Microsystem Fabrication with Advance Manufacturing Techniques

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Lecture – 24

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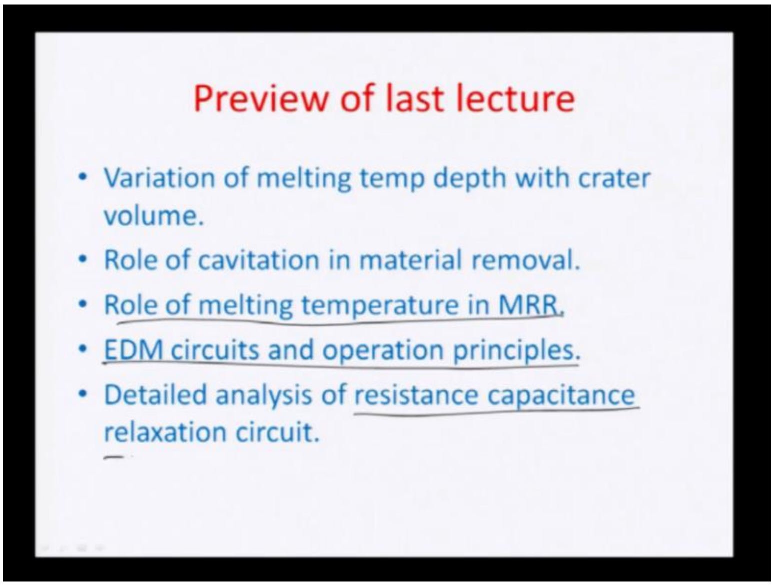

Hello I am welcome to this twenty fourth lecture of microsystems fabrication by advanced manufacturing processes, you had the following things covered in your last lecture one was the variation of melting temperature depth with crater volume in e d m processes we also covered the role of cavitation material removal particularly, because of the formation of plasma within the e d m there is a tendency of a low pressure region to be created which actually drys away most of the material, and is responsible for most of the material removal, and the e d m process.

We also considered the role of melting temperature a in the m r r melt in material removal rate, and then we discuss some basic principles of e d m circuits for example, the resistance capacitance relaxation circuit the the circuit was very briefly analyze also mathematically as well you also had the rotary impulse a generator type circuit, and then we had this solid state controlled pulse circuit another three main circuits of e d m which an the various operation principles we also covered detailed analysis particularly of this resistance capacitance relaxation circuit, and just like go through once more before starting.

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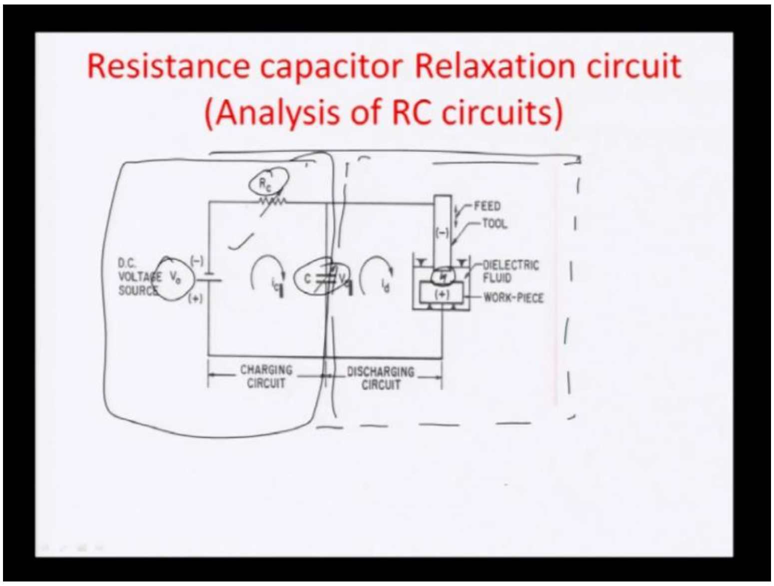

So, basically this is the figure of the resistance capacitance capacitor relaxation circuit as a, you can see here there is one part of the circuit here, which is the charging circuit, and similarly other part here given by the dotted line is the discharging part of the circuit the a d i is there is an operating voltage, which feeds in charging circuit there is in the central capacitor, which is the only electrical connection between the charging, and the discharging side both the circuits and. So, this actually is a r c network as can be seen with the variable resistor, and the capacitor charges in once cycle, and then this charges based on this gap potential which is there between the tool in the work piece in the e d m tank the the electric distance machine in tank.

