Introduction to Mechanical Micro Machining
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Lecture – 50
Micro Tools (Contd.)

A good morning everybody again and let us continue our discussion on the fabrication of micro cutting tools. In the last class we have seen that there are many processes available which can machine micro tool, at the micro level, with a diameter of less than 50 micron also and we have seen that there are grinding process available and after that we have seen the ultrasonic vibration grinding, so that we can reduce the forces on the cutting tool and we can get the very very fine features on the surface.

So, let us continue further and our discussion on fabrication of micro cutting tools.

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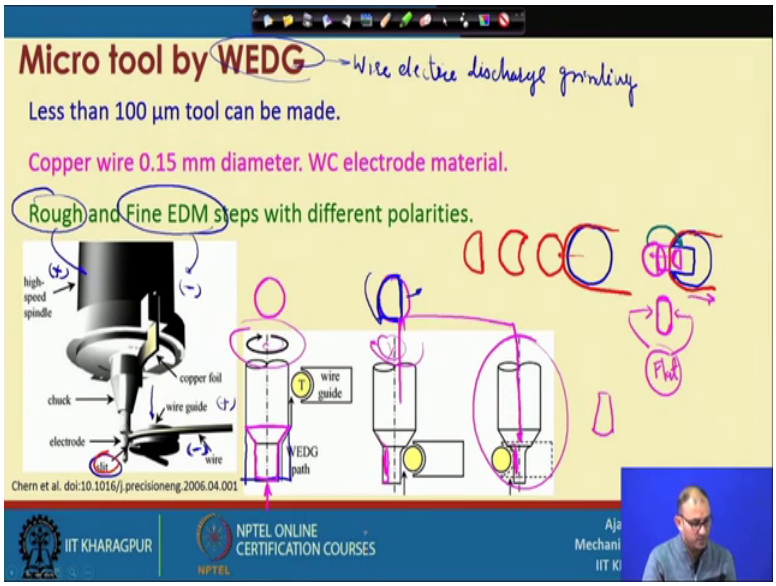

Then there is once process that is called wire electrode discharge grinding process. So, this particular thing is called wire electric discharge grinding right. So, you can get the tool diameter less than 100 micron also, because now we have seen that electric discharge is a force free and earlier grinding it is actually the mechanical contact.

So, even though it is a small contact or whatever the way you are using a find diamond greet or anything, but still there is a physical contact. So, wherever there is a contact you

always get some type of vibration or some type of bending on to the work piece and that is enough to break the cutting tool. So, this known conversional process is all called the advanced machining processes, EDM electrochemical machining, laser beam machining, electron beam machining.

So, those things are very convenient to use in this particular domain, but we can say, you can also tell that this processor comparative this slower compare to the mechanical machining processes and that is also one of the reasons that why mechanical micromachining is very important, compare to the conventional micro machining operation that advanced machining operation; like EDM ECM and other processes.

So, here you can get the diameter less than 100 micron. So, what where we can do it, that this is the high speed spindle which we can directly use for fabrication of the cutting tool and this is the copper-copper foil, because this foil is required to compete the electric discharge, circuit chuck is there. So, by chuck you can actually hold the electrode and then you provide the wire guide here.

So, instead of a normal cutting tool, we are using a wire here and that is the reason we are using it a, we called it as a wire electric discharge grinding and we will tell it grinding here, because what we are doing that we are actually doing some type of cylindrical grinding type of operation here, and you can get the different-different type of geometry on the part.

So, here what we are using the copper diameter there, using with a 0.15 millimeter diameter 150 micron is the diameter and work piece material is the tungsten carbide and there are two different steps available; one in the rough EDM and another is the fine EDM with the different polarities. Why we do different polarities, because now for a rough EDM, what we are doing here in this case. In this case the work piece what we are using; that is actually the positive one, because that is what we want to remove more part and the wire what is here that is the negative part.

So, we know than an EDM whichever electrode is connected with the negative terminal, it will we are very less compared to the positively connected electrode. So, while doing this thing what we do that, we actually quickly remove the material enrich to the some type of particular shape and once you want to get the fine EDM, then what we do that we

actually move this thing to the negative, because now we do not want to remove more material from the work piece and this will become the positive.

