Metal Cutting and Machine Tools

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Lecture-02
Geometry of Single Point Turning Tools-I

Welcome viewers to the second lecture of the course metal cutting and machine tools. So, last day we had discussed about different types of manufacturing processes which help us in attaining our desired shape and size on a particular part. So, we take a blank piece and on that we apply some manufacturing processes with the help of which we attain the final shape and size. So, among these processes we identified metal cutting or material cutting or material removal by it is special characteristics that it removes the material in the form of chips and it employs powered a power device or power equipment which is called a machine tool.

We also came across the idea of the cutting tool which is the active element which actually removes material from the workpiece. So, we have the workpiece or the part which we want of a definite shape and size. We have the cutting tool which actually removes material from the blank to attain the final shape or the part.

And we have the machine tool which holds the workpiece and the cutting tool securely rigidly and provides relative motion between them in order to remove material. The machine tool also has other functions. So, let us first discuss something about the basic relationship between machine tools and cutting tools and then onto the geometry of cutting tools. So, today we are going to discuss the geometry of single point turning tool.

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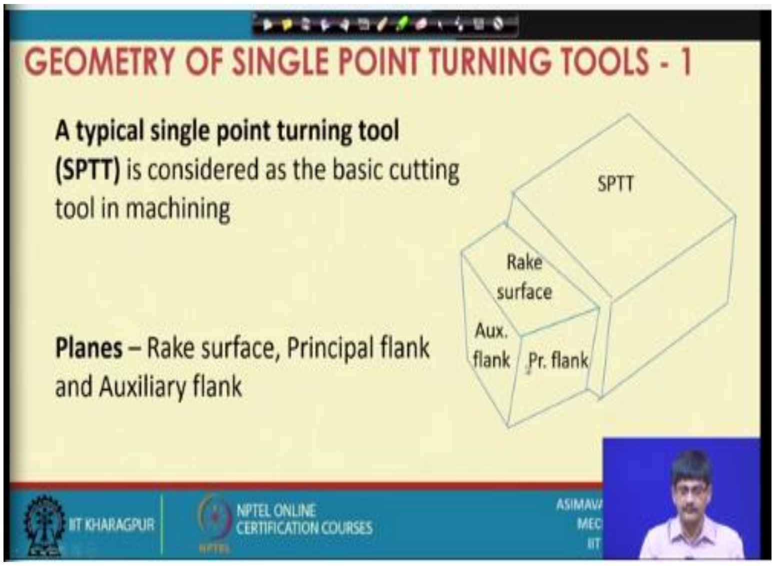

So, first of all on the screen you can see the shape of a single point turning tool, SPTT. So, this is considered to be as the basic cutting tool or cutting element in machining. All cutting tools can ultimately be related to this particular single point turning tool. That is all cutting tools can be ultimately shown to be composed of different single point turning tools or a modification of the single point turning tool.

So, what do we see here? On the surface of the turning tool we have first of all let us see the back portion of the turning tool. So, this is the shank or the base or the rear portion of the tool which is held on the machine tool. If we can hold it on the machine tool it will be securely placed in position with rigidity. On the front of the cutting tool we have 3 main surfaces or planes; these are called the rake surface, the auxiliary flank and the principal flank.

Flank means side, so these are the sides of the tool, this is the top surface of the tool, the top surface is called rake surface or face.

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So, the machine tool holds the tool workpiece pair rigidly and provides relative motion between them. The tool that we saw just now is held on the machine tool. Examples of machine tools are lathe, milling machine, shaping machine, grinding machine, drilling machine. Let us have a quick look at some of these machines.

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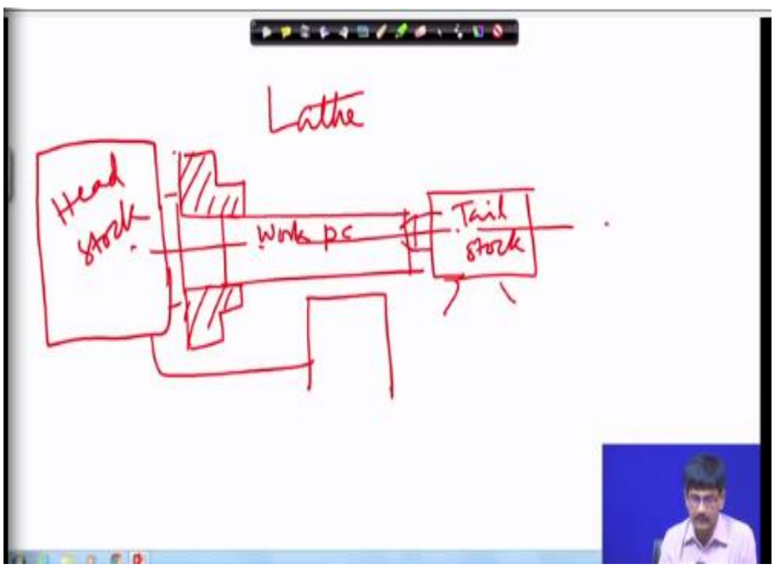

So, for that let us select the white board. On the lathe what kind of machines do we have rather yes? So, on the lathe we have the basic work piece, it is held securely on a device called a chuck or center. So, it is holding onto the workpiece, this one is made to rotate; it has ultimately connection with something called a headstock.

