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NPTEL ONLINE CERTIFICATION COURSE

Course
on

Spur and Helical Gear Cutting

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Lecture 11: Gear Shaping - I

Welcome viewers to the 11th lecture of the course spur and helical gear cutting.

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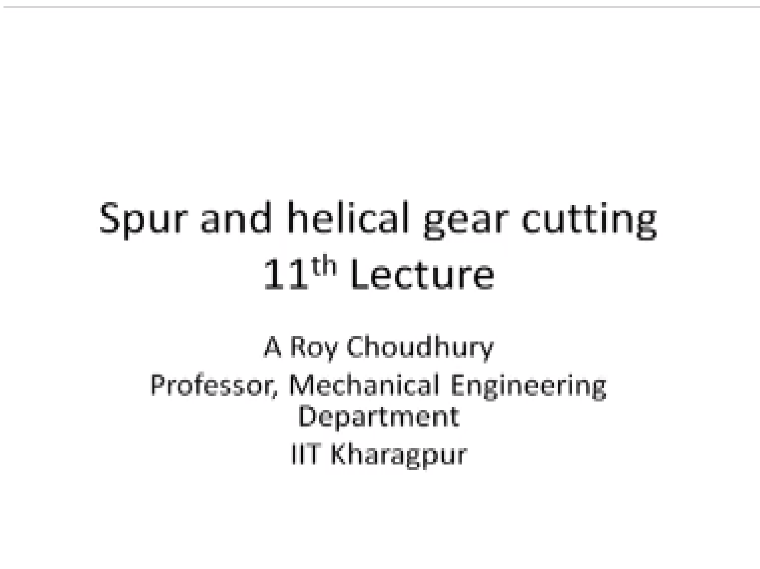

So we have discussed on the last day some numerical problems in differential and helical sorry differential indexing and helical gear cutting and today we are going to start a new topic which is basically gear shaping gear shaping falls under the category of a method you know our number of methods called generation processes it is not restricted only to gear cutting generation processes can be you know can generate different types of profiles and gears fall into that category.

Generation process is basically you know in colloquial language it is basically like this if you are having two elements rolling against each other then one of the elements that means one of the same mechanical elements in our case can be obtained by taking the envelope of the conjugate what I call it conjugate profiles of the other, so it means if something is rolling against say elements a is rolling is element B go on taking the you know positions of be mapped them continuously one after the other the successive positions and take the conjugate of that and you will get a.

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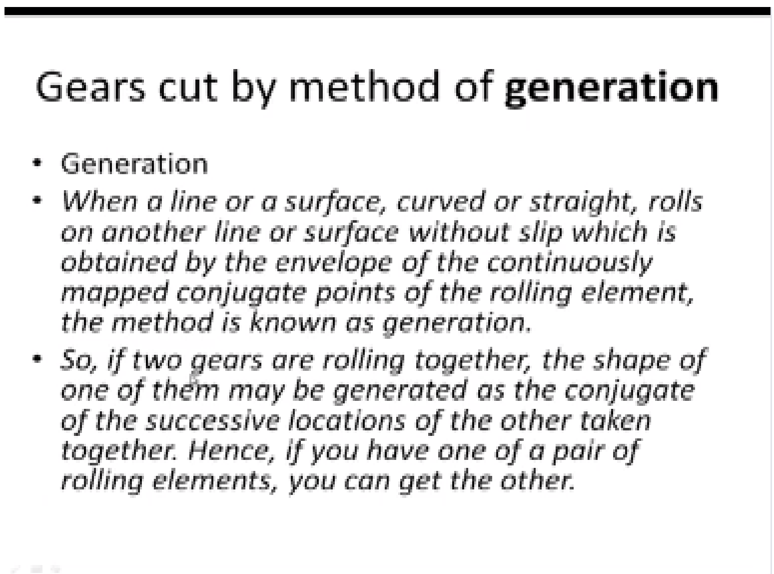

So let us start formally with the classical definition of generation when a line or a surface curved or straight rolls on another line or surface without slip which is obtained by the envelope of the continuously mapped conjugate points of the rolling element the method is known as generation this definition is taken from principles of machine tools by a Bhattacharya, so if we make it in simpler language, so if to that means in case of gears so if two gears are rolling together the shape of one of them may be generated as the conjugate of the successive locations of the other taken together. Hence if you have one pair of rolling elements sorry if you have one of a pair of rolling elements you can get the other from the rolling motion of the first one.

