Introduction to Abrasive Machining and Finishing Processes

Dr. Mamilla Ravi Sankar
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture - 17
Advanced Abrasive Machining Process (Electrical Discharge Diamond Grinding)

Now we proceed to one of the Advanced Abrasive Machining Process that is called Electric Discharge Grinding and Electric Discharge Diamond Grinding process. This particular process is hybrid version of electric discharge machining process ok. So, to go into this particular lecture, we will see what are we are going to see those are nothing, but introduction.

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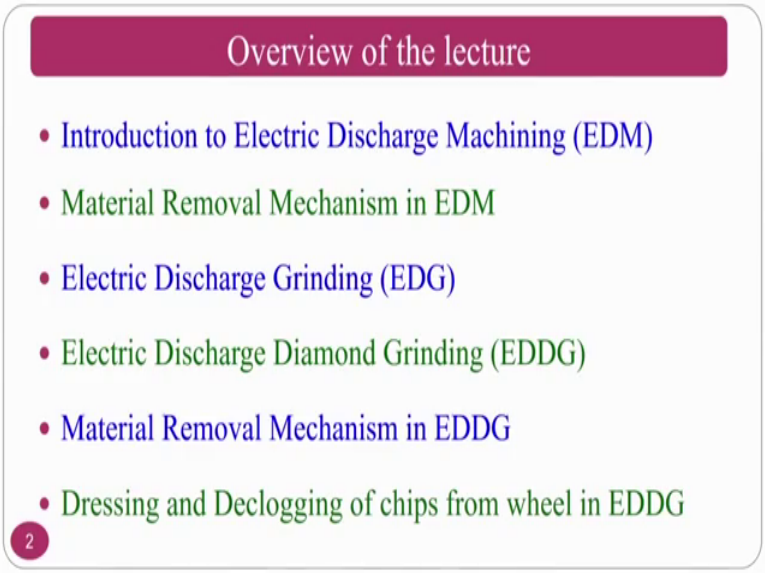

To electric discharge machining first of all we should know what is electrical discharge machining, many people you might know already, but some of the people who are new to electric discharge machining and other things I will explain you what is electric discharge machining and material removal mechanism. Many of the you may be well acquainted with material removal mechanism over you, but how internally the in a explanatory manner how the material removal mechanism takes place in electric discharge machining I will explain to you.

Then we proceed to the hybrid processes that is called electric discharge grinding, then electric discharge diamond grinding. In the material removal mechanism in electric discharge grinding dressing Declogging of chips from the grinding wheel in electric discharge grinding process. What I want to specify in this particular slide is since this particular process is abrasive oriented process. So, we deal mostly about electric discharge diamond grinding process rather than electric discharge grinding process ok.

Why E D D G is important rather than E D g that you will come across whenever I am teaching the course because in E D G mostly you may not acquaint you may not use the abrasive particles on a grinding wheel. But in electric discharge diamond grinding process you will use the diamond abrasives on a metallic bonded abrasive wheel ok; that is a difference. In the electric discharge grind diamond grinding you will have the abrasive particles on the wheel in electric discharge grinding sometimes are the most of the times you will have only the metallic wheel there would not be abrasive particles since this particular course deals with abrasive oriented process. So, we deal mostly in E D D G process.

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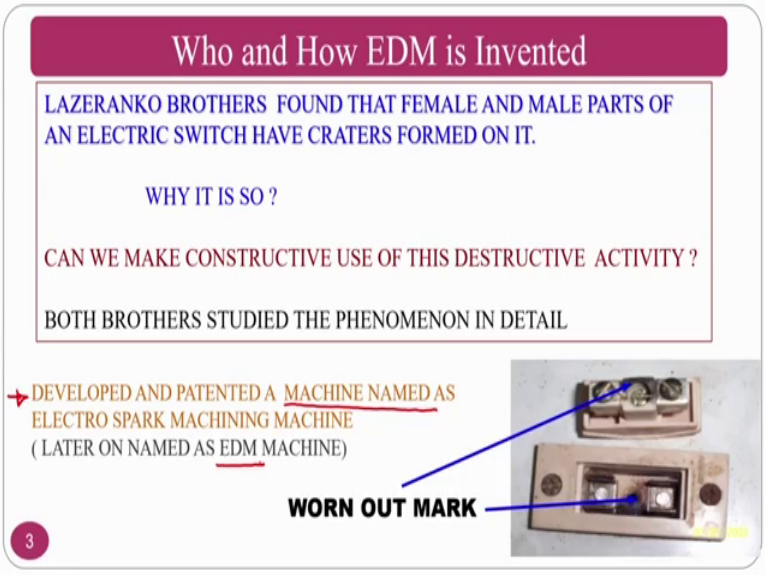
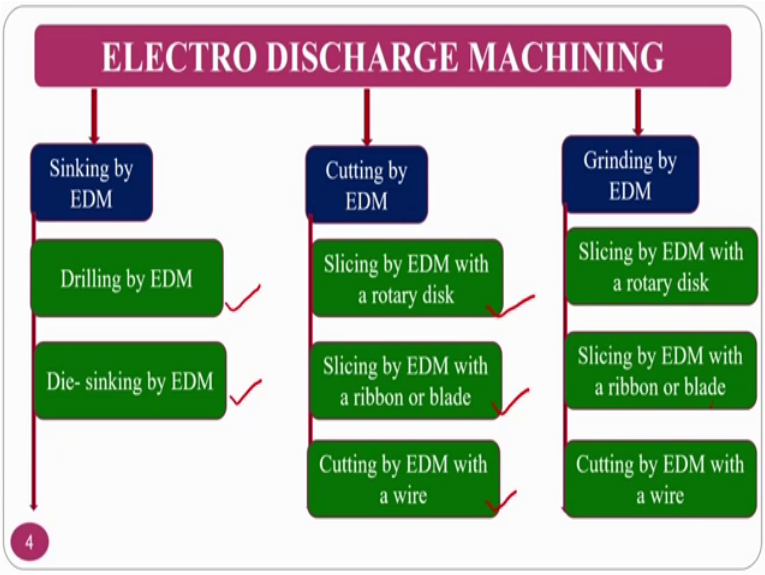


So, who and how E D M is invented. So, the LAZERANKO Brothers found that the female and male parts of an electric switch have craters formed on it. So, what will happen? So, whenever you see most of the in commonly houses if you see the electric connections have the switches where you have male and female part because of which if

there is a loose connection or the connection is not proper, there will be a spark and the spark will leads to erosion of the material ok. This was observed by Lazeranko brothers and they invented the electric discharge machining ok.

So, previously what they have done is, they have patented it with the name called Electros Spark Machining Machine, later it is named as electric discharge machine ok. So, they have patented it and this is how the people invented this particular process, like Isaac Newton invented the gravity, when the apple fall on his head similarly, this people also observed the natural phenomena and they have invented this particular process. (Refer Slide Time: 04:17).



If you see electric discharge machining, normally you have die sinking E D M, then you can do by E D M drilling and die sinking E D M and other things cutting, slicing you can do by a rotating this that is called electric discharge grinding also. You can say slicing done by the ribbon blade and other thing slicing cutting done by the E D M then the grinding process you can do the slicing to by E D M with a ribbon or a blade cutting by the E D M with a wire and other things are the sum of the varieties that you can do a and this shows the classification you can do the electric discharge machining.

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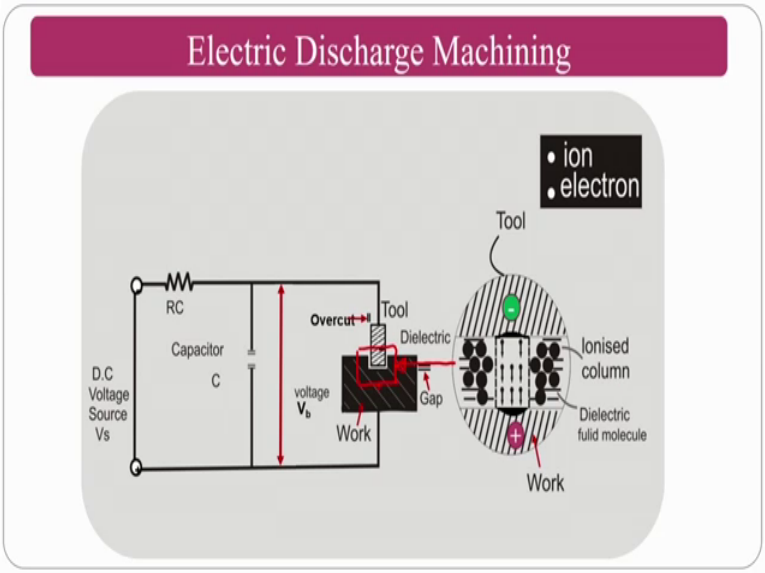

So, the electric discharge machining process if you see here, what will happen is this is a over view and I am going to tell you how the material removal mechanism will takes place and if you see this particular area is zoomed up here ok. So, the tool is given negative terminal and the positive terminal is given to workpiece and you can see here some of the things are ions some of the things are electrons how these are all will flow and the material removal mechanism will takes place.

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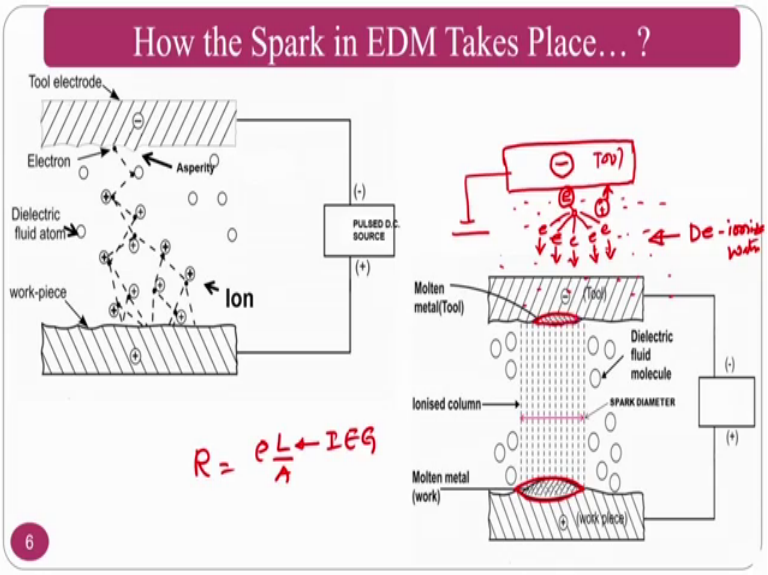

You will see here, what is here it is going to happen is assume that I have a negative terminal here and the workpiece is positive terminal ok, connection is provided. So, dielectric fluid is there and other things are there ok. So, when the electrons moves from here normally some of the books for simplicity sake and other things, what they explain is you have a negative terminal you have positive terminal and because of the dielectric fluid present in between there will be a potential difference, if there is a potential difference the spark will occur. So, the spark will occur this type of mechanism is explained by some of the books for the simplicity purpose.

Now, the question is how the spark is generating that is most important to understand from the point of physics ok. Dielectric fluid will have dielectric strength ok, below which what will happen it will act as a inculcator above which it will act as a conductor ok. So, assume that our dielectric fluid is a deionized water ok, there are many varieties of dielectric fluids let me consider this is a deionized water deionized water ok. What do you mean by deionized water- i deion? Dehydration means water is gone out of the body similarly, deionized water deionized water means the ions are mostly removed you cannot remove all ions, but it is reduced in ions number ok.

So, whenever you give the negative terminal to the tool and positive terminal to the workpiece. What will happen? Electron start flowing from this particular shape and this electrons where it will go, this electrons will heat to one molecule of deionized water when it heats one molecule of deionized water. So what will happen? It will release lot of electrons and since it is a deionized water ions are very less and it also develop some of the ions and ions move towards negative terminal and electrons start moving towards positive terminal ok.

So, this electrons will go and heat the next set of deionized water that is called dielectric fluid and generate. So, on it will generate and a millions and millions of electrons will move towards the workpiece that is the positive terminal and the kinetic energy of all these electrons will convert into the thermal energy, that is why there will be a spark and this spark will a remove the material by melting and evaporation ok.

That is how the spark will generate it is not that if there is a potential difference then the spark will generate, it is the kinetic energy of millions and millions of electrons that are generated by the dielectric fluid because of few electrons that are coming from the

negative terminal and this kinetic energy converts into the thermal energy and this thermal energy is concentrated on a specifically one zone, where the distance is very less; that means, that inter electrode gap is very less, normally if you see R is equal to rho l by A; that means, l specifies inter electrode gap ok, wherever the inter electronic gap is very minimal there that particular position only the melting and evaporation takes place for that particular moment ok. That is how you will see the spark on the positive terminal are the workpiece ok, the channel that is formed here is ionization channel ok.

Normally some of the books they will explain like a ionization channel where you can see the some of the ion that are moving towards negative terminal and electrons are causing the thermal energy on the workpiece. So, that melting and evaporation will takes place ok.

