Manufacturing Processes II
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Lecture No.3
On Tool Geometry

Our subject you know is Manufacturing Process - II and today our Module – II.

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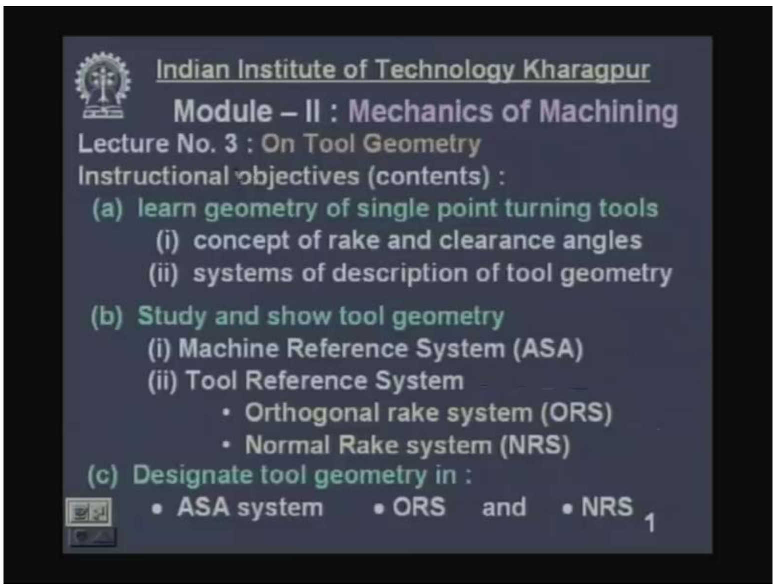

So Module II starts and topic is Mechanics of Machining. This mechanics of machining will deal with tool geometry, mechanism of chip formation and mechanics of machining, that is cutting forces. Now lecture number 3 : the first lecture for the Module II - On Tool Geometry. The instructional objectives what will be the contents. (a) learn geometry of single point turning tools. (i) concept of rake and clearance angles then (ii) systems of description of tool geometry (b) Study and show tools geometry in Machine Reference System. It is also called ASA system, Tool Reference System. Within tool reference system, there are two Orthogonal rake system ORS and normal rake system NRS, and finally designate or specify tool geometry in ASA system, orthogonal system and normal rake system. Now before we go into the real tool geometry, let us go to the workshop, the laboratory to demonstrate the real life some machining operations of in conventional machine tools.

Young friends look this is a conventional machine tool and called plaining machine.

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The main constructional features are - it has got a long bed, you see on which a table that will reciprocate and on the table the job will be mounted and this is the cutting tool which is mounted on the tool holder and this cutting tool moves in two directions, in horizontal direction and as well as in vertical direction. This is called the rail and this is called the frame and the operational characteristics are this produces generally flat surfaces.

It can be horizontal flat surface in the vertical plane and even in inclined plane it can produce flat surface besides it can produce grooves of different sections. Now, this machine is looks very large but basically it is a baby machine of its kind. So such machine is used mainly for large jobs, heavy duty work for heavy duty work and if this cutting tool is replaced by say milling cutters then this will be converted into or called plano miller and instead of one cutting tool there can be number of cutting tools.

You see one, two there can be more than four or five cutting tools and there can be large number of milling cutters and if the milling cutters are replaced by grinding wheels then this will be called planogrinder. For example, this table which has got flat surface and large number of grooves and other surfaces this is a single piece how this part can be machined such a large part can be machined only in this kind of machine tool by either straight single point cutting tools or a large number of milling cutters and finally finished by grinding wheels. In this planing machine, in any machining you know there should be

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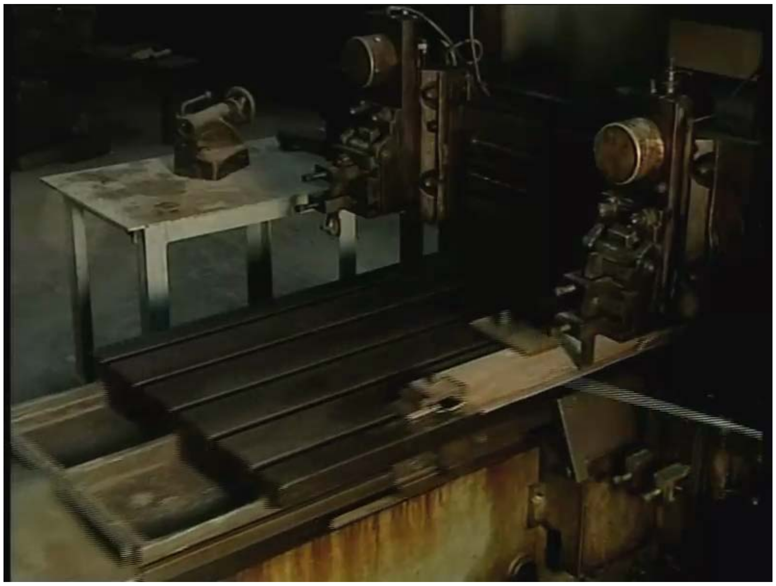

one work piece to be machined and a cutting tool which will produce the machining work and for machining there must be a relative movement between the job and the tool. Here the job is making a longitudinal movement straight longitudinal movement and this is called cutting motion and this cutting tool that is moving horizontally that is called feed motion and this feed motion in this direction is very slow and the combination of this cutting motion on the job and feed motion on the tool in this direction will result a horizontal flat surface. These are the chips and these two relative movements will

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continue until the work is complete. Combination of this cutting motion and the feed motion produces what is called a flat surface. Now here in front of us, we see one machine tool called the lathe and this is the most primitive widely used common

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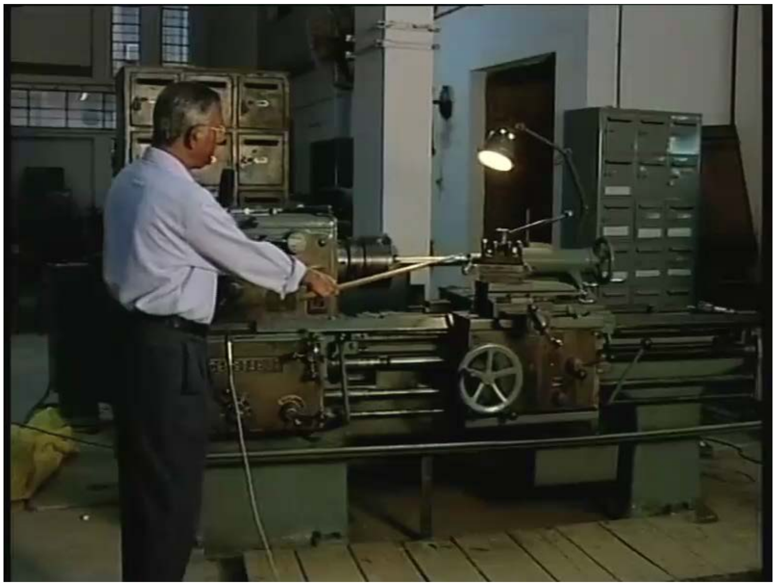

and very versatile machine tool. The main components are this is the head stock. On the head stock there is a job holding device called chuck and this is the work piece which is cylindrical in nature which is mounted here on the chuck and this head stock provides power and rotation to the work piece and this is the tail stock. Tail stock gives the support to the work piece at this end and these head stock and tail stock both are mounted on a long bed called lathe bed and this lathe bed rests on two columns on the floor.

Now this is the vital part of the machine tool called cutting tools. There may be two or one cutting tool mounted on the tool holder. This cutting tool comes into contact with the job and when this job rotates the cutting tool moves axially and gradually removes the material for finishing the cylindrical surface. Now this cutting tool is mounted on the tool holder. Tool holder is mounted on the tool post. Tool post is mounted on the compound slide. Compound slide is resting on the cross slide and cross slide is resting on the saddle and saddle on the entire carriage and this portion which is hanging with a lot of mechanisms inside is called apron box, and this job which is rotated derives this motion power from the head stock and in the head stock power comes from the motor inside, and this cutting tool which moves linearly derives this motion from the feed rods.