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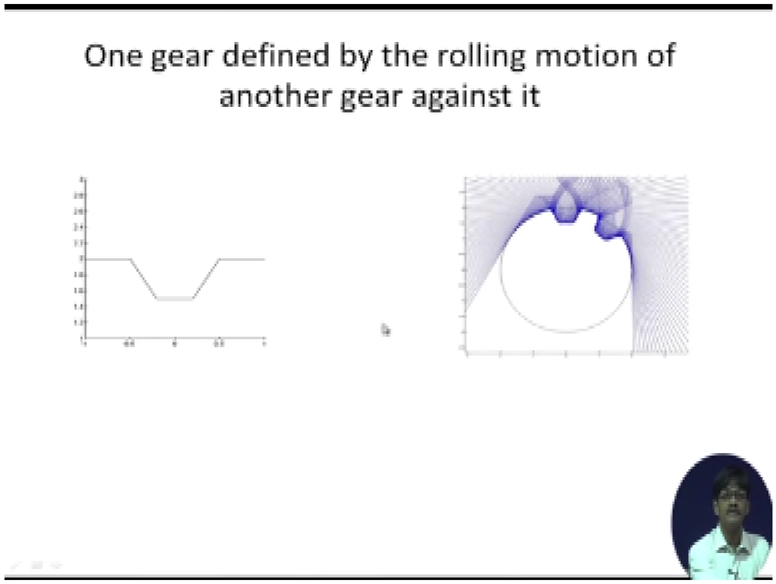

This shows that this is the you know rack geometry that I have and I am rolling it against okay I am moving it as if it is rolling against a virtual gear and the continuous positions of the rack they are recorded here and when I am taking the conjugate envelope this one conjugate means just the opposite space, so all these are the positions of the rack and when I am taking the conjugate space I find that it is generating a gear tooth shape, so this way if I had allowed the rack to move all around it would have generated the complete gear tooth a gear teeth profile okay.

Now let us have a practical you know demonstration of the same just allow me one or two moments yeah. So if you have a look this one is the rolling rack and it is generating the surface the gear tooth profile okay I have made a MATLAB program I mean one of my students Aditya Sriram thanks to him he had generated this program for generating the gear teeth okay so this way as the demonstration shows if I go on rolling one element gainst the virtual I mean the other one is not existing but if I give all the movements as if they are rolling together then the continuously mapped conjugate positions of one element would give me the other surface So this we utilize in our case utilize in our case to generate gear teeth.

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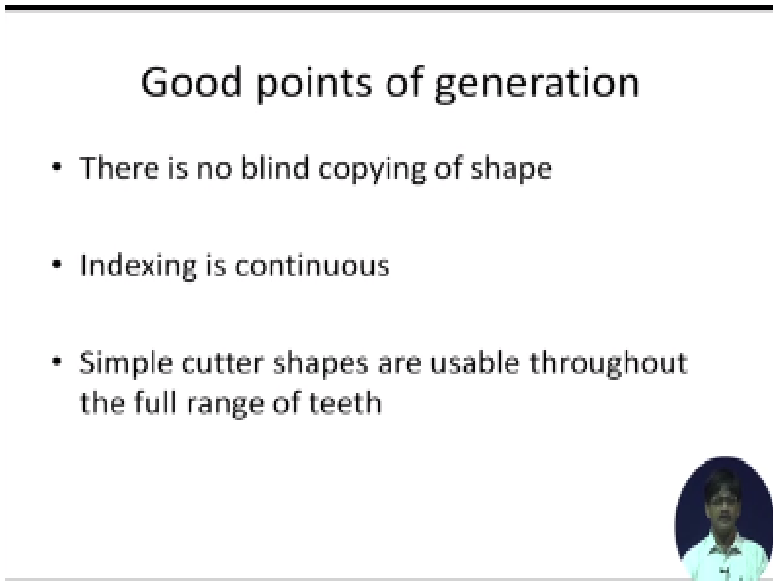

What is the advantage of this particular method there are distinctly three advantages that we have in comparison to milling of gears first one there is no blind copying of shape it is not a forming sorry it is not a gear forming process forming essentially means that you are copying one geometry from one machine element one cutting element into the onto the blank surface, so we are not blindly copying if you do blind copying then the problem is whatever errors you have they get generated again and again and you have to have different types of cutting elements different you know a number of cutting elements have to be there in order to develop a number of such shapes.

Because it is blind copying variations between the end shapes as per your requirement cannot be obtained by the same cutting element all the time next one is indexing is continuous the process of indexing that we have learnt in case of milling it is not continuous why because we have to stop the cutting process we have to rotate the gear blank and then only we can start the cutting of one more gear tooth space.

So as indexing is discontinuous inherent you know inherent errors in discontinuity of a process will bring in inaccuracies in the work piece what sort of inherent errors one is clamping unclamping moving, making mistakes due to you know backlash error okay and then I estimation of the amount of rotation I by I estimation I mean that the not I estimation we should make say human errors of the estimation of rotation and then inherent errors of you know the angular spacing of the holes on a whole circle in milling index plate all these things will be brought in.

In case of methods of generation indexing discontinuous indexing is not at all existing it is replaced by continuous indexing that means while cutting is going on the tool and the work piece they rotate against each other, so that the cutting action is distributed over all the teeth also simple cutter shapes are usable throughout the full range of the teeth, so starting from say 12 to 13 teeth right up to the rack you can use the same cutter this is a big advantage because in case of milling at least we are having how many 8 cutters a set of 8 cutters are handling from 12, 13 teeth to the rack. So with this discussion we come to the conclusion that generation definitely has it is advantages over milling of gayety.

