Advanced Machining Processes
Prof. Vijay. K. Jain
Department of Mechanical Engineering
Indian Institute of Technology Kanpur
Lecture No 14

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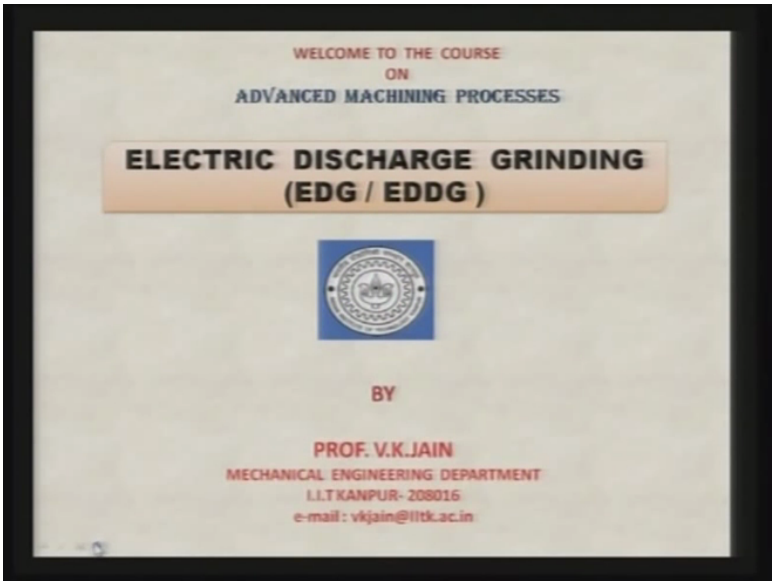

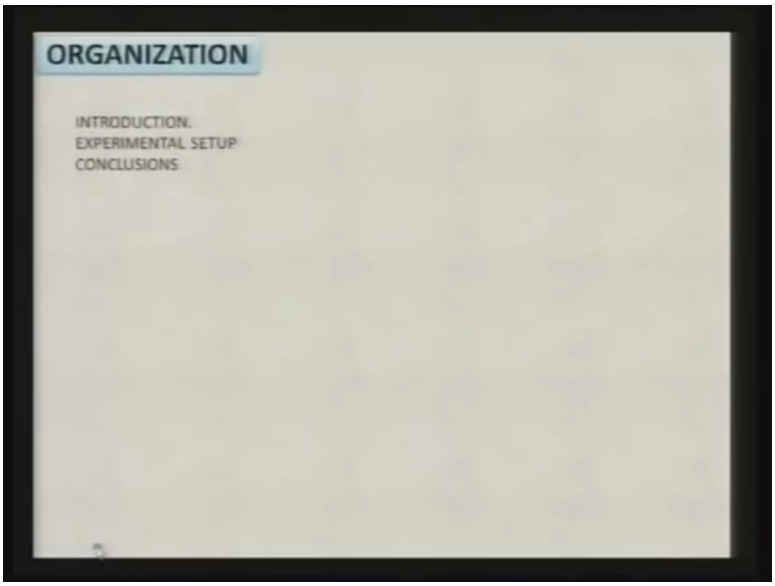

Welcome to the course on advanced machining processes. Today I am going to discuss about electric discharge grinding sometimes it is also called as electric discharge diamond grinding. Organization is like this, I am going to talk about the introduction where I will talk general grinding and electric discharge grinding or electric discharge abrasive grinding and electric discharge diamond grinding. Then some details of experimental setup, some results of experiments and then conclusions.

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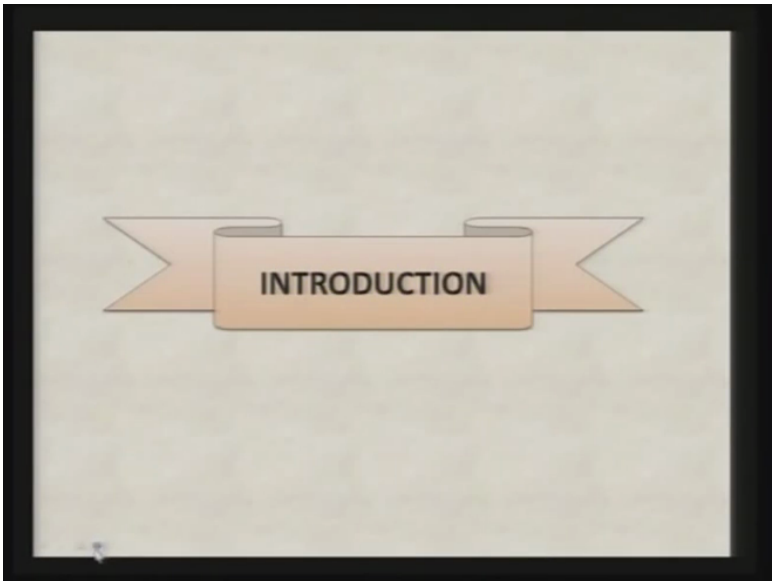

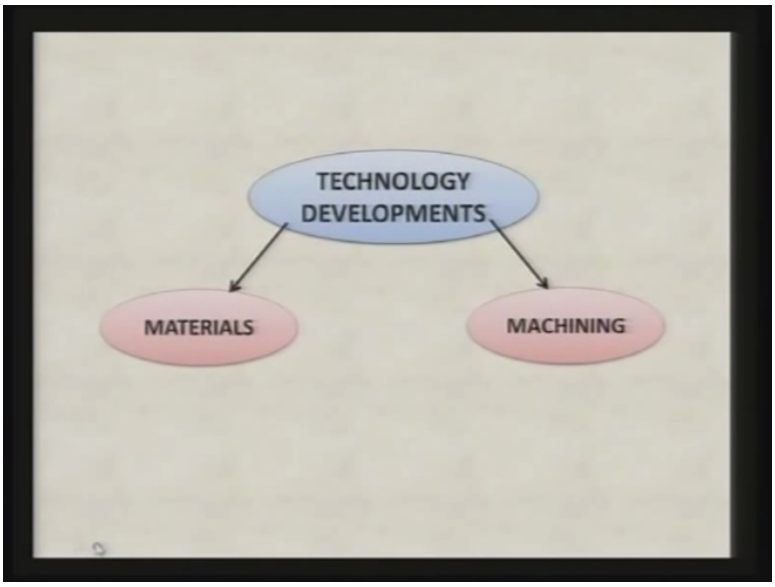

Now a lot of technology developments are taking place in different fields especially the materials, a large amount of research is going on across the globe in the area of material science and material engineering. Everyday materials are being developed according to the requirements they also call it as engineered materials where you can have the properties of the material as per your requirements.

They have many times very hard materials, high strength, high temperature resistance and the shape and size these materials really becomes a challenge for a manufacturing engineers and when you want to shape and size these materials components somewhere or other you have to perform machining operations on these materials as well as sometimes finishing operations on these materials and these materials are so hard that conventional cutting tools cannot

machine these materials because these materials are either equal to the hardness of the convention cutting tools or more than convention cutting tools, so my name materials are designed and engineered such that they can be machined and finish by the unconventional machining processes especially EDM or electric discharge grinding or electric discharge diamond grinding.

