Microsystem Fabrication with Advance Manufacturing Techniques

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EDM Micro Machining

Hello and welcome today to this new experiment on the electro discharge machining process. I think, I earlier illustrated about e d m drill which was the limited degree of freedom system. Here today, we would be illustrating another kind of machine, the electro discharge machine where actually any kind of topology, any kind of operation can be done in a di single mode. I think, I earlier illustrated the basic principle; I just like to recall that of the e d m process.

So, there is actually a tool which is made the cathode, and then there is a work piece which is the anode, and there is always a discharger stream of electron which comes from the cathode all the way to the anode, to create ablation or heat treatment of the surface to its melting point. And, there is always the condensing to formulate a melt pool because of this fast electron heating on the surface of the anode work piece. And, because of that, there is always also a momentary electron pressure which is created near the surface which gets distillated away very quickly.

And, actually there is some kind of a low pressure region created, because when the electron goes into the anodic material, the surrounding medium comes and occupies its place, but it has a high inertia level, because it is being fluid, the molecules are heavy to move. And so, there is a typically a delay or a lag in filling up the sudden wide which has been created by electrons depreciating into the anode, because of which there is a low pressure region. So, the melt pool formulation because of the strike of the electron, along with this sudden creation of the low pressure region would actually get all this molten material off into the dielectric fluid.

And, if you circulate the fluid then when sure that you carry away the material which comes in this way, to create the pocket, ok, which is the like the machined area or the machined surface. This is basically the basic principle of the e d m process. I think, I had derived it earlier, made many illustration, today we will see in practically how it happens.

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This right here is a e d m tool, electro discharge machine. And, you can see that, there is a, you know, server controlled stage here which actually is able to feed the tool and take it close to the work piece surface. Here the, again the tool is the cathode and the work piece is the anode here. There are several discharges or nozzles of the dielectric fluid in this region of the machining zone, and the e d m oil which is actually some kind of a hydro carbon is, flowed at a certain pressure at a certain fluoride within this material. So, it always creates a sort of area or a zone where there is immersion of the work piece. And, there is some dielectric between the two land over piece.

This e d m can be used because principally it is the di-machining operation, I remember the way we had solved the electric field between the 2 plates which would lead to the automatic leveling of one surface with respect to the other, and parallelism between the surfaces. And, the same process, whatever is on the tool gets imprinted on the surface. It is same as any other identical process like may be c m where the same di-singhing operation would happen.

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So here I would show a set of characteristics which are possible by this e d m machine. You can see, here 2 surfaces, ok. This is the tool surface, this is the tool surface made in copper, and this is actually made in mile steel, this is the machined surface. And, you can see that it is exactly the replica of another, one another. So, the tool surface is the exact replica of this work piece surface. And, the way it has been achieved is again through e d m. There is a very good setting of these 2 surfaces, which means that when the machining had been done probably, these cavities removed the materials form the respective zones in an identical manner, thus creating a surface topology like this. So, e d m that way, is a very important process for the industry.

Another issue here is that, any kind of hardness of the material if it is provided in this conducting, can be machined using the e d m process, which may not be a phase to metal to metal contact machining where the question of hardness always bother the tool engineer. And, there is always the tendency of the tools to get one out faster when the materials have slight fluctuation in the hardness value. So, here it is independent of ban because the process itself thermal inflation process is not any kind of contacts which is creating the removal in the e d m process. So, in a way that is also very beneficial.

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There are other issues or aspects related to the e d m. For example, if you go to, sort of map this complex architecture, this is like the comma, ok, so if we have to map this architecture into, let us say, the work piece surface, very easily, you can probably do using this non conventional e d m process. Whereas, such a thing if you want to really machine on a c n c layout, would probably take a lot of time; also sometimes it is even not feasible, and you cannot get this quality or this finish, to do the operation as you can have in this particular e d m operation.

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So, you can see here, for example, so this has been embedded into a tungsten carbide material which has a very high hardness value. Typically, it is used sometime for cooling in the case of contact machining. And, you can see, exactly this comma has been embedded on to the surface of this tungsten carbide. And, this is only possible, you can see the finish of the machining here; exact shape has been sort of printed on to the surface which again gives you very good illustration of the power behind this e d m machining process. You can also go very small, and this course as an mandate of mostly I would say, micro channel based fabrication. So, you can actually look into the micro feature and surfaces which can be machined using this process.

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And, I would just like to illustrate that in the e d m, there are this collids which are specially designed for holding such micro architecture. There is a typically head for this collid which comes off, ok, and then there is the possibility that you can, you know, that is if you look at it very closely, there are jaws on this collid, which would be able to grip this small tool and give a certain positive pressure of the cap slides in and bolds itself to the remaining portion of the collid, it is sort of self posing action is there, and this would close off so that it can tighten the tool.

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For example, suppose in I where to put it in this small, probably about close to 2 mm diameter of, 1 and half mm diameter of copper, and what to suppose do similar kind of drilling action on the top of this surface, so that is a very easy way to do it, which is put it inside this collid and close the cap, ok, and so therefore you can obtain the necessary pressure. And now, it has become, it sort of tool which can be further held into the system, and used to give a down feeding to the work piece which can create a hole of, probably, the same size or same value.

