Advanced Machining Processes
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Lecture 07
Electrochemical Machining Processes 1

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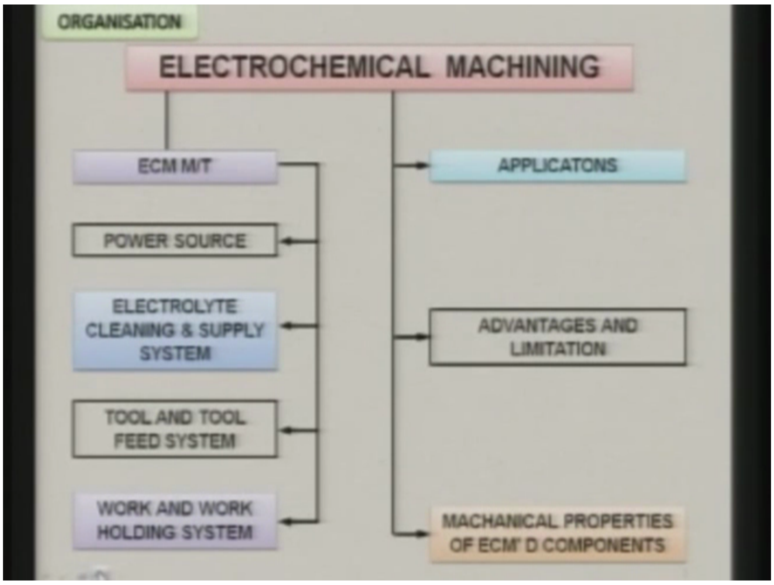

Welcome to the course on Advanced Machining Processes, today I am going to talk on electrochemical machining processes part 1. Organization of the talk will be as follows, I will show you electrochemical machining machine tool which consist various elements namely power source, electrolyte cleaning and supply system, tool and tool feed system, work and work holding system.

I will also show some applications of electrochemical machining, advantages and limitations and the properties of the electrochemically machined components, is there any change in the properties of the machined component or not.

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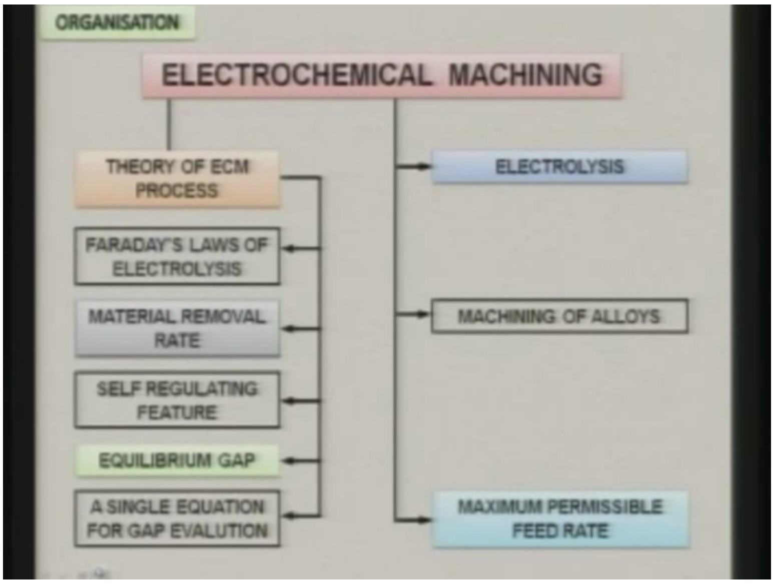

Then I will discuss in the next lecture, theory of electrochemical machining processes, Faraday's law of electrolysis, material removal rate, calculation of material removal rate, self regulating features of the electrochemical machining process and equilibrium gap and then we will derive a equation, single equation which will be applicable for zero feed rate as well as finite feed rate.

And what is this electrolysis process, machining of different types of alloys and what are the problems that are faced during theoretical calculations of material removal rate or anode shape prediction while you are using alloy as the work piece material and what is the maximum permissible feed rate in electrochemical machining we will derive the equation for the same.

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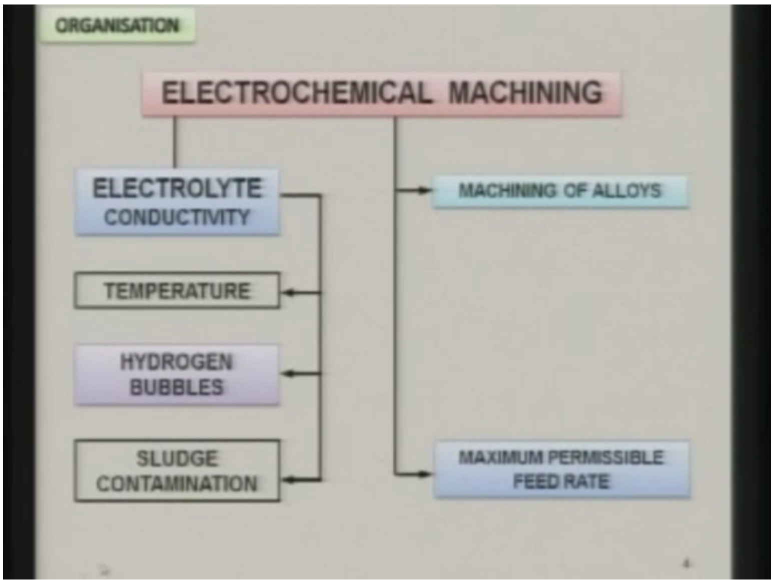

I will also discuss about the electrical conductivity of the electrolytes, what are the effects of temperature, hydrogen bubbles or gas bubbles evolved during the process on the electrolyte conductivity and sludge contamination of the electrolyte which directly affects the conductivity of the electrolyte which also affects material removal rate, anode shape that is going to be obtained and finally the design of the cathode that is the tool.

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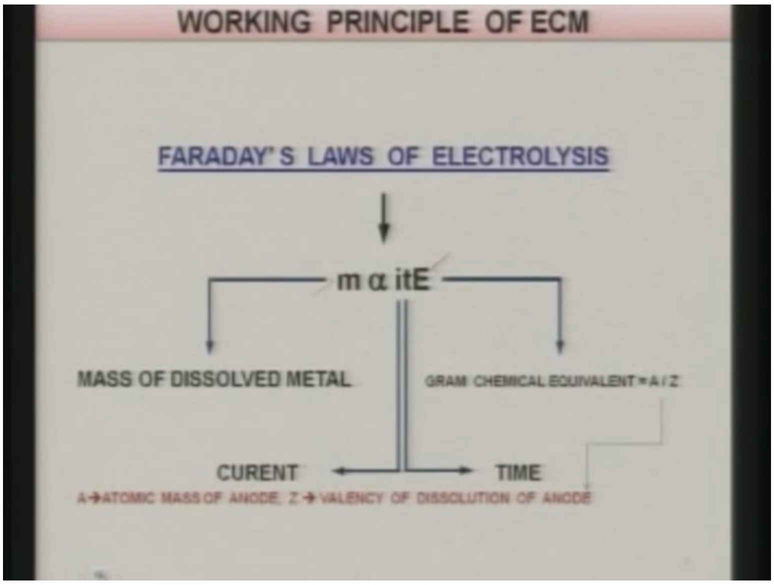

Let us discuss working principle of electrochemical machining process, now Faraday's laws if you see, according to the laws of Faraday, material removed during electrolysis is directly proportional to the current flowing in the circuit, time of machining or the current flowing in the circuit and chemical equivalent of the work piece material that is the anode during the electrochemical machining process, I is the current, T is the time, E is the chemical equivalent of the anode work material and M is the amount of material removed during the process.

