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 rather 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 the you know its perpendicular to the velocity vector and it is basically with respect to this that most of the other planes will be defined.

So, we have assumed that the reference plane is corresponding I mean its aligned in exactly as the orientation of the X Y 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 3 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 the velocity vector as before, and the orthogonal plane was perpendicular to the cutting plane and perpendicular to the reference plane.

After this we had we came across the definitions of rake angles and clearance angles defined between two planes placed in a particular sectional plane. For example, orthogonal plane would be; sorry 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 you know express the relationships existing between different

angles in different systems. For example, we might be having a particular you know nomenclature given in the American system of reference and you would like to get the corresponding angles in the orthogonal system. So, you know conversion formulae they are available and we will be now having a look how they are obtained. So, let us start.

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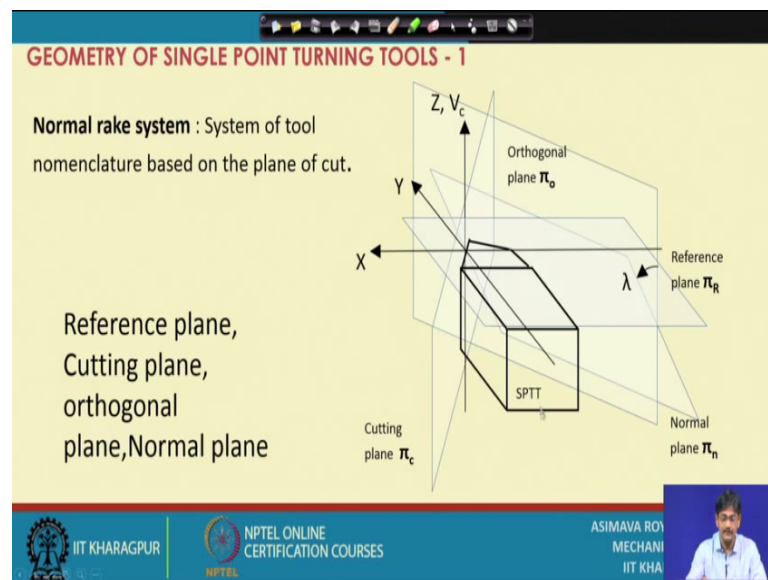
Previous to that I would just touch yet another reference system which is called normal rake reference system as you can see here, as you can see there is another plane defined as this basic plane is the reference plane there is another plane defined as the normal plane. Ordinarily what is this one plane 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 lambda or inclination angle. So, it is as if we are simply taking hold of the orthogonal plane and rotating it through lambda 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 its making an angle of lambda with the orthogonal plane it is an inclined plane it is not vertical that in that sense.

So, with respect to this plane we can define rake angle and that is called a normal rake angle, and that in that system we have lambda and gamma n defining the rake surface orientation. So, it would look somewhat like this.

