Introduction to Machining and Machining Fluids
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Lecture – 02(a)
Cutting Tools

So, now we are moving to the cutting tools this is the second chapter that we are going into.

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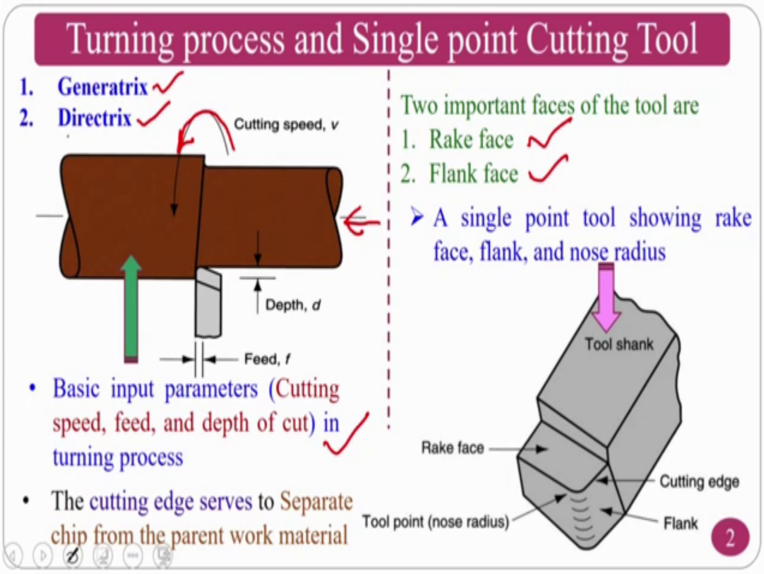

And as you can see the turning process which is a single point cutting tool process the simple process we consider is a basic turning process. In the turning process we have 2 things one is Generatrix, another one is a Directrix, you can see here Generatrix and Directrix. So, whenever you are considering the turning process the rotary motion will generate the surface that is called Generatrix and the direction that you are giving in the feed are the feed direction that will called as a Directrix; that means, the cutting speed whatever the arrow that you are seeing here generate the Generatix at the same time this one will give the Directrix.

Normally it is a circle generatix is a circle and the directrix is a line. So, indirectly you will get a cylindrical surface that is about the generatix and the directrix we are going to study in detail about the cutting tool. Normally two important phases are the surfaces in a cutting tool are Rakes face or rake surface and Flank face. So, we go in detail about these things before going to these we should know also what are the input conditions in the turning process, that is a single point machining process the basic input parameters are cutting speed feed and depth of cut. These are the basic 3 input parameters that one give and the cutting edge that is a most important thing which separates the work piece and the chip.

This is the overview of tool geometry.

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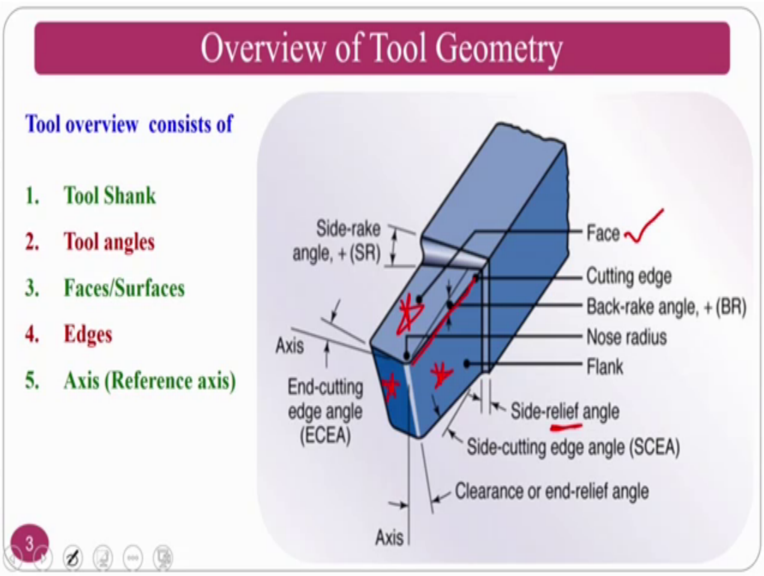

The tool geometry will have many things some of the important things are shown in this slide the tool shank, this is the tool shank and the tool angles different tool angles are there on the different-different faces of the tool and different-different faces the faces will have this angles and the edges cutting edge and principal cutting edge, auxiliary cutting edge and all those things and the axises, how you are referring to the axises and all those things also we see in the tool signatures.

If you see this picture it will have a one is the rake face this is called a rake face the cutting edge normally this is a principal cutting edge which normally involve in the cutting process. So, back rake angle nose radius this is the flank surface this is the flank surface this is the rake surface and this is the, another flank surface that is called some people it called as a auxiliary flank surface, this is called principal flank surface. So, there are different terminologies are there that are used by the different authors of the books and the researchers. So, relief angle, some people they say flank angle, some people they say clearance angle, some people they say relief angle. So, these are the same the different books will give you different varieties, that is some people say relief, some people say clearance, some people say flank angles.