There is one feed rod, one lead screw and one clutch rod. By operating these wheels, we can give depth and we can give the manual feed and automatic feed and this can be rotated at different rpm. This is the basic construction of a lathe. Now lathe can be of different type - this is an automatic, manually operated, center lathe.

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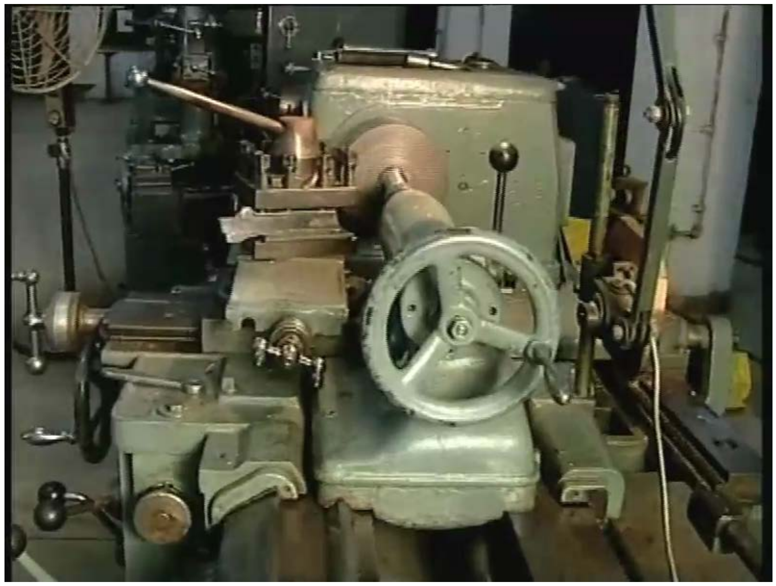

Now you will see some of the machining operations done in this kind of center lathe. I already told that in this machine, various type of machining operations are done but I shall show you only few. Here you can see that this is the work piece which is subject to rotation. Now we are making a small hole by a drill center drill mounted on the chuck and this is the tailstock. Now next operation will be facing. This surface will be smoothened, flattened. This operation is called facing operation. So the relative movement between the job rotation and the linear motion of the tool that is called feed motion in this direction produces the flat surface.

Now next you will see the turning operation. Turning operation means that the cylindrical surface will be produced. Now, presently the cylindrical surface is not very smooth. Now this will be smoothened by removing excess material in the form of chips. You see the chips are formed and you get a very beautiful smooth, cylindrical straight surface. This is called straight turning. Like this various other types of operations can be shown.

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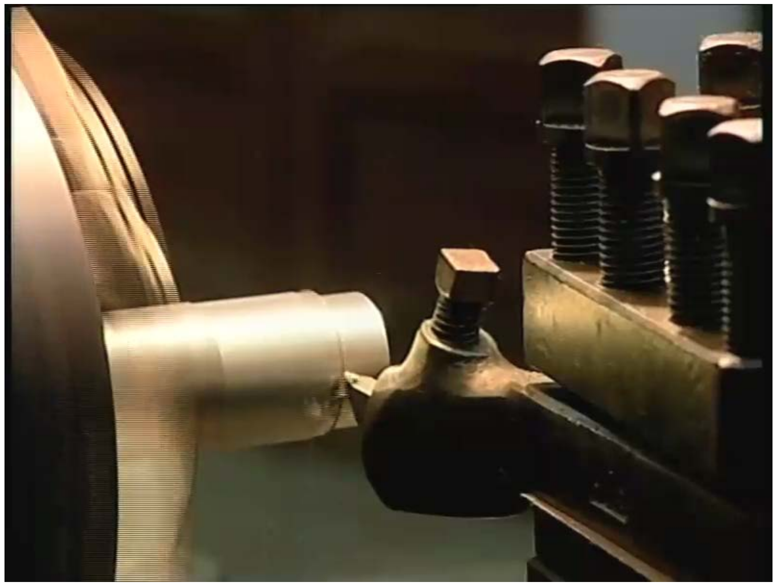

Now this is another very primitive but commonly used machine tool called shaping machine. This basically produces flat surfaces which may be horizontal, vertical or inclined. This can also produce slots and grooves. Principle is here is a work piece,

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suppose this top layer has to be smoothened and flattened by removing this layer gradually. Now here the metal will be removed in the form of chips strip by strip with the help of the cutting tool. This cutting tool is mounted on the tool holder which is fixed in to the rim which is main part of the shaping machine which reciprocates forward and

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backward and the forward motion is the cutting motion that removes the chip then it comes back. After removing one strip of material, this work piece will come this side or that side and that is called feed motion. So combination of this cutting motion of the tool and feed motion of the job produce the flat surface. Now this flat surface is produced by removing the excess material from the top,that is the top layer strip by strip with help of the cutting tool in the form of chip.

Now this rim reciprocates on the guide and the guide is part of the main structure housing of the body and this is the motor - source of power and this is the table on which vice is mounted and on the vice the job is fixed. This job can be made to move with the help of the screw arrangement. This is the feeding automatic feeding arrangement step by step, and this is the arrangement for changing the length of stroke and the speed of stroke and this is used for small lot production not for mass production or heavy job production. This is used in tool rooms mainly. Now this machine tool is called milling machine.

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There are different types of milling machines. This is conventional milling machine and here you see, this is the cutter which is mounted on a rod like called arbor

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and this is the base of the body which is looking like a knee. So this machine milling machine is called knee type horizontal arbor conventional milling machine. Basically it is used to produce flat surfaces like this flat surface. This flat surface can be again vertical, incline or say horizontal. It can produce other forms also like slots, straight slots, circular slots, semicircular slots for various purposes. Milling arbor is fitted into the rim and this rim can be shifted according to requirement.

It is resting on the machine body. It is a machine body, power comes to this cutter which rotates from this motor and there are gear boxes. Here speed gear box and feed gear box inside which controls these rotation speed of the cutter and this is the work piece. Work piece is mounted firmly on a vice. Vice is fixed on the table. This table is made to move on a bed, this is the bed and the bed is resting on a cross bed and this is entire body which can make this job move vertically up and down. It can move in x axis, it can move in y axis, it can move in z axis and combination of this cutting motion and feed motion produces the desired machine surface. This shows another configuration of the same conventional milling machine.

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Previously you saw horizontal axis cutting tool. Now here, this is the axis of the cutter and this is vertical, of course it can be inclined also, swiveled with the help of this swiveling arrangement and now you see the cutter along this axis. This is the actual cutting tool, this is called end milling cutter. This rotates about this axis at high speed and this is the work piece. Here you can see that it is producing a slot, so this is called slot milling with the help of an end milling cutter. Now you will see the actual machining operation in this process.

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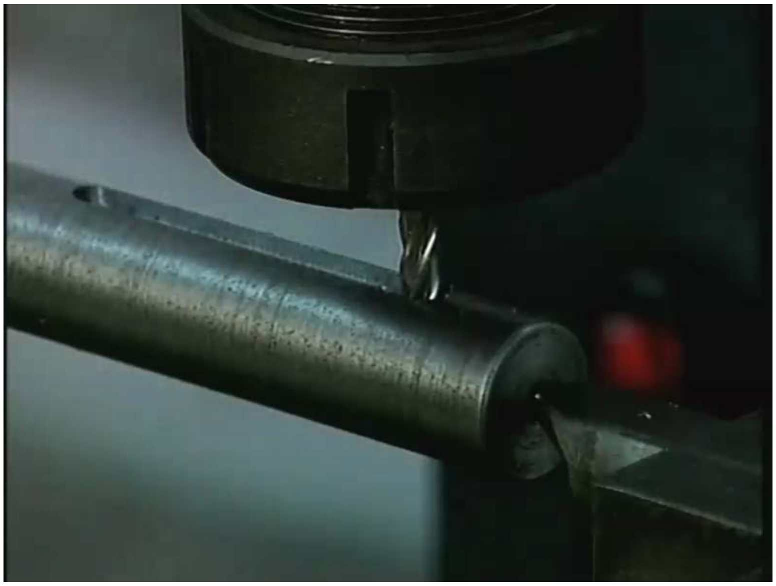

This is the slot which is going to be cut by this end mill cutter and this will rotate about its own axis and the job will be gradually moving in that direction. So the cutting tool is now rotating at high speed that imparts what is called cutting motion and now the job is moving to produce the slot. You see the job work piece the rod like is moving slowly along its axis and relatively the cutting tool is moving along the slot. The slot was cut earlier but not finished. Now it is going to be finished with full depth. This is called slot milling, the milling cutter can be of different size. It may vary from half millimeter to about thirty millimeters. This shows a drilling machine.