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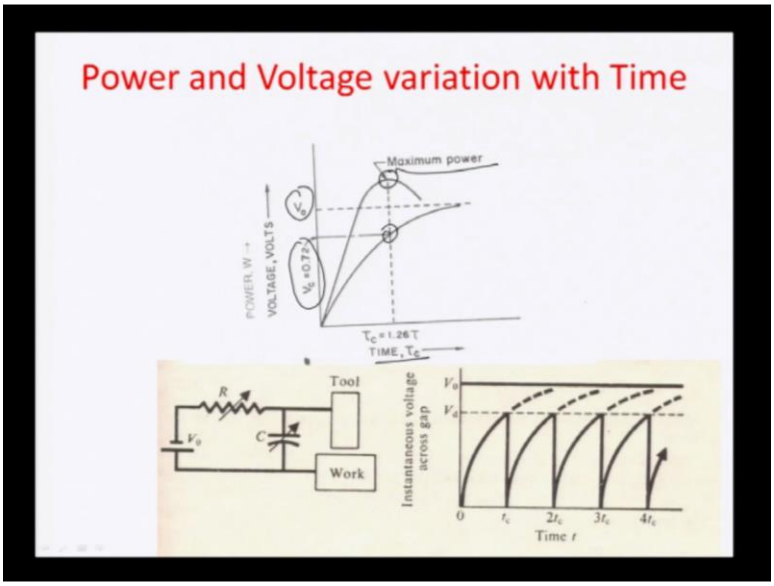

So, we found out that using some r c modeling r c circuit modeling the this we see corresponding to the maximum power transfer is actually seventy two percent of the operator voltage. So, the the operating point of the capacitor or the capacitor voltage is only about about seventy two percent, and that corresponds to the maximum power you can see here in this particular figure with respect to the time constant you are actually plotting voltage, and you can see that corresponding to this point right here seventy two percent of the operating voltage you have maximum power, and some retinues the calculation were made doing that now if we really want this power to be fully delivered on to the the charging part of circuit we should somehow be able to equate the break down voltage of the directly medium we doing the tool, and the work piece to this this seventy two percent of the we operating or v o voltage of the charging part of the circuit.

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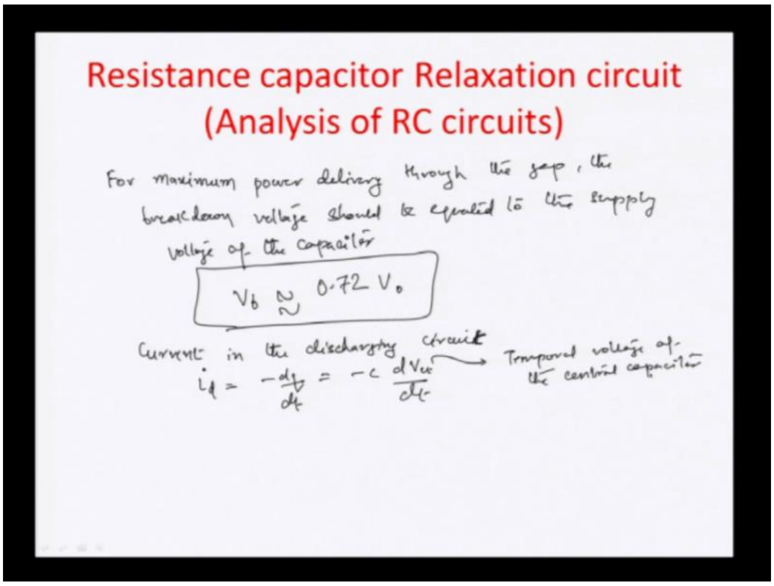

So, therefore, for maximum power delivery through the gap the break down voltage should be equated to the supply voltage of the capacitor, and other words v zero sensitively equal to zero point seven two v o v b i am sorry the break down voltage vb is equal to seventy two percent of the operating voltage s current in the discharging circuit can also we evaluated by using law. If you just go back own slide in see what the discharging circuits like you have really this part this dotted part of the circuits discharging circuit. So, you have an operational voltage seventy two percent of the v o are the charging voltage in the capacitor, and if you apply ohms law here in this particular circuit in the i d what is the current across the under charging circuit also can written down as minus d q by d t it which is minus c v c t by d t, we city is the temporal voltage of the central capacitor you apply the ohms law.

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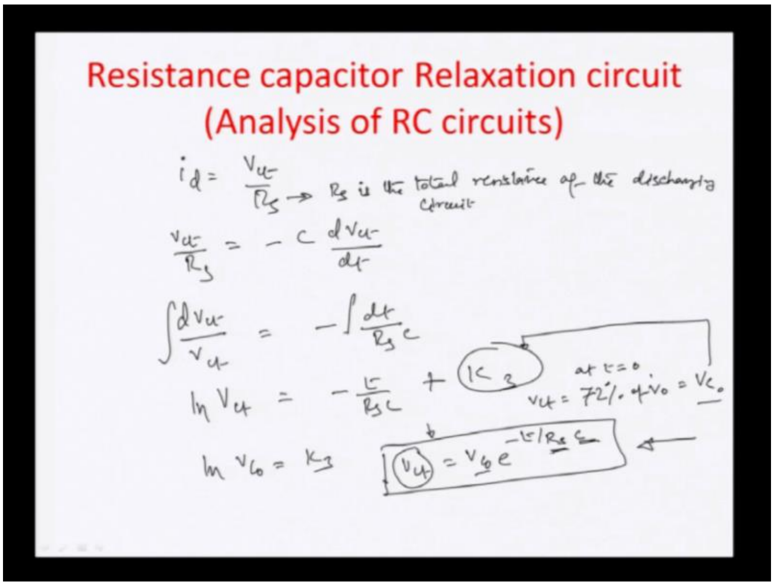

The total current in the discharging circuit nothing, but this v c t by the total resistance cut take, total resistance r s which is this resistance of the discharging side. So, the v c t by r s becomes equal to minus c v c t t v c t by d t and. So, we try to integrate this in time, and see what is the outcome. So, d v c t by v c t the actually equal to minus of d t by r s c integrate both on time we get natural log of v c t comes equal to minus t by r s c plus integration constant in call this k three it is find out what this k three is. So, at time t equal to zero.