That is how the mechanism works in the electric discharge machining and you hope you understood, how the spark is generated it is not because of the potential difference directly spark would not takes place because of the potential difference electrons that are there on the negative terminal try to move towards the positive terminal. But in between there is a dielectric fluid is there this dielectric fluid molecules are interacted by the electrons that are coming from the negative terminal and does this one molecule of dielectric fluid will dissociate into many of electrons and few of ions at the same time you should note that electrons are much smaller compared to ions at the same time you are workpiece is below.

So, the gravity also will help at the same time the electrons being a smaller size. It will move with higher velocity and heats, if the kinetic energy is very high half in the square velocity is very high; that means, that kinetic energy is very high if the kinetic energy is very high; obviously, the material removal will be very high ok. So, that is how the kinetic energy converse into thermal energy and there you will see the spark ok, that is spark will generate lot of heat and that heat will makes the workpiece material to melt and evaporate ok. At the same time this molten metal will be carried away by the dielectric fluid that is flowing across the two terminals.

Same thing will also happen on the other side like ions also go on the opposite direction and hit the tool, but being a higher size against the gravity and being the number of ions are less. So, the tool wear will be always less compare to the workpiece material

removal. If you see here this is ionization channel form and the melting and evaporation takes place and the material is removed you see the material how much material is removed on the workpiece and at the same time there is some area is effected on the tool also, that is why the material removal on the workpiece is higher compared to the material removal on the tool ok.

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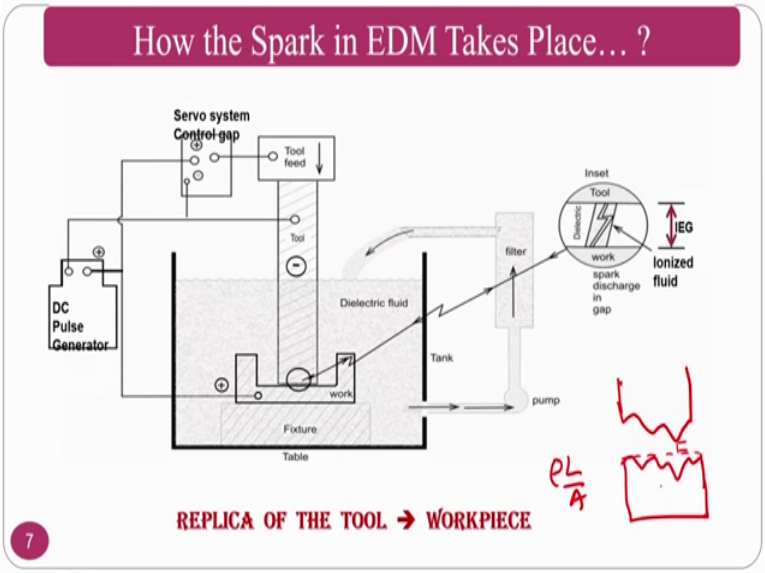

So, Spark in E D M that is for how the spark as I said, there will be a negative terminal and positive terminal electrons moves and the material removal takes place because of the spark, that is generated when the electrons hits the workpiece and indirectly what you are going to get is replica of the tool assume that you are tool is like this you are going to get the convership of this one ok. So, you will get a conversion because they affect is rho l by A wherever the l is minimum there the concentration of this electrons will be more; that means, that kinetic energy will be more and that particular portion the spark will generate and material will remove.

So, if this is the original material and because the distances is less here so, the material will removed more in this one; so, that you can get a replica of the cutting tool.

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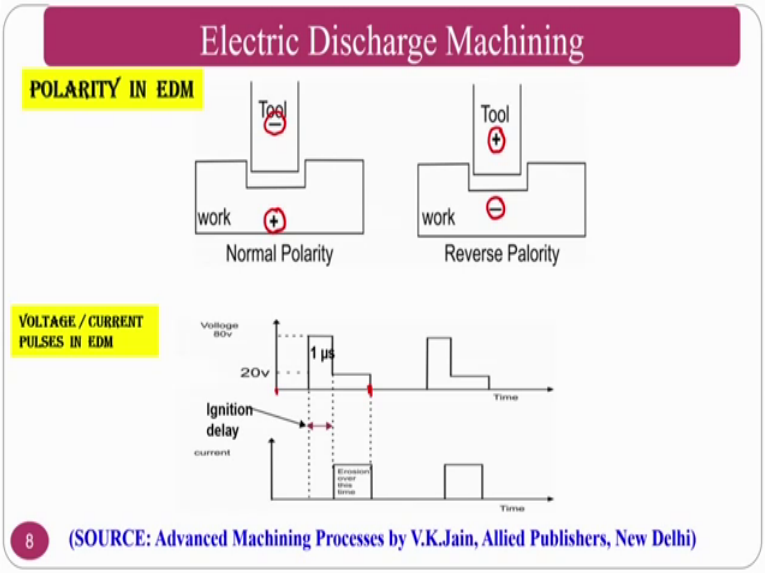

So, there are two Polarity one is the Normal Polarity and Reverse Polarity. So, normal polarity normally tool will be given negative terminal positive terminal will be given to the workpiece, in the reverse polarity some of the people they do the literature some of the people do the research on reverse polarity for electric discharge coating and other things people will say, in that circumstances people will use negative terminal to the workpiece and positive terminal to the tool ok.

So, the voltage and current if you see the voltage and current, there will be a like duty cycle and other things normally there will be a ignition delay there will be sparking will takes place and other things. Starting point to the starting point of this one normally is called one duty cycle, duty cycle comprises of two segments one is the sparking region and non sparking region are where the voltage will be applied and where the voltages will be 0 ok. This whenever the duty cycle is on the spark we will takes place ok. That is how the material removal will takes place.

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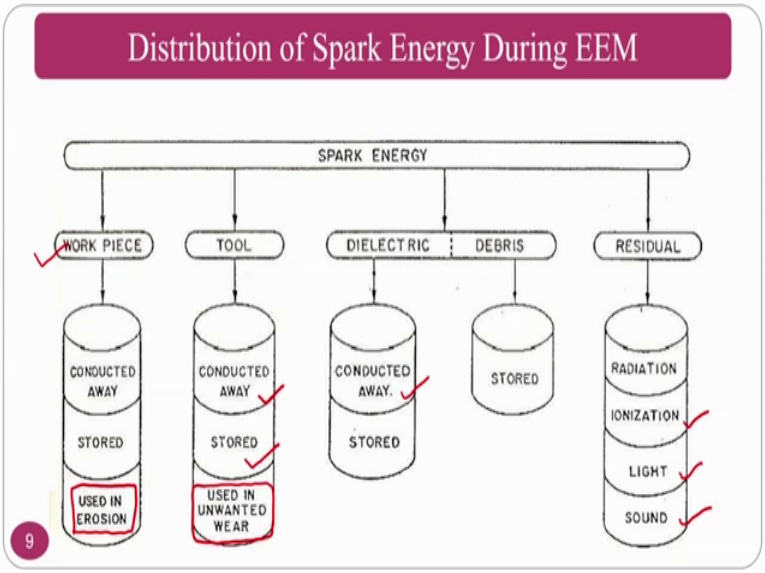

So, the Distribution of Spark Energy normally it will be conducted away by the workpiece stored in the workpiece as well as used for the erosion, normally if you are using mostly used for the erosion; that means, that material removal will increase. In the tool the sparking energy always conducted away basically the tools are like copper, brass any conductive materials will be used some of the things will be stored at the same time some will be used for the unwanted wear. So, if you are going to use tungsten carbide type of tool and other things, where the melting point is very high the unwanted wear will be minimal.

So, dielectric fluid you conducts away it will take away the energy and it will store inside debris. Normally it will be stored and residual normally is some of the spark energy goes by radiation, ionization, channel formation as a light and as a sound whenever you do that E D M process you will see the some sparking and the sparking sound and the other things ok.

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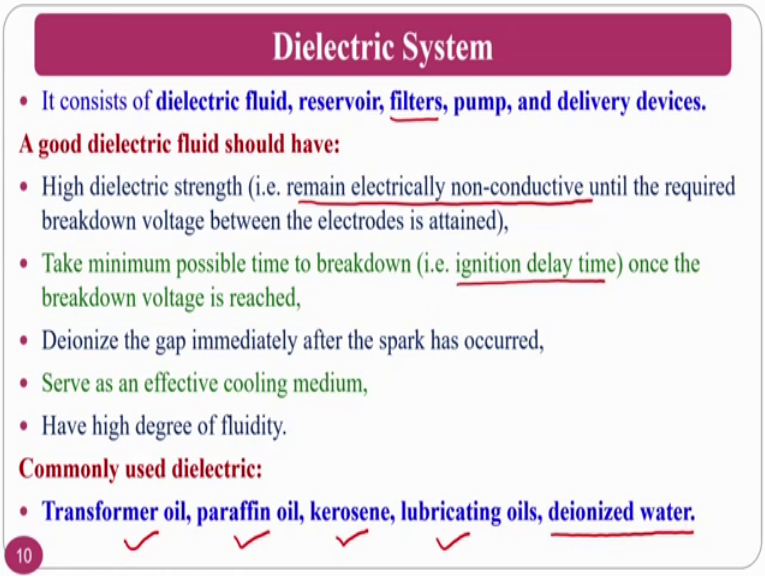

Dielectric System it consists of dielectric fluid, reservoir, filters, pumps and delivery devices normally you require filters because the debris will be a big problem if you do not have filters that the debris will re circulated the process. A good dielectric fluid should have the following properties, it should have high dielectric strength; that means, that remain electrically non-conductive until the required breakdown voltage is applied across the electrodes ok.

Take minimum possible time to break down; that means, ignition delay will be very less, that is what we have seen the previous slide also. Deionize the gap immediately after the spark is occurred serve as an effective cooling system because melting and evaporation takes place and the dielectric fluid has to flow.

So, this dielectric fluid should cool the tool at the same otherwise; if it is continuously heating up the tool also will wear out, at the same time this cooling what will happen the molten metal will be carried away in the form of steroids and other things, that is why whenever you see the E D M surface in a surface morphology of an E D M surface, if you seen what will happen if you can see the some of the steroids on the recast layers.

This recast layer heat affected zone another things we will come across in the upcoming slides have high degree of fluid; that means, that the viscosity should be low. If the viscosity is low, what will happen? It can move to each move can corner of the complex geometry, that tool processes and which you want to replicate on the workpiece. The

commonly used dielectric fluids are the transformer oils, paraffin oils, kerosene also people can use lubricating oils and mostly people been used deionized water.

So, here one of the research point that, I want to telling you is you can use paraffin oil which is a carbon based at the same time deionized water. If the people want to do the finishing operation followed by the E D M process normally you should prefer deionized water because if you are going to use paraffin based, what will be happening here is if the paraffin is there the carbon will be there.

So, the surface will form carbides, carbides are much harder and your polishing work or a finishing work will not remove this carbide layers, if you are going to use deionized water in that circumstances what is you are going to get benefit is it will formed oxide layers and oxides are easy to remove by the polishing or the finishing action, that is why whenever if you at all people want to do for machining using electric discharge machining followed by some polishing operation on that particular surface or whole or any other geometry you are recommended to use the oxide based fluids rather than carbon based fluids.

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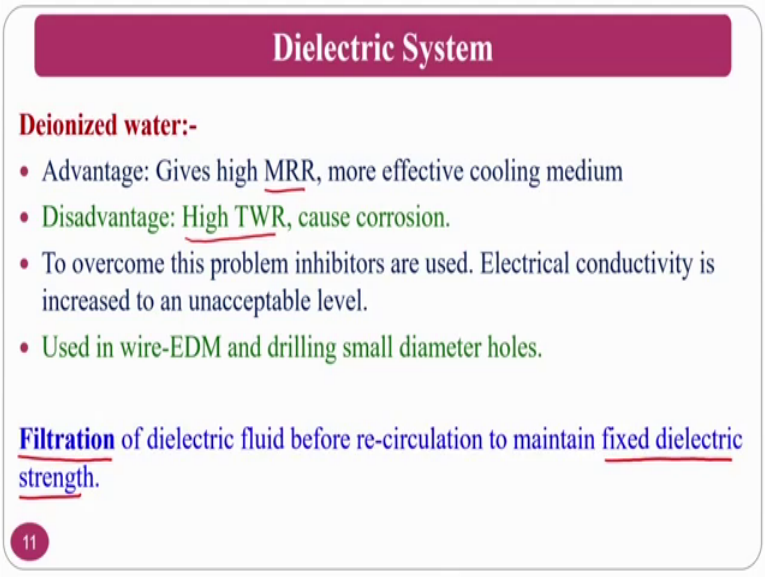

So, the dielectric system deionized water is a better one that is what I said at the same time the advantage is it gives higher MRR, more effective cooling system. Disadvantages it also will have high tool wear rate and causes the corrosion that is what I said now oxide film formed. So, if at all your requirement is to finish then this corrosion will goes

off ok, to overcome this problem in habitors are used electrically conductive increase for an acceptable level used for wire E D M drilling a small holes and the thing. As I said filtration of this dielectric fluid before the recirculation to maintain the fixed dielectric strength; that means, that if you are going to use directly without the filtration system.

