Introduction to Mechanical Micro Machining
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Lecture - 17
Difference between macro and micro machining (Contd.)

Good morning again, and welcome to our course on Introduction to Micro Mechanical Machining. In the last class, we started a topic on burr formation. And we understood a burrs are some of the, one of the things which is not desirable in the micro machining as well as the micro machining. But, we have seen that it is difficult to remove these burrs in the micro machining because of the size limitation. And we have seen some of the disadvantages because of the presence of the burrs and that will create a problem in the component which is going to use for a different application. So, let us further go in to the detail of the burr formation at the micro scale.

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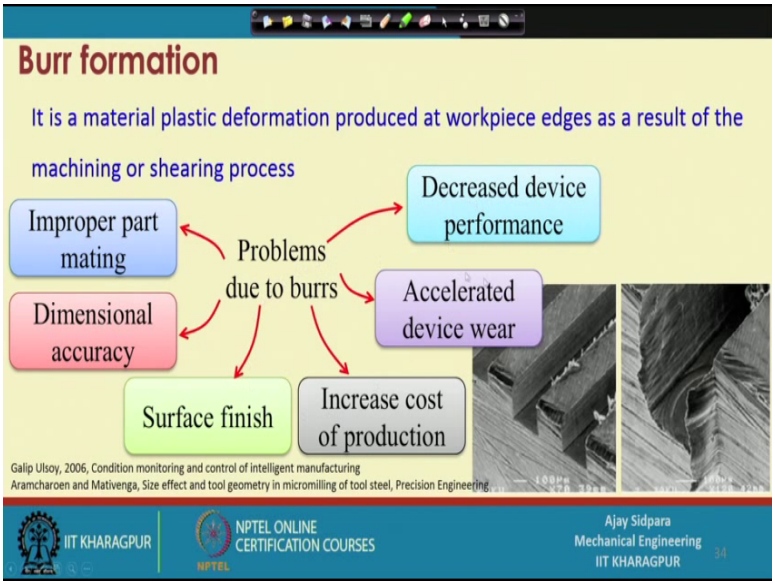

So, this we have seen in the last class that there are lot of problems because of the Burr formation. So, these are the problems of Burr formation.

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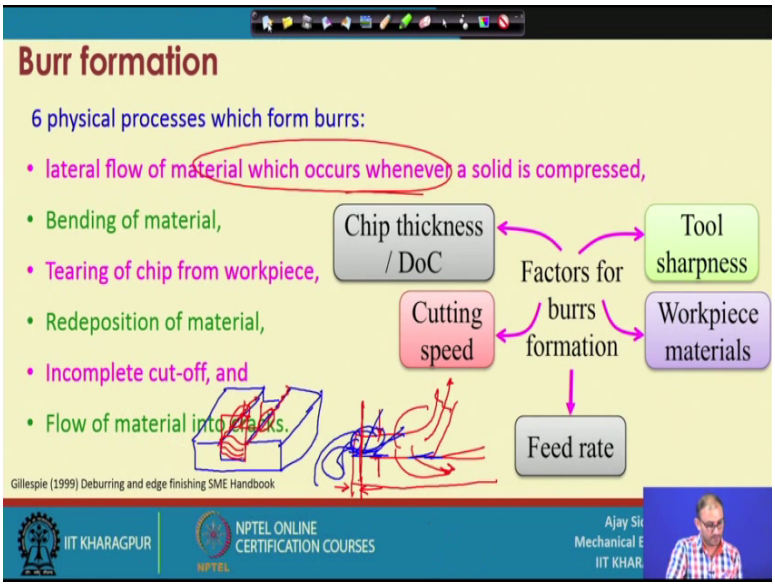

Then what are the ways because of that burrs are farming into the workpiece. So, let us see those things. So, factors of the burr formation. So, one is the tools sharpness play important role because if you are machining with a blunt tool at that time we know that, you are cutting edge radius is very less compared to the uncut chip thickness.

And that is the reason you are not able to remove material is clearly and you are end up in the rubbing and the blowing mechanism, which we have discussed some time back workpiece material, because if you are machining a hard material or the brittle material or the ductile material, every times your burr formation will be different. And whatever parameter we are setting up for a one particular material that may not be applicable for the burr for reduction bur burr reduction in the another material, because materials behave differently when you operate under the same condition and so that burr formations are also different.