Now chemical gram chemical equivalent of the anode material E is equal to the AYZ where A is the atomic mass of the anode that is the work piece material and Z is the valency of dissolution of the anode, it is not necessary that one particular material is dissolving at a particular valency only some materials have two valencies or even three valency so it is not always sure at which valency it is dissolving during the electrochemical machining process, so we should know accurately and in advance for theoretical calculations at what valency it is dissolving.

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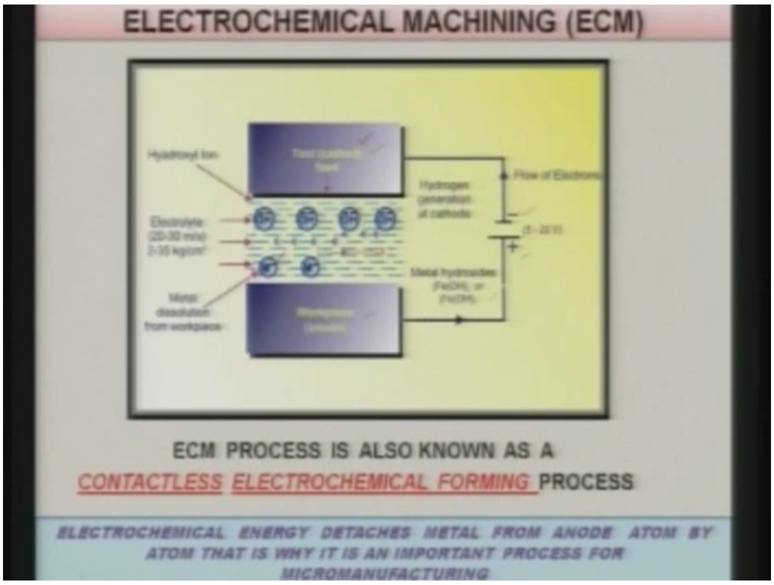

Now let us understand the working principle of electrochemical machining with the help of this particular figure. Now before I discuss this particular figure let me tell you that this process is also known as contactless electrochemical forming process where you are changing the shape and size of the component without really making any physical contact between the tool and the work piece as we do in case of traditional machining processes where single point cutting tool or multi point cutting tool removes the material in the form of the chip and changes the shape and size of the component so this is different in that reference.

Now let us come here in this figure as you can see tool is the cathode and work piece is the anode now during electrolysis the electrolyte which is flowing between the tool and the work piece the electrolysis takes place now as you can see here cathode is connected to the negative terminal and work piece is connected to the positive terminal and the voltage applied across the cathode and the anode normally ranges between 5 to 20 volt.

During the electrolysis the electrolyte flows at a high velocity that velocity may be ranging between 20 to 30 meter per second and the pressure for flowing the electrolyte at such a high velocity is normally between the 2 to 35 kilogram per centimeter square during the electrolysis the metal dissolution takes place from the work piece as you can see here shown by AM plus plus and hydroxyl ions are evolved during the electrolysis of the electrolyte.

And these metal ions and hydroxyl ions having positive and negative charge they combine and they form ferrous hydroxide or ferric hydroxide if you are dissolving iron and as this electrolyte flows there is also the evolution of the hydrogen gas at the cathode and oxygen gas at the anode we will see the chemical reaction in the following slides, so you can see here either iron is dissolved in as ferrous hydroxide or ferric hydroxide.

It is very clear here which is very important to note that here material from the work piece is dissolved atom by atom and since material is dissolved atom by atom this process is becoming very important for micro machining purposes where we want that material should be removed atom by atom not in the form of the chips or microchips.

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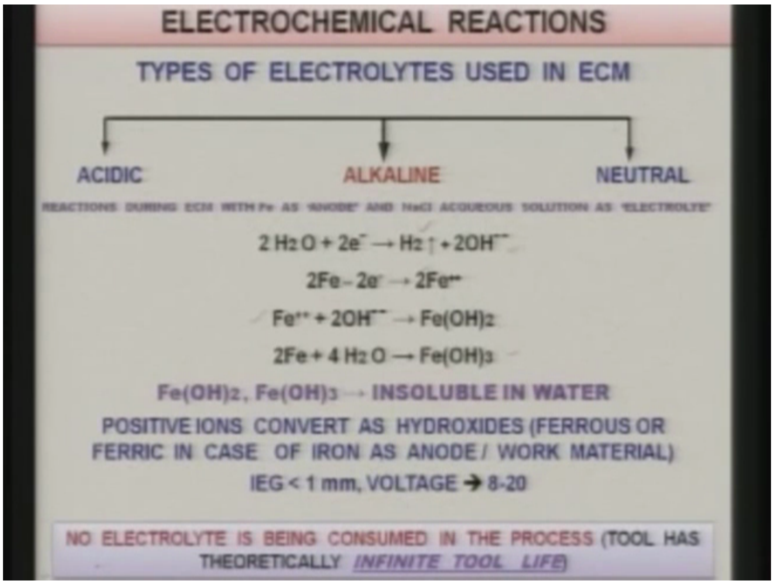

Now there are various kind of the electrolytes which are used in electrochemical machining process, some of them are acidic in nature, some are alkaline in nature and some are neutral salts. Reactions during electrochemical machining while machining iron FE as anode and sodium chloride that is the normal salt which we eat every day its aqua solution is used as the electrolyte and you will find that electrolysis of water that is the solvent of the sodium chloride salt takes place and you get hydrogen gas at the cathode and hydroxyl ions 2OH with 2 negative charge is removed, formed rather and iron is dissolved from the anode that is the work piece and you get iron ions with two charges on each one.

Now this iron ions and hydroxyl ions they combine together and they form what is known as ferrous hydroxide under certain circumstances in place of ferrous hydroxide, ferric hydroxide also is formed and that is FeOH thrice. Now it is very important for theoretical calculations to know whether it is dissolving as ferrous hydroxide or ferric hydroxide if we do not know exactly in which form it is dissolving then our calculations may go wrong as compared to the experimental results.

Now another point which is to be noted is that ferrous hydroxide or ferric hydroxide they are insoluble in water and if they are insoluble in water and if they get collected in the electrolyte tank then they will be stopping or they will be rather slowing down the flow of the current between the anode and the cathode so they should be quickly removed from the inter electrode gap that is the gap between the tool and the work piece.

Now positive ions convert as hydroxide we have already seen ferrous or ferric hydroxide in case of iron as anode work piece material, another point is that inter electrode gap should be less than 1 millimeter and normal volt is used is 8 to 20 volts. Another point to note here is that no electrolyte is being consumed in the process you can see all this equation, electrolyte is not being consumed hence the concentration of the electrolyte that changes that is due to the loss of the water during the electrolysis process.

Hence we have to maintain the conductivity of the electrolyte regularly to have the predictive material removal from the work piece and another point is there are no forces acting on the tool, temperature is also not very high, there are no sparking so there is no loss of material from the tool since there is no loss of the material from the tool the theoretically life of the tool is infinite although there are some practical regions because of which the life of the tool in ECM is finite we will some later on we will discuss this particular point in other lectures.