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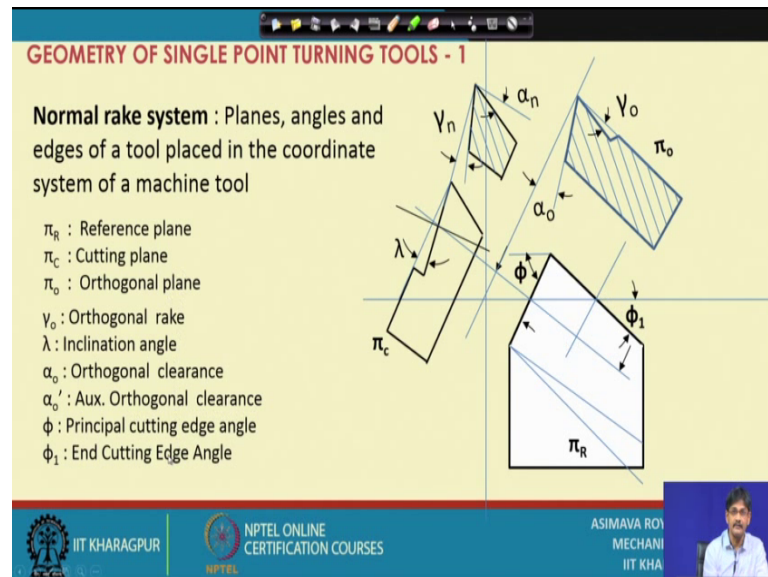
We have this tool in the plan view we have the section in the orthogonal plane, we have the section sorry we have the view in the cutting plane and then if we make a section this way sorry I have not shown the section arrows if we make a section along this particular line then we will get a sectional 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 have 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.
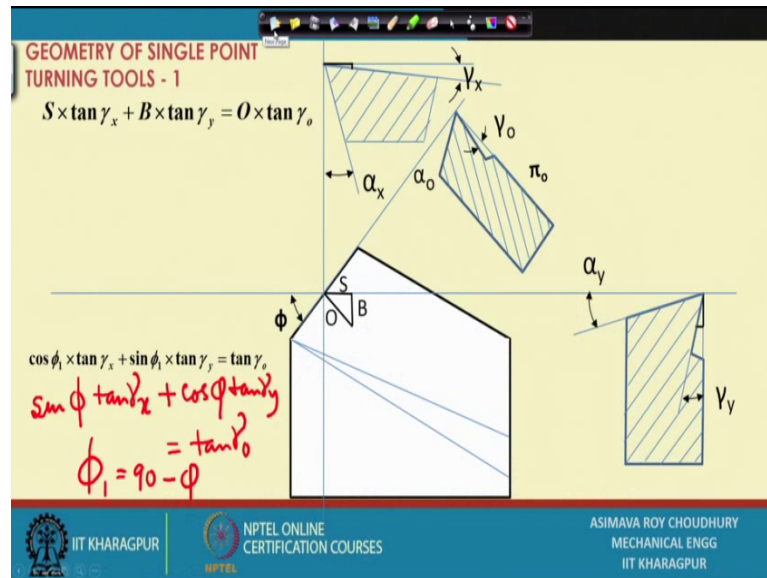
This is the first exercise that we have in angle conversion. For example, suppose I am interested to know what is the relation between orthogonal rake which is coming out here in this particular sorry yeah suppose I am interested to know what is the relation between orthogonal rake here and the two hang 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 orthogonal rake if the inclination of the rake surface in the orthogonal plane indicates that its 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 its inclined this distance that we go down vertically will be exactly equal to the two you know segments, vertical segments that we go down if we take yet another path. 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 its equal to the distance some 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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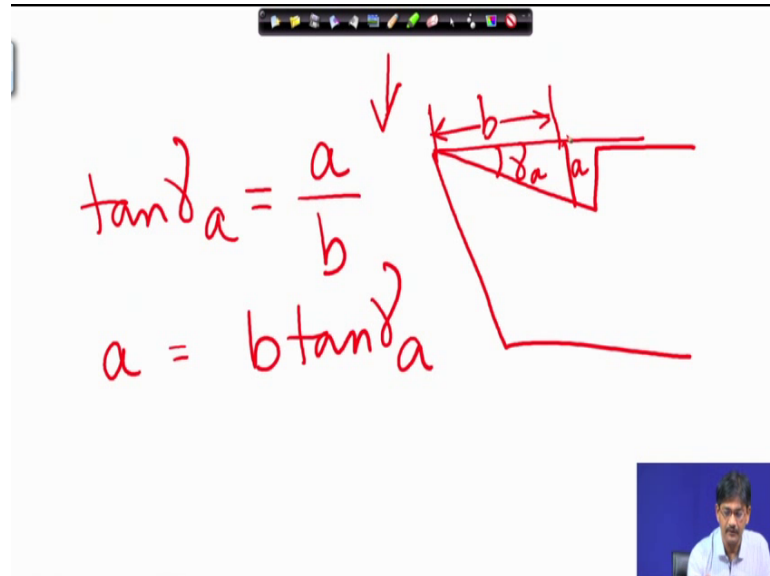
A tool in any section if I am going down by this distance vertically, say I name this a if this angle is given say gamma a; sorry if this distance is not given a is this and say b is this much b is this much gamma a is this therefore, in this case I can write tan gamma a is equal to simply a by b perpendicular 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 you know 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 what you call it machine transverse plane, sorry machine longitudinal plane and machine transverse plane. So, O is equal to S sorry the vertical distance down along O will simply be as we discussed is equal to O tan gamma 0; sorry tan gamma O tan gamma O is identified here and therefore, the vertical distance I am going down here is equal to O into 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 two, these two distances so once again we will have S tan gamma x tan gamma x is this angle in this, this plane this plane is the phi x plane. S tan gamma x plus B these two 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 plus 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 phi. If this angle is called phi the principle cutting edge angle or the plan approach angle we can definitely say as this is a right angle, angle between these two sides angle between these two sides must be equal to 90 degree minus phi.

So, this one angle must be equal to phi this must be equal to phi 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 phi. So, instead of this one we write sin phi by the way I have expressed this I am sorry I have expressed this in terms of phi 1, please understand that phi 1 is equal to 90 minus phi I will do one thing I will let me see if I can write here then that will be an advantage. So, we can write here sin S by O is nothing, but sin phi into tan gamma x plus. What is this term? This is B by O I have divided everything by O. So, B by O B by O is nothing, but cos phi, cos phi into 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 phi one is equal to phi one is referred in the American system is equal to 90 minus phi.

