Introduction to Mechanical Micro Machining
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Lecture – 49
Micro Tools

Good morning everybody and welcome again to our course on introduction to mechanical micromachining. Today, we are going to discuss about micro tools, we have seen about the machines also and we have also seen about the different type of mechanism by which material is getting removed in micromachining part, we have also seen that there are different type of errors in the geometries.

So, that we can avoid those thing and we have to understand that what are the different geometrical error and how they will affect the machining performance, but today is our topic is on micro tools.

That we have seen that there are different type of end mill cutters and turn micro normal conventional turning operation tools are available single point cutting tools where in micro domain those size are very very small.

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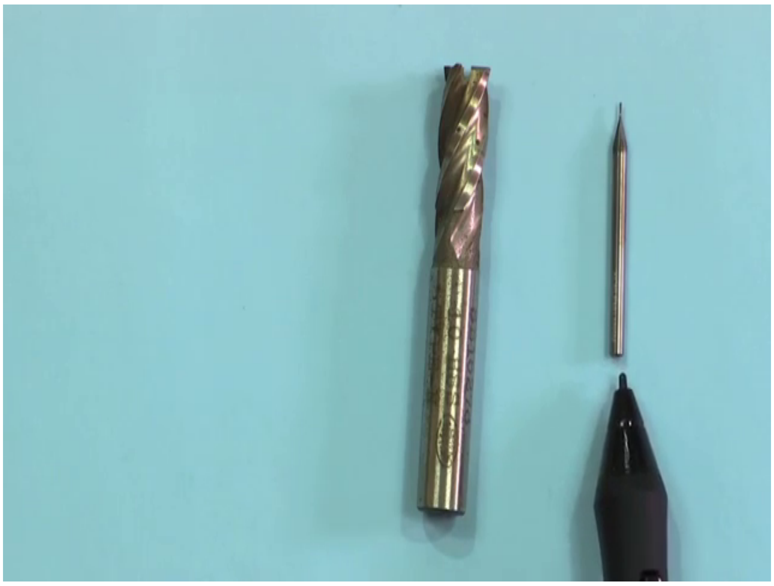

So, if you see this particular two tools that this is one is the conventional cutting tool both are we are using an end mill cutter and this one is the micron side that is a diameter is 500 micron, if you see this geometry, it is a 4 fluid cutter and here also it is a 4 fluid. So, geometric point of you both are same, but size is the very different. So, here it is a 10 millimeter side, here it is a 0.5 millimeter.

Now, question is that first thing that; how we can make this type of tools. So, we will discuss some of the processes which are used for fabrication of these particular tools and then we will discuss about the different type of issues which we have to address and we have to take care during machining by using this type of cutting tool. So, today we are discussing about micro tools or let us see that what are the ways, we can address this part. So, first thing is that the size of the micro tool.

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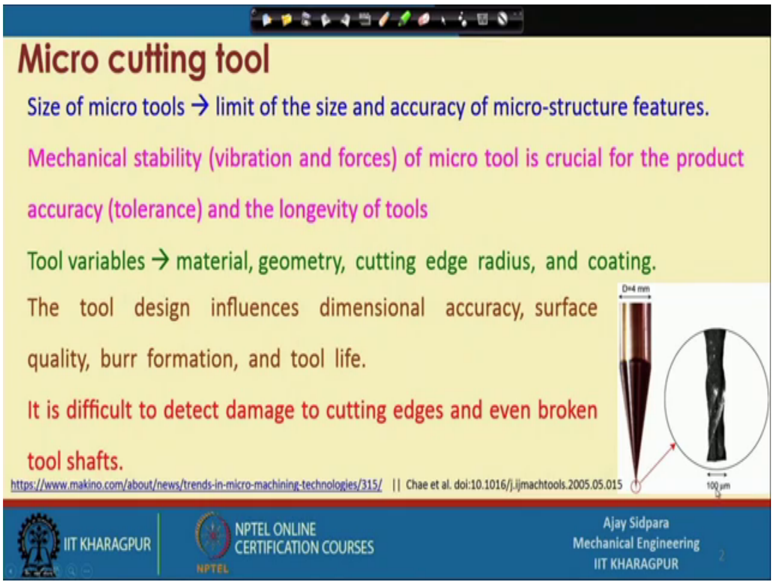

So, if you see this particular thing that whatever features we want to create everything depends on the; what is the minimum size; we are using for cutting of that particular feature.

So, smaller the micro tools or small the cutting tools smaller the features we can create out of it and then again problem is the accuracy that we know that if the size of the cutting tool is very small there it is very difficult to make it very very accurate. So, there are some issues related to the accuracy of the features also now this is the one figure is shown.

So, here the same diameter is for millimeter and this is the end mill cutter and this one is the magnified view of that cutting zone. So, here you can say this total diameter cutting diameter is the 100 micron is the diameter and still you can see the there are fluids available and you can get the almost all the features which is available in our conventional cutting tool.

