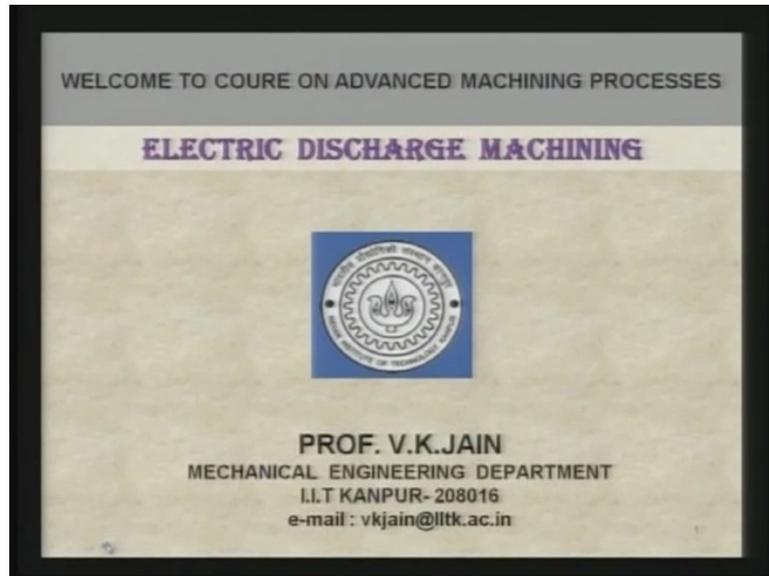


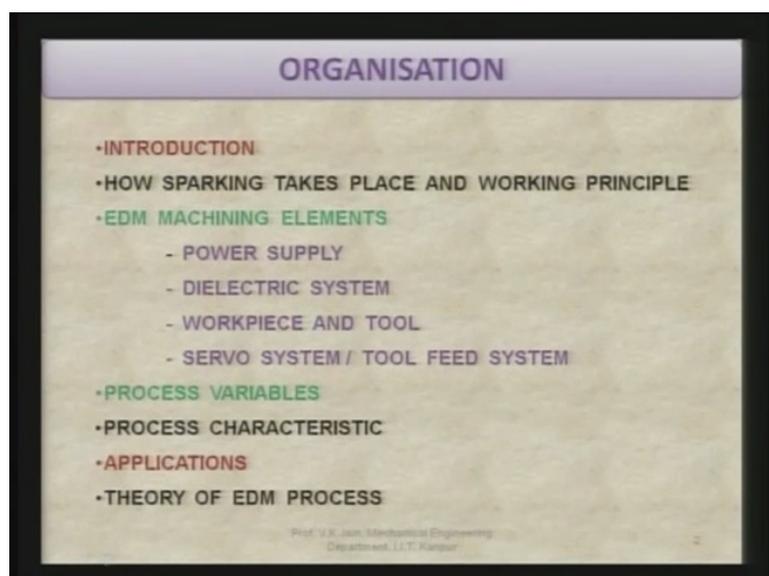
**Advanced Machining Processes**  
**Prof. Vijay. K. Jain**  
**Department of Mechanical Engineering**  
**Indian Institute of Technology Kanpur**  
**Lecture No 16**

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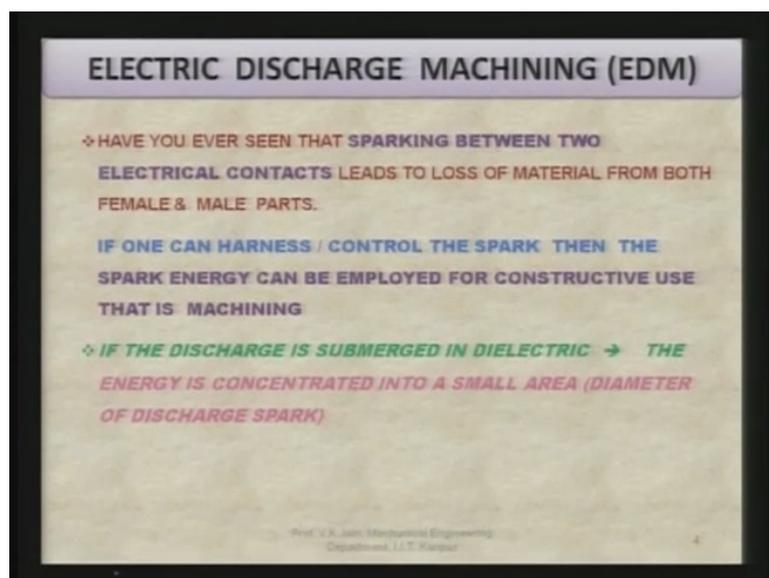
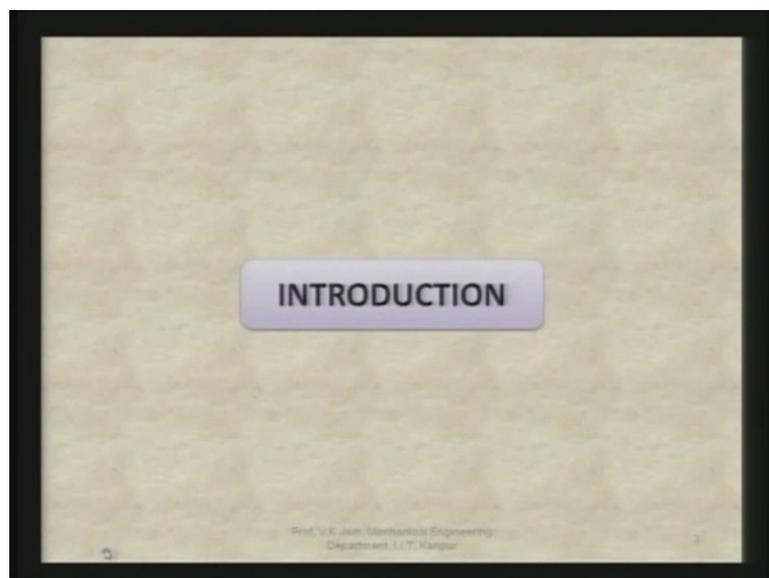
Welcome to the course on advanced machining processes, today we are going to discuss a very important advanced machining process which is most commonly used in even small-scale industries, medium scale industries as well as large scale industries that is electric discharge machining.

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The organization of this chapter is as follows first I will give you the introduction to the electric discharge machining process then how the sparking takes place and what is the working principle of EDM process then I will discuss the EDM machining machine elements or rather EDM elements which will include power supply, dielectric system, work piece and tool, server system and tool feed system. Then we will move to the process variables, what other various process variables of the EDM process, process characteristics and what are the very interesting some simple applications of electric discharge machining process and then we will move to the theory of EDM process.

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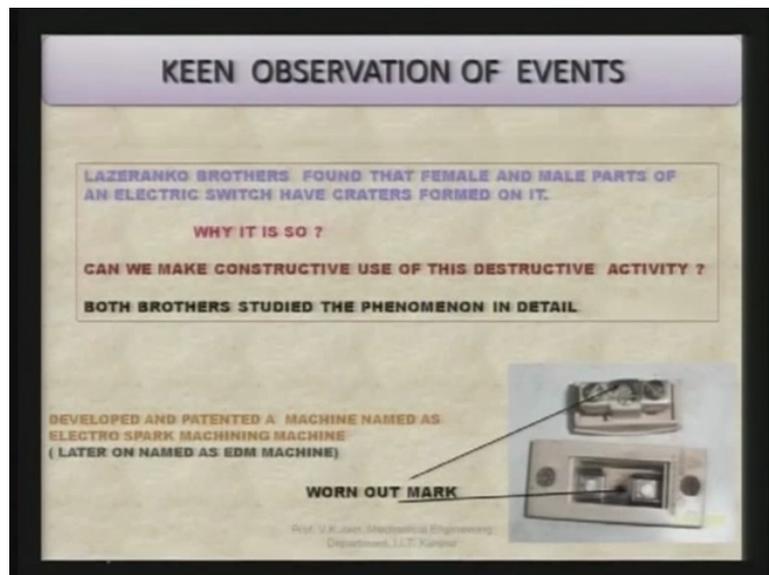


Let us start with the introduction of EDM that is electric discharge machining process. I have a simple question to all of you, have you ever seen that sparking between 2 electrical

contracts, those contacts that are there in our house, in our offices or elsewhere, they lead to loss of material from both female and male part of the connections. If one can harness or control the spark then the spark energy can be employed for constructive use that is for machining purposes in this particular reference.

Now if the discharge is submerged in dielectric, normally the dielectric use is the kerosene oil or some other oils. The energy is concentrated or can be concentrated into a small area and that small area the heat intensity of this spark is so high that you can melt and even vaporise many materials that we know and diameter of discharge will decide what is the diameter or discharge or spark will decide what is the area where it is rise in temperature is going to take place.

