Mechanics of Machining
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Lecture - 04
Tool Geometry: Single Point Cutting Tool Specifications

Hello students, this is the fourth lecture on the course of Mechanics of Machining. In this lecture, I will be talking about the Tool Geometry. In the last lecture, we discussed about the types of chips you remove, the material in the form of the chips in machining and who removes that material a cutting tool. So, cutting tool is very essential and we have to understand the geometry of the cutting tool, geometry of the cutting tool is very important and it has large bearing on the performance of the machining.

Earlier, making the proper tool was considered as an art, you know some craft band will make his tool in such a way that he will be able to accomplish good amount of machining, whereas, some other person he will not be able to make that type of tool. So, earlier days, it was considered as an art because it is not really obvious that any type of tool will function, you have to use proper angle to its various lines and surfaces. So, therefore, it is very essential. Before about 1950s, some research papers was published in the machining, but they did not even mention proper tool geometry. So, it becomes very difficult to inform that what forces they should have got and what are the issues, but now there is a standard system.

In fact, there are 4 popular standards of defining the tool geometry. We will discuss all of them in the workshop course, you must have got some exposure about the tool geometry and in most of the books on workshop technologies they mention will be the American system of tool geometry, but here we will see other type of tool geometry. And, in the subsequent lecture, we will also discuss that how this can be converted; that means, conversion from one system to the other system.

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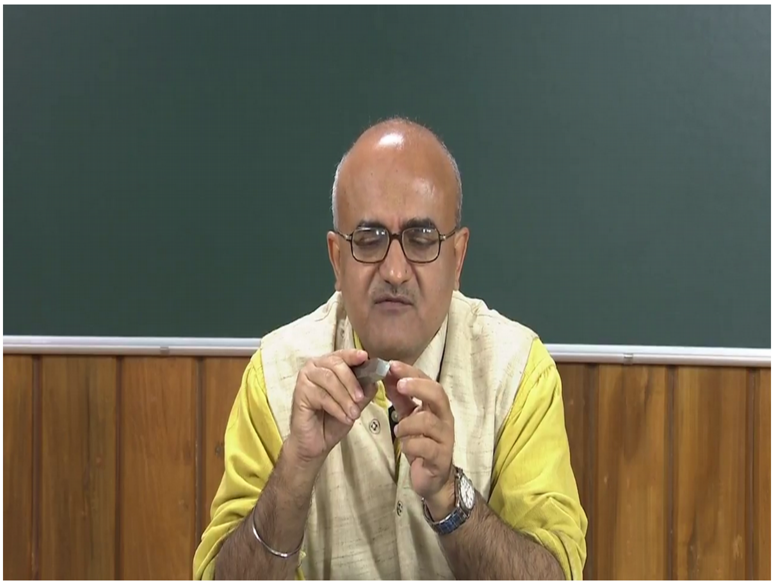

So, this is a typical lathe tool in this, this is a shank this portion is a shank, then this is a cutting edge, it is a primary cutting edge and this is secondary cutting edge auxiliary cutting edge, we can say and in between there is a nose radius. And, you are seeing that suppose, I putting on the lathe machine like this, then the job is moving in this direction; that means, job is rotating and relative velocity is vertical. So, this is relative velocity vector. So, perpendicular to that we can say that it is a reference plane.

So, one plane is this and then so, one direction is this one vertical z direction and then the tool is actually moving diversing like this; that means, in feed direction. So that means, feed is in this direction and radial depth is actually in this direction; that means, towards you that it is coming. So, this one is a typical cutting tool.

Now, we will trying to understand its various type of angles by means of the figures, 3D figures and 2D figures. This topic may appear to be difficult for some people because, you how to rewrite the 3 dimensional geometry and many people face difficulty in understanding the 3 dimensional things, but we will try to make you understand these concepts with the help of some figures and visual acts.

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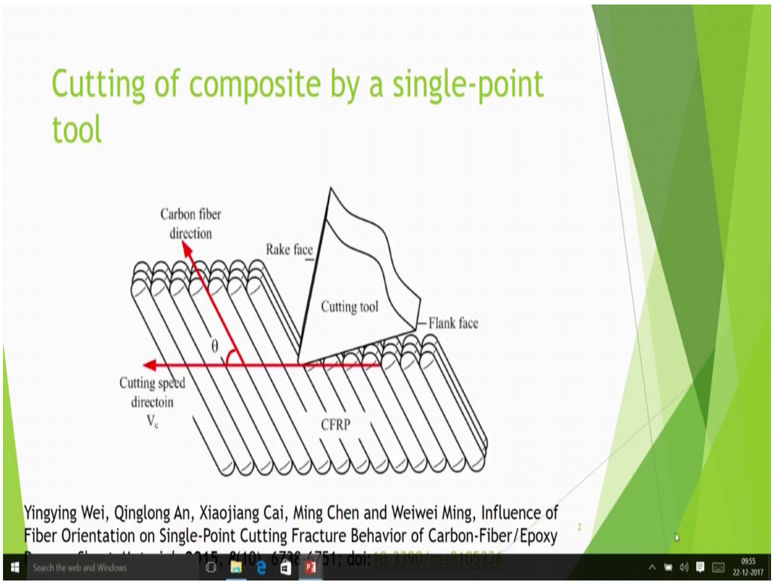

Now, just going to this one, this is a simple that cutting tool, it is showing the cutting of composite by a single point tool, here this is a cutting tool and this one is a basically perpendicular to the plane of this a screen, they are use a that cutting edge. And, this face is the rake face on which the chips will slide, in this type of tool rake face is actually this because, the chips are flowing here and then this is a flank face.

Rake face and flank face they need at some angle and this makes some included angle of the cutting tool. So, in this particular case, flank face is really this is the rake face and this one is the flank face ok. Now, here this is the cutting speed direction, cutting speed direction is this machine surface, you all making it here and this.

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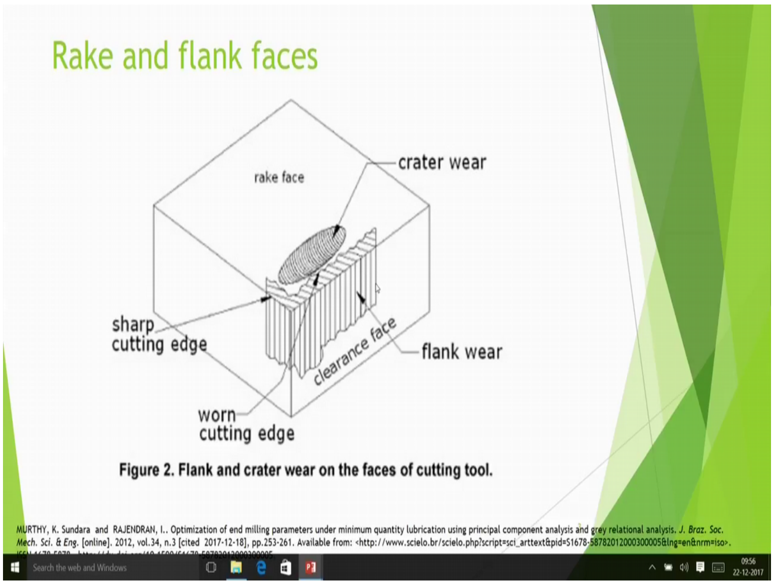

Then I am showing now a 3 dimensional view of the cutting tool, here cutting tool may be here it is just rectangular type of shape. If you see the top surface that is rake face, we can see in that two edges are making meeting. So, this one is a cutting edge and this one is also a cutting edge. This may be primary cutting edge, this may be secondary cutting edge. So, secondary cutting edge, primary cutting edge then there is a rake face and which this slide chips slides and because of the abrasion of the chips etcetera there may be and even temperature is also very high. So, vl phenomena we will discuss these things in detail, but you are seeing that there is some crater type of vl; crater means a type of pit you have got on the rake surface. So, that type of thing is shown here.

