Polymer Assisted Abrasive Finishing Processes

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Lecture – 11
Advances in Abrasive Flow Finishing: DBGAFF, CFAAFM

Welcome to the course. And, now I am going to start with the advances in Abrasive Flow Finishing Process. Till now you have seen, what is abrasive flow finishing process and other things. Now, we are going in to few of advances that the researchers have done in this area.

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So, the overview of the lecture so, we will go ahead with introduction to various advancements, what are the advancements? There are 3 advancements that I am talking about majorly. And, the first one is drill bit guided abrasive flow finishing process, then second one is centrifugal force assisted abrasive flow machining process, or finishing process. Because, the author whenever you are going through the literature, or whenever you are going through the papers that I am talking about the concept here.

So, the paper say some centrifugal force assisted abrasive flow machining process. However, as you know that nowadays abrasive flow finishing process is for the finishing process. So, the machining part has been partially converted by some of the researchers in to finishing, some of authors still follow machining only. It means that abrasive flow

machining; some of the people will follow abrasive flow finishing. So, both are same. That is why I have written here abrasive flow machining bar finishing process ok. So, then the spiral polishing process and the advantages and disadvantages of this advancements then we will see the summary of the particular class.

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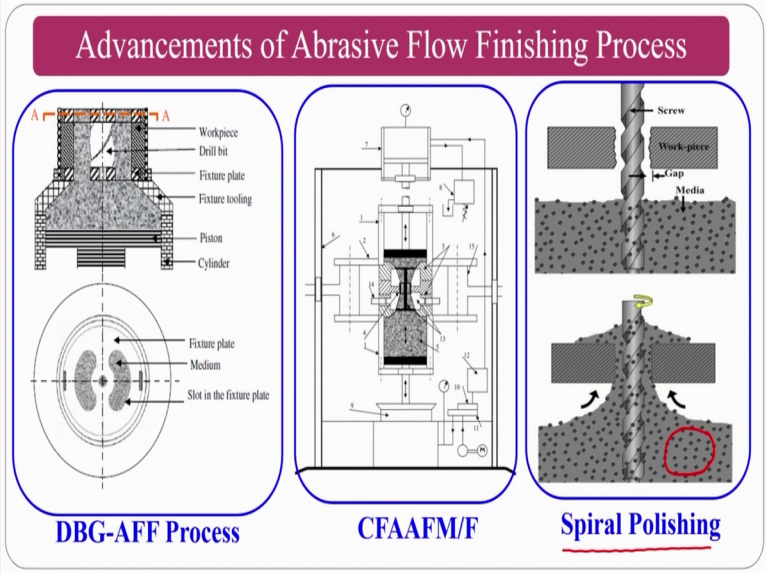

So, the advancements, first advancements is drill bit guided abrasive flow finishing process. And, I will come each and every things in a elaborative way in the upcoming slides. The second one is centrifugal force assisted abrasive flow finishing process, or the machining process and the third one is spiral polishing. But, spiral polishing there is no reciprocation motion such as drill bit guided and centrifugal force assisted, but we are talking this as one of the advancements. Because, here silicone based and modified silicone based medium is used, that is one type of polymer based medium is used.

Since our subject is polymer assisted abrasive finishing processes. So, silicone polymer is also subset of that one. So, the medium that is shown here is a silicone based medium blended with abrasive particles and some of the rheological additives. That is why we are taking up this as also as one of the advancements. The first one that we are going to see is drill bit guided abrasive flow finishing process.

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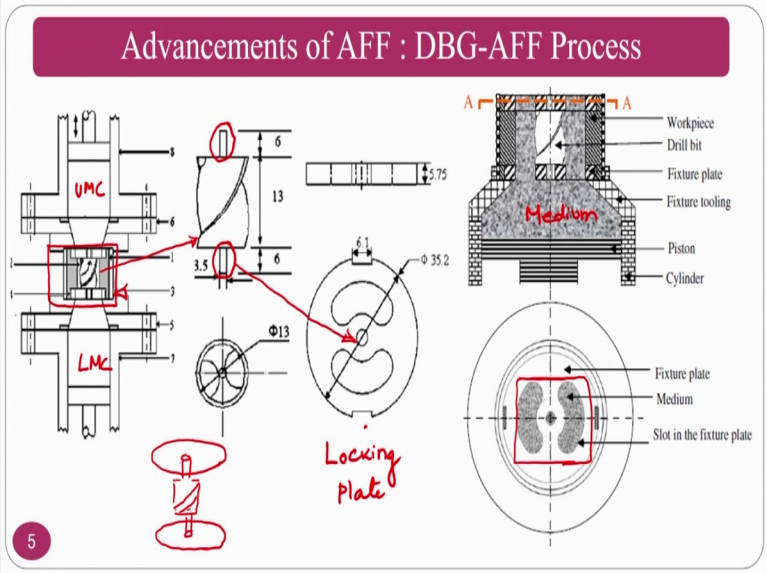

And, the advancements in this one, you can see here the only difference that you can see in the drill bit guided abrasive flow finishing process and the abrasive flow finishing process is fixturing. That means, this is the lower medium cylinder, and this upper medium cylinder, and this is the fixture region where you are going to place your drill bit and under work piece materials and, other things. Same thing the drill bit, you can see here and, this complete region, whatever you are seeing here you can see here practically.

So, I am having a medium here and you are having 2 locking plates that you have seen in the abrasive flow machining process, you will need to lock the work pieces. So, this locking system has been changed and you can see here you have 2 locking plates; this is locking plate ok. Where your drill bit, 2 edges this edge and these edges are fixed to the hole that is provided in a locking plate ok.

So, I mean to say is I have one locking plate here and another locking plate here, in between you there is a hole and there is a openings all the, kidney shape over openings are there these one. So, here you will fix the your drill bit ok. You can vary your drill bit diameter in the current scenario and you can check the finishing.

The main purpose of this one is to reduce the medium that is going at the centre; that means, that ineffective abrasive particles are to be made active in the drill bit guided abrasive flow finishing process, how? That we will see in the next slides. And, what you

have to see here is you have 2 kidney shaped openings are there at the bottom and at the top through which medium will come.

So; that means, that whenever a medium is coming out from the finishing region to the upper medium cylinder whenever you are pushing from the bottom cylinder. So, this will become a split one. So, this split will come into the upper medium cylinder, because the medium is a self-deforming medium it and it is freely flowing medium. So, the mixing and the inter mixing of the medium will takes place and the abrasives the new abrasives will come into picture.

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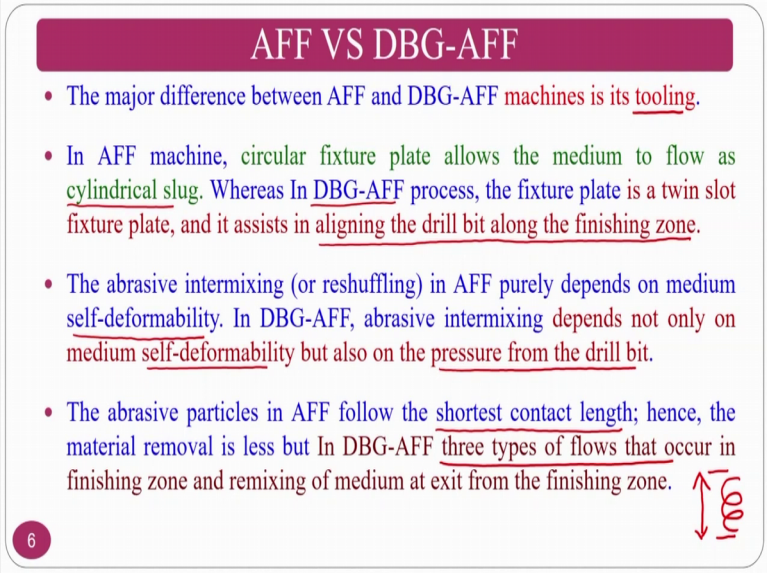

So, the difference between abrasive flow finishing process and drill bit guided abrasive flow finishing process: the major difference is tooling as I said the tooling that you have seen till now that the drill bit will be there. And, drill bit will be accompanied by a 2 locking plates with kidney type of openings. In abrasive flow machine the circular plate allows the medium to flow as a cylindrical slug ok, but whereas, in drill bit guided abrasive flow finishing process, you have a twin slot and a fixture and it assist aligning the drill bit along the fixture plate. The main function of this one is it will align the drill bit. At the same time it will also split the medium ok.

The abrasive intermixing or reshuffling in abrasive flow finishing process is purely depend on medium self-deformability only ok. So, in drill bit guided abrasive flow finishing process, the abrasive mixing depend not only on the self-deformability, but also

on the pressure of the drill bit that is there in the finishing region ok. If, the finishing region drill bit is there what will happen the medium has to split into 2 halves, because the drill bit has 2 flutes. Normally even flutes will be there in any type of conventional drill bits ok.

So, it can go in a 2 flutes at the same time the medium far away from the drill bit may grow as a slug, but the abrasive particles which are there in the near the drill bit can be pressurised towards the active region that we will see.

The abrasive particles in the abrasive flow finishing process is the shortest contact length that is a straight line; normally extrusion pressure is there then you will have a shortest path, but in the shortest path; that means, that number of peaks encountered by the abrasive particle is minimum. Assume that you have a helical path; that means, if this height is same and you have a helical path in that one. So, you have a more distance that the abrasive particle is covering. For that purpose there are 3 types of flows that you will see in the upcoming slides and intermixing of the medium will also takes place so that the new abrasive particles will come. So, this will enhance the finishing ability of the process.

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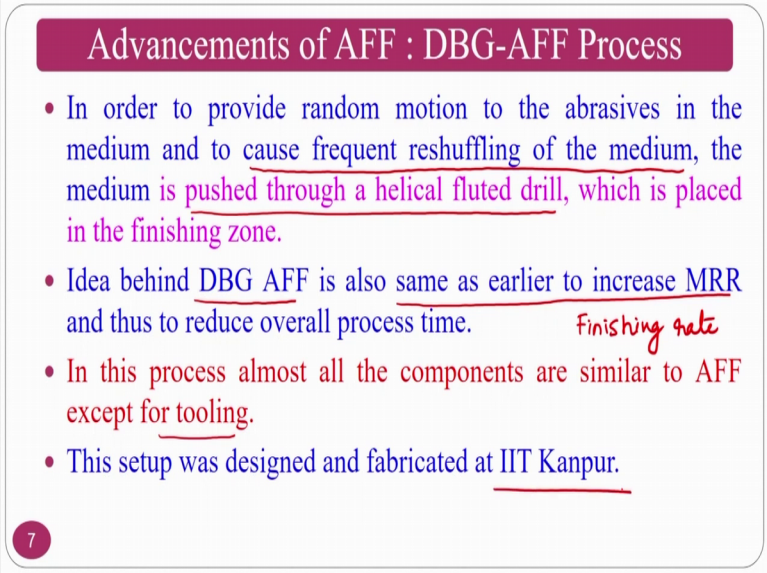

So, advancement in order to provide random motion to the abrasives in the medium, it causes the frequent reshuffling of the medium, that is drill bit causes the frequently shuffling, because the curvature of the flute changing point to point that is why the

abrasive particles also will vary in the finishing region ok. And, the medium is pushed through the helical flute drill, which placed in the finishing region. The idea behind the drill bit guided abrasive flow finishing process is same as earlier to increase the material removal rate and finishing rate.