You have seen similar kind of holes done before in e d m drill which is the dedicated system for the drilling action; this is the multi tasking system. So, not only it can do the e d m machining but it can also do even e d m drilling. One of the advantages that this machine has to offer is that, is actually able to create blind pockets within system. So, supposing you have to create a micro channel inside or on the surface of a metal piece where the lower end of the channel is closed really, so it is like a blind pocket. So, you can easily use this e d m tool for doing such a blank blind pockets.

You also saw that this particular example was a case where you doing the blind pocket ok, you can see this is the blind pocket, the several such pocket which have been created here. So, it is not really a through machining operation, as would happen in some of the other cases like e d m, drilling, etcetera.

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You can also make various shapes; for example, you know, if you look at this picture size closely, this is like a pointed tip, but it is more on a flat that this tip has been created. So, in some cases, you may have to use this for writing something like, maybe a square channel, ok. So, you can easily monitor or change the taper, and use this as a tool and scribe on the surface, so that wherever it goes, creates a blind channel on that particular surface. So, in a nutshell, that is about the capability and the quality of the machine.

And now, we will get started with the real machining operation, where you want to actually use a work piece and cut a very complex slot here, ok, using a tool which is like a comma, ok. So, this is like a, the shape of a comma, and I would just like to cut this for embedded this into, this otherwise hard work piece which has been already clamped in this system. So, there is tool, there is a work piece holder, there is the bed for the work piece, and you can actually clamp the work piece here by using this gripper this vise.

And, subsequently, there is a collid specially designed for this particular tool which would hold this tool in place. And, you can actually mount this tool all the way to some distance inside, and then tighten this lid screw right here which actually gives pressure to hold this particular tool placed inside the collid. The collid, of course, is connected to the stage for the translation of the tools. And, as I earlier defined the stage is actually severo control.

So, let me illustrate little bit about why it is servo control using the e d m process about establishing of a break down electric field of the medium when there is a sparked charge which happens between the cathode and the anode. I think, I had earlier illustrated it in great detail that, how the e d m process would actually go, and what are the numerical aspects of the process. So, here the question always is, the inter electrode distance, ok. And, this distance has to be below the certain value for the field to go above the break down field of the medium, so that there is always a sparking condition which is arrived at.

And, supposing, if you have to look at the surface which was wavy like, and there is another surface which is wavy like, there may be a case where there are hills on one of the surface, the tool surface, and pointing out to hills on the work piece surface. So, there is always the minimum distance condition based on that. There may be a case that when the tools surface among the waviness on the surface of the tool, a grater which is, they are, let us say, values which is there, maybe pointing to another valley on the work piece surface which can be the condition for the maximum distance.

And then, there can be a hill to a valley, or a valley to a hill, between the 2 electrodes. So, in all the events, different distances which are formulated with minimum distance between 2 hills pointing each other between the electrodes - the anode and the cathode. You have to remember that irrespective of how hard we try to finish machine, there is always going to be some kind of roughness in the topology on the surface which would be the cause of the hills and valleys. And, therefore, if there is the voltage v between the cathode and the anode, and the electric field you know, if voltage for in the distance, so smaller is the distance, the higher is the electric field.

So, therefore, a hill facing a hill, with minimum distance, would correspond to a maximum electric field. And, if this field goes down, the break down field, there will be a discharge. And, this discharge would create, the distance again increase, ok, because now these spark has come and it is been the work piece surface created the melt pool, the melt pool goes away. And then, this now creator the spacing hill, ok.

So, in the similar manner, once this process has been de-established, and the dielectric fluid has destroyed the iron column, the possibility of another spark does not happen unless the voltages increase in little bit, or the distance is decreased a little bit. And so, a server control here, is very important to do that monitoring of the voltage across the gap and trying to make the distance go down, ok, to another value where the break down field will be hit upon. So, always there is a control based on the gap voltage monitoring, and this voltage should be over a number of certain value, assuming a small inter electrode distance, ok, so that the field also goes down the, break down field.

And in fact there is a p I d which has been designed here, where it can actually give the servo a command to go either towards the work piece, or away from the work piece, based on if you want a sparking or a de sparking condition in the machining. And in fact what we are trying to do is, we want to give a pulse the signal, rather than complete d c signal. And then, there is a tendency of some relaxation time given in the process because you want to get rid of the iron column every time it is formulated, ok. So, this is another important thing, so I think I had mentioned during my earlier classes where I had talked about that you do not want to repeat the spark go in the same zone again, ok.

And, how is the sparking created? it a plasma which is formulated in the medium with irons and electrons, so the electrons rushing towards the work piece surface. And so, therefore, a continuous flow of the system would ensure that the column gets destroyed once the spark has been delivered from the anode to the cathode. However, this is a operation which select but laid back because of the high inertial level of the medium with which you are flowing, and there is always a tendency of sometime gap between which there may be the re-establishment of another sparking process, particularly because the path that has been formulated here is the conducting path.

