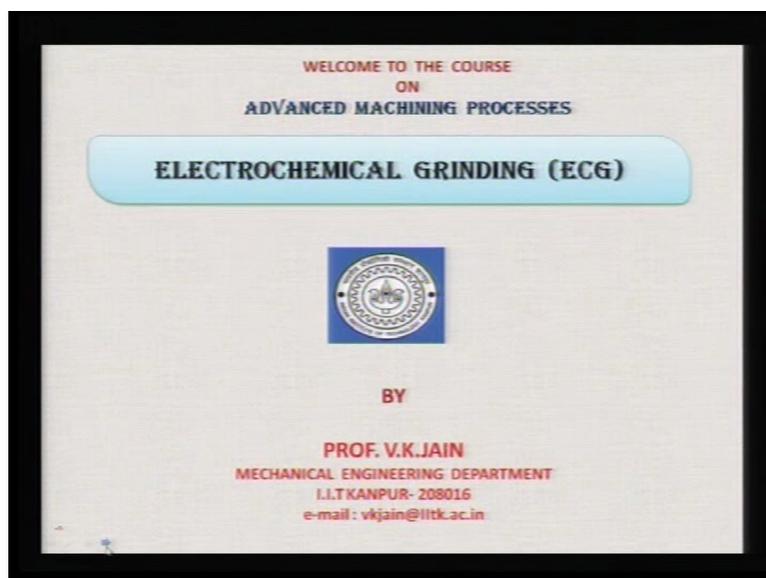


Advanced Machining Processes
Professor Vijay K Jain
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Indian Institute of Technology Kanpur
Lecture 21
Electrochemical Grinding (ECG)

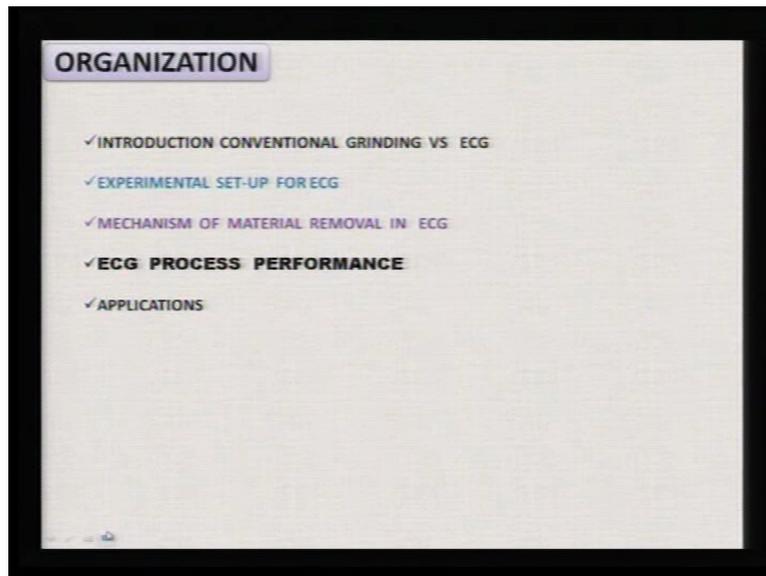
Welcome to the course on advanced machining processes. Today I am going to discuss about electrochemical grinding. This is an allied process to electrochemical machining and also named as hybrid process.

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The organization of the stock is as follows. Introduction to conventional grinding versus electrochemical grinding, experimental setup for electrochemical grinding, mechanism of material removal in electrochemical grinding, electrochemical grinding process performance and applications.

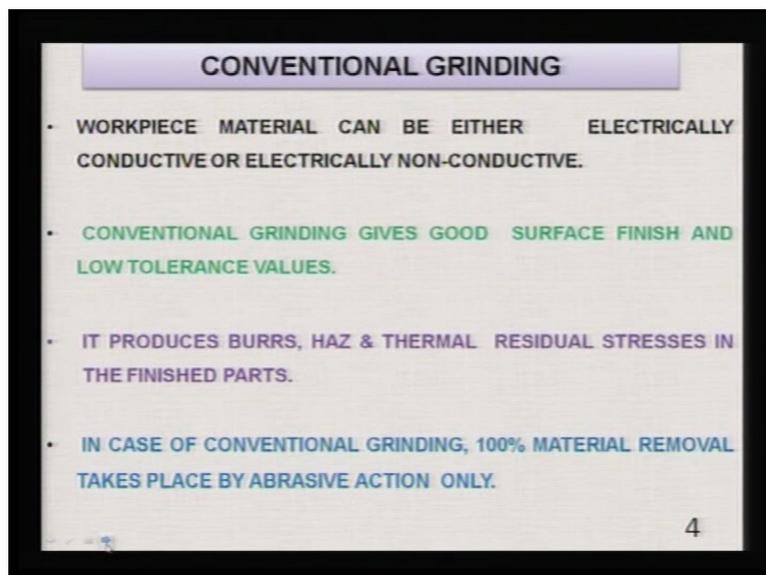
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After that I will discuss one numerical example also. Introduction to conventional grinding versus electrochemical grinding. In conventional grinding as we all know workpiece material can be either electrically conductive or electrically non-conductive. That condition is not required that workpiece should be electrically conductive. Conventional grinding gives good surface finish and low tolerance values.

It produces burrs, heat affected zone HAZ and thermal residual stresses in the finished parts and definitely finishing rate is okay. In case of conventional grinding 100 percent material removal takes place by abrasive action only.

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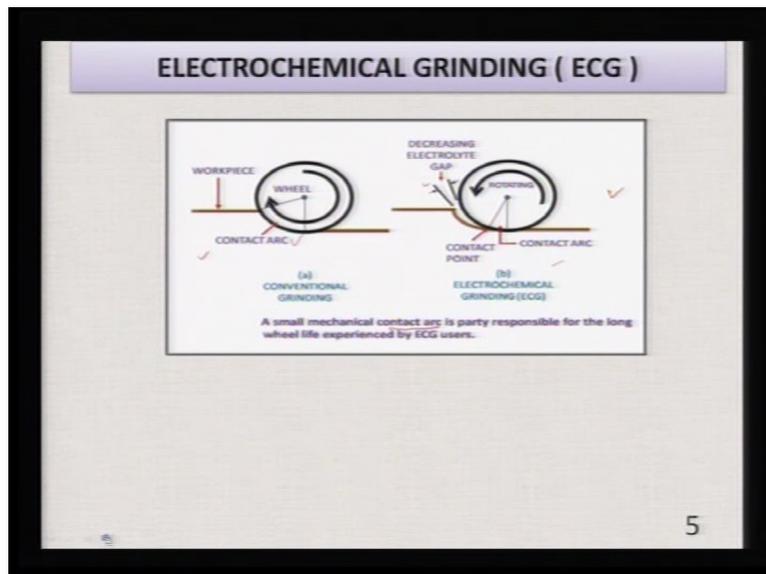


In case of electrochemical grinding as you will see in this particular figure on the left side conventional grinding is shown where you can see rotation of the wheel, workpiece, depth of cut is shown there. While on the right side if you see the figure is showing electrochemical grinding where you can see that decreasing electrolyte gap is there. Here you are supplying the electrolyte through this nozzle kind of arrangement and electrochemical dissolution takes place as well as grinding takes place.

So both the reactions keep going on simultaneously. We will discuss that shortly. A small mechanical contact arc is partly responsible for long wheel life experienced by electrochemical grinding users. That means in electrochemical grinding the life of the grinding wheel is much larger than the life in the case of conventional grinding.

You can see here that the contact arc is much larger in case of conventional grinding as compared to the electrical grinding. That is why the grinding wheel life is much larger in case of electrochemical grinding compared to conventional grinding.

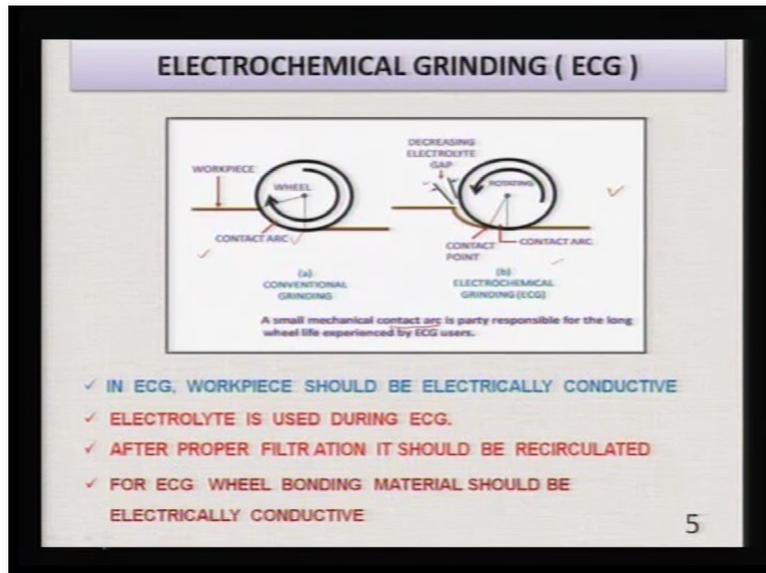
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In ECG, workpiece should be electrically conductive. This is the first basic requirement because as I will show the workpiece is made as cathode. Exactly say as in case of electrochemical machining. Sorry workpiece is made anode, not the cathode and grinding wheel is made as the cathode. So both grinding wheel as well as workpiece should be electrically conductive. Electrolyte is used during electrochemical grinding and this is being supplied with the help of the nozzle as shown in the right hand side on the figure.

