# Metal Cutting and Machine Tools

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## Lecture-03
## Geometry of Turning Tools-II

Hello viewers, so welcome to the third lecture of the course metal cutting and machine tools. Today we will be discussing more about the geometry of single point turning tools. As you have learnt in the previous lectures, a single point turning tool may be referred to in the tool in hand system and there we can identify the different planes the edges which are invariant with the orientation of the tool. After that we learnt about the machine reference system in which the tool is placed in a Cartesian coordinate system where the basic planes correspond to the machine longitudinal plane, the machine transverse plane and a reference plane.

The reference plane is the most important because it is perpendicular to the velocity vector and it is basically with respect to that most of the other planes will be defined. So, we have assumed that the reference plane is corresponding I mean it is aligned in exactly as the orientation of the xy plane, which means that we have assumed that the velocity vector in our calculations is corresponding to I mean is aligned in the Z axis.

So, with this introduction we have already covered machine reference system and the orthogonal reference system. In the orthogonal reference system, we had the three planes as the cutting plane, the reference plane and the orthogonal plane. The cutting plane contained the cutting edge and it was also containing the velocity vector. The reference plane was perpendicular to the velocity vector as before.

And the orthogonal plane was perpendicular to the cutting plane and perpendicular to the reference plane. After this we came across the definitions of rake angles and clearance angles defined between two planes placed in a particular sectional plane. For example, orthogonal rake angle was defined to be the angle between the reference plane and the rake surface considered in the orthogonal plane.

So, this way I do not want to repeat all those definitions that we have come across, this way we have defined rake angles, clearance angles, cutting angles. And that way we have we are in a position now to express the relationships existing between different angles in different systems. For example, we might be having a particular nomenclature given in the American system of reference and you would like to get the corresponding angles in the orthogonal system. So, conversion formally they are available and we will be now having a look how they are obtained, so let us start.

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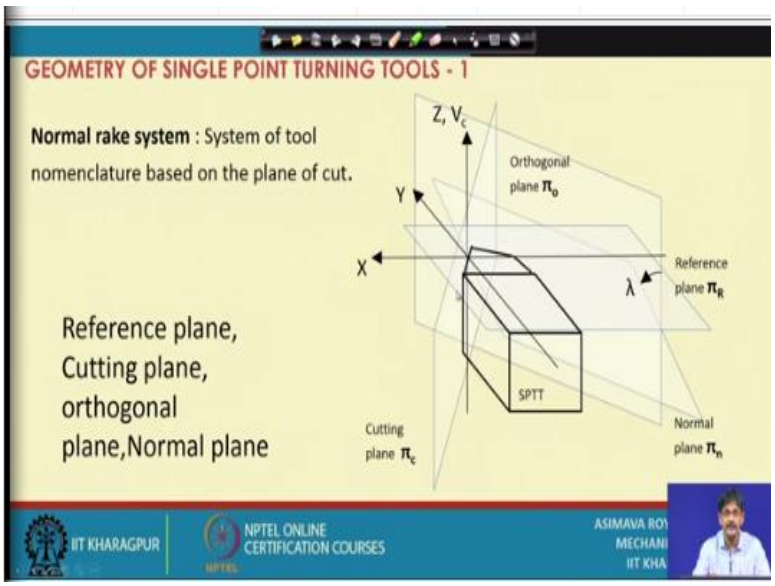


Previous to that I would just touch yet another reference system which is called normal rake reference system. As you can see here as you can see there is another plane defined as this basic plane is the reference plane, there is another plane defined as the normal plane. Ordinarily what is this one plane that we are having here? This is the orthogonal plane; first of all, if we start with the cutting edge, this is our cutting edge.

The plane containing the cutting edge and containing also the velocity vector here, this is the cutting plane, perpendicular to the cutting plane and perpendicular to the reference plane we have the orthogonal plane. But instead of being perpendicular to the cutting plane, if we have a plane perpendicular to the cutting edge it will be inclined from the orthogonal plane by the angle λ or inclination angle.

