Polymer Assisted Abrasive Finishing Processes
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Lecture – 13
AFF Processes: Magnetio AFF (MRAFF), UAA- AFF, EC-AFF

So, as you see the abrasive particles are held by the chains how we can represent this in a schematic way.

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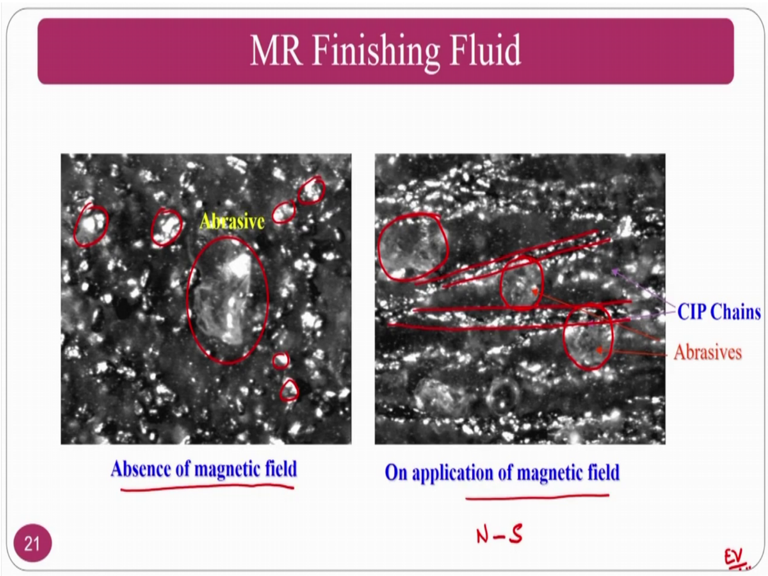

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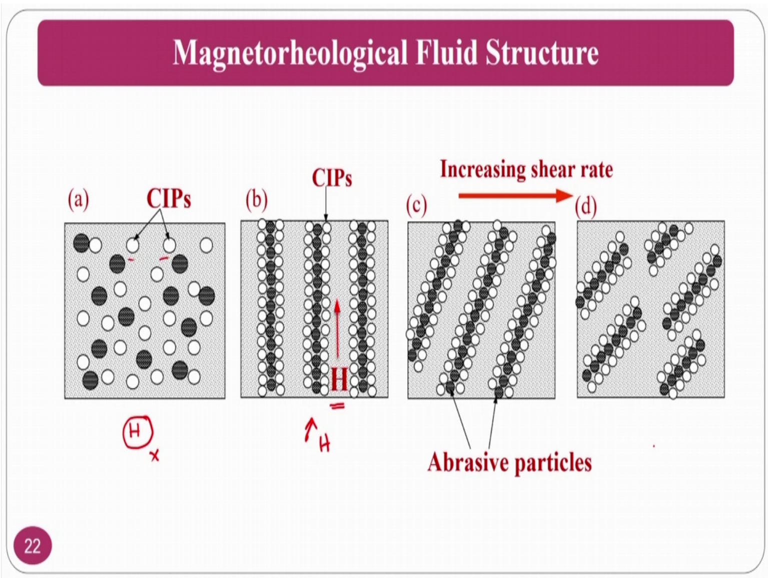

If you see the magnetorheological fluid structure as a CIP particles or the white ones, these are the CIP particles and the abrasive particles. So, how whenever the magnetic field is applied; that means, that H represents the magnetic field whenever the magnetic field is applied. This forms a chain and chain holds the abrasive particle, that is what the schematic diagram is shown here ok, that mean that when H is not there here and when the magnetic field is applied here H is applied.

Then whenever you were using the hydraulic power pack to reciprocate; that means that you are giving the shearing action. In that circumstances normally this chains will move and they may shear also, sometime if the shear strength of the chain is less than the shear strength required or applied by the hydraulic power pack in that circumstances this chains also will break into smaller chains. However the abrasive particles are intact in a less amount because, number of chains may be increasing because these are breaking.

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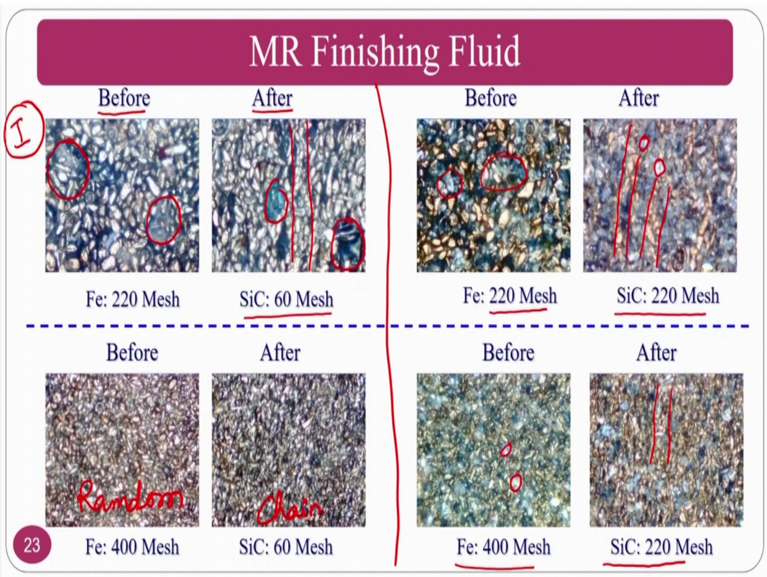

So, magnetic finishing fluid as you can see here before and after you can see the abrasive particles are randomly oriented and whenever you are going to apply the magnetic field. That means, that this is a before and after for the 60 mesh size of abrasive particle the chains are forming and this chains are held by the abrasive particles. You can see the abrasive particles are held, the similarly 220 mesh size iron particle are there and 220 mesh size silicon carbide is also there.

Here there is no holding ability abrasive particles are randomly oriented and you can see here the abrasive particle are held by the polymer chains, if you can see the chains the chains are like this, chains are forming and this chains are entrapping the abrasive particles ok. The main motto of this particular slide is how the abrasive particles are held by the CIP particles that is Carbonyl Iron Particles whenever the magnetic field is applied.

You can clearly see in this one also and the most importantly you can see at the last one iron and the silicon carbide basically, what is the motive is that different different particle sizes. If I am using the bigger sized iron particle what is the chain formation, if I am using the smaller particles of iron particles what is the, how the chains are forming and other things. Normally the literatures recommends that your abrasive particle will be slightly bigger than the CIP particles that is what you can see in the case 1.

So, in this last case also, in the third case you may seeing the randomness of the particles in the other case the chains are freely forming chain formation will be there ok, similarly you can see in the fourth image also where you can divide. So, in the fourth one also before randomly oriented after the chains formation is predominant and the abrasive particles are held.

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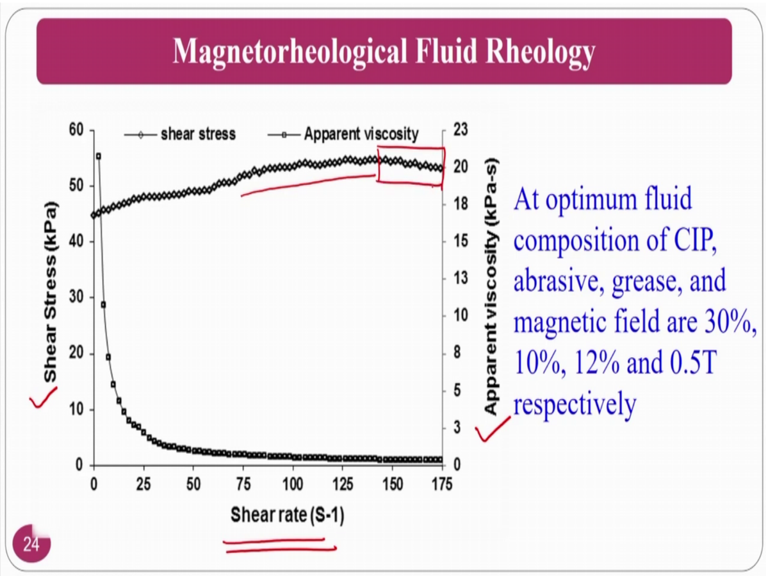

So, Magnetorheological Fluid Rheology, rheology is nothing, but signs of loan deformation that we have seen in the abrasive flow finishing process. So, we have studied there about the shear stress viscosity and many many things here also we will see what is the shear stress and what is the viscosity and other things.

If you see the x axis shear rate there on y axis one side we have shear stress on other side we have apparent viscosity; that means, that the viscosity what is at particular that instant. So, as the shear rate increases what normally you can see here is, that apparent viscosity gradually decreases so; that means, that; obviously, if your shear rate is increasing. Normally shear rate a full name of this one is shear strain rate; if your shear strain rate is increasing, what will happen? Here is that your viscosity is reducing. That means, that it is a shear thinning fluid the viscosity is decreasing; that means, that if you are increasing the extrusion pressure; that means, that your shear rate is increasing.

If you increase shear rate what will happen the viscosity will go down, however, you can see slight improvement in terms of the shear stress, but it is approximately stagnant after some time.

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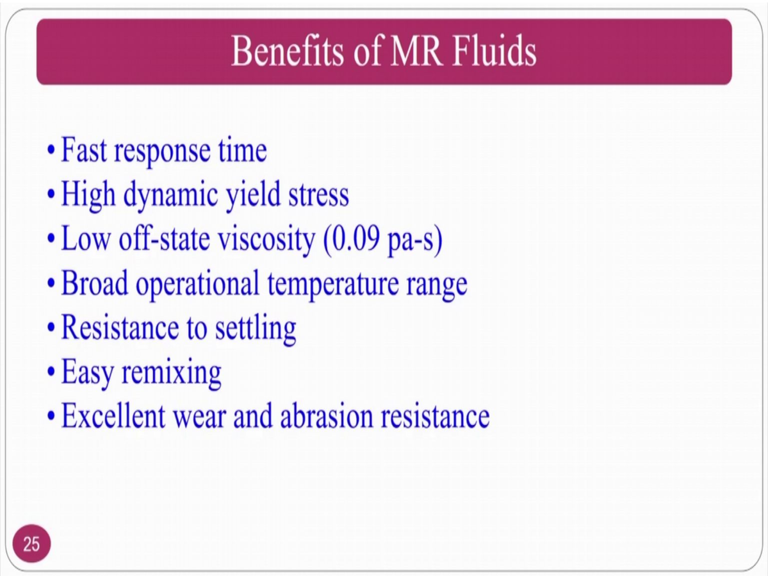

So, benefits of magnetorheological fluids then fast in response time, high dynamic yield, low off state viscosity, operational temperature range is very big and resistance to settling and easy mixing and excellent wear and abrasion resistant and other things.

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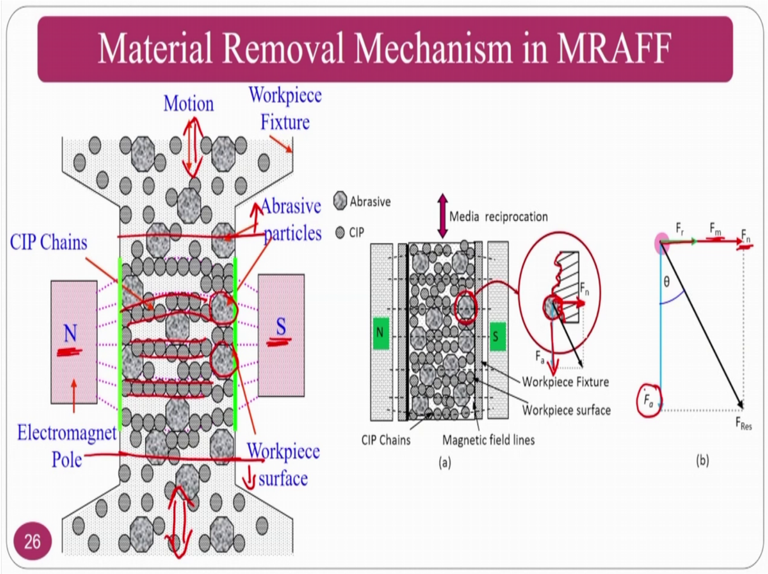

Now, we will see the material removal mechanism, how the material removal will takes place in the MRAFF process. So, if you see the North Pole here, South Pole here as I said in the vicinity of the magnetic field this will form the chains; what about other region? It will be still, will be a liquid state. So, if you see in the above condition and below condition this 2 lines if the below condition and above condition what is here you are CIP particles and abrasive particles both are in a liquid sate and they are on random. But whenever these are coming in to magnetic field zone that is between the North Pole and South Pole what is happening is, CIP particles form the chain between North Pole to South Pole.

