Production Technology: Theory and Practice
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Lecture – 20
Electrochemical Machining

Hello and welcome to the discussion sessions. In our last session we have started discussing the electrochemical machining process in the non-traditional machining. It was told that electrochemical machining process is one of the important processes in the non-traditional machining processes. The unique feature of the electrochemical machining is that the material is removed from the work piece and nothing happens to the tool, that means the tool does not wear out.

Therefore, the tool can be used repeatedly that is one of the very big advantages of the ECM process, that is electro chemical machining process. And the electro chemical machining process therefore, this is the reverse of the electroplating that was also told to you.

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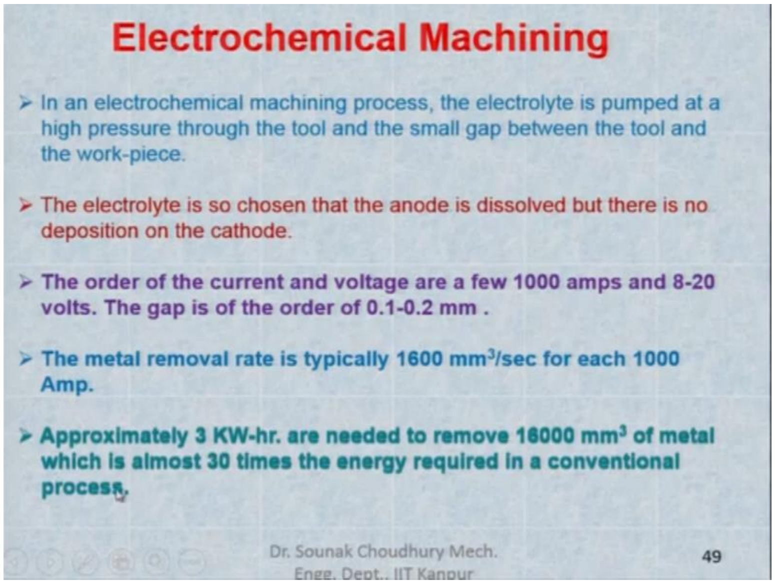

During this process the electrolyte is pumped at a high pressure through the tool and the small gap between the tool and the work piece. It is some kind of an electrolyte which is used that is pumped through either the tool or at the interelectrode gap. If it is pumped through the tool, it goes to the gap between the tool and the work piece. The electrolyte is so chosen that the anode is dissolved but there is no deposition in the cathode.

The order of the current and voltage: 1000 amperes current is used which is a high current and low voltage that is 8 to 20 volts. The operation is basically high current and the low voltage operation. Now the gap between the tool and the work piece is of the order of 0.1 to 0.2 millimeter. This is the stand-off distance we talked about in case of abrasive jet machining and ultrasonic machining and so on.

The material removal rate is typically 1600 millimeters cube per second for each 1000 ampere. Approximately 3 kilowatt hour is needed to remove 16000 millimeter cube of metal which is almost 30 times the energy required in the conventional process. As you can see that here energy required will be very high, it is about 30 times the energy required in a conventional process.

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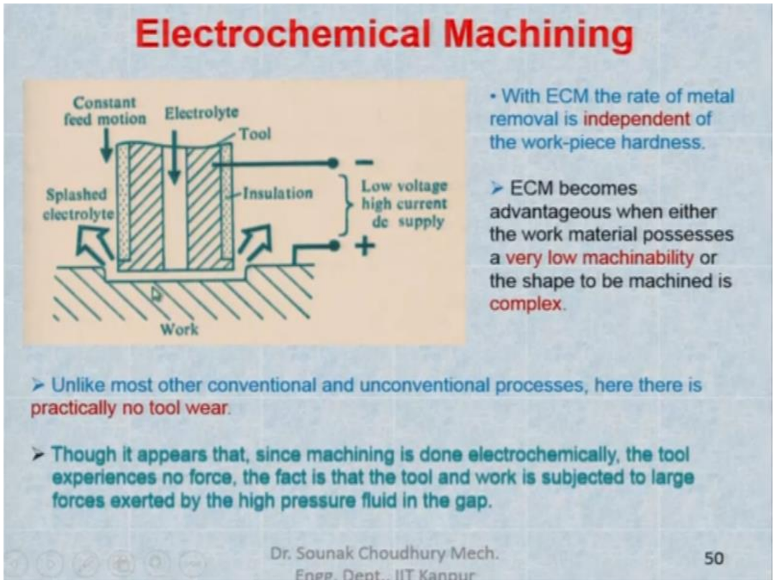

This is a schematic diagram of the electrochemical machining process here the electrolyte is passed through the tool and this is insulated and this insulation is made because otherwise this material removal will be from the sides as well. Therefore, the sides of the tool are normally insulated. Now the material removal rate is independent of the work piece hardness; any kind of work piece of any hardness can be used, only factor is that the work piece has to be conducting.

And as we have said that the work piece has to be anode and the tool has to be cathode and it is a low voltage and the high current DC supplies. It becomes advantages when either the work material possesses a very low machinability or the shape to be machined is complex. If it is hard to machine material or a very intricate shape then ECM is convenient to use. Unlike most other conventional and unconventional processes, there is practically no tool wear.

Though it appears that since machining is done electrochemically, the tool experiences no force. The fact is that the tool and work is subjected to large forces exerted by the high pressure of fluid in the gap that is the only pressure which the work piece as well as the tool will be experiencing that is because it is at a high pressure. So, that pressure is experienced by both the work piece and the tool.

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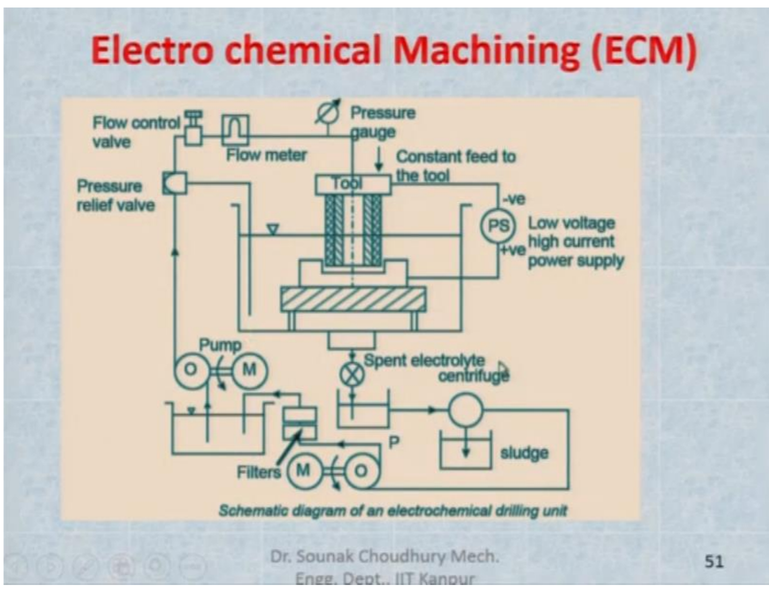

This is more elaborate schematic diagram of the electrochemical machining but otherwise this is the same as in here only thing is that it is in details shown how the electrolyte is re-circulated taken from the tank and how it is being re-circulated after being filtered and so on, you can see it from here.

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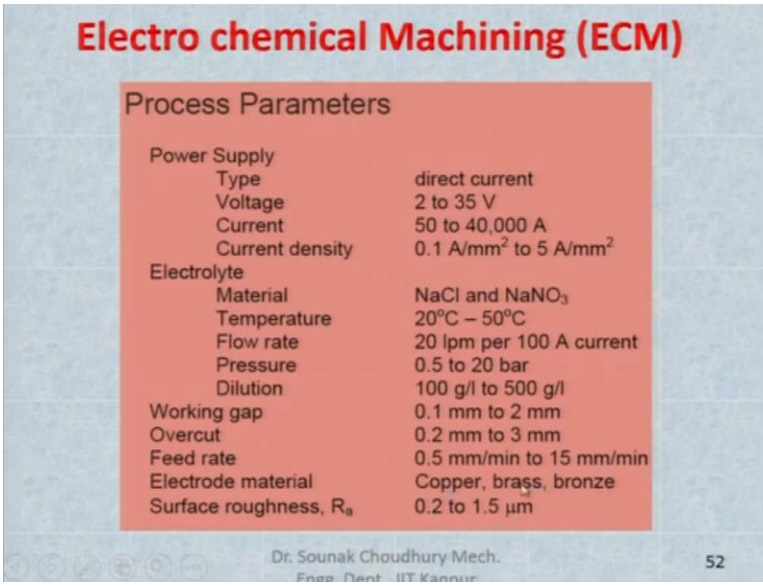

The process parameters have already been said, which is summarized here. Only thing is that electrolyte, we did not say that either you can use the sodium chloride, salt water or $NaNo_3$ sodium nitrate, temperature will be normally 20- 50^{0}C, flow rate is 20 *l/min* per 100 ampere of current and working gap is 0.1 to 2 *mm* over cut could be 0.2 to 3 *mm*. I already said that overcut is when the hole is not exactly straight .

And the surface roughness is about 0.2 to 1.5 micron. You can see that the surface roughness is good, electrode that is a tool material can be copper, brass or bronze because the tool does not wear out, and hence it can be a soft material.

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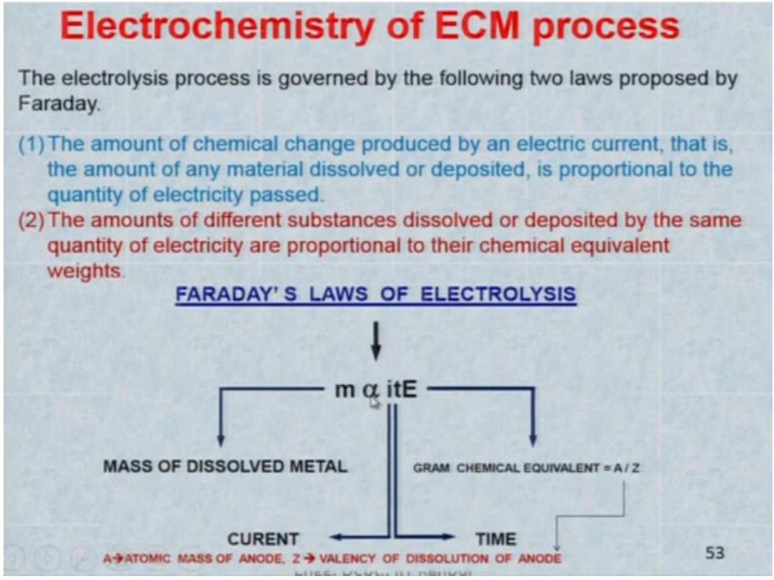

Now I will not go into electrochemistry in details that follows the Faradays law of electrolysis, material removal is proportional to the current, time and the and the E. E is the gram chemical equivalent which is *A / Z*.