We already know v c t is actually equal to seventy two percent of the output v o the the input voltage the operating voltage on we call this d v c o. So, this is corresponding to the value of v c at time equal to zero an. So, if you put this back in to equation here corresponding t equal to zero we get ln v c o is equal to k three on other words v c t can be written down us v c o e to the power of minus t by r s c therefore, the relationship on the discharge side of the second si simplistically given by the charging voltage on the capacitor on settle capacitor v co s the charging voltage on the central capacitor act at been show the discharging process happened times of exponential minus t by r s times of c c is the capacitor the capacitors on the capacitor, and r s is the total resistance of the discharging circuit. So, as we know that we know we city of is already defined.

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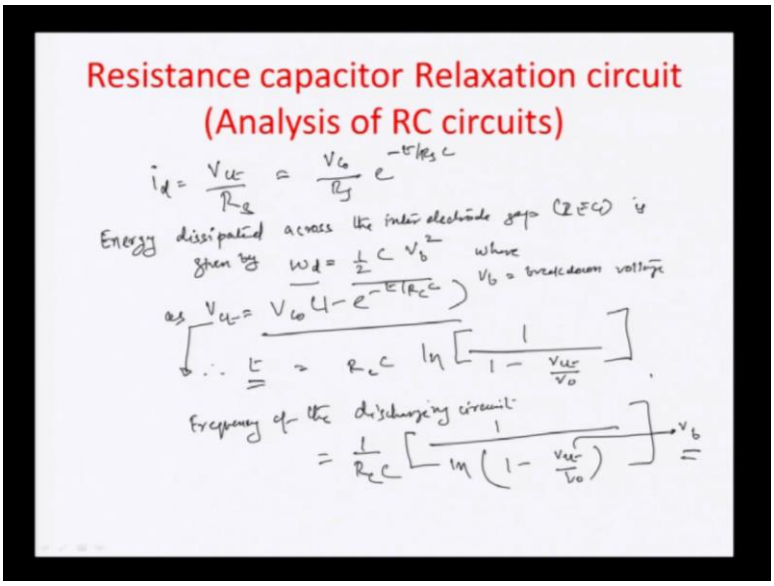

So, we can find out id again which initially defined as v c t by r s the resistance of the charging circuit in this case we can write this terms simplistically as v c o by r s e to the bar of minus t by r s c. So, energy dissipated a cross the inter electro gap is given by half c v square, and in this case the v is corresponding to the break down voltage of the medium we called it v b an. So, w d the total amount of energy dissipated a cross the gap to have cv v square v b is break down voltage as v c t is equal to v c zero one minus e to the bar of minus t by r c c remember the charging part of the circuit, but this equation at come therefore, we can say from this particular equation the time t can be computed as R c c in natural log of one minus one minus v c t by v zero an. So, frequency of the discharging circuit which is the time inwards on. So, therefore, the frequency is one by rc c one divided by is whole term ln one minus v c t by v zero were v c t is nothing, but the breakdown voltage v b as be already seen before in the last illustration.

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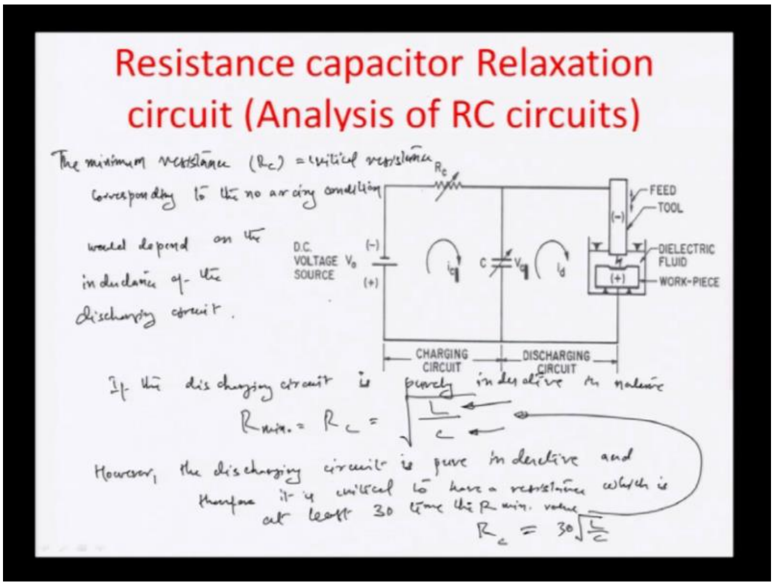

So, that minimum resistance r c that will result in a control of the process without the formation of any arking a such is known as the critical resistance for this particular circuit an. So, then the critical value of resistance corresponding to the no arking condition.