Finishing rate; that means, that the amount of change in roughness that you are getting per unit time, this process almost components similar to abrasive flow finishing process except the tooling. So, the setup was designed and fabricated normally at IIT Kanpur. So, I am very thankful for IIT Kanpur.

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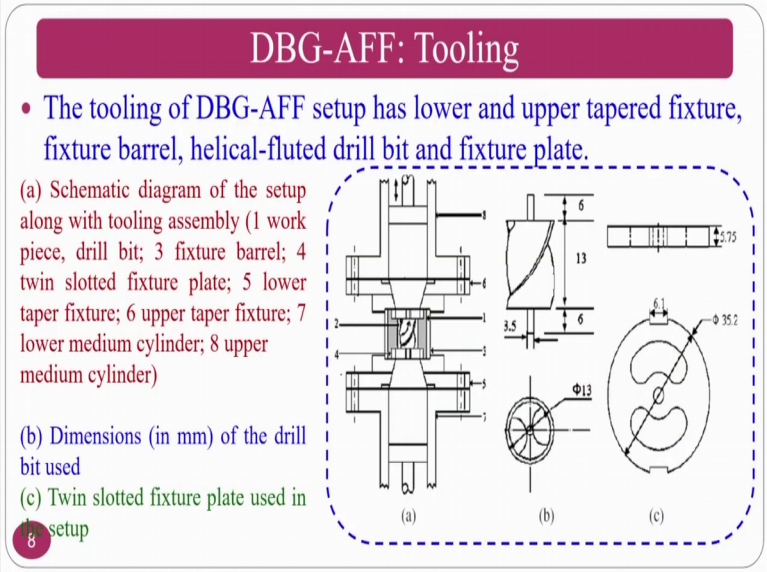

So, the tooling of Drill Bit Guided Abrasive Flow Finishing setup at a lower and upper medium cylinders and you can see here the same picture again it is there. So, these are the various elements are there; what you have to observe is how the medium is entering, how the medium is exiting.

So, this is the plate here, and this is the plate again here, same plates are there 2 plates are there ok. The 2 plates whenever you are pushing from this side medium. So, this will enter through this kidney shaped structures and compresses because of the drill bit that is a presence in the finishing region, because of this exit in a 2 way. So, medium is self-deformability. So, the new cutting edges will come because this will have intermixing in the medium cylinders.

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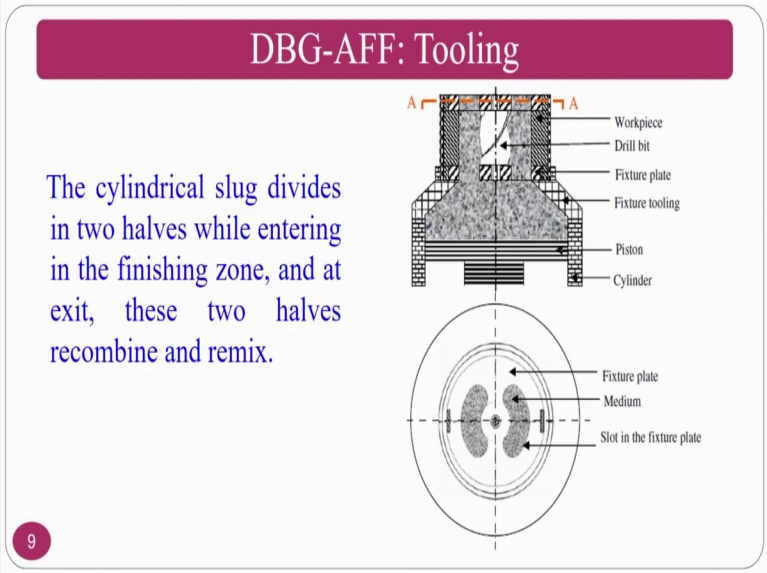

That you can see here, how the medium slug divides into 2 halves. So, the medium slug which is coming from here the section A A if you see the section A A. So, the medium slug is coming out and here the drill bit is holding at this position in the top view. And, this medium slug will intermix and new abrasive particles will come, but whereas, in abrasive flow finishing process it is a cylindrical slug. So, the complete intermixing of the medium is completely depend on self-deformability characteristics of the medium, that is polymer rheological abrasive medium only here.

The drill bit also helping the intermixing of abrasive particle. If, there is a intermixing of abrasive particles what will happen is the new abrasive particles may come into the finishing region, and the weighed out particles may go inside, or it may have new cutting edges of the existing abrasive particles will come into picture for the finishing action. That is the beauty about the drill bit guided abrasive flow finishing process.

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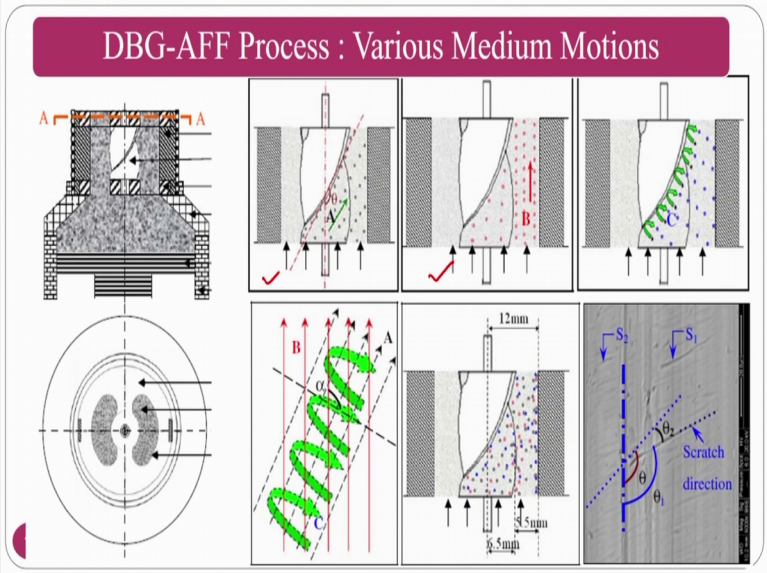

Whereas, medium motions if you see in the picture so because of the drill bit we have various motions. The first motion that you can see here is because of the flute, this is the flute, there is a motion along the flute. And, because of the reciprocation the abrasive particles away from the drill bit may reciprocate that is the second one. The third one is scooping flow, because you know always the drill bit will have certain cutting edge slightly bigger than the flute. So, it will come like a ice cream scooping.

So, all these motions I will explain. And, these are the 3 motions combinely work and reshuffling of abrasive particle and pressure will be generated on the medium so that this pressure will be carried and exerted on the finishing surface.

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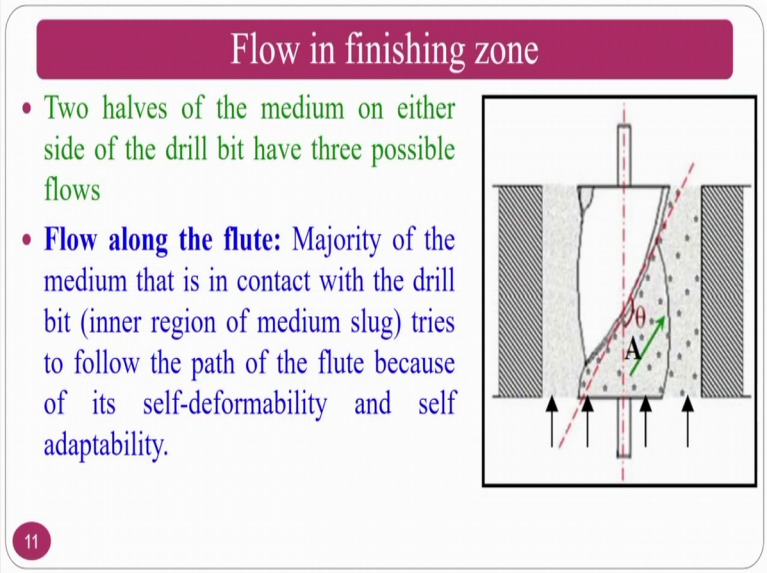

The first motion that you can see here is the helical motion that is because of the flute. 2 halves of the medium either side of the drill bit have the 3 possibles ok. So, first possibility is flow along the flute, because the flute will have cavity, big cavity. So, medium tries to go wherever the space is there; means that the flute having maximum space so it will occupy and the medium flow will be faster at the centre compared to at the finishing region. Because of that what will happen is medium tries to flow through the flute ok. That is the inner region of the medium slug tries to flow along the path of the flute, because of it is self-deformability and self-adaptability will takes place, it will adapt all the motion along with the flute.

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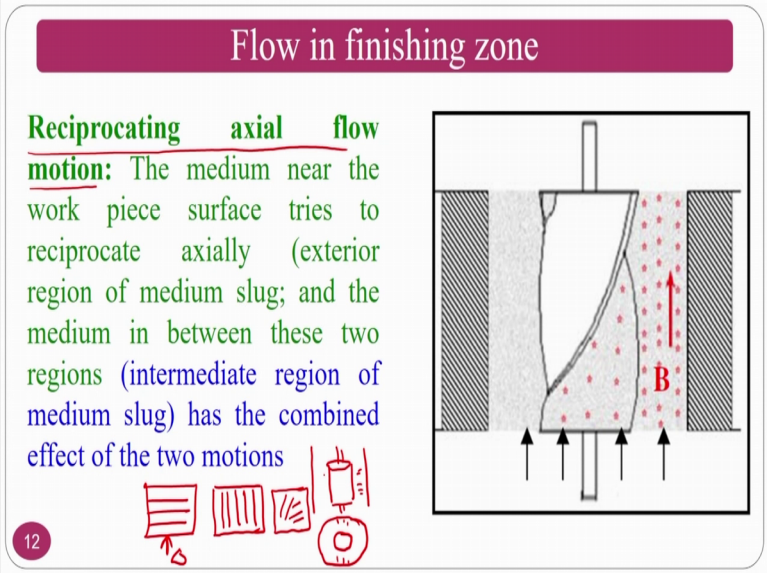

The second one is reciprocating axial motion; the medium near to the work piece. Because, this is slightly away from the flute and away from the drill bit in that circumstances. At the same time drill bit is a cylindrical surface, if you see my drill bit is a cylindrical surface and my work piece is like this ok. In that circumstances if you see the top view it will be like this.

