Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part- 2

Module- 25
Design for Electrolyte flow in ECM

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Hello and welcome to this manufacturing process technology part 2 module 25.

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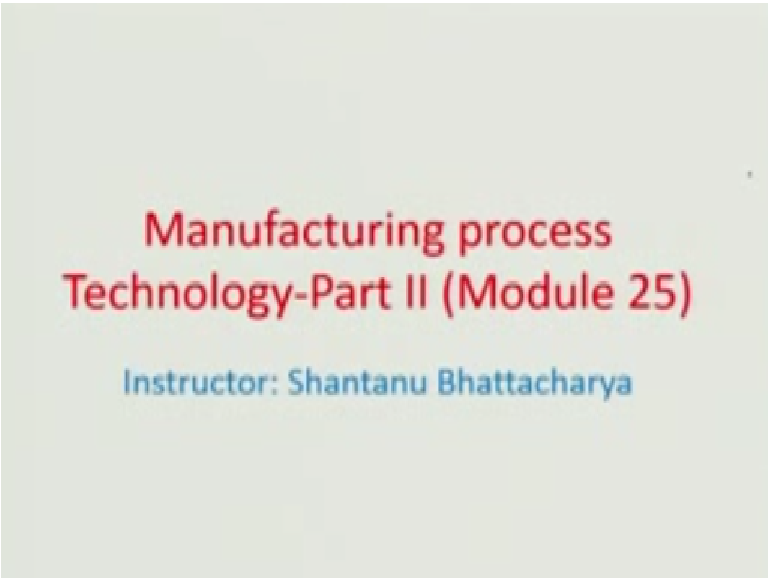

We were talking in the last module mostly about how to design the tool surface given in a certain where this geometry or a function relationship on the work piece surface and we arrived at in general two dimensional and 3 dimensional shapes of the tool given a certain work piece for 5 that has to be finally achieved through the dicing thing ECM process today we are going to look into a little different aspect once we have a estimated the shape of the tool the other aspect which is important is how to control the electrolyte flow.

And the whole idea here is that there should not be any flow separation or there should not be any local ID's or local circulations or recirculation zones which are formulated in the path of the flow so that there may be issues related to the no uniformity of conductivity and there by the material removal rate so some of the pints we should generally remember or that generally in the.

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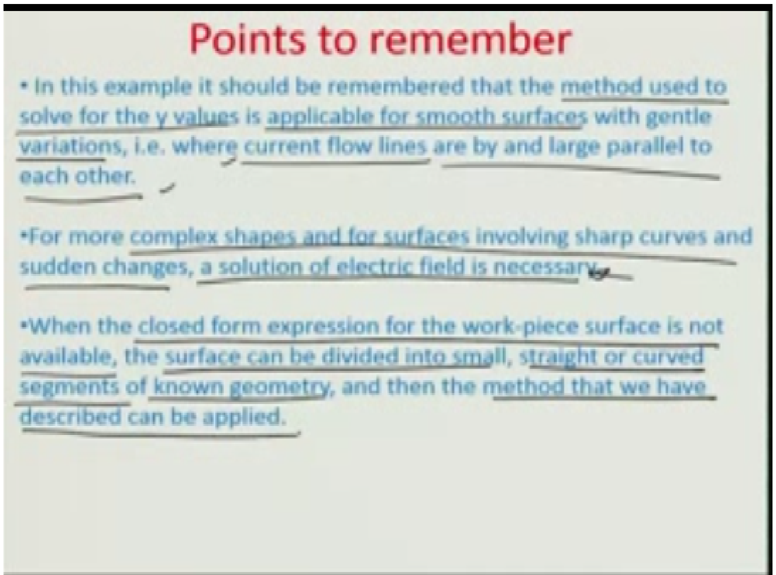

Example that you had noted in the last module where we try to estimate a shape the method sued to solve the y values if you may remember there was functional relationship between the y t and the x it is okay so this is generally applicable for smooth surfaces with gentle variations where as we should be applicability can only span in domain where the current flow lines which are formulated or by enlarge parallel to each other but however when the electric field and therefore the current paths they get stayed or they get you know concentrated may be because of some small points.

