Advanced Manufacturing Processes
Prof. Dr. Apurbba Kumar Sharma
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 3
Advanced Machining Processes
Lecture - 15
ECM Kinematics and Tool Design

Welcome to this another session on electro chemical machining, under the course advanced manufacturing processes. In the previous session, we have discussed about the ECM process, its basic principles, the electrolysis process and the chemical reactions involved in it along with the basic features of the electro chemical machining process. In this present session, we will study about the ECM sub systems, the advantages and limitations of this process, the application of ECM process and some major variance and process parameters in electro chemical machining process. Let us look at the major sub systems in electro chemical machining. The major sub systems are, the power supply unit, the electrolyte circulation system, the control system and the machine itself.

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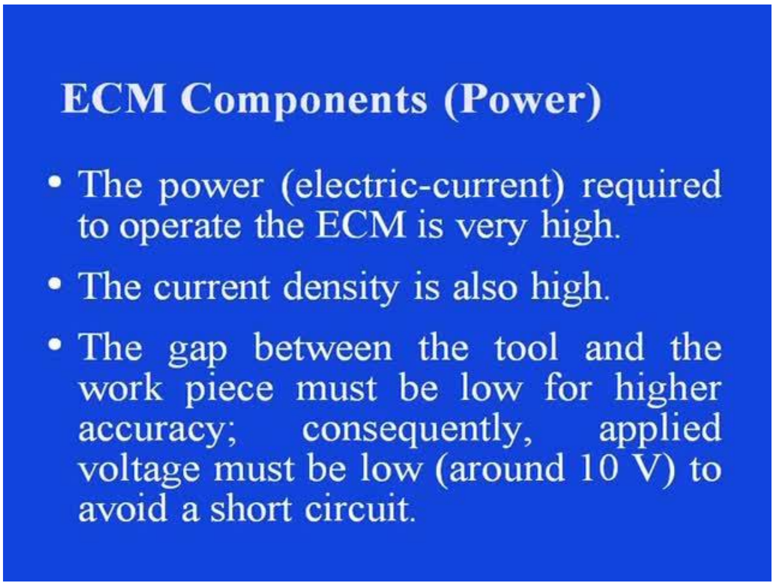

Let us see the power unit in electro chemical machining. The power required to operate an ECM setup is very high. The current density is also very high. The gap between the tool and the work piece must be low for higher accuracy, consequently applied voltage must be low something around 10 volt, as we have already indicated in the previous session, to avoid shot circuit conditions. Then the electrolyte circulation system must be injected in the gap at the high speed.

So, this should be within 1500 to 3000 meter per minute. The inlet pressure of this fluid must be between 0.15 to 3 mega pascal. The electrolyte system must include a fairly strong pump and a storage tank the system also includes a filter sludge removal system and 220 units. As we have already indicated, this metallic sludge if it again being circulated in to the gap, this can cause a disruption in the machining process. It may clock the gap, inter electrode gap and therefore, they need to be removed from being circulated again and again. Moreover this metallic sludge may be harmful for human being etcetera or the living beings, therefore they should be carefully fitted once separated.

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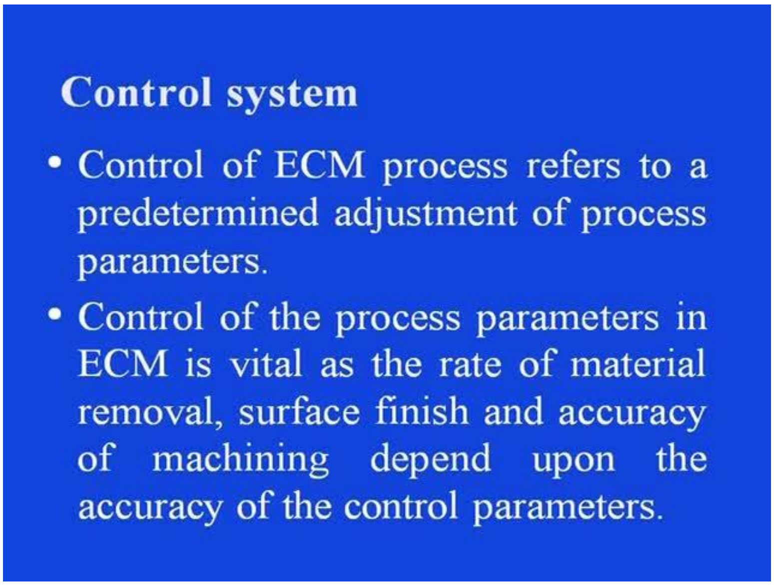

Let us see the control system involved in ECM system. The control of ECM process refers to a predetermined adjustment of process parameters. Control of the process parameters in ECM is vital, as the rate of material removal surface finish and accuracy of machining depends upon the accuracy of the control parameters. Control parameters include here voltage, inlet and outlet pressures of the electrolyte, temperature of the electrolyte etcetera. The current is dependent on the above parameters and of course, on the feed weight. Let us see the machine used in ECM.

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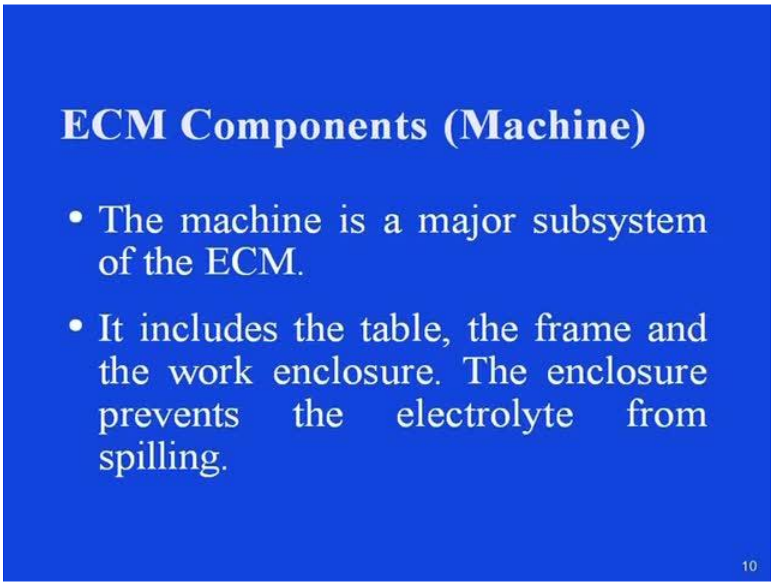

The machine is a major subsystem in this system and it includes the table, the frame and the work enclosure. The enclosure prevents the electrolyte from spilling. Moreover if any toxic gases are developed, this can prevent from getting spread and making the environment polluted. Now, let us see the process parameters involved in ECM. An Ishikawa cause an effect diagram can be prepared like this which is on screen.

