Advanced Machining Processes

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Module - 06

Lecture - 15

Electrochemical Grinding , Electrostream Drilling, Shaped Tube Electrolytic Machining

Welcome to the course on advanced machining processes. Today we shall continue that electrochemical machining process. So already we have discussed the working principle of electrochemical machining process. Today we shall discuss some hybrid machining process using electrochemical machining concept. So first we shall discuss electrochemical grinding process. So already we have discussed that hybrid process means here we shall combine one non-traditional machining process and one conventional machining process.

In electrochemical grinding process we combine that electrochemical machining plus grinding operation so it is a electrochemical grinding operation. So so we shall start with electrochemical grinding.

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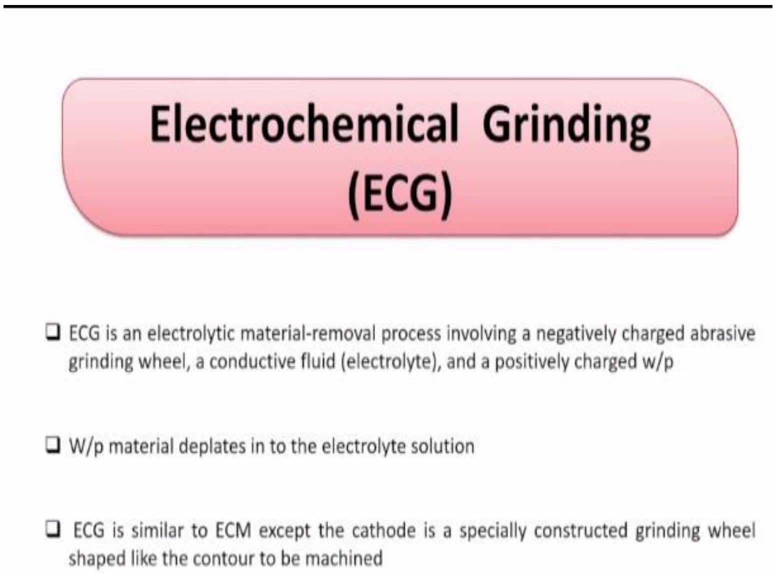

So electrochemical grinding is an electrolytic material removal process involving negatively charged abrasive grinding wheel, a conductive fluid electrolyte and a positively charged workpiece. Workpiece material deplates to the electrolyte solution. electrochemical grinding is similar to ECM except that the cathode is a specially constructed grinding wheel shaped like the contour to be machined.

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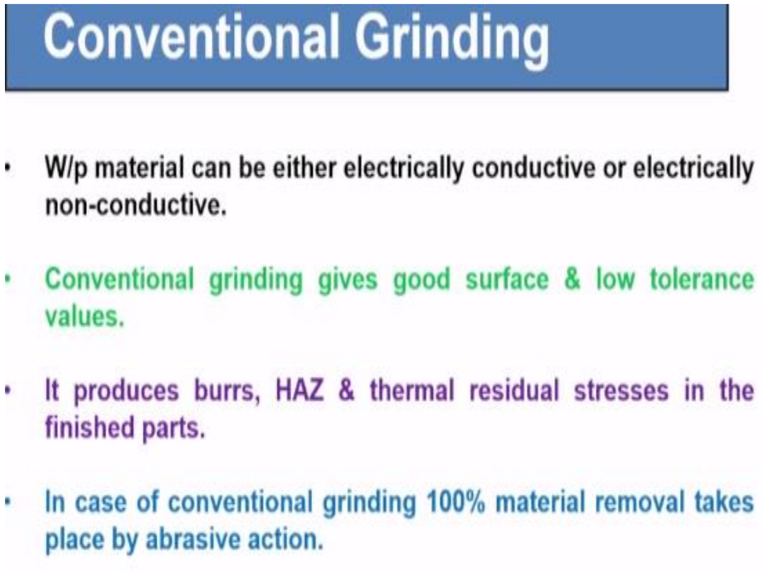

So what is the conventional grinding wheel? In conventional grinding wheel this abrasive particles are actually bonded together, you need bonding material like resin bond like in a bonding material it is bonded together and so workpiece material so for workpiece material maybe electrically conducting or electrically non-conducting material. So any kind of material can be polished by normal conventional grinding operation.

And conventional grinding gives good surface finish and low tolerance value. So but it produces burrs. So after means whatever after grinding operation you will see there are burrs formation at the edge. Also there is a heat affected zone is there in conventional grinding operation and also there are thermal residual stresses are there because it is a shearing operation by abrasive particles from the workpiece material.

So there is a deformation takes place during shearing operation by this abrasive particles in conventional grinding operation so there is a burrs are formed and then there is a heat affected zone is there. So these are the disadvantage of conventional grinding operation and another disadvantage is that there is a thermal residual stress is generated on the workpiece surface okay. So in case of conventional grinding 100% material removal takes place by the abrasive action. So by shearing by this abrasive particles totally 100% removal by abrasive action.

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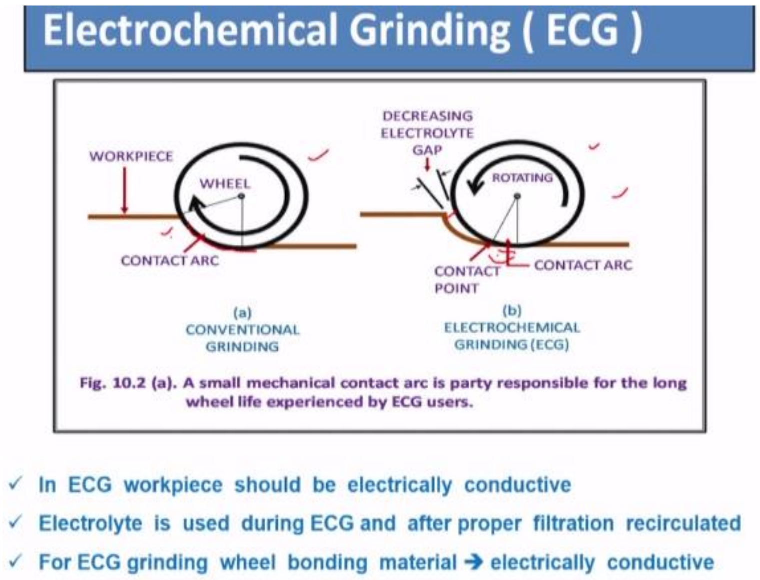

But in case of electrochemical grinding operation 90% of the material removal is by grinding operation and 10% of the material removal is by grinding operation and 90% of material removal by electrochemical machining operation. So these are the 2 views, 2 pictures of first one is the normal conventional grinding operation and second one is the electrochemical grinding operation. So in first case you will see that there is a upgrinding here.

So this is the contact arc length here. So here this contact arc length it is totally it is in contact. So this grinding wheel this abrasive particles are totally in contact with the workpiece material here you can see here. But in this case you can see so there is a rotation of this grinding wheel okay, so there is a rotation of the grinding wheel in case of electrochemical grinding operation.

So here there is a decreasing gap. So initially this gap between this wheel and workpiece is more, here you can see wheel is more and this gap is actually it is reducing in case of electrochemical grinding operation and after that in this zone you can see it is totally, in this zone it is totally actually this grinding wheel in contact with the workpiece. So initially you can see there is a no contact between the grinding wheel and the workpiece okay.

So there are 3 different zones are there, 3 different machining zones are there in case of electrochemical grinding operation. So these kind of decreasing gap is not visible in case of conventional grinding operation. So in conventional grinding operation this grinding wheel it is totally in contact with the workpiece material but in case of electrochemical grinding there is a little bit of gap is there in between this grinding wheel and the workpiece. So in electrochemical grinding workpiece should be electrically conductive so that is the main constant. So but in normal conventional grinding any kind of workpiece whether it is electrically conducting and nonconducting can be machined by this process by conventional grinding operation but in case of electrochemical grinding operation that workpiece material should be electrically conductive, so electrolyte is used during electrochemical grinding and after proper filtration it is recirculated.

So in electrochemical grinding operation this grinding wheel and the workpiece it is dipped inside a inside the electrolyte chamber and electrolyte, same electrolyte is recirculated. So as it is recirculated it should be filtered during machining operation, during electrochemical grinding operation otherwise whatever debris particles are there it will it will be there in between this interelectrode gap okay. So that is why this electrolyte, this property also changes because of sludges it comes into the electrolyte.

So it has to be filtered okay. So in case of electrochemical grinding the bonding material of the grinding wheel should be electrically conductive but which is not there in case of conventional grinding operation. In conventional grinding operation this bonding material is not electrically conducting but in case of electrochemical grinding metallic bonding material, metallic bonding material is used so that this bonding material should be electrically conducting. So for electrochemical grinding wheel bonding material should be electrically conductive.

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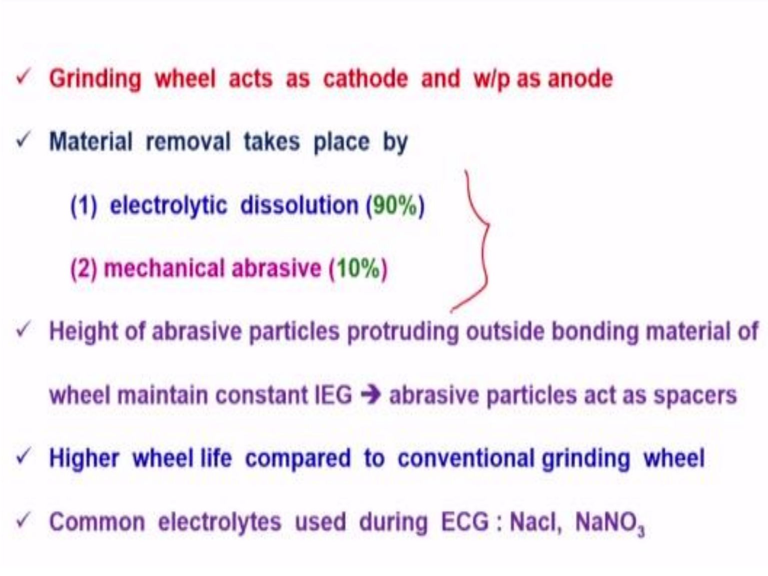

So grinding wheel act as a cathode. So in electrochemical grinding machine, so grinding wheel it acts as a cathode and workpiece acts as a anode. So material removal takes place by electrochemical dissolution by electrochemical machining is 90% and 10% material removal is by mechanical abrasion or mechanical shear. So you can see here 90% by electrochemical abrasion or anodic dissolution and 10% is mechanical abrasion. So high material removal rate is achieved in case of electrochemical grinding operation.

