Introduction to Mechanical Micro Machining
Prof. Ajay M Sidpara
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 18
Deference between macro and micro machining

Good morning everybody. And welcome again our course on introduction to mechanical micro machining. In the last class we are discussing about the burr formation, and we understood that burr formation is not a good thing about any process, like let it be micromachining or the macro machining.

So, we have to find out some of the ways to reduce this burr formation, or we have to make sure that burrs are form at the location where we can reduce or we can remove them comfortably. So, and we have also seen that material properties also play important role, because ductile material and brittle material both are creating a different types of burr. And that we have to understand that how we can deal with the material properties. So, let us continue this topic further in micromachining domain.

So, this particular slide we have seen in the last class.

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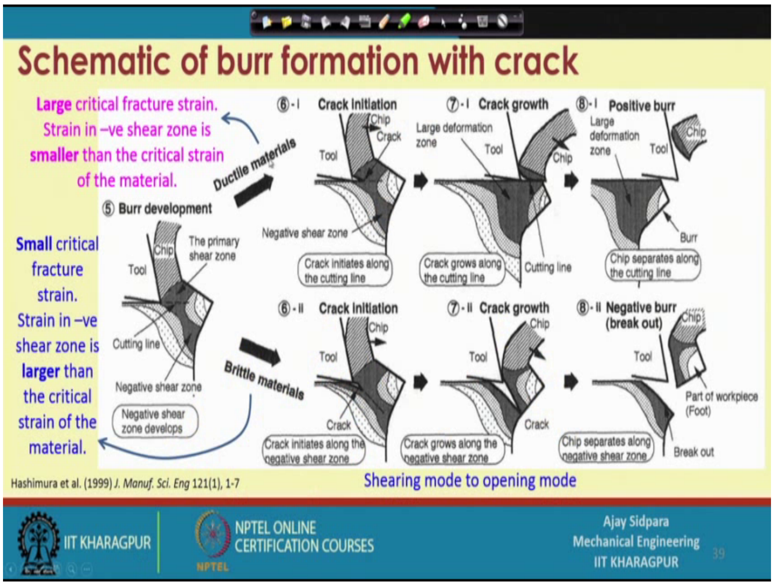

That may ductile material and brittle material forms burr in different, different ways. And in this case, we have seen that, these are the positive burrs because it removes material of the chips only and these are called the break out; that means, the some portion of the work piece also get removed, and that is the problem in the ductile or brittle material burr formation.

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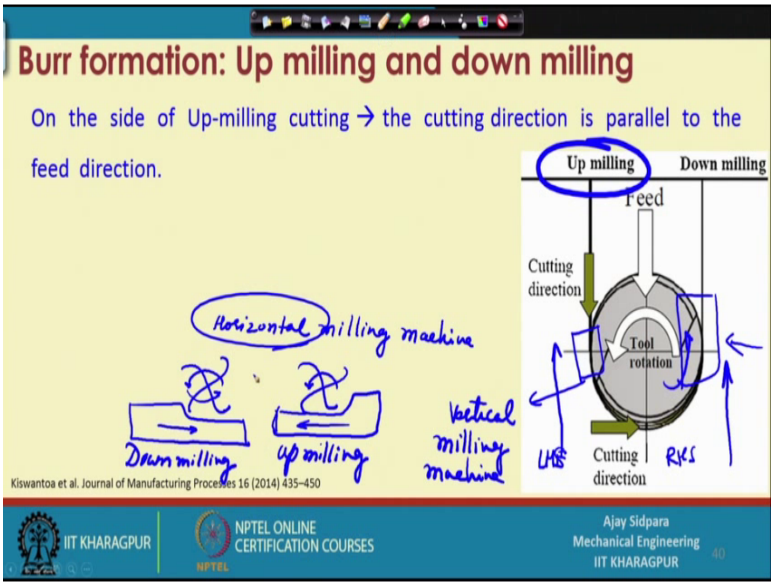

So now coming to 2 different theories; that is, one is the up milling and another is the down milling. So, these 2 things are different in this sense that how the cutter is approaching the work piece material. So, let us see that thing. So, this is the case of a slot cutting in the micro milling operation. So, we know that there are 2 ways.

Suppose this is your cutter, correct and this is your work piece. If this is rotating in this direction and this one is moving in this direction, then what you can tell? That this is the up milling; that means, it is up mill it is climbing these work piece, and if you do not change the rotation of this work piece, but you change the direction of the work piece not the direction of the cutting tool, then what happens in this particular case? That your work piece will move in a different direction.

So, let us see this thing also. So, this is the directions now your work piece is moving in this direction. We are not changing the rotation of the cutting tool. So, this is a another way of representing the same thing.

This is in case of a horizontal milling machine. Because here the cutter is located horizontally. So, you will get a this particular up milling or the down milling in a different, different object. So now, if you see the same thing in the these particular thing, that then in the cutting of a vertical milling. So, this is a vertical milling machine right. So, here what happens? When you are cutting a (Refer Time: 03:53) you will encounter both these things in a single operation.