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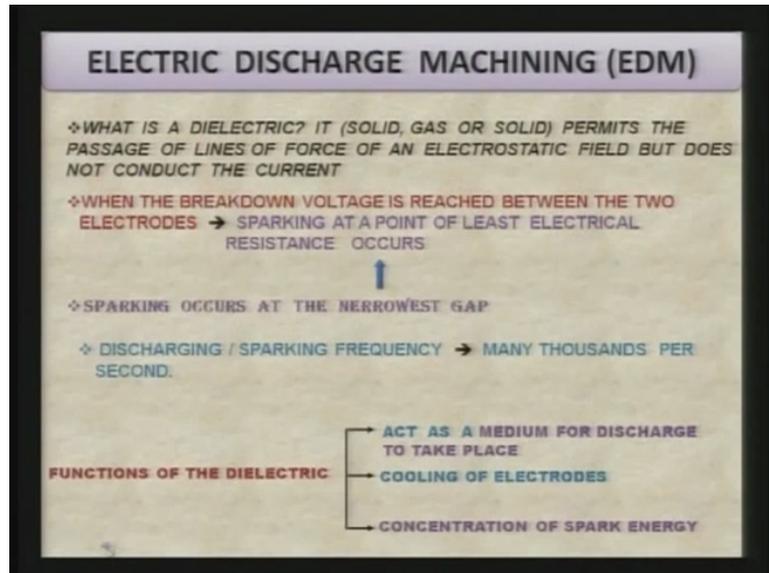


Now let us see very keen observation, in the old USSR Lazranko brothers found that female and male part of an electric switch have craters formed on it. The natural question which arose in the mind was, why do so? Can we make constructive use of this destructive phenomena or destructive activity? Both brothers studied the phenomena in detail for many years as you can see here clearly you have the male and female parts over here and black spots are there which are the worn out marks and this has the deposit of the carbon and the material has been removed from both male as well as from female parts.

After studying this particular phenomena of sparking in the male and female parts of the connections or switches that tried many times to developed a machine such that it can be used for constructive purposes especially for machining purpose and finally they got the success,

they developed a machine and patented a machine and they named it as electrode spark machining machine because sparking was taking place, so they named it electrode spark machining machine and later on this machine was named by various researchers as electric discharge machining that is EDM machine which we all know.

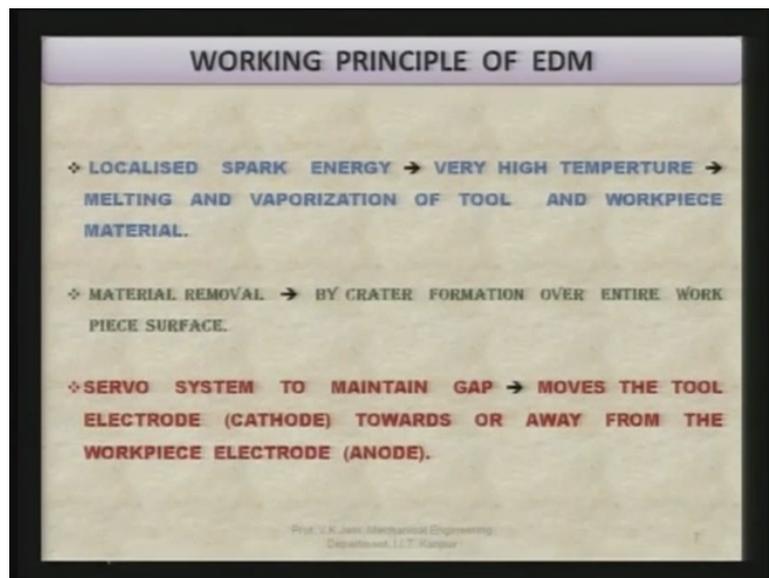
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What is dielectric? It may be solid, it may be gas or it may be liquid, this dielectric permits the passage of lines of force of an electrostatic field but it does not conduct the current that is electrically non-conducting in general. Now when the breakdown of voltage is reached between the 2 electrodes which are separated by the dielectric then sparking at a point of least electrical resistance occurs. Sparking occurs at the nearest gap or the least electrical resistance or minimum gap between the 2 electric electrodes and that discharging or sparking frequency in EDM process that we use is many thousands per second.

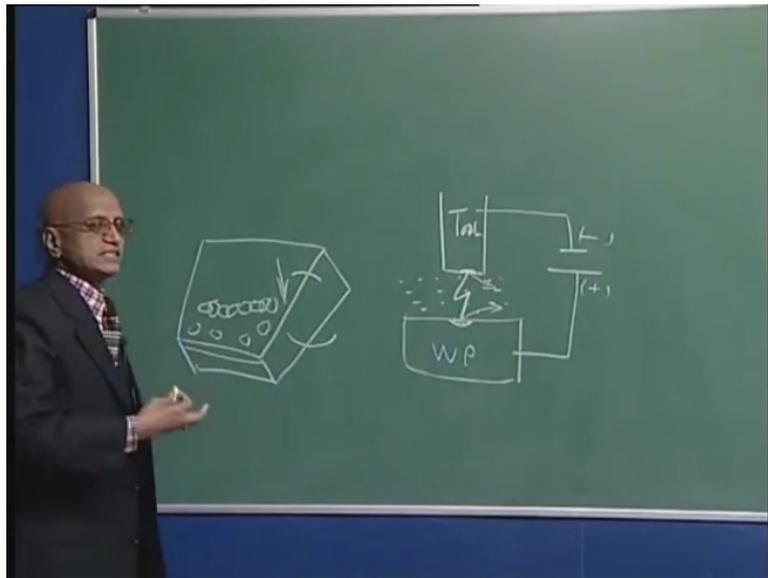
Now the question arises, how we going to use this dielectric and what are going to be the functions of dielectric in EDM process? It is going to perform 3 functions in the EDM process, it acts as a medium for discharge to take place because discharge will take place which may be arc or spark we do not want arc in this particular case, we always are interested in spark, so in that case this dielectric acts as a medium for discharge to take place. This medium or dielectric also cools the electrodes, we have 2 electrodes one is known as cathode that is normally the tool and another is known as anode which is the workpiece in case of EDM process and dielectric also helps in the concentration of the spark energy in a very localised area we will discuss it in the following slide, how this concentration takes place?

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Now let us discuss working principle of EDM process that localised spark energy creates or develops very high temperature on the anode that is the workpiece and cathode that is the tool and the temperature is so high that melting and vaporisation of tool and workpiece both takes place. Now when melting takes place a crater is formed on the tool as well as on the workpiece, so when craters formed and if the molten material is removed from those craters then material removal takes place and by crater formation over entire workpiece surface you can remove the material from the workpiece in that the desired shape and size. There is so system to maintain the gap between the tool and the workpiece because that maintenance of the gap is very important, so that the breakdown voltage between the 2 electrodes takes place and you have the spark. The servo system moves the tool, electrode that is the cathode towards or away from the workpiece electrodes that is the anode.

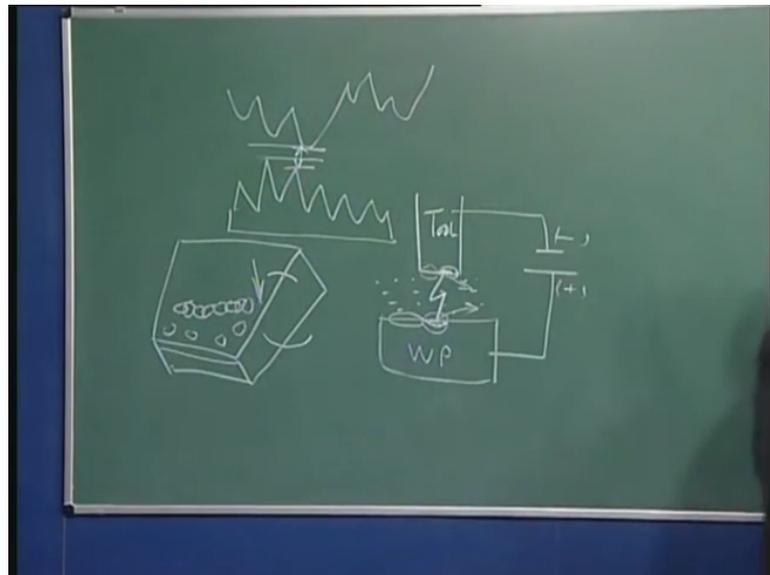
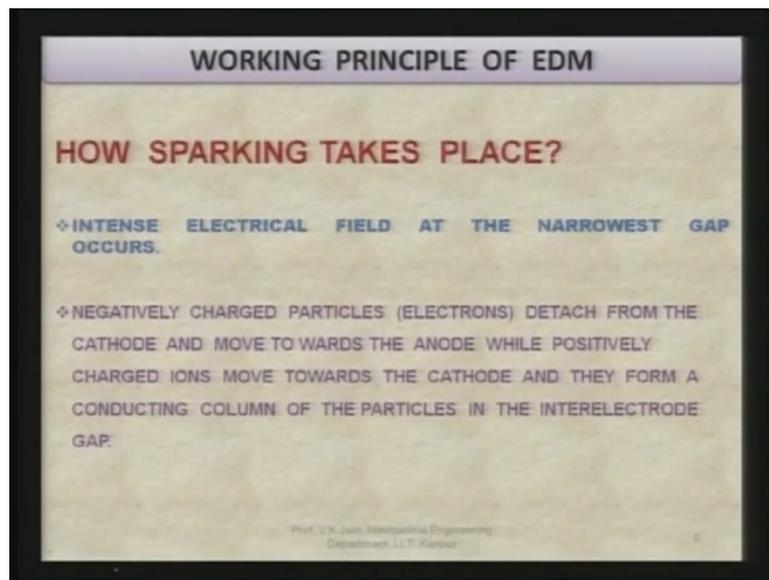
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Now let us see it, it works something like this here is tool here is the workpiece and in between the 2 (())(9:16) dielectric and this is connected to the negative terminal this is connected to the positive terminal and wherever there is a least resistance between these 2 sparking takes place and due to the sparking very high temperature is created which is many thousand degrees centigrade and small amount of material is removed from the tool or melted from the tool and a larger amount of the material is melted on the workpiece.