So it is very obvious. So this abrasive particles in electrochemical grinding operation, this abrasive particles which is actually protruding from the grinding wheel acts as a barrier. So it acts as a interelectrode gap. So it acts as a barrier in between this grinding wheel and the workpiece. So it acts as a barrier so it does not allow this grinding wheel metallic bonding material to touch the workpiece surface because this abrasive which are protruding from the grinding wheel it acts as a barrier okay so it does not allow this metallic bonding material to touch the workpiece surface okay. So interelectrode gap is already it is maintained.

So height of the abrasive particles protruding outside the bonding material of the wheel maintains constant interelectrode gap. So this abrasive particles are acting as a spacers. So this abrasive particles are acting as a spacers. So that is why as only 10% machining is by the mechanical abrasion and 90% by electrochemical grinding operation so there is a high wheel life which is expected from electrochemical grinding operation.

So if we consider this conventional grinding and electrochemical grinding, in electrochemical grinding wheel life is more than 10 times than the conventional grinding operation because in electrochemical grinding there only 10% mechanical abrasion is there. So commonly used electrolytes in electrochemical grinding is sodium chloride NaCl solution or sodium nitrate solution. So these are the commonly used electrolytes which is used during electrochemical grinding operation.

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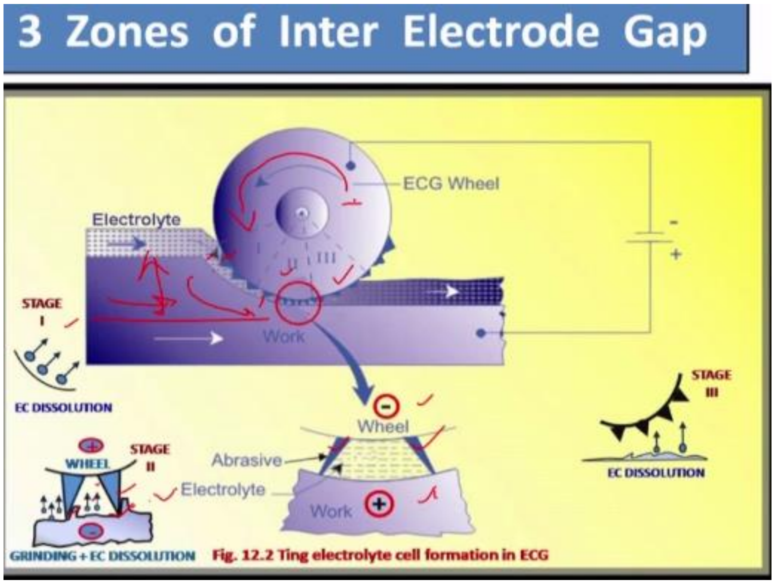

So you can see this is the working principle of electrochemical grinding operation. So this is the grinding wheel which is rotating here. So this grinding wheel which is rotating in the anticlockwise direction here and here this workpiece actually it is moving from left to right okay. So this is the it is like a down wheeling operation, so it is like a down wheeling operation. Already I told there is a decreasing gap. So interelectrode gap if you see here, interelectrode gap is more here and while coming to this point it is interelectrode gap is reducing.

So from here to here interelectrode gap is reducing okay. So here in so there are 3 different zones are there. So this is zone 1, this is zone 2 and 3 and this is the zone 3. After that this much material is removed. So this much material is removed from this process. So individual zones are actually shown here. So this is zone 2 you can see this is the zone 1, you can see here. So in zone 1 only this electrochemical machining predominates because here this grinding wheel does not touch the workpiece material here.

So in zone 1 this grinding wheel does not touch the material here workpiece material here. So only there is a electrochemical machining operation which or anodic dissolution is there into in zone because this abrasive particles this grinding wheel does not touch the workpiece surface because there is a decrease in gap in the zone 1 but in zone 2 you can see there is a this abrasive particles or grinding wheel it touches the workpiece surface. So here both electrochemical machining and grinding operation both mechanical abrasion both takes place okay so in zone 2. How about in zone 3 if you see in zone 3 again this abrasive wheel grinding wheel actually it is lifted from the workpiece material. So it is lifted there.

Again it does not touch the workpiece surface in zone 3. So in zone 3 also there is a there is abrasive particles or there is no mechanical abrasion only that electrochemical grinding electrochemical or anodic dissolution or electrochemical machining operation is there in zone 3. So in zone 1 electrochemical grinding and little bit of mechanical abrasion is there but in zone 2 mostly this electrochemical grinding electrochemical operation and mechanical abrasion both are there and in zone 3 only this anodic dissolution is there in zone 3.

So in zone 2 you can see here in stage II you can see there is a this is one abrasive particle, this is one abrasive particles is there and bonding material of the wheel which is metallic bonding material so that is negative charged cathode so grinding wheel it is negatively charged it is cathode and workpiece it is anode here. So in between these 2 abrasive particles you can see this electrolyte it is making a small cell here.

You can see there is a small cell is here, small electrochemical cell it is generated so in that cell actually by electrochemical machining operation or by anodic dissolution material is removed from the workpiece surface. So you can see here in this stage II there is a small cell electrochemical grinding, electrochemical cell, small cell is there. From that cell actually machining is going on by electrochemical machining and also at the same time this abrasive particles are touching to the workpiece surface okay. So by mechanical abrasion also material is removed from the workpiece material. So there are 2 process in stage II by electrochemical operation or anodic dissolution plus mechanical abrasion so which is visible in this figure.

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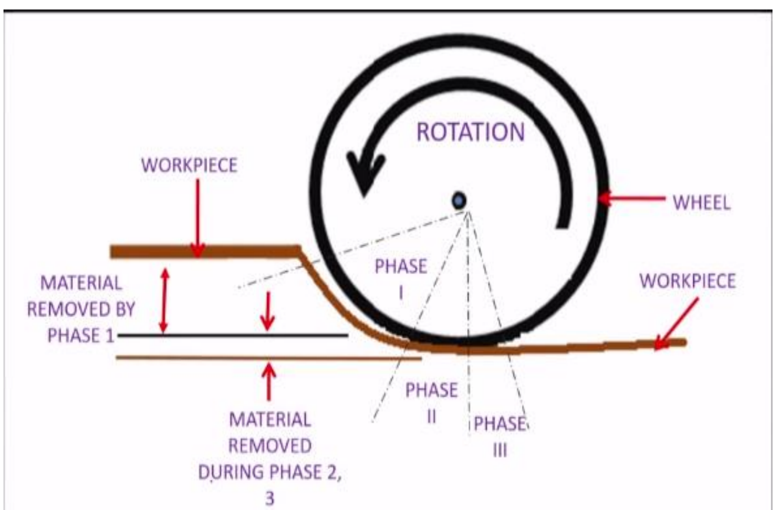

Fig. Three phases of ECG material removal

So here you can see in phase 1 this much of material is removed by phase 1 material removed by phase 1 and this much material is removed by phase 2 and phase 3. So most of the materials are removed in phase 1 here and in phase 2 this much of material is removed in phase 2.

So here you can see this interelectrode gap there is a decrease in trend in between this grinding wheel and the workpiece so this gap is actually reducing here and here actually it is touching, at this point it is touching to the workpiece surface. So this is the metallic bonded grinding wheel, this is the workpiece here. There are 3 zones; zone 1, zone 2, and this is zone 3 and different zones there are different kind of material is removed.

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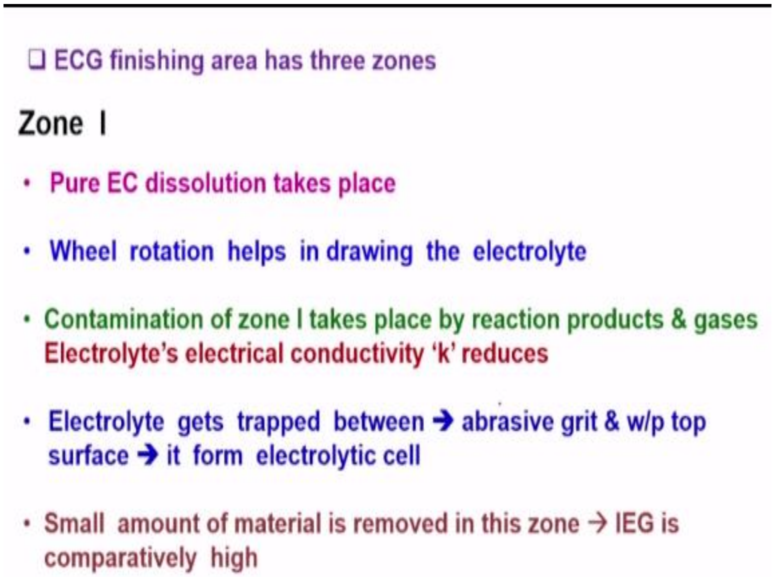

So electrochemical grinding finishing area there are 3 zones already I told. In zone 1 it is purely electrochemical dissolution takes place. So purely electrochemical dissolution takes place in zone 1. So there is a wheel rotation is there. Because of this wheel rotation it drags the electrolyte into the interelectrode gap. So because of this rotation of this wheel it drags the electrolyte into the interelectrode gap in zone 1 okay.

