Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part- 2

Module- 30
Effect of various process parameters on EDM process

by
Prof. Shantanu Bhattacharya
Department of Mechanical Engineering,
IIT, Kanpur

Hello and welcome to this manufacturing process technology part 2 module 30.

(Refer Slide Time: 00:16)

We were talking about the role of melting temperature in EDM and we showed and I actually shared with you empirical relationship that happens of the total material removal rate as a function of the melting temperature theta M as you can recall that if theta M goes up or the material has a higher melting point then obviously the material removal rate falls down in that particular case.

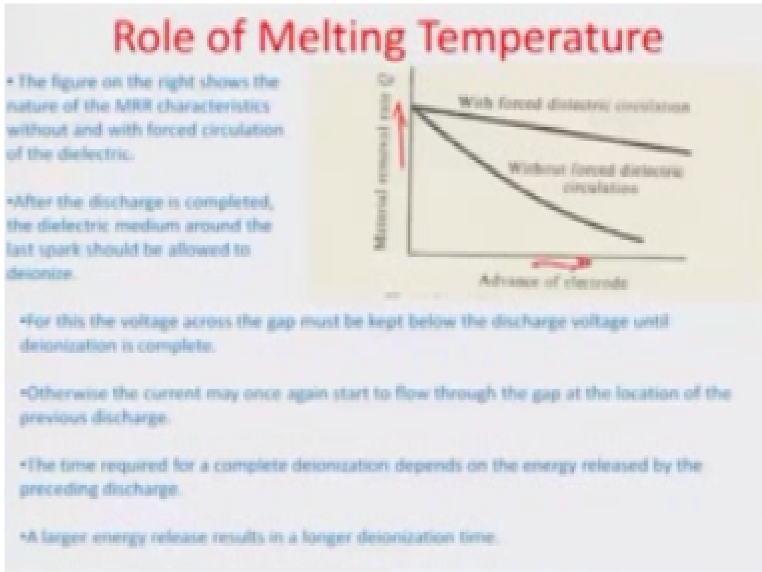
So we were talking about the role of dielectric fluid and how the circulation of fluid would alter the EDM process if in an EDM process if the dielectric is force Lee I mean it is there directly subjected to forced circulation in the machining zone there is a tendency of the material removal rate to go up and the reason that we were talking about mostly is that there is a formation of an eye on column every time there is a spark as we all recalling EDM and then if the circulation is forced there is a tendency to disobey the way that I on column quickly.

So that the next can get formulated and so obviously if the ion is or if the ion path is there in still in the dielectric then there is no generation of the spark because it is a conducting column and whatever electron you know excess would-be there on one side would actually get conducted and the electron would rather follow the conducting path to get shorted on to the anode rather than getting into a space and creating a spark or a plasma which otherwise happens.

So therefore D establishing the column or maybe taking off the column and the removal of the ion city which has been occurred or which is hard because in the dielectric fluid because of the sparking process is very important at every step so between two sparks you have to ensure that the column fades away are the total ions and electrons which have been generated they should somehow be either absorbed at electrodes or go away from the machining zone for another column to get established.

So this happens faster if the fluids are circulating in nature in fact let us look at a trend here of the material removal rate with respect to the you know advance of the electrodes for two different cases one is with and without the for circulation you can always see that with advanced.

(Refer Slide Time: 02:39)



It is advance of electrodes to each other or a reduction in the IG the inter electrode gap you can always so this is the reduction in the IG okay you can always find that material removal rate is better or higher with forced dielectric fluid circulation so the figure on this showsright shows the nature of the m r characteristics with and without the for circulation and after the discharge is completed the dielectric medium around the last spark should be allowed to doneness and for this the voltage across the gap must be kept below the discharge voltage until the DIA negations is complete.

