Mechanics of Machining
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Lecture – 05
Tool Specifications, Conversion Of Tool Angles, Multi-Point Cutting Tools

Hello students. Welcome to the fifth lecture on Mechanics of Machining. In the last lecture, I introduced with tool nomenclature. In this lecture, I am going to tell about the Conversion of Tool Angles.

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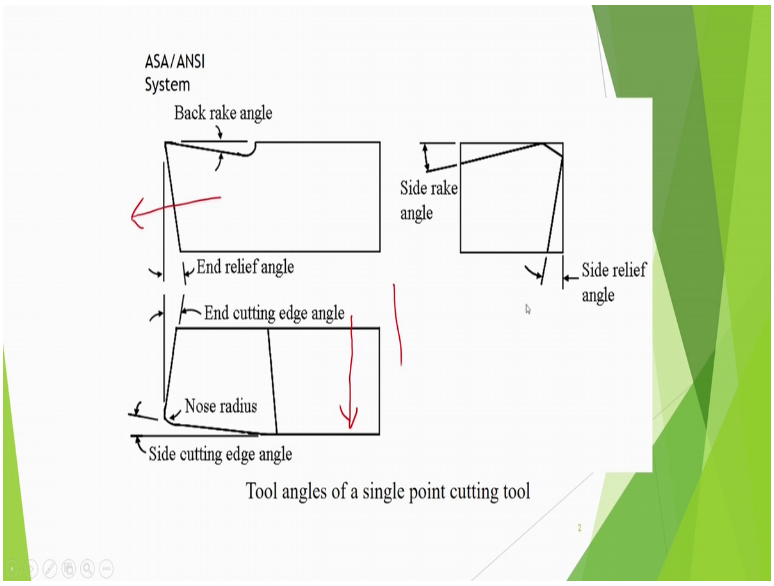

So, let us just see that what are the various type of tool angles in different systems American system. In American system, I said that if we make three orthographic projections; in those projections, we can show the angles; in each one, I can show 2-2 angles.

So, if we see the front view of the tool, then we are seeing that back rake angle, it is also called top rake angle, then we are having end relief angle, and we are having in the top view we are having side cutting edge angle and we are having end cutting edge angle and this one is the nose radius that is apparent in the top view; that means, nose radius is there. And I also told that your radial direction in ASA system is this. That means, depth of cut is you are taking in this direction and feed is naturally in this direction; that means, in this direction there is a feed here in the top view the tool is moving like this.

In the side view, I can see the side rake angle and also I can see the side relief angle. So, side rake angle and side relief angle these are the tool angles of a single point cutting tool in ASA system.

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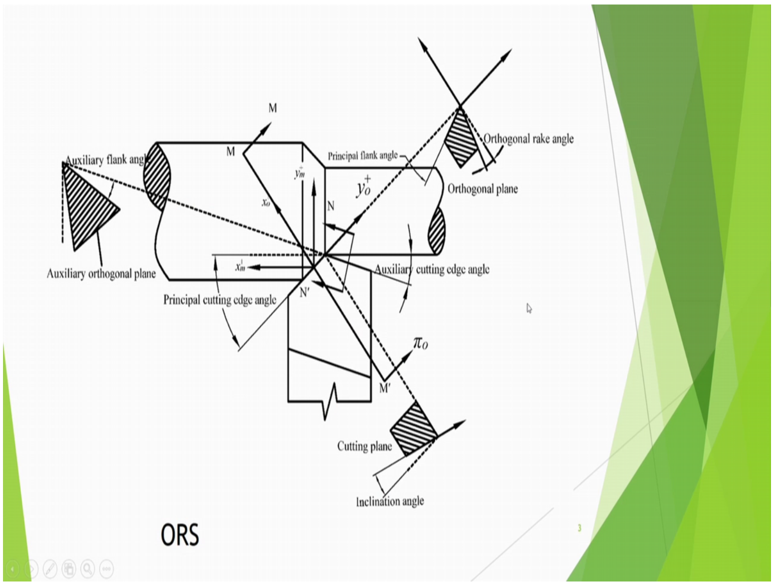

Then in ORS system also, we can see the angles in the top view, we can see principal cutting edge angle, which is complementary of side cutting edge angle and we can get auxiliary cutting edge angle. And in the cutting plane, we it will be apparent that inclination angle. Inclination angle can be seen in the cutting plane and we can see the orthogonal rake angle in the orthogonal plane; that means, we can see the slope of that surface in the orthogonal plane. That is what it is orthogonal rake angle.

And then, here we can also see the principal flank angle in the orthogonal plane.

Then similarly we can make one auxiliary orthogonal plane; main cutting edge is there based on the main cutting edge, we have made. One orthogonal plane similarly from a based on auxiliary cutting edge also, you have made. One grew that is a auxiliary orthogonal plane, and in that you are seeing that there is a auxiliary flank angle that will be visible here that is also the part of ORS nomenclature, orthogonal rake system it is also called continental system.

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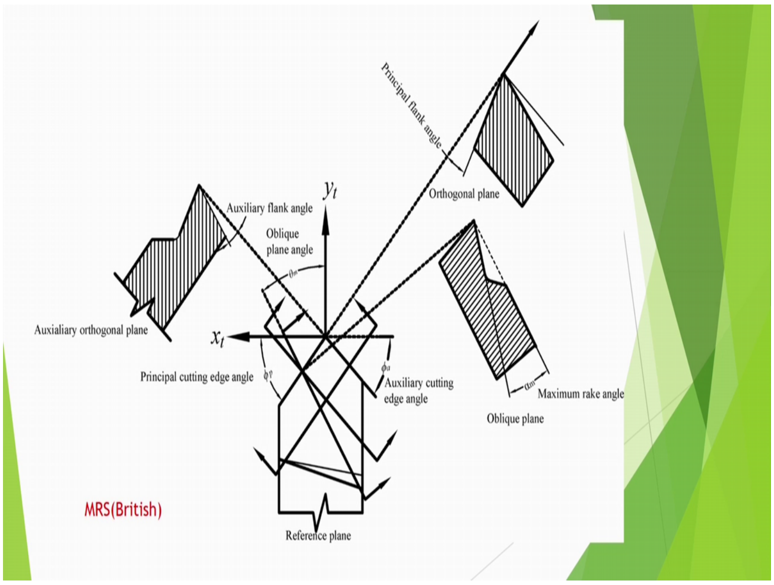

Then, we have British system that is called maximum rake angle. Here in the top view, we designate one plane means if we want to cut a section here in. That plane this slope of that rake surface will be maximum. So, it will be called a plane of maximum rake angle and this is inclined with this radial direction this inclination angle is called theta m or oblique plane angle you are seeing it here, and in the top view. Of course, you will get principal cutting edge angle in the same way you will be getting the auxiliary cutting edge angle here, and you will get orthogonal plane here in the same way in MRS system in which as usual, you will be getting principal flank angle, but you will not designate here the orthogonal rake angle here, because that is not this system ok.

Orthogonal rake angle is also you can tell there is of course, relation between systems, but you have to specify only 6 angles say. So, 6 angles are sufficient ASA system also, I am specifying 6 angle and one nose radius this 7 elements, they provide tool signature. So, similarly here also I hope you give 6. So, why I will be telling this angle is orthogonal rake angle when I am telling the maximum rake angle in this plane. That means, I am cutting a maximum rake angle plane here this section and this is maximum rake angle.

Here this loop is maximum. So, it will give a idea that how the chips are flowing here. And then similarly we will make auxiliary orthogonal plane in which I can show auxiliary flank angle and this is complete ok. So, this is this system is there.

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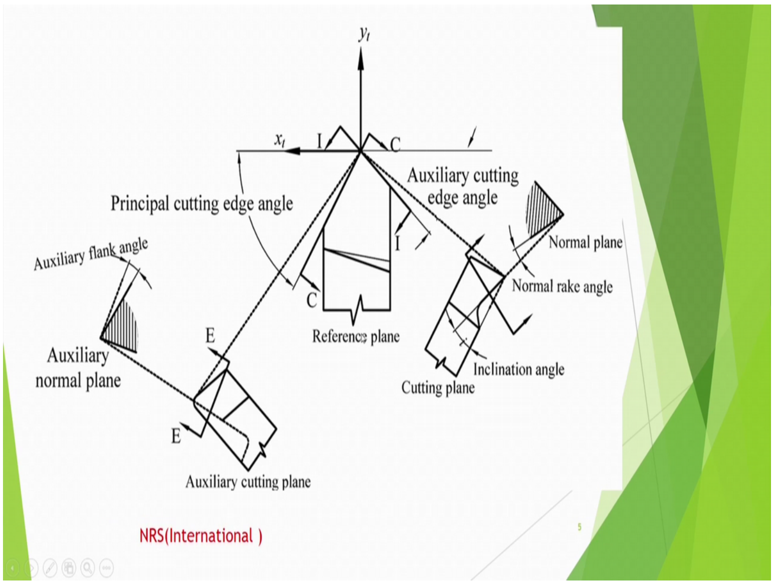

Now, we come to this one NRS system that is normal rakes system normal rake standard. And in this it is international system in this international system in the top view, you are showing in the same way there is a principal cutting edge and there is a auxiliary cutting edge angle is there.