The debris particles will be there and these debric particles are conductive because your workpiece and tool both are the conductive materials and if this debris are steroids come in between if these are comes along with a dielectric fluid between the two electrodes. That is positive terminal and a negative terminal what will happen is the strength or the dielectric strength of the dielectric fluid will reduce.

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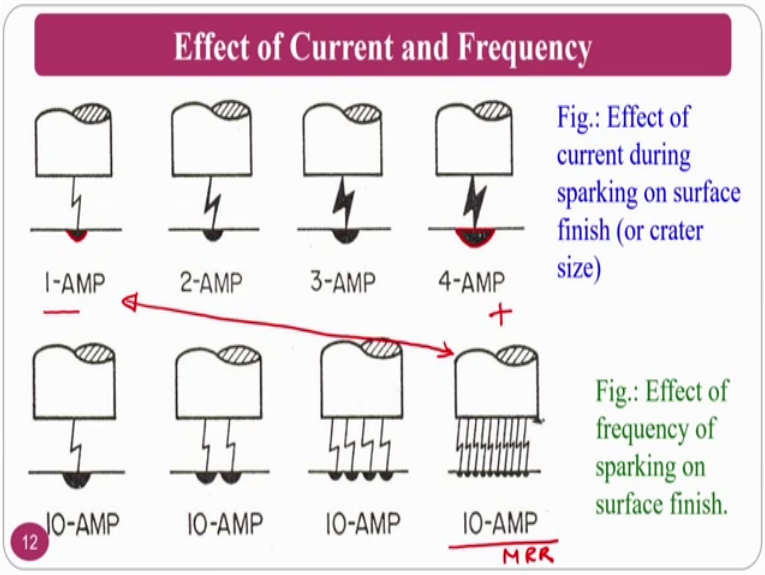

So, if it reduce then there will be different mechanism people some of the people or studying about this powder mix E D M and other things, people use conductive, people use the ceramic and many many abrasive particles also people are using so, you can go through it.

So, some of the people who are interested in using the powder mix E D M and other things, you almost welcome and you can use for proper cost. The effect of current and frequency if you see the effect of current in the current if you are going to increase 1 ampere to 4 ampere for example, what is happening is you are sparking strength will be very high and the sparking size will increase high if you are sparking size will increase, what will happen here is your crater size formation. If you see here in the this is the

crater size formation with 1 ampere and if you see 4 ampere the crater size formation is very high; that means, that if at all I want the material to be removed what its what you have to do is you have to go for more and more current rather than less current ok.

If you are if you want to use for the better surface finish, assume that you want to use one condition for material removal application then you are; obviously, go for higher currents if you are going for the finishing application then you are to go for less current, why I am saying is in this condition your surface roughness will be like this.

So, the surface roughness is very high in higher currents and surface roughness will be very low in low currents, at the same time if you see the frequency of sparking if at all if you see the frequency effect frequency of sparking effect on the surface if at all you want to remove more and more material then you are to go for high current along with high frequency ok. So, this combination will give you better M R R ok; at the same time if at all you want to go for better surface finish at the same time at the faster rates then you can go for this particular combination, 1 ampere with high frequency ok.

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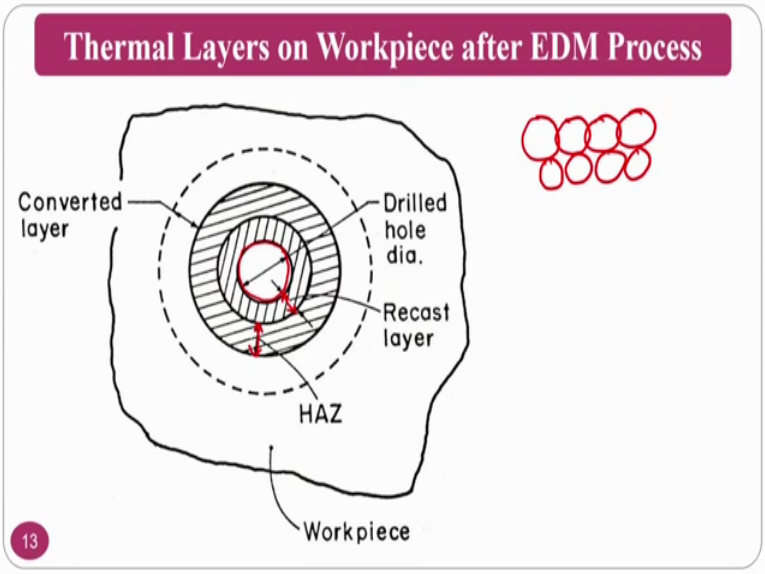

So, as I said that debris formation and other things. So, what you are going to see around the micro hole or the hole that developed using E D M process is this is my diametrical hole across it what is happening I said melting and evaporation ok. So, if there is a melting and evaporation if there is a spark because of the kinetic energy that is converted into thermal energy melting and evaporation, if there is a evaporation well and good if

there is a melting what will happen the dielectric fluid it is a responsibilities to carry this molten material and the dielectric fluid may not carry all the molten material some of the molten material will cool down there because the main one of the main functions of your dielectric fluid is too cool the inter electrode gap.

That means that it has to cool the workpiece it has to cool the tool also ok, in that circumstances what is happening here is the molten material which is unable to plush by the dielectric fluid will cool down; that means, it is forming a layer that is called Recast Layer. What do you mean by casting? Casting means you have a molten metal you have cope and drag pattern then just pour it and you solidify it ok, then you are going to get that is called casting, here melting taking place, but unable to goes off because of the dielectric fluid through it cooling effect it is solidifying that is why recast layer. So, it is recasting on a assume that the workpiece is casted previously on which you want to do the E D M process it is in molten metal unable to goes out.

So, it is casted again around the whole that is nothing, but recasting taking place that is why it is named as recast layer because in the recast layer the temperature is so high that is developed because of the kinetic energy of the electrons, which is converted into thermal energy the grain structure will be very high ok. So, if you see the next layer that is called heat affected zone because of the heat that is generated during the whole generation or drilling the hole by E D M process the molten metal which is unable to go that is recast layer experiences the maximum temperature because you have seen the workpiece carries the by the conduction action ok.

So, by the conduction action heat carries. So, this heat carries what will happen there is a grain structure is slightly lesser than that one, that is called heat affected zone you can see here this is called the heat affected zone this is recast layer in the re heat affected zone also what will happen is you are going to see the constant grain structure, which is starting from the recast layer and the last layer where it has its own size and heat affected zone also will have some size, which is less than recast layer and the conversion layer conversion layer means the layer or the converted layer. That means, that heat affected zone have their own microstructure, which is bigger size compared to the parent material microstructure.

So, the microstructure changing from the heat affected zone to the parent material gradual change of the microstructure or the size is nothing, but the converted layer; that means, that conversion of heat affected zone grain size to the parent grain size that conversion thickness is nothing, but the converted layer. These are the three layers that if at all if you want you can Google it and you can see this layers microstructure how it will change. So, now, we move on to the, a hybrid version that is called Electric Discharge Grinding.

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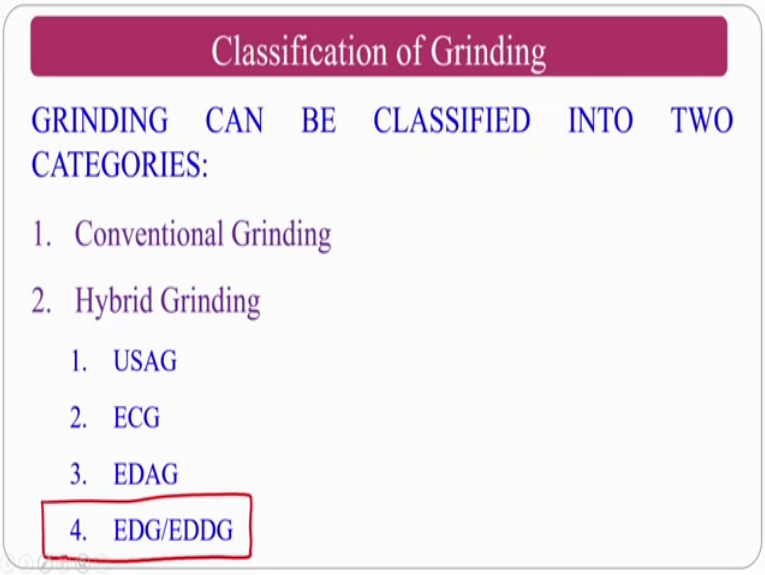

In the electric discharge grinding, grinding can be classified into Conventional grinding, Hybrid grinding. Hybrid grinding we have many things but in that particular class, we are going to see about electric discharge grinding and electric discharge diamond grinding process.

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So, what are the basic industrial problems these normally diamond grinding, which is a limitation basically problem is high cost and at the high specific material removal energy is required; that means, a specific energy is high strength degradation because whenever you want to do the polishing of this one using mechanical methods. What will happen is the strength may go down and the wheel wear will be a high and big problem and the dressing problems also will be there in this particular process. That is why you can incorporate the positives of E D M; however, the problem with the E D M means low material removal efficiency at the same time re solidified and white layer intensified micro cracks because this grinding of this diamond and other things,. What will happen is it will induce the micro cracks.

Normally in a ceramic materials diamond, sybian and ceramits these are all some of the ceramic, silicon carbide, alumina these are these are ceramic materials. The basic problem with a ceramic materials is these are not very good at conducting the heat, what will happen on one edge assume that this is my abrasive particle if temperature is high here point A so, it is a bad conductor point B it will be room temperature there will be a problem of because of the temperature difference there will be a problem of cracking. So, that is a biggest problem in the ceramics. So, that is why ceramics machining is one of the biggest challenges that normally manufacturing engineer faces ok.

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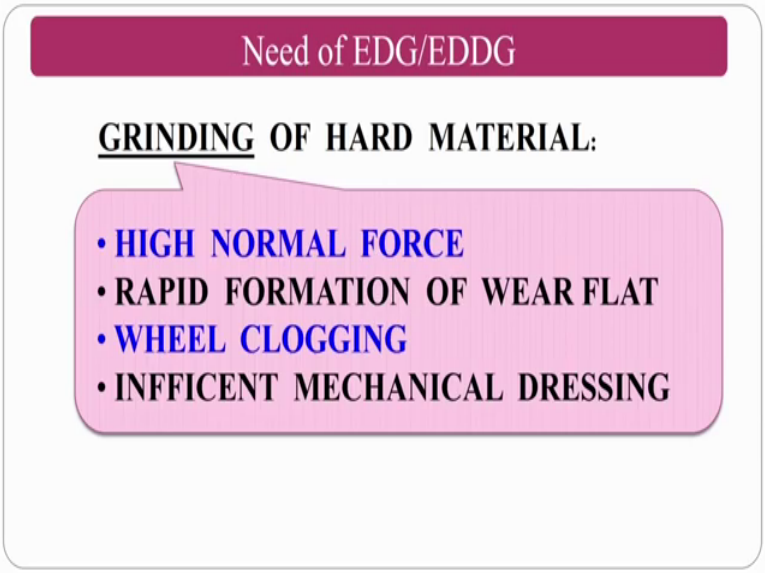

Grinding of hard material if you see what is high normal forces will be there ok. So, that is why you have to reduce the forces. So, rapid formation of the wheel flat; that means, that the glazing of the will be takes place early and the wheel clogging the abrasive particles adjacent to the abrasive particles clogging will be occurred and inefficient mechanical dressing ok.

So, mechanical dressing may not work ok, if at all I want to go for hard materials grinding process these are the biggest challenges. How to overcome? The overcome you can overcome by electric discharge diamond grinding process.

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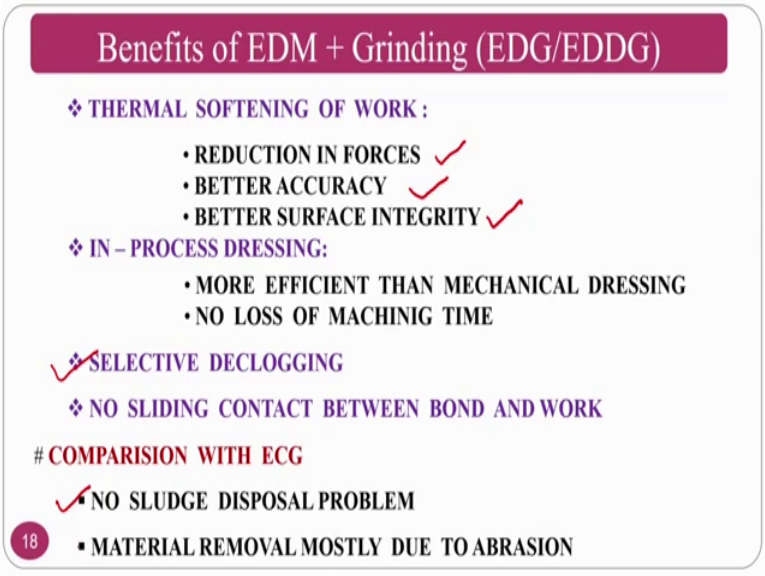

So, how you will can overcome that we will see in the upcoming slides. So, what will happen if you are going to add E D M process to the grinding process, what will happen here is the E D M in the this particular wheel normally will be made up of metallic which is which is electrical conductive material. So, that what will happen the sparks will be generated between wheel materials which is the bonding material to the workpiece material because of which what will happening is that is the spark will be generated and the spark will melts the workpiece material ok.

