Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-2

Module-28

Electric Discharge Machining Process

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Hello and welcome to this manufacturing process technology part 2 module 28. I was talking about the basic electro discharge machining process, and I was further discussing about how spark is generated in a medium, because of a discharge of electrons and then how it creates ion column, it creates ionization and secondary electrons and then how those electrons actually responsible for a mole on material similar to the ions.

And electrons remove more material comparison to the ions, because there are more numbers and also are able to transfer more amount of momentum to the surface in which it was strike. So the anode is not when you made to also further we kind of discussed how the spark would be generated all over the surface depending on what is going to be the nearest distance between the surface or the peak on the two surface with respect to the working surface.

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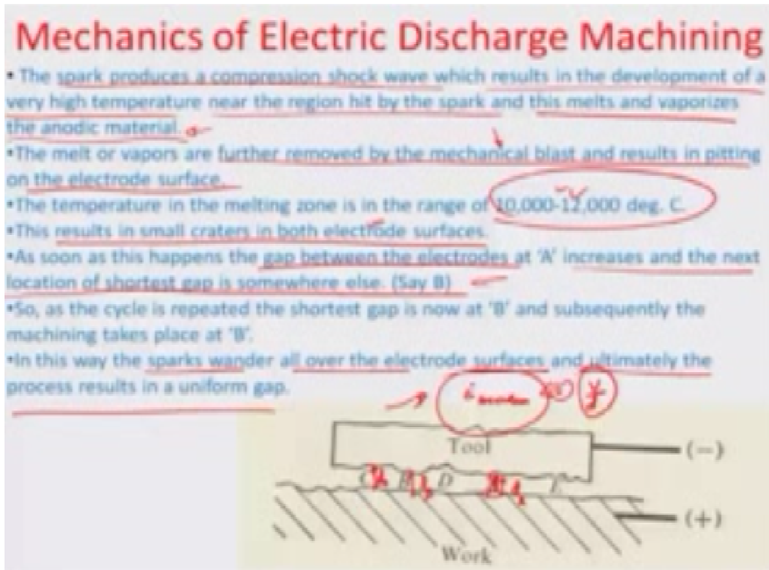

So in line with that in what we learned is that the spark produces a compression short wave okay, which results in the development of a very high temperature near the region hit by the spark and this melts and vaporizes the anodic materials. The melt of vapors are further removed by the mechanical blast and obviously there is also going to be an electron pressure and this results in, it is not of a pitting on the electrode surface.

So the temperature in the melting zone is roughly in the range of about 10,000 to 12,000 degree Celsius. The dialectic fluid or the dialectic coil has a flash point, but, you know it is so momentary and so small, then it is not able to generate and there is also a quick dissipation with the heat which is generated or accumulated. And so, this hotspot that is generated may not be enough to create a chain reaction and then general an ignition on the fluid oil.

So this results in small craters in both the electrode surfaces and number of craters created on the anode surface is of course more than the cathode surface. And as soon as this happens the gap between the electrode at A increases and the next location is the shortest gap is somewhere else say B. For example, let us say A was the one where the A goes smallest, there was a spark because of where there is a meant and the gap is now increased.

And maybe some other place B has the smallest gap where there would be a breakdown again. Because obviously you have to remember that the E breakdown has to be arrived at and the voltage here E should be at this greater than this E breakdown which is actually a function with the voltage applied in the inter electrode distance. So the D is varying quite a bit between, let us say D at A or D at B or maybe D at C okay.

And so, therefore whatever creates this condition first at the first part. So it is in a way as described above that the spark wonders all over the electrode surfaces like a dancing sparks, if you see a EDM machine, you will find that the sparks which are created are not at one place, but at several places along the total electrode surface, and they keep on changing orientation randomly and you do not know what at what place the spark would get generated. And ultimately the process results in a uniform gap over the whole surface. So EDM also in a way can be treated as more or less as dye seeking process.