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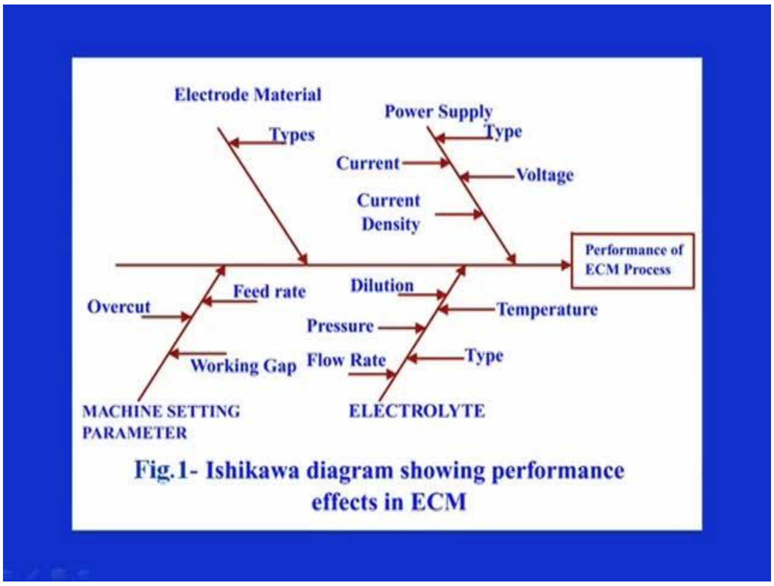

So, there are basically four types of parameters, electrode material based, power supply based, electrolyte based and machine setting parameters. In electrode material, so type of the electrode material is of highly important like whether we are using copper or other material aluminium or graphite etcetera. Then the power supply based like the type of power supply the voltage applied, which is usually around 10 volt. Then the current which depends on number of other parameters as as we have already discussed and the material removal rate as well as the finish will will depend heavily on this current, the current density, in squire unit area.

Then as far as the machine setting parameters are concerned, the overcut, the feed rate, the working gap, how they are to be maintained? As far as the electrolyte is concerned, the flow rate of the electrolyte, pressure of the electrolyte, dilution of the electrolyte, temperature and type of the electrolyte, that might affect the performance of an ECM process. The power supply as we we have already discussed should be of d c power supply with the following features. Like voltage should be in the range of 2 to 30 volt, it could be pulsed or it could be continuous.

The current can range from 50 to 10,000 amperes, which allows current densities of 5 to 500 ampere per centimetre square. So, this is very, very important, we can see the ampere is used is very high, which is why the power consumed in this process is also very high. As well as the risk factors like the electrocution etcetera are also very could be very dangerous.

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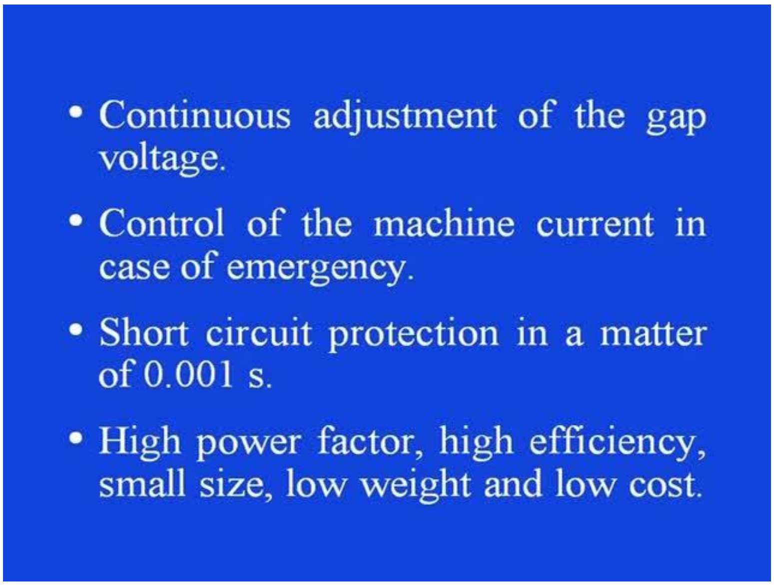

Continuous adjustment of the gap voltage control of the machine current in case of emergency, short circuit protection in a matter of 0.001 second or one millisecond, high power factor high efficiency small size low weight and low cost. Now, let us look at the characteristics or the functions of the electrolyte in ECM.

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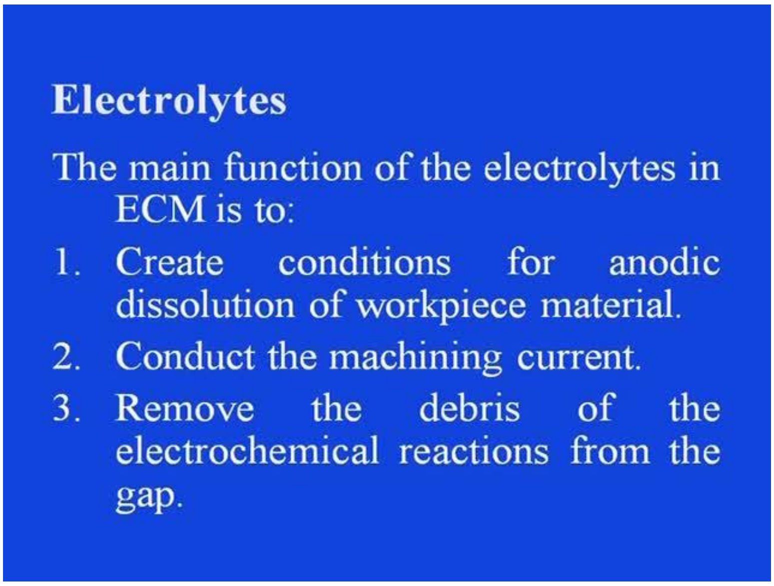

The main main functions include, number one, create conditions for anodic dissolution of the work piece material. Number two, conduct the machining current as we have already discussed, this is responsible for movement of the ions. Then number three, remove the debris of the electrochemical reactions from the gap, this also we have discussed already. Number five, carry away the heat generated by the machining process, thereby maintain a constant pressure in the machining region. Therefore, there are number of characteristics have been listed out for performing this functions.