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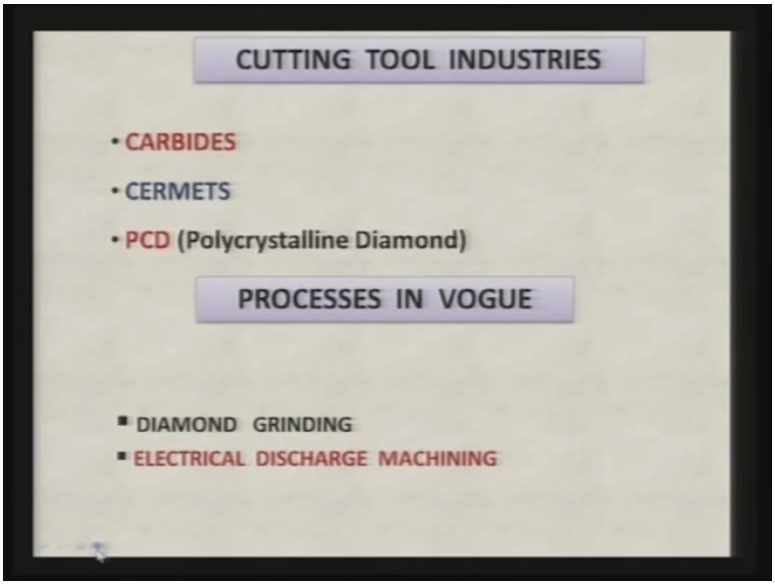

Cutting tool industries deal with carbide, tungsten carbide and other kind of carbide tools, Cermets which has ceramic as well as metal components and PCD polycrystalline diamond cutting tools are made. Process in vogue, you may times performs the operation known as diamond grinding where the abrasive wheel is having diamond particles as the abrasive or the grinding wheel is having the bonding material and the diamond as the abrasive particles for performing the grinding operations.

Now there is another process known as electric discharge machining, now in case of electric discharge machining you can shape and size the components but the material removal rate is very small and in case of diamond grinding surface finish is good but wear and tear of the grinding will keep taking place. These grinding wheels are very expensive, moreover both these processes are thermal processes, so thermal cracks are developed in the finished component or machine component.

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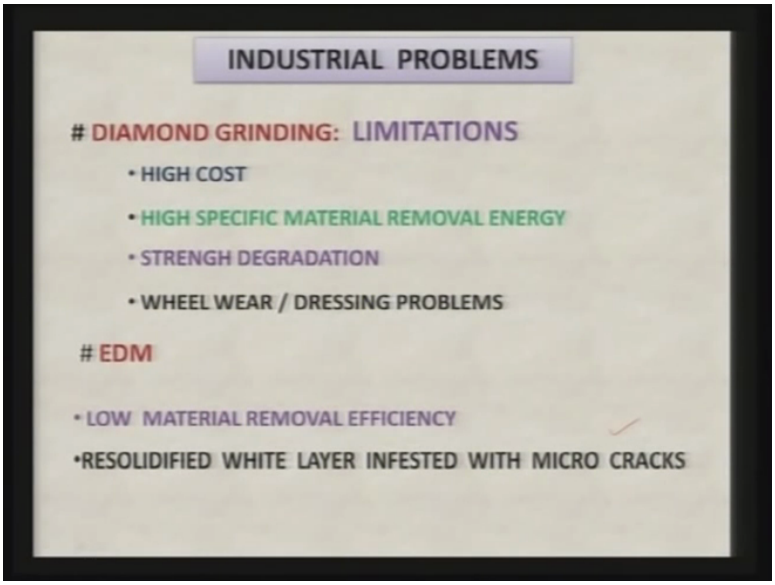

With diamond grinding which is quite common in various types of high-tech industries, there are certain limitations because of which this process has limited applications. First thing is diamond grinding, initial equipment itself is very expensive and the cost of the grinding wheel is also quite high. Then high specific material removal energy requirement is there that means the energy requirement per unit volume of material remover is much higher compared to other machining processes.

As a result of high amount of heat generation on the workpiece as well as on the grinding wheel there is the degradation of the strength of the workpiece takes place mainly the micro cracks may develop, thermal residual stresses in the finished components or machine components are observed and due to the wheel wear dressing becomes really a problem as per conventional dressing of the grinding wheel, a large amount of abrasive particles or diamond particles are lost and diamond grinding becomes quite expensive and low productivity process EDM process, electric discharge machining process about which we have already discussed quite a bit.

Now this process gives very low material removal rate and the material removal efficiency is also low that means the energy required per unit volume of material removed is quite high. After EDM process you get a resolidified layer that is known as white layer or recast layer on the machine component and this recast layer is very hard, it may be 2 to 3 times harder than the base material or the parent material of the workpiece and it has micro cracks, so after EDM process the component cannot be used as such in the subassembly or assembly. It has to

be subjected such that this recast layer resolidified layer or white layer is removed and that require additional time one more operation and it cost something to the component.

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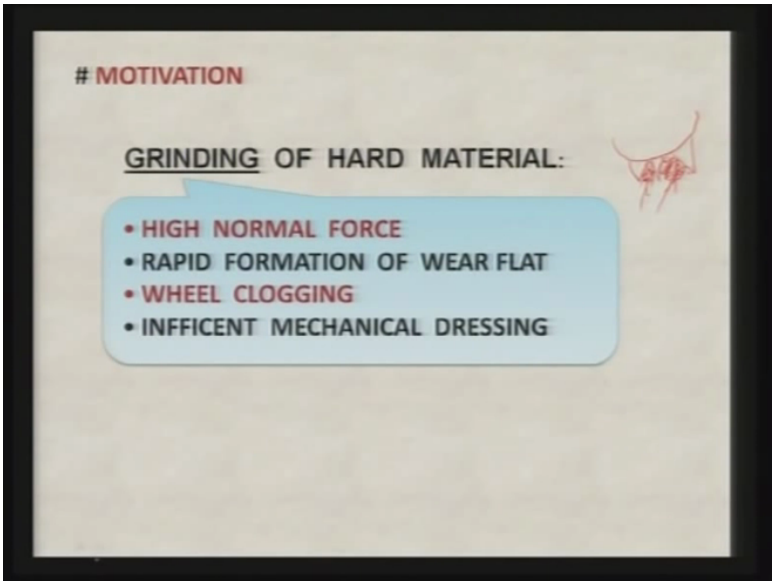

That is why in new grinding process or hybrid grinding processes are being developed, some of them are like electric discharge abrasive grinding or diamond grinding, electrochemical grinding and other processes. We are today going to discuss about the electric discharge grinding, electric discharge abrasive grinding and electric discharge diamond grinding. Now grinding of hard materials requires higher force, high normal force because normal force is responsible for penetration of the abrasive particles into the workpiece surface and sheer force is responsible for the removal of the material in the form of the micro-nano chip and then rapid formation of wear flat, when you are doing the grinding operation then the abrasive particles which are projecting out of the grinding wheel, they wear and wear flat is created, as a result of that grinding efficiency goes down.

Wheel clogging is a common practice or rather a common event that take place during grinding process, as you can see here that say this is the wheel and there are the abrasive particles on the wheel then what happens when you are performing the grinding operation then between the abrasive particles the chips get locked up and as a result of this the sharpness of the grinding wheel which is in contact with the workpiece reduces and because of this clogging of the grinding wheel the machining efficiency and the grinding efficiency goes down force required becomes much larger than really anticipated hence to overcome this problem you have to go for what is known as dressing of the grinding wheel, so that these clogged material is removed and some of these abrasive particles are you know plucked out

of the grinding wheel without being used, so there is an additional loss of the abrasive particles during the dressing which is really not needed hence it makes inefficient mechanical dressing process.