So, you have to ensure that you give it enough relaxation time where the voltage is pulsed voltage between some v value and 0, so that, once the voltage comes to the 0 value, ok, you get the time for relaxing the medium, so that, the newer material can flow in, dielectric fluid can flow in destroyed iron column, so that same part cannot be used for sparking twice. And, one of the reason why in e d m operation you see spark turns all around is, that whenever actually doing the server control to take the distance or, you know, change the inter electrode gap, there may be another region which comes up, whether it is a hill facing a hill, and a problem of minimum distance and maximum electric field comes where there is another spark.

So, the spark would be dependent on wherever the hills are facing each other on the surface, provided there are servo controls, ok. And, on the other hand we have venture, thereby giving a switch on, switch off time, when a pulse signal. For a particular amount of time during one cycle you are actually letting the medium to relax, so the iron column vanishes away, and it is ready for the next discharge process to happen. So, with this, I think, the fundamental part of the machining that you need to understand is kind of done, you want to now go ahead and do the machining.

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So, the first thing here that we need to take care for the machining is the tool positioning system. And, we have done similar kind of operation earlier in the e d m easy drill. So, here, there is the manual system of control which is given by these 2 axis, motion controlling, axises, access. And then, also there is a control which is given to the servo system, right here, which drives this tool and goes towards the work piece actually. And, doing this is not a problem to because you can actually use these, up and down arrows, in order to do this controlling, ok. So, we can actually press up and down, and let the tool either go away, or towards the work piece surface, ok.

So, here, what we are first trying to do is to, sort of, position the tool in the manner, so that it is in the center of this particular work piece. We want to drill this hole, we want to do this blind pocket, we want machine with e d m at exactly the symmetrical centre of this particular cylindrical work piece surface. So, in order to do that we tentatively move this tool in the x and y direction; so, basically, you can take it to the center here. And then, also you know, in the y axis towards a center.

The machine is designed in a manner, so that it has 2 covers, as you can see here, right here. And, these are, you know, sort of sealing, self sealing covers because ultimately this is going to contain the e d m, oil, etcetera, like a tank, it is going to behave like a tank. So, there are some seals or sealings which are there on both hand. Here, you can see, which would actually prevent the leakage from happening. But, why the covers are open, is that have to manually do the adjustment by seeing across the x and y axis in this direction as well as in this direction. And, we are able to position the tool based on that particular reference.

So, as the tool has been positioned, and you can actually take it down a little bit more tentatively in the geometrically center; in fact, a better idea would also be to, a sort of, you know, mark this tool with some kind of a dies and take the impression on the work piece surface to actually locate that where the tool if it is a complex architecture, is positioned with respect to the work piece. So, we just take this down a little further, and then tentatively we can actually see that it is in the geometrical center from both sides. So, once we do that, then we leave it to how, you know, to the controller to do the programming action, would actually investigate what is there on the controller.

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So, in fact, there is this punching box which is there in this machine, for doing the various, punching the various commands. And, this right here, the screen is what you can see is the display of the controller, so this is actually the controller unit which will do the servo controller action. And here, what we can do is, by standing at a little bit distance we can actually do this controlling.

So, there are various aspects of the controller. And, the first aspect that I would like to mention is that irrespective of whatever may be the display here, you have to escape the existing commend, ok. Right now, it is in that mode it is initialized. So, therefore, anything on this controller which says, escape, there is a button for escape; you just do this escape to quit any of the program that may have been running from the earlier runs, or in any other process settings that may have been restored from the earlier runs.

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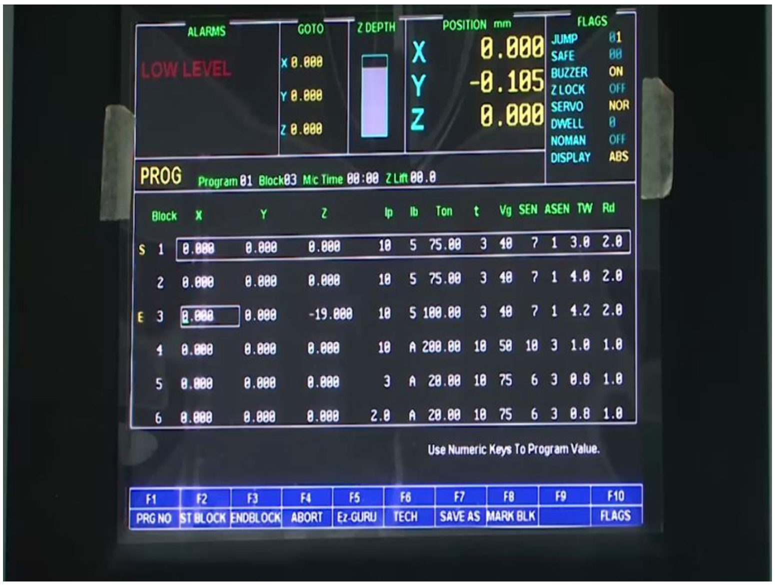

So, once the position has been escaped, so this is the, how the program, you know, looks like on the display. And, if you look at the line which is towards the end of this, in the bottom portion of the screen, you can find various functions f 1 to f 10, where it is indicated individually what f 1, f 2 are as matter factor f 5, f 9, f 10, would do. So here, the first goal that we have is to actually go and enter into a program which is already being done. It is a good idea to sort of modify an existing program and save it under a new name, rather than doing the job setting, although that option is already there as f 9, to do the direct job setting.