What typically depend on the induction of the discharging circuit an supposing if the discharging circuit it is purely inductive nature of the critical resistance are minimum can be written down as the total amount of inductance of the discharging circuit permanent of the capacitance in central capacitance value c; however, the discharging circuit it is hardly pure inductive, and therefore, it is critical to have a resistance which is at least thirty times the r minimum value as shown here thirty root l by c is operating point for the resistance corresponding to no arking condition. So, in an shall we have kind of see in that the relaxation the resistance capacitance relaxation circuit is limited by the resistance of the charging side, and the most to the case that is around thirty times we root of l by c l is inductance of the discharging circuit, and c is the capacitance the central capacitance between the charging, and discharging circuit.

So, in case of machining t is there are certain convention, then there are certain correlation data, which are followed by for estimating real relationship between the material removal rate, and the amount of power that is delivered on to the work piece by the e d m system an…

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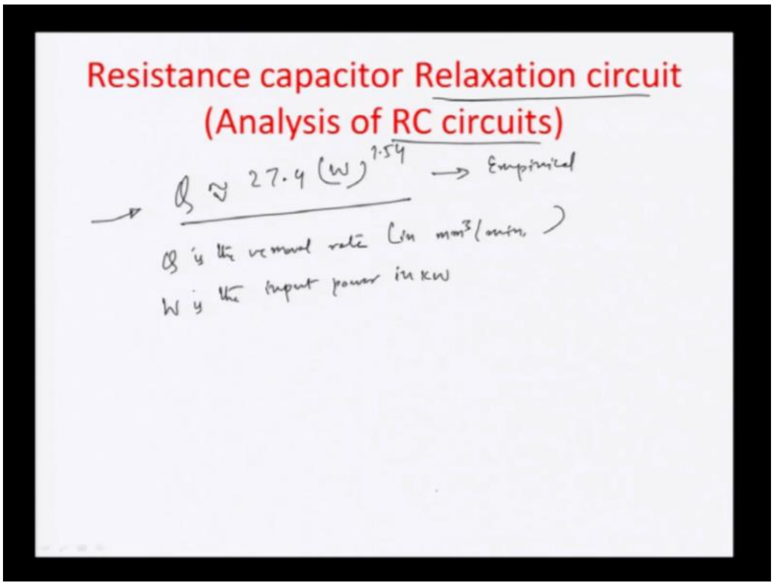

So, one such relationship which is very common we used is a mathematically q equals twenty seven point four w to the power of one point five four, and this is purely empirical based on experiment the various parameters that are used to the experiments here there are q is the removal rate typically it is millimeter per minute millimeter cube per meter volume per unit time of material removal, and w is the power delivered of the input power you can say on the relaxation is the discharging side of circuit in kilowatts. So, such relationships are very of an used in e d m process we should also help us understand, and designing the r c circuit of the relaxation circuit for feeding, and e d m tool.

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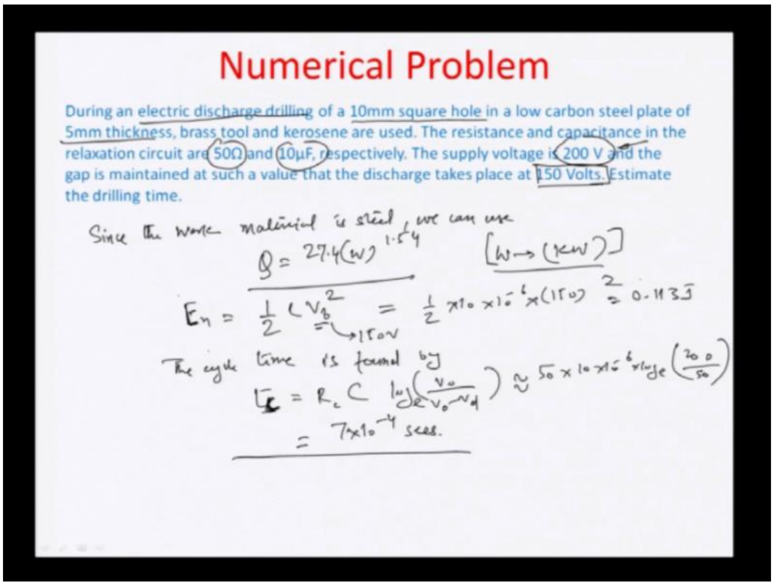

So, do an numerical problem based on that as illustrated here that in electric discharge drilling processes of a ten mm square hole in a low carbon steel plate of thickness of five mm brass tool, and kerosene are used as kerosene is dielectric brass is tool the resistance, and capacitance of the relaxation circuit that have been designed the given a fifty ohms, and ten micro respectively, and it also indicating or or it is also indicator.

