Introduction to Mechanical Micro Machining
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Lecture - 12
Difference between macro and micro machining (Contd.)

Good morning to everybody, and welcome to our course on Introduction to Mechanical Micro Machining. In the last class we have started about looking at the aspect of different machining processes, and we have seen that how the location that is the interface between the tool and work piece behaves when we do cutting at the micro machining or at micro level.

And, here we have seen some of the size effects. Size effects means that when you scale down any system or any component how does it behave, when it is at a macro or bigger scale. So, what are the differences? We have to look after so that we can understand the process or the process mechanics much better way and we can get the amount of required results very carefully and other way it is important things.

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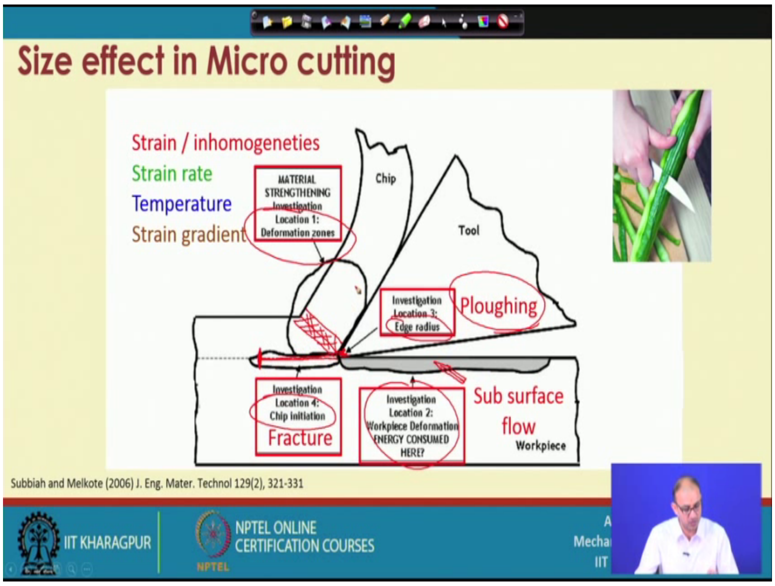

And, we have seen one diagram. So, this is the first diagram we have seen in this case and if you see this thing, we have targeted 4 locations. So, this is the location 1, that is the deformation zone and we have seen that there is a snip band through which material start deforming from the uncut chip thickness to the original chip thickness. And, there was a another one, second one, was the material deformation or the work piece deformation where what happens to this particular level because this is the part which we have decide out of machining process. So, is there any property difference in the material or there are some other defects created because of this machining at a micro scale, those things should be discussed, those things should be keep into mind to understand the machining at a micro scale.

Third one was the edge radius and because of the edge radius we may encounter ploughing effect which is not good thing for the cutting operation and the last one was the location 4 that is the chip initiation region. So, when the sharp tool or the blunt tool interact with material at that time what happen that it may create some type of chip initiation because when it interacts at this particular location at that time deformation may get started from some location and then it will propagate to facilitate removal of the chip from the work piece.

So, these are some of the things we have discussed in the last class.

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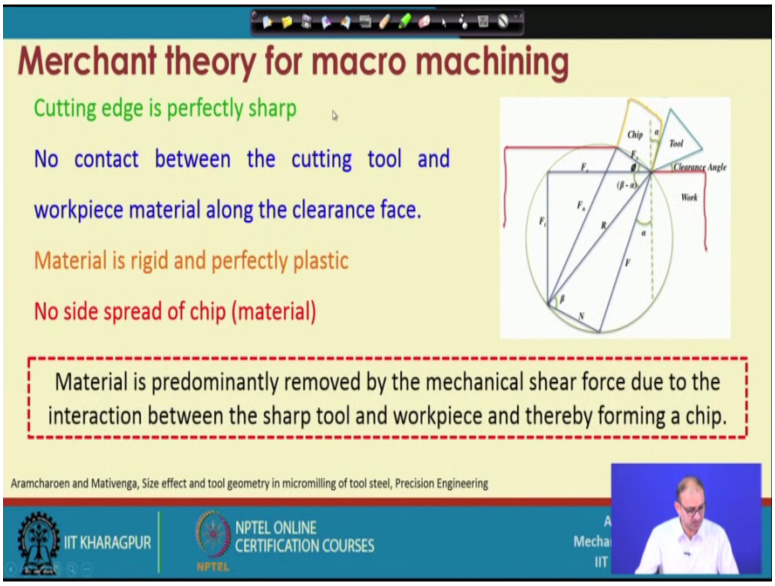

And, then we have seen the, what are the problems with the merchant theory, say application to the micro machining processes.