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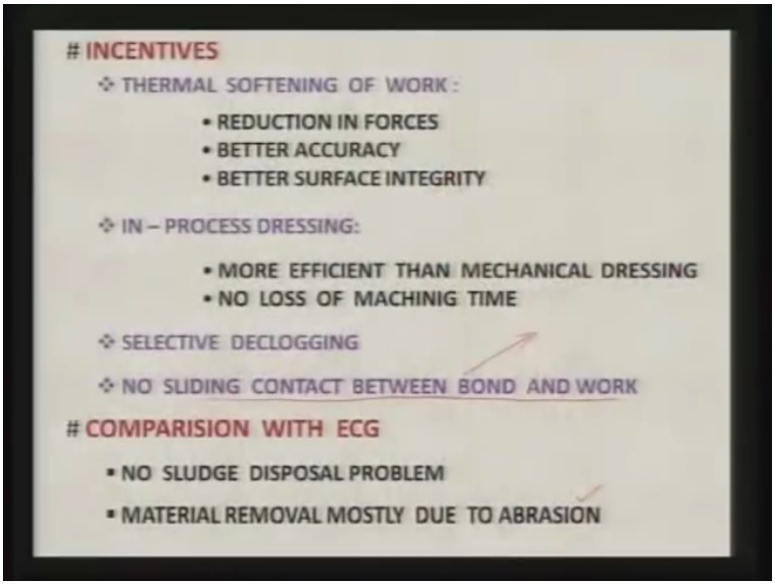

Now since the materials are very hard which we are intending to grind, it requires a very high normal force and definitely large sheer force also. The solution for this can be at somehow if we can soften this very hard workpiece material in the normal force required as well as sheer force required both of them will reduce hence we will see how to do the thermal softening of the workpiece during the grinding operation. If thermal softening is taking place there will be reaction in the sheer as well as in the normal forces, you can achieve better accuracy on the finished component better surface integrity because once the material is soft and you are removing the material then definitely the probability of the micro cracks and thermal residual stresses goes down.

Now here in case of electric discharge abrasive grinding as well as electric discharge diamond grinding I will show you in the following slides that in process dressing takes place without performing any additional dressing operation manually. This in process dressing is more efficient than mechanical dressing which I explained you. There is no loss of machining time that means you are not stopping the grinding operation and then performing the dressing operation is normally done in case of conventional grinding or even diamond grinding. Here it is a part of the process itself that is electric discharge diamond grinding or electric discharge abrasive grinding that during grinding operation itself dressing keeps taking place and selective declogging is also going on.

No sliding contact between bond and workpiece, now since continuous dressing and declogging of the grinding wheel are taking place, so abrasive particles and only abrasive particles are always in contact with the workpiece as a result of that no sliding contact takes place between the bond material and the workpiece material. Now here one point is very important to note, here bonding material should be metallic it should be electrically conducting otherwise it will not work in electric discharge abrasive grinding or electric discharge diamond grinding because we have already seen that in EDM the cutting tool acts as a cathode, workpiece act as a anode.

Now in electric discharge diamond grinding also, the grinding wheel is acting as a cathode and workpiece is acting as the anode. Now if wheel is to act as the cathode then definitely it should be electrically conducting material. Composition or rather comparison of comparison with electrochemical grinding, there is another process, hybrid process which is known as electrochemical grinding, now in case of electrochemical grinding as you will see a lot of sludge problem is there, sludge formation is taking place because of electrochemical reaction in the electrolytic cell as we have seen in case of electrochemical machining that ferrous hydroxide and ferric hydroxide are formed then you are doing electrochemical machining.

Same way when you are doing electrochemical grinding of say ferrous materials then ferrous hydroxide and ferric hydroxide that is the (())(14:07) and the disposal of these (())(14:10) becomes a problem, they block many times the interelectrode gap and short-circuit probability is much higher in case of electrochemical grinding compared to electrochemical machining but in case of electric discharge diamond grinding or electric discharge abrasive grinding, no such sludge formation is there, so short-circuit probability is minimal. Now material removal mostly due to abrasion is taking place in general grinding but in electrochemical grinding this is not really very true that most of the material removal is taking place due to the abrasive action, no. In this case, in case of electrochemical grinding about 10 percent of the material removal take place due to the abrasive action while 90 percent take place due to the electrochemical dissolution.

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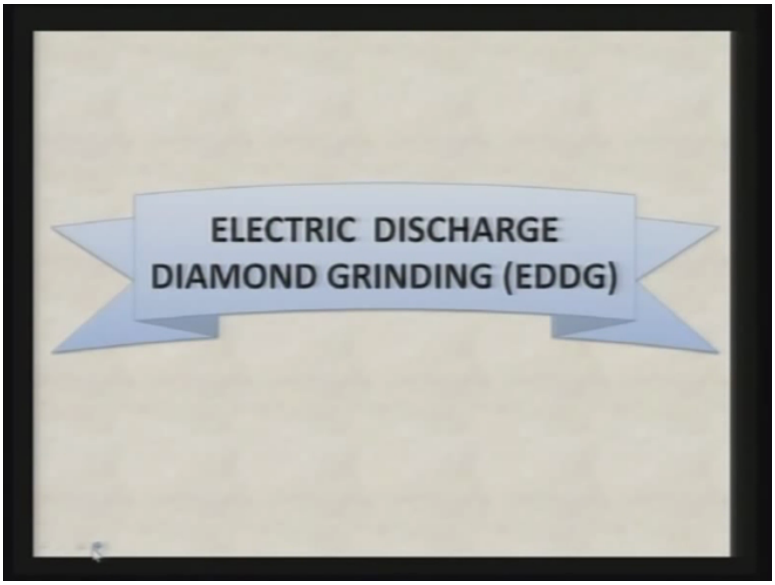

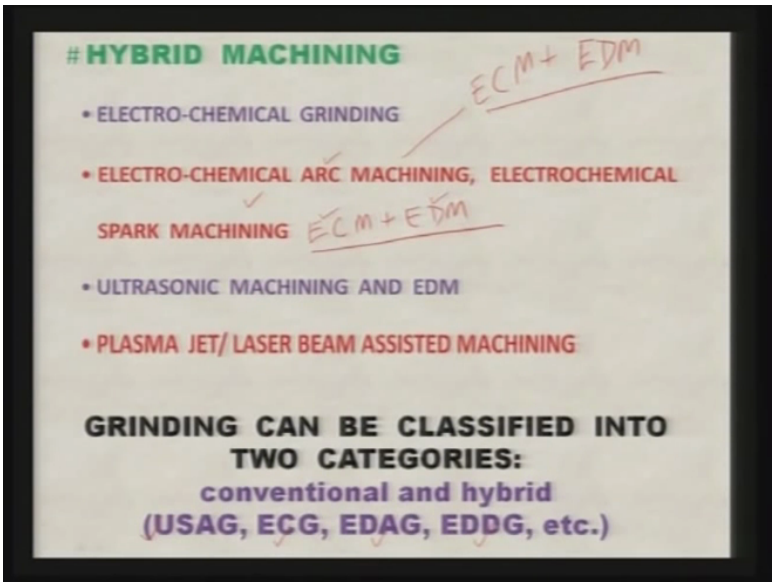

Let us see electric discharge diamond grinding, now here 2 words are there one is electric discharge and second is the grinding and electric discharge diamond is used as the abrasive particles on the grinding wheel, so it is called as electric discharge diamond grinding. I have already mentioned some details about the electrochemical grinding, this is again a hybrid process or very useful process. Then you have electrochemical arc machining, this particular process is another hybrid process where ECM and EDM both are combined together to take the advantage of ECM process as well as EDM process while ECM process has very high material removal rate while EDM process have very low material removal rate.

EDM creates a problem of surface integrity especially of micro cracks while ECM does not do so, so while combining these 2 processes are unique feature of this ECSM or sorry

electrochemical arc machining is that, it combines the 2 and material removal rate goes much higher than ECM or EDM and it becomes combination of ECM as well as EDM process. Then there is another very interesting process known as electrochemical spark machining process where ECM and EDM again both are combined but in this particular process…it is basically used for electrically on conducting materials like ceramic materials, while electrochemical arc machining is used for electrically conducting material, so there is a big difference although in case of ECSM, ECM is used for electrically conducting material EDM is used for electrically conducting material but what beauty of this ECSM or electrochemical spark machining process is that it is used for electrically non-conducting material.

Then there is a hybrid process where EDM process is taking the help of ultrasonic vibration and combining ultrasonic machining and EDM process and you can call it as ultrasonic assisted EDM process. Then there is a plasma jet laser beam assisted machining process, again a hybrid process is there, so these are the general hybrid processes for machining. Same way grinding process can also be classified into 2 categories conventional grinding and hybrid grinding, hybrid grinding I have already mention to you. Ultrasonic assisted abrasive grinding, electrochemical grinding which I have already discussed, electric discharge abrasive grinding, electric discharge diamond grinding, et cetera there are various other processes.