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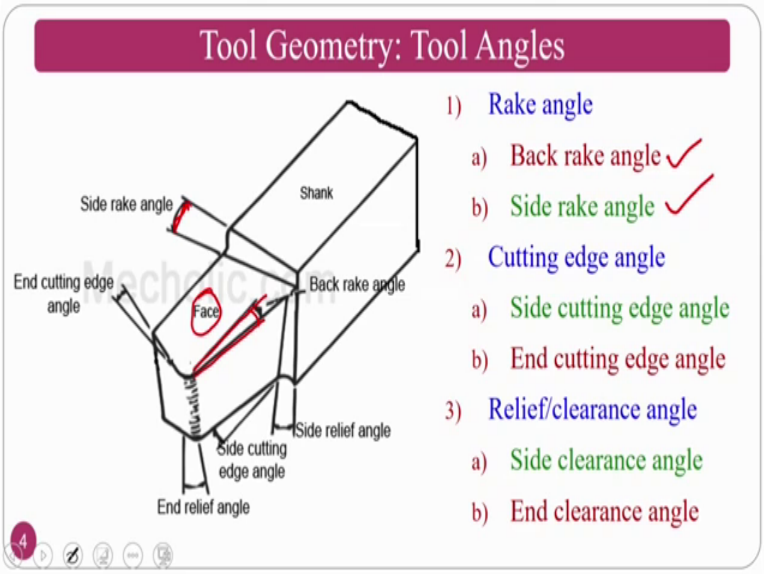

So, tool geometry if you see the tool geometry normally tool geometry has angles now we are going to see only the tool angles. So, if the 2 angles on the rake surface are nothing, but the rake angles one is the back rake angle, another one is side rake angle see this is the rake surface.

The rake surface will have this is the back rake angle and the side rake angle this is the side rake angle. So, these are the 2 angles that is on the rake surface let me is explain you how it looks like in the normal sample that we fabricated specially for you using a single point cutting tool.

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So, this is a single point cutting tool and this is the rake surface and this is the principal flank surface some people say this is end flank surface and this auxiliary flank surface this rake surface will define 2 rake angles one is the back rake angle another one is side rake angle. This is the surface which is defined by a back rake angle like this at the same time if you see it is having slantness here so, this is called side rake angle. So, at the same time this is my cutting edge another one is this is another one cutting edge.

So, this cutting edge will have one angle if you put a plane like this it will have certain angle that is called one of the cutting edge angles. If you put a plane like this it will have certain angle so, these are the 2 cutting edge angles if you call it as a principal cutting edge then it is called principal cutting edge angle or end cutting edge angle if you say this is the side cutting edge if you put a plane like this, this is called side cutting edge angle, at the same time this is my one flank surface or the clearance surface or the relief surface this is another one flank surface.

Normally in this course we take it as a flank surface so, this a one flank surface, another one this is another flank surface this also makes some slantness that is called one of the flank angle this also make the some slantness that is called another flank angle this flank angles always use to avoid the rubbing action with the final product.

Coming to the slide we can see the cutting edge angle one is side cutting edge angle and end cutting edge angle. So, if you consider this is principal then this angle is the end cutting edge angle if you consider this as a side cutting edge then it is called side cutting edge angles. ASA system follow one nomenclature, ORS system follow another nomenclature that why there is slightly confusion. So, relief angle or the clearance angle or the flank angle this surfaces has some slantness and those are the flank angle.

So, we see rake surface and it is angles flank face and it is angles rake face directs a chip flow this is the rake face whenever you are cutting the material it will flow like this; that means, that it will directs the flow of newly formed chip.

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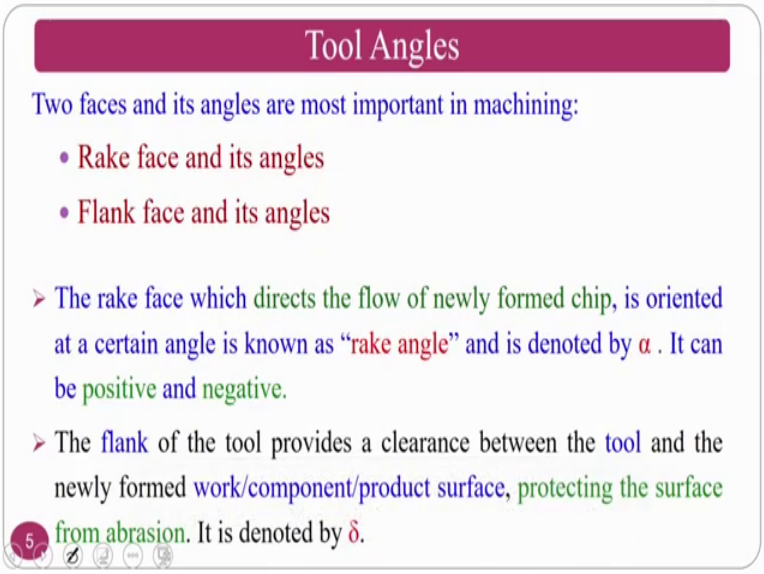

So, that is the rakes face function and it can be 0 rake angle it can be positive rake angle, it can negative rake angle also when it called 0 if it is parallel to the shank it is called as 0, normally if you take like this, this is called positive if it is filled like this, like this, it is called negative rake angle so, this is about the rake angle.