Where the field is centered particularly at the corners or at the tips then it is very difficult to maintain the parallely of the various field lines or the current flow lines and therefore the close form solution that we sort of obtain by just a function mapping as not work in that phase so for more complex shapes and for surface involving sharp curves and sudden changes a sort of a solution of what would be the electric field density with respect to the space coordinates would be a very important aspect for estimating the actual MRR at different places on the same surface okay.

So the closed form expression of the work piece surface is not available and typically you know this are in 3rd where ever necessary there is a strategy that we follow that we divide the whole surface into synthetic curves and try to join the synthetic curves together a small segments probably together in each of them would have a function relationship and that way we could estimate the overall topology of what is to be done or machined.

So the surface can be divided into small straight or curved segments of known geometry and then a method can be just used where mapping individual segments on to the tool side to develop the tool the whole tool map or the tool or the tool surface map is created so that the final tool shape can be estimated so now if once we have looked into the shape estimation the other point as I just motioned.

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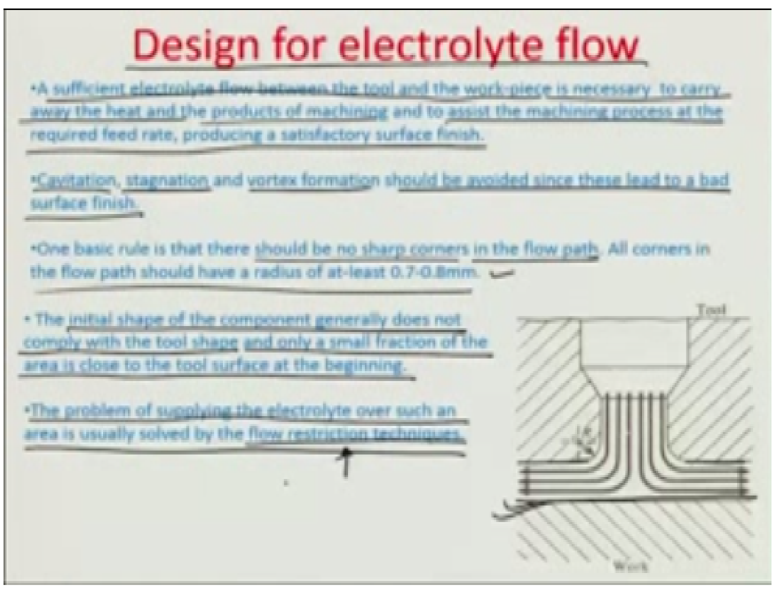

Minute a goes how to design for the electrolyte flow the electrolyte flow is a very important component because you want to avoid any kind of recirculation zones or any kind ideas where suddenly there can be a shot of the conductivity also we want to avoid any kind of flow separations suddenly where because of the electrolyte not been available there is less machining and eventually creation of boss or a rig because of improper reach of the electrolyte so sufficient electrolyte flow between the tool and the work pieces necessary to carry away the heat and the product of the machining and to assist the machining process at the required feed rate producing satisfactory surface finish.

So also one should avoid such kind of flows where there may be possibility of cavitations ort because of sudden separation of the flow there may be a tendency of bubbles to get generated in the flow or sudden let us say terming in the flow direction there may be some kind of pressure loss and because of these term there may be mix phase which may come there can be stagnation there can be vortex formation and so all be should be avoided in this lead to a bad surface finish and that is one normally we not wanted to in ECM.

So one basically it is that there should be no sharp corners in this flow path should be smooth and minor all formals in the flow path should have radius were at least allowed above 0.7 0.8 microns I mean thus about some into the microns and the differentiate of the component generally does not comply with the tool shape and only a small fraction of the area is close to the tool surface at very beginning.

So we because of the by sent needs or very seen of penalties in victim and work the surface and tools that come in and the role seen is from, so the problem of supplying the electro light particularly at the initial stages in there is no problem been diffused surface in the work piece surface is then you solved by using some flow respect in techniques and this is a very good ideal case where you can see that the tool surfaces almost parallel to the work piece with this send some samples.