If it is melts what will happen is the thermal softening of the workpiece material will takes place and it is easy to remove the material by grinding action. That is what we are going to see if the thermal softening will occur what will happen reduction in forces will occur better accuracy will be there and better surface integrity will be also there, in process dressing basically more efficient than the mechanical dressing and no loss of machining time. Normally what will happen if there is a spark generation as I said I also move towards the negative terminal then, what will happen? If there is a chip on the grinding wheel that will melt and goes off.

So, there is no requirement of dressing additionally in this particular process that is why there would be any clogging. So, declogging will be done automatically in the electric discharge diamond grinding process, no slide contact between the bond and work and the comparison with E C G there will be a another one where I will introduce to you

electrochemical grinding if time permits. So, no sludge disposal problem because in electrochemical grinding process the problem is your fluid is a chemical that your using a dielectric fluid which is deionized water there would be much problem in disposing it.

But here in electrochemical grinding the chemical has to be disposed which is already having the debris. So, it will be very difficult. So, material removal mostly due to by the abrasion action in electric discharge diamond Grinding.

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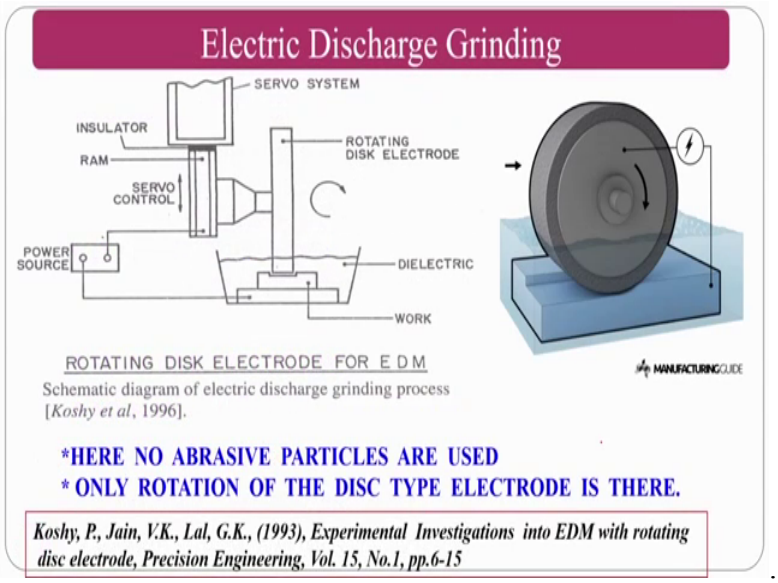

If you see electric discharge grinding in particular, here there is no abrasive particles are used and only rotation of the disk is taken place, if you are going to see here the servo controls are there and insulating material and other things are there. So, that there would not be any problem of conduction and other things, you have only the disk this is the disk where there is no abrasive particles and workpiece material here you are rotating the disk which is a metallic disk again is the workpiece and your plushing the along with the dielectric fluid, what you are going to get is the temperature generation.

Because of the sparking that is came into existence because of the kinetic energy of the electrons will use the molten material and sometimes evaporates because of the kinetic energy of this grinding wheel. So, the flushing will be good and the material removal mechanism will be good the same thing you can see here. So, the negative and positive terminals are given to the wheel and the workpiece respectively and the dielectric fluid is there you can remove the material, but please note that there would not be any abrasive

particles in this particular research work, that is done by professor Koshy and professor Jain and professor G K Lal.

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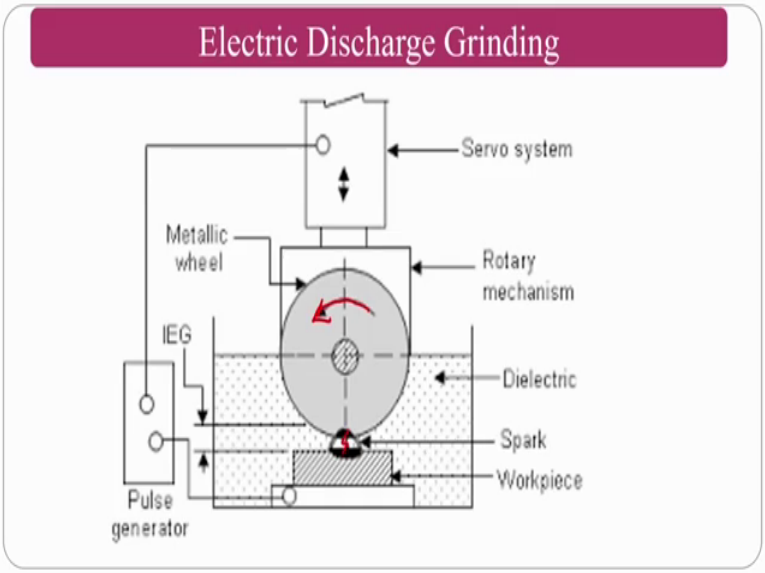

So, there will be a spark how the material will be removed there will be a spark like E D M and the material will be removed. Now what is the difference between original E D M that is die sinking E D M and this particular E D G. You have a grinding disk because of the conductivity of the disk, which is made up of copper or brass or stainless steel are any conductive material, what is going to happen is because of this rotation the flushing will be very good and melting and evaporation; obviously, will be taken care by the E D M mechanism. So, the material removal is good, but the big problem here is to remove the material removal further what the people have done is they have gone for electric discharge diamond grinding process.

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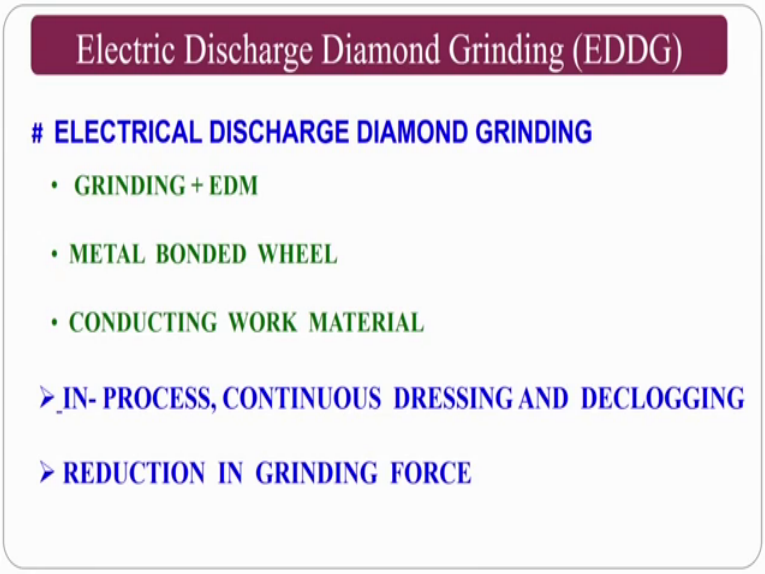

Now, we move to electric discharge diamond grinding. In short it is called as E D D G. So, in electric discharge diamond grinding process it is a mixture of or the combination of grinding process and the electric discharge machining and where in you will use metal bonded wheel, as we have seen in the grinding wheel specification we have vitrified bond, resinoid bond, shellac bond, metallic bond and other things, metallic bond specified by M basically ok.

So, metallic bond as if you see the metal having the good conductivity a whenever you are using this particular wheel in terms of electric discharge diamond grinding process you should have the tool and workpiece both are conductive in nature for that purpose you will use the metal bonded wheel where in you brass or you can mix the abrasive particles on that in if you are using the diamond particles then it is called as electric discharge diamond grinding process.

Conducting of the workpiece material is mandatory that is why you are going for the metal. In process and continuous dressing and declogging will takes place in this one, how it will takes place you will see the mechanism and other things reduction of the grinding forces because the electric discharge machining process makes or give some sparks on the workpiece surface if you are going to give the sparks, what will happen them thermal softening of the workpiece takes place. If the thermal softening of the workpiece takes place, then the workpiece material experiences very less forces from the abrasive particles in order to shear out the workpiece material.

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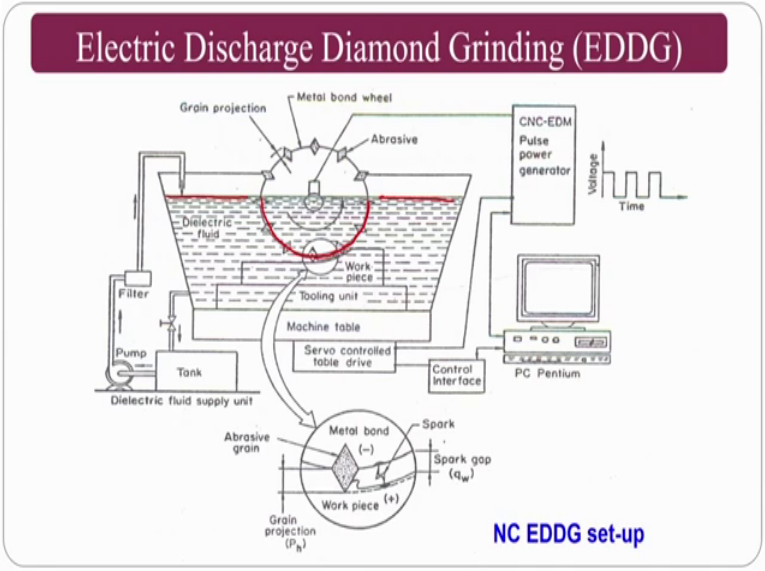

So, if you see here in this particular this is the schematic view of electric discharge diamond grinding process, where in the wheel as well as the workpiece both are inside the dielectric fluid; that means, that dielectric fluid chamber is there where in the dielectric fluid is filled and you have the abrasive particles which are in contact with the workpiece and there will be a spark that is generated which makes the workpiece softer, then the abrasion action of the abrasive will takes place and it will shear of the workpiece material.

So, it is a combination as I said the electric discharge machining and at the same time grinding process, that is why this particular process is called as a hybrid process where two mechanism or two individual physics is merged here in this particular process.

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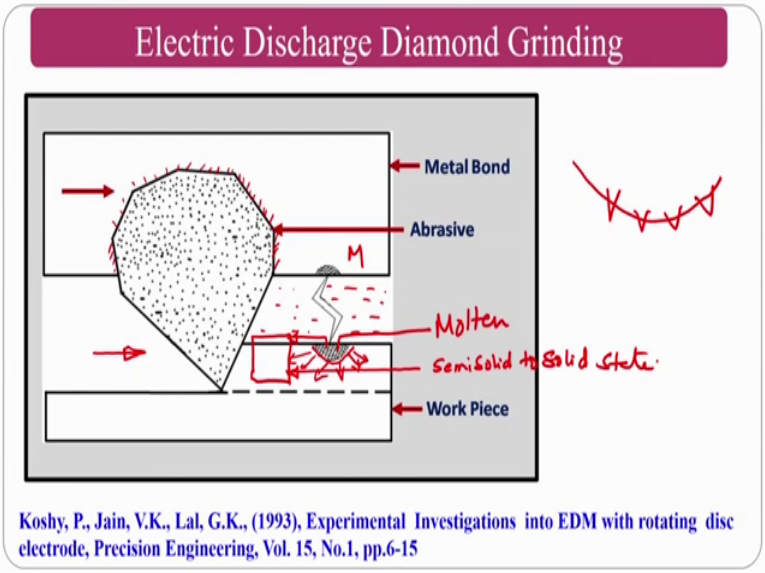

So, electric discharge diamond grinding process, what I was speaking to you if you take the particular wheel will be have lot of abrasive particles if you take a one individual abrasive particle if it looks like this, we see this is a metal metallic bonding is there as you have seen the grade, grade says that the how strongly the bonding material that is a metal bonding material is held the abrasive particle that is decides the grade ok. This particular bonding whatever I am giving the lines this particular bonding will gives the grade of the grinding wheel ok.

So, what is happening here my shearing action is taking in this direction ok. So, thus there is a spark as you know the spark when the electrons are moving from the negative terminal to positive terminal in between come across the dielectric fluid, dielectric fluid is assume that it is a deionized water it will gives lot of electrons this electrons goes and heat again the dielectric molecules with again gives millions and millions of electrons and this goes and heats the workpiece because if the workpiece is hits like this there will be a spark and this spark generate the melting and evaporation and if at all you do not want evaporation you can go for low current and other things. So, that you will have way on the melting and because of the thermal conductivity of the workpiece what will happen this thermal conductivity pass on into the workpiece material ok.