This headstock will typically contain gears which can change the speed of this workpiece; I mean speed of rotation of this workpiece. So, on this workpiece we have maybe it is held on a center on this side, we have headstock just like that we have tail stock. And where is the tool figure? The tool is brought in I am drawing it.

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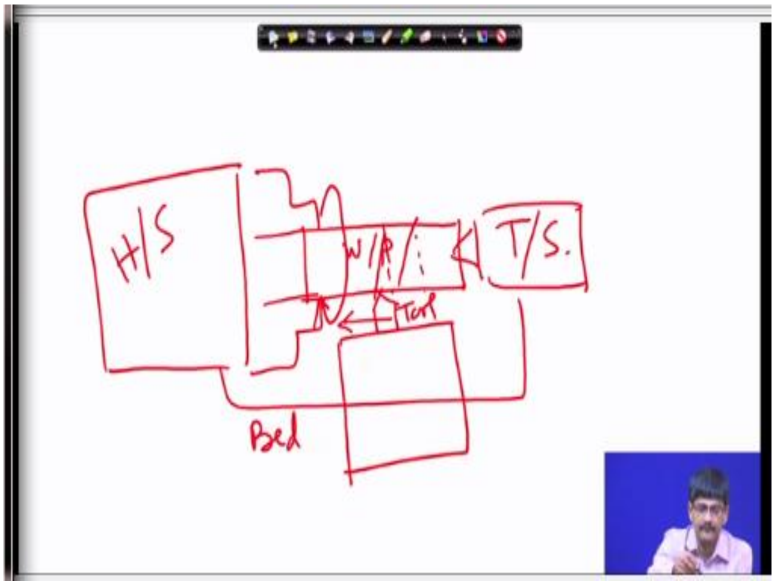

I will just repeat those workpiece, work holding device, headstock, tailstock, basic body of the machine, the lathe bed. On that there is a sort of saddle which can move this way, that way and the tool is typically held on this saddle, I mean carriage. So, this is the lathe bed, this is the tool. So, just see I am going to make the workpiece rotate and the tool is going to move this way, and therefore it primarily describes the helix, the tool describes a helix like that.

Because the rotation is combined with longitudinal motion and we can make smaller cylinders with the help of this particular device. So, if we return to the power point presentation slides, lathe looks like that, what does the milling machine look like? We will be discussing milling machines in more detail. So, milling machines are machines in which the cutter rotates, on the lathe the job rotates generally and the cutter moves either axially or at an angle to that particular rotating job.

On the milling machine, the cutter generally rotates and the workpiece moves past the cutter, the workpiece might also rotate. But in general shaping machine the cutter reciprocates and removes material from the workpiece. So, this way there are different machine tools we will take them up in more detail later on.

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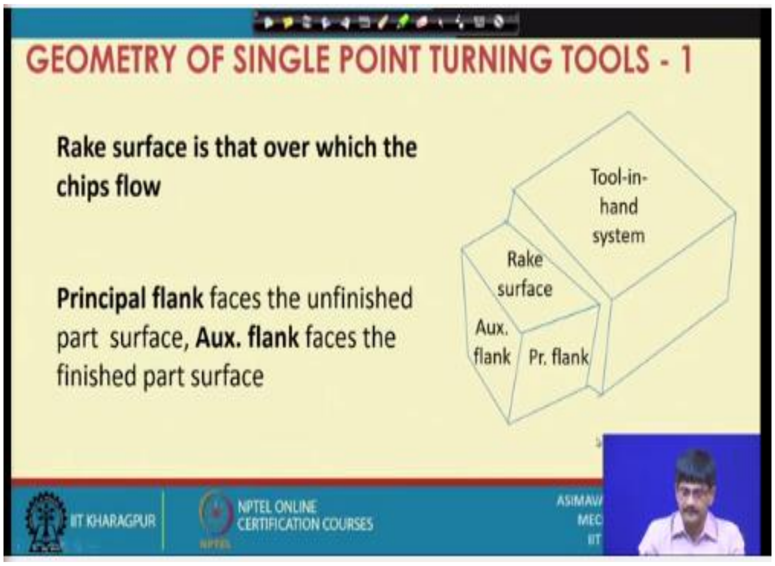

Coming back to our tool now the initial way in which we can refer to the tool is the tool in hand system. So, if we take the tool in our hand and we move it this way, that way, there are some things which will not change, what are those? The rake surface will not change the principal flank and the auxiliary flanks they are not going to change. What is going to change? Well, the angles which these planes make with the different directions for example the XYZ directions etcetera, those are going to change.

