Manufacturing Processes II

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Lecture No. 6
Orthogonal and Oblique Cutting

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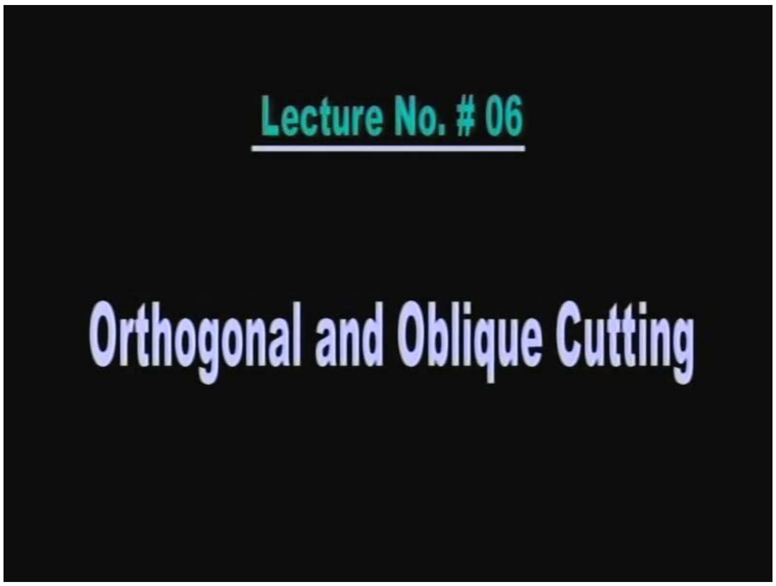

Dear friends our subject is Manufacturing Process II and we are still in Module - 2, that is Mechanics of Machining. Today is lecture No.6 and the topic today is Orthogonal and Oblique Cutting under Mechanism of Machining or chip formation.

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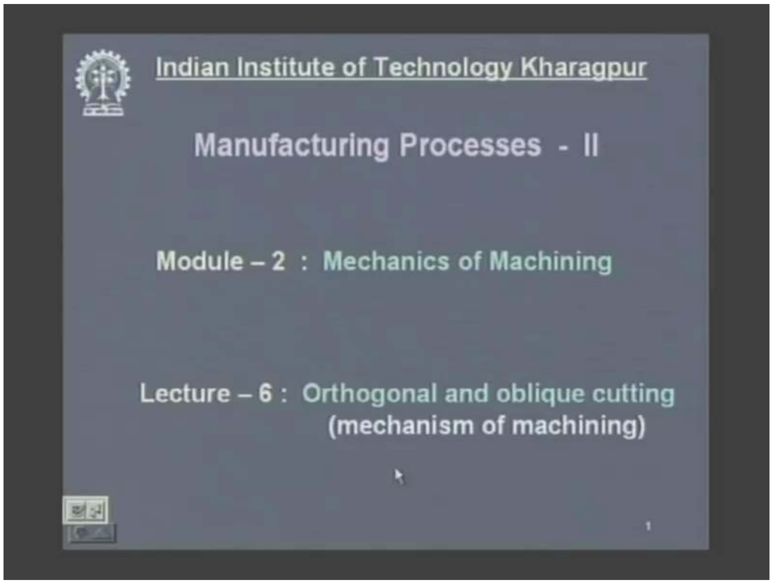

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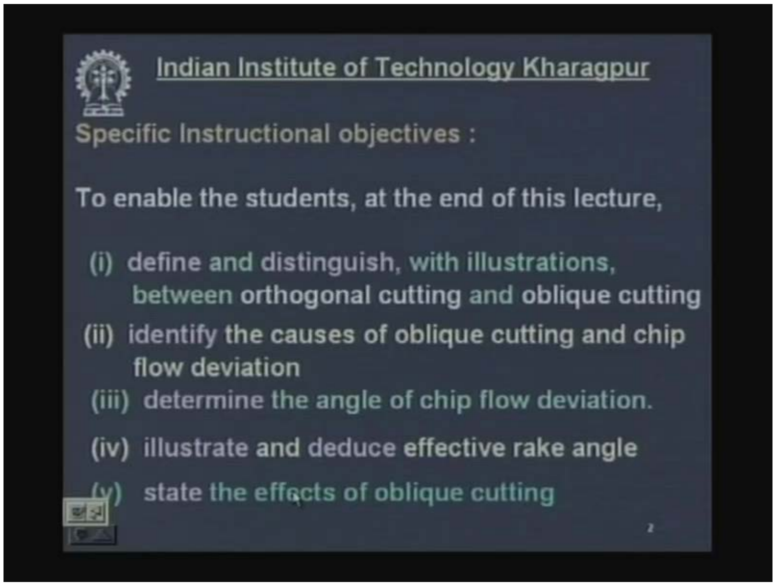

So, what are the specific instructional objectives of the today's lecture? After hearing this lecture, the students should be able to define and distinguish with illustrations between orthogonal cutting and oblique cutting. Next they will be able to identify the causes of oblique cutting and the chip flow deviation. Next determine the angle of chip flow deviation from the normal course. Fourth illustrate and deduce effective rake angle, now we are introducing another rake angle called effective rake. State the effects of oblique cutting.

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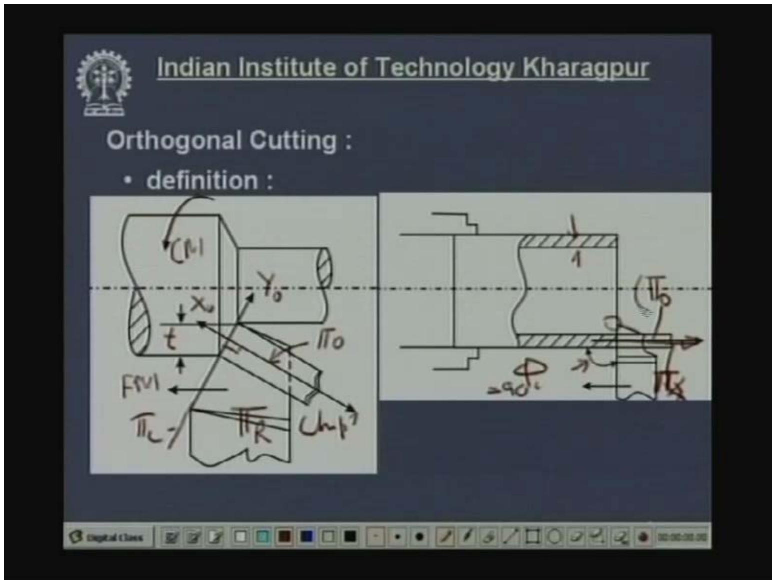

Now start with orthogonal cutting. What is mean by orthogonal cutting and then what is oblique cutting? Here you can see that, in the reference plane the turning process is shown in the reference plane. This is the cutting motion this one. Job is rotating, this is feed motion given to the cutting tool, this is depth of cut, this is orthogonal plane perpendicular to pi R, this diagram is drawn on pi R reference plane, this is X_O axis and this is Y_O axis, Z axis is perpendicular to the board.