So, it is as if we are simply taking hold of the orthogonal plane and rotating it through λ, so that it becomes perpendicular to the cutting edge, perpendicular to the cutting edge there is a plane which is called this normal plane. This normal plane as you can see it is making an angle of λ with the orthogonal plane, it is an inclined plane, it is not vertical that sense. So, with respect to this plane we can define rake angle and that is called the normal rake angle. And in that system we have λ and $\gamma_n$ defining the rake surface orientation.

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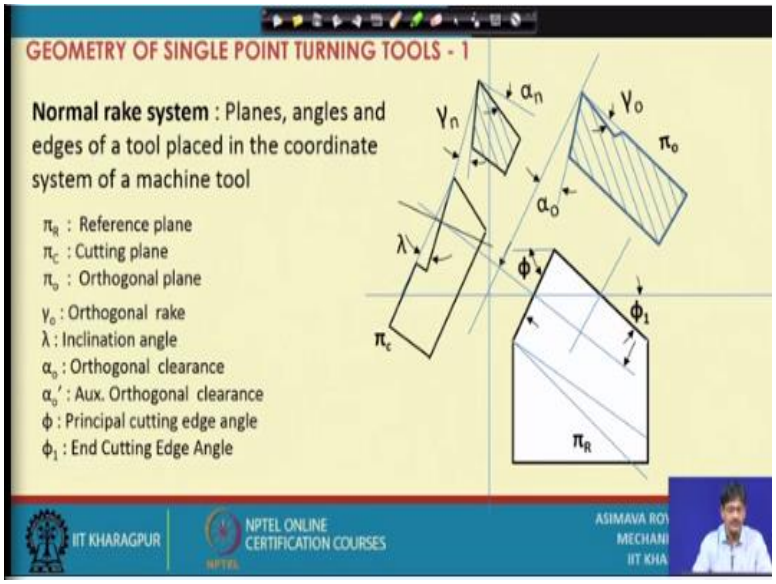


So, it would look somewhat like this, we have this tool in the plan view, we have the section in the orthogonal plane, we have the view in the cutting plane. And then if we make a section this way sorry I have not shown the section arrows, if we make a section along this particular line then we will get a sectional view in which normal rake will be coming out here.

So, we would be learning about this system also during our calculations in the later lectures. So, I will quickly go through the additional angles that we are defining here in addition to the American system. And we have already defined most of them like orthogonal rake, inclination angle, orthogonal clearance, auxiliary orthogonal clearance which is on the other flank etcetera and we will be making use of them as we go for the angle conversions.

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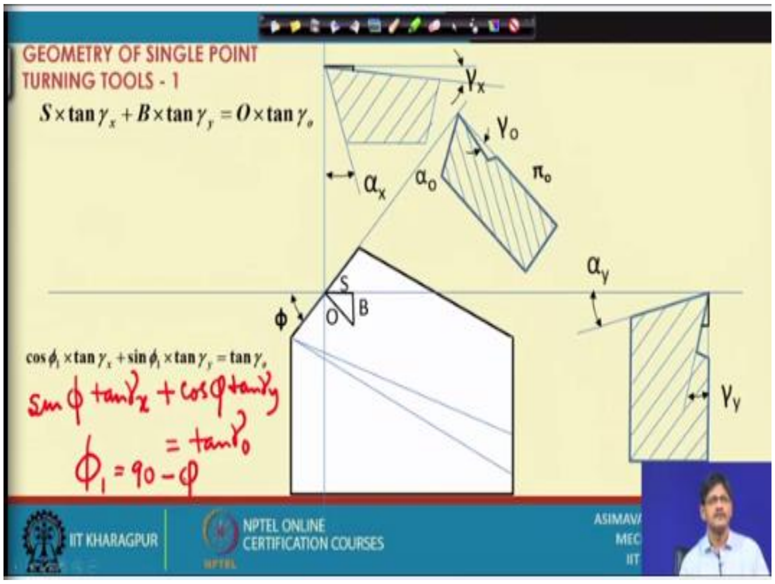


This is the first exercise that we have in angle conversion. For example, suppose I am interested to know what is the relation between orthogonal rake here and the 2 rake angles in the American system $\gamma_x$ and $\gamma_y$. So, I start from here from this relation, what does this relation state? It states that from this point if we move down the rake surface in the orthogonal direction we will reach a point.