Now, you consider this is the work piece rotation. So, we are saying these work piece rotations in a similar way. And your work this is a tool rotations sorry not work piece rotation, and your work piece is moving in this particular direction, correct? So, this is the work piece direction this is the cutting direction. So, when you are looking at this particular thing that tool rotation is in this direction. And your work piece movement is in this direction. Then only you are able to cut the surface.

So, this both the things now your tool in a you consider this particular location correct. So, your tool is rotating in the anticlockwise direction, and your work pieces is moving from bottom to the top direction. So, it is equivalent to this particular thing. Let me remove this part, correct? So, it is rotating in crow anticlockwise direction, and work piece you are moving in this direction. So, this is the condition. So now, that one is called the up milling. And now you look at this particular location from this, direction correct? So now, you are we are not changing the direction of the 2 rotation, but now our work piece is moving in this direction. So, this called left side, left hand left hand side and this is the right hand side, right?

So, this both the phenomena, now you can see here in this case the rotation is in this direction and the speed of the work piece is also in the same direction. So now, you will encounter this particular phenomena. So, rotation is in this direction and your speed is to the work piece is also in this direction. So, this is called down milling, correct? So, this both the things you will encounter different way in the horizontal milling, but both thing will happen together in the vertical milling machine. So, this is how it works. So now, let us see then how this process is over this particular methods up milling or down millings are different and how they are responsible for burr formation correct. So, one the side of up milling cutter the cutting direction is parallel to the feed direction. So, that is in this particular direction.

Now, earlier case we have seen that in terms of the work piece now if you say that cutting direction then the cutting directions are this is the tool rotation, this is the cutting direction, that both the things are in the same direction.

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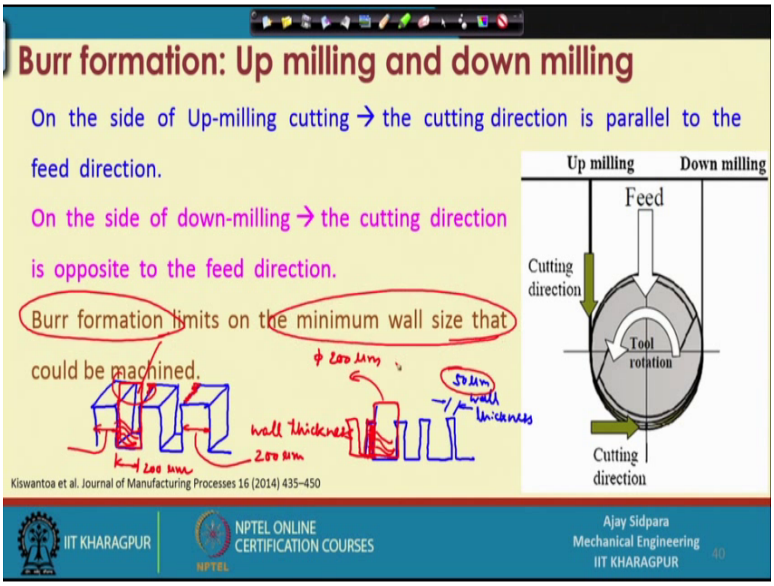

So, that is why it is called up milling. And if you consider the second one in the side of the down milling in this particular direction the cutting direction is opposite to the feed directions.

So now so, this is the feed direction to the tool now, but work piece will move in opposite direction, correct? So, when your tool moving in this direction, your work piece will go in that direction. So, this is the feed direction and this is the work piece rotation. So, it is a cutting. So, it is opposite to each other in this case. So, this is how it is named as a down milling.

But if you consider work piece then we can also define in terms of the work piece. Because when you are giving feed to the tool generally actually, you are moving the work piece you are not moving the tool. So, work piece movement is exactly opposite to the feed direction, then only you can do a opposite cutting. So, this is the opposite direction. So, if it is a feed direction is this this then the work piece movement direction is always opposite to that direction. So, that is why you can do this thing.

Now, burr formation limits the minimum wall thickness or the wall size that could be machined. Now we have encountered many, many different types of operation. Now consider so, this is one thing we want to cut correct. So, this is the wall thickness, correct? This is the wall.

And now your cutter is here. Now consider the whatever the size of this slot the same size oh is the cutter size. So, this is your cutter. So now, consider this one is a 200 micron. And whatever is this size of this pillar, that is also let us considered 200 micron correct. So now, we can see here the size of the cutting tool and this is called wall thickness, right. So, this is also called wall thickness.

So now you can see that when you are cutting one slot at the time now consider this is the slot. So now, here everything is available, right now this is this on machine material, this is the machine part. So, when you are moving in this direction at that time what will happen that there is no material available in this location. So, the strength of this particular part is little bit less correct. So now, here in this case what is going to happen that, this particular thing if it is a 200 micron right now, then it may not create more problem. Because the strength or the thickness is enough to withstand those forces.