The flank angle provides the clearance as I said if I am if I have a work piece and I am cutting the work piece in this type. So, if I am cutting this is the clearance this is the clearance or this is the flank angle this flank angle provides to the tool because to avoid the rubbing action. Assume that it is the same distance then what will happen it will rub so, to avoid the rubbing action normally the flank angle is provided.

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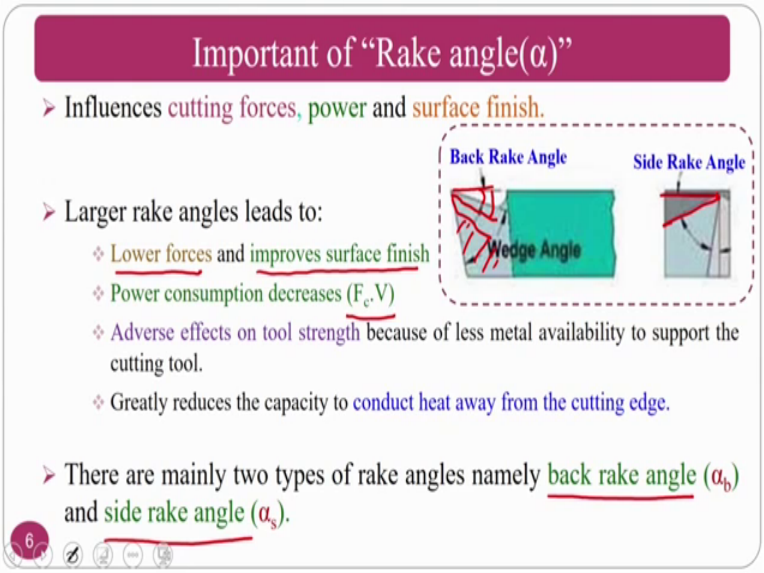

Importance of the rake angle so, if you can see as I said this is my rake angle back rake angle. So, if the rake angle is increased; that means, I am going to increase like this. This is my new rake angle. So, if I am going to increase my tool become much sharp. So, if it is sharp assume that I have knife with high sharp what will happen it is very easy to cut a vegetables and all those things. That means the force required for by a person to cut the vegetables is les; that means, lower forces required at same time it also improve the surface finish.

In terms of if I say the vegetables cutting it will you can slice it properly without any much disturbance or no change in the surface roughnesses. So, if my forces are less in a cutting tool to machine a material because of increase in the rake angle what will happen power consumption also goes down because power consumption is nothing, but F c into V, if my cutting force decreases; obviously, cutting force multiplied by cutting velocity will also goes down so, the power consumption will be less.

But the basic problem if I am going to increase rake angle like this, what will happen tools strength goes down because I have very less tool to cut the work piece material that is the problem. So, at the same time if I have a less material to cut what will happen temperature is continuously going into tool from the chip side from the shearing side from the work piece side and all 3 sides because of which if my conducting area is very less, what is happening is it thermal softening of the tool takes place and it may fail at early stages. So, these are the 2 drawbacks if I increase the back rake angle.

However, it is good from the point of our consumption as well as less forces, this is a side rake angle as I we can see the from the tool that we have seen there are mainly 2 types of rake angles one is back rake angle and side rake angle.

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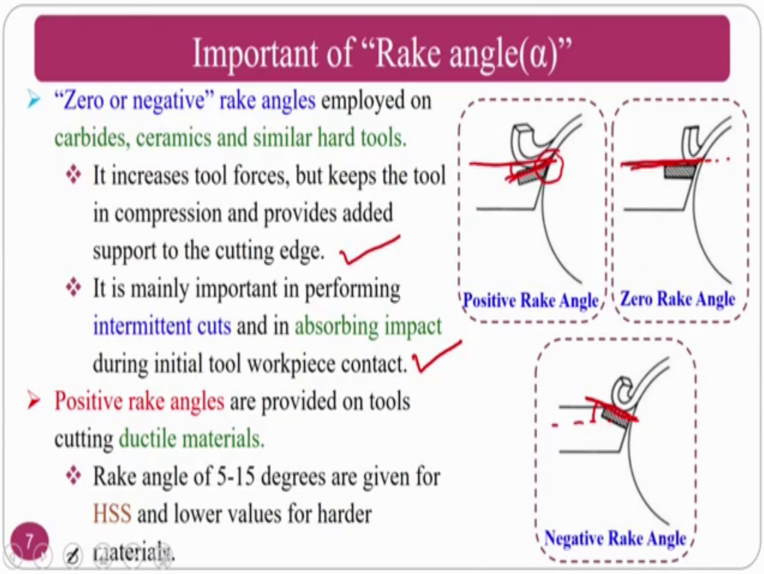

So, normally as I said we have a 3 types of a rake angles, one is positive rake angle this is called positive rake angle where chip can be easily flown on top of it, another one is zero rake angle as I said it is parallel to the tool shack and the negative rake angle if you see the negative rake angle it is like this. This is the negative rake angle, this is the positive rake angle and here angle is 0. So, 0 are negative rake angle or employed in the carbide ceramics and similar hard tools.