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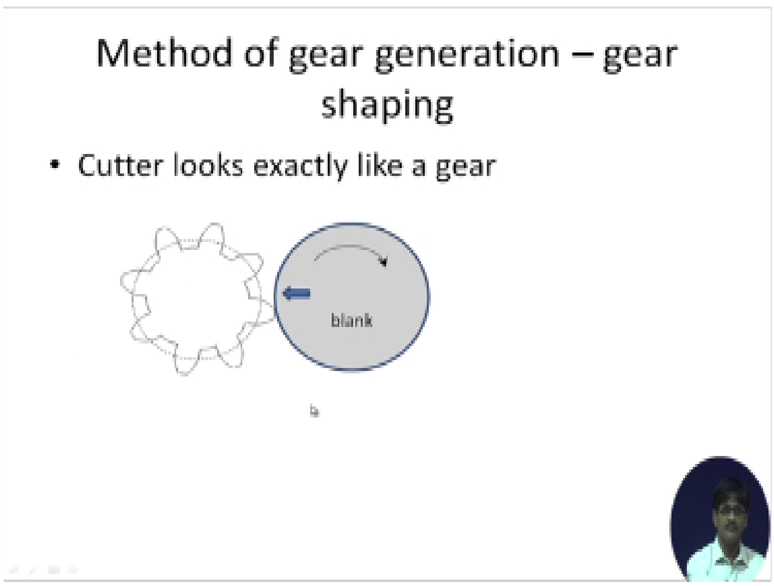

So let us have a look how the method proceeds in case of gear shaping this is a cutting element it is made of you know absolutely hard rigid material which is not deforming and in contact with it we have the gear black that is also metallic or it can be plastic or some other material but it is relatively softer that this one because conventional cutting is going on, so work piece material has to be softer but it has to be cut it cannot be deformed out of shape no we essentially have to cut it out of you know off of a cylindrical blank material that the gear.

So let us see how the movement proceeds in gear shaping first of all the cutter, so this is the cutter the cutter and the give land they are made to touch almost tip to tip and after that cutter rotates blank rotates and the blank gradually moves forward towards the cutter let us see yeah I think you can see very slow rotation of the cutter taking place and the blank is also rotating as if they are rolling are they rolling together no they are no teeth but they are me to rotate by us individually I am rotating the cutter I am rotating the blank and I am making the blank move gradually towards the cutter.

So that the interference between them it is gradually increasing but if this is made of metal or some other material which is hard okay not as hard as the cutter but quite hard in that case there will be this interference will result in some sort of scene or damage or breakage or some kind of you know metal forming cannot take place just like that, so this material which is you know in the interference zone this would not get removed just like that unless we have the cut you have a cutting action incorporated.

What is the cutting action and on the axis of the cutter the cutter goes on reciprocating cutting off everything it meets on it is way, so in addition to these three movements one is rotation of cutter rotation of blank and movement of the blank towards the cutter we also have this movement okay.

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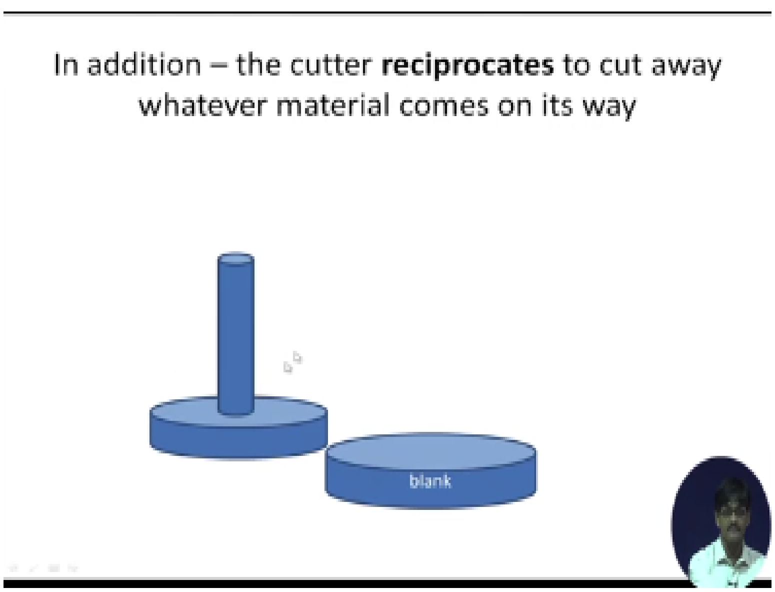

This is the cutter this is the blank and the cutter is also moving this way together with rotation of the cutter rotation of the blank as we have seen before and movement of the blank towards the cutter okay, so this reciprocation removes all the material the cutter needs on its way remember the cutter is having teeth on its periphery and those teeth have sharp edges and they are given cutting angles in order to facilitate material removal and also for providing clearance. So that the finished surface of the blank is not touched by the cutter on its you know during its movement okay.