Now, this orthogonal plane pi o is perpendicular to the cutting edge or cutting plane, this is the cutting plane also. Now the chip is expected to flow in this direction that is called chip flow direction, the chip is flowing along this direction. And if it flows along the orthogonal plane, then the cutting process will be called orthogonal cutting. So, what is the definition of orthogonal cutting? The cutting condition when the chip will flow along orthogonal plane irrespective of any other geometry whenever the chip will flow along orthogonal plane then we shall call it orthogonal cutting.

Now there is another term called pure orthogonal cutting, what is that? This is an example; here you can see that, a pipe turning a pipe with the limited thickness, which is less than the length of the cutting edge. So here the tool tip and auxiliary cutting edge are not involved, only a part of the main cutting is making the cutting action and this angle phi is ninety degree, that has to be noted. The principle cutting edge angle phi is equal to ninety degree, that means this plane along which the chip flows according to the definition of orthogonal cutting it has to be orthogonal plane. But at the same time, this is machine longitudinal plane and orthogonal plane will be same under the condition when phi is ninety degree and if the chip flows in this direction, this will be called pure orthogonal cutting, that means pure orthogonal cutting is the orthogonal cutting when the principle cutting angle phi is ninety degree, that is phi O and phi X are same.

Now oblique cutting: What is oblique cutting? Now we have understood that orthogonal cutting means, when the chip flows along orthogonal plane, but when it does not flow along the orthogonal plane this will be called oblique cutting. So that is the definition. When the chip does not flow along the orthogonal plane is called oblique cutting.

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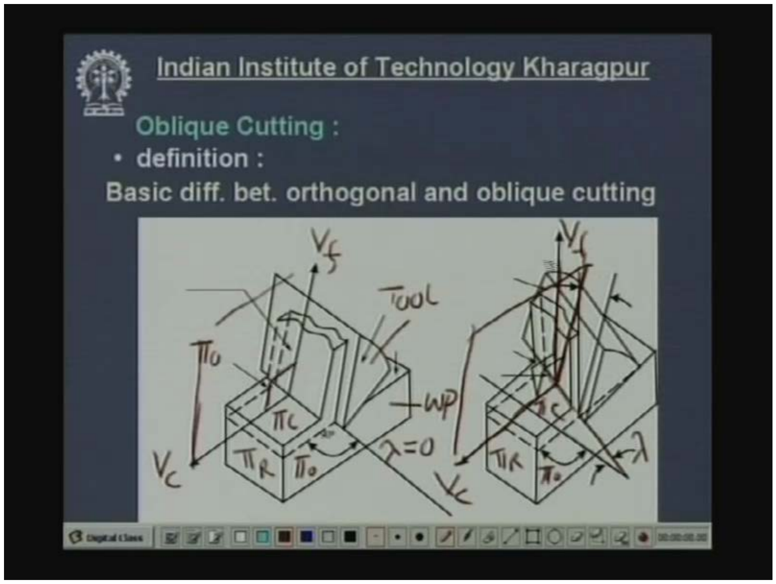

Now the basic difference between orthogonal and oblique cutting: Here you can see a cutting process just like shaping kind of thing. So, this is cutting tool, this is the work piece, this is the cutting edge of the tool, this the angle, this is the velocity vector along which the cutting tool moves, this is the chip which is coming out from the layer, this is the chip and it is coming out with the velocity V_f along which is the chip flows. Now this V_f and V_c that constitute the orthogonal plane.

Now according to definition if this with the velocity vector then reference plane will be perpendicular to that, so in that sense this is phi R plane and this is the cutting plane and perpendicular to this two, is orthogonal plane. So this plane the side surface of the job and this plane containing V_c and V_f is the orthogonal plane. Now here you see that when there is no lambda, lambda is zero here, because the cutting edge is perpendicular to the velocity vector, that means it is situated on reference plane so lambda is zero. In that case you will find that V_f is containing at the chip flow along with the orthogonal plane. This is the orthogonal plane. So this is the orthogonal cutting.

Now come to this one, here the cutting edge is inclined with respect to the reference plane and this is lambda, which means lambda exists, this is the velocity vector, this is the reference plane this is the cutting plane and this is the orthogonal plane. Now the cutting edge is inclined with respect to the phi R by an angle lambda and chip is flowing in this direction V_f .Now this is the orthogonal plane, this two line constitute the orthogonal plane. Now you see the chip is not flowing along the orthogonal plane, it is deviated that is the angle of deviation, this is the angle of deviation of the chip and this is called rho c. All angle of deviation and this chip flow deviation from orthogonal plane will be more or less equal to lambda if other geometry or normal. So this is called oblique cutting.

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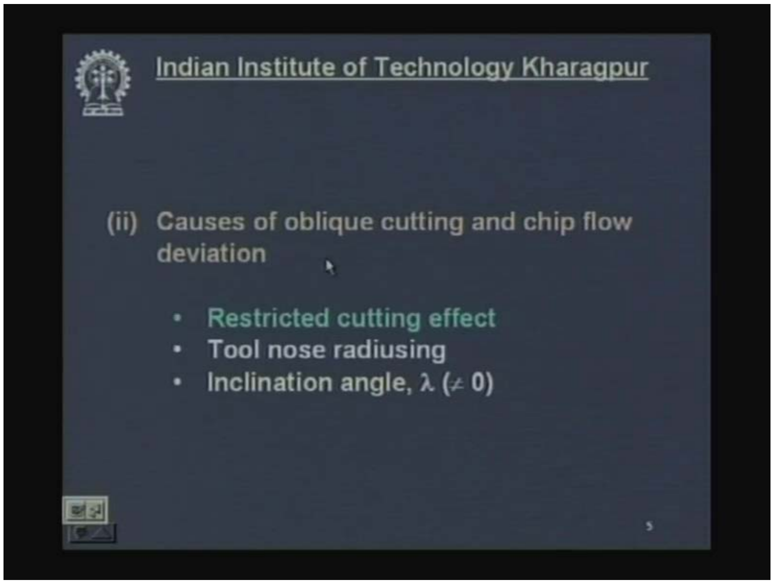

Now the causes of the oblique cutting and chip flow deviation. What is the meaning of chip flow deviation? The chip does not flow along the orthogonal plane, but it deviates by an angle that is called chip flow deviation angle denoted by rho c. Now what are the causes of this chip flow deviation from orthogonal plane causing oblique cutting, 1.Is the restricted cutting effect, this we would describe in detail, 2. Tool nose radiusing and 3. Inclination angle lambda, if exist, if not zero