But, we generally prefer because there are lines written in a program. So, in order to, avoid the wastage of time you could actually save this program in a different name, etcetera, once you modify the program. So, we go to f 10 first, and you can see that it has led to another, sort of, command line where it is talking about program number selection, the start block for the program, the end block for the program, even the about, the program about option.

And then, some 2 other options z grew and tech which actually gives you the detail description of the process as such or the process details related to the e d m. And then, there is a f 7 which is corresponding to save as; and similarly, f 10 which is actually related to the flags. So, the flags actually can be obtained on the right upper corner of the screen here, where it talks about various options like, whether the buzzer should be off run, whether the z lock of runs server, whether it is going to be in the normal position, whether the display is going to be in the absolute mode or the incremental mode.

So, all these different aspects are being looked at as the basic initial guidelines for setting up a process, cut. So, we want to first actually change some of these flag properties; and you can say that, you know, it is about the way that the machine would read the programs to an extent. And, here, in this particular case, what is important to us is that, right now the buzzer as you can see is in the off mode, we want to make this into the on mode, because then we will given an indication of the start and stopping of the process, or even when there is no gap, you know in between the electrode, there would be a buzzer sounding off.

So, what we are going to do is to, sort of, go to the flags, and then use this cursor, up cursor, and go all the way to the, you know, you can see the text getting red end as you toggle between the various options. So, you can go all the way upto the buzzer, ok. And then, with a page up and page down, you can actually turn this back on, so that now the buzzer is actually turned on. And similarly, you can do the z lock which means that you can lock the z axis, servo can be in the normal mode of operation, and then, of course, the display can be in the absolute mode of operation. So, these are some of the details, machining details which are important to be saved here in this process.

So, once you are done that, we go to f 10 again back, because now we are talking about the job set option, ok. So, we just go to that job set option. And, you can see here that, as soon as it has been done, we are in a position to actually set of the x, y and z values is in the various functions, and try to make a sort of reference 0, for the machine, from which the machining would start to take place. So, we want to first now setup the z value and make it auto position on the surface, so that the gap can be close to 0; this could be the 0 reference with similar manner in the easy drill as well.

So, you go all the way to this toggle board or this, you know, punching board. And, there is a auto positioning option right here which we have to sort of press now, so that there is a slow movement of the machine until the machine touches the surface, that is in question, ok. So, you can see the buzzer now sounding which indicates that the gap has closed, ok, of the machine. Again, we go back to f 10, because we had to escape that mode in order to do this saving option. And then, we already have the flag set, so, we go to the again the f 10, the job setting.

So, we are back to the same screen here, and you can say that there are different, this, x, y, z, values which will now lead to 0. For the first thing we want to do, as the gap has closed on, and it has been set to 0 between the electrode and the work piece surface, is to basically go to the c value using f 4, ok. And, you can see, the red cursor coming on to the z value here, and we want to set this value to 0. So, we punch 0 on the punch board here, and automatically this would be accepted as 0 value for the particular system.

So, basically, once you have typed 0, you set enter value, so that this is machine 0 for z axis. You do a similar thing for both the other x and y. So, we go to f 2 which indicates x motion, make that 0 as well, 0 and enter. And similarly, go to f 3 which makes y, and then you basically make that 0 and enter, so that these all x, y, cs are now set to machine reference position through which the machining process will begin as 0, 0, 0. So, once we have done that then the question of going into the program happens because, supposing we want to add actually set of a certain time on value or pluse time or several other aspects related to the machining, we have to now individually go and modify the command blocks, ok.

So, this all thing is called blocks, ok, of several commands. And, then there are several such blocks in series which would actually start at a certain position. Here, you can see f option, meaning thereby this is a start of the block, ok. And, e option which is end of the block, so there is a scanning of the blocks, scanning of the commands in a line by line manner, block by block manner, till the whole program gets completed.

So, basically, now we come to set up this program actually. And, for doing that the first thing we have to do is to sort of vary the start and the end positions, on the various command lines that you can see here. In this particular case, for example, the start position is at line 4, and the end position is at 5. So, I would like to build my program where I want to start at in the line 1 itself. So, what I am going to do is to, sort of, go to this f 10 program mode; the f 10, here is program mode. And then, I can actually take this cursor to the, you can see the cursor moving across the various command lines.

So, I will go to this first line, the first block of the command, and I will make this the start position, the new start position by pressing f 2. So, you can see that the start has come from line 4 to line 1 because of that. Similarly, I can go, scroll down here, may be command 3, is the one where I want to really end the machining process. So, I can make this f 3, so that the end has now shifted; and, the program is now between the line 1 and the line 3. So, it executes line 1 first, then at the same sequence it executes line 2, and then it executes line 3, then we can change the independent values of x, y and z, and the way that we want to do it, is following the conventional c and c Climent lecture.