If we can flush out this molten material out from this working gap then the crater will be formed of this nature on the tool and this nature on the workpiece. Now if on the surface of the workpiece which is say like this and if you have thousands of craters over the whole entire surface and craters will be overlapping also with each other then whole the layer of the workpiece surface of a very small thickness is removed from here on the tool keeps moving downward, so you reduce the thickness of this work piece also you get the shape of the cavity on the workpiece just the replica of the shape of the tool, we will discuss more details.

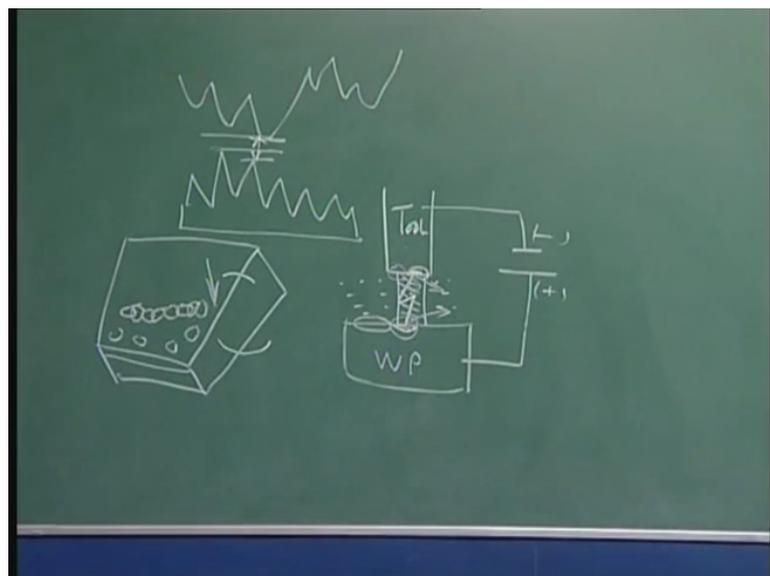
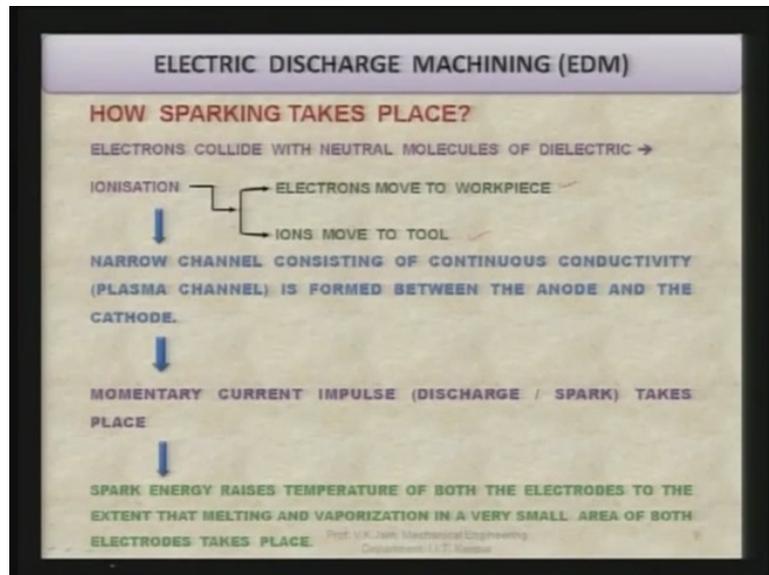
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How sparking takes place that is very important, intense electrical field is developed at the narrowest gap wherever it occurs as I show it to you there. The main thing is if you see the surface of the workpiece then you will find that peaks and valleys are there on the workpiece surface throughout the whole surface. Same way if you see the surface of the tool again you will find peaks and valleys are there on the surface of the tool also and wherever there is a minimum gap between the tool and the workpiece surface here the gap is between this as well as this one then sparking will take place at this particular point and that sparking will create the crater on the tool as well as the crater on the workpiece surface. So the negatively...what happens when that sparking takes place then negatively charged particles that are electrons detached from the cathode and move towards the anode that is the workpiece while positively

charged ions move towards the cathode that is the tool and they form a conducting column of the particles in the interelectrode gap.

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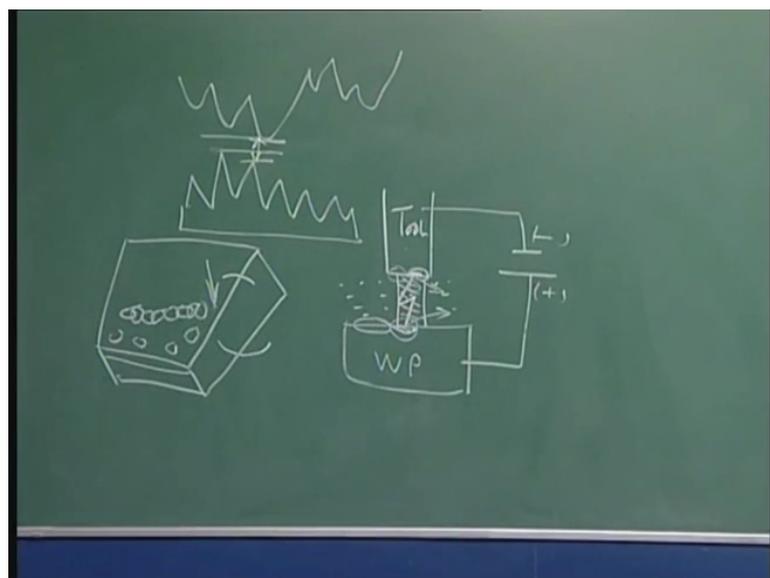
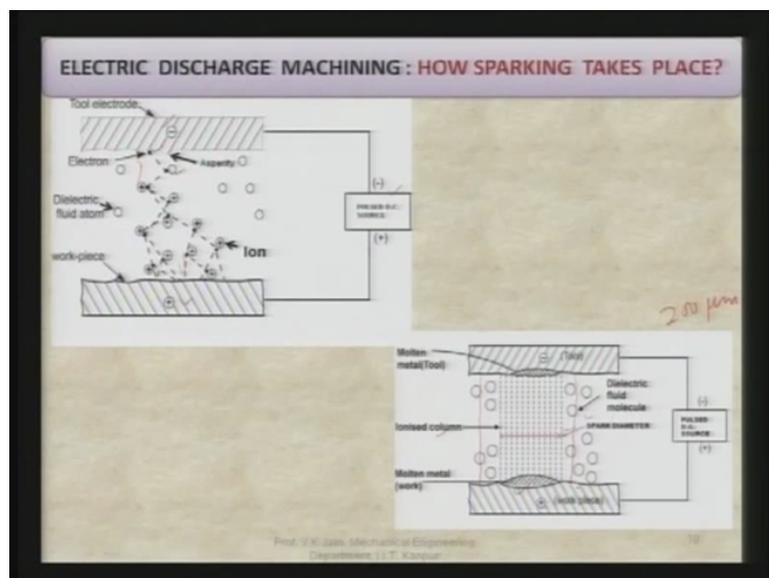


How sparking takes place? Let us go further electrons collide with the neutral molecules of the dielectric because this gap is filled up with the dielectric, so when electrons they detached from the tool that is the cathode they come and strike the molecule of the dielectric and then dissociation or the molecules of dielectric takes place or ionisation takes place and that leads formation and ion formation of the molecules of the dielectric.

Then electrons move towards the workpiece which is positively charged and ions move towards it tool that is negatively charged. Narrow channel consisting of continuous conductivity that is a plasma channel is formed between the anode and the cathode, so as a

result of that wherever that sparking is taking place a narrow channel of the continuously conducting particles is formed and this consist of ions as well as electrons over there. Momentary current impulse discharge or spark takes place, once that columns is formed then it works as a continuously conducting channel and the current flows for a short duration of period depending upon the pulse on...so spark energy that is due to the continuous column, plasma column formed over there, spark energy raises temperature of both the electrodes to the extent that melting and vaporisation in a very small area of both the electrodes takes place.