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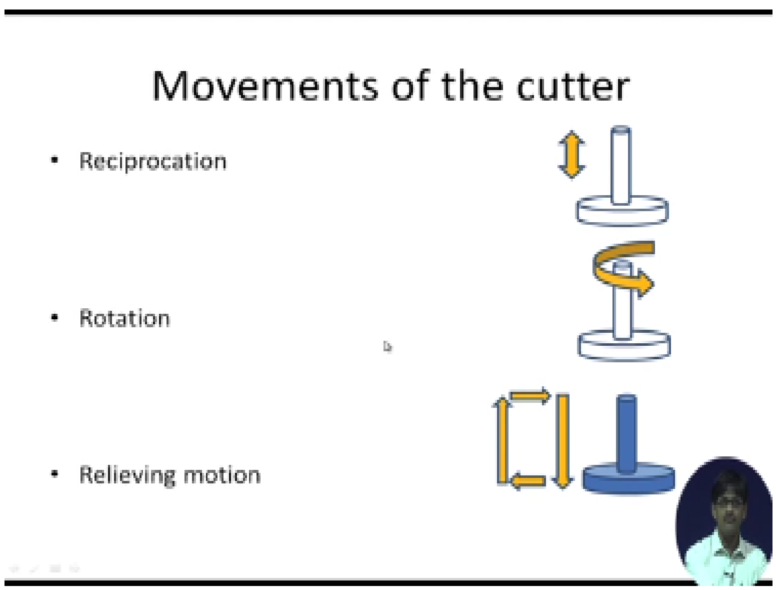

So what are the movements that we are providing we are providing as we have seen reciprocation this reciprocation provides the cutting action the cutter cuts off all the material it finds on its way and that way material is removed by cutting action no pressing no damaging no denting but cutting in addition to that as we have noticed the cutter also has a rotation okay because we have to create a situation in which as if cutter and the work piece they are already formed gears and they are rotating against each other as if they are rolling together.

We are creating that condition, so in that case if the cutter removes all the material it meets on its way it will be providing ultimately it will give rise to a completely machined gear out of the blank so this one is one motion which we have not discussed up till now when the cutter is moving up it slightly recedes away from the work piece, so that it does not rub against the finished surface of the work piece unnecessarily this movement would have you know damaged the finished surface.

So it slightly recedes away and moves up comes back to the original line of cutting and then comes down and does the next cutting I mean carries out the next cutting stroke, so this is a relieving motion okay, so how many movements do we have here 1, 2, 3.
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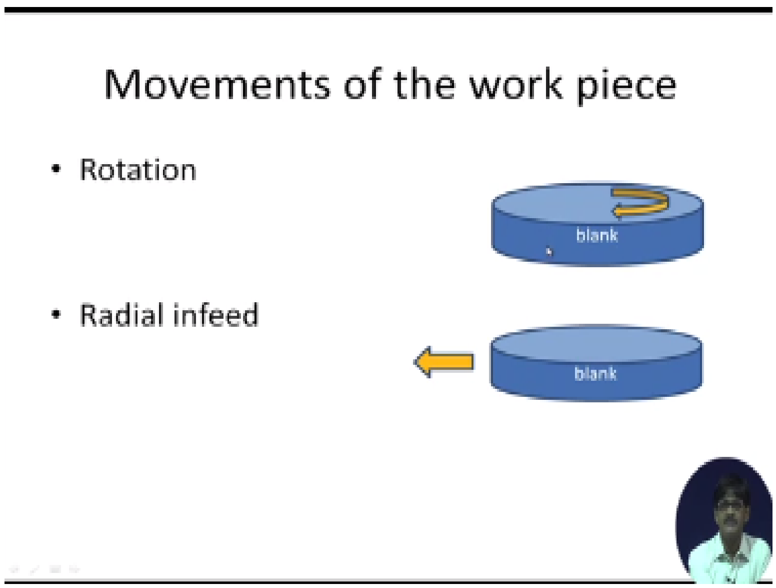

Work piece is also rotating because we are creating a condition of you know rotation of the cutter and the blank together so this motion has to be provided as well and work piece is having radial in feed which we have noticed during the simulation why does the work piece have gradual you know radial that means towards the cutter radially it is moving this is because the cutting action is made to increase slowly from zero depth of cut to the full depth of cut this is because if we give the full depth of cut in the beginning itself the cutter coming down with the during it is stroke if it meets with the full depth of cut there will be you know breakage .

Instead of cutting it off the blank might be broken or the cutter might be damaged, so gradually this is move while rotation of the cutter on the work piece and the depth of cut increases gradually from zero to the full, so five motions in total are required to make this thing work and we have a machine called the gear shaping machine in which all these movements are incorporated.