Let the wire be, we are very fast, because we are not worried about that particular wire quality or wire condition. So, here what we are doing that by making this thing, the material removal will be very less here and you can actually finely tune the different features on to the surface right. So, this is the way it is happening. So, here what is happening that this is the rotation. So, initial stage what we are doing that, we are doing EDM process.

So, we are reducing. So, initial diameter was something like this. So, this was the initial part and the after that EDM then what we are doing the, we are making this particular shape. So, this is the same after EDM or the rough surface of the rough machining and once this part is over then what you can do that, you can stop the rotation here, because we want to create some features on the top on this type.

So, if you look from this particulars thing, then your initial diameter is this much when you are looking from. So, this is the bottom view of the cutting tool and then what you do that, you create some type of features on the top. So, now, whatever is the thing here what we are doing now that we are cutting something like this? So, now, these part will be away and then this is the shape of this part or the shape of the cutting tool correct. So, now, if you are rotating in this direction, then this will be a cutting edge and if you rotate in the opposite direction, this will be the cutting edge.

So, now, we are stopping the part and now what you are doing that, again the same why we are using and then giving the shape and one direction. Now you can say there is a offset between. So, here a material is more and here material is less at this location and then what you are doing then, then we are creating one slot here.

So, now what is important here, this slit is playing important role here. Now if you look from this particular grinding wire and wire guide, this is something like this. So, this is the wire guide and wire is located on the top of it. So, wire is coming something like this. So, wire is coming on the top of it, something like this. Now if you see, if you do this particular thing then what is happening a. Suppose this is your cutting tool and we know that wire diameter is 150 micron and our cutting tool diameter is almost a 100 micron.

So, this is our cutting tool. Now what is happening that when you are plunging in this thing direction then what is happening that, you are actually cutting something like this right. So, whatever is the diameter of this particular guide is the, that diameter will be reflected on to the cutting part. So, we do not want this type of curved surface what we need that, we need something like this part. So, we have to make sure that wire is straight here at this location and that is the use of this particular slide.

So, now how this slit will create this wire. So, now, what is happening then, our thing is something like this right. So, this is the slit by which we are making the thing. So, now, when you are wire is rotating from here at that time, it was straightly go from here to here correct. So, now, you are reducing this particular curvature here and now you are getting a straight wire. So, now, you are tool is here, suppose. So, now, your tool is here and your tool will actually give a similar cut here, because now this straightness whatever is the same straightness will be created on this particular part. So, once this operation is over.

Now, we know that we do not want to remove the rotation ok, because if you rotate the thing, you will not get the same surface again, because that is also problem. So, now, some what we have to do that we want to cut similar thing from here to here also this way. So, now, what is happening that this particular slot will be little bit? So, you have to make this particular slot, it will be in a such way the. Once you complete this part then what you have to do that, you have to move this particular cutting tool into this particular slot. So, now, your cutting tool will be here in this location.

So, your cutting tool is cut down something from here, it is cut down and now your shape is something like this and then you move your cutting wire guide in this direction or your cutting in this direction. So, this is another portion which is curvature in this location that will be also cut down. So, finally, what you are getting something like this surface. So, this curvature already made with that, is the whatever the diameter is there, but you will get two flat surface here at this location, at this location. These are the two flat surfaces correct and then you remove this thing.

So, after doing this thing whatever you move this thing off and then you enter this particular tool into this sleet, whatever is small sleet available here and then do the. Now wire is located at this direction. So now, it will do removal of this particular portion

water is available. So, it is cut down from this part. So, by this way what we are doing actually we are, actually reducing the error, because of the different type of motions, because now see that even if we it is rotated a 1 degree here then what is going to happen that two this faces will not be parallel. So, if one way you will get something like this, another way you will get something like this correct.

So, that is the problem. If you do not actually provide this type of facility, so that you can get the two faces machine without changing the setup of them. So, now, advantage the, now your whole setup is ready and now you can do the machining operation without any problem right.