After proper filtration the electrolyte can be reused or recirculated as we do in case of electrochemical machining. For electrochemical grinding wheel bonding material should be electrically conductive as I just mentioned that it is made as cathode, so the material should be electrically conductive and it forms (elec) a part of the electrical circuit of electrochemical grinding process.

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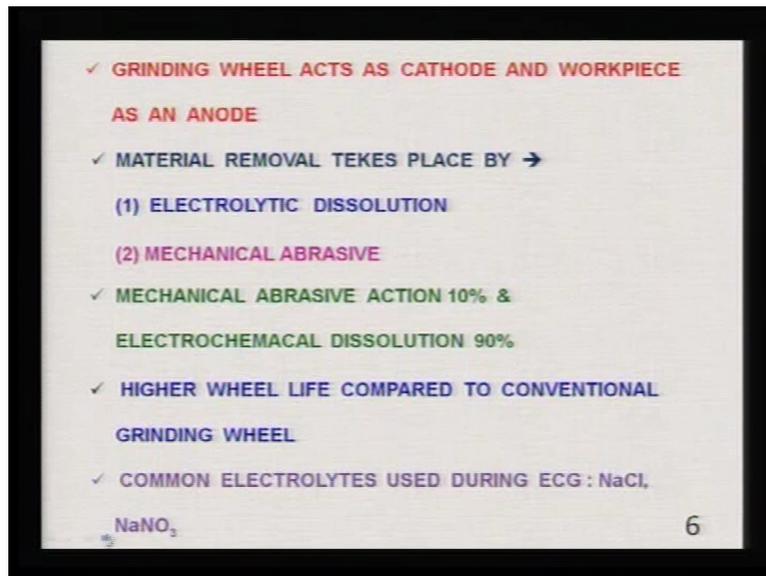


Grinding wheel acts as a cathode and workpiece acts as an anode. Here it is very similar or same as in case of electrochemical machining where workpiece is made as anode and tool is made as cathode. So here grinding will act as a tool. Material removal takes place by electrolytic dissolution, mechanical abrasion by abrasive particles. They are part of the electrochemical grinding wheel.

It is found experimentally that mechanical abrasive action is around 10 percent of the total material removal while remaining 90 percent is due to the electrochemical dissolution or as in case of ECM where 100 percent removal of the material is due to electrochemical dissolution only. Higher wheel life is obtained in case of electrochemical grinding as compared to conventional grinding wheel life.

Common electrolytes used during electrochemical grinding are as same as used in electrochemical machining. They are something like sodium chloride, sodium nitrate and others can also be used depending upon the combination of tool and workpiece material.

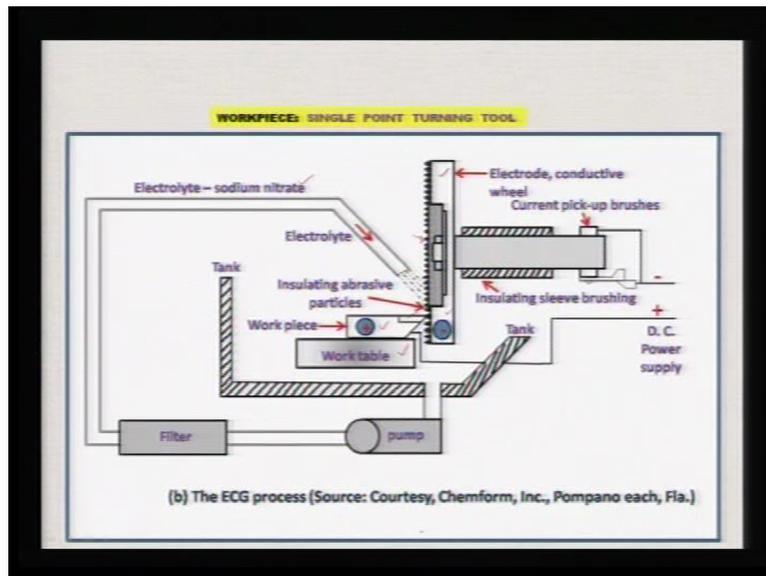
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Let us see the experimental setup of electrochemical grinding process. Now here various features of any electrochemical grinding set up are shown as you will see here is the electrode, that is the cathode, conductive wheel or grinding wheel that acts as the cathode and you can clearly see the protruding abrasive particles which contributes the abrasive action in the removal of the material. And here you can see the electrolyte is used as sodium nitrate as the electrolyte. It is being supplied at the inter electrode gap.

Here is the workpiece which is to be ground and there is a single point turning tool as a workpiece. Now it is made as anode shown over there and the grinding wheel is made as cathode that is shown here. And it is connected to the negative terminal of the power supply while workpiece is connected to the positive terminal of the power supply. Workpiece is held on the work table and work table part of the grinding wheel they are in the machining area or the tank where you have the electrolyte.

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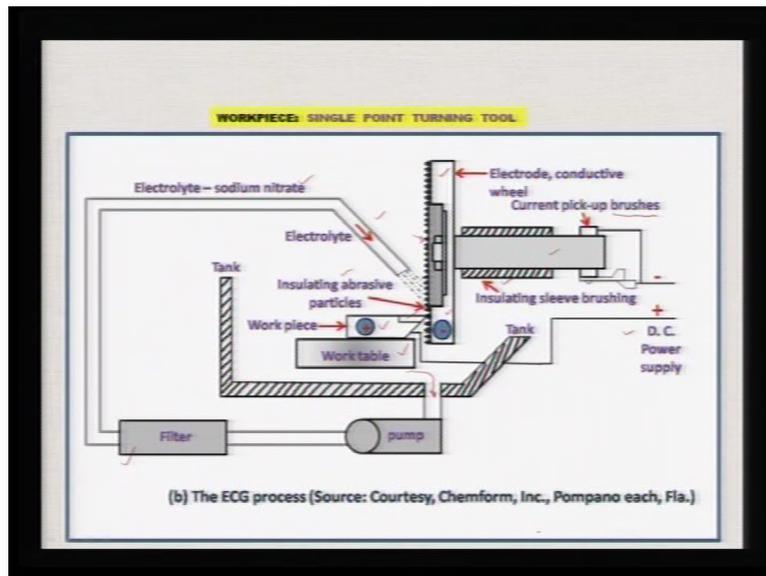


Now here abrasive particles are written as insulating abrasive particles. All these abrasive particles alumina, silicon carbide, etc. they are electrically non-conductive. So therefore ascertain minimum gap which does not permit the short circuit by contacting the tool and the bonding material of the grinding wheel.

Now for supplying the current to the cathode here you can see insulating sleeve brushing is there so that you know this shaft or its fennel on which the grinding wheel is mounted is not getting in contact with other parts of the machine tool and the current is being supplied to this (())(08:51) through the brushes as written over here. This is the current pick-up brushes which are connected to this and then that brushes connected the negative terminal of the power supply and positive terminal of the power supply is connected to the work table as you can see over here.

Now tank which is also the machining zone or machining area where electrochemical grinding is taking place, the electrolyte is supplied here with the help of the nozzle between the tool that is the grinding wheel and the workpiece. Now this electrolyte after being used comes out and with the help of the pump it is recirculated. But before recirculation it has to be properly filtered or cleaned. So various sizes of the filters can be used to clearly clean the electrolyte before recirculation.

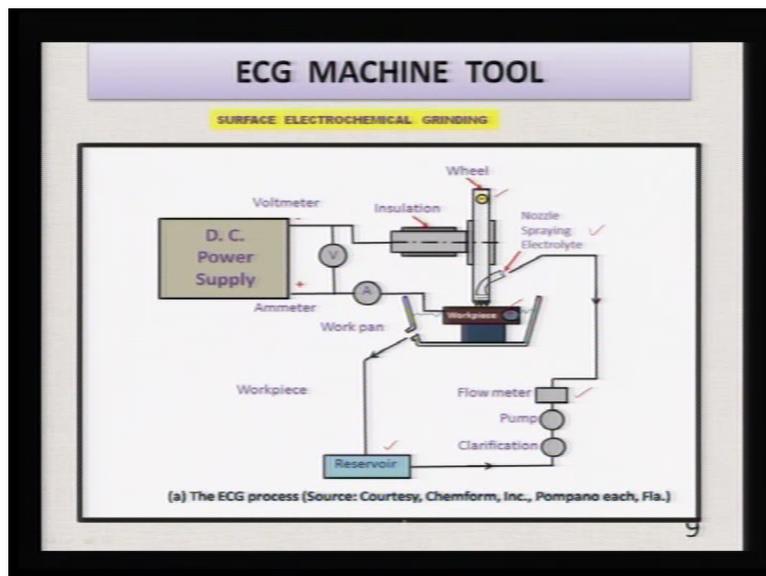
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Now this process and setup is for surface grinding while earlier one we have just seen was for face grinding. Now in surface grinding set up again remains the same except that the larger area in this particular case of the workpiece is in contact with the grinding wheel because in the earlier case it was a single point turning tool which was being finished. So smaller area was in contact with the grinding wheel. Otherwise normally inelectrochemical face grinding much larger area or the workpiece is being ground.