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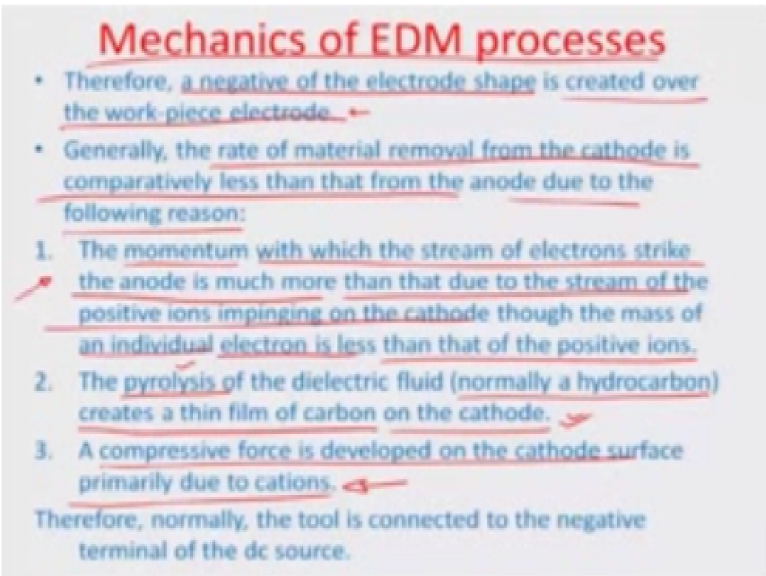

So having said that let us learn a little bit about the mechanics of the EDM process. So the first important aspect here is that a negative of the electrode chip is created okay, and I just told you in the last step forward it is a dye seeking process. And generally the rate of material remover from the cathode is compatibly lesser than that from the anode.

And more because of two reason I think I have pointed it out in summary the momentum is one of the reasons the momentum with this with reach the stream of elections strike the anode is much more than that due to the stream of the positive once is impinging on the cathode to the mass of an individual electron is less.

What the number density of the electrons or simply humongous in comparisons to the once created in the column in forms of positive ions also there is a tendency of some kind of breakdown of the EDM oil or the dielectric medium which is there between the electrode we call this break down process pyrolysis and because the dielectric fluid is normally a hydrocarbon pyrolysis of such hydro carbons create very thin films of carbon deposits particularly on the cathode.

Because obviously there are ions moving or created through this pyrolysis process in the medium which would be going to ultimately deposit you know at on the anode surface cathode surface and that to with high amount of momentum where the local temperature may reach to a level where it may burn down the hydrocarbon and produce only carbon deposit so slowly you will see the tool surface being covered with carbon as process continues and the compressive force that is developed on the cathode surface is primarily because of the cations and it is a normal strategy that the tool is connected to the cathode side of the DC term and allow the DC source in a EDM process so that is about the mechanics of the EDM process.

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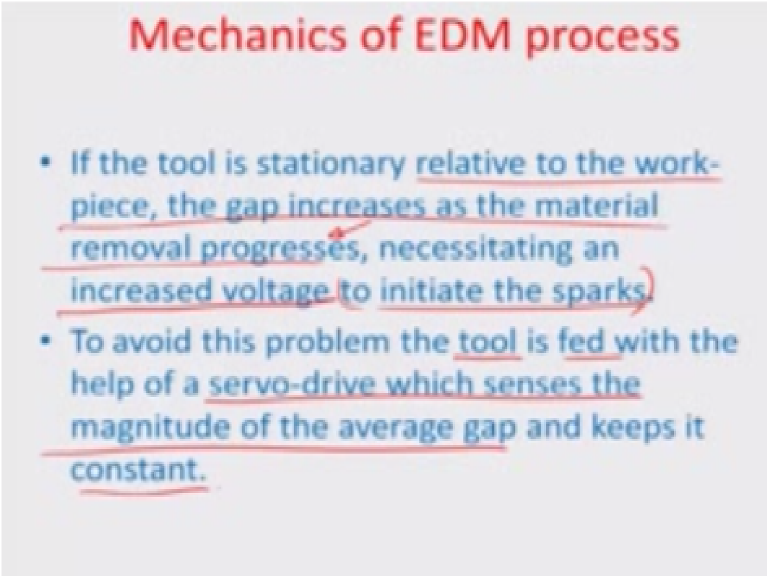

Also if the toll is stationary relative to the work piece the gab increases as the material removal progresses and if do not close on the gab through server control or something some other mechanism obviously they would not be any sparking action any more so if the voltage is not increased so either unit to increase the voltage in case the gab increases or you need to change the gab in order to have a sustained initiation of sparks across the medium between the electrodes.

So the tool feed is the common strategy which is used for closing on the gab as a gab gets you know enhanced because of this process of material removal and so typically a servo drive which sense the gab voltage and you know determines by a comparative with a pres set voltage keeps the gab more less constant so that the sparking process can be sustained.