So, this works this thermal conductivity because of the high thermal conductivity at this position it will move towards other also. So, the thermal softening of the workpiece takes

place, the here it is a Molten state this is molten and if you see here this particular portion will be like a hard portion; that means, that it is in a semi solid to solid motion, it is in a semi solid to solid shape it means in a semi solid to solid state ok, semi solid to solid state ok. That is why thermal softening of this hard material will takes place and the abrasion action of this abrasive will takes away the this intermittent are the thermally softened layers of this particular material and thus the force is required for shearing of this particle material will decrease.

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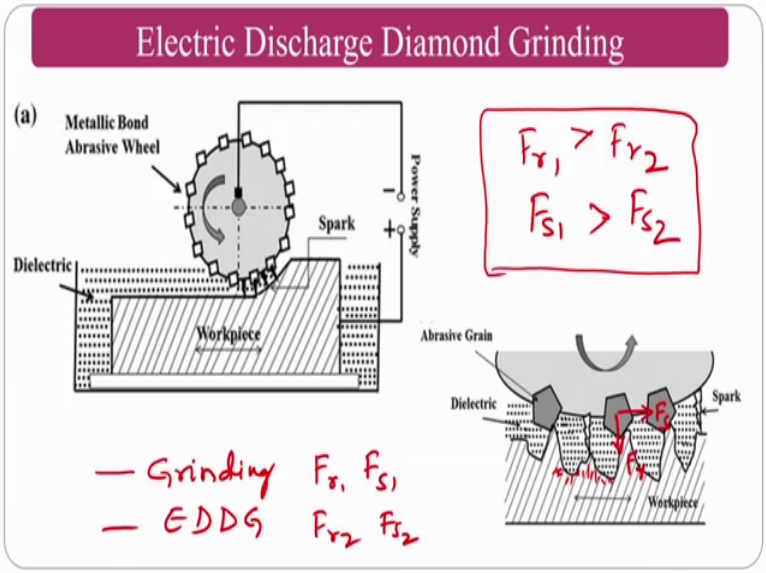

You can see here. So, how the material and other things are happening if you see the same mechanism here, what is happening here is the spark is taking place. If the spark is taking place this particular material will become melt and the thermal conductivity will pass on to this particular section and this particular section what will happen become the thermal is soften. So, the force required to shear, shearing force and the inertial radial force both are less compared to the grinding process.

What I mean to say here is if you are taking a grinding process and if you are taking electric discharge diamond grinding process in this one the forces requirement F r 1 F s 1 F r 2 F s 2 what I mean to say is your F r 1 will be greater than F r 2 F s 1 greater than F s 2; that means, that for the same workpiece and tool materials at; that means, that grinding wheel even though you are using a vitrified bond along with the diamond particles. If you are going to experience the radial forces and the shear forces in this way

the if you are going for electric discharge diamond grinding process thermal softening action will be dominating because of which your both the forces shearing as well as the radial forces will be lower compared to your normal grinding process, that is what the comparison.

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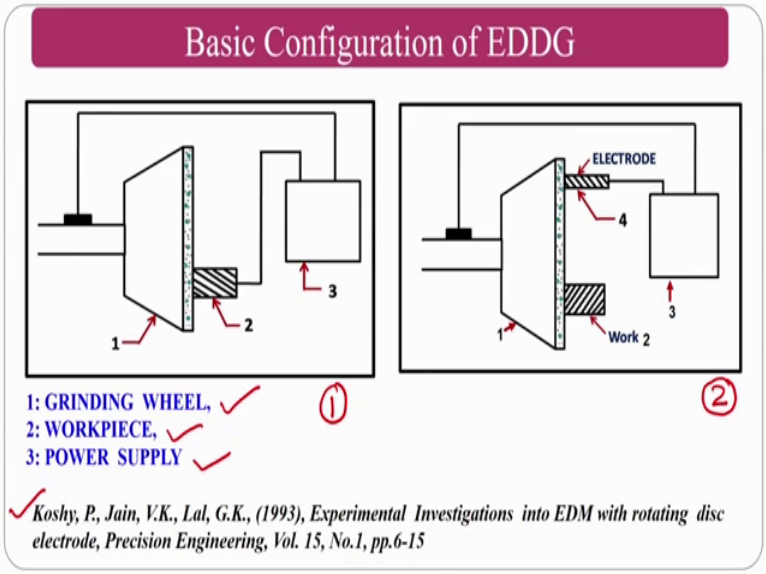

If you see the basic configuration of electric discharge diamond grinding process, you can directly you if you see 1 and 1 2 1 3 specifies the grinding wheel workpiece and power supply. So, normally you can supply directly to the workpiece itself and the grinding wheel are you can also give to certain electrode and you can go for the workpiece.

These are the two configuration 1 and configuration 2. These are the basic configuration that if at all you want more details you can proceed to the professor Koshys Paper and you can understand more and more about this particular electric discharge diamond grinding and its basic configurations and the paper details are given here at the bottom of the slide.

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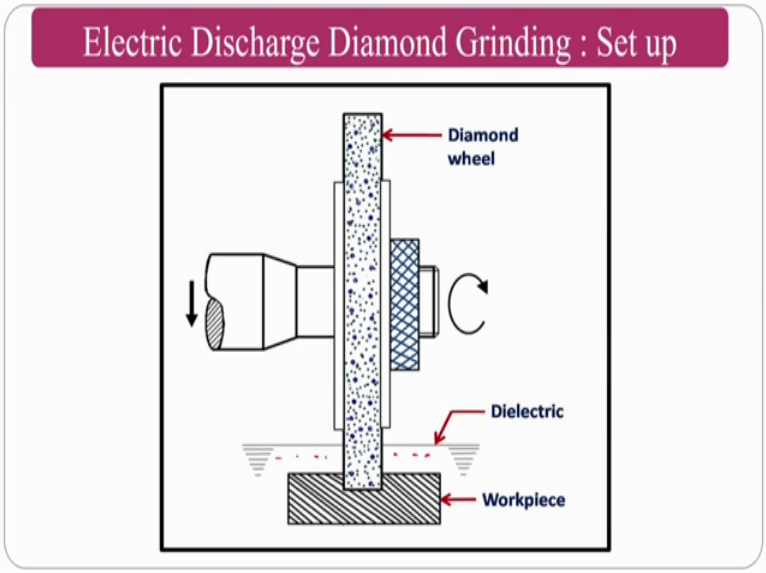

So, if you see the diamond grinding setup, normally the setup will be like this and dielectric fluid is fed at the same time the workpiece will be there inside, this is how you are grinding process looks like ok. Whatever you are seen in the previous one that is the machining region only of the electric discharge diamond grinding process in this one you can see the overview where you can give the negative terminal and positive terminal.

Normal negative terminal you are going to give to the grinding wheel and the positive terminal you are going to give the workpiece and you have to make sure that in the spindle it should be normally insulated. So, that would not conduct the a negative terminal to the complete machine and other things, that we should that is the precautionary statement. And if at all you are going to do certain experiments on this one be cautious about insulation to the complete setup from the grinding wheel ok.

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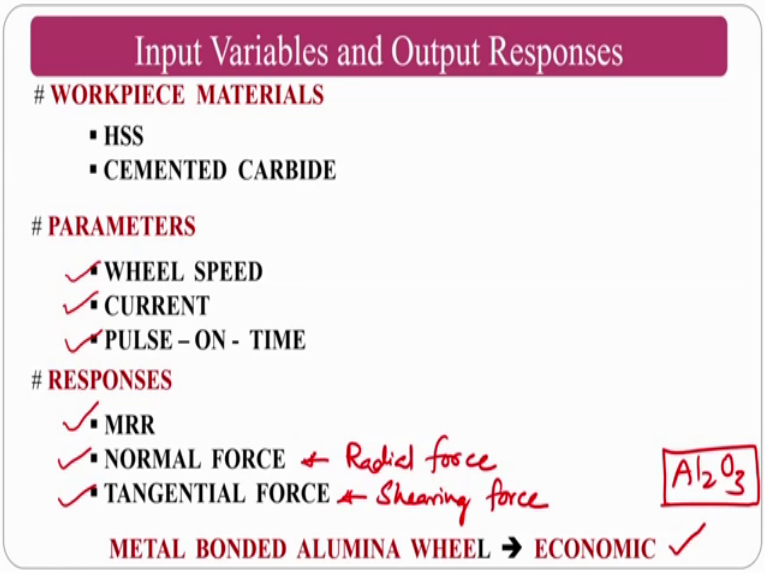

Input variables normally workpiece materials like H S S cemented carbide and the parameter will be wheel speed, current how much current you are going to give and the pulse on time and pulse of time and although if you want controlling the pulse on time automatically pulse on time and pulse of time which is called as a duty cycle will be varied ok. So, there are responses normally this particular processes will be basically used for material removal applications of very hard materials. You can also measure the forces using dynamometers like normal force tangential force as I said in the preview slide it is the radial force also people can call in many ways, this is itself you can call the Radial force and this also called Shearing force call shear force ok.

So, metal bonded normally alumina wheel is economics. So, what I mean to say from this particular statement is if you are not having the diamond, diamond normally will cost more much higher cost. So, you can go for metallic bonding along with alumina oxide ok, aluminum oxide abrasive particles; that means, that alumina A l 2 o 3 particles you can go and this can be a economic viable solution, if at all you want to go for this particular process.

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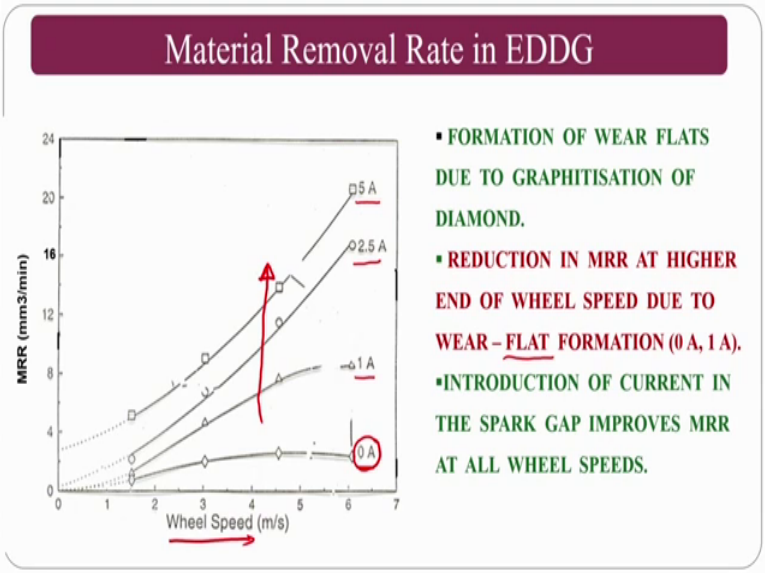

So, material removal if you see the material removal as the wheel speed increases the M R R gradually increases in the all current, if you see is 0 current; that means, that there is no removal of materials using the erosion techniques, the spark technique if you are going to increase the current what is going to happen here is the material removal gradually increases. Why the material removal is less? If you see at 0 amperes what is happening it is purely the grinding process because there is no sparking, there is no melting and evaporation for the same material and tool combination; that means, the material as well as a grinding wheel combination you do not have the sparking here because your current is less that is D C power supply you are going to switch off for this particular experiment.

Since there is no sparking there is no melting and evaporation because of which the workpiece hardness original hardness plays a major role and it will if you cannot remove much material and you may observe very fast glazing because normally this E D D G application is for harder materials and diamond particles is also harder at the grade; that means, that your metallic bonding is also will be like grade will be hard grade ok, it is not soft in that circumstances you may experience the glazing; that means, that your abrasive particles goes off ok.

So, you should be very careful that is why the material removal is less, as you see for 1 ampere; that means that you are giving very less amount of current. So, reduction of M R

R at higher end of the wheel speed is due to wear and flat formation that is nothing, but the you are appearing the glazing and at the same time introduction of the current in the spark gap reimproves the M R R and all; that means, that as you increase what is going to takes place is you are your sparking will be improved, at the same time your melting and evaporation will be improved and most of the material you can remove by the two action what is melting and evaporation as well as your abrasion action ok. In all the conditions abrasion is constant; however, melting and evaporation will vary and it will increase in this direction ok.

If you are melting and evaporation increases in this direction. So, your material removal rate; obviously, increases. So, if you see the gap current versus normal force.