So, in the tool in hand system these are fixed. So, these are basically surfaces or planes. What is the rake surface? The rake surface is that over which the chips flow, this is the rake surface. And on the lathe it is placed in such a way that over the rake surface the chips will be flowing. This is the principal flank, it faces the unfinished part of the workpiece and this is the auxiliary flank which places I mean which faces the finished part of the workpiece. So, these are the definitions of these 3 planes.

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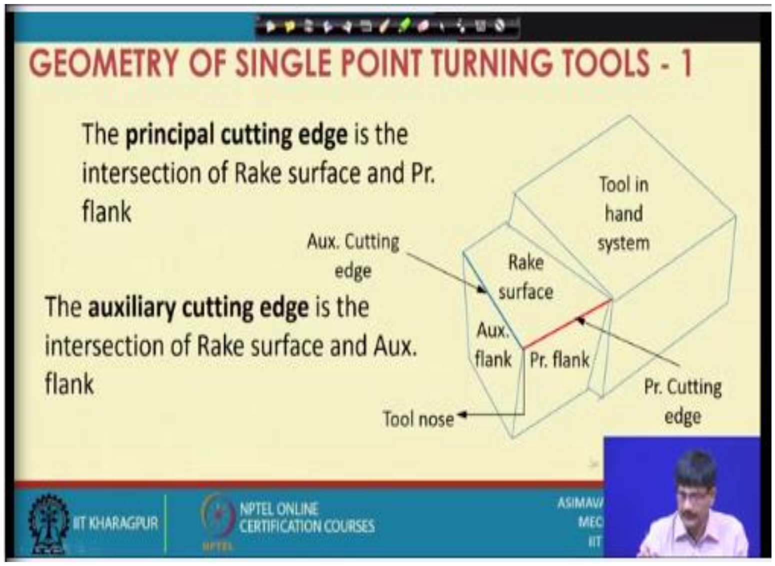

So, after that we come to the definition of the different edges which are present and the different points. Once we have 2 planes intersecting, their intersecting edge can easily be identified and here we have identified the intersection between rake surface and principal flank as this line, this red line and we have named it as the principal cutting edge. In the same way the rake surface and the auxiliary flank will also have an intersection that is called auxiliary cutting edge.

Why do we name these things as cutting edges? This is because they are involved in the removal of material by providing a sharp edge. So, there are in the single point turning tool 2 cutting edges, one is the principal cutting edge and another one is the auxiliary cutting edge. And when all these three planes meet they define a point which is called the tool nose, this one is the tool nose. So, if we draw the tool with relation to the job it would look somewhat like this, just a moment, yes.

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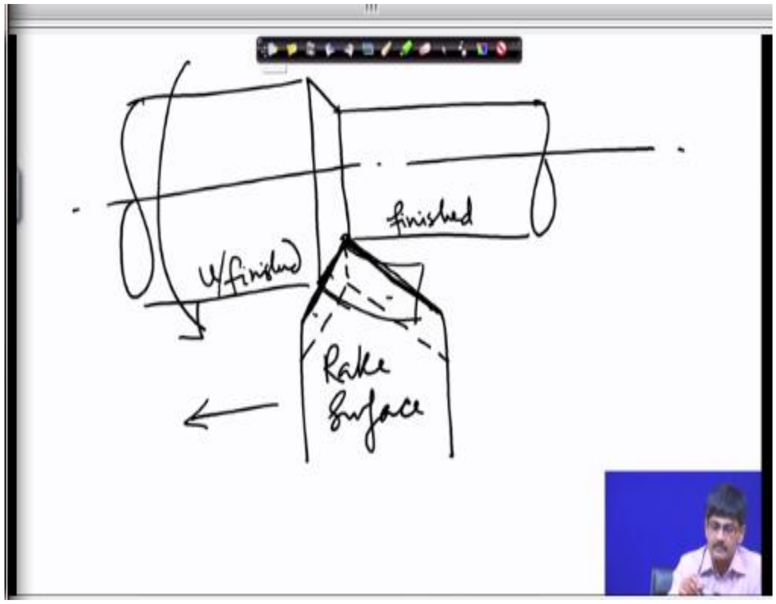

We are looking at the tool from the top, therefore this is the rake surface, where is our job? The job is on this side. It is rotating, the tool is moving this way, so the chips are going to come out as we saw the last day the chips are going to come out here. Over which the chips flow the rake surface and this is the finished part, this is the unfinished part. So, the principal flank is to on this side, we cannot see it from the top but it is there.