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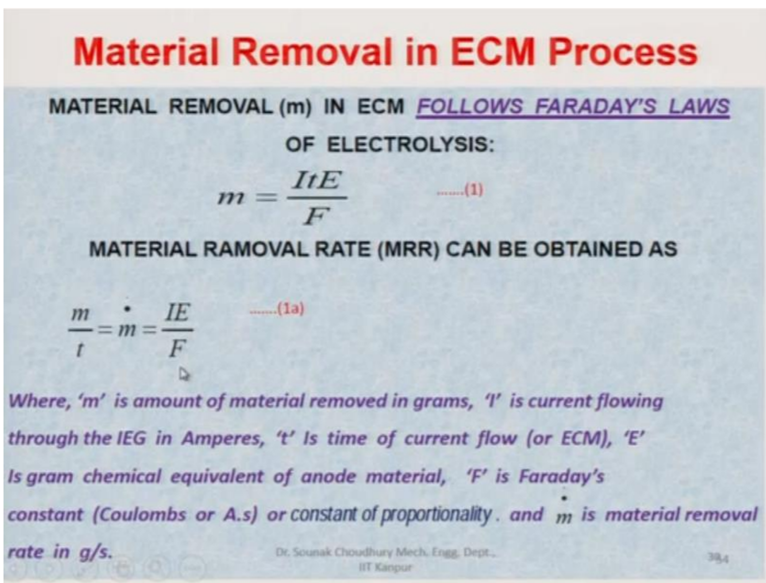

And you can find out that what the material removal of the process since this follows the Faradays law. F is the Faraday's constant which will be given in the handbook. So, if you find out the time, the gram chemical equivalent that can be found out from this atomic mass of the anode and the relevancy of the dissolved dissolution of the anode. So, this E will be known, time you know, you can find out what is the current that is going through.

And divided that by Faraday's constant that would be the material removal as shown in the slide.

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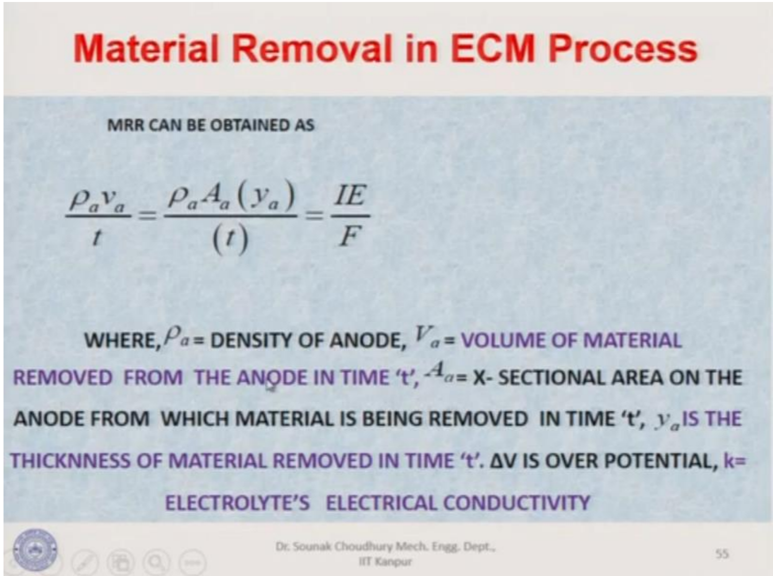

Well, MRR also can be obtained like that, but here it is not very important we are not going into detail. What is important for you to understand is that this is the one (*IE / F)* that you can find out.

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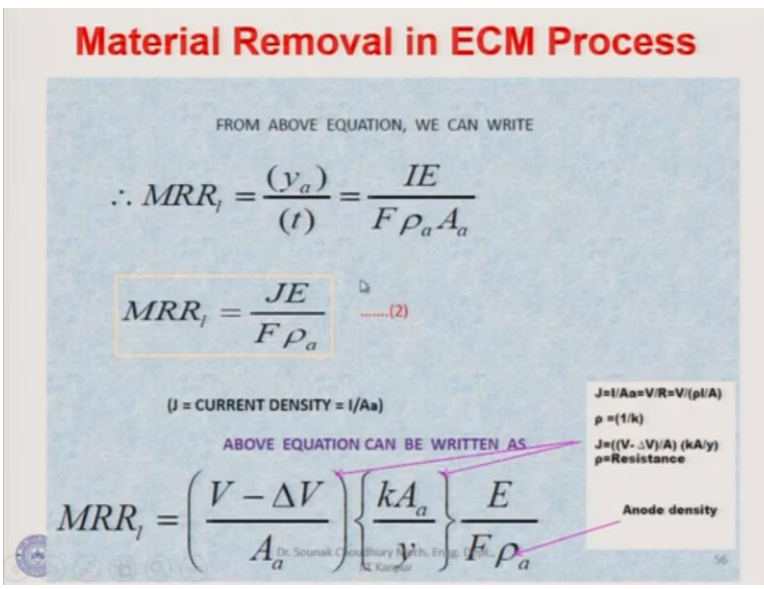

This is in details that you can simplify and finally, find out how the material removal rate can be expressed, but as I said that this will be enough for you to understand that this is the simpler way of finding out what is the material removal rate.

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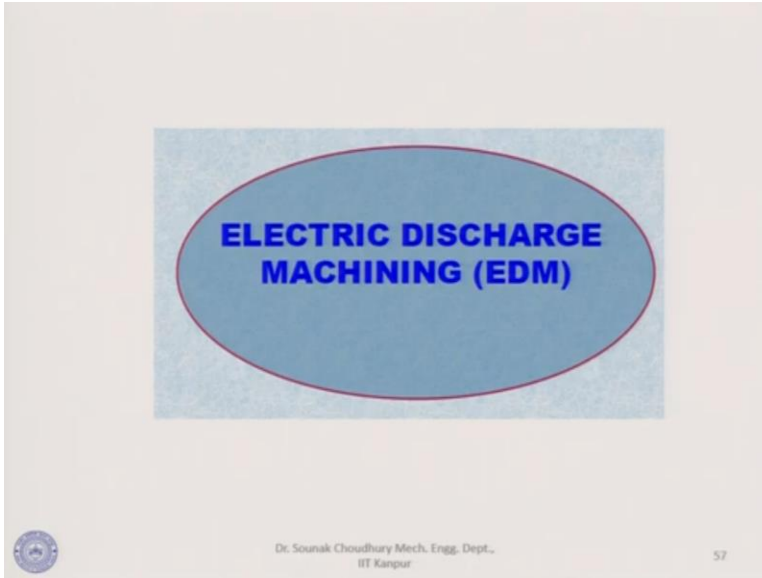

Now, let us discuss a little bit about the electric discharge machining. And we said in the discussion that electric discharge machining is a thermal process where a very high temperature is produced between the tool and the in the gap between the tool and the work piece and that temperature actually removes the material by melting and sometimes evaporating.

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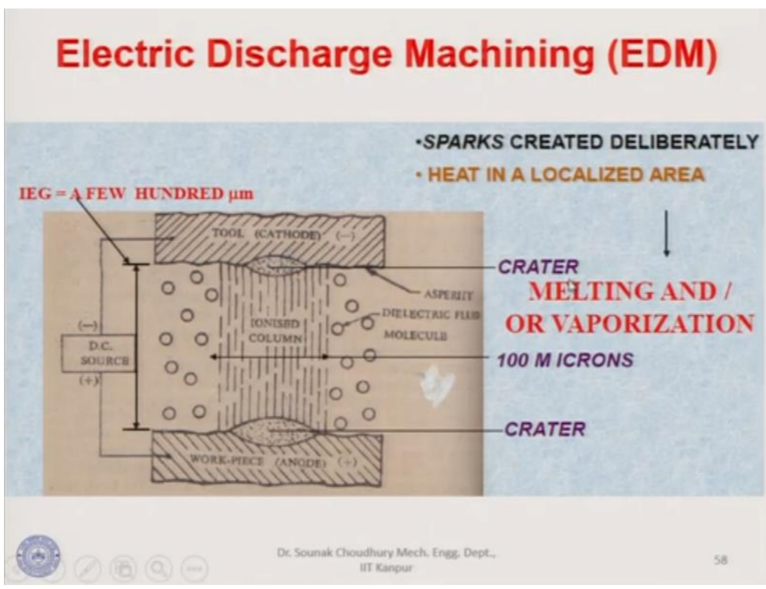

So, this is the mechanism. Here is the tool which is cathode and work piece is anode and between these two, there is an ionized column which actually is a flow of avalanche of electrons from the tool to the work piece side as the current is passed between the tool and the work piece.

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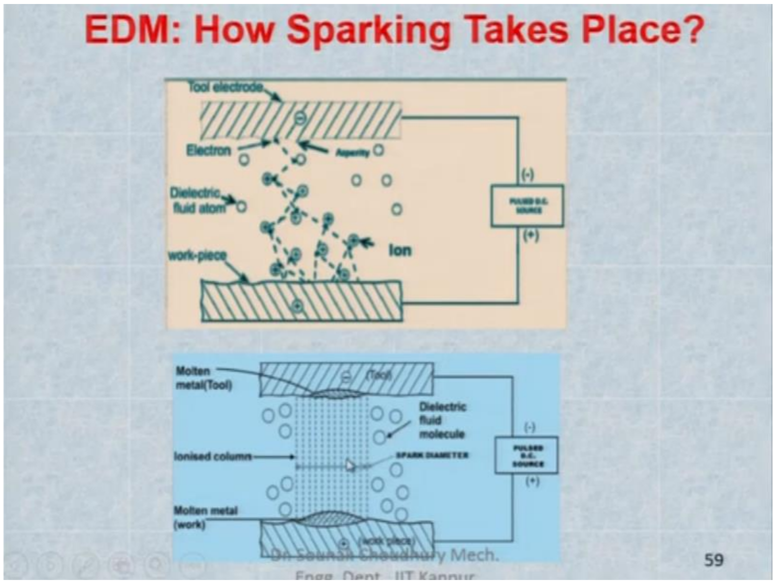

When the proper current is established then the electron moves from the tool at a certain speed towards the work piece. On the way this meets the molecules of the dielectric fluid dividing these molecules into ions and the electrons. Those electrons again rush towards the work piece.

And on the way they meet the molecules of the dielectric fluid breaking them into ions and more electrons. That way the electrons keep on getting formed. And ultimately there will be an avalanche of electrons, and that avalanche of electrons while moving from the tool to the work piece side, it will look like a spark. So that creates very high temperature and that high temperature at a very tiny spot of the work piece will melt and it can evaporate the work piece.

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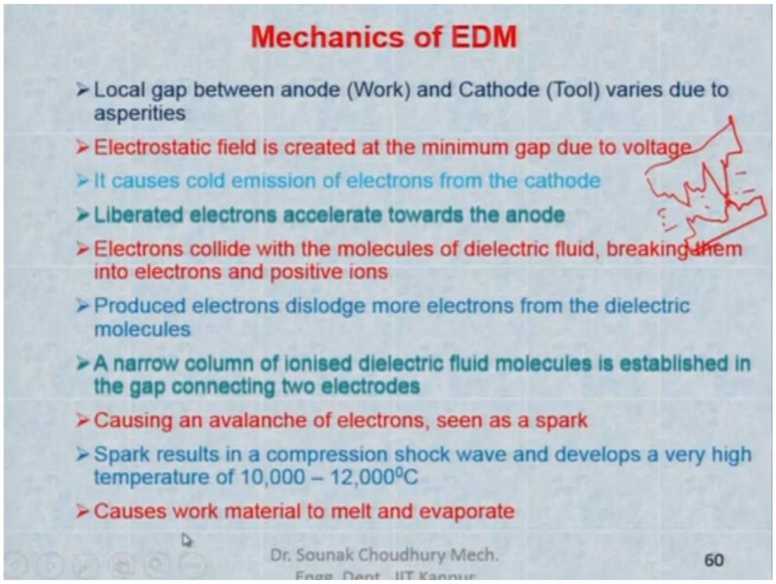

I have already explained the mechanics to you that the local gap between anode and cathode varies due to the asperities. So, electrostatic field is created at the minimum gap due to the voltage. Suppose, this is the tool and this is the work piece, in between there is a gap. This distance is the nearest distance. Here electron will flow and it will meet the molecules on the way because here you have the dielectric fluid.