In that there is no difference with the other two systems except that there is some difference in ASA system in ASA system, we tell side rake angle. So, side rake angle is 90 degree minus principal cutting edge angle and, but there we also tell end cutting edge angle end cutting angle edge angle is same as the auxiliary cutting edge angle. So, this is basically same in all these systems auxiliary cutting edge angle and now here we can take a cutting plane here.

Now, we take the cutting plane and in that cutting plane I can see the inclination angle see it is inclined, because it is a oblique cutting. So, inclination angle is non 0 suppose inclination angle is 0. That means, it is a orthogonal system and then I can take a orthographic view here you get a normal rake angle. So, you get here and this plane you are seeing that normal rake angle it is in the normal plane. So, this you have seen in this one. So, difference is that in the ASA system rake surface is specified by two types of angles one is along the feed direction; how it is sloping other is that radial direction how it is sloping.

So, you have got top rake and back rake, but in the orthogonal rake system you are showing its slope in the orthogonal plane in normal rake angle you are showing its slope in the normal plane that normal plane is basically perpendicular to the cutting edge. And then you have auxiliary cutting plane in the same way then we have got auxiliary normal plane ok. So, here auxiliary normal plane you are having auxiliary flank angle. So, this is the flank angle here that is what you are able to see here in the auxiliary normal plane.

So, this is NRS system that is international system now we have got four type of systems we want to see the conversion. That means, if I know the 7 events in one system, 7 events means including nodes radius. So, nodes radius is basically same in all the systems, but other angles are different. Now you want to convert from one system to the other system where, then how you will go above that question is that why we want to study the conversion form one system to the other system, it is reason is that different researchers may tell their results in different systems.

So, therefore, we must understand if we want to meet from one system to the other system in order to understand the other words one can decide you can decide, I will follow only ASA system, because it really simple. Of course ASA system in some sense it is simple also it is convenient sometimes are tool grinding etcetera, but sometimes normal rake system use better idea about the mechanics of the cutting.

In fact, a sometimes, if we want to do some analysis in approximate way based on the orthogonal mechanics if you want to get inference about oblique cutting then instead of side cutting edge angle you generally use normal rake angle. So, normal rake angle can be in that case called 2 angle. So, that one thing is that sometimes if you want to do analysis then normal rake angle system is a better in the normal rake angle system whatever is the your rake angle normal rake, you have got that can be called as a proximate rake angle and that you can use in even orthogonal formula, if you have got you can use that.

So, one thing is that we need to know about the conversion etcetera second thing is that this exercise will actually help you to visualize all the angles. And it is a good exercise you get such type of situations where there are three dimensional surfaces in other fields of mechanical engineering also. So, this is a good intellectual exercise it is better to understand this. These concepts many in many books this is omitted and many places this is not taught in detail because it is the painful sometimes to understand from you have to know three d coordinate geometry are vatter, but even then it is worth studying.

So, we are going to study this one by one that how we convert from one system to the other system this I am going to discuss. Now we will move somewhat slow in each slide and we will show you that concept.

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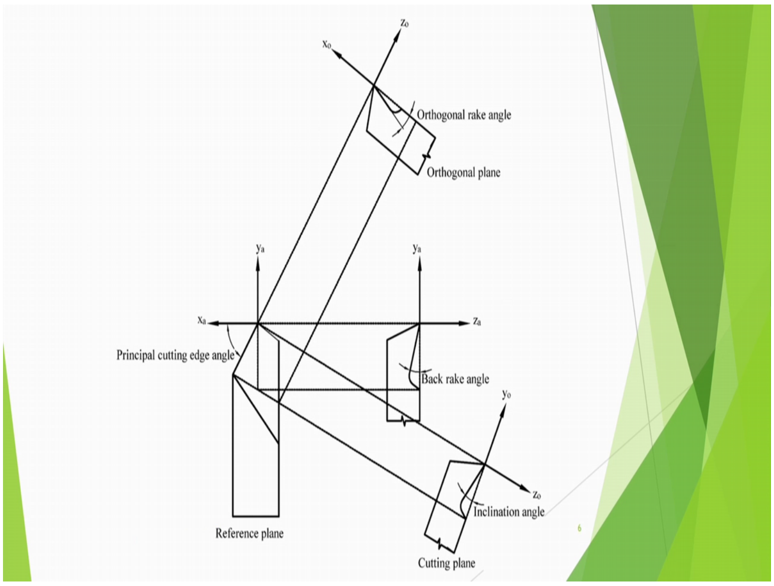

So, let us see that suppose, we just concentrate I am converting the angles say from ASA system to orthogonal system or vice versa. In that case how we can go about that I will have to make one reference plane which can be considered common in the both the systems.

In the reference plane when I take the view of the tool I will be getting principle cutting edge angle this is principal cutting edge angle then if I cut a section in this one; that means, one something like radial plane if I am cutting, then I am getting section y in y direction, then I am getting back rake angle back rake angle in a tool grew and see that back rake means you towards your side you know. That means, you have put a tool like this and in this tool you are having this plane is like this. So, this is the slope whatever slope you are seeing in the slide; that means, it is towards you that point is up and towards you it is sloping.

So, it is something like that, but this point was up and it is sloping this book is horizontal, but I have made is sloping. So, something like this. So, this way it is coming that back rake angle and then in the cutting plane you know the cutting plane is plane that contains and also it contains the cutting edge. So, that cutting plane it is orthogonal to the reference plane in this angle in this plane you are getting inclination angle this is the inclination angle that is visible to you inclination angle 0 means this orthogonal cutting. Then here you are having orthogonal plane which is perpendicular to the reference plane and cutting plane and in the orthogonal rake angle, you are observing an orthogonal plane this is orthogonal rake angle this is back rake angle all these relations are there.

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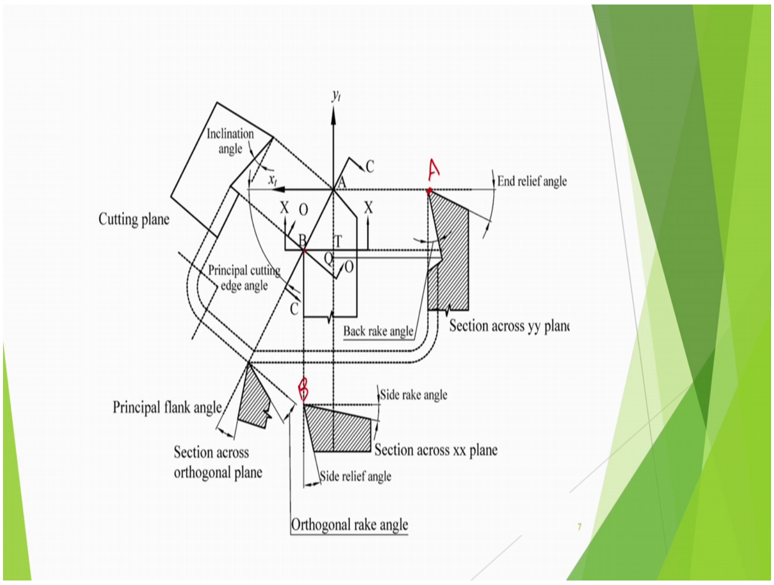

So, now here I have put the levels in detail and we are taking the sections suppose there is some tools I am shown in the top view if I take a section y y. Here I am getting end relief and I am seeing the back rake angle in ASA system in ASA system if I take a section x x. Here then I am seeing the side rake angle here and I am seeing the side relief angle here in ASA system. So, ASA system is complete with these three views one view is this other view is this third view is this we have this time, we have taken a sections.

And cutting plane is in this direction in the cutting direction this B c point moves here. So, you are having cutting plane and here this is inclination angle and if I take the orthogonal plane I just rotate it here. That means, in the cutting plane and orthogonal plane basically the heights will appearing to be same, because both are the vertical type of plane [FL] although one plane is multi degree with the other. So, in this orthogonal plane you will be getting principal flank angle and you will also get orthogonal rake angle here that type of thing you will be observing.

And observe that motion that here point A, in this view that point A has gone here that it will be shown here. Similarly B is here that B point is here like that you have to designate that what are the things which are going suppose this point T is there. Now T if I take the section of the T in the top view there is a one T. But here if you see there is a one T in the surface and one in the T dash and we can say T double dash and one is at the same level; that means, height [FL] if two things are at some particular height, one point is this another point is in the top view both the points will appear as one entity.

But actually in the other view they will be distinctly apparent. So, you have to visualize this type of things concept of your drawing are here useful. So, this we have to see and now we will see that how it can be converted.