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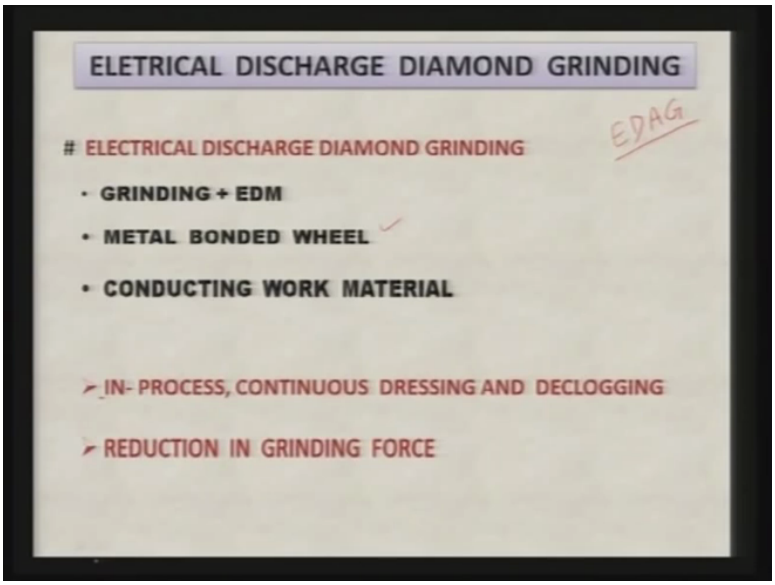

Now electric discharge diamond grinding as I have mentioned that diamond particles abrasive part diamond particles are used as the abrasive particles, now there is…there was another process in the earlier slide I called it as EDAG electric discharge abrasive grinding. Here in

place of diamond particles other abrasive particles are used just like alumina Al 2 O 3 or tungsten silicon carbide SiC or CBN cubic boron nitride particle they can be used as the abrasive particles then you call it as electric discharge abrasive grinding. Now again here grinding operation is coupled with the EDM operation, now since EDM require electrically conducting cathode, so bonding material in the grinding wheel is electrically conducting material.

This is using metal bonded grinding wheel, so workpiece material also has to be electrically conducting because this EDM process is applicable only for electrically conducting materials. In process, continuous dressing and declogging is the main feature of this particular process which are have mentioned. Now because of in process, continuous dressing and declogging, all the time abrasive sharp abrasive particles are in contact with the workpiece surface during grinding operation that is why the force is reduced.

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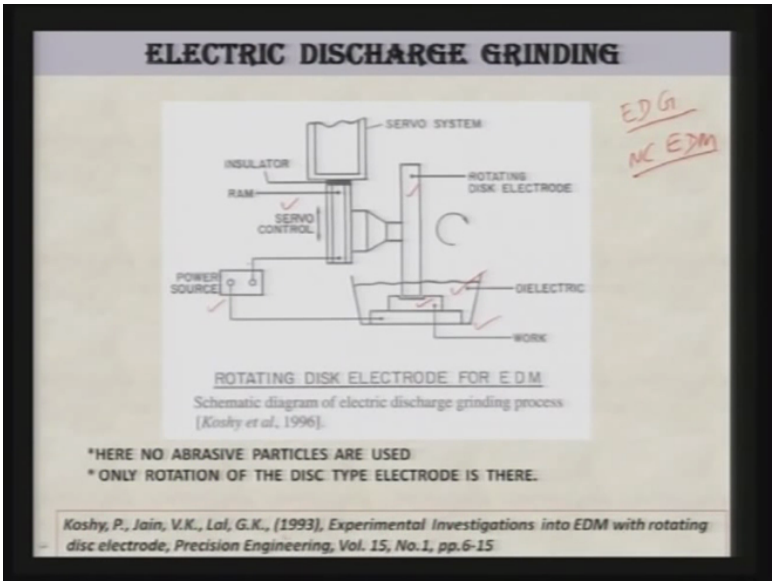

This gives a clear picture of the rotating disk electrodes for EDM process I will explain it. Now here we can call it as electric discharge grinding. Please note it carefully I am calling electric discharge grinding rather than an electric discharge abrasive grain or electric discharge diamond grinding. What is being done here is? You can see here is a rotating disk which is rotating just like a grinding wheel and the setup has been connected to the NC EDM machine. Now the main thing here is that this is that disk which is not having any abrasive particle neither alumina nor silicon carbide or diamond particles because this discuss rotating and then removing the material.

Here is the workpiece as you can see, so they people call it as electric discharge grinding, in real sense it is really not a grinding operation because abrasive particles are not being used you for slicing purpose or machining flat surfaces, et cetera this process can be used. Here, you can see the interelectrode gap is controlled by the servo control servo system and RAM is there and you know servo system is already there, rotating disk is there, dielectric it is partially dipped in the dielectric and normally kerosene is used as the dielectric and here is the workpiece which is connected to the positive terminal of the power source. So it is really simply a EDM process at called as electric discharge grinding because the grinding because the disk is rotating. Here no abrasive particles are used, only rotation of that this type electrode is there hence is it is called as the electric discharge grinding, this has been taken from the paper as referred over here which was published in Precision Engineering Journal.

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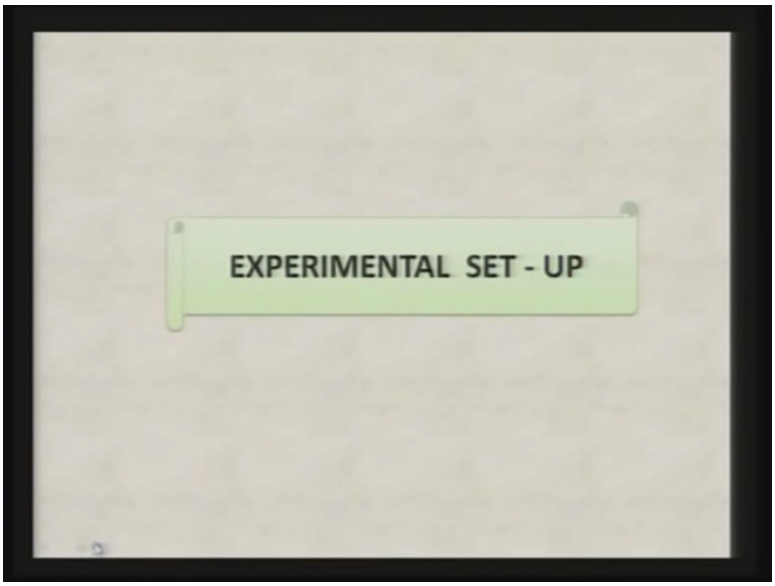

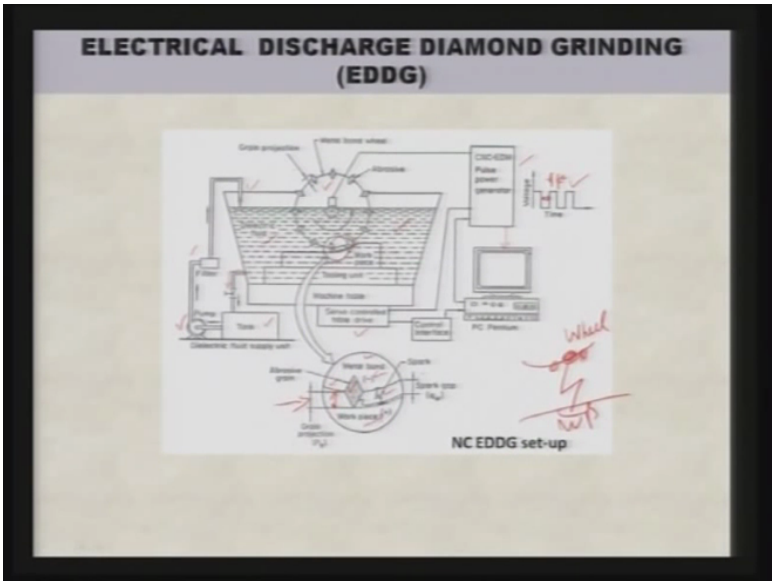

Now let us see the experimental setup for electric discharge diamond grinding? Now here you can see all the features of the electric discharge diamond grinding process are shown over there. Let us see them early, now here is the CNC EDM pulsed power generator and the grinding wheel, this is the grinding wheel, diamond grinding wheel which is connected to the negative terminal of the pulse power supply. Generator and the nature of the pulse you can see here this is the voltage pulse which is having on-time and off time, this is the on-time over there and this is the off time of the power pulse power supply and this is connected to the computer or PC from where you can control the different features that is the on-time and the duty cycle and be controlled the help of the computer.

