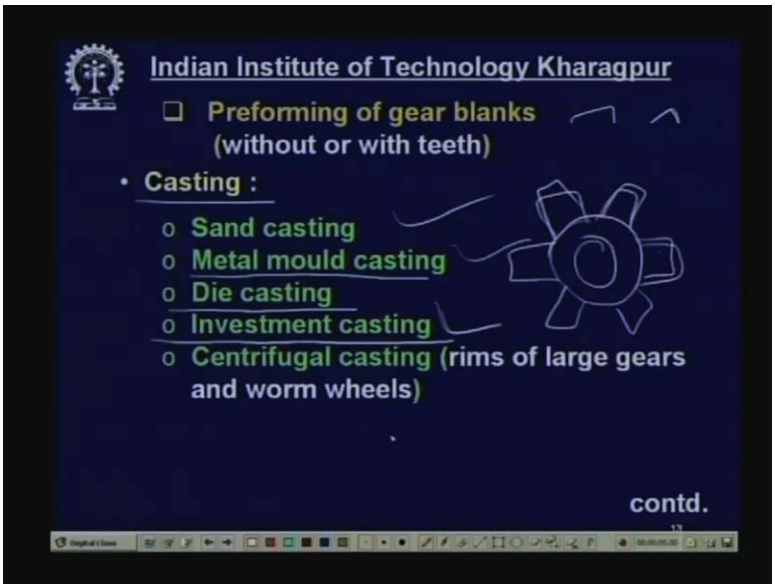

Sometimes, these gears can be used directly after die casting but if it is a precision work then definitely this will require certain amount of finishing by subsequent operation like machining investment casting. So this investment casting is costly process but this is used for making very precision accurate gears straight way by casting and the material will be exotic material and the shape will be total shape will be complicated. So for manufacture of few pieces or say lot production of precision gears of exotic materials with complicated geometry are done by investment casting. Centrifugal casting which is employed for large gears. Suppose you want to produce a very large gear, then what you do?

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In case of large gears, first of all you produce you know some internal surface, internal ring type and then another ring sorry a pulley type on that a ring is mounted. Now this ring can be used for rims. So centrifugal casting this rim used for large gears and worm wheels are made by centrifugal casting and you know what centrifugal casting is? Rims of large gears and worm wheels; now let us see next gear teeth by rolling.

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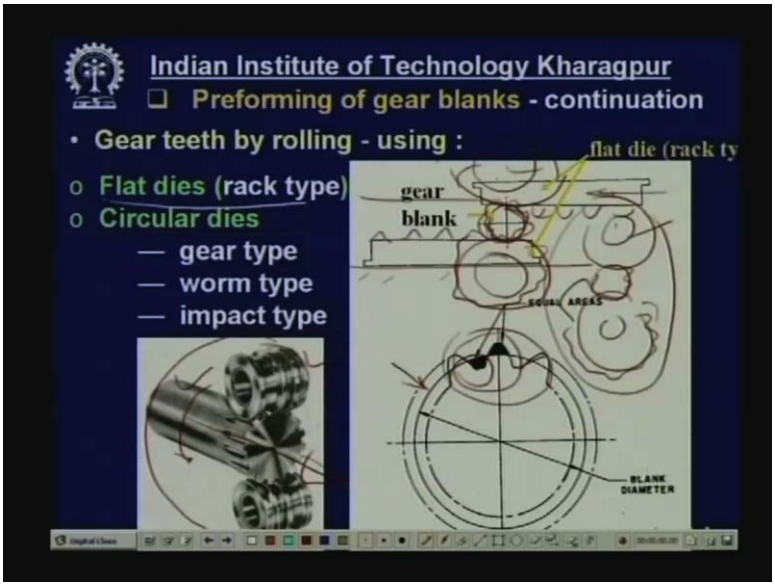

So what we discuss there is casting process performing by casting. Now we shall see the gear teeth by rolling which can be done by flat dies. Now you remember that threads, screw threads can be produced by machining, as well as rolling. Similarly the teeth of

gears can also be produced by machining as well as rolling. It can be done by flat dies, this is the example. So this is one flat die which is moving and this is suppose another flat die which is fixed and this is the gear blank. Inside is the gear blank, now if you move into this direction, then what will happen? Nothing will happen but if there are teeth like this protruded teeth and here also there are teeth like a rack.

Now if you move it, then this and the high pressure then lot of deformation will take place on the periphery and there will be lot of yet will be produced on the periphery like this. Here there is no removal process. Only the material from below the blank diameter or the piece will be shifted at the top. So material will flow from bottom to top and there this will produce the teeth like this and this kind of gears, roll gears are very strong and very accurate good surface finish and surface integrity. Now we can you also use circular dies. Now, if this one can be converted into say gradually circular this rack is also converted in to circular ring. So then is will circular die the circular dies are harder.

So in between two circular dies, there are basically gears and put one blank. These will also a tip the gears according to the teeth of the rolling that the dies rolling dies. It can be circular, can gear type as explained. Here, it can be worm type shown over here this once looks like a worm and this like a worm wheel. So this keeps on rotating and this also moves is also rotates and tooth and the throughout the surface is developed and the blank is pushed like this. This is a rolling process and another one is impact type where we have this rollers work by impact on the surface to intensify the metal deformation and quick process. Preforming by I am sorry other methods other methods of preforming.