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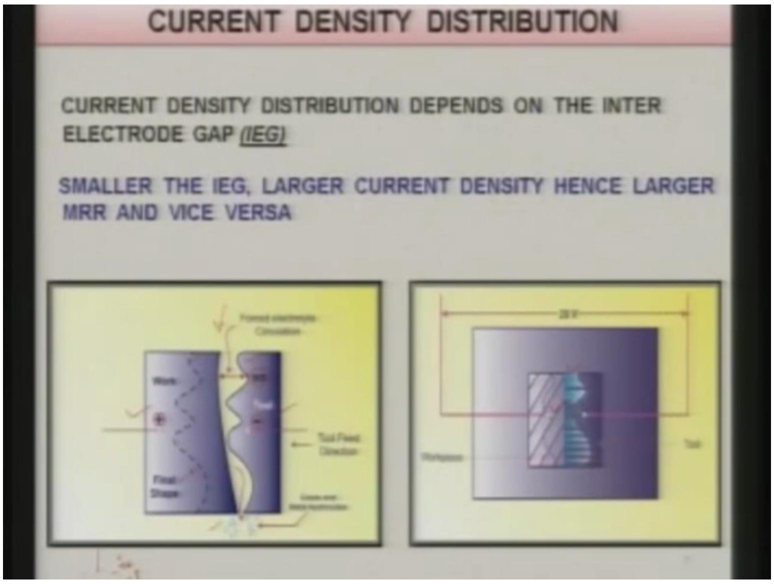

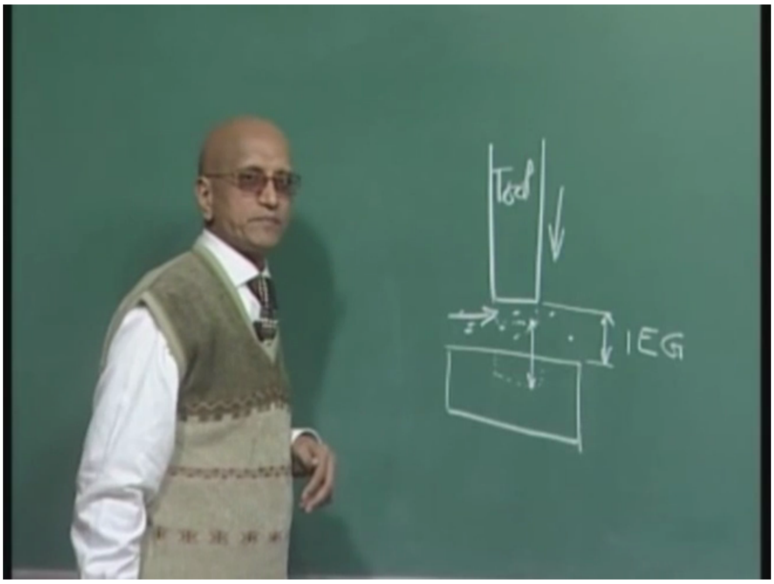

Current density is very important parameter in electrochemical machining process current density distribution depends on the inter electrode gap, let me again explain you here what is inter electrode gap we have tool and work piece, electrolyte is flowing in the inter electrode gap, the gap between the bottom face of the tool and top face of the work piece that is known as inter electrode gap and it is abbreviated as IEG.

But as the tool is been given feed also to move towards work piece now as suppose the tool comes over here and work piece shape is like this then at this point this will become the inter electrode gap, so it is really the gap between the bottom face of the tool and top face of the work piece from where material is being removed.

Now smaller the inter electrode gap larger is the current density hence larger material removal rate and vice versa as you can see in this particular figure the inter electrode gap is varying at different points and wherever is the smallest inter electrode gap, the current density is going to be the highest at that particular point.

Now you can see here, here this is the inter electrode gap but here the inter electrode gap is very small so the current density is high electrolyte is flowing in this particular direction, now this is the shape of the tool after complete machining this is going to be the shape of the work piece as you can see here in this particular figure and work piece is connected to the positive terminal so it becomes anode, tool is connected to the negative terminal so it becomes cathode.

And here you can see the gases which are evolved during the process and metal hydroxides are coming out from the inter electrode gap, you can see here the distribution of the current density wherever dense lines are there that means the current density is high so highest or most dense lines are over here so it indicates that here inter electrode gap is low, lowest and the current density is high while here it is very thin so current density over here becomes small.

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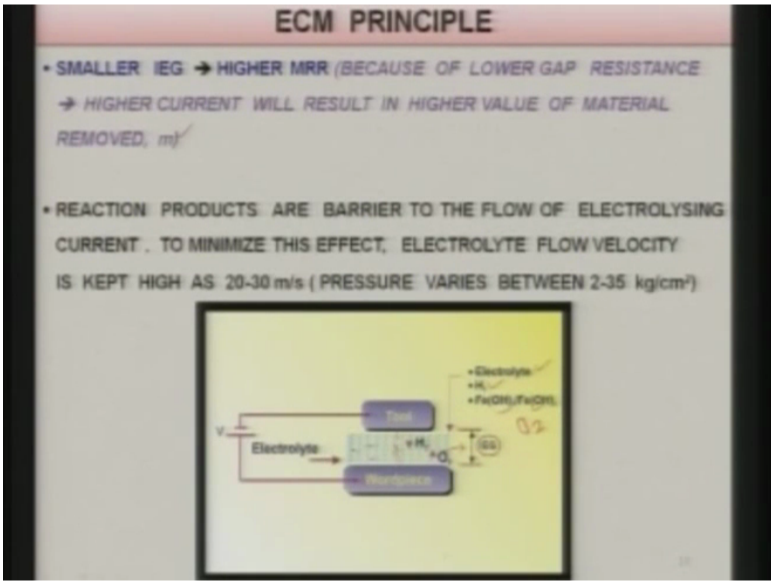

So we can conclude that smaller is the inter electrode gap higher is the material removal rate because of lower gap or lower inter electrode gap resistance to the flow of the current will be less so higher current will result in the higher value of material removed and material removed is normally indicated in this particular chapter by M, small letter M.

Reaction products are barrier to the flow of electrolyzing current as you can see here there are lot of reaction products over here then current cannot flow between the tool and the work piece so easily, so to minimize this effect electrolyte flow velocity is kept high that ranges normally 20 to 30 meter per second and for this, for achieving such high velocity of the electrolyte the pressure of the pumps which is supplying the electrolyte normally ranges between 2 to 35 kilogram per centimeter square.

And you can see here the products that are coming out of the inter electrode gap are electrolyte, hydrogen bubbles, ferrous or ferric hydroxide and oxygen gas is also there which is not shown over here and depending upon the material that you are machining or anode material it may be copper, it may be alloy or some other one, so accordingly different reaction products are formed.

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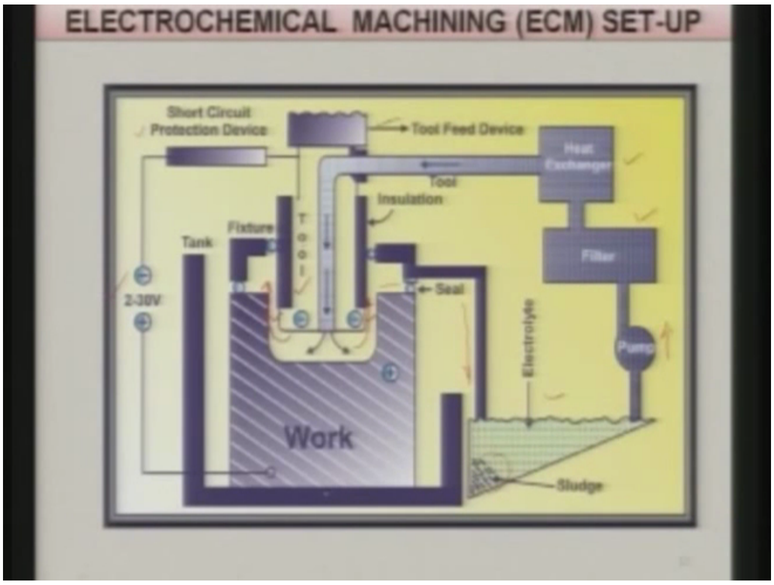

Let us see the experimental setup and some applications of electrochemical machining process, it gives an overview of various elements of any experimental setup you can see here on the left side it is connected to the power source, DC power source which is normally 2 to 30 volts then you have a short circuit protection device. This will protect the device from short circuit between the tool and the work piece if short circuit takes place then tool and work piece both will get damaged so that protection is very important.