So there is a because of dragging of this electrolyte there and at the same time electrochemical dissolution is there so this hydrogen gas bubbles are evolved at the cathode. Also there is a mechanical means metallic sludges are actually generated. So because of this metallic sludges or debris or whatever machining products actually this mechanical sludges it little bit increase the electrical conductivity but whatever this hydrogen gas bubbles are generated because of that this electrical conductivity of the electrolyte actually it reduces.

So this both phenomena actually happens there in this zone 1. So because of this contamination of this electrolyte in zone 1 because of this machining operation which happens there so overall this electrical conductivity of the electrolyte reduces okay. So contamination on zone 1 takes place by reaction products and gasses electrolyte's electrical conductivity k reduces there. So electrolytes gets trapped between the abrasive grit and workpiece surface and it form a electrolytic cell also okay.

So electrolytes get trapped in between these 2 abrasive particles and the workpiece so it forms the electrolytic cell, small small electrolytic cell. So as the electrical conductivity reduces electrolyte's electrical conductivity reduces so this interelectrode gap also then will reduces. Interelectrode gap also reduces in zone 1. So that is why this wheel comes closer from interelectrode gap from a higher value it comes closer to the lower value at the end of zone 1 okay. So small amount of material is removed in this zone. So here interelectrode gap is comparatively high and mostly this material removal takes place because of this electrochemical dissolution in this zone.

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In zone 2 actually this pressure is high because this electrolyte because this grinding wheel is rotating with a very high RPM 1200 to 1800, 1200 to 1400 meter per minute this peripheral velocity of this grinding wheel, so it is rotating at a very high RPM so because of that actually huge amount of pressure actually generated in zone 2. So also there is a converging gap there. So there in this zone 2 actually this abrasive grinding this grinding wheel and the workpiece it comes very closer okay. So this abrasive particles are touching to the workpiece surface in that zone. So because of this converging gap in that zone higher pressure exist.

So pressure this pressure on the electrolyte is more in that zone 2. So it suppresses the formation of the gas bubbles. Whatever gas bubbles are there it suppress it because of this high pressure this formation of this hydrogen gas bubbles actually suppressed is suppressed. So because of this less formation of this hydrogen gas bubbles because of this high pressure of this electrolyte in that zone so electrolyte's electrical conductivity will be more in that zone in zone 2, electrolyte's conductivity because there is no formation of hydrogen gas bubbles because of this high pressure so electrical conductivity of the electrolyte's electrical conductivity will be more okay. So material removal rate will be high because this higher the electrical conductivity of the electrolyte more material will be removed by electrochemical dissolution.

So in this zone actually this abrasive particles also touching to the workpiece surface. So in this zone abrasive grains abrade the surface as a result they remove material from the workpiece and oxide layers also whatever oxide or precipitation layers are generated on the workpiece surface this oxide layers also removed in this zone 2 because this abrasive particles are touching to the workpiece surface.

Also in this zone this in between this abrasive particles on the workpiece there is a tiny small small cells electrochemical cells are generated or formed. From this electrochemical cells material is removed by electrochemical dissolution or anodic dissolution. So material removed in the form of small chips here. So oxide layers removal of helps in electrochemical dissolution because this precipitation layer because of this electrochemical or any chemical process there is a passivation layers are generated.

This passivation layer has to be removed to come to the fresh metallic surface exposed to the electrolyte to make the fresh metallic surface (()) (21:29) to the electrolyte so this oxide layer or passivation layer has to be removed. As the abrasive particles are reviewing the passivation layer in zone 2 fresh metals actually coming out in front of this electrolyte so more machining will be there. So that is why it is called mechanical assisted electrochemical grinding process because here more material removal is in zone 2 by electrochemical dissolution and also mechanical grinding operation.

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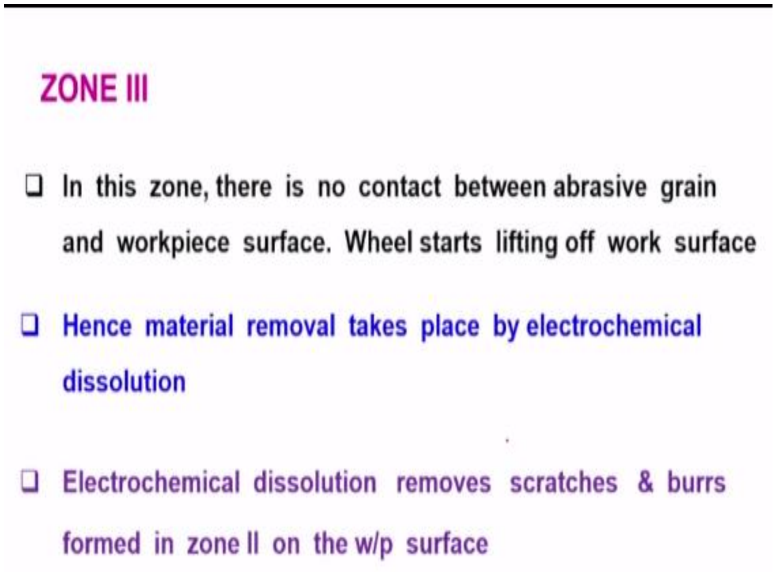

Now come to zone 3. Now in zone 3 actually suddenly this it is lifting so this grinding wheel is lifting from the workpiece surface. Now pressure is also released now in this zone but this abrasive wheels also not touching to the workpiece surface. So grinding wheel also not touching to the workpiece surface it is lifting from the workpiece surface. So in this zone also material removal is by electrochemical dissolution only, only anodic dissolution only okay.

So in this zone there is no contact between the abrasive grain and workpiece surface. Will starts lifting off from the workpiece surface. Hence material removal takes place by electrochemical dissolution only and electrochemical dissolution removes scratches and burrs formed in zone 2 and whatever burrs and scratches formed in zone 2 by abrasive particles it is removed in zone 3 by electrochemical dissolution. So electrochemical dissolution removes scratches and burrs formed in zone 2 on the workpiece surface.

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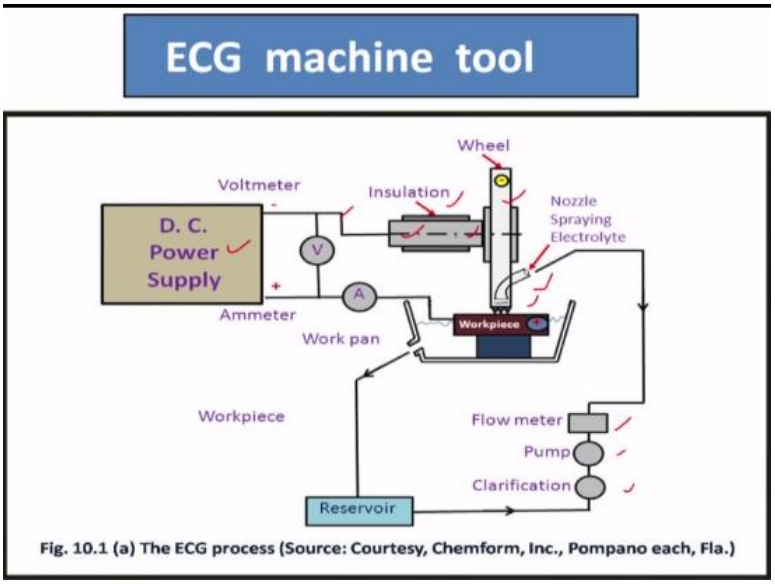

Fig. 10.1 (a) The ECG process (Source: Courtesy, Chemform, Inc., Pompano each, Fla.)

So now this is the electrochemical grinding machining tool. So we can see here this is the grinding wheel here metal bonded grinding wheel which is negatively charged which is conducted to the cathode negative charged here. So there is a nozzle here. So this nozzle this working of this nozzle actually it flows the electrolyte in between this grinding wheel peripheral surface and the workpiece in between that interelctrode gap it flows the electrolyte into the interelectrode gap. Now this grinding wheel, this is the grinding wheel shaft.

So it is a rotating shaft. So now this grinding wheel shaft it is negatively charged. So how to give curent to this negatively charged current to this shaft. So there are 2 different ways you can give current to this shaft here. So either you can use a brass here so you can use a brass. Generally in the market this graphite brasses are there.

Within this graphite brasses you can use you can you can give current to this grinding wheel shaft or you can dip this shaft inside a mercury content. So inside a mercury content you can dip this shaft and there because this mercury it is electrically conducting material okay so you can flow the current to the shaft by this 2 different ways, either brass or mercury dipping. So this is the DC power supply here. So from this DC power supply this negative one it is connected to the grinding wheel and this positive terminal it is connected to the workpiece okay.

So now here through this nozzle you are giving this electrolyte flowing that electrolyte at the interelectrode gap and both the grinding wheel, part of the grinding wheel and the workpiece it is dipped inside the electrolyte, electrolyte chamber okay. So as the wheel is rotating with a high RPM this effective flowing of electrolyte at the interelectrode gap can be ensured. So there is a flow meter and pump and then and there is a this fluid it is also clear means cleaned okay filtration system is there. After filtering actually it is again it is flown through the nozzle here. So there is this wheel and this electrolyte it is recirculated during electrochemical grinding operation.