Then the Feed rate also play important because if you go with a very high feed rate at that time, you may end with the high burr, but now what we are looking here that, if you tell that feed rate is high feed rate will result in the low burr, but that is applicable for a certain material and certain specific condition only. So, there are no any generalized sentences is available; that means, you cannot generalize anything that low feed rate equal to low burr high or the high feed rate equal to high burr rate. So, that is specific for a specific condition as specific materials only. So, generalization of any type of

conclusion is very difficult in the micro skill. Because we know that there are a lot of other parameters. We are also playing important role and that is why it is difficult. So, we will see a material point of view in the next few slides that how this feed rate also play important role.

Cutting speed is very important here because if you go with the low cutting speed and if you are cutting a ductile material, then your end up with the high burr. End depth of cut and obviously the Chip thickness. So from this, we can understand that speed feed and depth of cut laro always presents for any type of optimise, any type of machine material removal because, these are the 3 parameter which are required to set perfectly or optimise in such a way that you are end up with a less amount of defects.

And Burr is one of the defects by which you are not able to use the path directly after machining. You took, go through one post processing operations. So, what are the 6 physical processes which forms the burr? So, one is the lateral flow of material which occurs when ever solid is compressed because we know that we have plunging the tool in the work piece material. So, what is happening because of that, that whenever you are puts putting a or pushing the workpiece. And this is our chip, this is our uncut chip thickness and this is our workpiece whatever we are machining out of it.

So, whenever we are pushing the material, we assume that everything is raised all the cheapest flowing over the rate face of the burred it. But we have seen in that flowing mechanism, the some material is actually moving on the side also. That is also creating problem. And lateral flow is that means, some material will also go through the machine surface. So, at that time there is also creating Burr formation, bending of the material because, whenever you are reaching at the end of the position, so this is the end position here. Now, when your tool is reaching to this location, so this is your tool, it is reach to this location. Now what is happening? The strength of this material is very less. So, instead of a clear cutting, what will happen, these particular materials bend and it will become a burr formation here.

So, that is also one of the reasons. The bending of material, mostly it happens in the ducktail material. Tearing of chip from the workpiece, this happens mostly in the brittle material because now, you consider this is the machining of a brittle material and now there is crack propagation. So, this is a crack generated during the machine. So, if you

continue this crack, this crack will present here at this location. So, when your tool is here at that time, this crack is already close this particular workpiece. And so this old thing whatever is available, this will bend here and then it will create a burr formation.

So, this is also one of the reasons. Redeposition of the material, that mostly happens in the milling operation because when you are cutting a slot milling, at that time, this is the correct, this is what you want to do a cutting. So, your milling cutter is a considered that the size of the slot is same as the diameter of the milling cutter. That make you different colours that is much better to understand.

So, this is your milling cutter. So, when you are cutting it, at that time what will happen that when your tool is at the centre this location somewhere, the chip will actually tried to accumulate at this location on the top face of the workpiece right. So, this sometimes what happen the chip is not completely removed by that time your tool is already moved ahead in the forward direction. So, this is that chip will whatever coming is the that is again actually redeposit on the top surface and it become the part of the top Burr. So, this is also one of the reasons. Incomplete cut off that you are not a, your tool is not reaching to the end of this position.

So, that is also one of the reasons for that, that you whatever you have calculated that this should come; your tool is not completely completing the path of the cutting the action. At the end, you are end up with the some material which is left here. So, your tool is not reaching to this location. So, this is the problem at this location. So, that is not enough. The Flow of material into the crack; so, whenever it is doing machining it a brittle material at the time the correct is propagated, and some material is also flow into the crack and that will become a part of the burrs. So, these are the different physical processed by which you get the burr formation in the machining operation.