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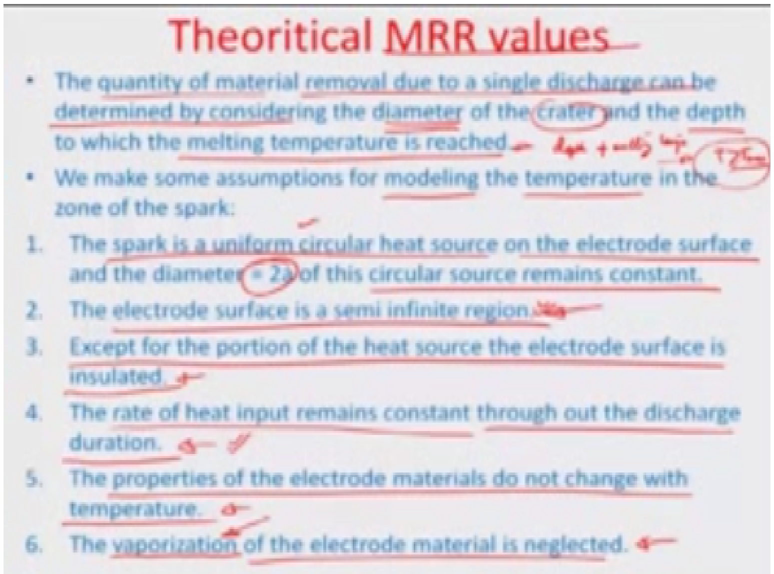

Let us look at some understating of how to generate the material removal rate values in a EDM process okay so the quantity of material which is removed due to a single discharge can be determined and then you could do something with multiplying that with the spark frequency so that you have an idea per unit time how much such material can be removed and you can also have an idea how one spark would be able to in terms of volumes of material removed contribute you know.

So such volume times these spark frequency or the frequency at which this volume gets separated would give you an idea of the overall material removal rate so we have to first look at the quantity of the material which will be determined by considering a sort if creator being formulated with the fixed diameter and depth you know up to which they melting temperature is reached and this is very important point in EDM which we better known as depth of melting temperature so obviously it is very clear.

That wherever the temperature of the material is above the melting point those are really the areas which get melted or above or equal to the melting point I should say those are the areas which shall melted and for the temperature distribution to each to that point, you also need to study how the temperature varies with respect to depth and obviously at a certain depth from the surface or up to a certain depth of this flow of the surface where this spark has hit the condition of temperature greater than the melting temperature or equal to the melting temperature.

Would exist so typically that is the zone which would give you how much melt is formulated and that is the zone which should be heated for estimation of the wall diameter of the greater and the depth the greater, so we make some assumptions for making a model simpler and for modeling the temperature the zone is spark the first assumption we make is the, the spark is the uniform circular heat source from the electrode surface, and the circular heart sources the diameter of two way so this is mostly.

Looking at the number of bits which have formulated after the EDM process under microscope, we would get the idea of what is going to be the overall diameter of such a heat source so the diameter of the circular source remains constant, and the electrode surface is again a semi infinite region this is more so because we want a distribution only in the radial direction and not as a function of the angle ζ so except for the portion of the heat source the electrode surface is considered to be insulated.

And there should only be any other heat inflow except what is coming from a spark obviously the rate of heat input remains constant that is what another assumption is of this model, and that should be throughout this charge duration all though this is ready something that can be modified quite a bit because the discharge really, all though it some momentary of air but when we talk about micro machining particularly.

There may be a finite time duration of the discharge and the volume of material that is bring moved there I very small okay, so that finite time of discharge may we played around with very easily to obtained at least for finishing process a very good estimation okay, so here for all practical purposes we would assume the time to be so small time of discharge to be so small and the machining overall time to be so huge, that the discharge can be treated as more or less some momentary affair and the properties of the electrode materials further do not change with temperature so we do not assume any kind of thermal expansively or any kind of change in conductance.

Because of a change in the temperature and also we further assume that there is no vaporization the one allow to material removal is melting and removal or material through diffusion into the electrode the electric fluid so the vaporization of the electro material is more or less neglected in our theoretical estimation of the MRR, so let us now look at the underlying a governing equations for solving this radial and you know z based or depth based distribution of the temperature.

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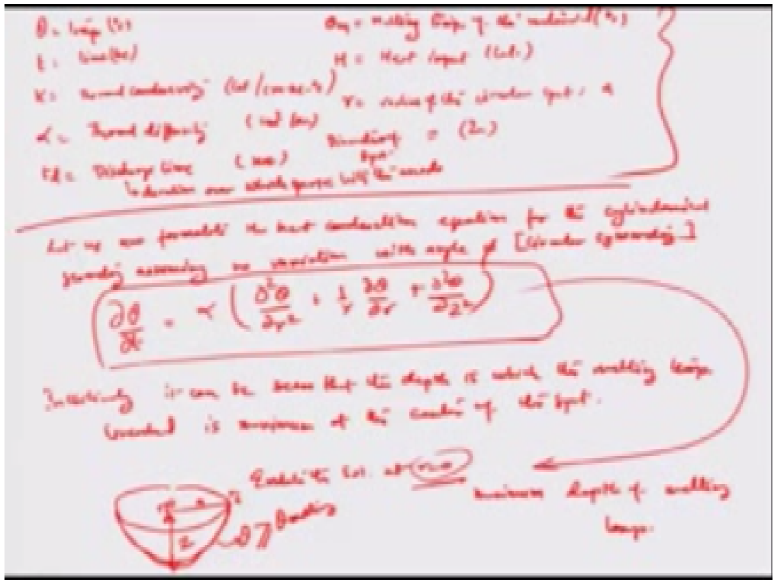