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In drilling machine the main function is to make circular hole or cylindrical hole

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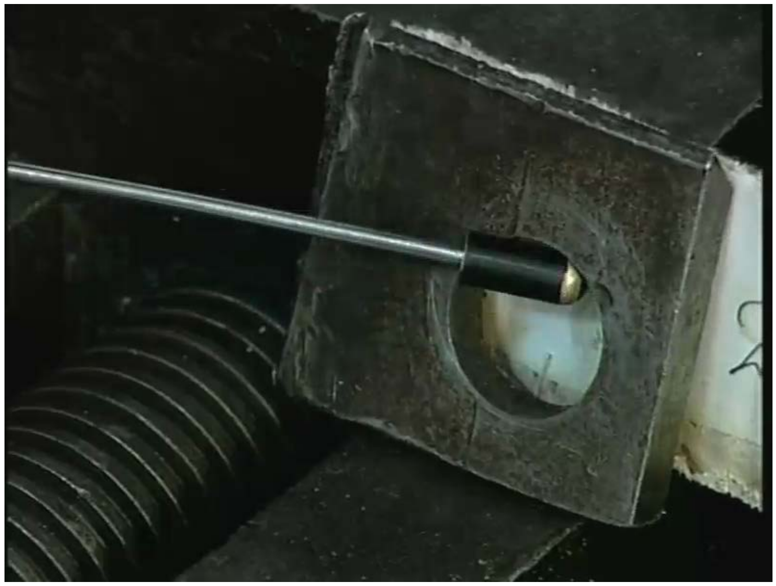

in solid body like this, which requires a cutter like this called drill or drill bit. The drilling cutter which makes the hole and this is the drill point which the main cutting

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point. It has got two cutting edges. One is here you can see. Other one is on this side, so one cutting edge is here and another cutting edge is here. This is the radial arm, you see the stress radial arm and this is the drilling head holding this drilling spindle in which the drill is fitted. So this drill spindle can move up and down to move this drill vertically up and down and this milling head can be made to move radially over a wide range. Secondly this radial arm can also be moved up and down along this column. Thirdly this arm can be rotated about the axis of this column by three sixty degree. This is the bed on which the vice is mounted on to the vice the job is fixed. There are different types of milling cutters sorry different types of drilling machines and this is the radial drilling machine which is the largest of its kind and is very versatile and it can work on work pieces of large size placed anywhere around it.

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So this is used for generally batch production not mass production, batch production or piece production and only for making circular holes. This is one of the grinding machines. Now what is the grinding machine, purpose of to make the surfaces accurate

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and smooth machining like shaping, milling, turning in lathe cannot produce very high accuracy and surface finish. For that, such kind of grinding operation is necessary. Grinding machines can produce flat surface, cylindrical surface and contour surface. This particular machine is called surface grinder which finishes only flat surfaces as shown over here.

Now this is the grinding wheel. This rotate this is a milling this is the cutter, grinding wheel cutter which rotates at high speed. Now you will be shown one surface grinding operation in this surface grinding machine, before that you see there are two pieces already finished by grinding and these shining surfaces are produced and this will be produced on this surface by grinding that is the grinding wheel which will rotate at high speed and this will reciprocate in this direction. Combination of these two motions will produce the surface. You can see the small chips which are coming out they are now getting burnt and coming out in the form of sparks.

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Now let us go back to the class.

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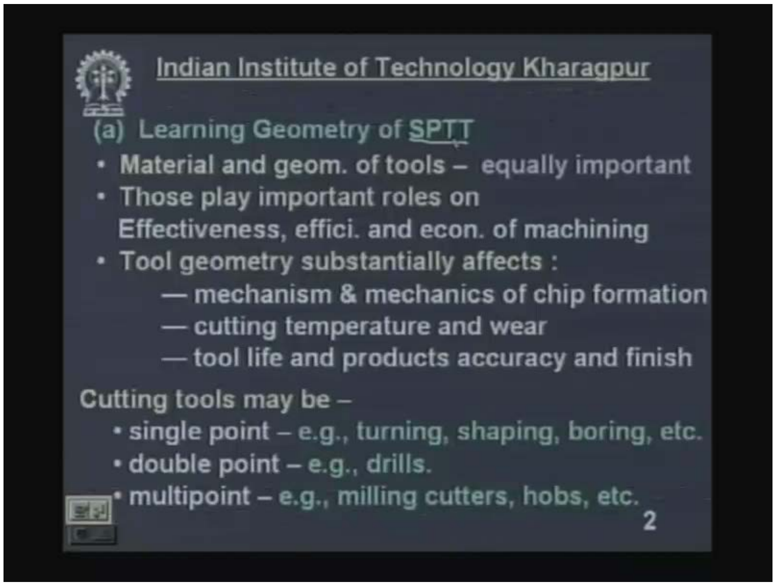

Start with learning tool geometry of SPTT that is, single point turning tool. It is simply told SPTT. Now we should remember before going to the tool geometry why it is so important. Material and geometry of cutting tools are very very important and both are equally important so far as machining, machinability, machine economy are concerned. This tool geometry and tool material plays important roles on effectiveness, efficiency and economy of machining.

This tool geometries substantially affects or governs mechanism and mechanics of chip formation that is, cutting forces, cutting temperature and tool wear also tool life and products accuracy and finish. So tool life and quality of the products. Now the cutting tools may be of three category. It can be single point - only one point will be there, only one cutting point. For example, turning in a lathe, shaping in shaping machine, planing machine, boring machine etcetera. Double point - there are two cutting edges, two primary cutting edges. For example drills then, multi point cutting tool where the cutting tool has got large number of cutting edges. For example, milling cutters, hobs for cutting the teeth of gears, gear shaping cutters, grinding wheel of course in grinding wheel large number of cutting edges are there etcetera. Now come to geometry of single point turning tool. So continued, concept of rake and clearance angles. When you talk about tool geometry, the rake angle and clearance angle are the most important. Tool geometry refers to when you talk about tool geometry what does it mean really?

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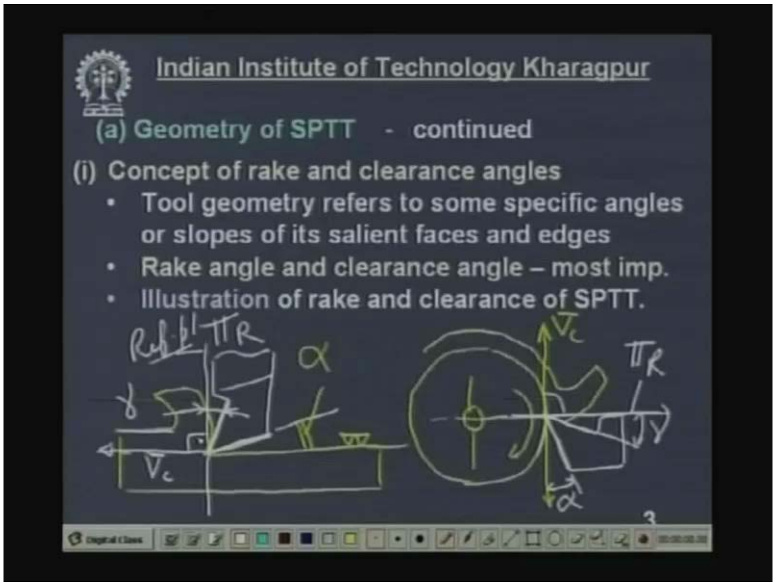

It refers to some specific angles or slopes of the cutting tools, salient faces and edges or like cutting edges rake angle and clearance angle are the most important features of the cutting tool. Now, illustration of rake and clearance of single point turning tool.

