# Spur and Helical Gear Cutting
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**Lecture – 32**
**Gear Shaping - II**

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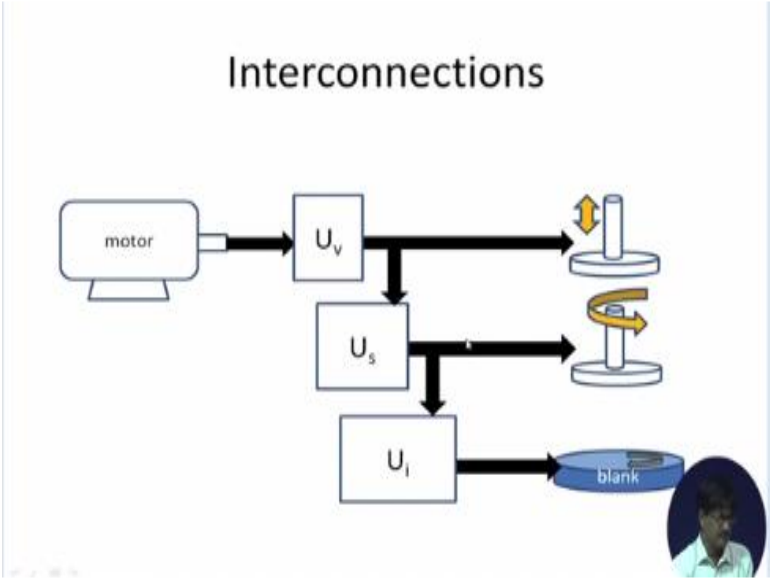


Welcome to the 12th lecture of the series Spur and Helical Gear Cutting. Last time, we were discussing a figure in which you know the setting of the gearboxes had been shown and we had discussed up to till this point that the location of the gearbox $U_v$ apparently affects everything downstream. So, that first the feed of the cutter against the work piece might be affected.

However, our discussion showed that the way in which field has been defined as millimetres per stroke, that remains the same even if $U_v$ setting is changed. So, we noticed that a change in $U_v$ made a change in case of the strokes per minute, but it did not affect the feed value. Now, comes to the question. We also need to check; does it affect the number of teeth being cut? How is the number of teeth decided?

That is very important. Let us have a look at that. So, for that, kindly have a look at this, at the paper.

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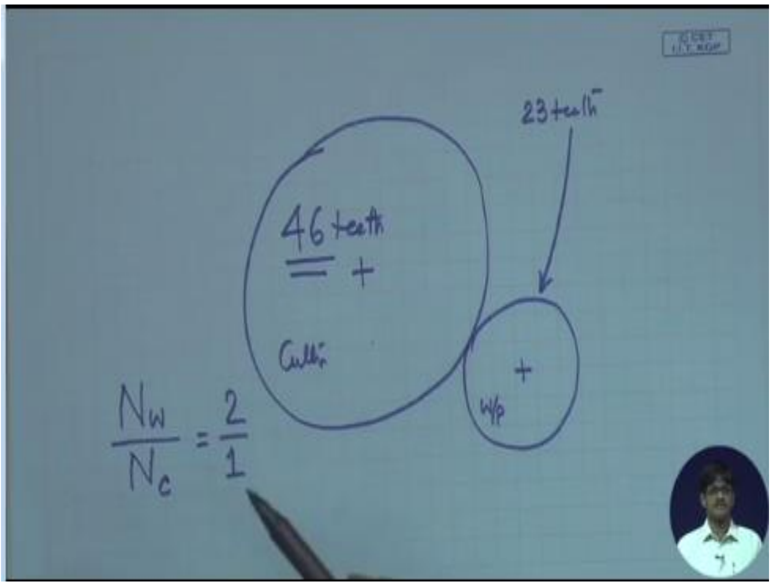


We have this as the cutter. The cutter is also a gear as you noticed in the simulation and say, this is the work piece. Now, how are we going to decide how many teeth are going to be cut? Suppose, I decide that I want to cut say 23 teeth. If I want to cut 23 teeth on the work piece, suppose, the cutter is having 46 teeth, then first by calculation, I have to find out the correct outer diameter.