So, what is important the mechanical stability; that is the vibration and forces of the micro tool is crucial for product accuracy that is mostly we are talking about the tolerance and longevity of the tools because we know that when we are talking about the micro tool of a 100 micron diameter and we get a vibration around 10 micron, 20 micron. So, it is a 10 times of the 10 percent of the diameter of the cutting tool and force is are also; sometimes very very high when we talk about the dimension at the micro level.

So, because of the vibration in forces what happen that many times; you will may get the features, but those features are not accurately made or the tolerance is out of the desired level or sometime directly; you will get them broken tool. So, these are the 2 different tissues which we have to address during the fabrication of the cutting tool. So, what are the different tool variable.

So, tool variables are the first in the material because we have a large amount of materials available for making cutting tools and what type of geometries, we can make because here problem is that as you go smaller and smaller the getting cutting fluids and everything it is very difficult because we should have tool also. So, that we can get this type of features made, but that is very difficult when you cross a particular domain mostly it is a 50 micron or something.

Then cutting edge radius because we have discussed many things about this thing when you are talking about the uncut chip thickness and the cutting edge radius comparison and we have seen that if you do not scale this uncut chip thickness and the cutting edge radius you may come across different type of mechanism that is rubbing and then it is elastic recovery and then the mixture of two different things and cutting also and there are different type of coatings available because what happens that when you operate this particular you or you use this particular cutting tool without any coating at the time you have to sacrifice the life because coating always increase the life.

And it will make sure that the cutting edge remain rubber for a longer time as well as sometimes it will also help to evacuate the cutting chips which you are for following this particular fluids and that is why coating is very one of the important parameters or variables for the cutting tools.

So, cutting tool design influence many things that is dimensional accuracy because now if you have different geometry you will get a different type of geometry or the accuracy of the features surface quality burr formation tool life. So, all this things depends on these parameters what is the material you are using what is the geometry what is the cutting edge radius and what is the coating your using. So, by a proper combination of this particular for variables what you will get you may get the higher dimensional accuracy very high surface finish less burr formation and the enhance tool life.

So, we have to finalize that which way we can get this thing and many times what happens at this sum of these parameters are very contradictory because now we know that surprised the cutting edge radius, we can easily remove the material and we can go down and down in terms of uncut chip thickness, but if you make more and more sharp what is going to happen that the material available for cutting is very very less and it will directly affect the coating and then the geometry also very difficult to create when it is a shaft pictures.

So, in that way, we have to come to a compromise situation in such a way that we can get maximum output or maximum benefit of this influences another thing is it is difficult to detect damage to cutting edges and even broken tool shaft. So, this is what bound to happen because we know the hundred micron diameter is difficult to even see also by naked eye.

So, problem is that that even the tool is not able to detect, then it is very much possible that you cannot see anything about the cutting edges. So, every time the microscope and some type of vision systems are important to use during machining and after machining; So, that you can get the actually status of the cutting tool.

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So, what are the different important areas which need to explored in the micro tooling, first thing is a fabrication methods, we will discuss about the fabrication method, but we can also try to find some alternative way. So, that we can get the required things done in a cheaper way and more efficient way, second thing is the optimization of geometric and coating properties of micro tool in order to improve tool life and the processor accuracy why this is important here because we will see that there are different type of geometry is available.

So, many times; what happened that the tools which we are fabricating, it is not the replica of the normal conventional cutting tools which we are using because conventional cutting tools are mostly very very large in diameter. So, you can easily get different type of fluid features and different type of angles, but as you go down and down getting those pictures are very difficult.

So, we will see very very primitive shaft that is a something like a d type of tool and square type rectangle type and circular type tool also without any type of fluid. So, we will say that why it is difficult to get those pictures because there is a problem with the process is available to make the step of features coating property is important which type of coating you are using and what type of material you are using for coating those material.

So, that is also issue with the part tool holding and balancing as well as the micro tools setting devices. Now, holding is another issue because we know that a there is a run out the tool run out place very very important only in the micro machining domain because even a small amount of run out will quickly break your cutting tool even without doing any machining operation also at the start itself.

Balancing is important because we have to make sure that it is a uniformly balance on both the side that is directly affected by the tool run out and the micro tool setting devices, then one you fit the tool inside, then you have to do x y and z 0 0 set up. So, those things are also very important because we have to find where is the work 0 so that you can start machining from the z equal to 0 dimension.

Then the micro tool characteristics machine ability in particular because we will see that there are different tools for us specific material because you cannot use same material same micro tool material for all different type of work piece material because if you go with the Tungsten hss say is that it is high speed steel than it has there are very tub, but it does not have so much of hardness. So, we generally go with the Tungsten carbide diamond is the hardness, but diamond has a problem with machining of a ferrous materials because there is a liberation of the carbon and it will quickly damage because of the car. So, mostly diamond is used for the non ferrous materials.