The ECM is normally because rise in process so how do we do for vectors so the inflow can be routed the wavelength can reach all this town for areas where areas
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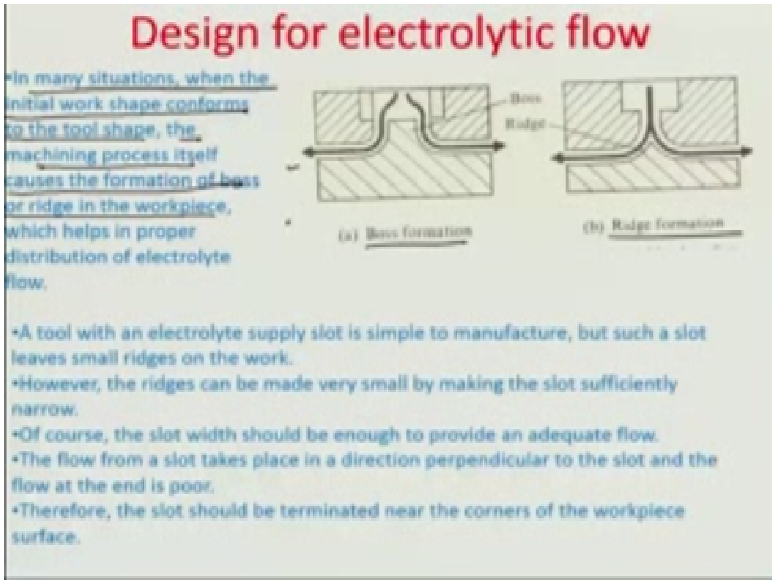

Machining so that so we will actually look at that just too little look that first a fall let us now see what could be difference situations because of the inappropriate flows or in appropriate presence of the electro light in various refine on work piece surface, so in many situations when the usual work surface conforms to be ensure and you can see here work surface is quite formal in a civil process itself causes the formation of the boxes or ridge in the work piece, so you can of it that berceuse just because you know from case one.

In the previous figure where you show that there is electrode be flown in direction particular to be in axial center and away from the two lexian center into be the outward direction there is a separation of the two flow tools it has these gaps here between work is and the tool ob both sides of the small, so this separation somewhere around the central pain where there is always a possibility that because of such a sudden separation in the of flow which is normally happens in such a small gap.

As the inter electrode gap there is less electrode which comes in this region or there is starvation, in this particular region which is shown by this you know sort of a dark circle, so because of the presence of the of less electrode in this region obviously, the machine rates here would be very, very small so the MRR is small okay, and because the mrr is small you know we find out the region there is a region which is getting developed or a box which is getting developed or a box which is getting level.

As you can see here now is a projected structure of from an otherwise flat surfaces, you can see or may be some kind of a region fact like this and this is because generally the replace separation causes seven flow separation causes as you know the region when there is a sudden starvation of the electrode which would happen, so the tool with an electrode electro light supplies slot is very simple to manufacture but again the n design was a constrained, that super slot may leaves small ridges on the work piece which is not desirable.

We do not really want to separate you know sort of a reaching or bossing of the work piece because of the electro light flow or the electro chemical machining process the whole idea is to make the machining happen as flat as possible so if we wanted to avoid this problem the best way to do that would be to make this electrolytes slot which is dispensive the electrolyte very narrow.

So that there is a small steam of fluid which can come and then this may result in the very low small region of the separation zone so the effective ridge dimensional of the above mention which may be formulated so small there it is more or less insignificant in comparison to the plane surface of the tool.

However the rejects can be made there is a small therefore by making a slots sufficiently narrow obviously one needs to certain electrolyte is enough so that there is proper supply it should not be that the slot is so small that the supplies constraints and then because of that constraint there is an another region or boxing which may happen and it should have just enough to supply the electrolyte but it should have the another very high width so that overall the region effect can be minimized, they flow from the slot would otherwise take place in a direction perpendicular to this slot and the flower behind is poor.

So in this slot should be terminated generally at the corners of the work piece surface otherwise that that may result in another issue related to deformation of the secondary boss at one of the surfaces.