The correct outer diameter has to be determined for the work piece and accordingly up blank with proper outside diameter has to be machined out for 23 teeth. And if it meshes with 46 gears of the same module, in that case, they would have a definite speed ratio. What will be the speed ratio? The one with larger number of teeth will definitely have slower RPM and then therefore, we can say:

$$\frac{N_{\text{work piece}}}{N_{\text{cutter}}} = \frac{2}{1}$$

This will be double the rotation of the RPM of this one and therefore, we can say this is equal 2:1. So, that means on the gear shaping machine where teeth are not existing on this one, if we can produce a speed ratio of 2:1 between the cutter and the work piece, in that case, a definite number of teeth will be cut.

So, if we provide this an RPM 100 and we separately provide this an RPM of 200, we will find that it will cut 23 teeth if the cutter has 46 teeth. This is basically the statement. So, with this idea, now, let us have a look how we are going to proceed for the cutting. So, to start with, let us come back to the figure. So, in the figure, $U_v$ has been doubled as we discussed previously.

So, to sum up this particular part, number of teeth on the work piece is completely determined by the ratio of the rotations that we are providing to the cutter and the work piece. If you set a different ratio, accordingly a particular number of teeth will be machined on the work piece provided; we provide the work piece with, the blank with the correct outside diameter.

If you provide a wrong diameter, something will you know, go wrong and rubbing will take place between the cutter and the work piece, which will ultimately spoil the teeth. So, to come back our discussion. $U_i$ is the gearbox for determining number of teeth, should determine the ratio of rotations of the cutter and work piece.

This ratio of rotations should not be affected either by $U_v$ or by $U_s$. So, now let us let us cross check that. How is the ratio of the cutter rotation and the work piece rotation affected? So, in the loop that we have between cutter and the work piece, this is the flow of power. Here, we were moving backwards. Here, we move forwards. We reach $U_i$ and then we reach the blank.

So, we understand that the ratio of rotations of the cutter and the work piece or the blank can only be affected by elements which are present in this loop. Who is present in this loop? Symbolically, we have shown only $U_i$ is present between the cutters and the black and that way, this configuration is correct. And if $U_v$ is changed, it will equally affect the rotation of the cutter as well as rotation of the work piece, because it is outside the loop.

What does this mean? This means that suppose if $U_v$ is doubled. So, that its output RPM gets doubled. If the output RPM is getting doubled, it passes through $U_s$ whatever change that brings in, then the change in rotation that means the factor getting multiplied due to the change in rotation that factor will be multiplying the RPM of the cutter and the same factor will be multiplying the RPM of the blank and their RPM ratio will remain the same.

So, if some machine element, gearbox or something like that, $U_v$ or $U_s$ or whatever else is outside this loop connecting up cutter and the work piece, they will not be able to affect the rotational ratio and therefore, the number of teeth being cut on the blank. This is what we understand. Therefore, this configuration is fool proof. $U_v$ affects only cutting speed.

$U_s$ affects only the feed of the cutter and $U_i$ affects only the number of teeth being cut on the blank. Suppose, I want to find out how is $U_s$ affecting the feed. Can I make this feed higher or lower by changing $U_s$? If we are changing $U_s$, the cutter starts rotating say faster. So, suppose, the setting of the $U_s$ is changed, so that this RPM is doubled.

So, the cutter starts rotating twice as fast. Now, in order that the cutter and the work piece should always have the same RPM ratio. This factor which has changed at the output of $U_s$ that is also brought here and the blank starts rotating twice as fast. So, they still retain the RPM ratio in between but in addition, they are moving fast against each other. So, that the circumferential movement does suffer per stroke that has changed.

Why? Because, the strokes per minute have remained constant while the millimetres of circumferential movement per minute that has changed. If that increases, therefore, millimetres of circumferential movement per stroke equal to the feed that will become higher.