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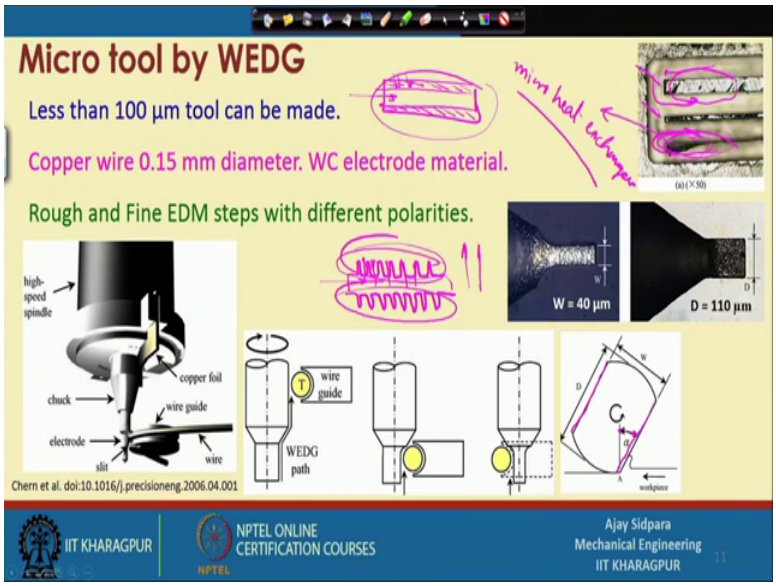

So, this is the tool what we were discussing. So, now, you can say that it has a two flat surfaces. So, this is the one flat surface and this is the another flat surface and then it is doing cutting operation, but still you can see this is a negative rake angle and that we have discussed many time that whenever this a negative rake angle you are end up with the very very high amount of flowing phenomena and this is the diameter and this is the width of that cutting tool right.

So, this is the features which are created. So, width is the, 40 micron is the width and the depth this particular D is the 110; that is the total depth of the cutting tool and what happened that, they did some experiment with a different type of wall thickness. Now

you can see here the feature which is created a. So, tool is passing through and the this is the wall thickness.

So, initial stage your tool is moving from here and then it is passing from here, at that time it is maintaining this. So, we can see the wherever wall thickness is more, it is mostly straight and it is getting whatever required dimension, even the same thing in here also. So, this is also acceptable, this is also acceptable, but when it is become more and more thing, what is happening that the material do not have so much of strength in there.

So, when you are cutting from here to here one direction and then you are entering here, because your material do not have so much of strength, then it will bend actually, and because of bending you will not get the required features, these things, so by this particular expand they found at this is the minimum wall thickness which you can great for a particular application. Why these types of things are important, because these are very very important some type of, we can say micro heat exchanger right. Why it is important. Now suppose consider that you have a surface here and your some fluid is passing through this part and you want to do cool this particular fluid right.

So, when it is passing through there and this is the conventional tube kind of things something like this, but now if you see that, if you want to makes very very have more cooling kind of thing, then what you can do that, you actually clear some type of features here on to the wall of the heat exchanger tube right. So, we, what we have done that, we have done some machining here as said that and we can actually do some.

Now when you are passing the fluid here; now here it has a high amount more amount of area. So, now, if you increase the total area then what happened that, you are literary more will be very very fast from this, because here you are not getting same amount of area and we have seen into the scaling effect that when you scale down the system, your volume actually goes down very quickly compared to the area.

So, here you will get more amount of area. So, your heat the hear release will be very very high compared to the other bigger size of component. So, there are different other area so well where you need a very very thin wall structure for different-different applications right.

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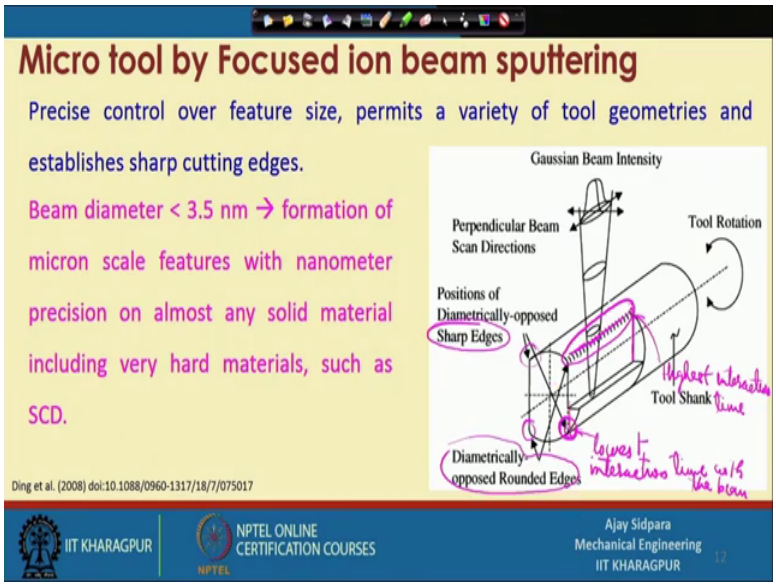