So, this I think you agree and accept so that we move on to the second problem.

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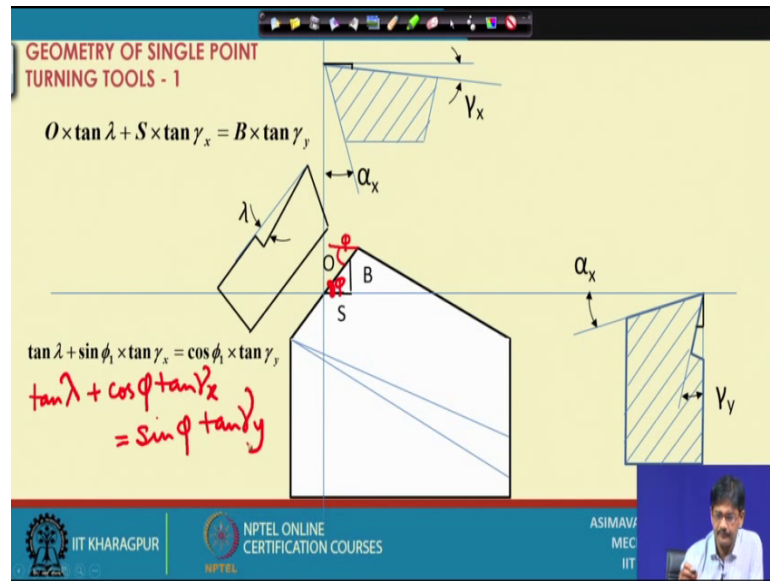
In the second problem we want to express a relationship between lambda gamma x gamma y you might say what was the relation that we expressed in the previous one. In the previous one we expressed relation between orthogonal rake and back rake and side rake. Now, we want to express a relationship between inclination angle lambda 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, just a moment. 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 travelling 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 it must be just for just one moment what is this right. Here what we have is that we are going down the orthogonal vertically 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 orthogonal along the cutting plane and then we go further down along this sorry, 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 lambda, O tan lambda gives us the distance we are going down along this direction assuming that lambda is positive this is a downward movement sorry.

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 lambda plus S tan gamma x is equal to B tan gamma y that is fine so once again let us divide everything by o. So, that we have tan lambda plus sin phi 1. How does sin phi 1 come? If we divide everything by O we have S by O here. S by O is equal to the sin of this angle, now what is this angle equal to? This is equal to the 90 degree minus phi let me use the pen and write it here this is equal to phi therefore, this must be equal to phi 1. So, this is equal to phi once again.

Now, I hope this figure is clear enough for you to understand. So, if this is phi then what happens is, this is phi in that case S by O S by O will come out as cos phi. So, we write tan lambda plus cos phi into this distance once again is tan gamma x as found out here equal to sin phi cos phi 1 sin phi y sin phi because B by O, B by O, so that is equal to sin phi sin phi into 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 two and back rake and side rake and also inclination angle and back rake and side rake. So, let us take up the next problem.
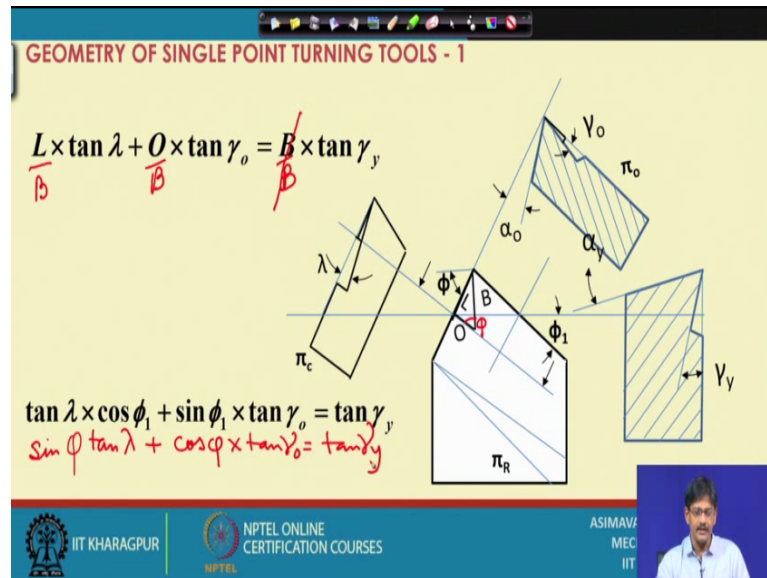
so here we have another relation in which we are bringing in something else that is a relationship between back rake and inclination angle and orthogonal rake. Previously we were doing if we were working with battery and side rake and one of the angles in the orthogonal rake system. Now, two of the angles of the orthogonal rake system can be brought in and only one angle of the what we call it 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 in the sorry, 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 this way, 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, 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 just a moment.

