Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-2

Module-32
Electrodischarge machining sytem

By
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Hello and welcome to this manufacturing process technology part 2 module 32.

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We were talking about designing of En circuits.

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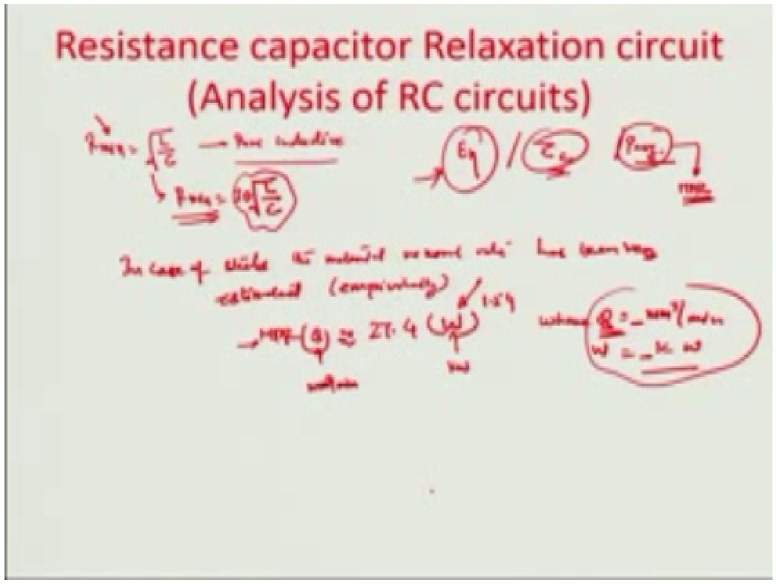

And the way that, you know you would setup the minimum resistance particularly in pure minimum circuits like the circuits. And we found out, we sort of postulated that these values of they are minimum in the charging circuit they seem to be typically route of L/C. However, these are randomly in pure inducting circuits, pure inducted circuits and such inductive circuits particularly if you have minimum applications in mind is not possible.

So therefore, you need to introduce sort of a huge safety factor, because you do not have pure inducted circuits normally in all the such, you know resistance capacitance in accession circuits for En operation, there is always going to be a capacitor in low in such a circuit. And you can actually than in this state, you viewed this value from our minimum of link L/C with 30 times root L/C.

So there is a lot of safety factors that you are introducing for calculating this minimum resistance or critical resistance. And you can at this time just borrow this as a thumb rule rather than derive with the details of how just would have happen. So let us now try and apply some of the formulations that we have mailed regarding the total amount of energy that is being discharged, let us say En and also the total time for which such energy is this charge, so that we could actually calculate the average power.

And then that the average power we can actually try to sort of correlate what is going to be the amount of the material removal rate for MRR, removal rate. So there have been minute studies particularly, empirically oriented studies and in case of steels, the MRR, the material removal rate had been very well estimated. Now I would say that this is being estimated empirically, so let us put this term here.

And it is being found that the MRR actually follows a condition probably 7.4 times of $w^{1.54}$ where the MRR Q is in millimeter cube per minute that is how the Q is represented. And the power of w in this case is represented as kilo watts, so many kilo watts. So there is a very nice to ablation between the power and kilo watts and MRR in mmq per minute, through this empirical relationship.

And so, if we are arriving at this exact power conditions by looking it toward the average power of, you know the total dumped charge through the capacitor this resistor relaxation circuit for a certain amount of time you can see. You should be able to predict MRR pretty well, you know based on this empirical formulation.