Say if the orthogonal rake is positive we go down, so then from the reference plane the rake surface is going down as we move away from the nose. As we go down if the inclination of the rake surface in the orthogonal plane indicates that it is going down, this is positive rake. So, if we are going down say a hillside which is inclined, if they are going down this way down the hillside to a particular point here where this is a plane surface but it is inclined.

This distance that we go down vertically will be exactly equal to the 2 segments vertical segments that we go down if we take yet another part. It simply means that whichever way you are going down the vertical distance you are covering if your final position and initial position are the same on a plane they will be the same. So, the distance I am going down this way it is equal to the sum of the distances I am going down this way and that way, that is very good.

But what is the distance I am going down along the orthogonal plane? Along the orthogonal plane we will argue that if we reproduce this distance here, in that case we have a tangential relationship. Let us quickly have a look at this.

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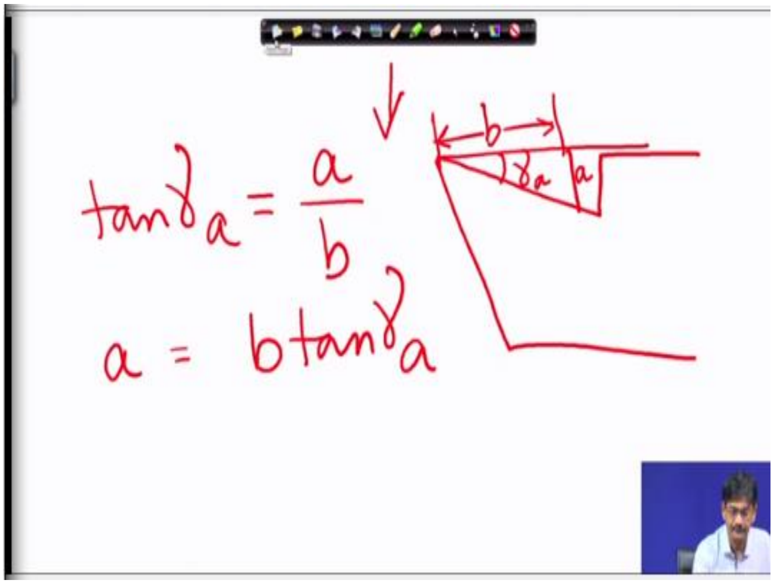


A tool in any section if I am going down by this distance vertically, say I name this a, if this angle is given say $\gamma_a$. Sorry if this distance is not given a is this and say b is this much, $\gamma_a$ is this. Therefore, in this case I can write $\tan \gamma_a$ is equal to simply $a/b$, perpendicular by base. This means that I can express 'a' as $b*\tan \gamma_a$, this is the relation that we will be using extensively in our calculations.

So, what we mean to say is this? If on a particular identified section, I have a rake angle as shown as $\gamma_a$. If this is the distance obtained in the plan view from the top that distance multiplied by this tangent will give me the vertical distance I am going down, this we will use extensively. So, let us now go back to our discussion here. For example, suppose as I have said distance I am going down in this direction orthogonal plane is equal to the addition of the two distances vertical distances I am going down in the machine longitudinal plane and machine transverse plane.