Now, consider a situation that you are reducing that wall thickness, but you are not changing the cutting tool diameter. So now, this is the second option something like this. So, this is now wall thickness, correct? Now let us consider it is a 50 micron. And your cutting tool is still has the same as earlier case is there 200-micron diameter cutting tool. Now what is going to happen now the thickness of the wall is very, very small. And we know the burr formation happens at many, many different location. It may happen here also that is called top burr, if it is entering tool from this side to this side, then these side are the entrance board and these are the exit burr, correct?

So, this burr formation will actually create some additional material sticking to the machine surface. And because of that now your dimension of this particular 50 micro may increased to a larger dimension. Or what will happen did this whole thing will banned. Because we have seen in earlier slide that there are 2 different ways the material behave, when it is a ductile material or the brittle material. So, in those case if the strength of this material is less at the time this whole thing or a whole structure will banned.

So, you may get something like this and your dimension of this particular middle part will be increased. So, that is the reason that you have to maintain a minimum wall thickness, otherwise this burr formation will create additional deformation or the additional material on to the work piece. And that the that is difficult to remove, because once the burr is attacched then you have to apply some deburring operations. And for deburring operation this wall thickness is so small that it will permanently damage when you apply some deburring operation

So, this particular burr formation will play important role that what is the minimum wall thickness or the wall size you can achieve in the micro machining operation, right.

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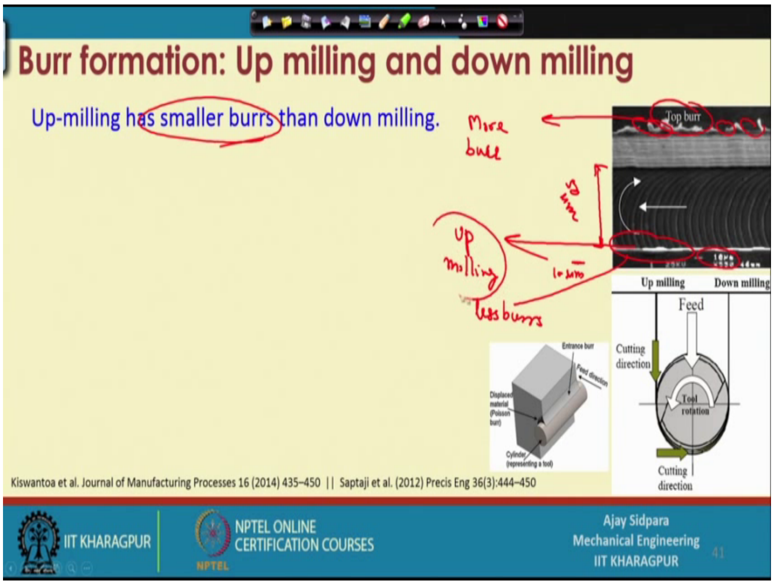

So, this is the way how this burr formation happens in the of milling and the down milling. So, again let us consider this figure again. And now if you see this particular scanning electron microscope, now you whenever I am showing this type image you always look at this particular scale.

Because, without looking at this scale you will not understand what is the dimension we are talking about. So, this particular thing is this much is the 10 micron. If you consider this particular burr this bar is the 10 micron. If you consider this 10 micron then this particular dimension maybe the 50 micron. And now you consider this is the direction of the rotation and your tool is moving in this direction. Now let us consider the same thing here that tool rotation is in the clockwise direction it is in anticlockwise direction. So, your up milling and down milling side will shift in this particular case. So, this is called the top burr position

And now what will happen in up milling has the smaller, but then the down milling. So, if you consider this particular slide this particular figure now you can consider these are the less burr, correct? And here if you see here these are the mini burrs you can easily identify those burrs here, more burr formation correct. So, up milling side has the smaller burrs. So, this is called up milling side. Because now if you see consider this is the rotation in this direction and this is the rotation in consider this is the direction and your moving your tool in this distance, this is the feed direction correct. So, feed direction and this particular cutting directions in the same direction. So, if you considered this particular line then this particular part is called the up milling.

And here when it leaves it this particular location, then this is called the down milling. Now why this is happening in this case?

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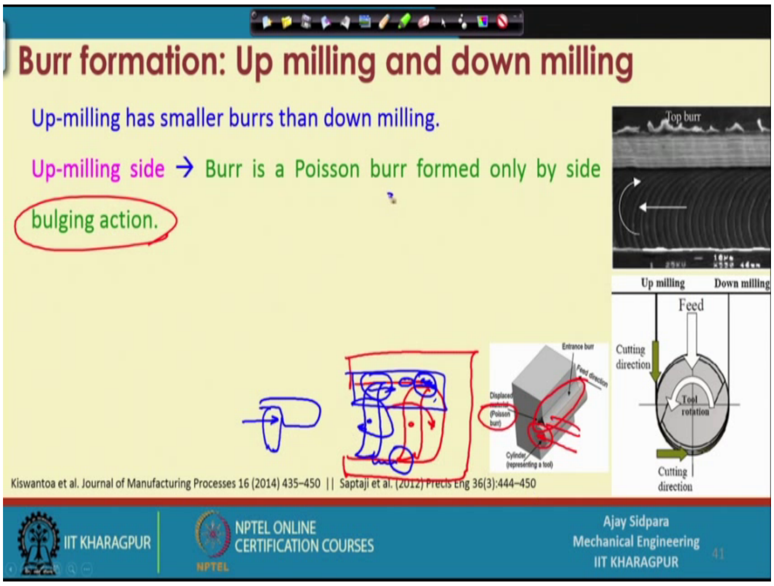