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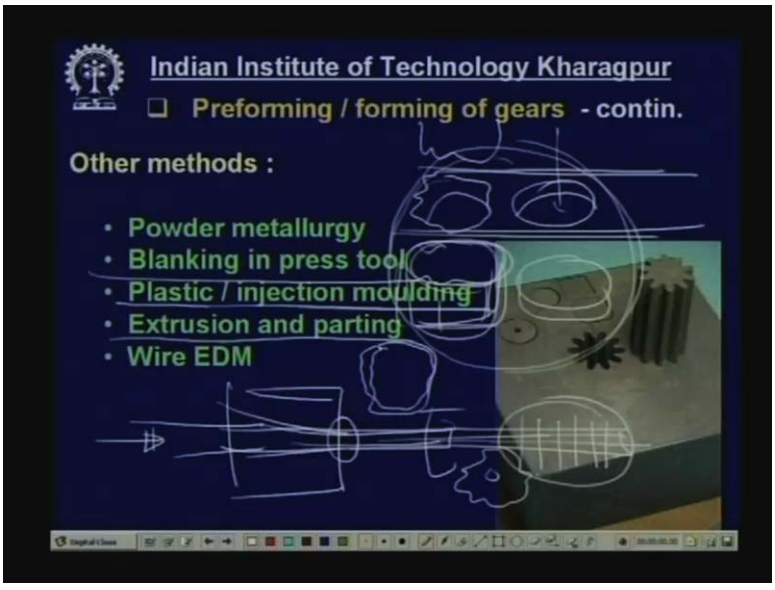

Powder metallurgy: yes, if you have proper die and punch your put the powder material and blank and bracket it in the form of gear blank made by sintering you get the gears and these gears are more or less very accurate and straight way it can be used and if you if somebody wishes for a precision, you may purpose then this has to be slightly finished

but basically the finishing requirement is very less. Now, the blanking in press tools: This is another method, blanking in press tools. Suppose there is a disc like plate or plate and now by here is by blanking you know, blanking is a process were there discs are produced by punching of blank. It was stamping but here this will be a gear like. So the punch will be a gear shaped and the job that will be them the blank that will come out that will be also a gear type.

So this way, you know you get internal gear into shaft and out external gear into the this out piece which is coming out. So now this produces more or less accurate gears and smooth surface. But, sometime it requires further finishing like machining and debarring etcetera but generally this have produced from say the gears are of small size, softer material, the thinner size, thin. So that amount of force required is reasonably low and can be done by stamping work, plastic work, injection moulding yes. Plastic gears can be produced by injection moulding that is the process, extrusion and parting.

Now you know we can produce you know rods of different cross section by extrusion. The rod will be put and this will go outside and this will pressed pushed from this side. If this cavity is like a gear, internal gear and through this material when this will pass. These will also if it is the cross section that will be also like gear. So now you get a long gear after that which has got teeth long teeth parallel teeth you cut to size. You get large number of gears this is also produce accurate gears but not that accurate and these are small gears can be used for toys or watch, clocks etcetera. Then another very new method has been developed called wire EDM. It is a new method.

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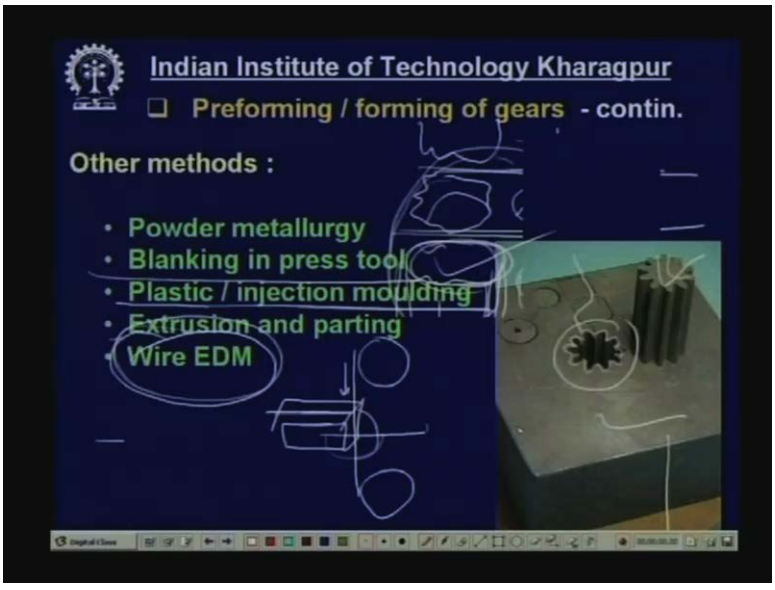

You know EDM means Electro Discharge Machining. Now wire EDM means, there is a wire which moves in this direction and at a potential now if you put one work piece near this with an electrolyte dielectric medium and then it will move into like this then this wire will get into the job and gradually get inside and split it and finally it will part it. So

this wire will gradually move inside just like a knife moves inside is called wire EDM. Here you can see, that application of this one large gears can be produced in this way. So this is the block. This is the block, this is the block of such more thickness and this wire will come from this source and reach here. Then, the wire will be made to move in a curve path the teeth, gear tooth profile path. After that, then we will get then you take the inner portion which has been separated out you get an external gear and inside this block one internal gear. So both internal gear and external gear with reasonable amount of accuracy and finish can produce of bigger size or small size by wire EDM and its wire EDM is very suitable for material of any hardness hard materials which are very difficult to make by other methods. Now come to machining: Production of gear teeth by machining.