So, O = S the vertical distance down along O will simply be as we discussed is equal to $\tan \gamma_o$. $\tan \gamma_o$ is identified here and therefore the vertical distance I am going down here is equal to

O * $tan\ \gamma_o$ as we discussed, that is the vertical distance down. So, here we have that particular vertical distance O $tan\ \gamma_o$, this must be equal to these 2 distances.

So, once again we will have $S\ tan\ \gamma_x$, $tan\ \gamma_x$ is this angle in this plane, this plane is the $\pi_x$ plane, $S*tan\ \gamma_x + B$, these 2 segments are equal to S and B respectively, O, S, B are the lengths of these segments. And naturally on this side $B\ tan\ \gamma_y$, so $B\ tan\ \gamma_y + S\ tan\ \gamma_x$ must be equal to $O\ tan\ \gamma_o$ that is it. We need no other things in order to establish this basic relationship.

However, we do not know S, we do not know B, we do not know O, but what we know is we know that this angle is called φ. If this angle is called φ the principal cutting edge angle or the plan approach angle we can definitely say as this is a right angle, angle between these two sides must be equal to $90^o - \varphi$. So, this one angle must be equal to φ, this must be equal to φ.

And immediately if we divide this whole expression I mean whole equation by O, we have S by O, here S by O, what is S by O? If we take this angle S by O is nothing but $sin\ \varphi$, so instead of this one we write $sin\ \varphi$. By the way I have expressed this in terms of $\varphi_1$, please understand that $\varphi_1$ is equal to $90^o - \varphi$. I will do one thing, let me see if I can write here then that will be an advantage.

So, we can write here S by O is nothing but $sin\ \varphi$, so $sin\ \varphi * tan\ \gamma_x$ plus what is this term? This is B by O, I have divided everything by O, so B by O is nothing but $cos\ \varphi$. So $cos\ \varphi * tan\ \gamma_y$ this must be equal to $tan\ \gamma_o$. This is the basic way in which we express relationships between the angles of one system and another. And please note $\varphi_1$ is referred in the American system is equal to $90^o - \varphi$. So, this I think you agree and accept, so that we move on to the second problem.

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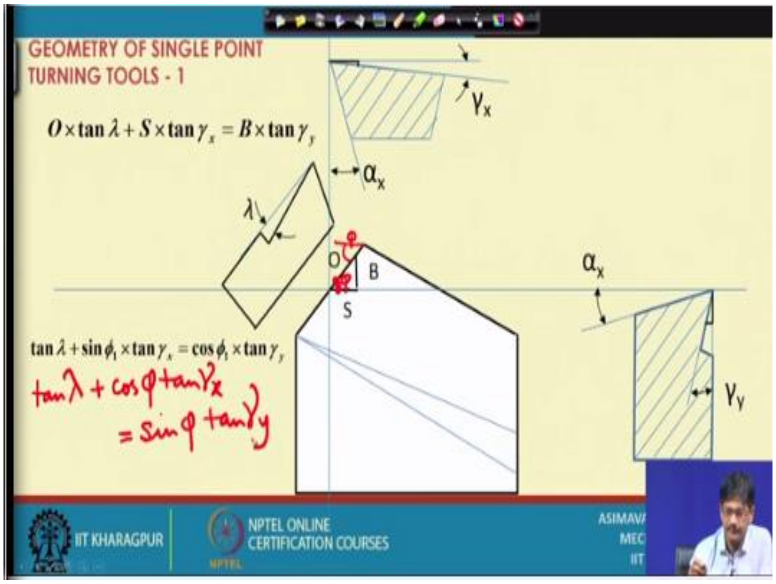


In the second problem we want to express a relationship between λ, $\gamma_x$ and $\gamma_y$. You might say what was the relation that we expressed in the previous one? In the previous one we expressed relation between orthogonal rake and back rake and side rake. Now we want to express a relationship between inclination angle γ and back rake and side rake. So, in that case the whole trick lies in the definition of this particular triangle that you are going to consider.