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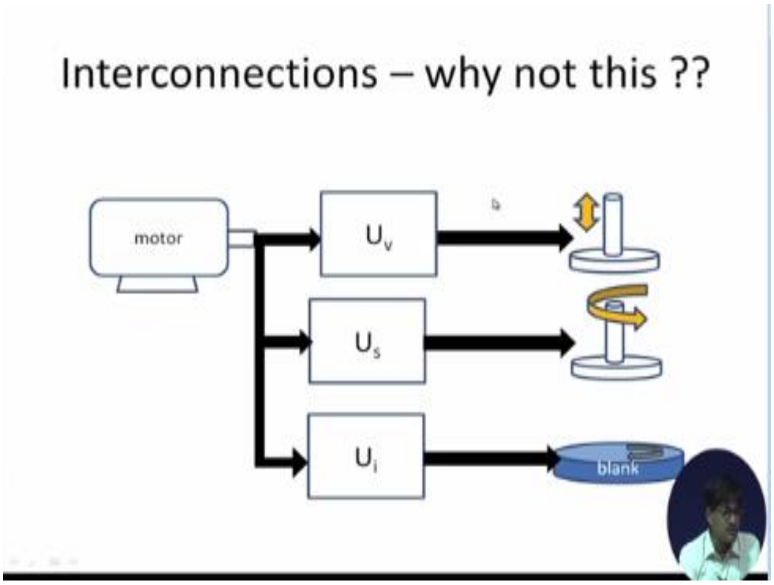


So, with this, let us move on to other configurations and check why we chose that particular configuration and not one of these. And sequentially, you will agree with me that all of these have some problem because of which the configuration that we started with can be considered as unique. So, if we consider this configuration.

Suppose, I am assigning a particular task to a student who has just become conversant with gear shaping, connect up all the gearboxes with the motor and all the machine elements that they are supposed to serve. So, the gearbox $U_v$ is supposed to serve the up and down movement, so, it is connected. $U_s$ is supposed to serve the circumferential movement of the cutter and of course, the work piece also and therefore, you connect it.

$U_i$ is supposed to control the ratio of rotations you connected with the blank rotation and instead of the previous connections suppose, I straight cut, I tap power from the motor and give the connection to all the gearboxes. Now, is this alright? So, let us check what possible problems it might be giving rise to. I changed the gearbox setting of $U_v$. I make a double. So, number of strokes get doubled.

I find that the millimetres per minute that is not changed. So, millimetres per minute divided by strokes per minute becomes half. So, if you double the speed in this configuration, unfortunately, you will find that you have reduced the feed by a factor of half. So, this sort of direct connection of the gearboxes with the motor at least for these 2, they are not admissible. Second one, we connect with the motor directly the $U_s$ and the $U_i$ gearboxes.

Suppose in this case, I change the feed by changing $U_s$. Suppose $U_s$ is doubled. the rotations per minute of this cutter becomes double. At the same time, since the $U_i$ is drawing power directly from the motor, it is rotating at the previous RPM and therefore, you will find that the rotational ratio of the gear blank and the cutter that has become different.

So, we started out to change the feed and we found that ultimately, the number of teeth being cut that has got affected. So, this particular connection also has direct connection between $U_i$ and the motor. This is also not acceptable. So, once you have got the hang of this logic, you can unravel any particular configuration that I will be providing you.

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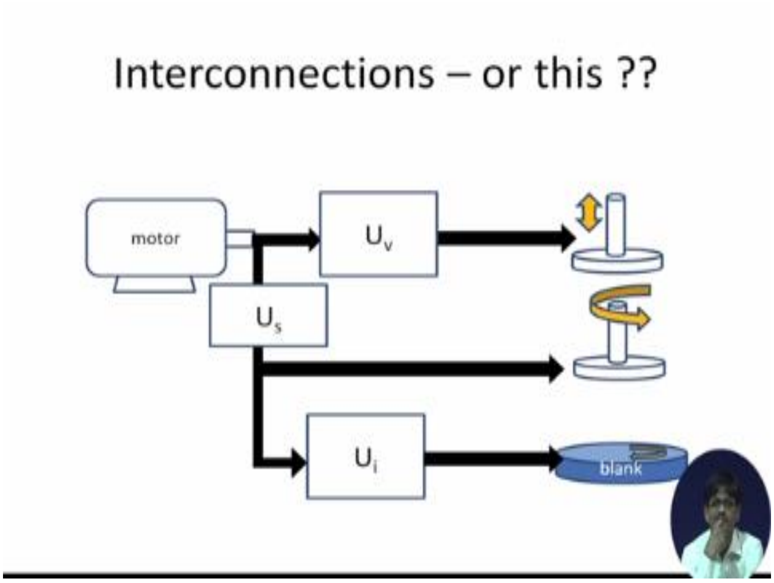