Now as I mentioned there also and earlier in the fair also that tool is being fed towards the work piece and this is very important to feed the tool if you do not feed the tool then you cannot maintain this inter electrode gap as constant and we want for constant material removal rate this gap to remain constant and for that purpose as the work piece surface is moving downward or recessing downward tool also should move downwards so that the gap between the bottom face of the tool and top face of the work piece face remains constant.

So feed is being given to the tool as shown over there now here the tool is shown that is here and you can see the, this is insulated all around but small part of the bottom face of the tool is left bare, you can see over here as well as here that it is left bare and this will give you additional over cut so that the electrolyte can flow out from this otherwise flow of the electrolyte will become difficult and you will not get a good shaped hole.

Now if you see on the other side here is a electrolyte collection tank, now at the bottom of the electrolyte storage tank sludge is there and this is the heavier particles or sludge that is formed during the electrochemical machining process.

The electrolyte is coming from there and it is being supplied to the electrolyte storage tank and there are the filters which are not shown here which will filter the electrolyte, they will separate out the sludge or other reaction products from the electrolyte and then it is pumped towards the other filters set and then there is a heat exchanger, heat exchanger is an important unit of any ECM process because the temperature during the year varies to a large extent if you take the example of temperature variation in India it may be between 1 or 2 degree centigrade to 48 to 50 degree centigrade in the desert areas like Rajasthan.

So if you do not control the temperature within a very small range then the predicted anode shape and designed tool shape will not work as per our requirement so heat exchanger is important and the temperature should be maintained within plus minus 1 degree centigrade or so and then this is supplied to the hole inside the tool and from the central hole inside the tool it comes out and then goes out of the machining chamber, whole of this area is known as machining chamber where machining of the work piece is taking place.

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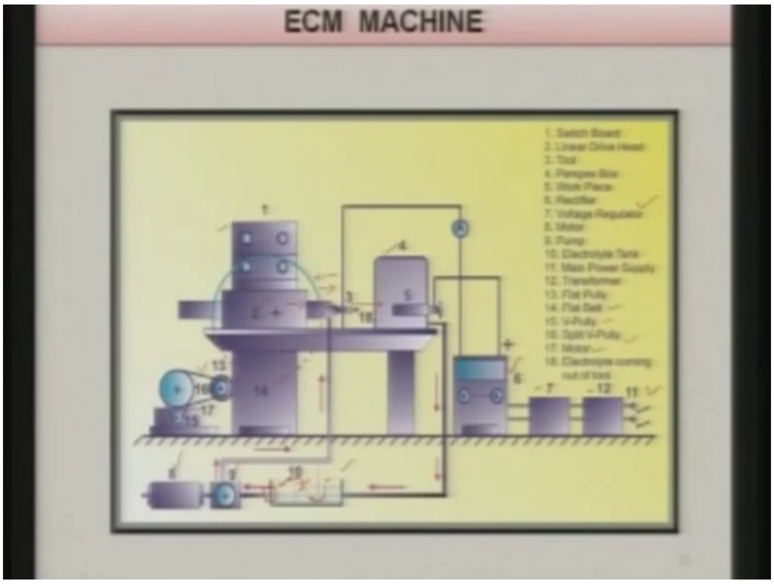

Now this shows an example of utilization of a lathe machine for electrochemical machining purposes it indicates finely various elements of any horizontal electrochemical machining machine, you can see here one is the switch board and then two is the linear drive head where you give the linear motion to the tool, three is the tool over there so tool can move in this direction or in this direction with the help of this particular drive, four is the perspex box that you can see here this is the perspex box where work piece is there tool will move inside the perspex box and then start machining this particular work piece, work piece is five. There is a rectifier, number six as you can see here rectifier, the purpose of the rectifier is to convert AC into the DC power supply and then there is a voltage regulator seven, this regulator regulates the voltage which is to be supplied to the rectifier.

Eight is the motor as you can see there, here this motor is used for driving or running the pump nine and there is a electrolyte tank ten, this is very interesting to see here electrolyte tank, it is divided into three zone one, two and three and in this whatever electrolyte is coming in region one which ends the reaction products which are lighter than the water they will remain in this electrolyte region one.

And then rest of the electrolyte will pass through the bottom and then it will come into the area two and in area two again whatever heavy particles are there they will remain in area two and whatever reaction products that could not be separated out in one they will get separated out here and again from the top of two it comes to the partition three where it is more or less a only electrolyte and having some fine particles or reaction products which have dissolved inside the electrolyte.

And then you will have a filter over here and that filter will separate out whatever reaction product very fine reaction product are left and then it will go to the pump which will pump the electrolyte to the tool over here, you can see the arrows which indicates the path of the flow of the electrolyte.

Eleven is the main power supply over here and twelve is the transformer because normal supply in India is around 220 volts and we need 5 to 30 volts in ECM so this step down transformer is to be used as a (())(23:01) and then there is the flat pulley thirteen over here this is used for moving this and with the help of this you can rotate further or move the tool linearly then there is a flat belt fourteen that is over here.

And then V pulley is there at fifteen over there which is connecting these two pulley and then split pulley is there and then motor seventeen is there and then electrolyte coming out of the tool you can see over here. So this is really very good example of how to utilize a lathe machine and make a horizontal electrochemical machining machine.

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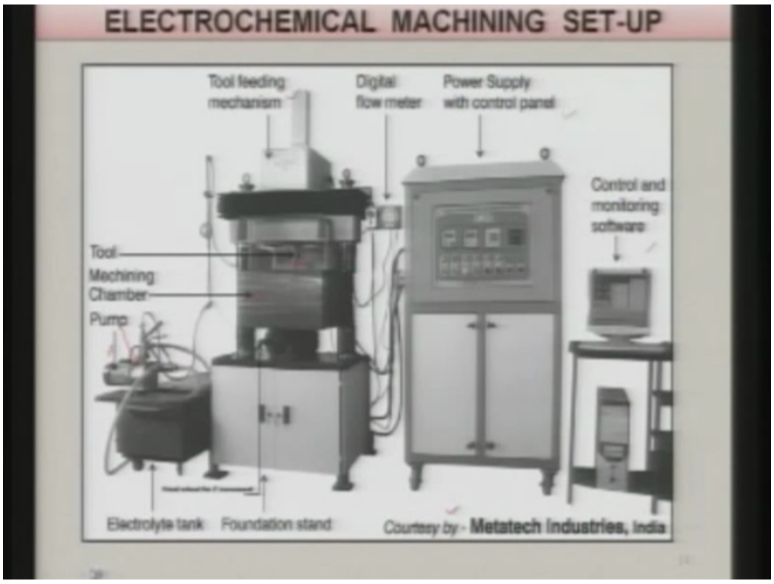

This is the setup photograph of actual ECM machine which is available in the market and this photographs are supplied by the manufacturer of ECM machine that is the Metatech Industries in India now some major parts we can see here actually this is not the pump, pump is here, you can see the pump over there, this is the motor which is used to run the pump.