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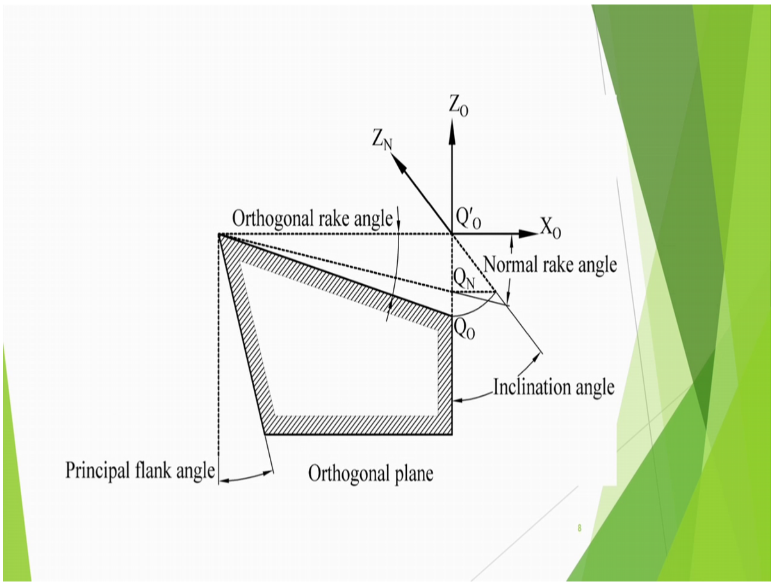

So, we are going to maybe next slide here, but before that let us discuss about orthogonal and normal plane what do we mean by orthogonal plane. Of course, orthogonal plane you may going in nicely that this plane is perpendicular to the cutting plane and also the reference plane involve the system we use.

And in that if we draw that this type of projection, then we have we see the principal flank angle in really apparent way and orthogonal rake angle appears here; that means, the slope of the surface will be distinct here this point will be up other point is down. So, by this we can know that this point is actually up, it is not the same inclination not same height level from the surface. So, inclination is different height level is different. So, this difference is there this difference is there that is why the chip will slide in that version ok; that means, chip will slide from here to here like that.

So, this is sloping like this now normal rake angle is actually, it is not orthogonal to the that cutting plane rather it is a normal to the cutting edge so; that means, it is inclined in a way that suppose you have got one book and this is the orthogonal plane, I know that that title of the book is visible, but that has been suppose I tilted a bit you know. So, that it becomes perpendicular to this thing. So, you can say that this surface actually becomes tilted compared to that previous surface. So, that type of phenomena will happen this is really not two d diagram. Here I am showing that Z 0 is the normal, then in that particular direction is out of the plane you have tilted it and you that axis has become Zn and in that system you will be measuring that normal rake angle and both the axis vertical axis will be inclined by your angle that is called inclination angle; that means, inclination angle.

Suppose this is the vertical is the cutting velocity, but since my plane has tilted. So, therefore, in the plane whatever is that line is that it is no longer vertical it is inclined with the vertical and that inclination with the velocity is actually called inclination angle. That means, how much is the extra inclined if the inclination angle is 0 then the orthogonal plane and normal plane both coincide. So, this you have understood then we will go to in detail we want to study that how these things are related and we are going to study this one that here.

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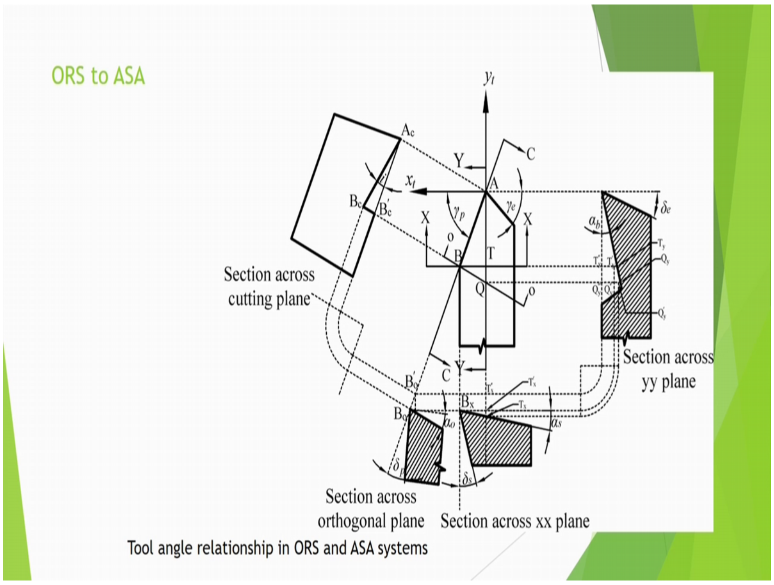

Now, let us go to tool angle relationship in ORS and ASA system. So, we want to go from ORS to ASA we want to understand here I have designated these angles in terms of the symbols alpha b back rake angle alpha s is a side rake angle alpha o is orthogonal rake angle i is the inclination angle delta p delta s gamma e is the you can say end cutting edge angle and gamma p is the name that a principal cutting edge angle or it is basically 90 minus side cutting edge angle. And then you have got some point T which I am showing here that it is this is T and A neither point is T y and we are taking different different sections

So, what is shown that this point T how it will be shown in the other in the other view it is here, but that one and this one is a showing that T x dash. That means, they are all these levels are different; that means, at the surface you are having T and here at the top you are having T x. So, because it is sloping; so, this difference between two T s; that means, one without dash other it with dash that will be apparent in the section across yy plane, but it will not be apparent in the top view

Similarly, you see that when I take a section across the cutting plane now my B c is looking simply straight line and b point is there, but when I take the section in the cutting plane then I am seeing that this B c prime that is up and B c this one is down; that means, I am clearly seeing the slope here. That means, we got the height top view does not show you the height, you know height above some level like C level or something it is not showing it is at the same level reference plane is showing the same, but here the height will be apparent you have identify that in the cutting plane this is basically a height.

So, vertically that point is down that is why you are saying that the cutting edge is inclined similarly here also it is down. So, you have you can always imagine in terms of that thing that you have something a horizontal surface reference plane from that whether it is coming down towards the earth or it is going away from the earth that type of idea you can have about the slope. Then it will be easy for you to visualize and you have to do it at many goes then only you can understand this one.

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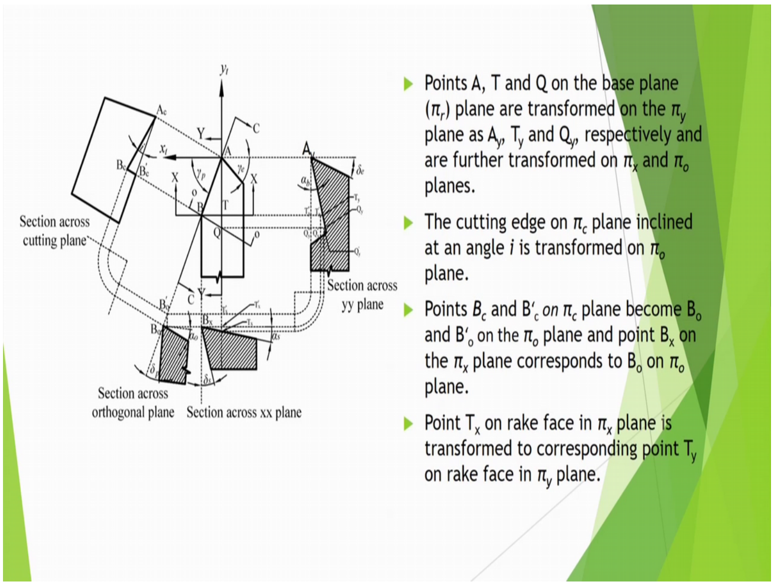

Now, here now if we go to this one; o, points say A, T and Q on the base plane; that means, are transformed on the pi y plane. That means, section across yy plane as ay T y and Q i respectively and they are further transformed on pi x and pi 0 plane also concept is that you have to see keep seeing the height suppose the height in orthogonal plane and yy plane will appear to be same some point is at some height in xx plane, it is a height in yy plane will also be same, because you can understand that I am taking the section in the xx and other is yy only in the top view height will change.

So, cutting edge on pi c plane inclined at an angle I is transformed on orthogonal plane points B c and B c prime on pi c plane. That means, cutting plane becomes B 0 and B 0 prime on the orthogonal plane and point B x on the pi x plane corresponds to B 0 and pi 0 plane point T x on rake face in pi x plane is transformed to corresponding point T y on the on the rake phase in pi y plane. So, like that we have got these types of relations and now let us see that how the equations will go.