What about this? $U_v$ is here; $U_s$ is here; $U_i$ is here. Let us take them one by one. Since, in fact, we can move very fast through it now. We can say here if $U_v$ is connected to the motor and $U_s$ is also connected to the motor directly, something is going to go wrong. What exactly? Suppose you change $U_v$ now, number of strokes get say doubled, but $U_s$ is not affected because it is drawing power from the motor directly.

So, millimetres per minute divided by strokes per minute that is again going to become half. Is it going to affect number of teeth being cut? So, if I change speed, the number of strokes per minute they are becoming changed, but the feed unfortunately is getting affected. But fortunately, the number of teeth being cut that is not going to get affected because the position of $U_v$ is such that it is not affecting the RPM ratio as you can see.

Bifurcation has taken place from the very beginning. So here, the problem is that feed gets affected. If I change the feed gearbox here, is the number of teeth going to get affected? No, because in the loop between a rotation of cutter and the rotation of work piece, $U_s$ is outside that loop. It is not getting affected.

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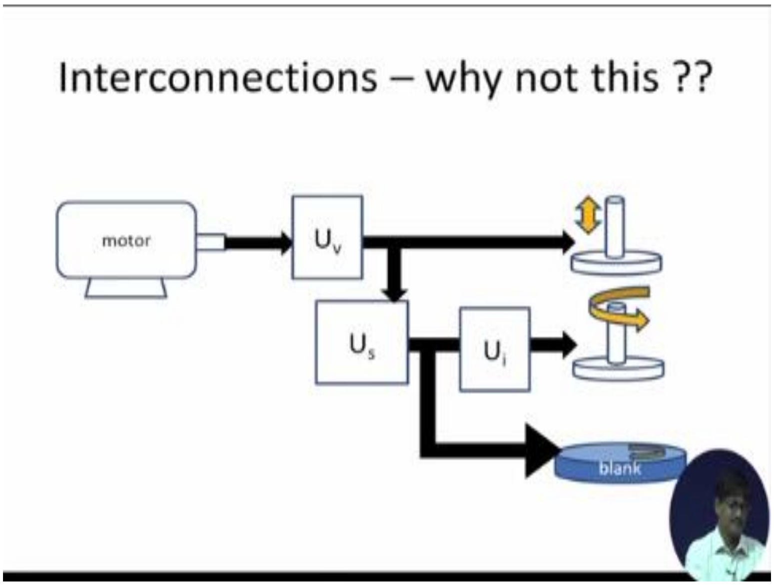


This configuration, this looks quite funny, $U_v$ and $U_s$, they are just side by side. Suppose, I change the speed, speed will change, there is absolutely no problem. What happens to $U_s$? $U_s$, unfortunately, is not in the line of cutter rotation at all. So, it will not be able to affect the cutter RPM. So, unfortunately, $U_s$ is not going to serve its purpose. If $U_s$ is changed, we will find that it is simply doing the task of changing the number of strokes per minute.

You might say; cannot we change the feed that way? Yes, we can. Why? Because we have now put $U_s$ in a particular location because of which it can affect the denominator of the expression of feed. Suppose, I make $U_s$ double, in that case, feed will become half. $U_v$ and $U_s$, since they are in series, they are going to serve the same purpose now. That is simply serving the purpose of changing the number of strokes per minute and as the bifurcation of power has taken place before them, they will also affect feed.