And here you can see this is the machining chamber and tool is a little lower than the arrows shown over there, this is the tool holding device which is shown over here and then you have the tool feeding mechanism which is moving the tool up and down then there is a digital flow meter which will show you the flow rate of the electrolyte.

And then power supply with control panel over here and you can control this various some of the parameters with the help of the computer so you have control and monitoring software computer is there. This machine at present cost around between 15 to 20 lakhs of rupees.

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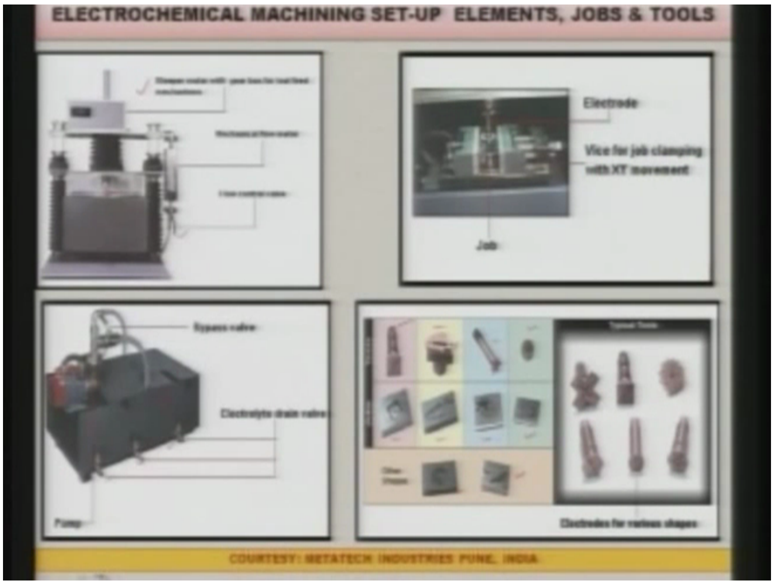

Some finer details of that you can see here stepper motor with gear box and tool feed mechanism is shown over there and then you have the mechanical type of flow meter and then flow control valve is there with the help of which you can change the control of the flow of the or you can change the flow of the or rate of flow of the electrolyte.

Now this is another kind of the machine which is not very sophisticated and if you see (()) (25:24) this is the tool and this is the tank where electrolyte is there. Now you can see in this figure clearly the job or the work piece and the vice for job clamping with X and Y movement you can give here and this is the electrode normally electrode is the tool.

This is the tank where you store the electrolyte then here is the motor pump is there and bypass valve is there and these are the three drainages through which you can take the used electrolytes you can empty this tank and fill up with the new fresh electrolyte.

Now here some interesting pictures are given you can see electrodes for various shapes to be machined these are the electrodes made of highly electrically conducting material, you can see the different shapes that have been made on the tool and using these shapes different the work pieces that have been made are you can see various types of the jobs that have been made, beauty of this process is that in one go you can get the final component rather than having different passes as we do in case of traditional machining processes like turning, milling, etc. and these are the different other kinds of the tools which are used for ECM purposes.

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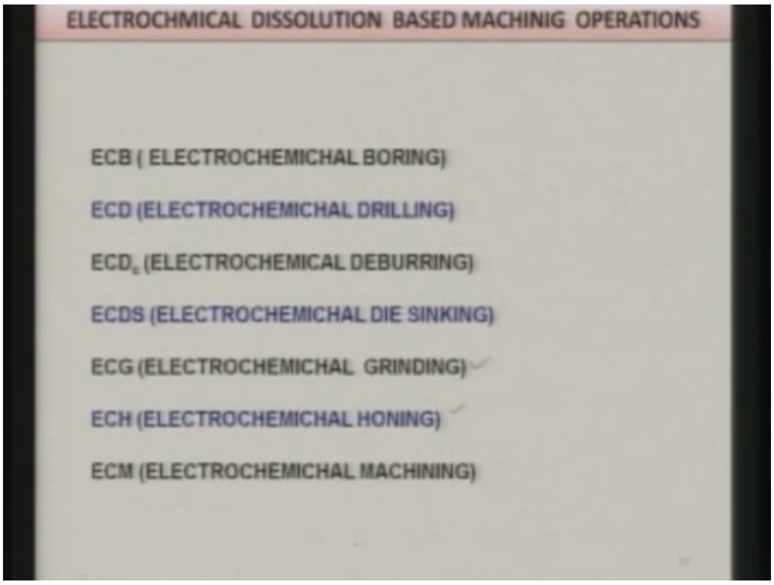

Now this is the basic principle of electrochemical machining but using this particular process you can perform various kind of machining operation. I will list and I will show some of them with the help of the figure to understand the huge capabilities of this particular process for machining purposes.

One of them is electrochemical boring operation and then there is another operation related to chemical drilling, you can do electrochemical deburring, electrochemical die sinking, electrochemical grinding, electrochemical honing and then electrochemical machining.

Now before I proceed further let me just tell you electrochemical grinding this is a hybrid process where you are using ECM plus grinding operations both are combined together to take the advantage of both the processes because ECM does not give very good surface finish but material removal rate is very high.

On the other hand grinding give very good surface finish but material removal rate is very low by combining these two we are able to achieve high material removal rate as well as good surface finish of the final product so we will keep discussing various kind of hybrid process and it is one of them. Another one is electrochemical honing which is also a hybrid process.

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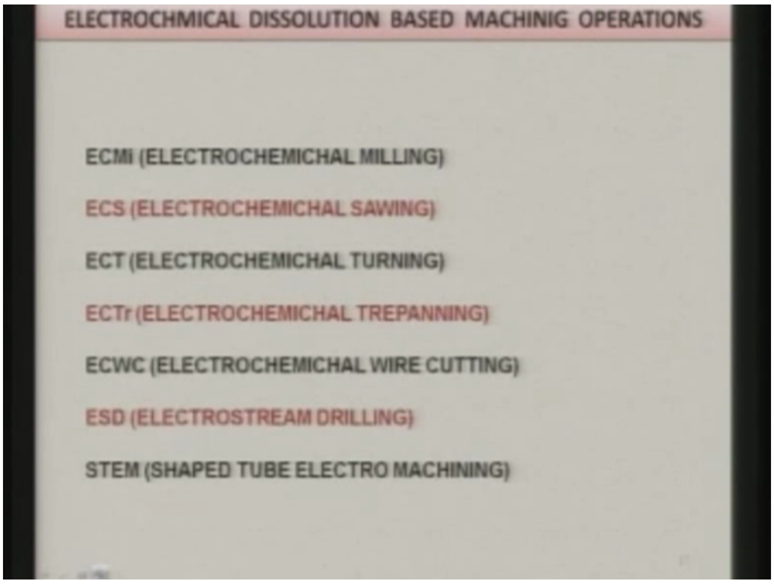

Then you can perform the operation like milling, electrochemical milling, electrochemical sawing operations, electrochemical turning, this is another very important process where you can do the turning operation cylindrical (())(28:57) can be made with the help of electrochemical machining principle. Then electrochemical trepanning, electrochemical wire cutting again just like electric discharge or wire EDM process, wire electric discharge machining process same way you have equivalent to electrochemical wire cutting process, then you have electrostream drilling and this is another very important process that is known as shaped tube electro machining, we will discuss it in some of these processes later on.