Now I shall show you really what is meant by rake and clearance angle. See here, this is a cutting tool and it is machining assuming the chip. So, this layer of material is getting removed by this cutting tool. So this is the cutting velocity, this is the direction of cutting velocity. This is called V_c cutting velocity, it is a velocity vector. Now this is the cutting process. Now what is rake angle? Rake angle means - what is angle? Angle means inclination of the some phase of tool with respect to certain plane some reference plane.

Now you take one reference plane. This plane is called reference plane denoted by pi R. Actually this reference plane pi R is nothing but a plane perpendicular to the velocity vector. Now what is rake angle? Rake angle is the inclination of the rake surface of the tool, from the reference plane. So, this angle is called rake angle denoted by gamma. What is clearance angle? Clearance angle is angle of inclination of the flying surface or clearance surface of the tool.

Clearance or flying surface of the tool from the machine surface, because this is the machine surface and this angle is called clearance angle denoted by alpha. Now in another case in turning, suppose this is a rod going to be machined by a cutting tool. The job is rotating like this and a layer of material is getting removed in the form of chip. In this case, we have to show the velocity vector. Now velocity vector in this case when this rotates and these are contact point. So this is the velocity vector either in this direction for the job and this is for the tool this is velocity vector.

Now what is reference plane? Reference plane is perpendicular to this plane, perpendicular to the velocity vector. So this is reference plane denoted by pi R then what is rake angle? Rake angle is the angle of the inclination of the rake surface of the tool from the reference plane so this is gamma, and this is the flying surface angle of the flying surface from the finished surface of this velocity vector is alpha. It is a concept of rake angle and clearance angle. Now see what is the function of rake angle? Rake angle is provided in cutting tool to facilitate machining work. The machining becomes easier that is with less effort, less cutting force then with less energy requirement, less temperature and so on if rake angle is given. What is the purpose of clearance angle? To avoid rubbing between the flying surface of the tool and the machine surface then the machine surface will be spoiled if rake angle is not there if this gap is not there it will be spoiled and tool will be also damaged. So this clearance angle will be provided like this. Now let us go to the concept of rake and clearance angle continued.

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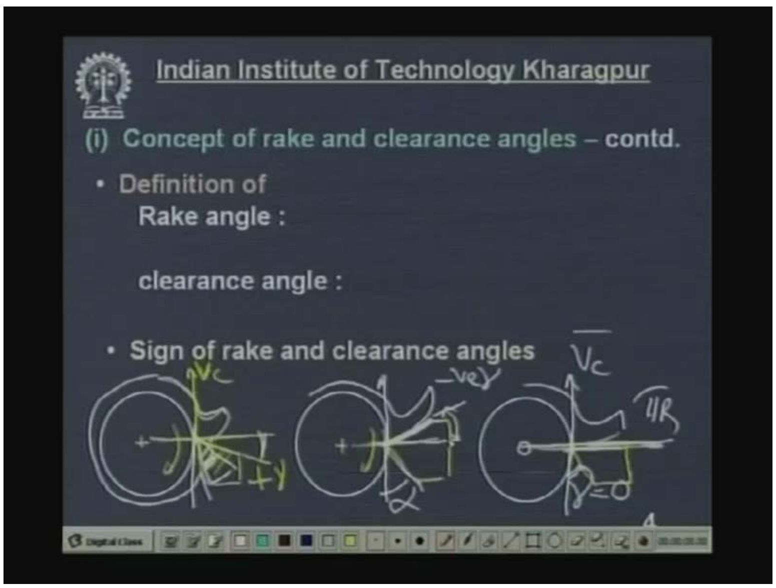

Definition of rake angle - I already told the rake angle is the angle of inclination of the rake surface of the tool from reference plane and what is reference plane? Plane perpendicular to the velocity vector. What is clearances angle? Angle of inclination of the tool flank or clearance surface from the finished surface. Sign of rake and clearance angles. Now friend, this rake angle can be positive, can be negative, can vary it can be zero also. So, this is a work piece. It is rotating in this direction. Now you take a tool and the chip flows like this from the work piece.

Now in this case, this is the tool and this is the velocity vector, this is the reference plane this is the rake surface and this is the rake angle, this is positive rake but, if the tool takes this shape and the chip flows like this, then this is the velocity vector, this is the reference plane, these are rake surface of the tool and this angle is the rake angle, but this is negative rake. It can be zero also if the cutting tool is taken in this form and the chip comes out like this. Then this is the velocity vector, this is the reference plane and this is the rake surface of the tool. So, the rake surface of the tool and reference plain aligned.

So there no gap, no angle this is called zero rake. So gamma is equal to zero, but it has to be remembered that the clearance angle in this case these are all clearance angle. Clearance angle has to be always positive. It cannot be negative. Positive say from four degree to sixteen degree depending upon the work material, velocity, tool material and it is a free kind of machining operation and so on but, it should be always positive, but rake angle can be positive and negative. Positive means lesser force, less stress and all these things less temperature but if the rake is positive and large then the tool becomes very thin. If this rake angle is very large, then this tool edge the wedge angle will be very small and it will be mechanically weak. So to strengthen the tool mechanically, we use negative rake particularly when the tool material is brittle in nature. Now reference systems of description of tool.

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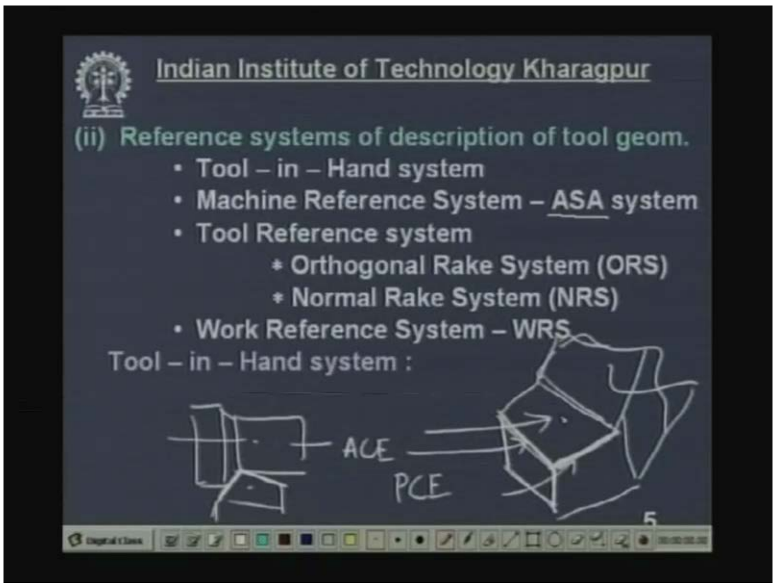

Now tool can be tool geometry can be described in different systems of reference followed in different countries for different purposes and different environment situations.

1.Tool - in - Hand system. It is one method. Machine reference system this is also called ASA system where ASA stands for American Standards Association. Then tool reference system. In machine reference Tool Reference System, Orthogonal rake system simply ORS Normal rake system NRS and work reference system in machine reference system machine configuration is taken as the reference.

In tool reference system the configuration of the cutting tools is taken as reference. In work reference system the configuration of the work piece and the cutting tool together are taken as reference. Now, Tool - in- Hand system, what is it? You take a tool the concept is you take a cutting tool on your hand and you identify some of the features or most important features like cutting edges, rake surface, clearances surface and so on.

Here you cannot describe or specify the angles. For example - say this is the machining operation, this is a cutting tool and this is the work piece, it is the turning operation.

This is the main cutting edge which removes the chip. This is called auxiliary cutting edge, this is the rake surface of the tool and clearance surface are vertical. Now, this can be shown in this way also in three D. So this is the cutting tool. This main cutting edge is here. This is the main cutting edge, auxiliary cutting edge is this one. This is the rake surface this is the this surface is rake surface this is main cutting edge or principle cutting edge this is main cutting edge or principle cutting edge. This one is auxiliary cutting edge ACE auxiliary cutting edge. This is the principle flank or principle clearance angle. This is the flank surface and this surface is called auxiliary flank surface or auxiliary clearance surface.