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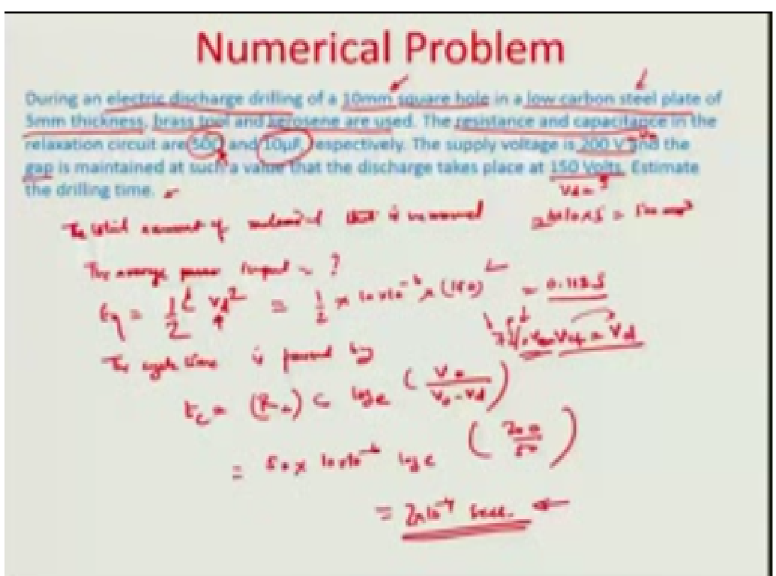

So let us actually like to, let us actually try to have numerically oriented problem where we will estimate the total machining time, so let us say we have a circuit with known parameters which is feeling to an indium setup and there is a electrode discharge drilling that we are performing where the target is to drill at 10mm square hole in a low carbon steel plate for which this relationship holds very well, the Q and W relationship that we showed in the past slide.

So the plate has about 5mm thickness and the tools that are used from this porpoise are made of brass, kerosene is the directed fluid that is being introduced inside in the inter electrode gap. And we also have resistances and capacitances defined in the relaxation circuit as 500 ohms and 10 micro farads respectively. So this has been taken into consideration of the minimum resistance etc, and this 500 ohms is definitely above the many in resistance that should be taken in this particular case.

And there is no R keying, but on this sparking in this circuit. The supplied voltage is around 200 volts that is over the input voltage V0 is, and the gap that is maintained between the braze tool and the local carbon steel plate is maintained a such a value that the discharge would happen corresponding to a VD discharge voltage of about 150 volts so that will estimate what is the drilling time.

So obviously there is a question of what is a volume that you need to del first and then you look at the material removal rate and try to find out what is the time that it would take for this EDM you know capacitor resister relaxation circuit to machine the particular $10mm^2$ hole over thickness about 5mm, so let us now try to find out what is going to be the total amount of material so the total amount of material in this case that is removed is basically a 10 times of $5mm^3$ so that is about 500 mm^3.

And the average power input actually has to be calculated and for that we need some values like finding out is the EN in this case En is ½ cv_d2 v_d voltage is already know the capacitor is at operating at about 10µF so we have total energy packet to that gets delivered through one spark as ½ times of 10 10^{-6} times of 150^2 which is actually yields 0.113 Joules so let us find out the cycle time.

So the cycle time is found by E_c = the R_c value of the charging circuit times of the capacitor which is their times of $\log_c$ which is natural log of v0/ $v_0 - v_d$ please remember we are operating at a vc_d value which equal to the gap voltage v_d where the when the discharge would actually start to happen, so the voltage should be at least above v_d for the hole discharge to take place anfc this in a maximum power transfer is operated typically at 72% of the input voltage.

Okay in this case may be we are just slightly of sifting because it is really not 72% here it is about it shifted a little bit having 72% the voltage at which it would have operated goes 144 in this case it is 150 so it is quite near through the maximum power transfer condition so let us look at what is the T_c value in this case so you have 50 Ω times of 10 10^{-6} F of capacitor times of $\log_e$ of 200 / 50 which gives you 7 10^{-4} s so that is called to be the charging time typically these sparking time is so small that the overall charge delivery happens in a time equal to the charging time.