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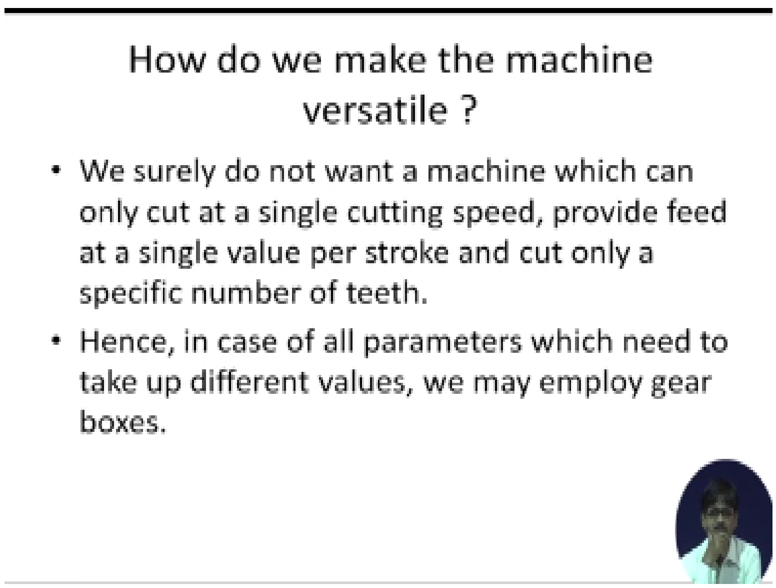

Now that now comes the question okay just making a machine in which all these things are possible is not the full solution I mean people would not be interested in your machine if you make a machine and you say yes my machine has all these 5 motions but it has only one you know one particular motion of one particular strokes per minute one particular gear can be held and you know one particular blank can be held and only a certain number of teeth can be cut may be it can only cut 50,60.

Then what is the use of it has to be versatile you can employ any cutting speed say within the range of say 30 meters per minute to say 150 meters per minute any cutting speed generally cuttings the instead of cutting speed we employ strokes per minute which means that now you can use say 30 strokes per minute you can use 300 strokes per minute like that with the strokes per minute the cutting speed will increase, so why should we have different strokes per minute because you might be using a more sophisticated cutting tool which can cut at a higher speed and you will be saving time.

You might be using a employing a blank that is you might be cutting the gear out of a blank material which is soft and you can imply a higher cutting speed, so in those cases we can employ a higher number of strokes per minute why would you require say what are the other cases where versatile is required you might be having the requirement of a gear with highly finished surface okay in that case we would have a provision through you know incorporation of a gear box in which you can have rough cut gears or you can have finished cut yours that means the surface finish will be either rough or fine.

Now you might say why should why should surface finish be rough this is because maybe this is just the you know rough cutting is to be done and after that you will be doing a finish cut and during the rough cut you need not have very fine surface and you can save time by using a coarse feed, so a feed gearbox is provided with the help of which you can have different feed values and feed is expressed in circumferential movement but stroke of the machine.

So now we have strokes per minute which can be changed by a gearbox which is called speed gear box we can have different feed values millimeters of circumferential movement per stroke, so two gearboxes and if you want to cut different numbers of teeth if you cannot cut different numbers of teeth the new machine is practically useless, so another gear box is incorporated with the help of which you will be having the provision to cut different numbers of teeth okay.

So basically we are able to incorporate these you know versatility with the help of incorporation of gearboxes. Gearboxes will give you distinct and discrete options it is not infinitely variable but you can predefined your requirements and accordingly gearboxes can be incorporated which will be providing you with those facilities, so we understand that this machine cannot stand alone just with the with providing the 5 motions but they have to be gearboxes as well.

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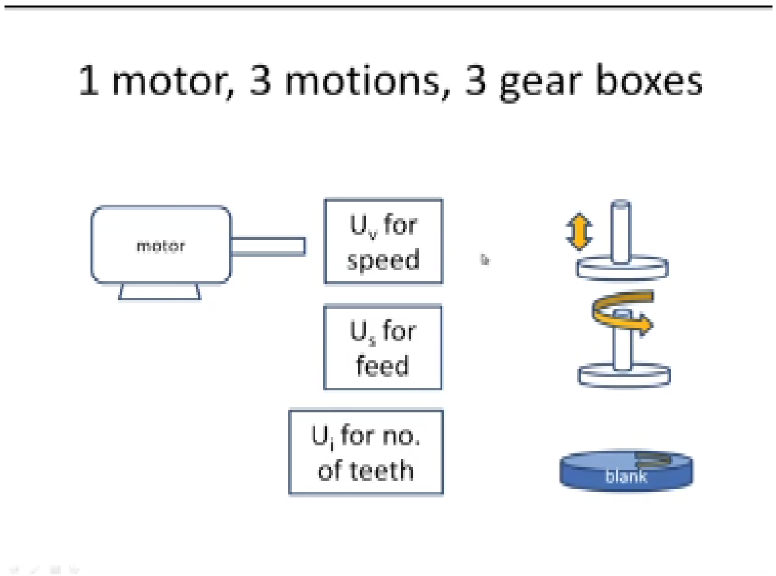

So that preliminary design of the machine required we are cutting down from five motions required to three motions we will incorporate those five motions definitely but these three emotions are the most important ones and we will restrict our discussion first to these 3 and then move on to the incorporation of the other two, so this is the motor there has to be a power source and this day we are at present working with a single motor that is quite strange we have so many motions by a single motor we will find that a single motor is also quite capable of providing all the motions that we want.