So, these CIP particles will hold the abrasive particle and because of the hydraulic power pack or extrusion pressure that is applied by the hydraulic power pack; what will happen? Reciprocation motion will takes place, this reciprocation motion will shear the work piece surface. Now you can see the enlargement of this finishing region where you can clearly see the abrasive particle how it is finishing the surface.

Assume that this is the surface peaks that are forming and because of the axial pressure it moves like this, normal pressure will be there and because it is moving in the along the direction and it will have a normal pressure whatever you have seen in the abrasive flow finishing is a radial force and you can see here radial force is there because of visco elastic nature, nothing in this world is completely viscous or completely elastic. So, there will be a elastic component because of the magnetic field you have magnetic and the normal force also will be there. So, axial force; obviously, will be there and axial velocity will be also will be there.

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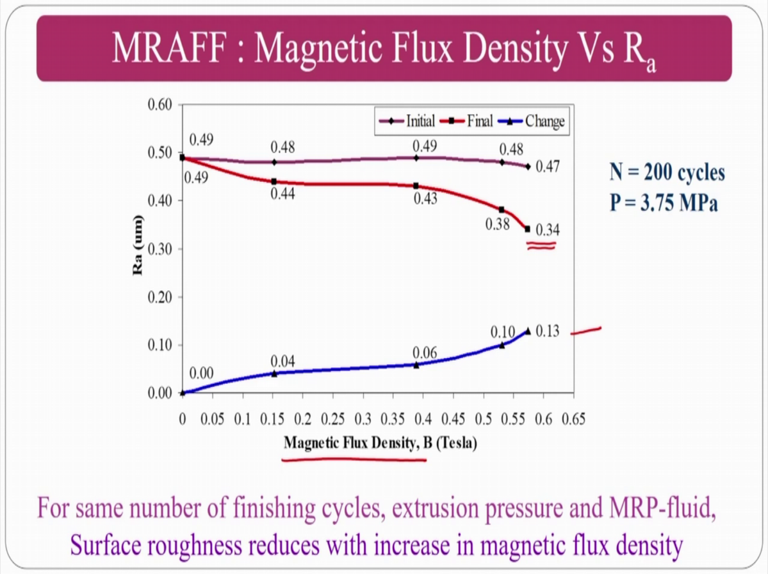

So, if you can see the magnetic flux density versus surface roughness achieved, the first the top most curve shows the initial surface roughness. So, then after finishing with the different magnetic flux density you can see the surface roughness is decreasing; that means, that your surface finish is improving, that at the same time you can see the change in roughness also at the bottom.

As you increase the magnetic flux what is happening here is that you can see the change in R a is gradually increasing; that means, that you are going to get a better results; that means, that whenever you are having high amount of magnetic flux your chain formation is strong and your shearing is predominant that is what you can see here.

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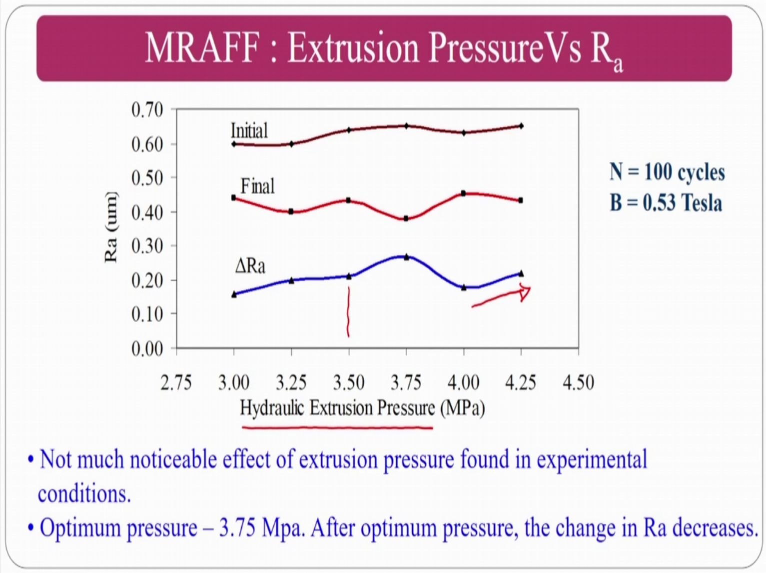

At the same time if you see the hydraulic extrusion pressure, if you are increasing and the extrusion pressure here also you can see that there is no much change up to 3.5 mega Pascal, but afterwards 3.75 it is increasing and if you can see here up to 4.25 it is slightly increasing; that means, that it is having not much influence, but it has it is own influence in terms of MRAFF process.

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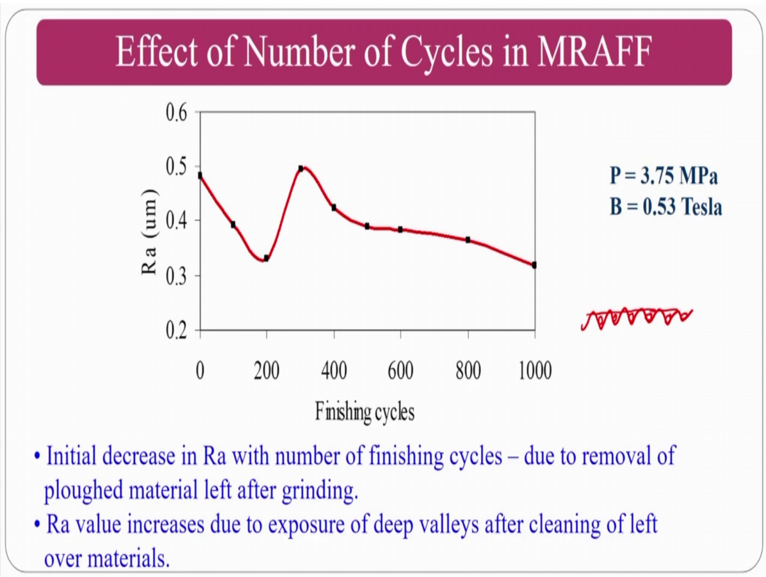

So; however, if you see the finishing cycles there is deep, there is a up and other things how this is going to analyze in this case. So, the researcher Professor Sunil Jha he has clearly explained what is happening in the MRAFF process as the number of cycles increases. If you have a grind surface normally the material, if you see the surface in a grind surface you will have approximately the lining surface will be like this.

So, the basic problem in grinding is material will fill up to certain portion because of the ploughing action and other things. So, as soon as you start the finishing action using MRAFF process what is happening here is, that it will start shearing the top things when it is shearing the top things let me draw a big one so that it will be easy.

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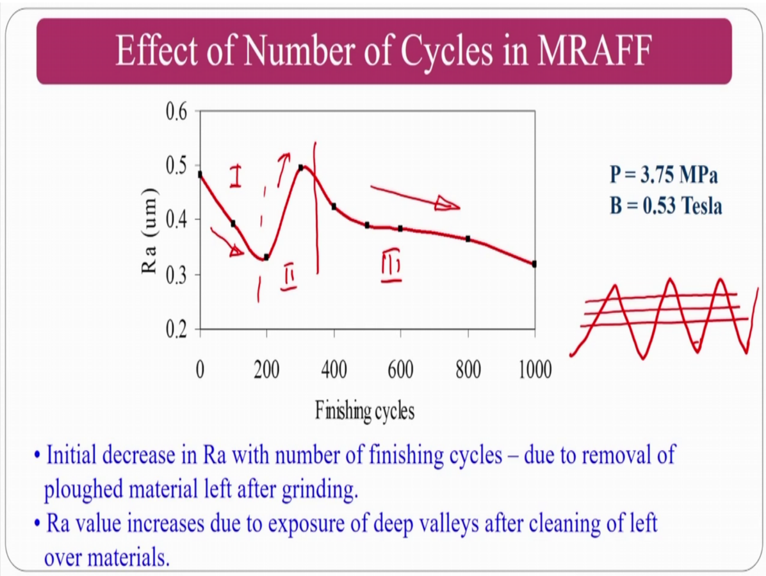

So, this is my surface and materials is here filled that is during the grinding process. So, initial cycles what is happening is here is it is shearing the surface because of which this region 1 I will divide into region 1, region 2 this is region 2, and this is region 3. So, region 1 what is happening is if you are sharing some of the peaks, what is the surface roughness is reducing that is what happening here.

So, after some time what is happening this is a low viscous medium and other things what will happen during this course of time if you increase few more number of cycles what is happening is, it is clearing off or it is removing the debris or the ploughed material that is there. If you remove this ploughed material what will happen? Your values are predominately visible now.

So, that is why the surface roughness will again it will increase, that is why in the second region you are seeing an increment, this is attributed to the cleaning or it removal of the debris that is formed during the grinding process, that is why it is increasing later on. Now it start a real finishing because of which you can see the third region, that is how it is attributed and the same thing you can clearly see here.

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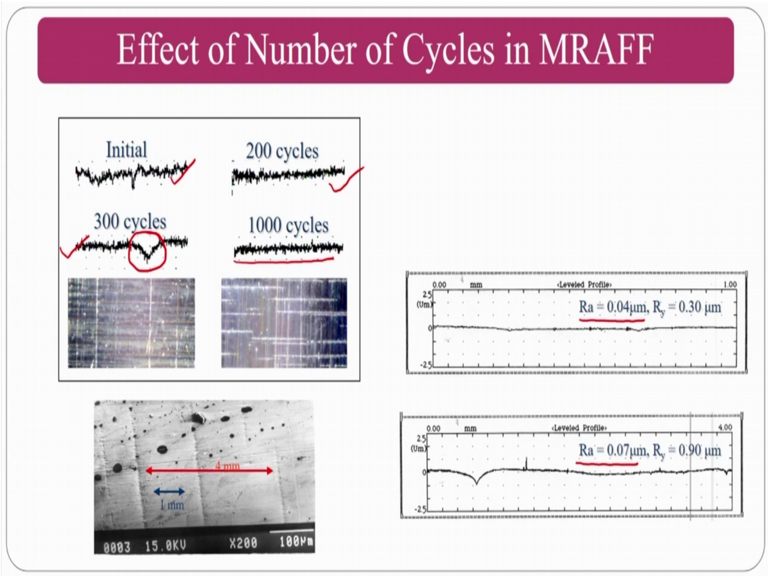

At the initial 300 cycle the surface finish is like this, but if you increase to higher number of cycles normally it will improve the number of cycles.

So, initial at a 200 cycles it looks very fine, but as you increase to 300 cycles because of the cleaning or removing of debris that is formed in the valleys, it is again you can see a pit or valley because of which surface roughness again increases; that means, that surface smoothness or surface finish will reduce and later on original surface finishing will takes place because of which you can see the good surface. So, you can also see that 2 dimensional views it is R a is point not 4 micrometers and R a normally it is 0.07 whenever this valleys are visible.

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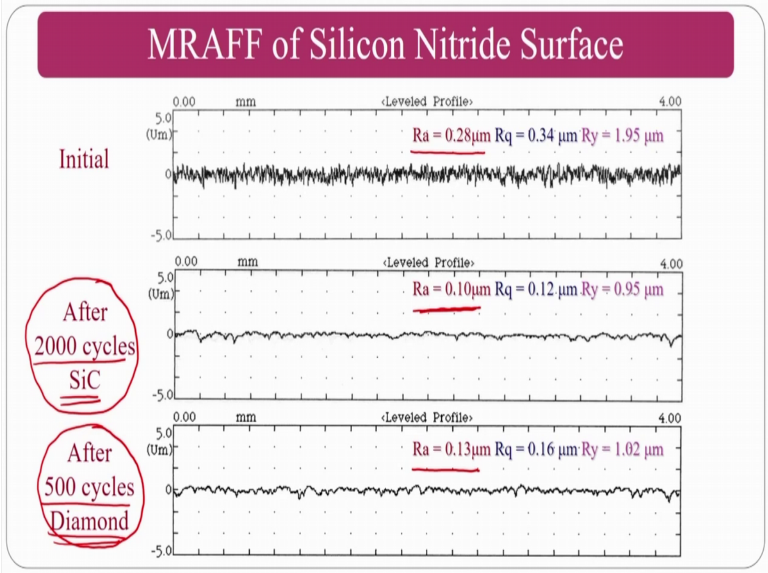

You can see initial surface roughness is then after 2000 cycles of using silicon carbide how the surface roughness look like, normally the initial surface roughness is 0.28 micro meters and with 2000 cycles of silicon carbide the archived is 10.1 micrometer and if you can see 500 cycles of diamond abrasive particles.