So what we see, that this tool will be in your hand and you can mention only this is the tool shank, this is the main cutting edge, this is the auxiliary cutting edge, this is the rake surface, this is the principle flank, auxiliary flank and this is the tool tip or tool nose this much. Here we do not tell or we cannot quantitatively specify the value of the angles.

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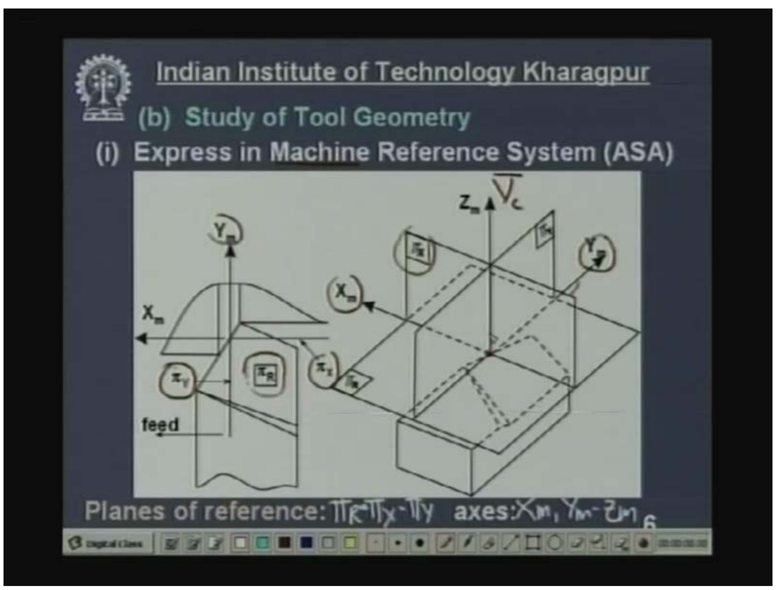

Now Express tool geometry in Machine Reference System. In machine reference system, you can visualize qualitatively and quantitatively also. Now, here we have to visualize the angles. I told that angle means inclination of some feature or phase of the tool with respect to certain planes. Now, we have to take some planes for reference with respect to which inclination have to be measured. Now what the planes of reference? The planes of reference will be, in this diagram this shows the turning the top view of turning operation and this is the horizon normally the horizontal plane. You take any point on the cutting edge, and since it is horizontal plane velocity vector will be perpendicular to this point. It will be perpendicular to this plane.

So this is the velocity vector perpendicular to this then what is reference plane? Reference plane is perpendicular to the velocity vector, when velocity vector is vertical then the reference plane will be this one. So this board or the plane refers to pi R reference plane. Now, there should be three planes, three orthogonal planes perpendicular to each other taken for reference. So this is pi R. So one is pi R, next you take another plane. This plane which is parallel to the direction of feed and this plane is perpendicular to pi R. It will be perpendicular to pi R that is, it will be vertical plane. This is called machine longitudinal plane expressed by pi X. So machine longitudinal plane pi X. Now this is another plane which is perpendicular to pi R as well as pi X.

So, this is taken in the direction perpendicular to the longitudinal feed or taken in the direction of cross feed and this is perpendicular to pi X as well as pi reference plane. So, this is also a vertical plane and this is called machine transverse plane. Now this can be visualized in a three D picture. Now in this diagram this shows the tool, this shows the cutting tool and at this point you take the velocity vector.

So this is velocity vector and Zm, axis Zm - m stands for Machine Reference System. This machine reference system and then this is taking the direction of machine longitudinal plane and this axis is Xm. So, this is the machine longitudinal plane and the machine transverse plane is this one. So machine this is the reference plane which contains Xm axis and Ym axis Ym. Then this machine longitudinal plane contains Zm axis and Xm axis and the machine transverse plane this machine transverse plane this one contains Ym axis and Zm axis. So the axes are Xm, Ym and Zm. Xm is taken in the direction of longitudinal feed or main axis of the machine tool. Ym is the transverse axis of the machine tool and Zm is the velocity vector that is vertical line.

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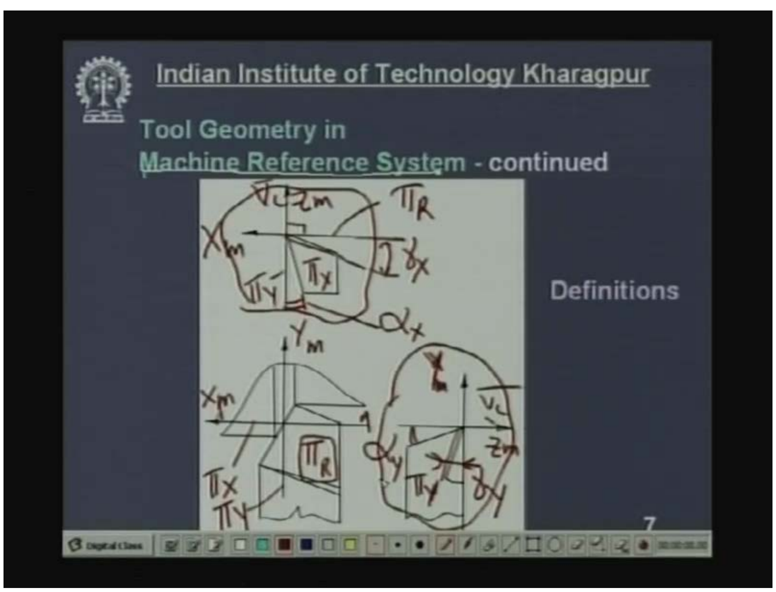

Now come to the tool geometry that would be the angles in the Machine Reference System. In Machine Reference System or this is also called ASA system. We shall visualize now the various angles. Say first rake angle what is this plane? This is the top view so this is pi R plane in which this diagram has been drawn because velocity vector is perpendicular to the plane. Now this is X axis Xm and what is this plane perpendicular to the pi R? This plane is pi X. What is this axis Ym m stands for machine reference system and this plane is machine transverse plane pi Y. Now if you take a section, cut the cutting tool by this plane which is pi X plane you cut it vertically and then you just remove this portion. Look at this portion of the remaining tool. So this is the view.

So in what plane this view has been drawn in pi X plane, because the tool has been cut by pi X plane. So this is drawn in pi X plane, this is the cutting tool. Now, this is Zm or this is the velocity vector. This is Xm and where is Ym? Ym is perpendicular to this plate. Now what is this plane? This is pi R because, this is perpendicular to the velocity vector and this one is pi Y plane, and this diagram has been drawn in pi X plane. Now friend, this is the rake angle why angle of inclination of the rake surface from reference plane. So, this is gamma but in which plane it has been drawn, in X plane pi X plane. So this will be denoted by gamma X and this gamma X is called side rake.

So, what is a side rake now and this is the clearance angle. So this is alpha and drawn taken on measured on X pi X plane so this will alpha X. Side clearance, side rake and side clearance. Now, if you now cut the cutting tool by this machine transverse plane pi Y vertical plane and look into this portion of the tool. So this is the diagram drawn in which plane? Pi Y, that is machine transverse plane. In this plane then this will be Zm and this will be Xm Ym this Ym. Now this is the rake surface of the tool, this is the reference plane because this is the velocity vector this one. So, this is the reference plane this is the rake surface. So this angle is a rake angle gamma but measured in which plane? Transverse plane gamma Y. This is the clearance angle alpha, in which plane it has been drawn? gamma pi Y. So this is alpha Y. This is called back rake and back clearance. Now here again in this diagram we can also show.