So, only this region not only this region it also will have this regions also will flow in a reciprocating way ok; that means, that it tries to reciprocate axially, because the influence of the drill bit from it surface towards a work piece surface will gradually reduce. So, if the influence of this one reduces what will happen? The reciprocation motion will be dominating; that means, that even though the reciprocation is there, but because of the this flute nature, because of the obstruction what will happen the abrasive particles may move in to that region and helps the reciprocation.

And, we will see how whether the surface is only by the virtue of reciprocation or flutes also play a major role in this process, that we will see whenever we are going to study about scanning electron micrographs, that is the surface morphology of the surface whenever we see we can understand, it is purely because of the reciprocation or any other motions also coming into picture. How do you define or how do you determine, if it is a purely reciprocation motion, then you will have the straight lines.

Assume that I have a grinding surface like this. And, I have the grinding lay that is predominant surface direction. So, if I am moving my abrasive particles like this, what will happen the final finishing lines are the surface lay in the abrasive flow finishing process will be like this. But, if we have a flute and if there is a direction it is giving.

So, in that circumstances it may not be exactly as a vertical, it may go any certain inclinations. So, if we are going to get certain inclinations on the surface morphology, then we can determine that it is not only by the virtue of the reciprocation, but also there is a domination by the flute or the inclinations that is developed by the drill bit.

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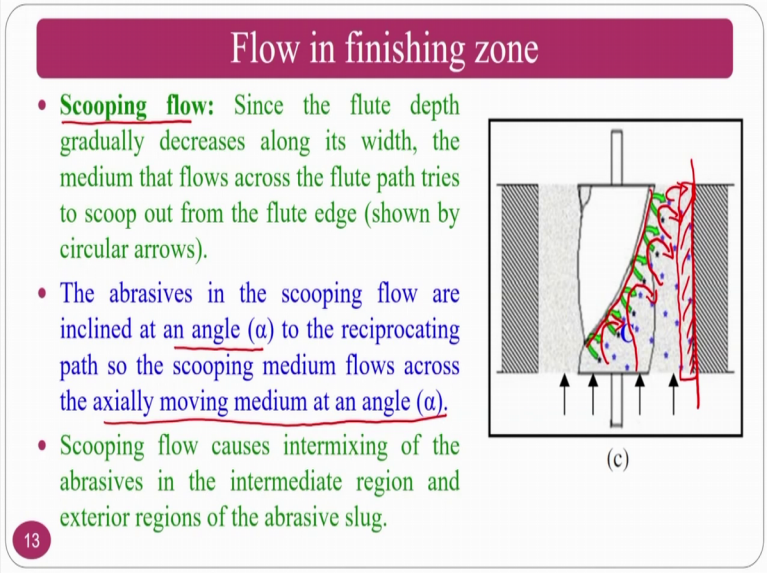

So, the flow in the finishing region, the third flow is a scooping flow familiar to the ice creams many people will see in the ice cream parlours. So, scooping will be done. So, they will just if you want ok, I want the strawberry, I want the vanilla, I want the butter scotch. So, other otherwise I want the mixed. So, you do the scooping, how the scooping? You will have a cup of thing and you will have a semisolid ice creams so, you can get the scoop.

Since the flute depth is gradually decreasing along it is width the medium, that flows across the flute path try to scoop out from the flute edge; that means, that you will have a flute edge this flute edge is big and you have a cavity also. So, my medium is going like this and comes like this because of the scooping action.

So, the abrasives in a scooping flow are inclined to at an angle that is called alpha that we have named to the reciprocating path of the scooping medium flows across the axial moving medium at an angle alpha. So, this is the scooping flow so; that means that the scooping flow causes intermixing of the abrasives in the intermediate region and exterior regions of abrasive slug; that means, it shows that if there is a scooping flow. If scooping is there like this and abrasive particles are moving like this so, if this moves like this what is the beauty about this particular process is the self-deformability medium will mix, and the velocity that is carrying will move like this, and it will flow towards the finishing region that is a beauty. And, I know my finishing region is this; this is my finishing region ok.

My scooping flow direction is like this and it will move along this direction and because of the self-deformability the abrasive particles, because of the self-deformability the abrasive particles in the scooping flow and along the direction of the flow. This will make the active abrasive particles; active abrasive particles means those particles which are there in the finishing region will become the active abrasive particles, the scooping flow of the medium at the same time the flow along the flute makes, the active abrasive particles. That is those particles which are there in the finishing region become more dynamic. That means, that the abrasive particles, which are there in the finishing region may get some dynamic motion and the new abrasive particles or the this dynamic motion causes the new cutting edges at least.

So, that is improves the finishing performance. So, if it is not going to change, but the medium velocity will be high compared to the abrasive velocity assume, in that circumstances my medium or by means the polymer chains will move. In if the polymer chains will move what will happen the abrasive particles at least may have some rotation or some random motion, because of which the new cutting edge may come into picture and this can improve the finishing ability of the abrasive process.

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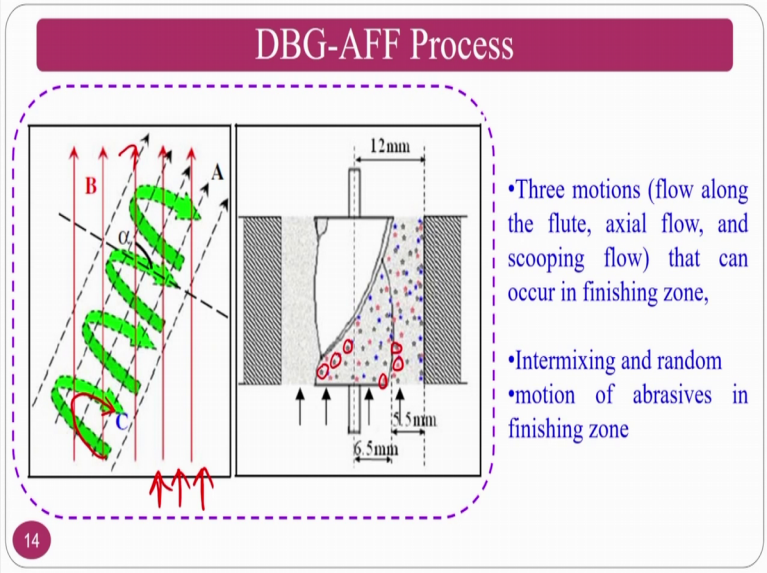

Now, we will see we have 3 motions; one is a reciprocation motion, and the second one is the along the flute direction motion, and the third one is scooping flow this green one is a scooping flow ok. So, the reciprocation shows the red colour one and the black colour arrow shows, the flow along the direction of the flute, and the green arrows shows the scooping flow.

Because of this 3 what is going to happen is the medium will get some random motion, at the same time the medium will be always continuous, always in the dynamic condition and the abrasive particles in the active finishing region will get reshuffled. If it is reshuffled that will be the best solution, if it is if the reshuffling is done; that means, that new abrasive particles will go. If there is not much reshuffling is there in that circumstances at least the new cutting edges, because of the motion of the abrasive particle new cutting edges will come into picture ok.

That you can see here, the abrasive particles which are red colour are suppose to be reciprocating in nature and the black ones are moving along the path you can see here, you may not exactly differentiate the green ones here. So, the green ones will have the scooping flow because of the blue ones. So, the blue ones also there this blue ones will have the scooping motion (Refer Time: 22:48), in that circumstances what is happening is completely randomization or the dynamic motion is there in the finishing region. Because of this what will happen, you can assume that there is a medium self-deformability along with scooping flow, flow along the flute and reciprocation causes the

medium enormous or increases the self-deformation, and the new abrasive particles will come into picture.

Because of these the finish action will be improved and the finishing rate, because in the abrasive flow finishing process if the self-deform abrasion is the only cause to reshuffle the abrasive particles. Here the reshuffling is done by motion, reshuffling is done by the scooping flow as well as flute flow through the flute also.

So, it increases the cutting edges it increases the reshuffling, because of which the finishing rate can improve. Because, the cutting new cutting edges will come, new abrasive particles will come; even though the number of cycles is same the finishing action will be improved.

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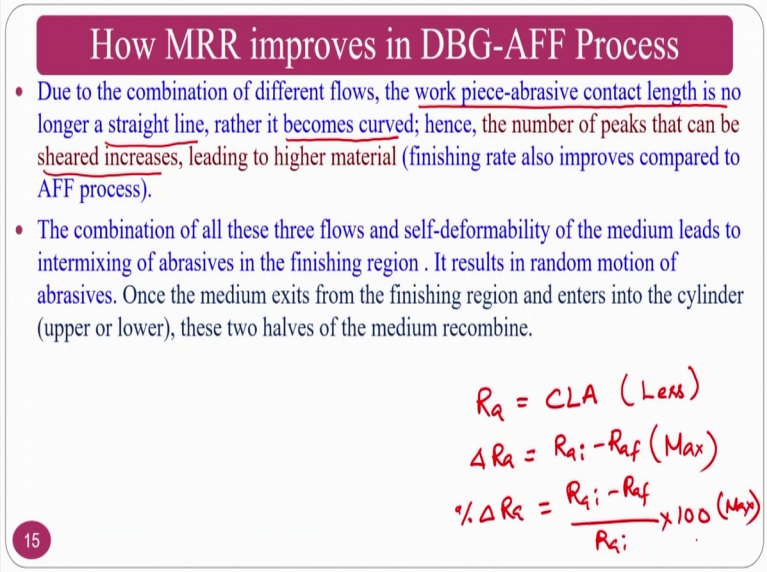

So, how MRR and other things will improve, due to the combination of different flows, the work piece abrasive contact length no longer a straight line, because the helical is there, scooping is there and other things rather it become non-linear basically.

So, hence the number of peaks that can be sheared will; obviously, increase because if the distance or the contact length of the abrasive particles with respect to surface peaks will increase. So, if it is increases and the abrasive particles also gain certain additional velocities. And, additional radial force because of these what will happen the material removal will increase; that means, that number of peaks shearing will improve; that

means, surface roughness will decrease; that means, change in surface roughness will increase.