Basically the hard tools are used to machine the hard materials if you want to machine very hard materials with positive rake angles as we have discussed in the earlier slides, the tool material to counter the machining is very less from that point of view the thermal softening or the strength of the tool will be less that is why always at the most of times the researchers uses the negative or 0 rake angle whenever the researchers want to cut the hard materials at the same time if the tool material is also ceramics or brittle materials.

It increases the tool forces, but keeps the tool in compression and provides added support to the cutting edge, this is the positiveness about the 0 or the negative rake angles important thing is performing a intermittent cuts if there is a intermittent cuts; that means, that there is a gap between cutting and cutting what will happen there will be a shack.

So, if it is positive rake angle there is a tendency of bending or catastrophic failure if you are taking a brittle tool material that is a another problem in a positive that is why you go or the people prefer 0 rake angle or negative rake angle positive rake angles are provided to the ductile tool materials like HSS the rake angle ranges from 5 to 15 degrees and lower values for the harder materials.

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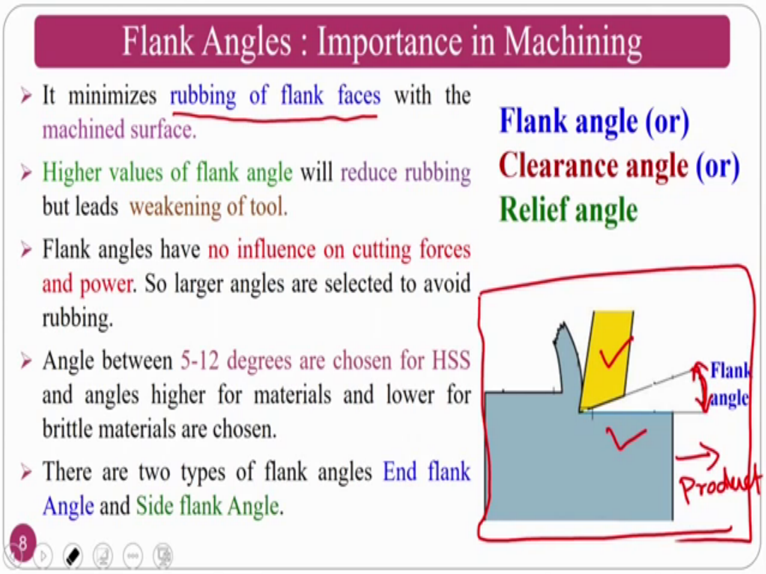

So, flank angles normally flank angles as I said that it uses for minimizing the rubbing or eliminating rubbing nothing in this world is 100 percent elimination. So, you try to minimize only so, normally you will provide a flank angle as you can see in this picture this is the clearance. So, that this particular tool would not touch this particular work piece so, this is the flank angle. So, that the clearance will be given and this is the final product that we are going to get which we want at a good level or the good surface finish good tolerance and all those things.

We do not want to any type of disturbance on the surface. So, if the flank angle is 0 what will happen this continuously rubs and the final product will be like this. So, we do not want the rubbing of this one higher flank angles will also reduce the strength if I am increasing the flank angle what will happen, my tools strength goes down again as we have seen in the rake angle type, but if you increase what will happen the rubbing action will reduce this is my tool new tool.

So, my rubbing action will reduce; however, the tool strength goes down the flank angles have no influence on cutting forces and power. So, the large angles have are selected. So, it may not have much affect I cannot say 0 affect, but it may not have much effect on tool or the cutting forces the machining forces that are there involved during the machining process so, you can choose the optimum not maximum, optimum so, that the rubbing action can be minimized normally 5 to 12 degrees were chosen for HSS tool and the lower for the brittle materials were chosen.

So, there are 2 types of flank angles one is end flank angle another one is a side flank angle whatever you are seeing is end flank angle in one way of system it is end flank angle. If you consider it has as a side flank face it is side flank angle. So, it is depend on system to system ASA system ORS system and all.

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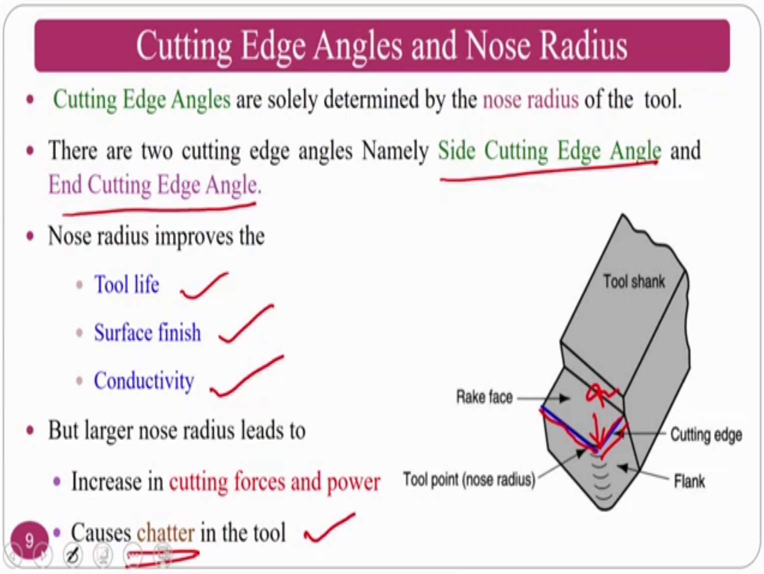