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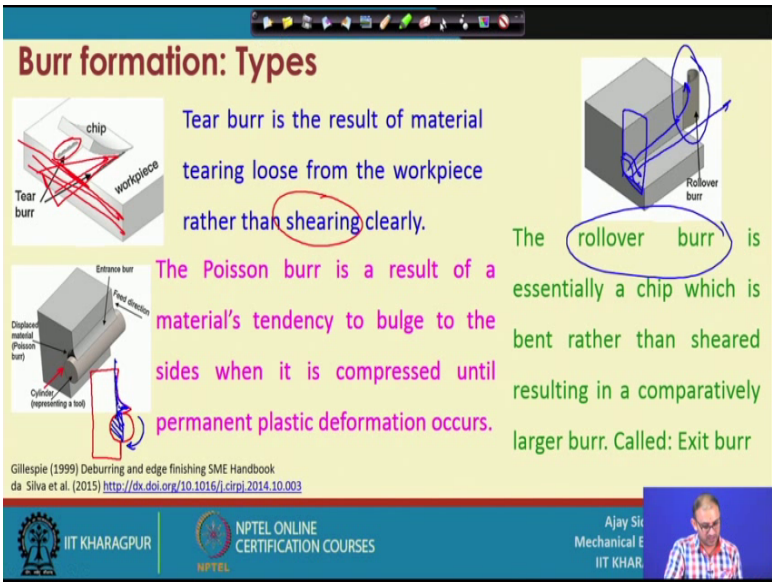

Let us. So, what are the types of burrs? So, here some burrs are given. So, this called Tear burr. So, what is tear burr? It is the result of material tearing loose from the workpiece rather than shearing actions. So now, if you consider this thing, that when you are removing chip. Now you considered your tool is located here, this is your tool location. That and you are penetrating your tool in this direction. So, instead of justice, sharing action purely that you workpieces getting teared away, because many times it happens in the lamination, laminated materials that is suppose you are talking about composite material where there are different type of layers available and when you do cutting of this think at that time, it will always find a interface of the play and that the time it will create this type of tearing burrs. So, these are called tearing burr.

Now, these are called Poisson burr. So, what is Poisson? Poisson burr is a result of a materials tendency to bulge to the side when it is compressed until the permanent plastic deformation occurs. Now, let us consider this situation. Now consider this one is a tool. So, this is the one cylinder, you are rotating this cylinder then you are pressing this cylinder inside. So, what is going to happen, that you consider the what tool is a blend tool. Now when you are pressing it inside, whatever there is amount of press; now consider while looking from this side, now this is the cutting tool and this is the workpiece over to here, looking at this location correct.

So now, whatever is this material because when you are pressing this tool insides, this the amount of material it is displace, it is inside, rotation is in this direction correct. So, when you are putting your ah, pushing this particular tool into this material, these amount of material will try to displace at some location. So, this material is going to this particular location correct. So now, this is called Poisson burr. So, whenever you are getting this type of Poisson burr, this is because of the displace material.

So, if you continue in this direction now rotation in this, at that time the high chance that this Poisson burr will be removed. And this is the rollover burr. It is essentially a chip which is bent rather than sheared resulting in a comparatively larger burr. So, this is mostly called Exit burr. So, your cutting tool is here. So, this is your cutting tool and you are going in this direction. So, once your cut is over, at that time what happened, at the end if some chips is available, at that time that chip is actually getting bended over instead of continuously removing out of the workpiece and your tool is completely past from these. And so whatever the bending of this chip, this is called rollover burr. And this is mostly happened, we have seen in the earlier slide also that this was the burr which was created at the end of the cutting tool or end of the workpiece. So, these are the 3 different way, we can there many other ways. Also we can give a definition to the burrs that we will see in the next slide.

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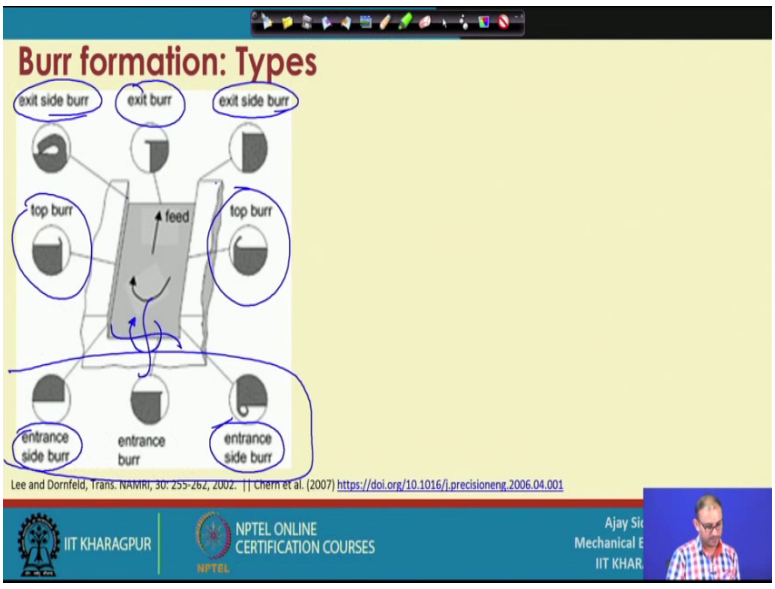