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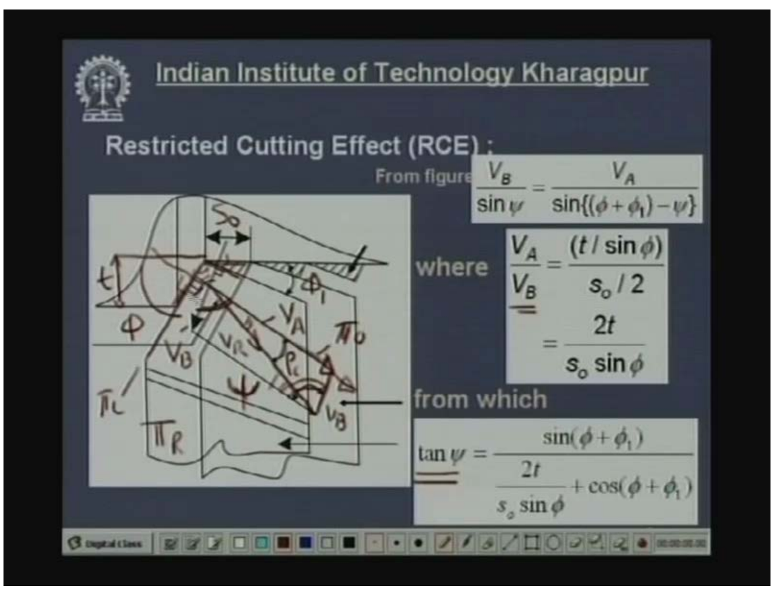

Now come to restricted cutting effect. This shows the cutting action, this diagram has been drawn in the reference plane, the top view velocity vector is perpendicular to this frame at this point and this is orthogonal plane and this is cutting plane. Now, here this is the cutting edge or the cutting plane and orthogonal plane is perpendicular to that, so if the chip flows in this direction then this will be called orthogonal cutting. But normally this is expected, but what happens though the main cutting edge plays the principle role in metal level (Slide Time: 09:57) sometime, the auxiliary cutting edge also takes part into the cutting action.

In this diagram you see, this one shows the position of the cutting tool, after one revolution of the job the position of the cutting tool shifts here and by an amount the feed per revolution S_o. Now this portion of the auxiliary cutting edge remains in contact with the job and this portion of the main cutting edge remains in contact and in this direction, suppose the chip is coming out with a velocity V_A and from the auxiliary cutting edge also a small chip comes out and suppose this is V_B. Interaction of V_B and V_A will result the direction of chip flow in this direction. It is not flowing along the orthogonal plane. It is deviated by an angle rho C or may be psi, we can call it if lambda is zero and this is the resultant velocity. Therefore the chip is flowing in another direction other than the orthogonal plane, so this is oblique cutting.

Now if this angle is denoted by psi, that is chip flow deviation only because of the restricted cutting effect when both the cutting edges take part into action, and the chip flow is deviated by the chip coming from the auxiliary cutting edge this is called restricted cutting effect. This happens when this auxiliary cutting edge angle is small. Now what is the value of psi? From this triangle, you consider this triangle, so this is V_A divided by sin of this angle. Now what is this angle V_B, so properties of the triangle V_B divided by sin of this angle sin psi and V_A divided by this angle sin phi plus phi one minus psi. How? You know this angle is phi, this is phi one, so this angle is one twenty degree minus phi plus phi 1, this will be phi plus phi 1, this is totally phi plus phi 1, so this total will be phi plus phi 1, but this angle is psi, this angle is psi. So this angle is phi plus phi one minus psi.

Now from this angle we write again, this ratio V_A and V_B is equal to t, depth of cut divided by sin phi that is the width of the cut divided by half of this angle. How it has come? These have been developed by research by two scientists Rosenberg and Armin. They established this relation, that V_A by V_B is the major velocity, the minor velocity will be proportional to this is equal 2 t by S_O sin psi. Now using this relation and breaking sin phi plus phi 1 into psi minus psi we get finally10 psi is equal to sin phi plus phi 1 divided by 2 t S_O sin phi plus phi one. So this angle of chip flow deviation because of restricted cutting effect alone is a function of the cutting edge angles, the depth of cut and the feed. And though this is deviation angle this will be small normally one to two degree. Now see the others, this is effect of nose radius on the cutting process that also deviates takes part into deviation of the chip flow. How?

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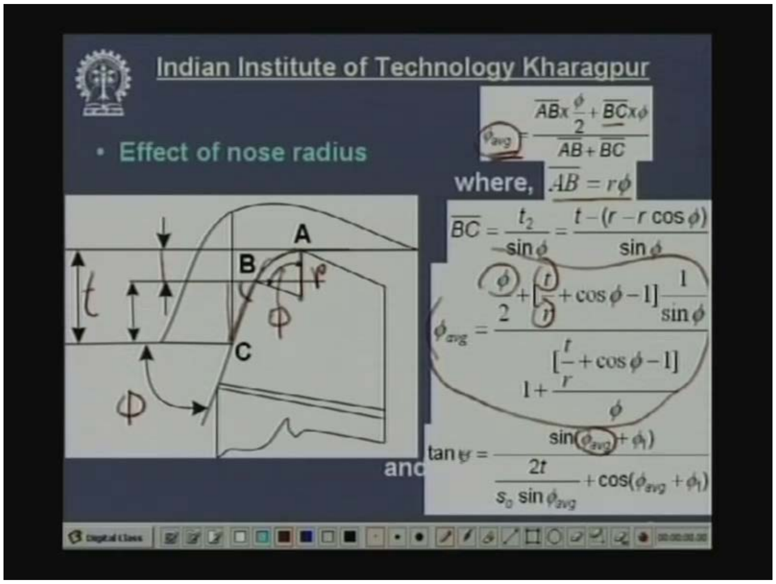

Now in the previous expression, because of restricted cutting effect what we found, we found that 10 psi is equal to sin phi plus phi 1. Now we are transferring this ten psi. Now here, if the cutting edge is rounded by nose radiusing then, the value of phi does not remain constant, at this point A it is zero and now it is gradually increasing towards B, now it becomes phi and from B to C it is phi constant. Now what is then the value phi plus phi in the previous expression this has to be replaced by phi average. So the principle cutting angle phi has to be replaced by phi average because of rounding of the cutting edge.

Now what is the value of phi average? This value of phi average will be equal to this length AB or this weighted average multiplied the average value of phi it is zero here, phi here, average is phi by two. So AB into phi by two and from the B to C the phi remains constant. So from B to C it remains phi constant, that divided by the total length that gives you the total weighted average of the principle cut edge angle phi where AB is equal to the nose radius r. What is AB and this is phi this angle, so this will be AB is equal to r phi. What is BC? BC will be the depth of cut t and what about this one? This is equal to r minus r cosine phi. So how much is this, t minus r minus r cosine phi that divided by this is BC and this angle is psi. So this is equal to this divided by sin psi. So phi average will be finally given by this expression, that is the function depends upon the main principle cut edge angle and the depth of cut, the nose radius etcetera. So, these two play important role and so the phi is changing to phi average, so the value of psi will also correspondingly change, so the chip flow angle will change.