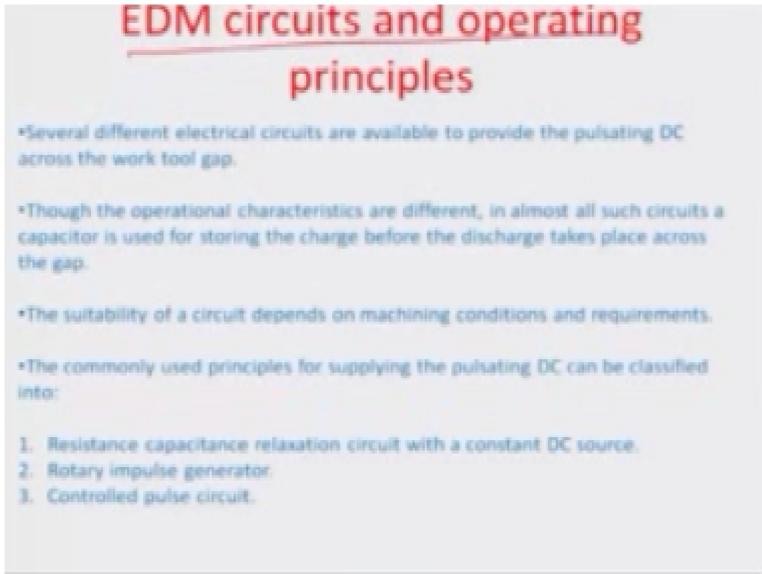
Otherwise the current by once again start to flow through the gap at location of the previous discharge and the time required for complete the ionization depends on the energy released by the preceding discharge of course so obviously if you force circulation then this quickly dissipated or dissipated so a larger energy release would always result in a longer deionization time which gives you some limitation about the sparking frequency.

So that is how the whole material removal process happens now we have looked into enough of physics behind the EDM and we have also gone across some of the empirical formulations regarding how the crater size can be defined in terms of let us say the height or depth of crater as well as the diameter of the crater we have also looked into aspects related to the melting temperature of the material and how you know material removal rate gets affected because of the melting temperature of the removal we have tried to estimate the crater volume of a EDM process given some of the empirical estimations of the diameter and the size of the crater based on the pulse power of the sparking power okay.

So all this was done with an intent to really try to find out what is the overall or material removal rate and so everything in EDM is really about how good you do the charge transport and the charge delivery and the electronic charge actually irresponsible for all the momentum transfer so that the m RR increases so having said that let us now try to look into some of the governing principles associated with how this delivery would happen how you can do the quick charging discharging of the IEG or the inter electrode gap.

So that you can have more material removal rate and for doing this it is important to find out some circuits associated circuits or some governing laws where the electron release rate can be controlled as a function of time so one of the circuits which comes into our mind immediately is the RC circuit the resistance capacitance circuit where such governance can be administered of the electron flow process okay as a function of time and so.

(Refer Slide Time: 05:51)



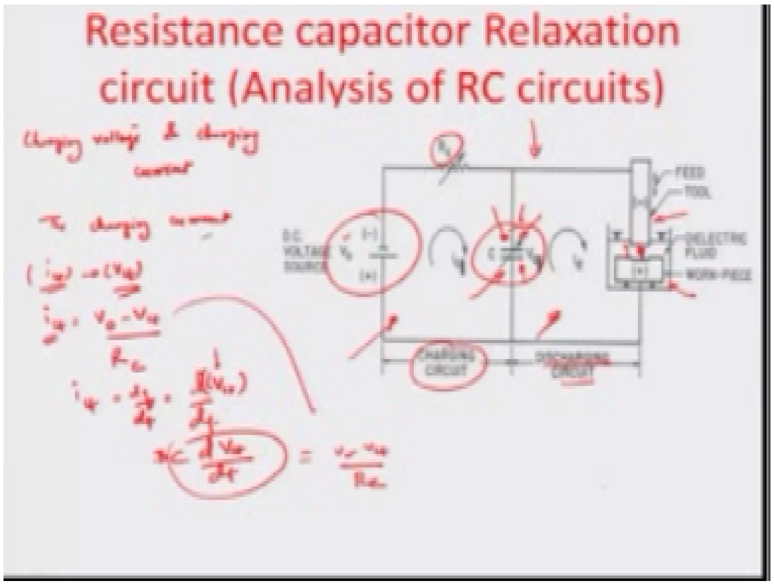
Let us look at some of these basic EDM circuits and operating principles where we could even have these circuits operated at some parameters where material removal rate is very easy to find out based on what is the capacitance or what is the energy is park energy that is delivered so several different electrical circuits are available to provide this pulsating across the work tool gap once this park is generated obviously and the ion column is dissipated then you ready to go for another DC search where again another spark could take place.

So though the operational characteristics are different in almost all circuits capacitor is by and large used to do this charging discharging action and the way you're supplying to the capacitor is again a function of the remaining components like resistance etcetera or the internal load resistor of the power source that you are using in the circuit and so capacitor is typically used for storing the chargebefore the discharge would happen okay.

