Advance Manufacturing Techniques
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EDM MicroDrilling

Lab Session – 3

Hello and welcome to this ah experimental module on EDM drilling today. We are actually going to today learn how to drill very small holes of the order of all the way from hundred microns to about close to few mm and with high aspect ratio. So typically ah for example in a metal, if we want to do a drilling of 500 microns for a length into the work piece over 35 mm, so it's a huge aspect ratio that we are talking about. And they are the conventional machining, the conventional drilling where there is a mechanical machining - metal to metal cutting action does not work out very well because of stresses and strains. Because ah the drill that is being made there ah doesn't achieve the hardness level ah that is leaded to sustain the pressure for drilling such as slender hole or slender structure.

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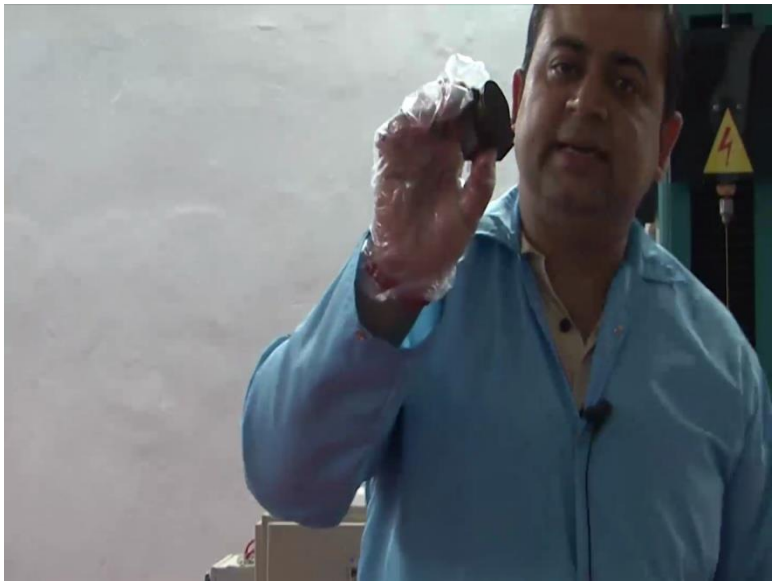

So this actually a module, where you can actually ah in a piece of irons you can see here drilled very small very fine holes, and even through holes using the process of EDM ah electrode discharge machining.

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So this for example is the kind of high aspect ratio hole that we are talking about. These two holes right here are about close to seven hundred microns each. And if you look at the length of it, this is all the way into the work piece for about close to thirty five mm ok. So such kind of structures, it's very difficult to make using conventional drilling. And you would this EDM drill for this purpose. So the EDM drill that I am talking about is based on a non-conventional process of machining, where you instead of having a mechanical action, I think I illustrated it in great detail earlier as basically focusing on ablation - thermal ablation. And the ablation is made by ah creating a local spark in a small region which would do heat transfer and would melting of certain region and then basically that melt is carried forward into the ah stream of electrolyte, which flows through the system.

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So there are few modifications which happened to the conventional EDM process when we talk about the drilling process. Here for example it's a machine the easy drill, which actually does this job ah very well. And if you look at the various components of this machine, there is work piece stage that you can see here, and this work piece stage is can be manually controlled using ah these two ah leads screws on both directions, you know x, y motion you can control that. There is a tool holder which actually can is able to move in a z direction, and it can either move towards the work piece or away from the work piece. And then there is a area of the work zone which is actually in this particular area which is well protected, because there is going to be flashes which come out ah because of the throw of the electric fluid. The machine itself is highly automated, because it's works on a controller and the controller can be found out on this part of the machine right here. So the controller can be found on this part of the machine right here, which would actually give ah a good basis of setting up the various x, y and z controls in this particular system.

There are certain stages, which are put in a cores manner or adjusted in a cores manner by pendant box, which is kept right in the bottom here or in the backside of the machine here on the tool column ok. And there is subsequently a motion in the positive as well as negative z direction when we work on this pendants. There is of course, another motion which happens because of ah the auto positioning of the controller, this controller. And you see here, this particular spindle

here shows the actual tool, which is actually cylindrical hollow, so this tube right here is about probably close to five hundred micrometers and the diameter of this ah this tube is close to about three hundred microns or so. The system apart from all the so this is actually the holder which would be able to move in the z direction to do all the drilling action. The tool is connected to this spindle here and adjusted for the length, and there is a screw, which is also called the rolling screw, which is fitted at the bottom, which actually grabs this ah particular tool all the way to the tip here, which actually is responsible for doing the spark disposal into the system.