Tool condition monitoring during process because this is very very important because we will see that sometimes, what happened that when you start machining operation at the time the tool is in good condition, but just after one or two minutes tool is broken, but still you continue because you do not have any monitoring system there.

So, to avoid this thing happened that view, it is better to put some monitoring devices, mostly, it is a force dynamometer or some type of other accelerometer by which you can get some type of indirect signals and you can see that there is always a contact between the tool and the work piece. So, if the tool is broken then you will not get that thing in contact with the to work piece and you will not get the signal in terms of force or any other type of signature.

So, if that time; you can understand that tool is broken or there is no contract. So, actually you monitoring of the cutting condition tool condition is very very important because you can save lot of time without spending so much time in the regulating or the finding some problem at the later stage.

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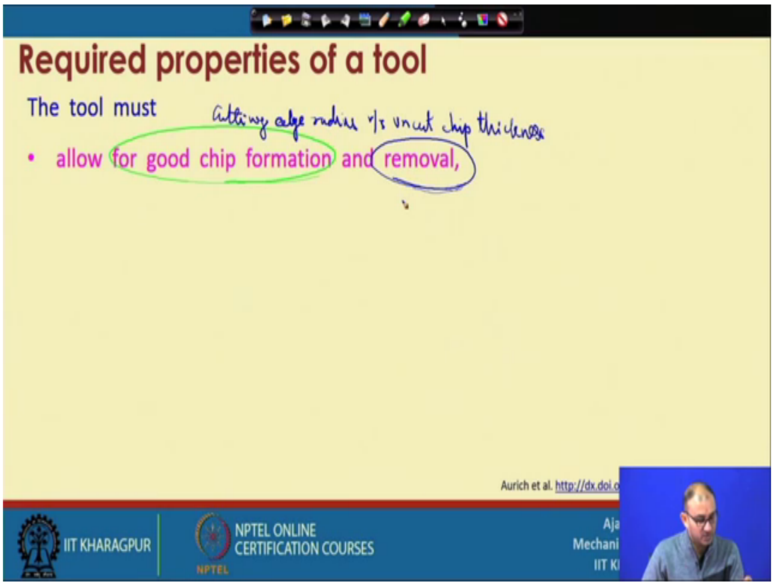

So, what are the required property of a tool. So, tool must allow for good chip formation and removal. Now this good chip formation; it directly depends on the cutting edge radius because we know that this particular thing is directly affected by the what is the cutting edge radius you have, all right cutting edge radius versus uncut chip thickness.

Then we have discuss lot of thing about this two parameter. So, we are not going to do that thing again, but this is what important because a good chip formation is very very important to make sure that you are efficiently removing the material and you do not need to give a second pass for the same location and once you get the chip formation then its removal is also important because what happen that when you do a cutting by micro tool you do not have so much space for evacuating this types of chips.

So, fluid size is very very small. So, you have to again compromise with the features or the geometry of the cutting tool have a sharp cutting edge at the time.

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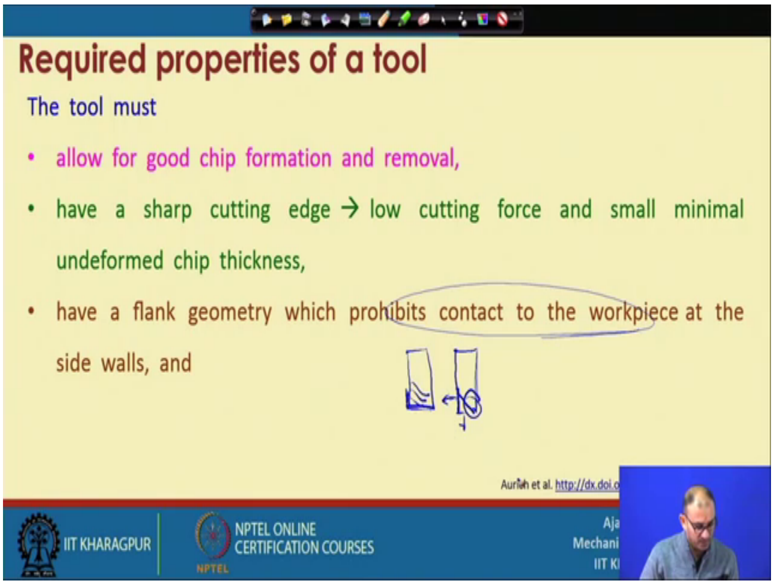

If it is a sharp then you will get the low cutting force and small minimal uncut chip thickness, you can select for that because sharp for the thing because we know that if it is a 5 micron of cutting edge, then you can get anything any value more than 5 micron for the uncut chip thickness and that way you can reduce the cutting force also.

