Machining Science - Part I
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Lecture – 05

Hello and welcome to the 5th lecture of the course on Machining Science. Let me remind you that in our earlier lecture earlier session we started discussing the Tool Nomenclature.

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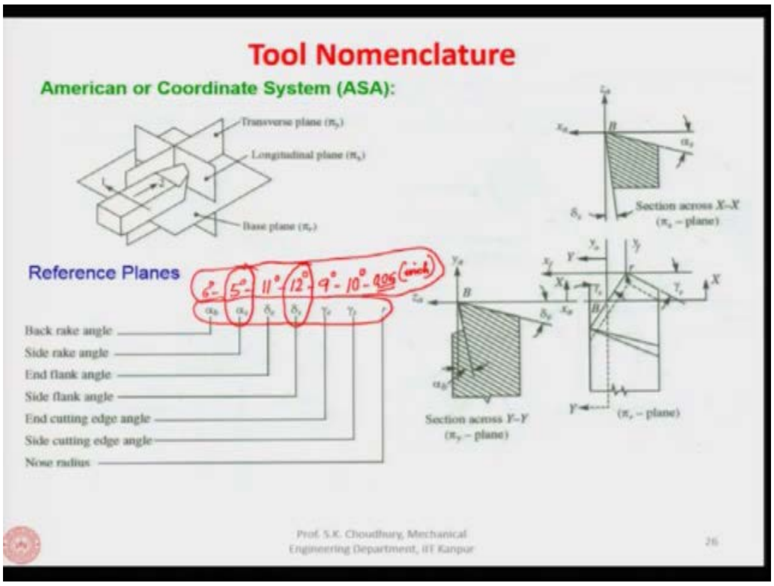

And, we said that different countries adopt different tool nomenclature; that means how to define the tool angles. And, we have seen that in the American system or the coordinate system it is the simplest one that is the basic coordinate system is used - x y z. Within the x y z, taking the base plane, longitudinal plane and the transverse plane, the 6 angles and the tool nose radius are defined.

Now, this is defined, as I said, in a certain sequence. In case of ASA the sequence is like this as it is given here; that is back rake, side rake, end cutting, end flank angle, side flank angle, end cutting edge angle, side cutting edge angle, and the tool nose radius.

So, mind it that the sequence means that if you take the tool, which is in the ASA system, what you will find is for example, here it can be written as 6^0, 5^0, it can be 11^0 and then it can be 12^0, it can be 9^0 for example, and it can be 10^0 let's say and the tool nose radius is 0.06, by the way this is given in inch.

Because, it is in American system so, the tool nose radius is given in inch which is here. The tool will be defined only in this way. And, from here you have to understand that the first one is the back rake angle, second one is the side rake angle and so on. In this sequence as it is given in here.

So, if you purchase the tool you will see that the tool specification will be given in this sequence and you will not be told that which one is what. You have to know that the angles are mentioned in this sequence.

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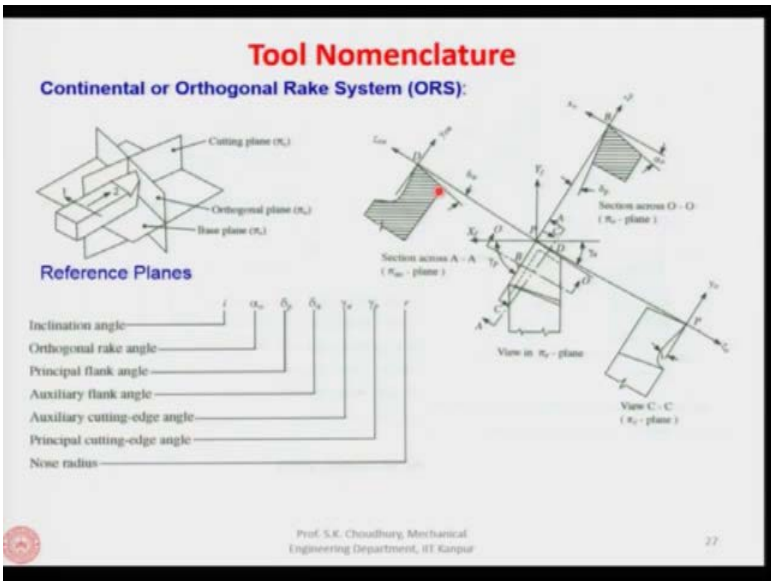

Then, we have discussed the orthogonal rake system and we said in the orthogonal rake system there are 3 mutually perpendicular planes that are used, which are the base plane, orthogonal plane and the cutting plane - these are the 3 planes which are used here. Now, we take the sections in different planes, one of which is orthogonal plane. Another, is the cutting plane and the third is the plane perpendicular to the auxiliary cutting edge.