It is interfaced with the servo controller system over there, now this is the tank is filled with the dielectric you can use kerosene, paraffin oil or some other oil as the dielectric but mostly it is the kerosene which is used as the dielectric. Now let us see what is happening as long as supply of dielectric is concerned, this dielectric comes from the tank from this machining zone or machining tank or machining pot whatever you want to call and it comes to the tank where filtration takes place, so that the debris et cetera are removed and after proper filtration you supply it to the pump and then it is further filtered at the 2nd stage, so that any unwanted debris or solid particles are removed, very fine solid particles also remove hear and then it is supplied to the machining area tank dielectric fluid is there.

Now in this zone if you see clearly where abrasive particle is there, the enlarge view of this particular zone is here you can see this is the abrasive particles, this is the metal (())(24:23) and it is acting as the cathode it is connected to the negative terminal as you can see and the workpiece is connected to the positive terminal, so it is acting as the anode. Now sparking is

taking place between the grinding wheel and the workpiece, now here the point to note is very important, this is the wheel and this is the workpiece and you can see here the sparking is taking place, so material is being removed from the grinding wheel as well as more amount of material is removed from the workpiece. Now point to note here is that material is being removed continuously from the grinding wheel also and because of this removal of the material, once the abrasive particle does not get sufficient support from the bonding material, it pulls out automatically due to the force being applied on it and as a result of that both the this dressing of the grinding will keeps taking place.

Now here heat is being generated on the grinding wheel, whatever is the clogging of the material that also gets melted out due to the heat generation between the on the grinding wheel as well as work piece, so from the grinding wheel the material is being melted out continuously that is why clogging problem does not arise to a large extent and because the material is being continues melted out on the grinding wheel clogging does not take place. That is why I mentioned earlier that in process, declogging and dressing of the grinding wheel keeps taking place and this is a big additional advantage of electric discharge diamond grinding.

Here you can see this is the grain projection that is shown over here and that also is making what is known as interelectrode gap like this over here. Now another important thing is because abrasive grains are always projecting out whatsoever small it may be in terms of view micron and they do not allow the bonding material or the grinding wheel to touch the workpiece material and lead to the short-circuiting so because of this projecting abrasive particle short-circuiting is avoided.

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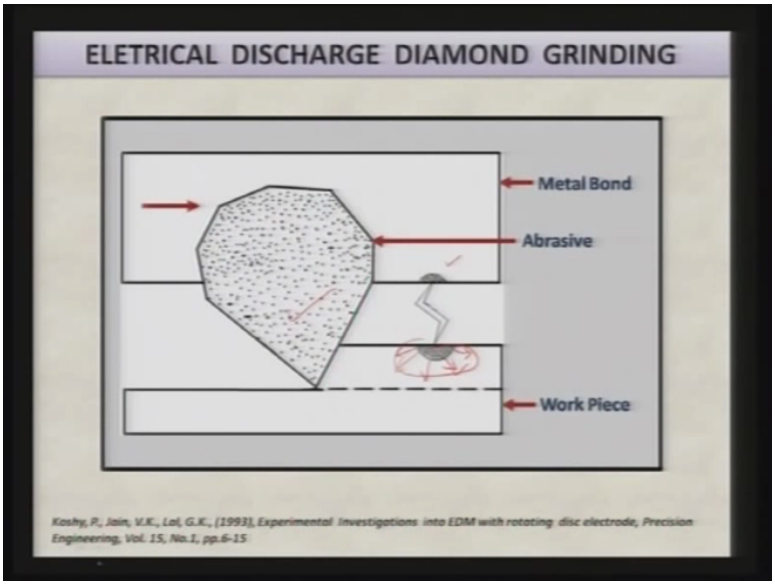

Now the question arises as I mentioned earlier that this particular process is good for grinding very hard materials the reason given was that the process is able to soften the workpiece to reduce the hardness of this or make it soft and then remove the material. Now this picture gives a clear-cut idea how this is happening, now sparking is taking place between the metal bond material and the workpiece and some amount of material is being removed from the tool but larger amount of material is been removed from the workpiece due to sparking but more important is large amount of heat is generated over here and this heat is conducted away in the workpiece and this heat of spark soften the workpiece and behind this sparkly you can see that abrasive particle is coming and since this material has soften out.

So this aggressive particle will be able to easily remove the softer material as compared to the harder material if spark was not there. So due to this sparking it is able to soft the workpiece material and behind the spark abrasive particle is there going to remove the softer material from the workpiece with low forces, normal as well as tangential compared to the case when you do not have the spark. This work has this photograph as been taken from this particular paper published in the Precision Engineering.

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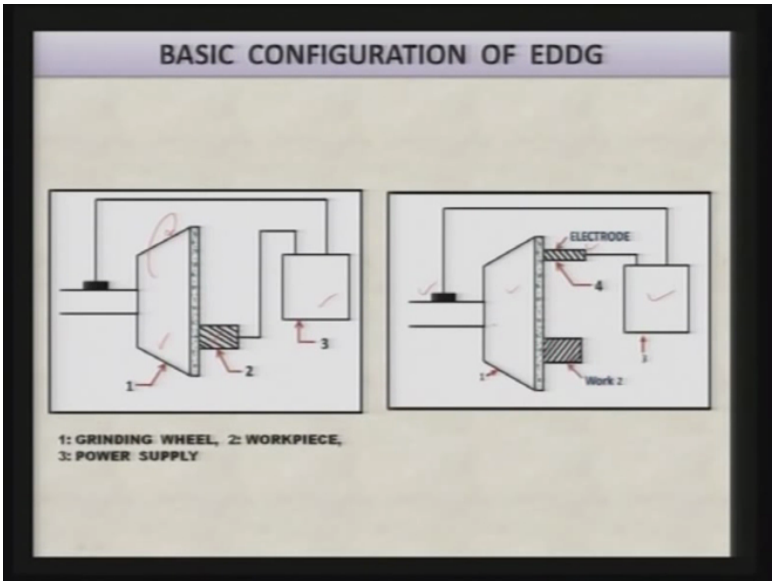

Now there are basically 2 configurations is of the grinding operation, one configuration you can see here that one this is the grinding wheel, maybe diamond grinding wheel or it may be the other abrasive grinding wheel then you have the workpiece over here and here is the power supply, so you are rotating this grinding wheel as you do the rotation of the grinding wheel is a relative motion between abrasive particle on the grinding wheel and the workpiece and this is able to remove the material in the form of the microchips workpiece.

Another configuration is like this that workpiece is electrically non-conducted and there is an electrode which is electrically conducting and there is a grinding wheel which is again electrically conducting bonding material and the mean electrodes and the grinding wheel, they are connected to the power supply 3 over here and here is the workpiece which may be electrically conducting it may be electrically non-conducting both of them can be machined or ground rather us there is a relative motion between the workpiece and he grinding wheel or in other words you can say that is a relative motion between the abrasive particle on the metal bonded grinding wheel and the workpiece and as a result of that it is able to remove the material or to grind the workpiece. Now on the back can see here there is a shaft which is connected to the grinding wheel and this shaft is connected to the power supply, brush is there which connects this to supply the or to connected it to the negative terminal of the power supply.

