Advanced Machining Processes
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Electric Discharge Machining- II

Hello and welcome to this 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 100 microns to about close to few mm and with a high aspect ratio. So, typically for example, in a metal if we want to do a drilling of 500 microns for a length into the workpiece of about 35 mm. So, it is a huge aspect ratio that we are talking about and there the conventional machining, the conventional drilling where there is a mechanical metal-to-metal cutting action does not work out very well because of stresses and strains. Because the drill that is being made there does not achieve the hardness level that is needed to sustain the pressure for drilling such a slender hole or slender structure. So, this actually is a module where you can actually in a piece of iron as you can see here drill very small, very fine holes and even through holes using the process of EDM electro-discharge machining.

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 700 microns each and if you look at the length of it this is all the way into the workpiece for about close to 35 mm. So, such kind of structures it is very difficult to make using conventional drilling and we would use 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 had illustrated it in great details earlier is basically focusing on ablation, thermal ablation, and the ablation is made by creating a local spark in a small region which would do heat transfer and it would local melting of a certain region.

And then basically that melt is carried forward into the stream of electrolyte which flows through the system. So, there are few modifications which happen to the conventional EDM process when we talk about the drilling process. Here for example is a machine the easydrill which actually does this job very well and if you look at the various components of this machine there is a workpiece stage that you can see here, and this workpiece stage can be manually controlled using these two lead screws on both directions in a XY motion you can control that. There is a tool holder which actually can is able to move in a Z direction, in a Z direction and it can either move towards the workpiece or away from the workpiece. 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 splashes which come out because of the throw of the dry electric fluid.

The machine itself is highly automated because it 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 a good basis of setting up the various XY and Z controls in this particular system. There are certain stages which are put in a coarse manner or adjusted in a coarse manner by pendant box which is kept right in the bottom here or in the back side of the machine here on the tool column. And there is subsequently a motion in the positive as well as the negative X direction or Z direction when we work on this pendants. There is of course another motion which happens because of the auto positioning of the controller, this controller.

And you see here this particular spindle here shows the actual tool which is actually a cylindrical hollow. So, this tube right here is about probably close to 500 micrometers and the diameter of this tube is close to about 300 microns or so. The system apart from all this, 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 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 for the servo motor of the tool. And it is very important to protect the system from voltage surges and this is designed for actually handling high voltages and being able to protect the tool properly. There is again a unit here as you can see right in this particular can you have the dielectric fluid which is typically a water-based system, emulsion kind of a system which would provide the necessary insulation between the tool and the workpiece when the machining happens. 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 tip right here and the fluid is dispensed coaxially in between this tube into the workpiece zone. There are of course some other electrical parts of this system like a transformer etc.

Which can feed voltages into the system. The EDM voltages can typically go very high which results in 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 this machine in the spec sheet here, the basic dimension of the tool travel or the relative tool-workpiece travel here, in this case, is about 300 millimeters in the x direction, about 200 millimeters in the y direction and the z travel is limited to something about 300 millimeters again. So, it is correspondingly for small-size workpieces one of the reasons why you can only use this tools for micro features and micro parts. The maximum workpiece weight that it can support is very high it is up to 250 kg although we do not need so much weight in the micro dimensions or micro components.

The pipe diameter that you have seen here which is actually this inlet diameter which would flush the dielectric fluid in the work zone is close to varying from 300 microns as I just told to all the way to about 3 millimeters and the distance from the table to the bottom of the guide is basically 120 to 370 millimeters that is what the span is. And of course, the power input which can be given to the system it can sustain a power input of all the way about 3-kilovolt ampere which is a pretty high power which is needed for all the EDM processes by thermal ablation trying to remove material not only that you are trying to create a corona discharge. So, it actually necessitates a huge amount of power in the process. The maximum current that the system can support is about 20 amperes and the input voltage that it can give is 415 volts in a three-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 support is about 6 MPa.

So which ensures that there is a continuous supply of the fluid as you will see from the small gap which is there in the electrode right here at the bottom and which actually results in the quick machining of small slender holes-like structures in the workpiece. So having said that the machining process can actually be set up and I would like to step by step now show what are the various aspects which are related to setting up of the 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 be able to locate the hole and the dimension of the hole through a marker which is otherwise visible. So let us say there is a certain point which you have located here with dimensioning etc. where you have actually given a small hole in this particular region here which is good to go for setting up the machining system.