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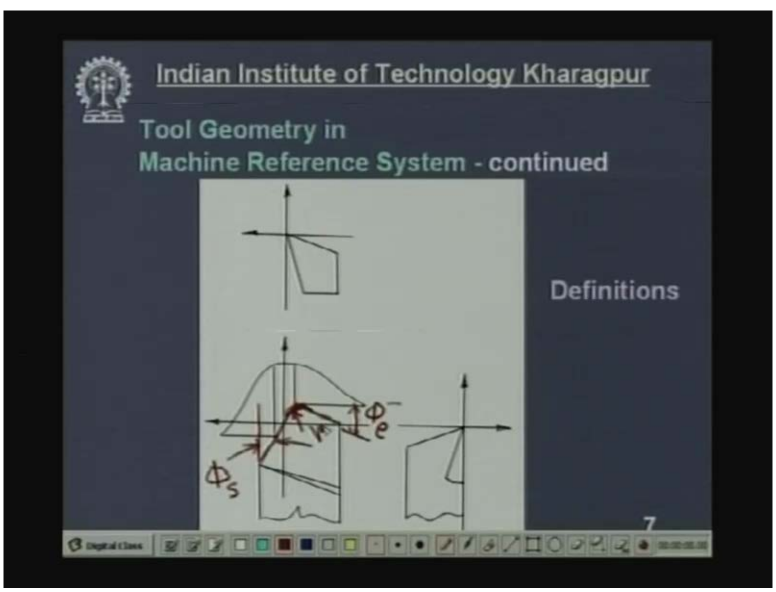

What is this angle? This is called cutting angle, this is the cutting edge main cutting edge this is the cutting angle and this is denoted by phi S. This is called approach angle angle of inclination of the main cutting edge from machine transverse plane. So this is pi Y machine transverse plane phi S and this angle is called end cutting edge angle phi e so what is the definition of approach angle this cutting angle.

Angle of inclination of the main cutting edge from machine transverse plane parallel to this plane and what is phi e end cutting angle angle of inclination of the auxiliary or end cutting edge from the this plane that is X pi X plane and this is called end cutting angle and deliberately this nose is radiused instead of leaving it very sharp then it will be very weak and this strengthens this rounding strengthens cutting point and also improves the surface finish and with the radius of curvature. Say this radius of curvature is denoted by R. Now what is the definition? Now come to the definition of the angles.

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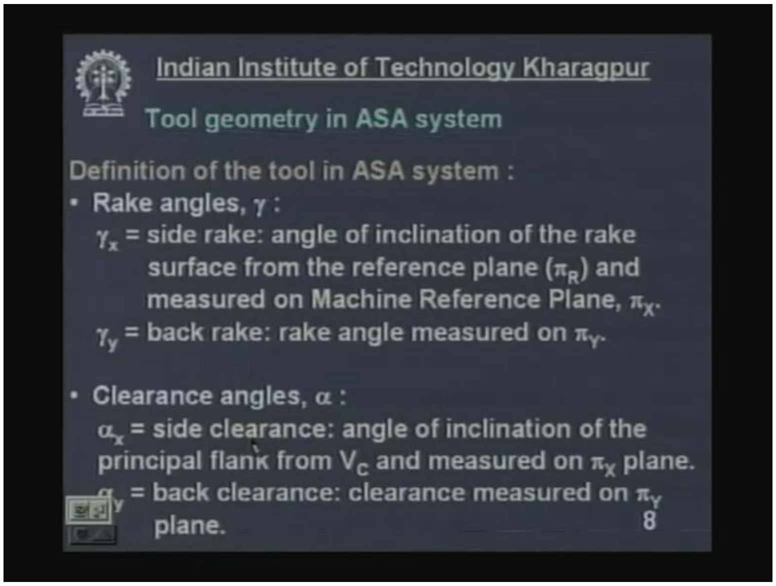

Definition of the tool angles in ASA system rake angles gamma, gamma X,side rake angle of inclination of the rake surface from the reference plane pi R and measured on machine reference plane pi X not machine reference plane machine longitudinal plane. This will be machine longitudinal plane gamma Y back rake, rake angle measured on machine transverse plane. Now the clearance angle already defined, that the cutting angles phi s the approach angle: inclination of principle cutting edge from machine

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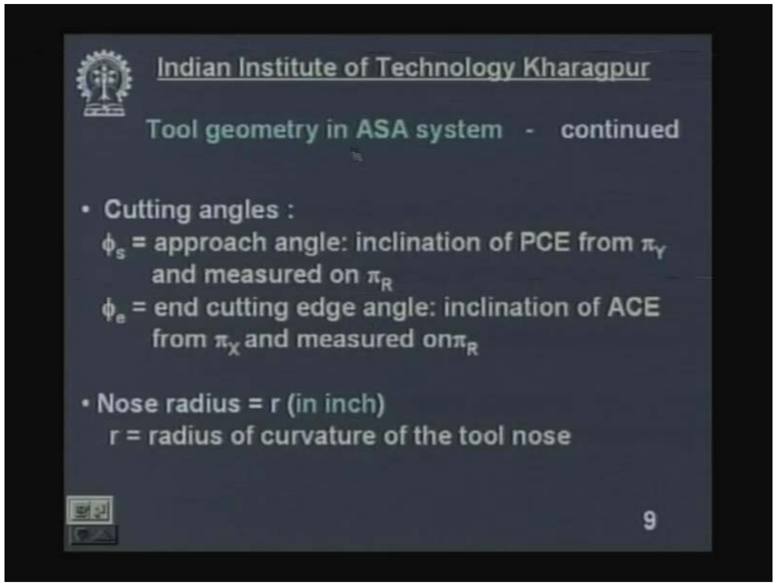

transverse plane and measured on reference plane. Both the cutting angles are measured on reference plane end cutting edge angle already defined. Now nose radius I already mentioned the purpose of radiusing the tool tip mechanically strengthen and better finish. This is expressed in inch in ASA system or machine reference system this has to be noted. Now R is the radius of curvature of the tool nose. Now come to tool reference systems.

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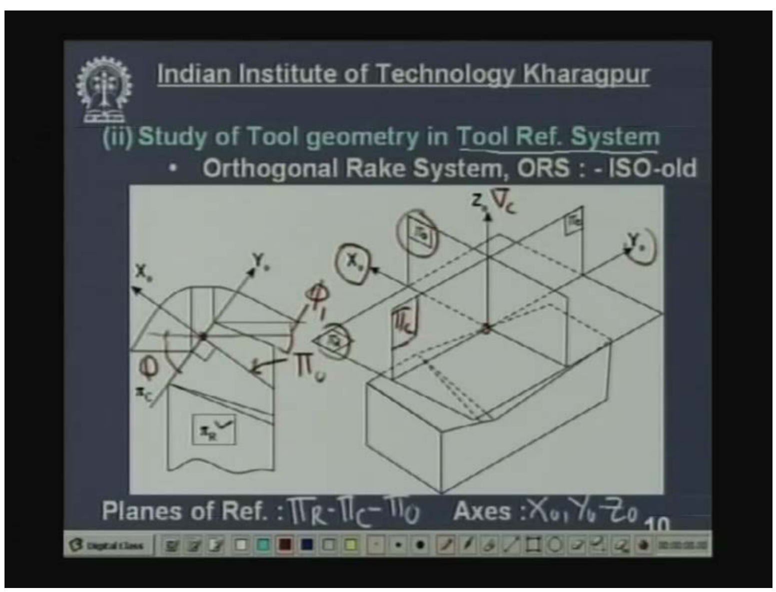

Study of Tool geometry in Tool reference system. Here, the configuration of the cutting tool is taken as a reference not the machine tool, again the tool reference system is classified into two type, orthogonal rake system symbolized ORS orthogonal rake system. This is also called ISO old International Standards Organization old technique and there is another new technique which kept in later on.

Now in this orthogonal rake system, you see the same top view of the cutting tool. Cutting tool this is the point on the cutting edge and this diagram has been drawn in a horizontal plane or pi R that is called reference plane. Velocity vector is perpendicular to this pi R perpendicular to this plate to this plane. Now, in machine reference system we took two planes in this direction, in the direction of feed and one perpendicular to that. Now in tool orthogonal rake system the axis are different one axis taken like this. This is called cutting plane, so here the reference are pi R that remains called reference plane. Then this plane called denoted by pi C cutting plane. What is cutting plane? Plane perpendicular to pi R and contains the main cutting edge. This is called cutting plane. Remember all these three planes should perpendicular to each other.