Now, what is happening in the up-milling side? The burr is a poisson burr formed only by the side bulging action. Now we and we have found or we have defined this particular poisson burr in such a way that that this is your tool and if you are rotating your tool and your plunging your tool inside the material, then there is a burr formation. So, these call this is called the entrance burr or the top burr.

If you are moving in vertical tool is there and you are moving in this then this equal to top burr, but if you are entering in this direction then it is called the entrance burr. So, this particular type of material displacement is called the poisson burr. So now, what is happening here in up milling side? That burr is a poisson burr formed only by the side bulging operation.

So, here what will happen that when your tool is entering inside it. So, let me explain it here. So, this is your cutting tool, and this is your work piece. And this one is moving in this particular direction. So, let us consider the same rotation direction, correct? And now so, this is the location it will interact with the work piece material it is a 2-flute cutter let us consider right now. And when it is cutting in this direction now, what is going to happen? So, this is whenever it is doing in this particular cutting. So, at the time your entrance will be very, very clear. So, whenever there is a chip formation here at this location at that time it will remove all the material. So, this is the first poisson now consider this was the earlier position, correct.

So, it rotating in this direction continuously. So, whenever if even if very small amount of burr is available, it will be removed in the subsequent machining operation when it is going forward, but that is not going to happen in the this particular slide, on the other side. So, here what is going to happen that when tool is more at that time your burr still remain here because it will not get any additional support from this part to remove those things.

And when you are putting this. So, you are actually pressing this material, correct? Because now your tool is moving in this direction, consider this is the linear motion in this at a very, very small scale. So, this is your material and your cutter is moving this material in this because this is similar to this question position. So, that is why it is called the poission burr formation. So, that is happens in the up milling side.

What is going to happen in the down milling side?

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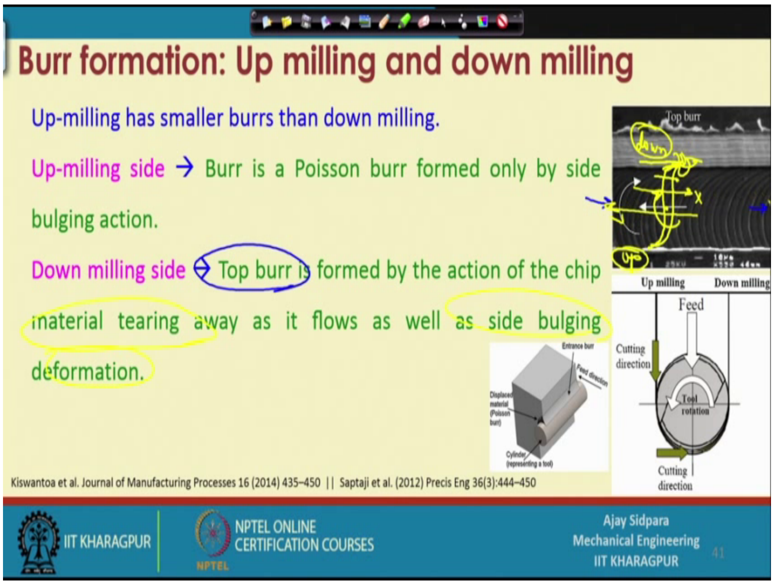

That top burrs now, you can consider the these are the things are different in different diction. Now let us consider this is a top burrsion. Now we have you understood the different type of burr formation. Top burr, entrance burr, in the exit burrs. And they a re also on the both the sides. Because up milling will behave differently, down milling is will behave differently for formation of the different kinds of burrs. So, in case of down milling in when you are talking about top burrs. So, these are the top burr because we have not considering anything at the entrance side what the exit side.

We are looking at the work piece from the top. So, that is why we are considering is a top burr. Top burr is formed by the action of the chip material tearing away is it flows as well as side bulging deformation. So, when it is moving in this direction, now consider your work piece cutting to like this. So now, let us give the cutting tool here that. So, this is a cutting tool and it is moving in this particular direction, correct?