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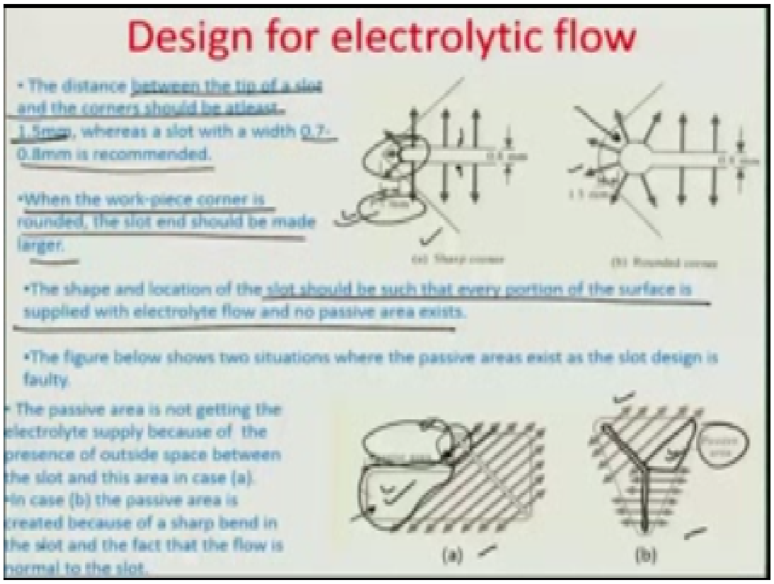

So there are several designs that has been illustrated here you can see this design as well as design B and what we are going to find out is that there are many aspects of both the designs here one is that the tune also getting loaded be by same process one is remember that there is always a minimum dimension that is needed between a slot and the end of the tool so that there is no leakage or there is no machining of the slot all the way to the edge.

Let there be a leakage of the electrolyte from the side of the tool so that should not happen, so the distance typically between the tip of the slot and the corners it should be atleast 1.5 mol that is what thumb rule of designs says where designing these tools whereas the slot would width of 700 to 800 microns is normally recommend so this slot should not be more than at the most about 1mm and is the better idea to have it in the sub millimeter range or some millimeter domain so when the work piece corner is rounded like for example in this particular case you can see the corner be rounded.

This slot time should be made larger because obviously the question here is that replied should flow out radically in all the directions so that it reaches all the corners and covers the whole surface added view in that particular case we would have the smallest slot and ending as is visible in this particular figure there may be a restriction of the flow because the flow may not be able to get enabled in this particular case over the whole surface.

So it is I think the idea so when the wept is corner is rounded in the slot and should be made larger okay as you can see here in this particular case, in the shaper position of the slot should be such that every portion of the surface is supplied with an electrolyte flow no passive area exist let us look at two example problems here, case A and case B in the case A for example you can see the presence of a passive area that the electrolyte does not teach.

Because obviously the electrolyte would moves out in perpendicular direction as shown by these arrows and the electrolyte that excess out in this particular region actually goes outside and it cannot be guided back into the passive area you have to remember that this is a hap between net tool and the work piece, so this is a open area there is no gap okay so the electrolyte is lost here and so therefore at this region which is shown by this dotted structure is the region where the electrolyte is not received.

There is another case here where electrolytes carnation happens because of sudden bending you can see that you can see there that this slot is you know it is corner slot or it is suddenly bending slot where there is a sharp corner okay and so the flow direction, so in this all of a sudden because of pitch there is a formulation again of important region which is a passive area, so be designed in appropriate and somehow it needs to you know design in a manner.

So that these passive areas shown that the dropped image here are eliminated, so how do we do the design.