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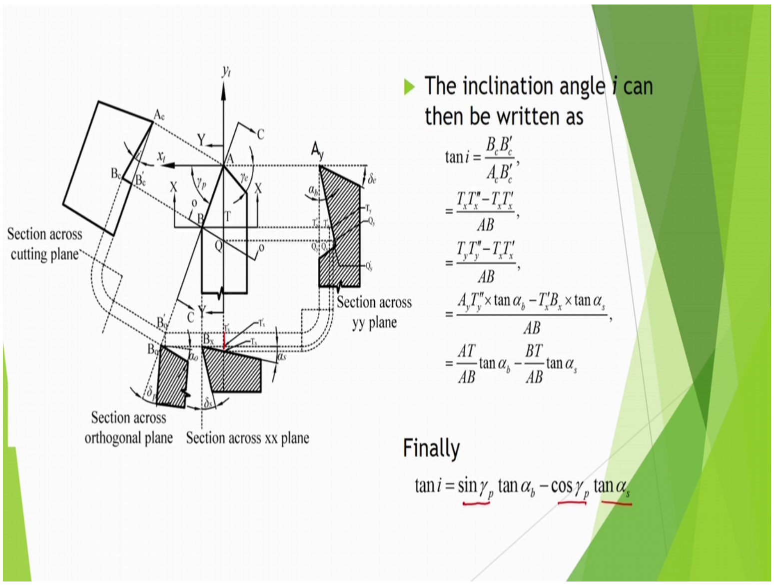

So, let us concentrate on the inclination angle inclination angle is getting measured in the cutting plane. So, in the cutting plane how should I measure the inclination angle tan I is equal to B c into B c prime divided by ac B c prime; that means, horizontal distance in this one and in the vertical direction how much it is going. So, vertical distance suppose it is going this much and divided by a horizontal distance. So, B c B c prime that this one how it is related to the other slopes etcetera. This can be done like this ac B c prime actually in denominator concentrate on that ac B c prime that is the horizontal distance that is basically same as A B in the top view because A B has been projected

So, A B on the top view is basically same this is A B and B c B c prime because it is showing the height difference. So, here it is something like this that if you have a one point here T x T x and this point here T x T x dash. So, T x and T x double dash this is top view this one is T x double dash on the top surface this is the basically corresponding to topmost point and T x and T x and this is basically the surface, because this point is at the surface; so, T x T x dash minus T x T x dash; that means, minus T x T x that this. So, then we get this difference.

This difference is what that means, this difference let me make it like this red this red point is basically showing me what that it is showing that vertically how much this horizontal surface at this place is down with respect to this b, because this maybe corresponding to the top B c point and this is corresponding to the bottom most that point. That means, this is what it is showing. So, that is how that it is T x T x double dash minus T x T x dash T x T x double dash T x is our lowest point here and B x is at the same level that is T x dash. So, that is why B x is at the same level that is T x dash.

So, that is why you are getting this type of thing. So, you are getting T x T x dash minus T x T x dash divided by A B. Now this T x T x double dash; that means, from here to here T x double dash is what topmost plane type of thing. That means, I have got a tool and in that I put some plane level thing at the top. So, it is basically the highest point it is at the same level at which B c prime is there. So, it will naturally look and T T x is what T x is at the bottom surface. So, it will naturally you look same in the yy plane in yy plane the plane T x T x double dash becomes actually equal to T y T y double prime.

So, it becomes T y T y double prime that height becomes and here minus T x T x dash that will remain as it is and we put AB. So, I have been written this type of relation whenever you have difficulty in the visualization you try to put coordinates of each and every point. Then you can very easily understand slope means suppose there is a surface it is horizontal no slope, but if the surface point comes down in the vertical direction then there is a slope.

If surface point can come in this one, but there are two ways this point can come down like this or it can come down in the other direction, it can come down towards my side, it can two ways that it can do all; that means, this is like this and I am low link I am tilting it like this or I can tilt it like this is it not. That means, my hand is there I can rise my hand like this or I can rise my hand like this. So, this is both the things are this one. So, I am showing with the book this is a horizontal now this is the slope I have tilted it like this or I can tilt it like this know it can suppose. This is a horizontal I want to make vertical it can become vertical like this right and it can also become vertical like this.

So, there are two directions you can give the notation this point you have understand. So, there is a if you write this thing whenever that there is a one point at the surface is lower means towards earth compare to the previous point naturally that time you have got slope. So, here T x T x double dash is basically T x T y double prime because it is in the same graphic view and this height wise it remains same and T x T x dash is this.

Now, T y T y double dash is basically A c A y A y; this point is ay T y double prime T y double prime is at the top into tan alpha b it is a obvious tan alpha b is equal to basically height divided by the base, and T x T x prime this will be apparent in the this view in which side rake angle is visible that will be minus T x prime B x into tan alpha s and divided by A B this much will be there. So, ay T y double prime is basically same as your T and T x prime B x say this is same as BT in the top view. So, this is at by A B you are getting at by A B and you are getting tan alpha b at by A B and you are getting tan alpha b; that means, you are getting the back rake angle tan alpha b at by AB.

Now, at by A B is very much apparent here at by ab. So, this is 90 minus this one gamma p this is basically gamma p because this is the interior angle. So, this is gamma p and this is gamma p. So, I can write it at by A B means sin gamma p. So, we have written sin gamma p. So, sin gamma p into tan alpha b b is coming here and then I have got a minus cos gamma p, because BT by A B is basically cos gamma p and this is tan alpha s. So, we have got sin gamma p into tan alpha b b back rake angle minus cos gamma p into tan alpha s is equal to tan I. That means, inclination angle can be obtained if I know if I know sin gamma p; that means, principal cutting edge angle and I know back rake angle I know side rake angle then I can calculate inclination angle.

If it is orthogonal cutting, then I will be 0. Then I can find out approximate relation also whether it is the process can be considered orthogonal or not depending on this type of situations sin gamma p tan alpha b minus cos gamma p into tan alpha s. So, one relation we have obtained like this.

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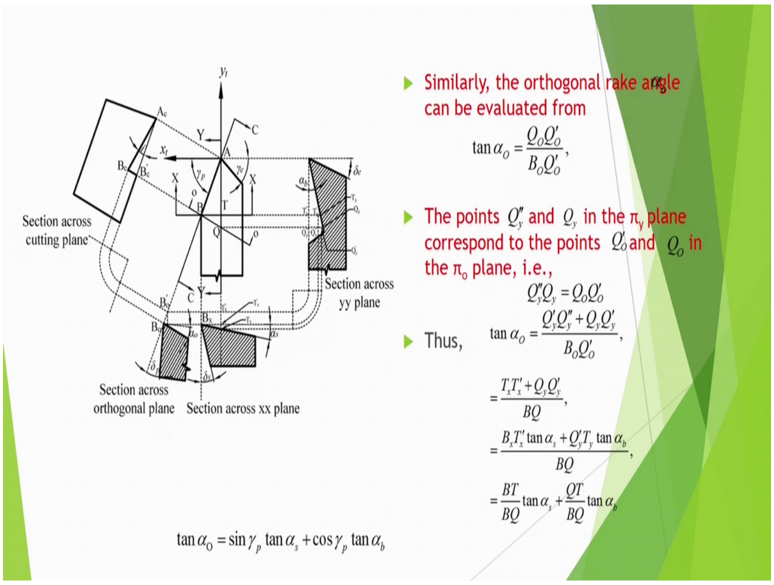

Now, let us try to understand the other relation. Similarly we can find out under understand orthogonal rake alpha 0 can be evaluated how alpha 0 can be evaluated we have to go to the orthogonal plane.

In orthogonal plane we have got this is the orthogonal plane that is which is shown in this o o o o in between there is a point Q here at the center. So, when I am cutting here then this point can go to this one orthogonal rake can be evaluated from tan alpha 0 is equal to Q 0 Q 0 prime and B 0, Q 0 prime ok.

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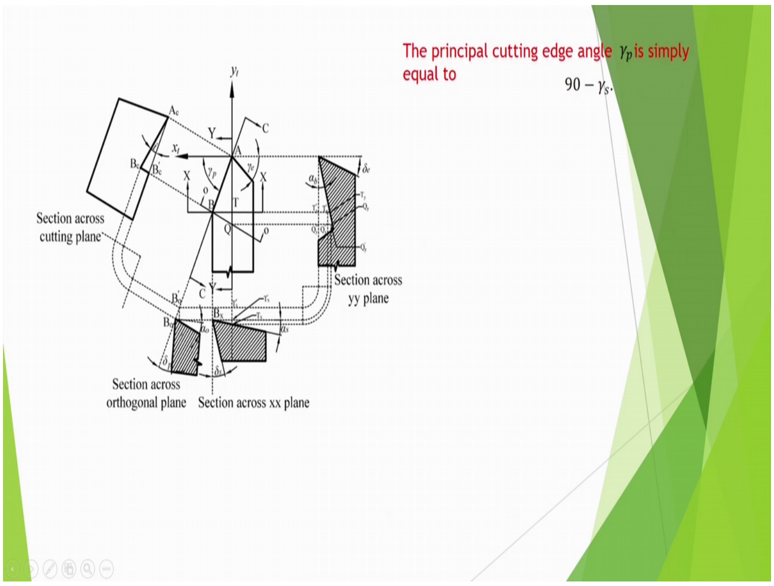

So, here suppose Q 0 is point just on the surface where I have cut ok, so let me just take go to this one it is basically here. That means, this Q point is here that Q point will come here you know here I have not shown earlier now I have showing Q is somewhere here and this will be tan alpha 0 is equal to B 0 and Q 0 dash; that means, tan alpha 0 is 0 B 0 and I am cutting it on the surface.