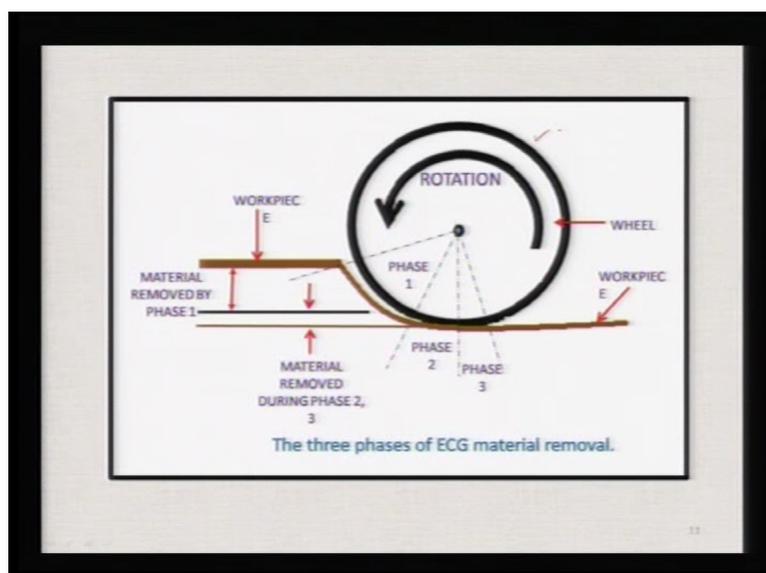
Now here you can clearly see workpiece is connected to the positive terminal, grinding wheel is connected to the negative terminal, nozzles used for spraying the electrolyte in between the workpiece and the grinding wheel. Now you can see here flowmeter is also added to thehydraulic circuit so that you can easily measure the rate of the flow of the electrolyte. And here reservoir is there which is storing the electrolyte before it is recirculated. And here you will have the filter also.

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Now let us discuss briefly the mechanism of material removal in case of electrochemical grinding. This electrochemical grinding is a hybrid process as I have already mentioned to you in couple of lectures where we have combined electrochemical machining and grinding both the processes. You can clearly see here to understand the mechanism of material removal in this hybrid process that is electrochemical grinding. This is the grinding wheel which is rotating.

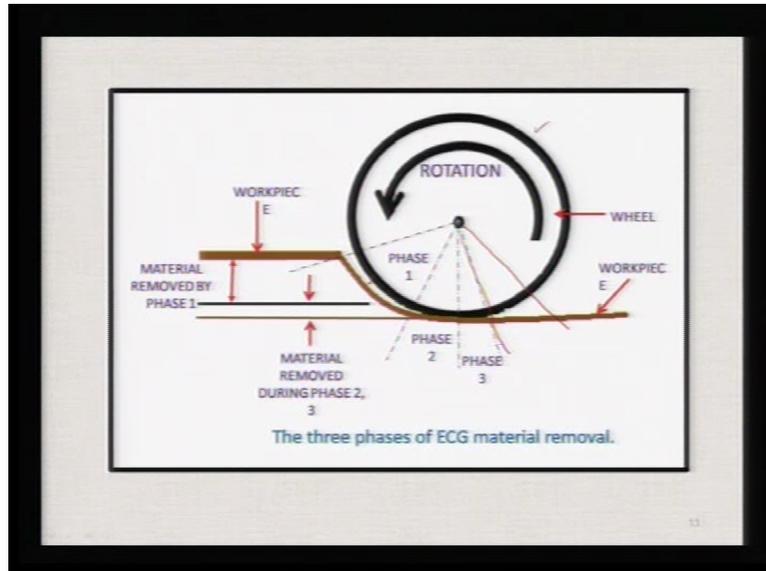
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Now whole working zone or grinding zone has been divided into three different zones or phases as shown over here. In this particular phase 1, no abrasive action is taking place because abrasive particles are not in contact with the workpiece. But in phase 2 or zone 2 as

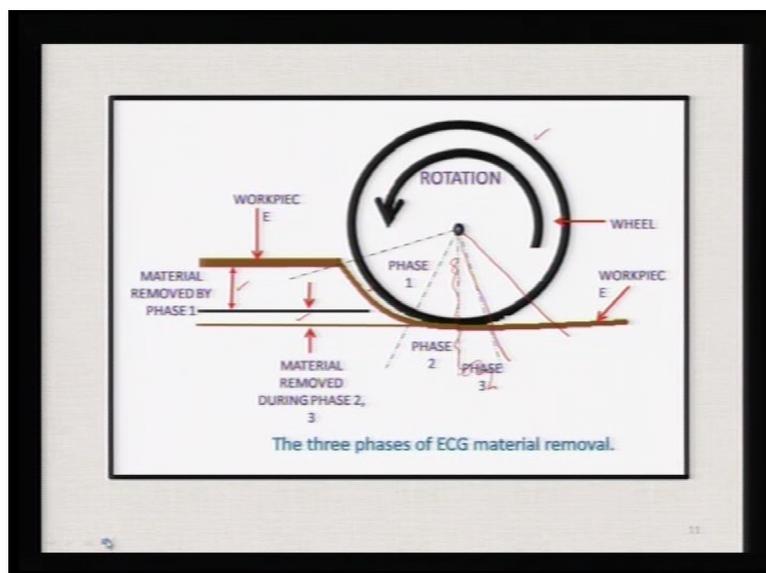
mentioned later, the abrasive particles are in contact with the workpiece surface and material is being removed by abrasive action as well as electrochemical dissolution. In phase 3 it should be really starting from here to somewhere here.

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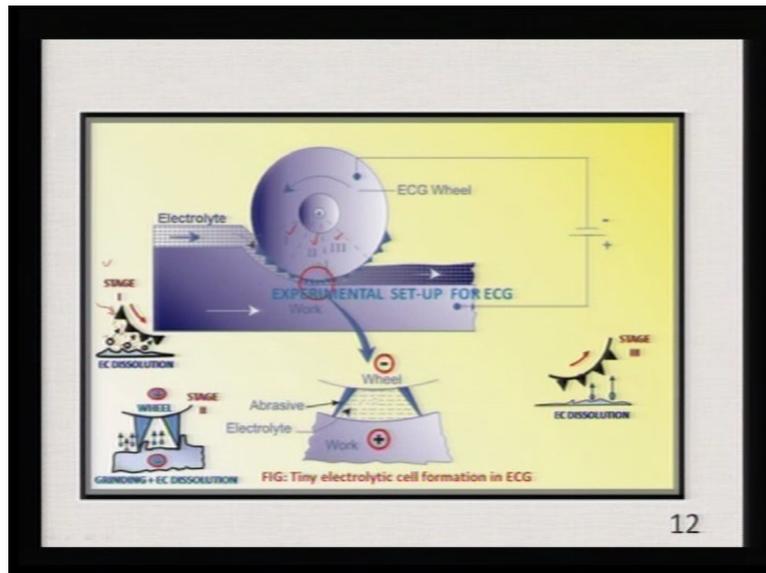
This is not very right and this will form a part of the phase 2 itself. And phase 3 the wheel has lifted over the workpiece surface and whatever burrs, etc. are formed they are being removed. We will discuss it. Now important thing here is to see that the material removed in phase 1 or zone 1 is shown over here. In this particular zone 1 material is being removed by the electrochemical dissolution. In zone 2 material is being removed by both the processes, electrochemical dissolution as well as abrasive action.

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Now this clearly gives the picture what I have mentioned in just the earlier slide that three zones are there, zone 1, zone 2, zone 3. Now if you see on the left side top stage 1 these are the abrasive particles which are shown in triangular in shape in black in color and between the abrasive particle and the workpiece electrolyte is there and grinding wheel is connected to the negative terminal and workpiece is connected to the positive terminal.