Now the other one is orthogonal plane. This is orthogonal plane denoted by pi o. So what are the planes of reference in orthogonal rake system pi R, pi C and pi o and they are perpendicular to each other and now this is Xo axis. o stands for orthogonal condition orthogonal tool o it is not zero. So they are three planes,, now what are the axis? One is Xo, next is Yo and third one is Zo. Zo is nothing but the velocity vector. Zo and Zm are same this is along the velocity vector. Now if we try to visualize these three planes along with the tool in a three D. So this will make give the better concept this is the cutting tool as you see the cutting tool and this is the point under consideration. This is the velocity vector which is nothing but the Z axis Zo and this Yo is this one is Yo, Yo axis and this X axis is shown over here.

Now this plane is cutting plane perpendicular to pi R. This is the pi R plane pi R and this is this cutting plane perpendicular to that. This is the cutting plane this is pi C cutting plane. Now, the orthogonal plane is perpendicular to pi R and pi R pi C cutting plane. So this is the plane this plane is shown over here. This is that orthogonal plane it is denoted by orthogonal plane so here you can see that pi R contains the X axis and Y, X axis and Y axis then pi C cutting plane that contains Yo axis and Zo axis and orthogonal plane Xo axis and Zo axis and Xo, Yo, Zo are perpendicular to each other. Now, in this diagram we can visualize the cutting angles. This is the principle cutting edge angle and this angle is called auxiliary cutting edge angle denoted by phi one. This will be shown once again. Now here you see the rake angles and clearance angles in orthogonal rake system.

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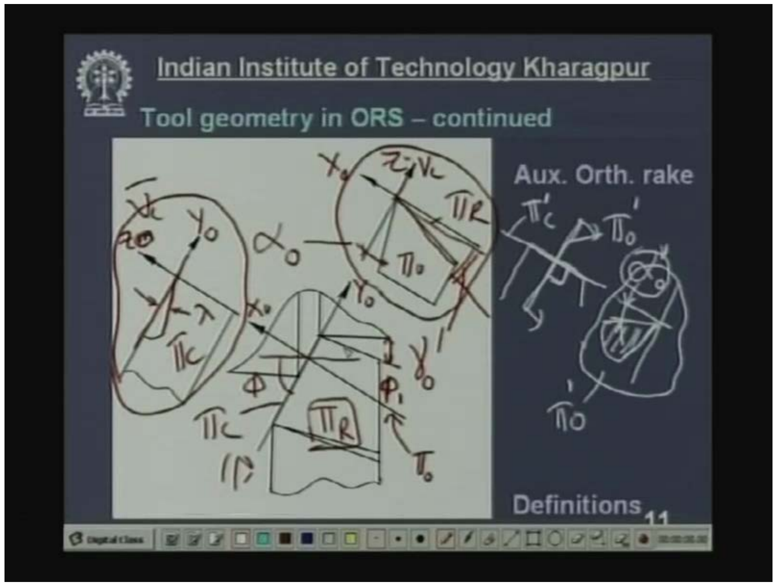

Now this is the cutting tool drawn in reference plane. This is drawn in reference plane top view of the cutting tool. This is pi X sorry this is cutting plane perpendicular to pi R and this is orthogonal plane perpendicular to pi R and pi C orthogonal plane. This is Xo axis, this is Yo and Zo is perpendicular to the plane Xo Yo. Now, you have to take the section of the cutting tool along this pi o plane orthogonal plane and if you take the section and look at this remaining portion of the cutting tool from this side then this is the view you get and this diagram has been drawn in which plane? In orthogonal plane.

Now this is the velocity vector or Zo this is Xo axis and Yo is perpendicular to the plane. So if this is the velocity vector then obviously this is the reference plane. This is rake surface of the tool. So this angle is rake angle but measured on which plane in orthogonal plane. So this will be denoted by gamma o and this is called orthogonal rake. Similarly, this clearance is taken in which plane? Orthogonal plane so this will be called orthogonal clearance alpha o. Now come see look at this cutting tool from this side along the along Xo axis and this is the cutting plane and then show the view here. So this is the cutting plane. This diagram has been drawn in cutting plane. So this is Zm or velocity vector and this is Y Y sorry Zo and this is Yo.

If this is the velocity vector Zo, then this is the reference plane and this is the rake surface of that tool because the main cutting edge is also part of the rake surface. So this angle is also a rake angle or angle inclination of the rake surface from reference plane but it is a main cutting edge, so this has got special name symbol lambda. This is lambda, inclination angle. Now cutting angles this is the main cutting edge an principle cutting edge angle and this angle is called auxiliary cutting edge angle phi one. In case of NRS system this is called phi e end cutting edge angle. Now here like this. Now auxiliary orthogonal rake, this is the main cutting edge, this is auxiliary cutting edge.

This is cutting plane what is cutting plane ? Plane contains perpendicular to pi R and contains the main cutting edge. Similarly, if you draw this tool, this is the main cutting edge this is auxiliary cutting edge and if you take a plane along this then this will be auxiliary cutting plane denoted by pi C prime and orthogonal plane is perpendicular to the cutting plane. Therefore there should be another orthogonal plane perpendicular to pi C prime. So this is another plane perpendicular to pi C this will be called orthogonal auxiliary orthogonal plane. Since the two cutting edges, main cutting edge this is the principle cutting plane, principle orthogonal plane and the auxiliary cutting edge auxiliary cutting plane and now if you take a section of the cutting tool by this plane then you take the view like this now in which plane you have drawn this diagram you have taken the section in pi o plane. So, this is pi o prime pi orthogonal or auxiliary orthogonal rake and this is the rake surface and this is the clearance surface.

So this clearance angle is denoted by alpha o prime and this is called auxiliary prime for auxiliary orthogonal clearance. Auxiliary orthogonal clearance of the auxiliary cutting edge and this is also radiused. Here also this is radiused with an value R. Now see the definition of the rake angles, clearance angles and cutting angles in orthogonal rake system.

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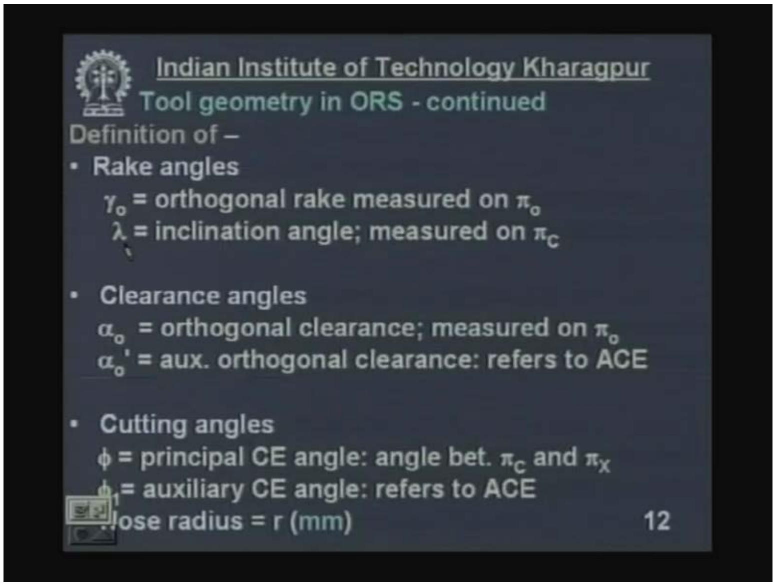

What is rake angle orthogonal rake? Orthogonal rake is measured on orthogonal plane but as such orthogonal rake means angular inclination of the rake surface from reference plane and measured on orthogonal plane then lambda inclination angle of the main cutting edge is also a rake angle, inclination angle is measured on cutting plane. Now the clearance angles. This is called orthogonal clearance of the main cutting edge.

Orthogonal clearance it is measured on orthogonal plane and what about auxiliary orthogonal clearance auxiliary ortho clearance? This refers to auxiliary cutting edge and this is measured on auxiliary orthogonal plane which have been shown. Now the cutting angles phi. Principle cutting edge angle angle between cutting plane and machine longitudinal plane. Phi one auxiliary cutting edge angle refers to auxiliary cutting edge angle it was shown. Now nose radius r but here you observe it is expressed in millimeters. Now, coming to tool reference system normal rake system.