So, this is a B 0 and multiplied by we have got here on the top we have got Q 0 and Q 0 prime. That means, this is the orthogonal rake angle then the points Q i double prime and Q i in the py plane they correspond to the points Q 0 prime and Q 0 in the orthogonal plane. So, if we see that Q i in this one is corresponding to Q 0 point there and this will be explained here. So, here that will be b 0. So, this will be shown here and then it will be Q. Therefore, Q i double prime Q i that will be equal to Q 0 Q 0 prime; that means, this height is same.

And now this tan alpha 0 can be basically written as Q i prime Q i prime plus Q i into Q i prime. So, Q i Q i prime is this and this is equal to this so; that means, this is basically the vertical height. So, in a way that basically I can say and divided by B 0 and Q 0 prime, because here I am cutting and I am calling it basically Q 0 prime. So, you it will be basically this one. So, you got B 0 Q 0 prime here and this is this one now here tan alpha 0 will be actually equal to T x T x prime T x T x prime in this view T x into T x prime; you know if you say that this is T x prime and this will be Q i Q i prime and B 0 Q 0 prime that basically can be written as B 0 Q 0.

So; that means, this is basically B 0 and Q 0. So, B 0 Q 0 is basically same as point B and Q here B 0 Q 0 here because this is B 0 Q 0 prime here that Q prime point is here. So, this becomes parallel to bq. So, this is basically BQ once we have establish this then it becomes very easy T x T x prime is equal to B x T x prime into tan alpha s. So, this is in this view it is a apparent B x T x this one. And similarly Q i qi prime is actually it is apparent that this will be Q i prime y into T y into tan alpha b and divided by B Q.

Now, B x T x prime is basically same as BT and Q prime y and T y here that is in this view yy plane that is same as a qt. So, therefore, you will get BT by BQ tan alpha S and plus QT by BQ is equal to tan alpha b now BT by BQ BT by BQ BT by BQ this one it is nothing, but sin gamma p your BT by BQ this is orthogonal to that. So, this angle is gamma p from horizontal. So, this becomes 90 minus gamma. So, BT by or this becomes gamma p. So, BT by BQ is equal to sin gamma p tan alpha S.

Similarly, QT by BQ QT is in this one QT by BQ in this. So, this will be here is shown in the top view this is cos gamma p into tan alpha b now you have got a relation between the orthogonal angle is also tan alpha 0 is equal to sin gamma p tan alpha is plus cos gamma p into tan alpha b suppose gamma p is equal to 90; that means, side cutting edge angle is 0. That means, cutting edge is perpendicular to the feed direction in the top view in that case you see tan alpha 0 will be tan alpha s; that means, side rake angle is same as the orthogonal angle in this one.

So, this side rake angle that which will decide mostly the flow not that one that has some effect, but here that factor is cos gamma p will here gamma p becomes 90. So, cos gamma p here 90 0 sin gamma 90 is equal to 1. That means, in a very rough way we can say that orthogonal angle will be more close to the side cutting edge angle in ASA system that is what we have obtained this relation. And otherwise you have got this type of relation I have try to explain with the help of this one.

But you have to see it again and again and visualize yourself, then only you can know yes these all the relations, you know basic concept you have understood otherwise by not if you understand. Then there will be lot of difficulty and I am trying to explain make to visualize with the help of these pictures. So, it is better that you yourself you do that and I have given enough hint here now about a. So, inclination angle and that relation you have obtained and principal cutting edge angle gamma p is very easy it is simply equal to 90 minus gamma s.

So, having known this thing we have understood that how the angles from ASA system are converted to orthogonal system or we can also have vice versa. So, these things you have already understood and this.

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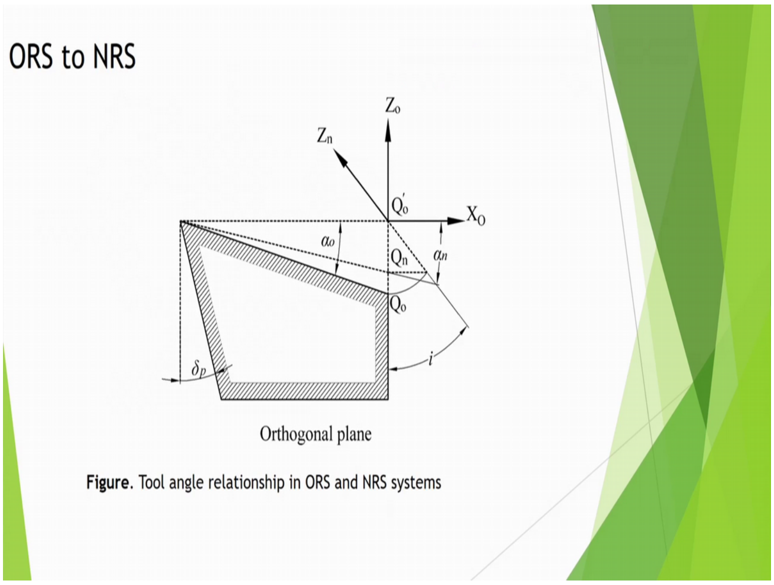

Now, we are telling something from ORS to NRS ORS to NRS, mainly, there is a difference of the rake angle. So, how the rake angle will be differing in a way apparently it appears that tan alpha m. That means, that particular slope in the orthogonal system maybe more, but there it will get slightly reduced depending on alpha n. That means, depending on inclination angle that point we have to show that how it is rotating.

So, here again you have to visualize this relationship is almost same that which you get something, when you derive the relation for universal joint where the two shafts are you know that connected, but they are is too debit it, and they are at angle I similar type of thing we are getting.

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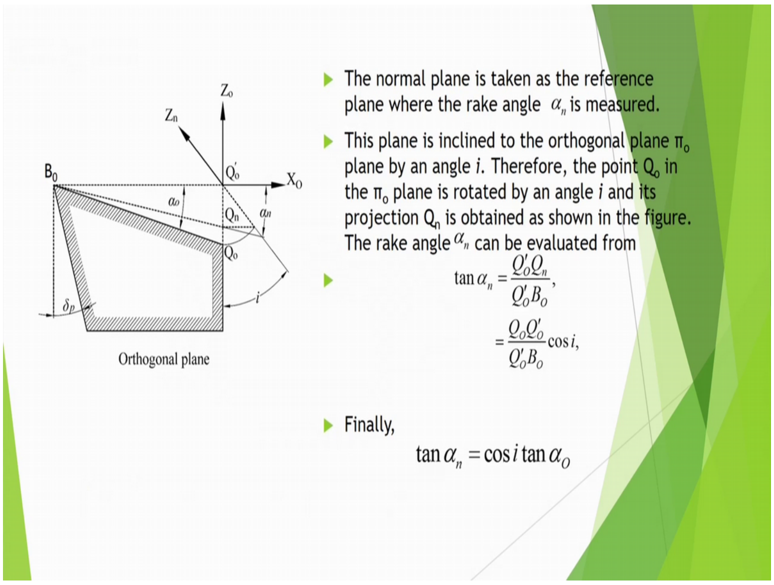

Here normal plane is taken as the reference plane where the rake angle alpha n is measured. Now this plane is inclined to the orthogonal plane by an angle i; that means, I is the inclination.

In a way, I have a orthogonal plane like this book and now I have inclined towards you or I have inclined towards me so; that means, the plane has become inclined. So, this plane is inclined to orthogonal plane by an angle I therefore, the point Q 0 in the pi 0 plane is rotated by your angle I and its projection Q n is a obtained as shown in the figure; that means, projection is taken like that and the rake angle can be evaluated from this one tan alpha n will be basically Q 0 point Q n. That means, basically the height portion here that the surface in the orthogonal system what were the tan alpha 0 it was Q 0 Q 0 prime; that means, vertical relation difference and B 0 Q 0 prime means horizontal difference between two points that ratio of these two; that means, first divided by this second one.

So, you have that type of relation is already there tan alpha 0. Similarly, now if I am doing that if I have inclined. So, that height difference that in the top tan alpha n is equal to something numerator divided by denominator remaining same. But in the numerator height will slightly reduce, because in a straightway there was this height between these two points and when I have tilted it then naturally the height has reduced actually vertical height has reduced this has come down and this has come down. So, vertically height has reduced because you tilted it.