So, cutting edges the cutting edges plays the major role if you can see here there are 2 cutting edges you can see the blue ones here. So, this is one cutting edge, this is another cutting edge.

So, this cutting edges are the prime things that will involve in the sharing of the work piece material, the cutting edge angles are solely determined by the nose radius this is nose radius. There are 2 cutting edge angles one is side cutting edge angle, another one is the side cutting edge angle so, which normally decides by which cutting surface you are talking about.

So, nose radius improves the tool life, surface finish and the tool conductivity if the thermal conductivity because the area that is interacting with the work piece will be high, but larger tool nose radius also have some adverse effect that is increases the forces and if the forces are high then the power also will increase it also imparts the chatter.

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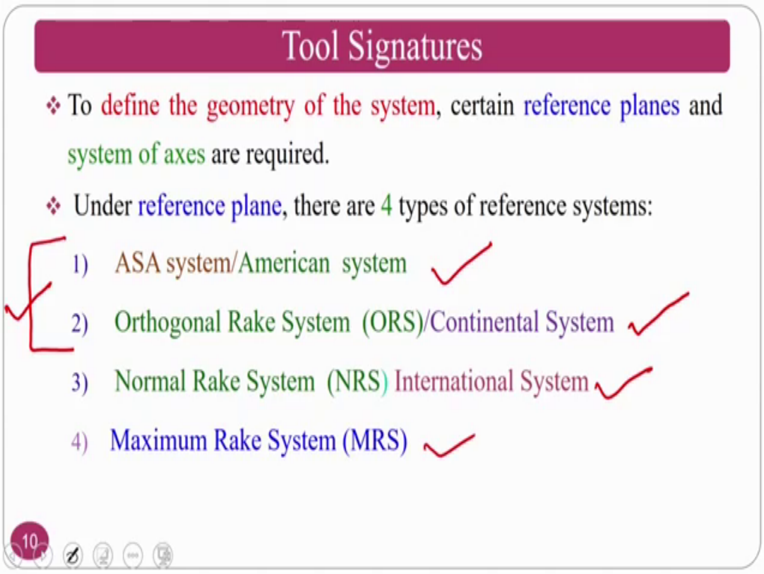

So, we should choose always optimum nose radius tool signatures there are 4 types of reference systems are there to explain the tool signatures one is ASA system that is American system, another one is orthogonal or continental system it is orthogonal rake system, third one is normal rake system and the final one is maximum rake system.

So, these are the 4 systems since it is a introductory course I am going to teach you the 2 that are ASA system and orthogonal rake system. So, those people who are interested it is the extension of these 2 systems are there in the normal rake system as well the maximum rake system. However the normal rake system is the system that is followed internationally that is why it is called SI system or international system.

So, we are going to ASA system.

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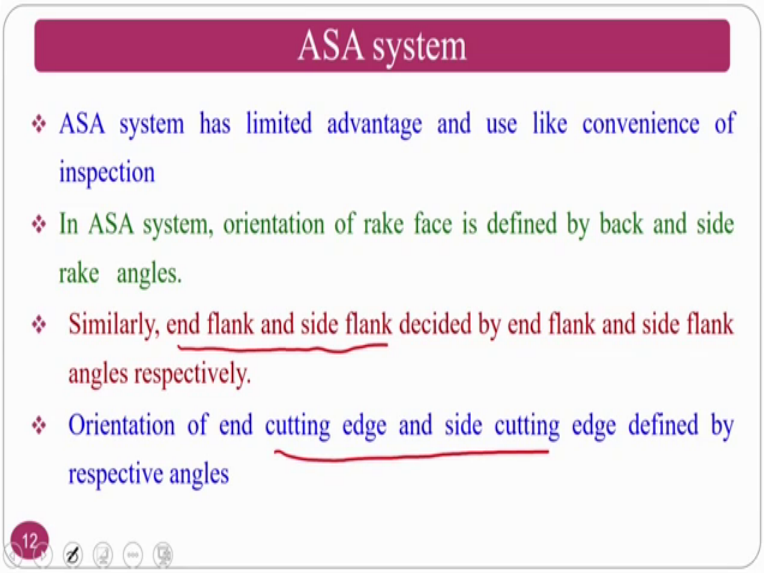

Which is the very basic system where it has a very limited advantage, but it is very convenient to understand the basic tool angles and all those things.Orientation of rake surface in ASA system is defined by the back and side rake angle and the side flank angle and end flank angle will be defined by the flank surfaces cutting edge angles are defined by the cutting surfaces.