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 phi,

this must be phi, this must be phi and therefore, we can say L by B is equal to sin phi and therefore, we write L by B is sin phi into tan lambda plus the other one is O by B that must be; obviously, cos phi, cos phi into tan gamma O equal to tan gamma y. So, this way we understand that we can establish relationships between the angles by this sort of you know addition of vertical distances covered in different sections and then adding them up.

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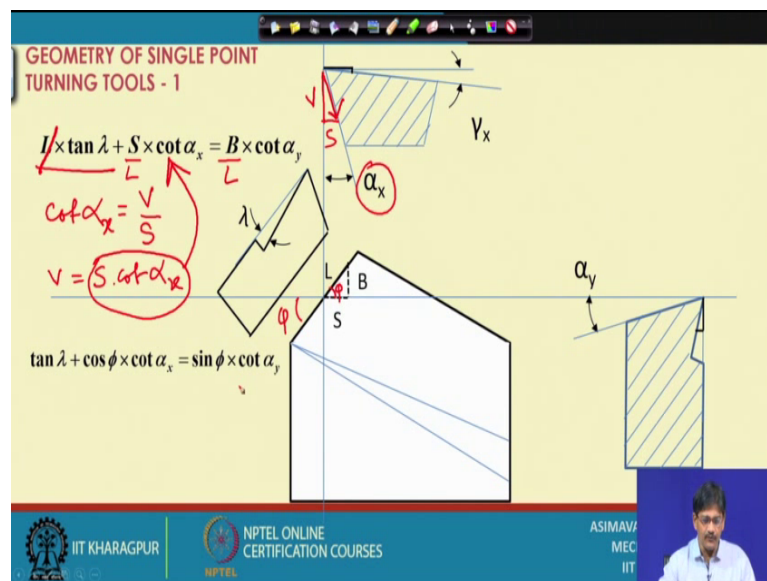
Next, first let me now we come on to something different up till now we have established relationships between orthogonal rake angles now he will be establishing relationships between clearance angles. And since the inclination angle is shared between the rake surface and the principal flag we can have a relation existing between the inclination angle and the two principal clearance angles in the American system. In main inclination angle and the two clearance angles existing in the American system for the principle 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 you know 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 just a moment, 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, very therefore, we can definitely express our 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 say the cot alpha 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 all right. 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 you know sorry this is side 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 phi as this angle is phi it is vertically opposite.

So, S by L is nothing but cos phi and therefore, we have this relationship tan lambda plus cos phi cot alpha must be equal to sin phi cot alpha y. So, this relation gives us a relation between lambda 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 what we call, it 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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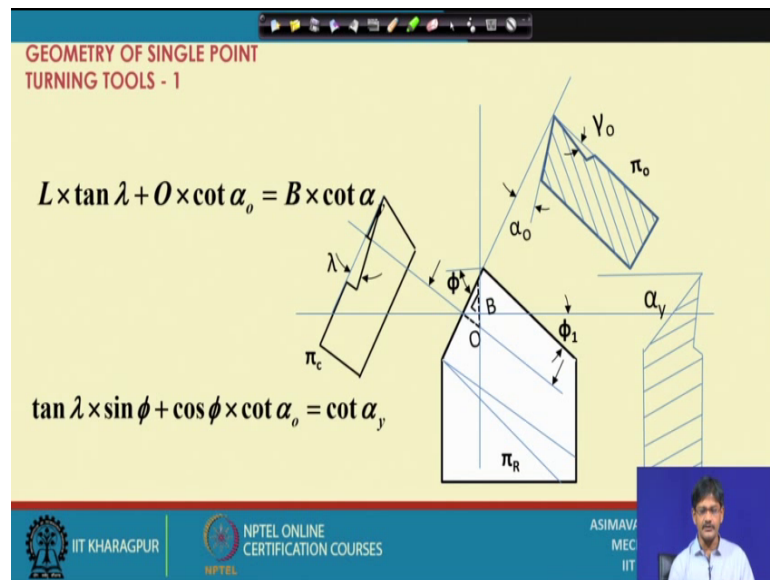
So, now we are going to as discussed we are going to have a relationship between the clearance angle in the orthogonal system, clearance angle in the orthogonal system clearance angle; and the clearance angle in the back rake system sorry, in the back clearance. So, relationship between back clearance and orthogonal clearance.

So, in order to establish this relationship what sort of relation we are going to get; 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 phi 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.

Thank you very much.