And normally this is kerosene, or some kind of a mineral oil. Once it happens then due to the high temperature the material is lost from here mostly and a bit from here because the ions are moving towards the tool then the minimum distance will be somewhere else and the same process will take place until the entire area that avalanche of electron is seen, electrostatic field is created causing cold emission of electrons from the cathode, liberated electrons accelerate towards the anode.

Electrons collide with the molecules of dielectric fluid breaking them into electrons and positive ions, ions will move towards the tool and the electrons will move towards the work piece bombarding the work piece surface and removing the material. That is because of the high temperature also. Produced electrons dislodge more electrons from the dielectric molecule and a narrow column of ionized dielectric fluid molecules is established in the gap connecting the two electrodes.

The temperature at which this avalanche of the electrons when they are hitting the work piece, at that moment the temperature can reach up to 10,000 to 12,000^{0}C that is spark. That causes work material to melt and evaporate.

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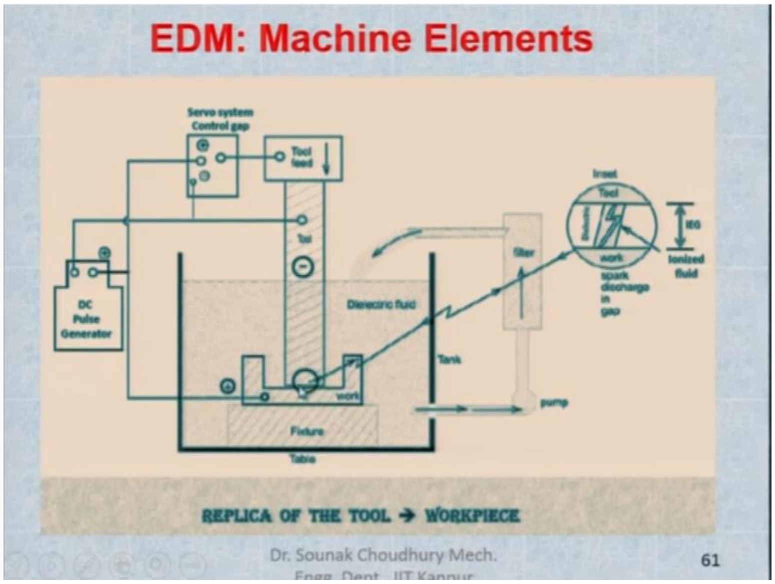

Here is the schematic diagram. This is the tool which is made as anode and this is the cathode which is the work piece work piece is plus, tool is the minus and in between we have the gap is the inter electrode gap and current is passed through this. When the current is passed through the tool and the work piece then the avalanche of electrons will appear in this I mean it will be seen in this gap between the tool and the work piece.

Creating very high temperature to remove the work piece material, here what happens is if we compare it with the electrochemical machining, in electrochemical machining we have seen that nothing happens to the tool, no material is removed from the tool. But in case of electro discharge machining, EDM the tool wears out because the heavier ions will hit the tool, it will go towards the tool.

Therefore, in that case the tool also wears out, it wears out much less than the work piece but nevertheless in comparison to electro chemical machining, in the electro discharge machining, the tool wears out.

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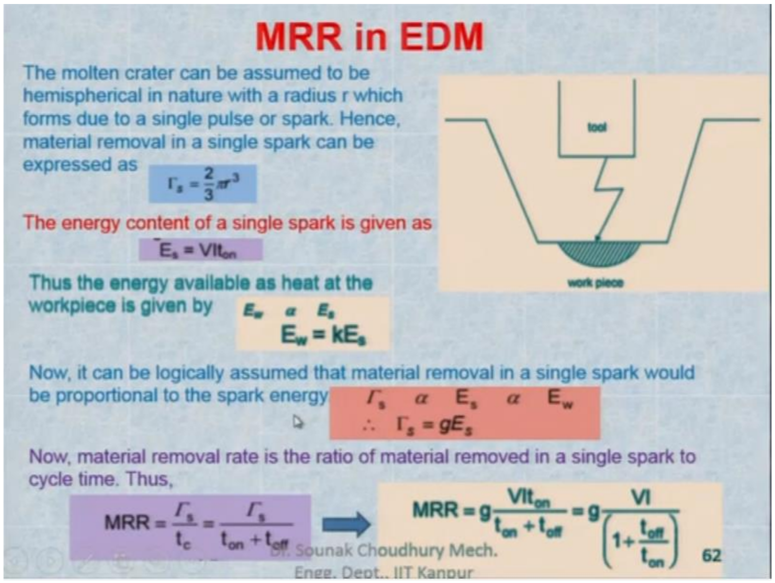

Here is the material removal rate in the EDM process. We may not go through this in detail. What I mean is that there are simple formulas which are readily available in the textbooks that can be used for finding out the material removal rate through the energy that is available as the heat at the work piece. And finally, you can find out the formula through this energy by equalizing this. This is the formula where all these things will be given and you can find out what is the material removal rate, we are not going into that details because this is not under the purview of this course.

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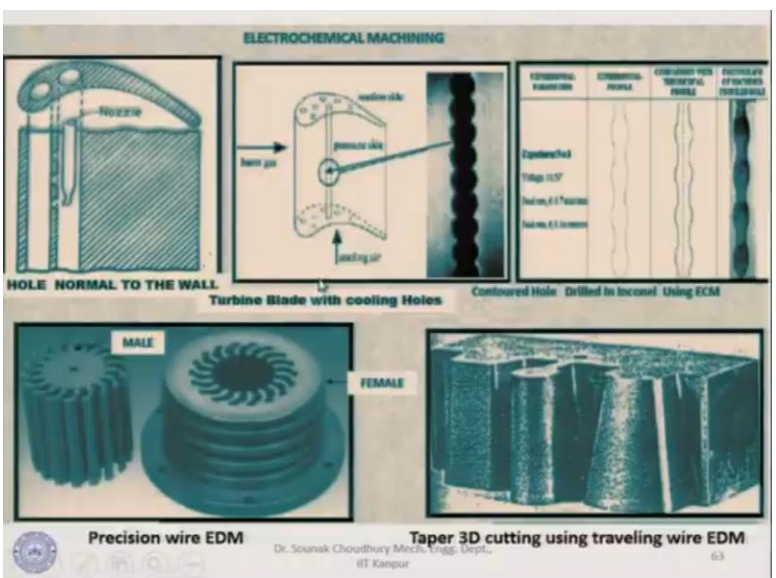

This slide shows the parts that we can fabricate using electrochemical machining and electro discharge machining processes. These are the turbine blades where the holes are very complicated.

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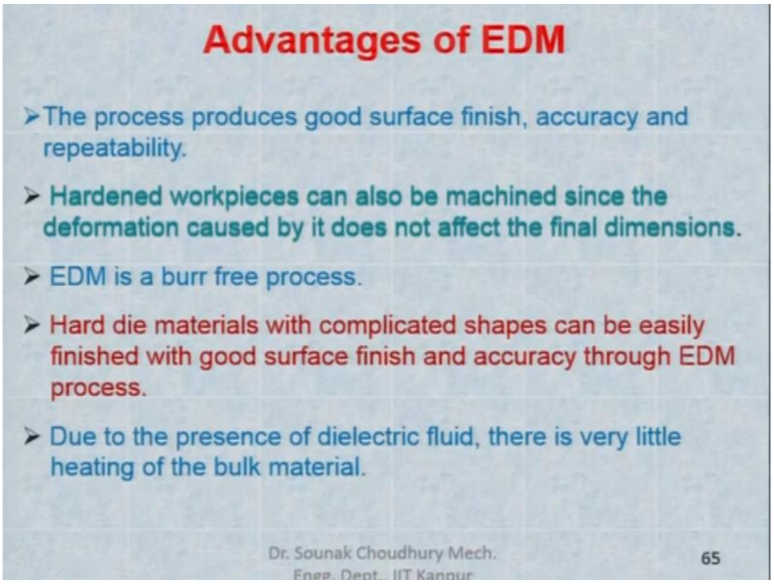

Any electrically conducting material can be machined by the electro discharge machining. Materials regard less of the hardness and the strength whatever is the toughness, whatever is the microstructure can be easily machined by the EDM, because as you understand that these properties of the material no longer stand on the way because it is only the avalanche of electron.

The temperature is so high that any material can be melted and evaporated, 15,000^{0}C as we said acting on a very tiny spot. Therefore, in the vicinity there would not have any kind of a heat affected zone because it is for a fraction of second at a very tiny zone and the material immediately goes off and this spot cools down and the spark happens on the other spot where as I said, the distance between the asperities will be minimum.

The tool and work piece are free from cutting forces. Edge machining and sharp corners are possible in the EDM process. The tool making is easier as it can be made from softer and easily formable materials like copper, brass, graphite also in this case, like in case of ECM also we said that the copper, brass also can be used as the ECM tool material. But here the graphite can also be used for making the tool in the EDM.

The process produces good surface finish; hardened work pieces can also be machined. EDM is a burr free process, when the EDM is used, there is no burr formed. Hard die materials with complicated shapes can be easily finished with good surface finish and accuracy. Due to the presence of dielectric fluid, there is very little heating of the bulk material.

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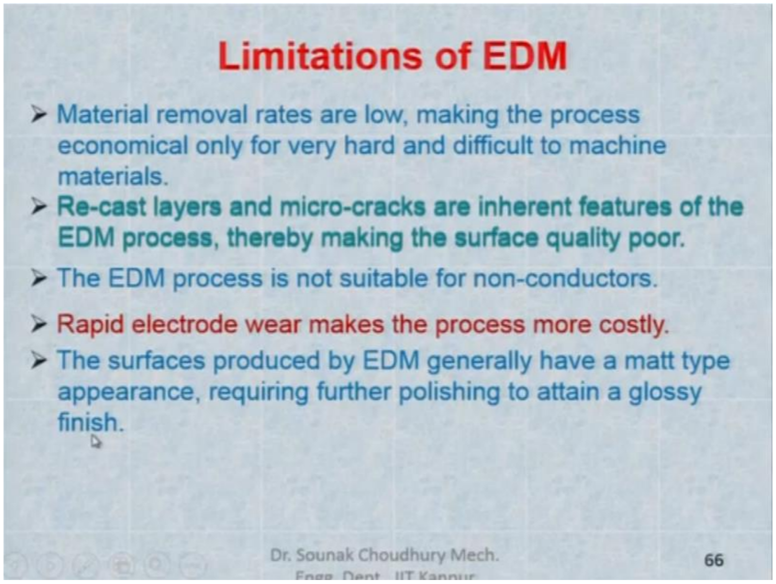

Limitations of EDM are the following. Material removal rates are low making the process economical only for very hard and difficult to machine material. It takes longer time of course. Recast layers and micro-cracks are the inherent features of the EDM process. Recast layer is the layer which is the hard layer and this is also known as the white layer. And this is a disadvantage of the EDM that when the EDM process happens that some of the molten material comes and precipitates on the surface.

