Introduction to Mechanical Micro Machining
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Lecture – 13
Difference between macro and micro machining (Contd.)

Good morning everybody, and let us go through some more information about the courses on introduction to micro mechanical machining.

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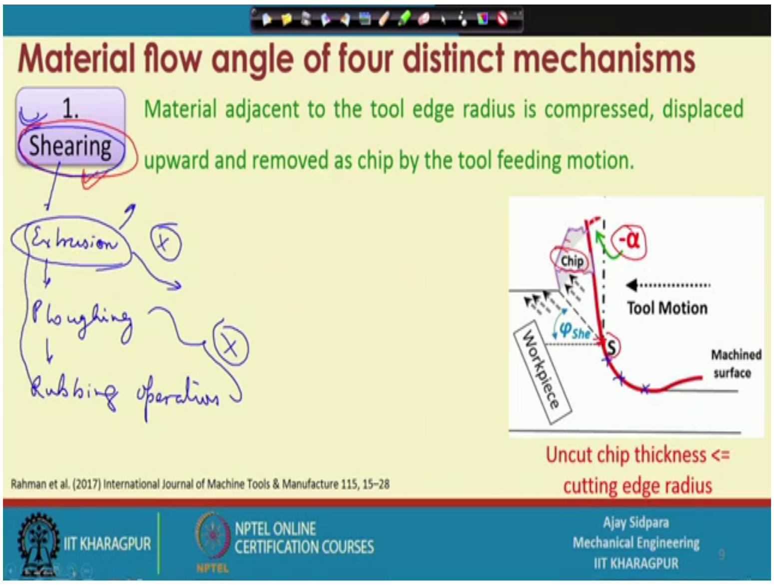

So, in the last class we have seen four different, mechanism by which you can remove the material, and that is in terms of the uncut chip thickness ratio to the cutting edge radius. So, we have seen this particular location of the point S here, and in the form of what is the angle of a rake angle.

So, mostly we know that in the when you do machining at a micro scale, you are mostly end up with the negative rake angle, and because of the negative rake angle the formation of the chip becomes little bit difficult. In the last class we have seen four mechanism one was the shearing mechanism, that shearing is important, because this is what we need to form a chip in this case, and then gradually we move this particular point from this location to the this location, then moving to this location, and then this location.

So, we have seen the different mechanism. So, one was the shearing mechanism, then it was a extrusion, then it was a ploughing, and then finally it was the rubbing operation. So, what is importance? So, this shearing is important these two things should be completely avoided, and in this particular extrusion case also you may get a small amount of chips, and some of the material will be extruded through the workpiece so, this should be also avoided. So, our objective is to do machining at a shearing operations, shearing or shearing mechanism come ah, but not to the extrusion ploughing or the rubbing operation.

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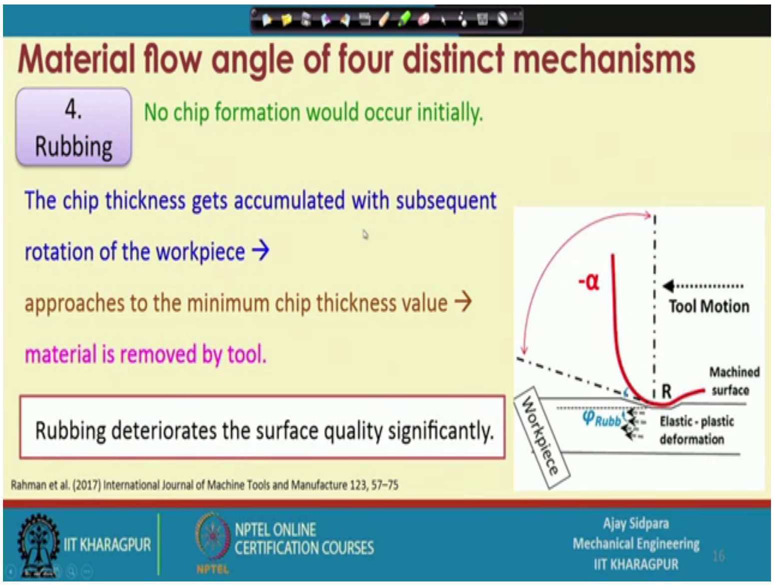

So, let us continue further that is fine last class we have complicated rubbing portion, and we have understood and concluded there the rubbing deteriorate the surface quality significantly. So, we have to avoid the rubbing operation.