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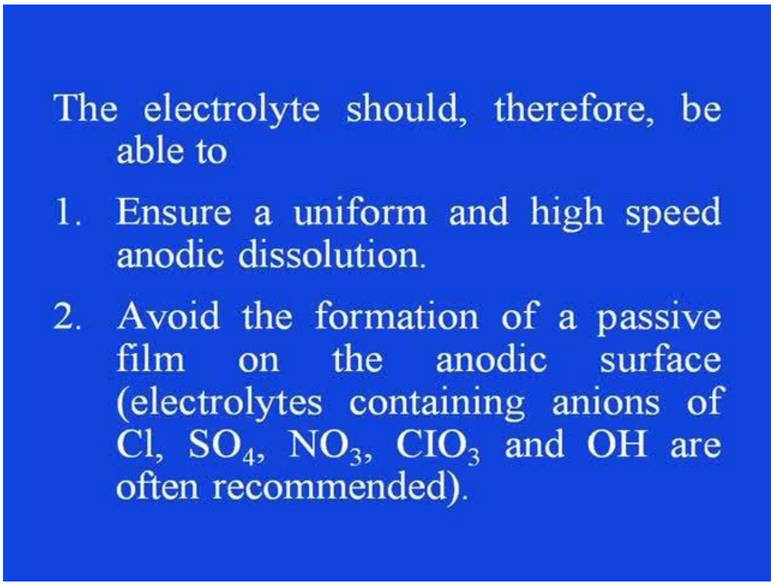

The electrolytes should be able to; number one, ensure a uniform and high speed anodic dissolution. Number two, it should be able to avoid the formation of passive film on the anode surface anodic surface.

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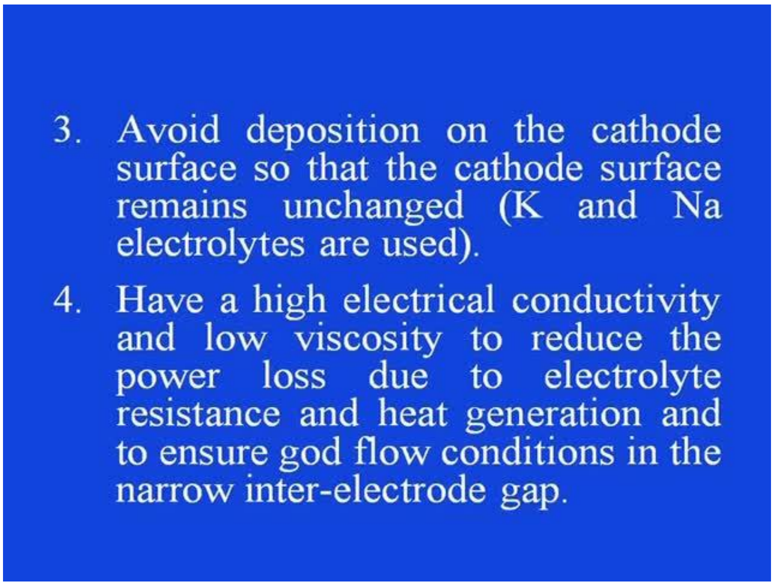

Then it should be able to avoid deposition on the cathode surface, so that the cathode surface remains unchanged. Therefore, potassium based and sodium based electrolytes are preferred. Then number four, it should have a high electrical conductivity and low viscosity to reduce the power loss due to electrolyte resistance and heat generation to ensure good flow conditions in the narrow inter electrode gap.

Number five, it should be safe, non toxic and less erosive to the machine body. Then it should maintain its stable ingredients and pH value during the machining. It should have small variation in its conductivity and viscosity due to temperature rise. Then number eight, it should be in expensive and easily available too.

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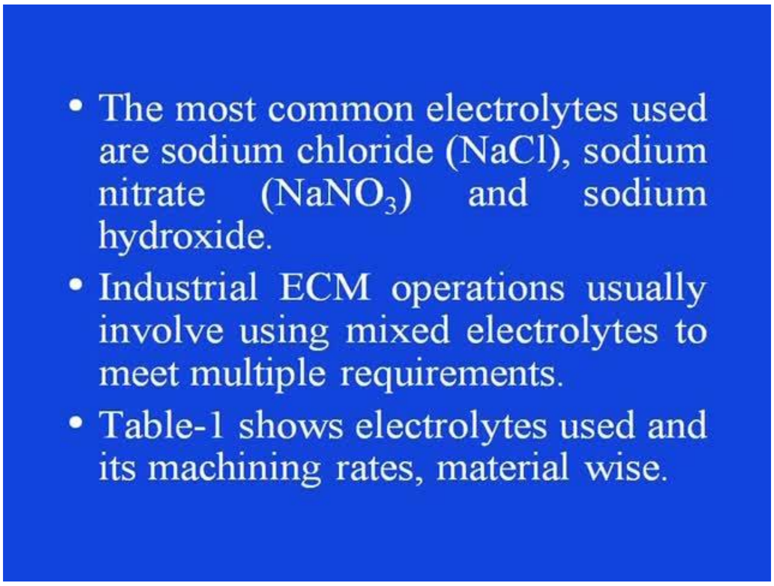

The most common electrolytes used in ECM process are sodium chloride, that is common salt solution, then sodium nitrate and sodium hydroxide. Industrial ECM operations usually involve using mixed electrolytes to meet multiple requirements. The next table shows the electrolytes used and its machining rates, as far as the different materials are concerned.

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Table-1: Electrolyte and machining rates for ECM

Work Material	Electrolyte Constituent	Electrolyte Concentration (gm/L H_20)	Removal rate (mm^3/min.A)
Grey Cast Iron	NaCl $NaNO_3$	300 600	2.0 2.0
White Cast Iron	$NaNO_3$	600	1.6
Hardened tool Steel	$NaClO_3$	780	2.0

For machining gray cast iron generally sodium chloride and sodium nitrates are used and the concentration varies. In case of sodium chloride 300 gram per litre of water is being added and then sodium nitrate 600 gram per litre of water is added and the corresponding material removal rate is 2 millimetre cube per minute per ampere. Whereas white cast iron and hardened tool steel sodium nitrate and sodium chlorate is used, with the concentration 600 and 780 gram per litter of water. Material removal rate for white cast iron is obtained as 1.6 millimetre cube per minute per ampere whereas, for hardened tool steel it is 2 millimetre cube per minute per ampere.

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Work Material	Electrolyte Constituent	Electrolyte Concentration (gm/L H_20)	Removal rate (mm^3/min.A)
Steel (Fe, Ni and Co based alloys)	$NaNO_3$ NaCl or KCl	600 300	2.1 2.1
Cu and Cu alloys	NaCl or KCl $NaNO_3$	300 600	4.4 3.3
Tungsten	NaOH	180	1.0

Similarly, for steel sodium nitrate, sodium chloride or potassium chloride is, these are the electrolytes suggested with material removal rate of 2.1 millimetre cube per minute per ampere. Then for copper and copper alloys, generally sodium chloride or potassium chloride or sodium nitrates are recommended. In this case material removal rates are found to be slightly higher that is 4.4 with sodium chloride and potassium chloride and 3.3 with sodium nitrate solutions for electrolytes. For tungsten on the other hand, sodium hydroxide is suggested as electrolyte with a concentration of 180 gram per litter of water. However, material removal rate is quite low, that is 1 millimetre cube per minute per ampere of current applied.