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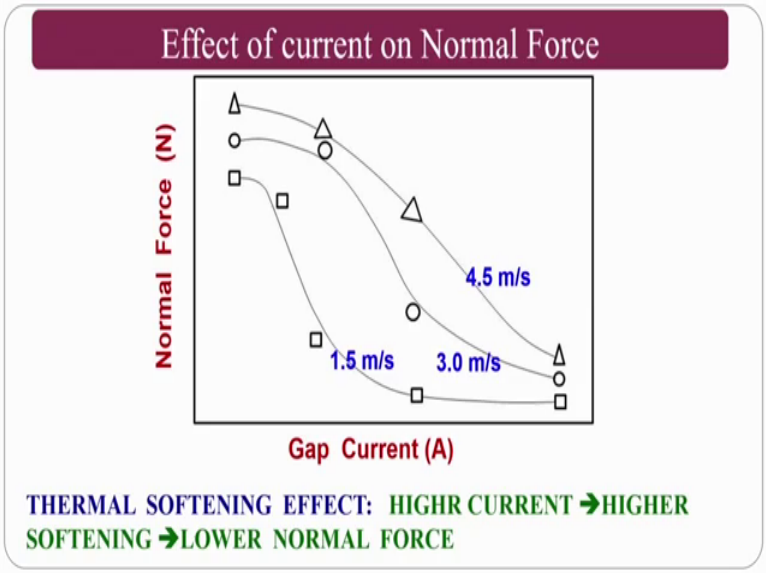

So, if you are you going to increase the gap current the thermal softening effect normally high current if you see use higher softening and lower normal forces; that means, that if you are observing the forces, what is our requirement basically transforming from the grinding operation to the electric discharge diamond grinding operation our requirement is if at all we get a hard materials to be machine, assume that I am going to get a workpiece material as H S S high speed steel which is normally consider as a tool material for the mild steel and other steels in a late process.

Assume that I want to do the machining on top of it what will be if you are going to use for the normal grinding process, you are going to experience enormous forces if your

forces are very high, then the abrasive particles goes off. So, you in order to counter it you are going for electric discharge diamond grinding process where you incorporate the L E D M process that is called electric discharge electric discharge machining where the sparking will takes place and thermal softening of the workpiece material takes place.

If you see the current increment as we have seen in the previous also and in the previous slide in electric discharge machining basics if you have seen if the current is increasing the amount of material are the spark size will increase. If the spark size increases, what will happen? The greater bigger and larger and larger craters will form, if the larger craters are form what will happen the thermal conductivity will be goes to large radius and you can remove the material easily for that purpose if you see the thermal softening will increase if you are going to increase the current.

That is the basic thing if you are going to increase the current, what is going to happen is thermal softening will takes place that is written in the bottom the thermal softening will takes place if the thermal softening will takes place what will happen the interaction forces between the grinding wheel at the same time the workpiece will decrease gradually that is what the graph shows. The, if you are going to increase the speed of the grinding wheel sufficient time will not be there to melt and evaporate. So, the forces are slightly higher ok, for the same current.

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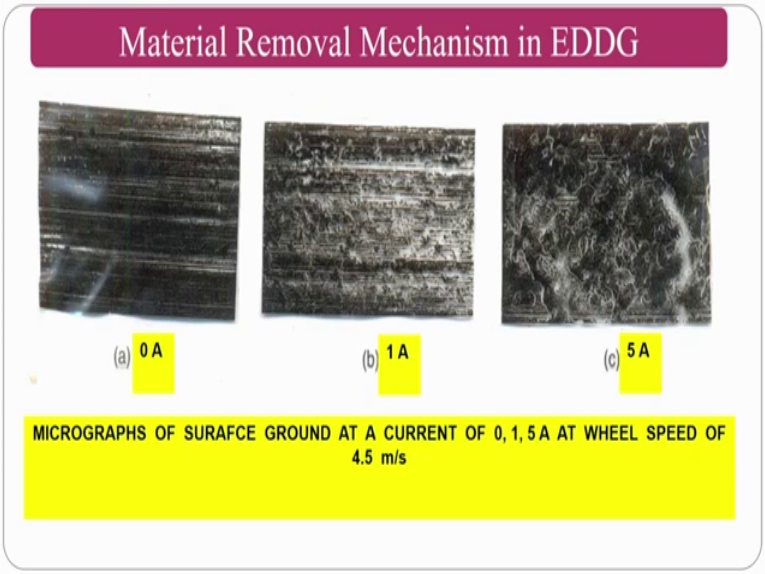

If you see here these are the surface morphology normally if you are going to use the 0 ampere; that means, that it is pure grinding if you are going to use very less current, very high current if you see the difference between figure 1 figure a and figure c you can clearly see that in the figure a only grinding marks are there. This is the predominant direction of surface roughness that is called lay is a straight line if you see here craters are there at the same time there are the scratch marks are there. This is the combination of the material removal is by the melting and evaporation as well as the shearing by the abrasive marks. This that is why the material will be material removal will be more in case of figure c compare to figure a you are going to put the current as well as abrasion action.

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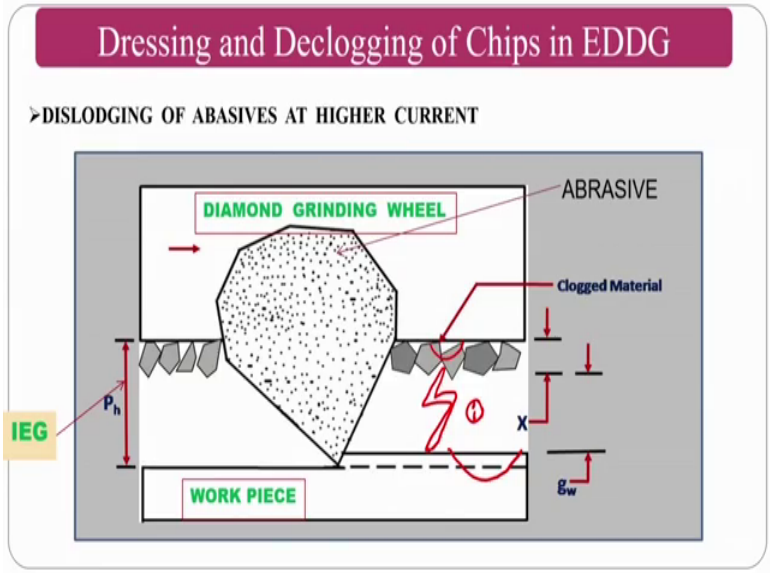

So, Dislodging if as I said whenever you are giving certain input conditions like depth of cut and other things, what happen is when you will have always the some chips will come and clog around the abrasive particle ok. There will be a gap between two abrasive particles normally in open structure, you have studied about the grinding wheel specification where there is a open structure and the close structure when open structure the distance between two abrasive particles normally will be high compare to the close structure. In the in that way what will happen in the open structure the chips will come here and your E D M process, how the E D M process will work there will be a spark because of the electrons and other tools ok.

This spark not only remove the material from the workpiece it also remove certain material from the tool also, in that way if the what is the material that will come in contact the chips will come in contact before the wheel bonding material. That is why it will declog the material that is a chip material from the grinding wheel that is why declogging and it is also known as the dressing operation. You do not require a diamond tool holding like this and rotating the grinding wheel in normal conventional process because here the what about the ions that are there generating during the electrons bombardment with respect to the dielectric molecules ions also will generate and its ions will try to move towards the grinding wheel and this will bombard on the clogged material and melting and evaporation takes place there also because of which declogging will takes place in directly dressing is in built process in this one. So, there is no requirement of dressing in this particular process additionally.

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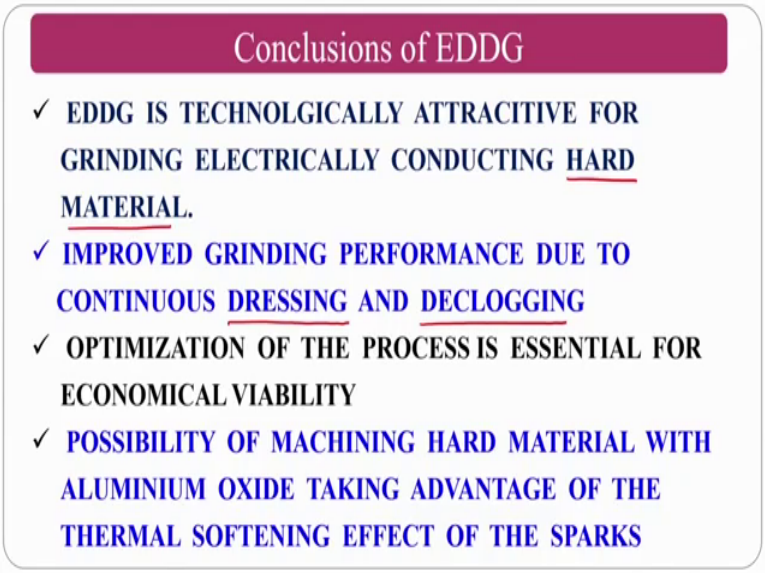

So, the Conclusion electric discharge grinding technology is alternative for grinding electrically conductive and hard materials, basically it will be basically uses for hard materials improve grinding performance due to continuous dressing because the dressing action and declogging action will be taking place continuously. This process is essential for economic viability and possibility of the hard material with aluminum oxide will be economic, instead of going for diamond particles you can go for alumina particles. Then this electric discharge diamond grinding the name will change to abrasive electric discharge grinding process, wherever you can use silicon carbide alumina or boron

carbide or cilium oxide, whatever the abrasive you use instead of diamond word will change that is all.

We move on to another process which is called as Abrasive wire electric discharge grinding process, this is also similar to the previous process that is called electric discharge diamond grinding process where in as I said

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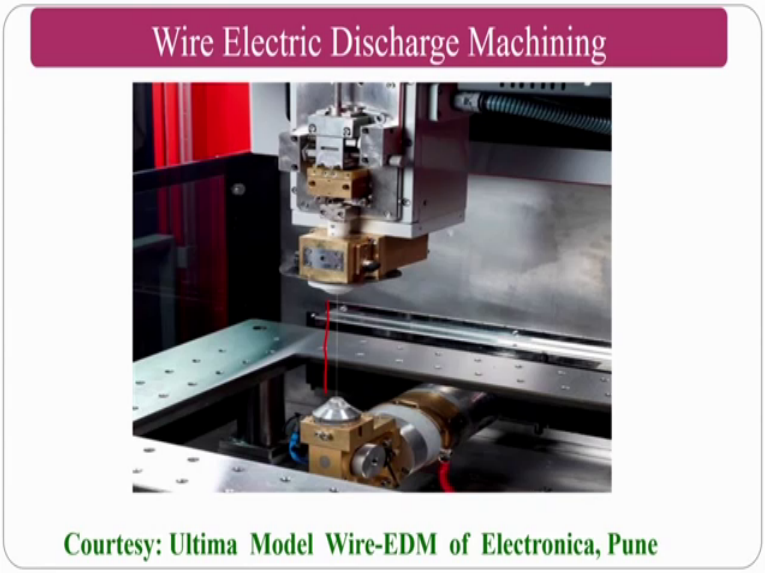

You can go for alumina and other thing that is why the word came at the start so; that means, abrasive wire electric discharge grinding process ok. So, before that we will just to see the wire electric discharge machining process this is the commercially available wire electric discharge machining process. You can see a wire here this wire will continuously rolling or it will be continuously moving by the spools and the material will be removed.

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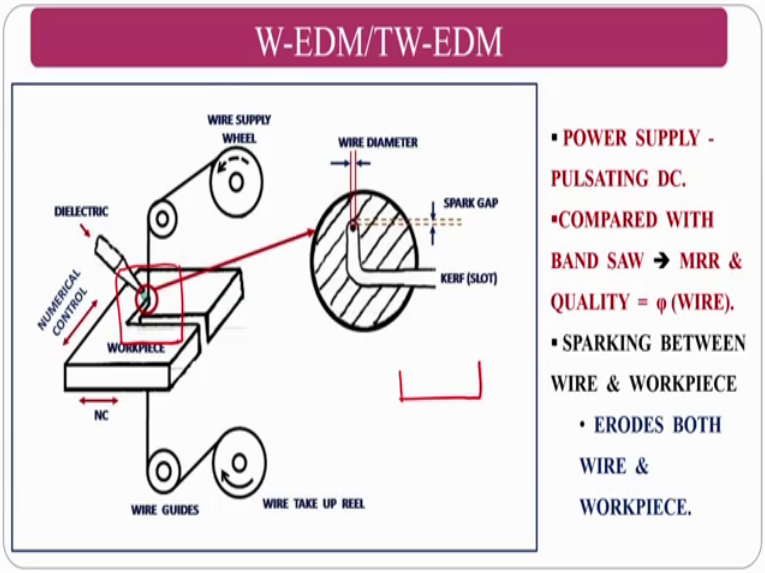

The material removal will action will be taken care by the electric discharge machining process mechanism only, here what will happen there will be a wire which is a conducting material workpiece also a conducting material wire is negative terminal as well as the workpiece is positive terminal and the dielectric fluid is fed here if you see here the dielectric fluid is fed. So, the mechanism of material removal will be same.