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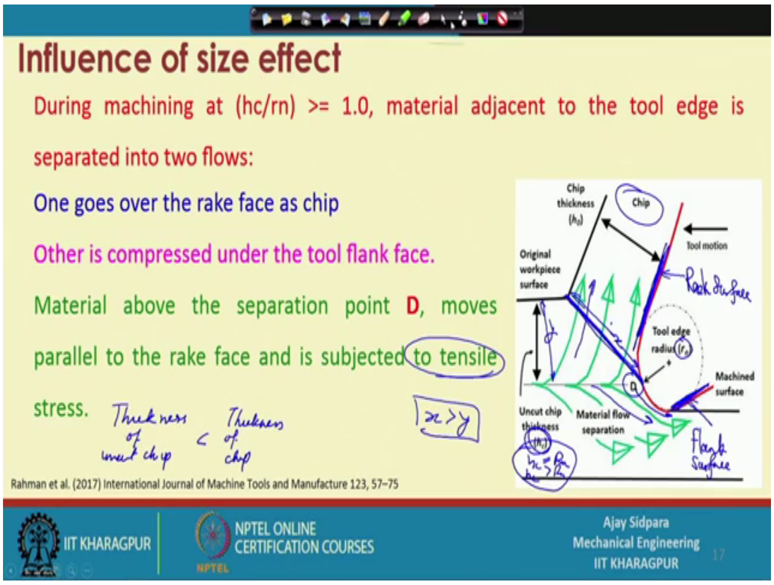

Now, let us see the, what is the size of the influence in size effect if influence of the size effect on the different parameters. Now this particular diagram tells us many things that when you do machining at a h c by r n that is this is your h c and this is your r n.

So, when you do these things so, h c is equal to R n or it is a little bit smaller than R n. So, we are not talking about a very very large negative rake angle. So, what is happening in this particular case, then your more material is separated into two flow. So, this is the one flow it is showing in this direction, and another flow is showing in this direction. So, this is called a material flow separation right. So, one goes over the red face as a chip this particular time, and the other is compressed under the tool ploughing surface. So, this is the ploughing surface of the tool.

So, let us see this thing is a rake surface, and this one is a ploughing surface correct. So, this is what is happening in this case. So, material above the separation point D. So, this is the point we have discussed in last class all the things that we have found that this D is moving from here to this downward. So, that you are getting a different different mechanism of material removal or sometime the material deformation mechanism not actually the removal mechanism, because in many case material was not removed in terms of chip. So, here the material above the separation point D moves parallel to the red face, and is subjected to do tensile stress.

So, this whatever material is coming out this will be in the tensile stress, because we know that whatever is material uncut chip thickness that the thickness of uncut chip is smaller than the thickness of chip. So, whatever chip it is coming out of there this will be bigger than the uncut chip thick, because this chip will be little bit expanded, when it is cutting out at that everything depends on the what is the size of the or length of your shearing angel.

So, now see the whatever with the shearing angle, this particular length you consider x and this one you consider y, so your x is larger than y, so in this case it will be mostly in a tensile stresses, and you are getting a chip out of this particular mechanism.

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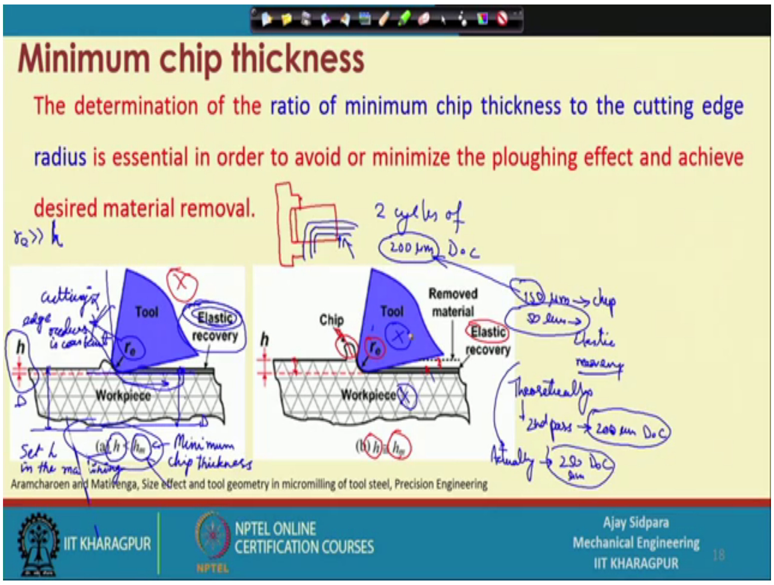