Whole trick is that you correctly assume the triangle here; this triangle means that you are establishing a relationship between 3 vertical distances, the vertical distance you travel down along the cutting edge in this case. That means this way you are traveling down the rake surface on the cutting plane. If you do that then what we have is that this segmental this vertical distance under B and plus the segmental distance covered by S must be equal to the vertical segmental distance defined by this segment O.

So, therefore what we do is once again we remember the tangential relationship. Right, here what we have is that we are going down the orthogonal we are going down the cutting plane by this distance. So, there is a vertical distance we have gone down, it should be equal to this distance that we go down plus this distance that we go up if this is vertical.

So, in that case let us do one thing, we first go down in the along the cutting plane and then we go further down along this and ultimately we reach down along the back rake, I mean in this direction by a certain amount. So, let us consider this particular relationship $O \tan \gamma$, $O \tan \gamma$ gives us the distance we are going down along this direction.

Assuming that γ is positive, this is a downward movement**.** Now assuming that the back rake angle is also positive, we will be going further down. So, we go down here and we go down here, so that these two distances are added up and they are together equal to the final distance that we move down in this direction. You might say that we are assuming some things here, what are they?

We are assuming the signs of the angles that we are considering; to some extent this is correct. So, if we have this particular assumption we have a relation as shown here, $O \tan \gamma + S \tan \gamma_x = B \tan \gamma_y$, that is fine. So, once again let us divide everything by O, so that we have $\tan \lambda + \sin \varphi_1$, how does $\sin \varphi_1$ come? If we divide everything by O we have S by O here, S by O is equal to the sine of this angle.

Now what is this angle equal to? This is equal to the $90^o - \varphi$ let me use the pen and write it here. This is equal to φ; therefore, this must be equal to $\varphi_1$, so this is equal to φ once again. Now I hope this figure is clear enough for you to understand. So, if this is φ then what happens is this is φ in that case S by O will come out as $\cos \varphi$. So, we write $\tan \lambda + \cos \varphi$ into this distance once again is $\tan \lambda_x$ as found out here equal to $\sin \varphi.\ \cos \varphi_1\ \sin \varphi$, why $\sin \varphi$?

Because B by O, so that is equal to $\sin \varphi * \tan \gamma_y$. So, we have a relation between $\tan \gamma_y$ $\tan \lambda$ and $\gamma_x$ and $\gamma_y$. Once we have established this we understand that now we have a relationship between orthogonal rake and the 2 and back rake side rake and also inclination angle and back rake and side rake. So, let us take up the next problem.

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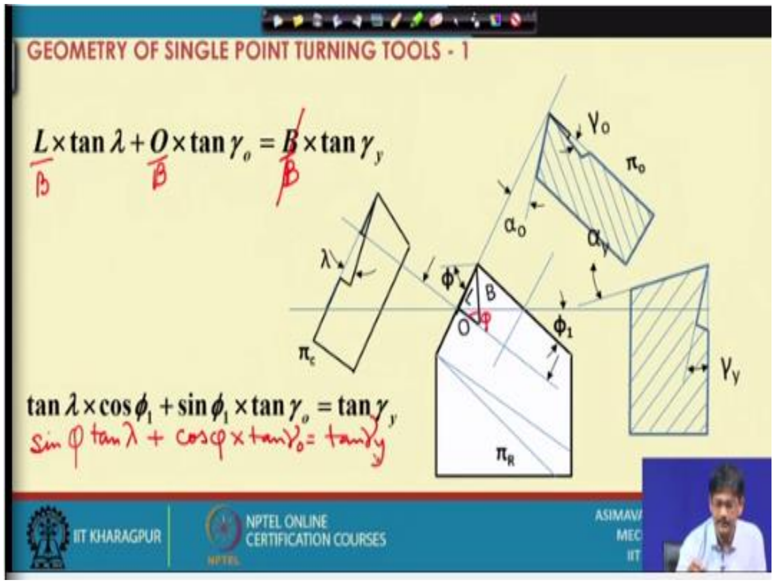


So, here we have another relation in which we are bringing in something else. That is a relationship between back rake and inclination angle and orthogonal rake. Previously we were working with back rake and side rake and one of the angles in the orthogonal rake system. Now two of the angles of the orthogonal rake system can be brought in and only one angle of the American system can be considered.