So, there will be a negative terminal, there will be a positive terminal and the material removal takes place by virtue of electron bombardment on the workpiece and kinetic energy of electrons will convert into the thermal energy. So, the melting and evaporation takes place, beauty of the this part the beauty of this viral E D M process is that you can make the complex shapes, but thickness wise it has a cum constraints, if you have minimum 5 mm 10 mm thicknesses. So, you can cut the complex shapes using wire E D M process.

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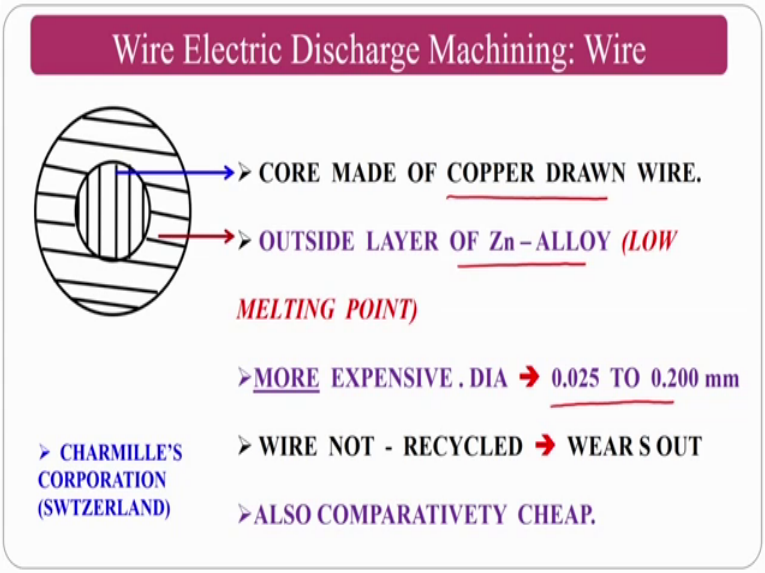

So, if you want to have the tool life, that is a wire life normally you will go for some of the advanced wires that is called stratified wire where in your core is made up of copper; that means, that one may tell and outside will be made up of another metal where is a zinc alloy which is low melting point basically this is a high this is expensive at the same time you cannot use the recycled because this wear out will takes place normally the stray currents and others can be avoided by this particular advanced wires ok.

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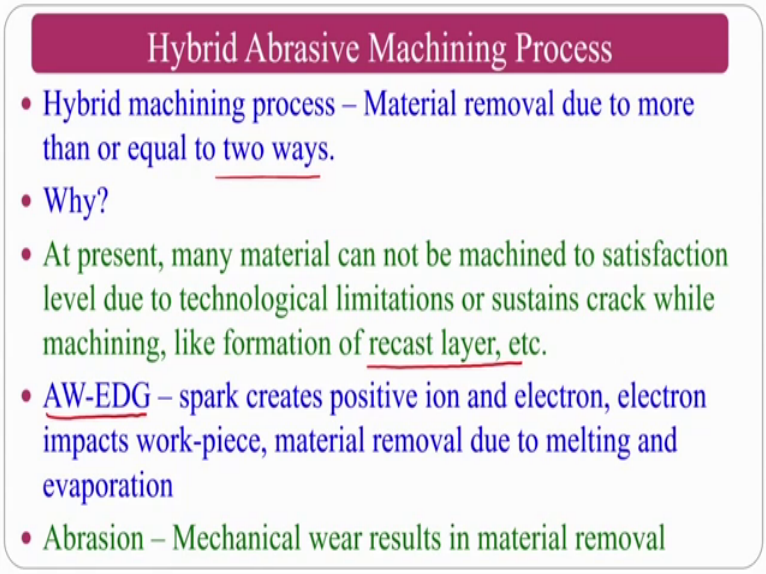

So, Hybrid abrasive machining process normally hybrid as I said some of the people might have not got the concept of hybrid there is slightly difference between advanced and hybrid. So, hybrid machining process material removal due to more than or equal to two ways; that means, that you will have combination of two ok, a portable T V in olden days nowadays L C D, L E D this is the advancement of T V ok, but the mechanism are some of the technologies are different, but the thing is that it is an advancement, but if at all you are going for hybridization you have to hybridize.

So, two mechanisms; so why it is required? The hybridization normally one process will have its own advantages and disadvantages another process also will have advantages and disadvantages, if at all I want to have the advantages of both two processes then you have to combine both two processes that is called hybridization.

At present many materials cannot be machined to the satisfaction level due to technological limitations or sustain crack while the machining this like formation of recast layer and other things, for that purpose abrasive wire E D G is came into picture the spark creates the positive ions and electrons. Electrons impact on the workpiece material and material removal due to melting and evaporation then abrasion action of the abrasive particles also will takes place; that means, that you have a wire E D M process plus grinding process.

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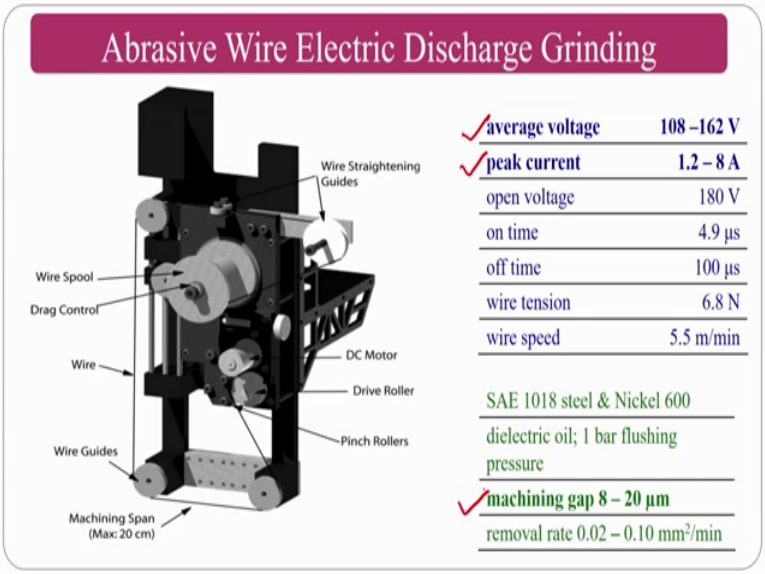

That is what is the advantage, if you see here this is how it also looks like wire E D M process only, but the thing is that here in the wire is having the abrasive particles. That current voltages are main important parameters here at the same time machine gap is also important factor which you can play in this particular process.

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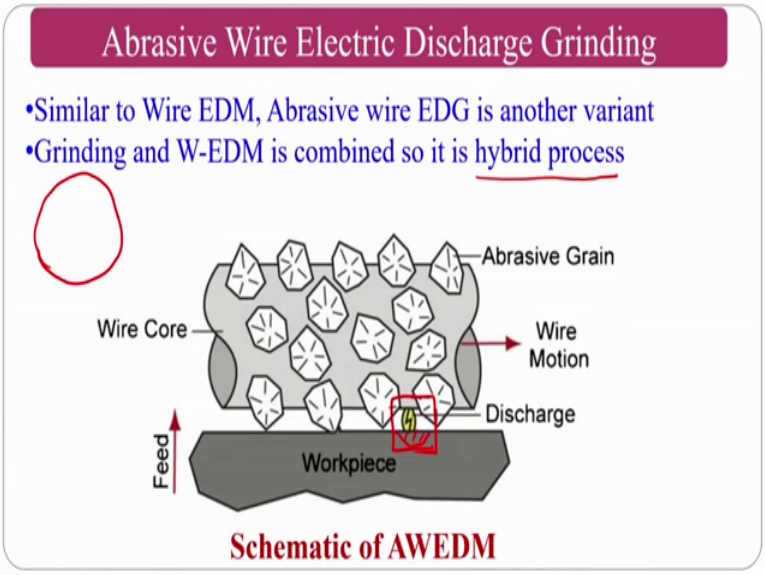

It is similar to wire E D M process, but abrasive wire E D G is another variant grinding and wire E D M is combination which is called as a hybrid process.

If you see here it is the mechanism of material removal is same as the previous process, but only thing is that here instead of a wheel what you have seen in the previous process here it is a wire ok, rest of the mechanism is approximately same. So, because of the metallic wire which possesses the abrasive particles metallic wire will have the spark, which makes my metal thermally softened and the abrasive action of the abrasive particles will takes place ok.

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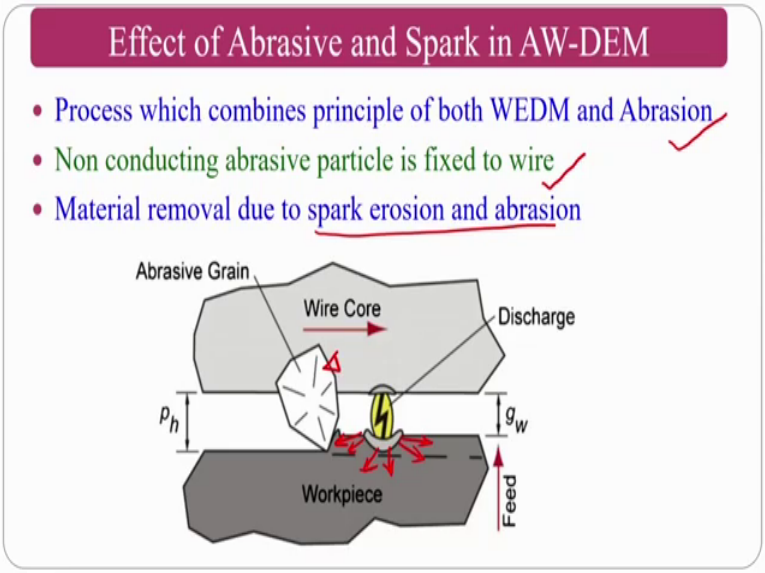

That is how it is the same explained in a close up view, this process combines a principle of wire E D M and abrasion non conducting abrasive particles are fixed on the wire; that means, that it will have the 2 D abrasion or the two body abrasion. The material removal due to spark erosion and abrasion that is called here what is your going to see here is erosion this is called the spark erosion and this is called abrasion ok.

So, because of these two actions materials is removed ok. So, the people who have not understood or if you are not there in a few minutes back mechanism is clearly explained here because of the spark erosion in this area, what will happen thermal melting and evaporation takes place, not only melting and evaporation takes place this also conducts the lot of heat inside ok, because of which what will happen the thermal softening of the workpiece will takes place and the abrasion action of the grinding wheel or that abrasive wire will remove with very less normal forces ok.

That is the beauty about this process that is why the material removal also will be very high if you are going to increase the current at the same time if you are going to increase the current the normal forces will be very less ok. This particular picture will clearly give you what you have studied in the previous graphs few slides back.

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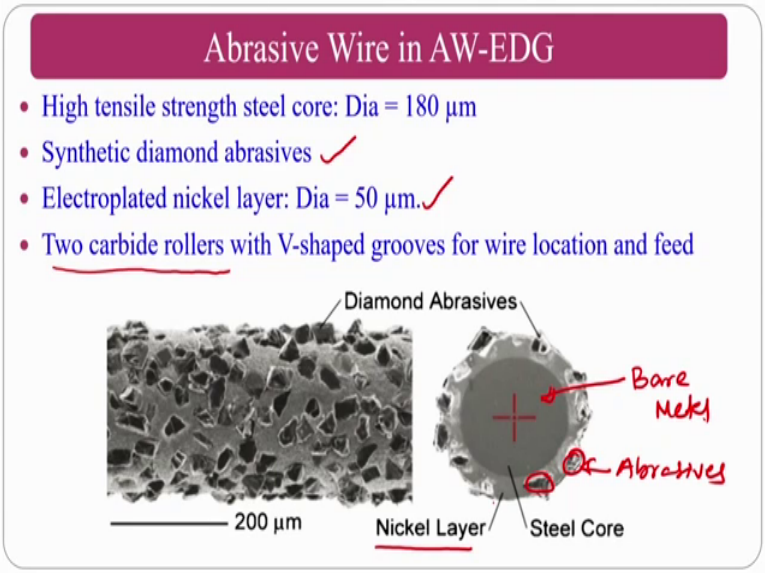

Abrasive wire basically it is a high tensile strength normally, if you see the abrasive wire how it look likes, normally it would should have high tensile strength because now this will have a carbide rollers with V shape and it will you need to have a tensile strength very good tensile strength because you have two spools which is rotating in the same direction. So, that the abrasive wire continuously moves and the tension between these two spools should be maintained constant.

So, that the material removal will be uniform otherwise it will be a big problem ok, for that purpose if at all I want to maintain the proper tensile nature of the wire, then you should have high tensile strength of this particle material and synthetic diamond abrasive you can have on this one electroplated nickel layer also you can have all that one. So, that the bonding will be proper ok, you can see also the abrasives and the metal if you are going to see here this is a bare material bare metal and on top of it you will have abrasive particles and nickel coated layer is also there ok, this is about the abrasive wire.