Suppose you make 90 degree naturally, it will become 0 so; that means, there will not be any difference there. So, the this is what the rake angle alpha n can be evaluated Q 0 prime Q n and Q 0 prime B 0 Q 0 prime B 0 is same, but Q 0 prime Q n is basically Q 0 Q 0 prime in the orthogonal view multiply by cos angle means height will reduced by a vector of cos I that you can always visualize that suppose this is a vertical line. If I rotate it by a I alpha then we can very well make out that my breaking a planar diagram here that how this length is changing, because the previous one will become the hypotenuse and this will become the base and this is alpha.

So, then naturally this will be Q 0 Q 0 prime cos I and therefore, you are getting tan alpha n is equal to cos I into tan alpha 0. That means, orthogonal rake angle is reduced by this relation normal rake angle becomes cos I tan say that tan alpha 0. So, that type of relation you are getting if I is equal to suppose 90 degree I is equal to 90 degree. That means, tan alpha will becomes 0 I 90 degree will never be then generally inclination angle is 5 degree 6 degree you know it is of that range, but I can be 0. That means, it is a orthogonal cutting no inclination angle is there in that case tan alpha n will be same as tan alpha 0.

So, this relation also has come.

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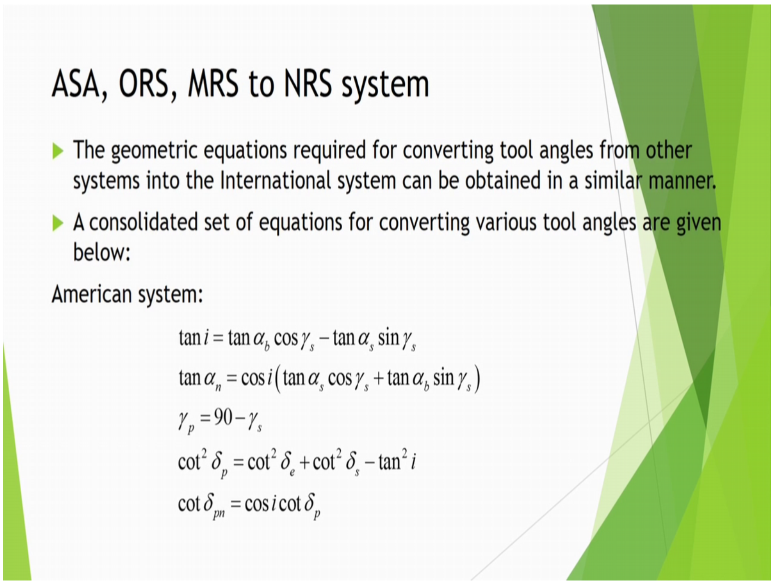

So, like that you can actually derive ASA to ORS MRS to NRS in many books these relations have been given or you are understanding; and for broughting the knowledge about the 3D things you I have introduced those things. And you should practice this one, but each derivation may take time actually if you do that maybe one hour for you to understand, but this way it has been derived and these relations are available in the books. So, these relations; so, when day to day life you can just take these relations and we can plug in and you can get the angle

Suppose geometric equations required for converting tool angle from other systems can be obtained in a similar way and these are like in American system I can obtain tan I is equal to tan alpha b inclination angle by this formula and normal rake angle is obtained by this where this is a things are given in American system you can obtain the inclination angle. And you can obtain the normal angle which is also called tool angle sometimes and gamma p is equal to 90 minus gamma s cot square delta p is equal to cot T square delta e plus cot square delta s minus tan square i and this is cot delta P n is equal to cos i cot delta p like this these are the relations.

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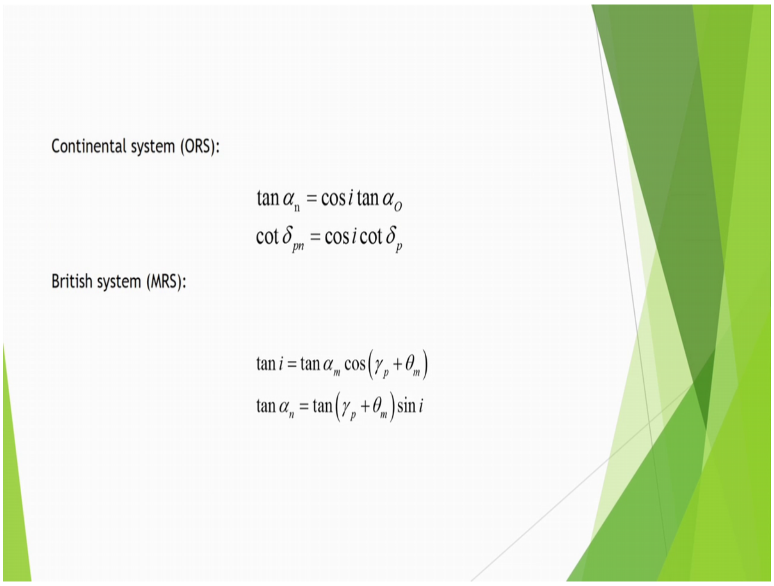

And in continental system tan alpha n is equal to cos I tan alpha 0 and similarly cot delta pn is equal to cos I into cot delta p delta pn delta p is the clearance relief angle here. And this is the corresponding relief in the normal system in British system.You have tan i is equal to tan alpha n into this relation and you have got also tan alpha n is equal to this much relation.

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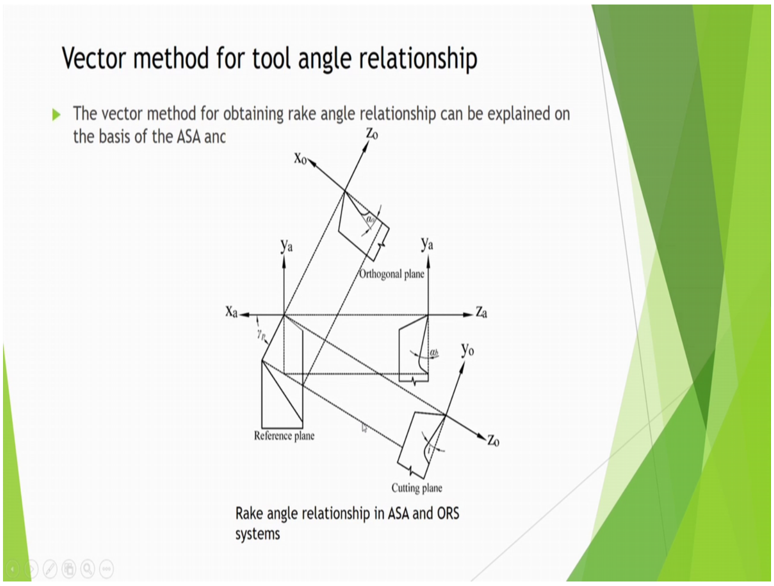

Now, here it is not the only way to understand the transformation you can use three d coordinate geometry there are many methods. In fact, if you see the old book of that Amithabh Bhattacharya about natal cutting mechanics he has given several methods to do that for 4-5 methods.

So, one method is suppose vector method far angle relationship you can make the vectors you can make the lines. And you can say these are the vectors and the condition that these vectors will be planar is that the triple product is 0.

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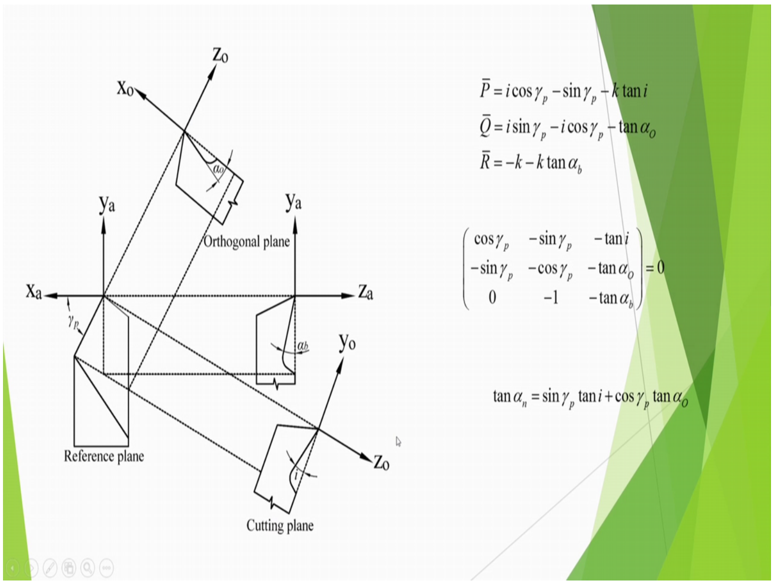

So, using this type of relation, you make one vector another vector then put the condition of making triple product of 0. Then automatically you will get relation this can be done in mathematical way, but I have told you in such a way. So, that it helps you in the visualization.