So how quickly you could charge or how efficiently you could discharge or at what criteria you could discharge is really what would govern what is the or the material removal rate so the suitability of a circuit depends on obviously machining conditions and requirements and commonly used principles are resistance capacitance relaxation circuits which talk about in great details because this is also another way of estimating aware.

You could operate this at a certain power parameter and also a distance parameter through which you could find out what is going to be the tentative amount of material removal rate from the empirical relationships that have been generated earlier there of course rotary impulse generator based circuits and control circuits which are used with solid-state electronics etc these days and so for the first basic circuit that comes into our mind is the resistance capacitance relaxation circuit.

(Refer Slide Time: 07:45)



So let us look at some of the analytical issues with such a circuit so the resistance capacitance relaxation circuit really is represented in this diagram here where there is a charging circuit as you can see which offers the charging circle starting with the voltage v-0 output voltage a capacitor which is placed in-between which would be responsible for the charging and discharging if needed and then the at the first instance through the resistance capacitance on the first part of the circuit.

Here the capacitor is being charged up to a maximum charge value that it can hold okay and so it has some kind of a time constant associated with this whole charging cycle once it is charged the dielectric fluid placed between the two electrodes here is somehow needed tube ionized okay by development of a spark so that the charge on the capacitance can be dumped onto theworkpiece okay.

So now what you do is to feed the tool so that again the distance here between the tool and workpiecereduces and the electric field goes above the breakdown electric field where there is a sudden generation of the spark okay so now it is all about in the second cycle how this capacitor right here discharges through the spark onto the work piece surface so that is why this discharging part is very important.

So we are going to do the analysis on two front one is of course the charging circuit side and another is going to be the discharging circuit side and one must remember that there is obviously a very important relationship in terms of maximum power transfer between the source voltage and the hinter electrode gap you have done this in great details when we looked at plasma systems earlier during the first few modules in the micro fabrication part of this lecture.

So let us look at now the charging circuit part so if we talk about charging voltage and charging current so the charging current we call this current ICT here because it is a function of time obviously as the voltage the potential difference is applied across this end and the capacitor plate right here which is charging with the voltage you know of the charging capacitor VCT again as a function of time so the charging current IC t is related to this VCT through the expression IC t equal to v-0 VC p by the circuit resistance RC which is also a variable resistance but at this time let us assume a fixed value of R C.

So that is how the itch the charging current is experienced in which the charging capacitor is being charged by the charging circuit also if we look at the capacity of side and the way the voltage and charge varies so the you know the current the charging current ICP is also expressed as a rate of flow of charge into the capacitor which can actually be recorded as see VCT where c v as you know is equal to the total charge on the capacitor.

So the capacitor C is capacitance C being constant we can record this as C VCT by DT so that is how you can record the Its this actually can be equated then as c v CT by DT equals V zero vf t by RC and if we try to solve this problem let us say let us just mention all the parameters before going ahead v-0 is the supply voltage RC and that to supply voltage of the source at time T RC is basically the charging circuit resistance and C is basically the capacitance of the condenser on the charging side of the charming side.

So obviously from the earlier equation you have see PCT by DT equals30 minus by t by RC so you have d v c by v-0_ vf t could be actually equal to dot 1 divided by croc so if we integrate both sides we have a definite integral in v 0 _ vf t equals _t by croc plus k1 k 1 is the constant of the integration and let us try to now estimate the k1 by looking at maybe one boundary so at time

T equal to zero we know that there is no charge so there is no so we know that there is no charge buildup in the condenser in other words.

We can say that you know the VCT which is because of the charge buildup remember q equal to V times of CC times of vf t is equal to zero okay so k1therefore becomes equal to simply in v 0and from this expression at time T equal to zero you put vf t equal to zero that becomes K 1 or in other words we have the final expression written here as land 0 _ v c t equal to minus t by Retimes' of the capacitance on the condenser c + l n v 0 r in other words.

You could write or if you just manipulate this equation algebraically you have v c t equals v 0 1_ c to the power of minus TR c times of see that is how the voltage v c would be determined in the interest of detailing and just wanted to mention the way that you solve this is in v 0 t- in v 0 becomes equal to _t by croc and so in v 0 _ vf tee by v0 becomes equal to minus t by cry or if wanted to just you know raise both sides to exponential.