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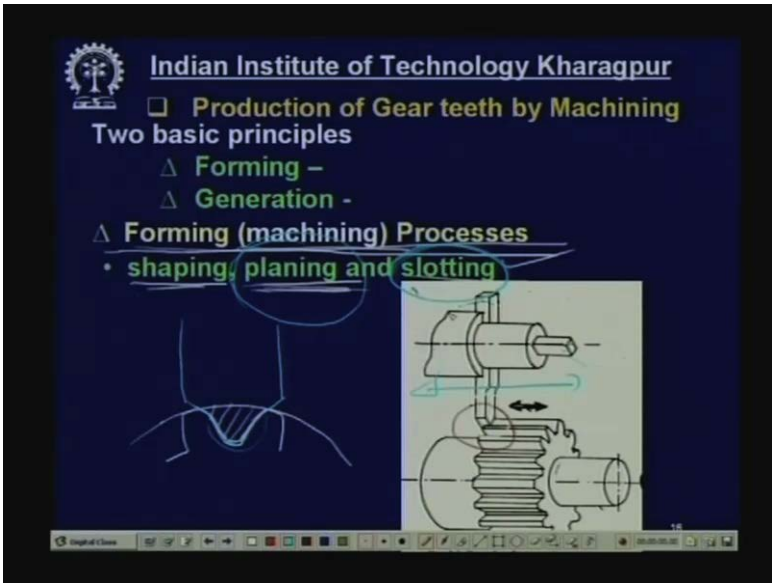

The two basic principles are there. One is called forming, other one is generation. Now what is forming? As I had been discussed earlier also in case of milling operations forming means where the job profile that you want will be the replica of the form of the cutting tool. Whatever form you want on the product has to be produced first on the cutting tool and then is a replica this form of the tool will be reproduced into the job this is called forming and what generation you can get very complicated shape from a simple form of the tool by method of rolling interaction. Let us see discuss. So forming processes forming; machining by forming principle; Shaping, Planning, Slotting etcetera.

Friend remember the shaping has already become almost obsolete. Slotting also planing has got some use because it has it deals with large jobs. So, these are not and secondly these are not really used for making gears, but if challenged or if required say for making one or two gears or two teeth of gears for maintenance or repair, then shaping, planing and slotting can be utilized. Now this shows the example. Here is the shaping tool. This is the shaping tool. Here the shaping tool, suppose this is the gear blank and we want to

produce two teeth or say number of teeth. So this is the material which has to be removed bounded by two involute profile.

Now you have to take a cutting tool of the same form like the shaping tool and this will produce these slots by shaping action by the movement. Shaping process, but shaping is applied only for very one or two pieces or one or two teeth for maintenance repair very of almost obsolete and this is for external gears. Planing if required at all then for big gears and big tool. What about slotting? Slotting occasionally used for making internal teeth, because slotting can produce internal teeth, internal teeth of gears. So it has got some application in tool room or maintenance shop. Otherwise, these are all say non-productive. Now come to milling:

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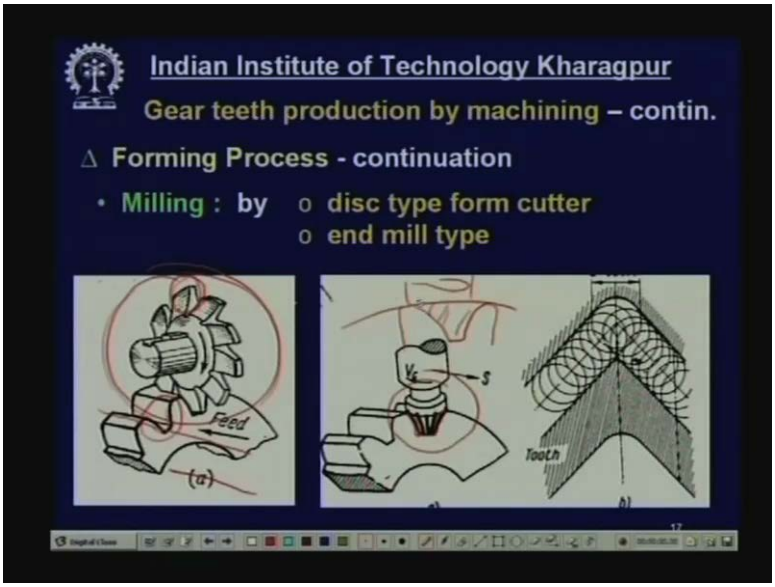

So forming these also forming processes; Milling is also a forming process but, it has got wide applications. You know milling by disc type form cutter and end mill type cutter. Now, this is the disc type. This is the cutter, this is the cutter you can see. Just like a milling cutter, but here you can see, this is the gear tooth form which has to be produced bounded by two involutes and here also the form of the tooth of the cutter will be also the same and this will keep on rotating and the blank will move along a direction parallel to its axis and this way the teeth will be produced.