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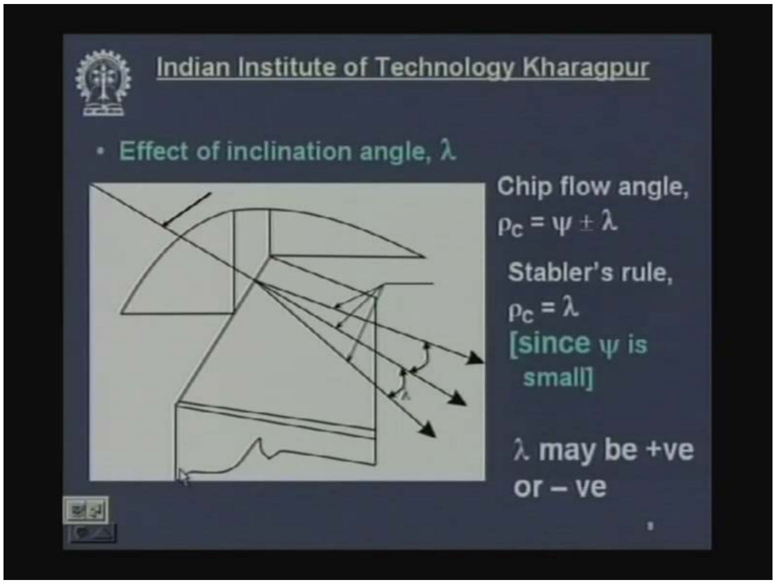

Now come to effect of inclination angle; suppose there is no restricted cutting effect, this angle, the auxiliary cutting edge angle phi 1, this is main cutting edge angle phi, principle cutting angle phi and this plane is orthogonal plane, the diagram has been drawn in reference plane pi R. Now, here suppose this phi one is quite large, so restricted cutting effect is not there and nose radius also very sharp. But the inclination angle lambda exist it is not zero. If lambda is zero then the chip will flow in this direction which is nothing but orthogonal plane then this will be called orthogonal cutting.

But if lambda is not zero, say for the example lambda is less than zero and this one lambda is greater than zero means positive, lambda exist but positive and lambda exist but negative then the chip will flow in this directions and this is the chip flow deviation angle. In absence of the restricted cutting effect and nose radius this chip flow angle will be very close to the value of lambda but the direction will depend upon the sin of the lambda.

Now here chip flow angle is denoted by rho C is equal to psi, is the chip flow deviation due to restricted cutting effect and nose radiusing and lambda is the presence of inclination angle. So summation of this two is the rho C. If lambda is zero then rho C will be caused only by psi that is restricted effect and nose radiusing. If this is zero then this rho C will be equal to lambda. Now Stabler's rule, he observed that rho C is more or less equal to lambda because the value of psi is very small compared to lambda, it is simple, since psi is very small, lambda may be positive or negative as I already told you.

Now come to effective rake, this is very interesting and now you come across another term introduce called effective rake.

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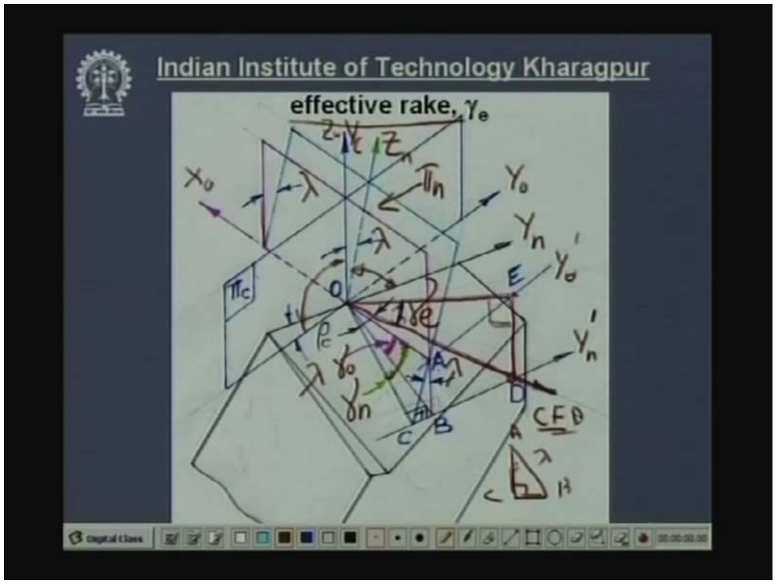

Now what is effective rake? Before we go to effective rake, let us recall the previous nomenclatures and the reference planes, axis and rake angles. Now, this black one shows the cutting tool in three D, this is the velocity vector or Z_O, this is the cutting plane so this is Y_O and this is X_O that is orthogonal plane. So this red one is orthogonal plane OA and so this is the velocity vector. Now this cutting edge is not along with Y_O, it is not situated on the reference plane, it is inclined from this one the cutting edge and this is lambda inclination angle and this one is called Y_n the cutting edge. And now draw the normal plane since lambda is not zero, there will be a normal plane and according to definition this is the normal plane and this is Z_n which is perpendicular to the cutting edge and the Z_O is perpendicular to Y_O. But Z_n is perpendicular to the cutting edge a normal plane this is normal plane pi n is perpendicular to the cutting edge.

Now come to rake angle, this is orthogonal plane say OA. A is situated on the reference plane. O is in the reference plane but there is a rake angle, so the rake surface is sloping down when this line is extended it meets the bottom surface at point B and OB if joint is situated on the rake surface. And then this is the angle of inclination of the rake surface OB from reference plane OA and measured on orthogonal plane. So this one is orthogonal rake.

Now normal plane: When the normal plane is extended along this line it meets the bottom surface, suppose at point C, So when OC join, OC is also situated on the reference plane and this is the phi R. So what is this angle of inclination of the reference plane OC with rake surface OC from the reference plane OA measured on normal plane, so this is gamma n. Now here AB, ACB, this is also lambda inclination angle, here chip suppose when this will happen. When lambda will exist the chip will flow neither along OB nor along OC will this flow along another direction, this is the actual chip flow direction and this is along the rake surface. So, this is situated along the rake surface and this meet suppose, if we join BC and extend it then the BC will be parallel to the main cutting edge. So, this will be Y_n prime, this will be parallel to main cutting edge. Because this line AC will be perpendicular to this normal plane and this is perpendicular to the cutting edge Z_n, so this will be parallel to cutting edge and ACB it looks different, but this is ACB this angle is lambda and this angle is ninety degree, because AC normal plane is perpendicular to this BC which is Y_n prime.