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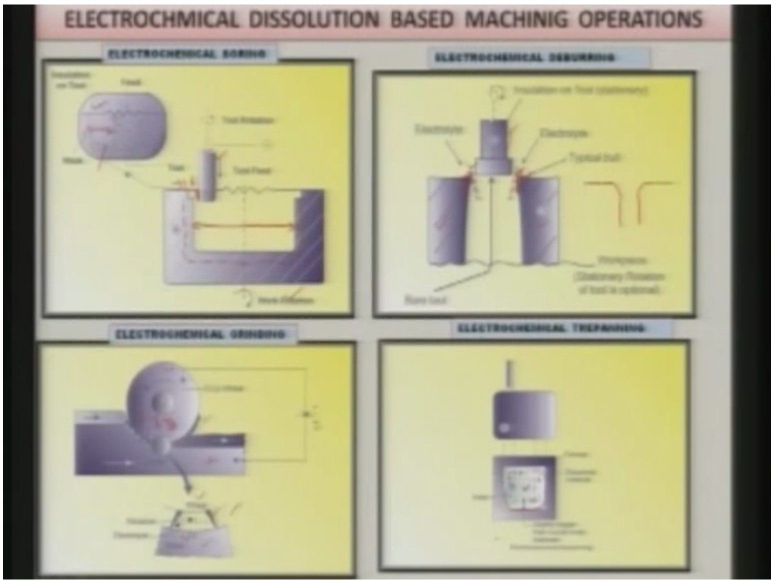

Now I will show you some of the operations which I named in the last two slides first one is the electrochemical boring operation, boring is what? We already have a certain diameter hole and we want to increase the size of the hole and we normally do not have that size of the drill then you perform the operation that is known as boring operation.

On the same principle because you cannot make very large hole in one go by ECM process also otherwise it requires high capability ECM machine so you can do it first slightly smaller or smaller hole by ECM process itself then you can enlarge it by electrochemical boring operation as you can see here that this is the hole diameter which was made initially either by ECM process or some other process.

And you want to make it accurate just like for example suppose you want this diameter to be 27.5 millimeter what you can do you can make a hole of 26 millimeter and then make it, enlarge it to 27.5 millimeter by boring operation that is what is being done this is the initial hole and you can see this is the tool and tool is here facing the wall to be machined and this is the additional material that you are going to remove by electrochemical boring operation and finally you will get the hole of this dimension so this is the operation.

As you can see here in this figure more clearly shown this is the another point you have to note that except a small part of the tool whole of it is insulated and that small part of the tool which is not insulated is this one this is not insulated because it is going to remove the material from the pre drilled hole and you can clearly see here that this the additional material being removed by boring operation over here and this shows the electrolyte and feed is given, being given to the tool.

Now since it is a boring operation you can rotate the work piece as shown over here so that the circularity that you obtain of the drilled hole is better than without rotating the work piece. Another application is electrochemical deburring operation, whenever you are drilling a hole by mechanical means with the help of the drill you always get the burrs as shown over here these are the burrs which are obtained by drilling operation, similar kind of the burrs you will get at the exit part of the drilled hole.

Now these burrs are highly undesirable, they should not remain there, they may lead to the malfunctioning of the component, they may hurt the operator while handling this particular component so deburring is very important operation. Now what is being done over here is you can see this is the work piece which is having the burrs over here and this is the tool, now this tool is coated part over here but this is the only part which is not coated and this part is in front of the burrs to be removed and electrolyte is flowing, the work piece is made as anode and the tool is made as cathode and the tool is rotating.

So what will happen this burr part will get dissolved due to the electrochemical dissolution process and finally you will get the component like this and this is what we want this burr is to be removed and you want the component of this type and since at the corner they are the sharp corner, the current density will be maximum and because of that these corners will be dissolved first compared to other and rest of the part is insulated so there is no danger of dissolution of rest of the part.

Now here is another one, electrochemical grinding let us see another very important operation that is electrochemical grinding, now in this electrochemical grinding process as I mentioned few minutes back we are using two processes grinding plus electrochemical machining, as you can see here three zones are shown, zone 1, zone 2 and zone 3.

In zone 1 and zone 3, abrasive particles as you can see are not in contact with the work piece surface and this grinding wheel is made of electrically conducting material that is metal and this is made as cathode as you can see it is connected to the negative terminal and work piece is made as anode because it is connected to the positive terminal so because of then electrolyte which is flowing in the gap between the grinding wheel as well as the work piece so electrochemical dissolution will take place in zone 1 and zone 3.

Since abrasive particles are not in contact with the work piece there will be no grinding operation but in zone 2 as you can see here in the enlarge view abrasive particles are in contact with the work piece surface and there is a small pocket where electrolyte is there and this pocket is called between two abrasive particles.

And since the wheel is made up of electrically conducting material and work piece is also made up of electrically conducting material so it will form electrolytic cell, electrolysis cell and the current is flowing between the two so electrochemical dissolution of the work piece in this particular region will take place as well as since abrasive particles are in contact with the work piece surface, grinding also will take place.

So you can see in zone 2 grinding is taking place as well as electrochemical dissolution is taking place, so here material is removed by both the processes and this will improve the surface finish of the machine component and when it goes to the zone 3 whatever burrs or irregularities are created due to the grinding operation they will be dissolved in zone 3 because there only electrochemical dissolution is taking place and whatever irregularities are created their (())(36:34) their current density will be higher and that is why they will be dissolved first rather than rest of the part so from that point of view this (())(36:43) process is very good.

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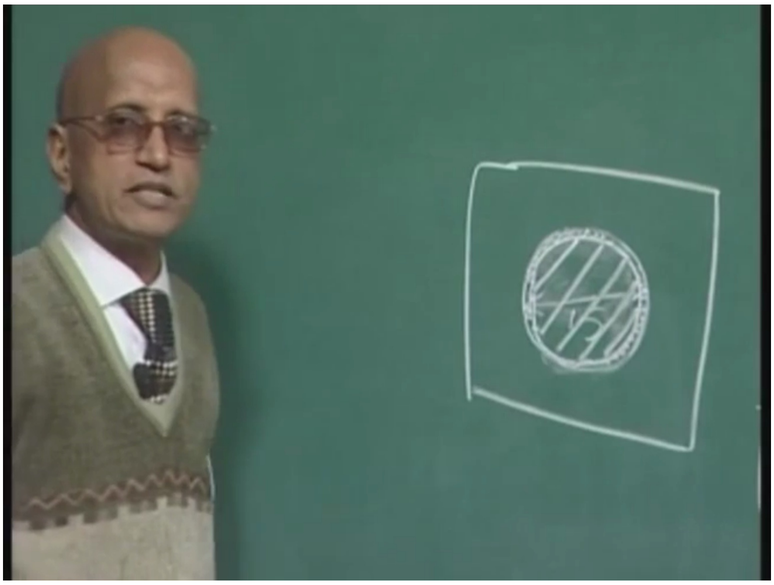

Another operation is trepanning operation, this is the electrochemical trepanning operation as you know that trepanning operation is very important when you want to remove a large amount of material just for example, this is the top view of the part and you want to create a hole over there and suppose the diameter of this hole is 15 millimeter and this is very costly material.

If you are doing it by electrochemical machining or electrochemical or electrodischarge machining, you have to dissolve or melt whole of this material so you are wasting lot of material and it is going to take lot of time in dissolving or melting this particular material so what is desirable is that you cut it along a certain periphery, this periphery and remove this material throughout its depth and once you remove this portion you take out as a solid part and then you will have it hole made by trepanning operation.

When you are removing, you are dissolving only this material which is a haste, this part will come as a solid part and this can be used for some other purposes so this trepanning operation can be performed as you can see here that this is moving like this and removing the material and this portion can be taken out as a solid part you can see the male and female parts, both are shown over there.