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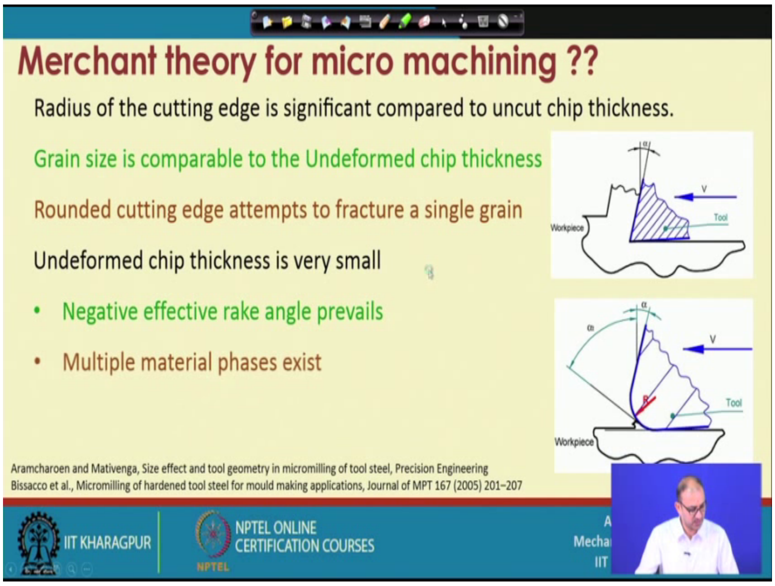

And, these are some of the things that radius of cutting edge was very small compared to the uncut chip thickness. Grain size is comparable with the thickness. Rounding of the edge also create problem, grain size is also creating problem. So, those are things we had discussed in the last class in detail.

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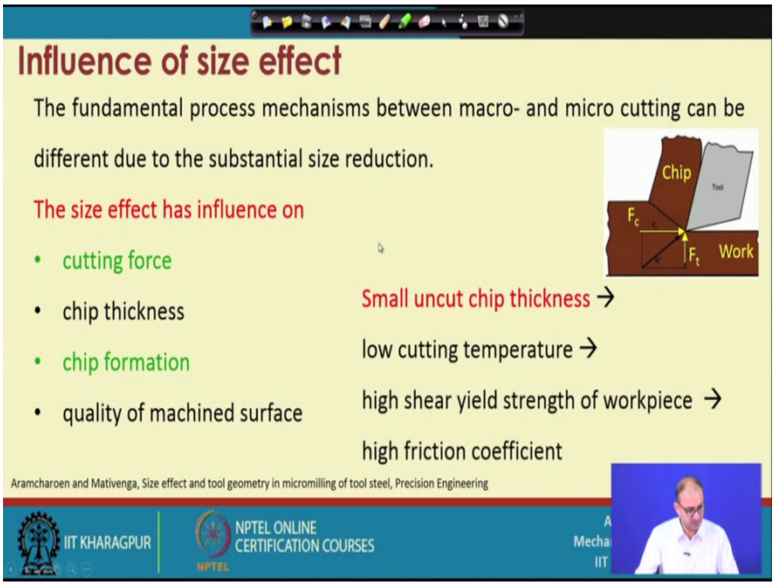

And, force is also important thing because forces will create a problem when you cut the material at the micro scale, chip thickness, chip formation and these things we had discussed.

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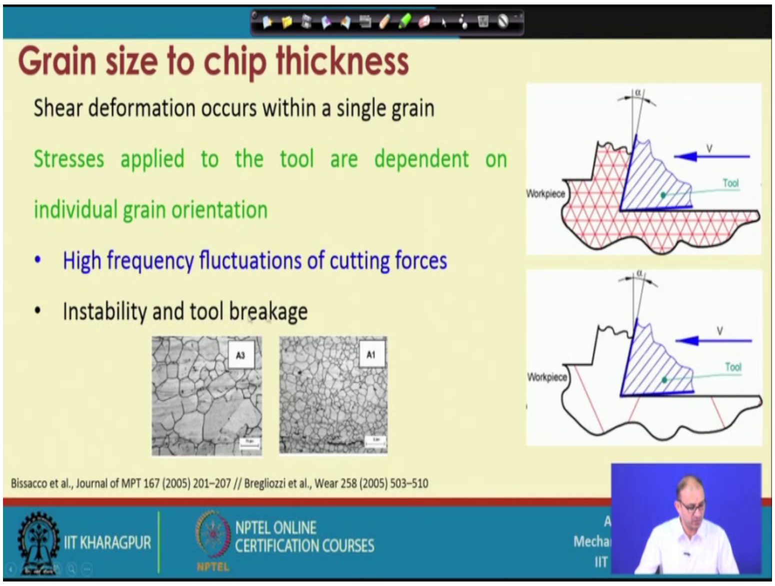

And, then we have seen that in the micro machining, many times a single point cutting tool or the milling tool will enter with a single grain compared to the macro machining or the conventional machining, where the large numbers of layers of the grains may pull out or may come out as a chip and it will not create any problem during the machining process. But, here it is not that case and you are end up with machining or the cutting of a single grain and then depends everything on the orientation of the grain and distribution of the grains.

And, because of that we have seen that there are large fluctuations for cutting forces because sometimes you may encounter a grain boundary. So, material removal will be very easy and sometime the grain is located exactly at the centre of this particular thing. So, you have to cut the grain. So, at that time you have to apply more force compared to the cutting at the grain boundary and because of that large variation in the cutting force many times you are not able to do machining at a stable rate and at the end your tool will be broken.