So, that means feed and speed will both be affected by the change in $U_v$ and $U_s$ now. Let us have a look at number of teeth. Are they going to affect the number of teeth? No, because they are not in that particular loop. What about this one? This one looks good. $U_v$ is coming first, as is supposed to be the case because we know the solution. But obviously after this something is going wrong, $U_i$ is placed just ahead of the cutter rotation.

Now, you might say; what is wrong in that? $U_i$ is supposed to be put in between the cutter rotation and the work piece rotation and it has been placed that way only. So, if I change $U_i$, it will affect the RPM ratio and therefore, it will affect the number of teeth being cut. The problem is if you change $U_i$ with that in mind, it will also affect the feed that means millimetres per stroke, because it is simply going to change the RPM of the cutter.

If the RPM of the cutter is changed per stroke, it is going to lead to a different feed value. But, wasn't it leading to a different feed value when it was put in the lower line? We will definitely discuss that as well. So, in this case, we understand $U_v$ has been placed correctly. $U_s$ has been placed correctly. But $U_i$ has been placed in such a way that it will affect the feed if we change it for cutting a different number of teeth.

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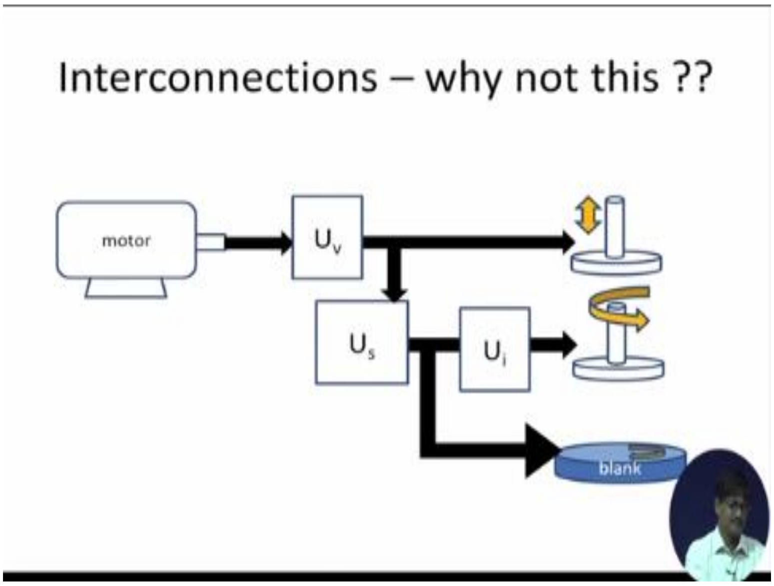


This one, we have interchanged the locations of $U_s$ and $U_i$. What does this mean? This means that $U_s$ is now in between the motor and the cutter. Just a moment, I think, we can discuss an even more interesting problem, slightly different from this one which comes to my mind. Let me draw it on the piece of paper. Please have a look at the paper.

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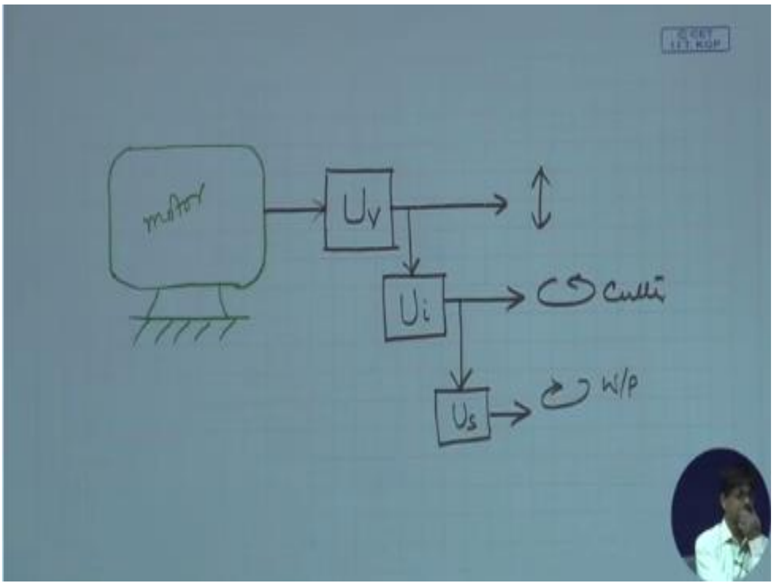


This is our motor. This is output from the motor. We have gearboxes, up down movement, rotation of cutters and rotation of work piece. And here, we put $U_i$ and here, we put $U_s$. And here, we are having $U_v$. That means if I change the positions of $U_s$ and $U_i$, what is going to happen? So, first of all, $U_v$ serving its purpose. And after that, $U_i$ is outside the loop of the cutter and the work piece.