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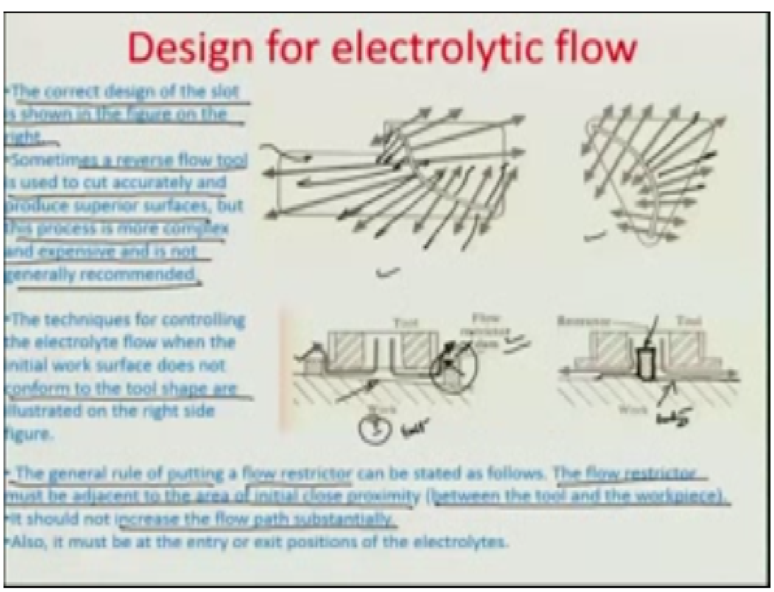

So here the same slots are formed rather than right slots and as you can now see probably that you know as that perpendicular as electrolyte is always losing out in a perpendicular manner and you know there is always recursive of the passive area because now the electrolyte is using in all different directions and which is perpendicular to various portions of the curve which describes this shorted regions.

Similarly it depends of a switch scampering in a curving of another wise available corner between the slots should be full coverage of the electrolyte is seen in this particular area sop the correct design of the slot has shown in this figures and obviously in some cases.

It may be number to use to reverse flow to where the electro light may flow from outside to inside and sometimes reverse flow tool is used to cut accurately and produces a superior surface but the process is more complex and expensive and is not generally recommended, so if I were to take the electro light from outside and send it into the to be the region the guidance of the electro light may not be a very simple issue to be done.

So the techniques where controlling the electro light flow when the initial work surface does not conform to the tool surface are illustrated here, if this is case 1 for example where you can see that is an inclined surface on which is ECM is being done. Now similarly in the case 2 the right here you could see again the surface is not very smooth there is a sort of a box coming out of the whole surface it is not a flat surface.

So in either of the cases as the tool does not conform to the surfaces that are going to be obviously different field values between the tool and the work piece electrode. So the general rule in order to guide the flow in a proper manner used to put a flow restrictor in this particular case you can have a dam like structure this one here which acts as a guiding mechanism for the electro light to lose out between the period tooth gap here in this region, okay.

And the flow resistor must be adjacent to the area of the initial proximity between the tool and the work piece so that you could create a sustainable confinement of the electro light before the electro light leaves these inter electrode region, so it should also not increase the flow path substantially when we doing a flow restrictor and it must be either at the entry or at the exit position of the electro light these are two different cases, case 1 is at the exit position of the electro light.

Case 2 is at the entry position and you can see here that just because of the presences of this restrictor which again I would like to reform is not a part of the surface they basically putting this restrictor by just either sticking to the surface or wielding it to the surface or placing it and bounding this somehow in semi permanent capacity to the surface. Similarly are these in restrictors here so it can be removed as the machining has been carried out or it is completed. So that is how you can conform the electro light in certain spaces where otherwise it may be difficult to hold the electro light for number amount of time.

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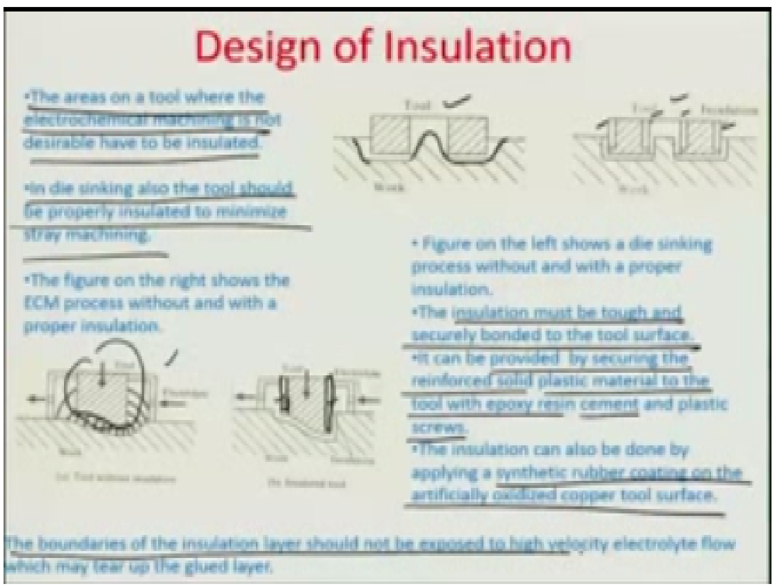