We are incorporating now three gearboxes for the three motions what are these first of all UV we name one gear box UV for changing the speed which basically is going to serve the purpose of changing the number of strokes per minute us for feed value which will basically control the circumferential movement per stroke okay the amount of circumferential movement per stroke and we will also have UI or index gearbox okay this is speed gearbox this is feed gear box this is index gearbox if you have the requirement of cutting different numbers of T's you will be having a different setting of the index gearbox okay.

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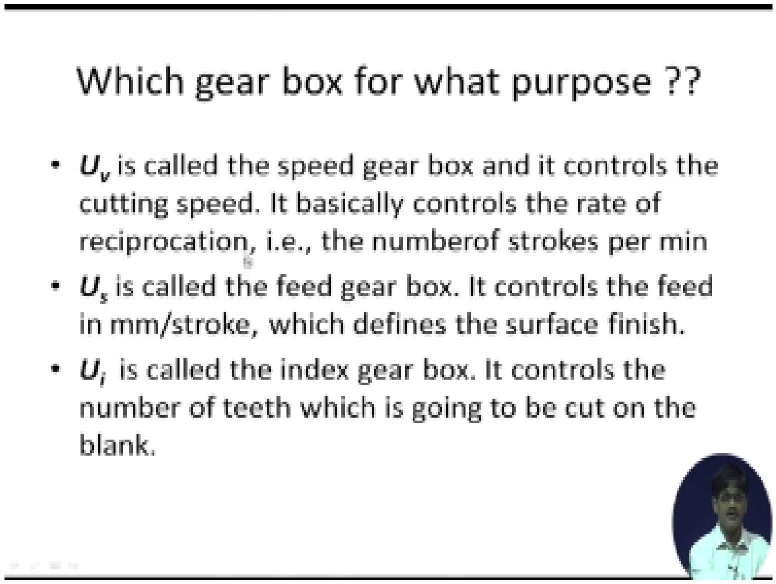

Now how do we connect these let us see, so we need to find out, so we have discussed this thing just now we need not know so the UV is called speed gearbox and interglacial control the rate of reciprocation, so I am skipping this one.

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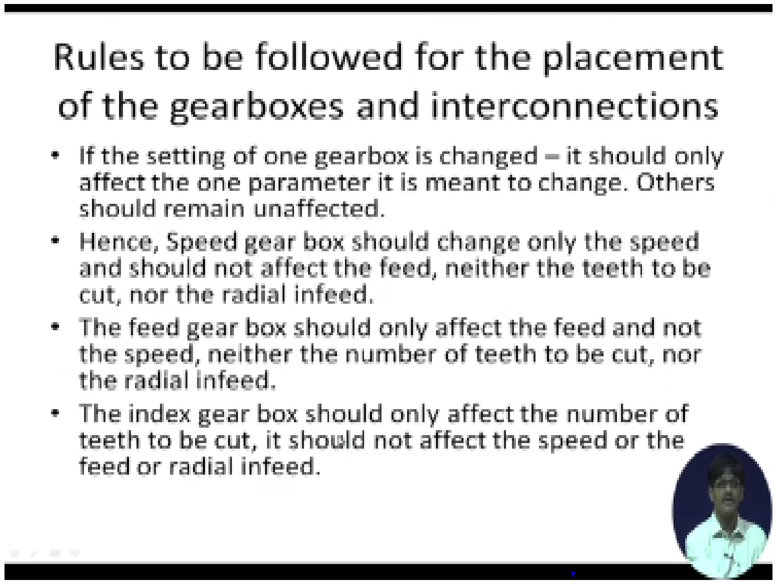

So the rules that have to be followed for the proper placement of the gearboxes and their interconnections first of all what do we mean by these rules it is inherently understood okay, it is inherently understood that the changing of the setting of one gearbox should affect whatever it is supposed to control and nothing else this is basically the what we understand by the rule, so let us read it up if the setting of one gearbox is changed it should only affect the one parameter it is meant to change others should remain unaffected that is all and then we give an example hence speed gearbox should change only the speed that means the number of strokes per minute.

And should not affect the feed neither the teeth to be cut nor the radial in feed and if we extend this to the others it means that the feed gearbox should only affect the feed and not the fee not the speed neither the number of teeth to be cut nor the radial in feed the index gearbox should only affect the number of teeth to be cut it should not affect the speed or the feed or the radial in feeding. So now we understand that they are mutually exclusive in their function the changing of one gearbox should not affect the working of the others.