It faces I mean the auxiliary flank we cannot see it from here but it faces the finished part of the workpiece. And we can draw dotted lines of course, so this is the auxiliary flank which we cannot see from the top. And this is the principal flank, this one also we cannot see it from the top but it is facing the unfinished portion of the workpiece. So, this gives us those names and as you can see the principal cutting edge is this one.

So, it is in contact with the work piece and the main geometry element responsible for cutting of the metal. Here also some cutting takes place, here some cutting takes place and this is the auxiliary cutting edge. So, now let us move on to our next discussion. So, we have identified rake surface, principal flank, auxiliary flank, cutting edges two of them etcetera in the tool in hand system.

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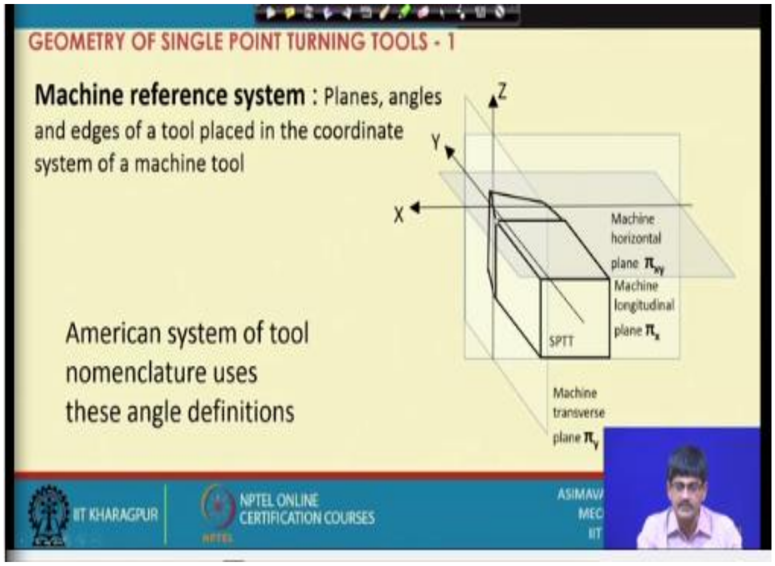

Now let us go on to the tool when placed in a coordinate system the machine coordinate system. And once the tool is placed in the machine coordinate system it starts having a relationship with the different planes, so this is our tool. What is this tool doing? The tool is having you know the 3 planes attached to it, these are the 3 directions Z axis, X axis, Y axis. What are these planes?

These planes are basically planes which define the space in relation to a machine. For example, suppose this is fitted on a lathe. So, this will be the feed direction longitudinal feed direction, this will be the direction of the velocity vector provided the tool is placed correctly and this one is the transverse direction of the machine. Just now that the figure that we drew, there you can easily find out these directions.

And corresponding to these directions if we combine them in pairs we get planes. So, the machine horizontal plane is the horizontal plane, it is basically the XY plane here. If the velocity vector is correctly in the direction of Z axis, in that case the machine horizontal plane gets a name called reference plane. Reference plane is defined as the plane perpendicular to the velocity vector.

So, if this is the direction of the velocity vector then XY plane is the reference plane and it will be called π_r. Now what is the machine longitudinal plane? It contains the direction of feed and the Z axis. What is the machine transverse plane? It contains the transverse axis, the Y axis and the Z axis. So, they will be cutting the tool along different planes and defining different angles.

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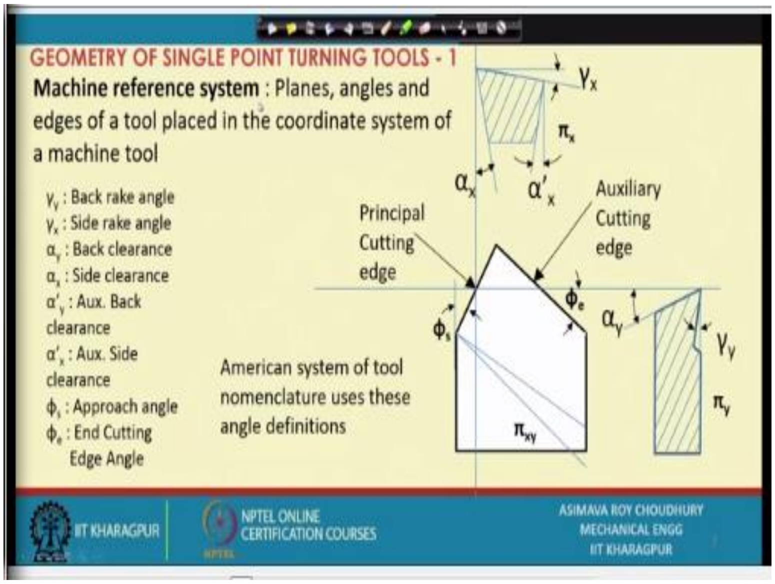

So, let us see the angles which are created by the intersection of these planes with the tool. First of all, I am seeing the tool here from the top, this is the tool from the top. And all angles and planes and edges etcetera are defined in this system of machine reference, it is called the machine reference system. And the American system of tool nomenclature uses these angle definitions, in what way?