The areas on a tool where the electro chemical machining is not desirable and need to be insulated so that is why the sides of the tools are almost always insulated and so are the axial centers of the tool from which the electro light comes out or which is out, so it ensures that there is no machining in the side wise area and then it can remove the possibility of paper. So in, by sinking also the tool should be properly insulated to be minimize the stray machining effects which may otherwise happen.

In this particular case for example when you are having this complex shape of the tool being in printed into the work piece there is a possibility that the sides may get shallow I may not be able to attend the correct topology, but if there where insulators as you can see in this particular case these two regions are the insulator regions of the tool then the tool may be able to by sink more appropriately in comparison to the one without insulation.

So the figure on the right shows the ECM process within and without a proper insulation again here this is without the insulation you can see the regions developing shallow and the di-sinking are appropriately done and with this insulation the same problem do not arise. Further the insulation must be tuff and secure with bonded to the tool surface because obviously if it comes out during a machining operation it is going to jupatize the surface of the tool over which is was pasted, and the tool which in shape and size because of the coming out of the insulation.

It can also be provided by securing the reinforce solid plastic material to the tool with epoxy return cement and plastic screws. The insulation can be done by applying a synthetic rubber coating on the artificially oxidized copper tools surface and the boundaries of the insulation layer should not be exposing to high velocity electro light flow which may tear up the glued layer otherwise. So that is how you design for the flow path you also design for the insulation of the tool.

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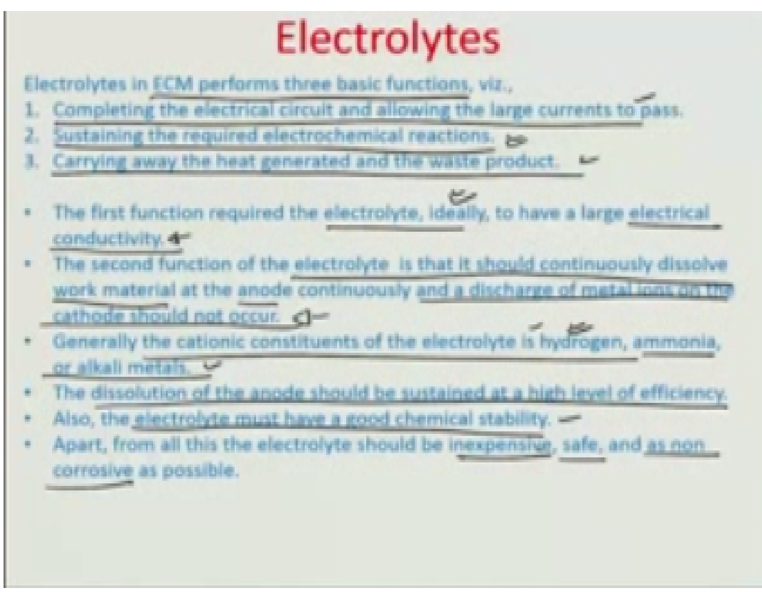

The other issue is choosing the right electro lights because obviously electro light is a main active element of this whole electro chemical machining system. It basically performs three different functions one is completely the electro tool circuit allowing the large current to pass by now there is sustaining the required electro chemical reaction to happen for a longer time so that the material removal rate can be continues phenomena material removal can be a continues phenomena.

And then obviously carrying away the heat generated from the waste product, so for the first function to accomplish that is completing the electrical circuit the electro light idea release to have a large conductivity. Obviously the conductivity of electro light or nowhere near the mat ally conductivities from the orders of line which we will lower in comparison to the metal conductivities.