These are the three planes in which you can show the angles. The cutting plane is the plane which will contain the cutting edge. So, the view that we will be getting is like this and it is not a sectional view, because this is the plane which will contain the cutting edge and as if you are looking at the tool from this side, perpendicular to this.

So, we will have a view like this and in this view this is the rake face, and that rake face is making an angle *i* with the Z axis and the *i* is the tool inclination angle as we said or this is also called the angle of obliquity. This is the characteristic feature of the oblique cutting, because the tool is inclined. This is the tool inclination angle. The orthogonal plane is perpendicular to the principal cutting edge and in this view you will see that the rake and the flank faces are here.

This rake face will make an angle perpendicular to the cutting velocity vector, which is the x axis actually, this is the angle which is called the orthogonal rake angle. Similarly, this angle which is made by the flank face and the Z axis, is called the principal flank angle. Similarly, here you will have the tool inclination angle and here you have the auxiliary flank angle.

This is because it is in the auxiliary plane. This is the flank face which is making an angle with the Z axis, this is the auxiliary flank angle. So, these are the six angles like in the case of the ASA system along with the tool nose radius and in this sequence the angles are specified.

First it will be the inclination angle, then the orthogonal rake angle, then the principal flank angle followed by auxiliary flank angle, auxiliary cutting edge angle, and the principal cutting edge angle and finally, the nose radius. Here the nose radius is given in millimeter. So, this is the sequence given in the tool nomenclature that is adopted by the continental or the orthogonal rake system, which is called the orthogonal rake system.

These angles, again, will be different than the angles which we have determined in the case of the ASA. These angles are different from those angles which are in the orthogonal rake system, because these angles are obtained in different planes and in different planes the inclination will be different.

The angles will be different; whereas, in case of the coordinate system it was a straight plane that is the x y z here the planes are different. So, these angles are different from the ones that we have obtained in the American system or ASA system.

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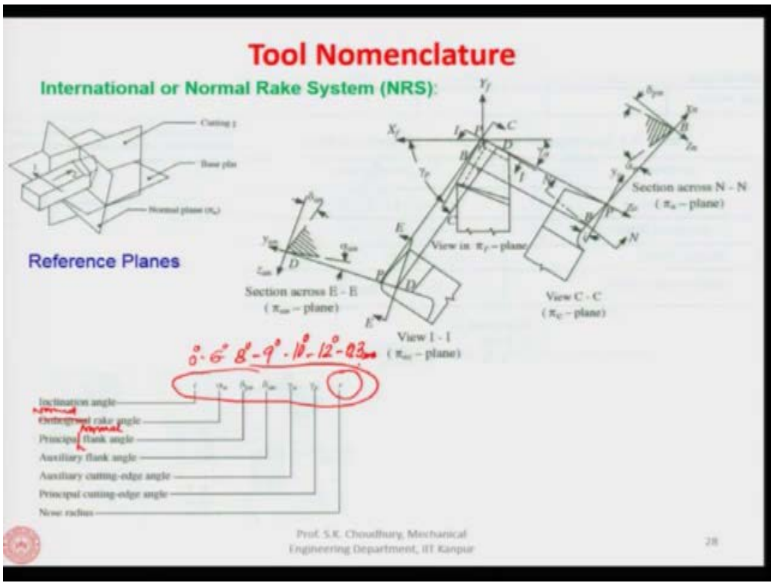

Another system of tool nomenclature is called the International or Normal Rake System. This is called international because this is the system which all the countries are trying to adopt gradually, so that all the tools, I mean, from anywhere you purchase the tool, you it can be used anywhere.

Right now, what is happening is that if you are purchasing a tool from the United States you cannot straight away use it here, because you have to convert those angles into the angles that you have adopted in your country that is in India, we are adopting the ORS that is the orthogonal rake system.

So, particularly when the tool is re-ground, when it has to be re-sharpened. For example, after the tool wears out, it has to be ground. During the grinding process the tool has to be placed in a particular way according to a particular angle. So, those angles are important and we are adopting those angles as given in the ORS system.

So, we have to convert those angles given by the ASA system so that the tool can be ground properly. Here in the international or normal rake system, this system is closer to the actual processing angles. By actual processing angle we mean the normal working angle, when the tool is removing the material.

At the time of machining when the tool is interacting with the work piece, what are the actual angles that we are getting this is more or less given in the normal rake system. So, here the planes that are used are - the base plane, this is the same as in case of the ASA or the ORS system.