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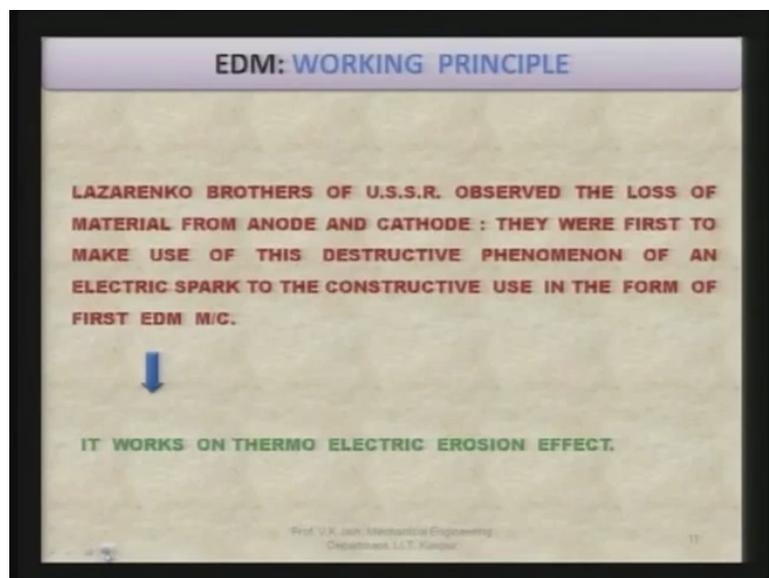


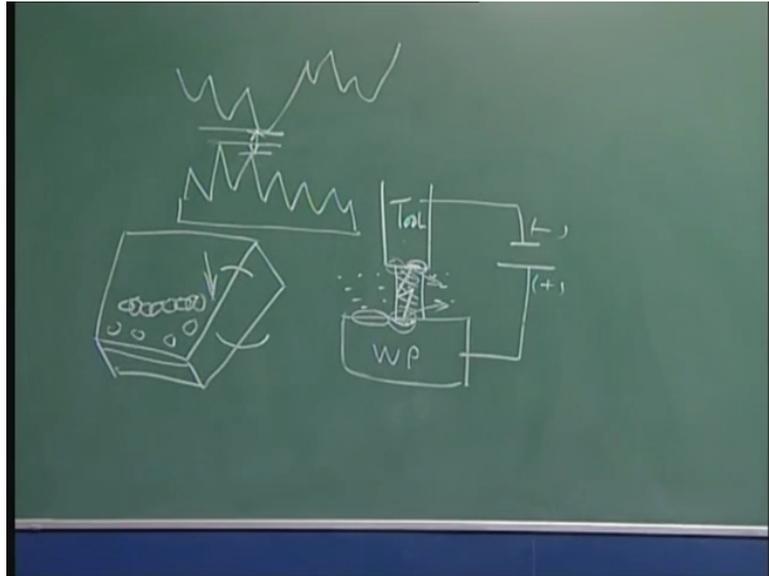
Here this picture tells you what I have explained the on the board you can see here in this picture that 2 electrodes is there which is negatively charged, workpiece is positively charged

and electrons that is here, there are coming, striking with the molecules of the dielectric and it dissociate into the ions and electrons and you can see here the ions are moving towards the tools and electrons they are moving towards the workpiece. Now the velocity with which electrons are moving towards the workpiece is very close the velocity of light.

However, the mass of the electrons is negligible because of this high, very high velocity the kinetic energy of these electrons that is half  $(\frac{1}{2})$ (15:02) is so high that they are able to raise the temperature of the workpiece to a high value and both the electrodes that is cathode and anode are connected towards the pulse DC, pulsed direct current source. Now this is what I have drawn there, you can see this is the molten metal, small craters formed on the tool and large crater is form on the workpiece because the energy released on the workpiece is much higher than the energy released by the ions on the tool and you can see here is the ionised column that is shown as diameter of the spark and this is normally 100 to 200 micron normally 100 to 200 micron depends upon the machining parameter and the dielectric characteristics. Now surrounding to this there will be some vapours of the dielectric then you will have the dielectric itself.

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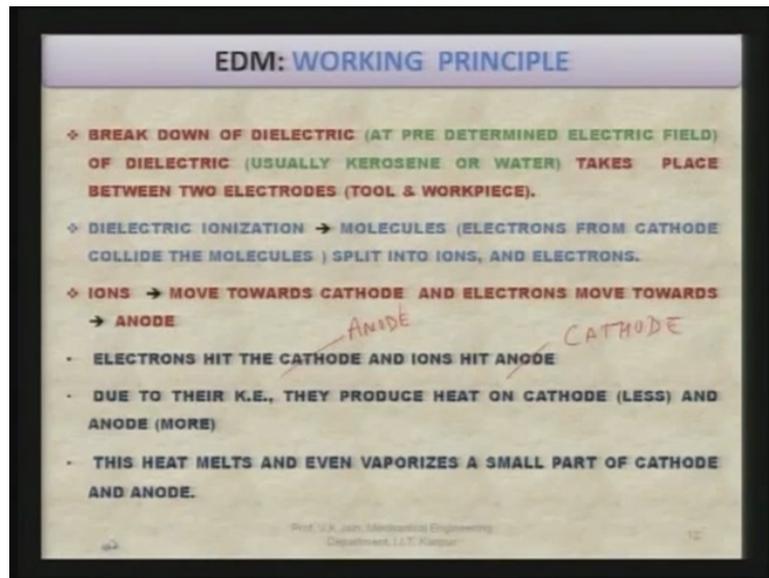




So Lazeranko brothers observed of USSR observed the loss of material from anode and cathode that I have already mentioned to you and they were 1<sup>st</sup> to make use of this destructive phenomenon of an electric spark to the constructive use in the form of 1<sup>st</sup> EDM machine. It works on thermoelectric erosion effect as I have just explain to you in my earlier slide that thermal erosion of the tool as well as thermal erosion of the workpiece is taking place, craters are being formed and when these craters are formed over the whole surface then finally get the desired shape and size because tool is being continuously moved, so the material from the workpiece is being continuously moved.

However, note it that some material is being removed from the tool also and really speaking we do not want that the material should be removed from the tool but it is a part of the phenomena or part of the process, we cannot get away with this, so researchers have tried to minimise the wear of the tools, so that the shape and size of the tool does not change substantially during the EDM process.

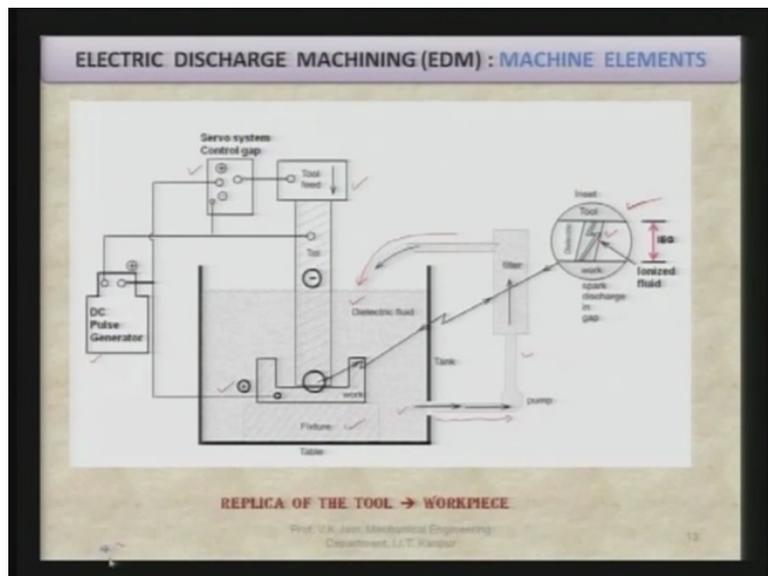
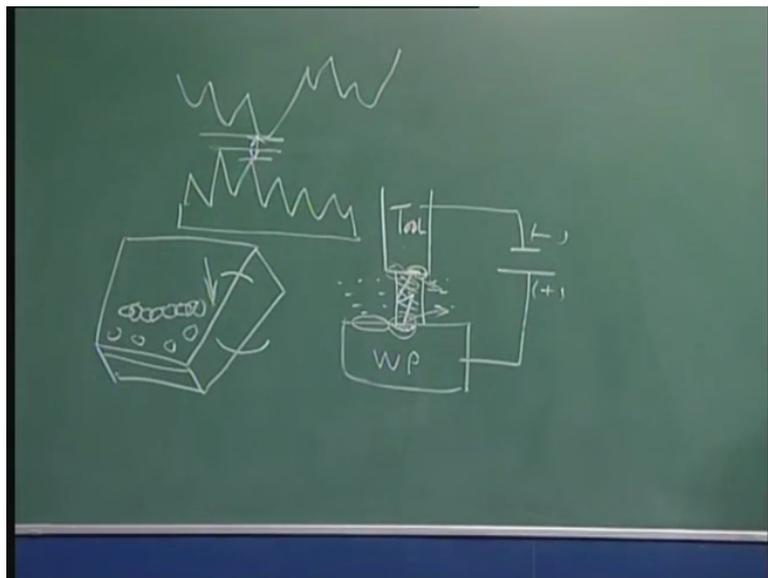
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Breakdown of dielectric at predetermined electric field of dielectric usually kerosene is used as the dielectric but in some cases live wire electric discharge machining which we will discuss later water is always used deionised water is always used as the dielectric. It takes place between 2 electrodes tool and the workpiece and dielectric ionisation takes place because molecules that is electrons from cathode collide the molecules of dielectric, they split into ions and electrons which have explained to you.

Ions move towards cathode and electrons move towards anode. Electron hit the anode and not the cathode and ions hit the cathode and since the velocity of the ion is much smaller than the velocity of the electrons. However, the mass of the ions is much larger than the mass of the electrons at total energy carried by electrons is higher than that carried by the ions that is why rising temperature or removal of the material from the workpiece is much larger than the removal of the material tool that is the cathode. Due to their kinetic energy they produce heat on cathode less and more on anode. This heat melts and even vaporise a small part of cathode and comparatively large part of anode.

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This shows various elements of an EDM machine that is electric discharge machining machine, now you can see here there is a DC pulse generator which creates the pulses of the electric voltage and then you have the servo system control that controls the gap between the tool and the workpiece. Servo system is responsible to maintain this particular gap more or less constant in a very narrow range then there is a tool fit system basically the servo motor or servo system gives the feed to the tool. Now depending upon if this gap is large then tool will move towards the workpiece, if this gap is smaller than the required one then the tool will move away from the workpiece and this function is performed by the servo system.