So, on their process equal to focused ion beam sputtering operation here, what we are doing then, we are using one iron beam as a tool for cutting different type of materials and we have to use a 5 axis or 6 axis table in such a way that you have, you can rotate your tool in a different different direction to get the cutting at a different faces of the cutting tool.

So, why this is important, because it can give a precise control over the feature size permits a variety of tool geometry and established the surf cutting edges. So, these are some of the advantages of going with this particular process. Another advantage of beam diameter you can go with a less than 3.5 nanometer, why this is important, because now you consider this much, whatever this dimension this diameter will consider the cutting tool, because ultimately you are cutting something.

So, if you are cutting tool itself is a 0.3 0.5 nanometer, than what is happening that formation of the micron size picture with a nanometer pieces and its possible and our energy level is extremely high. So, you can even cut the single crystal and diamond material. So, hardness is not an issue and you have very very fine size of the, where very small size of the beam diameter and that is advantage that micron size picture with the nanometer pieces and you can easily get. So, that is the advantage of going this, but with this particular process, but what is the problem that you can see this.

Now whenever your beam is interacting with the work is what is happening here that it is, it is starting cutting from this location right, it is cutting here and then gradually it is going down and down and it is cutting completely this particular component. So, whatever this location is there, this location is coming into contact with the beam for the longest time right, was soon as cutting is over, then you are switching off the supply. So, this is the location with, this is interacting with the lowest time.

So, this is the lowest interaction time with the beam interaction time with the beam and this particular location has the highest interaction time right. So, when it is highest instruction time what is happening that, you are getting here at this particular location very very rounded edge. So, now, this particular edges is rounded edge, so this is what you are telling. Now this is the diametrically round.

So now, if you rotated at this location, then this will be rounded edge and once you complete the operation, wherever the beam is coming out the this particular edges will be surfaces right. So, you have to rotate, where you have to kinematically arrange your workpiece in such a way that you at least get one or two surfaces in such a way that you can remove the material very efficiently in this case. So, let us see that which, where we are do this particular moment of the cutting tool right.

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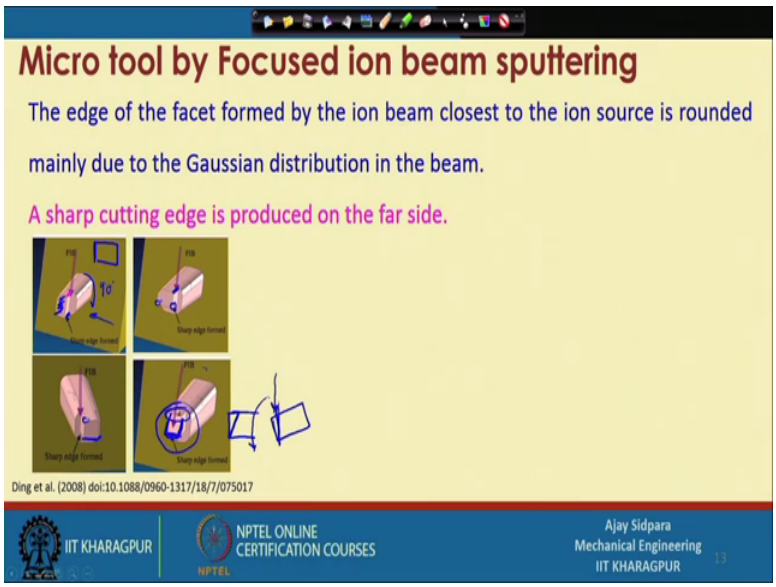

So, here what is written the edge of the facet formed by the iron beam closest to the iron source is rounded, mainly due to Gaussian distribution of the beam. So, that is what is

happening in the less card and the sharp cutting edges produce at the far side. So, whatever side, which is actually away from the beam and which is coming into contact at the last location or the last time at the time, this things are very sharp compare to that part. So, now, what we have to do that we want to create a one single point cutting tool by this particular for acoustic banding in operation.