So the teeth will be produced one by one by indexing process. Now in the gear is gear is very large may be thirty feet or forty feet and tooth are also very big may be say fifty or sixty millimeter like that, then the cutter will be if we take this type cutter it will be very large cutter as well as the machine tool will be also very large. In such case, for such large gear say end mill type gear cutters are used whose outer profile resembles the gap of the gap tooth gap the gap between two teeth. So, this is the shape of the cutter milling cutter, it was the forming process. Now double helical gear double helical gear where

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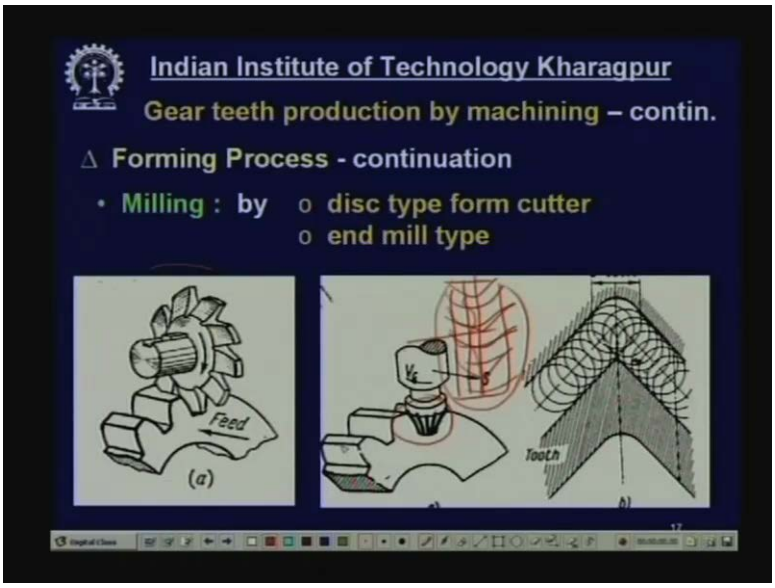

suppose this is the gear which has got double helical like this. So, it comes down and goes up. Comes down and goes up. How this can be done? This can be done only by this method. Only by end mill cutter, but if there be one slit or gap, one gap then the other method like sunderland method can be used. Now the gear teeth production by machining, we are continuing.

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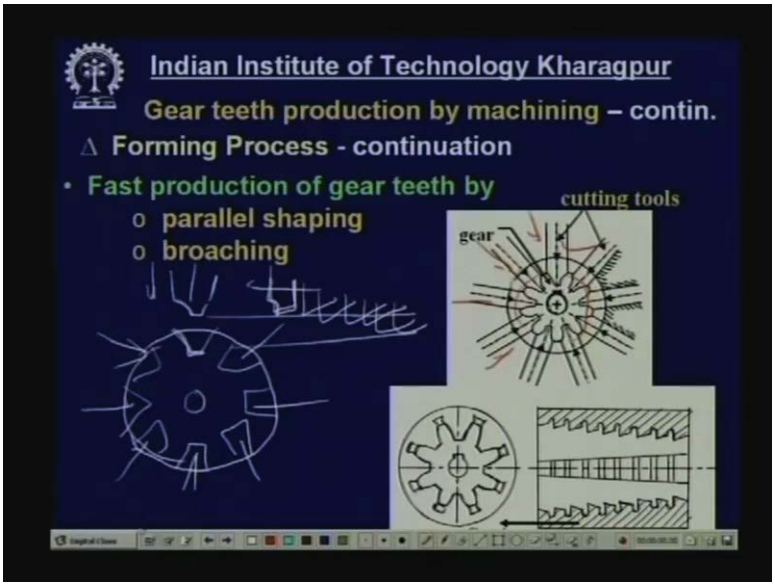

Forming process but here we shall discuss first production of gear teeth, that is gear teeth will be produced at very high rate, very high speed. Now this can be made but these are forming process which is again of two types: parallel shaping or broaching. Now let me

try to make it clear. Now, suppose there is a gear blank. Let us take white. There is a gear blank sorry, this is a gear blank and you have to produce suppose one tooth gap you have to produce first. You can produce it by a shaping tool of same configuration. So, this tooth will be like this and this will be moved in this direction and then this will gradually moved inside.

So next time this will move like this. The teeth will be gradually entering. You know this gap will be done. So in number of passes, you have to make this but you can make two tooth gap simultaneously you can make four teeth gap. You can make eight you can make sixteen that means all the teeth radially will will be made to move simultaneously equally and radially that is here you can see that this is the gear blank. This is the gear blank i am sorry, this is the gear blank and these are the tooth which is gradually moving radially and all of them are moving radially, simultaneously and finally all the teeth are produced in one spin. So, this is very fast process and productivity is very high accuracy is high surface is very good but even then it is not very popular because is very complicated the machine is very expensive maintenance is expensive and it can produce or one you know change of the gear from one to model to another one number to another is be also very expensive. So this is not very viable. Now another example: here the same example.