Recast layer it is hardened layer and that has to be removed. The EDM process is not suitable for non-conductors of course. Rapid electrode wear makes the process more costly. This I have already mentioned that tool wears out, the surface produced by EDM generally have a matte type appearance requiring further polishing to attain a glossy finish meaning the surface finish is not very good.

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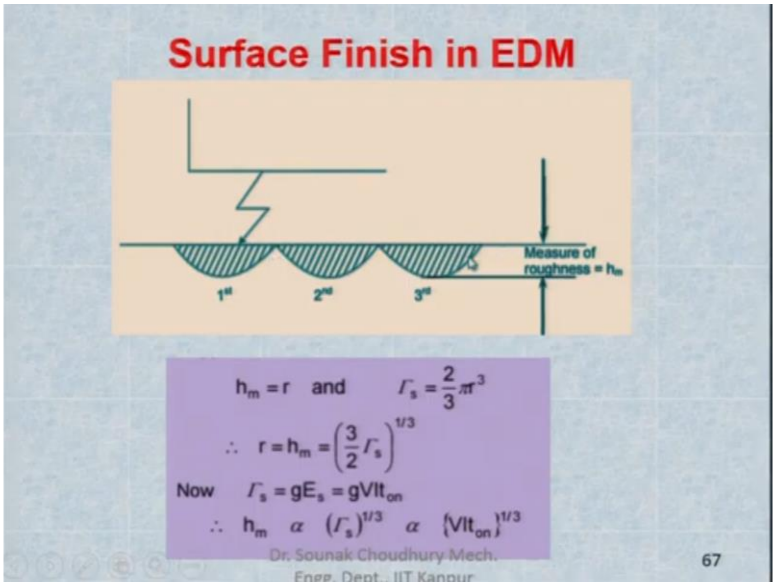

This is the surface finish in EDM, this is how you can actually see the surface produced because these are the sparks which happen in spots, this is of course highly exaggerated.

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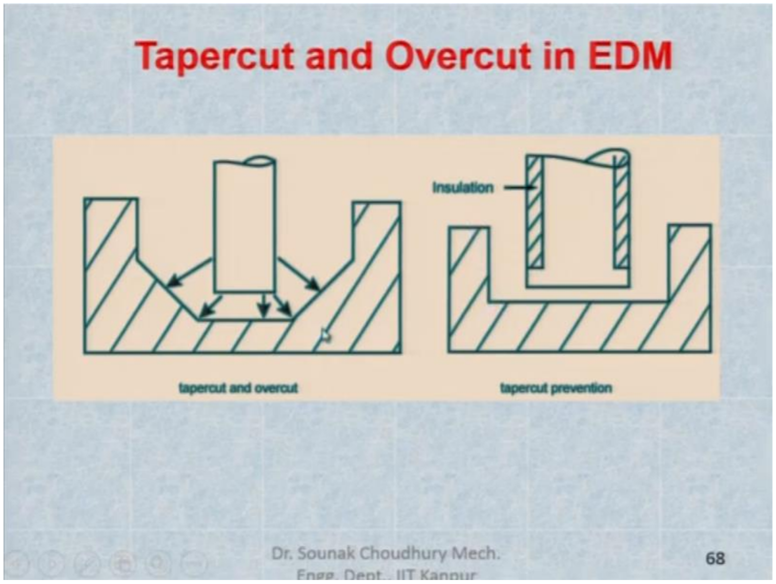

This is the tapering and overcut. This is when it is not insulated, the sides are not insulated, this is what may happen because the formation of avalanche of electron may happen from this sides also. Therefore, it is insulated and in that case the tampering can be prevented.

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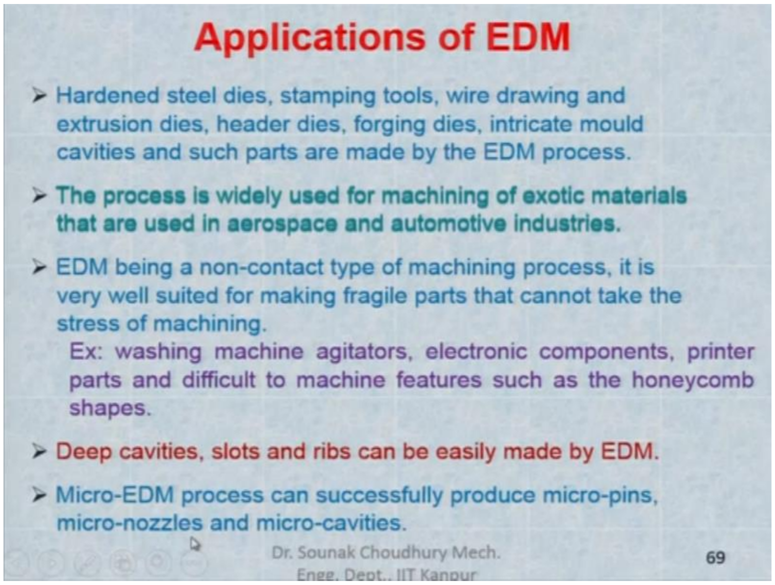

Application of EDM is for hardened steel dies, stamping tools, wire drawing and the extrusion dies. Then we have the header dies, forging dies, intricate mould cavities and such parts are made by the EDM process. Of course, the process is slow process as I said, but nevertheless these materials are very hard and very tough. By EDM it is convenient to produce these parts. The process is widely used for machining of exotic materials that are used in the aerospace and automobile industries.

This is simply because those materials are hard to machine by the conventional machining or any other process. EDM being a non-contact type of machining process, it is very well suited for making fragile parts that cannot take the stress of machining. This I said already in the introduction that as a drawback of the conventional machining that you cannot have a very fragile part machined.

But here there is no contact between the tool and the work piece and therefore fragile parts can be machined. Deep cavities, slots and ribs can be easily made. Micro- EDM process can successfully produce the micro-pins, micro-nozzles, micro-cavities and so on.

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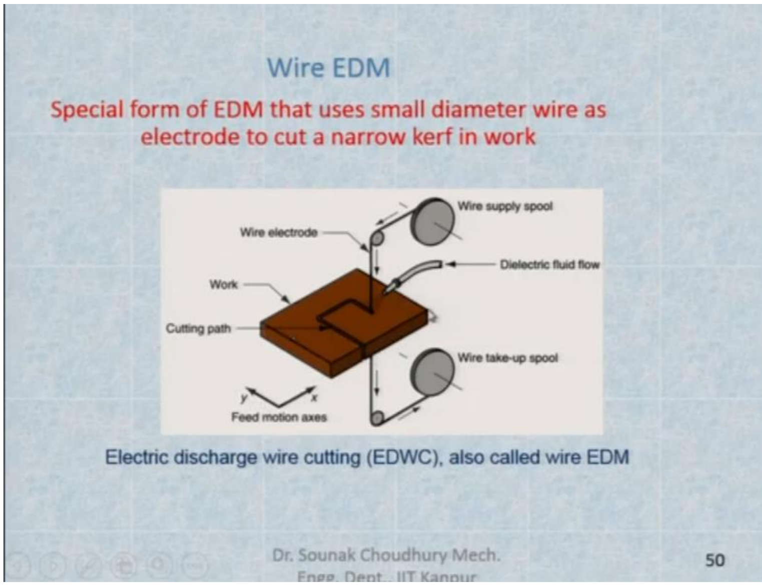

Wire EDM is a type of the EDM process that is the electro discharge machining. Because wire is used as a tool for the EDM process and that were actually is continuously being it is not only the stationary work but it is continuously moved. Wire is used as a tool and this is the work piece. In this case you can see that if we can move the work piece or the tool, a contour can be machined which is difficult in case of the normal EDM.

This is a special form of EDM that uses small diameter wire as electrode to cut a narrow kerf curve as this. Here you can see that there is a spool and here the dielectric fluid is passed through the nozzle, this is the wire electrode. This is a work, cutting path is here and the feed motion in this axis it can be moved in this axis or in this axis or jointly it can be moved also to make a very complicated contour.

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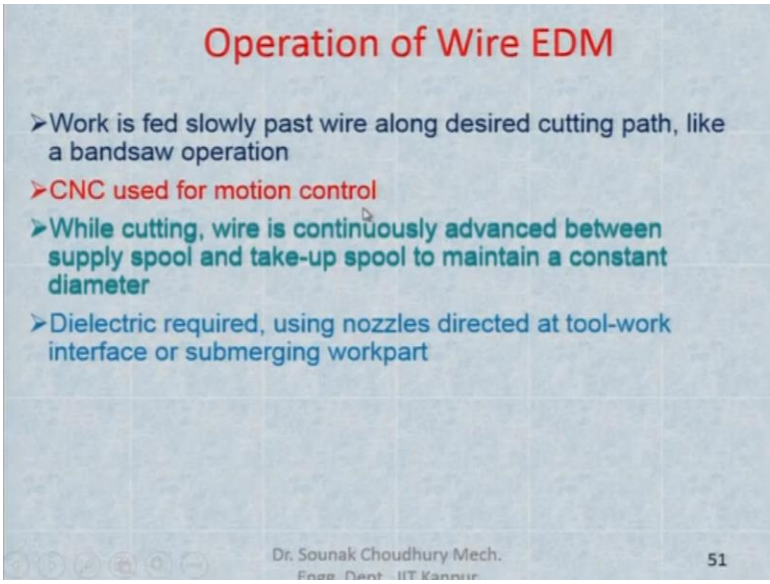

Operation of wire EDM is I already told you that CNC can be used for motion control. For very complicated shape, cutting wire is continuously advanced between the supply pool and the take up spool, this is the supply spool and this is the take up spool. Dialectic required using the nozzles is directed at tool work interface or submerged lower part it can be either submerged or the dielectric fluid can be injected here in the working zone.

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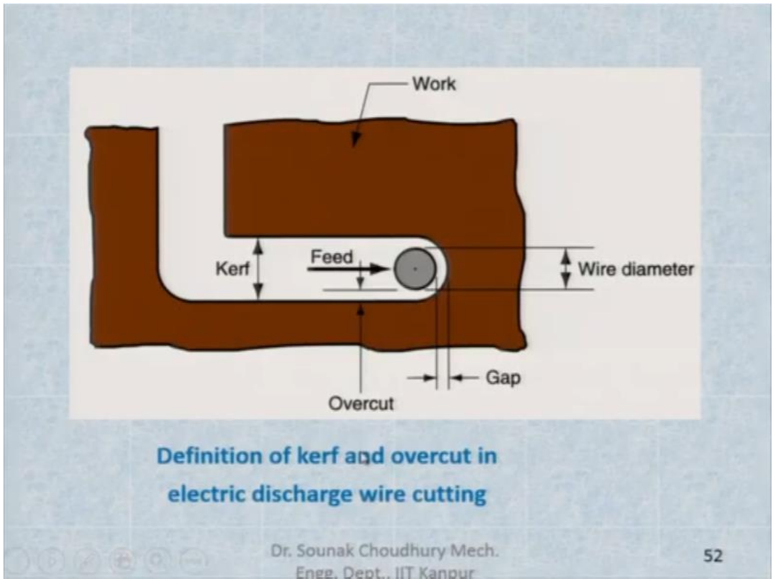

This is the schematic, it is an enlarged part this the kerf, this is the wire and the slot is being made. This is the overcut.