And have a flank geometry which prohibit contact to the work piece at the side walls because what happens that many times, what happened that you do one machining operation and now consider the this is the cutting tool and it bottom is the flat be atom. So, what happens then these particular things will create a problem here because what happened that you will end up with the cutting at the bottom surface also and as well as side surface also.

So, in that case it is better to go with some type of cutting tool something like this that it has very small amount of face here, but it will not touch at the side surface at these two location. So, at that time you have to actually device some different geometries in such a way that you can avoid the contact of the work piece because once the machining is over, then it is better that we should not actually provide some contact with the cutting tool, otherwise, it will again generate some additional mark and then you have to apply some type of debarring operation or the planning operation, all right.

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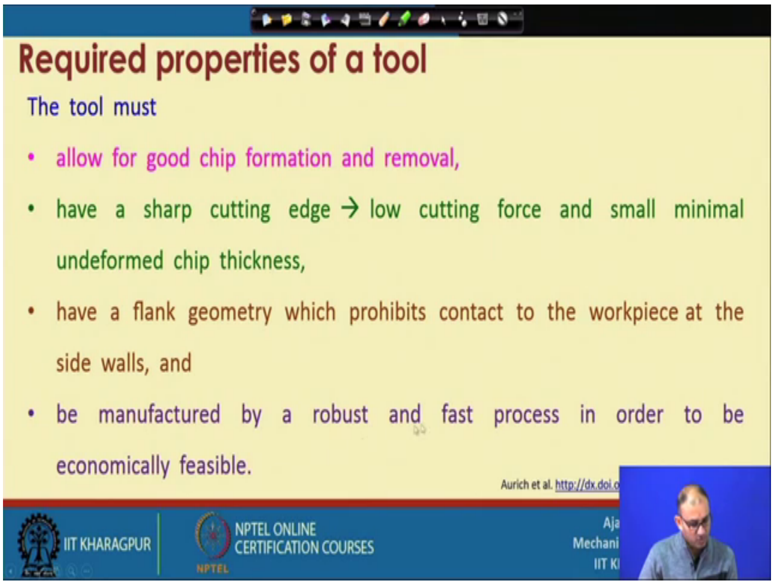

So, be manufactured by a robust and the first process in order to be economically feasible because again, we have to see that if you spend more and more time and cost in the fabrication of the cutting tool then the cost of each and every cutting tool will be very very high. So, we have to also make sure that it is economically feasible for different manufacture. So, that we can easily by this particular cutting tool and do some type if micro machining operations.

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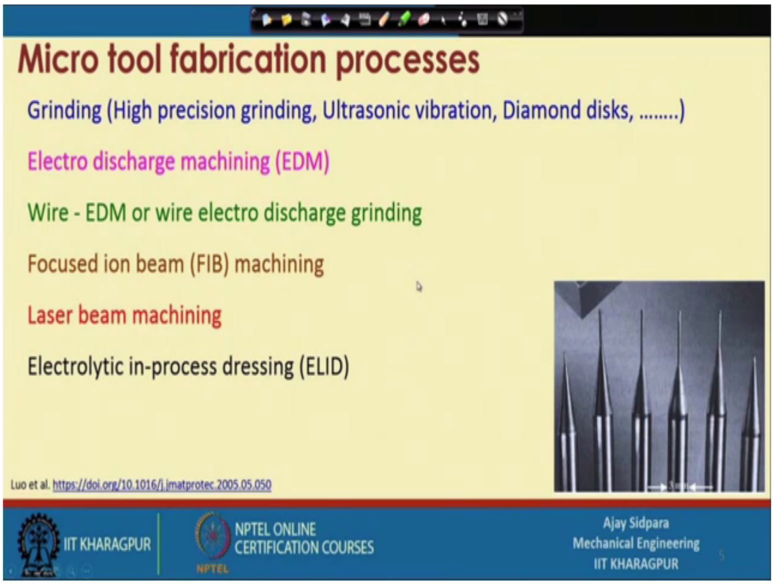

So, what are the different processes are unavailable here we have I am showing you you the few only, but there are very customize process is also available, but these are mostly use. So, grinding is the; obviously, the first process which people mostly used for that.

So, it is a high precision grinding process high precision; that means, the accuracy and the feedback resolution is very very high in this people also use the ultrasonic vibration to reduce the cutting forces and the diamond disc available with a diamond particle. So, at a nanometer level and then you can do some type of feature cutting on the different type of cutting tools 10 electro discharge machining because this is widely used because it is a non contact type of thing because there is no contact between the cutting tool and the work piece mostly material is removed by the evaporation and the melting and evaporation.

So, in this case is the advantage that you will mostly get the force pre machining. So, force is will not act on to the surface. So, you will get the very very fine features from this electric discharge machine.

So, there is another variant of this that is called wire electric discharge machining where wire is used in place of a cutting tool and there is a also called the wire electro discharge grinding operation because grinding is performed by the wire. So, that is why it is written in a wire electro discharge grinding operation focused ion beam is widely is because it has a you can go with a few nanometer of diameter of the beam.