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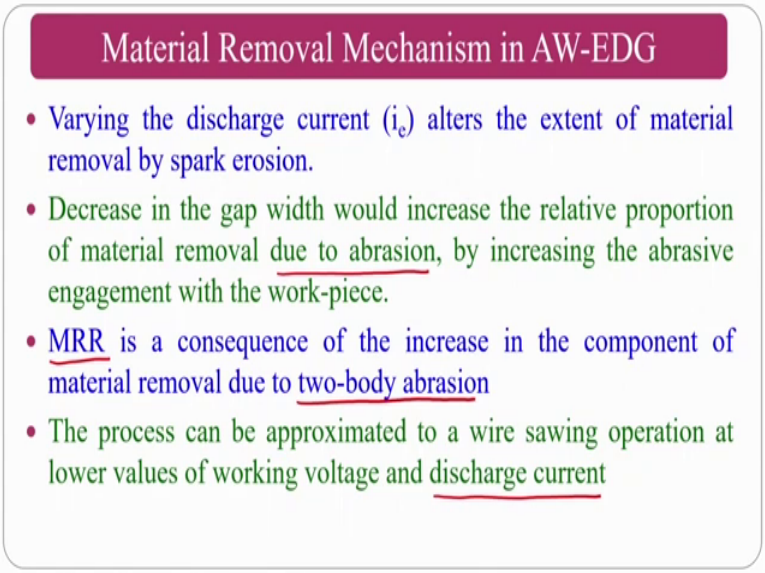

Varying the discharge current alters extent of material removal as I said if you are going to increase the current with the melting will takes place and thermal softening of the workpiece takes place. Decrease in the gap width would increase the relative proportion and the material removal due to abrasion, if you have very little gap what will happen if you have see in the clearly the previous mechanism of the thermal softening and abrasive particles protruded out. So, normally the abrasion action will takes place more; that means, the dominating abrasion action will takes place.

M R R is; that means, that material removal rate is the consequence of increasing the component of material removal due to two body abrasion; that means, that if your current is very less normally you will have material removal is the consequence of the increase of the component of two body abrasion; that means, that you are abrasive particle on a wheel is fixed; that means, that there is no rotation of your abrasive particle about its axis. That is why it is a two body abrasion in a wire, wire based abrasive machining process.

The process can be approximated to wire sawing operation at the lower values of voltage and discharge current; that means, that if your current is minimum at the same time if your voltage is minimum, what will happen it is dominated by the abrasion action ok, at the same time in the previous statement I also said this abrasion action will be two body

abrasion because the abrasive particle is fixed. So, there will be a abrasion action between work piece and the abrasive particle in only one position ok.

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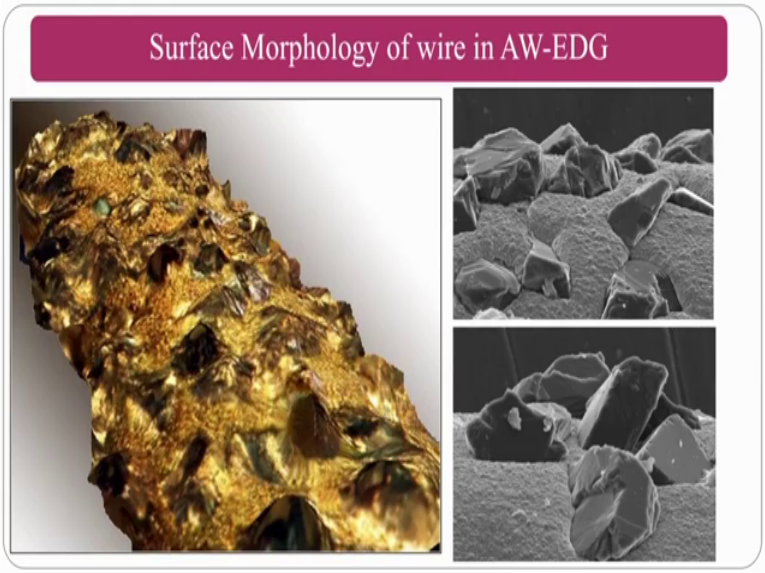

If you see the surface morphology of wire this is the wire the courtesy to Professor Philip Koshy. So, I have taken from the some of the available internet available source. So, I am very thankful to professor Koshy and this is the abrasive wire where in you can see the abrasive particles diamond particles are there at the same time this is quoted on top of it and if you see the same images.

So, these are the abrasive particles and the morphology some of the locations it is uniformly located this is abrasive this is abrasive and the nickel coating is there here and some of the places you will have the agglomerations also, whenever you have agglomerations there will be two problems the material removal will be normally high whenever this agglomeration particles will come into picture at the same time if the bonding between two abrasive particles is there then the bonding will not be proper.

So, there will be a the delamination of abrasive some of the abrasive particles will takes place because if the bonding is between the wire and the coating material and the abrasive particle it will be always good if it is the bonding between every group of abrasive particles. So, the bonding will not be good so, this abrasive mays goes off. So, whenever you are going to prepare or purchase you should characterize the wire ok. So, this is also the simulated view.

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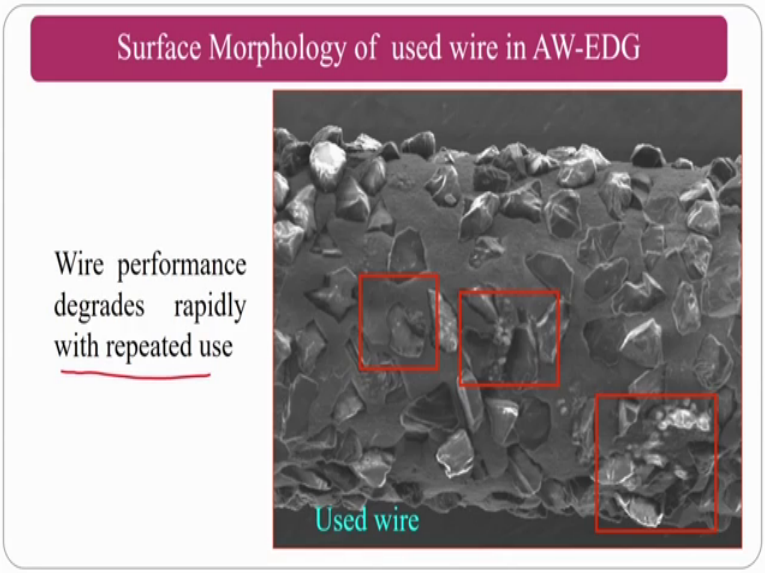

Surface Morphology of the used wire normally the basic problem with the used wire is the abrasive goes off ok, that is why you are not recommended for multiple reusers. So, you can go for few users like one or two I exactly if at all you want. So, you can go through the papers of professor Koshy for more detailed information. So, wire performance decreases rapidly with repeated use. So, if at all you want good performance you use one or two or three times if you are going to use multiple times then the performance will goes down ok.

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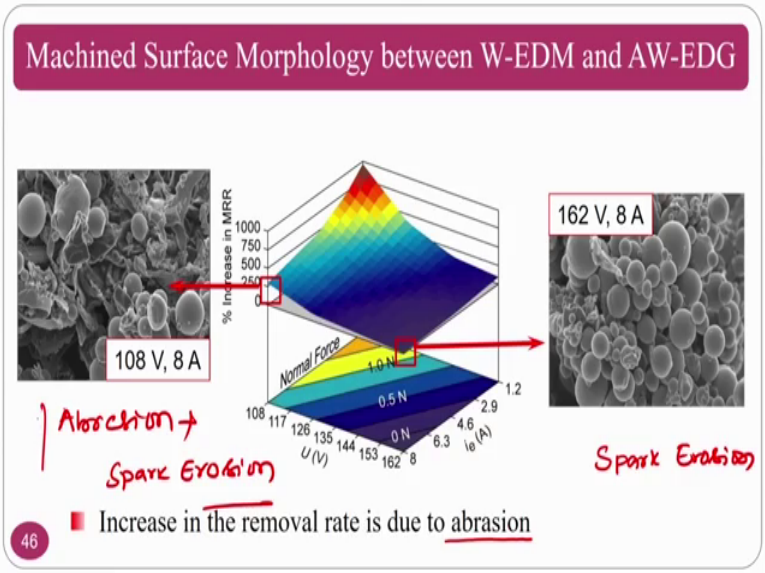

If you see the surface morphology between the surfaces, so, why I said why radium means if you are going to use the high current and the normally what will happen is it will dominated by the Spark Erosion. If you are going to use the high current along with the low voltage, what is happening is here the abrasion action will also takes place and here Abrasion plus Spark Erosion both will takes place because of which material removal will be very high in this area ok, increasing the material removal rate due to abrasion action will you can see in this figure.

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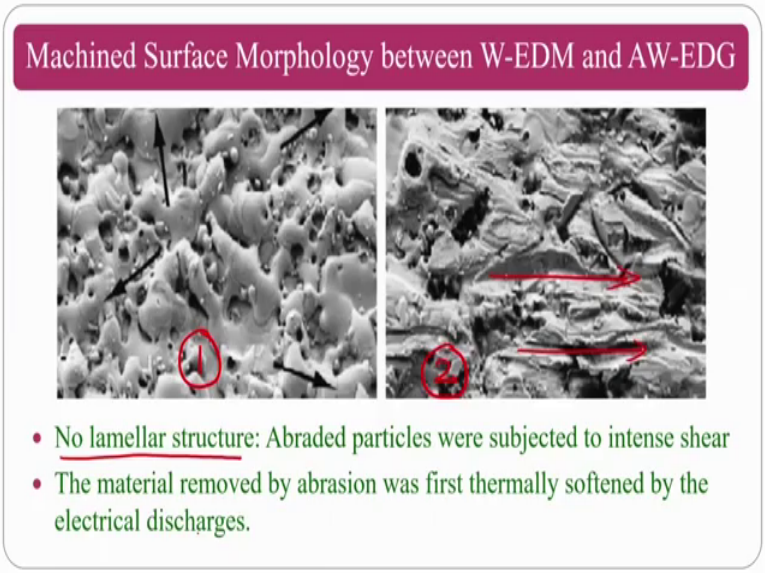

So, machine surface morphology normally if you see here wire E D M surface as well as so, now no laminar structure. So, abraded particles were subjected to the intense shear; that means, that you can see these are the shearing marks of the abrasive particles at the same time erosion, spark erosion also the spark erosion main work is to melt and evaporate at least to melt, but abrasive particles will remove the material in their first case what will happen there will be only spark erosion, that is why material removal will be very less in the case one material removal will be very high in case 2 ok. So, what is the difference here abrasion plus spark erosion will be in second case in first case only spark erosion.

That is why material removal by abrasion was the first thermally softened by the electrical discharge; that means that first it will be thermally softened by the electric discharge then it will be removed by the abrasion action.

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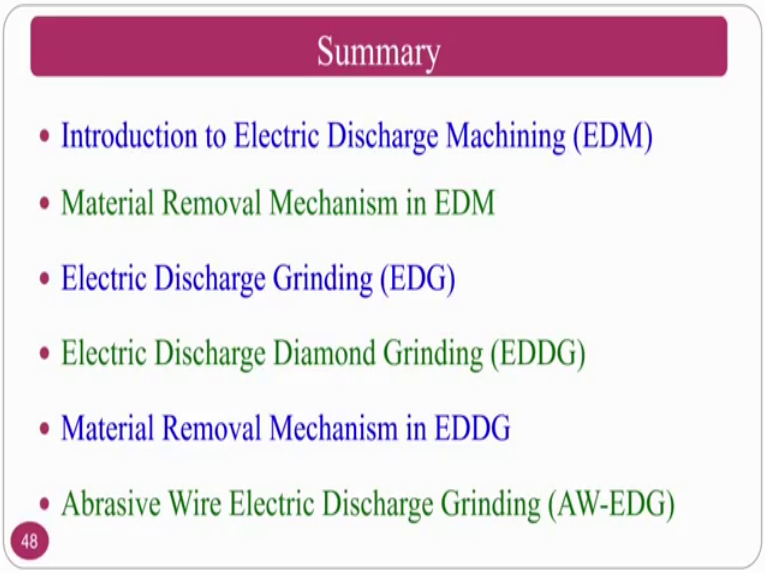

So, summary of the today's class introduction to Electric Discharge Machining we have studied material removal mechanism in electric discharge machining. Electric discharge grinding we have seen where the only metallic disk will be there then we proceeded to electric discharge diamond grinding process where the abrasive wheel will be there.

So, metallic bonding to wheel is braced with diamond particle or it is clubbed with diamond particle at the same time material removal mechanism in electric discharge diamond grinding we have seen and at last we have seen in the finally, finally, we have seen abrasive wire electric discharge grinding process and the mechanism of the electric discharge diamond grinding and abrasive wire electric discharge grinding both are the same, only thing is it application wise you may have slightly different.

Thank you for your kind attention and I am very thankful for professor V K Jain for supporting me in some of the slides at the same time I am very thankful for professor Philip Koshy for his slides that, I procured from the internet and other sources

Thank you.