For example, if you are cutting the tool along this particular line, if this is the XY plane, this is the projection in the XY plane, the plan view. Here if you cut it with this particular plane, now you will say what is this plane? This is the machine transverse plane. So, the machine transverse plane which is π_y, I cut it and I get a section of the tool and I draw that section here. When I am drawing this section two angles appear and I name them γ_y and α_y.

You might say what are these angles? I can formally define them but let me give you a basic idea, they give the slant of the rake surface with reference to the π_{xy} plane or the reference plane. That means if the velocity vector is correctly in I will not say correctly, if the velocity vector is exactly in the Z-axis the π_{xy} plane becomes the reference plane. Reference plane is defined as perpendicular to the velocity vector of cut.

So, if the velocity vector is exactly perpendicular if it is exactly in Z-axis we will have the reference plane equal to π_{xy}. So, we will formally define γ_y as back rake and it is the angle between the rake surface and the reference plane in the machine transverse plane.

So, γ_y is defined as the back rake angle which is the angle between the rake surface and reference plane in the π_y plane. So, this formally defines the back rake. Now that we have defined back rake, we can define other angles very easily. α_y is the angle between, if you notice this is the trace of the cutting tool in the π_y plane. And which part of the cutting tool, this is the flank surface we cannot see it here, we cannot see it in the plan view but it is hidden.

So, here clearance angle, back clearance can be defined as the angle between the principal flank and this particular plane, what is this plane? This plane must be π_x plane, trace of the π_x plane in the π_y plane. So, angle between two planes which are these planes. Principal flank and π_x plane and it is considered this angle is considered in the π_y plane. So, this way we are going to define each and every angle to be between 2 planes and considered on a particular plane.

For example, say I am defining γ_x, γ_x is given a name side rake if you notice I have defined all the angles here. Side rake is defined to be the plane between the rake surface and the reference plane considered in the π_x plane, so this way we can define each and every angle. Moreover, in the plan view, in this view where we are looking at the tool as seen along Z axis. We have two angles defining the positions of the cutting edges, φ_s defined as the approach angle and φ_e defined as the end cutting edge angle.

Approach angle sometimes it is called side cutting edge angle and this one is end cutting edge angle, these 2 angles. When we have defined these then the tool is defined with its relation with the 3 machine reference and machine planes reference planes. So, generally let us see how we can completely define the tool in the ASA system.

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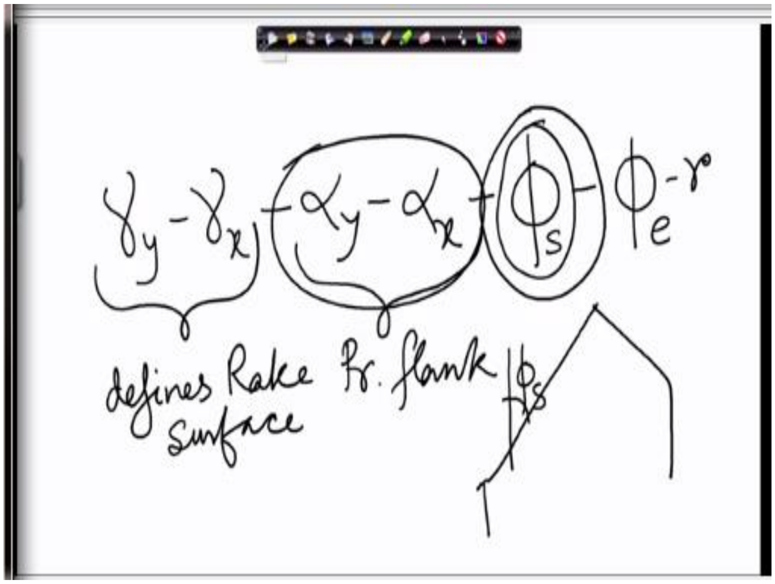

For that in the ASA system in many literature it is given that the tool can be completely defined by this particular nomenclature γ_y, γ_x, α_y, α_x, φ_e, I think it is φ_s, φ_e, r, we will check this out, r is the nose radius. Now I would not like to follow this particular nomenclature. Because as you would see there are certain problems with this, for example there is no information about the auxiliary flank.

And secondly we might have problems with such definition if we use α_y, α_x together. So, we will know about these angles but we will not accept this as a standard nomenclature for a cutting tool because it might lead to problems. I will tell you what the problem is. Problem is this, if I define γ_y and γ_x it defines the rake surface position in space, rake surface becomes invariant.