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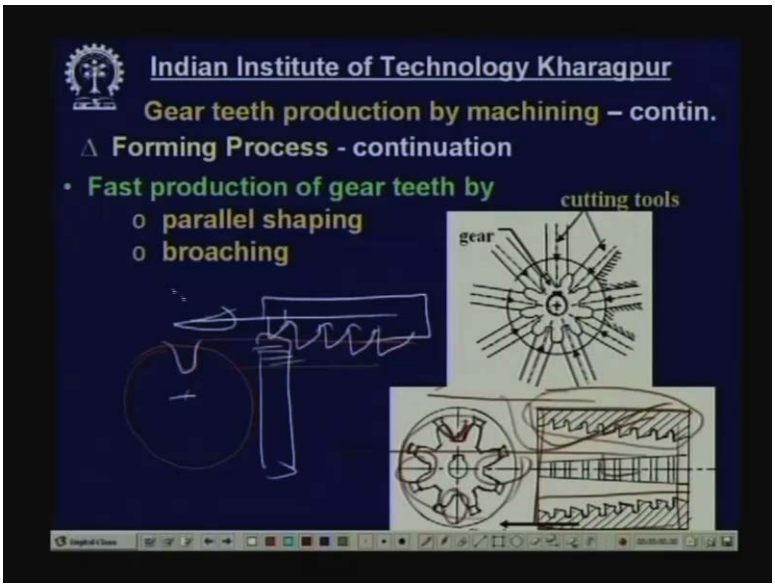

So this is the gear blank and as I told you that you have to produce the tooth gap by a shaping tool. First, you place the shaping tool here, then next here, then next here, then next here. So this will keep on moving like this. This is the front view and this is the gear blank and this will keep on making the slots but if you just joint them, it will make single piece. Now if you move the single piece in one stroke, the entire tooth will be produced in one stroke unlike shaping if one so this is the broaching okay. Here you can see that these teeth are joint into a strip and now if you move it in this direction, this tooth gap will be produced. If you take another piece, this tooth gap will be produced. If you take another here, this will be produced that means if you take all these things in the form of a

a tube and move in this direction then all the teeth will be cut in one stroke. This is called broaching. It is the maximum productive, very high accuracy, very good finish but the problem is the machine is costly. The broaches are costly and maintenance repair, design, etcetera, everything is very complex. This is economically viable only for very very large production of particular gears. Now the gear teeth production by machining continued:

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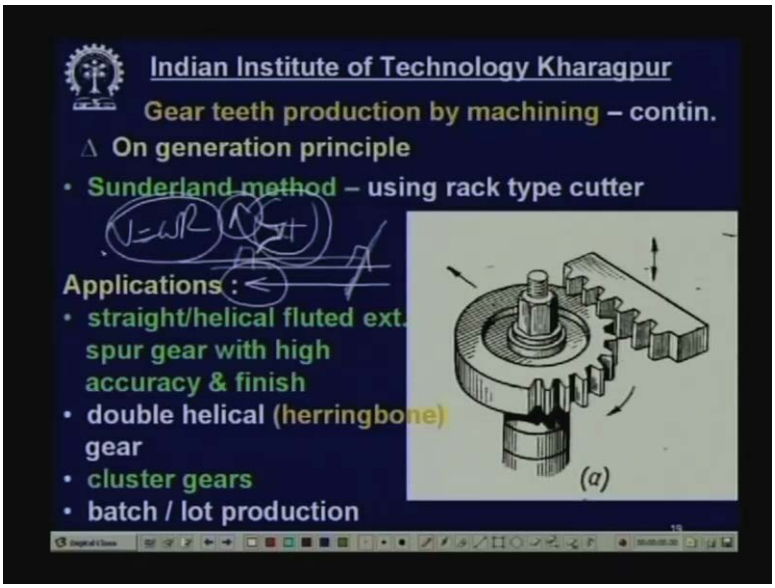

Now the generation principle: What is generation principle? As I told you that, production of complicated shape by simple tools. Here is a blank. Now you take a blank and the tool and this is the reciprocating like a shaping tool and then when this will pass come over here. This will produce a tooth gap bounded by involute. So this will reciprocate perpendicular to the plane or parallel to the axis of the gear blank and this will move in this direction and the blank will rotate in this direction. So this velocity and this velocity should be same that is v is equal to omega R that is the condition of rolling so this rolling is an essential future of generation process.