Another plane is the cutting plane; cutting plane is the same as in case of ORS system, this cutting plane contains the cutting edge. Another plane is the normal plane, which is different than the planes taken in the ASA or the ORS system and this normal plane is perpendicular to both of the base plane and the cutting plane.

These are the three mutually perpendicular planes in which the angles are given in the NRS system, NRS stands for the Normal Rake System. So, we have the base plane here, in the base plane, we will take the sections in different planes like this - one is the cutting plane, this was given like in case of the ORS. This view will be same as in ORS. Here we will have the rake face. The rake face making an angle with the Y axis this will be the tool inclination angle. This remains the same as in case of the ORS.

Next, here it will be another plane that we are taking is the plane which contains the auxiliary cutting edge. View of the plane which contains the auxiliary cutting edge, we will call it as I-I. So, in this plane we will take another plane, which is perpendicular to the cutting edge, this is the cutting edge and E-E is perpendicular to the cutting edge.

So, this is the plane which will be called as the auxiliary normal plane, because it is normal to the cutting edge, this is the auxiliary plane and this is normal to the auxiliary plane. In this view this is the C-C that is along the cutting plane.

In this perpendicular to the cutting edge again we will take another section. Let us call this sectional view as N-N and in this sectional view, because it is section, what we see is the rake face here and the flank face here.

So, this rake angle will be called as the normal rake angle, because it is again in a plane which is normal to the cutting edge. This angle which is between the flank face and the line here along the Z axis is the principal normal flank angle.

So, this angle will be called as the principal normal flank angle. So, we have the auxiliary normal rake and the auxiliary normal flank angles, here we have the normal rake angle and the principal normal flank angle. So, these are the four angles, 5th is the tool inclination angle.

Here we have the two cutting edge angles; one with the principal cutting edge which is called the principal cutting edge angle γ_p and another along the auxiliary cutting edge and the x axis, which is called the auxiliary cutting edge angle.

Mind that it is principal cutting edge angle here. Here also we have given the principal cutting edge angle and the auxiliary cutting edge angle which is in the ORS, but in case of ASA system, as you can see, here it is not the principal cutting edge, but it is 90^0 minus principal cutting edge angle. So, this is given in the ASA as the γ_s. And, γ_s is the side cutting edge angle. Side cutting edge angle is 90^0 minus the principle cutting edge angle. So, this is the difference.

So, here, there are two angles, one, which you are having as the principal cutting edge angle - this is between the principal cutting edge and the x axis, and between the x axis and the auxiliary cutting edge is the auxiliary cutting edge angle. Now, the inclination of the rake face can be defined by two angles.

So, here this angle is redundant. One of these angles like for example, here we have the normal rake angle, here we have the inclination angle which is also related to the rake face and here we have the rake angle which is auxiliary normal rake angle. So, in the nomenclature the auxiliary normal rake angle is not taken.

And, the sequence given in the tool nomenclature adopted in the normal rake system, which is also called international or normal rake system, is the following. First we have the tool inclination angle.

Then we have the principal normal flank angle. This is the auxiliary flank angle; this is the auxiliary cutting edge angle and the principal cutting edge angle. So, these are the six angles along with the tool nose radius and here also the tool nose radius is given in millimeter, because it is the international system.

These six angles plus the cutting tool nose radius are defined in the normal rake system in this particular sequence. Once again, when you are purchasing a tool which is in the NRS system, the angles will be given like 0^0 , 6^0, let's say then it can be 8^0, it can be 9^0, it can be 10^0, just an example 12^0 and 0.3 *mm*. Millimeter may not be written here, but you have to assume that it is in *mm* since this is the NRS system. So, the tool nose radius will be given in millimeter.

If it is in ASA system, after tool nose radius value, inch will not be mentioned but you have to take it as inch since the nomenclature is in ASA system. You have to always convert it into micron or millimeter. This is the sequence and you have to read it in the way that 0^0 means 0^0 inclination angle. 6^0 means the normal rake angle will be 6^0 and so on.

As, I told earlier that if we have one tool purchased from the ASA system, and being used in the ORS system, these angles have to be converted when the tool has to be reground. This conversion is not a very difficult one, because if you combine these planes that is the coordinate system planes and the orthogonal rake system planes, and, in these planes if you show all those angles you can always relate them.

Or for example, if you are converting the ORS system to NRS system, then you have to put both ORS and the NRS planes together.