If I define α_y, α_x, the principal flank becomes invariant that is this position orientation is fixed. So, the orientation of the rake surface is fixed, the orientation of the principal flank is fixed and therefore their intersection which is the cutting edge that will also be fixed. You cannot have a free definition of the cutting edge after this, cutting edge is fixed which means φ_s is also fixed, φ_s is fixed after this.

So, in that case we cannot freely define φ_s, that is if I say let us take a tool with γ_y 15º, γ_x 5º, α_y 10º, α_x 5º, φ_s say 25º and φ_e is 65º, no, φ_s will be pre decided you cannot assign a particular value to φ_s just like that once you have defined these 4 angles. So, though in many literatures the nomenclature of the ASA system is given this way, we are not going to follow it.

We will accept that the ASA system uses these angles but the nomenclature of the tool in the ASA system; we will not adopt this one. After this, so this way all the angles can be defined, we are not going to go through all the definitions. But all these definitions can be obtained this way that is we take 2 planes, find out the angle between them in another plane. And our basic definitions start from the velocity vector of cut. So, let us have a look velocity vector, can it really change?

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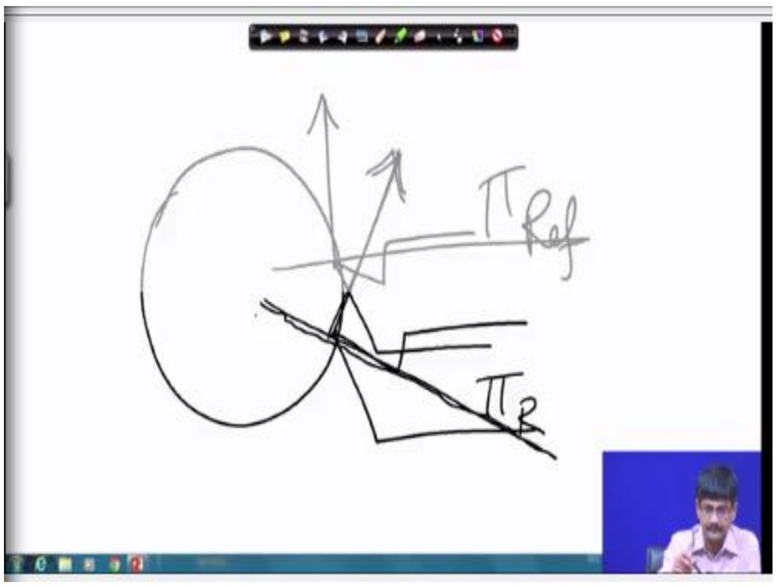

Suppose we are having this as the work piece and this as the tool, in that case the velocity vector will be directed this way. Now suppose someone puts the tool by mistake at a lower height. Suppose this is the tool you have a problem; in that case the velocity vector is this way. And all the tool angles will be changing because the reference plane is now here; previously the reference plane was here.

Reference plane $\pi_{reference}$ or π_r, this is the reference plane now. Because it is always perpendicular to the velocity vector, that is a problem. So, we always start the definition of tool angles from the velocity vector of cut. So, the American system is not the only system there are other systems which have being formalized and let us have a quick look at those.

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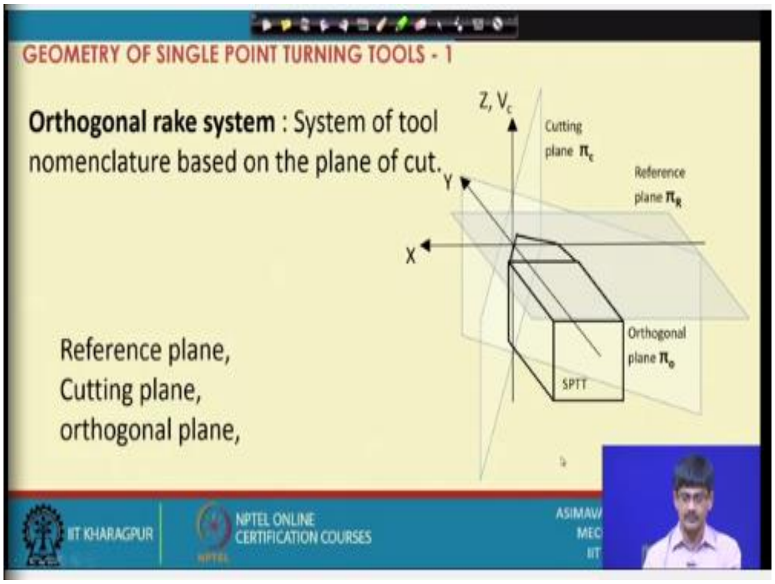

Another one is where the cutting edge, the cutting edge forms the basis of the definition of the geometries that means the angles and the edges etcetera. So, whenever we have cutting edge or other cutting plane based system we call it the orthogonal rake system, what is it? It basically defines a coordinate system where the planes are defined with relation to the cutting edge, in what way?