And then there is a this surface is the flank face also it is called clearance face. So, this is clearance face now, and the this surface is that surface which may rub against the machine surface like that, when you are cutting like this it may rub like this and that is why on this you are so, get some vl that is flank vl and these are the. So, you are seeing that here because, of the vl some material will be removed and you will get expose to one either type of that edge that is called the warn cutting edge. So, these things are there.

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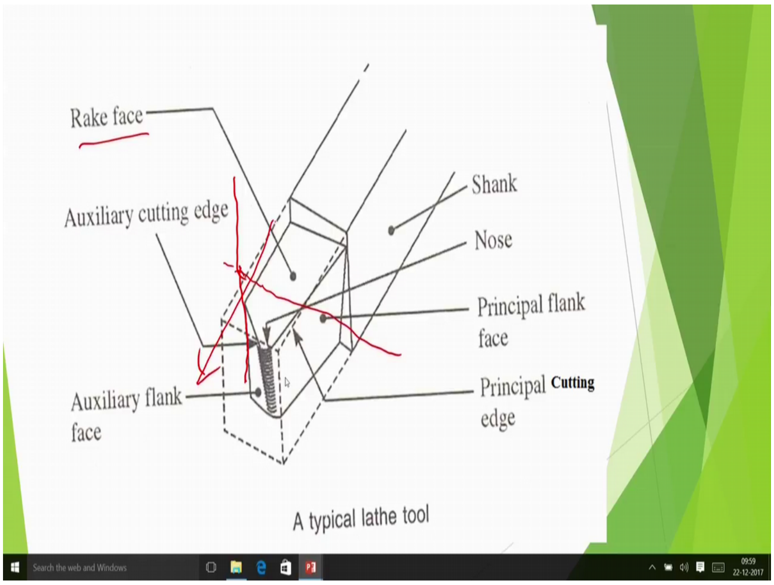

Now, again I am this tool is in my hand, but a stills I have made a in the screen a typical lathe tool I have shown here. In the typical lathe tool there is a shank here, then there is a primary cutting edge and this is auxiliary cutting edge. Then this surface downwards is auxiliary flank face and this one is the principal flank face. Then we have got principal cutting edge that is doing the main cutting operation and the tool is actually may be feed is given in this direction, that is the direction of the feed ok.

So, feed is in this direction as I have shown by the red one, depth you give in this direction and that is if you see from the top, then you will see that this type of surface rake face is very prominently will be visible. And, cutting speed is actually like this vertically upward; so, this is a thing. So, this surface is the rake face rake face is very important rake face, you can see here and this one is the nose two cutting edges are meeting at some nose. So, this is the typical tool. Now, if we make the 3 views of the this cutting tool, it will be very nice we can understand.

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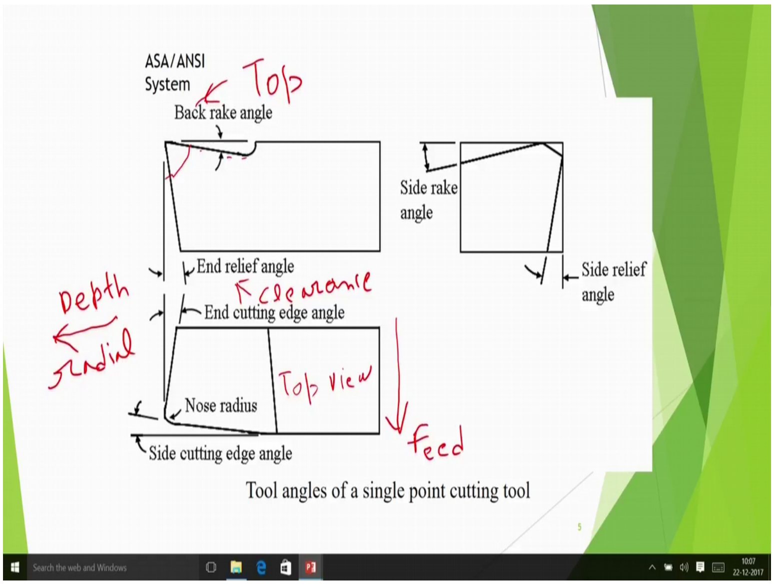

So, 3 views of the tool they are shown like that top view is actually this, this nose radius and this one is there and side front view is this and then we have got a side view. Now, here this is the top view and you can understand that the feed direction may be here; that means, it may be feed direction I have shown feed is this way. So, it is like this, it is going this way and naturally this direction is the depth direction depth direction; that means, depth or radial we can say radial. So, radial direction is this; that means, tool may be moving like this.

So, here in this case, a now we can understand the angles in ASA system we just define based on these 3 views, we can explain the angles many lines we only we can take 3 views 3 orthogonal views and we can explain, we will try to understand according to American standard system what is the what are the tool angles and this you see very careful. So, coming to the top view; that means, this view top viewer. So, in this view you are seeing what, you are seeing that this cutting edge is actually a bit inclined to the direction from the direction of it is not really totally perpendicular to the feed direction; it is inclined and this angle is called side cutting edge angle.

So, you are having side cutting edge angle; that means, it is this may be inclined it may be 5 degree or it may be some other degrees 10 degree depends on that. Of course, it can be 0 degree also; that means, cutting edge is perpendicular to the feed direction in the top view and similarly here we have got end cutting edge angle and then. So, side cutting edge angle end cutting edge angel. So, two important angles are seen in this view and then you have got a nose radius they are moving this one typical nose radius may be about 0.2 mm, it may be 0.3 mm, 0.1 mm like that. So, these two angles are shown here.

Then in the front view; that means, if I just put it like this may be the front view you are seeing like this and in this if you see that this face is moving downwards; that means, it is slanted. So, then you have got that is back rake angle, this is the called back rake it is also called instead of back we can called top. We can say top rake angle and this is the rake face this face is the rake face and in this you are showing that angle that is called back rake angle. So, we give some slanting type of thing in this position it is called positive rake angle.

So, positive rake angle is there negative means the surface will move up as you go from left to right. So, this when will be there and then; so, in this we are getting one back rake angle and either angle we are getting here this surface; that means, this are this that surface you see that this one is slightly inclined. So that means, this surface this line if you see that it is in this plane also; that means, are generally flank plane this line is not really vertical; rather it is having some type of inclination why so that the tool should not rub against the work piece. So, that is why you are having share that there is end relief angle. So, we say that it is end relief angle.

And it can also we called instead of relief it can be called clearance angle; clearance angle instead relief and clearance means basically both have the same thing clearance is provided so, that there is no rubbing of the tool against the work piece surface. And, relief also it basically the same thing it converts and that is why that it is shown as a end relief angle and then this angle is also really very small may be 2 degree, 3 degree, 5 degree, those type of things we will discuss. And, what is a here that angle between these two this one of course, it is not the part ASA system, but naturally you can find out that this can be called a some included angle here. So, this is the angle and really you cannot give that very large back rake angle and very large end relief angle otherwise, this portion will become very thin and then the tool will become weak.

So, here we have shown in the front view, now again two angles and that is back rake angle and then we have discussed end relief angle. Now, let us come to the side view of this tool here from the side. So, if from the side if you see, then you will see that this is the main that nose portion, from here this surface will be slanting and this surface primarily because cutting is only by side cutting edge mostly in the lathe. So, this is more important than even the top rake angle, instead side rake angle is more important chip flow will take place on the this one. So, this is slanting down. So, chip flow will take place on this rake surface through that side rake angle.

And then if we see that an either flank this one is also inclined in the other direction from the side. So, this we have get side relief angle; that means, it is here otherwise this one tool give rub that is why this is shown as a side relief angle, here it is side rake angle and you have seen this one. So, two angles are shown in the top view, two angles are shown in the front view and two angles are shown in the side view. So, we have got total six angles now here, they designate proper tool geometry, they will be influencing more. And, this is the primary cutting edge and it is secondary cutting edge plus one seventh element is the nose radius, that is also shown here. It is visible in the top view that means, this is a type of the nose radius and that is showing the effect of, it also has effect and the machining performance this is how it is shown.