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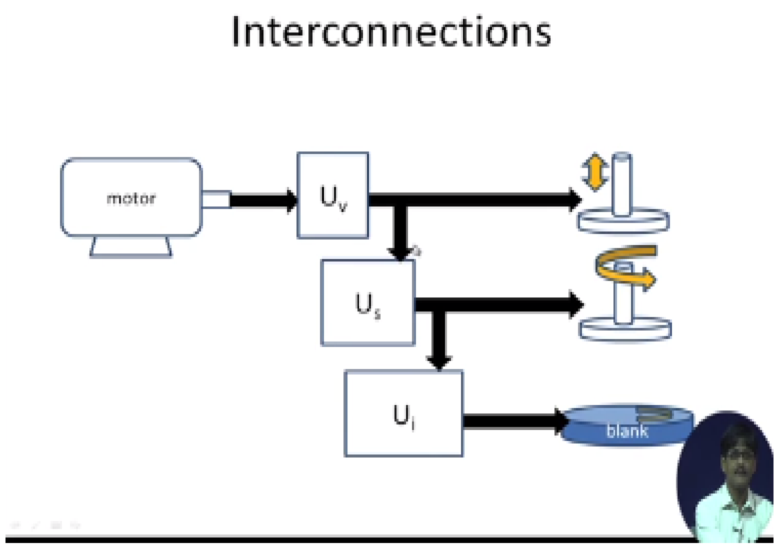

So let us have a look at this particular interconnection what do we notice here the motor is first of all serving UV the speed gearbox, so rotation of the motor everything we have you know represented symbolically, so it means that the power is flowing from the motor to the speed gearbox how does the power flow, so the motor shaft is rotating and that shaft goes inside the gearbox UV there \will be a cluster of gears and these cluster of gears would be changing the RPM.

Then a different RPM which we will be coming out of the gearbox and serving the subsequent machine elements or other gearboxes as the case may be, so let us have a look the speed gearbox is being connected directly to the motor, so that means downstream of the speed gearbox whatever is there they are going to be affected by the change in the speed gearbox but that seems to be exactly the opposite of what we had been planning what had we planned we had planned that the speed gearbox or whatever gearbox it should only affect the parameter it was supposed to change and nothing else.

But obviously if the speed gearbox is connected upstream of everything all others would be affected, so let us look at it and find out what is exactly going on here, now at this juncture I will just bring back a discussion that we had had regarding the placement of the lead gearboxes namely the speed the feed gearboxes I will just draw figure please have a look at the piece of paper.

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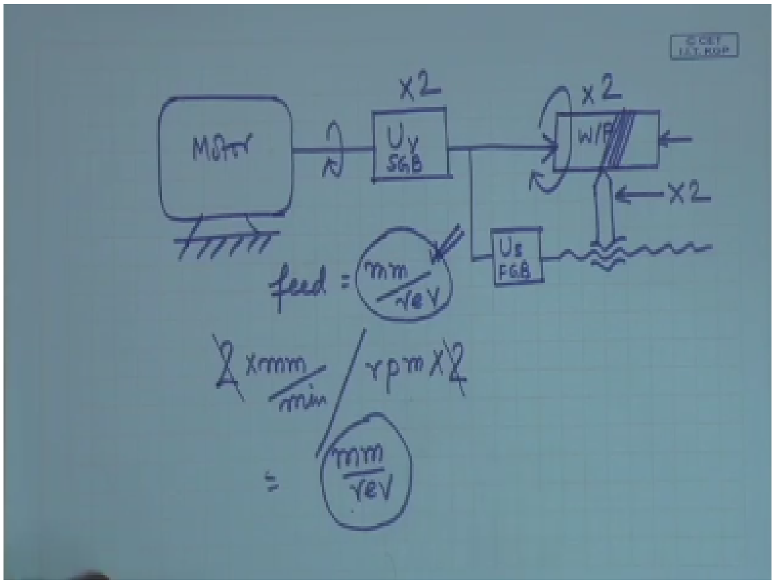

And I think that will make subsequent discussions extremely clear on the lead we have a motor from which we are drawing power and if you remember we have the location of speed gear box let us call it SGP speed gear box here and after this just like as in the gear shaper we have the spindle to contain the work piece and we draw the power from here for US feed gear box and from here you might be having a lead screw and you can mount your nut and the cutter this way.

This was the figure in case of the lead the same thing was happening UV is placed ahead of everything and therefore if UV is doubled suppose I make a setting of the UV, so that the output our team is doubled in that case the cuttings the rotation of the work piece doubles and the cutting speed is made double exactly what we wanted the speed cutting speed is doubled, so this also becomes multiplied by 2.

But what about this place this also the movement of this one also appears to have been doubled this is not real not what we want we want that whatever changes UV will create it can only be restricted to the change in cutting speed what about the feed motion feed motion is the motion of the cutter pass to the work piece to extend the cutting action to newer areas of the work piece here if we notice that feed is actually remaining same point because of the definition of feed is defined in millimeters per revolution.

Millimeters of tool movement not per unit time no millimeters of tool movement per revolution of work piece, so if the work piece rotates once whatever movement the tool has suffered that is known as the feed and that will remain constant because if this motion in millimeters per minute is getting doubled into two divided by revolutions per minute of the work piece that is also getting doubled the two and two from the numerator and denominator will cancel therefore millimeters per minute by revolutions per minute per minute and per minute will cancel and you will have millimeters per revolution.

Same as before no multiplying factor is remaining, so millimeters per minute is remaining same and therefore we say that the feed is not affected but the question is why should we define this one as millimeters per revolution okay we are getting away with it remains constant but why go for such a unit this is because this is the factor or the parameter of the variable which defines a very important thing on the work piece the surface finish okay the surface finish is defined by the small amount of movement you are making per revolution of the work piece.