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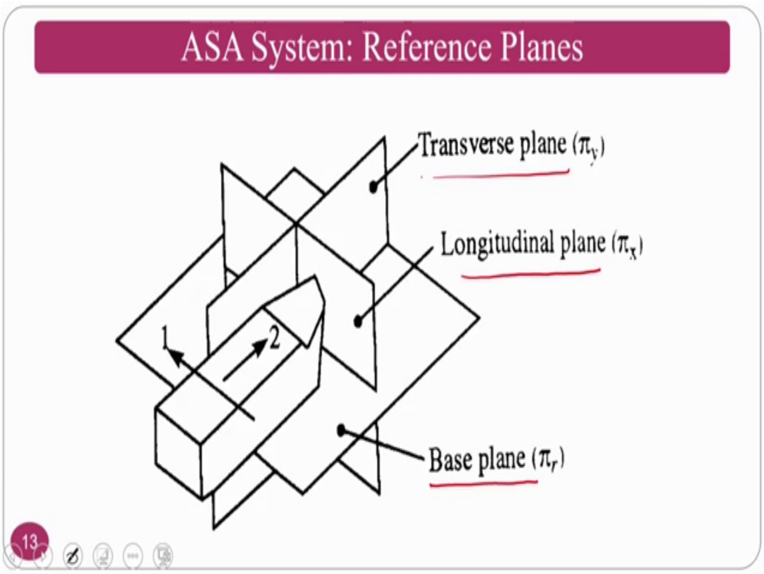

You can see the ASA system the referencing planes. There are 3 planes.

One is a base plane on which the tool is just kept another one is a longitudinal plane and the transverse plane. These are the 3 planes that are used as a reference planes in the ASA system you can see this is nothing, but the base plane and the second one is longitudinal plane this is called a longitudinal plane and the transverse plane these are the 3 planes.

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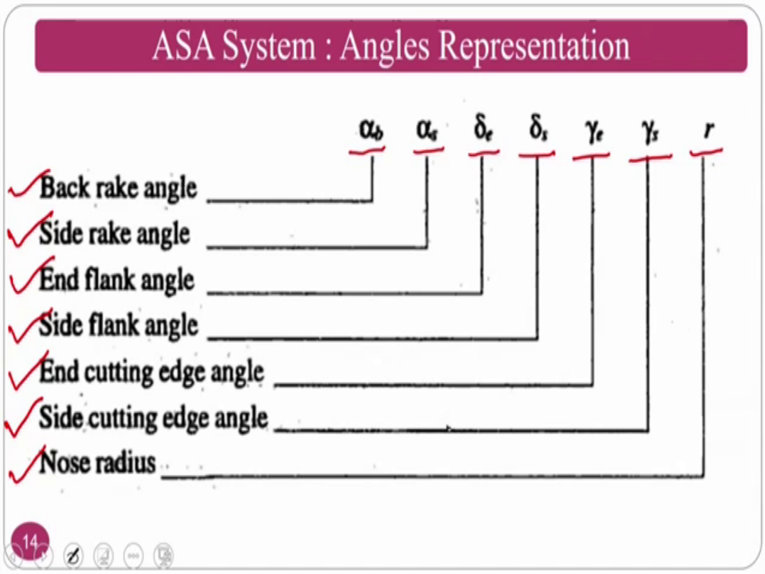

So, the ASA system goes like this first comes the back rake angle, side rake angle end flank angle, side flank angle, end cutting edge angle, side cutting edge angle and nose radius. So, alpha b represents the back rake angle, alpha s represent the side rake angle, delta e represent the end flank angle, delta s represents the side flank angle, gamma e represents the end cutting edge angle, gamma s represents the side cutting edge angle and small r represents the nose radius. This is the tool signature or the angle representation in a ASA system.

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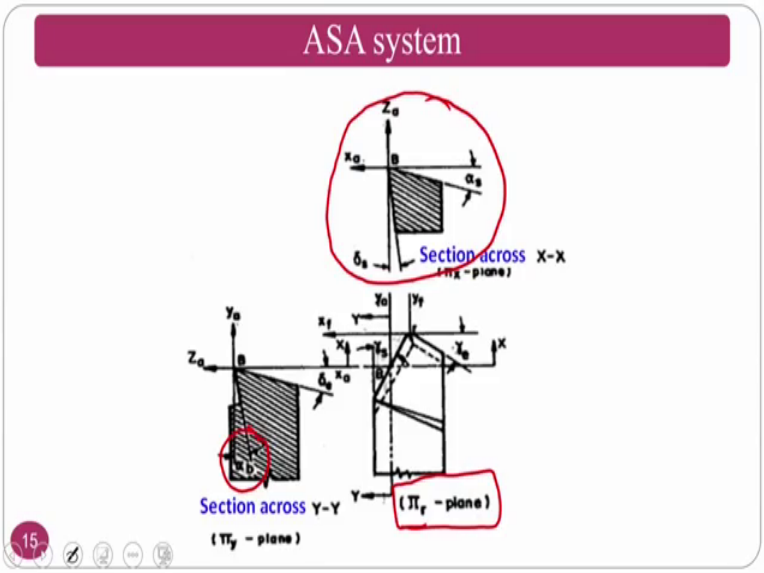

So, now we go to the ASA System how the angles are defines for a tool in the 3 views. So, these are the orthogonal views that you can see here whatever you see in the phi r plane this plane this is nothing, but this one so, you are seeing from the top. This is the tool is there on a base plane and I am seeing from the top. So, this is one cutting edge which is primarily called as a side cutting edge in the ASA system and this is represents the end cutting edge.