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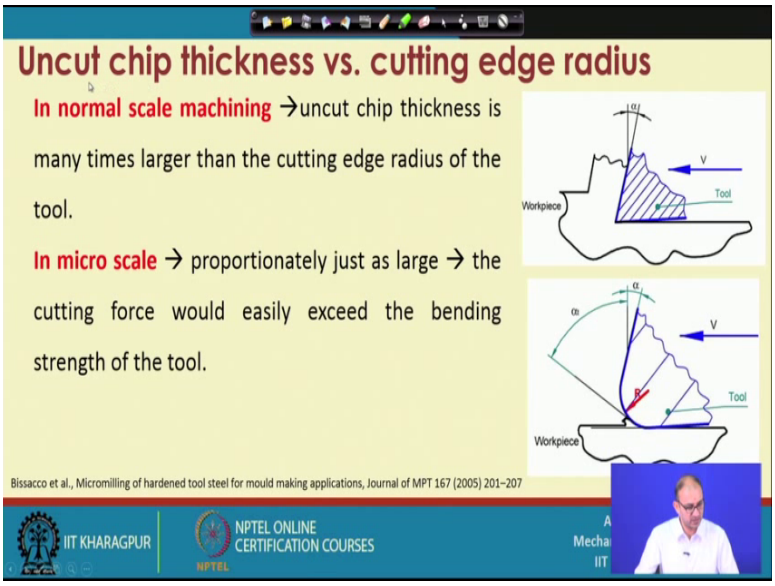

And, we have seen what is the difference the uncut chip thickness and the cutting edge radius and because of this particular large difference, you are end up with a negative rake angle. Your original rake angle was positive, but when you cut with a size reduction you are end up with uncut chip cutting edge in a negative side.

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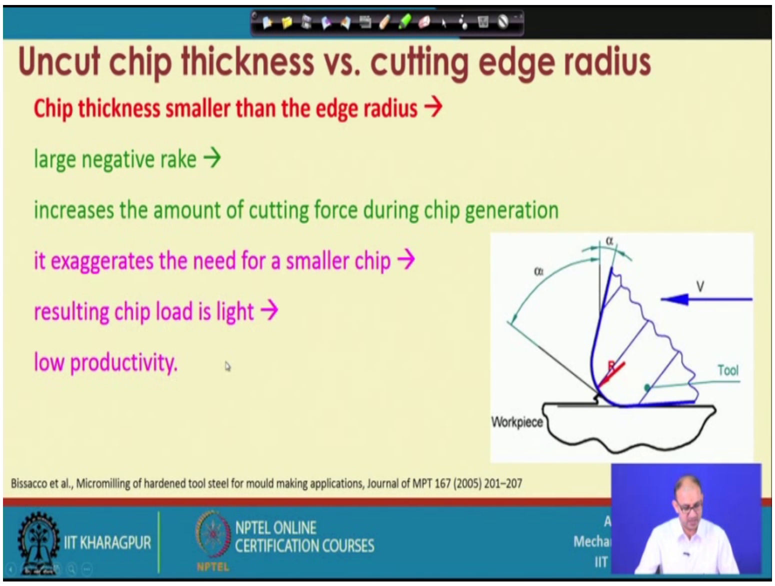

And, these are the reasons what is going to happen because of the small chip thickness, you have to reduce chip load and when you reduce the chip load; that means, you have to reduce the depth of cut and your low productivity will be resulted in this case.

And, to encounter and to remove this particular thing, what you have to do you have to operate a machine at a very high rpm, so that you can reduce the low productivity issues.

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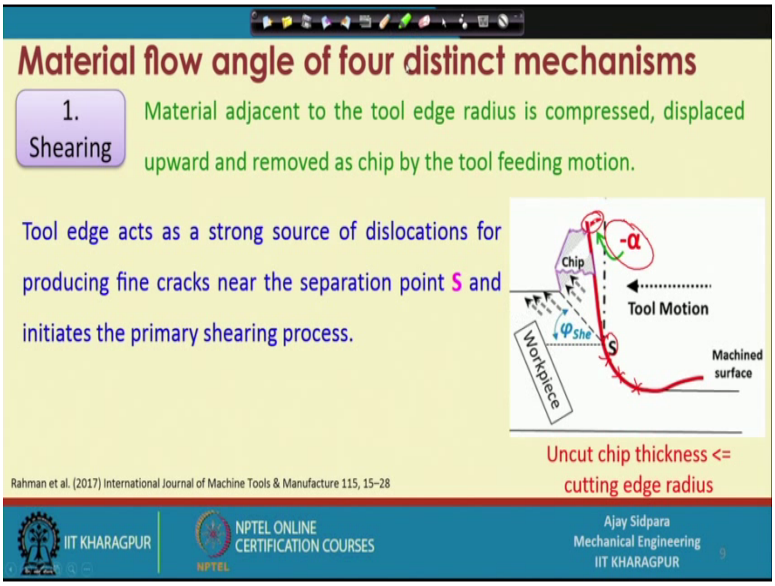

And, then we started with the 4 different mechanism through which the material flows and that was based on this cutting edge angle. So, back rake angle or we can say the rake angle or the orthogonal rake angle, there are many ways we can define this thing. And, here what we have started learning that this is the rake angle right now, it is very small in a negative side. Then, we will see in the next class in this particular class, what happens when this S point is moved at a different location along the cutting edge radius of the cutting tool. So, this thing we have seen that it is a first phenomena we have encountered is shearing. So, shearing is important and that is required to remove material in form of chip.

So, here we have seen the material is removed in terms of chip here, but some of the material is also moves along the direction of the chip tool motion and that will again squeeze and then again it will become the part of the chip and that will happens in a subsequent processing step. So, one after another sequence will occur and then it will remove the material in form of chip.