So, this is the different state movement of the cutting tool, so that we can get the surface out of this particular operation. So, what is happening here? So, now, here what is happening that when beam is coming into contact this particular edge is the rounded edge. So, let us color it red. So, this is the rounded edge and this particular edge is the surface. So, this is the surface correct. So, after that the next operation is now you rotate the work piece. So, now, what you are doing that this particular edge is the surface right.

So, now, you are equally rotating into this direction. So, we are rotating this thing is a 90 degree. Now we know that this is the surface right. So, this is the surface and only this one was around a edge, but now when it is cutting from this. So, this will be also become surface, but this is the round edge now.

So, after that we again rotate into the 90 degree then what is happening that, now you are getting a surface at this location also right. So, we have rotated at further in this direction. So, now, you have surface here, you have surface of, this whole is a surface and this is round edge at this location correct and then you, what you do you little bit tilt in this direction right.

Now because what is happening here right now, that this particular face is completely flat case. So, this surface is at the same location, this is the flat surface when you look from this direction you are getting surface something like this. So, now we have to create a cutting edge. So, now, if you see from this direction what we are doing that, we are cutting this particular face here right. So, the angle will be from this to this direction. So, this will be angled away.

So, if you rotated this direction a little bit, then what is happening that what you are doing, we are doing something like this. So, beam is always perpendicular vertical direction. So, it will cut down this particular portion from here to here and you will get a single point cutting tool something like right. This all edge will be the surface and this

particular part and these are the edges which are rounded away, it will not participate in material removal. So, you do not worried about that part right.

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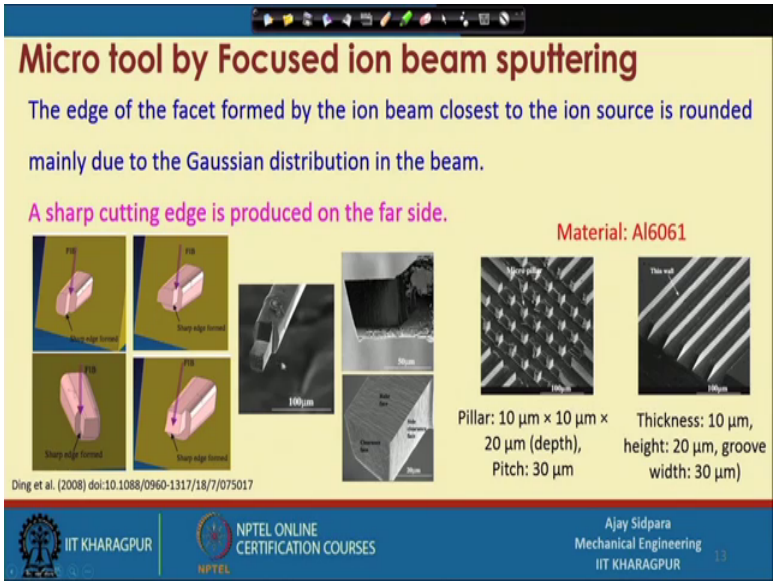

So, this is the fabricated cutting tool. Now you can see that this is the, this dimension is 100 micron, this is round 25 micron or something and this is all the things, it has the red face, then it has a clearance face and other things also and this is the schedule when you look from this part. So, this is the clearance space available. So, you do not get any type of contact with the work piece surface and these are the clear way this red face side, clearance face, this is the clearance face and diameter is a, the size is around 20 micron. So, now, once you get this tool, then we have to actually operate this tool for the different operation. So, they did some experiment on the aluminium material and this is what is done here.

So, what is thing here that this particular, whatever is this width is the width of this, then they actually did some type of machining in this direction. So, one machining is done in there, after that they did machining in this direction right. So, by doing this thing they are getting a different type of pillars on the workpiece material. So, here objective is that, you get some patra material here, then you can use this thing as a for embossing purpose also or you can used EDM 12 for creating some type of multiple holes on to some type of filter application or something.