Now so, this is more a comprehensive figure compared to earlier case. So, here this is a slot cutting by milling cutter. So now, you are rotational direction is in the clockwise direction and then you are moving in the opposite directions, your workpiece is feeding down. Now you are cutting tool is like here. So, now, consider let us draw your, this is your, consider your cutting tool correct. So, it is rotating in this direction. So, when it is rotating at that time, you consider this is called entrance side burr and this is called entrance side burr at this location. So, whenever your tool is entering inside, at the time all the burrs are related to entrance parts.

So, if you consider, this is called side burr. Side burr, this is the entrance of burr because it is at the location which is other than the side burr. If you, when your tool is moving up; that means in the feed direction, at the time some tools will be, some burrs will be formed at the top position of the (Refer Time: 12:31). So, those things are called the top burrs. And when your tool is completely exit out of the workpiece, at that time again you can call the exit side burr, that is on this side, exist side burr on the right side and something at the, in between this side that is called exit burr. So, we have a 3 entry burr, 3 entry burr, 3 exit burr and some top burr on this particular side.

So, these are the much better definition because by just understanding the exit burr, you understand that that is at the end of the cut. And when you are talking my entrance burr, that is when your tool is about to penetrate into the workpiece material. Some more things are also there.

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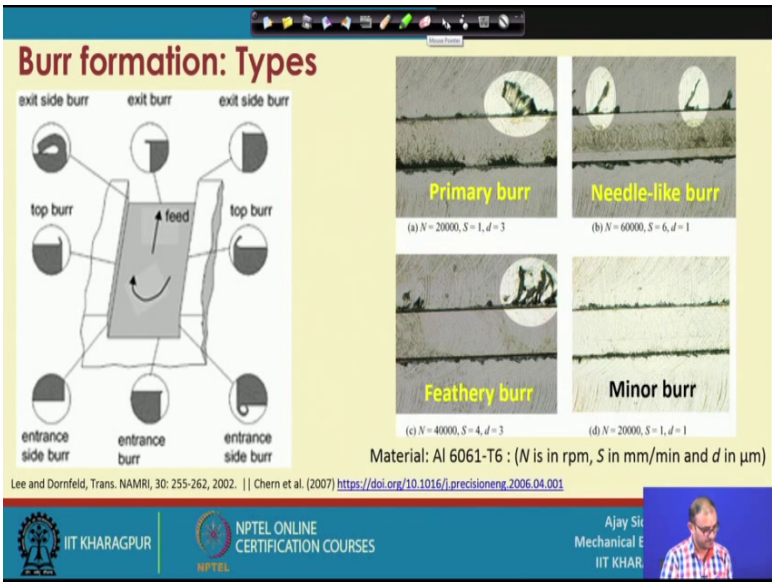

So, these are the some more things, of these are, this is the one material because we know that burr formations also affect the different material properties because if you change the material and change the process by parameter, your burr formation will be different. So, you cannot have the same definition for the same. So, every time whenever we are still looking at the burr formation, it is better to understand which material it is there and what are the parameters settings.

So, now this is the one thing. So, this is rpm, 20000 rpm and the feed rate of 1 millimetre per minute and the depth of cut is a 3 micron. So, what are the different way of telling those things, this is the one thing is the Primary burr. Primary burr means that is this old things considered is a primary burr. Because that is which you cannot able to a word in this case. So, this looks like a primary whatever we have shown the schematically diagram in earlier slide we have seen by (Refer Time: 14:11) image, that is old things are called the primary burr. Then another called the Needle-like burrs where the dimensions are very, thickness is very small and it is more sharp compared to the primary burr that is why it name is a needle like burr. And now you consider the that happen when you increase the rpm, you increase the feed rate and you reduce the depth of cut. Because when you reduce the depth of cut, your thickness is reduces and because of a reduction in thickness, your thickness of the burr also reduces. This is called of Feathery burr. So, it is something like a very woollen type of things, it does not have any perfect shape, but it looks like a mixture of a very small amount of needle like burr.

Now, if you see for this particular parameter setting, your rpm is in between the 20000 and 60000, feed rate is 4. It is also again in between these 2 and depth of cut is 3 micron in this case.