I think, let me just recall that the cnc programming in that aspect, when particularly you are doing the absolute positioning mode, you have to consider that whenever the tool is moving away from the work piece, or tool is moving away from the job, it is treated to be the positive z motion. So, actually the movement here being a sort of disinking activity is mostly along the vertical motion, unless we desire to, sort of, you know, print whole channel or a whole feature over several different lengths of the work piece. So, only that, even we need to use the different values of x, y every time.

But here, for example, we are just wanting to diesing the particular complex shape into the particular system. So, we want to only use the c axis for that. And here, we will see, if you are going into work piece, or towards the work piece, the z axis would be negative. So, basically, what we are going to do on the cnc program is, to give a negative value of the z axis, so that this tool can actually diesink into the work piece. And, mind that, we have already set up a reference 0 position, before from which the drilling production would start to take place within the work piece material.

So, let us now go back to the screen here, and try to change the various parameters. And, for doing that, I would just like to illustrate that there are, you can see, several parameters on this command line, of course, the block as x, y and z values which does make sense. But then, there are different other options like i p, i b, T on, t, v g, s e n, a c e n, t w n, r d. So, I am going to now slowly describe one by one what this parameters do, or what they mean? And, for that, I have to refer back to the manual of this particular process where the different parameters are given.

Of course, as you may understand the x, y and z values, do represent the x, y, z, displacements, ok. So, in the particular case, this machine can vary between minus 999 to about 9999 millimeters range. And similarly, the same goes to for y, as well as z. So, that is about defined by the size of machine which it has, and how it can move, when the span can be accordingly programmed.

The, other aspect is the sparking current ip which is actually the 5th line on this particular block, where it says ip. And, this basically is commensurate with the sparking current. So, this is really the current at the time of sparking of initiating of the spark from the tool to the electrode surface. There is a line i b which actually, such as the pulse current. So, therefore, this is actually, this pre sparking condition where you have given the voltage pulse to the system, there is a certain current which flows and that is limited by that.

So, here, as per the machine manufacturer, a maximum of 200 amperes can be programmed for normal machining purposes in the ip value. And, it can start from 0, anywhere to 200 amperes. Similarly, the i b value, that is the pulse current value can be set between 0 and 5 amperes. You have to understand one thing, that the current which is the sparking current is much higher in comparison to the pulse current, because of the fact that sparking actually is a electron discharge; and, this happens at a extremely high value of charge, ok.

So, basically, the point from which the spark has emanated, is actually across the dielectric gap. And, we are measuring the current flow across that gap. It should only correspond when the electric field break down as happened by the medium, which means that the amount of charge that has been stored in the particular instant or moment of time on the tool electrode, the cathode, is so high that it results in a very high momentary discharge of that electron, one of the reasons why the current value is very, very high in that particular case.

There is also a T on here, which represents what is the portion of the pulse where the voltage actually from the power supply is on, you will of course add a duty cycle factor to it, which means that further you can actually make 100 percent duty cycle where this whole time on, that means the time for which the voltage is supplied to the electrode is utilized, ok. Or, you can make a subsequently lesser percentage where you have a on time and a off time in the same pulse. So, if you are creating a time on here the manufactural, again says, the pulse on time can vary anywhere between 0.25 to about 4000 micro seconds.

And, you know, you can place the percentage duty cycle anywhere between 1 to 12 percent. So, the maximum utilization that you can make of a whole T on is only about 12 percent the whole time that you are suggesting here. In this particular case, for the particular sample that is in use, you want to use a ip values above 10 ampere. And, this is more an exponential gathering. And, there is some kind of a literature survey which we have to do for different materials to come to this particular estimation.

The iv value, we want as about 5 amperes. And then, the T on, the pulse on time here, that we are setting about 75 microseconds to the duty cycle of 3 percent, meaning thereby about 2 micro seconds between that 75 microseconds is actually the on time, and the remaining 73 microseconds is the off time. So, that is how the duty cycle is signifying. So, therefore the actual time for which the voltage is being supplied to the tool is very small when comparison to the full pulse on time, there has been set here.

And then, of course, you have the gap voltage; the gap voltage as you know is has to be set commands to rate with the break down field. The field depends on 2 properties again- one is the voltage difference between the tool and the work piece, and another is the gap between, the gap in this case is extremely small making the voltage to be reasonably high, so that the electric field goes to a very high level, overall. So, here the voltage that we are going to set is about 40 volts, although there is an option of going to all the way to about 150 volts, and some cases upto 240 volts, ok. So, that can be probably there is a selection switch in the set up menu, where you can vary the voltage between 150 to 240 volts, so that the maximum limit can be extended that way.