Now what about effective rake? So chip flows in this direction. Now we draw a plane OED which is perpendicular to phi R, because OE is on phi R, because from A, you draw a line Y_O prime, so this is extended reference plane and this plane is perpendicular to that you draw. So, this is a plane perpendicular to pi R and taken in the direction of chip flow and this angle is called effective rake. Then what is effective rake? Angle of inclination of the rake surface from reference plane measured on a plane, which is perpendicular to pi R and taken in the direction of actual chip flow. This is effective rake. This is different from normal rake and orthogonal rake if lambda prevails and this was the expected direction of chip flow. Now the chip has gone to that direction then what is the amount of chip flow deviation? This is the amount of chip flow deviation that is denoted by rho C and this angle is ninety degree. OC and CD are at ninety degree. Then what is the value gamma e that has to be evaluated?

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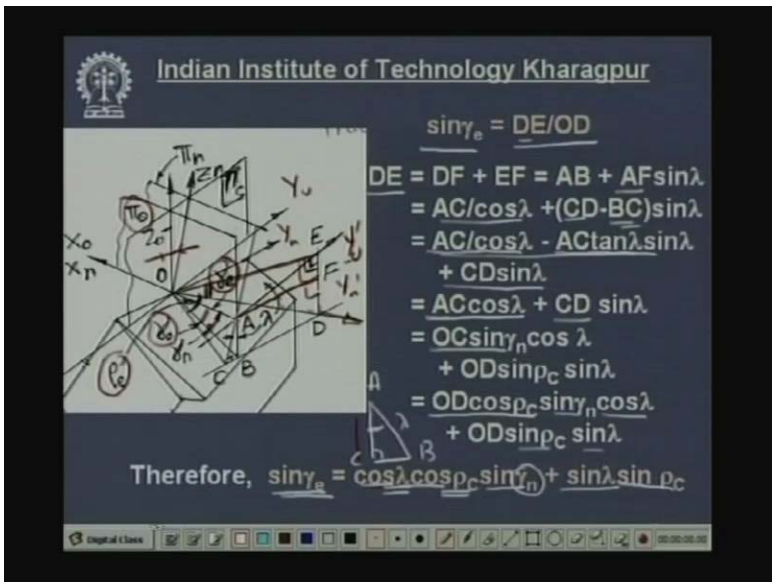

Now come to this diagram. It looks little complex, but you need not bother about this part. You look into this area only. Here this is the orthogonal plane, OA is a reference plane and this is orthogonal plane pi o and this is normal plane, normal plane makes this normal rake and OAB that is this portion is orthogonal rake. And this is the direction of actual chip flow that is OD which is on the rake surface and this angle is according to definition effective rake. Therefore this effective rake, you consider this triangle which is right angle triangle and this is ninety degree. Then what is sin gamma e, the sin gamma e will be equal to DE divided by OD. So look here, that sin of gamma e will be equal to DE divided by the hypotenuse OD. Now come to DE, break this DE. What is DE? DE is equal to DF plus EF, what is F? From A you draw a line parallel to CD. So this axis is Y_O, this is Y_n, this is Y_n prime and this one is Y_O prime and this angle is lambda.

Now what is DF and DE? What is DF? DF is equal to AB which is parallelogram and what is EF? EF is equal to AF sin lambda, so this is right angle triangle sin lambda. Now what is AB? AB is equal to AC. Now this is A B C right angle lambda. Now what is AB? AB is equal to AC divided by cosine lambda and then what is AF? AF is equal to BD and BD is equal to CD minus BC and sin lambda remains. So, what is BC? BC is equal to AC tangent of lambda sin lambda and this CD into sin lambda remains then what we get? So, this becomes AC cosine lambda this AC cosine lambda and AC tan lambda sin lambda together will form AC cosine lambda and CD lambda remains.

Then what is AC? AC is equal to OC is a hypotenuse sin gamma n, this angle is gamma n sin gamma n and cosine lambda. What is CD? CD is equal to this is O C D it is right angle triangle. So CD is equal to OC or OD sin lambda. AC is equal to OC sin gamma n and CD is equal to OD sin rho$_c$ and this lambda remains. Now OC again equal to OD cosine rho$_c$ this angle is rho$_c$. So all together finally OD OD cancels and what remain is the cos lambda. So sin gamma e is equal to cos lambda cos rho$_c$ sin gamma n. Sin gamma n is equal to cos lambda, this cosine lambda, cosine rho, cosine rho$_c$, sin gamma n and sin rho$_c$, sin lambda. So this is the expression for effective rake gamma e. Now it is evident that effective rake value depends upon the lambda, the chip flow deviation angle and normal rake of the cutting tool. If lambda is zero then this will be orthogonal rake. This will become one and this will become totally zero. So this will be more simple. Now let us see the effect.

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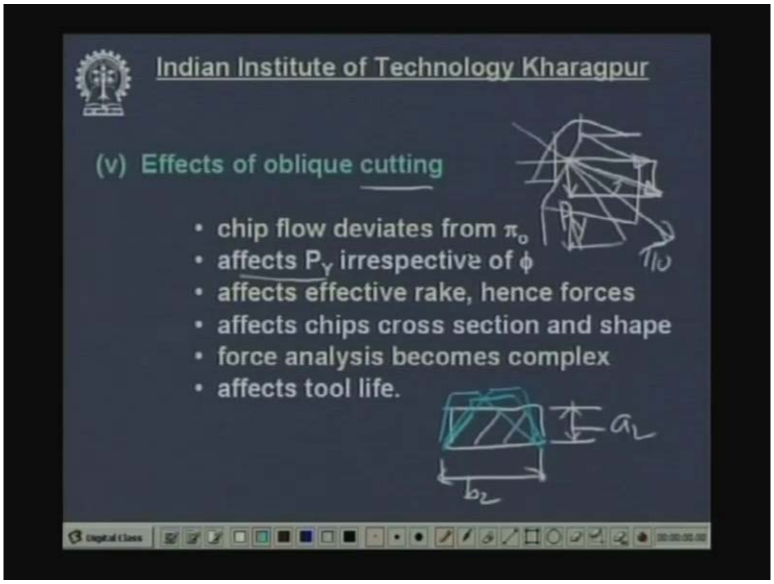

Effects of oblique cutting: Now before we go into that what are the implications of gamma e effective rake, when there will be oblique cutting then the chip oblique cutting means chip does not flow along the orthogonal plane, it flows along a different plane and in that case the rake angle will be different effective rake and chip will flow in this direction. So friction will take place in this direction. Normal force, friction force, coefficient of friction all these things will be taken in reference to this, in reference to this direction of chip flow and in that condition what is the rake angle? Rake angle is gamma e effective rake.