So you have _ by RC times of c e to the power should be equal to v-0 minus vf t by v0 another words PCT becomes equal to 1 _ e to the power minus t by crc times of v0that is exactly what we arrived at here just in the interest of detailing although it's probably not littered at the level in which this course is being operated so as we all know the time required by the condenser to achieve around sixty-three percent of its charging voltage.

So therefore point638 v-0 okay this is called time constant tau and this can be represented as RCC obviously if T equal to RC c v c should be equal to 1 e to the power of minus 1 times of v0 this value is about0.6 38 that is what exactly what we are talking about so that is how you can actually find out from this RCC values what c times or the capacitor of the condenser times the variable resistance of the charging circuit what is the time constant involved in charging part of the circuitry.

So as I CT is basicallyv-0_ vf t by RC I can always substitute the value of v CT here as _ p 0 1 _ e to the power by RC times of c divided by R C and obtain ICT as V 0 e to the power of_ T by RC c / RCS that is how you actually can know the value of current I as a function of time in the charging circuit okay so this value here right here ICT.

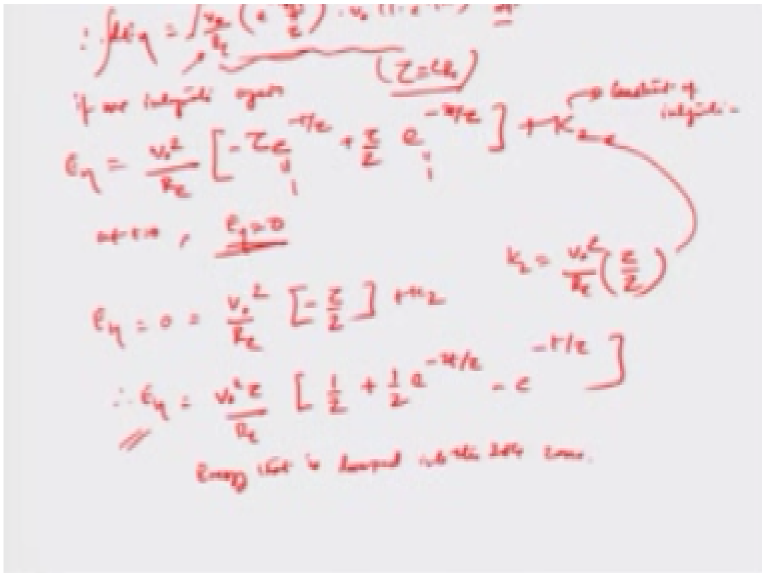
So the power delivered to the discharging circuit is now of importance to us because obviously once the capacitor has charged we would like to look forward to sort of the capacitor getting discharged through the IEG or the intellect Road gap so that the spark can fall on the work piece and start melting so the power delivered to the discharging capacitor what discharging sorry circuit can we also mathematically or analytically found out the energy delivered to this discharging circuit.

It can be expressed as may be at any time instants T can be expressed aside n which is actually the current voltage product of the charging capacitor times of d t okay so obviously the current voltage product is the power as a function of time and we are talking about an instance DT for which an energy could be delivered and so the amount of energy delivered would be equal to the current voltage product times DT the time.

So if we look at you know the current voltage product from some of the earlier definitions that we had obtained in the last one or two slides we would-be really looking at de n as the VCT value which is v-0 by RC times of e to the power of minus T by RC c times of the ICT value or sorry the ICT value which is v-0 by RC times of e to the power of T by RC c times of thethe VCT which is v01 _ e to the power of .T by RC into C times DT ok so if we integrate on both sides again the great again with respect to time the total amount of energy.

And comes out which has to be delivered from the capacitor all the way to the work piece and the product you know this product can be integrated in time as 0 square by the charging circuit resistance times a minus tau e to the power of minus T by tau we assume tau to be the time constant CRC okay, as just the right in the last step so I am just replacing the crc everywhere with the value tau so minus tau e to the power of minus t by tau plus r by 2 e to the power of minus twice t by tau plus the constant of the indefinite solution okay.