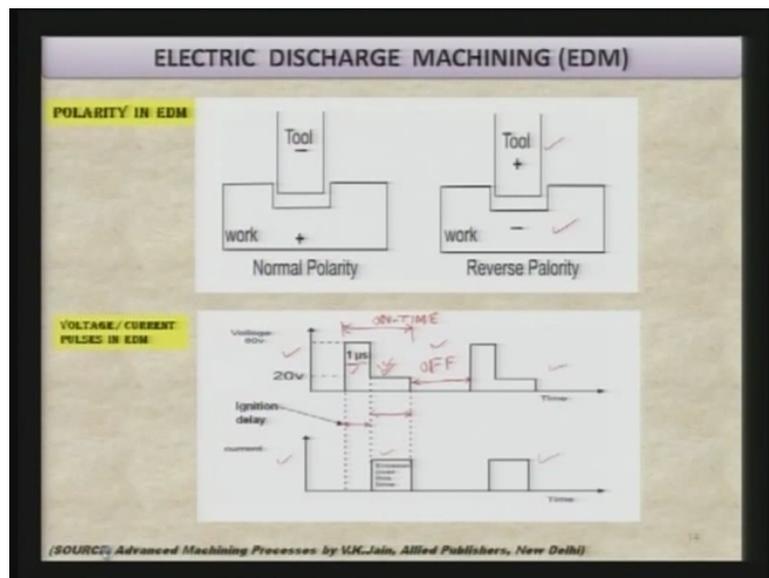
You can see here dielectric fluid is there and the enlarge view of the interelectrode gap between the tool and the workpiece shown over here, tool is there, workpiece is there and

dielectric is there between the 2 and you can see the ionised fluid which has the electrons as well as the ions and the gap between the tool and the workpiece is indicated as IEG that is interelectrode gap, this is the abbreviation of interelectrode gap IEG. Now if you come back again here you have the fixture which is holding the workpiece and the workpiece is connected to the positive terminal of DC, pulse generator that is it becomes anode, so what does it mean really that workpiece is connected the positive terminal of the DC power supply.

This simply tells that the workpiece has to be electrically conducting, if workpiece is not electrically conducting this becomes the limitation of this particular process that you cannot machine that particular work piece or that particular material with the help of EDM process, so it from this you can also conclude that all the workpiece is which are to be machined by EDM process should have certain minimum electrical conductivity otherwise they cannot be machined or in other words you can say that electrically non-conducting materials or insulators cannot be machined by EDM process.

Now dielectric plays very important role and you can see the gap between the tool and the workpiece is filled with the dielectric, so when this dielectric that is filled in the tank it you can see its path, the pump pumps the dielectric from the tank to the filter and the filter takes away the debris or the residues which are added to the dielectric in the dielectric tank or the machining area they are filtered out and then again dielectric is applied to the tank. Now there are various ways how you supply the dielectric to the tank and 1<sup>st</sup> and foremost condition is that dielectric should reach to the interelectrode gap as you can see here on the right-hand side if dielectric is not there then some part of dielectric that means liquid and some part of air will be there which may not function very well. What the workpiece you are going to get is going to be the replica of the tool.

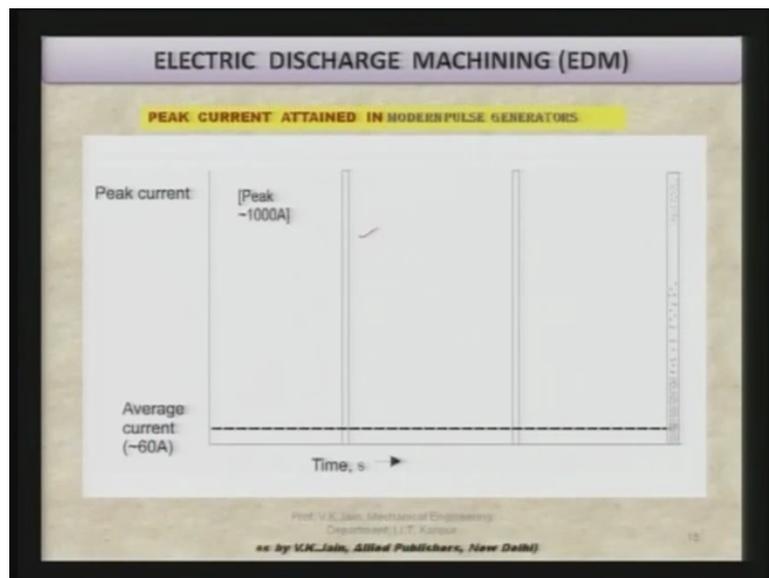
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Now electric discharge machining you can see there are 2 polarities shown over here, I have mentioned to you in the earlier discussion that tool is cathode and workpiece is anode and that polarities known as normal polarity, but under certain combination of the tool and workpiece material it is found that reverse polarity performs better than the normal polarity. In case of reverse polarity tool is made anode that is connected to the positive terminal and workpiece is made cathode connected to the negative terminal. Now when you connect the tool and the workpiece to be pulsed power supply what is happening to the current and voltage pulses.

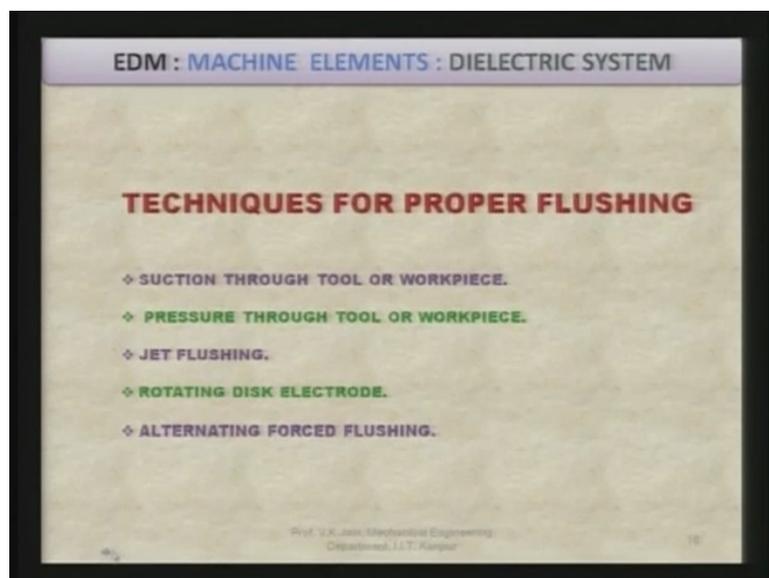
Let us see here this is the voltage pulses, now this is the off time and this is the on-time. Now in the on-time there are 2 divisions one is shown over here that is around 1 microsecond and rest is the there, so this portion is known as ignition delay time and this is the one where really sparking is taking place and you can see here during this period erosion over this time takes place and here is the current pulse because during ignition delay time there is no flow of the current but during this particular period flow of the current is taking place or ignition period ignition delay sorry during the ignition or sparking only the current is flowing, off time there is no flow of the current, so this indicates that really material removal takes place only in this period not in this period nor in this period there is no removal of the material that is the ignition delay time. So you can see the difference between the voltage pulses and the current pulses.

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Now in today's pulsed power supply or pulse generator the peak current is very high compare to really what you want for melting and vaporisation of many materials and you can see here are shown over in this figure that peak current can be as high as 1000 ampere which is really much larger than what you really need, so although these are there but they help of modern pulse generator you can current control the peak current also.

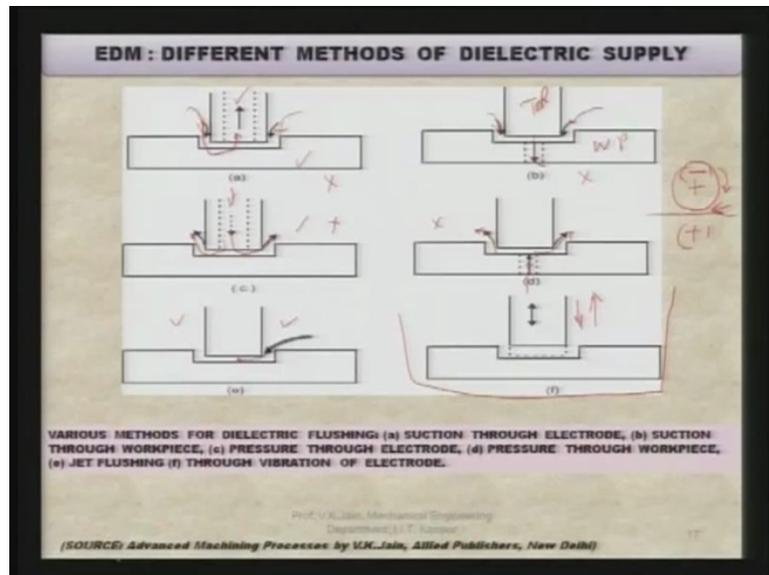
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Now supply of the dielectric in the interelectrode gap is very important and there are various ways by which you can supply the dielectric between the tool and the work piece that is interelectrode gap, let us see there is one is through suction suction through tool or

workpiece, pressure through tool or workpiece, jet flushing, rotating disk electrode, alternating forced flushing.

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Now let us see the figures, now if you see these figures figure a is the suction through the electrodes dielectric is been supplied the side over here and it is sucked through the electrodes and the electrodes there is the tool and it has the hole in the center of the tool, so that dielectric will come this way and it will be sucked inside the tool through the tool. Now in the 2<sup>nd</sup> case that is suction through the workpiece you are supplying the dielectric from the sides and then it is being sucked through the hole in the workpiece and this is the workpiece and this is the tool.