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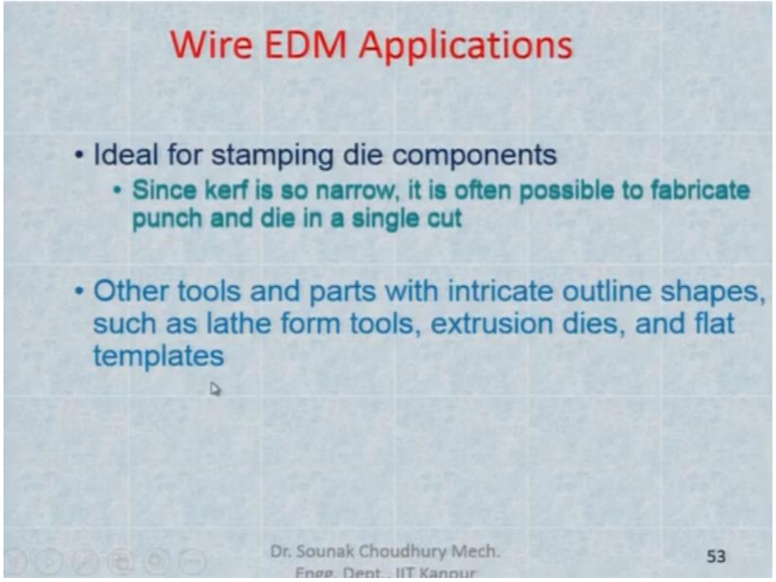

Application is ideal for stamping die components since kerf is so narrow, it is often possible to fabricate punch and die in a single cut, you understand that from material square plate if you cut it from it in the middle with a complicated shape that is the punch. The rest of the thing can be used as a die. Other tools and parts with intricate outline shapes such as lathe form tools, extrusion dies, flat templates, this can also be used using the EDM.

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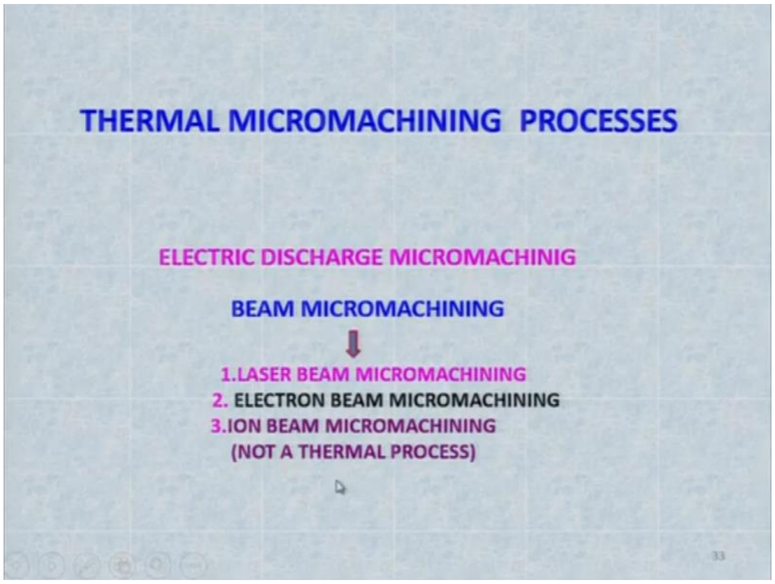

Next is the thermal micromachining processes. The electric discharge micromachining is one of them. Electro discharge machining we have seen. This is micromachining which is the miniature version of the electric discharge machining because the principle remains the same. And the principle I have already discussed that how this avalanche of electron is generated because this is the electron dividing the molecule of the dielectric fluid into ions and more electrons and on.

Other processes are the laser beam micromachining, electron beam micromachining, ion beam micromachining. Except ion beam, others are of course, the thermal process. Ion beam is not counted as a thermal process, because here the temperature occurring is not high.

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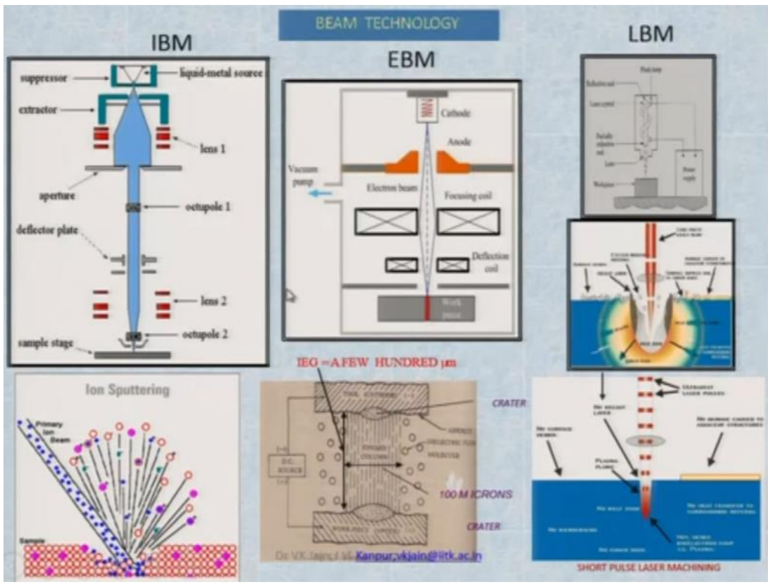

These are the schematic diagrams of the ion beam, this is the electron beam this is how it happens in the as in case of the electric discharge machining, this is the laser beam machining and the laser is used for heating and removing the material. Therefore, all these are the thermal processes.

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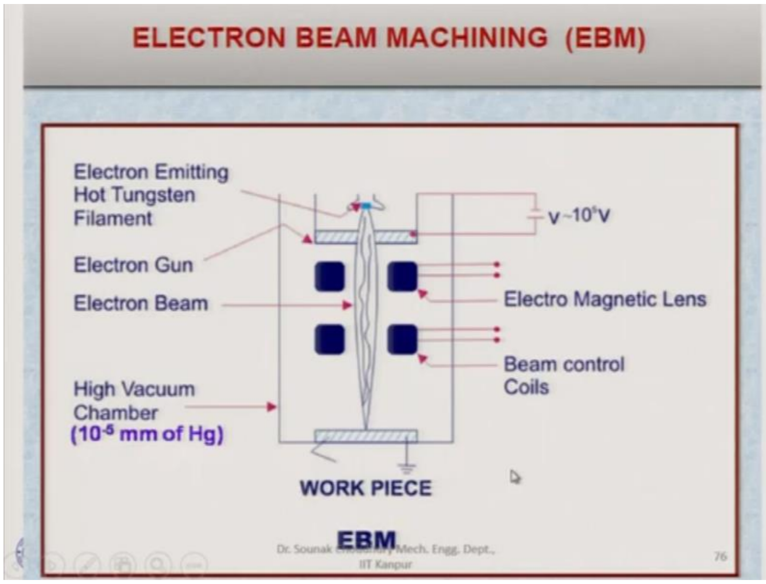

I will describe some of them, for example electron beam machining, in electron beam machining there is an electron gun, electron emitting this is hot tungsten, filament and when the high voltage is passed through this circuit with the hot tungsten filament, then the electron beam is emitted. That electron beam can be concentrated and moved with the help of the electromagnetic lens and the beam control coil.

Electromagnetic lens will concentrate the beam of electrons and the beam Control coil will move the beam if a contour has to be machined or contour has to be made on the work piece surface. Here only thing is that electron beam machining has to be done in a high vacuum chamber. It is about 10^{-5} mm of mercury. This is because otherwise electron beam will collide with the molecules of the air and their energy is lost.

Therefore, this is a disadvantage of the electron beam machining that each time you have to make another part you have to open the chamber take out the machine part and put the new part. In that case, again you have to make the vacuum and the vacuum is quite high this is 10^{-5} mm of mercury. Therefore, this process becomes a little inconvenient and expensive as well.

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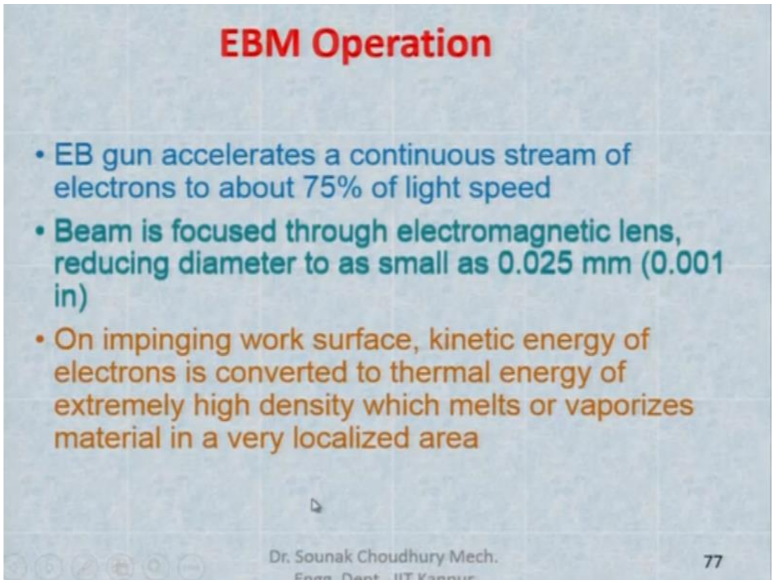

I have already told you how EBM process is performed. These are the quantitative measures that is the electrons to about 75% of light speed acceleration. Beam is focused through the electromagnetic lens reducing diameter to as small as 0.25 millimeter this is the spot. On impinging work surface kinetic energy of electrons is converted to thermal energy of extremely high density which melts and vaporizes material in a very localized area.

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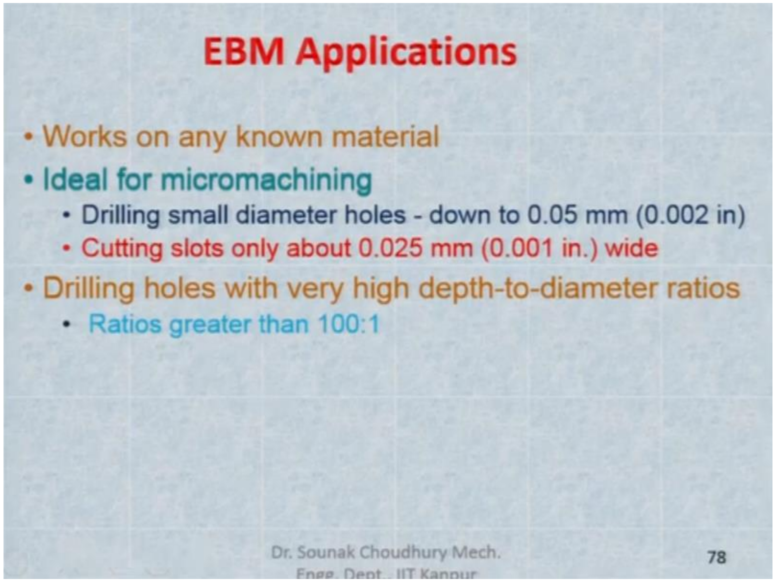

Application is ideal for micro machining, drilling small diameter holes down 0.05 millimeter, cutting slots about 0.025 millimeter wide, drilling holes with very high depth to diameter ratio and ratios can be as greater as 100 is to 1. So, you can see that this is actually advantage over the conventional machines, there it is very difficult.