So, when it is moving now you consider the same situation here. So, when it is moving in this. So, this is called up side and this is called down side correct. So, when it is moving in this particular direction, what is going to happen; that at this particular location now you have the work piece like consider, this is the chip. So, when it is penetrating this part what will happen sometimes? This particular thing material will be cleared away from their part and you are not able to remove that material completely, because now detection of the motion in this direction, not in this direction, correct

If it is in this direction then whatever material is that it will be removed, but now that will consider as up milling, not that down milling, right. Now our tool is moving in this direction. So, whatever is the steered away material is there. So, that material still remain there only, it will not be displayed by any other action, because now tool is already passed that location and again if you want to remove those thing again you have to give a fresh path. So, that is not the case.

So, this is there to lower end and another thing is the side bulging deformation. Because similar to this material then when you are plunging these material, here the some material will be located on the top surface. So, that material will not be removed in subsequent pass, because your tool is not again going into contact with that particular location. Only thing is possible that it will move in this path without any location.

So, that material will not be removed in subsequent path, because your tool is not again going into contact with that particular location only thing is possible that it will move in this part without any location. So, that is not going to happen. So, that is the reason that you mostly get the small burr formation in the up milling, because that is this particular side and then compared to that down milling sas.

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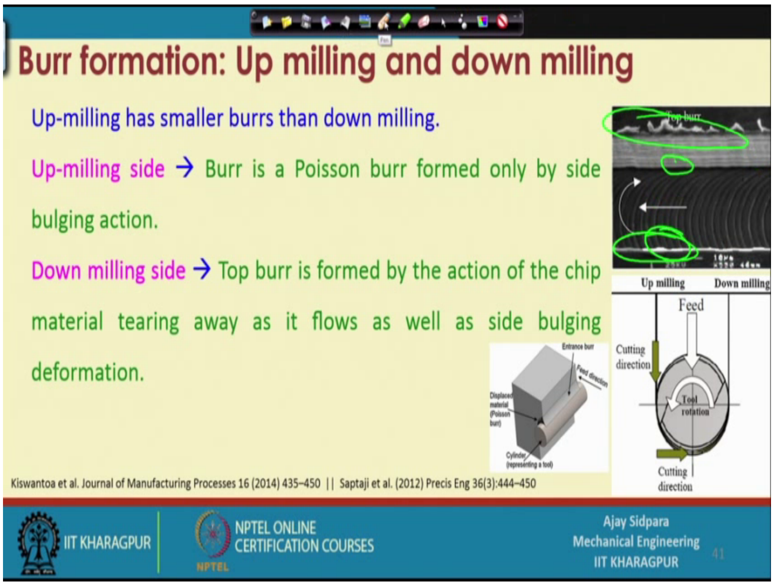

So, down milling you always get the most part because your tool is actually leaving this per piece location and your tool is actually entering at this location. So, that is the reason for getting those things.

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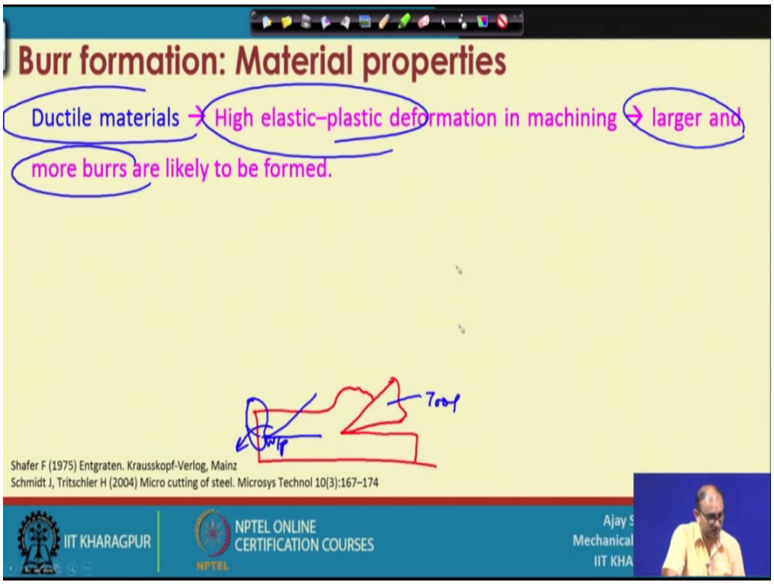

Now, coming to material property, how property will behave differently? So, if you considered ductile material what is going to happen the ductile material has the lay high elastic plastic deformation in machining. So, it will elongate a little bit more. Than because of that what will happened the large and the more burrs are likely to be form. So, let us see it here. So, what is going to happen?

So, let us consider a single point cutting tool. So, this is a chip, this is the work piece, what we say. So now, what is going to happen that you know that burr formation will be not too much here mostly it is at the edges of the work piece. So, when your tool will reach at this location at that time what will happen, that ductile material has the large elastic plastic deformation. So, it will actually not break away from this location, it will actually band in this location. So, whatever is the thickness, more the thickness more will be the burr formation here in this location. That is highly happens when your material is very, very ductile, but if it is brittle the phenomena will be completely different than this part.