So, as I said if at all you want the high finishing rate normally you have to go for the hardest materials, you can go up to 0.13 micrometers. So, normally we talk about only surface roughness as we have seen the lecture on, what is surface roughness, what is surface metallurgy and what is surface integrity and all those we have seen in the previous classes, that is why there we have understood that most of the people follow the surface roughness, average surface roughness that is central line average value.

So, we will look into the 0.3 only. So, if you see here 2000 cycle; that means, that finishing time is too high, but your silicon carbide is the abrasive particle. If your finishing time is 500 cycles then the finishing rate; that means, the time is less, but you are achieving approximately similar surface roughness value.

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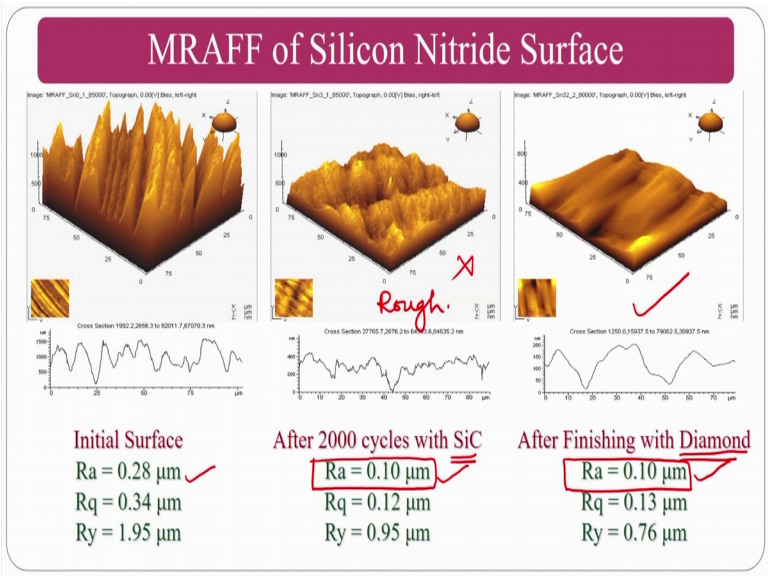

So, this is for silicon nitrate basically the work piece material is silicon nitrate. So, if you see the initial surface 0.28 micrometers 0.1 and 0.1 approximately with the diamond, but you can see the surface morphology, as I said their surface value may be looking same, but the thing that you have to see is how the surface morphology in the 3 dimensional look like.

This is how slightly looking rough in case of silicon carbide abrasive particles, but in case of diamond particles the surface is bit smooth even though the average surface roughness value, that is the R a vale is approximately same in the both conditions, but the surface morphology is different, but you have hope you got it.

Even though the surface roughness value using diamond particles and using silicon carbide may be the value may be the same, but the appearance or the morphology of that particular surface is completely different. If you are going to put these particular components in the practical application your diamond surface may give better life compared to your silicon carbide.

So, that that is what is the beauty, but at the same time the diamond abrasive particles are slightly expensive compared to the silicon carbide particles. Till now you have seen the magneto abrasive finishing process, but magneto rheological abrasive finishing process also goes in the similar lines, only difference as I said is polymer continuity in this one magneto rheological abrasive flow finishing process is slightly less ok. But however, complete mechanics of machining or mechanics of finishing and other ingredients and other things are approximately same because you have North and South Poles there also. Here also fluid is approximately same that is why instead of magneto abrasive finishing process we have started with that one and we have come to magneto rheological abrasive finishing process to understand the better way of both the processes.

After seeing the magneto abrasive finishing process and magneto rheological abrasive flow finishing process both are approximately same processes that is why we have seen magneto rheological process plus abrasive flow finishing process which combines to be magneto rheological abrasive flow finishing process, which is approximately similar to magneto abrasive finishing process. Now, we move on to the second category or the second variety of hybrid abrasive flow finishing process that is called electrochemical assisted abrasive flow finishing process.

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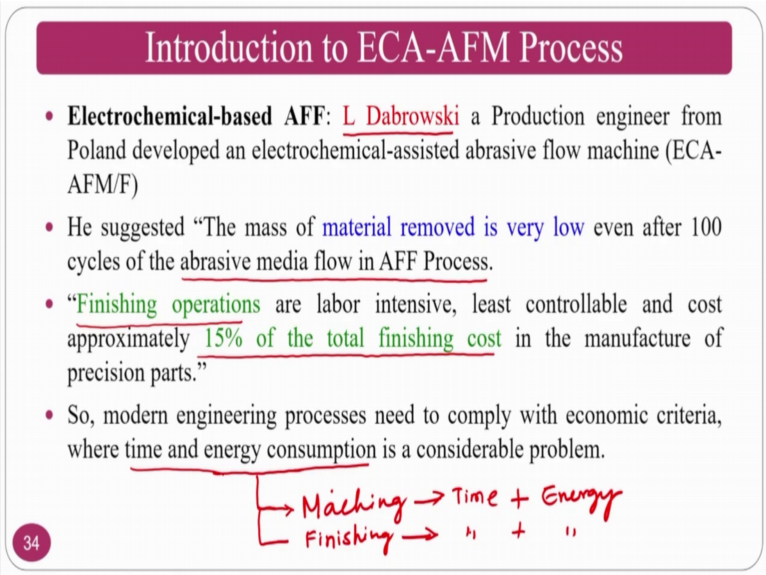

This particular process is the combination of electro chemical machining plus abrasive flow machining process or abrasive flow finishing process, as I said whenever I talk about abrasive flow machining or abrasive flow finishing process both are approximately same.

The electrochemical based abrasive flow finishing process L Dabrowski a production engineer from the Poland developed this electro chemical assisted abrasive flow machining process. He has suggested that the mass of material removal is very low even after 100 cycles in abrasive flow finishing process. The main concern he expressed is that the finishing rate or the material removal rate if you consider it as a abrasive flow machining material removal rate you can say as per the Dabrowski is concerned. So, in our terms as a polymer assisted abrasive finishing processes we can see that finishing rate is very slow in conventional type of abrasive flow finishing process. That is why Dabrowski has concern and he moved towards a hybrid process that is called electrochemical abrasive flow finishing process.

Now, the finishing operations are labor incentive, least controllable and approximately 15 percent of the total finishing cost will be the manufacturing cost; that means, that if a particular component is 1000 rupees approximately 150 rupees will goes to the finishing operation. Normally finishing process will be the final process in the most of the subtractive based manufacturing processes.

So, the modern engineering possesses need to comply with the economic criteria where time and energy consumption is considerable problem; that means, that if you can increase the finishing rate and if you can reduce the time. I mean to say if at all I want to do some machining process followed by a finishing process. Here time is also there and for example, what I mean to say is time and energy consumption, if I want to take 2 processes one product has to go through machining then followed by finishing process.

In this circumstances machining will take some time plus some energy because you have to supply some energy. So, in finishing also then you have to give again time because the finishing will take certain time plus certain energy also; so, this is individual. Now, what is the best solution if you can club both, if you find their finishing process that can do somewhat machining as well as the finishing action then your time will be saved, at the same time your energy will be utilized in only one machine.

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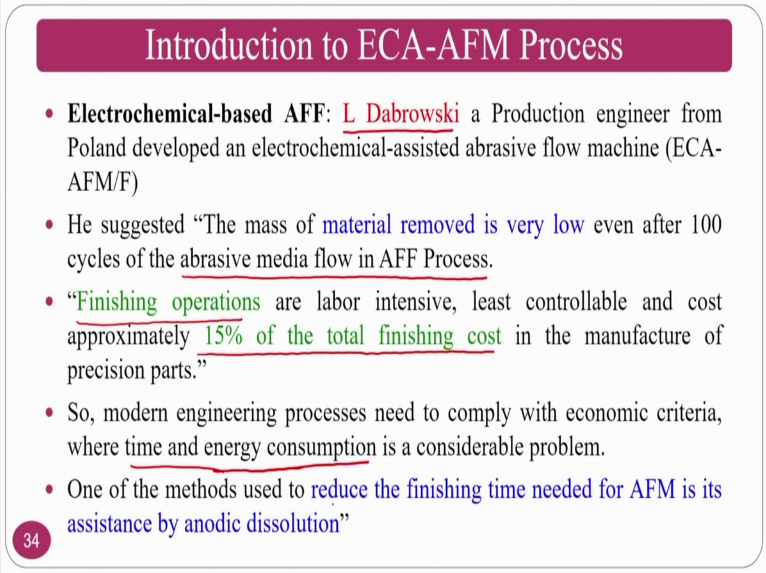

So, one of the methods to reduce the finishing time needed for abrasive flow finishing and it is assistance by anodic dissolution, one of the methods used to reduce the finishing time needed for abrasive flow finishing process and it is assistance by anodic dissolution process.

The electro chemical machining process is a material removal process which is considered to be advanced version of manufacturing process, where the material removal takes place by anodic dissolution. If you can club this anodic dissolution with respect to the finishing action, if you are going to do separately electro chemical machining so, it will take time and you have to supply certain energy. If you are going to do abrasive flow machining process then you have to supply certain energy as well as it is takes it is own time if you can club both, that is what the Dabrowski want to convey.

Then what will happen your machining time and finishing time can be reduced and single source of energy will be supplied so that the production cost of the product can come down so, that your 15 percent that is mentioned here can be reduced.

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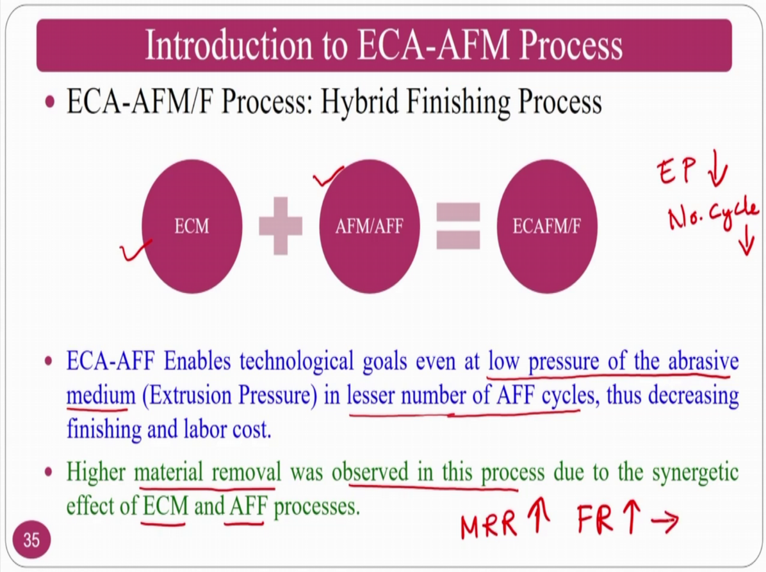

Electro chemical assisted abrasive flow machining process as I said this is the combination of electro chemical machining plus abrasive flow finishing operation, then it is called electro chemical abrasive flow machining or electro chemical abrasive flow finishing process. Electro chemical abrasive flow finishing process enables the goals even at low pressures of abrasive medium on less number of AFF cycles thus decreasing the finishing and labor cost.

If at all you want to extrusion pressure high then; obviously, you have to give input to the hydraulic power pack high; that means, that your energy requirements will be very high, what this particular scientist Dabrowski want to explain is if at all you are going to finish using only the abrasive flow finishing process you need to more extrusion pressure, if at all you want to more extrusion pressure your input energy also should be more for the hydraulic power pack.