Now coming to the minimum chip thickness; now we have seen here that in many cases what is happening that you are not able to remove material. So, there are 2 parameters one was the rake angle that is mostly going into the negative side, and another one is the chip thickness. And we are constantly comparing these 2 parameters in the last many many cases. So, what this the minimum chip thickness that determination of the ratio of minimum chip thickness to the cutting edge radius is essential, in order to avoid or minimize ploughing effective ploughing effect and achieve the desired material removal.

So, let us see the first figure here, now what this figure tells us that now this one is the minimum chip thickness required, there this is the minimum required to get the material in terms of chip. So, this is called the minimum chip thickness correct, and this is what we have said right now, set h in the machine correct. So, now right now you consider h is smaller than the h m. So, what is happening right now we are keeping r e constant that is a cutting edge radius is constant right. So, cutting edge cutting edge radius is constant.

So, we are continuously changing this edge. So, ultimately if you change one of this parameter of r e or h, you are getting different different ratio of the uncut chip thickness right. So, the first thing let us see that you will setting edge or whatever you have given depth occur that is smaller than the uncut minimum uncut chip thickness. So, what is happening in this case your re is very very large in this case, r is very very large than the m not h m, but only m h. So, this is what is happening.

So, in this case we know that negative rake angle is very very large again, and because of that what is happening here this one is called the rubbing operation that it is elastic recovery. So, in it is also different than rubbing operation, because recovery means that you are just display you are just r e moving this particular tool over the surface, and once this particular tool is passed your surface again resurface on this your surface is again recovered.

So, whatever is this particular edge, if you consider this particular line, or consider this is the end of the surface for this whatever is this total thickness it is b. So, same thickness will remain here in this case this. So, in earlier we have seen some of the operation, where the material was deformed but deform material became a part of the machine surface right, but here there is no machine surface.

So, whatever we are doing here we are working within the elastic range of the material. So, within the elastic range what is going to happen that, if you remove the load, then material come into the original step. So, that is this is what is happening in this particular case your tool thicken or the uncut chip thick that minimum cut chip thick chip thickness is so low, there your material is not crossing this elastic limit of the material.

And that is the reason that we as soon as tool is passes through this workpiece, at h at that time your material will be resurface here, at this location it can recover and again thing part. So, this is completely not acceptable in the machining part, because what is our objective to remove the material.

Now, this is the second case now here what will what is the difference here, the difference is only one thing that your h is similar to h m. So, now, we have little bit increase our h. Now if you see h here this h is little bit larger than the h m still r e is constant here, in this case we are not changing r e in the different different cases.

So, now once this is the h now what is happening that now your tool is little bit penetrated inside, and it has cross the limit of the elastic recovery, but here still it is within this particular zone. So, what is happening that some of the material will escaped as a chip, but still some of the material which will be recovered as a elastic deformation, but still you will get some material removal.

Now see your h is this much but you are getting material removal this much only and remaining part will be consume as a elastic recovery of this particular part. So, what is the problem of this particular this is completely unacceptable by chance you are getting here, but your chip is not required is our h, then some of the material will be recovered.

So, now in the next round of this particular machining have what is happening, now see the suppose this is your workpiece this is the chuck, and this is the material. Now you are removing the material considering that you needed 2 pass to reduce this particular diameter, and now this is the 2 pass this is the first pass. Now considering the first pass you have remove this material right. So, whatever depth of cut you are giving here, suppose depth of cut is we have given that 200 micron, 200 micron depth of cut.

Now out of 200 micron, now consider depths that 150 micron is going as a chip, because that is what is showing here some part will be going as a chip, and 50 micron is elastic recovery ok. So, now, what is happening that, now you have 2 constant depth of cut that 2 cycle of 200 micron of depth of cut.