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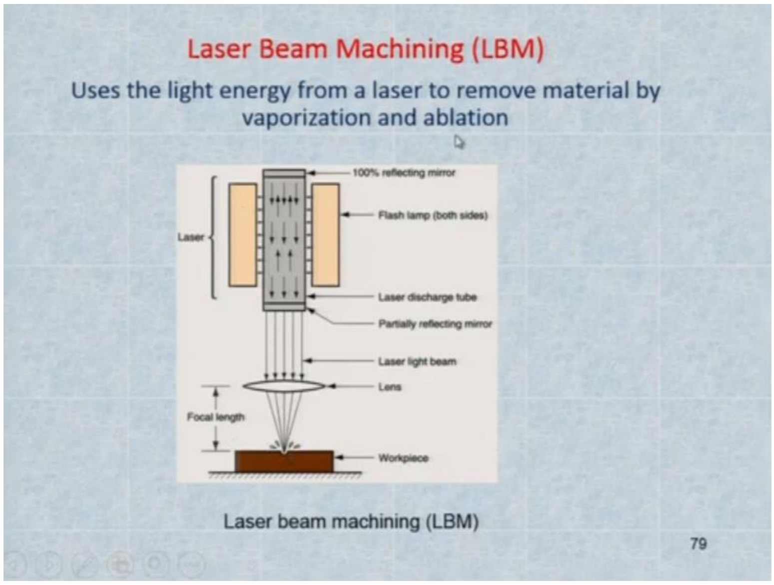

This is the laser beam machining. that the schematic shows the laser gun, this is being concentrated and the putting it on the work piece this we have already discussed.

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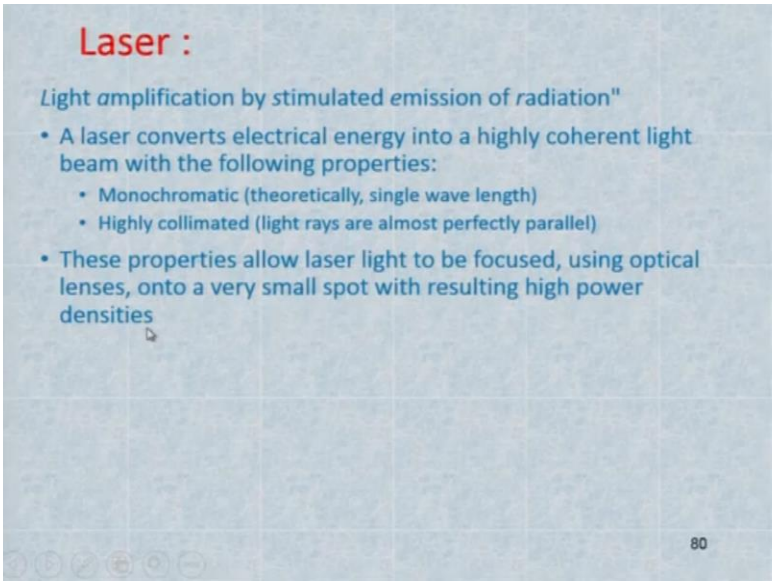

Laser is the light amplification of stimulated emission of radiation. The laser converts electrical energy into a highly coherent light beam with the following properties, monochromatic theoretically single wavelength in the case of laser. Here as you can see that it is different from the electron beam machining in that if you have a laser gun, it can be used in the presence of air.

Here air does not interfere with its operation. Molecules of the air do not interfere with it. This is the laser light beam and the lens will concentrate at a very tiny spot where the energy of that will be very high. So high that it will actually create very high temperature to melt and evaporate the work piece material irrespective of the strength hardness of this material. These properties allow the laser light to be focused using optical lenses on a very small spot with the resulting high power densities.

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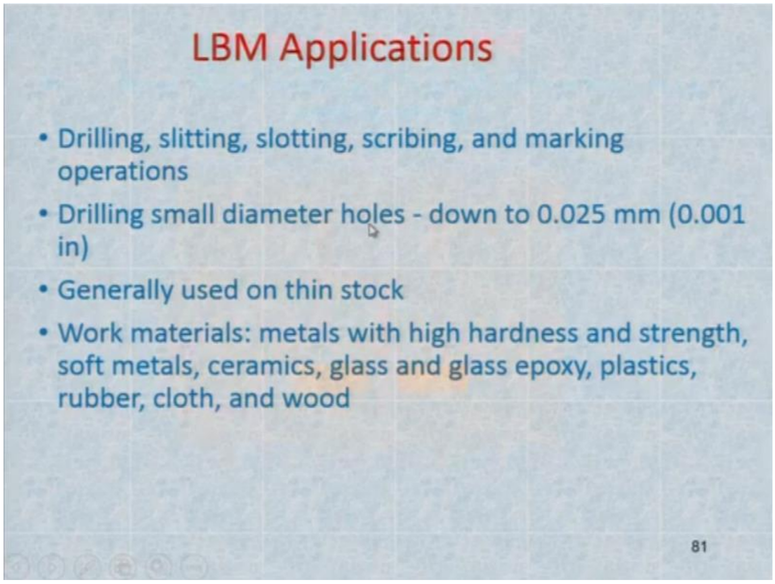

Applications are drilling, slitting, slotting, scribing and marking operations. Drilling small diameter holes down to 0.025 millimeter and generally used on the thin stock because otherwise those are otherwise very difficult to machine because they are very thin and fragile. Work materials are metals with high hardness and strength, soft metals, ceramics, glass, glass, epoxy plastic, rubber, cloth and wood. on these materials we can use the laser beam machining for machining.

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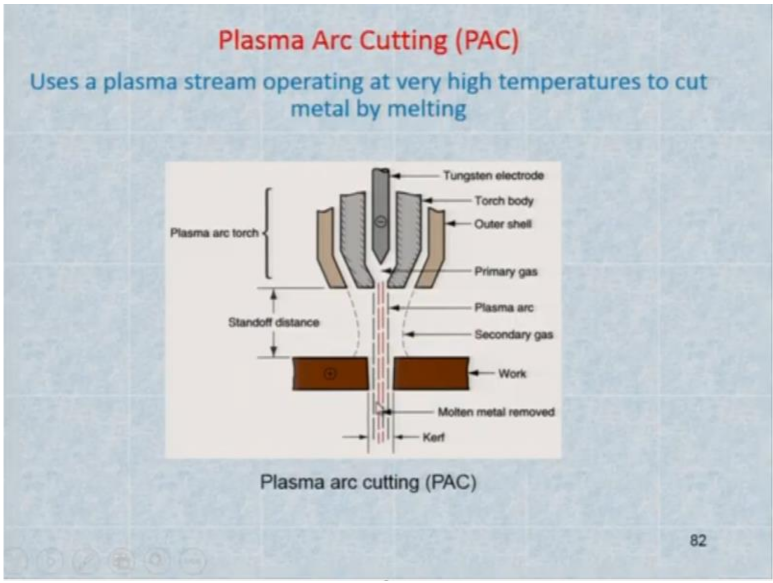

Plasma arc cutting (PAC)

This is another process which is called the plasma arc cutting. Here it is the plasma which is created by the tungsten electrode here again and the plasma arc has the primary gas the column and the secondary gas column that protects that this is a stand-off distance and this is the plasma arc torch and here also it creates very high temperatures and with that high temperature the material is melted. And the molten material is removed from here this is the curve which is being made; this is slot or the groove of the curve.

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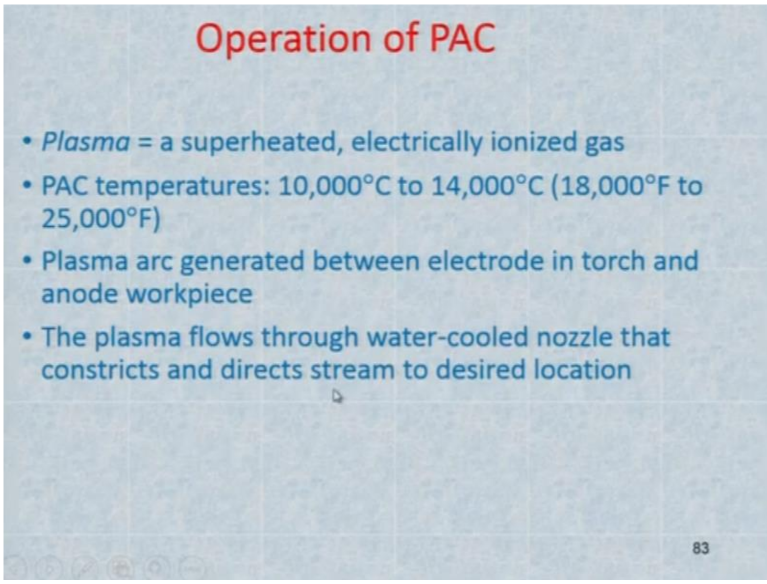

Plasma is a superheated electrically ionized gas and the temperature is 10,000^{0}C to 14,000^{0}C. As you can understand that at this temperature any material can be melted and evaporated. It really evaporates the material because it is such a high temperature, but it is at a small spot. Therefore, once again I repeat that in the vicinity there is no heat affected zone.

Plasma arc generated between electrode in torch and anode work piece, the plasma flows through water cooled nozzle that constricts and directs stream to desired location. These are the processes that I basically wanted to discuss with you to give you a basic idea about the unconventional or non-traditional machining. Now, we will start a new chapter in this lecture series.

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This topic is now Computer Numerical Control. Let me give you a preamble about the Computer Numerical Control of course, we will be having a hands on training in the laboratory, I will show you the entire video of how the programming can be made and how the machines can be operated using those programmes. I will show you a PPT separately before we go to the lab.

But here what we are going to discuss is what the NC and the CNC machines are? What is the difference between them? Why the NC and the CNC machines, they come into picture why we need them. When we use the conventional machines, you must have seen that there is a prime mover and that prime mover gives the movement to all the parts.

In the sense that it will move the spindle, it will move the lead screw for the feed and the feed motion will be taken from the gear drive, gear train in the headstock and so on. There is one prime mover and you will not have much choice of the relative movement between the tool and the work piece, as a result, in a particular machine you cannot have the possibility of changing the configuration of the part.

Meaning that suppose you take the example of the turning lathe. In a turning lathe you cannot cut the gear teeth or vice versa in the case of the milling machine, you can make a flat surface, you can cut gear teeth, but you cannot make a cylindrical surface for that you have to have the turning lathe this is because the configuration of the machine is such that you will have a particular relative movement between the tool and the workpiece.

By means of that relative movement you have only certain types of surfaces that can be made. As a result, what we are having is that the conventional machines are fixed you cannot have the flexibility. As long as the mass production is concerned where you are producing one particular part in a very large number this is OK but if you have to change the configuration of the parts, it is almost not possible.

And if you have to change the types of the parts of the types of the product that you are producing, which you call as the batch production for example, in that case those machines cannot be utilized that you are using in the mass production, then you have to have machines which will offer you more flexibility that is using a particular machine you can have different kinds of configurations, for that purpose.

These machines are the numerically controlled machines and the computer numerically controlled machines which have been invented way back in about 1950s when in 1952, 54the prototype came from the Massachusetts Institute of Technology and then it was introduced somewhere around 1955-56 whereas in 1960 this has already been started being used in the FMS that is flexible manufacturing system.

So, you can see that with the invention of the CNC and the NC machines, our possibilities have increased and the very rapid growth has taken place from the time the NC and the CNC machines were invented and that has made a revolution in the process of machining in the manufacturing.