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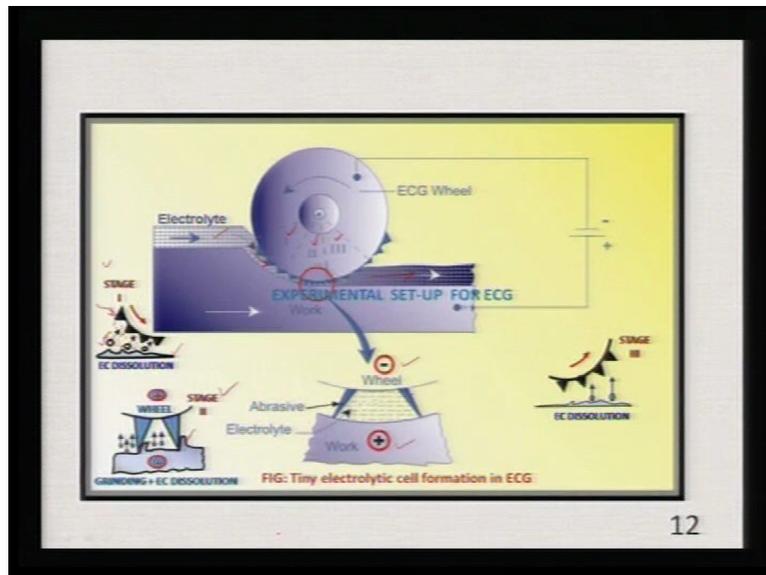
So electrochemical dissolution takes place of the material from the workpiece surface as that is shown here with the arrows that material being taken away from the workpiece surface and hills and valleys are being formed over there. And so in stage 1 or zone 1 material is being removed due to the electrochemical dissolution only. Now electrolyte is clearly shown over here certainly layer. It is entering from this side and going out from this side. Now in zone 2 see here stage 2 shown over here, wheel is connected to the negative terminal.

I mentioned workpiece is connected to the positive terminal and they are two abrasive particles shown over here in the zone view. And you can clearly see the electrolyte is there between the two abrasive particles. And since there is a negative terminal grinding wheel, positive terminal workpiece and electrolyte between the two, so it forms a (mi) tiny electrolytic cells.

And that if you see just on the left side that abrasive particles are removing the material in the form of the micro-chips as you can clearly see here but material is also being removed by electrolytic dissolution and that is shown by these arrows. And the material is taken away

from the workpiece by electrolytic dissolution. So it is clear that material is removed by both the processes, abrasive action as well as electrolytic dissolution in zone 2.

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But in zone 3 as you see in the right side (mat) there is no contact between the abrasive particle and the workpiece surface. There is only electrolytic dissolution. So material is being removed only due to the electrolytic dissolution in zone 3. There is no abrasive action. Same thing is described in the following slides. ECG has three distinct zones as I have shown to you and zone 1, pure electrochemical dissolution takes place as you can see here also in the figure that electrochemical dissolution is taking place in the zone 1.

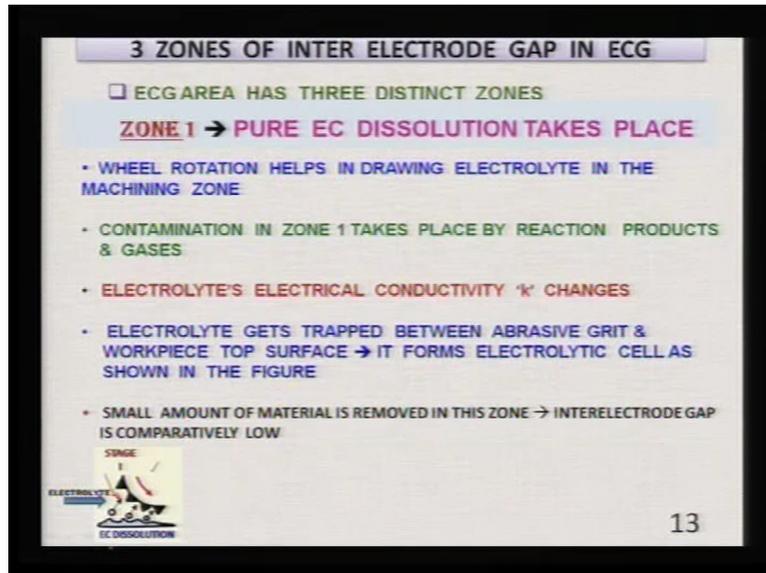
No abrasive contact with the workpiece is there. Wheel rotation helps in drawing the electrolyte in the machining zone because wheel is rotating in this direction as shown by arrow. So electrolyte will be drawn in the gap between the wheel and the workpiece apart from whatever is the pressure at which it is being supplied.

Then contamination in zone 1 takes place by reaction products and gases because electrochemical reaction is taking place. So ferrous hydroxide or ferric hydroxide will be formed if iron is being machined. Then this ferrous hydroxide or ferric hydroxide along with the gases that are evolved because we know that at the anode oxygen gases evolve while at the cathode hydrogen gases evolve. All these gases along with the reaction products they will move forward in the zone 2.

Then electrolytes electrical conductivity k will change because apart from the pure electrolyte it now has reaction products as well as the gases. And control is very difficult as long as

control of electrical conductivity of the electrolyte is concerned. Electrolyte gets trapped between abrasive grit and workpiece top surface and it forms electrolytic cell as shown in the figure. Small amount of material is removed in this zone and interelectrode gap is comparatively low.

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In zone 2 higher pressure exists due to converging gap between wheel and workpiece. It suppresses formation of gas, bubbles and higher k hence higher MRR because size of the gas bubbles is decreased. So definitely comparatively the k increases as compared to the zone 1 and secondly some reaction products are added. They also change the electrical conductivity of the electrolyte. In this zone 2 abrasive grains abrade the workpiece surface as you can see here in the figure.

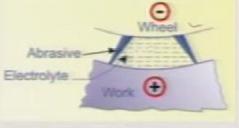
As a result they remove material from workpiece and oxide layer is formed if any on the workpiece surface. Material is removed in the form of the microchips due to the abrasive action and reaction products are formed due to the electrochemical dissolution. Oxide layer removal helps in electrochemical dissolution.

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ZONE 2 →

- IN THIS ZONE, HIGHER PRESSURE EXISTS DUE TO CONVERGING GAP BETWEEN WHEEL & WORKPIECE. IT SUPPRESSES FORMATION OF GAS BUBBLES → HIGHER 'k' HENCE HIGHER MRR.
- IN THIS ZONE, ABRASIVE GRAINS ABRASIVE THE WORKPIECE SURFACE. AS A RESULT THEY REMOVE MATERIAL FROM WORKPIECE AND OXIDE LAYER IS FORMED, IF ANY, ON THE WORKPIECE SURFACE.
- MATERIAL IS REMOVED IN THE FORM OF MICROCHIPS
- OXIDE LAYER REMOVAL HELPS IN EC DISSOLUTION

*MATERIAL REMOVAL ALSO TAKES PLACE DUE TO EC DISSOLUTION IN THE ELECTROLYTIC CELL AS DISCUSSED IN THE FOLLOWING SLIDE ALSO.

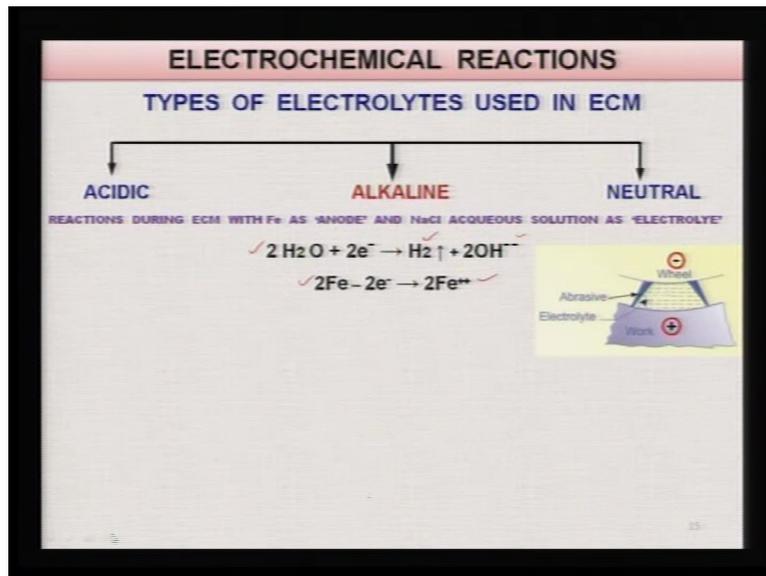


The diagram illustrates the Zone 2 setup in electrochemical machining. It shows a 'Wheel' at the top, which is the cathode (indicated by a minus sign). Below it is the 'Work' piece, which is the anode (indicated by a plus sign). The space between them is filled with 'Abrasive' grains and 'Electrolyte'. Arrows indicate the flow of material from the workpiece to the wheel, representing the removal of microchips.

Now here whatever oxide layer was formed in zone 1 that is removed due to the abrasive action of the abrasive particles so that rate of electrochemical dissolution increases. Material removal also takes place due to electrochemical dissolution in electrolytic cell as discussed in the following slide also. Types of electrolytes used in ECM. You can use acidic electrolyte, alkaline electrolyte, neutral electrolyte that all these electrolytes we have discussed while discussing the electrochemical machining process.