Whenever I put a plane I have a gap you can see a gap that is nothing, but side cutting edge angle at the same time if I am putting a plane like this, this is called another cutting edge which is having another angle that is called end cutting edge angle 2 angles are represented in this area at the same time if you see from side view you can see clearly the back rake angle.

Now, if I show you like this, this is nothing, but my back rake angle if I put a plane like this or like this if I put a plane I have a slantness here this is nothing, but my back rake angle at the same time if I see like this there is a slantness here also there is slantness here also there is a slantness here also this is nothing, but the my back rake angle this slantness is nothing, but my side rake angle that is about the 2 rake angles.

But; however, you can see this is back rake angle you can see here that is called back rake angle you can see from this view you can also see this angle since this is called end cutting edge angle and end flank angle whatever the slantness that you can see in this direction this is nothing, but end flank angle.

So, the third one is like this, if you see like this; that means, that if you see like this what you can see is this slantness that is nothing, but my side rake angle at the same time you can also see the side flank angle that is nothing, but this one, because this is my side cutting edge and this is called as a side flanks face whatever you can see is this slantness also you can see; that means, you can see 2 angles one is a side rake angle as well as side flank angle that is what you have seen in this one, this is all about the ASA system.

So, the rake surface will explain you 2 angles one is the back rake angle another one is the side rake angle since this is in ASA system called as a side rake cutting edge if I am putting a plane this is called side cutting edge angle if I am putting a plane like this, this is called this is called the end cutting edge angle. So, 2 rake angles 2 cutting edge angles now if I am seeing like from this side.

So, I can see side rake angle as well as side flank angle 2 rake angles 2 cutting edge angles and 2 flank angles corresponding to the 6 angles at the same time if you see this is my nose radius. So, 7 the tool specification in ASA system is explained like this, this is alpha b and alpha s end flank angle, this is end flank angle, this is the side flank angle and this end cutting edge angle and this is the side cutting edge angle and the nose radius this is about the ASA system.

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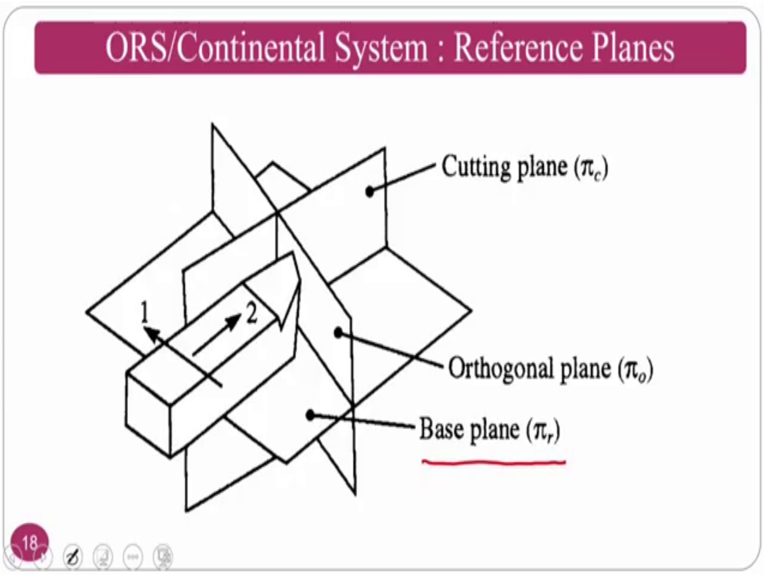

In orthogonal rake system in the other system it is slightly different the base plane is same cutting plane will change. So, the base plane is like this, but my second plane is parallel to my cutting edge. So, my third plane which I am going to see is orthogonal plane that is perpendicular to this plane. In ASA system this is my base plane this is my second plane and a x it is like a x y z axis, but in this system it is one plane is same as ASA system, the second plane is parallel to my principal cutting edge and the third one is perpendicular to that one that is called as cutting plane as well as orthogonal plane.