So, what is going to happen here? That you are high plastic deformation elastic plastic deformation will end up with the large and more, but we are more burr formation at the end of the work piece, or at the starting up also.

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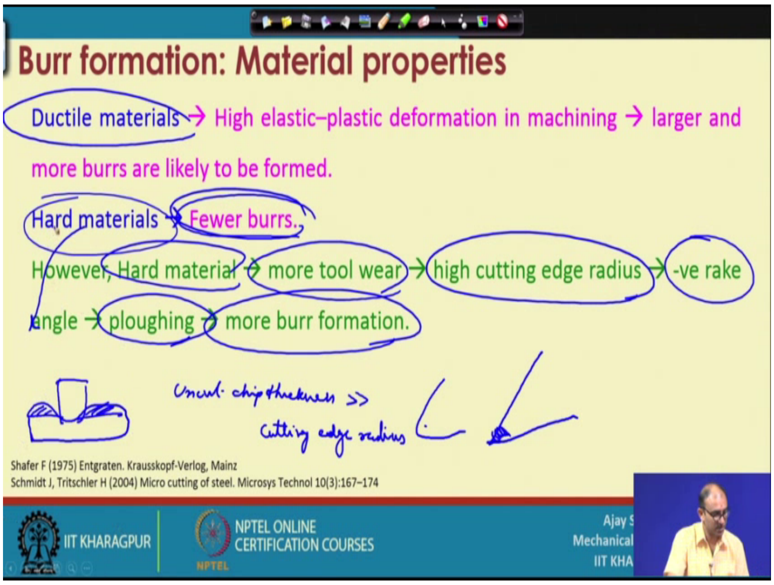

Now, coming to hard material. Hard materials is fever burrs, because we have seen in the ductile material burr formation the brittle material burr formation in terms of stigmatic diagram step by step, and at the end we have seen there in the hard material there was a additional amount of material which was removed, but in the ductile material there was a same material. But more material was stayed on the work piece, but here the material more staying on the work piece was little bit smaller. So, here mostly you will get a cut, but it will also take away some portion of the work piece material. So, that is only bad thing about the hard material.

But if that particular location does not have any functional requirement then you can expect those particular part without any problems, correct? But here what is going to happen? That when you are cutting a hard material you always not end up with the fewer burrs. Because when you are what is machine with hard material your tool is going to hear more. And when it is more than a initial condition this was the tool. So, consider this was a one particular cutting edge, but if it is a wire out then your end up your end up with the high cutting-edge radius. And we know that again we have to maintain those 2 things that is the uncut chip thickness, uncut chip thickness should be bigger than the cutting-edge radius, got it?

So, we should not forget this particular condition. Otherwise you always get that the different of the elastic recovery, then the elastic recovery plus material removal rate and the pure material removal rate, when you are uncut chip thickness is bigger than the cutting with radius. But when you are cutting a hard material initially you will get a fever burrs, but that will not remain for a long time, because your tool wear rate is also very, very high. So, you are end up with the cutting edge with a dull surface. And then it will create negative rake angle that we have explain understood in more detail long time before. If it is a negative rake angle your end up with the following reaction because material will not be remove will be displace in the different, different location. So, this is what is going to happen, that your tool is here and then this is a extra material which will be ploughed from the side surface. And that is not good in things that is reason in the more burr formation.

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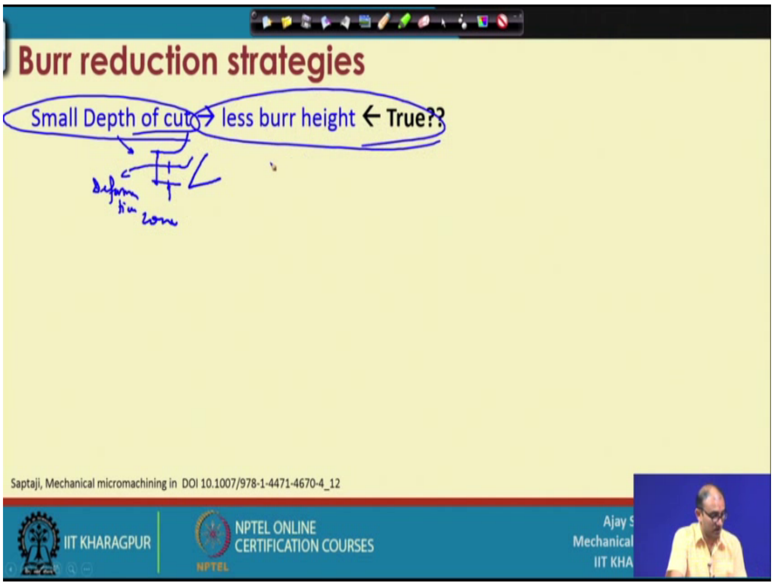

So, what is the outcome of this particular thing that whether you made seen at ductile material or the hard material, you always end up with the burrs. How far or means a how much is the size of the burr that depends on the process parameter setting. Then the hardness and which way you are machining the part. What are the composition of this hard material ductile material grain size of those particular material. Those things play important role in the size of the burr formation in the low case of the burr formation, correct? So, ultimately, we cannot avoid the burr formation, but we can reduce this burr formation by optimise parameter setting. So, what are the burr formation reduction strategies? So now, we are we know that it is difficult to remove completely this burr formation, but we can actually reduce this burr formation by different, different strategies.