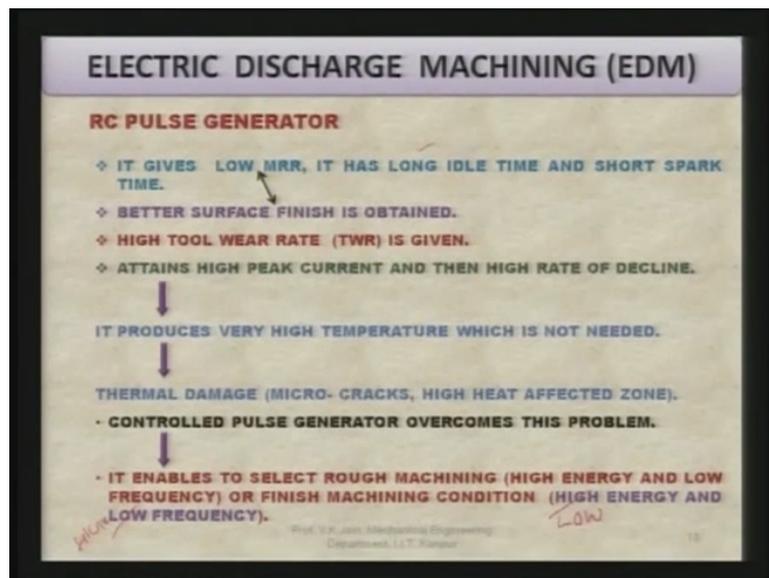
Third case is pressure through the electrode you apply or supply the dielectric at high pressure through the hole in the centre of the tool, normally it is in the center of the tool and then the dielectric comes and it goes through the sides or the gap between the outer surface of the tool and inner surface of the machine hole, you can in the next case that is the pressure through the workpiece again in place of coming through the tool you can supply at a high pressure the dielectric through the whole in the workpiece and then the dielectric will go or come out from the sides and the commonly used is the one which is known as jet flushing, here your supplying the dielectric at a high pressure through the jet and that forces the dielectric to come between the tool and the workpiece, whole of the system is immersed in the tank of the dielectric, so supplying the dielectric through the jet becomes comparatively more effective than other means.

Now the last one is through vibration of the electrodes, what you can do that whole of the system is kept inside the tank which is filled with the dielectric and you vibrate the tool at a high-frequency, so due to the pushing up and down the pumping of the dielectric takes place in the interelectrode gap and that flushes out the dielectric and brings in the fresh dielectric in the interelectrode gap, so that debris are removed out and fresh electrodes fresh dielectric is continuously fed in, in the interelectrode gap. So there are various these 6 ways are there other ways also can be developed by combination of these or a new method can be developed.

One of them is as I have mentioned in the earlier slide that rotating the die rotating the electrodes. Suppose your trying to remove the material with the help of a rotating electrodes that is the cathode here and this is the workpiece here, if you are rotating this then due to the rotation it will suck the dielectric in the interelectrode gap and that dielectric will help in generation of the sparks between the tool that is the rotating disk in the workpiece and you will be able to remove the material and you will be able to cut it 2 parts or create a slot or cavity whatever you like. So there are various ways in one is to opt most suitable method for a particular case because in many cases you may not be having the hole in the workpiece, so you cannot use the method that is b and d you are left with the hole in the tool.

Now if the size of the tool is sufficient enough and you can use a or c and you have to decide what should be the size of hole in the tool. If size of the tool is very small and really you cannot drill the holes so easily, so you will not be able to use these 2 methods also in your left with the option that is shown here e or f. Now depending upon the size and other constraints, you have to opt either e or f. So my recommendation is that depending upon the situation you decide which method you should use for the supply of the dielectric in the interelectrode gap. The source is the book on advanced machining processes.

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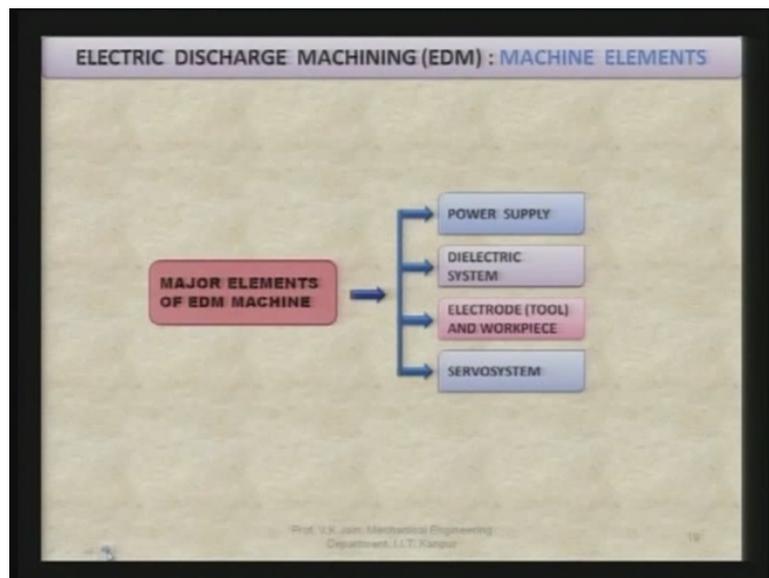


RC pulse generator, I will discuss this RC pulse generator probably in the 3<sup>rd</sup> lecture, today is the 1<sup>st</sup> lecture on EDM, now it gives low material removal rate, it has long idle time and short spark time, idle time I have shown to you sometime back in I think 2 slides back where it was 1 microsecond and in RC pulse generator that is resistance capacitance pulse generator. This is little longer than really 1 microsecond but the surface finish better surface finish is obtained with the help of RC pulse generator compared to modern pulse generator but material removal rate is low.

High tool wear rate in case of RC pulse generator, it attains high peak current and then high rate of decline of the current. So it produces very high temperature which is not really needed, in case of RC pulse generator the peak current is very high then the temperature rise of the electrodes is very high which is really not needed and if the temperature rises very high it may damage the tool as well as the workpiece just like it may create large amount of thermal residual stress, micro cracks and other defects. Thermal damage to the workpiece as well as the tool something like micro cracks may happen, heat affected zone may be large also recasts layer may be large, so you should have controlled pulse generator overcomes this problem.

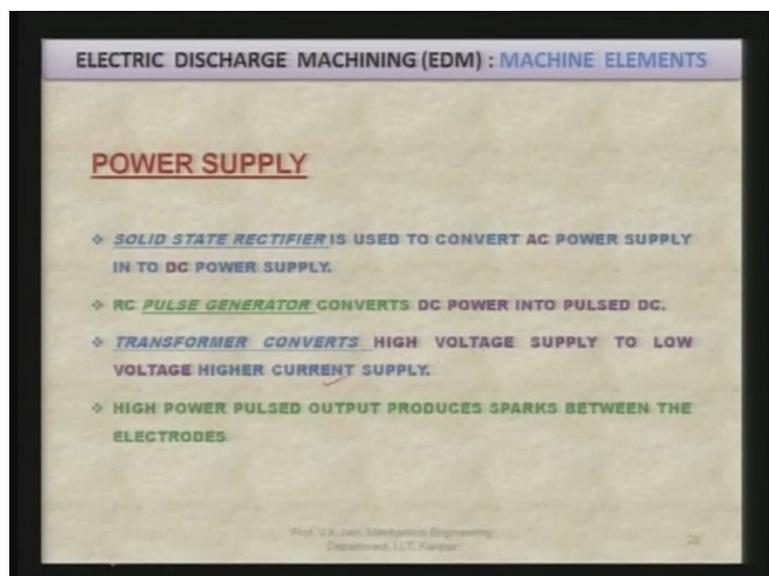
It enables to select rough machining that is high energy and low-frequency or finish machining condition that is low energy and high-frequency, please correct it. In case of finishing condition it will be lower energy and frequency will be high, so with the help of modern pulse generator you can select either finishing condition or rough machining condition depending upon your workpiece requirement which you are machining.

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Now let us discuss what are the various elements of EDM machine? There are 4 basic major elements of any EDM machine one is the power supply another is the dielectric system 3<sup>rd</sup> is the electrode that is the tool and workpiece and 4<sup>th</sup> is the servo system which is controlling the gap between the tool and the workpiece.

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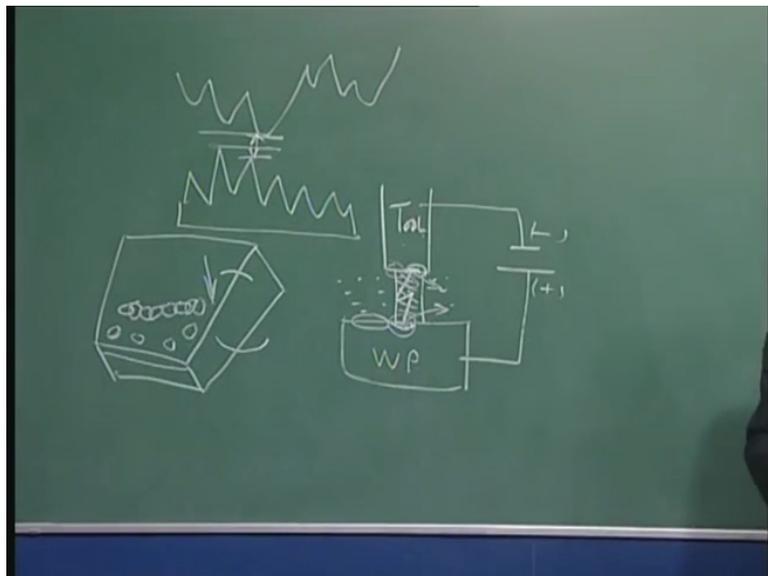


Let us discuss little more detail about the power supply, let us take the 1<sup>st</sup> element of EDM machine that is the pulse power, it...solid-state rectifier is used to convert alternating current there is AC power supply into DC power supply because most of the places we have AC supply but we want pulse DC power supply, for that purpose solid-state rectifier can be used. Then you have RC pulse generator that converts direct current power into the pulse direct

current power, in place of RC pulse generator you can use other pulse generator also that are available in the market but RC pulse generator was the 1<sup>st</sup> one was used in the initial EDM machines.