So, obviously, $U_i$ is not going to serve its purpose. Why? Because, even if you change $U_i$, we will find that the ratio of the rotations of the cutter and the work piece, it is not changing. And what about $U_s$ being put here? $U_s$, if you change it, it is simply going to affect the number of teeth being cut. So, if you by chance, put it this way, the problem will be that this is going to affect feed and this is going to affect the number of teeth.

Just the opposite of what they are supposed to do. So, in this one, we were discussing that only so, I made it the correct configuration and then we discussed what is going to be the problem.

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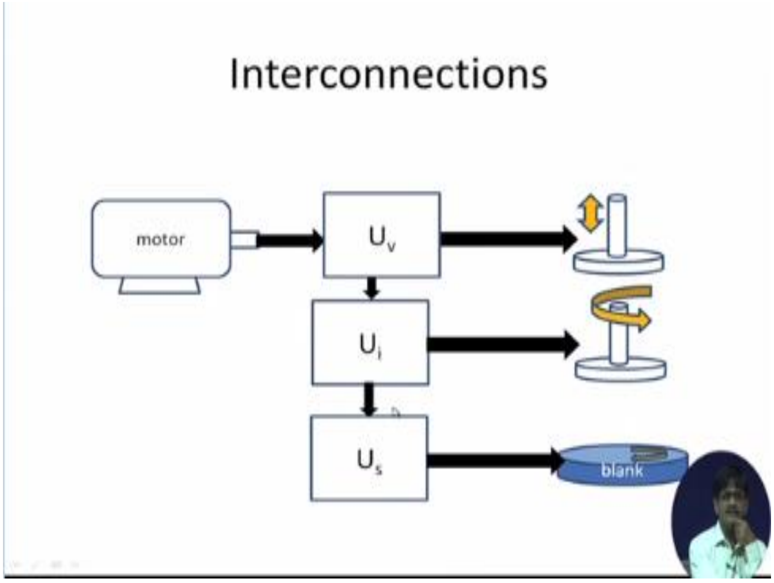


Now, what is the configuration here? The inter-connections that we have been discussing all this time, I think, this is the correct one.

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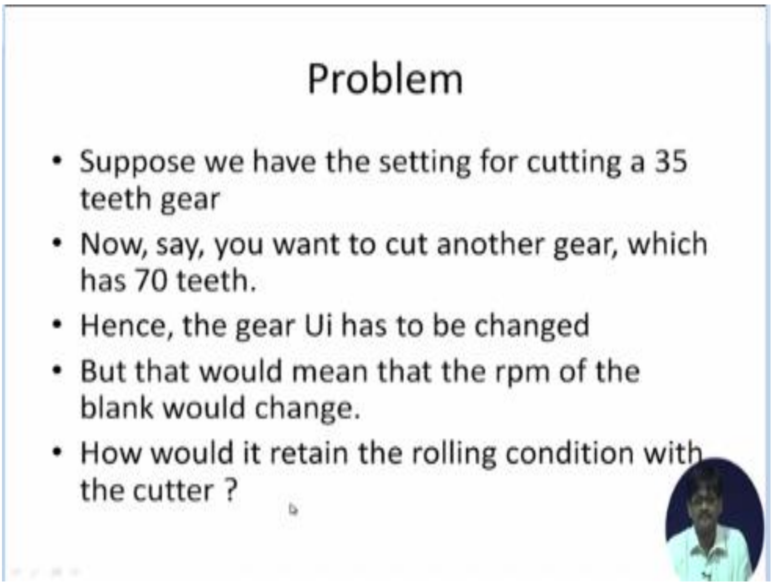


Now, let us take up this particular problem. What does this problem say? Suppose, we have the setting for cutting a 35 teeth gear. Now, say, you want to cut another gear which has 70 teeth. So, 35 teeth spur gear has to be cut and you have cut it and the setting of the machine is for the 35 teeth gear.