This also defines the pitch of the thread your you are attempting to cut on the lathe, so we find that the gearboxes are affecting only the parameters they are supposed to affect in this case by virtue of the definition of feed here.

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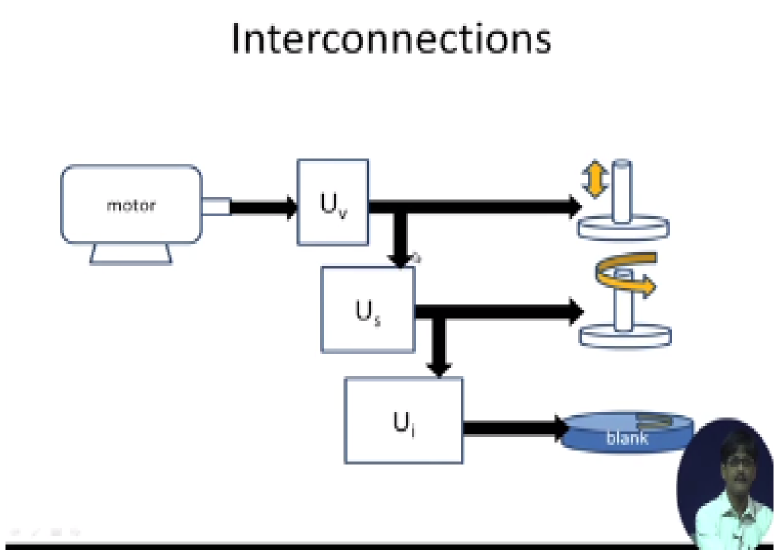

Now we come back to our discussion on the gear shaper and have a quick look that exactly the same thing is going to happen, if you look at the figure now in the figure U V is going to double say UI double UV, UV is going to double the reciprocation rate, so the number of strokes per minute becomes double and therefore speed becomes higher double I am there for US okay whatever is passing through US that also becomes double.

So the rotations per minute will become double okay, so just as before the if a certain number of millimeters on this on the circumference they were passing per stroke okay passing they were undergoing rotation per stroke that will also double but number of strokes have also increased twice, so that twice two factor of two cancels if you can you have a look here it is something like this.

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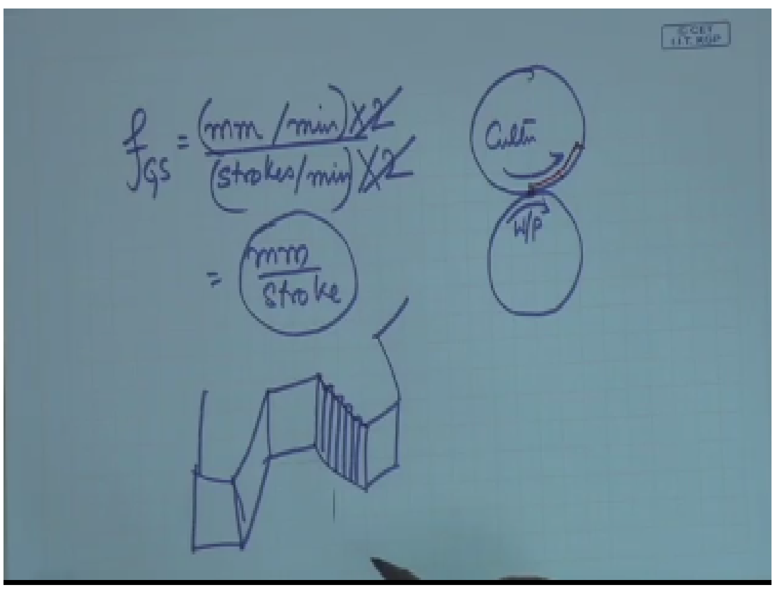

Millimeters so the feed in case of gear shaper in case of gear shaper millimeters per minute by strokes per minute strokes per minute is getting doubled millimeters per minute circumferential movement okay it is like this is the cutter this is the work piece and therefore this one is rotating against each other and therefore the movement it suffers say I will draw with a different color the movement it suffers per stroke this becomes double this becomes double per minute sorry per minute yes suppose this amount of movement is taking place per minute that is they are rolling against each other and this amount of movement per minute it is moving.

So now you will find double the amount of movement is taking place per minute, so this is doubled okay and therefore these two cancel per minute per minute cancels and millimeters per stroke will remain as before and therefore feed is not affected and once again why do we define feed is millimeters per stroke because it defines okay the tool is going on moving this way it defines exactly and while the cutter is rotating while the cutter is rotating it is something like this while the cutter is rotating it also moving up and down.

And therefore that also defines the roughness of the gear teeth okay I will draw a figure so that you will agree with me the roughness left behind on the gear teeth when cutting takes place is like this rough surface that the lay lines of the cut will be like this and this will be rougher in a coarse cut will be there if you use higher value of S the cutter has gone this way okay and cut the material, so this millimeters per stroke will remain the same even if you double the UV setting, so with this we come to the end of the first lecture on gear shaping we will again meet in the 12th lecture thank you very much.