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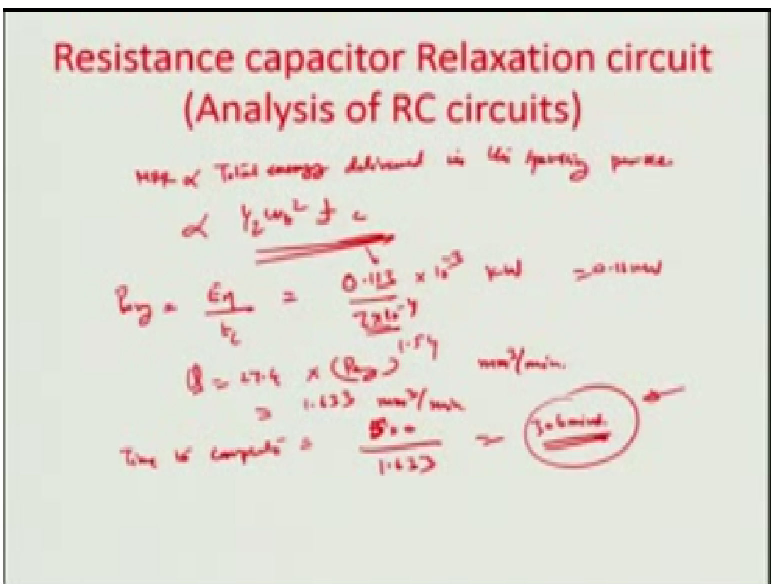

And how you said that we try to core the next step to sort of see what is the spark frequency MRR as you know from the plus rate as you know is also being by totaled energy delivered, in the sparking precept okay so we can consider this to be like ½ Cvb^2 times of the frequency at which sparking would happen which is one upon the PC value which is going to be so the average power in this case, the average comes to be En/ Ec which is 0.113 times of you know let us make it kilo joules for example and V^{-3} kj/ 7 into 10^{-4} seconds this is the total discharge in time.

In which this start this as energy so many kilo watts is power and so this becomes it could 0.16kw we all be know there is a well defined relationship and pre call relationship that exist to be mrr 27.4 times of total power which is there 10kw $V^{1.54}$ and a q show try that is in min3 / per unit so we have the total mrr to be 1.623 min^3 / minute of total amount of trying to compute the drilling okay, so time to complete drilling process then becomes $500m^3$ / 1.66 and few per minute.

Which is close to about 306 minutes so we can think of it that a 5mm takes place of from steel takes about 306 minutes to get ready to this process, so therefore which process has quite high specific energy of material removal as well very less very, very high time which you can even typically would have or very low rate of material removal is this high point of machine, but still the process is referable because you know you can oh, to this process attempt some of the alloy so which is very hard in a device.

And it becomes allowing the fair if you very wanted to be material the machine and also sometimes complex a shapes or cavities into the drill where is not there are alternate but if we go through this spark machine process so that is how we can actually define rcc circuit to credit the total MRR value or the material removal rates of a system let us look at how the material removal rates.

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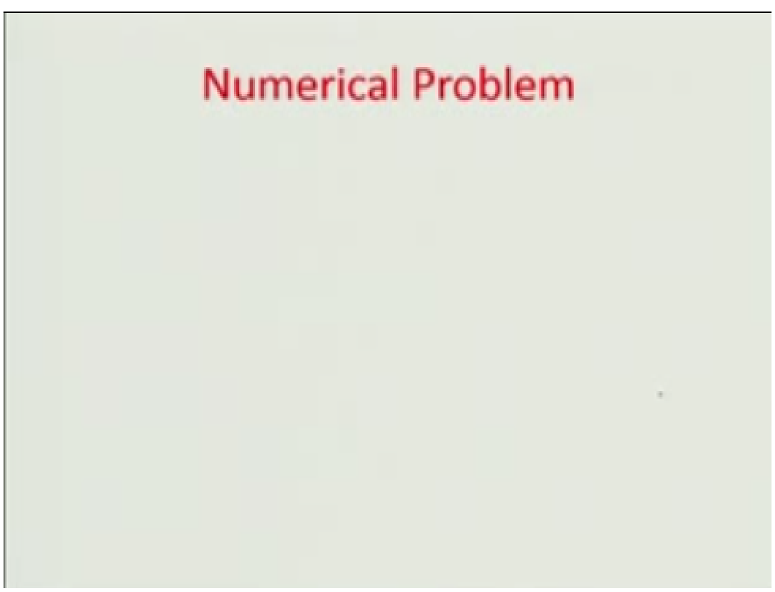

Value the different parameters related to this system.