Here you can see that only one tooth can produce one tooth gap but if you want say number of teeth be produced in one stroke, then what you have to do? You have to take rack like this which has got you see one, two, three, four, so many teeth and now you rotate in this direction. This will be moved in this direction. That will cause rolling action and at the same time is a cutting action. This will enable production of say involute bounded number of say four or five teeth in one stroke, one spell, the one travel. Then if suppose there are forty teeth and four teeth it can make in one spell. So ten times this has to be indexed but even then the productivity is quite big and this surface finish is and all these but what are the applications? Applications are straight and helical fluted gas can be produced both straight and helical to spur gearshift with high accuracy and finish double helical gears like herringbone gear can be produced by this method cluster gears of machine tools gear box and this is for batch production to lot production, not for mass production. Next comes gear shaping:

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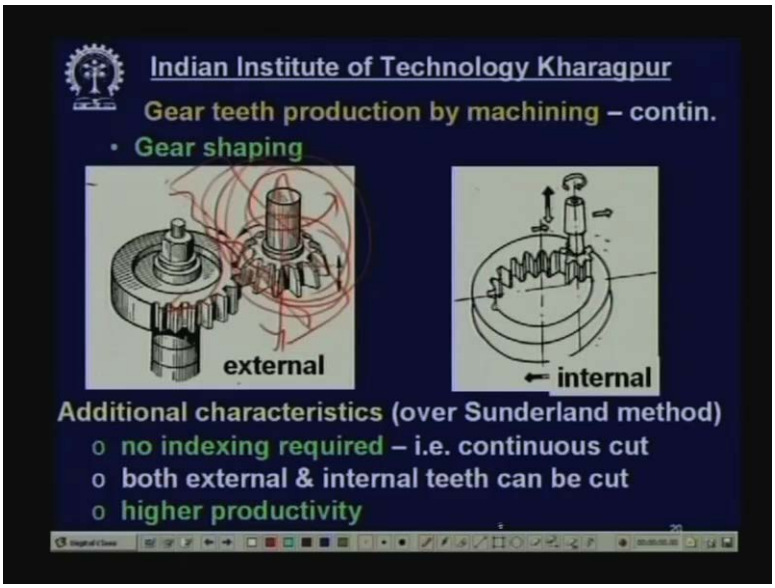

This is very similar to gear the sunderland method, the previous method rack type cutter but in this case, the rack the rack cutter the rack cutter which has got a rack cutter is converted in to a this is gradually bend and then found into a circular rack and circular rack is nothing but a gear. So this cutter is a gear, but remember, it looks like a gear but basically is a high speed steel cutter and its cutting edges are very sharp and this reciprocates that is called cutting motion and this rotates in this direction. This rotates in this direction, and you get all the teeth simultaneously all the teeth in one spell. You need not do any indexing operation. This is external, this is internal. So internal teeth can also produced by this gear shaping process. This is one additional feature. Briefly, additional characteristics. What are the additional characteristics over sunderland method? Those are no indexing required, both external and internal made and higher productivity. Next comes hobbing:

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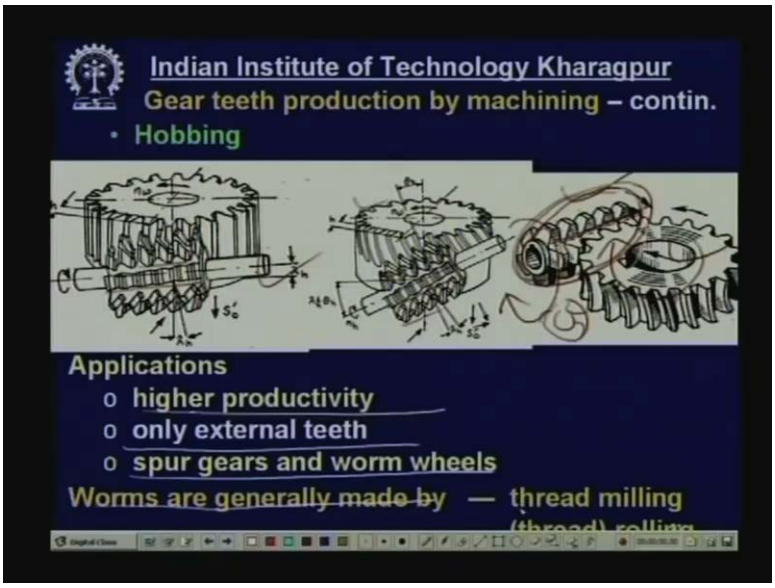

Hobbing is very similar to worm and worm wheel. Here you can see that, this is a worm wheel. This is the worm wheel and this is the worm. Worm is nothing but a screw. When a screw rotates, the worm wheel rotates the worm and worm wheel, but this screw has got some gassings. So that the threads are converted in to some cutting edges. You see from this, cutting edges. Basically, this was a ring like and now it is converted in to a milling cutter which was discussed earlier. So, this is called hob. This kind of cutter which looks like worm but having number of teeth cutting edges.

You see these are the cutting edges because of the groove inside because of the groove cut inside the teeth are generated and these of made of high speed steel because it has to cut and the cutter and the gear blank behave as if a pair of worm and worm wheel. This is also generation process. Now this gives higher productivity, because no index is required. Minimum number, less number of motions but only external teeth can be produced. spur gears and worm wheels can be produced. Worms are manufactured, worms are nothing but a screws thread like. So they are produced by thread milling, as well as thread rolling then comes gear machining teeth of bevel gears.