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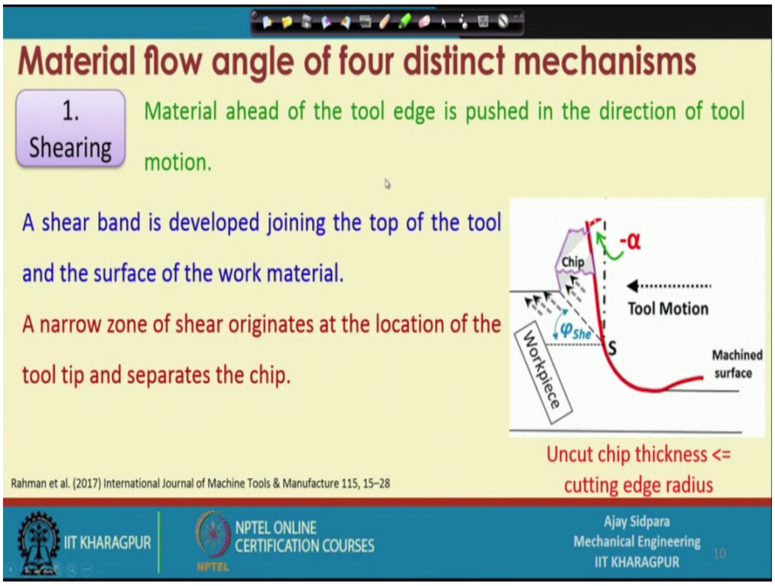

So, we completed the shearing portion in the last class.

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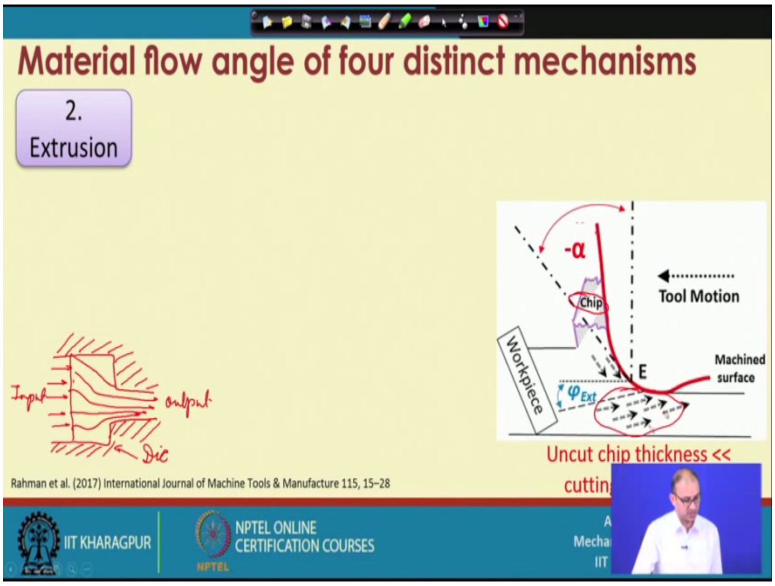

Now, second one is the extrusion. Now, what is extrusion here? Because, we know extrusion in the form of metal forming process because in the metal forming what happens that suppose you have a die and then you have material. So, this material will pass through this line and then everything will be squeezed away and then you will get reduction in the diameter or the reduction in the area.

So, this is the output and this is the input material and this is the die. So, what we are doing here, that we are extruding the material to reduce the area. Area maybe radius also, diameter also or the cross section of any square section or rectangular section whatever it may be. So, here same thing is happening in this particular case, because the material is extruding through this part and only small amount of part of this particular uncut chip thickness will come out as a chip, but remaining materials will extrudate through the flank place and become a part of the machine surface. So, let us see that what are the reasons for happening this thing?

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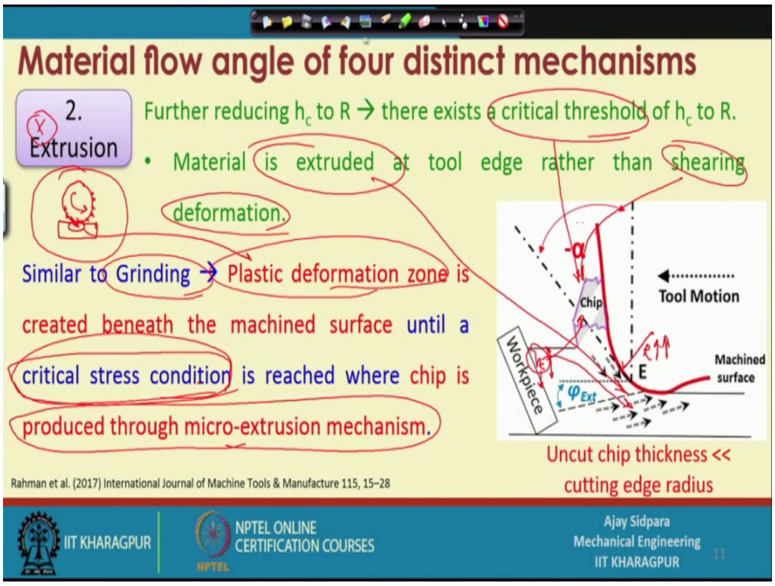

So, when we reduce further h c to R, now, our h c is this one. So, this is h c and whatever is this is the R. So, what we are doing, we are reducing h c by R. So, your R is very larger than the h c. So, your uncut chip thickness small, but your R is very large. So, here what happen here? There exist critical threshold of h c by R. So, this critical threshold is for what purpose, that is to form a chip; because, ultimately in our machining part we need chip because we want to remove some material from the work piece and if you do not get the chip then you are end up with the losing the energy and all your required part in terms of just mechanical workout only, but not any type of actual working. So, because of that you have to maintain this particular ratio in such a way that you are getting a chip, but not the just flow of the material or the displacement of the material from here and there.