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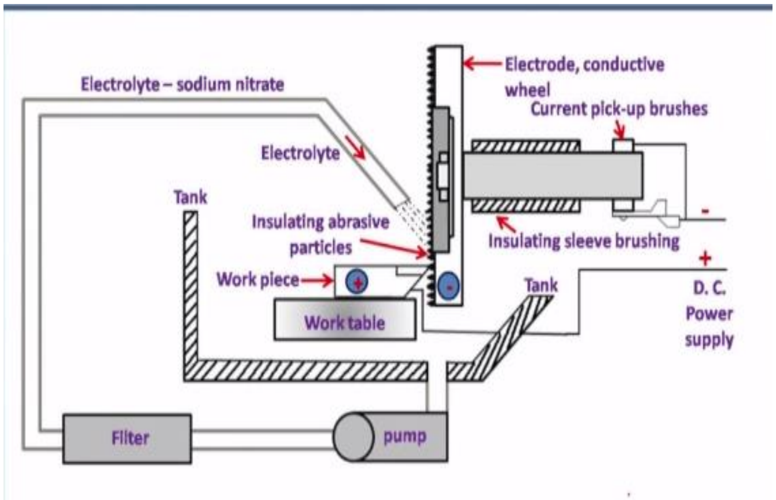

Fig. 10.1 (b) The ECG process (Source: Courtesy, Chemform, Inc., Pompano each, Fla.)

So you can see here this this carbide tip of a cutting tool it is actually sharpened okay so this carbide tip is sharpened here. Through this nozzle you can see this at this interelectrode gap this electrolyte is flown at this interelectrode gap. So here actually it is through this brushes actually in this shaft, grinding wheel shaft you are you are giving current using this brush, current to the shaft. So this is the electrode here again it is a conducting bonded metal bonded grinding wheel okay. So this is the container here so at this container we kept your work table here.

On that work table this carbide tip is kept. So in between this carbide tip and this grinding wheel there is a insulating abrasive particles are there. So it is making the gap between this grinding wheel and the workpiece material, it maintains the gap, so this abrasive particles okay. So this there is a filtering system is there. So as the electrolyte is recirculated it should be filtered properly and through pump it is again flown through the nozzle here and there is a DC power supply here.

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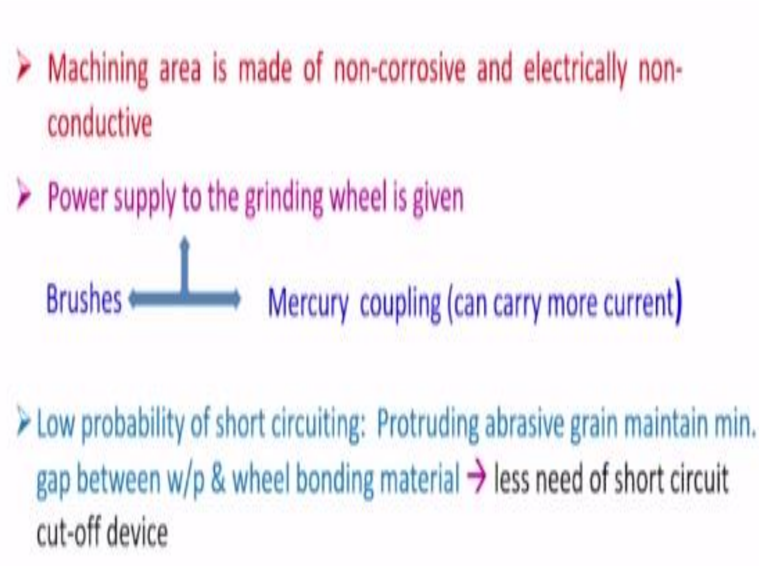

So machining are made of noncorrosive because total machining area electrolyte is there. So this electrolyte it is corrosive, corrosive electrolyte is used. So total machining area has to be made of noncorrosive material. So this machining area, all the components in the machining area are made of noncorrosive and electrically nonconductive material okay. Power supply to the grinding wheel is given either through brasses or through mercury coupling and if you are using mercury coupling it can carry more current also.

So there is a low probability of short circuiting because protruding abrasive maintain the interelectrode gap between the workpiece and the wheel bonding material. So there is a no need of short circuit protection circuit. So there is a no need of short circuit protection circuit in case of electrochemical grinding because this abrasive particles are maintaining the gap in between this grinding wheel and the workpiece so there is no need of short circuit protecting circuit. So there is there will not be any short circuit during machining.

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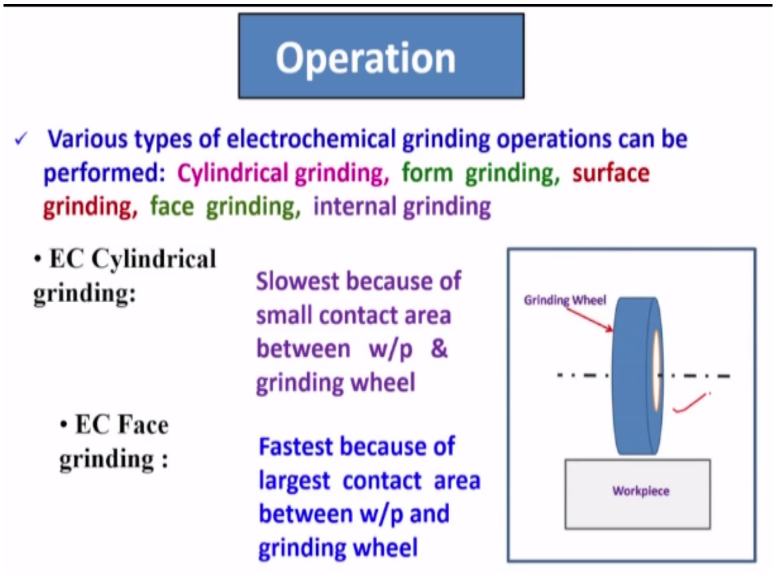

So there are different kinds of grinding operation, electrochemical grinding operations are available like cylindrical grinding you can see here this is the cylindrical grinding, form grinding. Using form grinding any kind of geometry you can generate in to the workpiece surface so that is called form grinding. So in that case we shall use form grinding wheel. There is a phrase grinding operation is also there. Top plate of the workpiece can be polished or finished by phrase grinding operation or internal grinding.

So you can do the internal grinding also okay. So electrochemical cylindrical grinding. So this is the slowest, slowest because the smallest contact area between the workpiece. Suppose this is the cylindrical grinding operation here so only this portion here actually it is in touch with the workpiece surface. So that is why this is the slowest process. Smallest contact, small contact area between workpiece and the grinding wheel. Face grinding actually it is the faster process because largest because it has a largest contact area between workpiece and the grinding wheel.

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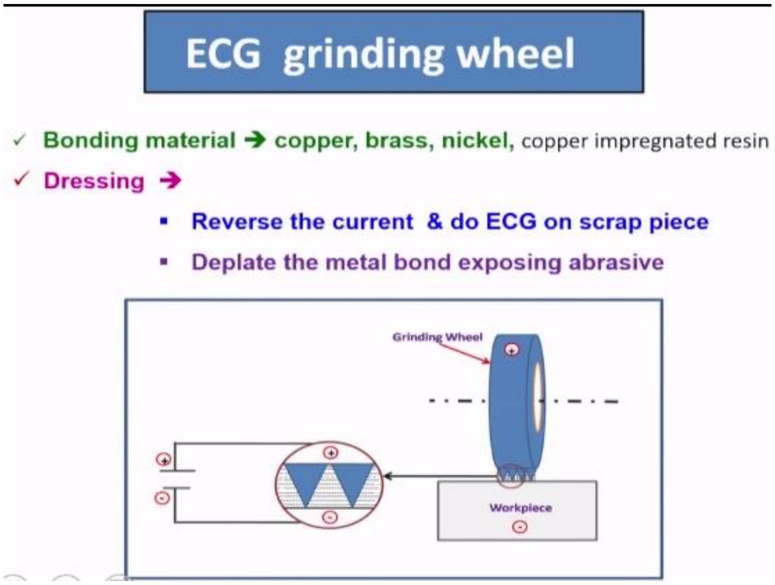

Now bonding material. So what kind of bonding materials are used for this grinding wheel. So you can use copper, brass, nickel, or copper impregnated resin also you can use as the metallic bonding material in case of electrochemical grinding operation. So now dressing is also required because as the machining as the 10% there is a mechanical abrasion is there so whatever this abrasive particles whatever the tiny chips are actually generated it may clog into the grinding wheel. So then its performance will be reduced. So for doing that thing for dressing operation reverse the current and do the electrochemical grinding on a scrap piece of scrap workpiece.

So in normal case actually this grinding wheel it is cathode and workpiece is negative. But in case of during dressing operation what you have to do you have to chase the polarity of the grinding wheel and the workpiece. So in that case your grinding wheel will be positively charged and your workpiece will be negatively charged okay.

So in that case what will happen, material will be removed from the metallic grinding material by anodic resolution okay so then phrase abrasive particles will come outside okay so reverse the current for dressing operation reverse the current and do the electrochemical grinding operation on a scrap piece of workpiece scrap workpiece so in that case that phrase abrasive particles will come outside so it will deplate the metal bond exposing the abrasive.

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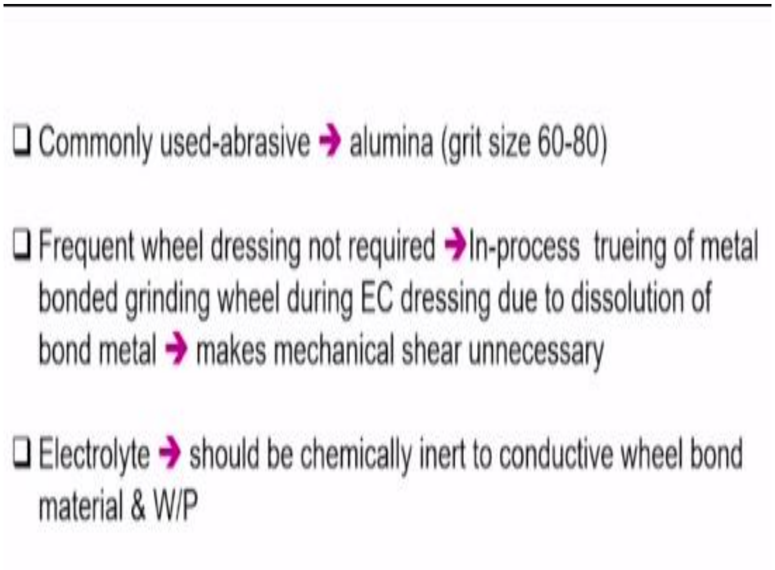

So commonly used abrasives are alumina oxide, its size 60-80 micron size is used grit size is 60-80 micron. Frequent wheel dressing is not required like in normal grinding operation so because in-process string of the metal bonded grinding wheel during electrochemical dressing due to the dissolution of bonding material. So that is why it does not need mechanical shear. So mechanical shear is unnecessary and water kind of electrolyte is used. Electrolyte should be electrically or chemically inert to conductive wheel bond material and workpiece. So electrolyte should be chemically inert to conduct wheel bond material and workpiece.