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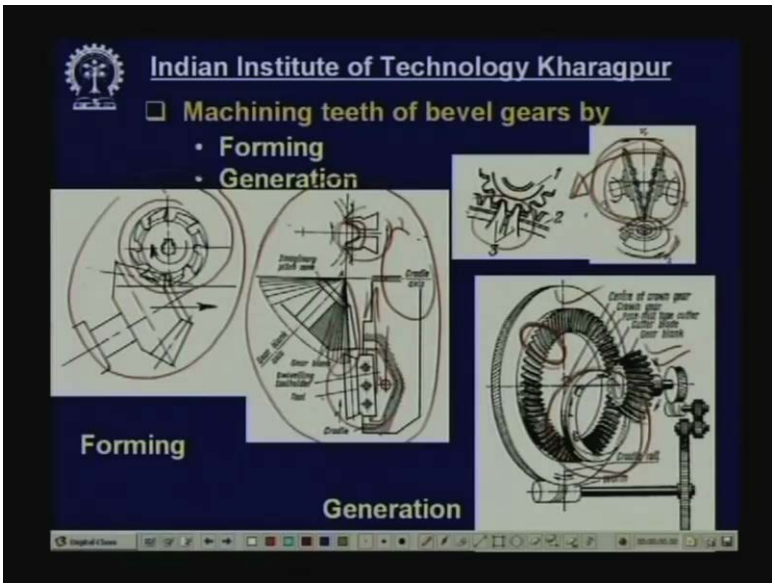

This is very interesting which can be done in two ways, either by forming process by a milling cutter for milling cutter as shown over here or this can be done by generation process. So, this generation process means this is a gear. Here this is a gear. So this is a bevel gear. This is another bevel gear, suppose this is the gear to be produced the teeth of the gear to be produced and this has to be kind of some of the teeth of this gear. You have taken one imaginary gear with only two or three teeth and this teeth will produce the teeth of the gear while interacting. For example; this big crown gear is taken this axis is here. So this thing the entire thing will rotate about this axis, a disc which has got two teeth. Only here which reciprocate radially and cut the teeth on the bevel gears like this and produce this tooth bounded by two involute.

So this is the principle. This two teeth reciprocating can be replaced by two rotary teeth also but remember here the gear blank rotates in this direction. This entire system also rotates in a particular direction, just as if two bevel gears are in action. Now, this is you know spiral bevel gears are hypoid bevel gears which also produced on the same principle by the special cutter. The movement of the cutter the path of the cutter very similar to the teeth of the crown gear which will match with the gear to be cut. Now the gear teeth finishing:

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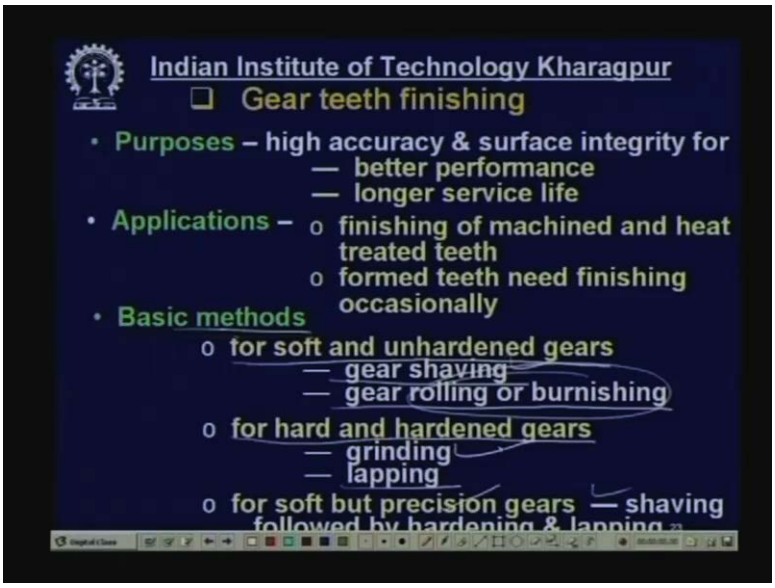

Gear teeth's are finished for better performance and longer service life, application, finishing of machine and heat treated teeth, formed teeth by produced by say powder metallurgy or centrifugal casting or investment casting. They are also produce finished by grinding process, similar process etcetera. Now what are the methods? There are two methods one is basic methods one is for soft and unhardened gears gear shaving and another; one is gear rolling or burnishing hard or harden gear are finished by grinding which cannot be done by shaving and lapping for soft but precision gears shaving followed by hardening slight hardening and then finishing by lapping.

Now rolling burnishing means the machine gear which has got slight deviations here and there we will be rolled along with three two or three hard very harder gears and which are accurate while rolling these in accuracies or deviations of the gear under constellation will be smeared of and you get a good gear by this burnishing action and lapping process may one gear. This is the you have to finish has to role along a cast iron gear and then you just put in between the teeth say paste of diamond and oil. So that will gradually remove the irregular teeth's and make an excellent gear. Now what is gear shaving?