(Refer Slide Time: 19:46)



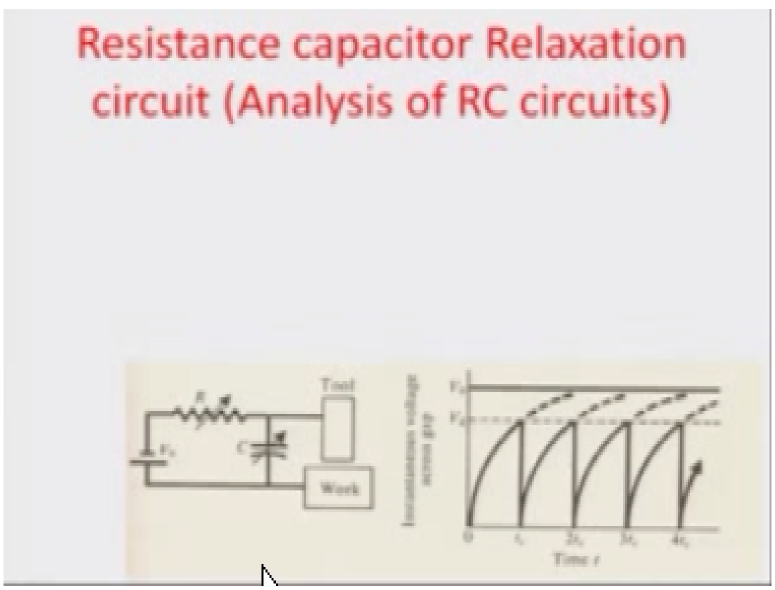
So a constant of integration so we are going to find out or estimate this value based on the boundaries again so at time equal to zero as we know the total energy that is dumped into the capacitor from the charging side of the circuit is equal to zero and considering that to happen the en value really 0 becomes equal to v-0 RC times of we can find out the k2 value on this guy becomes equal to 1 and so does this so we have this times of x to the _ sign+ k2 equals 0 or k2 is basically V 0 squared RC 1 by RC times of by 2.

So if we substitute this value back into this expression right here we obtain value of which is equal to v-0 square by Retimes tau x 1 x 2 plus 1 by 2 e to the power of minus twice t by tau _ e to the power of minus T by tau so this is finally what is the kind of energy that is dumped into the IEG zone or inter electrode gap in electro gap zone for doing the machining okay so obviously you would like to get a some kind of a you know average power based on the you know just division of this energy.

By the by the time for which this energy is dumped or we can say the time for which energy n is delivered to the discharging circuit so if TC were the total time for which energy en is delivered to the discharging circuit then obviously power average here could be en by TC and I can easily express you know by substituting the value of en corresponding to the time t equal to t see here as V 0 squarely RC times of some value X where X we have assumed to be the time ratios TC and tau being the time constant RC can TC is the total discharging

Time for the capacitor times of one half plus half e to the power of minus two X to the power of X so that is how we can have an average power and further we need to operate at the maximum power transfer condition which says that you know the lap average with respect to let us say del X which is the new variable here the time ratio equal to zero so we are going to find this out in the next module in the interest of time we are going to close this particular module but the whole idea here is the you know the charging cycle as you can see here so the charging happens over different and this is actually the discharging okay.

(Refer Slide Time: 23:03)



So as soon as the voltage of the capacitor goes you know to the sort of discharge voltage across the gap there is going to be a discharge so the capacitor is not loud anymore to charge up to its highest limit and so there isomer kind of a discharge so this whole time represented by red here is actually one charging time cycle so typically this is how the signal within the capacitor would look like so you have charging time and then the discharging time and the total time.

There is TC so you can operate the capacitor many times at TC twice tc3 DC for TC so on so forth so that is how the instantaneous gap voltage across the tool and work piece would vary which is actually pretty much the voltage and how it varies across this capacity so in the next module were going to sort of look at this average power and try to find out an operating point X corresponding to which this maximum power would transfer from the source voltage all the way to the gap till then I would like to end this module now so till then thank you very much and meet you or see you in the next module thank you.

Acknowledgement

Ministry of Human Resources & Development

Prof. Satyaki Roy
Co – ordinator, NPTEL IIT Kanpur

NPTEL Team
Sanjay Pal
Ashish Singh
Badal Pradhan
Tapobrata Das
Ram Chandra
Dilip Tripathi
Manoj Shrivastava
Padam Shukla
Sanjay Mishra
Shubham Rawat
Shikha Gupta
K.K Mishra
Aradhana Singh
Sweta
Ashutosh Gairola
Dilip Katiyar
Sharwan
Hari Ram
Bhadra Rao
Puneet Kumar Bajpai
Lalty Dutta
Ajay Kanaujia
Shivendra Kumar Tiwari

an IIT Kanpur Production