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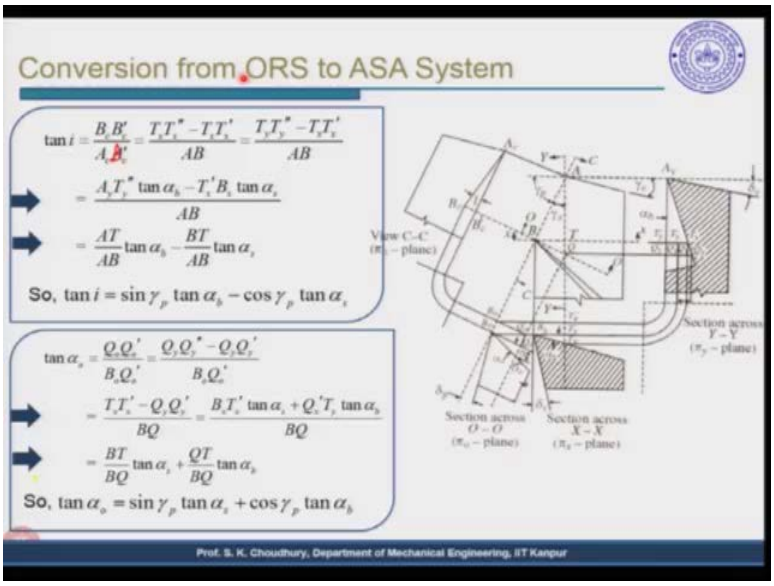

Let us take an example here. This is how the conversion can be made. Let's say this is the conversion from ORS to ASA, that is orthogonal rake system to American system, coordinate system. So, let us look at this how we are combining these planes together, let's say this is the base plane. In the base plane we will take sections C-C, this is the cutting plane as in case of the ORS or as in case of the NRS, then we will take the Y-Y as in case of coordinate system, we will take another plane X-X as in case of coordinate system.

So, you have the coordinate system X and Y. Now, in the ORS we have taken C-C. Then we have to take another plane which will be perpendicular to the principal cutting edge, which is the orthogonal plane and we are taking this orthogonal plane. Within these planes we can show all those angles in the coordinate system and the ORS system, then we can correlate them together. So, this is what it is shown here.

Now, in the C-C section given here, since this is the view so, it is not hatched. In this view we have the rake face here, and this is the tool inclination angle as the tool is inclined and Y-Y section is given here. So, this is the sectional view of Y-Y and this is the transverse plane. So, in the transverse plane you have the rake face here, the flank face here.

So, this angle will be the back rake angle as in case of the coordinate system and this angle is the end flank angle as in case of the ORS as in case of the ASA system. So, this is the view along the Y-Y section, which is the ASA system. Similarly, this view along the X-X it will be in the ASA system and this in this view, sectional view, this is the rake face this the flank face. So, this is the side flank angle and this is the side rake angle as in ASA and so on.

Similarly, here is the orthogonal section O-O. This is the orthogonal rake system and this is the orthogonal rake angle and this is the principal flank angle and so on. So, you can see that all the angles of the ASA system are here and of the ORS in this view and in this view.

Now, if you correlate them, then we can actually have the combination or the relationship between the angles from the ORS to ASA and vice versa ASA to ORS. Let's see how it can be done. Let's consider $\tan i$ in this view, this is $\dfrac{B_c B_c'}{A_c B_c'}$.

$A_c B_c'$ is equivalent to AB. So, I will not go into all the details, what I will like to show you is how this conversion can be made in one example, then all other examples will be similar. This is simply a geometric conversion; in this view this is the tan *i*.

This can be correlated to all other planes. Since we are converting angles from ORS to ASA system, we will initially relate the cutting plane C-C to the base plane.

The base plane is common in the ASA, ORS and the NRS systems. $B_c B_c'$ from cutting plane can be projected to orthogonal plane, O-O. This can be done by taking two mutually perpendicular planes, you project these points here and from here you take it to the other planes.

These points can be taken from the cutting plane to the orthogonal plane, and then through the X-X plane to the Y-Y plane as shown in the slide above. For example, you can see from the slide that the $B_c B_c'$ has been projected to Y-Y plane as $T_X T_X''$.

So, as you can see that the views in base plane, cutting plane, orthogonal plane, longitudinal plane and transverse plane can be correlated to correlate the angles in ASA and ORS systems.

By correlating the views and therefore, the angles, finally, what we get is that $\tan i = \sin\gamma_P \tan\alpha_b - \cos\gamma_P \tan\alpha_s$, where, the γ_P is in the base plane, both the back rake angle, α_b and the side rake angle, α_s are in the ASA system, whereas, i and γ_P are in the ORS system. So, you can see that this equation which is nothing but geometrically obtained from all these views, which are the combination of the ASA and the ORS systems that you can correlate.