What the supply voltages an order of the supply voltages is about two hundred volts, and a you maintained gap between the tool, and the work piece in the manner. So, that at one fifty volts breakdown happens. So, you can see here break down takes places one fifty volts that is how you estimates the gap, and you have to estimate how much time is needed for drilling the soal. So, one way of looking added is that since the work material is steal here we can use are the coefficient that is talk about earlier for steal q equal to twenty seven point four w to the power of one point five four for m r r estimation, and the w of course, needs to be indicates kilowatts there is the assumption that we made in the last an curriculum an…

So, that therefore, we have to really calculate what is the energy being this charge is already know that the energy in delivered by the capacitor c in the breakdown of side is given by half c v b square were v b is the break down voltage, and this break down voltage has already been illustrated here in this an example hundred, and fifty volts for the capacitance of ten microfarads on these becomes equal to half time is of ten bar of minus six time of square of one fifty is zero point one one three joule, and cycle time in cases found by t c the equation, that was discussion earlier is r c times of c loge of v zero by v zero minus v d v d is the discharge voltage in this is loge the v c. So, this becomes equal to fifty times of ten twenty for of minus six the capacitance of times of loge to the base e of the operating voltage which is taken are to hundred volts in the example divided by the v d minus v o which is fifty volts in the particular case. So, this corresponds to a time of brought seven ten to the bar of minus four seconds. So, once is the time is known should be able to find out.

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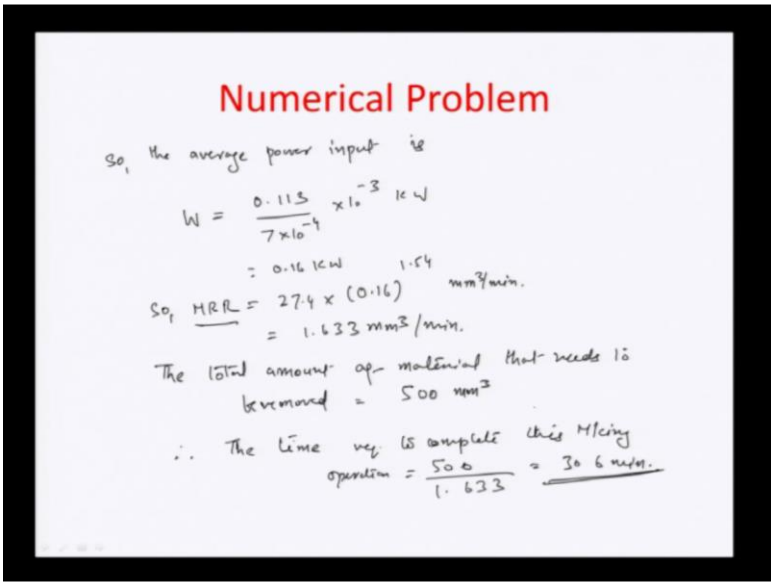

How much power is being delivered as the average power input is w equals zero point one one three joules the energy the there has been this charged by the d machine divided by seven ten to the par of minus four seconds an this power is kilowatts. So, which basically ten to the bar of minus three kilowatts which make zero point sixteen zero point one six kilowatts, and using the equation that we had discuss about mile steal particularly m r r a can be represented as to as twenty seven point four times of this value of w in kilowatts to the bar of 1.54 in millimeter cube per minute to this is the estimation of what would be the material removal rate at this in our case comes out to be equal to one point six three three millimeter cube per minute we also know by of of the question that the total amount of material that needs to be removed is calculated about five hundred millimeter cubes it is can be geometrically done the dimension of the hole the thickness of the provided in the question an. So, therefore, the time required to complete this machine in operation comes out be equal to five hundred by one point six three three that is three hundred an six minutes. So, you can estimate.

The rate of a medium process an particular rate of removal an realize that a in about three hundred an six minutes you can actually just be able to drill a very small hole on a thickness of the sheet which is about five millimeters. So, in comparison to any conventional process a this process of course, is a slow process, but the medium has an advantage that you can work using some of the lawyers way of probical mentional machine in may not be that helpful in this particular case as you see there is low carbon steel plate which is bring drill a who with some times is very challenging in the conventional machine in when it comes to tool designing etc for the particular surface also this is the of course, a regular to topology**,** but, then topology is very complex correct profile matching of the conventional machine in side on see an see or some other set up becomes absolutely complex an. So, e d m can work as the very good tool in those illustration all though the time of machining may be little higher rate of material remover may be slower.

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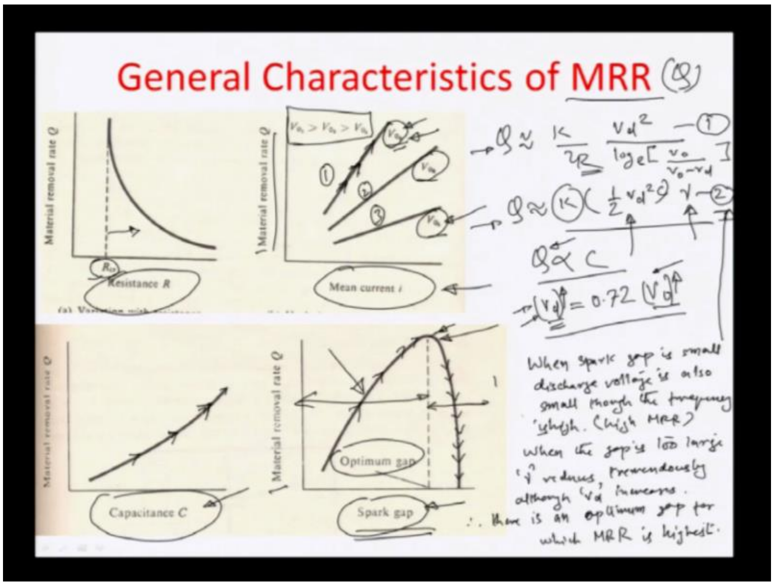