And this is called Minor burr, that mostly happen if you are feed rate and the depth of cut is very small and rpm is also small. So, most of the material is removed in terms of chip, but very small amount of material is left on the top surface and because of that, you are getting a minor burr. So, anyhow whatever is the burr, we have to remove at the later stage. If burr formation is very small, sometimes in some application, it is negligible so you do not need to do any deburring operation, but in this type of burrs where the primary burr and in this bigger size of burrs are available, you have to remove those burrs with by later stage by some different deburring operations.

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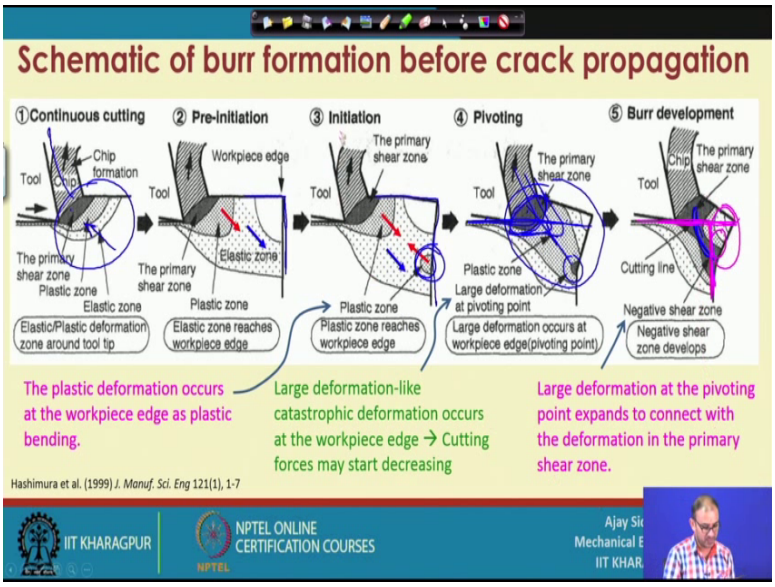

So, let us see that how the burr formation occurs when you penetrate your tool into the workpieces. What are the different stages? So, this particular slide will tell you that before crack propagation how the tool is interacting with the workpiece material. So, this is the first thing. So, it is a continuous cutting. So, what is continuous cutting, that is your proper cutting of the material. So, you are getting a chip come for very easily here. So, this is the chip formation, no problem in that. And this is the primary shear zone, this is the plastic zone and this is the elastic zone. Because when your tool is trying to

penetrate into the workpiece material, at that time you will get a small deformation head of the tool movement.

So, because you have to, there is a displacement of, there is a deformation of the material; that deformation is actually inside the material. It always create one of the ways to facilitate the material removal, that means that the material is not deformed directly at the shear plane, but that initiated much before the shear plane and that initiation will continuously convert in terms of the shear plane angles. So, that is what is showing here. So, elastic plastic deformation zone around the tools. This is the elastic zone plastic zone and this is the shearing zone.

So, this is what we needed. So, when you continue in this particular direction, what is happening that your, whatever is the plastic zone and elastic zone that will try to propagate. Now this is the end edge of the workpiece, work because we know that work mostly burrs are formed on the top surface over the edge of the workpiece. So, this is what is happening. So, your plastic zone will try to go or it will expand in this direction. Elastic zone is further expanded and this is what is happened when the elastic zone reaches to the workpiece.

So now, once because now it will be you are continuously pushing your tool in this direction. So, because of the pushing you are expanding the elastic plastic zone also and once you continue this thing, at the time because we know this is the edge of the workpiece. So, your elastic zone will reach to the cutting edge of the or the edge of the workpiece. Now in the third step, it is initiation. Why it is called initiation, because now this is a plastic zone and again there is one more plastic zone occurs because now if you see this particular thing, now this is bended little bit.

Now, see this particular thing. This is right angle, but now it is bending. So now, these particular thing is called a nucleation that means, where your plastic zone also occurs it because, whenever your pushing this material, your material is a deforming from the other side because now whole thing is a plastic zone now here if this particular location. So, plastic zone reaches to the workpieces and this particular plastic zone deformation in the work piece at the plastic has plastic bending. So now, you are workpiece start bending in this direction and because of that, you will against you get one more plastic zone at this location.