If you are going to use only abrasive flow finishing process number of abrasive flow finishing’s cycles are more. If you can hybridize it with electro chemical machining process your extrusion pressure will come down or number of cycles also come down so, that your finishing time will be reduced or your finishing rate can be improved by clubbing electro chemical machining and abrasive flow finishing process.

Higher material removal rate was observed in this process due to the synergic effect of ECM and abrasive flow finishing process. That means, that simultaneous action of electro chemical machining as well as abrasive flow finishing process will takes place not only the finishing, it will also helps in removing the material in great way. That means, your MRR will also be high and your finishing rate also will be high so, that your time consumption will be very less and your energy consumption will be very less that is what the concept that Dabrowski want to explain.

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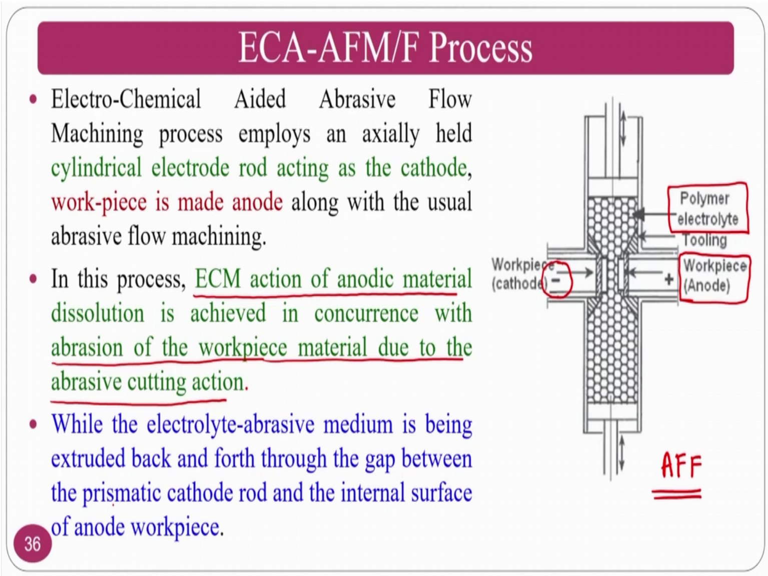

You can see here how the electrochemical process looks like, electrochemical aided abrasive flow finishing process employees an axially held cylindrical electrode rod acting as a cathode, work-piece is made as a anode which usually in the abrasive flow finishing process or abrasive flow machining process.

This set up look like a abrasive flow finishing process 2 way abrasive flow finishing process in which you can have a cathode which is a rod that is placed and in another case you have a work piece which is anode and the material removal takes place by anodic dissolution in electrochemical process. So, in this process you have the medium which is polymer electrolyte based medium or salt solutions also will be included in the polymer solutions that is why this is called polymer electrolytes.

In this electrochemical action of anodic material dissolution is achieved in concurrences with the abrasion action of the work-piece material due to the abrasive cutting action. You can understand now see anodic dissolution because of the electro chemical machining process plus abrasive action of the abrasives also will take place.

Whenever there is a anodic dissolution; that means, that what there is a surface may be becoming oxides and the material removes as you know the surface metallurgy whenever you are forming oxides, oxides are easy to remove; that means, that the hardness of the parent material. For example, I have a certain material iron based material I put into the rain and normal environmental conditions after some time what will happen it will rust.

This rust you can scratch with your nail that much soft it will be, but you cannot scratch the original parent affy material, because the oxides are much less harder and easily scratch able or easily upgradable or easily sharable; that means, that you can do the abrasion action by abrasive flow machining process. That means, that whenever electro chemical machining process can make the oxides and it makes the surface smooth the abrasive action of abrasive flow medium will remove that medium because of these 2 additional effects the material removal and finishing both will improve.

So, while electrolyte abrasive medium is being extruded back and forth the gap between the prismatic cathode rod and internal surface anode can be maintained basically the rod will be there as a cathode and anode work - piece will be there and you can maintain the gap and in between these gap you can pass the medium. Hope you understand here if you could not understand let me explain you again in a simple concept, because if you can understand the basic physics then what will happen it is easy to understand most of the electro chemical assisted abrasive flow finishing process.

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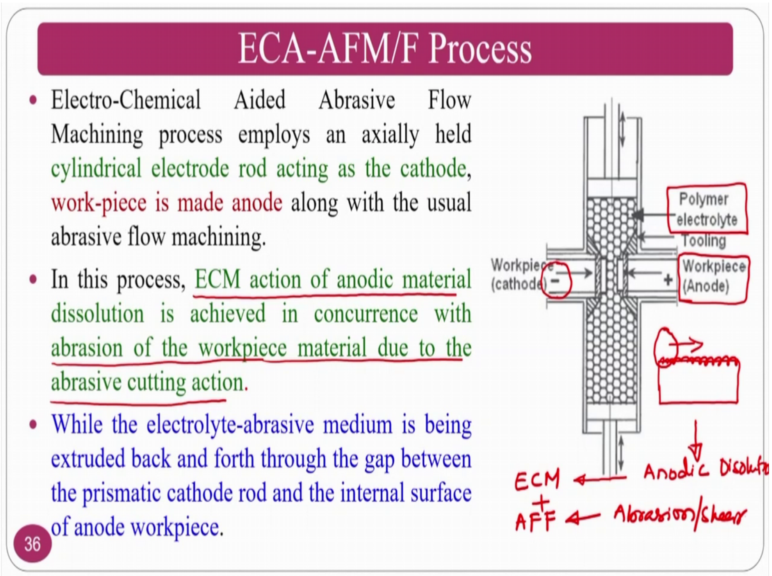

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You have 2 things, one is ECM electro chemical machining plus you have abrasive flow finishing process or machining process, whenever you have a work piece material it will do anodic dissolution then abrasive process will have abrasion action or shearing by abrasive process. Now because of this anodic dissolution process work-piece will become oxides, assume that my surface is like this, this surface will become oxides so, become very soft, later on what will happen, your abrasive particle because of the abrasive action will come and will shear off so, your material removal will increase.

If you do not have electro chemical machining process here what will happen, you will have the only parent material like this, it is very hard to remove if we have electro chemical machining process you will have a corrosion or oxides formation and this can be removed easily. That is the basic simple mechanism of electro chemical assisted abrasive flow machining process or finishing process.

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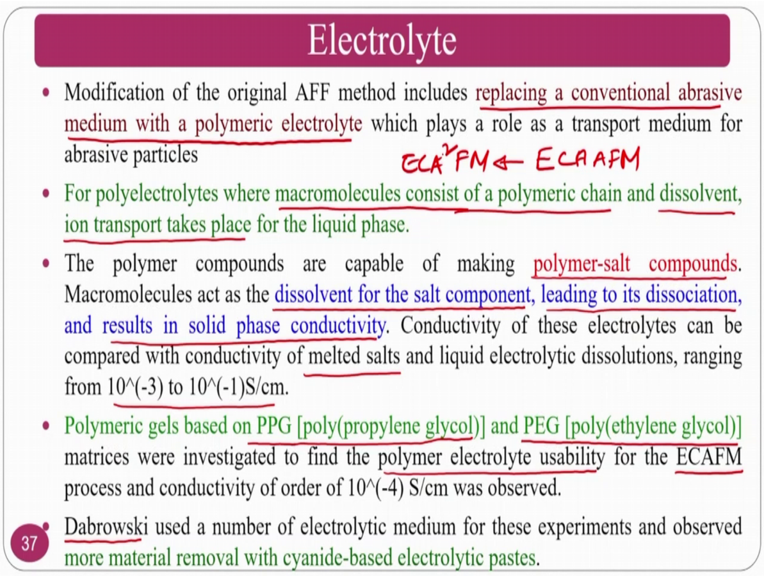

What is a electrolyte that people are using here, the modification of original AFF method includes replacing of conventional abrasive flow medium with a polymeric electrolyte which plays a role of transport medium in abrasive particles. This convectional abrasive flow finishing medium normally comprises of your base polymers, plasticizers, rheological additives, abrasive particles and so on these are replaced by some of the polymer electrolytes along with abrasive particles. What we will see what are these polymer electrolytes and what are these gels and other things we will see in upcoming slides.

For polymer electrolytes this way the macro molecules consist of polymeric chain like a base polymer in abrasive flow finishing medium and a dissolvent, because you have to dissolve the base polymer, dissolvent is required for dissolving various polymers and other things then iron transport takes place for the liquid phase. The polymer compounds capable of making the polymer - salt compounds, macromolecules act as a dissolvent for the salt component so, that you have to dissolve it and leading to a dissociation, as a result of solid phase conductivity so, it will dissolve into a polymer gel.

Conductivity of these electrolytes can be compared with a conductivity of melted salts and liquid electrolyte dissolutions ranging these values. Polymer gels based on PPG Poly Propylene Glycol these are one of the polymers that are used and poly ethylene glycol this is a biodegradable polymer one can use and matrixes where investigated to find the polymer electrolytes usability for electro chemical assisted abrasive flow finishing process and it is conductivity.

Dabrowski as we are seeing most of the work is done by the Dabrowski some of the works are recently done by Dr. Walia and his group also, you can go through some of the papers they represent it as EA square the papers looks like FM or something the papers. And it can be also written as electro chemical assisted abrasive flow finishing process machining process or something just like this they have electro chemical assisted like this. Some things are there just to some people who are interested to work in this area can explore some of the papers of Dabrowski, Dabrowski has done extensively in this area and you can also refer to a Google scholar and you check with the Professor Walia.

Debrowski used number of electrolytic medium for these experiments and observed the material removal rate and a cyanide based electrolytes based. So, the cyanide based electrolytes gave the better material removal; that means, that your finishing rate is better for cyanide based electrolytes. You can use polyethylene glycol which is one of the biodegradable polymers and your medium also can be clubbed with the other green ingredients, at the same time you can also use PPG propyl propylene glycol and other things. So, these are some of the electrolytic compositions that you can use in the electro chemical assisted abrasive flow finishing process.

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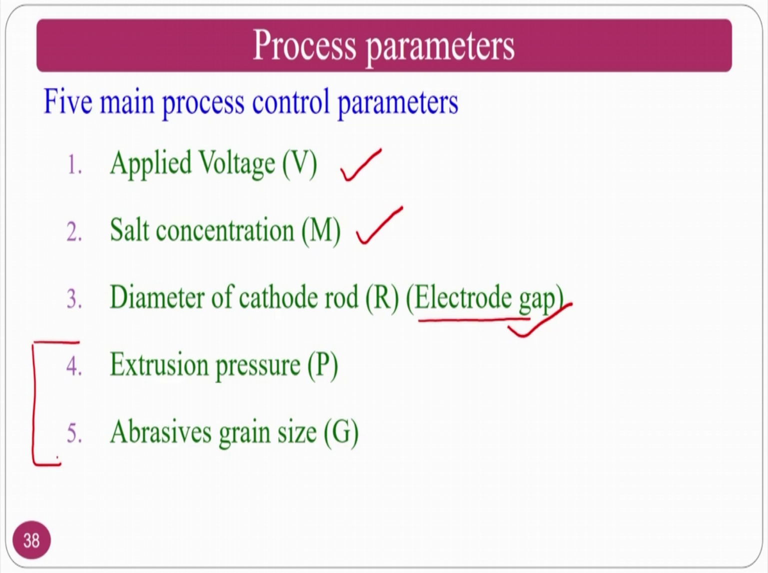

Process parameters 5 main process parameters are there. So, the first process parameter is applied voltage, then salt concentration, which is represented by M, diameter of the cathode rod that decides the electrode gap if the cathode rod size is more than the gap between the cathode and anode will be less so, the material removal or the finishing rate will be improved. Extrusion pressure and the abrasive grain size these 2 you can see in the abrasive flow finishing process also, similar to the abrasive flow finishing process also.