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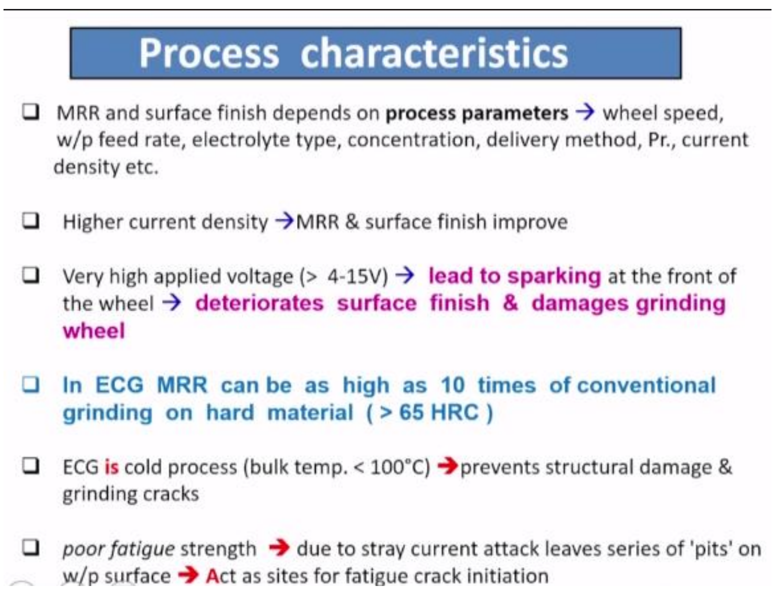

So what are the process characteristics. Material removal rate surface finish depends on the process parameters like wheel speed, at what RPM we are rotating that wheel. So what is the wheel field or workpiece speed rate in case of fixed grinding wheel. Electrolyte type, concentration of this electrolyte, delivery method, pressure, current, density etc. So these are the different means process parameters.

So higher current density if we if we want to get high material removal rate and high surface finish better surface finish so in that case we have to apply high feed rate. High current density will increase the material removal rate as well as surface finish. It will improve the surface finish also it will increase the material removal rate but if we increase the voltage so in case of if we increase the voltage more than 4-15V in that case due to sparking so it leads to sparking at the wheel at the front of the wheel it leads to sparking and deteriorates the surface of this surface finish and damages on the grinding wheel.

So it deteriorates the surface finish and damages in the grinding wheel. So in case of electrochemical grinding operation material removal rate as high as 10 times higher than the material removal rate in conventional machining for a 65 HRC workpiece. So it is a bulk process, it is a cold process. So here this temperature does not go beyond 100 degree centigrade because whatever this temperature is generated because this electrolyte is forced to flow in between this grinding wheel and the workpiece so this temperature actually it is automatically controlled okay. So whatever this heat is generated it is taken outside okay. So it is automatically, temperature is automatically controlled.

So it does not go beyond 100 degree centigrade. So if goes beyond that then there is a structural damage and grinding cracks may be generated. So poor fatigue strength is observed in case of electrochemically grinded workpiece because there is a stray cuttings are there by the grinding wheel so because of stray cuttings are there the small small pits are actually generated on the machined surface. So due to the stray cutting stray cutting current attack leaves the series of pits on the workpiece surface. It acts as a sites for fatigue crack initiation. So it acts as a sites for fatigue crack initiation.

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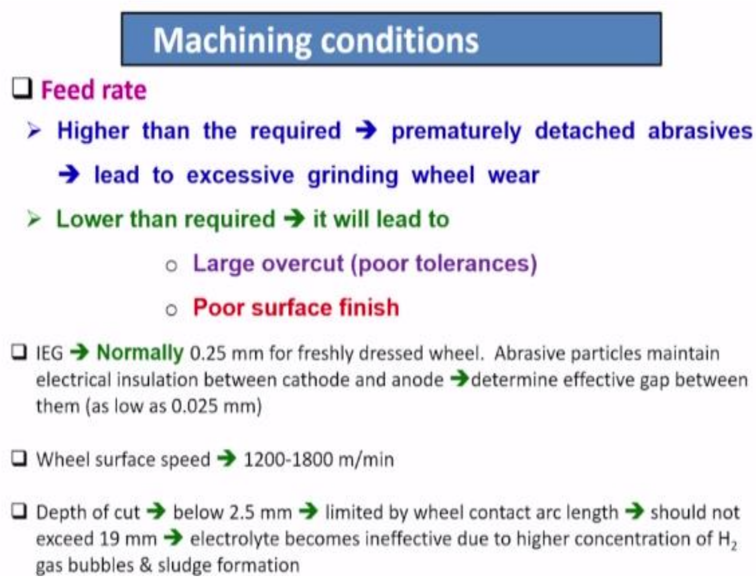

So machining condition. If we if we give feed rate in that case than the required one okay. Premature detachment of the abrasive will be there so because this abrasive particles will be more loaded there in that case if we give more feed rate so there will be premature detached abrasive will be there. So it will lead to the excessive grinding wheel here. So grinding wheel will wear out because if we give more shear more feed rate.

So interelectrode gap generally 0.25 mm for a freshly dressed wheel. Abrasive particles maintain the electrical insulation between the cathode and anode and determine effective gap between them as well as 0.025. So wheel surface speed is 1200-1800 m/min and depth of cut it is below 2.5 mm, so it is limited by the wheel contact arc length. So it is limited by the wheel contact arc length. So contact arc length already we have shown there. So this is the contact so this is the contact arc length.

So if we increase the feed this contact arc length increases. As the contact arc length increases limited to the wheel contact length should not exceed 19 mm. If the contact arc length between the grinding wheel and the workpiece it is more than 19 mm in that case electrolytes become ineffective due to the higher concentration because contact arc length if we if it is increasing okay so more hydrogen gas bubbles will be generated okay. So electrolytes become ineffective in that case due to the higher concentration of hydrogen gas bubbles and sludge formation. So current generally it is maintained in between 50 to 3000 A. So in between this 50 to 3000 A in between this current is maintained in case of electrochemical grinding operation.

So if feed rate is lower than the required one in that case what will happen? Large work cart will be there okay so if it is lower than the required one then it that case large work cart will be there or poor tolerances will be there and poor surface finish will be achieved is achieved if we decrease the feed rate beyond a lower value.

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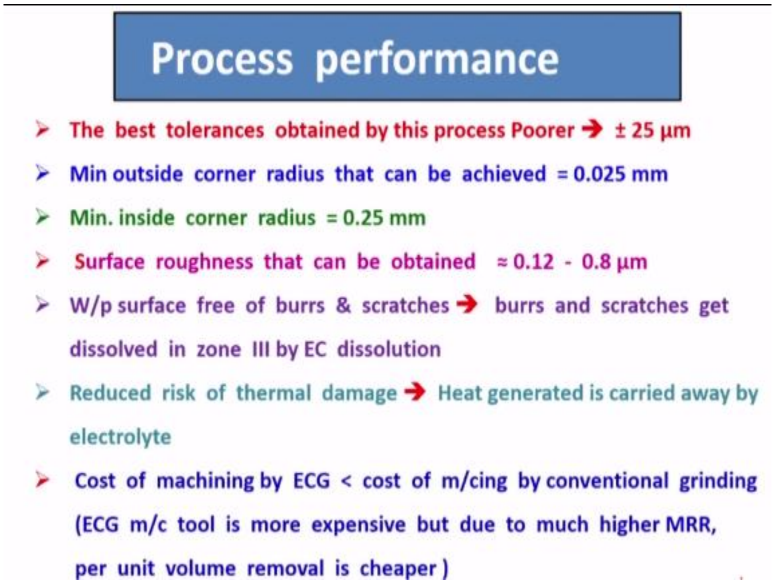

So these are the process performance. Best tolerances obtained by this process is plus minus 25 micron. Minimum outside corner radius is 0.025 but inner radius minimum inner radius corner radius is 0.25 only. So surface roughness that can be obtained 0.12 to 0.8 micron. So workpiece surface there is no burrs there is no scratches are there. Burrs and scratches get dissolved in the zone III by electrochemical dissolution.

So there is a very reduced risk of thermal damage because temperature does not go beyond 100 degree centigrade and whatever heat is generated is carried away by the electrolyte. So cost of machining in case of electrochemical grinding is very less because here in electrochemical grinding material removal rate is very high than normal grinding operation so that is why cost of machining is very high in case of electrochemical grinding operation cost of machining is less in case of electrochemical grinding operation. So cost of machining by conventional grinding operation is more and cost of machining in case of electrochemical grinding operation is less but electrochemical grinding machine tools are actually costlier than conventional grinding operation okay.