Here we have something called the cutting plane. What is the cutting plane? The cutting plane contains the cutting edge and also the velocity vector. Velocity vector of cut is here and therefore this is the cutting plane. What is what you call it orthogonal plane? Orthogonal plane is perpendicular to the cutting plane and it is perpendicular to the reference plane, what is the reference plane?

Just to remind you reference plane is perpendicular to the velocity vector. So, this is the velocity vector if it happens to be along Z-axis, matters are simplified this is the reference plane which becomes π_{xy} plane only. The cutting plane contains the velocity vector and the cutting edge. An orthogonal plane is perpendicular to the reference plane and perpendicular to the cutting plane. So, we have these definitions reference plane, cutting plane, orthogonal plane.

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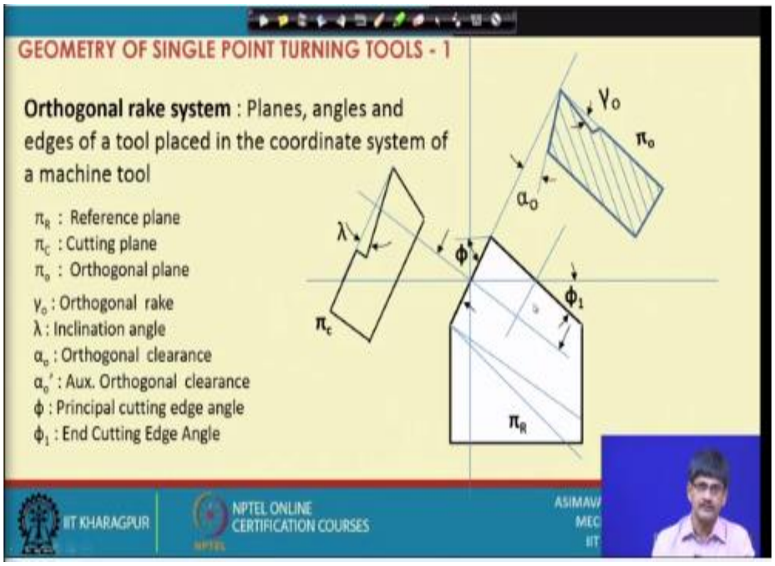

And let us see how the sections come out to be in that case. The sections I mean the angles, first of all if you look at this figure this is the cutting edge, once again this is the cutting edge. Where is the cutting plane? The cutting plane is appearing as a line here, it cannot be seen from the top. As it is a vertical plane it cannot be seen from the top but here it is appearing as this is the trace of the cutting plane.

Then what is this section? We have cut it here I have not given the name of this sectioning lines. So, we have cut it along this line, what is this line? This is what the orthogonal plane looks like π_o. So, this being the orthogonal plane if the section which is obtained on the orthogonal plane looks like this. And the angle between the rake surface and the reference plane in the orthogonal plane is called γ_o or orthogonal rake.

In the same way the same section will be producing a relation between the principal flank and the cutting plane, principal flank and the cutting plane measured in the orthogonal plane once again. So, that is why this π_o has appeared here and the 2 angles of cut are shown on the two sides, one is orthogonal rake and another is orthogonal clearance.

So, if you ask me so how is orthogonal clearance defined? It is defined between this plane which is principal flank and that plane which is cutting plane and the whole thing is measured or considered in the orthogonal plane that defines orthogonal clearance. On this side if we look at the tool section is required, we are simply looking at the tool and drawing view.

And we may see that the cutting edge, actually it is inclined, it is not straight, here it is looking straight but from the top. As it goes backwards it might be inclined downwards or it might be inclined upwards also. But it is basically having an inclined it is not moving horizontally here. This is reflected in this view, I mean captured in this view, it is inclined from the nose.

So, if it is inclined in that case this angle of inclination is given a name called λ, how is lambda defined? λ is the angle between the rake surface and the reference plane measured in the cutting plane**.** Hence this way we come across inclination angle, so λ is called inclination angle, it is also a type of rake, it is also a type of rake angle. So, inclination angle is understood, orthogonal rake is understood, orthogonal clearance is understood.

And in this system instead of referring to the approach angle or the sight cutting edge angle we define an angle called principal cutting edge angle just $90^{o} - \varphi_s$ and we still have the end cutting edge angle as φ_1. So, we learn of different angles in the orthogonal rake system alright. So, after learning about this mind you, you might say you have not mentioned anything about the auxiliary flank.

On the auxiliary flank also we can make a section like this perpendicular to it, so we will have auxiliary cutting plane, we will have auxiliary orthogonal plane. They will be forming similar angles like auxiliary orthogonal rake, auxiliary orthogonal clearance etcetera. I have not drawn this on the same figure because it will turn out to be confusing if I start giving all the details in the same figure at one go.