So, the people who are watching should understand the some of the graphs I am talking about R a; that means, CLA, that is nothing, but centre line average value, that you have already studied. And delta R a, delta R a means change in R a normally R a should be less, if it is less; that means, that your surface roughness is less; that means, your surface finish is good.

So, delta R a is R a initial minus R a final ok. So; that means, that if it is as maximum as possible; that means, that my surface improvement is maximum. So, you require here maximum and percentage delta R a; that means, that the percentage R a i minus R a f by R a i into 100. So; that means, that this also I require maximum ok. This please make sure that whenever some of the graphs, because these are the things that I have taken from the research papers. So, some people they have reported in terms of R a, some people they have reported in terms of delta R a, some people or the researchers represented their graphs in percentage delta R a.

So, whenever you have delta; that means, that change you always require maximum if only R a you are talking about then you require minimum ok. As minimum as possible, the surface roughness decreases means you will get a better smooth surface. So, this is about the clarification on the surface roughness and other things. So, you should be careful whenever you see the graphs, anyhow I will remind you that I am talking about delta R a, change in R a, percentage change in R a R average surface and other things.

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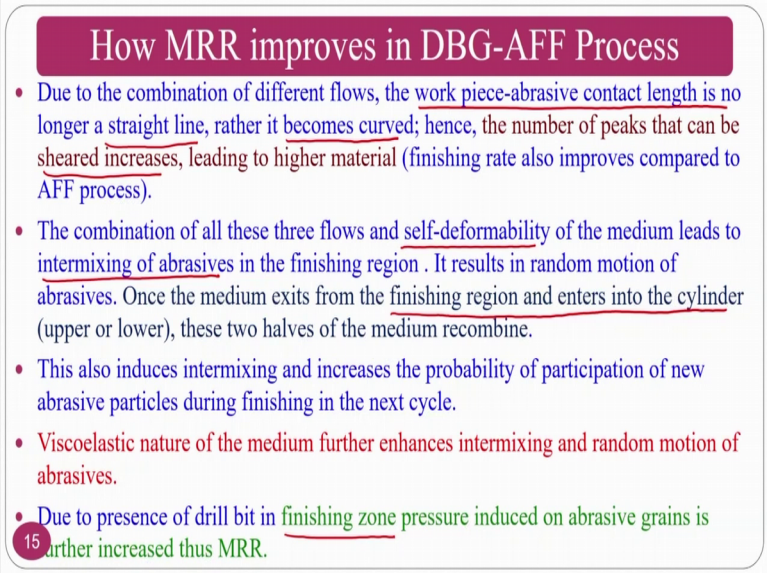

Now, we come back to the drill bit guided abrasive flow finishing process. The combination of all these flows along with a self-deformability leads to intermixing of abrasive particles and in the finishing region. And random motion of the abrasive particles when the medium exit from the finishing region it enters into the medium cylinder through the half valves; that means, that as I said 2 kidney shapes through it will enter and mixing will also takes place there, not only in the finishing region.

This also include intermixing and increasing of the probability of participation of new abrasive particles in the finishing that I have already discussed. And, the viscoelastic nature of the medium further enhances the intermixing, because the viscoelasticity as I said that whenever you have a shear force, the in this direction axial motion will be in the same direction radial motion will be perpendicular to it. That also will have sudden effect on the intermixing. Due to the presence of drill bit in the finishing (Refer Time: 28:17), due to the presence of drill bit in the finishing zone or the finishing region pressure induced on the abrasive particles, and this will indirectly work on the work piece from the point of radial force ok.

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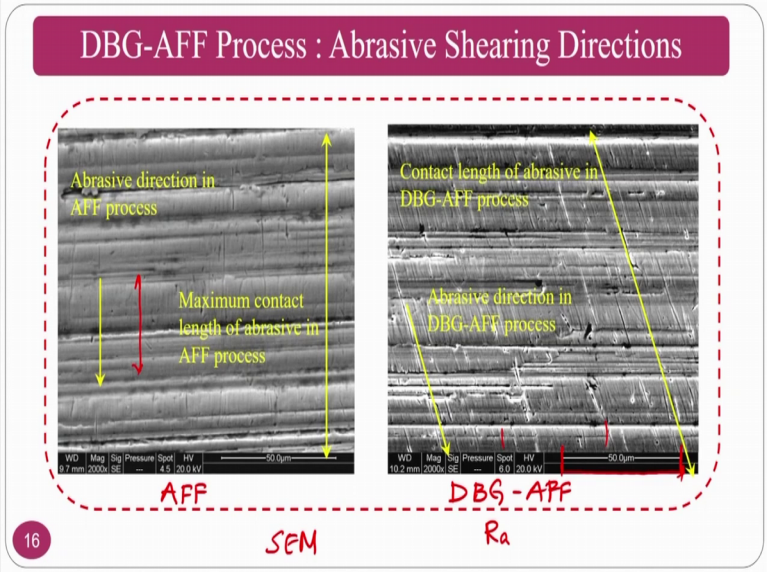

So, the radial force is high; obviously, your indentation will improve. So, you can see here in the abrasive flow finishing process and drill bit guided abrasive flow finishing process. In abrasive flow finishing process you normally see the minimum traverse length, because you are reciprocating. So, most of the time, it will be the shortest distance ok.

So, in terms of drill bit guided abrasive flow finishing process ok. This is the experiment is stopped at certain number of cycles to understand the direction of the path ok. So, it is a inclined path, if it is a inclined path normally the distance that is covered will be enhanced. And, at the same time these are SEM images; that is Scanning Electron Microscope images that you are going to see in a particular very very small region. That you can see here what is the distance this much distance is 50 microns.

And some of the students may not know how to measure and other things in a scanning electron microscope; assume that if you are a bachelor student. So, you may get some doubt what is a scanning electron microscope, how it works and other things that is a different story, but the thing is that from the picture. You can understand what is a area that can cover or something normally if you see, this much distance is 50 microns. So; obviously, approximately I can say, this you can divide into 3 halves or something 350 microns maximum that it covered is 150 microns by 150 microns area ok. In that area

even though it is a curved surface, you are taking a very very minute area, you will see a as a inclined surface only does not matter.

So, the what the inference that you can get from this one is our scooping flow and the inclinization flow along the flute helped the abrasive particles, which are there in the finishing region to move in the inclined the direction so that the shearing length will increase. If the shearing length increases what will happen the finishing will improve, if the shearing length per unit time because your reciprocation is same.

So, per unit time the number of peaks it is cutting or shearing is high compared to the straight line path. That is why in drill bit guided abrasive flow finishing process your R a will be slightly less compared to abrasive flow finishing, but do not go by this particular image, because this is taken after few cycles only ok. So, if you take after some time what will happen it can improve.

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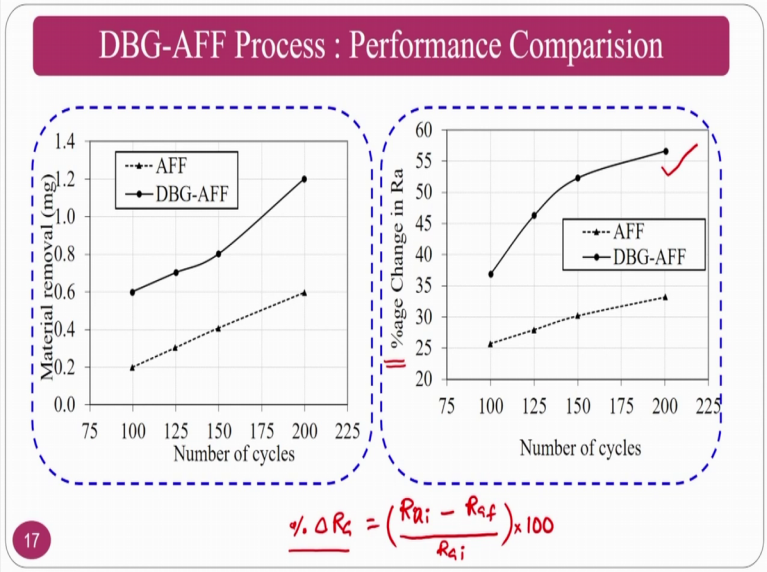

That you can see here the proper performance comparison of this process will with respect to abrasive flow finishing process. So, as the number of cycles versus material removal, if the number of cycles are going to increase; obviously, the abrasive particles that are cutting or the shearing the surface peaks will increase, number of times abrasive particles will cut increases; obviously, number of shear peak shearing also increases. So, the material removal will gradually increase.

However, if you see the change in R a you have to note just now I told, it is mentioned in the terms of percentage change in R a; that means, that you need as maximum as possible. Because, you are talking about percentage delta R a is nothing, but R a initial minus R a final, by R a initial this multiplied by 100 ok. So, in this way you just consider. So, if you want good surface; that means, that your value of percentage delta R a should be high value.

So, you can clearly see that is there in drill bit guided abrasive flow finishing process. Because of whatever the physics that I have explained and that is confirmed by the surface morphology scanning electron microscope images, because of the flute direction motion, because of the scooping motion, and reciprocation motion. The active abrasive particles will reshuffle and reshuffle and reshuffle and intermixing of the medium will also takes place, because of that the new cutting edges will encounter the surface peaks and finishing will improve.

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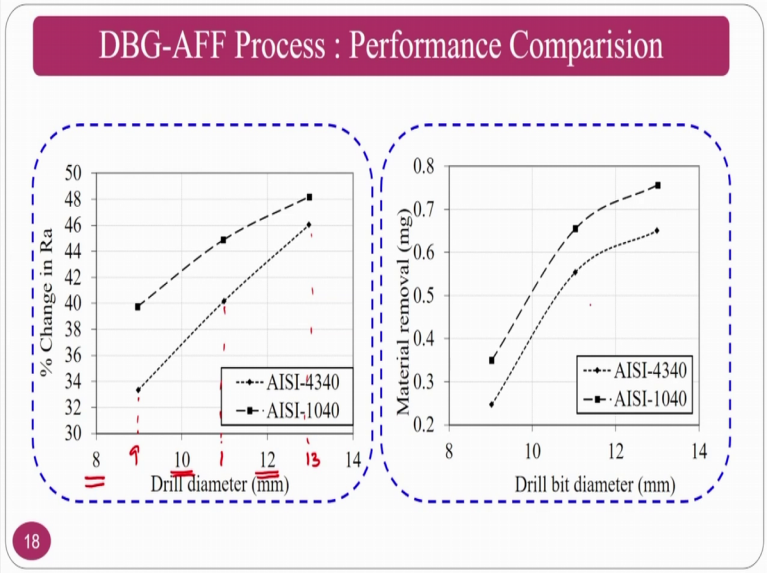

So, you can see the drill diameter, if the drill diameter is increased from 8 m m to 10 m m to world 12 m m. Normally, the size of the work piece that we are going to finish is approximately 25 (Refer Time: 33:49) So, half of this is covered, if you are going with 12 or 2.5 or something. As you can see here if I am using 8 10 and 12 and other things, but it will be 9, 11 and 13 ok.