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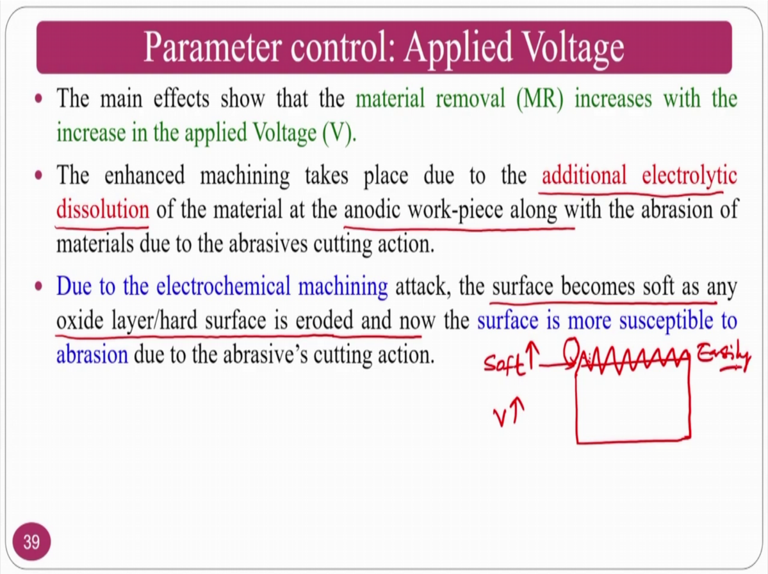

The first one is applied voltage the main effect shows that the material removal increases with the increasing applied voltage. The enhanced machining takes place due to additional electrolytic dissolution of the material at the anode work-piece along with the abrasion material, as I said if your applied voltage is more what will happen at the increment of the anodic dissolution will takes place, what I mean to say is if your voltage is high anodic dissolution will be proportionally high. So, what will happen? The material removal will be more because you have additional effect of abrasive action by the medium.

Even though your abrasive action is common, but anodic dissolution is high, if the anodic dissolution is high the material removal will be high. Due to the electrochemical machining attack the surface becomes soft as the oxide layer hard surface is eroded; now and the surface is more susceptible to abrasion due to abrasive cutting action. As I was saying whenever anodic dissolution increases because of the voltage increment what will happen the work-piece surface will start anodic dissolution. If it is starting anodic dissolution oxides will form, oxides will form means surface will become smooth.

As I was telling this is my surface, let me take practically this is my rough surface when I have to finish and because of the anodic dissolution what will happen, this particular surface become soft as you increase the voltage what will happen the softness also will increase. So, my abrasive is same, my extrusion pressure is same if the my surface peaks are soft what will happen, this will be sheared off easily; that means, that your material removal rate will be increased.

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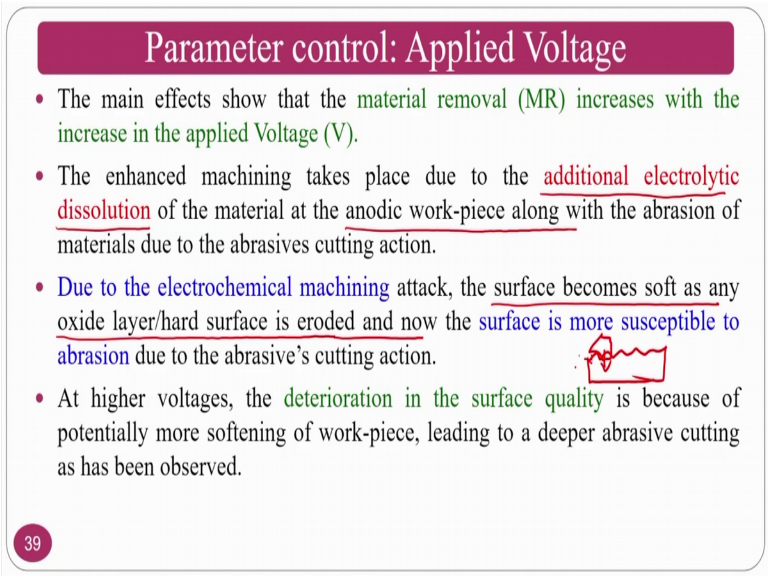

So, at higher voltages, the deterioration of the surface quality is because of the potentially softening of the work piece leading to a deeper abrasive action has been observed; that means, that if you are still increasing the voltage what will happen is that your softness of your work piece will increase. If the softness of your work-piece will increase what will happen? The abrasive indentation, as I was telling this is my surface and it is soft so, my abrasive will indent more. That means, that your penetration or what is meant by hardness resistance to penetration, if it is soft; that means, that my penetration will be more. If the penetration is more; that means what? Your abrasive action will become deeper and deeper for the same extrusion pressure and abrasive particle size.

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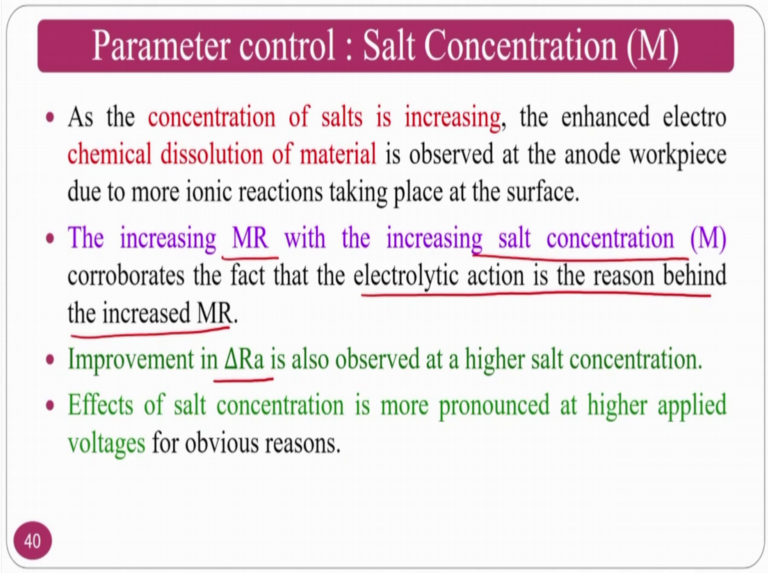

The salt concentration or polymer electrolyte concentration, if the concentration of salts is increasing, the enhanced electrochemical dissolution of petrol is observed. If you are keeping the voltage constant and if you are increasing the electrolyte concentration or the salt composition in the electrolyte composition or salt element in the electrolyte composition if you are increasing for the same voltage what will happen is your anodic dissolution will increase. If the anodic dissolution will increase again a same phenomena, oxide formation will be predominant, if the oxidation formation is predominant work piece will become soft and shearing action by the abrasive particle in the medium will be more.

The increasing material removal with the increasing the salt concentration correlates the fact that electrolytic action is a reason behind the increasing MR, because for the same voltage if your electrolytic concertation is high; obviously, you are material removal will high. The improvement in change in surface roughness is observed at high higher concentration if the soft concentration is more pronounced dot higher voltages.

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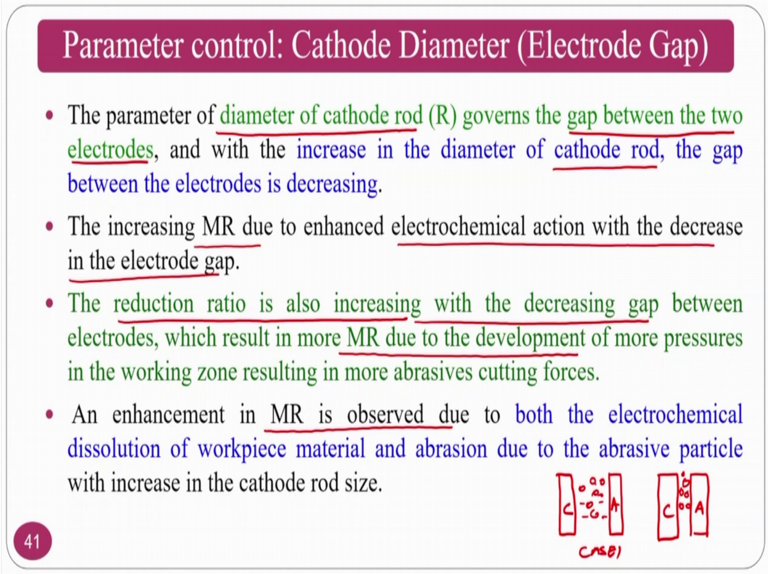

The third one which is cathode diameter because if the cathode diameter increases, electrode gap or inter electrode gap will reduce; the parameter the diameter of the cathode rod governs the gap between 2 electrodes anode and cathode, with a increase in the diameter of the cathode rod; obviously, the gap will start decreasing. The increasing MR or material removal will enhance due to electrochemical action with the decrease in the electrode gap. If the electrode gap is less what will happen the density will be more and what will happen the material removal again it will increase.

The reduction ratio is also increasing with the decrease in the gap between the electrodes which results in higher material removal for the pressure. What will happen, if the inter electrode gap is less where my abrasive fluid is passing it is indirectly correlating to the work-piece, assume that you are finishing a cylindrical work-piece and you are reducing the size of the hole, if your size of the hole or cylinder that you are going to finish is reducing what will happen.

The stresses by the medium or the shearing action by the medium will be enormous because of which what will happen shearing action will be predominant and material removal will be dominant. And enhancement of material removal is observed due to the both electrolytic dissolution of the work-piece material and abrasive action, because if your electrode gap is less and this is your cathode, this is your anode, for this what will happen you have certain anodic dissolution, apart from it there is a medium is going this is case 1.

Another case 2 you have a cathode here and anode here, in this circumstances what will happen anodic dissolution will increase at the same time the abrasives are more because the gap is less and the shear stress that is developed by the medium for the constant pressure what will happen, it will increase because of which what will happen the material removal will increase.

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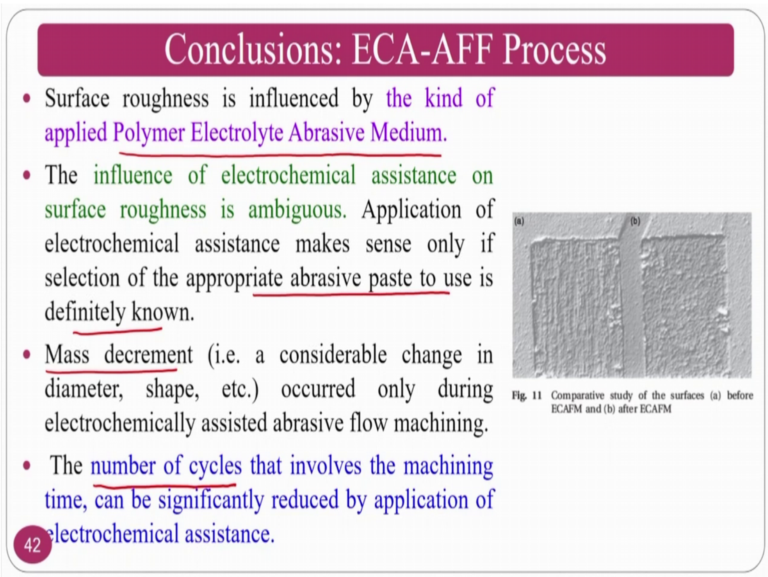

You can see the conclusions, about this abrasive flow finishing process where in electrochemical assistance is taken. Surface roughness is influenced by the kind of applied polymer electrolyte abrasive medium, you have a polymer electrolyte based abrasive medium will influence whether it is PEG based or PPG based or other salts based or something, it will be function of what is the medium which is important.

Influence of electro chemical assistance on the surface roughness is ambiguous, application of electrochemical assistance makes sense only in the appropriate abrasive paste to use. And the third one is mass decrement considerable change in the diameter shape and occurred only during the electrochemical assistance abrasive flow finishing process. Number of cycles that involved the machining can be significantly reduced, what I the author want to say here is that what the researchers aim in this particular thing is he want to reduce the extrusion pressure that is applying, at the same time he want to reduce the number of cycles so, that you are finishing can be achieved or material removal can be achieved with less time with less energy by hybridizing electrochemical machining along with the abrasive flow finishing process.

That is what the thing that is explained number of cycles less; that means, that if the 1 cycle is taking 1 minute, if 100 cycles are taking 100 minutes, if this process electrochemical assisted abrasive flow finishing process can do in 30 minutes in 30 cycles. That means, that your production rate as well as the power supply that you are doing for 30 minutes only instead of 100 minutes in case of conventional abrasive flow finishing process, that is the beauty about electrochemical assisted abrasive flow finishing process.