Then we used transformer that converts high-voltage supply to low voltage higher current supply because normal supply of the power is 220 volt in India in in the EDM we do not need more than 100 volts, so transformer is used to reduce the voltage from 220 to 100 or lower than that, so we have the transformer which can give 0 to 100 or 0 to 120 volts for EDM machine. Also another thing is this should be able to give higher current, current required is normally higher in case of EDM. Then you have high-power pulsed output that produces spark between the 2 electrodes that is the anode and the cathode.

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**ELECTRIC DISCHARGE MACHINING (EDM) : MACHINE ELEMENTS**

**POWER SUPPLY**

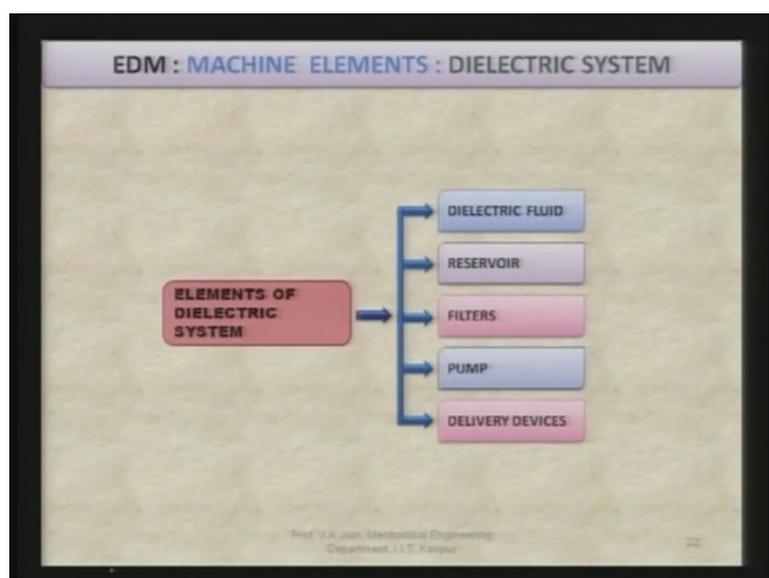
- ◇ FOR A GIVEN VOLTAGE, SPARKING TAKES PLACE AT OR BELOW A MINIMUM GAP.
- ◇ EDM POWER SUPPLY SIGNALS IN THE GAP ARE FED TO SERVO SYSTEM THAT CONTROLS GAP VALUE.
- ◇ POWER SUPPLY ALSO CONTROLS ELECTRICAL PARAMETERS SUCH AS V, I, PULSE DURATION, DUTY FACTOR, FREQUENCY AND POLARITY.
- ◇ POWER SUPPLY IS EQUIPPED WITH CUT-OFF PROTECTION CIRCUIT THAT ACTIVATES AUTOMATICALLY IN CASE OF OVER-VOLTAGE OR OVER CURRENT IN THE IEG. *Factor Int. control 1/4 sec*
- ◇ IN THIS CASE POWER IS CUT OFF AUTOMATICALLY BEFORE THE ELECTRODES GET DAMAGED.

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For a given voltage sparking takes place at or below a minimum gap that is what I had explained here that is the minimum gap between the tool in the workpiece where the sparking takes place. EDM power supply signals in the gap are fed to the servo system that controls the gap value because once the material is being removed from the tool as well as the workpiece then the gap between the 2 will keep increasing but we should maintain a certain minimum gap, so that the sparking takes place at the pre-decided value and that work is performed by the servo system.

Power supply also controls electrical parameters such as voltage  $V$ , current  $I$ , pulse duration, duty factor, frequency and polarity we will discuss about the duty factor this is nothing but the on-time divided by on-time plus off time and this play an important role this is the duty factor we will discuss it later on in detail. Power supply is equipped with cut-off protection circuit that activates automatically in case of overvoltage or over current in the interelectrode gap, if there is over current in the interelectrode gap then it may damage both tool and workpiece and we do not want either of the 2 to get damage, so there is a protection that if the current reaches above  $x$  value then it will automatically cut off and give the signal that there is something wrong in the system that is why over current is there or some machine they may have the arrangement that they will rectify or they will correct the situation automatically. Now in case of over current in the interelectrode gap, in this case power supply is cut off automatically before the electrodes get damaged.

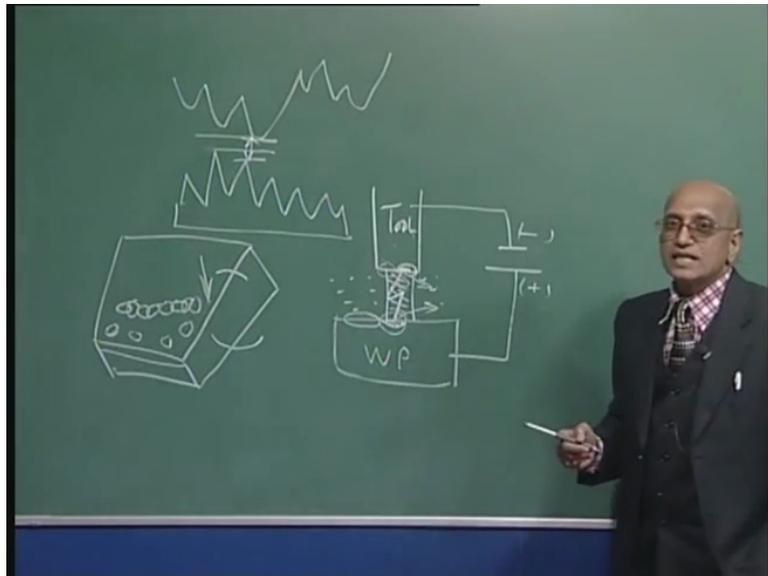
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Now 2<sup>nd</sup> element of the EDM machine is the dielectric system, elements of dielectric system itself has many elements, sub-elements rather that is the dielectric fluid, reservoir, filters that

we have seen in one of the diagrams, pump and the delivery devices, now let us see little more details of each of these in the following slides.

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**EDM : MACHINE ELEMENTS : DIELECTRIC SYSTEM**

**GOOD DIELECTRIC FLUID SHOULD POSSESS THE FOLLOWING PROPERTIES :**

- ❖ HIGH DIELECTRIC STRENGTH,
- ❖ MINIMUM IGNITION DELAY TIME,
- ❖ MINIMUM DEIONISATION TIME,
- ❖ EFFECTIVE COOLING ✓
- ❖ HIGH DEGREE OF FLUIDITY

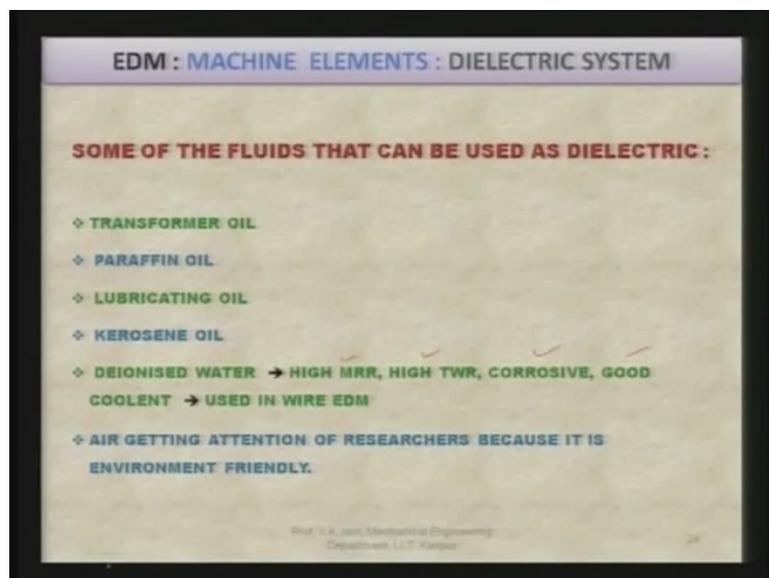
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Now before I discuss that let us see which is the good dielectric fluid? So the liquid or even the gas which you are going to use as the dielectric should have certain properties to be used as a dielectric in EDM process, so good dielectric fluid should process the following properties, it should have high dielectric strength, it should have minimum possible ignition delay time because in the ignition delay time there is no flow of the current no removal of the materials, so it really adds to the off time that means the time during which no machining is taking place.

So we want this to the minimum possible and minimum deionisation time because when ionisation has taken place like here the ionisation has taken place, now once unless it deionise it another spark will not be there, so once it deionise it then again the ionisation will take place, so that deionisation time should be as low as possible and the dielectric should be effective coolant also so that the temperature of the tool and the work piece does not keep increasing continuously otherwise the control material removal will not be there because we want high temperature only in a very narrow localised area and this will be possible only when the dielectric functions as the effective coolant and high degree of fluidity.