So let us assume θ to be the temperature of a certain point within the material degree Celsius let us also assume time t in seconds okay, to be a parameter which is responsible and contributed of the variation of the temperatures θ and we also assume some standard k value thermal conductivity value as per our assumptions made earlier we do not assume this conductivity into change based on temperature increase or enhancements so this can be constant calorie/ centimeter second degree Celsius there is also a constant thermal diffusivity that we assume units of thermal diffusivity in this case can be cm^2/second.

We can further assume at a charge time of TD in seconds and this could be more like a duration over which these spark hits the anode, now we assume a certain melting temperature of the material let us say θ_m this is the melting temperature of the material this can be degree Celsius and further we have H as the total heat input out of a circular spark and this can be mentioned in calories.

So having assumed all these parameters let us now formulate the heat conduction equation, particular ly for the cylindrical geometry that we are considering including the z direction the radial distribution and also the distribution with respect to θ where because you assume an infinite boundary condition there the difference because of θ angle really does not matter it is all about the radius and the depth that.

So we formulate the heat conduction equation for cylindrical geometry assuming on now variation with angle ϕ, or we can call this circular symmetry. So we can write this equation as $\partial\theta/\partial t$ = thermal diffusivity α times of $\partial^2 \theta/\partial r^2$ r being the radius let us decide here r is the radius of the circular spot which in this case is A the diameter is 2a, diameter of the spot or spot size so $\partial^2 \theta/ \partial r^2 + 1/r\ \partial \theta/ \partial r + \partial^2 \theta/ \partial z^2 = \partial^2 \theta/ \partial t$ so that is how the equations are the governing equations represented for this circular geometry and intuitively it can be.

So intuitively it can be seen that the depth to which the melting temperature is reached is maximum at the center of the port and really we have to evaluate the solution at r=0 or at the center so this will give us the maximum depth of melting temperature so if this is radius a we are talking about a creator where this z which corresponds to the boundary condition θ greater than or equal to θ melting okay.

So this z formulated on the basis of this boundary or this you know θ=θ melting boundary is obviously going to be maximum corresponding to r=0 and it is going to be 0 and r=a okay. So let us now evaluate the equation that r=0 with certain boundary conditions.

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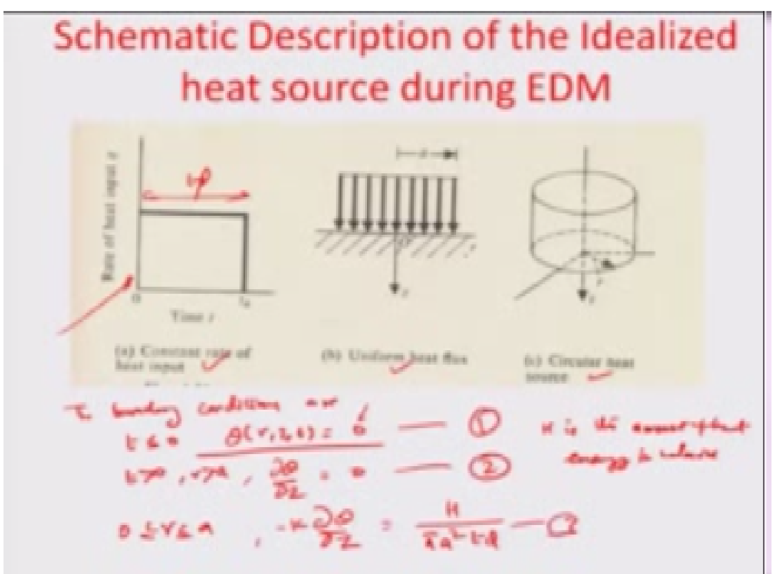

We have a three different boundary conditions will be using in this case one is the constant rate heat input one is the uniform heat flux another is the circular heat source so if you write the boundary conditions mathematically we assume that the first condition can be the net all values of t=0 or less than 0, the temperature is a function of r,z and t is same as 0 we consider this to be the room temperature so we are having a temperature differential with the respect to the room temperature in a scale and so therefore $\theta=0$ okay.