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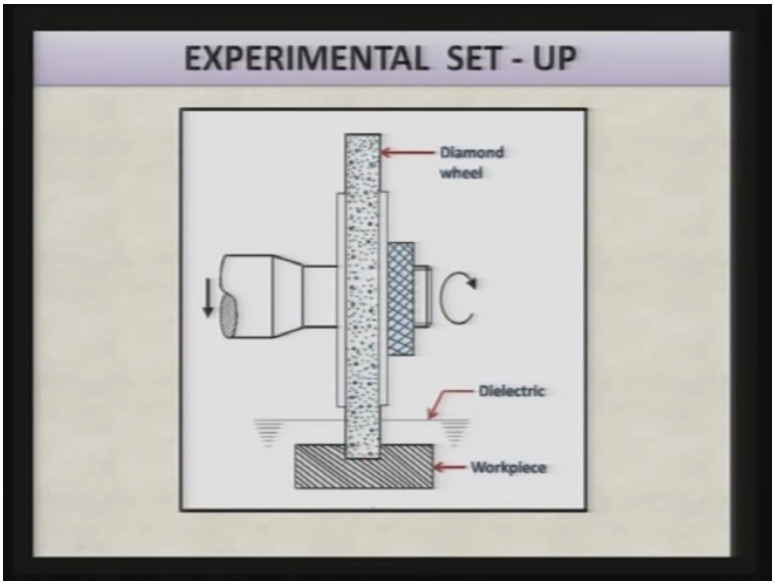

So the grinding wheel setup looks like this that this is the wheel metal bonded grinding wheel or diamond wheel which is rotating and here is the partially the grinding wheel is dipped inside the dielectric and then it is removing the material from the workpiece as you can see here in this particular picture.

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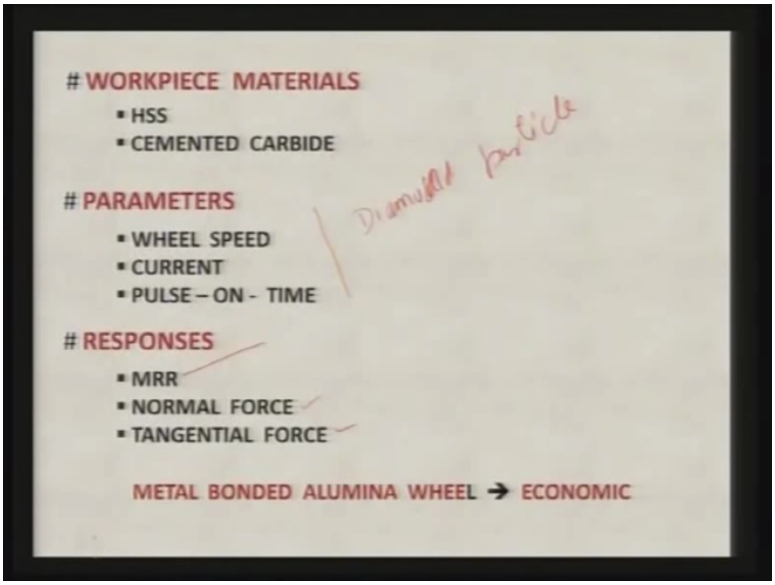

Now workpiece materials can be very hard as we have mentioned earlier also it can be high speed steel, it can be cemented carbide what all these materials should have a certain minimum electrical conductivity, so that they can be a part of electrical circuit, this I had mentioned to you in the earlier lecture. There are various parameters in this particular process as you can see wheel speed is there, current is there, pulse on time is there. I have not

mentioned here other parameters like diamond particles size and then I have also not mentioned the density of the diamond particles on the grinding wheel to some extend bonding materials electrical conductivity or electrical properties will also make a difference in the grinding electric discharge diamond grinding process also which dielectric you are using that will also make the difference and then what is the voltage or the current what is the voltage you using this particular process.

The responses that can be measured to evaluate the performance of this electric discharge diamond grinding are material removal rate, this you can give either in terms of volumetric material removal rate or mass material removal rate. Then the normal force that is acting on the grinding wheel and then there is the tangential force, now this normal force is responsible for penetration, tangential force is responsible for removal of the material from the workpiece, so metal bonded alumina wheels and he more economic than the metal bonded diamond wheels because the cost of the alumina is much lower than the diamond particles, so they can be tried upon for various materials is the workpiece.

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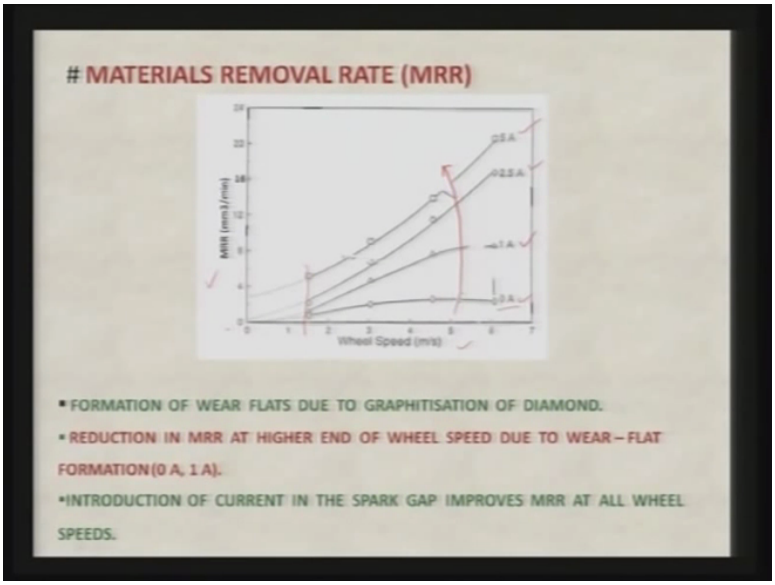

Now some experiments have been conducted by various researchers to find out or to evaluate the performance of the electric discharge diamond grinding process or electric discharge abrasive grinding process. Now here you can see the main parameter is wheel speed that is the RPM of a grinding wheel and here is the volumetric material removal rate in terms of cubic millimetre per minute. Now important thing you can see here is that as the current is increasing the volumetric material removal rate is increasing, here is the 0 current that means it becomes a normal grinding operation with the help of diamond wheel, so you can call it as

diamond grinding where you have the 0 and appear as the current but as you are increasing the current the volumetric material removal rate is also increasing here is the 1 ampere, 2.5 ampere and 5 ampere.

Now apart from that formation of wear flats due to the graphitisation of diamond takes place and then you have reduction in material removal rate at higher end of wheel speed due to wear flats formation as you can see here. Introduction of current in the spark gap improves material removal rate at all wheel speed that we have seen that as the wheel speed is increasing the yes another point is as the wheel speed is increasing a material removal rate is also increasing, so with the increase in the current or the wheel speed, material removal rate is increasing continuously and this is the minimum wheel speed that we use while performing the experiment, so we have extra (())(34:48) this to the material removal rate axis and you can see that with the even with the 0 current you are able to get certain material removal rate.