There is also a, s e n, which actually means sensitivity of motion of the quil or the tool holder in this particular case, and we need to actually illustrate what is the level of sensitivity of motion; meaning, what is the response, and how important this is for determining the, you know, the voltage gap, or determining the servo conditions. So, if I say that it is the high sensitive system, therefore a lot of emphasis is given on to the gap, in comparison of you can say, it is a low sensitive system.

And then, again you have the anti arc sensitivity, and the sensitivity in this case can be changed between 1 and 10; meaning, thereby one is on a lower sensitivity scale; that means, the gap may be not so much matterable for controlling the servo. And, 10 is probably the highest on the sensitivity scale, meaning thereby the gap is very highly sensitive, and servo controls based on almost the gap value. This is how it has been set by the manufacturer.

And then, e s n, is basically the anti arc sensitivity. You have to remember sometimes that instead of making a spark, there is a ark formulation which happens in this process. Because, if the tool duals or the voltage pulse, or the I would say the iron column duals in a particular region for a longer time, there is a continuous flow of electrons from the tool cathode to the work piece anode. And, this is the condition which you must avoid in e d m, because e d m actually is about all spark machine, it is not actually arc machining. And, for preventing that for happening, one of the reasons is why we do the flow of the dielectric, is to sort of destroy the arc column in the formulated.

But, sometimes it does not happen, and therefore there is an aspect of the sensitivity of the system here again. But, how sensitive this system should be to this anti arc, you know. So, here we are making less sensitive because of the fact that may be machining of this material is not that hard, ok, in this particular case. It is only mile steel that we are going to machine with the copper tool in the shape of a comma that has been earlier demonstrated to you.

And then, of course, there is this 2 other parameters, t w and r d, which actually the total working time which in this case comes out to be about, close to between the start and end of the blocks, it is about close to 11, so close to about 11 and half seconds, you know, if you look at all the 3 different times, working time is 3 plus, 4 plus, 4.2, so 11.2 seconds. So, that is how we are programming it although, you know, you can actually go on all the way upto 30 seconds, to support the machining operations in this particular case, as defined in the controller by the manufacturer.

And then, of course, the retraction distance is the sort of, you know, distance upto which the electrode will move away from the job. And, if take due care, so as to avoid in the colloids while setting up this parameter because actually it colloids then there is no, you know, I mean, that is no reason why retraction should happen, ok. So, the retraction distance in this case can be set all the way to 20 millimeter. So, we are actually keeping this value at about 2 millimeter. Whenever there is a case where there is some kind of a shorting, the tool would automatically retract to a distance about 2 millimeter, that is creating a inter electrode gap of the same value, that is what the sole system is about.

So, we have kind of values programmed our controller in the manner, so you know, you can see that in the line 1, you have x, y and z values are 0s, and we have kept the ip, the current to be 10 amperes, ib to be 5 amperes. The T on to be about 150 micron seconds, the percentage duty cycle that you would like to be is about 3 percent which meaning therefore, meaning thereby that we use the total pulse on time, so it is 4.5 microseconds. Obviously, because this is an initial cut, we are trying to, at the first step we are trying to give a hard cut to the hard surface. Beyond a point when the cutting would start, you can actually, subsequently, reduce this T on times.

The vg value, the gap voltage is about 40 volts in the first case. The sensitivity of the collid is about 4, and the anti arc sensitivity is kept at 1, and also the working time is kept at about close to 3 seconds. And, the r d, that is the retraction distance is about 2 millimeters.

So, when we go the next step, you see, there are, this is the first cut really that would happen after the initial surface has been, sort of, hardened, ok. And here, you can see that the only change that is there is in a, y, in z value. And, the z value is minus 12, meaning, thereby there it goes minus 12 millimeter within the surface. I would like to just illustrate here that it is just the cnc programming you have a surface, an obsolete mode, so anyway the tool approaches the surface, or goes into the surface is treated as negative.

And, the tool goes up away from the surface, it is treated as positive z axis motion, in this case it is a negative z axis motion. Just in case of drilling or hole making where you are going within the surface. So, therefore, it has to be negative, so, minus 12. And then, of course, we have ip value; now, this is said to be about 8 amps because now the hard cutting which was actually needing a lot of sparking current is no longer left over because the surface integrity has been lost in this particular case because of the first cut. So, this is set at 8 amperes; there is a total, you know, the ip value of about 5 amperes in this case.

And, the T on, also has been reduced to 75 microseconds with the 3 percent duty cycle, meaning thereby about 2 seconds or 2.5 seconds, I would say the wait period, or the dual period for the voltage to be on, or it is that 3 percent of the total time cycle being used for the actual voltage being added on the tool. The gap voltage is kept at 40 volts. It does not change much because, and then sensitivity of the coolers increase a little bit because, now the motion of the tool because it is going into the depth of the work piece becomes a little bit critical. And, this sensitivity should be hired for the servo controller to be able to close the, monitor the inter electrode gap because of that.

The arc sensitivity is also enhanced a little bit, ok, to 2. And then, you have the tw, the working time is now increased to about 4 seconds. And, rd, the retraction distance also is increasing because it is already came to a depth of about 90 millimeter. So, the retraction depth is now kept at about 5 millimeters. So, these parameters are set almost by exponential, in experiential manner, with a prior cutting experience of the particular tool with a particular electrode surface that we are talking about.