But still they are highly conducting and if the conductivity is more ideally the material removal rate is more as we have seen earlier in all our derivations. The second function of sustainability of the reactions basically depends on the fact that the electro light should continuously dissolve the work material ate their node and at discharge of metal line on the cathode should not occur. So there has to be a combination of the process is of dissolution as well as the process of precipitation simultaneously.

So there are one hand the work piece get dissolve in the predisposition on the toll does not happened. So generally the cationic constituents of the electro lights are hydrogen, ammonia or alkali metals, so by enlarge the dissolution of the anode should be sustained at a high level of efficiency, hydrogen of course is also an agent which can in dissolved the state reduce the conductivity of the electro light.

So we should avoid the presence of gives as hydrogen dissolved in the electro light. However if hydrogen is fabulist hydrogen iron for dissolution of the basic salt which makes the electro light, that is more appropriate for having a good conductivity of the electro light. So electro light must also have god chemical stability it should not vaporized it should not create toxic fumes etc, so generally it should have over all safety as non corrosion responsible ECM is tools.

Otherwise are insulated at all different regions because of avoiding the problems of corrosion and dissolution the electro light does not continues contact with the different metallic parts of the different systems associated with the 2d. And obviously it should be an expensive from the point of view of the process economics to happen.

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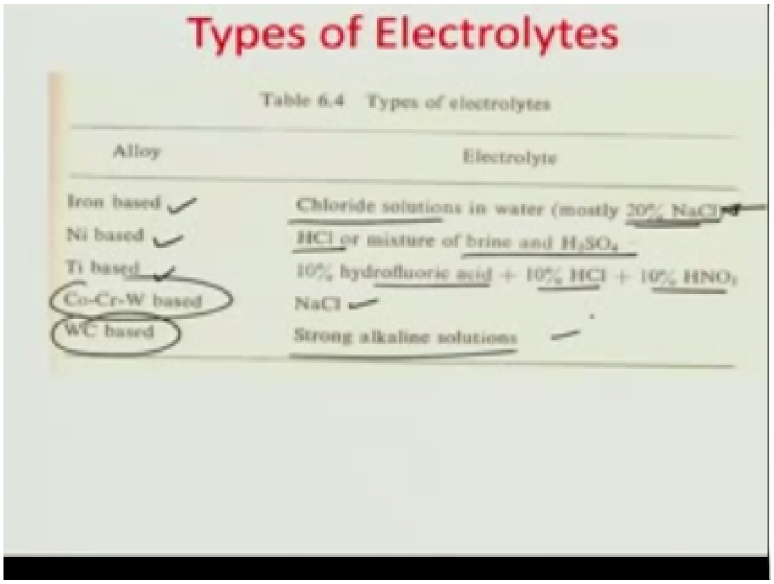

Alloy	Electrolyte
Iron based	Chloride solutions in water (mostly 20% NaCl)
Ni based	HCl or mixture of brine and H_2SO_4
Ti based	10% hydrofluoric acid + 10% HCl + 10% HNO_3
Co-Cr-W based	NaCl
WC based	Strong alkaline solutions

These are some of type of electro lights which are normally used you can have for RMB is the alloys and resolution of RMB is alloys chlorine solution in water this is the very common example the brain solution normal sort in chloride 20% by weight in water for the nickel based alloy is you could have a combination of hydro choleric acid HCL or a measure of salt water and H_2SO_4 sulphuric acid again for tungsten based alloys you could have a 10% hydro fluoric acid with gain 10% HCL and then HNO_3.

For these Co- Cr- W tungsten based law is you could have a normal NaCl normal tungsten solve based solution all for tungsten cur vied you could have a very strong alkaline solution serving as electro lights. So these are some of the different kind of electrodes as regards the different single phase alloyed systems.