So, there are many applications for of this particular type of features and other than that. Though here the pillar size is the 10 by 10 micron is the and depth is or; that means, height in the 20 micron and the peach is the distance between these two is the 30 micron. So, mostly it is the width of this cutting tool other than that the, they also, it some experiment with the thing for fabrication.

So, here they are not giving the vertical and the horizontal cutting, the only one direction it is given and then they did measurement on what is the thin wall thins. So, here the thickness of this particular wall is 10 micron, height is 20 micron and this groove width is 30 micron. So, peach and groove with its, mostly depend on the what is the minimum width of the cutting tool, which we are using and that we have seen that smaller the size of the cutting tool, smaller. We can get the width of this particular groove as well as the peach of these particular features, what we are creating.

So, this is the way of fabrication of the single point cutting tool other than single point cutting tool, they have also fabricated end wheel cutter add.

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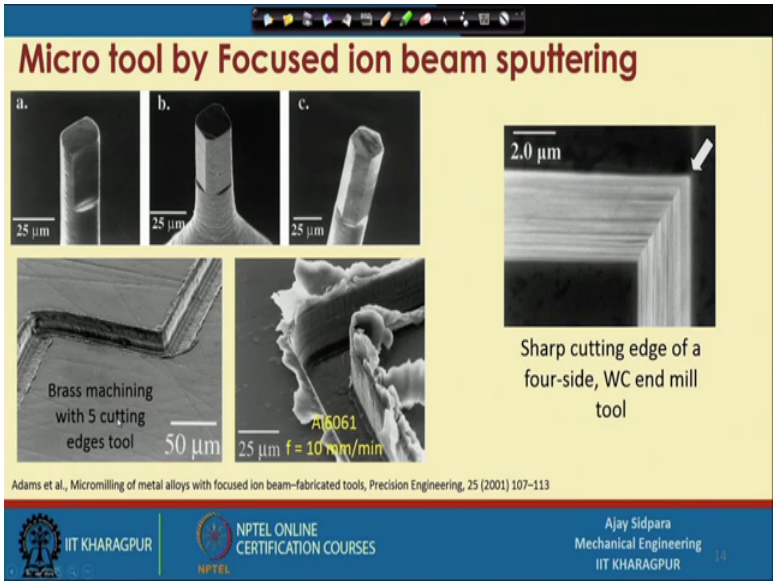

So, there are the different end wheel cutters than we can see that the diameter is 25 micron and we have seen that creating helix angle is sometimes very difficult or even if it is possible your rigidity or the strength of the tool will be sacrificed. So, that is a reason that these are the sum 2 3 different tools are the. This is the 2 edges tool, this is 4 edges tool and this is the 5 edges, 6 edges tool 1 2 3 4 and 5, 5 which is 2.

So, here this is the sharpness of the cutting edge of the 4 sided tool. So, here this is the we can see that how sharp it is there and then they did some x cement on the elimination. Now you can see that lot of burr formation is that, because we know the alumina is we ductile material and when you do not have a surface here and we have seen that there is, it will create a flowing effect and sometime rubbing effect and steel, if you continue machining then this is the burr formation and what we have to do that.

Once you get this thing the then you have to apply some debarring operation very very gentle. So, that it should not damage these particular features, but it will remove the burr from the surfaces only and this is on the brass machining and brass also. You can see the burr formation is not as large as the alumina, but here you steel get some burr formation and that burr formation is creating problem at the later stage, when you want to use this particular work piece of this particular micro machine component for different type of applications. So, this was done with the 5 cutting edge tool.