So, if you know the α_b and the α_s and the γ_P then you can find out what will be the tool inclination angle. Similarly, for $\tan\alpha_o$, which is given here in the orthogonal plane, from this geometry you can find out that $\tan\alpha_o = \sin\gamma_P \tan\alpha_s + \cos\gamma_P \tan\alpha_b$.

Similarly, as we have done it earlier, in this case, we are actually converting - taking them from one plane to another plane and we are getting the final equation here. So, look at these equations carefully and correlate with these planes, you can visualize this very well; it is simple geometry like I have explained.

So, now we have discussed three different systems in which the tool can be nomenclatured or tool angles can be defined and these three systems are different, these three systems can be correlated. For example, here we have shown the conversion from ORS to ASA.

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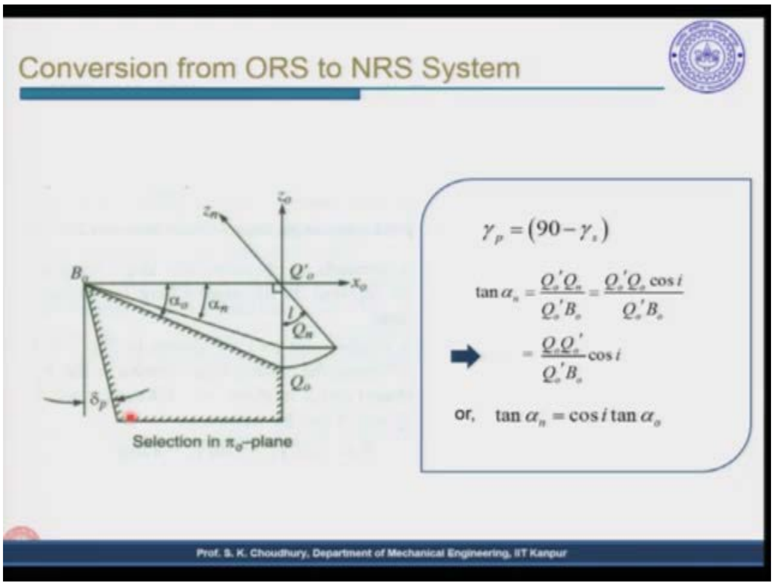

Similarly, we can convert from the ORS to the normal rake system, international system. Suppose we have the tool in the ORS system. So, this is the tool in the ORS system. Therefore, this is the angle which will be orthogonal rake angle in the orthogonal rake system and this will be the principal flank angle because the tool is in the ORS.

Now, in this system, which is in the ORS, with respect to this system of axes we are inclining this Z_0 at an angle of i and we are getting an axis which is Z_n . So, Z_n will be pertaining to the normal rake system, because it is inclined to the ORS by an angle of i, that is the tool is inclined.

Now, we can project all these points on this axis. This tool we will redraw in the normal rake system. This point we are projecting like this here and on the Z_n axis and then from here we are coming to the Z_0 axis. So, this point is transferred from here to here. Once again, this is the tool which is in the ORS system.

Now, this tool we will convert to the normal rake system. To convert that we are making a system of axes which will be inclined by an angle of i. Therefore, this point can be projected to the Z_n axis and from Z_n axis we are coming back to the ORS system Z_0. So, this point is converted here, then if you join this line, this point B_0, and, this point let say this is Q_n, then this angle that we are getting will be normal rake angle.

This is the rake face, newly made rake face which will be in the normal rake system, because this is inclined. So, earlier we had this face which was the rake face for the ORS system making an angle of orthogonal rake system with the X_0 axis.

Now, this angle that is between the B_0 Q_n and the X axis, this angle will be the normal rake angle, because we have projected this tool to the normal rake system, that is the Z_n. And this system is inclined to the Z_0 by an angle of i. So, after you do that then you use simple geometry; as we said that the principal cutting edge angle is $(90-\gamma_s)$.

So, then you take the tan of this angle, α_n and by simple geometry you can find out, that $\tan\alpha_n = \cos i \tan\alpha_0$. So, as you can see that α_n is in the normal rake system whereas, i and the α_0 are in the ORS. So, this is a conversion from the orthogonal rake system to the NRS.

α_0 is the orthogonal rake angle, i is the tool inclination angle and α_n is the normal rake angle, this is in the NRS and the orthogonal rake angle is in the ORS. So, this is relating the NRS and the ORS system. Rest of the things we will discuss in the next class.

Thank you very much.