So, the accuracy and the precision of that machining or the fabrication of cutting tool is very very high in this particular case and you can get very very fine features on to the side different diameters laser beam machining is also use for different making of different cutting tools and there is one process called electrolytic in process dressing. So, it is similar to grinding process.

But what we are doing here that we are doing in process dressing into the grinding operation. So, the objective is to make sure that the projection of the abrasive particles of the protrusion of the abrasive particles remains always same without spending any additional time or the off time. So, these are some of the processes which are routinely used for fabrication of the cutting tools.

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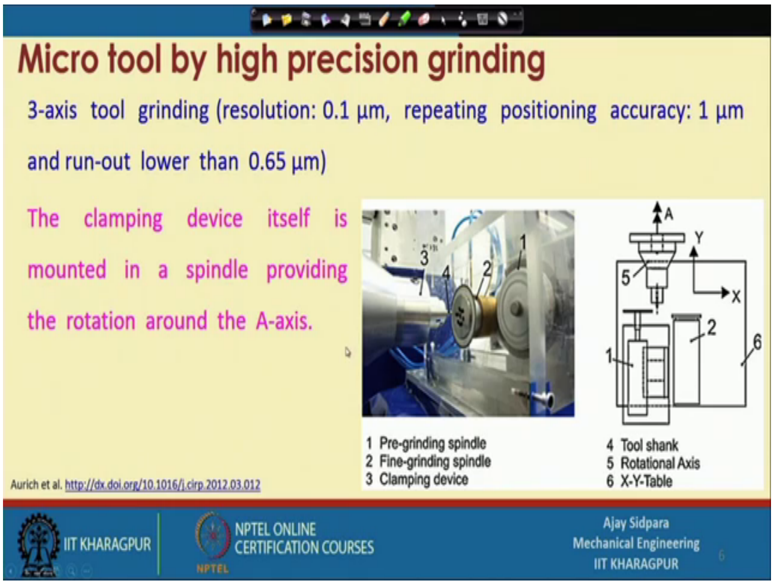

So, let us discuss one by one. So, this is first thing is the high precision grinding. So, this is the set up. Now if you see this is the pre grinding setup. So, this is the bigger size of wheel. So, where the diameter of or the particle size what we are using here it is diamond particle size is very large because initially what happened then we need to remove more amount of material out of it.

So, initially you do not do a fine grinding operations. So, first part is the shaping of the particular cutting tool and once the shaping is over, then you transferred to the second part that is a fine grinding wheel fine grinding wheel why we are telling 5 grinding wheel. So, because here that particles which we are using for this grinding wheel it will be a sub micron level or even finer then that then what additional thing a the clamping devices this one.

So, this is a spindle itself. So, you do not need to sometime remove the tool also, so, directly a mount this thing to the machining centre. So, that you can avoid the sum of the errors or some type of what we can say that placement errors that is run out and everything when you have direct mounting want to the spindle itself and this is the tool shank which is with the tool and rotational axis is given here.

So, you rotate this particular tool and then you have a two grinding with and this is the x y table so that you can get the different features down on to the different side of the cutting tool. So, it is a 3 axis grinding tool grinding machine why equal to high precision and because if you see the resolution is point one micron. So, you can give a moment with a point one micron of resolution repeating position accuracy is one micron, now why it is important because sometimes what happen that first you move this thing to this pre grinding; that means, in a course grinding in machining.

So, you do that thing here and then again you have to maintain that position accuracy because if you are not reaching the same position again after at the same location then what will happen that you may be doing machining at a wrong position.

So, within one micron we can get the a position accuracy and run out is lower than 0.65 micron. So, here that is also important because here also it is in a rotation because if that grinding wheel or your tool they have your run out the consider 10 micron or something, then fabrication of the cutting tool itself is difficult, then all the things even if it is possible, then what is going to happen then their run out will be reflected on to the geometry of the cutting tool and once you do machining with this type of cutting tool you may not get the required features of the liquid dimension onto the micro component.

So, clamping device itself is mounted on to the spindle providing the rotation around the a axis. So, this is what we have discussed that you can actually reduce the run out problem when you directly mount this particular cutting tool on to the spindle and the same spindle is used for machining at the later stage.