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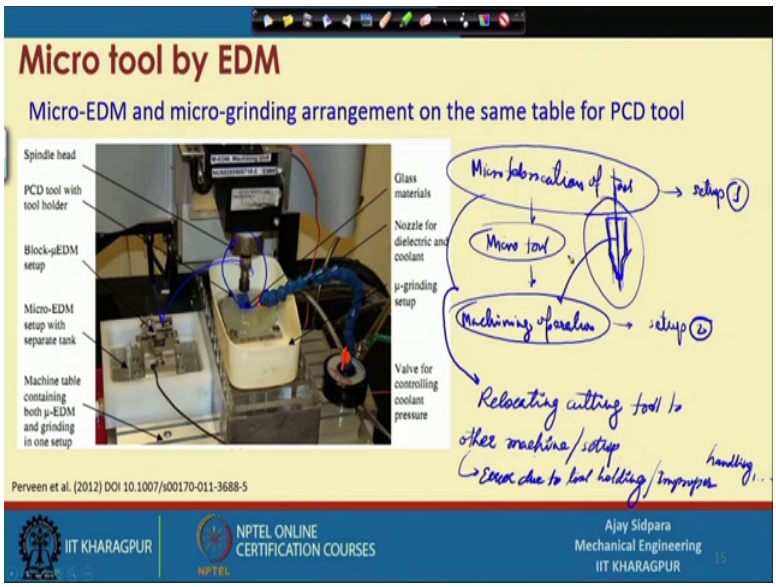

Now, coming to the EDM, because we know that we have already seen one example, it is a virus or produce discharge grinding, but EDM also you can use here. So, here, what is done here that micro EDM and micro grinding arrangement are on the same machine for the polycrystalline and diamond material. So, now, what is advantage here that, now first you do the fabrication of the cutting tool on the without changing any type of machine setup. Now there are two ways.

Now see that suppose you have a fabric, micro fabrication cutting tool, micro fabrication of the tool, this is the one setup 1. So, once you get this micro tool, then what you do that. You do a machining operation right ok. So, now, this one is the second setup. Now what is problem with this particular methodology that when you are cutting something here that, suppose your diameter, you are getting something here and this is your cutting tool, this is what you have fabricated out of this particular process and after that you are removing this thing and then your mounting on to this particular part. So, now, when you mount it, so you are actually shifting the location from the one machine to another.

So, you are actually relocating cutting tool to other machine or setup. So, what are the problem here. The problem is the turnout or suppose you are not actually fixing the properly, then it is a problem. So, here are your to tool holding or because of the in proper handling and many more here. So, what is our objective that if you can do something like that. You first complete this particular machining operation by EDM and do not change the spindle that you use the same set up and just move your cutting tool to the another setup, where you can perform the grinding operation or the machining operation. So, what we are doing that we are not shifting or we are not remove the cutting tool itself.

So, whatever is the accuracy or whatever is the geometry were getting here geometric accuracy, because we know that we have got all the things by a reference of this particular axis. So, spindle axis and the tool axis are co inside perfectly and that will not happen, it may not happen when you are actually changing the workpiece setup; that means, you are using second machine and then you are transporting this particular electrode to the or the cutting to the another setup, but if you do everything in a single setup that you can actually avoid many different type of tool holding related errors, and you can get them run out very very less in this case.

So, this is what is the set up available. So, here what things are there in this particular table is the EDM part and once you complete that particular the EDM, micro EDM and this, a particular set up, then what you are doing that, you are just shifting the table right.

In the steel the spindle and everything, everything remains same and this is the machine setup now. So, what you are doing here then without change. So, this is called the hybrid machining for something like that you are fabricating tool on the same spindle and then

you are using that particular tool for machining without changing any type of setup, just move the table. So, you have two machine here; one is the EDM machine and another is the micro milling or the micro grinding operation right. So, these are the different shape of cutting tool

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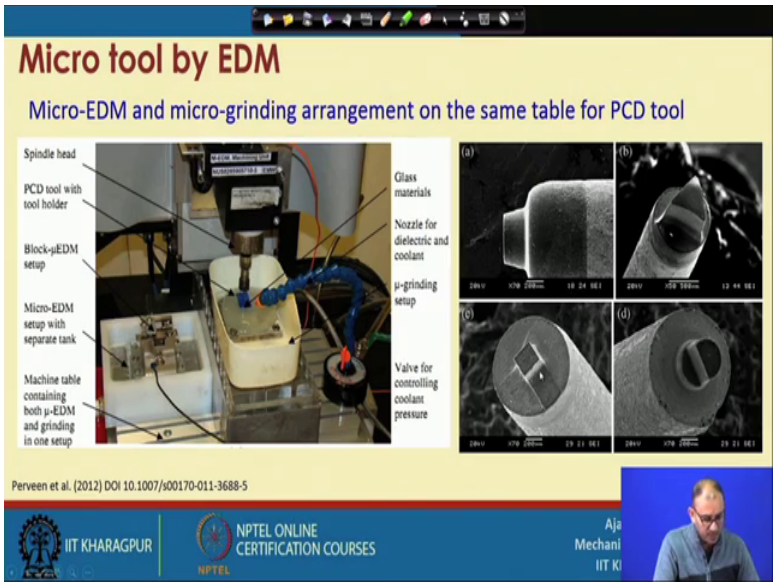