So, I have only given you details about the principal cutting edge and it is associated angles, I am sure that you will be able to find out similar angles for the auxiliary cutting edge if it is required. How do we define them? Just like α_o has been defined here, we have α_o' also, the auxiliary orthogonal clearance. How do we define this system? Let us have a look.

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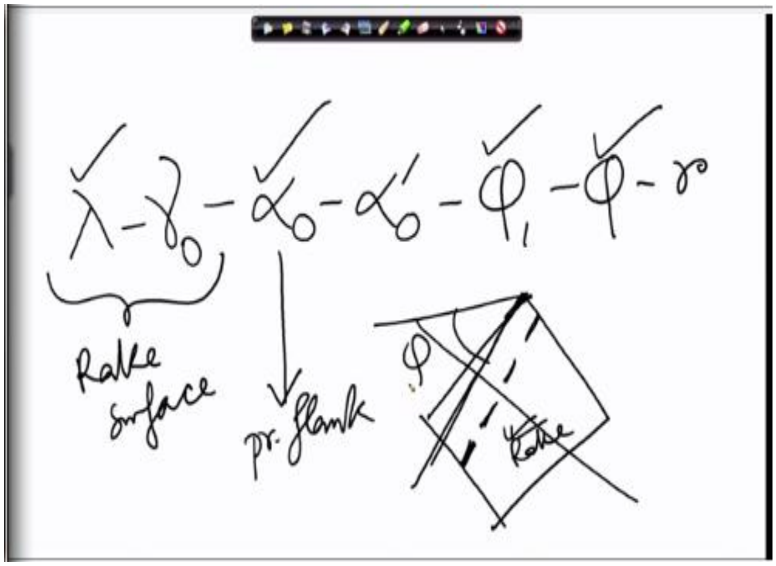

We can define it this way, lambda, γ_o, α_o, α_o', φ_1, φ, r. You might say is in the same problem that you mentioned about ASA system going to occur here as well, no. Because here you will find that we are defining the rake surface orientation by these two angles. We are defining the principal flank by this one, you might say can the principal flank be defined completely this way; just a single angle is there.

Well, some information is going to come from this one. For example, with these suppose I define the rake surfaces with these two. And on that I define the principal cutting edge, so I use up this information. So, this one is oriented in space the rake surface, on that I use up this information to draw the main cutting edge. From the main cutting edge, in this direction I get the incline of the principal flank I cannot see it from this side; I get the incline of the principal flank by this angle, so I use this up also.

Now I made a mistake φ is used for getting the inclination of φ, just a moment let me rub off some of those unnecessary lines, what is this one?

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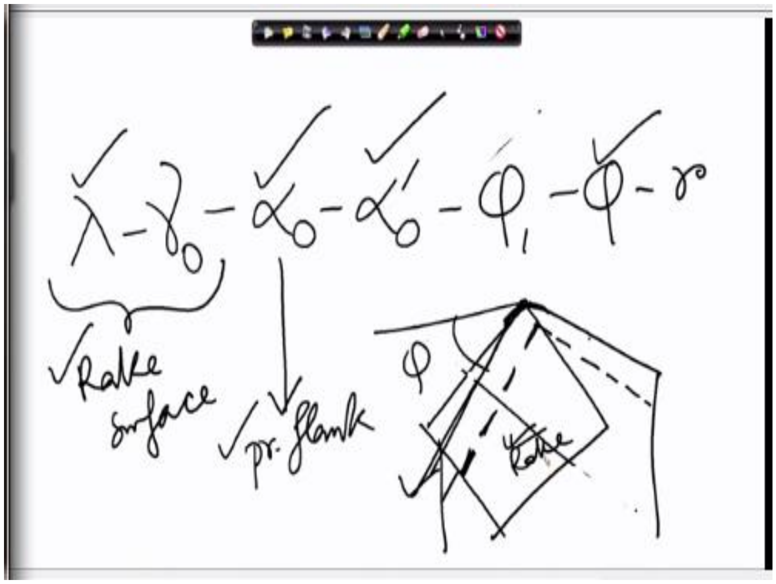

So, φ is used so I am sorry let us remove this first, φ is used up to define the principal cutting edge and after that I define the inclination of the principal flank by α_o and therefore I define the principal flank as well. So, principal flank is defined, rake surface is defined, principal cutting edge is defined. After that α_1 helps me define the auxiliary cutting edge position. You know rake surface is not just this square but it is extended to infinity in all directions.

It is an infinite plane from there we are segmenting small portion of it, so this is the auxiliary cutting edge. And in the same way we define the orientation of the auxiliary flank by using up this information. And see now that we have got this particular shape and of course the rounding of this point is defined by r. Now we had used all information to get the complete picture, the 3 planes that we had talked about.

And hence this definition is alright, this string or this nomenclature of the orthogonal system is alright. So, we will discuss other aspects of tool geometry in the subsequent classes, thank you very much.