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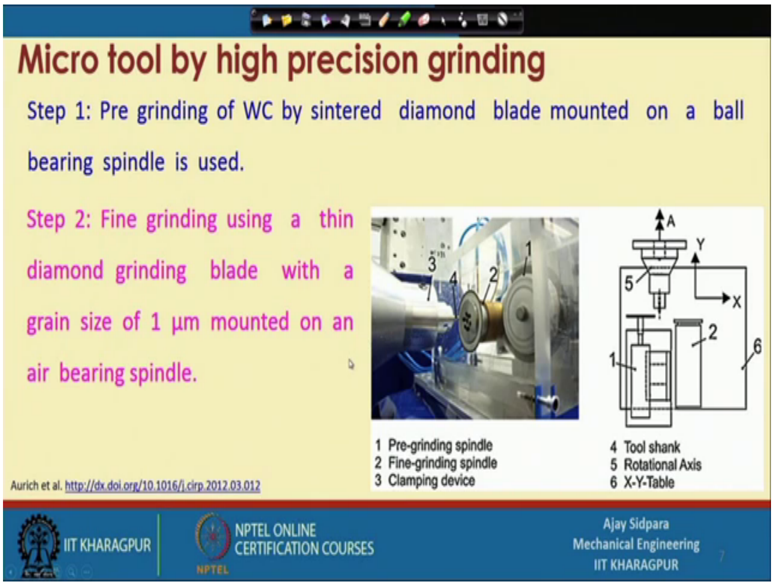

So, what are the two stage? The first stage is that the pre grinding of the tungsten carbide by sintered diamond blade mounted on a ball bearing spindle it is used. So, this is where a rough machining because here our objective is not to give a find features, but initially we shape in such a way that the next operation will be very very easy and second step is the fine grinding using a thin diamond grinding blade with a grain size of a one micron mounted on a air bearing spindle.

Now, you can see that there are two differences one is the we are what we are using that one micron diamond particles we are using why are the particle size is very large here, what we are using we are using a ball bearing spindle when we have seen lot of things in the ball bearing and the air bearing things that air bearing is much convenient or more recommended for the micro machining operations.

So, here by using this thing what we are doing the we are doing some type of fine feature fabrication on the cutting tool so that you can get the required geometry.

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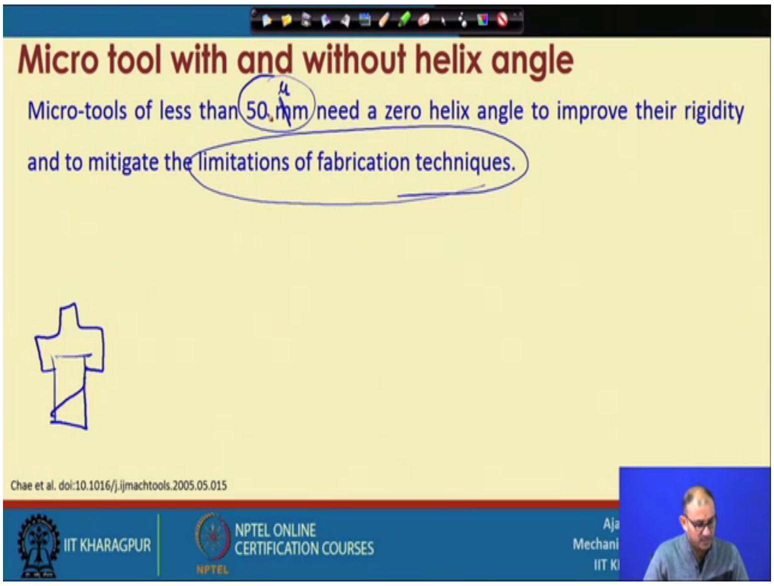

Now, coming to the helix angle because we know that there are different different things which are available helix angle is very very important to get the chips and everything coming out of it, but what the things are there because when that cutting tool is less than 50 micron.

So, this is the micron not millimeter once it less than fifteen micron, then what happened the 0 rectangle is mostly required because to improve the rigidity and to mitigate the limitation of the fabrication process because once you cross this particular domain, what is happening the 50 micron that if you want to give a helix angle, then what is happening the you have to sacrifice the rigidity of the cutting tool because we know the diameter itself is a 50 micron and then you are giving on the on the top of that some type of helix angle.

So, getting this helix angle itself is difficult because we do not have so much of available processes which will do this particular things when you are crossing a 50 micron of diameter, even if you give some type of costly processes, but what is the problem that you can get this thing that, but the rigidity of the cutting tool will be very very low in this particular case.

So, when you use this particular cutting tool in the machining operation either, it will be want completely or it will broken within a few cycles of operations. So, that is a big problem here. So, mostly when we find some cutting tool with a less than 50 micron diameter then you will get a very very primitive shape, mostly it is a square and triangle or some type of rectangle also, right.