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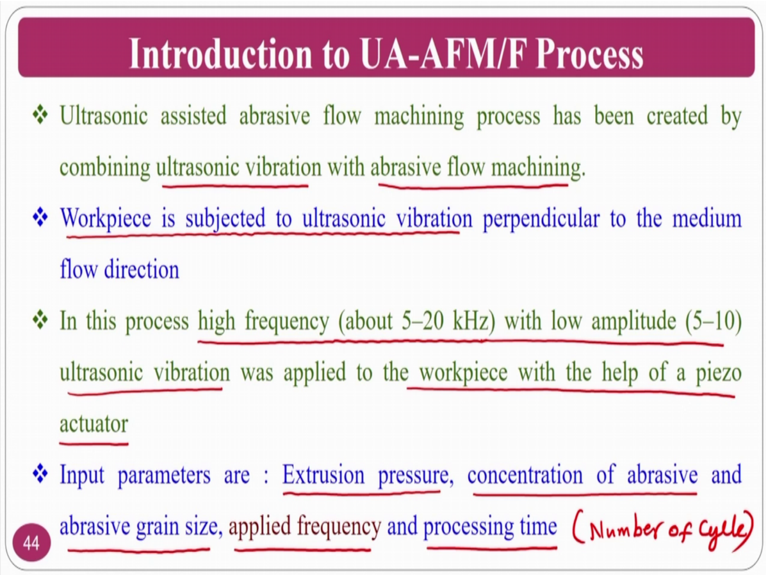

Now, after completion of 2 hybrid processes such as magneto abrasive flow finishing process and electro mechanical assisted abrasive flow finishing process where in magnetic field and electrochemical action are utilized respectively. Now we move on to another process which is also a hybrid abrasive flow finishing process that is called ultrasonic assisted abrasive flow finishing process.

Ultrasonic assisted abrasive flow machining process or the finishing process has created by the combination of ultra sonic vibrations with the abrasive flow machining process. Here what the authors or the researchers are doing is, they are clubbing or they are blending or they are additionally applying the ultrasonic vibrations to the work-piece of the abrasive flow machining process ok. That means that indirectly or that will be known to you in upcoming slides, what they are doing is they are utilizing the ultrasonic vibrations to the abrasive flow finishing process.

You know ultrasonic machining process where you have a ultrasonic vibrations will be given to your tool and the abrasive slurry will be there in between tool and work-piece because of this ultrasonic vibration of the tool the abrasive slurry that comes in contact with the tool will heat and this abrasive particle will go and heat the work-piece and the material removal will takes place that is the ultrasonic machining. This ultrasonic machining is combining with abrasive flow finishing process then it is called ultrasonic assisted abrasive flow finishing process.

As I said abrasive flow finishing process work piece is subjected to ultrasonic vibrations, which is perpendicular to the medium flow direction, every this pictures and other things with shown in the upcoming slides. This process uses high frequency with low amplitude vibration or ultrasonic vibrations to the work-piece with the help of piezo actuator. There will be a piezo actuator attached to the work-piece; the main function of this piezo actuator is to give ultrasonic vibrations to the work-piece in the direction perpendicular to the flow of your abrasive medium or polymer rheological abrasive medium.

Here the medium that normally using is convectional abrasive flow finishing medium only such as base polymers, rheological additives, abrasive particles and so on. Input parameters as you seen extrusion pressure, concentration of abrasive particles size of the abrasive grains applied frequency and processing time. That means, that processing time you can understand in terms of number of cycles also, instead of number of cycles if you know what is the one cycle time you can convert into processing time or finishing time. So, only new thing that we can understand here is applied frequency, that we will see.

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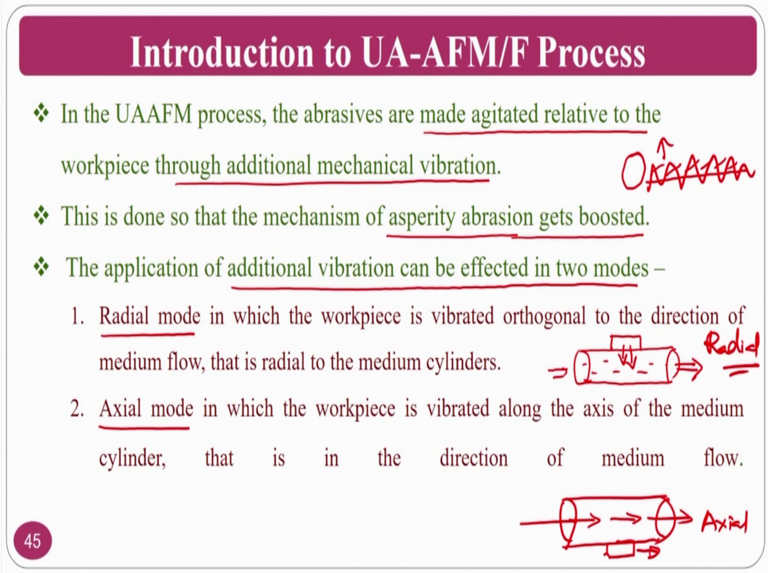

So, ultrasonic assistance abrasive flow finishing process abrasives are made agitated relative to the work-piece through the additional mechanical vibration; that means that the mechanical vibration is provided to the work-piece. This mechanical vibrations will try to agitate or try to make the work-piece into a dynamic one so, that the finishing action can be improved and material removal can be improved and the finishing time can be reduced.

This is done; that means, that the mechanical vibration is provided to the work-piece. So, that the asperity abrasive gets boosted; that means, that if their surface peaks are there, these are the surface peaks if this asperities finishing by the abrasive particle can be enhanced so, that it can do most of the finishing action and the material removal can be increased.

The application of additional vibrations can be effected in 2 modes, one is radial mode in which the work-piece is vibrated orthogonal to the direction of medium flow; that means, that our medium is assume that this is a cylinder where my medium is flowing like this. So, your ultrasonic vibration will be provided in this direction. So, axial mode in which the work piece is vibrated along the axis of the medium in this case as you know it will be medium is moving in this direction. So, actuation also will be provided in this direction only. So, this is called axial, this is called radial; in radial it is perpendicular, in axial in the same direction. So, 2 modes are observed and the finishing action can be checked with respect to radial mode and axial mode.

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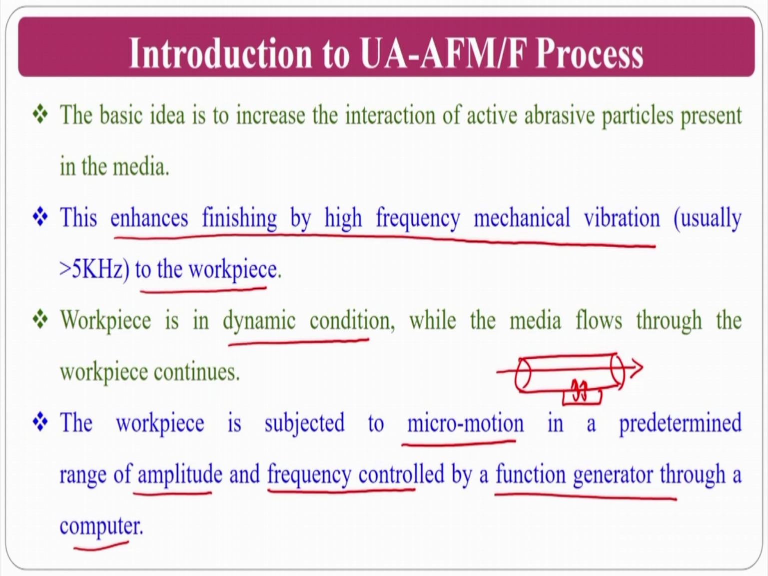

The basic idea is to increase the interaction of active abrasive particles present in the medium, the basic idea of providing vibrations is increasing the interaction of abrasive particles, what is happening if the surface is there abrasives are acting on it because of extrusion pressure plus polymer rheological characteristics of the medium composition. These are 2 things as we know from the conventional abrasive flow finishing process we have elastic component and viscous component elastic component is giving the radial force and viscous component is giving axial force and extrusion pressure is also giving us axial velocity.

This is completely because of 2 things, one is medium composition that decides the polymer rheological characteristics or medium rheological characteristics and extrusion pressure, but in this case additionally the vibrations that are provided to the work-piece also play a crucial role so that the finishing action can be improved. How and other things we will see the mechanics of material removal how the abrasive action can be improved with the vibrations and other things will be coming soon in the upcoming slides.

This enhances the finishing by high frequency mechanical vibration to the work piece and the work piece is in dynamic condition while the medium flow through the work-piece continuous; that means, that medium is flowing and work piece is getting agitated. So, my work-piece is here this is agitated by the piezo electric actuator and this actuator will provide you this agitation; this agitation and medium flow is in this direction. So, agitation makes the work piece in a dynamic state.

The work piece is subjected to micro - motion in the pre determined range of amplitude and frequency controlled by the function generated through the computer. There will be a computer controlled where in you have connected the piezoelectric sensor and through the computer you can say that this much is the amplitude that I want, this much frequency I want so, that the work piece will be in dynamic state.

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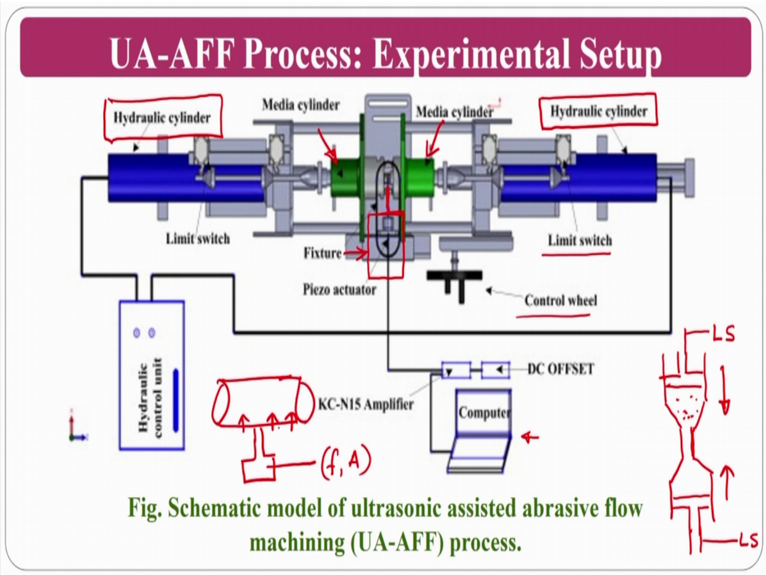

We can see now how the vibrations are given to the work-piece and other things in this experimental setup. This is the computer where you are going to give input to your piezo actuator, rest of the things are approximately same as you see here the medium cylinders are horizontal in case, in a previous case what you have seen is a vertical one. So, let me explain you here the various elements, the blue ones are hydraulic cylinders, one can be upper hydraulic cylinder, another one will be lower hydraulic cylinder, if we do they have been in vertical motion, but both are in horizontal condition.

Another green ones are your medium cylinders, where you can place your medium and this is the fixturing region where you can do the fixture. So, this fixturing is the only new thing that different from the convention abrasive flow finishing process. So, there will be a controlling wheel, there will be limits which, the function of limits which is to maintain the stroke length. Stoke length means assume that I am taking a vertical abrasive flow finishing setup. This is my work-piece region assume, this is my medium and other region what will happen, my hydraulic piston is here.

So, this will be indirectly connected to limit switch this will decide how much distance my piston has to move in one cylinder. Once it goes to the maximum position that limits which will click, when the limits which will click what automatically what will happen, the hydraulic power that is coming from hydraulic power pack will deactivate and it will activate the other side; that means, that all bottom side also you will have a limit switch.

So, once it goes to the maximum limit automatically this will also switch, tuck sound will come in a micro switch or limit switches what will happen that will deactivate; that means, that hydraulic power that is coming from hydraulic power pack will deactivate so that the other will activate. So, in this way 2 pistons will reciprocate in the same direction so, that the finishing action can be done.