So, what I mean to say is that if I am increasing does not matter whatever the size of that drill bit that I am taking, whether it is 9, 11, 13 ok. So, if my work piece diameter internal diameter what I am finishing is 25 or 26; that means, that if I am using 13 diameter so; that means, that half of the thing I am covering.

So, very less space is there for the medium so; that means, that radial forces will be enormous not only the intermixing will takes place radial force also play a major role because of which what will happen the indentation on the surface will be high and shearing is; obviously, is there because of the your scooping flow, reciprocation flow, as well as inclined flow and other things. So, the material removal also will increase as you increase the drill bit diameter.

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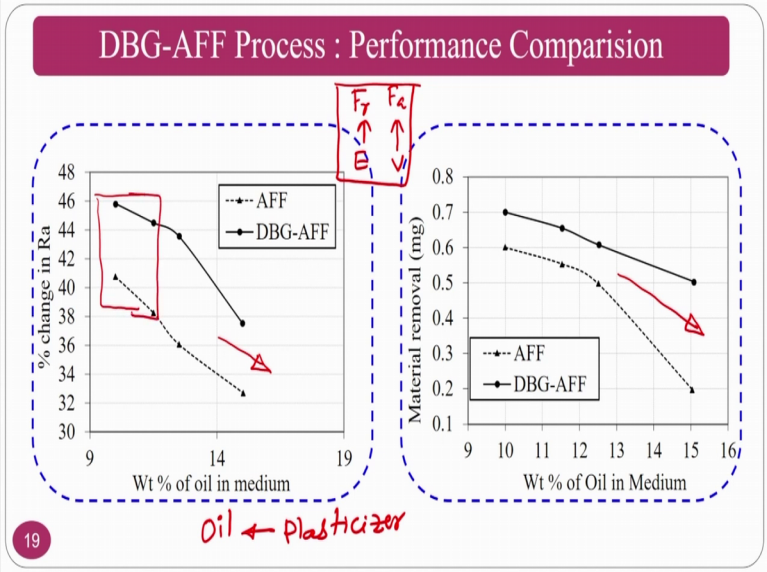

If, you see the weight percentage of oil; oil means plasticizer ok. So, you know in the abrasive flow finishing process what is the function of plasticizer and other things. Plasticizers are low molecular weight materials and polymers are high molecular weight materials, whenever you try to blend this, what will happen low molecular weight materials will go an sit between 2 polymer molecular chains and try to move apart.

So, the flexibility of the medium increases; if you go on increase the oil content or a plasticizer content what will happen, the polymer molecular chains will gradually increase the distance and it will become a liquid or 2 low viscous ok. Your polymer has certain viscosity whenever you add abrasive particles the viscosity will goes up, if you

start adding the plasticizers and plasticizers if then what is happening here is the inter molecular polymer distance will increase and the viscosity gradually decrease.

If the viscosity decreases what will happen, the medium flow along the reciprocation will be dominating and radial force will be very less. As you have seen there is a radial component that is F r and axial component. Your F r is responsible because of the elastic nature and F a is responsible because of the viscous nature. If your elastic component is less; that means, that radial indentation will be less; that means, radial force is less. If the radial force is less what will happen the interaction with respect to the surface peak will reduce that is the problem ok.

So, if your plasticizer increases your elastic component will reduce. Why the elastic component will reduce? Because your polymer molecular chains are far away so, they are not cohesive enough to support the abrasive particles to push radially that is a problem, that is why the viscosity of the medium goes low in a qualitative statement, if the viscosity is low; that means, that your finishing ability gradually decreases, that you can see here, because of that material removal also will fall down and your change in roughness or delta change in roughness also fall down.

So, you need to choose certain value of a viscosity where you can do the good for that purpose normally you have to choose approximately 10 or in this region so, that you can get better results.

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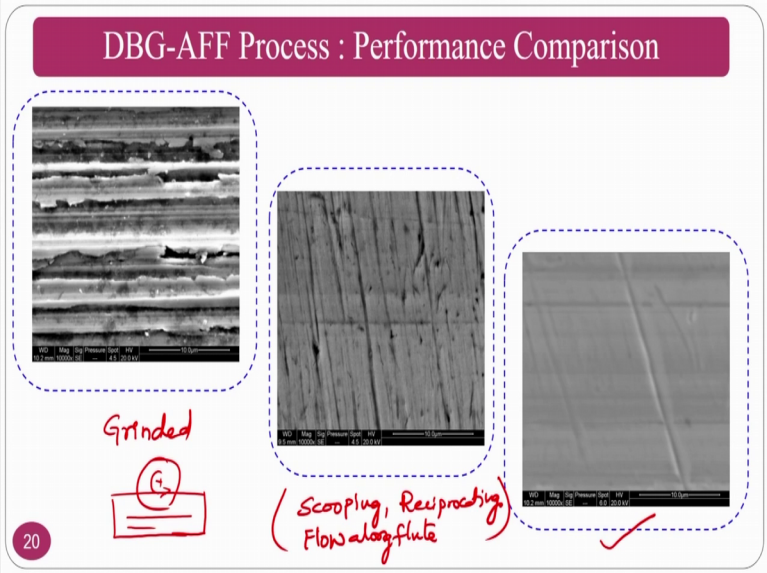

You can see here this is the grind surface. Normally this is grinded surface or some people they say ground surface, because the grinding motion is like this, if your work piece is like this, and your grinding is like this. So, because of which you got the straight lines.

So, what is happening here is after few number of cycles as I said that the you will get because of the scooping flow, flow along flute, and reciprocating ok. The 3 motions and you can see at the end ok. As, you increase number of cycles and you have to optimize the all the things, you have to optimize the drill bit diameter, you have to optimize the number of cycles, you have to optimize the medium composition and other things. Whenever you get all good you will get the better surface finish, that and the surface finish that you will get at lesser time compared to your abrasive flow finishing process.

And, what is a inference that it will give is if you have a drill bit or another abstraction is there. So, you can change the path of the abrasive ok. Just you remember this one because we come across some of the advancements like rotational abrasive flow finishing process, and there your work piece is rotated not the medium.

So, now we move on to the another advancement that is called a centrifugal force assisted abrasive flow finishing process or abrasive flow machining process. So, one thing you have to understand. So, this is taken from the papers from IIT Roorkee Professor H S Shan [Fl] and Pradeep Kumar [FL] and Ravindra Walia [FL]. So, the papers if you are referring, it is always given centrifugal force assisted abrasive flow machining. As I said it is a same abrasive flow machining abrasive flow finishing both are the same ok. So, that is why I have written abrasive flow machining bar finishing process.

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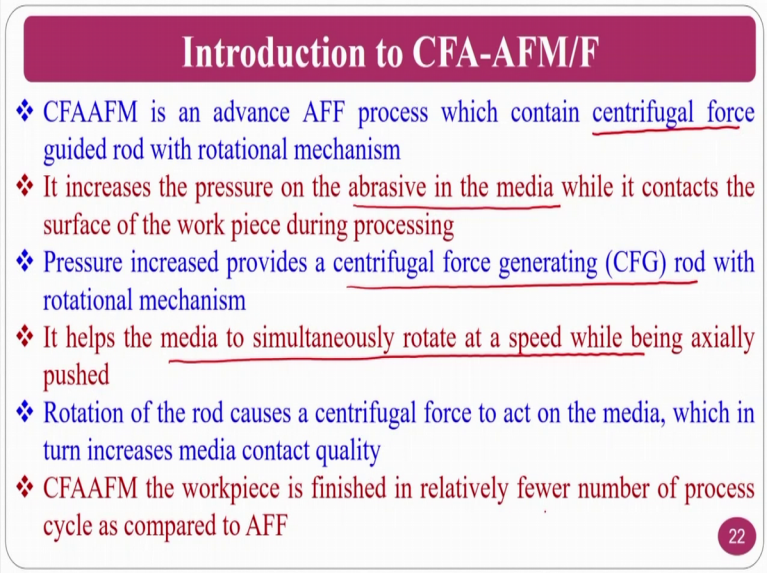

Introduction to centrifugal force assisted abrasive flow finishing process; just you have to get one correction here that is called CFA. So, centrifugal force assisted abrasive flow finishing process. So, introduction to centrifugal force assisted abrasive flow finishing process, it is an advancement of abrasive flow finishing process where centrifugal force guided rod will be there. So, they are going to place a rod with a different shapes and rotates at different speeds ok.

So, in that circumstances how the finishing will improve, whether the finishing improves or do not improves what the authors have done we will see. It increases the pressure on the abrasive in the medium and while it contacts the surface during the processing. The pressure increased provides the centrifugal force generating rod will be there and rotational mechanism is developed, and it helps the medium simultaneously to rotate at speeds and along with the axially pushing.

So, you know abrasive flow finishing process where the only reciprocation is there ok. Along with it what the research has they have done is in the finishing region instead of the drill bit, that you have seen in the drill bit guided abrasive flow finishing process. They have used different shapes like spline, triangular, rectangular, square type of rods they have used ok.

Rod means do not think that it is a big rod or something, if your work piece is assume that it is the 40 mm or 50 mm, the rod will be like 10 mm or below 10 mm. So,

centrifugal force assisted abrasive flow finishing process work piece is finished relatively fewer number of processes compared to abrasive flow finishing process; that means, that the authors or the researchers Professor Walia and group, they have demonstrated that the number of cycles required in centrifugal force assisted abrasive flow finishing process is less compared to conventional abrasive flow finishing process.

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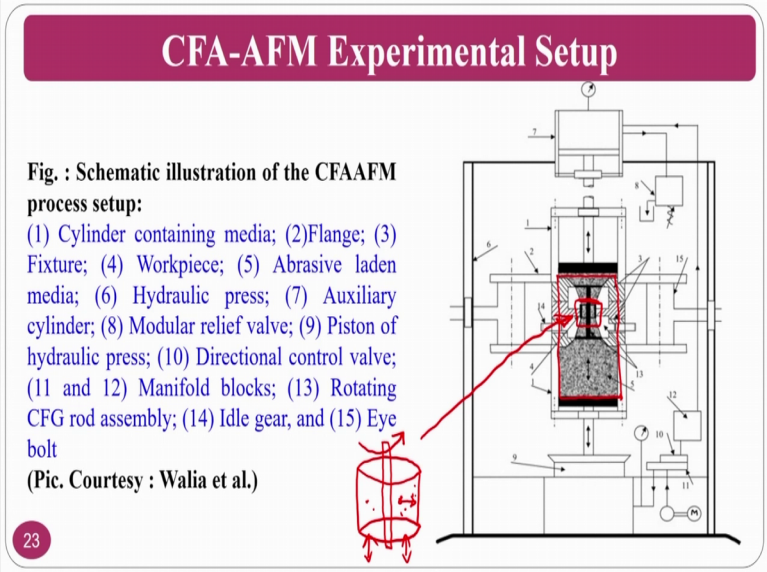

This is a setup that you can see here. So, the set up may not be that much easy to understand, but; however, I will explain you in the upcoming slides, but only thing that you have to understand here is in this is the finishing region, where you are seeing is the medium and the finishing is occurring in this square.