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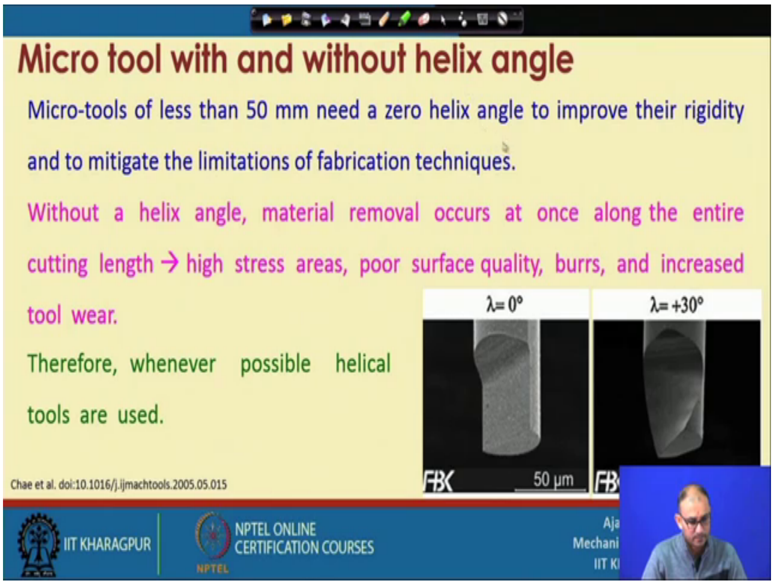

So, this is a zero helix single. Now, you can say that it does not have any type of angle. So, it is a purely a straight is here. So, this is the d type of thing. So, you have if it is rotating in this direction then you this will be the cutting edge and if you rotates in opposite direction then this will be the cutting edge. So, it has only single cutting edge without a flange helix angle whatever material removal occurs at once along the entire cutting lengths.

So, this is what is going to happen here. So, what is problem that if this is happening then in single rotation you are getting only at the one cutting length? So, highest stress is our area areas you will get a very very high stress area at the different different location and we know that we are growing at the one location only sub surface finish will be very very poor in this case.

And there will be burr formation because if it is a one cutting edge only the we are of that cutting edge very very will be very very a high and within a 1 cycle or 2 cycle of operations depending on the how much it is moving and what is the cutting velocity and the feed rate, you will get lot of burr formation because it will not retain that sharpness for a longer time and the increase to here that is obvious that whenever you are getting burr formation mostly it is because of the blond edge is. So, that is the problem.

So, it is better that wherever it is possible you create the helix on the on the on that. So, this is the positive 30 degree helix angle. Now you can see here that this particular edge is this particular edge will perform machining operation this particular thing and you have a sharp helix angle here. So, movement of this chip will be very very finely tuned in this particular case, but still you have one only, but it is sharpness will play important role in the movement of the cut a material is very very easy in this particular case.

So, whenever you are working with a more than 50 micron better to go with the helix angle and if you have problem with the rigidity and the problem fabrication technique then better to go with the 50 micron or less without any type of helix angle right.

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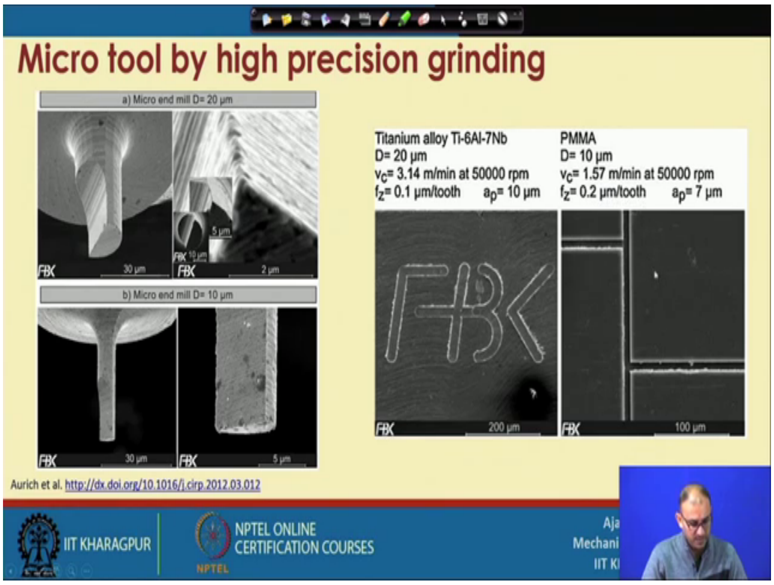

So, these are the different types of steps which are fabricated by that particular precision grinding machine and you can see that this is the diameter is around 10 micron or something. So, here it is a 20 micron diameter and this is the 10 micron diameter and what is possible. Now you can see that there is a other two different materials which are machine by despite. So, here the diameter is 20 micron material was the titanium alloy and this is the polymer material poly methyl methyl acrylate.

And here diameter was used 10 micron and here if you see the 50,000 is the rpm, but if you see the diameter is large. So, you have you will get the cutting velocity 3.14. So, if the diameter is half, but if you maintain the cutting rpm, but then what is happening that your cutting velocity is half of that particular part, right. So, that way you can see the higher is the diameter at a one particular rpm you will get the high cutting velocity and that is very important.

So, that you can get the reasonable amount of material removal here depth of cut is 10 micron a 7 micron and feed rate part two which is point one micron here is a point two micron because why we are giving higher lower feed rate here because it is a metallic component. So, if you go with very very high thing high feed rate, then there is a chance of tool breakage or the tool bending, but here it is a polymer material.