Now, you say that, my second or next assignment is to cut a 70 teeth gear of the same module. You want to cut a 70 teeth gear now. Hence, the gear $U_i$ has to be changed. So, if the gear $U_i$ has to be changed, what are the changes in the others? No other change. So, this would mean that the RPM of the blank has to be changed. Will the RPM of the cutter become different? There is no need.

If we can change the RPM of the blank by a different value of $U_i$, that should serve the purpose. But, how would it retain the rolling condition with the cutter? Now, let us try to understand what it means. It means that I am keeping the cutter RPM constant. So, that the peripheral speed is remaining constant. At the same time, I am changing the work piece RPM. If the work piece RPM is changed, therefore, previously it was having rolling action with the cutter.

How come it will retain that rolling action still? Shall I draw a figure to discuss this one? Let us see. Please have a look at this paper.

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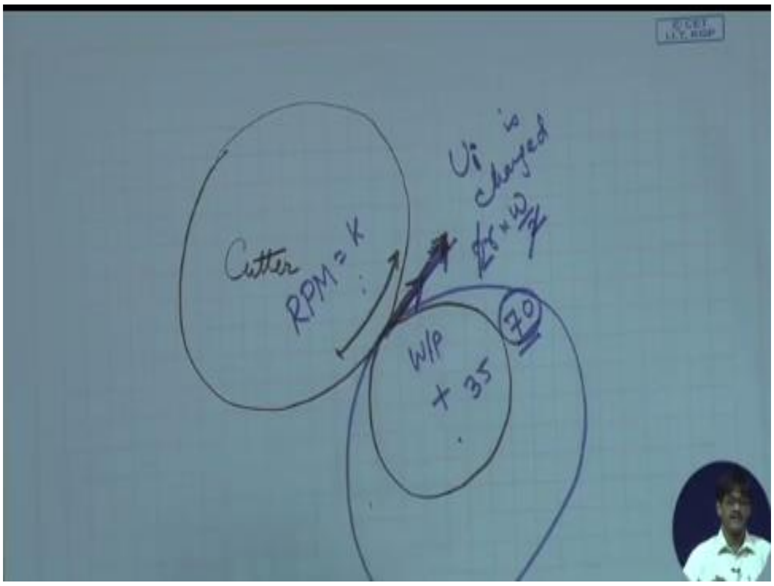


This is the cutter and this is the work piece. Say this represents the rotational speed of the cutter. So, this is the speed which develops the velocity at its periphery. Now, when the work piece was rotating, it was matching the speed. It was having at the point of contact; they had the same speed.

Now, for 35 teeth, this was the case. Now, I am making the setting for a 70 teeth, which shows me from the figure that $U_i$ is to be changed. If $U_i$ is changed, that will give rise to a different RPM of the work piece and therefore, it appears that this peripheral velocity should be changing.

It will become this much. Then how can they have the same velocity of the peripheral? Cutter is not changing its RPM, so, we write RPM is constant but this one is changing its RPM. So, that this peripheral velocity is becoming say half apparently. Then they will not be in rolling condition anymore. So, how to solve this problem?

The solution to this problem is this that when you are going for a 70 tooth gear, you are surely changing $U_i$ and that is surely going to reduce the RPM of the work piece to half of its value, but, this one, this velocity will still remain the same because for a 70 tooth gear, the blank is going to be a larger. So, since this velocity = $r \times \omega$, $\omega = 2\omega$ and r =2 r.

So, that $r \times \omega$ still remains constant. Physically, I am putting a larger blank here which is bringing in a larger radius and therefore, this peripheral velocity still remains the same and matches with the cutter and therefore, rolling still takes place. $U_i$ is definitely changing and reducing the rotation and larger diameters still ensures that the velocity remains same as that of the cutter.