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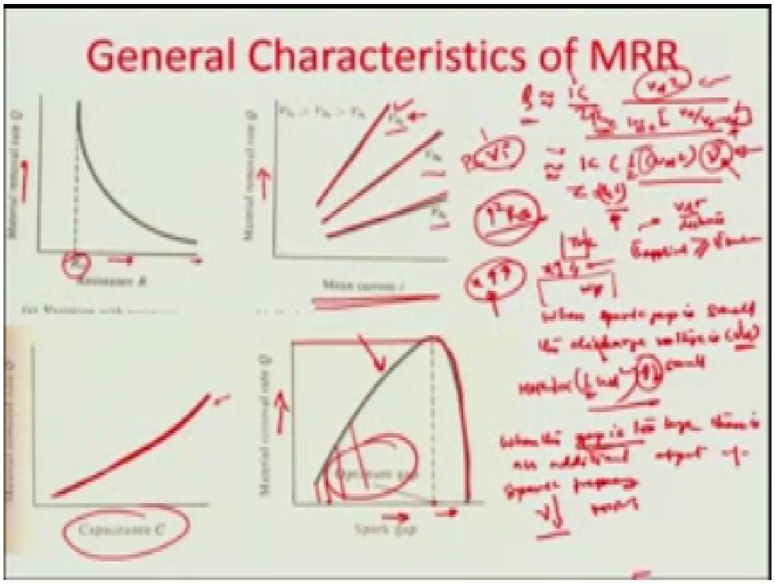

So here we have 4 different trends where in one thing we are shown variation of true with respect to the value of r the resistance of the circuit and remember Q id actually almost equal to some constants time f twice as seen and V^2/log (log$_e$ V0/v0 –vb) okay that is how the energy frequency product kind of looks like this form the last step the cd^2 is out of the ½ cbb^2 cb constant is club that would be overall constant here.

And so that is how you can probably think of so you can just write it down here let us K times of ½ cbb^2 times spark frequency μ at which is typically this RC, 1/RC times log(log$_e$ VO/ vo – vb) so here if you look at the distance for example it is it has an inverse relationship with respect to the material who will rate.

So basically the resistance increases the rate should fall down okay and so it is asymptotic here that the distance is infinity material new rate ideally slashes to 0 obviously it starts at a critical distance beyond which really this sparking condition would away I have just shows you how a minimum distance is needed for this path frequency do not be infinity okay so which really is a condition we should avoid in EDM.

And then obviously if we look at the variation of material removal with respect to capacitance so as capacitance is a proportional relationship with respect to MRR you have almost you know an increase in the MRR with respect to the capacitance obviously the you know the clubbing of capacitance may not be linear in this case because sometimes so the non linear behavior of the capacitance may really be because you have a component of capacitance also determined this factor μ.

If you remember we are operating at a certain gap voltage Vb which really depends on a lot of other parameters including what is going to be deal capacitor at a part of the discharging circuit etc, so typically you have a contribution in you know the of the capacitance remember the time constant that we look it was actually RC times of C which was a very critical parameter needed in all our calculations related to the 1.26 τ = Tc criteria.

The maximum power transfer criteria so all sudden done the capacitance therefore at a higher capacitance value shows a non linear behavior it will not be that important towards the beginning but the continuation gets coupled as the capacitance increases, similarly if you looked at the mean current obviously this is the gap current we are talking about so the current is more then there is going to be a a change in the way the power is transferred.

So you always have to remember I^2 Rs this distance the power so if I increases or the current increases so the power should increase and that to a different voltages if supposing the I is more you will have more and more material removal rate because this Vo3 is basically the input voltage and the power really is also a voltage current product so the current is more and voltage is more obviously the total amount of power delivered will be more and so the material input would increase.