So, it is a I hope that now you have understood nomenclature of the tool in ASA system I can illustrate it by means of a bigger object say for example, I am taking this book for example, this one and I am trying to explain you that how 3 dimensional things comes into picture. Suppose this is a book and it has got this type of surface you see that it has got this surface this one is there and then and the bottom another surface is there in this case both the surfaces are at 90 degree.

I can say this bottom surface which is testing on my palm as the flanks face and the top vertical one; that means, in which the title rub this book is written it is considered as the rake face. So, both the faces in this case are perpendicular to each other, but you understand that this is the rake face and this is actually the flank face and both the faces are meeting at one edge this edge direct sharp edge is called cutting edge ok.

Now, what happens that this one it is a cutting like this suppose I cut of course, if I move that this book on the my palm, then some portion of the shape will naturally material ahead will come out of the form of the chip and it will write on the vertical surface; that means, chip will be moving on the rake surface it may have some resistance. So, therefore, better to inclined it towards this; that means, positive rake angle side so that the chip can easily proved moved if I incline it in the other direction then. In fact, it will be compressing the chip. So, it will have even more difficulty to move on the surface. So, if I increase the rake angle my easy moment of the chip can take place and this is this one.

But now in this position suppose I moving this one at my palm there is a lot of friction. So, it is not moving properly. So, it is better to provide some inclination also here then it can actually do only proper cutting, but this surface will not be rubbing against the machine surface or against the surface of the work piece so; that means, we have to give the clearance angle at least these two angles; that means, rake angle and clearance angle I have explained here.

So, I have inclined it like this, but if I also inclined like this in this other direction then that will be called top rake angle; that means, you have got a surface can be inclined this way and also this way. So, then it gives a totally 3 dimensional type of picture that is why it is under you have to understand.

That in the top surface is only one rake surface, but you are having side rake angle because it is tilted in the side direction and it is also tilted in the top direction like this. So, that is why you are having the back rake angle; that means, it is tilted in one direction and it is also tilted in the other direction. So, you are getting this one; so, this typical thing that you always understand.

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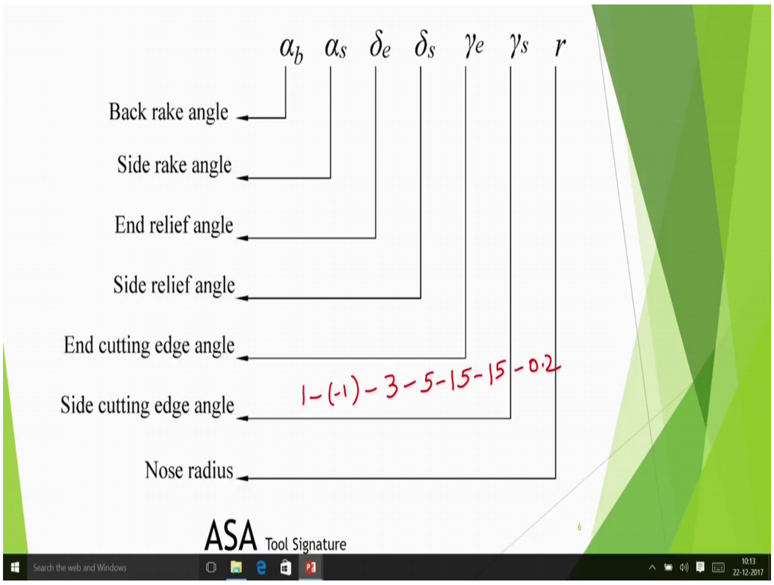

And now in ASA system we defined nomenclature of the tool is called tool signature. So, we have got the tool signature here. Now in the tool signature wise, we have proper system we have designated again and again I may not say that which is what angle I will just say that my tool designation is this and I will write six quantities separated in the form of dash and you will understand that which one means what that is called tool signature.

So, first thing is that back rake angle second thing is side rake angle third one is end relief angle and this delta is side relief angle and then end cutting edge angle and side cutting edge angle and another one is the nose radius in mm. So; that means, this is the thing. So, if I can designate in various ways I can suppose, I can write say suppose one and then minus one I have like that and then I say 3, then I am giving 5 and I am giving 15 and I am giving again 15 and I am giving 0.2.

So, if I write like this you should understand that here the back rake angle is 1 degree side rake angle is actually minus 1 degree and then relief angle end relief angle is 3 degree side relief angle is 5 degree end cutting edge angle is 15 degree side cutting edge angle is 15 degree and nose radius is 0.2, this you can understand by this one. So, this is ASA tool signature. Now, I am coming to the next one.

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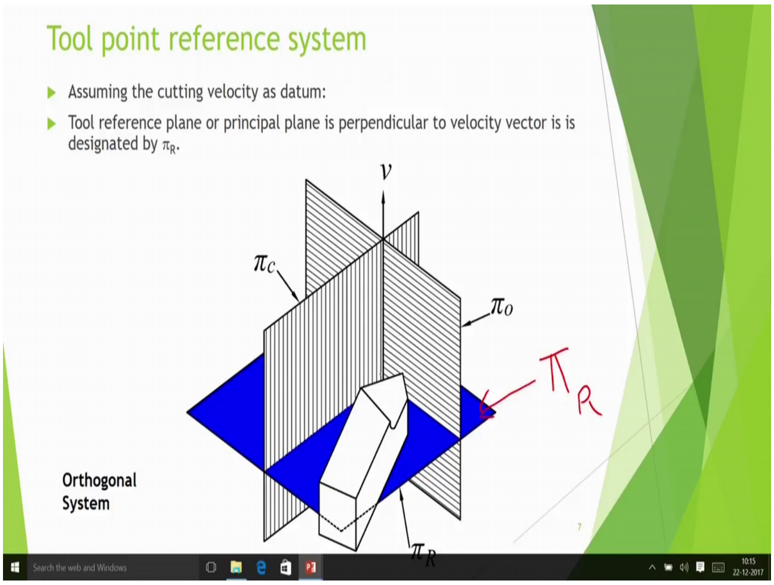

But it is ASA tool signature system is not the only one there are other systems also and there are other 3 more popular systems are also there we must discuss because some researchers in research may be people find convenient to use other type of tool point to difference system because it tells nicely that how the chip is flowing in that particular plane. And, this one is more convenient American system from the machine point of view that you know that because one plane is in the feed direction other plane is in this direction cutting direction like that.

So, in general we will understand. So, first let me discuss general orthogonal system in the orthogonal system, we make tool point reference system we discuss. So, what we do that we assume the cutting velocity as a datum there is a relative motion between the job and tool that is designated by v, it is denoted by v this velocity vector is there I can take one plane for example, here the blue plane pi R that can be written as pi R this one is pi R actually this plane is pi R.

So, this plane that blue one is perpendicular to the cutting velocity you very well know that a plane is characterized by its normal if I tell normal to the plane; that means, I understand the plane suppose this is the book and in this you draw a normal to the plane normal this one this is normal line then this becomes that designation of the plane. So, cutting velocity is there perpendicular to that you take a plane and that you are calling as the reference plane.

Then having may it is a reference plane I hope make other orthogonal planes. So, I take another plane that is which is containing the cutting velocity vector in it and also the cutting edge you see this cutting edge is there that is contained in this thing and this plane is perpendicular to the reference plane. So, this one will be called cutting plane that is second plane. Now, third plane I take simply orthogonal to the other planes that is why this system is called orthogonal system. So, in these planes we can understand all the angels we have got reference plane we have got cutting plane and we have got orthogonal plane and tool is kept here you are seeing this here.