So, in the small amount of time that we have in this discussion, I will just touch the case of the infeed, which we have not discussed up till now. How does the infeed take place?

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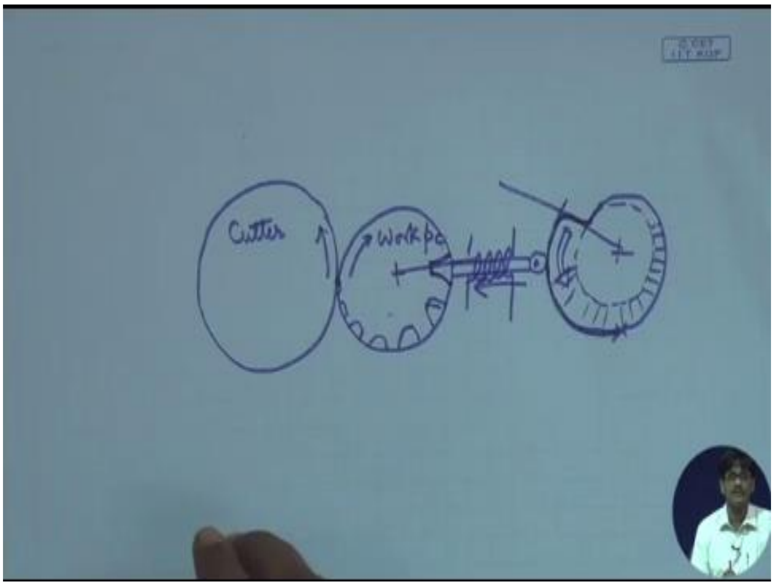


Infeed takes place this way. We have the cutter. We have the work piece. Initially, they are touching tip to tip. There is no cutting taking place and then they start, when they are rolling at the same time, this is moving in. Gradually, these teeth will be getting higher and higher values of cut. That means when this one comes here, it undergoes this amount of cut.

This one comes here. It undergoes a little more time amount of cut etc. So, this way after a certain amount of rotation, we will find that the full depth gets reached. So, maybe theoretically say, after this amount of rotation though is much higher than this, maybe 2 or 3. At this stage, you reach the full depth. After that, do you give infeed?

No because, if you still go on giving infeed, so, this one comes here, gets a particular cut. This one comes here, gets a particular cut like that. So, when this one will come here, it will get the full depth because it went on moving towards the cutter while the cutter remains stationary. So, when this particular radial position comes, it will undergo full cut.

And when it undergoes the full cut, after that radial infeed stops. At that time, there will be a dwell, that means, they will go on rotating still while this one does not undergo any infeed. And at that position, we have to ensure that all of the teeth, they undergo this particular full depth and therefore, say at least more than one rotation is made so, that the cut is now taken up by all the teeth on the periphery.

Once that has been done, it is ensured that all the teeth have been cut properly and after that, it can rapidly retract at the end of the cut. This can be provided by a cam. How does the cam look like? It might be looking like this. So, in this cam, first of all, this is the base circle. So, from this circle, as this particular profile is deviating, it means that if there is a push rod, as this is rotating this way, it will push this rod towards the cutter.

And if the work piece is somehow attached to it, it will start moving this way in addition to each rotation. So, if we start from here, that is when this position is here, this one starts rotating and gradually the amount of push that is increasing and after some time we will find that further increase is not required. Because it is reached its full depth. So, this one may be an Archimedean spiral up till this point and after that, it can have a dwell period.

Dwell period means that the radius does not increase after that and when it is ensured that the full number of teeth have been cut after the end of that there will be a rapid fall. This is the total rise of the cam equal to the full depth. There will be rapid retraction if it is pressed by the help of a spring. If it is pressed with the help of a spring, it will rapidly retract and take it away when this particular section radial position comes here.

So, throughout the cycle of the cam, we can have an infeed like that. If time permits, I will incorporate some small numerical problems on this one. So, with that, we come to the end of the 12th lecture. Thank you very much. We will again take up this discussion with some numerical problems in the next lecture. Thank you very much.