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Work Material	Electrolyte constituent	concentration ($gm/L\ H_20$)	Removal rate ($mm^3/min.A$)
Ti alloys	Nacl or KCl	120	1.6
Molybdenum	NaCl or KCl	300	1.0
Zirconium	NaCl or KCl	300	2.1

For titanium alloys sodium chloride or potassium chloride solutions are used with 120 gram per litter of water concentration. Then for molybdenum sodium chloride or potassium chloride both can be used, so is the case with zirconium. And the concentrations are also identical like 300 grams per litter of water. However, material removal rate in case of molybdenum is much low, that is only 1 millimetre cube per minute per ampere of current.

While in case of zirconium it can be 2.1 millimetre cube per minute per ampere of current has been recorded. Other parameters, important parameters are machine setting parameters, which include working gap, overcut and feed weight. Electric, electrode material, this is also one of the parameters, the type of the material used for manufacturing the electrodes. This is important as they will be responsible for carrying the current.

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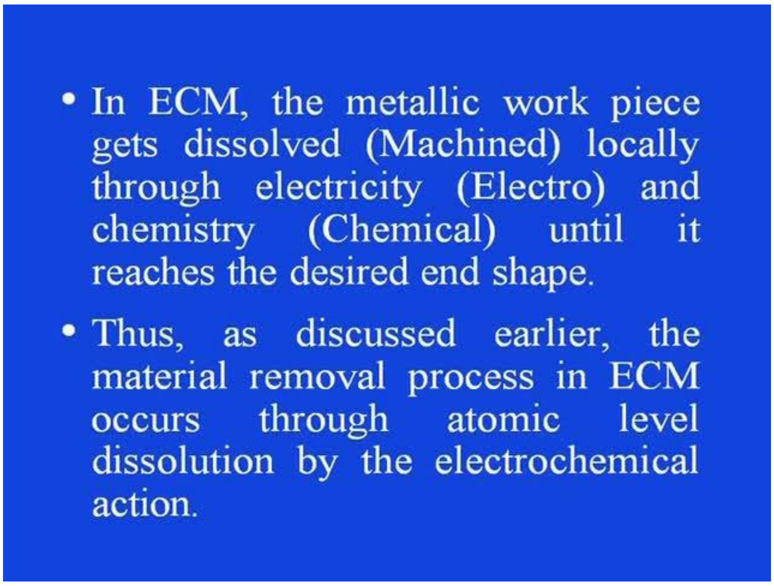

In electro chemical machining, the metallic work piece gets dissolved, which we call in manufacturing as machined locally through electricity and also chemistry that is chemical reactions. Electrical dissolution and chemical reactions both are present in this process, until it reaches the desired end shape, thus as discussed earlier the material removal process in ECM occurs through atomic level dissolution by the electro chemical action. The material removal rate or the machining rate is therefore, not dependent on the mechanical or physical properties of the work piece, rather it only depends on the atomic weight and valancy of the work material. The important condition is that the material should be electrically conductive.

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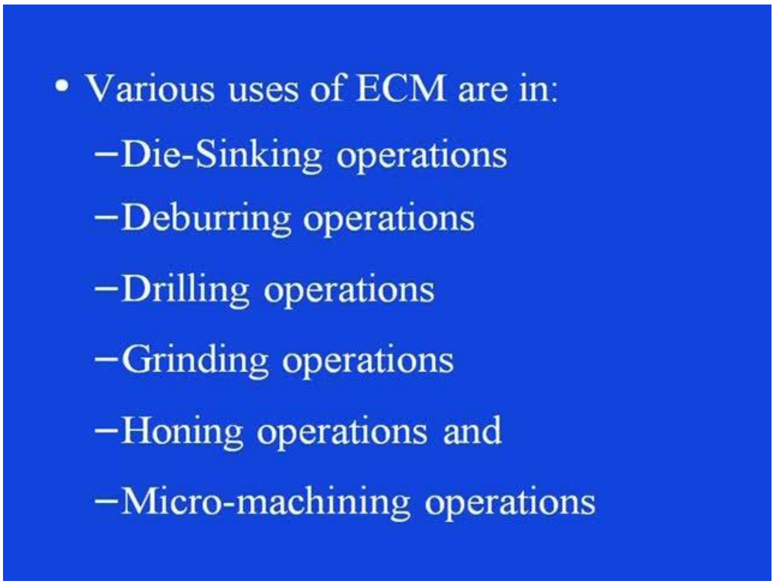

Now, let us see the uses of this EMC process in what are the different applications, where this can be effectively used. For die sinking operations for example, for deburring operations, for drilling operations, for grinding operations, for honing operations, for micro machining operations, this process are found to be very, very effective. Some uses and variants of ECM say die sinking and deburring, have been shown in the following figures.

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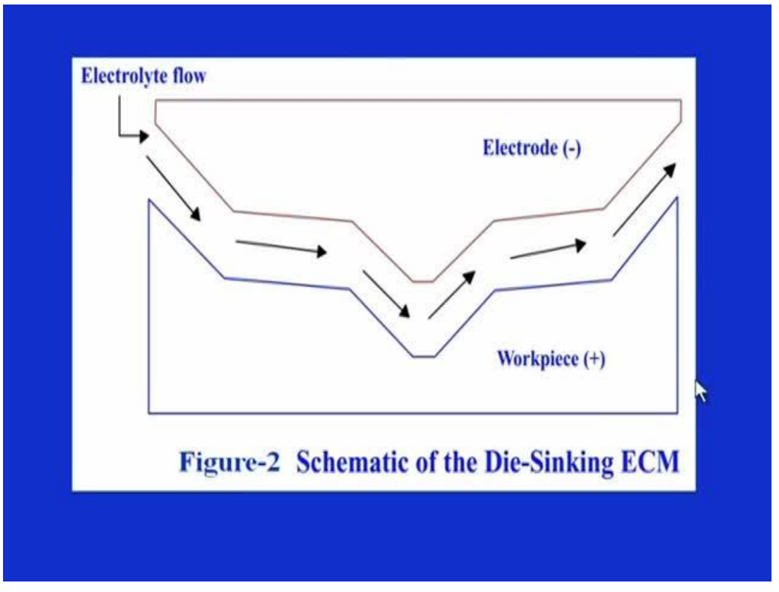

Figure-2 Schematic of the Die-Sinking ECM

So, this is schematic of die sinking process, where this is this is the die or or you can say the cathode and this is the anode and this, in this anode we will take the shape of this die after the electro chemical machining process. So, this this can used later on as the die for some other fabrication process.