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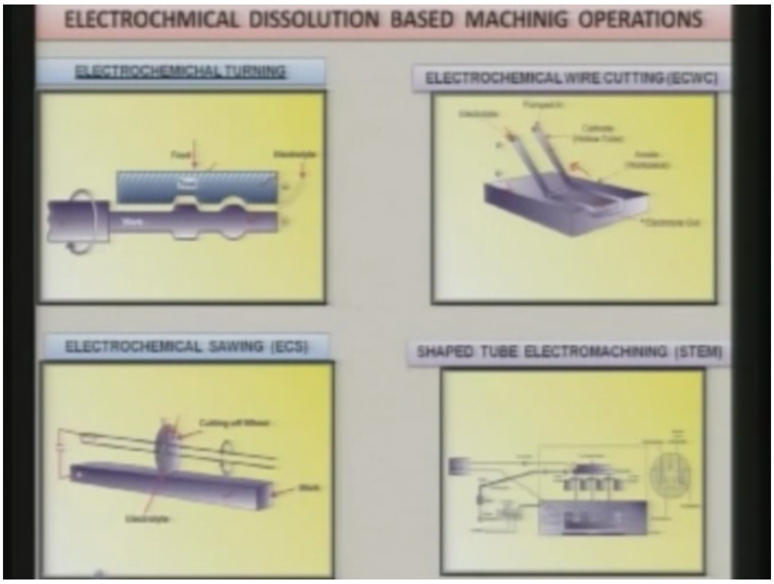

Turning operation there are many papers, research papers coming in various journals on electrochemical turning and this is very simple but very interesting and very useful operation here is the work piece you can rotate it and here is the tool which is having a replica shape of the work piece that you want now you can see when you are rotating this work piece and this is the tool electrolyte is flowing between the tool and the work piece.

So electrolysis is going to take place electrochemical dissolution of the anode work piece material is going to take place and current density will be different in different regions initially because of the different inter electrode gaps, finally when component has been made you will find that the inter electrode gap is more or less constant which will depend upon the design of the tool.

So this is the cathode, this is the anode and electrolyte is flowing in this direction and you can get very hard materials and super alloys can be turned like this rather than turning them by traditional turning operation. Another good application is electrochemical wire cutting or tube cutting, you can see here again the work piece is made as the anode and this is the tube cathode which is made as the cathode, hollow tube is there and electrolyte is being supplied through this tube and here are the holes through which electrolyte is coming.

And you can see this tube is moving in this direction so it is removing this work piece material as if it is a wire cutting although it is a tube in place of tube you can use a wire so it will become electrochemical wire cutting and the rate at which it is cutting or shaping the work piece is much higher than any other process and here important point is this part you can reuse or rather you can use it for some other purposes.

Sawing operation, again you are using electrochemical dissolution principle here again this is the work piece, this is the anode and this is the metallic saw cutting of wheel which is the cathode and electrolyte is being supplied between the cathode and the anode and you can see this is rotating, your cathode is rotating and this is not in contact with the work piece only due to electrochemical dissolution, cutting is taking place because at the sharp edges of the saw the current density is the highest and because of that it is cutting or dissolving the material, maximum material from there.

Now there is another application as I mentioned earlier also shaped tube electro machining, now here tube is used as the cathode and you are drilling the holes in the super alloys specifically the materials like nimonic super alloy which are used in making the turbine blades and this process was developed mainly for drilling the holes, cooling holes in the turbine blade, the basic difference is electrochemical machining in normal way is that instead of sodium chloride salt, acid is being used as the electrolyte I will discuss separately this whole process.

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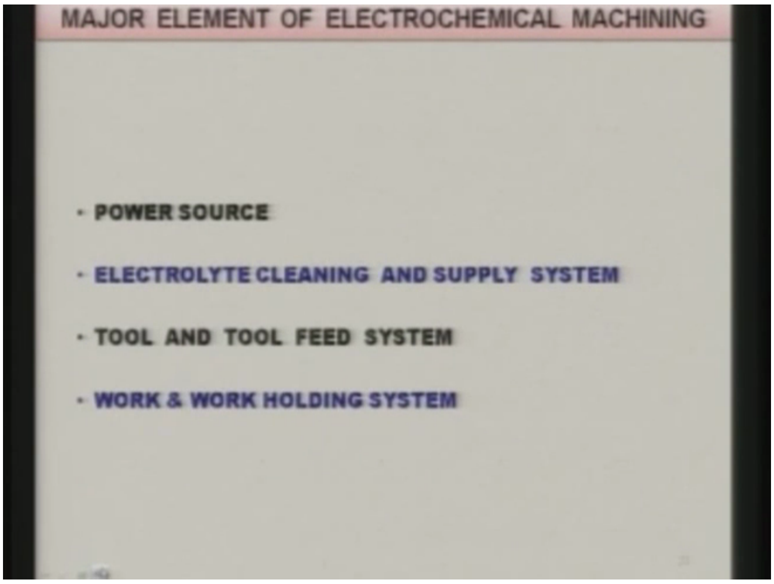

Now let us see the more details of the elements of electrochemical machining system, we are using the power source I have already mentioned to you that AC power is converted into DC with the help of the rectifier its voltage is reduced with the help of the transformer, there is a electrolyte cleaning and supply system, tool and tool feed system and work and work holding system these are the four major elements.

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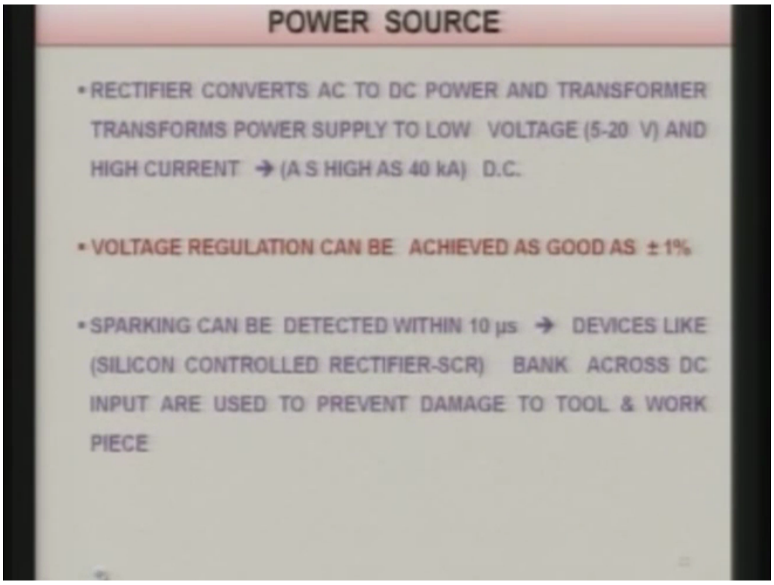

Now rectifier converts alternating current to direct current power and transformer transforms or converts power supply to low voltage that is normally 5 to 20 volts or 5 to 30 volts depending upon the requirement and normal supply is 220 volts and you require high current in electrochemical machining, sometimes the current, highest value of the current that is utilized by some industries is as high as 40 thousand ampere depending upon the inter electrode gap, depending upon the area which is to be machined and so.

Voltage regulation can be achieved as good as plus minus 1 percent, sparking can be detected within 10 microseconds because sparking should be detected and it should be avoided at any cost because if sparking takes place then it will damage the tool as well as the work piece both. So devices like silicon controlled rectifiers that is SCR bank across direct current input are used to prevent damage to the tool and work piece both.