It is more physical, you can I think appreciate I am following what I am taking the projections I am seeing the height of the points in one plane. And I am seeing that what happens in the other plane by that way I have done derivation.

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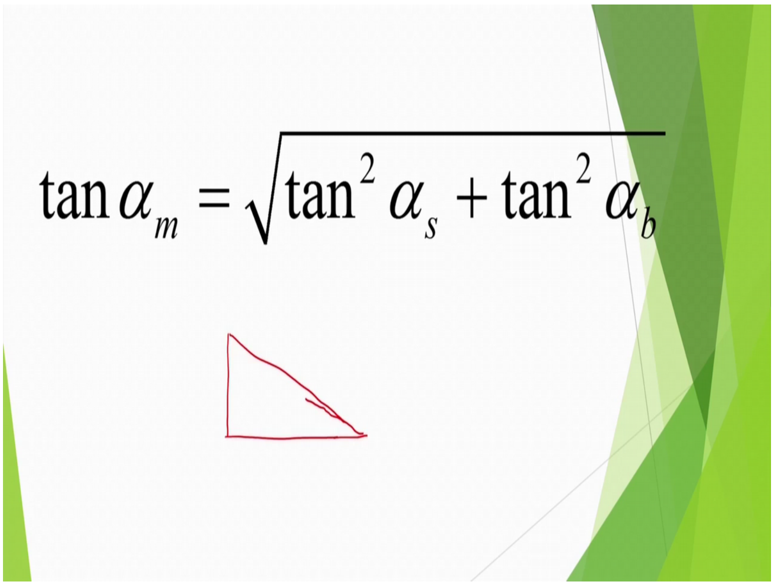

There is a relation between alpha m and side rake angle and back rake angle is this tan alpha m is equal to under root tan square alpha s plus tan square alpha b. That means, in maximum rake angle this is the relation.

So, simply suppose there is only slope in one direction side rake angle, but alpha B 0 then that is the maximum slope that direction, you have to do suppose you have got one straight mode which is sloping [FL], this is the sloping in that case you very well know that only if you go in the direction of that load then you will counter maximum slope [FL]. Suppose you start moving perpendicular to that direction we will get 0 slope, I am I have inclined this like this I am going from here too. Here I am getting maximum slope if I go from here to here 0 slope in between if I go if I follow this path then my slope will be reduced because between two extremes it will change. So, that is why that it happens tan alpha m is equal to under root tan square alpha is plus tan square alpha b.

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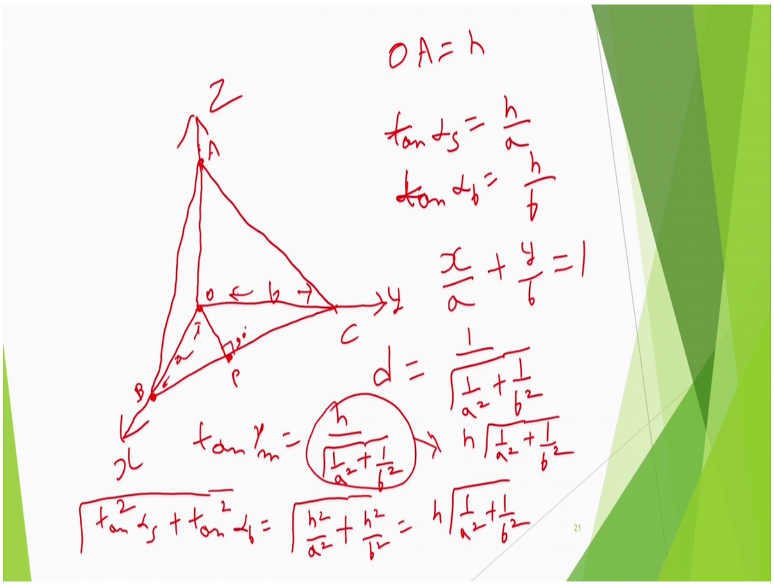

I can derive it also very nicely for this I am say suppose I want to derive in your presence that is why I have not already made the slide. Suppose, this is this is y suppose I have make a three dimensional picture type of thing this is xy and this is the vertical plane here a vertical line z. So, xyz I can say this is xy, it is basically out of your screen, but I am showing that a forty five degree inclined an angle x that you very well understand and suppose I have this point here then I have got this point here and I have something like this point here.

So, supposing this you see that this point is o is the origin let us say this point at the top is a. So, that basically height OA is fixed in all the cases let us say it h. So, what will happen that in this x plane in this rather xz plane you have got this type of concept that suppose this projection was a this. That means, this length was a and this length was b; that means, this length was. So, I can say A B ABC.

So, let us say ob was equal to A and this was equal to B ok. So, in that case what would have happened; that means, I would have got something like tan; tan and I will get a tan alpha s suppose is equal to h by a type of thing if I define and tan alpha b, I define I am just trying to derive it tan alpha b, I define h by b. That means, this divided by b so; that means, if you moved on the plane in the plane there are three lines a A B line is there ac line is there and B C is there.

And now if you move from A to B, your slope will be this if you move from here to here the slope will be this. Now if you move at any other plane suppose instead of that I moved at point P; that means, op; that means, AP line. So, in AP line, you will encounter how much slope downward the overcoming the same distance h, but horizontal distance is changing so; that means your angle will be different.

So, since the height is same in all the cases. So, therefore, in this particular case if the horizontal distance this distance is minimum that will give you maximum slope so; that means, what is the condition that these two distance should be minimum. That means, maximum rake p will give the maximum slope if I go from A to B will encounter maximum slope provided I drop from OA perpendicular and BC. So, basically OP is that 90 degree. So, that is what.

Now, the question is that how much is that OP. So, if I can do like this suppose this B c line is there equation of a line B C is x by a plus y by b is equal to 1 and if I drop o is a point of 0 0 point. So, if I drop the perpendicular you know the equation how to how do I find the perpendicular distance let us call it D. So, d will be simply one divided by under root one square plus 1 by b square right. So, therefore, tan gamma m in a sense will be basically h divided by d; that means, h divided by 1 by a square plus one by b square like that ok.

Now, this one, 1 by ASA one by A is basically one by a. So, here you are getting tan alpha is equal to h by A so; that means, you are having. So, if I also do tan alpha s is square suppose I take under root tan alpha s square plus tan alpha tan square alpha B, then I will be writing under root x square by a square right and plus I will be getting this is a this will be h by B. So, I that when you do h by d here tan gamma m is equal to not really h by this 1

rather this will go up. So, it becomes h by under root one square plus one by square this is small mistake I have done that you have just see carefully that is why you know it is better that suppose I have done mistake, but collected.

So, it will appear that if you are attentive you can make out that this is dd is equal to this one. So, it is h by this one and here tan square alpha is plus tan square alpha b is equal to h square by b tan square which also comes out to be h 1 by a square plus one by b square. So, what that it shows that it shows that tan gamma m is equal to really under root tan square alpha s plus tan square alpha b. So, this, I have proved you for your purpose that you have seen know. So, this one; so, like that you can prove that you should have some interest in doing this type of mathematics then you can make it out.

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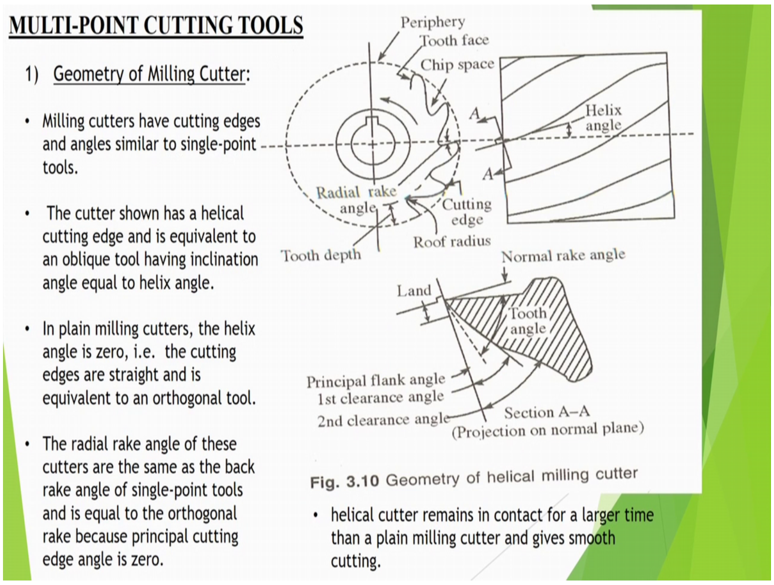

Now, if I go to this one we till now we talked about single point tools in the single point tools in lathe machine burin machine we use that.,Bbut now we have to understand multi point cutting tool is also by the same logic by the same type of geometry. Suppose, example is that we can have milling cutter in milling cutter there are number of teeth are there and there is a chip space there is a two three space in here. And this is the periphery in the same way we can define the radial rake angle just like we defining the single point cutting tool this surface is slightly slanted.