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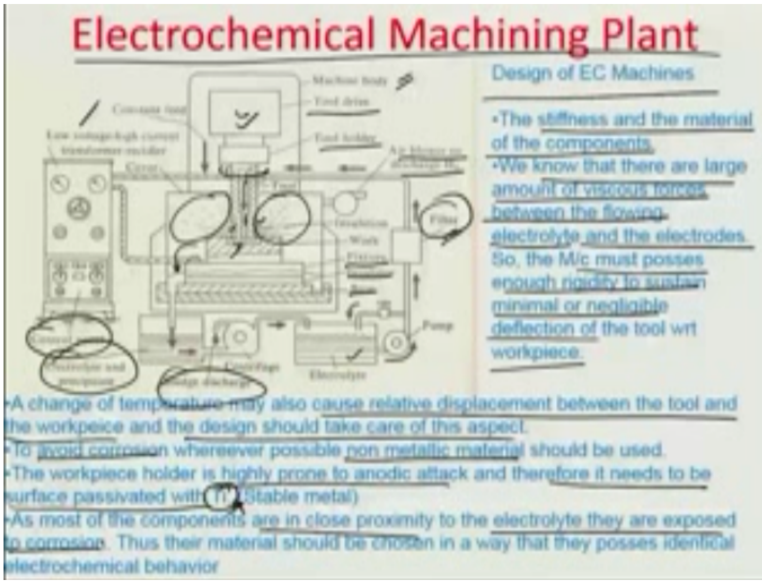

I would also like to give brief schematic of the machining plan and how it would look likes so you should have system or circulation here where the electro light and the perspective data sort of pumped from a tank in to the main zone of machining the broken lines coming here are basically slashes of the electro light this is zone of machining here between the work piece the electrolyte the question to this squared CL sample region of the tool so which depends out and the impression the high voltage high current transformer rectifier for supplying the voltage signals between the two work piece and also the tool panel to drive the amount of power.

That you do the system for executing the machine imposes the tool drive which senses the gap and tries to reduce the gap as machine process happens between the tool and electrode as you have seen earlier there is always the possibility of getting constant equilibrium that between the tool and electrode does the function of time over all machine bodies is highly insulated in nature there are many regions which have to be protected from the frozen or the corrosion the supply electrolyte.

There is of course air blower to discharge adverging tool holder and insulation on the tools you can see these tools relation ends or insulated the tool there is a work in surface that is a fixed term insulate there and the base sometimes it is good idea to filter the electrolyte because it may have some result typical some matter which may create problems are related to the surface machining parameters.

So up strainer or filter is needed highly needed for purifying the electrolyte before supplying to the zone of machining and almost there is removed and started back by the electrolyte by circulating the electrolyte from the machining zone of chamber in to this sludge discharge tank which collects the disorder electrolyte with metal parts so some of the design guidelines for such electro chemical machines the stiffness and the material f the components need to be cordial evaluated.

They should not be any wobble of the two holder so that whatever is to be machined as certain degree operations we know that they are large amount of viscous forces between the flowing electrolyte particularly it goes the gap is been narrow and the electrodes so the machine must possess enough rigidity to sustain minimal or negligible deflection of the tool with respect to the work piece.

And also sustain the any kind of vibration which will be because of the tool drive unit or the motor because of imbalance so achieve the temperature are also cause relative displacement between the tool and the work piece design should take care of this aspect wherever possible but it should be non metallic materials which are much prone to corrosion which can avoid corrosion the work piece holder is highly prone to anodic attack.

And therefore it reached to be surface passivated attaining the good materials passivate the surface this is the metal as most of the components are in close proximity to the electrolyte they are exposed to corrosion so therefore it is a good idea to choose the material in such a manner so that they sort of wherever there are non-working zones in machine should have scheduling overall from the electrolyte.

And they should possess identical so their material normally should be chosen away that it not possess any identical electrons behavior to be insulators are the most prefer materials in this particular purpose so this brings us to an end of the electro chemical machining generally there are many other variants of the electro chemical machining process like electro chemical grinding electro handling which would probably cover in the following module.

But in just of a time I like to choose this particular module and in the next session we would talk about some associated processes related to whatever we are learned in the mechanical removal as well as the electro chemical removal of the material so it is done thank you and goodbye.

<u>Acknowledgement</u>

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