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The gear shaving cutter it can be of different type. It can be this type, it can be a gear cutter. It can be rack like. It can be worm like. Here you can see the function. This is the gear to be finished teeth and this is the gear shaving cutter. Now the gear from the distance with look like a gear, it is so looks like a gear but difference is here you see the teeth of the shaving cutter. This is the teeth of the shaving cutter which has got small grooves and range shaft cutting edges. So, when they interact roll this will have some relative movement, you know axial movement. So there will be some axial movement in this direction and that will remove the irregularities on the gear to be cut.

So this is a shaving process that means when two gears are mesh the gear and the shaving cutter there will be a rolling action as usual as well as some axial movement along the tooth. So, the irregularities of the tooth will be removed. Now, this is a rack type. So this rack will interact with this one and as I say this will move in this direction. This will rotate in this direction, but at the same time this will move in this direction. This kind of shaving cutters are used for finishing the teeth of worm wheel, then gear teeth finishing by grinding.

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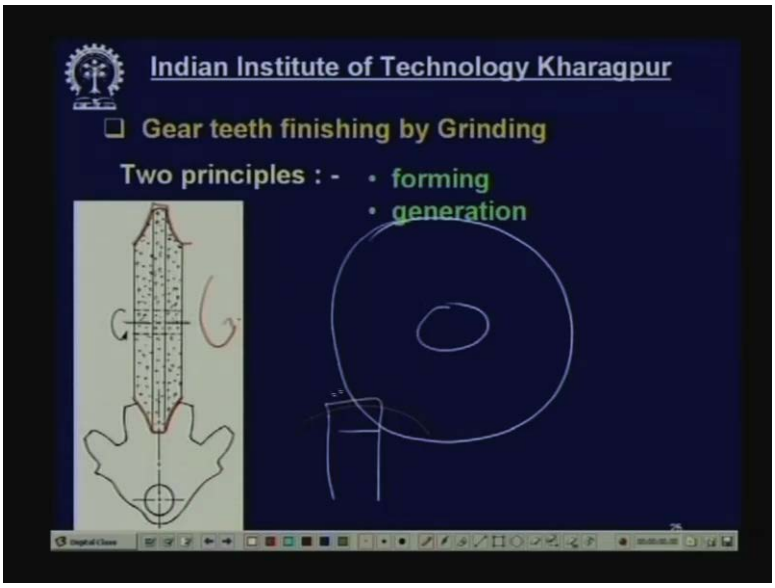

This is a grinding process, very similar to milling. This is the tooth formed. This is the tooth form to be produced and you take a grinding wheel of the same profile and you rotate it and this is the gear blank. This is the gear blank. here the tooth and this is the grinding wheel okay. So the grinding wheel will rotate at high speed and then you move it downward. So, gradually this entire tooth will be finished. Now the generation principle:

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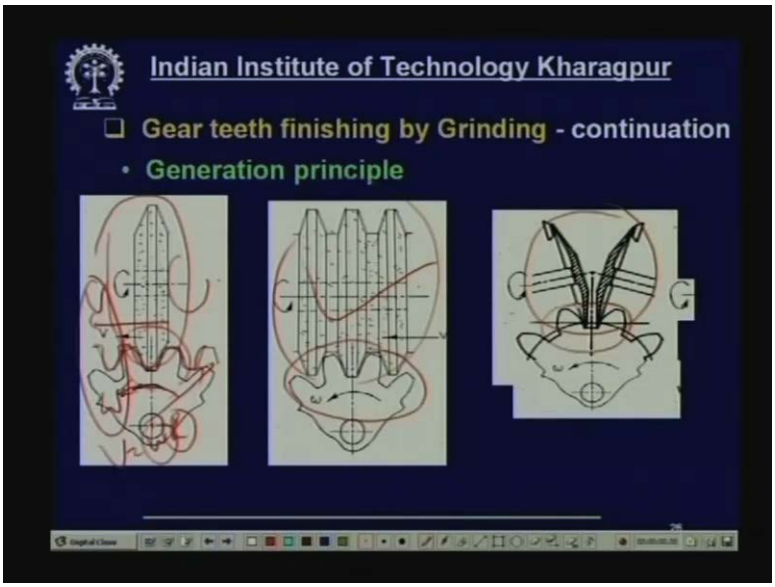

Here, it looks similar use. This is the this is the rack. This is basically a rack. Here you can see a rack. These are rack like the straight tooth. So one of the rack tooth has been taken on the form of grinding wheel. So the grinding wheel will reciprocate parallel to the axis of the wheel is a move parallel to this axis as well as, this will move in this direction.

This will move in this direction. These two motion say v and omega will be so related that v is equal to omega R. v is equal to omega R. R is the radius of the gear. Omega is the angular speed of the gear. This will cause a rolling action and this grinding wheel will rotate at high speed and it will move parallel to the axis of the grinding wheel as you saw in the previous diagram.

Now this will produce tooth by tooth, but if you want to increase the productivity say two or three or four teeth together, then you have to take this kind of grinding wheel to produce number of teeth simultaneously. But, for large gears of large tooth instead of the large wheel, you can take small wheels where the end of this type wheels confirmed the profile. So dear friends, you have now seen there are many many methods of making gear and tooth and finishing and now you can further study from books.

Thank you.