Reactions during electrochemical machining while iron as anode and NaCl aqueous solution as electrolyte is used. What happens electrolysis takes place on water and once electrolysis takes place you get hydrogen gas which is evolved as a cathode and you get the hydroxyl ions twice OH and when iron is as the workplace then you get the ferrous ions that detach from the workpiece. They have the positive charge and electrons are also detached.

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Then ferrous ions and hydroxyl ions they react with each other and they form what is known as ferrous hydroxide. In some cases under certain conditions in place of ferrous hydroxide, ferric hydroxide can also be formed. Now this ferrous hydroxide and ferric hydroxide they are insoluble in water so they remain as such or as reaction products in the electrolyte and positive ions convert as hydroxides ferrous or ferric in case of iron as anode or work material.

Now in this particular case as you can see here interelectrode gap is quite low and it depends upon what is the projection of the abrasive particle out of the grinding wheel and normally it is quite less than 1 millimeter. The voltage applied is in the range of 8 to 20 volts. Now we can clearly see from these reactions that no electrolyte is being consumed in the electrochemical grinding process.

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ELECTROCHEMICAL REACTIONS
TYPES OF ELECTROLYTES USED IN ECM

ACIDIC ALKALINE NEUTRAL

REACTIONS DURING ECM WITH Fe AS 'ANODE' AND NaCl AQUEOUS SOLUTION AS 'ELECTROLYTE'

$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 \uparrow + 2\text{OH}^-$
 $2\text{Fe} - 2\text{e}^- \rightarrow 2\text{Fe}^{++}$
 $\text{Fe}^{++} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2$
 $2\text{Fe} + 4\text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_3$



Fe(OH)₂, Fe(OH)₃ → INSOLUBLE IN WATER
POSITIVE IONS CONVERT AS HYDROXIDES (FERROUS OR FERRIC IN CASE OF IRON AS ANODE / WORK MATERIAL)
IEG < 1 mm, VOLTAGE → 8-20 V

NO ELECTROLYTE IS BEING CONSUMED IN THE ECM PROCESS

And this was true in case of electrochemical machining. In zone 3 there is no contact again between abrasive grain and workpiece surface. As you can see here this is the workpiece surface and this is the abrasive grain and there is no contact between the two. Wheel starts lifting off the work surface that is why you can see the interelectrode gap is continuously increasing in the direction of the arrow I have just made.

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ZONE 3 →

□ **IN THIS ZONE, THERE IS NO CONTACT BETWEEN ABRASIVE GRAIN AND WORKPIECE SURFACE. WHEEL STARTS LIFTING OFF THE WORK SURFACE.**



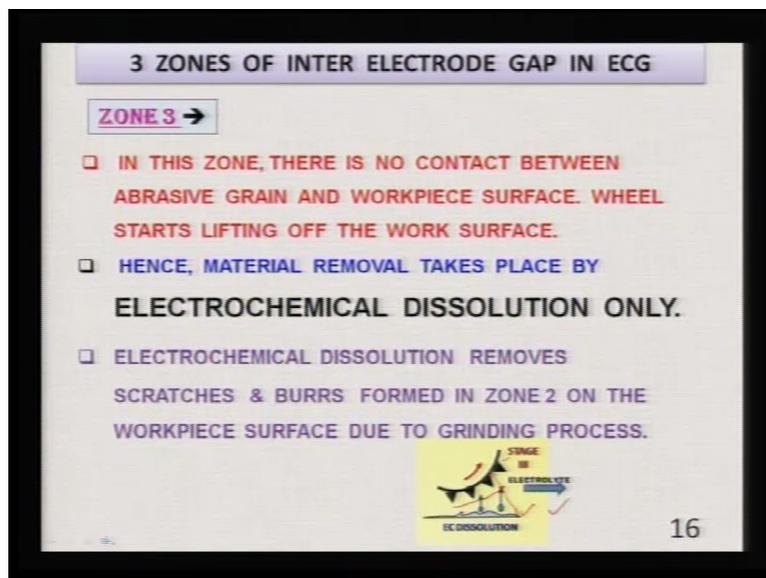
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Hence material removal takes place by electrochemical dissolution only because there is no physical contact between abrasive particle and the workpiece so no abrasive action is taking place. And secondly the rate of electrochemical dissolution or amount of material removed will keep decreasing because the interelectrode gap is continuously increasing in the direction

of the flow of the electrolyte. Electrochemical dissolution removes scratches and burrs formed in zone 2 on the workpiece surface due to grinding process.

We have seen in the last one slide that material was removed by abrasive particles from the workpiece surface and that was a grinding process and due to grinding burrs are formed and scratches are formed on the workpiece surface. And these scratches and burrs are removed in the zone 3 that is shown over here. So you get burr free surface and scratch free surface after zone 3 in case of electrochemical grinding. So this is an additional advantage of electrochemical grinding over the conventional grinding process.

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Now electrochemical process performance. Material removal rate and surface finish are governed by current density as in case of electrochemical machining because as I have mentioned 90 percent of the total material removed in electrochemical grinding is due to the electrochemical dissolution. That means current density is going to cover the material removal rate.

Very high voltage across the electrodes would lead to sparking so we should not use very high voltage between the two electrode that is the grinding wheel and the workpiece otherwise sparking will take place and this sparking will damage the grinding wheel as well as the workpiece both and it is undesirable and it will deteriorate the surface finish also.

In case of electrochemical grinding it should be ECG not EGC, MRR can be as high as 10 times of conventional grinding on hard materials and the hardness greater than 65 HRC can be

machined by this one. And 10 times greater MRR is a very high value compared to conventional grinding. So this is an additional advantage of electrochemical grinding.

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PROCESS CHARACTERISTICS

- MATERIAL REMOVAL RATE (MRR) AND SURFACE FINISH (SF) ARE GOVERNED BY CURRENT DENSITY
- VERY HIGH VOLTAGE ACROSS THE ELECTRODES WOULD LEAD TO SPARKING WHICH DETERIORATES SURFACE FINISH & DAMAGES GRINDING WHEEL AS WELL AS WORKPIECE
- IN EGC ^{EGC} MRR CAN BE AS HIGH AS 10 TIMES OF CONVENTIONAL GRINDING ON HARD MATERIALS (HARDNESS > 65 HRC)

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Now we have to control the machining conditions appropriately in case of electrochemical grinding also and feed rate is one of the important finishing or machining conditions. If feed rate that can be calculated from the formula given in the theory of electrochemical machining, if a feed rate is higher than the required feed rate then the abrasives detach prematurely due to higher depth of cut which lead to excessive grinding wheel wear and this will give you low wheel life and higher cost.

Because if feed rate is higher, see this is the grinding wheel and this is the workpiece and if the feed rate is higher then what will happen that the abrasive particles will penetrate more inside the workpiece and due to the larger forces some of the abrasive particle will fracture or they will detach from the grinding wheel prematurely.

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MACHINING CONDITIONS

FEED RATE

> IF FEED RATE (CAN BE CALCULATED FROM THE FORMULA GIVEN IN THEORY OF ECM) IS HIGHER THAN THE REQUIRED → ABRASIVES DETACH PREMATURELY (DUE TO HIGHER DEPTH OF CUT) WHICH LEAD TO EXCESSIVE GRINDING WHEEL WEAR → LOW WHEEL LIFE AND HIGHER COST

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As a result of that the life of the grinding wheel will go down and definitely the cost of electrochemical grinding will increase. If feed rate is lower than the required one then what will happen? If the feed rate is lower than the required one then the interelectrode gap will increase. That means this gap will increase.

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MACHINING CONDITIONS

FEED RATE

> IF FEED RATE (CAN BE CALCULATED FROM THE FORMULA GIVEN IN THEORY OF ECM) IS HIGHER THAN THE REQUIRED → ABRASIVES DETACH PREMATURELY (DUE TO HIGHER DEPTH OF CUT) WHICH LEAD TO EXCESSIVE GRINDING WHEEL WEAR → LOW WHEEL LIFE AND HIGHER COST

> IF FEED RATE IS LOWER THAN THE REQUIRED ONE → IT WILL LEAD TO

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And if this gap is more than really the required one then you will get larger overcut that is the poor tolerances and you will also get poor surface finish and both are undesirable features. And wheels peripheral speed normally is 20 to 30 meter per second in case of electrochemical grinding.