So, let us now look at some of the other important accepts some of the machine in trends with the different parameters that we have discuss. So, far. So, here a in this particulars slides we are illustrating in variation of the material removal rate q with respect would a parameter like the resistance of the charging circuit the mean current i, and this particular resistance that is the capacitance c of the the illustration circuit, and then of course, the variation of a m r r with respective the part gap. So, as we already in know the equation for material removal rate had been earlier defined as to be proportional to this terrm v d is square divided by log to the base e v zero by v zero minus v d, and q was found us k times of half v d square c times of new were new is the frequency c of generation of the spark of c vd square is the total amount of discharge energy that is needed by the e d m process an of course, q proportional to this both this terms together. So, if you look at the various accepts in these two equation we will have different times for example, as you can see it is a involves variation of it is registrations. So, within increase an registration the m r r goes down absolutely from this equation.

And as we already discuss before the relaxation circuit is supposed to have a minimum critical resistance particularly as for as the this charge gap is concerned, because if a supposing the resistances very small there may be a arking instead of sparking an it may be a continuous phenomena arking instead of sparking which is a not really to the e d m process. So, its start set up minimum value of resistance a critical resistance which needs to be necessarily maintain in the inter electro gap. So, that successfully e d m operation can be carry doubt one of the reasons why if you look at this trend here the range of resists in really starts r c r on words or critical resistance on words, and as the resistance increases.

Material removal rate course down similar kind of trend can be discussed for the capacitance here for example, in this equation two that is call the equation one these are equation two the king is proportional to in capacitation three much it should very linear; however, in actual experiment a set up the material removal rate is found to very close to linear not exactly linear with respective the capacitance let us look at the variation of the material removal rate with respect mean current i as can be found in this g r af here if you can see that there are different operating voltages have v o three v o two, and v o o one with in inter relationship mentioned at the top left corner of the g r af here the operating voltage v o three is the highest followed by v o two followed by vo one, and as v d are the charge voltage is actually equal to seventy two percent of the operating voltage which maximum power transfer which we had actually calculated an in detail shown earlier an...

So, therefore, if the v operating is more the the discharge voltage also subsequently raises in actually it is a cause in effect which is the cause an, which is the effect. So, basically discharge voltage this is the independent parameter which is dependent on various parameters various various property of the gap the dielectric of the gap dielectric constant of the gap over the gap its self, and they are four vd is really that point of voltage which starts the discharge an. So, the V o has to be said in according this v d, and they are four, if v o is higher is automatically means the v o operating matter higher gap discharge voltage v d, and v d being proportional to q means that higher v o operating meaning there by higher v dis charge would have a higher machine rate or material newel rate in comparison to way in lower operating voltage v o one thus this different range.

So, the we thus the thus the characteristics of different v operating on different state lines from one two three as can be seen in the particular g r a f one more important point is that as the mean current increases means are the discharge voltage also is increasing, because it is a really a function of the gap resistance, and therefore, with in increasing mean current as we can see the material removal rate dissolve increasing the other important factor in this characteristics, how the material removal rate where is with thus per gap, and if you may recall this equation number two there are two components of the equation one is this half v d square c component which is the spark energy, and the other is new which is the spark frequency, and when it comes to optimizing the energy versus frequency the following things may thought of an a physical way in the e d m machine.

So, as the gap the inter electro gap is lessor you need lessor amount of this charge voltage, because the gap is very small the electric feel which is a cause take of a electrical break down is dependent on vd by inter electro distance d, and d b in small v d can also be resalable small for the discharge to occur or the break down feel to reach; however, if the distance is small there is a tendency of the spark frequency to increase, and although the v d is a smaller at lower electro distance or lower spark gap as you may better called on the frequency is extremely high on the other hand if the electron gap increases you need higher discharge voltage v d to cause the electrical feel break down, and, because the spark has to travel through all this distance a which is now higher income percent what was before in this spark frequency suitability dues. So, its a essentially a inter play between these components as a shown here in this spark energy in this spark frequency.

So, if spark lets called one, and two respectively, and of the reason why this material removal removal rate with the respective the spark gap is like plating curve as illustrated in this particular diagram here is that on the left portion of the optimum gap; that means, on this particular port the the frequency in dominate, because of lower gap, and on the right side of the optimum gap the the v d increases, because of increased gap, and the energy dominates the frequency term an. So,, because it an inter play sometimes the frequencies higher on it it increases at the material removal rate, because its dominating an in the other hand if the energy may not be that you know the rate of increase of energy may not be that high income to the frequency it leads to the fall down of the material removal rate a shown by these set of narrows on the right side of the per gap.