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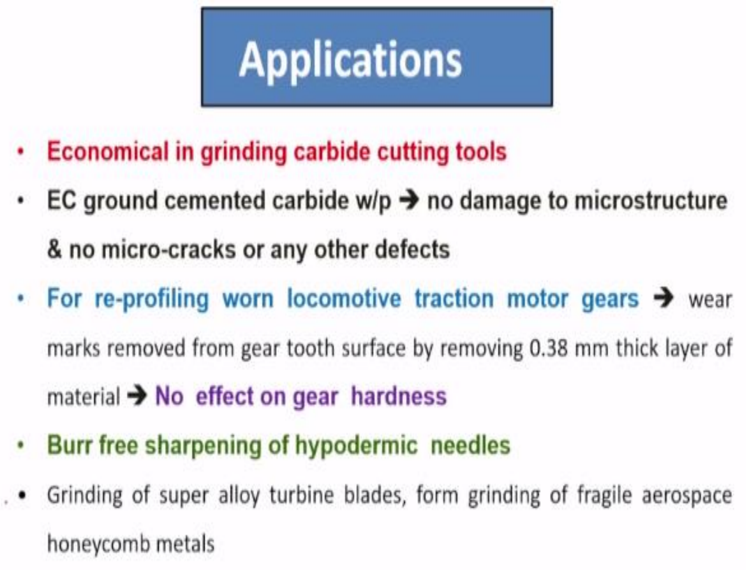

So these are the applications for this electrochemical grinding operation. So it is used for grinding of carbide cutting tools okay. So it is economical in grinding carbide cutting tools. Electrochemical grinding cemented carbide workpiece no damage to the microstructure no micro-cracks or any other defects are there.

For re-profiling worn locomotive traction gear wear marks removed from the gear tooth surface by removing 0.38 mm thick layer of material from the gear and there is it does not the gear hardness actually does not deter the machining process. So it is also used for burr free sharpening of the hypodermic needle this electrochemical grinding. So grinding of super alloy turbine blades, form grinding of fragile aerospace honeycomb structures of metals actually it is done by this electrochemical grinding operation.

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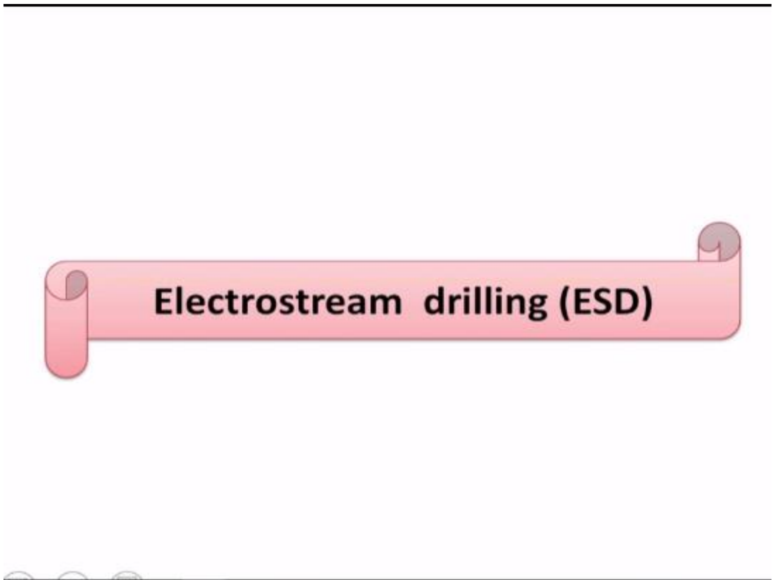

So now we shall start with another process that is another hybrid process that is called electrostream drilling operation. So this kind of electrostream drilling so it is used for high aspect ratio holes. Suppose if you want to make a holes of 40:1. This much of high aspiration holes with small diameter holes you want to maintain.

So in that case this kind of electrostream drilling operation can be used. So in conventional electrochemical drilling operation hollow metal tubes are used as the cathode. So required force at high velocity through this hollow tube and cathode penetrates in the hole and hole diameter in that case this hole diameter is greater than the cathode diameter because through the hole through the tool metallic tube actually you are flowing the electrolyte with a very high velocity and it is coming outside okay.

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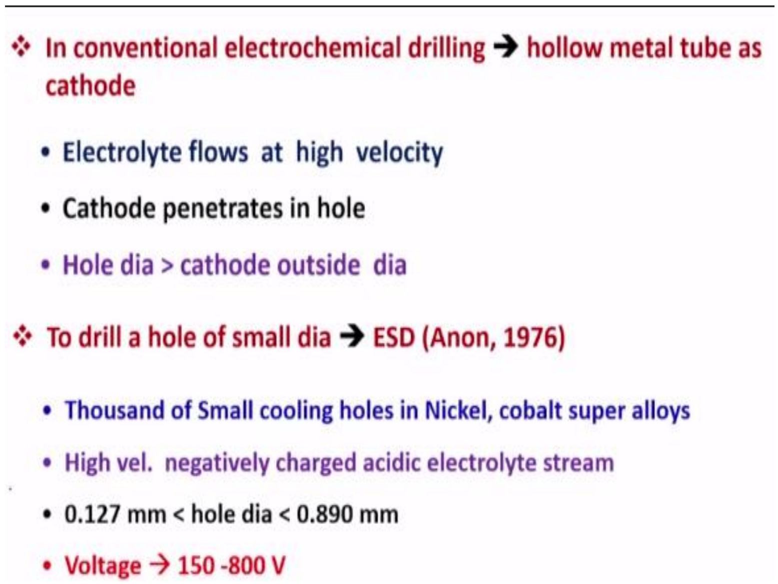

So outside actually because of this stray cutting it will become stray cutting by this electrode, metallic electrode this diameter of the hole which is made by this process will be higher than the cathode diameter. So for drilling of a very small diameter hole with a high aspect ratio this kind of electrostream drilling operation is utilised. Thousands of small cooling holes in nickel, cobalt, and super alloys can be made by this process. High velocity negatively charged acidic electrolyte is used. Because acidic in case of normal ECM process whatever this metallic hydroxides are there actually it does not reacts with the electrolyte. It precipitates into the electrolyte. So it does not react with the electrolyte.

But in case of electrostream drilling operation, acidic electrolyte is used. So whatever this debris particles are generated metallic hydroxides are generated it dissolves, it is dissolved into the this metallic hydroxides are dissolved into the acidic electrolyte. So as it dissolves into the electrolyte, so it does not clog in between this interelectrode gap okay. So that is why you can generate any kind of hole any dimension of the hole you can generate.

So using this electrostream drilling thousands of small holes are can be made in nickel, cobalt, and super alloys. High velocity negatively charged acidic electrolyte, stream of acidic electrolyte is used and diameter of the holes are generated 0.127- 0.89 mm and voltage applied 150-850 V. So this much of voltage is applied. So this is the schematic diagram of the electrostream drilling operation. So here you can see in electrostream drilling operation we do not use any metallic tube. So here actually non-conducting material generally glass is used as a nozzle.

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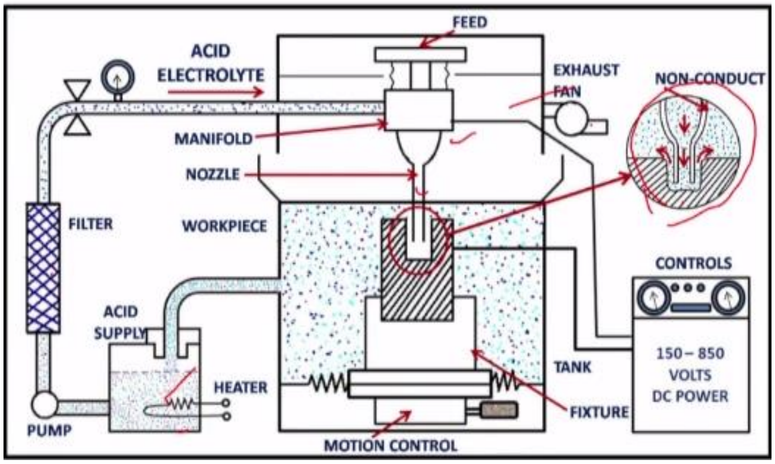

So this electrostream stream of electrolyte with a high velocity it is flowing through this nozzle. So this nozzle actually its diameter is as less as possible and it is given a it is feeded towards the workpiece surface okay. So that is why this small interelectrode gap is maintained and acidic electrolyte is used. This acidic electrolyte after impinging into the workpiece surface, material removal rate will be there. So it will start removing material from the workpiece material. So this exhaust fan is required actually because from this zone whatever this volatile material is means whatever this gas bubbles are generated so this gas bubbles are actually it is released from this exhaust fan.

So this is the exaggerated view of the machining. So you can see through this hole actually through this glass tube this acidic non-electrical charge acidic electrolyte is coming and it is going outside. So there is a heater is there inside this container, electrolyte container, to maintain the temperature at a certain value. So there is a filter is there. Through this filter actually this electrolyte is passed. So while passing it will remove the debris particles from metallic hydroxide. So motion control is given to this workpiece and here this tool is actually kept fixed.

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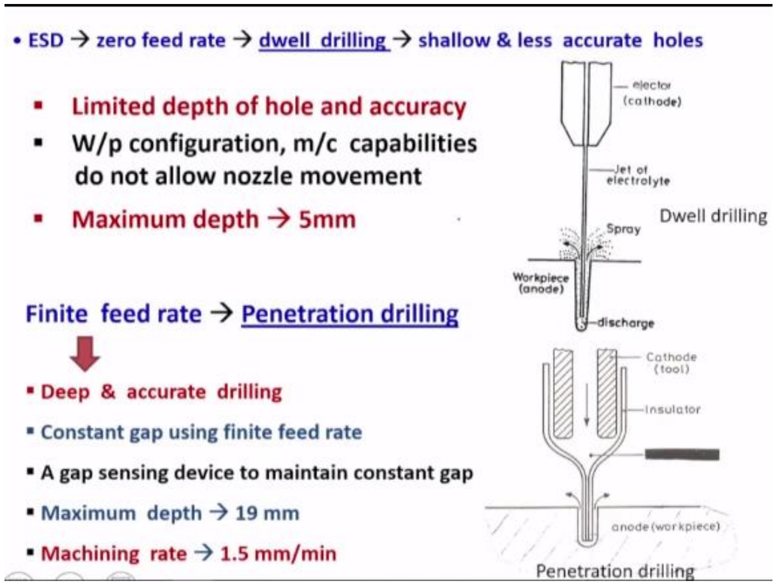

So there are 2 different process is there, one is dual drilling and another one is the penetration drilling. Dual drilling is used when this nozzle actually it is kept fixed and penetration drilling, in case of penetration drilling this nozzle actually it is not fixed, it is given certain feed towards the workpiece surface okay so when there is a zero feed rate to this nozzle then it is called dual drilling. This dual drilling actually it is done for shallow holes, for shallow holes it is done. Shallow and less accurate holes this dual drilling is done.