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MACHINING CONDITIONS

- FEED RATE**
 - > IF FEED RATE (CAN BE CALCULATED FROM THE FORMULA GIVEN IN THEORY OF ECM) IS HIGHER THAN THE REQUIRED → ABRASIVES DETACH PREMATURELY (DUE TO HIGHER DEPTH OF CUT) WHICH LEAD TO EXCESSIVE GRINDING WHEEL WEAR → **LOW WHEEL LIFE AND HIGHER COST**
 - > IF FEED RATE IS LOWER THAN THE REQUIRED ONE → IT WILL LEAD TO
 - LARGE OVERCUT (POOR TOLERANCES)
 - **POOR SURFACE FINISH**
- WHEEL'S PERIPHERAL (OR SURFACE) SPEED → 20 – 30 m/s**

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Process performance continues, the best tolerances that can be obtained by this electrochemical grinding process are within plus minus 25 micron or more. Outside corner radius that can be achieved by electrochemical grinding is greater than or equal to point 25 millimeter that is 250 micron. Inside corner radius that can be achieved is again the same that is greater than or equal to point 25 millimeter. Surface roughness that can be obtained is approximately point 1 to point 8 micron.

It lie in this particular range. Surface obtained after electrochemical grinding is free of scratches. That I have already explained in the earlier slide because burrs and scratches get dissolved in zone 3 of electrochemical grinding process by electrochemical dissolution. Reduced risk of thermal damage because the workpiece is in contact with water during electrochemical grinding.

Because during electrochemical grinding workpiece is always in contact with the electrolyte and that is nothing but the (sol) solution of electrolyte, maybe sodium chloride, sodium nitrate or other in water and water is a very good coolant. So the temperature of the workpiece does not rise to a large extent that is why there is hardly any thermal damages risk in case of electrochemical grinding. ECG machine tool is more expensive compared to normal grinding machine.

But due to much higher material removal rate per unit volume, removal is cheaper. Hence electrochemical grinding process is cheaper than conventional grinding especially in case of

grinding of very hard materials. Cost of electrochemical grinding is less than cost of conventional grinding.

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PROCESS PERFORMANCE

- THE BEST TOLERANCES OBTAINED BY THIS PROCESS → $\pm 25 \mu\text{m}$ OR MORE
- OUTSIDE CORNER RADIUS THAT CAN BE ACHIEVED $\geq 0.25 \text{ mm}$
- INSIDE CORNER RADIUS $\geq 0.25 \text{ mm}$
- SURFACE ROUGHNESS THAT CAN BE OBTAINED = $0.12 - 0.8 \mu\text{m}$
- SURFACE OBTAINED AFTER ECG IS **FREE OF BURRS & SCRATCHES** →
BECAUSE BURRS AND SCRATCHES GET DISSOLVED IN ZONE - 3 BY ELECTROCHEMICAL DISSOLUTION
- REDUCED RISK OF THERMAL DAMAGE BECAUSE THE WORK SURFACE IS IN CONTACT WITH WATER DURING ECG.
- COST OF ECG < COST OF CONVENTIONAL GRINDING

ECG MACHINE TOOL IS MORE EXPENSIVE BUT DUE TO MUCH HIGHER MRR PER UNIT VOLUME REMOVAL IS CHEAPER.

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Electrochemical grinding machining chamber is made of non-corrosive material or it should be made of non-corrosive and electrically non-conductive material. Second point, power supply to the grinding wheel is given with the help of the brushes as I have shown you in the earlier slide of the setup. However in some cases you can use mercury coupling that can carry more current compared to the brushes but it depends upon the designer.

Low probability of sparking in case of electrochemical grinding because abrasive grains always maintain a minimum gap between workpiece and wheel bonding material. As you can see here this is the abrasive. So (wor) depending upon the magnitude of the projection of an abrasive particle outside the grinding wheel that decide the interelectrode gap more or less. And since that gap is always there so probability of sparking between the wheel and the workpiece are minimized.

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PROCESS PERFORMANCE

- **MACHINING CHAMBER IS MADE OF NON-CORROSIVE AND ELECTRICALLY NON-CONDUCTIVE MATERIAL**
- **POWER SUPPLY TO THE GRINDING WHEEL IS GIVEN**

BRUSHES ↔ **MERCURY COUPLING (CAN CARRY MORE CURRENT)**

- **LOW PROBABILITY OF SPARKING : ABRASIVE GRAINS ALWAYS MAINTAIN A MINIMUM GAP BETWEEN WORKPIECE AND WHEEL BONDING MATERIAL**



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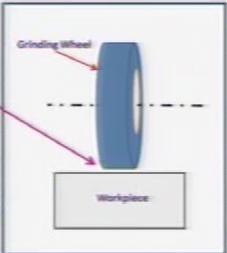
Types of ECG operation is electrochemical grinding. Various types of electrochemical grinding operations can be performed. They may be cylindrical grinding, form grinding, surface grinding, face grinding and internal grinding. You can see hear clearly this is the surface grinding operation some setup is shown. Surface grinding, it is slow because of small area of contact between workpiece and the grinding wheel as you can see here.

Here it is the line contact theoretically so the total area in contact of the grinding wheel is very small. Hence material removal rate and finishing rate are also low. In case of face grinding, it is fastest because of largest area of contact between workpiece and grinding wheel.

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TYPES OF ECG OPERATIONS

- ✓ **VARIOUS TYPES OF ELECTROCHEMICAL GRINDING OPERATIONS CAN BE PERFORMED : CYLINDRIAL GRINDING, FORM GRINDING, SURFACE GRINDING, FACE GRINDING & INTERNAL GRINDING**
- **SURFACE GRINDING: SLOWEST BECAUSE OF SMALL AREA OF CONTACT BETWEEN WORKPIECE AND GRINDING WHEEL**
- **FACE GRINDING : FASTESTST BECAUSE OF LARGEST AREA OF CONTACT BETWEEN WORKPIECE AND GRINDING WHEEL**

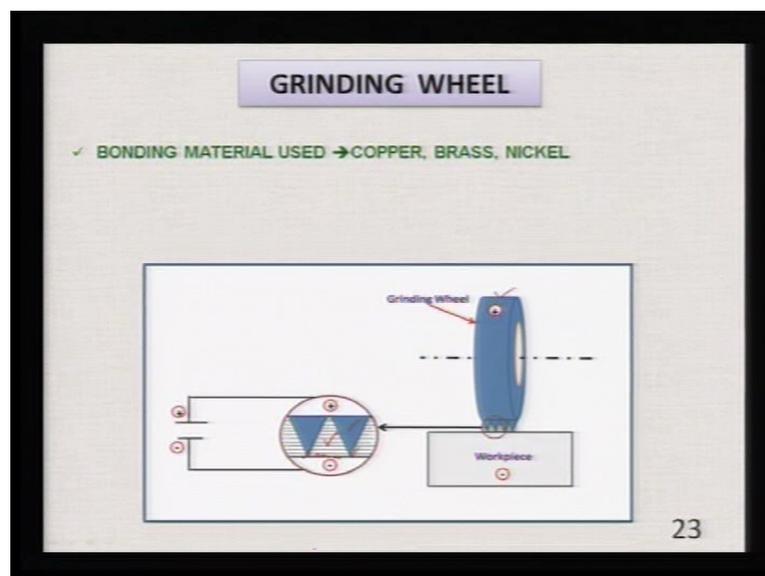


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Now here you can see here this is the bonding material is used for bonding the abrasive particles in the electrochemical grinding wheel as shown over here and the bonding materials are copper, brass, nickel because they should be electrically conducted. So these materials have good electrical conductivity. So they are commonly used as bonding material for electrochemical grinding wheel.

Now you can clearly see the role of the abrasive particle in surface grinding and here these are the abrasive particles which is removing the material by abrasion while this is forming the electrolytic cell. And because of this electrolytic cell formation, material is also removed due to the electrochemical dissolution from this area and these abrasive particles are removing the material by chip formation.

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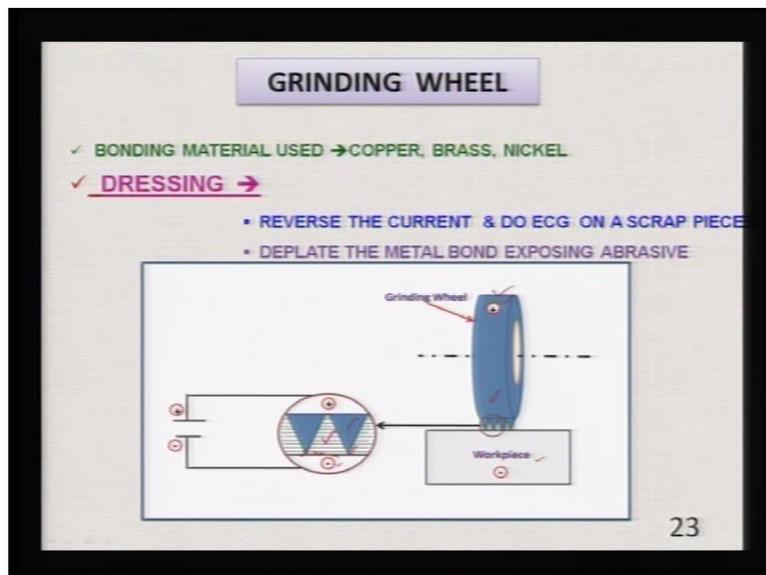
Now dressing is very important. It takes lot of time in dressing of grinding wheel and it cost a lot in case of conventional grinding wheel dressing. Now what is done in case of electrochemical grinding dressing? As you can see here in the earlier slide if you see carefully grinding wheel was made as the cathode but here in this particular case grinding wheel has been made as the anode and workpiece has been made as the cathode. Now material is removed from the anode.