So, material is extruded at tool edge rather than shearing deformation. So, what is the shearing deformation? So, shearing deformation is a chip and this material extruded part this is the extrusion. So, ultimately you are not removing all the material from the h c the part of the h c will go as a chip and remaining part will go as a extruding material in the machine surface.

So, how you can understand this phenomena? This can be understood by grinding process because we know that what is grinding. So, in grinding this is grinding will and very small this particles are located on the periphery and then when it rotates at that time this is the work piece and when it rotates and then what will happen it will push the material in this particular zone.

So, this particular zone is the plastic deformation zone, so that is below the machine until this, how this particular thing will remove the material? That, when particular grain will interact with the surface it will create a plastic deformation zone and that plastic deformation zone will enlarge or it will continue to form or continue to enlarge in such a way that you finally, end up with a one critical stress condition where the chip will be removed in form of a small fragment of the work piece material. So, what we can do that? We can actually understand this particular phenomena and whatever is happening in machining in form of a grinding process. So, here also what we are doing, our depth of cut is very small compared to the machining process in grinding and similar way micro machining or depth of cut is small.

So, it is not a very bad idea to understand this particular extrusion phenomenon in the form of a grinding process. So, this is how it is happening in this particular case. So, it continuously deforms the material and then it will reach to one particular critical stress control condition. Once it crosses this particular condition at that time chip is produced through the micro mechanism. So, in this particular case also you get chip, but the chip maybe smaller than the shearing mechanism because in the shearing it is the size of chip is bigger and it may be uniform also in this case, but comparatively this particular phenomena is also not suggested in the micro machining for efficient removal.

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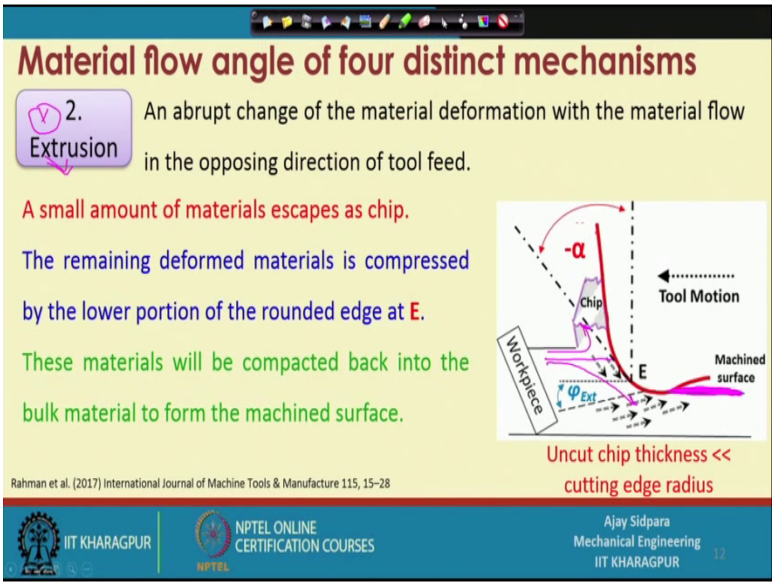

So, what happens in this particular case? So, there is abrupt change in the material deformation with material flow in the opposing direction of the tool. So, now, we know that tool is moving in this direction and our objective is to remove that material. And now we know that this is the one particular zone through which the material deformation takes place. So, only small amount of material, so, this is our h c. So, you consider the small amount of h c part, this part; this part may go as a chip and the remaining part whatever is here this part will be extruded into the machine zone. So, this is the deformation of the (Refer Time: 13:33). So, what this material, h c will be deformed completely, but it may not come out as a chip, but some of the part will be become a machine surface in terms of the extrusion process.

So, small amount of material escape as a chip so that is what is showing here and the remaining deformed material is compressed by a lower portion of the rounded edge. So, what is the lower portion of rounded edge? So, this the lower portion of the rounded edge. This whole edge is rounded, but now we have divided this whole edge in terms of 2 parts. So, this is the upper portion and this one is the lower portion and this is the E point, which is important to understand that this is the location through which you are end up with the 2 different phenomena and you are getting a shear plain angle in this particular case.

So, somewhat you will escape as chip and while the remaining material is compressed by the lower part of this particular location and then this particular material will be compacted back in the material to form the machine surface. So, now, where this material will go? Because, here you do not have any other thing, so, now, whatever is part of this particular thing this will go in this direction and this will go in this direction now it will be compacted further.

So, here it will be very compressed situation. So, in this case the property the top whatever the surface property may also get change. So, in this case if you are not required or intended to get the change in the property then this particular phenomena is also not advisable for the micro machining operation.