Because of that, that is why at a higher voltage you are having more material being removed with respect to mean current in comparison to a lower operating voltage v_0^1. This is also a very interesting you know trend between spark cap and material removal rate and as you can see there is always an optimal spark gap over which the material removal rate maximizes itself so let us look at why that happens because you know if this spark gap is small let us say you know when the spark gap is small the discharged voltage vd is small.

Why is vd small as I earlier mentioned that you have a tool and a work piece and there is a question of breakdown of the medium which happens where the total you know applied electric field should actually be either more or equal to the break down electric field. so obviously vd equal to the total you know gap voltage at the discharge point per unit the distance you know between the two electrodes so at a smaller gap at lower value of voltage obviously there would be a sparking condition which are polarize that.

So because the vd is small and MMR typically you know really a function of $1/2cvd^2$ and also the operating sparking frequency new so vd small makes the MMR smaller, so smaller is the spark gap here as you can see the MMR kind of declines. Now after certain critical limit has been crossed you know or let us put it this way when the gap is too large there is an additional aspect of spark frequency.

See the spark which is created has to travel across the gap and in the gap is more and more let us say this distance is higher and higher this park would take considerable amount of time to travel from the tool to the work piece and because of which this spark frequency where it come down like nothing, okay so at a higher gap the new comes down the spark frequency comes down because of which the MMR again comes down.

So therefore after certain gap if you keep on increasing the gap and the frequency is the dominant term here in that case you know the coming down to the frequency will be so over dominant that the MMR will fall down all of a sudden, so that is how this optimum gap criteria is a kind of build in a you know idiom system so typically all the CNC driven systems they have as a part of the program the gap optimization where this gap optimization is done through volt at sensing across the gap.

And there is a close to feedback control which actually drive so the tool will move towards the tool move towards to the work piece so that it may operate at a gap where material will rate that take places maximized, so it basically operates a dominant gap condition. So that is one aspect about how the different parameters would lead to a variation in MMR. Let us now look at some of the other circuits which are very important apart from the capacitor resistance relaxation circuit that you saw in the last few slides.

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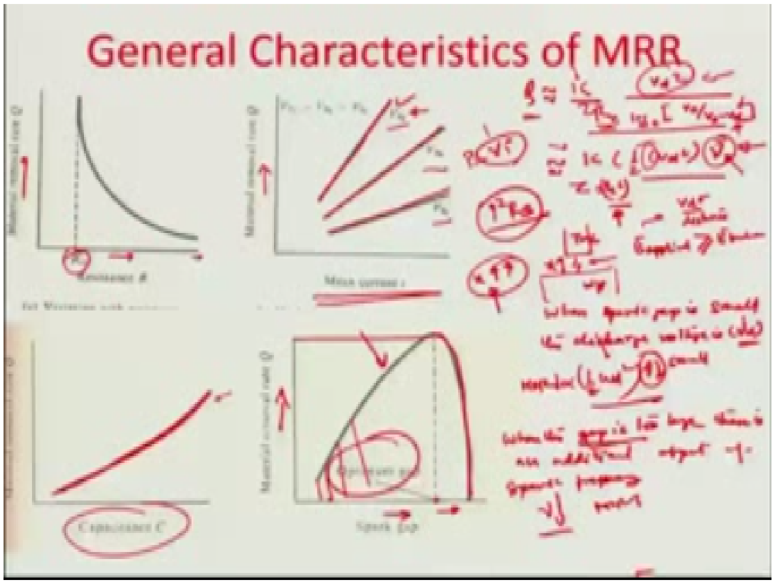

The other power transfer circuit which is very commonly used is the rotary impulse generator circuit.