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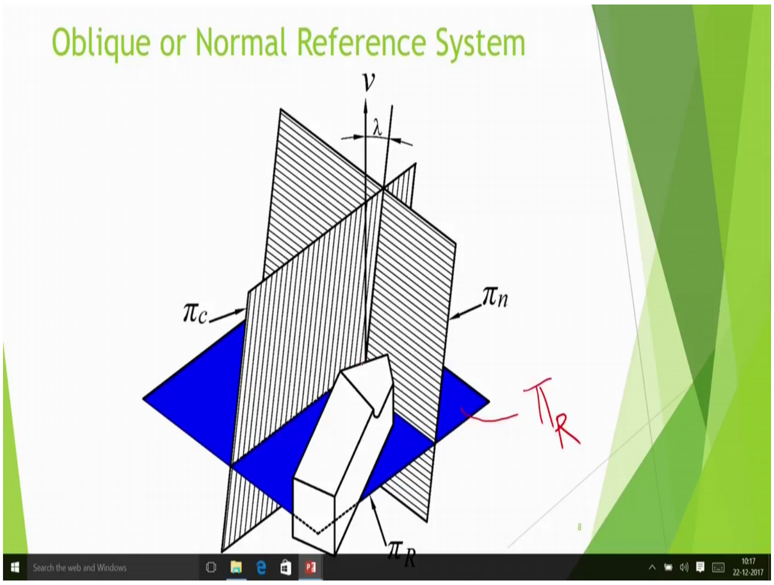

Now, we have another plane system of nomenclature this is one I told ASA system I told ors system then there is one more that is called oblique or normal reference system in this what happens reference plane is as usual the same; that means, reference plane it is not changing in most of the cases reference plane is basically same, it is perpendicular to the cutting velocity. And, then we have got the cutting plane cutting plane is containing the velocity vector and it is also containing the cutting edge that one is there it is orthogonal tool pi R the, but the third plane is not orthogonal two other two planes it is not pi o instead it is pi n it is what type of plane it is normal to the cutting edge; that means, cutting edge is perpendicular to that.

So, sometimes pi n may coincide with pi o, but sometimes it may not coincide because cutting edge itself is inclined suppose cutting edge is inclined then from the velocity direction cutting edge need not be perpendicular to the velocity vector. So, in that case you are getting that pi n and this one; that means, on this particular plane. So, intersection of pi c and pi n will give you a line and this line is making lambda angle from the velocity vector because these two are not meeting you know the these two are not orthogonal.

So, it will not coincide with the velocity direction. So, this is lambda is called the inclination angle; that means, cutting edge is inclined with the direction of the velocity; that means, cutting edge is not exactly perpendicular to the velocity vector that is why you are getting inclination angle. So, this is a lambda this happens in the normal reference system.

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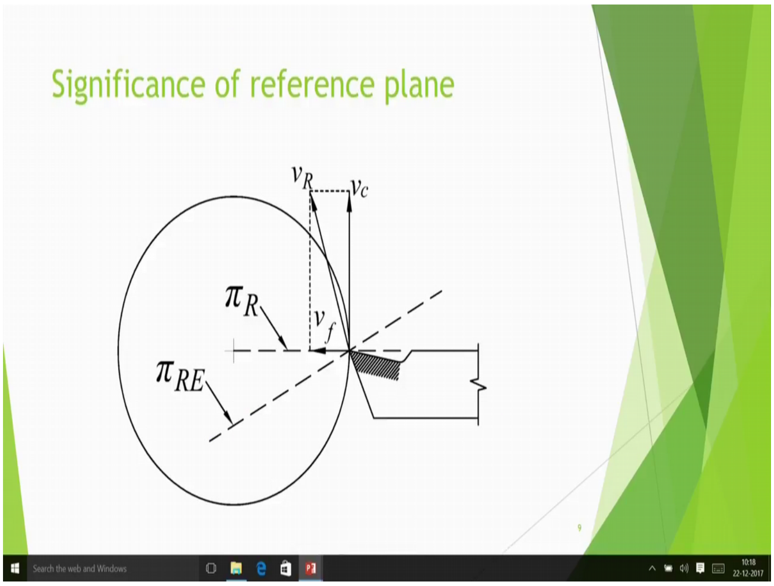

Now, what is the significance of the reference plane that I will be explaining significance of reference plane as I said reference plane is actually normal to the cutting velocity. So, suppose you have got v c and then you have perpendicular to this is one plane that is called pi R this is reference plane and here the cutting tool is just kept here. So, from here you are measuring the rake angle this becomes the top rake angle.

Now, what happens? So, well if suppose feed velocity is also there tool is getting feed in this transaction v f in that case you can get a resultant velocity. So, if you draw perpendicular to the resultant velocity this line this is denoting equivalent reference plane that reference plane based on the equivalent velocity to be very precise, you can measure that way I mean this you see the angle rake angle has changed. So; that means, it is up to you that you can always decide this one, but most of the cases you know cutting speed is much more compare to feed speed. So, that effect is very negligible and that is why most of the cases we find it a propate to take the reference plane based on the main cutting velocity; that means, suppose my tool is moving on lathe machine like this.

Then naturally we can have this type of phenomena here horizontal plane if it is moved can be called as a reference plane because the cutting velocity is vertical feed velocity is very small that effect I am neglecting that can be always done in this way.

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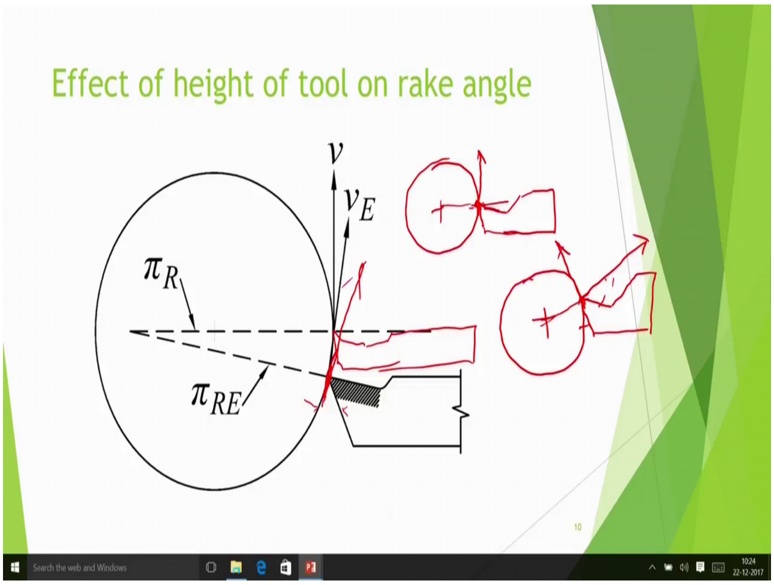

So, this is the significance of the reference plane and there is one question often asked that what is the effect of the height of tool on rake angle suppose you are machining in a lathe machine usually you mount your tool at the center of the work piece and it makes the it that is machining and produces cylindrical surface I can move it a bit above the central line or I can keep it a bit above the central line in both of these cases. It will no doubt make cylindrical surface, but angles will change that there is a significance of that what is that significance that it will just created it like this here that suppose a; I have moved my suppose reference plane I am considering horizontal.

Now I have moved my tool a bit down in that case my reference plane has become like this because my tangential velocity here is like this and you can see the reference plane is perpendicular then this reference plane is impact a in this way it is showing that it is coinciding with the rake surface. So; that means, here really there is a no rake angle; that means, rake angle virtually has reduced.

Earlier the same tool if it verge here then it verged having some rake angle this is how that it verged moving, but now why you have moved it down. So, it is like that and if you see that earlier their verge is less gap between the surface and the flank surface now here this angle you have increased that means relief has increased and rake has reduced rake has reduced so; that means, somewhat less easy flow here of the chips. So, this is I can illustrate it to like this is a job and I can say that here if it verge at the center some tool if I mount then why I am observing that it is like this that is one that is one thing.

So, here naturally the velocity is tangential since the velocity is tangential here. So, naturally here I have got the plane here. So, we see we will have some particular rake angle and we have got to relief angle here this is the relief angle, but if I do like this same that tool like this, but I am mounting it a bit upside suppose this time. So, since I mounted it upside I am showing exuberated and here it is it is like this same way and if I am doing like this.