Now, in the next year what is going to happen, this particular plastic will try to connect with each other because as your tool is further moving inside, now you can see in this particular diagram. So now, what is happening that, now this whole thing is a plastic zone now. And now it is a Pivoting. Pivoting means, it is a initiation of the deformation, large deformation. So, now what is happening, whatever it is shear zone is that, you will get again get shear zone here at this location, but is not because of the cutting tool interaction, but because of the bending of the workpiece.

So, now what is a happening, the large deformation like catastrophic deformation occurs at the workpiece edge, that is if this one. This is the re. And cutting force may start decreasing because now what happened that your total resistance of the deformation from the workplace reduces, because now you are getting one additional deformation, that is from the workpiece side, not from them tool side. Because now this deformation, again this whole thing will become little bit stop, this whole thing part. And our objective is to cut from here to here, this is what is our objective right. It should move like that, but it is not happening here because you are getting one another deformation, the plastic zone here and because of this start.

So now, if you continue this whole thing is in more unstable situation. Now if you further go in this direction, now large plastic deformation at the pivoting point expands to contact with the deformation in the primary shear zone. So now, whatever it is particular location is there, this particular zone, this will try to connect with this particular part, because now you are getting one additional deformation here and this is also deformation. So, your tools continue in this direction, this direction, this direction, at that time your shear plane angle also moves ahead of the tool. At one location, this both thing will match. And once the matching is over, now we can understand and how things are different for different material, bitter material in the ducktail material. So, now this is the cutting lines, our objective is to cut the material from these lines over, this is our objective.

But now we know that, our object is to get these workpiece correct. This is our workpiece, but we have already got something which is extended beyond the workpiece edge. So, this particular thing is the burr. So now, characterization of this particular burr is different for the brittle material and ductile material. So, let us see in the next slide how these things are different.

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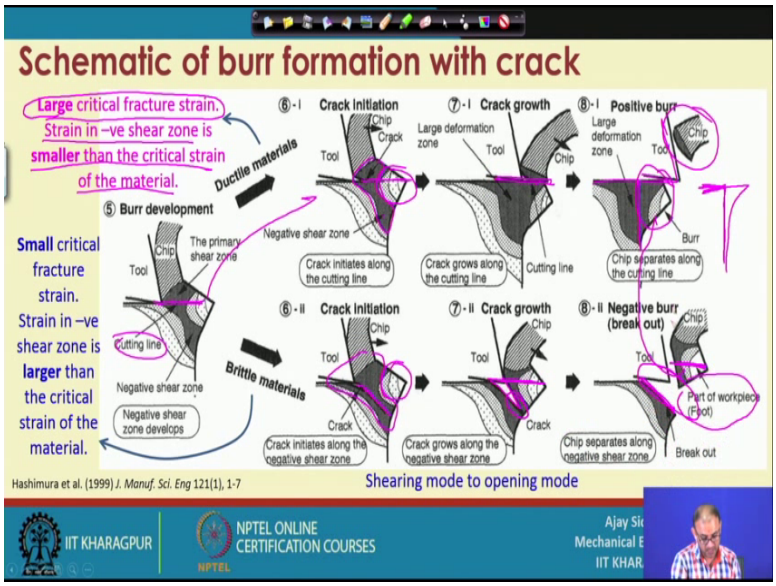

So now, earlier slide was the before the crack propagation and now this one is the with crack propagation. So, let us take this particular image again to the next slide and so can we can understand what things are shown. This is the earlier figures whatever it has created here, correct. So, this is the same figure. So, now, or objective is to cut material from these, but and these also. So, this is the extra thing.

Extra material, correct. So now, we have tools on, one is the ductile material what is going to happen if this particular crack is in a ductile material, this is a brittle material correct right. So, what is happening in the ductile material, because in ductile material, your it has a large critical fracture strain, because it does not fracture very easily and strain in the negative shear zone is smaller than the critical strain of the material. So, wherever with this is the particular shear zone. So, whatever this is the shear zone. Now, because it is extended one, the edge of the workpiece, so strain in negative shear zone is smaller than the critical strain of the material. So, material will not actually separated out by easily compare to the brittle material.

So, now let us go in these directions. If it is a material cracks in this case, now there is a crack initiation. So now, this particular crack whatever it is dashed line is showing, we expect that a material should move in the same direction because it is a ductile material. You are not getting the fracture of the material. So, unless the tool is completely passing through the workpiece, you will not get a chip out of it; will still sticking to the surface.