And we further assume that corresponding to any time values greater than 0 and radius greater than a there is no temperature gradient which exists or $\partial\theta/\partial z=0$ and the z direction outside the spot or outside the radius so there is no temperature gradient along the z direction and inside the radius let us between values of r between 0 and a we do have a sort of a constant heat flux boundary condition here, where we say that $-k\, d\theta/dz$ equals to the heat per unit area per unit time, okay.

So this is the power per unit area so we can say that h is the amount of heat energy in calories and we can say the heat per unit area per unit time for the discharge duration dt okay, so we assume a step function as for us the rate of heat input goes with respect to time this duration here is the whole sparking duration and this uniform heat flux when the spark is operating so this is the quite bit of simplification so this is $\pi s^2 dt$. So these are the three boundary conditions that can be used to evaluate the governing equation that has been written in the section here.

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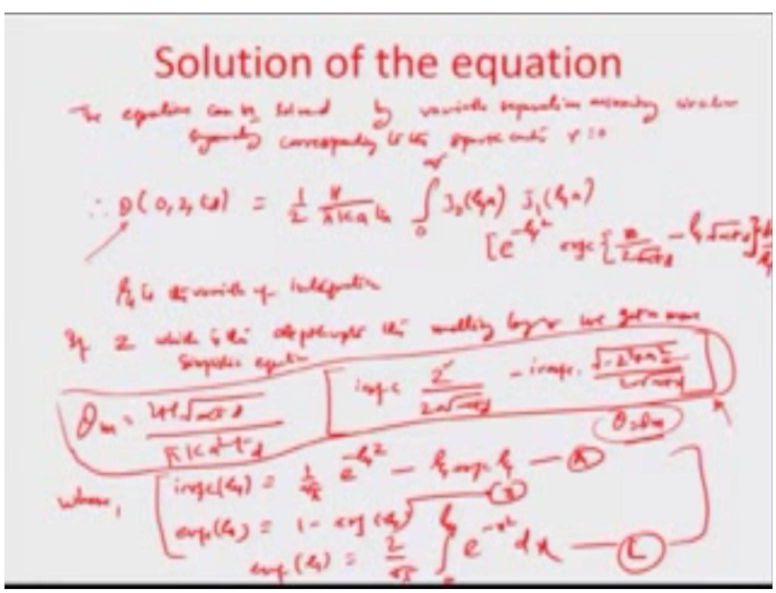

And the equation can be solve by variable separation or some other technique as being no variation in θ or no variation in ψ or assuming circular symmetry and corresponding to the spark center are equal to 0, we have the θ at 0 z td = ½ h π k times of a times of td, integral 0 to infinity bezel function of dummy variable ζ a of index 0. Times of the first special function of ζ a times of $e^{-\zeta 2}$ times of the error function of set kind of the term z / 2 √α td – ζ √α td d ζ / ζ.

Z is the variable of the integration here and out of the solution if we wanted to find out z which is the depth up to the melting layer we get a more simplistic equation θ m = π h √ α td /π ik^2 td times of the error function of the third kind z / 2√ α td. error function the third kind root of Z^2+a^2/root f αtd were I would just like to write these different notation son different formulations of the different error function so the ierfc ζ and we written down as 1/π $e^{-\zeta 2}$ – ζerfc ζ and erfc ζ can further be written down as 1-e error function of ζ and as you all know the error function of ζ is in numerical integral given by root of π 0 to ζ into the power of $-x^2$ –vx okay.

So this is A B and C so this expression right here is merely representational but t gives you A condition there are the ζ or the temperature is actually equal to the Melton temperature or greater than the Melton temperature so this can be very good iterative means of estimating what is going to be a value of ζ for a corresponding value of radius okay.

So this can be vary between anywhere between 0 and A for example and it could give you, it could give you an estimate of where are those points where the ζ really is within the ambit off or its more than or equal to the melting temperature so I think I will like to stop here may be take this up a little further and may be try to do something so that we can have a prediction of the Z value through which we can actually have a great volume estimation.

I did not intentionally solve this solution of the equations because we just want to utilize what is the final solution in terms of the variation of ζ with respect to Z and the radius and however if there is query on how we are done this process detail notes or we can be shared over the chart platform data so with this I will like to stop this particular module and the next module we will try to estimate the material removal rate from the Z value that we obtain corresponding to the different values of R okay.

The ζ equals to ζM and then estimate the volume and then multiply with these spark frequency or to get a theoretical estimation about spark value what is going to be MRR so with this I would like to stop this particular module thank you very much for being with me thank you.

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