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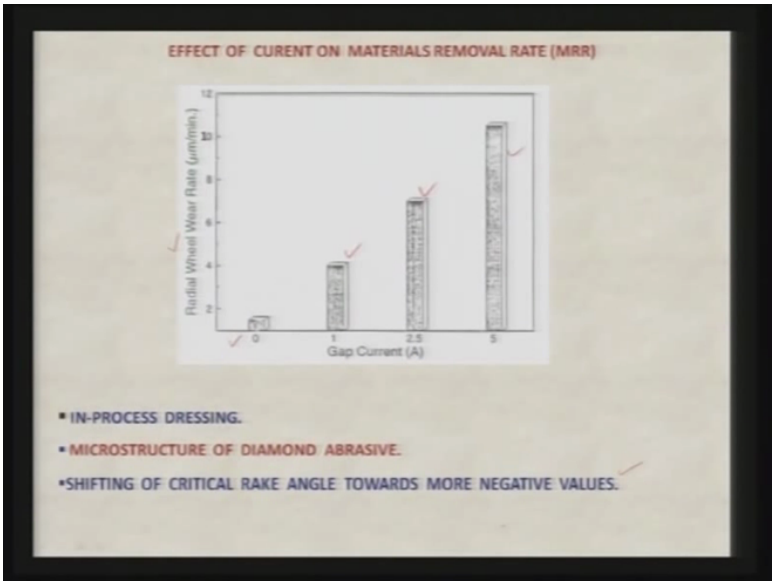

Now effect of current on material removal rate, we can see at 0 current in the gap the material removal rate is very low while as the current is increasing 1 ampere, 2.5 ampere and 5 ampere it is continuously increasing and a radial wheel wear is another important parameter which decides the total wheel life and this should be minimum, so here you can see as the current is increasing the radial wheel wear is also increasing it is in terms of micro-meter per minute. In process dressing is taking place continuously in this particular case, micro structure of diamond abrasive particle, shifting of critical rake angle towards or negative values takes place during this electric discharge diamond grinding.

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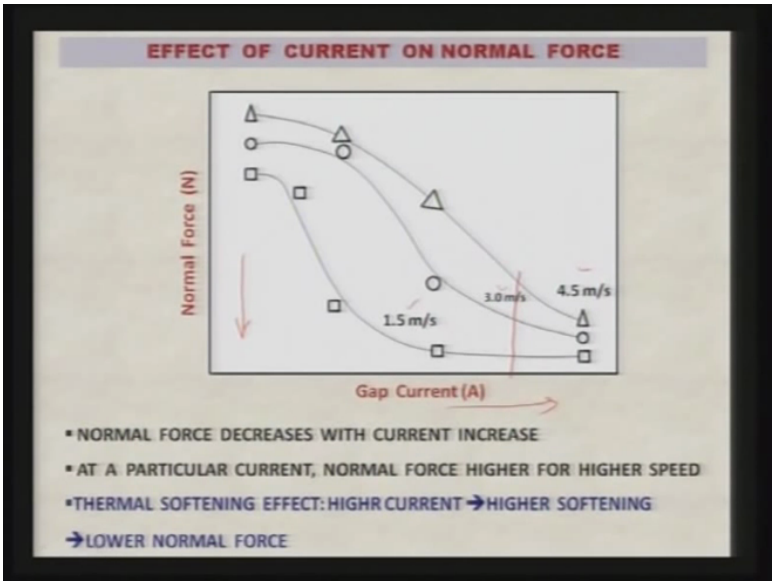

Now let us see the effect of current on normal force, here this picture shows the effect of gap current, interelectrode gap current on the normal force, now as the gap current increases in normal force is decreasing not in a linear way rather in the non-linear way as you can see at different speeds of the table that is 1.5 metre per second, 3 meter per second and 4.5 metre per second. Normal force decreases with the current increases and we can see at a particular current, normal force is higher for higher speed, this is the speed so if you take a particular current as the speed increases also the normal force is increasing.

The reason is very simple that as speed increases then the time for the heat to soften the workpiece is low and if the time for the heat to penetrate inside the workpiece and soften it is low then definitely its hardness will be more and if hardness is more than normal force or penetration of the abrasive particle inside the workpiece will be more, so that is what is very clear over here and as the gap current increases the amount of heat input to the workpiece is more and if the amount of heat input to the workpiece is more then definitely its temperature will be higher and if it has the higher temperature than workpiece will become softer and that is why you can see that as the gap current is increasing the workpiece becomes soft more and more soft and the normal force decreases as you can see over here on any speed. Now thermal softening effect, higher the current higher softening and lower is the normal force which is very obvious over here and also higher the speed of the moment of the table or the workpiece with respect to the spark and higher is the normal force or lower is the softening.

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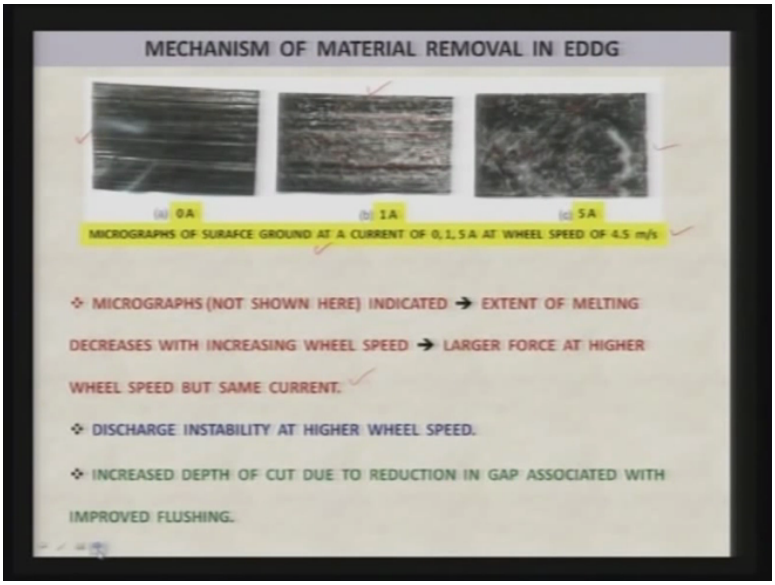

Now let us see here mechanism of material removal in electric discharge diamond grinding, it is very important to know how the material is being removed. Basically we anticipate the 2 things to happen simultaneously, one is the abrasive or abrasion of the workpiece material by the abrasive grinding operation or the diamond grinding operation which is going to produce the chips of irregular shape depending upon the shape of the abrasive particles. There is a significant role of the EDM processes also, now how the material is being removed or what is the mechanism of material removal then both processes are acting simultaneously, so what we did?

We took the micrograph of surface ground at different current that is 0 ampere, 1 ampere and 5 ampere at wheel speed of 4.5 ampere and let us see these features, now if you see the first one where it is A written and 0 ampere they are clearly visible marks of the grinding operation and there is hardly any evidence of sparking in this particular first figure. If we see the second one where one ampere current is being supplied in the interelectrode gap, there are the grinding marks visible as you can say I have marked over here but at the same time if you see carefully there are some marks of the crater, crater formation some kind of very close to spherical crater formation with marks indicates that it is not only grinding rather some EDM process with some extent is also taking place and that is very obvious from this second micrograph.

Now if you go for 3rd micrograph where 5 ampere is current is being supplied in between that grinding wheel and the workpiece, there are very minimal 1 or 2 grinding marks clearly visible over there otherwise rest of it is very clearly visible craters of different sizes as you

can see I have marked some of them were here, so this indicates that major removal of the material at 5 ampere is due to the EDM process. However, grinding is also contributing substantially but they are not visible because frequency of a sparking is quite high and whatever grinding marks that we see in the 1st and 2nd micrographs they become invisible or they get overlapped by the crater formation, so micrograph not shown here indicated.

Extent of melting decreases with increasing wheel speed, I have not shown those micrographs here but we observed it, also larger force at larger higher wheel speed but same current I have already explain in the earlier slide, so it clearly indicates that both the both the mechanism grinding or abrasion as well as EDM process are taking place simultaneously in case of electric discharge diamond grinding. Discharge instability at higher wheel speed takes place, so as wheel speed is keeps increasing the increase in the material removal rate is not linear that is why it is nonlinear because at higher wheel speed in stability comes into picture. Increased depth of cut due to reduction in gap associated with improved flushing.