Now, here the velocity is in this direction tangential. So, perpendicular will be in this direction. So, you see that this angle you have increased. So, effectively the rake angle you have increased if you mounted it up, but the more rubbing need occur because the relief angle you have decreased. So; that means, if moved a cutting tool in the lathe above the center, then the rake angle positive rake angle increases, but the relief angle decreases and if you move the tool downward then the rake angle decreases, but the relief angle increases. So, you understand that the measurement system is usually based on the reference plane in most of the cases of courses, we keep the tool horizontal and at the center.

So, therefore, your cutting velocity is exactly vertical, if it is at the center because at the center the velocity vector is vertical it is not inclined this way or that way. So, that is why most of the cases we think that just you take the horizontal plane and that becomes the reference plane and see that surface is how much it is inclined from that horizontal plane that is why we do that in American system, but in general it is not to like that always that if we our referencing system and our measurement system will change if I move the tool up and down.

So, this tool cutting tool angles; that means, they it is not that a particular tool is they are and therefore, all these things are fixed way it is mounted will also change that it is a geometry that way it is mounted tool is same this is the tool, but I can have it inclined I can do this thing; that means, I on a tool holder I can mount it in such a way. So, that it is a tool angles you can change that point also has to be kept in mind. Now, so, we have shown here that a significance of reference planes effect of height and of tool on rake angle.

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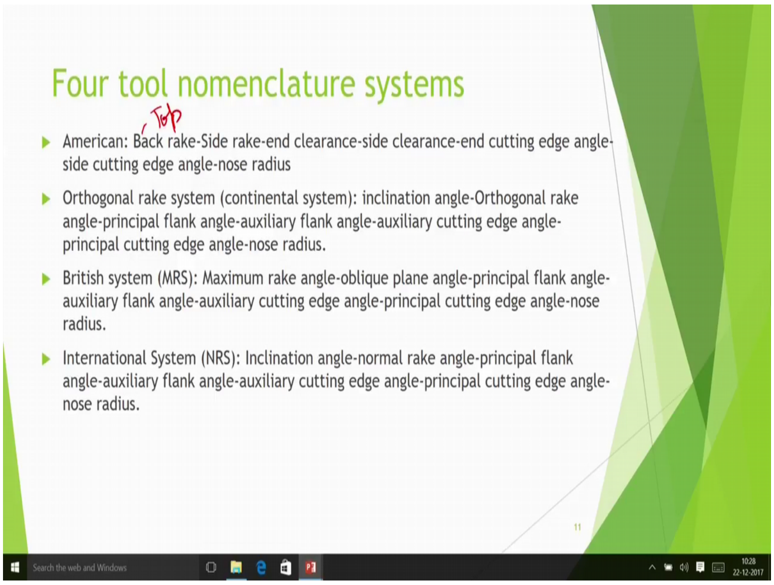

Then I now discuss they are in fact, four type of nomenclature systems just now, I have told only one that is American system in the American system we have got back rake angle which is also called side rake angle sorry back rake which is also called top rake. So, back or top back rake angle and we have got top rake angle.

Then we have got side rake angle then we have got end clearance angle then we have got side clearance angle then we have got end cutting edge angle and side cutting edge angle which is the primary cutting edge angle remember side is the primary one in determining. And, then there is a nose radius we have another system that is orthogonal rake system I told you it is based on 3 particular planes reference plane cutting plane and orthogonal plane it is also called continental system in this.

We have got inclination angle; that means, it shows the inclination of the cutting edge and then we have got orthogonal rake angle that is in the orthogonal plane then we have got principal flank angle flank is basically same as the relief angle you can say principal relief angle the flank. Flank means, it is basically the surface side and then auxiliary flank angle and the auxiliary face then auxiliary cutting edge angle and then principal cutting edge angle and nose radius is there.

Then we have one British system also that is called maximum rake angle see if something is inclined in two directions this plane is inclined this way and as well as other way; that means, there is a slope suppose in x direction, there is a slope in y direction also there is a slope in the feed direction there is a slope towards the radial direction also then there will be one particular slope that will be having maximum slope of that surface. So, in that plane, we find out maximum rake angle suppose one suppose side rake angle is 5 degree top rake angle is 10 degree then maximum rake angle will be something may be in between 5 and 10.

Then oblique plane angle; that means, in the normal plane, we show that that is called normal angle maximum rake angle and then we show oblique plane angle then we show principal flank angle auxiliary flank angle relief angle auxiliary cutting edge angle. Then we show principal cutting edge angle and then we show nose radius nose radius is common in all these things that is the seventh element.

Then we have international system that is normal rake angle here we show inclination angle then we say normal rake angel; that means, rake angle in the normal plane I already told you what do you mean by normal plane that is normal to the cutting edge you have cutting edge just take one plane normal to the cutting edge. Then we have got principal flank angle, then we have got auxiliary flank angel, we have got auxiliary cutting edge angle and we have got principal cutting edge angle these are nose radius.

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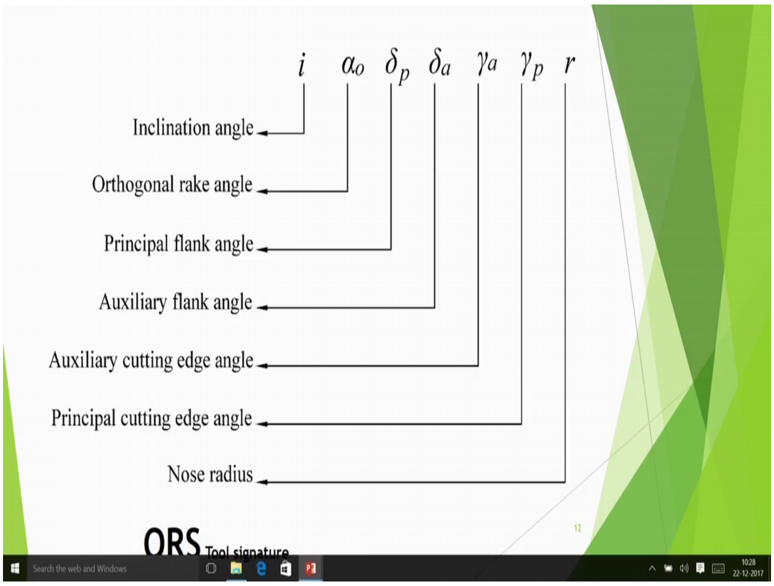

So, here in ors system again tool signature is like this, this is we have got inclination angle. So, I am showing you here let me just move by concern up here this is i inclination angle I, then we have orthogonal rake angle, then we have principal flak angle by delta p, then we have auxiliary flank angle denoted by delta a symbol auxiliary cutting edge angle, then principal cutting edge angle that is main cutting edge and then you have got nose radius.

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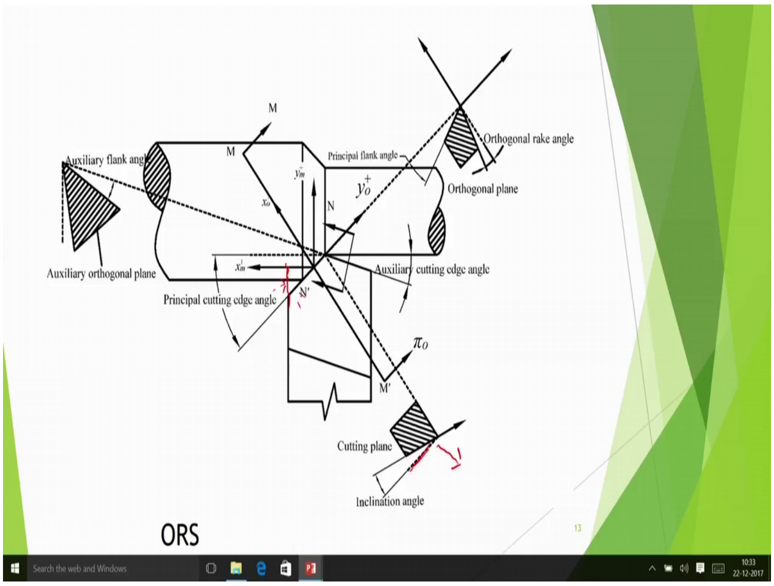

So, this is a ors system in ORS system, I am showing that this diagram, it is because things are 3 dimensional. So, one can easily understand by means of taking various views orthogonal views that is how we understood for ASA system. So, you will be able to understand for this system also.