So effective rake is the most important rake angle to be considered for analysis of mechanics and machining or wear of the cutting tool everything when it is oblique cutting. When it is orthogonal cutting, this effective rake, normal rake, orthogonal rake all becomes same there is no difficulties. Otherwise if it is oblique cutting, most of the machining works in industry are oblique cutting and the rake that should be considered for all purposes is effective rake. Now effect of oblique cutting which is most common. The chip flow deviates from orthogonal plane is a definition first affects P_y irrespective of phi, now how does it? Say this is the cutting tool the chip is this is the orthogonal cutting say pi o orthogonal cutting. Now the chip flows in this direction it is oblique cutting, then the cutting force will act in this direction, the orthogonal cutting force and this will have two components one along this direction, one along this direction this is called P_y or transverse force which is very detrimental it cause lot of problems.

Now if the chip flows in this direction, then P_y will be large so the value of P_y will depend upon the chip flow angle and that is causing the oblique cutting that is why stated that that the oblique affects Py irrespective of phi what about the value of phi. Next affects effective rake hence forces if is not oblique cutting orthogonal cutting. The question of effective rake does not arise because effective rake, normal rake, orthogonal rake all be same affects chips cross section and shape. Now here the cross section of the chip is expected to be rectangular. This is the width of the chip after cut b2 and this is the thickness of the chip after cut a2 and this is the thickness of the cross section of the chip but when this will be oblique cutting, then this will not be like this. This will be trapezium like because it is oblique cutting.

So this will not remain rectangular it will be trapezium and will not be symmetrical trapezium, it can be skewed trapezium inclined on one side or it can be on this side like this, as such there is no difficulty in machining but this is the effect on the chip form beside that because oblique cutting the chip gets more close curved which is not very desirable that makes the tool faster. The force analysis becomes complex because of the deviation of chip from its normal course and as a result this affects the tool life also because P_y is affected by oblique cutting of phi or this chip deviation angle that causes vibration. If it is very large or then if due to vibration the tool will fail faster and this will be damaged, life will be reduced. So this ends the topic today but let us have some exercise practicing what we learn about it, what did you learn about oblique cutting and orthogonal cutting and what is of definitions what are the causes of oblique cutting and what are the effects of oblique cutting, effective rake all these things we learnt.

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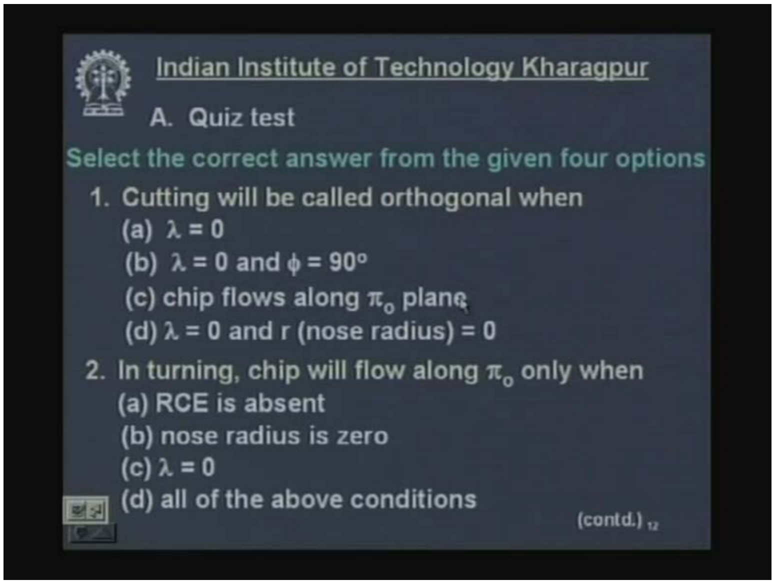

Now let us have some exercise say quiz test, very quick answering. Select the correct answer from the given four options. The first question is cutting will be called orthogonal when the options of the angles are the options are the answers are when lambda is zero, when lambda is zero and phi is ninety degree, chip flows along orthogonal plane, lambda is zero and nose radius is also zero, which is the correct answer? Now how do you decide? What is the definition of orthogonal cutting? Definition of orthogonal cutting is whenever the chip flows along the orthogonal plane chip flows along the orthogonal plane. This is correct, this is the definition. So this is the correct answer why not (a) because when it is not orthogonal cutting when it lambda when this oblique cutting when oblique cutting takes place chip deviates because of lambda zero because of nose radius lambda is not zero when the nose radius exists and when there is restricted cutting effect it will be oblique cutting. So simply when lambda is zero it may not be orthogonal cutting restricted cutting effect and nose radius may cause chip flow deviation and oblique cutting. So the correct answer is chip flows along orthogonal plane.

Now next question is, in turning chip will flow along orthogonal plane only when? Restricted Cutting Effect (RCE) is absent, nose radius is zero, lambda (inclination angle) is also zero, all of the above conditions. As I told you just now that, this is the orthogonal cutting will take place on when the chip will flow along orthogonal plane and the chip is made to deviate because of restricted cutting effect, nose radiusing and lambda. Therefore for orthogonal cutting all these three condition should be true. The restricted cutting should not be there. Nose radius should be not there lambda should be zero and that means this is the correct answer. So this is the correct answer all of the above condition that is (d).

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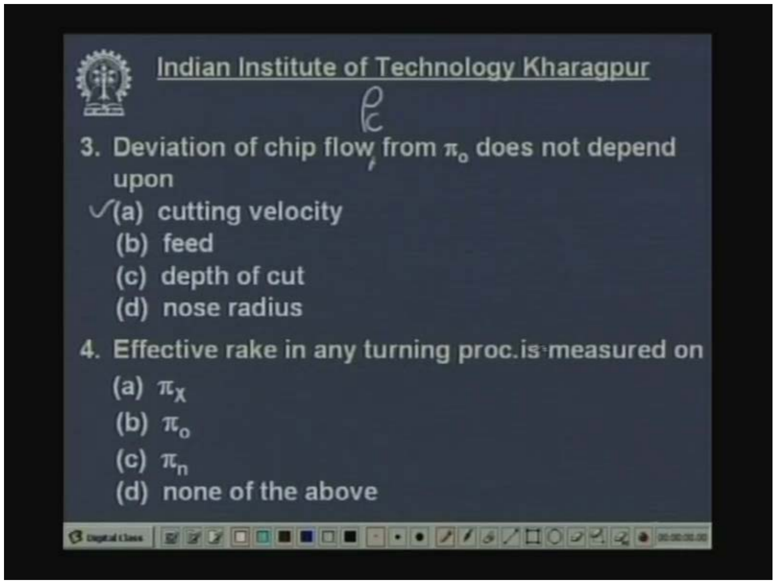