Let us see what sort of relation we have in that case. First of all, in this case once again the whole thing lies in the consideration of the triangle. So, we will consider here that while we are going down along the cutting edge we go further down along the orthogonal direction and the summation of these two distances will be equal to the distance that we cover on the back rake. Once again here we are considering that $\lambda$ and $\gamma_o$, they are both positive.

So, first of all this the vertical distance covered by this segment must be $L \tan \lambda$, so we write $L \tan \lambda$. The vertical distance covered by O must be $O \tan \gamma_o$, this way $O \tan \gamma_o$ and the vertical distance covered along this direction along the transverse direction must be $B \tan \gamma_y$. So, in this case we establish a relationship as shown here and if we divide it by B all through we have L by B.

So, let me use yes, if we use this expression, so we have divided by B divided by B, divided by B and this cancels out. So, that finally what we have is L by B, what is L by B? If this is $\varphi$, this must be φ. And therefore we can say L by B = *sin φ* and therefore we write L by B is $\sin\varphi * \tan\lambda$ + the other one is O by B, that must be obviously $\cos\varphi$, $\cos\varphi * \tan\gamma_o = \tan\gamma_y$. So, this way we understand that we can establish relationships between the angles by this sort of addition of vertical distances covered in different sections and then adding them up.

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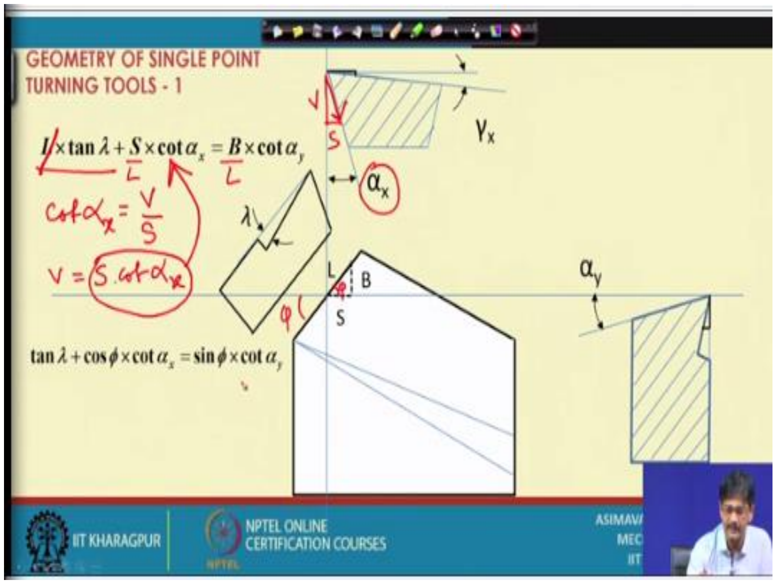


Next, so first let me, now we come on to something different, up till now we have established relationships between orthogonal rake angles now we will be establishing relationships between clearance angles. And since the inclination angle is shared between the rake surface and the principal flank, we can have a relation existing between the inclination angle and the 2 principal clearance angles in the American system.

In main inclination angle and the two clearance angles existing in the American system for the principal flank. So, first of all here what we do is, I have shown in dotted lines that distances that we are covering in two directions, what are these two distances? We are saying here that if we are moving down along this particular cutting edge, I am moving down the cutting edge by a certain distance and therefore I am undergoing some vertical distance which is given by $L\tan\lambda$.