In the ors system if I just show the top view of the tool this is the top view of the tool. So, in the top view what you are seeing that in the top view, you are seeing that nose radius this is the nose radius you are seeing this is the auxiliary cutting edge angle and you are showing seeing principal cutting edge here. So, auxiliary cutting edge is angle between the feed direction and this is on the top view. So, you are having auxiliary cutting edge angle and principal cutting edge angle is what it is the angle between the feed direction and this cutting edge.

So, that is why it is principal cutting edge and now so, in the top view, you have seen these two angles now what I should do that here if I take a orthogonal plane; that means, we told you or before that you can understand that if I take a cutting plane; that means, which is containing the cutting edge. So, I cut it like this along this like this. So, you get you see that this edge from the sharp point of nose it is just reining back so; that means, it is at some angle and from the top reference surface; that means, this is perpendicular to the velocity vector. So, from here that inclination is called inclination angle; that means, this is this one if it was orthogonal cutting, then inclination angle would have been 0.

And in that case cutting edge would have been really this; that means, this dotted line in that case would have been cutting edge because the velocity vector was vertical here in this direction. So, both these one orthogonal to each other, but in this case what happens velocity vector is in this direction only, but this cutting edge is actually really inclined in the cutting plane in this manner that is why you are getting inclination angle. So, in the orthogonal in the cutting plane you are getting one angle that is called inclination angle. So, out of 6 angles, now you understand 3 angles here.

Now, take the orthogonal plane which will be perpendicular to the cutting plane as well as the reference plane in that orthogonal plane you are seeing that this surface is leaning down rake surface. So, which gives you orthogonal rake angle the rake surface is leaning backward and similarly other flank surface is also leaning in this direction from left to right and this angle is called principal flank angle or principal relief angle. So, this is visible in the orthogonal plane you are getting principal flank angle and you are getting orthogonal rake angle you have seen here 2, 2, 4 and 5.

Now, you will see one more angle this is auxiliary cutting edge angle if I cut a auxiliary orthogonal plane; that means, here I have made a orthogonal plane based on the cutting edge and here. Similarly, I cut it here orthogonal plane which is orthogonal in this direction, then you are seeing that here that surface is inclined flank surface is inclined and that is called auxiliary flank angle; that means, flank surface is really down that is called auxiliary flank angle somewhat similar to the end relief angle in a ASA system. So, that is a type of thing.

And in ORS system you are seeing that principal cutting edge angle is basically nothing, but 90 minus side cutting edge angle because they will be defined side cutting edge angle as this and here I am defining like this. So, this way we have shown these are the various angles in the orthogonal system rake system. So, this also I hope that now this point is also clear to you orthogonal system.

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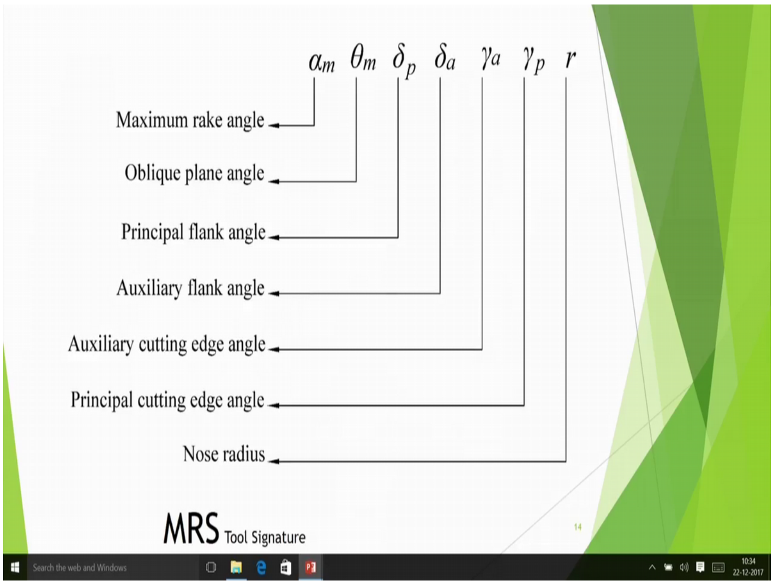

Now, we go to this one MRS system. In MRS system maximum rake angle system you will have again six seven elements of the tool signature first one is the maximum rake angle alpha m another is oblique plane angle. And, then the third one is the principal flank angle and the fourth one is the auxiliary flank angle then you have got auxiliary cutting edge angle and then you have got principal cutting edge angle and then you have got principal cutting edge angle after that you have got nose radius. So, this is called maximum rake system.

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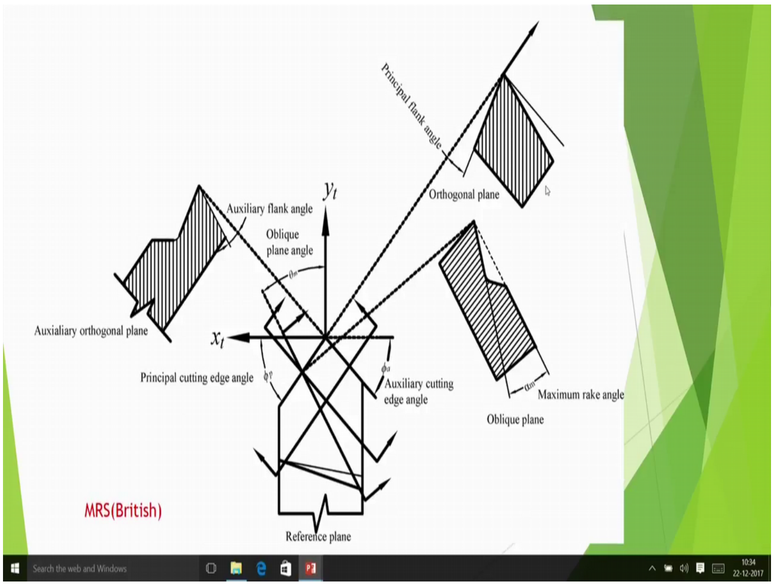

In this which is also called British system it how do we designate the angles just see that let us moving the same way one by one top view this is the reference plane like in oblique cutting system sorry like in orthogonal cutting system, here also you are getting principal cutting edge here auxiliary cutting edge here. So, you are getting principal cutting edge angle theta p this is principal cutting edge angle and this is auxiliary cutting edge angle and then we have got now we have to understand various things.

Now, if I say maximum rake plane is this. So, I have cut it in this direction this is the maximum this is called oblique plane this is somewhat oblique, but in this particular plane if you cut a section like this your rake angle will be maximum and that is designated here that is alpha m. So, that system is there and in this direction if I go to this one principal in one orthogonal plane in orthogonal plane I am getting principal flank angle. So, orthogonal plane view is also shown this line plane I have taken along this orthogonal to the that basically cutting edge direction side cutting edge direct or principal cutting edge direction and you are getting that principal flank angle in the same way.

Then similarly I take a orthogonal plane considering this as a focus that auxiliary cutting edge, then we get auxiliary orthogonal plane and here also I am getting auxiliary flank angle and I am getting this one; this oblique plane angle is basically theta m it is defined here. So, if we see that we need one oblique plane angle; that means, really that particular plane in which the rake angle is maximum how much it is inclined with this direction. So, that will give theta m, you know which will give theta m and that is what you that also you have to be specify. So, you have understood that maximum rake system also.