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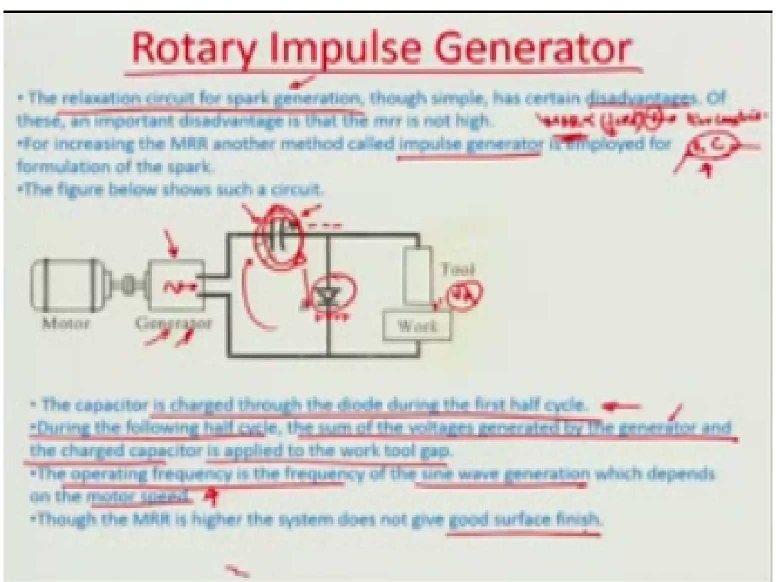

And this is typically having some advantages over the relaxation circuit for spark generation, you know one of the disadvantages that such relaxation circuit for spark generation would have is limited MRR because as you can see MRR really depends on the spark frequency or also this spark energy and the frequency is again particularly dependent on the time constant which is the limiting step in this particular case because frequency really is a function of rc x c okay. So time constant.

So if something had time constant defined by you know parameters of resistance the capacitance which are in the circuit with variability that you would able to be able to influence you know in determining this frequency would be very limited and so you cannot really operated of very high MRR in that condition. So how else do you operate at high MRR, because the industry really wants that the yield of the process is too improved? So one the method are mentioned her is called impulse generated method, so if you look at this circuit diagram write here you can see that there is a diode which is actually connected across you know the charging circuit.

And you can think of that the generator produces an operating voltage where in one cycle then you know it is an AC cycle that comes in, so you generating in AC signal here so in one cycle when the capacitance when this particular polarity is positive let us say okay and it forward by as the diode the current would go in the charging circuit and charger. This capacitance in the second illustration when this becomes again reverse bias that I would changes or imitation and this you know second cycle it becomes negative and this is becomes positive so the diode is reverse bias and it is like a open circuit, so there is no charging which comes in.

So what this generator dos is to create a signal very quickly as a function of time where with different time scales you can built up the charge on the capacitor v liquidly for all those cycles where the diode is forward bias. So the capacitor is charged through the diode during first half cycle during the following half cycle the sum of the voltage is generated by the generator and this charge capacitor is directly applied to the work tool gap.

So you know as soon as the VD voltage is arrived that of the capacitor in to this charge as you know there is one capacitor which is being used normally for operating for the charging as well as the discharging sight and you know you basically adding up or building up on the voltage by charging this capacitor probably one time or many times will be positive with the cycle of the generator which would enhanced in voltage.

Till and then tell the gap voltage is crossed over, so that there is a discharge from the tool side in to the work piece side. So this is a very nice node of quickly having a discharge and the velocity of the or let us say the velocity at which the rooter would be operating of the generator would really determine how many quick sparks can be deployed, and generally the overall material removal yield would be higher because the generator velocity can be or the rooter velocity here of the generator could be change significantly to achieve a high spark frequency condition.

So the operating frequency obviously the frequency of the sine wave and I can leave it in the motor speed so that the frequency can be elevated and so it gives you a generally a higher MRR although there is a problem there is an issue of not having good surface finish because it is a fast process, so set of sparks can be very damaging overall on the whole work piece system. There are other circuits as well which can also take care of you know some kind of search protection.