So, this is the crack initiation. The crack initiate along the cutting land. So, this is a crack initiation in this line and this is the negative shear zone what you are talking here.

So, it is a smaller than the critical strain of the material. So, it will not exceed the particular strain of the material. So, it will stay there. The crack grows along the cutting line. So now, whatever is this the crack growth in the cutting line it is continuously in this direction and this is the cutting line. A large deformation zone that is what we have started with this particular location. And once your tool is passing through this part, your chip is coming out of that and whatever is this part. So, this part is the burr. Because this is the extra thing, whatever you wanted this is our objective to get something like this, but we are getting something like this.

So, this is the burr formation in the ductile material. What is happening in the brittle material, brittle material situation completed different than this, exactly opposite. And so here the small critical fracture strain, because it was large here because brittle material it will fracture more quickly and whatever is the negative shear zone, strain in the negative shear zone is larger than the critical strain of the material. So, now, how these things are different? Now if you follow this particular line cutting line where. So, our cutting line was this one and if you consider the ductile material, your material is removed through the cutting line correct, but what is happening here that we have a critical fracture.

So, now instead of that, because now if you say this is the material which is not completely shear; that means, still some other best deal still you are tool is moving in that direction. But here what is happening, that crack imitate along the negative shear zone because now this whole thing is shear zone. And if you are moving so this is not, this is comparatively hard material compared to the soft material because in sharing zone, your materials become more and more strain. So, your crack which should be in this direction. Now it is moving in this direction because now this is the easy part to follow while removing the material.

So, if that is the case, if you continue now you are tool dependent, now crack is propagated now, that is the thing what is happening in the brittle material. So, this is called crack propagation. So, crack grows along the negative shear zone. That is shearing mode converts into the opening mode. So now, that is opening. So now, these

particular thing will try to open, now because in if it continuation, this reaction it has to remove so much amount of material. But now here in this location, at that time you are material removal requirement is very small in this case. So now, when it is coming out of that, now you see the difference how much is the difference.

So, this is the amount of material which was staying in this particular ductile material. But now we know that our crack propagation is moved in the different direction compared to the cutting line so this much amount of material is removed and this part of the workpiece whatever is written here, that is called Foot. That is one researchers has given the name that is called Foot burr. And this is called the break out. So now it is a break out. Because the crack is initiated in this location and because of that you are getting a chip out of this part, but still there are some burrs available. Now how these things are different in both the cases, now considered 2 situations here, this is our objective that this should be the workpiece, but here we go to an additional part correct.

So, now if you apply deburring operation here, there is a still chance that you can get this workpiece out of it correct. This is because you remove this part, you apply some type of lapping operation or some type of cutting operation then you can remove those things, but problem is here because now our requirement was this much correct. This was our requirement. So, even if you apply some deburring operation or something you can remove this much of amount only, but there is no material at this location.

So, I would, even if you apply deburring operation what is going to get here, this is what you will get correct. So, this is dimensionally accurate. So, if you consider ductile material machining and you end up with this type of exit burr, at that time there is a chance that you can still use this component with the condition that the deburring operation does not destroy the actual component, removes the burrs only. But in this particular case where the some amount of the material which should stay on to the surface, but it is also removed as a part of the chip, then you are actually getting it dimensionally inaccurate component.

So, if this particular thing is some functional requirement, than it will create a problem. If it is not function recommend, than here what happen, your burr removal operation is very less because the burr formation is very small compared to the ductile material and the brittle material. So in this case, your reworking will be less only if this whatever

material removed from this location does not have any functional requirement. So, these are 2 different ways by which we can remove the material, but it is not the only thing. Now if you see that this is correct for a one particular setting of a speed, feed and depth of cut correct. If you change this particular setting, then you will get a different phenomenal was schematic at in particular instant.

So, these particular parameters play important role. Other than this parameter what is the material homogeneity, what are the defects. Now consider even if it is a ductile material you will get some porosities in this location, then this ductile material also actually move along the brittle material whatever way it is moving in this direction. So, in that case that means whatever we are showing here, it is a very generic idea. It should not be actually copy or it should not be understood for the different material because we know that if you change the material, if you change the material property, everywhere it this particular mechanism will change depending on the conditions of the machining operation.

So, let me finish this class here and still we have some slides on this burr formation, those things you will discuss in the next class.

Thank you very much.