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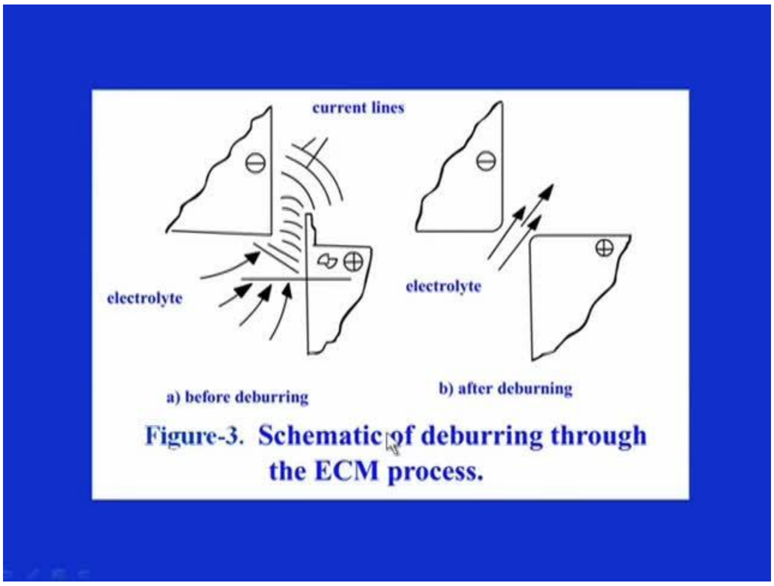

This is an application of this process, in which the bar removal is is carried out. So, this is a bar which is a result of some other process and as such this is undesired portion, as we can see in this screen. So, this needs to be removed, so ECM is one of the processes which is very effective in this case. Here this and this can be used as as two terminals of this electro chemical cell, in which particularly where the bar is to be removed is connected to the positive terminal, as one can see in this screen.

We can see in this screen, this is connected to the positive terminal, in which the actual material dissolution will take place. On performing this ECM, this bar will be removed as in the case of here as in, can be seen here and this corners also will get will get filleted out or you can say this smoothen out. This is one of the very important functions or capabilities of this particular process. Now, let us look in to the unique advantages of electro chemical machining process.

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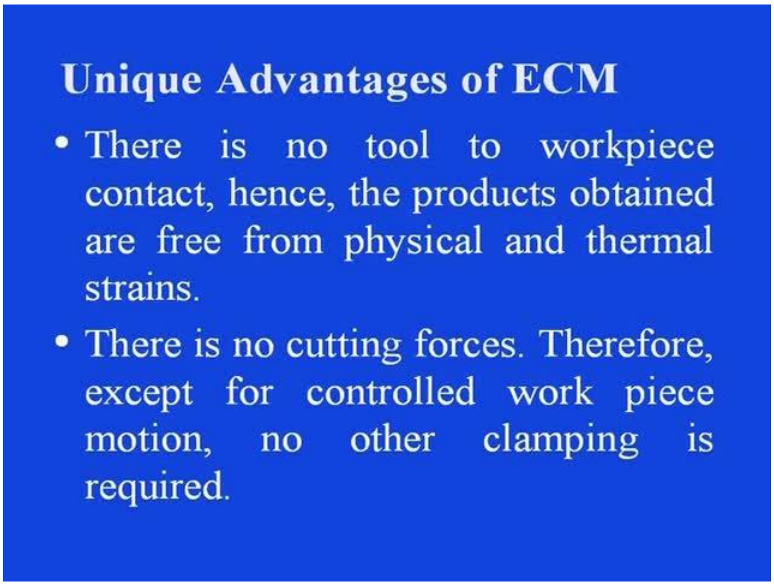

As we have said in the earlier, so there is no tool to work piece contact, no physical contact. Hence, the products obtained are free from physical and thermal strains. There is no cutting forces, therefore except for controlled work piece motion, no other clamping is required. No heat effected zone is formed, as in the case of EDM, where it is a big problem as far as the heat effect zone is concerned. But ECM is free from that as there will the heat produced will be very minimal, as it is basically not a thermal process it is a chemical based process, electro chemical based process.

Being a chemical process, even a material harder and the tool can be very easily machined and this does not affect the MRR, which is very, very unique in this case, in comparison to conventional machining processes. Complex shapes can be machined on hard materials.

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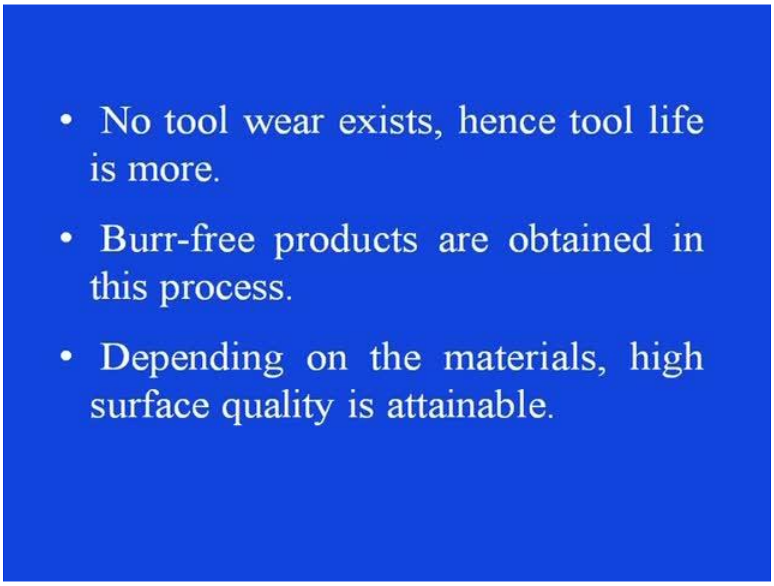

No tool were exists, hence no tool life problems. Burr-free products are obtained in this process, in fact this process can be used for removing burrs. Depending on the materials high surface quality is also attainable. Now, let us see few limitations of this process. This process is basically expensive and of course, not environment friendly as we have already indicated. Another important constraint in this process is the material has to be electrically conductive, then only it is possible to machine. Also we have already indicated that energy consumption in this process is very high. Power consumption is more as in as compare to the other processes, because the high current at low voltage is required in this process.

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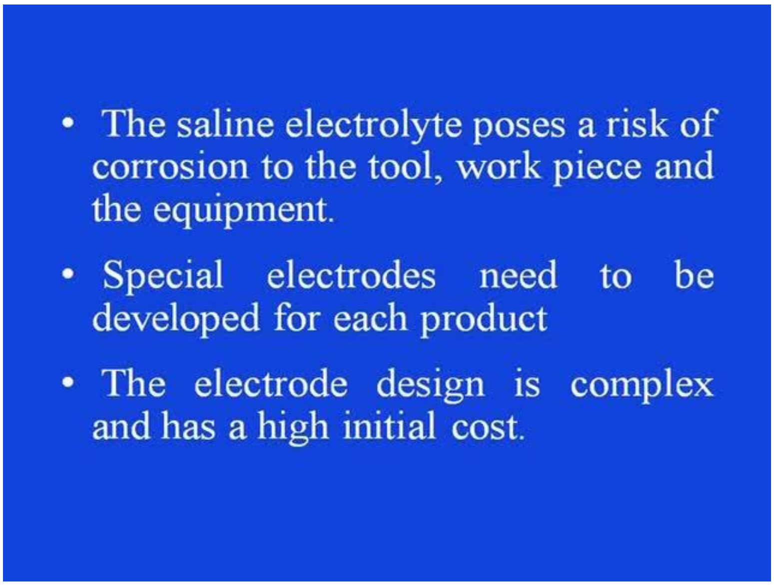

The saline electrolyte used in this process poses a risk of corrosion to the tool, work piece and the equipment. Therefore, this can be counterproductive in long run. Then the special electrodes need to be developed for its product, depending on the geometry of the product requirement. The electrode design is complex and has a high initial cost. Then sharp corners or flat bottoms are not suitable through the ECM process, as there is a tendency of the electrolyte to erode away the sharp profiles, as we have seen in the previous, one of the previous figures, that the sharp corners are being filleted means smoothened out. Therefore, probably (( )) features one cannot expect in this process.