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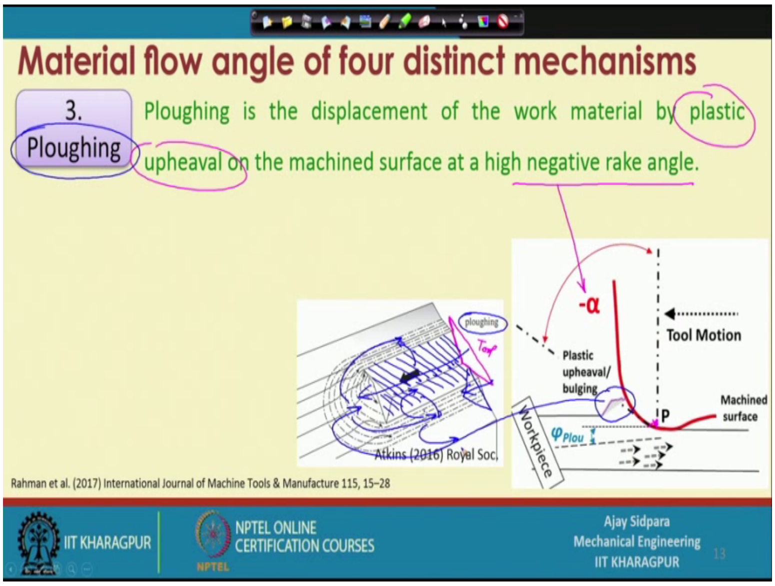

So, third one is the ploughing phenomena. So, what is the ploughing phenomenon? So, this is the ploughing. So, ploughing is the displacement of the work material by plastic upheaval on the machined surface at a higher negative rake angle. So, let us see each and every term. So, we know what the higher negative rake angle is. So, this is the higher negative rake angle, because if you see from this now, you consider in earlier case the point was somewhere here the earlier point, now, we are considering suppose alpha is extremely negative in this case. So, now, we are point the point of concentration is the peak point. So, this is the negative rake angle and displacement of the material by a plastic upheaval.

So, now what is this thing plastic upheaval? So, this is the cut. So, now, consider your cutting tool is something like this is your cutting tool and it is moving in this direction. Now, what we need? That we need a chip, to make this efficient, but instead of chip what is happening here. So, whatever is this material let me give this different colour. So, this is the material which is displaced from this particular location, but it has not come out as a chip. So, where is going this material? Some of this material will be displaced on both the sides and some of the things will create this type of bulging. So, this is the bulging of this particular part.

So, once bulging is sufficiently higher height then what will happen the some of the material will go in this direction and some of the material will go in this direction so that is given by this arrows. Now, if you follow these arrows, black arrows, then this is what is going to happen. So, this phenomena is called ploughing operation.

So, now, we know that if you continue your machining in ploughing region or in this particular ploughing operation basically you are not removing the material. You are just moving material from one side to another side and at the end what is going to happen that once this path is over, then what happen suppose you want to remove some more material from here. So, your second path will be from this location. So, now, your (Refer Slide Time: 17:54) creation will be here. So, what are the materials you are removing from here? Some material will be go in this direction, some will go in this direction.

So, basically you are displacing the material within the machine area. So, ultimately you are not getting any material removed out of this region.

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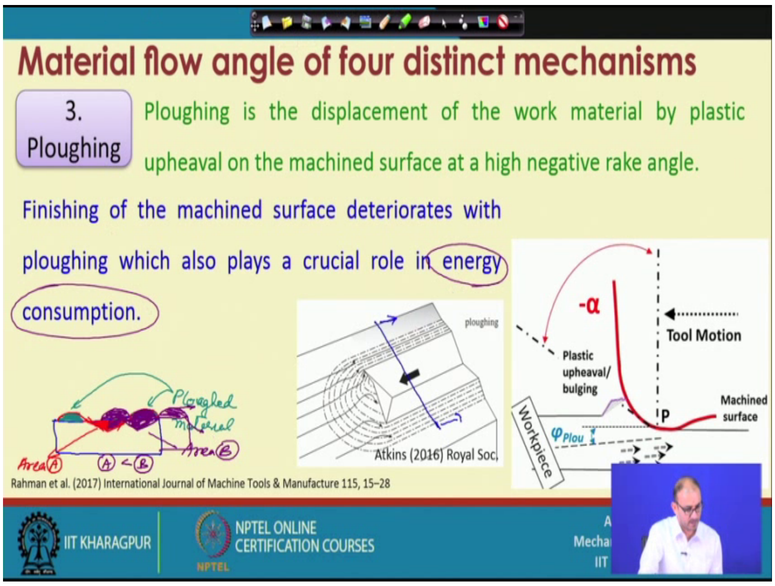

So, finishing of the machine surface deteriorate with ploughing which also play a crucial role in the energy consumption. Now, you know in this particular case. Now, let us see what is going to happen, now, if you see this cross section from here now what is going to happen. So, this is your original surface, suppose and this one is your tool. Now, tool is already penetrated to this area. So, now, this much amount of material whatever is here this much amount of material will be displaced somewhere. So, now, consider this material is displays in the side surface. So, whatever is here, so, this is the ploughed material. So, this is the; and this material.

Now, this part is now let us see that- your tool is moving to the next location. Now, this part is over our depth of cut is this much now consider this is the depth of cut and now we want to remove some material from here. So, again now see the how much amount of material we are removing from here. So, if you calculate this area, just a minute. So, now, this is our tool part and this one let us call area a now your tool is moving from this location to this location. So, now, the next location of your tool is this one. So, this is your next location of your tool, same depth of cut, but it is just moving to the next location. So, this is the next location but, problem here that some of the material, from this particular part, it is already piled up here.

So, your tool now, what is the area in this location? Now, area will be this much. This whole area will be removed by the cutting tool in the next operation. So, this is the area B. So, what is here, that B is bigger than A. So, next case tool may encounter more amount of material and because of that you have to spend more energy to remove that much amount of material and it may continue because now whatever you are ending here, so, this much amount of material some of the material will pile up here again. Even though some material is removed here, it may fold down in this particular area only also and if you extend the work piece, then some material will be here also and that is again then called the ploughed material. So, that way you are actually wasting the energy without any efficient material removal from the work piece.