So, essentially you can summaries all these a by saying the when the spark gap is small discharge voltage is also small though the frequency is high result in a high a m r r on the gap is to large the frequency new reduces tremendously although the charge voltage v d increases therefore, an there is an optimum gap for which m r r is the highest. So, we have moral discuss about the general characteristics of how the machine in rate of the material removal rate in a medium process would very several process parameters they other important issue is about how surface finish machine in a accuracy can be depended on some of these parameters like for example, the capacitance or the operating voltage, and for doing that let us just see some of the important accepts to be considered in this particular slide.

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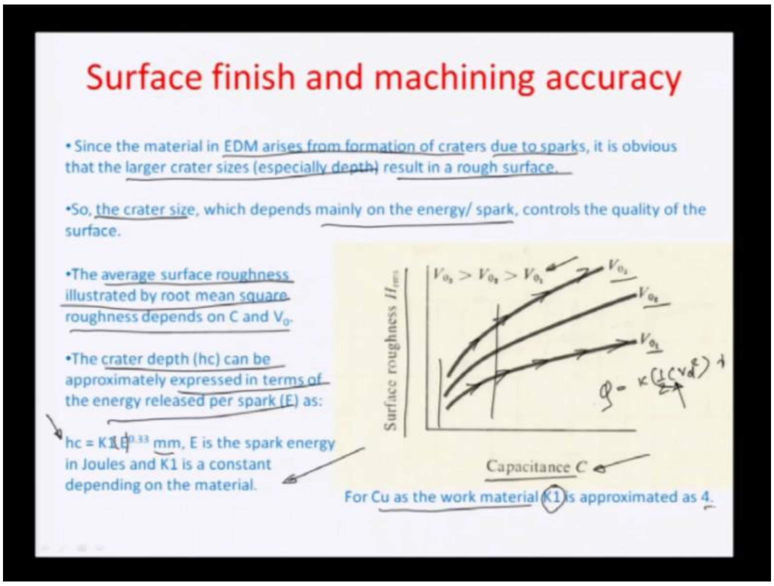

So, a you know is the material in e d m arises from formation a material removal in e d m arises from formation of the craters due to sparks an essentially it is obvious that the larger craters sizes especially creator depth result in rough surfaces. So, was we talked before about thermal energy, and the way the depth of melting temperature reaches on a crater a if the depth of temperature is higher there are roughness would go of when why worst of obvious reasons a, because you will have a deeper crater an crater by crater removal of the material over the a hole surface.

So, the crater size if we really look at mathematically we have done this are real this mainly depends on a this spark energy, and if you are realizing this energy is packet with high intensity; obviously, the crater will be deeper, and side the energy delivered is smaller, and probably the frequency is larger, then the crater would have a lower depth and; obviously, from a engineering stand point in to to be one can think that higher energy deliverance corresponds to a rough surface, and a look over energy deliverance corresponds to a smooth surface as for as matching quality is concerned. So, its controls a quality of the surface. So, the average roughness is illustrated by a root mean square roughness, and this mainly depends on two important accepts one is the capacitance another is the operating voltage, I think we have already mentioned design number of times before that a the q are q the material removal rate is really proportional to the half c v d square, and the frequency an…

So, as one can c here easily if c is more the material removal less more meaning there by the half c v d square is essentially that energy packet that we are talking about during one e d m exposer one e d m spark. So, if half cvd square is more in a automatically means that the energy density which is been delivered on to the material is much higher, and the crater size would be greater in nature, and if this lessor a meaning there by that you have a lower operating voltage on which are operating the the have c v d square would again in the way depend on that lower operating voltage on the surface of ness would be lessor or surface would be move there. So, here for example, v o three is a higher operating voltage greater than v o two greater than v o one you can see all the surface roughness trench very with capacitance as high roughness on the higher a voltage operating voltage characteristic, and the lower roughness on the lower operating voltage characteristic on the variation is moral less proportion although there are certain parts to at the very beginning were the trend is not that linear, because probably at there is still not a completely established charging discharging presidents or relationship between both the circuits both the circuits, and that is all the average surface roughness have were is with respect to capacitance also you can think of it as, but looking at that if may recall earlier we talked about the crater depth h c which can be expressed in terms of spark energy a released, and we are I would upon a formulation were this crater depth was when perically determined in terms of k one times of spark energy to the pare of zero point three three millimeters. So, if half c v d square is more; obviously, e is more an h c is more. So, that is also from a mathematical stand point some co relationship between the crater depth, and spark energy. So, copper when used it a work material experimentally leads this k one value to be approximately four, and you can accordingly find out an estimate.