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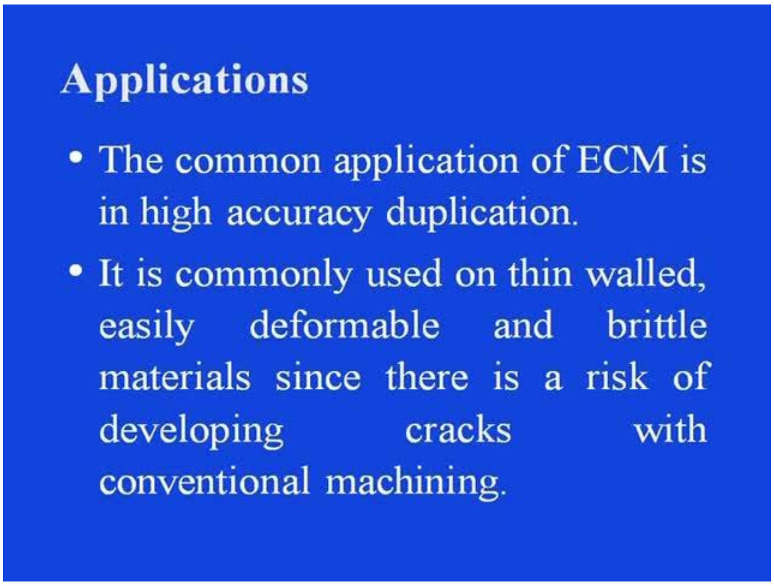

Now, let us quickly look at the applications of this process. The common applications of this process is in high accuracy duplications. It is commonly used on thin walled easily deformable and brittle materials. Since, there is a risk of developing cracks with conventional machining. The most common products of ECM are turbine or compressor blades and riffle barrels. Each of those parts require machining of extremely hard metals with certain mechanical specifications, that are difficult to perform on conventional machines.

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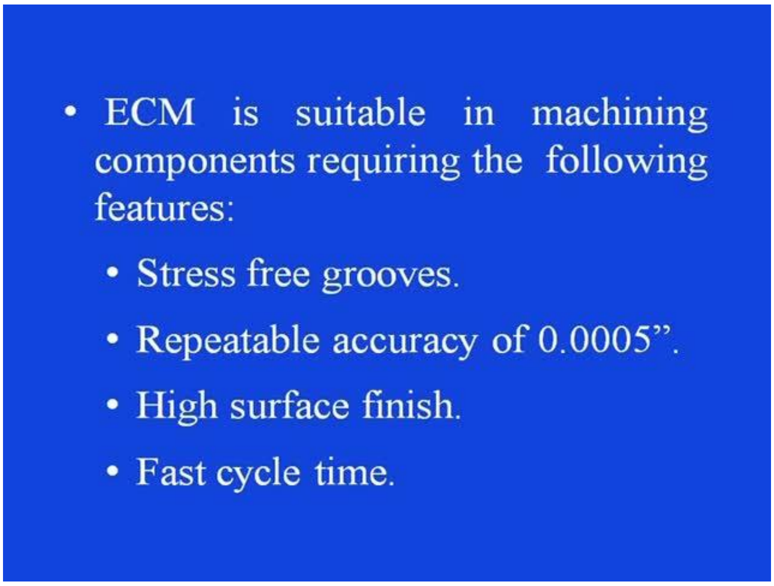

ECM is suitable in machining components, requiring the following features like stress free groups, as there is no mechanical machining phenomena involved in this process. Therefore, the stresses mechanical stresses are not developed, then repeatable accuracy something to the tune of 0.0005 inches. Then the parts were very high surface finish is required, the sub micron level and where the first cycle time is requirement.

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The ECM product examples include the following; number one, turbine plate, which can be of say nickel alloy, which are very hard. The hardness could be as high as 360 in the final scale, adjacently shown in the tool used in making it. Then fine slots made on steel roller bearing case etcetera. Then integral aerofoils on compressor discs etcetera. Then let us look at another development in the form of micro ECM. ECM is usually characterised as a low accuracy machining process because of its wider machining gap in micro ESM ECM sorry, an electrolyte z is used as a micro tool. Moving the work piece and controlling or switching, the pulse current products pulse current produce a small in dense or cavities in pre designed alignment.

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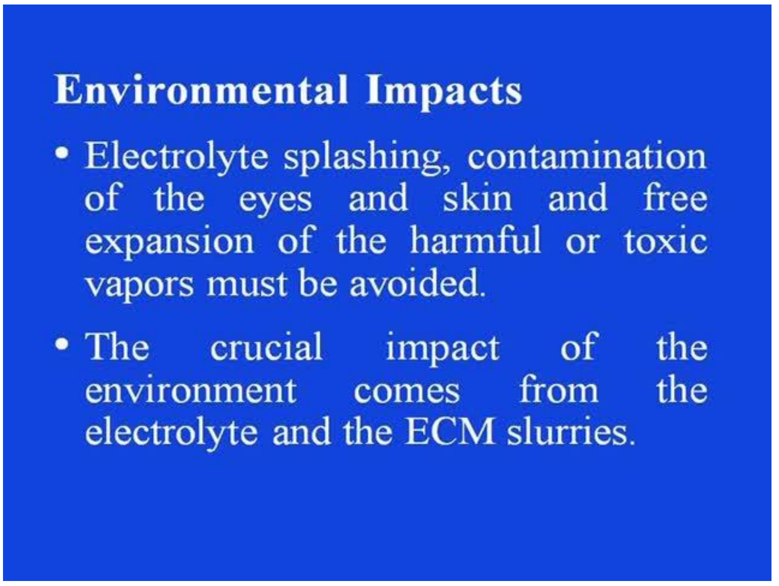

Environmental impacts: Electrolyte splashing, contamination of the eyes and skin, and free expansion of the harmful or toxic vapours must be avoided. The crucial impact of the environment comes from the electrolyte and the ECM slurries. Most of the times sodium nitrate, fulfils the requirement of high removal rate and surface quality. However, through the dissolution of metals containing chrome and due to a nitrate reduction at the tool cathode, the medium accumulates toxic chromites and ammonia.