So the first aspect that we want to actually do is to place this particular workpiece in a region which is close to the close to the tool and try to now position the workpiece in a manner so that it just goes right above the tool. So, you can actually see the hole in a certain region and then go down in this direction so that we can actually have 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 whole position where we have to align this particular work stage and pinpoint the tube to fit to that position. So, what I am going to do is to sort of manually control the stage in a manner so that the drill head actually goes to that particular region and then we can do the fine control of this thing by using this z-axis motion where we can actually align this the electrode by feeding the electrode all the way to the tool surface. I will just keep a little bit of gap between them and then try to approximately position it based on this set of x, y stages as you can see here.

I just go a little bit more. So now it appears to be almost on the particular hole or particular point there we want to drill actually. So we will now go ahead and 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 length up to which the tool would go we are targeting to be about 35 millimeters. So the reason why A-pose button is used is basically you have to ensure that the tool touches the workpiece for setting the zero gap mode. One has to remember that there is a plasma formulation that we are talking about between the tool and the workpiece 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 this information where it is supposed to not reach. So therefore, you have to sort of zero 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 A-pose button actually is related to the setting up of the zero gap between the tool and the workpiece surface and in fact, if you want to really further check this with the sound there is an option here called the buzzer button which you have to switch on for the buzzer to actually sound whenever the gap has been zeroed down and the electrode tool electrode is touching the workpiece. So let us switch this on and you can see now that there is a buzzer which has come because of the tool touching the particular workpiece. You can of course just set this buzzer off actually and this you can ensure now that the gap is 100 percent closed and this is the zero setting for the tool which you want to illustrate.

So now what we have eventually done here is basically we have given an x position and y position by means of the controller by means of the lead screws manually and then also have been able to control the z value in a manner so that the gap is reset to zero. So, in this controller, there is an option here called the DRO which leads you to actually monitor the gap x, y, z where you can do the zero-setting action. So, after doing this position setting you use the stop button here. So, you ensure that the oppose 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 take this cursor all the way down between x and y and z and shift it in the manner you can actually zero set all these different coordinates so that you can actually put the tool at this particular place as the origin and once this zero 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 workpiece.

So when I have taught about this EDM process I think I have already illustrated to all of you that there is something called an equilibrium gap which establishes between one of the tools and the workpiece. And the equilibrium gap is done in a manner so that the workpiece recedes away because of the sparking and then the tool is close on to the workpiece and the gaps eventually keep on digging because of the dissolution of the workpiece and that equilibrium gap has to be established here in this particular module also. We have already told you that there is a zero position for the tool so we need to slightly take this tool up by one monitor maneuvering this z-axis and then stopping it after some distance and the tool now you can see as a clearance and the idea is that whenever the machining process starts it 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 programs which are called steps right here in the controller, so you have 1 to 5 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 values of x and y in which drilling action would be needed and then the z value can be commensurately defined at every step so there can be multiple holes of different aspect ratios all over a 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 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 program edit mode which is another key right here and which brings up a cursor here as you can see which can be subsequently moved in the x, in the y and in the z-direction. So, x and y as I told you earlier are already zero set and there is a single hole being drilled so we really need not change the x and y value but actually we want to change the z value so here we want to drill the hole in two steps. In the first step, we want to go about 25 millimeters into the workpiece and in the second program step which can actually be taken by moving the cursor in the downward direction we want to go for a remaining amount of 10 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 zero in the system.

So you know in the first instance it scores 25 millimeters, in the second instance in the second step it goes additional 10 millimeters but we have to define the z from the surface itself just like we do in the CNC absolute mode of programming and so therefore we are setting up at 35 mm here. So once we have done that we can again enter these values and go out of the system and now we are program-ready for the CNC controller to take over and the machining to happen. So here now especially we have completed the CNC program on the controller we 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 or the proper dielectric fluid supply is there in the central portion of the tube and that is 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 a sort of indication to the user as alarm button or a buzzer signal.