So, let us see this thing. So, first thing is the small depth of cut less burr height. So, this is mostly actually true in case of the macro machining or the conversion machining. Because we know that we are considering our cutting edge a very, very short, but that is not the case here because when you are reducing the cut this particular depth of cut what is going to happen here? That your material deformation will be very, very small. So, suppose this is the depth of cut, and your cutting tool is here. Then this much amount of material only removed, but if your depth of cut is this much then this much will be the deformation zone, correct? So, but that is true in case of a bigger scale what the macro scale only not to the micro.

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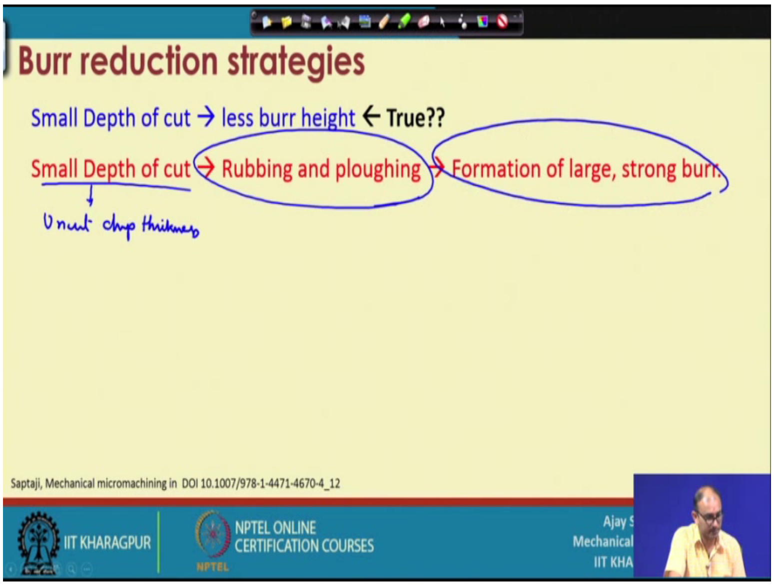

So, at the micro scale what is going to this the smaller depth of cut rubbing and ploughing happen, because if you are reduce the uncut chip thickness for this is actually uncut chip thickness, correct? So, this is a uncut chip thickness, correct? So, if you reduce it we know that we are not scaling this particular thing with respect to the cutting-edge radius. So, again that particular 2 parameter balancing will be disturbed, and because of that you are end up with the rubbing and ploughing and formation of the large and the strong burr. So, that is what is going to happen. And more number of flutes what is going to happen that you have a cutter of a 2 cutting edge only. So, this is the cut 2 flute cutter.

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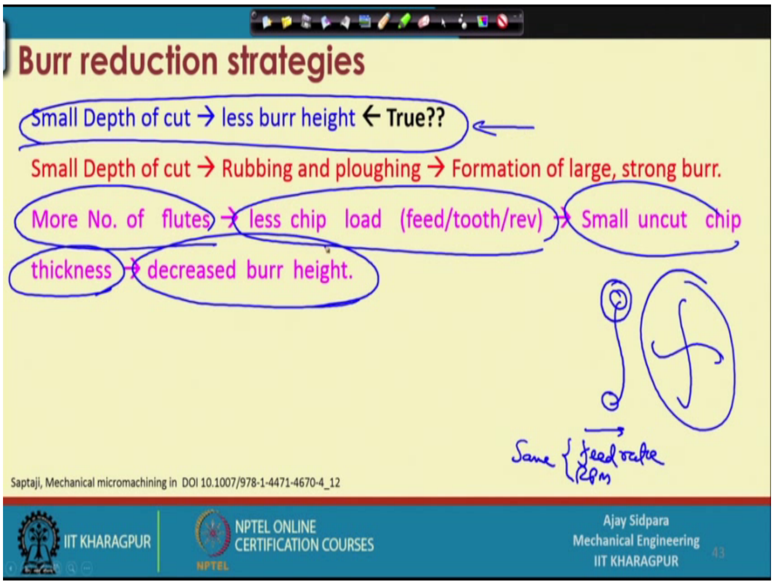

And if you have a 4-flute cutter. So, what is going to happen if you keep the same feed rate an RPM, then what will happened? That this particular 2 flute cutter will end up with the more amount of material removed. Because right in this particular you have only 2 edges which will remove the same particular amount, but that that much amount of material will be shared by the 4 number of cutting tool cutting edge.