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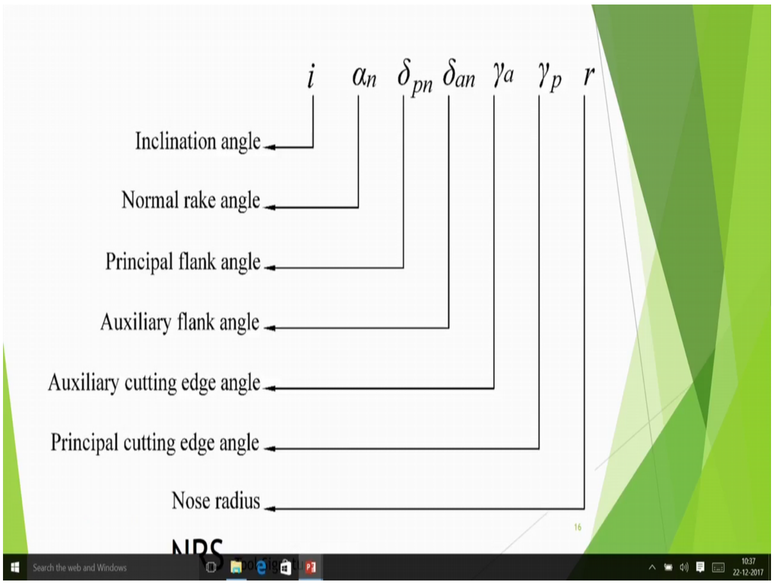

And now we discussed NRS; that means, normal rake system in the normal rake system you have got inclination angle then you have got normal rake angle, then you have got principal flank angle or relief angle and then you have got auxiliary flank angle then we have got auxiliary cutting edge angle and then we have got principal cutting edge angle and then we have got nose radius nose radius is also there. So, this one we have already shown and this one we now have to understand in this diagram.

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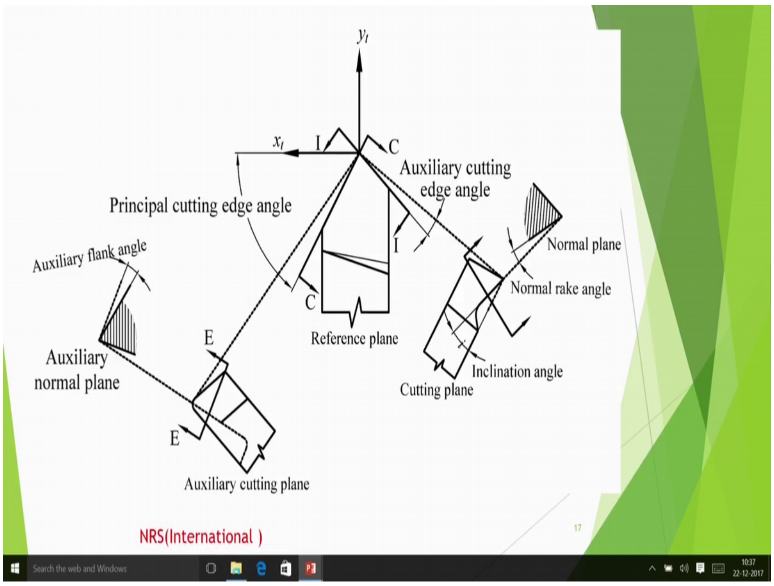

So, here again you make the top view in the same manner you get a side cutting edge here this is the side cutting edge and then here it is end cutting edge you are as usual as in all the systems you are getting principal cutting edge angle which is basically in ASA system, it is 90 minus side cutting edge angle. And, then you are having auxiliary cutting angel; that means, this is also principal cutting edge angle and you can have that direction here you can define auxiliary cutting edge angle in this way; that means, from here how much it is inclined ok.

If you have take a ninety degree line here. So, you have auxiliary cutting edge angle and you have got principal cutting edge angle and then if I take a plane cutting plane this is the cutting plane like we did in the orthogonal system. So, this plane is the common and in this particular plane we have got inclination angle this is inclination angle I and if I cut it; this one some plane normal to the cutting edge then you get another plane that is called normal plane and this plane whatever is the angle that you are designating it by normal rake angel. So, that type of system you have done and on the auxiliary I can obtain like I have obtained the cutting plane here in which the cutting edge is contained and the velocity vector is contained.

Similarly, I can obtain one particular plane which is called a basically auxiliary edge. So, auxiliary edge is contained in that velocity vector is contained in that. So, we get a auxiliary cutting plane and if I cut it perpendicular to that auxiliary edge here we get basically auxiliary normal plane and in the auxiliary normal plane I can get auxiliary flank angle of course, I can get auxiliary rake angle, but that is not specified here we have specified this one normal rake angle. So, we get auxiliary flank angle and this way we can define it for in earlier system that is normal rake system.

So, I have told you now whole systems of tool designation ASA we commonly use ASA system very easy to understand and orthogonal most of the books metal cutting literature they may use orthogonal rake system also or even normal rake system also maximum rake system which is a British system is not in much use either by research community or by practicing engineers, but I have told you that system also that in which designation is based and a plane in which the rake angle is maximum that also has been explained and this one will ok. So, NRS system has been explained, MRS system has been explained.

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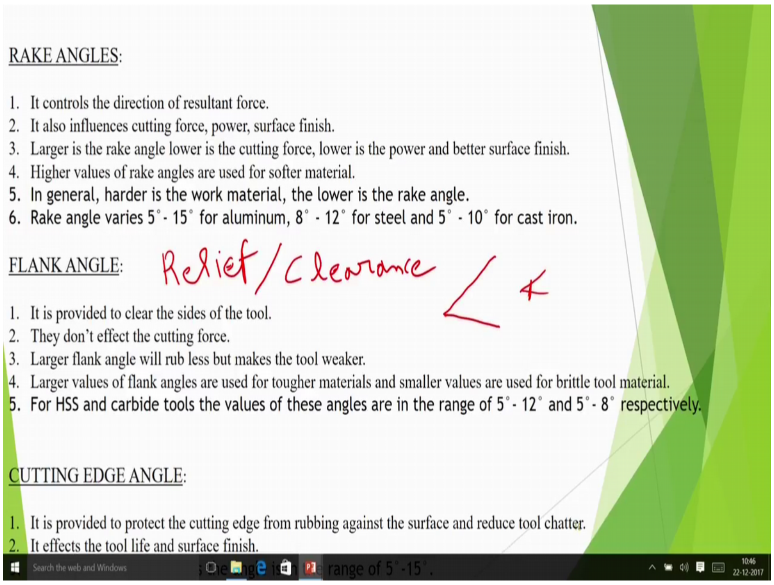

Now, in this slide, we will discuss that what all the effects of the various rake angles based on textbooks that I am explaining rake angle angles whether it is side rake angle or it is the top rake angle basically, it controls the direction of resultant force it also influences cutting force power surface finish in general higher is the rake angle lower is the cutting force; that means, if you increase the rake angle your cutting force decreases.

Accordingly the power also decreases surface finish improves; that means, if you give more amount of rake angle chances all that surface finish will be better that will be there then larger is the rake angle lower is the cutting force lower is the power and better surface finish higher values of rake angles are used for softer materials because softer materials anyway will be easy to machine they. So, not offer much resistance. So, not much forces are generated, then why we want more rake angle towards the reduce the force no objective is not to reduce the force actually if you increase the rake angle as I told the tool becomes weaker nah because less amount of included angle is valuable. So, that I have already explained.

Now, since they are soft material no problem even if it will be tool is weak also, but in the harder materials you have to give that rake angle particularly, if the material tool is cutting tool material is very brittle and it may brick under the impact like carbide tools most of the carbide tools are given negative row rake angle here higher value of rake angle are used for softer material. So, that continues chips will be generated and they can easily flow on the surface.

In general harder is the work material the lower is the rake angle if it material is harder then you give the lower rake angel. So, rake angle generally while each from 5 degree to 15 degree for aluminum mostly this data is for HSS tool, this is high speed steel tool this was seeing that high speed steel tool in this we are showing these things. So, it is rake angle may vary between 5 to 15 degree in the carbide the angle may be somewhat is smaller 8 to 12 degree for steel and we can have 5 to 10 degree for cast iron, these are this one as I told that adjust what should be the proper angle that has to be either scientifically optimized otherwise people do it by experience and by experience we understand that this particular amount of rake angle will give me good result and that is what.