So having said that there are some other subunits of the system, which you can find here, this for example is a stabilizer ah for the servomotor of the tool, and it is very important to protect the system from voltage surges. And this is designed for actually handling high voltage as being can be able to protect the tool properly. There is again a unit here, as you can see right in this particular cane, you have the bioelectric fluid which is typically a water based system, a emulsion kind of a system, ah which would provide the necessary insulation between the tool and work piece on the machining happen. There are certain other aspects inside the tool, if you go into this box right here, there is a pumping system that you can see inside and this is able to pump the fluid from this particular box all the way to this ah tip right here. And the fluid is dispense coaxially in between this tube into the work piece zone.

There was of course some other electrical parts of this system like a transformer etcetera which can feed voltages into the system. The EDM voltages can typically go very high, which results in ah the discharge, the corona discharge of the electrode tip on the top of the tool surface. So some of the basic parameters, which come with the machine in the spread sheet here, the ah basic dimension of the tool travel or the relative tool work piece travel this case is about 300millimeters in the x direction, about 200 millimeters in the y direction, and ah the z travel is limited to something about 300 millimeters again. So, it is correspondingly for small size work pieces one of the reasons why you can only use this tools for micro features and micro parts. The maximum work piece where that it can support is very high, it support up to 250 kg, although we don’t need so much weight in the micro ah dimensions or micro components.

The pipe diameters that you have seen here, which is actually this inlet diameter which would flesh the ah dielectric fluid in the work zone is close to varying from three hundred microns as I just told to all the way to about three millimeters. And the distance from the table to the bottom

of the guide ah is basically 120 to 370 millimeters that's what the span is ok. And of course the power input which can be given to the system, it can sustain ah a power input of all the way about three kilo volts ampere, which is the pretty high power, which is needed for all the EDM process. By thermal ablation trying to ah remove material not only that you are trying to create a corona discharge, so it actually necessitates huge amount of power in the process.

The maximum current that the system can support is about twenty amperes and the input voltage there it can give is 415 volts in a 3 phase supply of about 50 hertz frequency so that is what the specification of this particular tool set is. And the maximum pressure that the pump can actually supports is about 6 mpa, so which ensures that there is continues supply of the fluid as you will see from the small gap which is there is in the electrode ah right here at the bottom ok. And which actually results in the quick machining of small slender holes like structures in the work piece.

So having said that ah the ah machining process can actually be ah set up and I would like to step-by-step now show. What are the various aspects, which are related to setting up of this system so that you can draw a small hole of diameter about close to 500 microns all the way to about 35 mm. So the first thing that you have to actually do is to able to locate the hole and the dimension of the hole through a marker which is otherwise visible. So let's say there is a certain point which you have located here with dimensioning etcetera, where you have actually a small hole ok, in this particular region here, which is good to go for setting up in the machining system. So the first aspect that we want to actually do is to place this particular work piece in a region, which is close to the tool and try to now position the ah the work piece in a manner, so that it just goes right above the the tool ok. So you can actually ah see the hole ah in a certain region, and then go down in this direction, so that we actually have ah the tool coming into that region tentatively where you want to position. And you can that way position the tool very easily.

So this right here is the hole position, where we have to align this particular work stage and pin point of the tube ah to fit to that position. So what I am going to do is to sort of manually control ah the stage in a manner, so that the ah the drilled actually goes to the particular region ok. And then we can do the fine control all this thing by using this z-axis motion, where we can actually align this ah the electrode by feeding the electrode all the (refer time: 10:00) way to the tool

surface. I will just keep little bit of gap between them and then try to approximately position it based on this ah set of x, y stages as you can see here ok. I just go little bit more, so now it appears to be almost on the particular hole, the particular point there we want to drill actually. So we will now go ahead and ah try to program the CNC controller and try to set up a situation where the hole size that we are drilling here is close to about 500 microns. And the the length up to which the tool would go we are targeting to about 35 millimeters.