So, in the first cycle we have given this command, and unfortunately this 50 micron is still available there, only 150 micron is removed, but we do not know during the machining that this has happened. Now first cycle is your, you are going for the second cycle. So, theoretically your second cycle or seconds not cycle, let us put a passed that is more appropriate word, in the second pass how much material we want to remove we want to removed 200 micron, what that is a 200 micron depth of cut, but what is happening actually that you are giving depth of cut of a 250 micron, because 50 micron is already recovered here.

So, now we know that we have said this particular speed feed and depth of cut parameter depending on the geometry of the cutting tool, the type of the cutting tool, in the workpiece material properties many things. Now we know that two hundred is giving the optimum result out of it, but now because of these particular phenomena what we have encountered that we are removal material as a 250 micron depth of cut. So, now, our set parameters are not effective here, because it has overcome that one particular parameter that is depth of cut is actually changed here.

So, because of that region what happened that, you are not working or you are not operating your machine as a optimum parameter, and that is the reason that you may encounter the breakage of the tool very very high tool here, all the different properties on the workpiece machine surface, and that is the reason because of this mixture of the elastic recovery and the removal of the material. So, that is what is happening in this particular case here, what is happening the, you are not removing material at all. So, nothing is going to happen to the workpiece.

Some of the material you are removing in this case, but some of the material is again resurface or the recovered on the part, and that is the reason that you may encounter the different failure of the tool, because every time you passed or no more number of pass you from here everywhere, every time you are end up with the more amount of depth of cut, then the said there set depth of cut and that the reason for degradation of the property of the workpiece, also and the degradation or the breakage of the tool also. So, now let us see what we have to do to get this thing correct.

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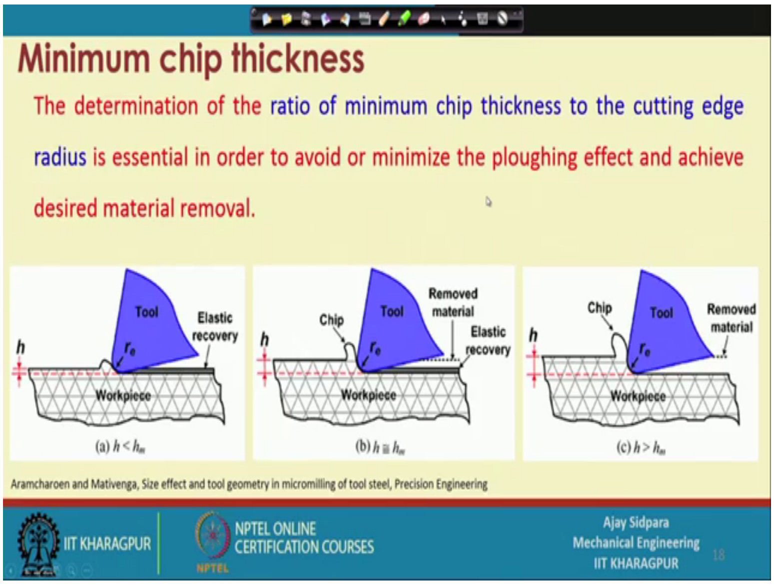

So, now this is the third case what is happening in these third case that your set h value it is higher than the minimum uncut chip thickness. So, now, this is the set value, now if you see this r value and this h value h will value slightly higher than the r e value. So, now what is happening here now your tool is already penetrated in such a high that you are not going to get a elastic recovery of the material and whatever is this thing here, you will get the chip out of this particular part.

And this is the, what is important thing here, that we have to maintain a minimum uncut chip thickness in such a way that you are always getting the chip from the uncut chip or the minimum cut thick minimum uncut chip thickness. So, that no material is getting the inside the workpiece material no any type of recovery from the machine zone. So, this is the required condition to get the material removal in terms of chip.