Now third question, deviation of chip flow from phi o orthogonal plane does not depend upon deviation of chip flow that is rho$_{c,}$ from orthogonal plane does not depend upon, cutting velocity, feed, depth of cut and nose radius. If you recollect the equations for the chip flow deviation angle psi or rho$_{c,}$ you will find their function of feed, depth of cut and nose radius that means the feed, depth of cut and nose radius affect the chip flow deviation angle but in those equations, no value will find cutting velocity. So answer is (a) the cutting velocity which does not influence the chip flow deviation angle. Effect of effective rake in any turning process is measured on which plane? Let us go back, here you see that the effective rake this one is taking place along OED,

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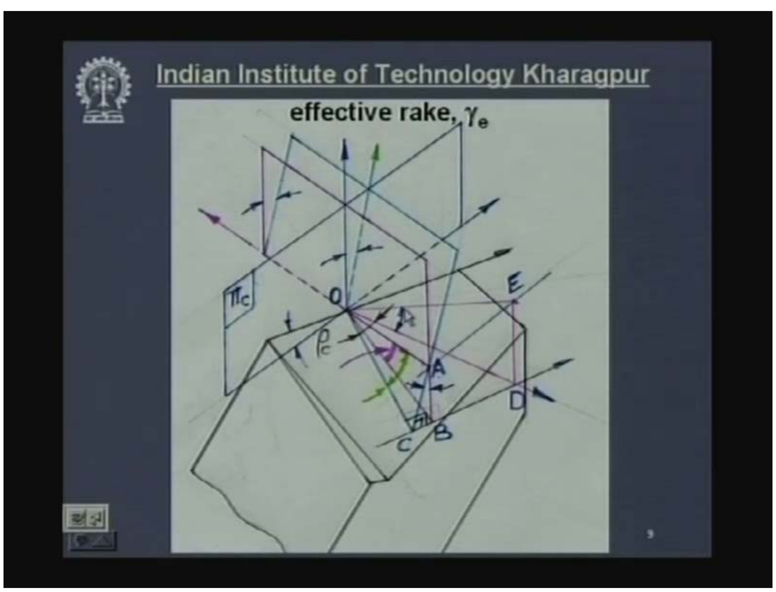

that is along the direction of chip flow and this plane is perpendicular to pi R, it is neither orthogonal plane, nor normal plane, nor axial plane. It is somewhat different, another plane taken in the direction of actual chip flow though it is perpendicular to pi R. Now let us go back. Effective rake in any turning process measured on pi x wrong. pi o no, pi n no, none of the above really. So this is the correct answer (d) none of the above.

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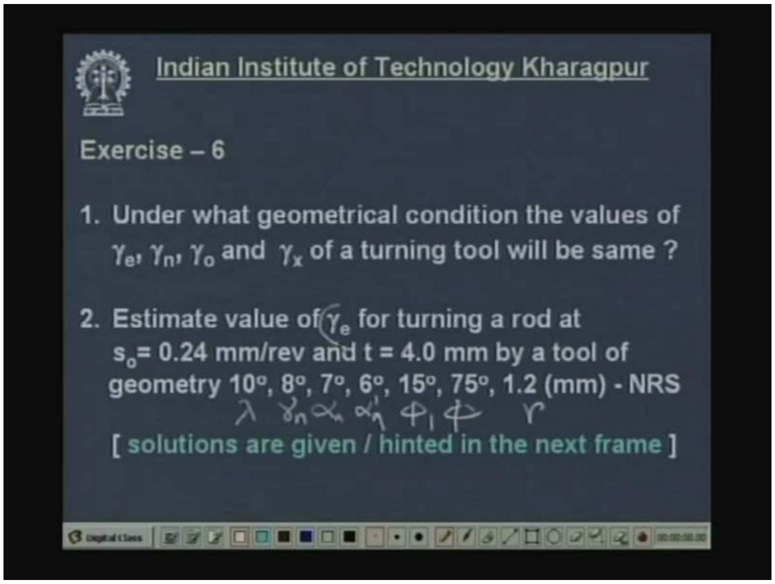

Now Exercise - 6 that it is with the Lecture 6. Question Number 1. Under what geometrical condition the values of effective rake, normal rake, orthogonal rake and even this side rake gamma x of a turning tool will be same? Very simple question under what geometrical condition of the cutting tool the values of all these angles will be same? Next question this answer will be in the next frame next question, Estimate value of effective rake gamma e for turning a rod at feed S_o zero point two four millimeter per revolution, depth of the cut four millimeter, by a rod of geometry, ten degree, eight degree, seven degree, six degree, fifteen, seventy-five and this is NRS. Now when it is NRS, what does it mean, it mean that this is lambda inclination angle, gamma n, normal rate alpha n normal clearance, alpha n prime auxiliary normal clearance, this is n cutting edge angle or auxiliary cutting edge angle. This is principle cutting edge angle and this is nose radius.

So if we write here, so this is lambda, this is gamma n, this is alpha n, alpha n prime, this is phi one, this is phi and this is r. Under this condition what will be the value of effective rake that has to be determined. Solution in the next page.

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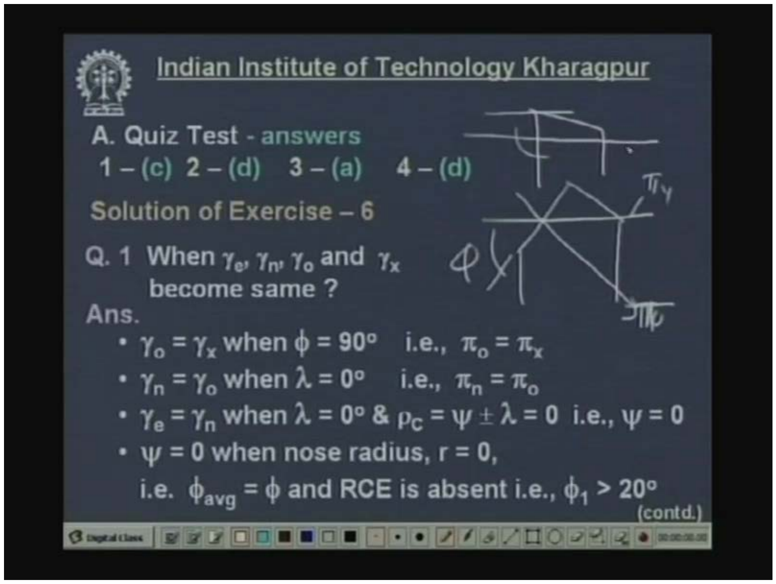

Come to the solutions. First quiz test – answers. The answer number one is (c), already we discussed that (c) will be the answer and the solution for Exercise - 6, what are the questions simply, When gamma e, gamma n, gamma o and gamma x will be same in magnitude, effective rake, normal rake, orthogonal rake and side rake will become same? Now answer is gamma o these are the steps, gamma o is equal to gamma x, orthogonal rake is equal to gamma orthogonal taken is orthogonal plane, gamma x is side rake taken in the machine longitudinal plane phi m. This will happen when these two planes are same. When these two planes will be same? when phi is ninety degree that is pi o and pi x.