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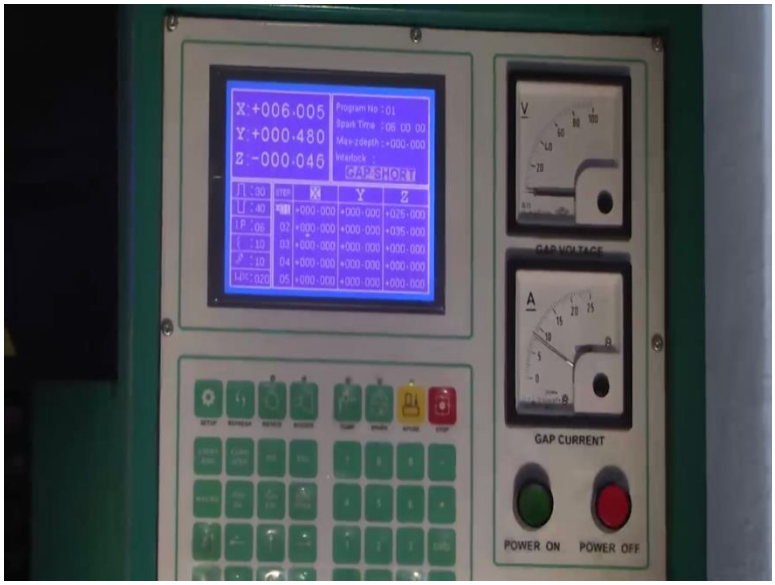

So the reason why APOSE button is used to basically, you have to ensure that the tool touches the work piece. For setting the 0 gap mode ah one has to remember that there is a plasma formulation that we are talking about between the tool and the work piece surface, and there has to be a gap which is filled with an insulator or a dielectric. So for that, we need to really know or the tool needs to give this information, get the information, where it is suppose to not reach ok, so therefore you have to sort of 0 set the gap and then work on that mode and do the various z values which can lead to the formulation of such arcs and plasmas. So the APOSE button actually is ah related to ah the setting up of the 0 gap between the tool and the work piece surface. And in fact if you want to really further check this with the sound, there is a option here call the buzzer button, which you have to switch on ok. For the buzzer ah to actually sound whenever the gap has been zeroed down, and the electrode – the tool electrode is touching the work piece.

So let's switch this on, and you can see now that there is a buzzer where has come because of the tool touching the particular work piece. You can of course ah just set this buzzer off actually and this you can ensure now that the gap is hundred percent closed and this is the 0 setting for the tool which we want to illustrate. So now what we have eventually done here is basically we have given a x position and a y position by means of the controller, by means of the leads screw manually. And then also have been able to ah control the z value in a manner, so the gap is reset to zero. So in this controller, there is an option here called the DRO, which leads you to actually ah monitor the gap ok, x, y, z where you can do the 0 setting action.

So after doing this position setting use the stop button here ok, so you ensure that the ah APOSE mode is now reset. And then you switch on the DRO button so that you can now see the cursor going to the x, y, z value. So once you ah take this cursor all the way down between x and y and z, and shit it in the manner. You can actually 0 set all the different coordinates, so that you can actually ah put the tool at this particular ah place as the origin. And once this 0 setting action has been done, in the x, y and z stage we ensure that now the tool is located to the origin with respect to the work piece.

So when I have taught about this ah EDM process, ah I think I have already illustrated to all of you that there is something called an equilibrium gap which has established between one of the tools and the work piece ok. And the equilibrium gap is done in a manner, so that the receives away because of the sparking and then the tool is close onto the work piece, and the gap eventually ah keeps on decreasing because of the resolution of the work piece. And that equilibrium gap has to be established here in this particular module also. We have already told you that there is a 0 position for the tool, so we need to slightly take this tool up ok, by one maneuvering this z-axis and then stopping it after some distance. In the tool now, you can see as a clearance and the idea is that ah whenever the machining process starts, it's just goes to near about the gap and then starts giving the high voltage signal, so that machining can happen.

Now one more issue here is to set up the program, so as you can see there are various command lines of the program, which are called steps ah right here in the controller. So you have one to five steps, and you are basically setting up the various values of x, y and z, so supposing there were an array of holes that you wanted to create on the surface, you would set up the various value of x and y in which drilling action would be needed. And then the z value can becomes

defined at every stage. So there can be multiple holes of different aspect ratios all over the surface. In this case, we are doing a single hole, so we would be more concerned with only one hole. We have already set up the x, y and we have already calibrated that to the zero, so ah what we are going to do is now as the gap has already been predefined, the z gap is already predefined. We are going to go to this controller to the ENTER mode here, so that you can ensure that it goes out of the DRO. And you can actually go to the programmatic mode, which is another key right here, and which brings up a cursor here as you can see, which it can subsequently move in the x, in the y and the z direction.

So x and y as I told you earlier are already 0 set, and this single hole being drilled, so we really need not change the x and y values, but actually we want to change the z value. So here we want to drill the hole into two steps. In the first step, we want to go about twenty-five millimeters into the work piece. And in the second programs that which can actually be taken by ah moving the cursor in the downward direction, we want to go for a remaining amount of ah ten mm more, this is an absolute positioning system, so we are considering the motion only from the surface corresponding to the z gap equal to 0 in the system. So you know in the first instance, it is called twenty-five millimeters; in the second instance, in the second steps, it goes additional 10millimeters, but we have to define the z from the surface itself. Just I would do in the CNC absolute mode a programming, and so therefore, we are setting up at 35 mm here.