Also, in the end step now, there is the final motion of the tool where you can go, the additional 7 millimeters over and above the 12 which had been cut in the last step. Because, it is an absolute mode of programming, we say, z equal to minus 19 here from the surface, ok. Just as the first step was minus 12, so the total amount of motion would be in absolute coordinate mode be referred to as minus 19. Although, the actual motion between the 2 positions is only about 7 millimeters.

So, you have i p here, slightly lower current value, because this is, sort of, the end of the process, ok. So, you need not heat the spark current to be very high. This ensure also a kind of finish on the surface, or fine finishing on the surface because of smaller current value. The i b current is also the kept as about 5 amperes, ok. And, then the T on has been now reduced to 50 micro seconds, utilizing 3 percent of the times about 1.5 micro seconds is the, really the application of the voltage pulse.

And then, the vg value, the inter electrode voltage is kept at about 40 volt same. The voltage does not change much because this is the quantity which controls actually the servo gap, ok, or the servo motion. The gap voltage is the main quantity for that. The sensitivity in this is case is even higher because it has gone down further to 19 millimeter. So, the sensitivity is given on a scale of 7 here, close to 10. And, similarly, the arc sensitivity also is increased to 3. And, the total working time here is kept slightly above what happened in the earlier minus 12 steps, so because it is actually at a certain depth, ok.

And, you want to make sure of, and also is for lower current value. So, you want make sure so that the whole, the hole has been completely carved out upto the depth of minus 19 millimeters; one of the reasons why we are keeping the working time to be about 0.2 seconds more, than the earlier step. And then, of course, you have about 10 millimeters of retraction distance because it is further down the hole, therefore the retraction distance is in this case has been increased. So, having set that this completes the end of the program, this is the end block, and we are now all ready to go for the machine to do the micro machining activity.

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So, now, you want to close this tank. Remember, this is the e d tank which is used for the dielectric fluid. The fluid will actually fill all the way upto the tool, so that immerses the tool as well as the work piece on the in between the oil, the dielectric medium. And then, you will have force flow through these nozzles which will always maintain a circulation in the zone of machining, and is very important for destroying the iron column created again and again. So, I am going to now close this tank. And, this as you know, it is like a sort of liquid tight compartment, and therefore there are these heavy duty clamps which should do the job of measuring the 2 sides together with a sealing between, so that oil does not come out.

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Now, we will go for the next step which is filling of this tank, beyond which will start the machining. So, here now, we would like to give a little bit of illustration about the dielectric dispensing system associated with this machine. And, for doing that, what is important is that, there are different valves on this machine as you can see which perform different from functions.

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One of them is, to actually control the flow in the local zone over this particular area right here which does the machine, machining. So, supposing there is the earlier machined area, from which there are excepts like chips, etcetera, coming out of the process, so you have to wash them with high pressure fluid. And, for doing that you need a high pressure to be injected to this particular zone by a circulating the dielectric fluid, and pressing it in a manner so that it flows in this particular zone.

So, what we are going to do is, we use again the punch box here, right here. If you look at the punch box, there is on option of, you know, oil flow or pump flow in this particular case here, given by this option where I will switch it on. And, this generates certain pressure in the system which actually leads to the oil flow.

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And, what I am going to do, it is a sort of, if you look at this area, if you focus on to this area, you can see that by changing the position of the valve, I can actually flush this area with dielectric fluid which is flowing to, sort of, ensure that all the chips, etcetera, are carried away from that area. Once the process begins, it should be clean completely clean. So, there are these nozzles which are now firing; this can be after some washing time closed, ok. And then, whatever is being pumped as right now, drained out from the system, because the chips need to be drained out. So, you wait for some time, till the whatever chips that are washed up goes out of the system.

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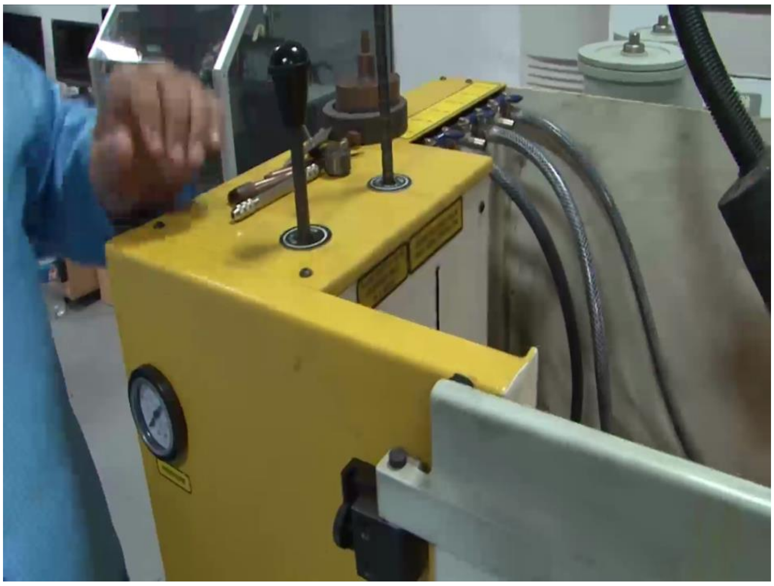

And then, what you do is the following. You basically use this leaver and try to close the valve, so that the e d m oil in the tank can now start raising. You can see that the oil level is now started to raise because of the closure of the valve. It is not been drained anymore. And, one important thing here is basically the level of the oil which is basically given by this indicator here which can actually change positions, and which can also give you an illustration upto what level will prevents sparking, or you know, in here, dry here.