Now you see, let me try to show that, if this be the cutting tool, this is pi x and this is pi o orthogonal plane, and this is phi, when these two plane will be same? when this cutting angle phi is ninety degree then, this is the machine longitudinal plane pi x and this is also orthogonal plane pi o. So when these will be same so the rake angle will also be same gamma o and gamma x will be same. Now next is when normal rake and orthogonal rake will be same, when lambda is zero, when inclination angle is zero then the normal plane and orthogonal plane become identically same. Therefore the rake angle should also be same. The gamma effective rake, sorry effective rake will be equal to normal rake. Now if you look into the equation.

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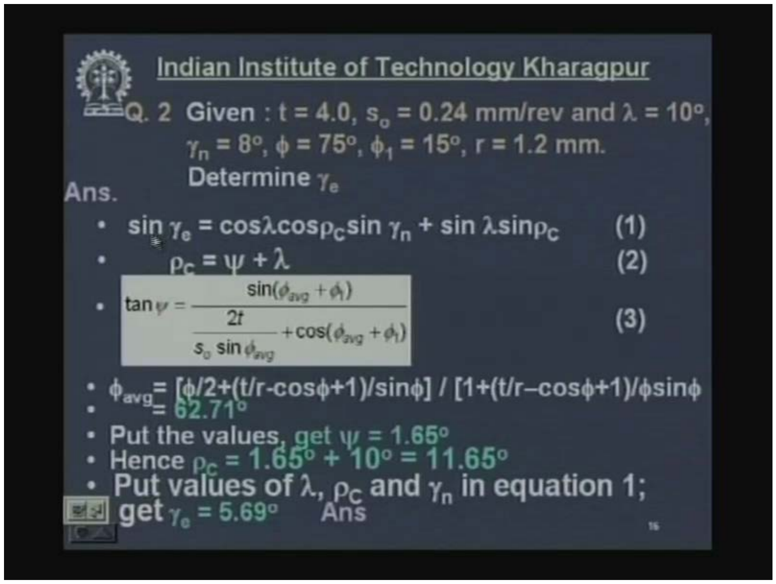

sin gamma e is equal to cos lambda cos rho_c sin gamma n plus sin lambda sin rho_c. So this gamma e will be equal to gamma n when this part will be zero and this part will be equal to one that means lambda will be zero and rho_c will be zero when both lambda and rho_c will be zero, then sin gamma e will be equal to sin gamma n, and then gamma e will be equal to gamma n. Now solution to this problem was simply question number two, given depth of the cut is equal to four millimeter feed given and lambda is equal to ten degree gamma n is equal to eight degree phi is equal to seventy-five degree, phi one fifteen degree and r is nose radius is one point two five. You can see this one. These are the values given, from here we get all the values. The values are given to determine the effective rake, this effective rake has to be determined.

Now we know that sin gamma is equal to cos lambda cos rho_c sin gamma n plus sin lambda sin rho_c and rho_c is equal to psi plus lambda, when this psi rho_c will be zero lambda will be zero, then gamma e will be sin gamma will be sin gamma n. Now we were discussing here. Now psi is equal to zero, it has to be zero because psi is equal to rho_c is equal to psi plus lambda, rho_c has to be zero then lambda has to be zero here, and psi also to be zero and psi is zero when nose radius r has also to be zero that is phi average will have to be phi. There is no nose radius a restricted cutting effect has to be absent and auxiliary cutting edge angle should be greater than twenty degree which means that it is the auxiliary cutting edge is not affecting the cutting action.

So there is no restricted cutting effect when phi is phi one, the auxiliary cutting edge angle is greater than twenty degree. So what is the condition then.. to get this condition effective rake, normal rake, orthogonal rake and side rake the magnitude of all these rakes will be same. First condition that phi has to be ninety the principle cutting edge angle. Next condition lambda has to be zero and third condition rho_c has to be zero, lambda is already zero. So psi has to be zero. This psi has to be zero, when psi will be zero, nose radius will be zero no nose radius effect and this restricted cutting effect is also absent under these conditions these value of effective rake, normal rake, orthogonal rake and side rake will be identical.

Now come to the question number two, the machining conditions and tool geometry are given. You have to determine gamma e. For example: depth of cut four millimeter, feed is point two four millimeter per revolution, lambda inclination angle ten degree, normal rake eight degree, principle cutting edge seventy-five degree, auxiliary cutting edge angle fifteen degree, and nose radius one point two millimeter. We have to determine the value of effective rake. Now how shall we determine solution? First we write the expression sin gamma e the effective rake, sin gamma is given by this special function of lambda $rho_{c,}$ the chip flow deviation angle normal rake and sin lambda sin rho_c.

Now first of all determine what is rho_c? rho_c is equal to psi plus lambda. Known value of lambda is given here, so we can put lambda here, but rho_c we do not know because we do not know psi. What is psi? From the previous expression analysis, we showed that ten psi is equal to sin phi average plus phi one two t by what is this depth of the cut divide by feed sin phi average cosine phi average phi one. Now this phi average has to be taken due to nose radius, when there is no nose radius this phi average will be taken as phi principle cutting edge angle. Anyway here you see that we can determine psi, depth of cut is known four millimeter, feed is known point two four millimeter, then phi one is fifteen degree. What is not known? phi average. So this phi average which very important this is not known, so this has to be known. Now what is phi average that is due to the nose radius is given by this expression. Where from this expression comes?

Here you see that phi average is given by this expression. This expression phi average which is function of principle cut edge angle, the value is given nose radius the value is given one point two. This is known all are known depth of cut is known. So from this expression the same expression it is written in different form in a linear path. So we get phi average if we put the values of phi depth of cut nose radius and all these things from the given value this phi average will appear sixty-two point seven one degree. Now put the other values into this expression. So phi average is known sixty-two point one seven one, phi one is fifteen degree, two e is four millimeter, S_o is point two four millimeter and these are known. So we get tan psi. How much value we get? psi is equal to one point six five degree, then what is rho_c ? psi plus lambda, psi is one point six five, lambda is ten degree. So rho_c will be equal to one point six five plus ten degree, eleven point six five degree.

So you put here in this expression rho_c is equal to eleven point six five degree, lambda ten degree and gamma n is eight degree and put into this equation, put values of all these things lambda rho_c and gamma n in equation number one, what we get sin gamma e and from sin gamma e we determine gamma e, this will appear five point six nine degree. This is how you can solve various problems and you practice it number of times, but effective rake I remind you that effective rake plays very important role for measuring the mechanics of forces, tool life, friction, chip tool interaction that is mainly for research but for industry purpose generally effective rake is not that sincerely considered. Normal rake is enough for in our general industrial applications. So this we have to learn thoroughly, you do it and so this is the end of today's lecture.

Thank you.