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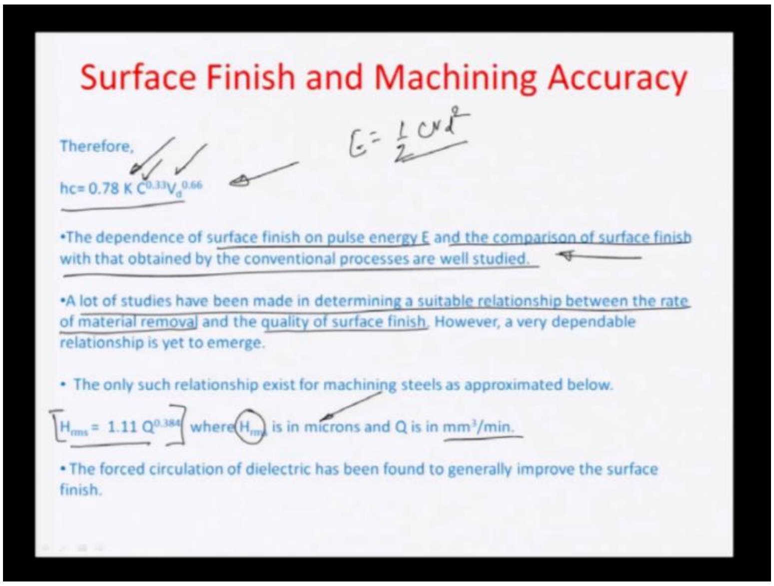

What is the surface ofness h r m s based on the material property is, and the energy deliverance on to the materials the are the other important accept therefore, is the take e to be half c v d square, and try to formulate this empirical relationship it results in to the this expression zero point seven eight k c to the par of 0.33 v d to the zero point six six k is again that constant of proportionality which in case of copper was four observe to have value four, and thus the relationship how the xv various with respect to capacitance, and also v d the discharge voltage which is again of somehow a function, and close the related to the operating voltage characteristic. So, the dependence of surface energy on pulse energy e, and the comparison of surface finish with that obtained by the conventional process are not quite well studied a lot of research has gone in the, and lot of studied have been made in determining a suitable relationship between the rate of material removal, and the quality of the surface finish; however, these are empirical nature, and very dependable kind of relationship haves not really emerged. So, for between the surface finish, and the spark energy works well in case of combinations of depend materials.

So, in particularly case of steels you have a very well defined relationship how h r m s is related to the material removal rate although it is quite empirical nature, but, then the H r m s equal to one point one one q to the par of zero point three eight four where h rms is the surface roughness the average surface the r m s roofing square roughness in microns, and q is in millimeter cube per minute generally one more accepts the we have illustrated before is that is the for circulation of dielectric in e d m tank it results in more than in the surface by lot of defuse a forces inter plate by the moving dielectric over the surface. So, it carries away the melt distributes the temperature an. So, therefore, over all there is the surface which comes, because of higher circulation rate.

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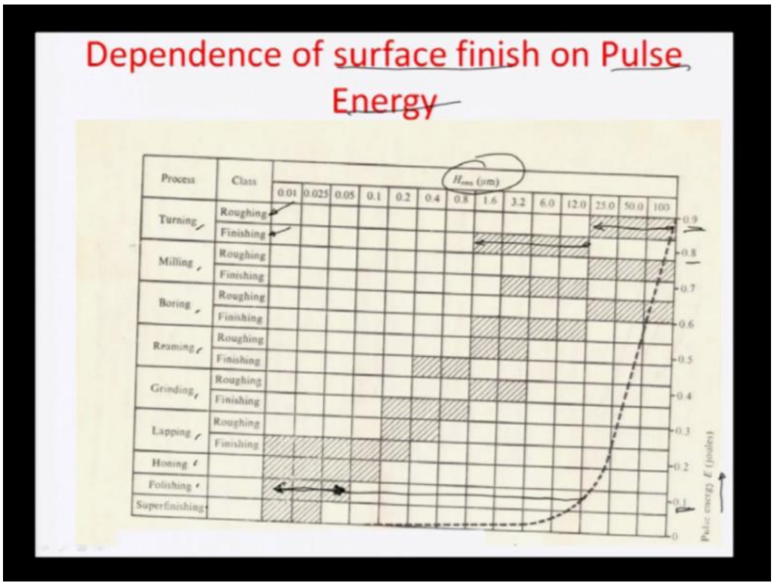

So, let us look now at the a more dependable relationship between in surface finish on pulse energy is illustrated in this process, here an you can see this spark energy on the right y access here in joules for the various operations a like electro discharge turning, and electro discharge milling boring reaming grinding lapping honing polishing super finishing, and you can see that there are two different regions of roughness of for each a one of them is the roughing a regime where there is rough cut finishing which has a lower value of roughness move that surface, and this describes the h r m s in microns. So, for example, corresponding to way pulse energy of zero point one a joule you can get a average roughness of around close to 0.01 microns when you talk about electro discharge polishing process, and as i has about zero point zero five microns. So, this is the operating range of the roughness for zero point one joule energy other side if you talk about turning operations.

So, in turning you can get a rough a range of roughness varying from twenty five to hundred microns were as corresponding to a really high pulse energy of zero point nine joule, and then you the pulse energy slightly reduced you have a finish turning finish electro discharging operation a were the roughness where is one point six two twelve microns the r m s square roughness. So, that is how you can read this particular figure this is an ensemble of the different electro discharge process with respective the roughing, and finishing roughness, and pulse energy. So, let us close this the lecture the interest of time by all this analysis about roughness an energy in the next lecture we will start from slightly newer topic of e b machining.

Thank you.