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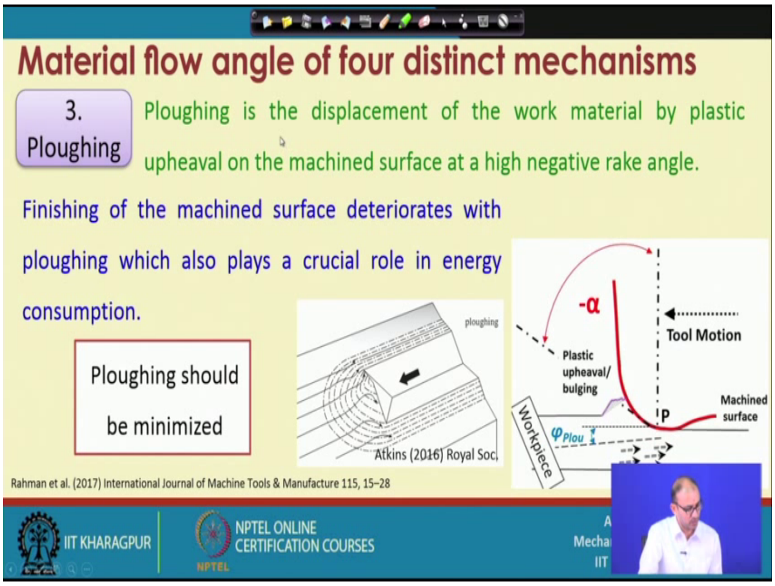

So, what is the final decision or conclusion out of this? The ploughing should be minimized to get the material removal.

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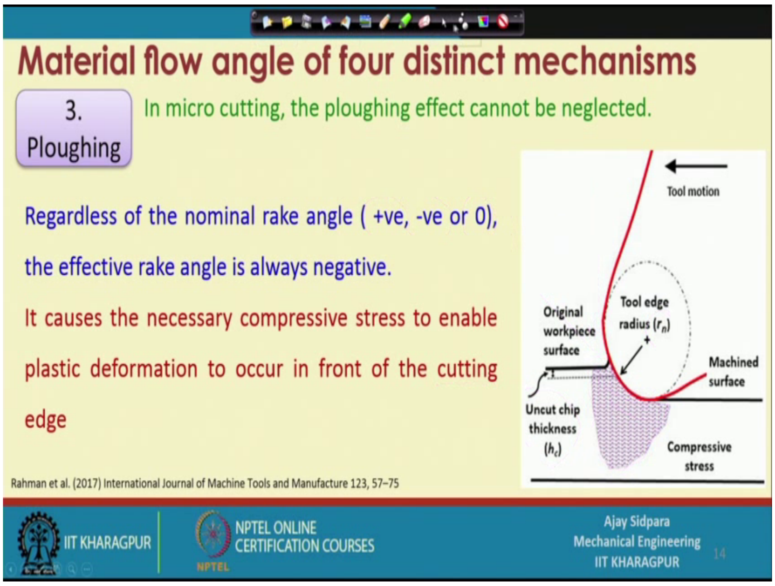

Now, what we do in the micro machine? The micro machining ploughing effect cannot be neglected because we know that whatever we do here we end up with the negative rake angle. So, regardless of the nominal rake angle whether you are positive, negative or the 0, so, what is the nominal rake angle? So, nominal rake angle what we are measuring is this one. So, this is your alpha but when it removes the material mostly happens in this region.

So, this is your effective alpha, so that is the negative part and this one is the positive it may be 0 also, if you are this red colour line that is a rake face if it is a straight lane here then it will be negative. So, whether it is a positive 0 or negative, your effective rake angle always in the negative part. So, that is what is happening here in this case and it causes the necessary compressive stresses to enable plastic deformation to occur in front of the cutting edge.

So, this is our cutting edge. So, this whole thing behaves as a cutting edge. So, wherever you are uncut chip thickness is coming into contact and then it is leaving the machine surface. So, this all part will behave as a cutting edge. So, now, we consider that we are not considering our tool as a sharp tool and because of that reason you are getting a compressive stress reason in this particular location, that is, front of the cutting edge. So, this particular compressive stress distribution in the plastic deformation zone, it will deform the material and then this particular ratio between the uncut chip thickness and r n will decide that which is going to happen? What things is going to happen here, whether it will remove as a chip, whether it all thing will just compressed through this machine surface or some part will go as a chip and some part as a compressive or the compacted material in the machine surface.

So, this cannot be neglected let it be one smaller depending on the radius of the cutting edge and the chip thickness, but some material also or some part will be ploughed in the later stage. So, we have to optimize our machining parameter that is the speed, feed and depth of cut in relation with the uncut chip thickness and cutting edge radius to get the efficient material removal.