So these three tabs on the controller we would like to operate. So, we want to rotate the workpiece 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 make the pump on but before doing that we ensure that this area is completely covered because then there can be splashes etc. Which comes onto the system and we have developed acrylic stage for doing the coverage of this particular area and you can see now it is quite well protected and I would do the pump on in this particular mode. So as soon as the pump is set on you can see that there is you know a lot of coolant being circulated onto the system and then there is a spark on mode which we have further done and you can now see the spark happening for the machining process to take place and this spark would happen all the way when you know so, therefore, the EDM drilling action is actually happening right now and tube in this manner goes and you will slowly see the spark going into the substrate and you will not be able to see the spark after a while anymore and automatically the intended drill size in terms of the diameter as well as in terms of the length which the drilling would necessitate does happen within the EDM machine. So, you can now see that the drill has gotten inside quite a bit actually and the spark is now whatever is happening is inside that periphery so you cannot visualize it anymore only some trace sparks are coming in the spot meant for it.

So this gives us a very fine micro-drilling operation based on just EDM process which is actually a non-metal-to-metal contact process for machining. So now the process is completed and it is been indicated by the buzzer signal. So we want to now actually extract the Z stage by pulling this all the way to the top surface and this can be actually done by using the course motion also of the particular stage and you can see that 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 to about 35 mm or so. So, this area right here of the tool you can see which has come out in the process of the EDM is about 35 mm and this is corresponding to the hole which has been created on the surface here. So, this hole here can be illustrated 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 fluid 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 ok or not. One of the way we can do it is to sort of cleave it into a piece and see along the depth how much is the length as well as the diameter of the particular hole. So, 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 this 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 workpiece 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 a resistive capacitive circuit. I think I had done a detailed illustration of this earlier and also some theoretical calculations and derivations. So, there is a on time and off time which is there of the circuit which actually gives you an essence of the duty cycle. See the EDM process is something where the spark is being discharged momentarily.

So it is a spark, not an arc. So therefore, the spark is just the sudden release of the charge from the cathode which is the tool in this case to the anode and the electrons are, the high velocity electrons are the mechanism or the agents which actually cause the thermal ablation process. So, it is actually the momentum transfer of the electrons onto the anodic surface which creates an energy delivery and subsequently, there is a melting of the material on the surface. That is how the whole process of EDM works in this particular case. 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 particular manual for the machine which talks about the different grades of steel and also with respect to the different diameters of the electrode, how you would switch on and off the and you do the time setting for the switching on and switching off mode of the EDM.

So in order to ensure that the machining is a high yield and the electrode wear is subsequently very less you have to operate on the characteristics which are given in this manual for the system. So, the tool parameters, the EDM parameters if you can look at towards the left here in this particular, the first column of this particular screen it has a mention of all the tool parameters. So, the column here as you can see mentions here the different T off, T on, T off that means the time for which the spark is in operation, the peak current in appears and then several other aspects like the maximum gap setting, which is there, the sensitivity which we really want and the tool wear rate that we are programming the system for. So, the idea is to sort of set up all these values for the grade of steel that we are machining. We need about a T on time of close to about 30 microseconds, okay and the T off time that is needed here is about 40 microseconds, and these values I am reporting from the manual itself.

We go to the maximum current setting and set it up at 6 ampere which is already set up. So, we do not need to actually set this up any further. The gap here is set between 0 and 10 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 10 mm and the sensitivity also correspondingly to the maximum sensitivity for about close to 10. The description of sensitivity in this particular case is the finesse with which you can control the Z-axis movement.

So gradation of 10 on that would be the extreme fine movement of Z that you would be able to achieve while the machining process is 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 mm assuming 100 mm of the length of the tool and you basically allow the total percentage wear of the tool to be around 35% or so. So, in this particular case, we have kept it slightly low, the tool wear slightly low because we do not want to go all the way to about 100 mm and so you allow for about close to 20% of the tool to be 1 while the electrode EDM process, the electrode drilling process is happening. So having set this tool parameters the whole process as we showed before continues and you have very fine high aspect ratio, old structures being drilled on microsystems. Thank you.