This is again very important point that the dielectric should have high degree of fluidity because you are going to machine the component which have complex shapes and when they have the complex shapes and the gap between the tool in the workpiece is very small you hundred microns, in that particular case if dielectric is not able to flow into those narrow complex areas then machining will not take place from there and if machining does not take place from those narrow areas then you will not get the desired shape and size of the workpiece, so fluidity of the dielectric is very important.

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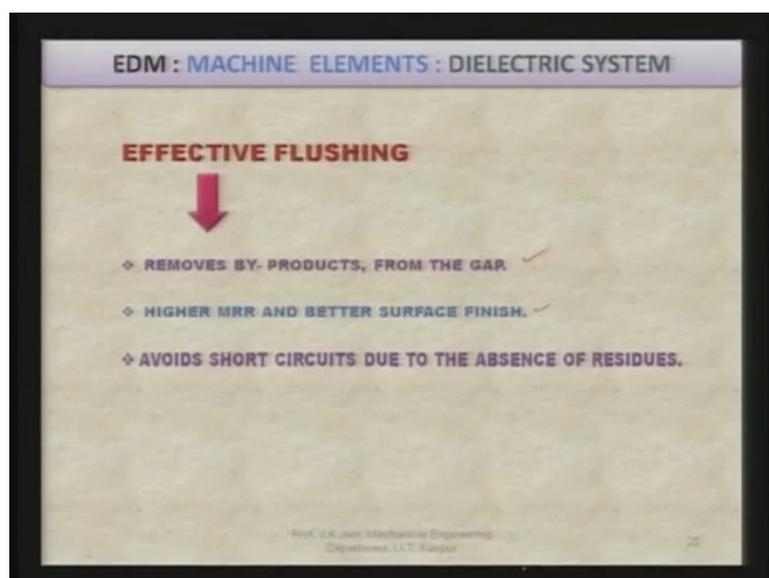
Some of the fluids that can be used as dielectric are transformer oil, paraffin oil, lubricating oil, kerosene. Now nowadays especially in case of wire EDM process deionised water is commonly used as the dielectric. The speciality of deionised water is that it gives higher material removal rate but at the same time it also gives higher tool wear rate which we really do not want, we want as low as possible tool wear rate, then another weak point or limitation of this deionised water is that it is corrosive in nature, which corrodes the workpiece and this

is undesirable feature of deionised water as dielectric but it works very good coolant and now it is basically used in case of wire EDM.

Now most of the Manufacturers of EDM machine these days they are developing their own dielectric and normally they do not tell the composition of those dielectric they patented them and they supply those dielectric along with the machines and whenever you want to use you want to purchase that dielectric, you have to purchase from the manufacturer or their supplier or the agent of that particular machine. So but those dielectrics have some specific qualities also which are good because they have developed those dielectric after lots of research activity in their own companies.

Air is also getting attention of researchers because it is environment friendly and many researchers are trying to use air as the dielectric because I mentioned in the beginning that dielectric can be solid, it can be liquid, it can be gas also, so because air is easily available in the environment it does not cost much to you because it may cost little bit for dehumidifying and other things but otherwise its cost is almost nil and so people are trying to use air as the dielectric specially nowadays is lots of talk, lots of work going on and environment friendly machining or green manufacturing, so under that category is a lot of research is going on how to use air as an efficient dielectric.

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Effective flushing, we have already discussed various ways 6 different ways of supplying the dielectric to the interelectrode gap, now what the flushing does in the interelectrode gap or in the machining zone? It removes by products from the gap that are formed by products include

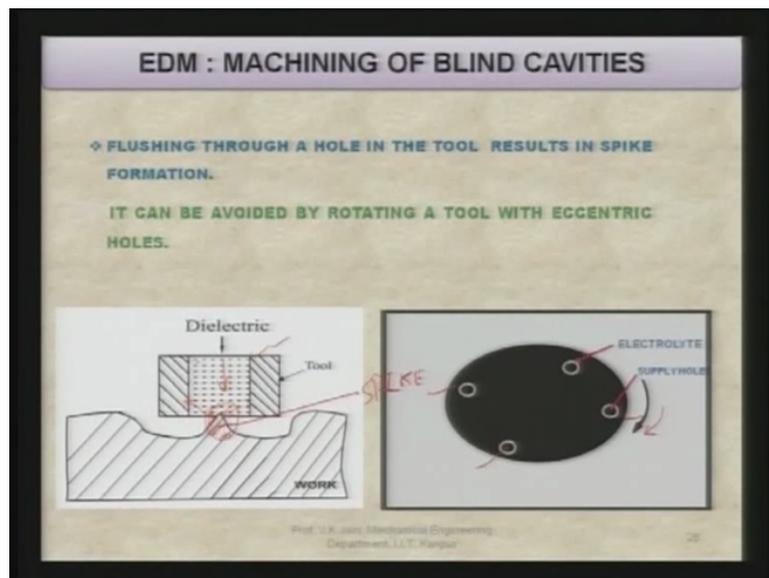
the reaction products that are formed in the machining zone also the molten material that gets solidified in the form of the (( ))(45:56) they have to be removed from the gap otherwise machining will halt and also various kind of gases are evolved because temperature is very high, so dielectric itself will get vaporised also part of molten material may get vaporised.

So these gases are also to be removed from the interelectrode gap, so all these reaction products should be efficiently effectively removed from the machining gap otherwise machining will be slow and because of effective flushing or removal of these by products from the gap as fast as possible you will get higher material removal rate in better surface finish because once these reaction products or whole lot of that particular dielectric is removed and replaced by the fresh dielectric then definitely it will have higher dielectric strength and higher dielectics strength means higher energy in each spark and if energy in each spark is higher then definitely it is going to give you higher material removal rate.

Now better surface finish will depend upon what is the size of the spark or the crater being formed, smaller the size of the crater better will be the final surface roughness but material removal rate is very high that means large crater is being formed then you will not get a better surface finish unless material is removed in a different fashion that means crater sizes small but large number of crater are formed every second then material removal rate will be higher and you can get better surface finish. It avoids short-circuits due to the absence of residues between the tool and the workpiece because if dielectric is not there then definitely 2 electrodes will touch each other and short-circuit will take place and that is the situation we do not want.

Another possibility of short-circuit is that if these debris that is the molten material which has got solidified remains in the interelectrode gap and they form a layer or they are of large size or the size larger than the interelectrode gap then definitely short-circuits is going to take place. However, as I mentioned in the earlier slide there are the protection made in the today's EDM machine because of which before really short-circuit takes place they will stop the supply or the servo system will move the tool up away from the workpiece so that is short-circuit does not take place.

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Now when you are making the hole in the tool for the supply of the dielectric in the interelectrode gap then what is happening as you see in this particular figure that dielectric is being supplied from here, there is no cathode or no metal over there, so material removal from its area is almost negligible unless this area moves up and it comes in contact or opposite to the walls of the tool of the hole made in the tool and so this spike formation takes place and this spike is not this spike is undesirable on the machined workpiece.

So there is a solution for minimising the size of this spike or even completely eliminating the spike formation in place of having a single hole in the center of the tool what one can do at say this is the tool then in place of one you equalise the area of single large hole into 4 small holes and put them away from the center and if you rotate this tool that is the cathode as shown here rotation then what...dissolved or melted out because immediately after that you will find that metal is there which will melt out or sparking will take place on those spikes and once sparking takes place against the spike then that material will get melted or vaporised and will get removed this is how you can really remove the spike formation.

So flushing through a hole in the tool results in spike formation as I have explained here this is the spike and it can be avoided or eliminated by rotating it to with eccentric holes, here I have shown 4 eccentric holes and if you are using this...these holes are on the supply of the dielectric and they will supply the dielectric of the same quantity as you supplying here through the single hole.

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**EDM : MACHINING OF BLIND CAVITIES**

- ✦ JET FLUSHING IS USUALLY LESS EFFECTIVE.
- ✦ SOME DIELECTRICS ARE INFLAMMABLE. ✓
- ✦ WORKPIECE IS IMMERSSED IN DIELECTRIC AND IT MINIMIZES A CHANGE OF FIRE.
- ✦ ARCS ARE UNDESIRABLE ← CAUSED DUE TO CONCENTRATION OF DEBRIS IN IEG. ✓

↓

**REQUIRES PROPER FILTRATION AND FLUSHING**

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**ELECTRODES → (TOOL AND WORKPIECE) BOTH SHOULD BE ELECTRICALLY CONDUCTIVE:**

- ✦ TOOL MATERIAL REQUIREMENTS
  - EASILY MACHINABLE
  - LOW TOOL WEAR RATE
  - GOOD CONDUCTOR OF ELECTRICITY AND HEAT
  - LOW COST AND READILY AVAILABLE

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Now in certain cases jet flushing is less effective, some dielectrics are inflammable this is another problem dielectrics are inflammable, workpiece is immersed in dielectric and it minimises a chance of fire but still many cases have been reported that dielectric specially the kerosene caught fire and damage the machine. Arcs are undesirable, we are always interested in having the spark rather than the arc because if arcs are there then they are going to damage tool as well as work piece both.

So it is caused due to the concentration of the debris is in the interelectrode gap, if there is a concentration of the debris in the interelectrode gap that will lead to the formation of the arc which we should avoid that is why the flushing or supply of the dielectric and flushing of the

dielectric, effective flushing of the dielectric is very important to avoid this arc. It requires proper filtration also of the dielectric before resupplying the dielectric that is very important.