Apart from this one the fixturing region is a slightly different from convectional where you have a piezoelectric actuator that is connected here, these piezo electric actuator will actuate the work-piece material. I am having a work-piece like this, piezoelectric actuator is actuating and this piezoelectric actuator is connected to the computer so, that you can give what is the frequency and amplitude that whatever you want.

So, that this will provide the motion in the perpendicular direction to this work-piece, that is what the set up says. You have similar to convectional abrasive flow finishing, but only you are giving some vibrations to the work-piece to check what is it is effect we have to proceed further.

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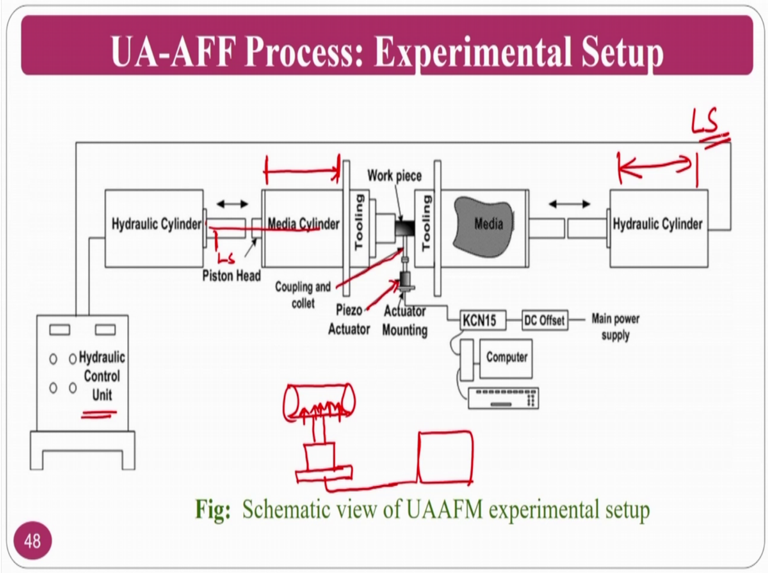

Fig: Schematic view of UAAFM experimental setup

This is also a schematic where I want to show you is how the piezoelectric actuator and mounting is done, you can see here piezoelectric actuator is here and it is coupled to a collate and work-piece is here. So, your work-piece is like this, the work-piece assembly or the tooling assembly was not clear in the previous image or previous figure that is why I have connected. And you have a coupling and collate will be there then you have a piezoelectric actuator and this is mounted on a mounting that it is called actuator mounting and this is connected to indirectly to the computer.

Now, computer will give you what is the amplitude and frequency so that this will get the dynamic motion or dynamic vibrations. Hope you understand now about how the ultrasonic assisted abrasive flow finishing process or abrasive flow machining process experimental set up works. And from here hydraulic control unit you will get hydraulic cylinder and this will go into the medium cylinder your limits switch will be here, this limit switch will activate and deactivate, whenever the piston goes from top dead center assume that this is my top position to the bottom dead center the limit switch will click then it will detective and makes other one active from the other side. That is the function of limit switch or you can also see some of the papers as a micro switch.

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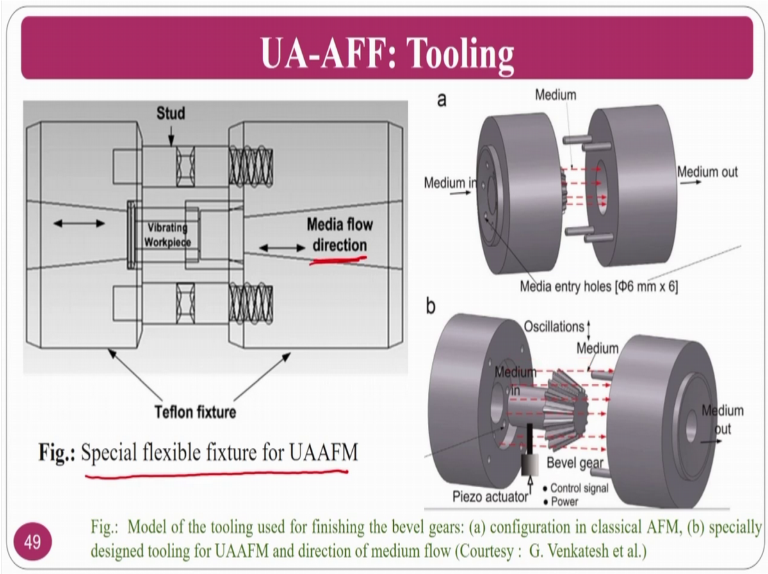

You can see the tooling, as I said the tooling is a only different one studs are there and other things are there, the medium flow direction and other things are there. Teflon pistons various things are there and vibrating work-piece will be there. Now what the researchers are doing is they are going to finish the bevel gears. So, the special flexible fixture to the ultrasonic assisted abrasive flow machining process is designed and to finish the bevel gears, how they are going to finish the bevel gears that we will see in the upcoming one.

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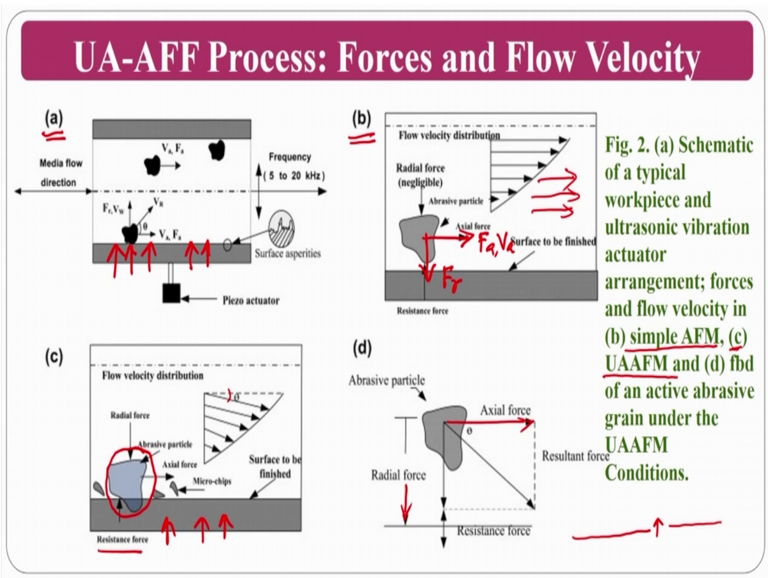

Now, we will see how the forces and the flow will takes place in the ultrasonic assisted abrasive flow finishing process. The first figure a represents the ultrasonic actuator assembly or connection to the normal work-piece in the abrasive flow finishing process and you can see here piezoelectric actuator is there which is connected to a couple and collate, where now you are going to give just vibrations to the work-piece.

We will compare with the simple abrasive flow finishing process, in a simple abrasive flow finishing process as you can see in figure b the radial force and axial force. Axial force will be there, axial velocity will be there and radial force will be there, these are 3 things that are commonly available in conventional abrasive flow finishing process.

But because of the dynamic action, because of the vibrations of the piezoelectric actuator what will happen here is, that sea shows ultrasonic assisted abrasive flow process because of the radial vibrations what will happen the penetration depth will be increased. How it will be increased, you can see here you have a radial force and axial force and axial velocity and abrasive particle is forced to indent more because of your radial vibrations.

Assume that, my work-piece is here, whatever it has to do it is doing by the medium action, assume that there is a slight change in the radial direction because instead of this if I am having some microns inside what will happen. The depth of indentation or the radial force that is indenting in to work-piece will increase because of which what will happen, material removal also will increase. At the same time flow distribution will be in the straight lines in the case of abrasive flow finishing process, but in case of dynamic action there will be a certain change in the angle of your medium flow because of which what will happen the shearing direction will be slightly away from your axial direction.

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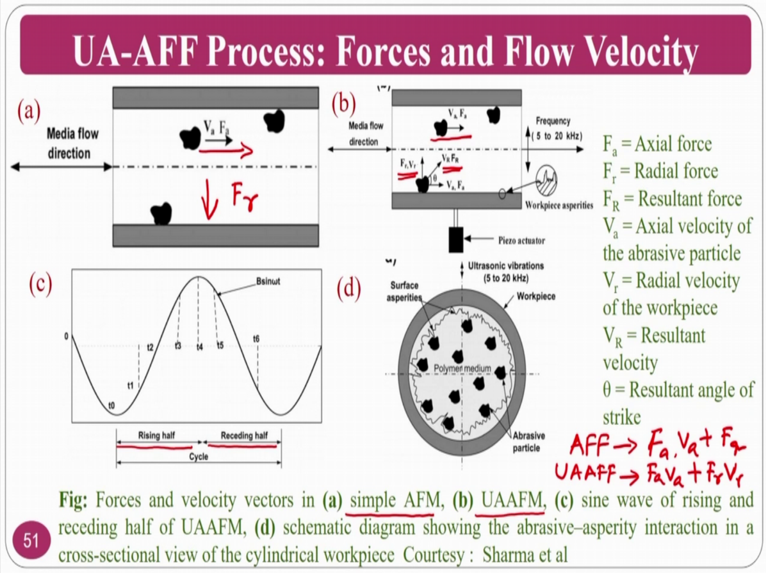

You can see here forces and flow velocities and other things, in the medium flow direction basically you are seeing the convectional abrasive flow finishing process, axial force and axial velocity and radial force will be in this direction. But if you see in case ultrasonic assisted abrasive flow finishing process axial force and axial velocity will be there, apart from it you have radial force and radial velocity; because your work piece also vibrating in the perpendicular direction to the medium.

In the previous case of abrasive flow finishing process your radial velocity is negligible because your medium indenting velocity is much much less compared to axial velocity, but here because of the vibrations effect radial velocity also can be considered. Because of this what will happen, you have the resultant velocity and resultant force; what I mean to say is that additional velocity is coming into picture because of your radial vibrations.

You can see a cycle, raising cycle or the raising half and the receding half because of which what will happen the velocity in the radial direction will be added advantage. What I mean to say is, in abrasive flow finishing process you will have axial force, axial velocity, plus radial force. In ultrasonic assisted abrasive flow finishing process you will have axial force, axial velocity, plus radial force and radial velocity because of this additional effect of radial velocity what will happen, the finishing action will be improved and the material removal can be improved.

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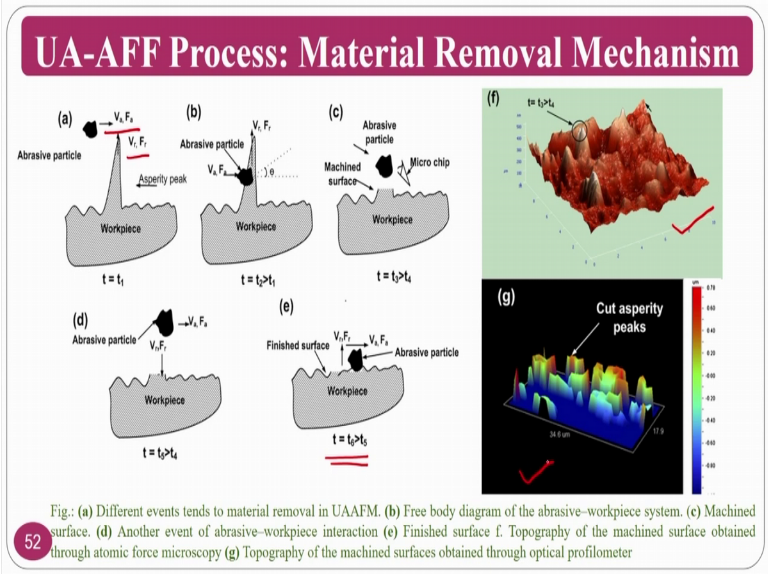

You can see because of the axial force and the axial velocity and radial force and radial velocity what will happen is it will be shearing properly and the material removal takes place in a good way. You can see again in the 3 dimensional view also and how this cuts are taking place and other things also can be shown in the 3 D surface profilometer using this process.