So limited depth of hole and accuracy. Workpiece configuration and machine capabilities do not allow the nozzle movement and maximum depth can be machined by this process is 5 mm, but in case of penetration drilling as the nozzle is actually it is coming towards the it is fed towards the workpiece so here this deep and accurate drilling can be possible. Constant gap using finite feed rate so constant gap is actually maintained using a finite feed rate. So a gap sensing device is used to maintain the constant gap. Maximum depth can be machined is 19 mm and machining rate is 1.5 millimeter per minute.

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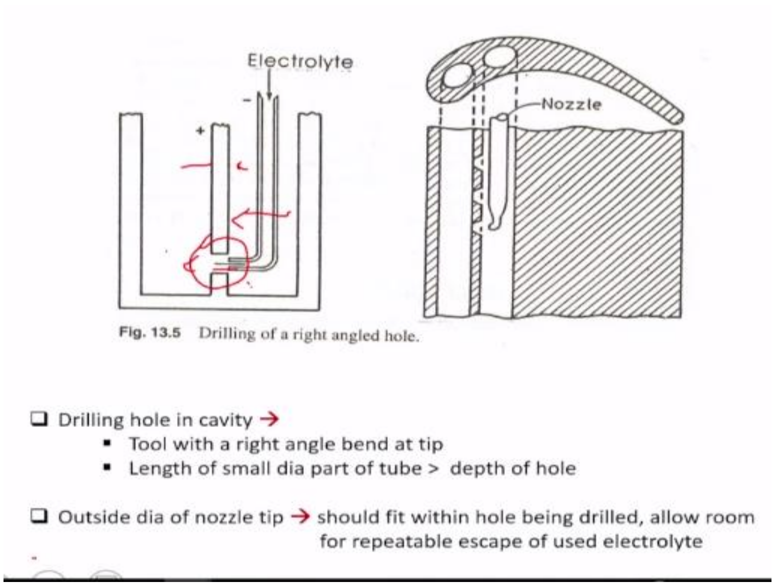

So now this kind of holes you have to make, so for making this kind of holes this electrostream drilling operation is the only solution. Here this diameter of the nozzle actually it is reduced here is further reduced and also there is a sufficient space is there to insert this electrolyte to insert the sufficient gap is available to insert this electrolyte inside the tube. So this tube actually this front portion of this tube actually it is bent and it is forwarded inside this hole okay. So this much of hole can be generated. So length of the bent tube is more than the thickness of this wall. So this kind of small small holes perpendicular to this wall it is generated by the electrochemical machining or electrostream drilling operation.

So this drilling hole in cavity tool with a straight angle bent at tip. Length of the small part of the tube is greater than the depth of hole, so this is the depth of hole. Outside diameter of the nozzle tip should fit within the hole being drilled, allow room for repeatable escape of used electrolytes.

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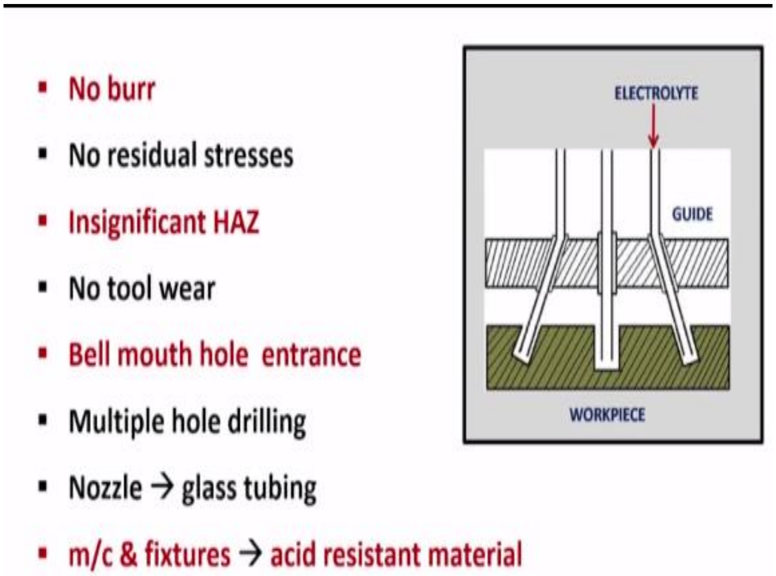

So electrostream, this is the electrostream drilling. There is no burrs are generated. No residual stress is generated and temperature it is maintained up to 100 degree centigrade so that is why there is no heat affected zone, insignificant heat affected zone. There is no tool wear. Bell mouth hole is generated. Multiple hole drilling. Nozzle, it is made of glass tubing. Machine and fixture, acid resistant materials are used. So this is the acid resistant material is used for machine and fixtures.

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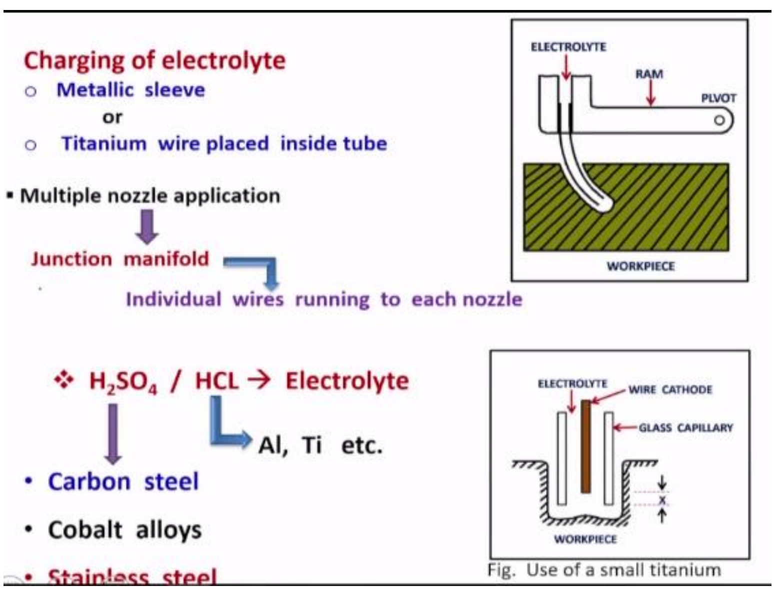

So charging of electrolyte, how to charge the electrolyte. So you can use the metallic sleeve or you can use a titanium wire. So this titanium wire it is fed towards the mouth of the hole okay. So it is fed towards the end of this hole. So you can see this wire, so this cathode it is fed towards the end of the nozzle okay so mouth of the nozzle it is fed. So this is the glass capillary here. So this is the electrolyte is flowing through this capillary the high velocity and this is the at the center this wire cathode wire is used at the center.

So 2 types of electrolyte is used in case of electrostream drilling. So HCl, hydrochloric acid which is used for aluminium or titanium or sulphuric acid H2So4 it is used for carbon steel, cobalt steel, and stainless steel, for machining this kind of material. So this kind of RAM is used if you are machining, you are making a hole which is inclined to the top surface okay so this kind of inclined holes also you can generate.

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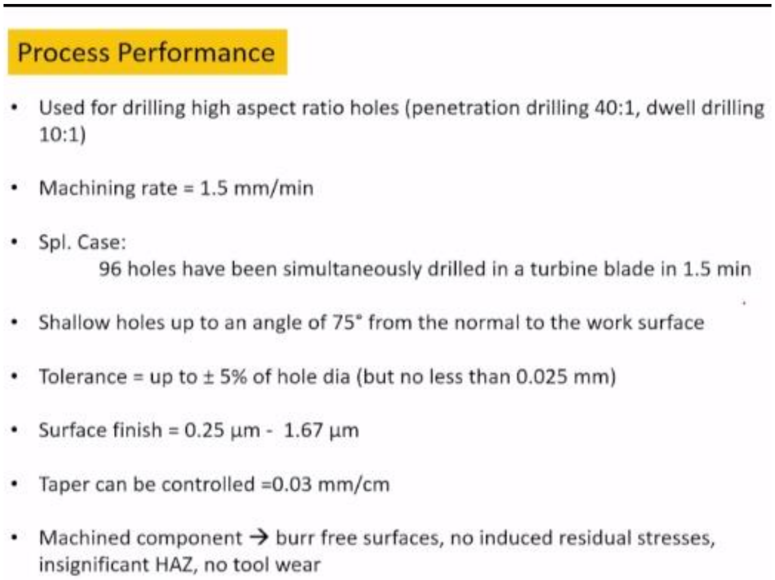

So process performance used for drilling high aspect ratio holes. Penetration for penetration drilling 40:1 so length to diameter ratio of the holes are 40:1 and for dual drilling it is 10:1. Machining rate is 1.5 mm/min. In special case 96 holes have been simultaneously drilled in a turbine blade in 1.5 minute. Shallow holes up to an angle 75 degree from the normal to the workpiece can be made. Tolerance up to plus minus 5% of the diameter of the hole to be machined but it should it is less than 0.025 mm. It should be less than 0.025 mm. Surface finish achieved is 0.25 micron to 1.67 micron. Taper can be controlled as 0.03 mm to per cm length of the wall. So this much is the taper. So this machine components are burr free. No induced residual stress. Insignificant heat affected zone and no tool wear is there.