So in this particular case material will be removed from the grinding wheel which is made as anode. As a result of that what will happen? Whatever material that was deposited on the grinding wheel due to clogging or you want to remove the material from the grinding wheel to allow fresh particles to project for grinding operation.

So what is done that material is dissolved from the grinding wheel and once material is dissolved from the grinding wheel fresh abrasive particles come outside or project outside the grinding wheel and they perform the grinding operation rather than the blunt abrasive particles.

Because once you are removing the material from the grinding wheel the blunt abrasive particle will be pulled out of the grinding wheel and you get better performance of electrochemical grinding once the dressing of the grinding wheel has taken place. So when you are making a grinding wheel as an anode it deplates the metal bond exposing the abrasive particles as shown over here.

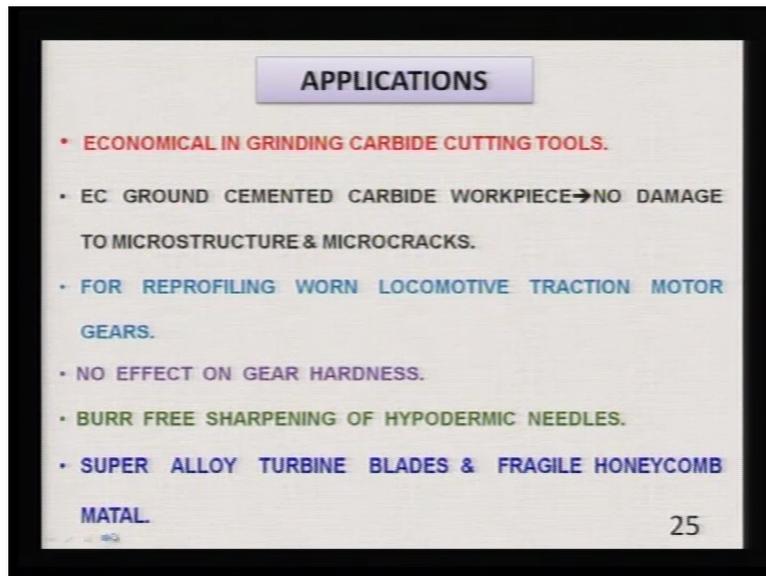
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Let us see some of the applications of electrochemical grinding process. Economical in grinding carbide cutting tools. Electrochemical ground cemented carbide workpiece have no damage to the microstructure and hardly any microcracks are created. For reprofiling worn locomotive traction motor gears, this particular process has been used. There is no effect on gear hardness when you are grinding or finishing the gears by electrochemical grinding operation. Then hardness is not affected or it is not changed.

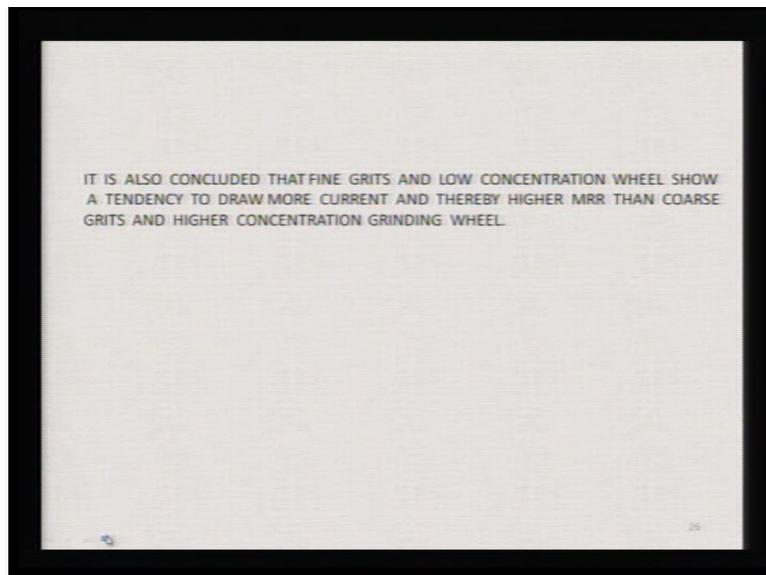
You get the burr free sharpening of hypodermic needles which is very important. Even a single work in this needle will create lot of pain to the patient. Super alloy turbine blades and fragile honeycomb metal can be ground by this particular process.

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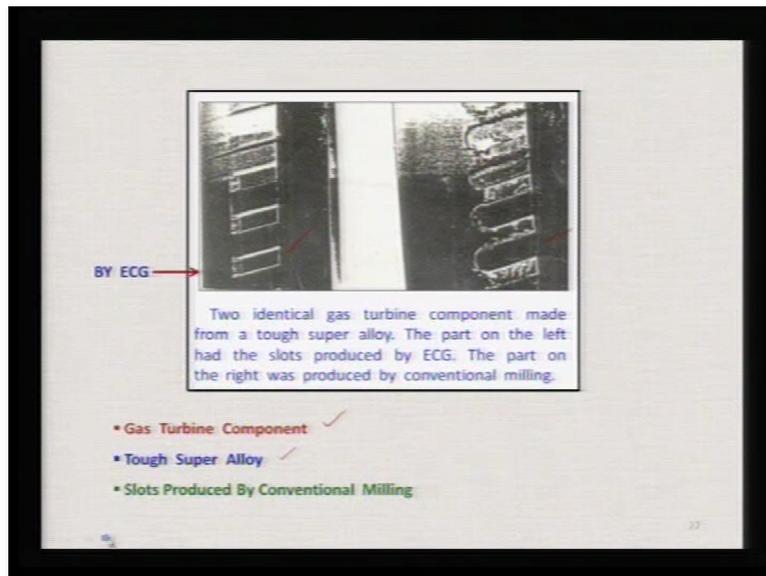
It is also concluded that finegrits and low concentration wheel show a tendency to draw more current and thereby higher material removal rate. Then coarse grits and higher concentration grinding wheel.

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You can see here two identical gas turbine component made from a tough super alloy. The part on the left hand had the slots produced by electrochemical grinding on this side you can see clearly. The part on the right was produced by conventional milling and you can see lot of burrs, etc. and consistency in the size of the burrs while on the left side there are no burrs. So it can be used for gas turbine components or grinding of tough super alloy for producing slots.

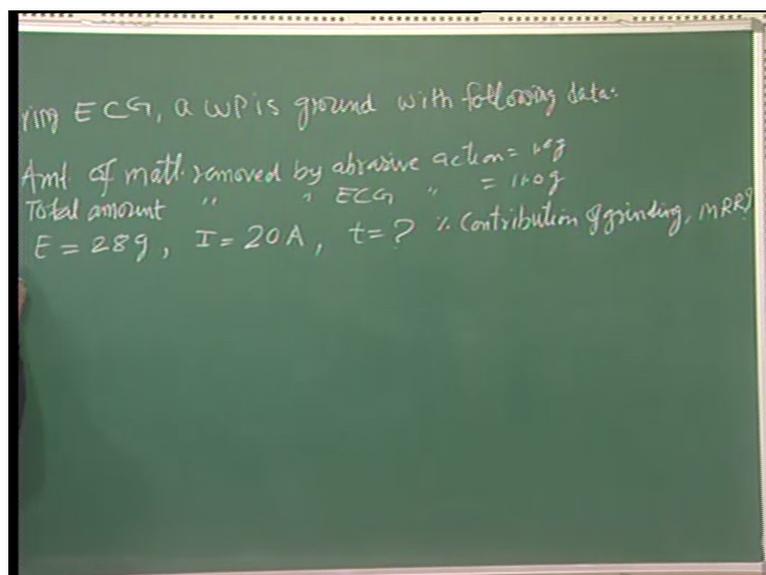
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Now let us take one numerical example related to grinding process. I will write here on the board. During electrochemical grinding a workpiece is ground with following data. Amount of material removed by grinding operation alone by abrasive action, 1 gram. Then total amount of material removed by ECG electrochemical grinding action is 11 gram. E value of the workpiece chemical equivalent is 28 gram.

Current being supplied I is equal to 20 ampere. Now with this data find out the time for electrochemical grinding and then percent contribution of grinding in ECG and MRR in ECG.