So, dry radial line that becomes like a reference plane and from here you are having this angle and this is the these are the cutting edge this is a cutting edge and this one and usually these are at the helix also. So that means, geometry may differ from in the axial direction also this need not be straight rather it is a this tool is helical. So, we designate the helix line also we take a section here we get some sort of land here in the flank surface. Then we get a it is slightly sloping we make a principal flank angle there which reference to that means whether it is a radial line here one. That means, whether it is having or not then this unable slope they also be there it is called first clearance angle.

And then we can have further sloping that maybe second clearance angle I mean to say actual tool geometry maybe very complicated, but you have to define and we have to systematically understand and this one is this. So, in the plain milling cutter the helix angle is 0. That means, cutting edges are straight and is equivalent to an orthogonal tool the radial rake angle of these cutters are the same as the back rake angle of single point tool and is equal to the orthogonal rake because principal cutting edge angle is 0.

Helical cutters remains in contact for a larger time that a plain milling cutter and they give a smooth cutting that is why we provide a helix.

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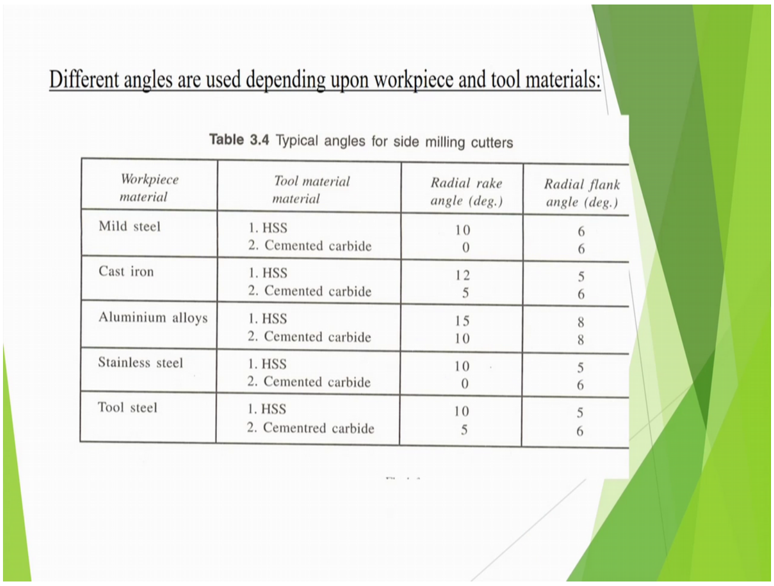

Workpiece material	Tool material	Radial rake angle (deg.)	Radial flank angle (deg.)
Mild steel	1. HSS 2. Cemented carbide	10 0	6 6
Cast iron	1. HSS 2. Cemented carbide	12 5	5 6
Aluminium alloys	1. HSS 2. Cemented carbide	15 10	8 8
Stainless steel	1. HSS 2. Cemented carbide	10 0	5 6
Tool steel	1. HSS 2. Cementred carbide	10 5	5 6

So, that all of a sudden a particular tool does not gift whole the workpiece some point of that particular edge is in contact is visual and um. So, here that one different angles are used. And now you are having side milling cutter different angles are shown 10 degree, 12 degree, 15 degree depending on that radial rake angle can be more if it is a soft material like aluminum. Here, I am getting 15 degree some places, I am getting 10 degree and radial flank degree angle is in 5 to 6 degree that one.

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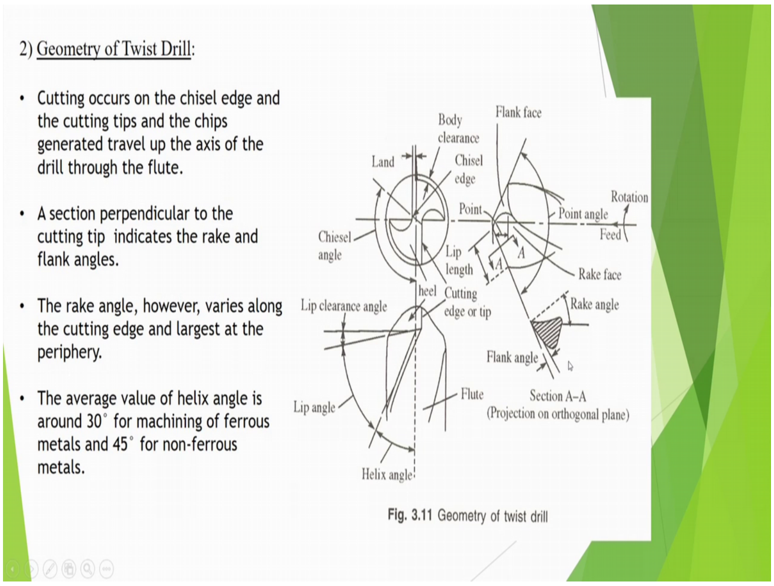

Similarly, you can have twist drill there are two main cutting edges which are cutting we are seeing that the cutting operation will go on the helix fashion. Here we define a helix angle this point is called a this edge, is called chisel edge. And here you are having there is a some you see outer place cutting is there and other part of the body will be slightly inside. So, that it does not come. So, that is why we are calling it a body clearance.

And in the same way, only thing that we have to visualize now it is in the curved profile otherwise it is the same way you have a one cutting edge here. And other cutting edge is here and in between that included angle is called point angle usually most of the drills, it is about 118 degree particularly for a steel etcetera. And this one is a this, one if you cut these sections. Here then you can get the same type of thing here you can get a rake angle then you can get here the flank angle.

And then you can and you have got the flute that space is called flute in which the chips will flow in a helical pattern it is helix helps in bringing the chip out and this is the chisel edge and these points are this one. So, it is a that is this is lip length is called this and cutting edge are tip. So, here cutting occurs on the chisel edge. And the cutting tips and the chips generated travel of the axis of the drill through the flute through the flute they go a section perpendicular to the cutting tip indicates the a rake and cutting angle.

And the rake angle; however, varies along the cutting edge and largest at the periphery. In this case it is largest at the periphery the average value of helix angle is around 30 degree for machining of ferrous and 45 degree for it can be for a non ferrous for a non ferrous you have even more.

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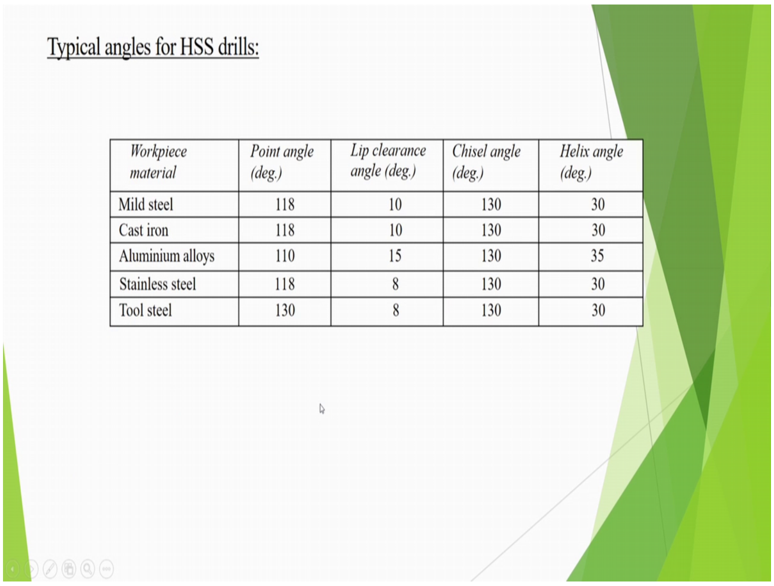

Workpiece material	Point angle (deg.)	Lip clearance angle (deg.)	Chisel angle (deg.)	Helix angle (deg.)
Mild steel	118	10	130	30
Cast iron	118	10	130	30
Aluminium alloys	110	15	130	35
Stainless steel	118	8	130	30
Tool steel	130	8	130	30

Typical angle is for HSS drills on point angle is 118 point angle is this angle included angle cos tan. And also it is like this aluminum 110 tool steel 130 and these are the chisel angles. And this is the helix angle or this data is provided here.

So, this way that I have introduced you with different type of systems that angle system in this way we understood we got some idea about the conversion of this one maybe when we discuss about the multi point cutting operations then we can again go back. And can see that so, but this understanding is very useful although it may be little bit painful, because you have to visualize sometimes you can make the model by Fevicol or by any in wood you can make the tool generally I make very big wooden type of. So, that I can touch it and we can visualize about the angles. So, here you can see only through pictures and you can get the idea, but actual 3 d things, you can make and you can visualize these angles; so this one.

So, for today only this much; and from in the next lecture, we will study about the cutting forces; how do we obtain cutting forces in machining ok.