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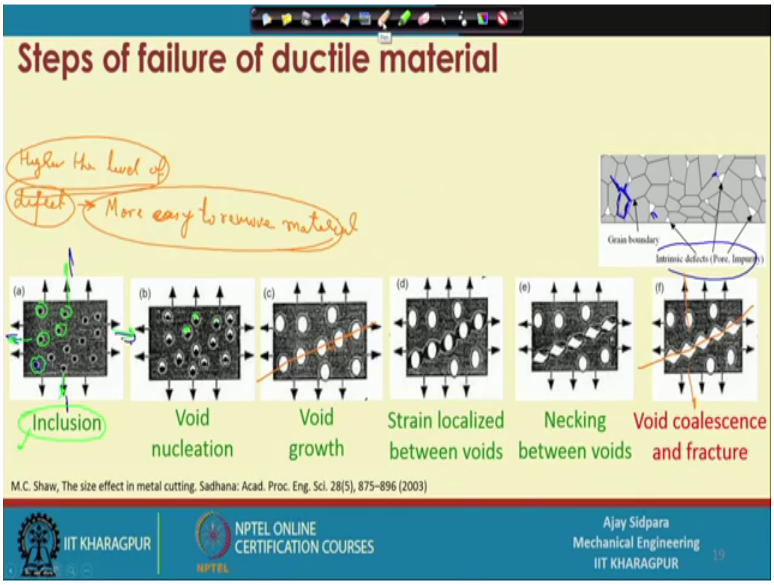

Now, what are the failure in the ductile material, now see we know that no material is perfect complete, it is there are low maybe different type of defects are available, and because of the defect you are always get a one type of initiation or the some type of propagation of the a cracks or propagation of the deformations surface. Now we know that this is one of the schematic diagram of the grain structure of this part. So, now, you know that there are grain boundaries available so, these are all the grain boundaries, these are all, the grain boundary.

Now, intrinsic defects are available there are pores available these wide portions are the pores, and there are some impurities also available impurities mean, some of the foreign element is available here; that means, it may be harder than this base material or it is softer than the base material also there. So, these are the some of the defects inside. So, now see what is happening when you have some type of defects in the material, and you are actually deforming this material in the both the direction, this is in the x direction let us consider, and this is in the y direction also.

Now, first thing is the inclusion. So, these are the inclusion. So, what are this inclusion means, there are some defects right. So, whatever this defects are there those defects are the inclusions, so these are the inclusions right. So, the whatever these things are showing here these are the inclusions, now you are actually putting this workpiece in the tension in both the directions. So, this inclusion will behave or it will be origin of the breakage or the origin of the void, and then it that void will continue to propagate and finally, you are getting a breakage right.

So, second after an inclusion what is a new void nucleation? So, once these particular inclusions are available within the material, what is happening that when you are actually putting these workpiece in tension in both the direction, this particular void will be original of the deformation of this particular workpiece. So, it is failure is created from this location. So, wherever it is a high load your workpiece will be elongated in this direction. So, this is whatever this white portion is available so, this is the extra amount of failure. So, now, your workpiece is getting elongated in this direction all right.

So, now if you continue this thing this void will be grow, and this growth of this void will create a one particular direction, where the distance between the voids are very less. So, now if you see this particular thing, then you are end up with this particular 5 thing, so this 5 are such a way that the distance between these two are very very less, now this is also little bit far away from that and this distance are very very small in this case.

So, now the next step is the strain localized between the voids. So, now the strain is getting localized between this, now the distances are very very small, and it is very easy to merge this particular void growth. So, now this is the black color part is showing the localizing between the voids, and then the necking between the voids. So, now necking started in this particular location, and then finally what I want the void colon is and the fracture happens. So, now, your part will be broken from this particular direction. So, this will be the first upper part, and this will be the lower part.

So, now, what is the meaning or what is the objective of showing this particular slide is that, every material has a defect and that defect will be a nucleation of the deformation or the cutting of the material. So, higher the level of this, defect more easy will be the material removal. So, higher the level of defects more easy to remove material, but that is not the case that you have to select the material with a higher defect, but our objective is to reduce the level of defect in a initial stage also.

Because this is what we are telling that material has some defect, but that does not mean that it should be have higher defect, our objective is to find out that at which particular defect level material is acceptable for the final application, and whatever defects are available within that material, how many defects are there that will originate or that will nucleate the deformation or the fracture of the particular workpiece material or the failure of the material.

So, this thing will decided how much is the energy required to remove the material, but that does not mean the defect should be present we need a defect free material, but no materials defect means there are some these type of things are available, and because of that you are getting the material removal at a different different mechanisms right. So, during the machining it when you are talking about, where this h c and this material adjacent to the tool is separated into 2 flows that we have seen in the last class.