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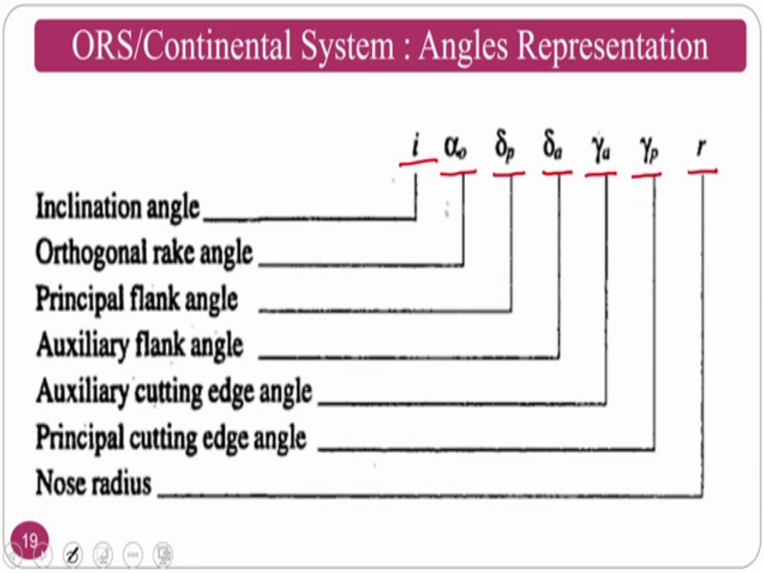

The angles representation goes like this first i represents the inclination angle, alpha o represents the orthogonal rake angle, then the principal flank angle auxiliary flank angle, auxiliary cutting edge principal cutting edge and nose radius this goes like this.

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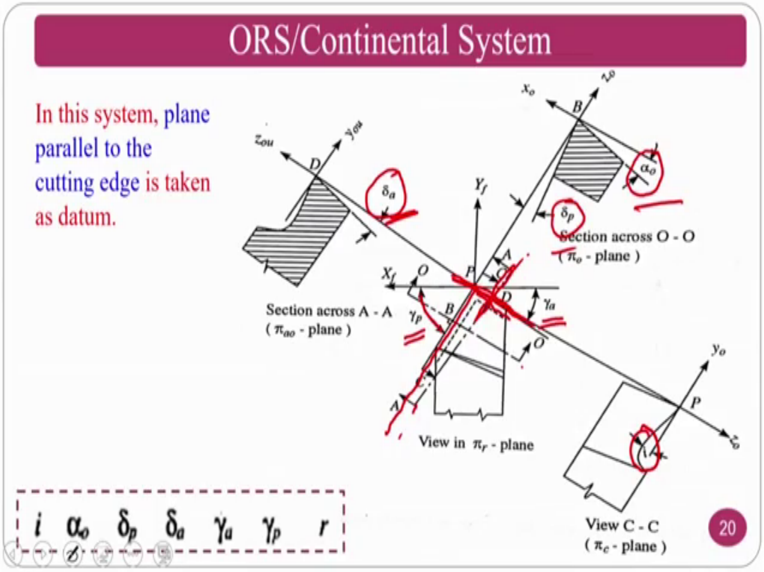

So, how do we represents the ORS system or the continental system this system is constant if you see the from the top since the base plane is constant if you see from this one and if you put a like this since orthogonal rake system or the orthogonal means perpendicular, if I am putting a base plane like this and I am putting another perpendicular to this one. You will get 2 angles since this is my principal cutting edge whatever the angle that I am going to get is principal cutting edge angle, this is my auxiliary cutting edge whatever the angle that I am going get is a auxiliary cutting edge angle.

So, you take the planes and you drop a perpendicular and you get a section of that one. So, that you will get the angles normally if you see the O - O section this is called O - O section this is the plane parallel to the cutting edge. So, you drop a perpendicular that is called O - O and you see it then you can observe that the principal flank angle as well as orthogonal rake angle.

At the same time if you see here you just drop the section C - C which is parallel to your principal cutting edge and you can see the inclination angle here that is going to come here is to find the auxiliary flank angle. For that purpose there is a section which is dropped at the A – A, this is called A - A section which looks like parallel to your principal cutting edge, but it is not parallel it is perpendicular to your auxiliary cutting edge ok.

Since I said this is orthogonal rake system orthogonal means you just drop a perpendicular to that surface. So, you are dropping to this one and you are getting the auxiliary angle so, that is how you get the different angles in that on. So, let me summarize on the orthogonal rake system base plane is constant as in the ASA system this is the second plane and the third plane is perpendicular to it.

So, once the base plane is there you just put a like this and you will get principal cutting edge this is the principal cutting edge and this is my auxiliary or side cutting edge. So, you have a another angle whenever you put the section O - O perpendicular to the cutting edge and you just find 2 angles and you can see from here one angle that is inclination angle and you drop the perpendicular to the auxiliary cutting edge or flank surface and you will get the auxiliary flank angle.

This is about the ORS system and as I said this is how you represent the ORS system that is inclination angle orthogonal rake angle principal flank angle auxiliary flank angle auxiliary cutting edge angle principal cutting edge angle and nose radius. So, nose radius is constant in both things. To summarize ASA system follow x y and z axises, but the ORS system follow x ax the base plane is constant that is what just I for remembrance I said x y z the x is same the y goes parallel to my cutting edge instead of going parallel to my shack it goes like this and the third one goes in perpendicular to my cutting edge. That means, if it this is the inclination of my second plane this goes perpendicular to it.