These chemical compounds are present at the metal hydroxide in the ECM slurry. Slurries resulting from electrolyte maintenance precipitated, solid maters and solution of electrolytes, have to be disposed of carefully with proper treatments. Now, let us move on to some variants and hybrid ECM processes.

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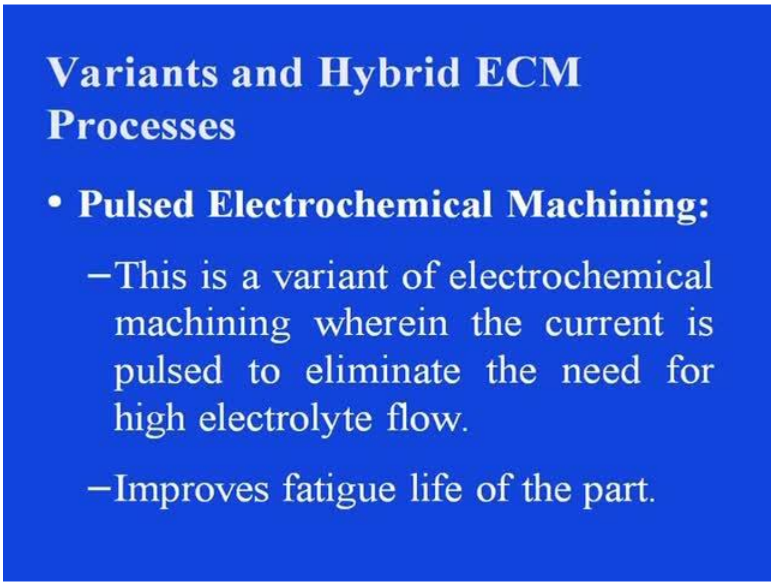

One of them is, pulsed electrochemical machining. This is considered to be a variant of electrochemical machining, normal electro chemical machining process, in which the current is pulsed to eliminate the need for high electrolyte flow. Otherwise in normal ECM process there is a continuous supply of current is being made. However, in this process supply is made pulsed. This was found to be improving the fatigue life of the part produced in this manner. Then another variant is electro chemical drilling also called ECDR.

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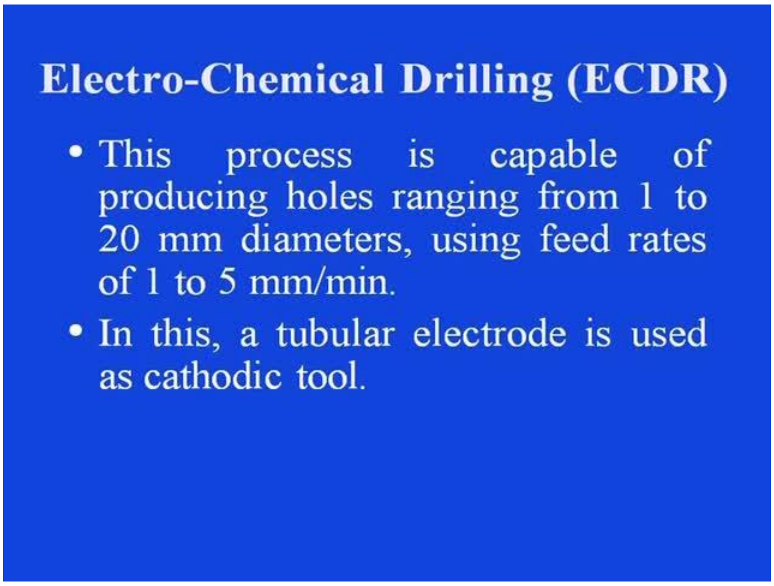

This process is capable of producing holes ranging from 1 to 20 millimetre in diameters, using feed rates of 1 to 5 millimetre per minute. In this, a tubular electrode is used as cathodic tool. The electrolyte is pumped from the centre of the tool and exits through the side machining gap form between the walls of the tube and a drilled hole. Machining occurs at current densities in the frontal inter electrode gap between the tool phase and the work piece. Side electro chemical dissolution acts, laterally between the side walls of the tool and the component.

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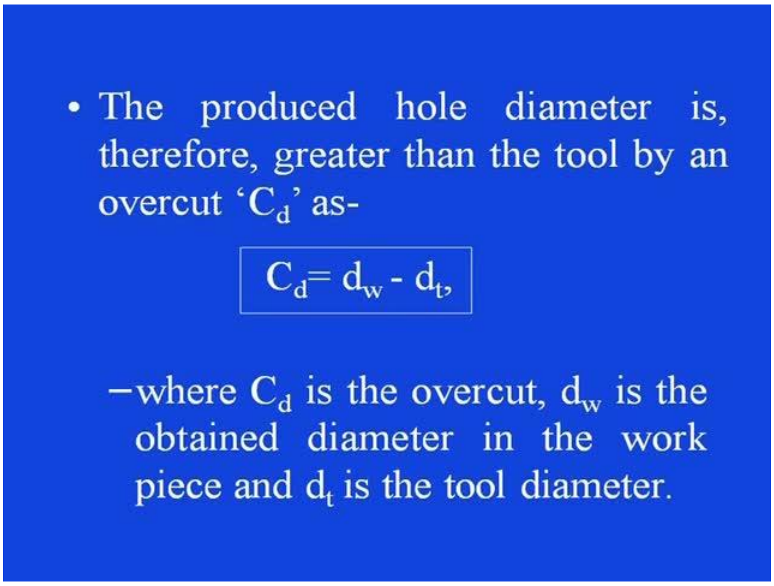

The produced hole diameter is therefore, greater than the tool by an overcut C d, which can be expressed as C d equals to d w minus d t, where C d is the amount of overcut and d w is the obtained diameter in the work piece and d t is the tool diameter. This is shown in this figure in the screen.