So, in this square you have a cylindrical work piece assume. So, this cylindrical work piece is at the centre of this cylindrical work piece you have a rod basically ok. And, this rod will be rotated external gearing system is there; that you will see in the upcoming slides this is provided reciprocations. This rod is rotated along with the medium reciprocation medium will be reciprocated ok.

Now, hope you understand that medium is reciprocated and with the help of external gear system there will be a small rod will be there and it is rotated. What will happen because of this rod rotation centrifugal action on the abrasive particle will be there and this abrasive particle will be push towards the surface. Assume that this is my abrasive

particle this will be pushed towards the surface and you can increase that. So, the finishing rate will improve.

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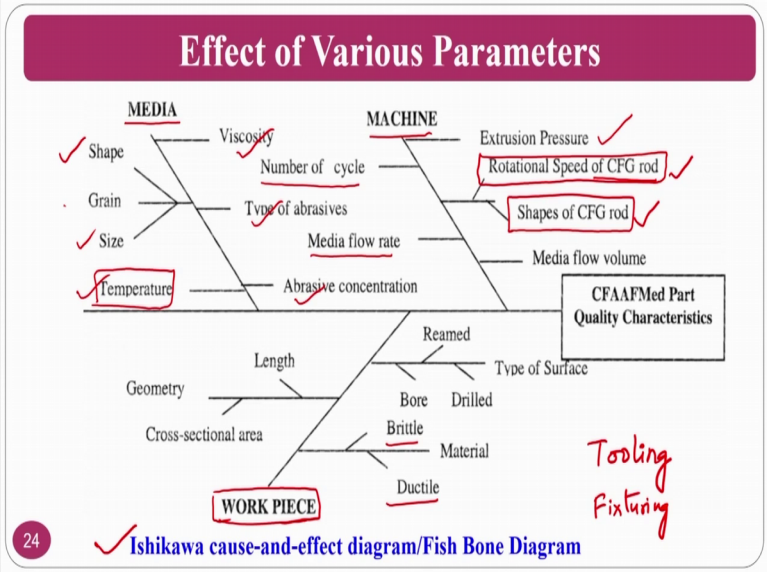

Various parameters normally people say that Ishikawa cause and effect diagram or fish bone diagram the medium is one of the most important machine, and work piece are the things in the machine. Basically here the change in the advancements, whether you talk about a centrifugal force assisted abrasive flow finishing process, or whether you talk about a drill bit guided abrasive flow finishing process, or spiral polishing, or any other thing the most important change that they have done is tooling ok. Tooling some of the papers they also say about fixturing ok.

In abrasive flow finishing process these means same. So, some people they may say tooling some people they may say fixturing, but in general there may be a slight difference is there, but pertaining to the abrasive flow finishing process and it is advancements this is approximately same.

So, the medium the shape of a abrasive particle, size of the abrasive particle, viscosity and types of abrasive particle, abrasive concentration temperature that you are using, if you are using at room temperature, you can neglect the temperature. So, they would not be much change, but during the operation because here also centrifugal force is there. And, reciprocation is also there because of which there will be always some tendency to

generate the temperature or the temperature will generate during the process, because of which viscosity may go down.

The second is the machine where you talk about number of cycles, medium flow rate medium flow rate is a function of extrusion pressure, and already extrusion pressure is here rotational speed of the centrifugal rod and shape of the centrifugal rod. So, mostly importantly you can see about rotational speed and we will see about shape of the rod.

This is the only variation that deviates this particular process from the conventional abrasive flow finishing process, because work piece and other things are approximately same, what is the length geometry, whether it is a board, or whether it is reamed, whether it is a drilled one, or whether it is a cylindrical grinding, or something that you can do, whether the material is a ductile or brittle these are constants. So, same thing goes in the abrasive flow finishing process also, but most importantly what is new particular to centrifugal force assisted abrasive flow finishing process is that rotational speed of the centrifugal rod, and shapes what are the shapes.

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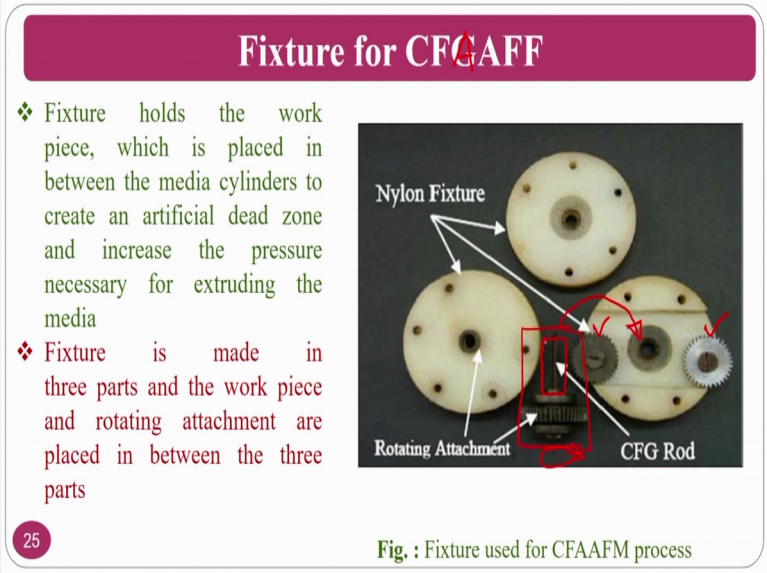

Fig. : Fixture used for CFAAFM process

Now, we can see the fixture or the tooling for centrifugal force assisted abrasive flow finishing process. The fixture holds the work piece, which is in place between a medium cylinder and create the artificial dead zone and increases the pressure necessary to extrude ok.

So, the fixture is made 3 parts a work piece rotating attachment, normally these are the nylon fixtures are designed, and there is a gear system, and what you have to observe is here you have a rotating attachment this rotating attachment will go and sit here ok.

So, because of the gear system that is externally protruded this one and this one this gear system will rotate ok. So, because of this rotation your centrifugal rod which is here will rotate ok. So, that is how the rotational motion is important to the medium via centrifugal rod ok.

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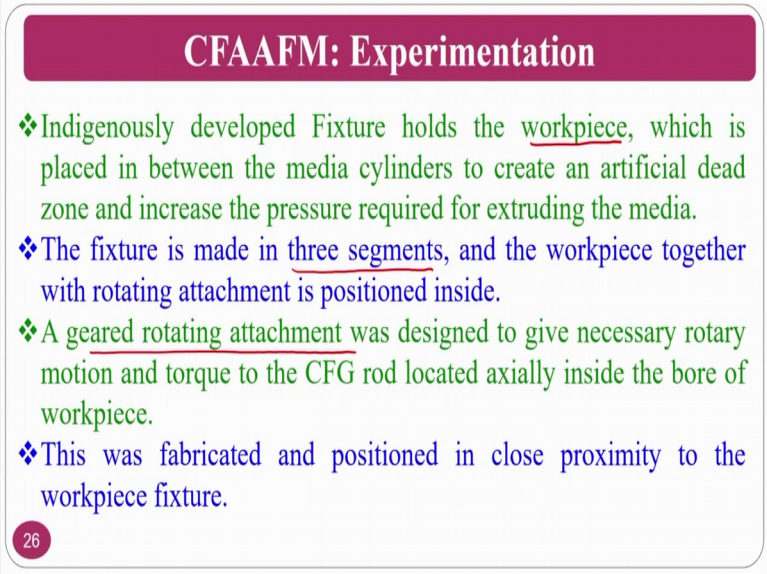

Experimentation indigenously developed the authors have developed indigenously this fixture that holds the work piece, and the centrifugal force assisted rod. The fixture is made in three segments that we have seen, work piece together along with the centrifugal rod, and you have the gearing system and other things. They gear rotating attachment was designed to give necessary rotary motion and torque the centrifugal rod and the fabricated and positioned close proximity to the work piece fixture ok.

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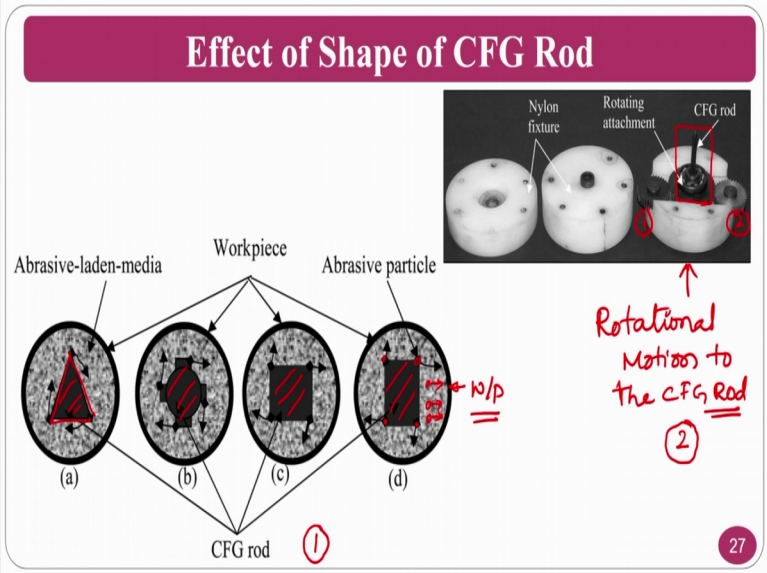

This is done and the shape of the rod. You can see here this is a nylon fixture that is what you have seen in a previous slide also. So, this is the rod centrifugal force assisted rod and which is get assistants from the other 2 gears gear 1 and gear 2, this will help to rotate at different speeds ok. So, the as I said the rotary motion will be provided from here, rotational motion to the CFG rod will be provided from here.

And, the rod shapes also considered these are the 2 new things ok. Rod shape is one new thing in this one compared to abrasive flow finishing process and second new thing that is there is rotational speed, that they are imparting using centrifugal rod ok. The normal shapes, that you can see is a triangular shape, spline ok. And, you can see a square and the rectangle these are the 4 shapes that are mentioned here.