So, material resistance will not be so much high so that you can go with the higher feed rate.

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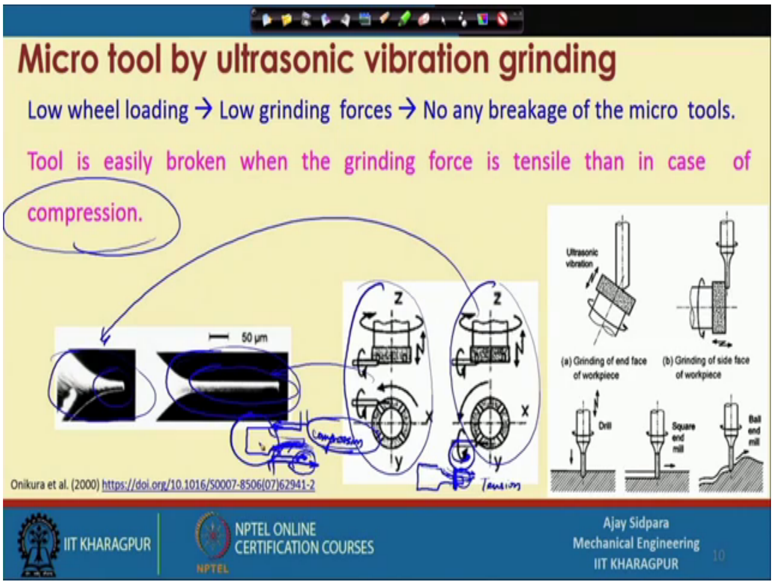

Then are coming to the under grinding operation that is called ultrasonic vibration. So, now, what is the advantage of doing this thing that when you provide a ultrasonic vibration now you can see that there are two different setups here. So, this particular setup is used for fabrication of the end face of the work piece work piece; that means it is our tool.

So, when you want to create sometime features yet then what you have to do that you have to create vibration on to the this particular surface. So, this is the grinding wheel and vibration is a parallel to the axis of the grinding wheel and once you would complete this thing then what you have to do then you have to reduce the diameter also.

So, at that time you actually give the side face grinding. So, that you can reduce the diameter and once this thing is done then the same tool you can use for different different operation drilling we can use you can use the milling was. So, if you are making a square and tool or if you are making a ball and tool then you can do some type of cover machining also.

So, once you provide this particular vibration what is happening that we are wheel loading will be very very less and that is very advantages here because when you talk about the micron size of diamond grinds then you do not have so much of space also in between the surfaces. So, once you do not have loading at the time the grinding force will be very very low in this case and you will not get the any breakage to the tool here because we have to avoid this particular breakage of the tool during fabrication also otherwise you will end up with the wrong geometry or the broken tool.

Right, so, these are the features this is the one of the ways it is fabricated now what is happening here. So, these are two different set up is given. So, here this is the rotation of the grinding and this is the rotation of the cutting tool. So, now, what is happening he has a cutting tool is here and your grinding wheel actually rotating in this direction right. So, it is moving in this way.

So, it is actually giving a compressive loading. So, here if you swing that this is a compression, then what is happening that by this particular process, what you are getting you are getting this diameter. So, the length of the cutting tool is very very large in this case, you see this particular thing now here the cutting tool is located here and your wheel is at located at this location and it is rotating in this direction, right.

So, the moment of the wheel is in this direction. So, now, your tool will be in tension and here it is in compression right. So, what is advantage here that when it is in tension at the time you will not get this particular feature here because now the length has an issue because once you cross one particular part here when we are machining at this location at that of strength of this part will be very very less, but that is not going to happen here because the compressive strength is all over higher than the tensile strength.

So, that is the advantage that when you do cutting or the fabrication of the cutting tool in a compressive manner or the come in the direction of the compressive forces, then you will end up with the higher cutting or the higher length of the cutting tool, but that is not happening at this particular location. So, it is better that every time when you give a feed direction and everything it is better to go in the same way the way we are doing a turning operation.

We do not give the turning operation they have something like this right because we always go with the this way because our material support is very very high at this location and that is the advantage of going with a compressive loading instead of a tensile loading right.

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So, higher compressive strength then the tensile strength; so that is the advantage of using this thing; so, once you get this particular tool, then what happen that you can do many things here that you create some type of slot here and that particulars of; that means, the you are cutting something half some half portion of this. So, if you see from this direction then what we are looking at the we are doing something like this or if you want something you can clear some square type of tools and you would remove material from all the 4 sides whatever you are getting that additional circle part of this part remove, then you can get the square type.

So, this is very primitive because if you see this is a 50 micron the tool diameter is not more than 20 micron or something. So, this way you can make the cutting tool much easier way compared to the landing without any tool vibration or ultrasonic vibration. So, let me stop write here and we will continue this talk further in the next class.

Thank you very much.