So, in this particular case is the chip load for flute will be less in this particular case, if you increase the number of cutting. So, so small uncut chip thickness in this particular case and if you maintain that particular cutting edge is reduced to the uncut chip thickness then you will get the reduction in the burr height. But if you continue redux reducing all this particular thing, but if you not maintaining with respect to uncut thick that cutting is radius then what will happen again it will increase.

So, you can understand here that if you are writing a one particular sentence that is not a universal. It depends on which particular condition your machining the path. So, you cannot generalize any this statement, because everywhere it will change depending on the material and depending on the process parameter settings, right? High cutting velocity will lead to less burr formation in the micro machining in the steel.

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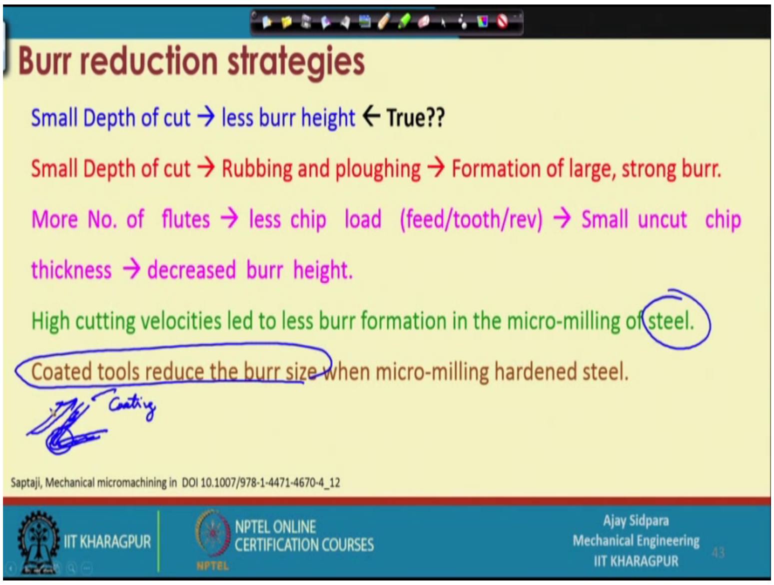

So now we have to write actually specifically for one material if you change the material this particular sentence will not be acceptable also. So, that is that thing, right. Coated tool reduce is the burr formation when machining of a hardened steel. So, what is going to happen here in coated tool? That why we apply coating. So, mostly we won some of the things which should maintain for a longer time. Because if you want to save the cutting-edge radius then you put a coat coating on the top of that, it may increase your cutting-edge radius little bit, but it should be within the permissible limit.

But advantage of this coating is that it will increase the life of your cutting tool, and it will retain this particular sharpness of the cutting-edge radius would a longer time. So, if you are maintaining the sharpness what is going to happen, that it will reduce the burr formation. Because you are cutting in a that particular condition. Other than that, that many times what happened it will also provide a easy flow or the smooth flow of the chip which is coming out of it. And chip plough is very, very difficult in the micro machining because you do not have so much of space for removal of the materials. So, that is the advantage of using a coated tool.

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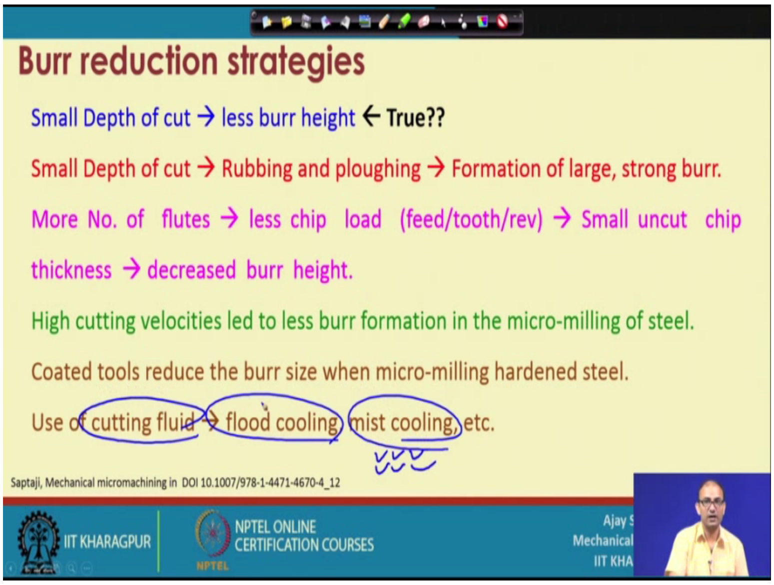

And another thing is the use of cutting tool, because why we use cutting tool cutting fluid because this particular cutting fluid will help to reduce the temperature of the cutting zone. And they are their name anyways mist cooling also you can use you can use flood cooling, but in the micro machining mostly people prefer mist cooling, because that is advantages compared to the flood cooling operation.

So, this particular thing will reduce the temperature, if you reduce the temperature you have advantage that your cutting tool life will be increase a little bit. So, let me finish this class here, and we will continue this further in the next class.

Thank you very much.