And, you can see the edges, the edges there are arrows these arrows shows how this will hit the abrasive particles and these abrasive particles will push towards a work piece, this is the assume that work piece, and the abrasive particles will move in this direction and take part along with a reciprocation motion; that means, that already reciprocation motion is there and additional centrifugal force is imparting to the abrasive particle. So, the finishing will improve.

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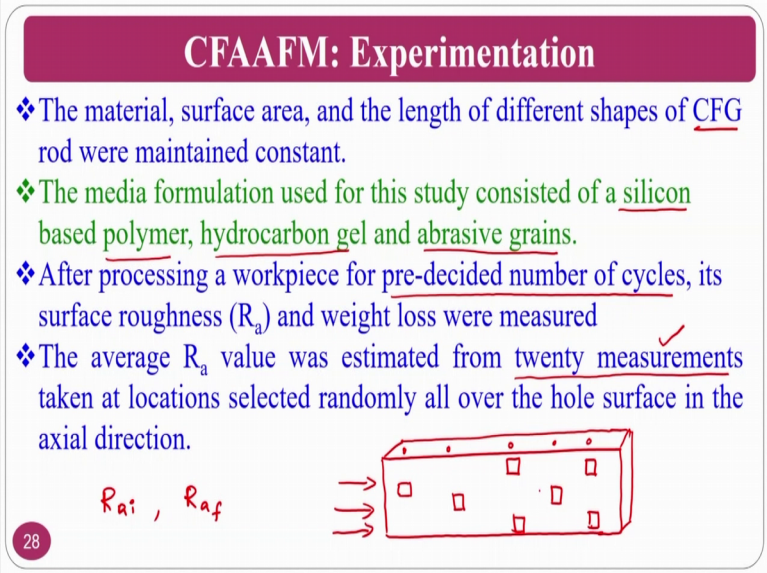

The material and surface area and the length of different shapes of centrifugal rods were maintained constant this is maintained; that means that the length of the rod is constant. However, the shapes are different, the medium formulation used in the study is a silicon base is polymer, and hydrocarbon gel and abrasive grains are used. After processing the work piece for pre decided number of cycles; that means, that the number of cycles are decided whether he want 100 cycles or 50 cycles or 10 cycles, that is in and the surface roughness and weight loss; that means, that the authors are going to measure the surface roughness value and the material removal.

The average surface roughness was estimated from 20 measurements ok, taken at different locations on the work piece surface; one thing you have to observe here what is the thing is that many people may not be knowing. Assume that this is my work piece surface, it is a cuboidal surface assume ok. So, this is initial surface roughness and final surface roughness, how we have to measure?

Since, the abrasive processes especially like 3 dimensional tribological processes; that means, that where the abrasive particle will have 3 D abrasion; that means, that abrasive particle can rotate about it is own axis is completely random, cutting edges are random. In abrasive processes cutting edges are random, the abrasive processes such as lapping such as abrasive flow finishing processes, where abrasive get free flow can rotate about it is own axis, and on top of it you have drill bit is there where the different flows are there

scooping flow flute flow and other things, centrifugal rod is there in CFA AFM. So, what will happen there is a centrifugal motion is imparted along with the reciprocation.

So, the system is completely random that is what I want to say, the abrasive particles are random in that circumstances the surface roughness that you are going to get on this particular surface is random, that is why the author rightly pointed out that the surface roughness has to be measured different different levels, or different different zones of the finishing zone before and after how. Assume that I want to do at 5 places. So, this is the one place that I want to do second place, third place, fourth place, fifth place, assume that sixth place I can do 7 th place I can do, I can mark it ok.

And, after finishing also we can measure the same location and initial we have measured final also same, approximately same location you can also measure and you can calculate the change in R a or how much final surface roughness is achieved or percentage change in R a and other things ok. Make sure that in abrasive finishing processes, if you are not maintaining the locations also it is ok, sometimes how the people will do is they just put the marker pen marker. So, like what I put on the surface.

And, due to finishing action this marks also will goes off, for that purpose people what they will do is they will do some indentation using the punch on the other side, which is not required for us, you can do the same punching there and you can measure also so, same location. At the centre line assume that I want to measure at the centre line or any other line you can measure only thing that you have to is you have to measure as much locations as possible. So, that the average value will give you good idea, you should not measure at one location wow I achieved a Nano surface finish that is not the right way.

So, you should always measure at a different different locations, if possible same locations before and after, if not possible as many as possible locations you measure and you take the average value, that you are going to report in to the research papers will have good value ok; that means, that you are doing right thing and you can also plot error burrs. So, that your research paper can be made in a good way and the reviewers also will express their good this paper is very good, because they have done huge number of measurements and the report is given average along with the error burrs.

So, that is good ok. So, that is a just a suggestion for the people who are watching like a PhD students or some of the faculty from the private engineering colleges or small

universities including many big institutes also people may be following may not be following, this is a suggestion that I received from my supervisors and well-wishers, who works in the similar lines. So, I am just passing on I am a mediator ok. I am just giving you what they have given me. I followed it and reviewers have appreciated that this work is rightly done and rightly measurements are taken and other things ok. So, you can also explain how you are going to measure in the paper also ok.

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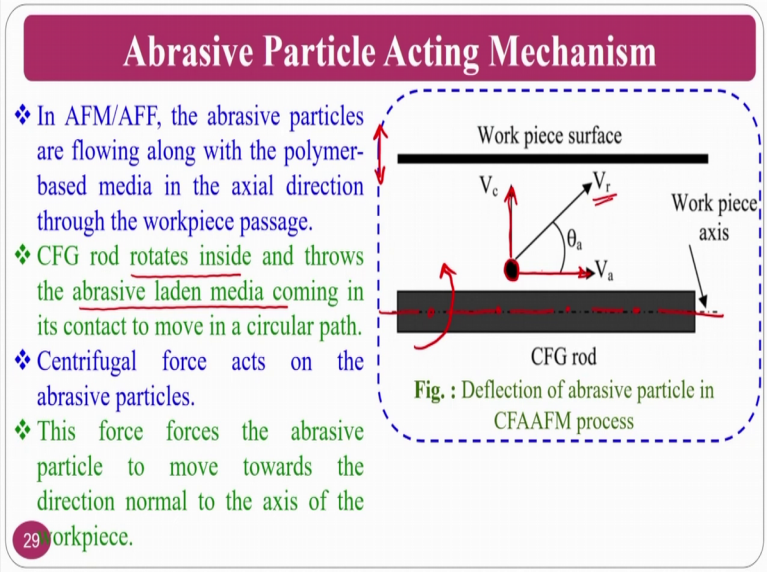

So, abrasive particle acting mechanism in the abrasive flow finishing process normally it will be axial direction. So, it will be like reciprocation motion, but in the centrifugal force assisted abrasive flow finishing process, there will be a rotation inside and this throws the abrasive particles in the medium, the abrasive particle in the medium throws towards the active finishing region ok. The centrifugal force acts on the abrasive particle and this force abrasive particle move towards the direction of normal to the axis of the work piece.

If you see here this is the axis of centrifugal rod; this rod is given rotary motion because of which what will happen if there is a abrasive particle in once it hits what will happen, this is because of the reciprocation and this is because of your centrifugal force and resulting direction will be like this.

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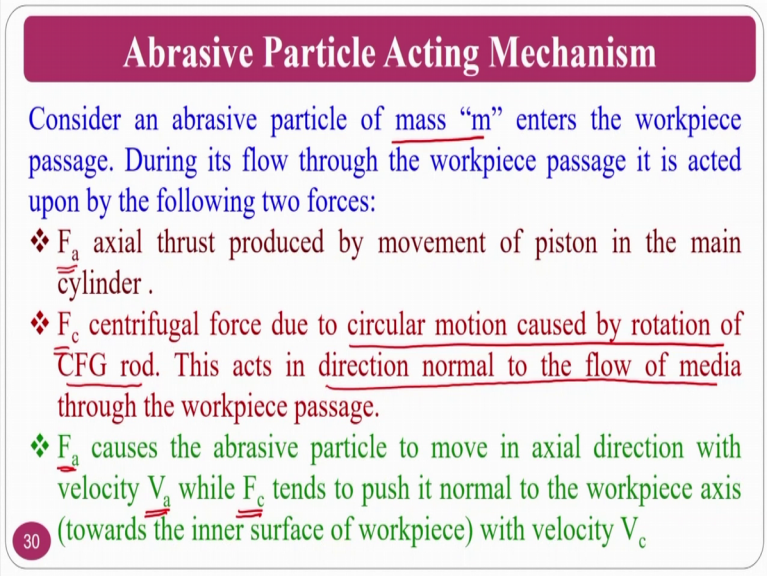

The considered abrasive particle with a mass "m" enters into the work piece. During the flow of through the work piece passage, F a is the axial force that is because of the medium reciprocation. I am explaining about the previous picture which you have seen. F c is nothing, but the centrifugal force due to circular motion caused by the rotation of centrifugal force assisted rod, which is normal to the flow of the medium.

And, F a causes the abrasive particles to move in the axial direction, V a is also in the reciprocating direction. F c will tend to push towards normal along with the viscoelastic nature also because of which what will happen the radial force, that is going will be assisted by radial velocity also ok. You know in abrasive flow finishing process which is a conventional abrasive flow finishing process that I am talking, you have axial velocity axial force, but indentation velocity is very less that is why we always neglect.

But, indentation force will be there that is called radial force; that means, that you have 3, 2 forces and 1 velocity in abrasive flow finishing process. In abrasive flow finishing process you have axial force, radial force, and axial velocity. But, here your rotational speed also pushes the abrasive particle radially towards the axial motion so; that means, that radial force is combination of your elastic component in the medium, at the same time combination of centrifugal force and abrasive particle is going at certain velocity. So, you can also have centrifugal velocity instead of radial velocity.