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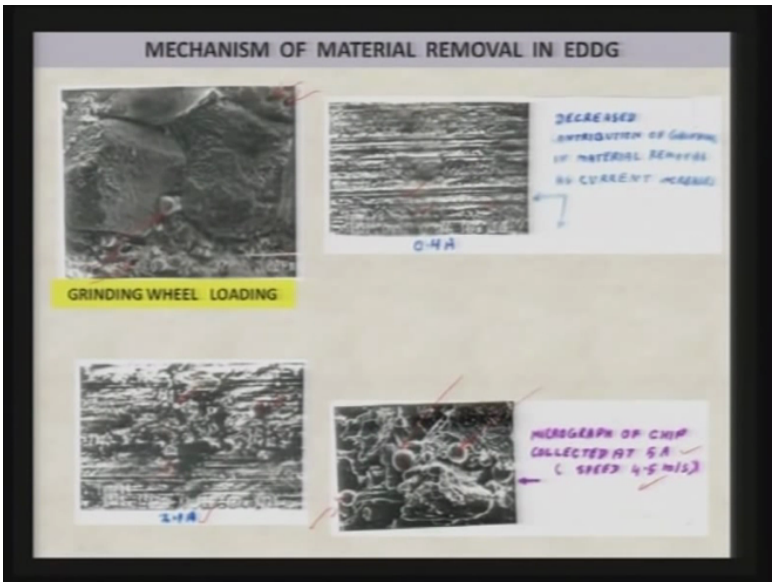

Now I also mentioned that wheel loading or clogging over there, now we try to took take some pictures of the wheel loading and this is the diamond grinding wheel here is shown as the (())(42:17). Now you can clearly see these debris between the abrasive particle and these debris they lead to what is known as wheel loading or clogging of the wheel abrasive particles with the help of the debris. Now another important point to note in this particular figure is this which I am showing by the arrows, these are the craters formed and these craters are formed due to the sparking phenomena taking place between the grinding wheel and the workpiece.

You can clearly see many craters that are visible clearly over here in this picture, so it also indicates that it is not only the grinding operation but EDM operation is continuously taking place. Now you can see here at 0.4 ampere current which is quite low, grinding marks are quite visible but there is a decreased contribution of grinding in material removal as current increases I have shown to you, I will show you again, now these are the grinding marks quite visible but (())(43:21) are at some places you can see the crater also visible over there that indicates that yes sparking is also contributing to the material removal over there. Now at higher current that is 2.1 ampere you can clearly see the crater formation, the removal of the material by the craters.

Now if you see this particular point here it looks like a glovioul and this glovioul or here is there, they indicate that the material is being removed by melting phenomena as well because when material gets melted out and it solidifies then its shape is spherical and that is what you can see over here and they will be more clear and this particular picture you can clearly see the ball kind of the things or glovioul kind of things which clearly indicate that this is at 5 ampere current and 4.5 metre per second speed that mechanism of material removal is melting as well as grinding. Melting evidences are very clearly visible over here and this work has been taken from the paper published by Koshi, Jain and G K Las.

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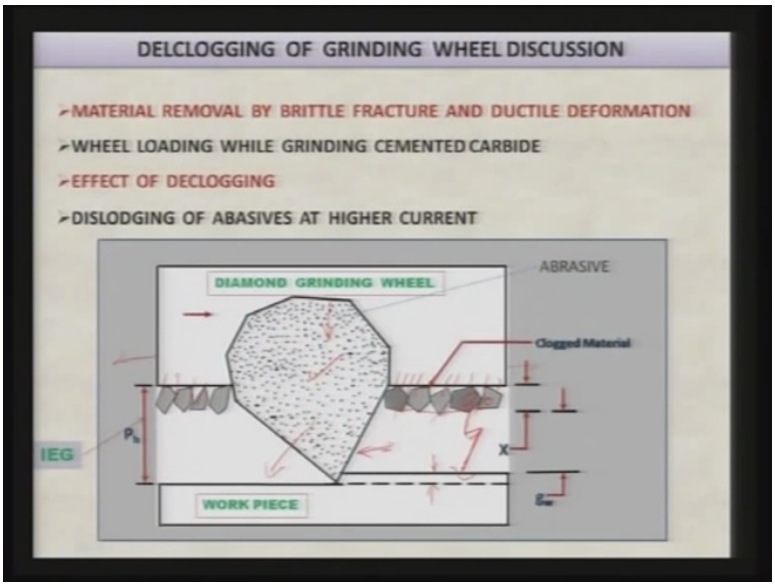

Now declogging of grinding wheel, how does it take place? So that is what we have tried to model it over here, you can see here this is the clogged material which has got deposited between the 2 abrasive particles, there will be another abrasive particle on this side and there will be another abrasive particle the left side. The gap between the bottom phase of the

diamond grinding wheel and top phase of the workpiece where material is being removed that is known as interelectrode gap and this is the height of the cloud material and this is the thickness to which the abrasive particle has penetrated inside the workpiece and when this is moving in this sparking takes place between this metal as well as the workpiece and due to that sparking is clogged material gets removed from the grinding wheel as well as some material is removed from the workpiece as well and it makes the workpiece soft compared to the parent material hardness.

So material removal by brittle fracture and ductile deformation it may take place depends upon the properties of the workpiece material whether it is brittle or ductile. Wheel loading while grinding cemented carbide as been demonstrated here with the help of a schematic model and effect of declogging is dislodging of abrasive at higher current, now as this gets dislodged these clogged material gets dislodged there is a gap between the continuous removal of the material from the grinding wheel also keeps taking place and once this becomes this abrasive particles becomes loosely held by the bonding material due to the force acting in this particular direction as well as normal force acting over here. This gets pulled out of the grinding wheel and you know continuously fresh abrasive particles are projecting on the grinding wheels and they are removing the materials more efficiently rather than worn out material continues removing the material from the workpiece.

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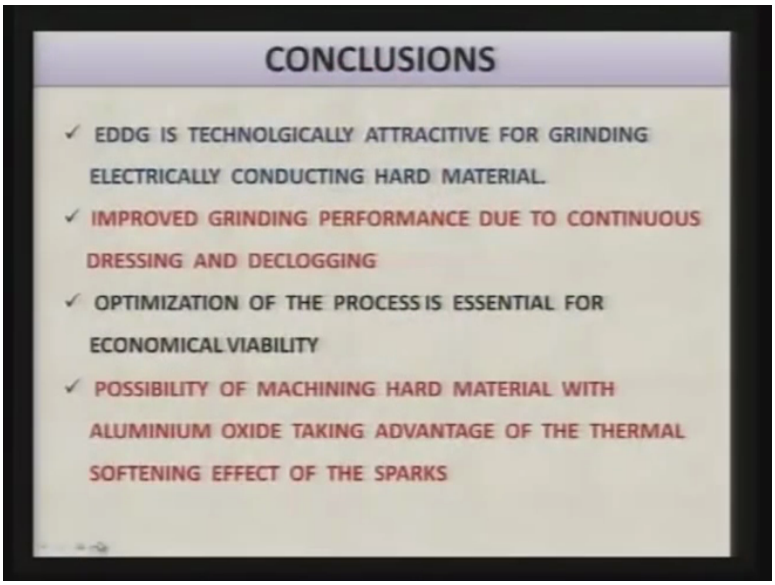

So based on this study certain conclusion have been made, first one is electric discharge diamond grinding is technology attractive for grinding electrically conducting hard materials. The improved grinding performance due to continuous dressing and declogging is obtained.

Optimisation of the process is essential for making this particular electric discharge diamond grinding or electric discharge abrasive grinding as economically viable and it is possible the possibility of machining hard materials with aluminium oxide is (())(47:51) because when the workpiece material is becoming soft then the aluminium oxide although not very hard, this can also remove the material for grinding purposes and advantages of the thermal softening effect due to the sparking can be taken because aluminium grinding wheels are much cheaper compared to the diamond grinding wheels. Thank you very much.