So once we have done that, we can again enter the values and go out of this system and now our program ready for this CNC controller to take over and the machining to happen. So here now ah especially we have completed the CNC program on the controller, we would now need to do three things on the machine; one is that we have to ensure that the tool has the rotation intended rotation. We also have to ensure that the proper coolant supply of the, proper dielectric fluid supply, there in the central portion of the tube and that because of the pumping circuit coming into picture and operating. And in the third mode, we also need the buzzer in this particular case, because any kind of abnormality has to be given sort of ah indication to the user as a alarm button or a buzzer signal.

So these three taps on the controller, we would like to operate, so we want to rotate the work piece and you can see this spindle rotating as soon as this has been put on, we want to indicate that if supposing of any abnormality, there is a buzzer. And then we want to actually ah make the

pump on, but before doing that we ensure that this area is completely covered, because then there can be splashes etcetera which comes onto the system, and we have developed a acrylic stage for doing this coverage of this particular area

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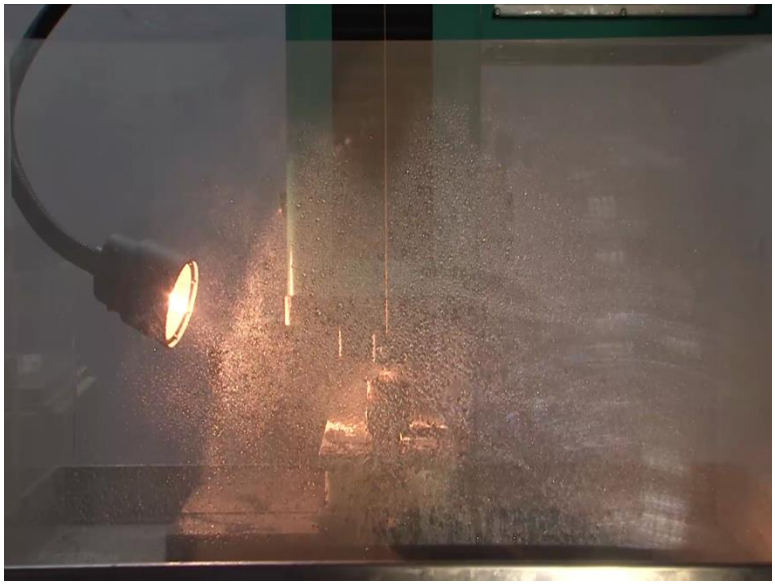

You can see now it is quite well protected and I would do the pump on in this particular mode ok. So as soon as the pump is set on, you can see that there is a you know ah a lot of coolant being circulated onto the system ok, ah and then there is a spark on mode which we have further done. And you can now see, this spark happening for the machining process to take place. And this spark would happen all the way when ah you know so therefore the drill the EDM drilling action is actually happening right now.

And tube in this manner goes slowly see the spark going into the substrate and you will not be able to see this spark after while anymore and dramatically the intended drill size in terms of the diameter as well as in terms of the ah length which the drilling would ah necessitate does happen within the EDM machine. So you can now see that the drill has gotten inside quite a bit actually, and this spark is now whatever is happening is inside that periphery, so you can't visualize it anymore, only some sparks are coming in a the spot meant for it. So this gives us a very fine micro drilling operation ah based on just EDM process, which is actually a non metal to metal contact process for machining.

So now the process has completed, and it is being indicated by the buzzer signal. So we want to now actually extract the z stage, ah by pulling this all the way to the top surface ok. And this can be actually done by using the cores motion also of the particular stage, and you can see that ah there is a hole size which has come out to be almost about 35 mm. As the tool feed, if you want to monitor very closely, actually has gone all the way ah to about 35 mm or so.