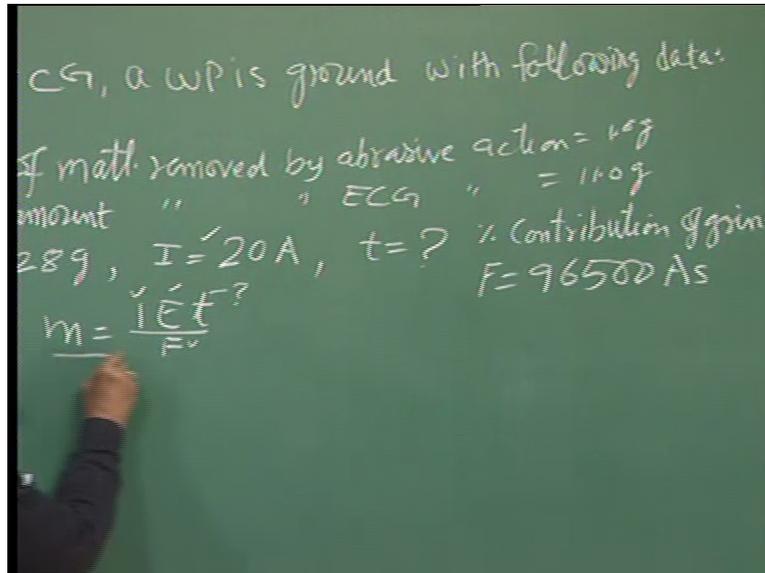
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Solution, we know the formula from Faraday's law of electrolysis that m is equal to $I E t$ where I is the current in amperes, E is given here, E is the chemical equivalent of the anode

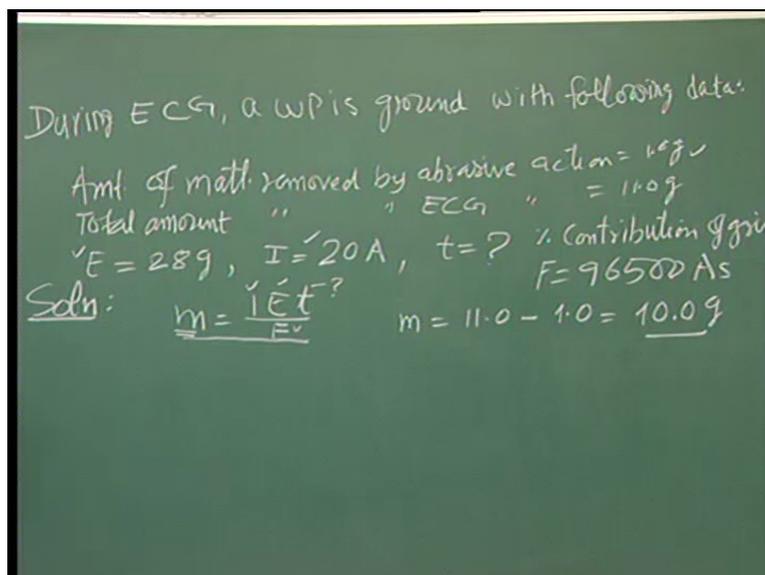
material that is the workpiece that is 28 gram, t is the machining time which we have to find out, F is the Faraday's constant which is 96500 amperesecond. Now let us see this formula for finding out the time.

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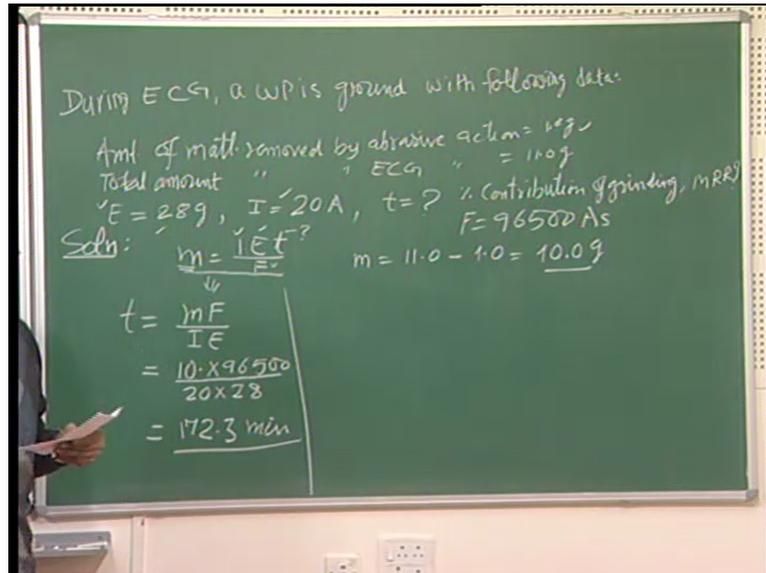
Now this m is the electrochemical dissolution contribution to total ECG. So we will calculate and this is given, what is this value of m? M is equal to 11 gram is the total material removed in electrochemical grinding and 1 gram is the amount of material removed due to the grinding operation or abrasive action. So it becomes equal to 10 gram as a contribution of electrochemical dissolution in electrochemical grinding process.

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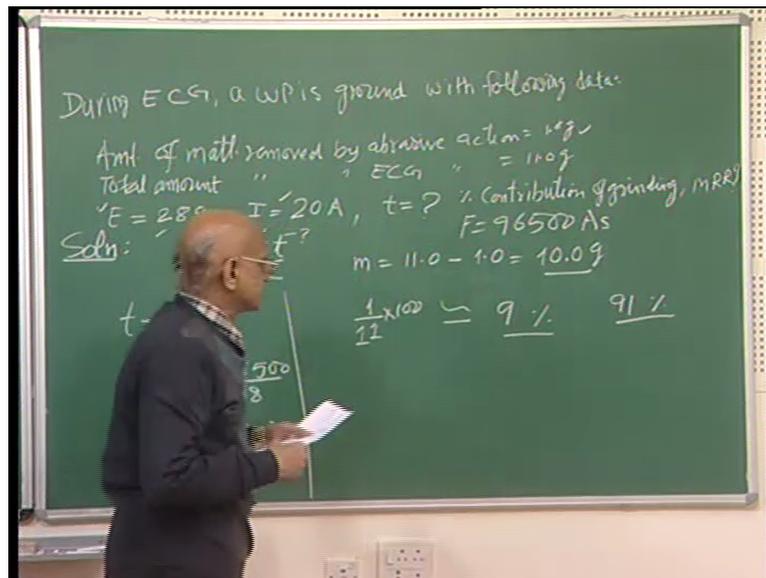
So from here we can write down t is equal to mF divided by IE . We already know the values. M is 10, F is 96500 and I is 20 amperes and E is given there 28. And if you simplify this it will give you approximately 172 point 3 minutes. So it is quite slow in this particular case because the current that is flowing in the electrochemical grinding process is quite low. So it is taking quite long time.

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Now the next question is, what is the contribution of grinding alone in percentage? So we can write down here that was 1 gram divided by 11 into 100. So you can calculate that will come out to be somewhere approximately 9 percent. So it indicates that grinding contribution in this particular case is just 9 percent while electrochemical dissolution contribution comes out to be 91 percent which is quite high.

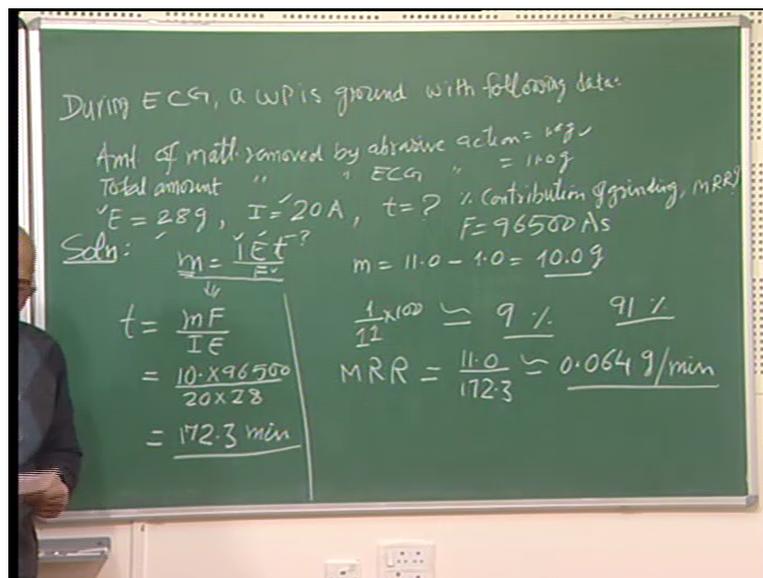
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Now we can also calculate material removal rate. In case of ECG we know already 11 gram is the amount of material removed in total time taken is 172 point 3 minutes. So we can divide it, 172 point 3. So this will give you approximately (six) 0 point 064 gram per minute. Now very important point here to note is that in grinding operation we are more concerned with the finishing rather than really removal of large amount of material.

So we do not want very high material removal rate also as in case of electrochemical grinding where the objective is to remove them or to shape the workpiece and size the workpiece where large amount material is removed and high material removal rate is needed. So in this way using the same principle what we used in case of electrochemical machining, you can calculate electrochemical dissolution contribution and rest of it will come out to be the amount of material removed by abrasive action. And you can solve different kind of the problems.

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Thank you very much.