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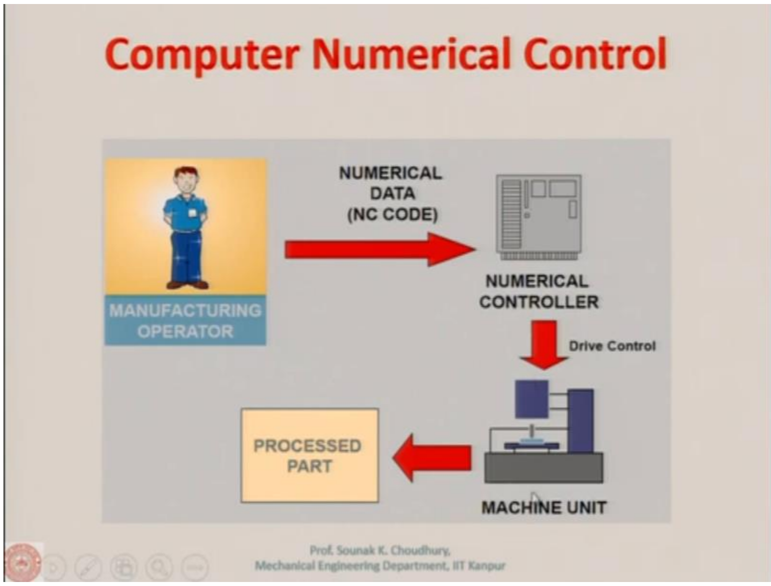

In the Computer Numerical Control machines, operator has much less responsibility in the sense that he will only be an observer in this case. He will actually have a numerical data he will put it in the numerical controller as the numerical control using the numerical control code. This will drive the machine automatically and the machine will produce the part.

That means, here it is the machine control unit that will actually read the data that the operator is putting here, it will interpret what the data means and after interpreting this it will send signal to the hardware that is the machine, about what to do. Let me tell you how this flexibility can be obtained. In case of NC and the CNC machines, we can have the flexibility that means we can change the configuration of the parts.

This is possible since these machines have instead of one prime mover motors for each of the 3 axes, x, y, z. Nowadays of course, there are 5 axis machines. So, there are more number of axes, but let us consider to begin with the 3 axes x, y, z. If we have 3 different motors for movement of these independent axes x, y, z then we can move them as per our requirement, we can move them one by one, we can move them simultaneously, we can move 2 of them simultaneously.

To make any kind of surface or any kind of relative movement between the tool and the work piece. That will make the flexibility possible, that means we can have the change in the configuration of the parts, we can make any kind of parts using the same machine and so on which will differ from the conventional machines.

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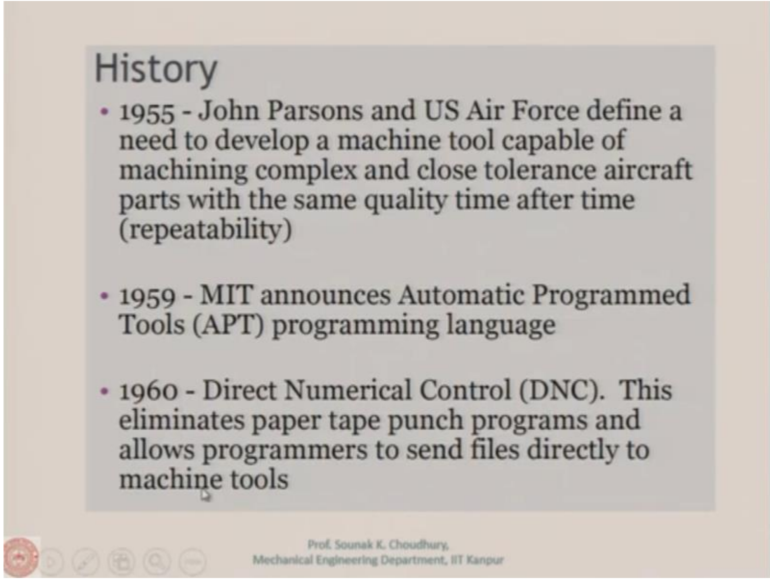

If you look at the history a little bit around 1955 the dates that I mentioned, john parson and the US Air Force define a need to develop a machine tool capable of machining complex and close tolerance aircraft parts, which will actually have the repeatability. About 1959 the Massachusetts Institute of Technology announces automatic programmed tools for programming language. this also has a concept they also came up with the concept of the Computer Numerical Control process.

And then they have offered the programming that is the automatic programming, in about 1960 there is a direct numerical control which came into picture along with the FMS, FMS also came around this time. This eliminates the paper tape punch programmes and allows programmers to send files directly to the machine tools. Earlier prior to that, we the paper tapes used to be used for the programming. From 1960 is the direct numerical control when the programme could have been directly input to the machine tools.

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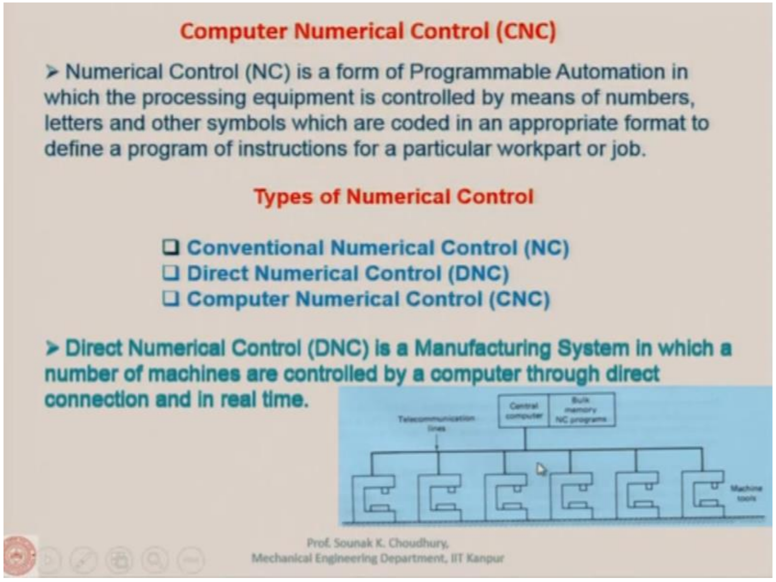

The Computer Numerical Control therefore is a form of Programmable Automation in which the processing equipment is controlled by means of numbers, letters and other symbols which are coded in an appropriate format to define a programme of instructions for a particular word part. Now, there are different types of numerical control, it can be NC that is conventional numerical control, it can be direct numerical control, DNC or the computer numerically control CNC.

In the direct numerical control when we say this is actually the manufacturing system in which the numbers of machines are controlled by a computer through a direct connection and in real time. If you see this here there is a central computer. The bulk memory NC programmes are kept in the central computer. This bulk memory will have the programme for all these machines. And all these missions are connected to the central computer by the electronically or electrically.

From the central computer the programme can be sent to the individual machines. These are the telecommunication lines. And the feedback from the machine can also be obtained to the central computer. Meaning that status of each of these machines can be found out from the central computer and the individual programmes what an individual machine would are supposed to does that will be sent also through the central computer from the central computer.

That means it is not required to have the computer system, standalone system for each of them individually, it is a bulk memory NC programme and those programmes are for all these machines and individual programme can be given to a particular machine. This is the direct numerical control and this is the first time as I said the milestone is the 1960 prior to that, it was of course the paper tape which was which used to be given to each of these machines individually.

So, this is the first step which came in about 1960 that it is directly given to the machines and there is a bulk memory problem for all the machines you do not have to have a standalone system.

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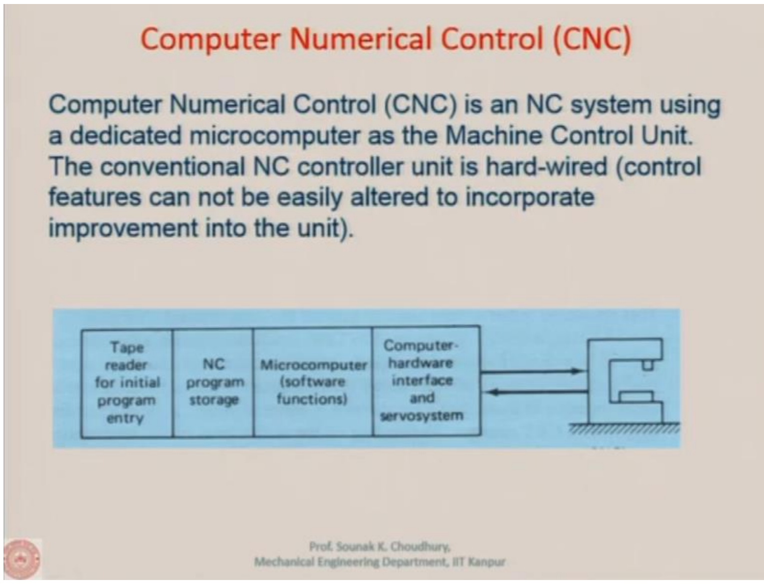

Computer Numerical Control in comparison to the DNC that is the direct numerical control: here we have one system that is it is an NC system numerically controlled system using a dedicated microcomputer as the machine control unit. Machine Control Unit will have a dedicated microcomputer, the conventional NC controller unit is a hard-wired that is control features cannot be easily altered to incorporate improvement into the unit.

Here what do you see is that tape reader, this is for initial programme entry tape reader is something where the programme is made and programme is kept. Programme is prepared in a certain fashion I will tell you how this programme can be made when we discuss the part programming and this programme is read once by the tape reader. The NC programme storage will store that programme when it is fed here.

And this is the microcomputer, this is software function, it will read and interpret what to do what this programme says line by line it will read and interpret and accordingly it will send the signal to the computer hardware interface and the server system. Here we have the interfacing, which actually then sends the signal to the machine that in which axis we have individual motors to different axis.

Signal is sent to different axes by the computer hardware interface depending upon the programme depending upon what we want to perform according to the drawing, how we want the tool to be moved or work piece to be rotated with in the spindle and so on. This in details I will tell you a little later.

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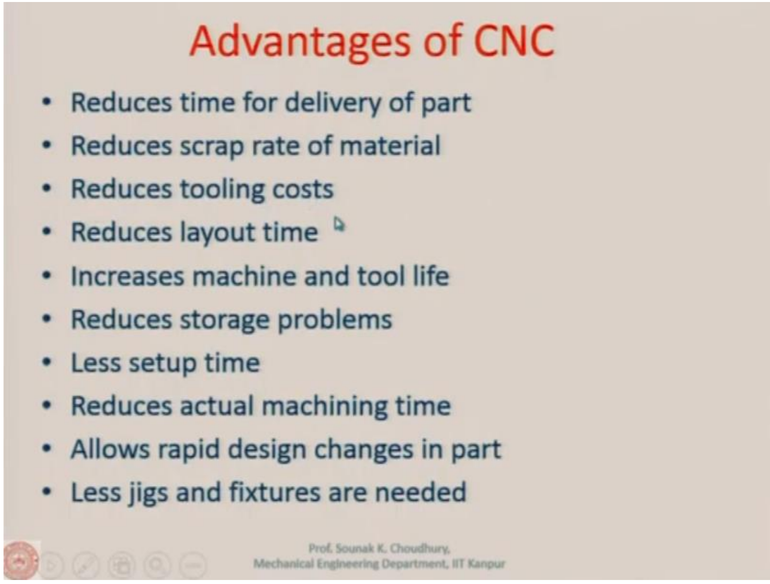

Advantages of the Computer Numerical Control: this reduces the time for delivery of the part of course, reduces scrap rate of material, why the scrap rate of material is reduced because the wastage is very less. The programme is made and if we are sure that the programme had does not have any tech, because we can actually run the programme ideally in the sense that we can simulate the programme I will show you how to simulate it.