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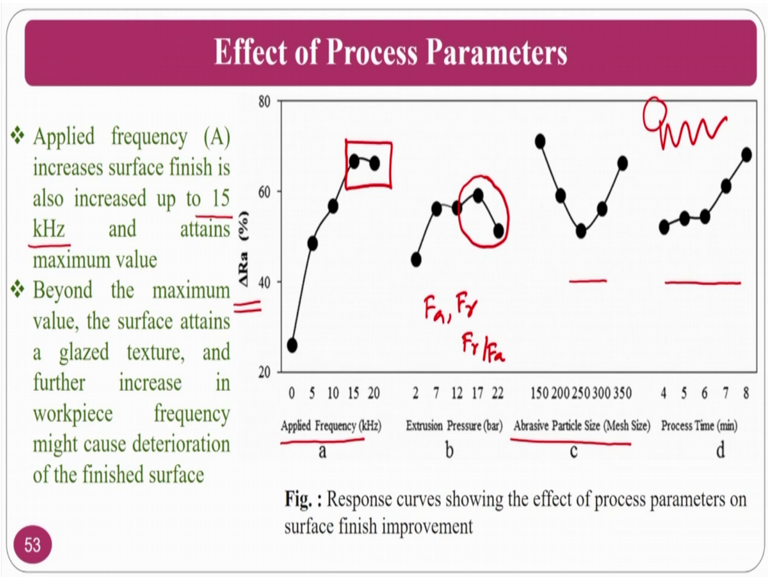

Apart from extrusion pressure abrasive particle size and processing time the only novel thing in this particular particle process is applied frequency, as you can see here as you increase the applied frequency up to 15 kilohertz it attains the maximum value beyond the value it is starting decreasing. If your frequency is very high what will happen, that number of times work piece is vibrating will very high, if that means, that your radial force will be also will be increasing, for the same amplitude because of which what will happen your material removal will increase at the same time surface roughness will decrease.

So, that what will your initial to the final surface roughness will increase; that means, that your change in roughness will increase, but beyond certain value what will happen there will be a indentation, but not the shearing action; that means, that shearing action will be there, but dominating will be indentation because your radial velocity will be very high. If your radial velocity is very high that is clubbing or mixing along with the radial force what will happen, indentation will dominate rather than shearing action, that is because of that what will happen there is a slight decrease.

As you can see the extrusion pressure and other things these are all commonly we have seen in the abrasive flow finishing process. If you increase the extrusion pressure your F a and F r will increase and at a higher extrusion pressure your F r by F a will increase that is called forced ratio will increase. If the force ratio is increased or increment in the radial force will be high compared to axial force, because of which what will happen indentation will be dominating that is why you can see a fall in the finishing region.

If you the abrasive particle size in terms of mesh, the similar trend that if the abrasive particle size is increasing indentation will increase, if the mesh size is increasing; that means, that your particle size is decreasing if the particle size you have to choose approximately optimum. Since the abrasive medium is a liquid to semisolid in that circumstances if you choose too small abrasive particle what happen it will just go inside to the medium whenever sufficient support is not there from the medium that is why there is always optimum value for different different medium compositions.

At the same time processing time processing time; obviously, if you are increasing more and more time; that means, that more number of cycles you are increasing more number of times abrasive particles will come in action with respect to the work-piece surfaces or if we have approximately this surface what will happen number of times abrasive particles will come and hit the surface peaks will be high.

So; obviously, cumulative finishing will be better in terms of number of cycles, but; however, there will be a critical surface roughness will be achieved beyond which normally there would not be much change in surface roughness.

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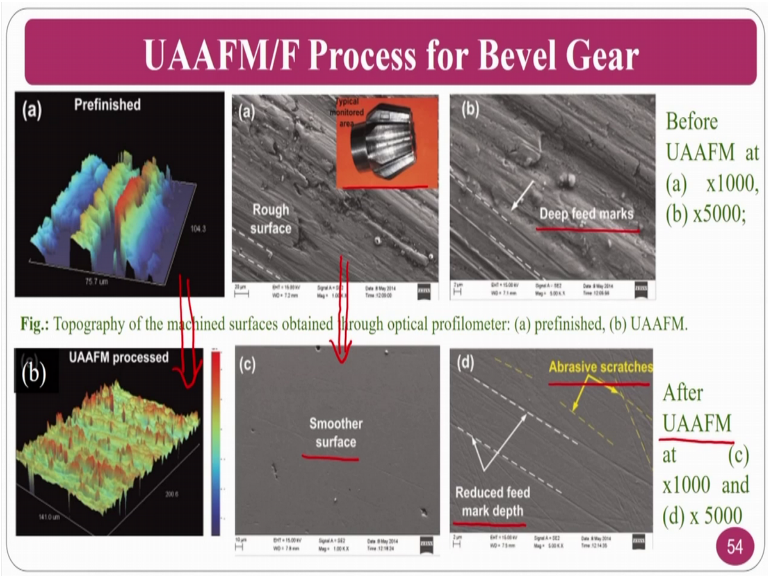

You can see here ultrasonic assisted abrasive flow finishing process bevel gears these are the initial surface which is rough and deep feed marks are there and after the finishing action you can see the smooth surface reduced peak depth and abrasive scratches also can be seen after ultrasonic assisted abrasive flow finishing process.

That means that transformation from this surface to this surface is taken place or this 3 D surface to this 3 D surface is taken place; that means, that better surface is achieved on the bevel gears. And the medium is passing through and the radial motion is given in perpendicular direction because of which what will happen the finishing action will be dominating.

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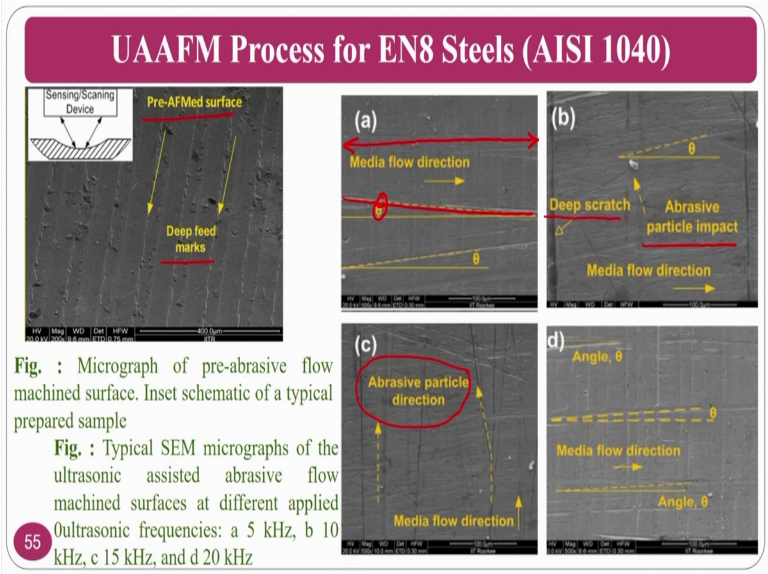

You can see here again the AISI- 1040 material the initial deep marks are there this is called a prefinishing operation they have done and after finishing what they want to represent is the direction of medium is not in the shortest distance.

Normally if you see in a conventional abrasive flow finishing process it will be shortest distance like a straight line here also it is a straight line, but the thing is there is certain angle will be there and that is moving in certain direction, because of which the finishing length also will be improved and finishing rate also will be improved.

You can also see some of the deep scratches, particle, impact and medium flow directions and particle directions also can be seen it is because of the vibrations effect the bottom line of this semi major shows that the because of the dynamic action of the work piece and because of the straight motion or the medium it is no more a straight. Because of this dynamics that is provided to the work-piece it is not going in a shortest distance it is going in a slightly inclined manner and the cutting length or the shearing length will be increased.

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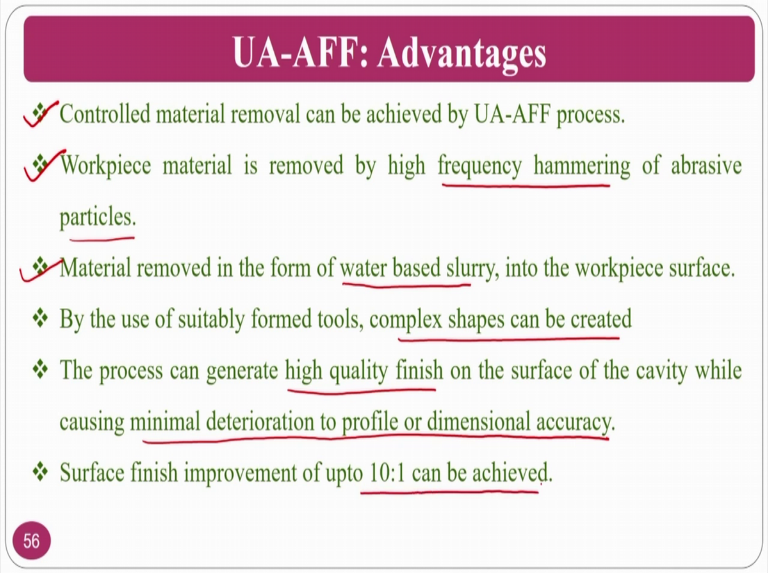

So, the advantages: the controlled material removal can be achieved by ultrasonic assisted abrasive flow finishing process, work-piece material removal by the high frequency hammering abrasive particles because of this high frequency dynamic motion what will happen, hammering will takes place and material removal will be increased.

Material removal in the form of water based slurry, into the work-piece. By the use of suitably formed tools, complex shapes can be created. The process can generate high quality surface finish and while causing the minimal deterioration to the profile and dimensional accuracy. That means, that surface finish can be improved at the same time dimensional accuracy can be improved. Surface improvement will be up to 10 is to 1 can be achieved by this ultrasonic assisted abrasive flow finishing process.

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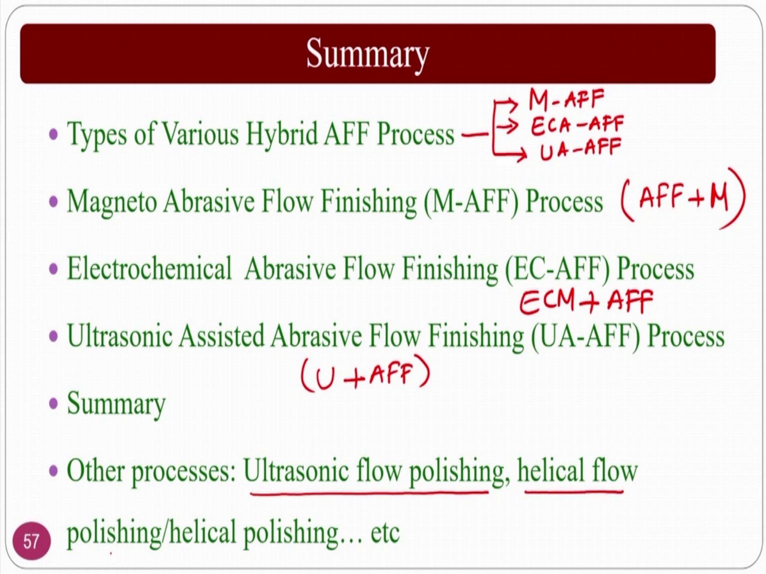

The summary of this all hybrid abrasive flow finishing processes if you see, we have gone through various hybrid abrasive flow finishing processes, we have 3 varieties of hybrid abrasive flow finishing processes that we have seen, one is magneto abrasive flow finishing process. Then we have seen electro chemical assisted abrasive flow finishing process and the third one which we have seen is ultrasonic assisted abrasive flow finishing process.

These are the 3 varieties of abrasive flow finishing process that are clubbed with different different other things that we will see, what here in the magneto abrasive flow finishing process what you are going to is abrasive flow finishing process clubbed with magnetic field.

In the second one electrochemical abrasive flow finishing process you are going to club electrochemical machining process with abrasive flow finishing process. In the third one ultrasonic vibrations; ultrasonic vibrations are clubbed with abrasive flow finishing process so, that ultrasonic assisted finishing process is achieved and the summary of this one and other process if somebody are interested. There is another similar process to ultrasonic assisted abrasive flow finishing process is called ultrasonic flow polishing it is similar you can see and other processes you can see helical flow polishing process at the same time helical polishing process also will be there.

Other processes helical flow polishing process or helical polishing process also will be there, most importantly all these processes will use polymers plus abrasives that is the beauty about this particular course where you study about enormous number of advanced finishing processes, where you use polymer assisted abrasive finishing processes.

Thank you for your kind attention for this particular class.