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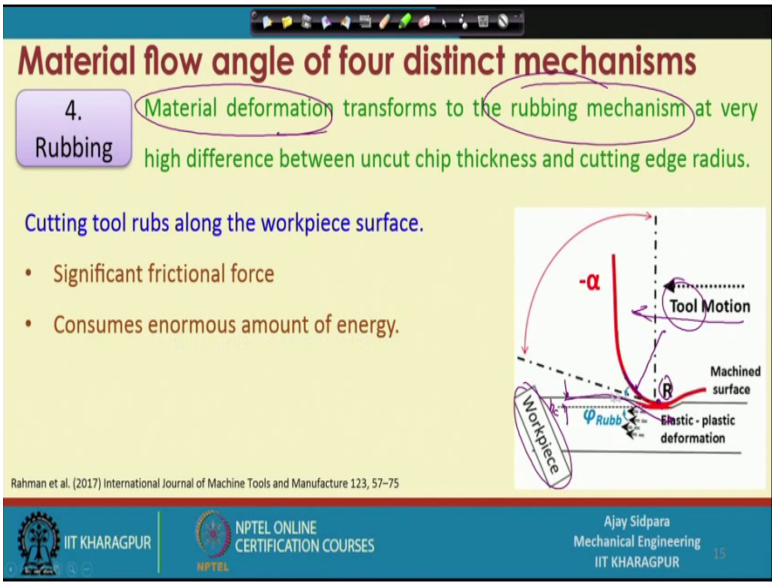

Now, fourth phenomenon is the rubbing. Now, rubbing is by word only we can understand what it means; that rubbing means when you rub 2 surfaces with each other that is called rubbing and there is no any type of material removal. So, now, let us see that how we can see this thing in the machining zone. So, again you consider this alpha is much larger than the earlier case.

Now, this is your alpha and now what is happening in the rubbing that material deformation transforms into rubbing mechanism at a very high difference between the uncut chip thickness and the cutting edge radius. This is our cutting edge radius and this is our uncut chip thickness. So, now, what is happening in here in this particular case, that now h c is very small and we are considering this r point it is further located towards the flank surface and not to the rake surface.

So, now if it is located here, now what is happening; tool is moving in this direction no material is located on this particular edge. So, there is a chance that most of the material will compress only, there will not be any type of material removal in this particular location. So, your material deformation it transfers into the rubbing mechanism; rubbing mechanism is that rubbing the 2 surface. One surface is the tool surface and another surface is the work piece surface and all things will be moved as elastic plastic deformation of this particular part.

Now, the cutting tool rubs along the work piece surface that is what is happening at this particular location. So, this is the location at which the rubbing is happening. And, significant frictional forces are high because now when you rub the surface if you cut the surface then at that time your frictional force will be very less compared to this particular.

Rubbing is the now tool surfaces which are no any sharp edges or anything and you are just rubbing with a normal force. So, at that time your frictional forces may be very high and it consumes enormous amount of energy, because here it is elastic plastic deformation. So, no material is removed in terms of chip. So, material is just getting compressed and compressed and finally, it will become the part of the machine surface. So that is the reason for the high energy of the machining process. So, this is also note, important.

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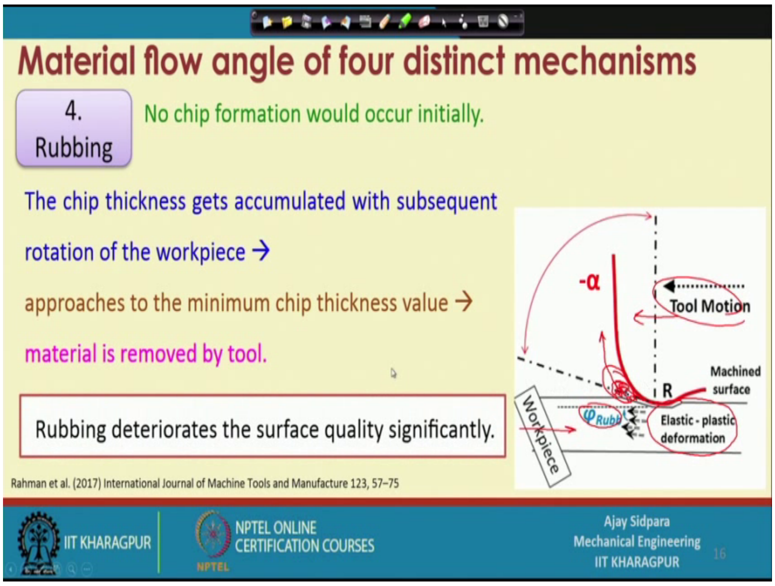

So, here what is happening that suppose in some case exceptional cases that where there is no chip formation initially, but what is happening in this case suppose you continue in this rubbing phase that you continue even you know that sometimes you do not something is happening at this location and you continue the machining operation considering or expecting the material is removing and you are getting the cutting, but actually the operation is being processed is the rubbing process.

So, if you continue in this particular cases initially you will not get any chip removal, but what happens that when later on you continue with this particular case there is one now see this particular region will be highly compressed in this case and because of the rubbing now your tool motion is in this direction and your work piece material is coming from this direction.

So, later on, if continue operation it will create a some type of extra material here and then well what is going to happen that it will continue to grow this particular region, this particular rubbing region and if you continue this growing of this particular thing at one particular instant what is happened that size of this particular thing is so high, that it will move as a chip, but that will happen in a rare case and in sometimes after long time.

But, most of the times you have already consumed most of the energy in this deformation without any removal and that is not the correct thing for making this particular thing. So, it get accumulated at this particular location and approaches to a minimum chip thickness value which is required to form a chip and once it reaches one particular location you can remove the material by a moving tool in this particular case.

So, what is the conclusion of this rubbing step? that rubbing deteriorates the quality surface significantly. So, you should avoid the formation of the rubbing or reaching to this rubbing location in terms of making one particular decision about the cutting edge radius and the uncut chip thickness.

So, let me stop from this particular slide. We will continue from the next slide in the next class.

Thank you very much.