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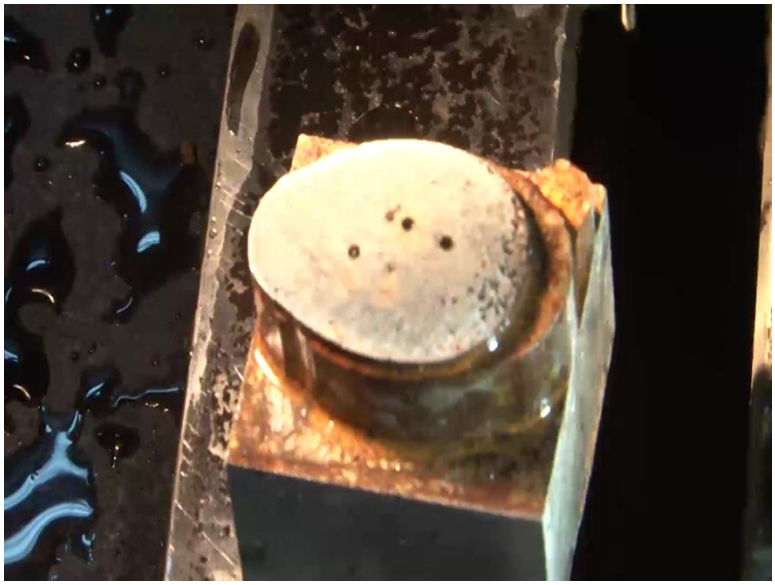

So, this area right here of the tool, you can see which has come out in the process of the EDM is about thirty-five mm, and this is corresponding to the hole, which has been created on the surface here ok. So this hole here ah can be illustrated, ah you can see the hole here, quite well made. So this was the hole which has been made here. You can see still a lot of dielectric is actually remaining in the system. So you can actually now see that this is the hole which has been made by our EDM drill in the substrate surface.

We will subsequently do some metrology aspects in a later module of this particular illustration to see whether the hole is perfectly or not. On the way, we can do it is to sort of cleave it pieces and see along the depth, how much is the length as well as the diameter of the particular hole. So ah you saw how the drilling action takes place. However, the physics of this has been quite well illustrated earlier. A few things that I would just like to recall, because we did the experiment today about the how the EDM process is happening here, is that there is a sparking action which

is happening between the tube and the surface the work piece surface, where the hole is being drilled. And the sparking action is also a function of the on-off duration of the sparking circuit which is actually ah resistive capacitated circuit, I think I have done detailed illustration of this earlier and also some theoretical calculation and derivations. So there is a on time and off time which is there of the circuit which actually gives you an sense of the duty cycle. So the EDM process is something where the spark is being discharged moment reel, so it is the spark not an arc. So therefore, the spark is just a sudden release of the charge from the cathode, which is the tool in the case to the anode, and the electrons are high velocity electrons are the mechanism or the agents which actually cause the thermal ablation process.

So it is actually the moment transfer of the electrons onto the anodic surface which creates a energy delivery and subsequently there is a melting of the material on the surface, that is how the whole process of the EDM works in the particular case ok. So here the idea is that for different materials you will have different amount of on and off times. And very nicely it has been illustrated in this technology chart, which has been prepared in this ah particular manual for the machine, which talks about the different ah grades of steel and also with respect to the different diameters of the electrode. How you would switch on and off the ah you do the time setting for the switching on and switching off mode of the EDM ok. So in order to ensure that the machining is the high yield and the electrode where is subsequently very less, you have to operate on the characteristics which are given in this manual ah for this system.

So the tool parameters, the EDM parameters if you can look at towards the left here in this particular the first column ah of this particular screen. It has ah mentioned of all the tool parameter. So the column here as you can see mentioned here that the difference T off, T on, T off, T on that means the time for this spark is in operation, the peak current in amperes. And then several other aspects like the maximum gaps setting with their sensitivity which we really want in the tool wear rate that we are programming the system for. So the idea is to sort of set of all these values for the grade of steel that we are machining, we need about a T on time of close to about thirty micro seconds ok. And ah the T off time that is needed here is about 40 micro seconds. Then these values I am reporting from the manual itself. We go to the maximum current setting and set it off a six ampere, which is already setup, so we do not need to actually ah set this value further.

The gap here is set between 0 and ten mm that is the maximum gap that the EDM tool can allow, so we are setting it up at the maximum gap level which is about ten mm and the sensitivity also correspondingly to the maximum sensitivity for about close to ah ten. The description of sensitivity in this particular case is the finest with which you can control the z-axis movement ok. So gradation of ten on that would be the extreme fine movement of the z, ah that you would able to achieve while the machining processes carried out.

And then finally the most important part, which is here is the tool wear rate and it has been specified in the manual that wear is calculated approximately on the basis of 100 millimeters, assuming hundred millimeters ah of the length of the tool. And you basically ah allow ah the total percentage wear of the tool to be around 35 percent or so. So in this particular case, we have kept it slightly low as the tool wear slightly low, because we don't want to go all the way to about 100 millimeters, and so you allow for about close to 20 percent of the tool to be one, while the electrode ah EDM process - the electrode drilling processes is happening. So having set the tool parameters, the whole process as we showed before continues and you have very fine ah a high aspect ratio, whole structures being drilled on micro systems.

Thank you.