And then that programme if we run in the machine, there will be no fault because we have already tested it and all the parts will be made according to the programme and they will be identical. There will be no wastage, therefore, the scrap rate will be much less. This is very important when the raw material is very expensive. If the raw material is expensive, then the scrap is very expensive. If a part is rejected, then we lose a lot of money in that.

That reduces the tooling cost also because here the tooling cost is not much since CNC reduces layout time; layout time is that where you have to plan for the location and orientation of the machines. Here it is not required; increases the machine and tool life because everything is optimum.

These machines will always work with optimum parameters. Therefore, the tool life is maximally used, tool life is maximum. It reduces storage problems because we can predict the production time preciously. Therefore, storage will not be required, then less setup time, as I said that layout time also will be less, tooling cost is less and the setup time accordingly will be less.

Reduces actual machining time because again it is optimally done although it allows rapid design changes in the part because once you change the design that means that you have to change the programme. So, you just make a change in the programme and then the programme will be accordingly working and the change in the design will be incorporated in the manufacturing, in the fabrication, less jigs and fixtures are needed.

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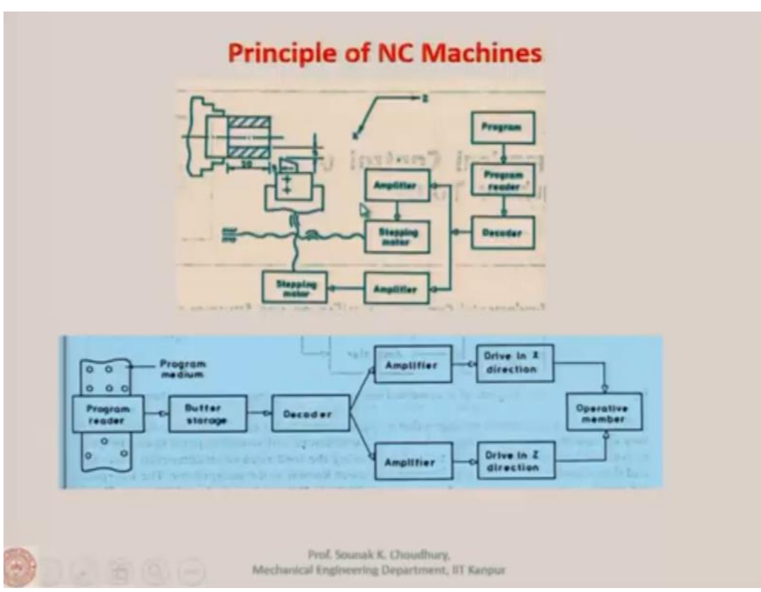

Here is the principle of working. Let us say we have X and Z axis. This is for turning where we have the cylindrical job which is mounted on the 3 jaw chuck here and this is the tool on the tool post. The tool can move apart from the rotation of the work piece which is on the spindle, so it will be rotating the tool can move along this axis that is the feed, when the feed is given. This axis in the turning is the x axis.

And this movement of the tool, along the axis parallel to the axis of the work piece is the z axis. This is particularly for the turning, I will show you for milling and drilling later, but for turning this is the system of axes which is internationally accepted. And mind it that these machines are used all over the world and we can get a machine which is from Germany or which is from USA and they have to use this kind of coordinates otherwise the movement will be erroneous, it cannot be correct.

And the fabrication of the parts can be erroneous. Here if you see that two individual motors, one stepping motor here, which is for the movement along the x axis in this direction and this is another stepping motor which is used for moving the tool on the lead screw this is in the z axis. So, this stepper motor is to move the tool along are parallel to the axis of the work piece and this is perpendicular to the axis of the work piece.

Here is the programme, which is made and run through the programme reader. The programme is read in the programme reader it is being decoded and after being decoded, it is amplified and it is sent to both the stepper motors which is in the z axis or in the x axis. According to the programme whatever is given in the programme as instruction, each individual stepping motor will understand what is to do and how to move.

Because this is the decoder it has read and interpreted according to the programme and sent the signal. If both the stepper motors move simultaneously it will be a movement like this, If only this stepper motor moves the tool will move like this. If only the stepper motor moves, the tool will move like this and so on. So, by taking the signal either to this stepping motor or sending to this stepping motor we can actually have different kinds of movements of this tool.

Once again, from the programme through the programme reader to the decoder, decoder actually decodes the programme. This means what do we want the machine to do and sends the signal to one of these amplifiers, this signal will be amplified and sent to the stepper motors and the stepper motor will move. You can see that here there are individual motors for each axis and not one like in the conventional machines.

Since there are individual motors for the individual axis, in this case it is the turning process x and z axis as I said therefore, we can have any kind of relative movement between the tool and the work piece. To make a cylindrical surface or it can make another movement to make a contour and so on, that we will see in the lab also. Here what is visible is the programme reader.

This is the line diagram of this shown here buffer storage this is a programme medium. This is what we have created he have created this programme medium that means you have to make the programme either on that you know you have to store it. These days the programme is made in a very different way. This is the programme medium which is the old example of when the programme used to be made on a tape, on a paper tape or on a magnetic tape and so on.

But these days we have the memory sticks, we have the direct input to the machine and so on. This is the buffer storage towards the programme for few part programmes, this decodes, amplifies and after amplification like in here it will drive along the x direction, or it will drive along the z direction. The signal will be sent to this stepper motor or this stepper motor. And this is the operative member; in this case it is the system of the work piece and the tool.

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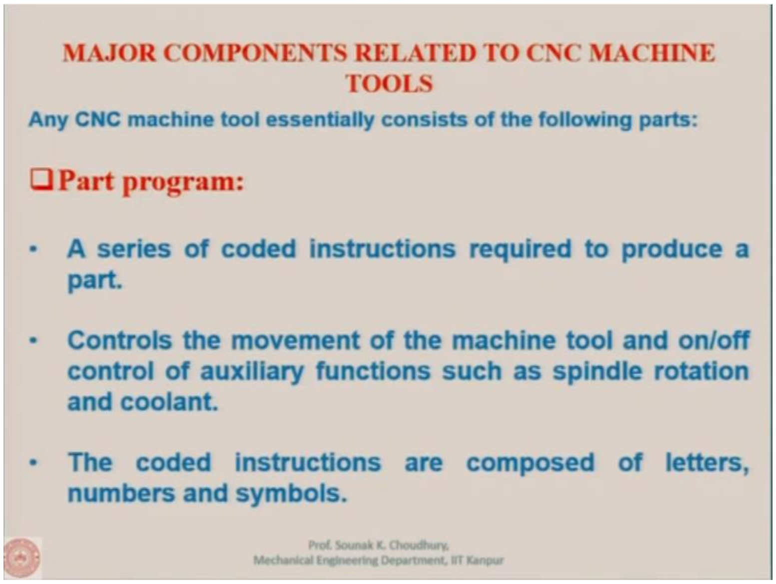

Now major components related to Computer Numerical Control machine tools, these are the following. Any Computer Numerical Control machine tool essentially consists of the following parts. As we have seen that major thing is the part programme. How you will programme the part meaning that how you have to fabricate a part. In conventional machine what do we do? We make a technological chart and the first stage is that we have to face. Let us take an example of a cylindrical job.

Then we have to turn the cylinder, then we have to turn around that fixing from the other end and then again face it. Then again turn it and probably then make steps, then grooves then holes and so on. So, there is a particular sequence of operations that we write down in a piece of paper. That will be the technological chart which will dictate that which process to be performed first. This is very important particularly when the process is very complicated.

Because depending on the sequence of processes we have to put the machines, now in 1 part it is not only the turning it may involve the drilling operation or it may involve the milling operation; in that case the part has to be rotated, part has to be moved from turning machine to the drilling machine, drilling machine to the milling machine depending on the sequence that you have made, sequence of operations that you have made.

Suppose there are many of such parts, some of them will require drilling, some of them will require milling, some of them turning and so on. That layout in this case is very important that the all milling machines will be together or all drilling machine will be together and so on or according to the sequence the machines layout can be planned so that the time is not wasted in the routing and time wasted means the production loss.

That means the time required will be more and the production rate will be less because production rate is 1 upon time that we set. Now part programme is a series of coded instructions required to produce a part. What are those coded instructions and for what type of machining that we will discuss later. Part programme controls the movement of the machine tool and on off control of auxiliary functions such as spindle rotation coolant.

For example, that you are fixing that part, you are mounting that part on the 3 jaw jack. Then you have to tighten it, clamping, then only the switching on the rotation of the spindle. So, in the programme, you have to be very specific that the spindle will be rotating and rotating clockwise or anti-clockwise in both ways the spindle can rotate. Depending on the programme, depending on your requirement, the spindle can be rotated according to the programme.

And it can be reprogrammed, can be written that the spindle is going to rotate clockwise or anti-clockwise. The coded instructions are composed of letters, numbers and symbols. Now by coded instructions we mean that what will be the overall, what will be the relative movement between the tool and the work piece. The coolant on off the spindle rotation, all these are coded instructions, all these comments have to be given in the coded instruction.

For writing the coded instructions, we said that we can use the letters, the numbers and the signs. Letters, all 26 alphabets of the English they are used, numbers used 1, 2, 3, 4 up to 99. And these signs like plus or minus meaning that you find out that you tell z axis and then you write the dimension or how much it has to move with the sign minus meaning that according to the selected system of access, whether it will be moving to the right or it will be moving to the left. These details these particulars, we will be looking at. They are composed of letters, numbers and symbols as I said.

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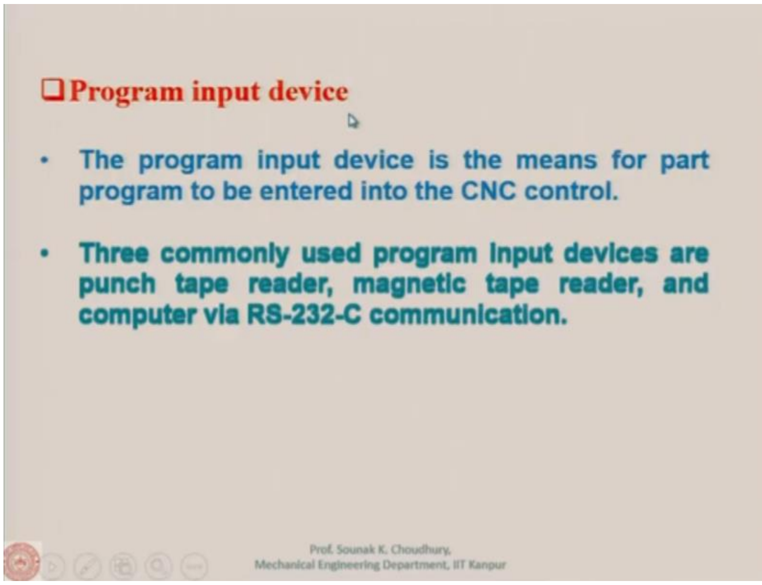

Next is the programme input device. This is also one of the important components of the CNC machine tools. Programme input device means for part programme to be entered into the CNC control. Now 3 commonly used programme input devices are punch tape reader, magnetic tape reader and computer via RS- 232-C communication. This is the latest one whereas the punch tape reader or magnetic tape they are pretty old. The rest of the material I will discuss in my next session of discussion. Thank you for your attention.