So, we have $L\tan\lambda$ here $L\tan\lambda$, this is the vertical distance I cover on the cutting edge. After that suppose I start moving down the flank now, in what way? I am moving down the flank in the transverse plane, so this is the way I am moving down. If I move down the flank then I am incurring some vertical distance I am covering some vertical distance, how do you find out that vertical distance?

We will be finding it out from this sort of a triangle, where this is nothing but S and this angle as shown is $\alpha_x$. So, therefore we can definitely express a relationship where you know S the vertical distance is of our interest. So, let us write it as V, so we can immediately say that $\cot \alpha_x$ must be equal to what is it equal to? V by S which means that the vertical distance is nothing but $S \cot \alpha_x$, that is it, $S \cot \alpha_x$.

Once we establish this we understand that again once again the vertical distance relationship that we were dealing with we can easily express the vertical distance this way and that is what we have done alright. And therefore we have vertical distance down the cutting edge plus vertical distance down the transverse plane must be equal to the vertical distance down the this is machine longitudinal plane must be equal to the vertical distance down in the transverse plane.

And therefore after dividing the whole equation by L, we have L cancelling out this by L and this by L. S by L, what is S by L? Once again we understand that this is nothing but φ, as this angle is φ, it is vertically opposite. So, S by L is nothing but $\cos \varphi$ and therefore we have this relationship $\tan \lambda + \cos \varphi \cot \alpha_x$ must be equal to $\sin \varphi \cot \alpha_y$. So, this relation gives us a relation between λ, $\alpha_x$ and $\alpha_y$.

So, we establish a relationship between clearance angles and the inclination angle. So, at this stage we understand that there is a relationship existing between rake angles, there is a relationship existing between the inclination angle and the clearance angles. So, there must be relationships existing between clearance angles in the American system and the clearance angle in the orthogonal system and the clearance angles in the normal rake system. So, one by one we are going to deal with them, so let us see what we have in store in the next case.

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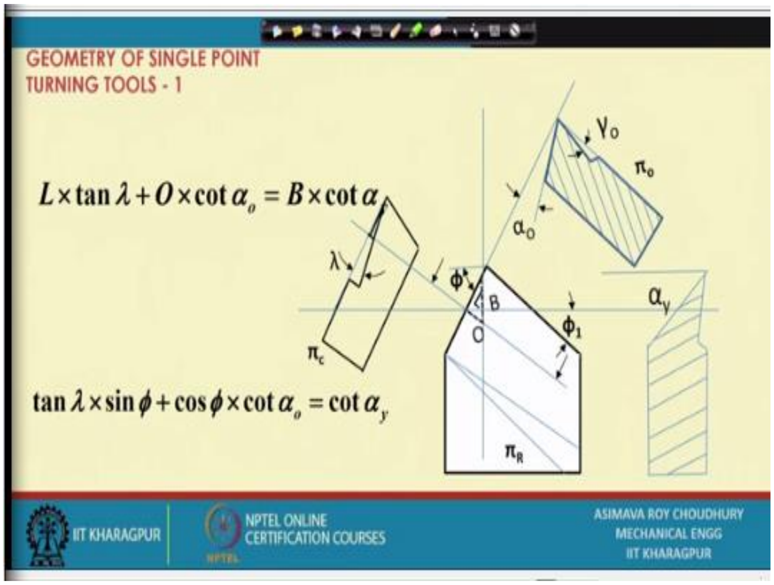


So, now as discussed we are going to have a relationship between the clearance angle in the orthogonal system and the clearance angle in the back clearance. So, relationship between back clearance and orthogonal clearance. So, in order to establish this relationship what sort of relation we are going to take? We are going to take this triangle shown here. One side is going to lie in this section, another side is going to lie in the section $\pi_o$ and the other one is going to be obtained in the view of the cutting plane.

But I think we have already crossed the time limit of the next lecture of this lecture. So, I leave this as an assignment to you, you can solve it yourselves and then we will compare notes, so thank you very much.