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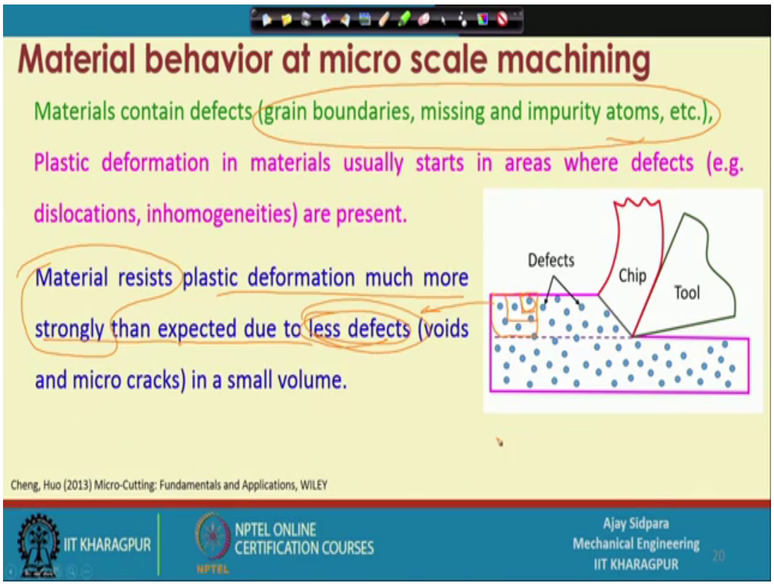

So, what is going to happened with this particular material contains defects. So, whatever defect we have seen the grain boundaries, are also considered as a one of the origin through which the material is separated out missing, and impurity atoms are also available in this particular case, now see these are the defect levels. So, we have seen that in earlier slide, then many things are created or nucleated because the presence of this particular defects. So, plastic deformation in materials usually starts in area where the defects are present.

So, now suppose this is the particular condition, now if you see this particular this is the point of the contact between the tool and the workpiece material, if you continue in this direction you are not encountering any defects till now, and then suddenly you are getting 1 defects, 2 defects, 3 defects depending on this particular property of the defect, whether the defect inclusion or porosity or something other than that depending or that the forces or the lord on the tool will be fluctuated, and when you are passing through this thing you are getting a different different magnitude of the forces on the tool and that will decide the tool life, and the efficiency of the machining operation right.

The material resists plastic deformation much more strongly than expected due to less defects. Now this is you consider as a normal machining operation; that means, you are considered a micro machining or conventional machining, where your depth of cut is very very larger than the uncut if thickness that we right. Now we are showing the sharp cutting tool so; that means, thus we are not we are neglecting the uncut chip the cutting edge radius in this location, and now this particular thing whatever is showing here, it contains many many grains many many layers of grains. So, these all things are the considered the grains layer, and now within that particular things that you are there is a high chance that you will end up with the grain boundary, and material removal is very easy to pass through these particular grain boundaries.

But now if you see that you reduce this particular scale of the machining part, and then what is happening here in this case that, now this is you consider this particular thing let me clear this part first. Now this is the deformation zone. Suppose now this is the uncut chip thickness, now you are reducing from here to here, and then you are reducing from here to here. Now you can see that within this particular area your number of defects were very very large, and if you reduce your machining area or uncut chip thickness the number of defects which will be encountered by the cutting tool will be little bit less.

Now what is ah; that means, that now we know the material resists plastically deformation much more strongly than expected due to less defects. Now we reduce the scale your defect level is very very less; that means, voids cracks whatever is there that is in small volume, if defects are less what will happened material will behave strongly. So, you have to apply more amount of force here for cutting of this material. So, now this is the problem in this particular case, and that is the reason that what we are doing right now that when you cut the material at this level, you have to find some of these particular things by which your material removal will be very very easy.

But that is not going to happen because, yes you are going down and down in the material removal, at that time the defect levels are very very small, and because of that

that is the what is happening in this particular case here, your material removal (Refer Time: 27:06) very difficult. Other than that right now we are considering our cutting tool is a sharp, but we have seen that our cutting tool has also 1 finite cutting edge radius, and many times we have seen there of cutting edge angle is very raw or cutting edge angle is very rounded, and because of that your tool is also not sharp, you are not getting the number of defects also very very large. So, both these things are combined and that will make the material removal very very difficult.

So, let me finish this lecture here, and we will continue from the next class about more detailing on the micromachining operations.

Thank you very much.