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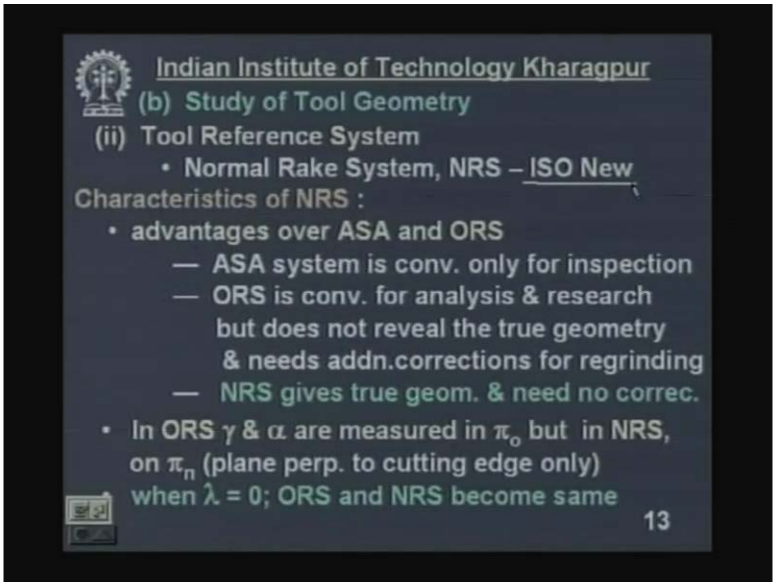

Tool Reference System are two category. One is orthogonal rake system and other one is normal rake system. This is normal rake system denoted by NRS and this is a new concept. It came recently compared to orthogonal rake system this is also called ISO New. New means may be thirty years or twenty five years. Now what are the characteristics of normal rake system over ASA system and orthogonal rake system? Let us have a look. ASA system is convenient only for inspection.

Now there are various things various applications of this system, inspection of the cutting tool then manufacture the cutting tool, then analysis of the tool geometry, research and regrinding resharpening and all this but ASA system is convenient only for inspection purpose but it is not that good for other purposes. Orthogonal rake system is very common and convenient for analysis tool geometrical analysis and research but does not reveal the true picture of the tool geometry geometry and it also needs additional correction some calculations for regrinding. Now NRS regrinding may be necessary or may be not be necessary. Normal rake system gives true geometry unlike ORS and need no correction. So this is very convenient.

In ORS system rake angle and clearance angle are measured in orthogonal plane but in normal rake system say pi n, rake angle and clearance angle are measured in normal plane in normal rake system. What is normal plane? Plane perpendicular to cutting edge only this will be shown later on. Now when lambda is zero, orthogonal rake system and normal rake system become same. Now this shows the concept of normal rake system.

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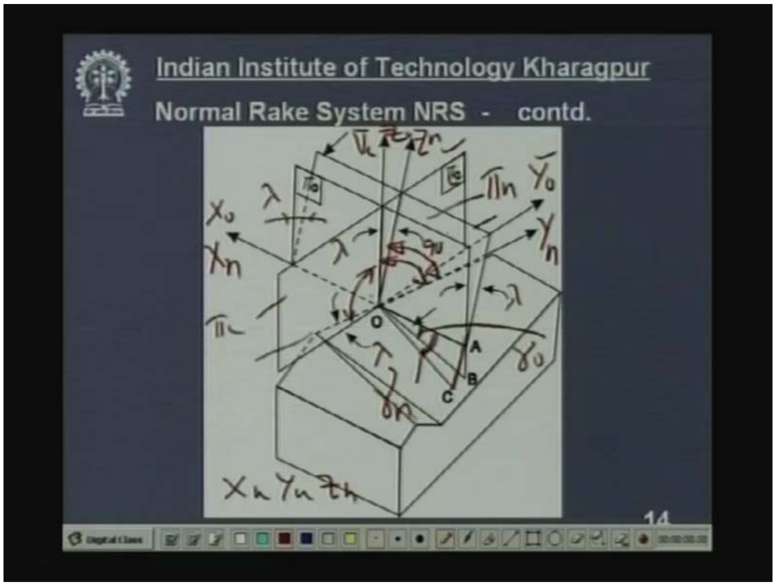

Here this is the cutting tool you see. Again I am showing you the orthogonal system. This is the velocity vector and these are cut these are cutting plane these are orthogonal plane this is a pi C and this is Yo axis, this is Xo axis and this is Zo axis this is Zo. Now, this is orthogonal plane. When this orthogonal plane is extended it meets rake surface OB and OA is part of the reference plane and this angle between the rake surface and 0the reference plane is rake angle and since it is orthogonal plane this is orthogonal rake angle orthogonal rake.

Now this orthogonal plane is perpendicular to pi o. It is not perpendicular to the cutting edge, the cutting edge is inclined this cutting edge is inclined and this inclination is denoted by lambda inclination angle. So this orthogonal plane is not perpendicular to the cutting edge because of lambda it is perpendicular to gamma. Now we have to consider a plane which will be perpendicular to the cutting edge that means this orthogonal has to be tilted by an angle alpha sorry has to be tilted by an angle lambda inclination angle so that this plane becomes perpendicular to the cutting edge and this plane is called this plane is called normal plane and this axis is called Yn axis this is Xn.

Now in normal rake system Xn, Yn and this axis is Zn which is perpendicular. This is perpendicular to the cutting edge ninety degree. So Xn, Yn, Zn are the axis. Xn Yn and Zn and the planes are shown the cutting plane and orthogonal plane those remain same and this one this is the normal plane which one extended and this is also lambda then it meets the rake surface and this is the rake angle but this rake angle is measured on which plane on the normal plane. So this will be denoted by gamma n that is called normal rake. Now the normal rake similarly on the same plane clearance angle has to be measured and finally see how the tools are specified or designated.

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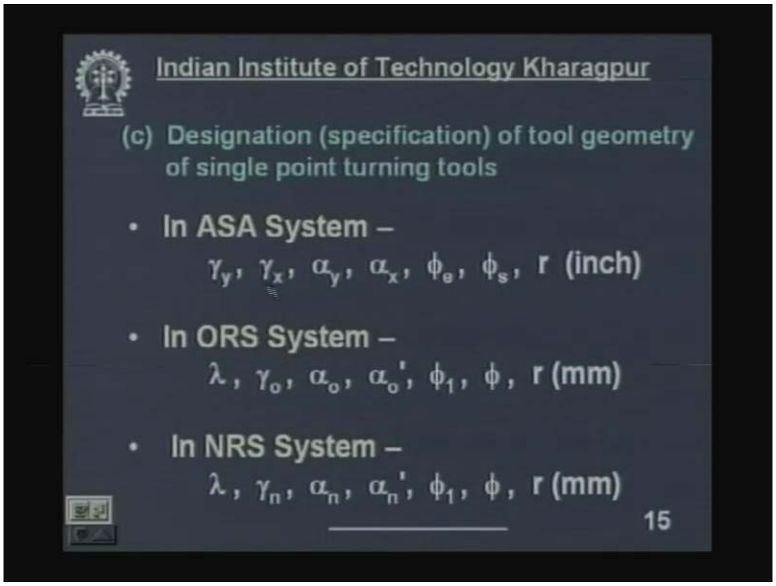

Designation or specification of tool geometry in different systems say in ASA system, in ASA system or machine reference system the sequence have to be noted the features items and the seven items one, two, three, four, five, six, seven and these are all independent and the sequence are gamma Y that is back rake gamma x side rake back clearance side clearance end cutting edge angle approach angle nose radius but is expressed in inch, but in ORS system starts with lambda inclination angle orthogonal rake orthogonal clearance, auxiliary orthogonal clearance.

This is auxiliary cutting edge angle. This is principle cutting edge angle and nose radius expressed in millimeter. In normal rake system and orthogonal rake system look alike only difference is here. o are replaced by n lambda remains inclination angle, normal rake normal clearance auxiliary normal clearance principle cutting edge angle auxiliary cutting edge angle, nose radius expressed in millimeter when lambda is zero then these two become same. There will be no difference.

Thank You