So, you do not want to be a dry e d m process. So, you want to atleast ensure that this pointer is in the level of the, atleast in 2 holder, which is actually placed somewhere here, ok. So, now, atonce it has been setup, it gives you a complete control of the process, and you can fill this tank up with the e d m fluid, and then perform the e d m operation on this particular sample cut. You can see the idiom oil level coming up, ok; and, will come all the way up, to this indicator here, and we will stop the pump upto that.

Now, we are actually let with the situation when more or less the, as you can see here, the pointer is quite summerit within the dielectric fluid. And now, you had also started the flow in this regions by opening the valves for the nozzles in that particular e d m area. And, we all need to do the machining finally. So, you, if you focus on particular toggle switch, or the this punching box, you see there is a spark option which is here. So, all you need to do is to create the spark on, so that there is a, e d m action which is now happening. If you go close by in the tooling system, you can see that there is a spark which would be created because of this particular process.

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And, this spark here can be easily virtualized, if you switch off this lamp actually. And, you can see here, that there is a intermittence sparking action which is actually coming in the zone which is being machined. And, you will have exact dies of the process synced into the system, so that you have a quite made in the particular syncing system. There is some kind of a vaporization action which does happen, which you can capture on the camera. And, one of the reasons why that is so is that, there is going to be a paralysis of the e d m oil to some extend which will also create subsequent layer deposited over the tool side or the surface, ok.

So, there is some kind of a chemical paralysis along with the physical breakdown of the irons and the electrons which happens in this particular process which creates, you know, the content, which creates problem sometimes for the e d m. Because, if a tool work not to be dressed properly in an used e d m for a long time, the paralytic layer which deposits out of the breakdown of the e d m oil, would cause the current to somehow get blocked, and the e d m can be self stopping process in that case.

So, you need to, sort of, after 2, 3, runs, take out the material, and be able to, sort of, you know, dress it properly, so that the paralytic layer on the surface gets removed every time. So, as you can see, now the tool has returned back to its initial position, after doing the e d m machining. I just take up this punch board, and then I just try to switch off the pump by pressing this, ok. And then, we need to some have drain this e d m oil which has been filled up in the tank.

So, I am going to go ahead, and just make this leaver in the, on position, so that the e d m can get drained, ok. And, the oil is actually now going out. And, you can see that the oil level inside this tank is residing, so it has to go all the way to, you know, the bottom before we can retrieve the work piece. And, as I you show you, there is the cut which has happened to this work piece actually in this particular case, by removing the work piece. So, you wait for the oil to, sort of, subside down, and then we can actually retrieve the work piece.

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So, you have to just open this clamps here. And, just declamp this, so that we can open up the box in both the cases. And, this is how, so you can actually open this cover as well as this, and then the whole idea is to be able to extract this work piece from this gig here.

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So, I just like to show you, how the e d m process has been done on this particular work piece. And, I just kept up the oil, and you can see that shape that we were indenting to was that, comma shape at object of which electrode was, is being now printed on to the surface. And, this can go upto, all the way from 100 microns to, almost about to few tens of millimeters, and that is the advantage behind e d m, that it can go upto any extent.

This is because we are talking about micro here. We have taken the work piece out. The process is still not work completed; it is 19 millimeter depth which was actually a earlier shown in the cnc code. We just wanted to show you that how this shallow channel or shallow feature would like on a surface. However, I will just show you another work piece which I have been recently completed, which actually would correspond to the, you know, higher feature depth.

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This is the case of 18, 19, millimeter. You can see that the comma has been inserted all way to about 19 millimeter, in the particular case also. So, therefore, I would say that, you know, various depths, particularly from few tens of micro, tens of millimeters, to all the way to the micron levels can be made using this very important useful process. One of the thing you have to remember about e d m, is that it is really a non contact process, irrespective of how hard the materials is. You can still be able to do machining because the way that machining happens here is purely by thermal ablation.

Of course, there is an issue about the final surface texture and the roughness, which is again very important parameter, as I have illustrated several times earlier in the lecture. And, there are different studies which talk about, what would be the ideal machining parameters, for the roughness to minimize in the particular case. But, in any event, sometimes particularly in construction of micro devices, we need to hybrid processes. Where, as the first step, the basic machining is done in e d m; and, in the next step again, some other etching process or suitable fine process has to be done over the e d m, in order to obtain a smoother channel, a smoother surface, or a smoother micro device, as the objective of this courses.