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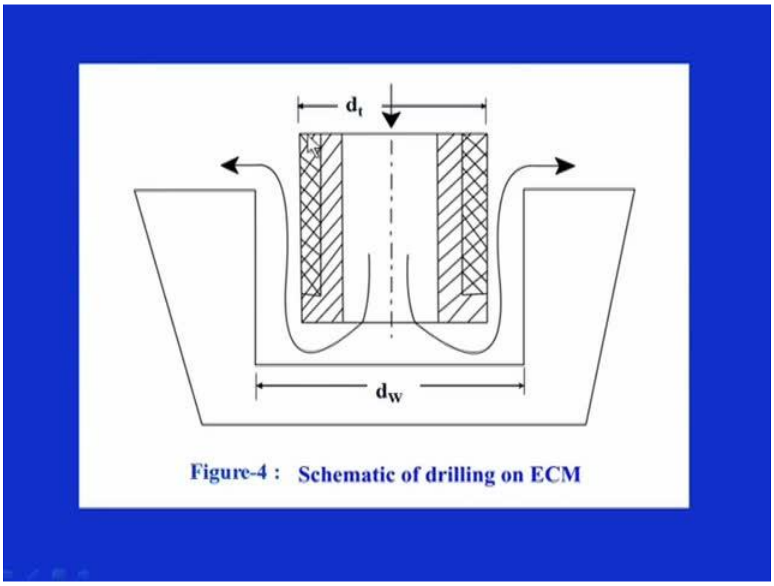

Figure-4 : Schematic of drilling on ECM

So this is the tool diameter d t, which is employed as one of the electrodes. This is the passage kept for the electrolyte flow and this is the resulting diameter; that is taking place because of this ECM action. Therefore, this whatever this amount of this side wise, this is considered to be overcut. So, this overcut will be on the both sides, so this way and this way. This can be minimised with certain arrangements, like this can be inculcated this sides can be insulated like like this.

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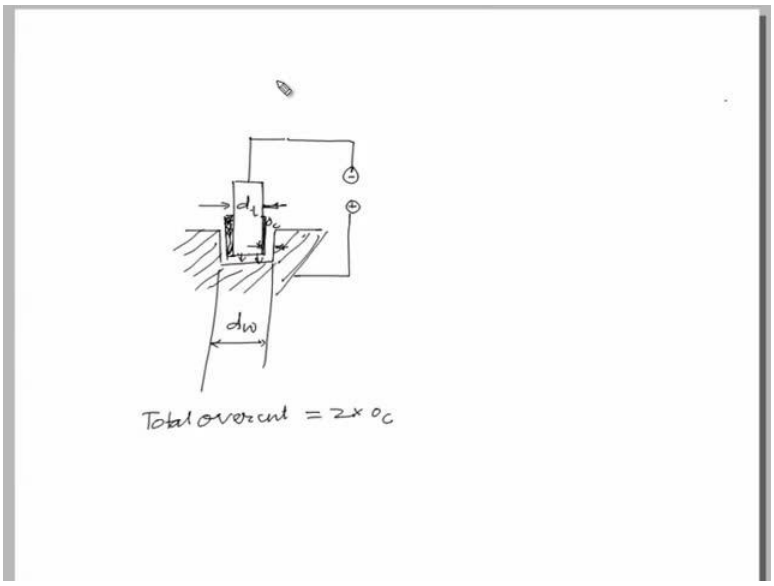

So, this is the tool and this is the work piece. Now, d w and d t, this is overcut we are obtaining. So, total overcut will be say, say this is if we can say this is O C, then total overcut will be will be two times the O C and this can be minimised by applying applying some insulations towards this side of this. That means, this will cause the side wise dissolution to take to stop and the cutting will or the dissolution or the electric current will flow through this part. The next variant in this process are electro chemical grinding. This is a hybrid ECM process and this uses a rotating cathode embedded with abrasive particles for applications comparable to milling grinding and sawing.

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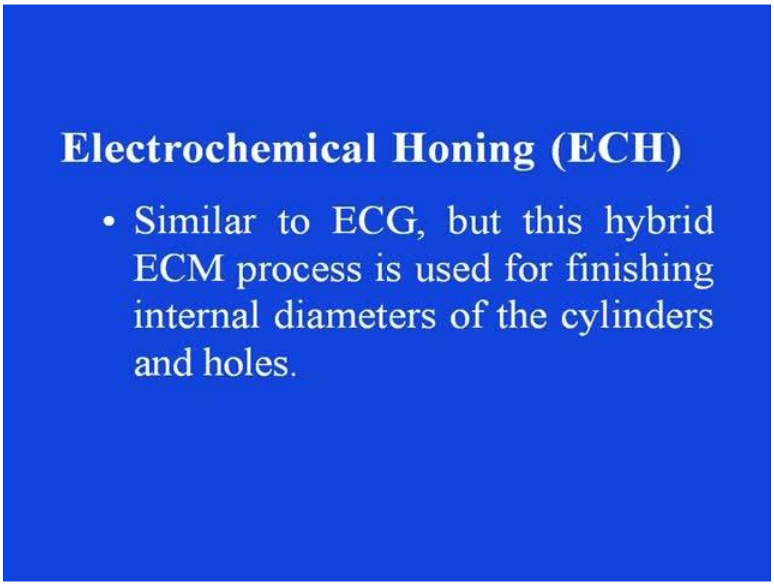

In electro chemical honing is another variant of this process or hybridisation. In this process similar to ECG, this hybrid process is used for internal diameters of the cylinders and holes, whereas the ECG is used for external surfaces basically. ECH, electro chemical honing is used for internal surfaces mostly for finishing of internal surfaces.

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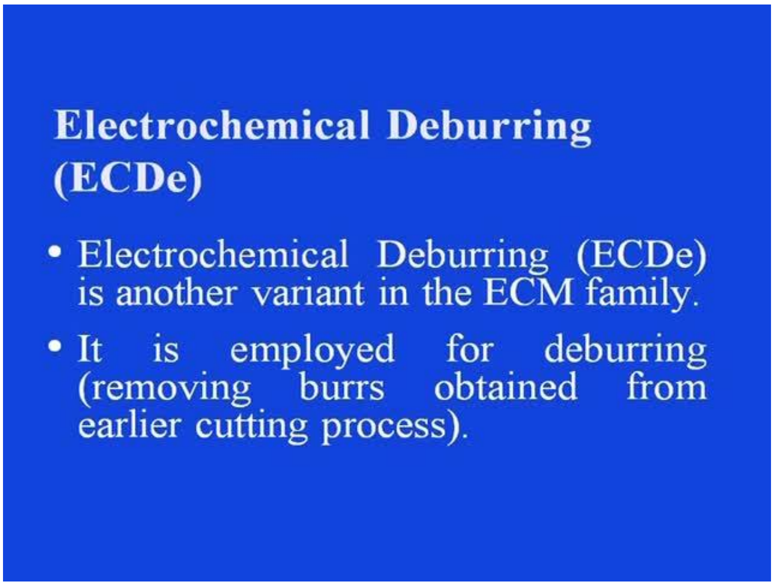

Another process electrochemical deburring ECDE, this is employed for employed for deburring, bar deburring, which is a result of some other conventional processes. Another variant is electro chemical discharge machining ECDM, which we have already EDM and this is mainly used to machine non conducting materials. Now, let us summarise what we studied in this in this session.

So, in this session we have discussed some important components of ECM, unique advantages and limitations of this process, applications of ECM and few variants of ECM; that is in process. Particularly ECG and ECH, these are two very widely used variants of this ECM process, this will be discussed again in another session in details. I hope this session was informative and interesting.

Thank you.