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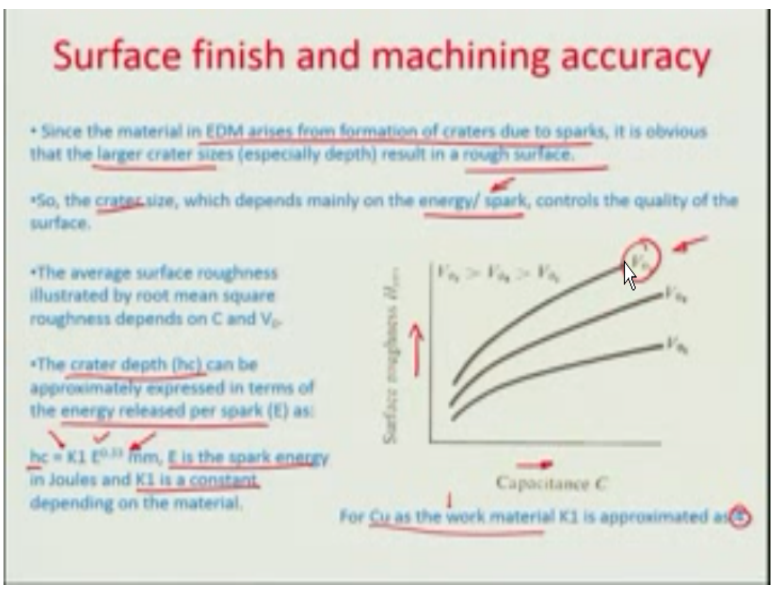

Particularly there is a busy source which is employed here or even in gen set and so there is a sort of requirement that you do not you say you know the remaining part of the circuit from the search which happens because of the sudden discharge across this two electrode gap. So we have solid state control pulse circuit for this kind of an operation which really use to have valve tubes earlier.

So this was like more like consistor and you know when current is to flow to the gap so the this kind of a valve tube were working to it was bias took it off and gave like an infinite resistance at some point.

So that it could save the other part of the circuit like an electron controlled module or the easy source but here during this sparking the current which flows to the gap comes from direct discharge of the capacitors you can see here so this is the osrt of a main you can say suitable resistor which can become controlled through the electronic controlled manner so that is the resistance can be changed.

And typically this can be replaced now by loss transistor there you can control the gate potential so that there can be a change in the drain source current and there can be a change in the certain resistance because of the change in the gate potential so this is the sort of an automatic control where vacuum tube was switching device and it would replaced the resistance of the resistance capacity and relaxation circuit.

So as soon as the current in the gap would sees the conductivity of the tube would increase and then could allow the flow of the current which charge the capacitor after every discharge cycle for the next charging cycle so that is how the controlled pulse circuit of the controlled pulse module would be utilized so there is a big issue of surface finishing machine as were in the EDM process goes.

And for that there are again certain guidelines which are laid out through different you know iterative machining modules so this graph here shows you know the variation in the module square surface finish off machining surface with respect to capacitors as you can see their higher capacitor of the voltages increased and the power actually increases because of all those there is a tendency of the roughness to increase because of increase power.

So really the goal here is to have a control power delivery from the tool to the work piece for any kind of you know surface finish also high surface finish is to happen in the whole process so since the material will be medium or rises from the formation of the creators particularly into the sparks is obvious that larger greater sizes would result in a rough surface.

And has a greater size typically depends on the energy per spark this would be any there aspect which controls equity of the surface so typically things like creator that for example X see they can be approximately expressed in terms of energy reduced per spark in the empirical relationships to do that earlier.

I think we have studied when we talked about how the greater volume can be estimated through the heat conduction process of a spark so we had a grater that the estimation depending on park energy given by k1 to the power of 0.33 millimeters were E was the sparking energy in Joules and K1 was a constant okay K1 was a constant depending on a material and as such you can estimate if this electrodes can be let us say copper, copper so if we have a copper work material in a copper electrode the K1 would be approximate as 4 etc.

So in general you have empirical formulations for medium process were we could correlate surface roughness to any of the operating parameters so I would like to finish today at this point this particular module but in the next module we will talk little more about surface finish also relating surface finish to things like material removal rate and may be also some other mortalities related to EDM which would related geometrical effects of EDM process on different work pieces. So today we will stop here and then see in the next module thank you very much.

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