So, this is the circular, this is a triangular, this is a D type and this is the square 1 right. So, if by this way you can fabricate different cutting tool and then you do operation here by that way you can actually save lot of time in the alignment and the correcting the different type of or the that geometrical error also. So, you do not need to spend lot of time there and you are making sure and you also sure that there, you will not being type of problem in the eccentricity related thing with the tool holder to the cutting edge diameter.

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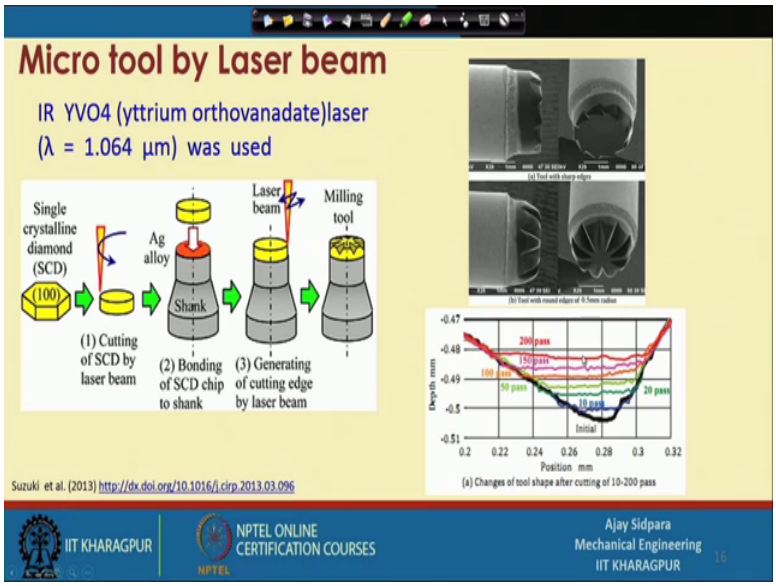

Now, coming to the laser beam. So, laser beam is also; so in this particular study, they use the infrared yttrium orthovanadated type of laser which has a wavelength of 1.06 per micron and this is the where they have done. So, it is a single crystal and diamond they have used.

So, in this cutting diamond by the laser beam; so this is done there and then what they are doing the bonding with another material. So, this way if they are actually making sure that the cost can be reduce further, because ultimately this particular top portion is only coming into contact with the workpiece. So, by bounding with their actually spending less time less money into the fabrication of this part, once the bonding is over.

Then there is the laser beam and then they navigate the laser beam for different location and then get the different type of pictures onto the top face of the cutting tool. So, these are the two different type of tools their making. So, this is something like the end mill cutter or something like a face mill cutter kind of thing

So, these are the cutting edges here this location, this location and there is something like that and this is for creating some type of cavities here. So, there specific application was the fabrication of some type of concavities. So, now, the edges are something, all this edges are there. So, when they flange it infinite completely then what it will do that, it will remove the material from the sides completely, but still it will that, the center portion you will get a different features here, because we know that when he rotate this thing at

the time you will get the theoretical zero velocity at the center, because R is zero at that location and maximum at the outer periphery.

The, still the what some results here and this is what is happening with the cutting edge. Now you can see that this particular this figure is belongs to that this first diagram that the tool with the surfaces and this is the rounded edges with the 0.2 0.5 micron radius. So, what is happening that this is the initial? So, how this tool, where is progress is with respect to the diameter of this part; that is what it is showing.

So, by this way you can say this is the 10 pass, this is the 20 pass 100 pass and something like that is happening here and by this way you can see that after 200 pass, the most of the part or the picture or geometry of the cutting tool is reduced drastically. So, it is better to reduce the word, change the cutting tool.

So, let me stop it here and we will continue this lecture further in the next. So, still that are one or two process is available, we will discuss this thing in the next class

Thank you very much.