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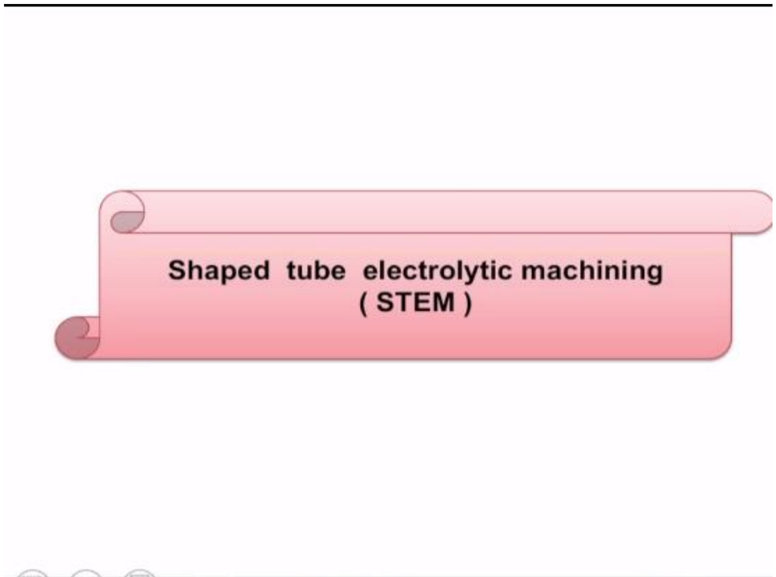

So now another process is there that is called shaped tube, shaped tube electrolytic machining, stem STEM, shaped tube electrolytic machining. In electrostream drilling we have seen this aspect ratio of the holes are maintained as 40:1 maximum, but in case of electrostream drilling the aspect ratio of the holes are maintained at around 300:1. So it is very high, for very high aspect ratio holes to making very high aspect ratio holes shaped tube electrolytic machining is used, STEM is used.

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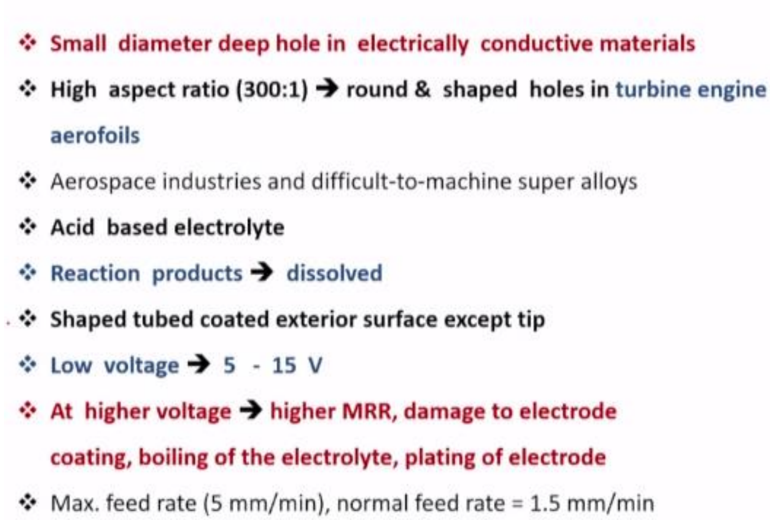

Small diameter hole in electrically conductive materials high aspect ratio 300:1, round or shaped holes can be any kind of holes can be in turbine engine aerofoils can be generated. So this kind of holes can be used in aerospace industries or difficult to machine materials super alloys. Acid based electrolyte is used because this acidic electrolyte it will react with the material so electrolyte will react by electrochemical dissolution and whatever this debris particles are there metallic hydroxide sludges are there it will dissolve into the acidic electrolyte so that it can be taken out from the machining zone.

So only 10% of the 10% of the electrolyte or 10% concentration of H2So4 or HCl is used as a electrolyte. So this reaction products are actually dissolved. Shaped tube coated exterior surface, so here actually this tool actually it is metallic tool is used. Generally this titanium tool is used but here this outside surface of the tool actually it is coated. Only machining is done by the tip of the tool. So this tip of the tool is not coated but outside surface of the tool, hollow tool is coated. So low voltage around 5-15 V is applied.

At higher voltage it will actually material removal rate will be higher. So it will damage the whatever coating material is there it will damage, delaminate the coating material. Also if it is delaminated then there will be stray cutting of this. Because of stray cutting you cannot generate high aspect ratio holes. Non-uniform holes will be generated and there may be, at higher voltage there maybe boiling of the electrolyte maybe there or there is a splitting of the electrolyte maybe there at high voltage. So maximum feed rate it is achieved is 5 mm/min and normal is 1.5 mm/min.

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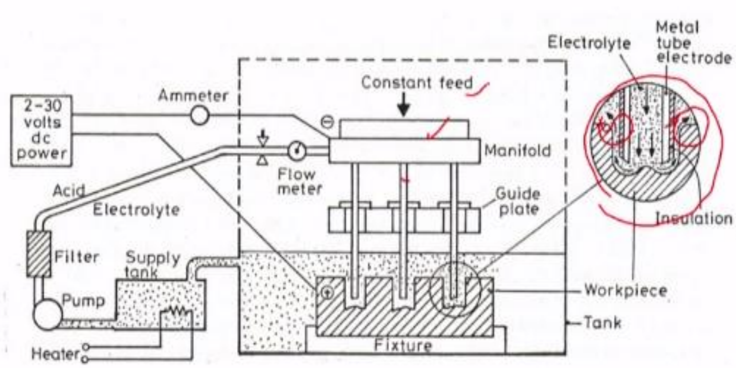

Schematic diagram of a shaped tube electrolytic machining system

So this is the schematic diagram. So these are the metallic tools hollow tubes are used, metallic hollow tubes are used. So this is the exaggerated view. So here you can see this kind of small corner radius is generated on the workpiece. So this there is a constant feed actually given to the tool here.

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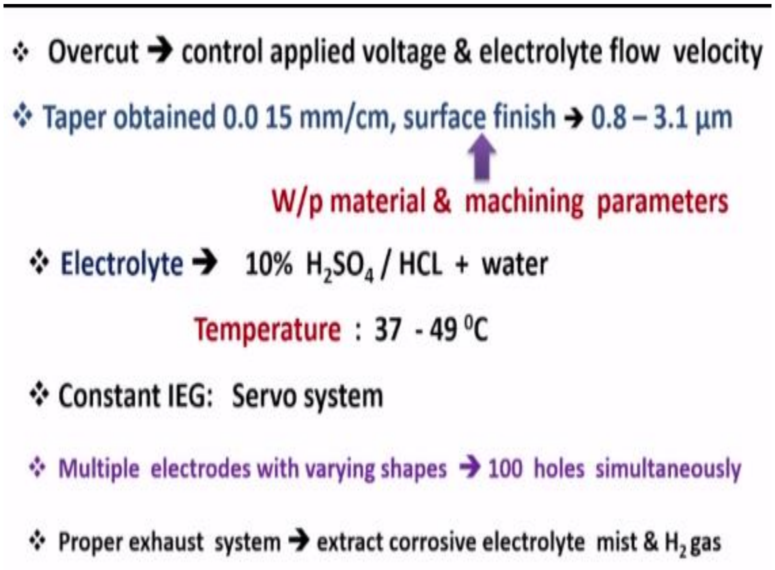

So overcut control applied voltage and electrolyte flow velocity show that overcut can be reduced. Taper obtained 0.015 mm/cm length of the hole. Surface finish is in between 0.8 to 3.1 micron. Electrolyte is 10% H2So4 or hydrochloric acid in water. Temperature is maintained from 37 degree centigrade to 49 degree centigrade so that this electrolyte's electrical conductivity can be maintained. Constant interelectrode gap can be maintained by using a servo system. Multiple electrodes with varying shapes 100 holes simultaneously can be generated. Proper exhaust systems will be there so whatever this gas bubbles or reaction products are generated, that can be released from the exhaust. So extract corrosive electrolyte mist and hydrogen gas is in the exhaust system.

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- After drilling → Thoroughly wash w/p by water to neutralize and remove residual acid
- Tube material: pure titanium to resist acidic action of the electrolyte
- Coating of tube → Saves from attack of electrolyte
  Eliminates stray cutting at the walls of the hole
- Pinhole scratches and delamination in the coating would result in stray cutting (i e non-uniform cutting)
- To obtain best results → tip is dressed at an angle of 10°
- To increase productivity and to make the process more versatile → tips may be made of different shapes and sizes even in multiple hole machining

Or

- To make these tips as independent, separate, bit type of tube of the desired shape and size, and then fasten (by threading or otherwise) them to the bit holder (or electrode)

So after drilling these workpieces are thoroughly actually washed by water to neutralize the remove the residual acid because acidic electrolyte is used for machining purpose. Tube material it is pure titanium to resist any kind of corrosive action. So this tube is made of pure titanium. Coating of the tube saves from the attack of the electrolyte and eliminates stray cutting to the wall of the hole. Pinhole scratches or delamination in the workpiece material or coating material would result in the stray cutting.

So to obtain best results tip is decreased at an angle of 10 degree. So this hollow tube their tip is decreased at an angle of 10 degree. To increase productivity to make the process more versatile tips may be made of different shapes and size even in multiple hole machining. So to make the tips independent and separate bit type of bit type of tube also may be used.

This bit type of tube because machining is done by this tube. So in that tube you can use the bit type tube okay so it can be connected to a non-conducting shaft. So bit type of tube of the desired shape and size and then fastened by threading or otherwise other method to the bit holder bit holder of the electrode. So after this electrochemical machining okay. Thank you.