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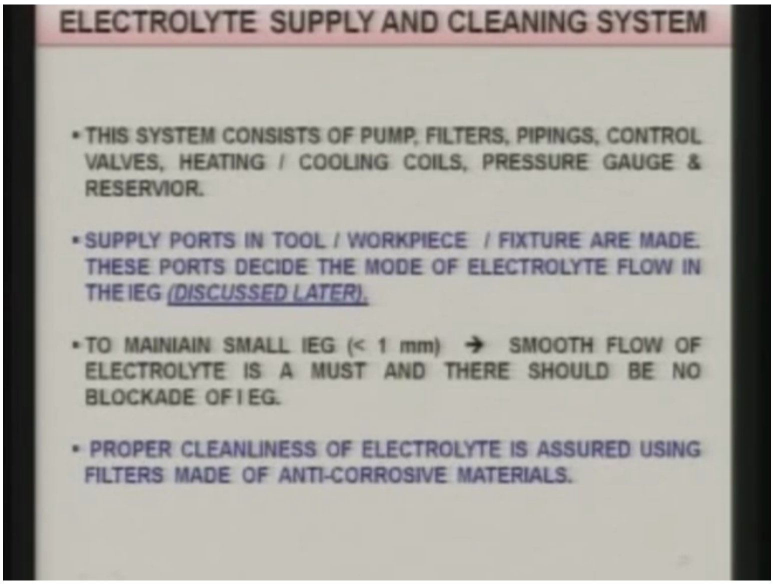

Electrolyte supply and cleaning system, very important element, this system consists of pump filters, pipings, control valves, heating cooling coils, pressure gauge and electrolyte reservoir tank. Supply ports in tool, work piece or fixture are made, now how to supply the electrolyte I will show you separately the figures various ways of this but it can be supplied through the hole in the tool or there can be a pre made hole in the work piece that can be utilized or it can also be supplied through the fixture depending upon the configuration of the system, these ports decide the mode of electrolyte flow in the inter electrode gap which I am going to discuss in the following slide there are various ways or various modes of the flow of the electrolyte in the inter electrode gap.

To maintain small inter electrode gap that is IEG which is normally less than 1 millimeter, smooth flow of electrolyte is a must and there should be no blockade of the inter electrode gap because inter electrode gap is less than 1 millimeter and if blockade takes place then it will stall the machining operation in that particular region hence this is very important to properly clean the electrolyte or filter the electrolyte very carefully so that no blockade of the inter electrode gap takes place.

Proper cleanliness of the electrolyte is assured using filters made of anti-corrosive materials, whatever filters you are using they should be anti-corrosive material otherwise they themself will corrode and the corroded particle which go along with the electrolyte they will block the passage between the tool and the work piece in the inter electrode gap or machining region.

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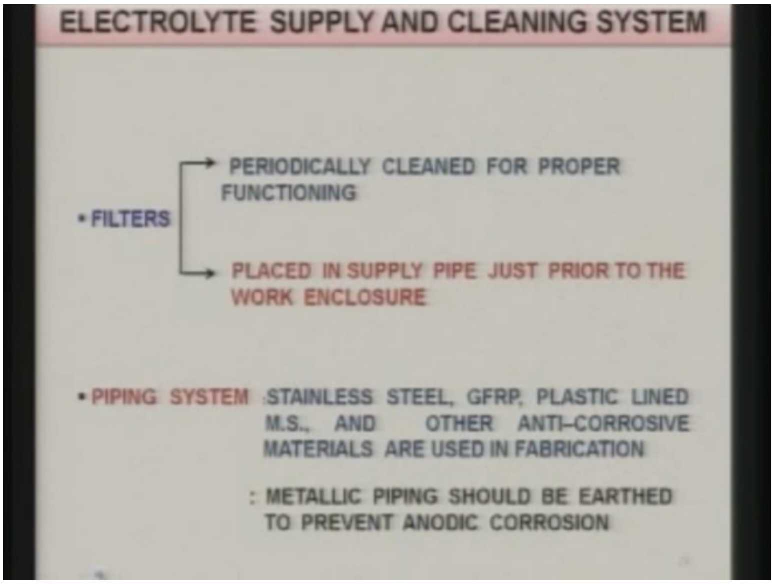

Electrolyte supply and cleaning system continues, filters they should be periodically cleaned for proper functioning and they should be placed in supply pipes just prior to the work enclosure, there may be more than once filter depending upon the requirement to make sure that no solid particle goes along with the electrolyte in the supply port then there is a piping system these piping system should be made of stainless steel, GFRP glass fiber reinforced plastic, plastic lined mild steel MS and other anti-corrosive materials they should be used for fabrication of these otherwise blockade problems may arise during the flow of the electrolyte in the different regions. Now whatever metallic piping is used it should be earthed to prevent anodic corrosion of that particular piping.

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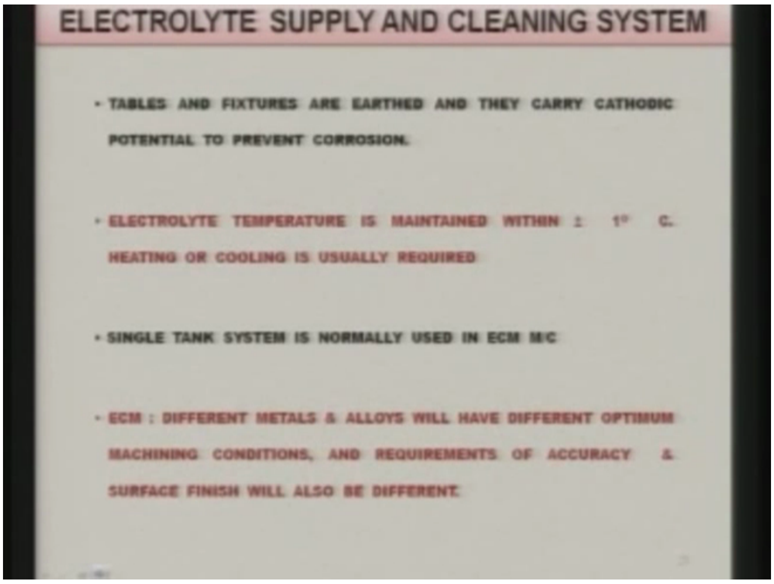

Electrolyte supply and cleaning continues, tables and fixtures are earthed and they carry cathodic potential to prevent corrosion, again this is very important safety of the operator is very very important so tables and fixtures should always be earthed if they are metallic and they should carry cathodic potential to prevent any kind of electrochemical dissolution of the tables or the fixtures.

Electrolyte temperature is maintained within plus minus 1 degree centigrade heating or cooling is usually required as I have mentioned the temperature in India may vary between 0 to 2 or at the lower side and 45 to 50 on the upper side, in western world it is much worse. Single tank system is normally used in ECM machine, this is something very important point for laboratory purposes or small scale industries use of single tank is okay but large scale industries where many ECM machines are being used different kind of work piece materials are being machined there you may require more than one type of electrolyte even on the single machine.

And then if you are using a single tank then you have to waste lot of electrolyte to prevent that to avoid that wastage and to make the things more easy multiple tanks can be used in the large scale and medium scale industries so that they store different kind of the electrolyte in different tanks and whichever is needed that can be utilized by a particular machine.

ECM, it can machine different metals and alloys, will have different optimum machining conditions depending upon the electrochemical equivalent or chemical equivalent of a particular work piece material and other conditions you will have different machining conditions or different optimum machining conditions and requirements of accuracy and surface finish also will direct what should be the optimum machining conditions.