Then flank angle flank angle means relief angle or it is also called clearance angle different books may use different type of word. So, this is relief angle or it can be also called clearance angle. So, it is provided to clear the sides of the tool. So, that it does not rub they do not generally a affect the cutting force cutting force there is not much effect on the cutting force, but larger flank angle will rub less, but make the tools weaker, if we make this is tool this is rakes face and this is flank face if I increase this angle this portion becomes every small when it becomes weak

So, for HSS and carbide tools the values of the these angles are in the range of 5 to 12 degree and 5 to 8 degree respectively; that means, HSS tools mostly have 5 to 12 degree, but carbide tools generally you have less amount of the relief angle and that may be about 5 to 8 degree and larger the use of flank angles are used for tougher materials; that means, which do not cause much impact they are tougher materials they can absorb lot of amount of energy and a smaller values are used for brittle tool materials.

Suppose, tougher materials tougher tool is there we can effort to give with larger amount of angle even though it is little bit weak does not might have because it can absorbed the shock, but if the tool material is brittle like in carbide tools then in that case you have to give that the small amount of that angle and cutting edge angle is provided to protect the cutting edge from rubbing against the surface and it reduces the tool chatter. Chatter means self existed vibrations then it also has effected on that and it effects tool life and surface finish.

So, cutting edge is also this one if you make that the straight cut like this then less amount of area is there more temperature increase will be there, but if I do oblique cutting then more surface area is there temperature generation may be less and it is very convenient. So, cutting edge angle is also important cutting edge angle large amount of cutting edge angle may be provided and this is what. So, effect of the cutting edge angle.

So, all these things have to be optimized you go to the lathe machines of machines of you see the lathe machine and try to understand these various type of angles and what is their significance you will get practical feels about that you touch your the tool by your hand and see and try to understand that 3D geometry, next lecture I am going to tell you about that how these angles are related with this one and that one.

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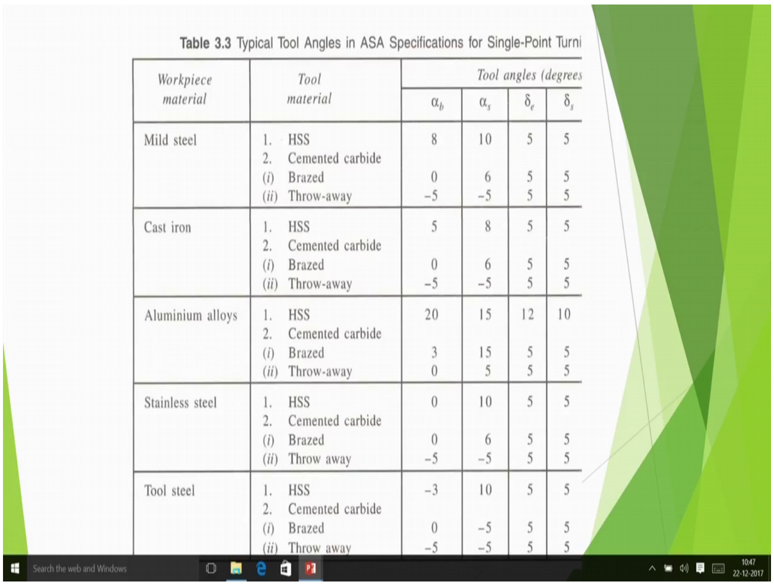
Table 3.3 Typical Tool Angles in ASA Specifications for Single-Point Turni

Workpiece material	*Tool material*	*Tool angles (degrees*			
		α_b	α_s	δ_e	δ_s
Mild steel	1. HSS	8	10	5	5
	2. Cemented carbide				
	(*i*) Brazed	0	6	5	5
	(*ii*) Throw-away	–5	–5	5	5
Cast iron	1. HSS	5	8	5	5
	2. Cemented carbide				
	(*i*) Brazed	0	6	5	5
	(*ii*) Throw-away	–5	–5	5	5
Aluminium alloys	1. HSS	20	15	12	10
	2. Cemented carbide				
	(*i*) Brazed	3	15	5	5
	(*ii*) Throw-away	0	5	5	5
Stainless steel	1. HSS	0	10	5	5
	2. Cemented carbide				
	(*i*) Brazed	0	6	5	5
	(*ii*) Throw away	–5	–5	5	5
Tool steel	1. HSS	–3	10	5	5
	2. Cemented carbide				
	(*i*) Brazed	0	–5	5	5
	(*ii*) Throw away	–5	–5	5	5

So, here typical tool angles in a ASA specification for single point turning are shown suppose work piece material is mild steel tool material is HSS cemented carbide brazed one then throw away tips can be there that machine and throw away the tip. So, these are the tool angles in degrees back rake angle side rake angle, then this is end relief and side relief, you are getting are these values 8, 10, 5, 5 brazed, one may have 0 throw away type of thing may be having rake angles as negative you see that negative rake angles are here.

And then suppose we go to cast iron cast iron in that we are machining by high speed steel then this is cemented carbide brazed and throw away. So, here you seeing cast iron machining also I am having more or less positive rake angle in high speed steel, but it becomes negative in case of throw away tips, etcetera may be tungsten carbide tips or something and clearance angles are almost relief angles are almost same 5 degree or something aluminium alloy, aluminium, is naturally much soft material.

So, therefore, HSS will angle tool may have back rake angle or side rake angles to the tool of 15-20 degree and throw away tips may have 0 or some positive angle we can afford and here this is I have been shown here stainless steel is a little bit hard material. So, here even in HSS I am giving the 0 angle this is 0, then here it is a side rake I have given some ten, but here I have given minus 5 minus 5.

Then tool steels in this HSS is minus 3 and then we have 10 and brazed one is of course, negative and you see that side clearance about 5 degree or something these are just the typical values; that means, these things are in the same way it is going you have to it is based on the experience you have to see lot of data base and there is always a scope have improvement and the move much research on that. So, no problem that, but I typical values; so, that you should get a field you should not see my top rake angle is 30 degree and it is a 60 degree, you should get realistic field that is why I have shown it table not that this table you have to memorize and you have to considered it as a guideline and something.

So, this I have explained and in the next lecture, I am going to tell that how the angles can be converted from one system to the other system. So, to summarize let me just glance through that I have told you about the rake face and flank face this is very important for you to understand about the rake face and flank face, then I have told about the flank wear crater wear, we will discuss in detail I have shown a typical lathe tool 3D diagram. This diagram you should be very familiar with this and always we make the 3 views of the tool in the ASA system, then very easily we can show are they related angles and in the workshop that operator he grinds angle accordingly even if your tool gets warn out then grinding can be done that operation is done there.

In ASA tool system we have told the tool signature there are tool is designated like this and this last digit is basically the nose radius this ASA tool signature system we have told we also told that how we take the reference planes based on which we major. So, we told you oblique or normal reference system and we also told orthogonal reference system we told, but what is the effect of the height of the tools on the rake angle. Then we have told 4 type of tool nomenclature system we have told ORS system then we have told MRS system maximum rake system that is British system. ORS system is called continental system and the normal rake system is called international system that is international system means NRS.

In that also we have shown normal rake angle and then normal rake angle and orthogonal rake system is somewhat similar not much difference or of course, the normal rake will be straightly different from orthogonal rake if there is a inclination angle of the cutting edge is there. Then it will be like this, but and this can be, but generally inclination angle is not very high.

So, most of the times you will find out practically the normal rake angle is basically same as the orthogonal rake angle and then I have told you designate means how we decide to make a rake angle what is positive point about the rake angles are this thing I hope that you have understood, what is our sign convention also the way, I have shown the pictures these angles are positive in the other way they will be negative. That means, easy flow of the chip; that means, the rake angle is positive we define otherwise it becomes the negative and this one. Then, I have shown the typical tool angles, this was the last slide and with this today's lecture is over.

We will be going to the next lecture.