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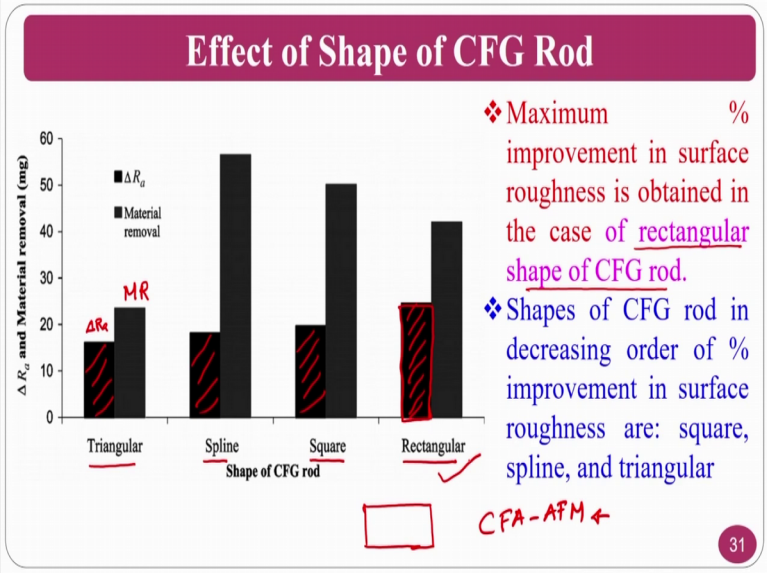

So, the shape of the rod, you can see here everything is black. So, do not worry. This is delta R a small structures or delta R a this is material removal ok. So, among all this if you see the triangular spline, square, and rectangular. So, since we are talking about the finishing process we talk about change in R a, that is why the change in R a is very good in terms of rectangular because it is a finishing process ok.

So, the maximum improvement of the surface roughness is obtained in case of rectangular rod. Because of it is inequal shapes, because in the square it is equal shapes, if it is triangular there are only 3 edges are there, in a spline normally it is considered to be the approximately circle. So, the circular motion will be there. Here the author explained is that rectangle will have 2 different sides, which are going to hit unequally.

So, the blending or the mixing of abrasives will be much better and this will this enhance. And, if you want more details about why rectangular and other things, you can go through the paper where the authors are you just type CFA-AFM process and you can cross check with Professor Ravinder Singh Walia, or H S Shan and Pradeep Kumar, Professor Pradeep Kumar in fact.

So, you can cross check this papers you will get much better idea about why rectangular. So, people you can do research in this direction also. So, very limited work is done. So, people Professor Ravinder Singh Walia is continuously doing in this area; so, you can contact him and you can get some of the idea and you can improve the work also.

So, what are the thing about this particular slide is the best change in R a is in the rectangular surface this is the cross; that means, that since we are talking about the finishing process we worried about what is the final surface roughness, or whether how much finish is required we do not bother about how much material removal is taken place ok. That is why the centrifugal force assisted finishing process, rectangular structure rod is good. Ok.

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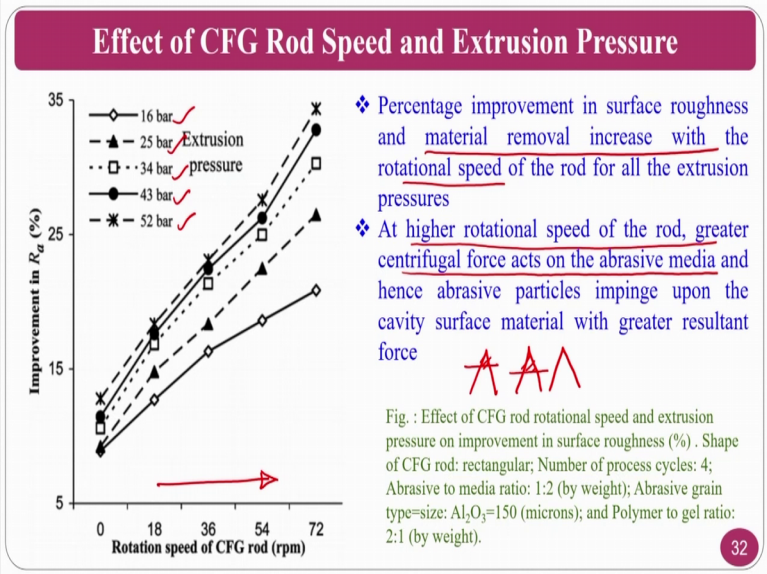

The rod on the speed and extrusion pressure, if you see here once the rod shape is fixed the preliminary experimentation is done and the author finalize that rectangular surface rectangular shape is giving better results. That is why the researcher done that particular preliminary work and now he is continuing with the rectangular rod ok.

So, you can see here the different extrusion pressures is changing and one thing you have to understand normally you have can give bars also and it is preferable to give mega Pascal a international standard and other things. So, rotational speed, as the rotational speed increases, you can see here the rotational speed increases what is happening is the centrifugal force will increase. The percentage improvement in surface roughness and the material removal increases with rotational speed.

At higher rotational speed of the rod greater centrifugal force act on the abrasive medium and hence the abrasive particle impinge upon the surface, and more number of peaks, and the more amount of the peak will be sheared; that means, if my peak is like this what

will happen. If my force is more less what will happen this much only removed if force is more this much will be removed. So, the change in roughness will be more.

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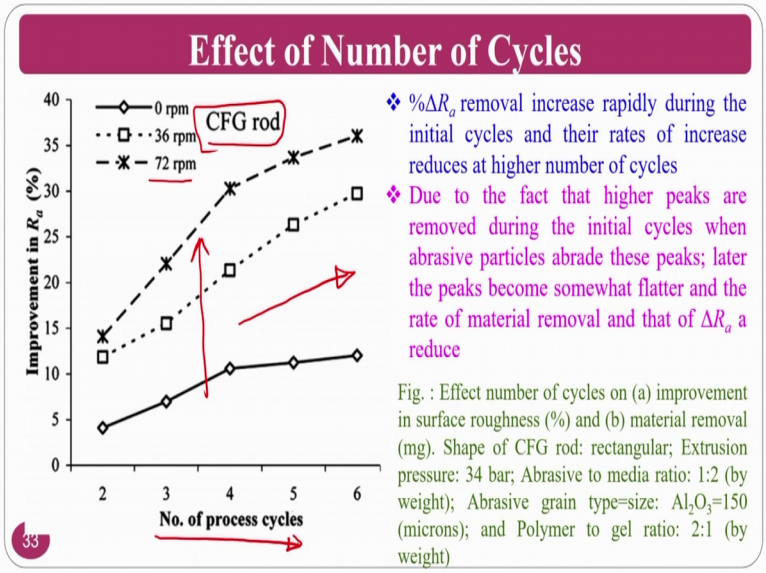

So, effect of number of cycles, if you increase the number of cycles what will happen is the number of times the abrasive particle will contact the surface will increase and what will happen your material removal will increase. At the same time you can also see the RPM rotational speed of the centrifugal rod also if you increase the RPM; obviously, as we have seen in the previous slide the centrifugal force, that is gained from the rod by the abrasive particle will enhance and this abrasive particle go and hit with a greater centrifugal velocity and radial force.

Because of which what will happen the material removal increases in this direction. And, number of times if the number of cycles are increasing what will happen, here also it will increase because number of times the abrasive particle hitting the or the shearing the work piece will increases.

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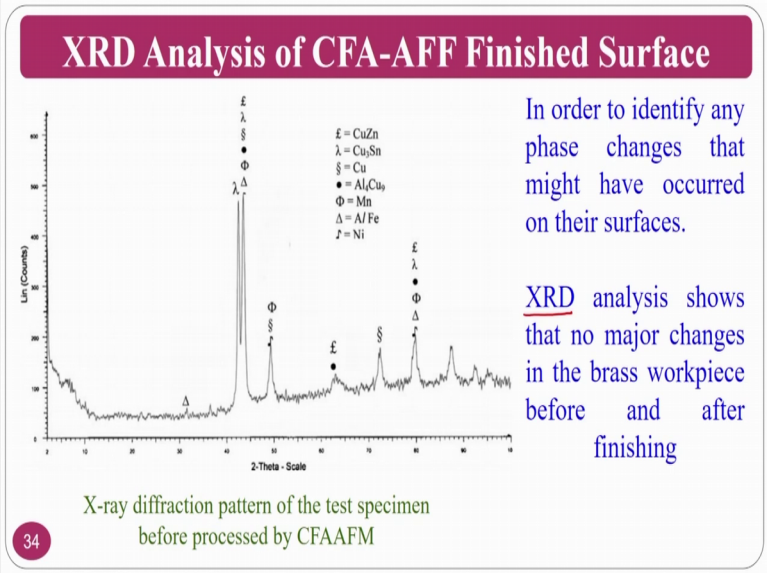

The people also understood that is there any change in the metallurgical part or before and after, and there was x R d analysis is done, and not much variation is there found. But, from the x R d they have also understood that some of the residual stresses are generated, that is compressive residual stresses are generated that is good for some of the applications.

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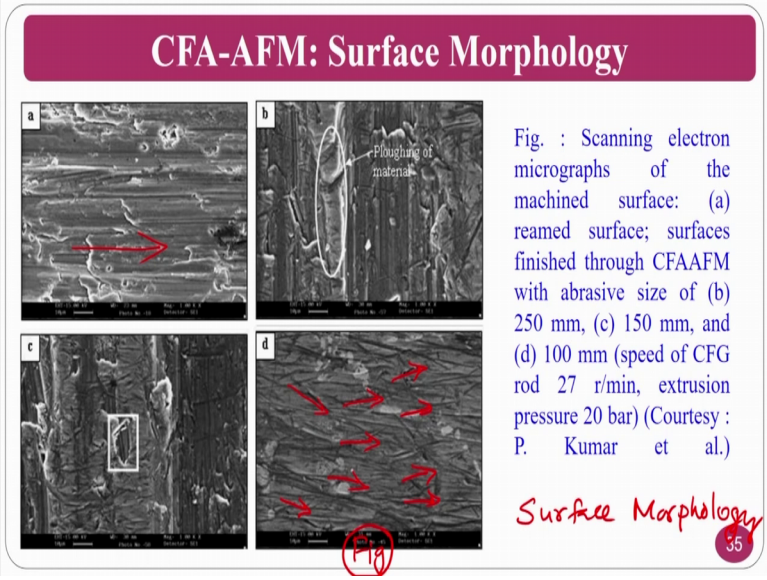

The authors from the XRD they have also analysed the compressive residual stresses. And this compressive residual stresses induced into the work piece, after finishing will

help in some of the applications ok. So, there is no change in the metallurgical structure and some other structure, but there is a induced compressive residual stresses, which will help in some of the applications ok.

These are the scanning electron microscope images where you can see the surface morphology ok. So, this is initial surface, then the surfaces are there because of the centrifugal action you can see random things are there ok. So, the advantage is surface finish is improving, but there is no perfect random direction. So, in the drill bit guided abrasive flow finishing process also we have seen, because you are having motion inside the medium slug or the medium what will happen is you do not have control on the finishing region abrasive particle.

Similarly, here also your centrifugal rod is rotated at the centre, because of which the randomness is generated, but how much it has to go that is not possible to understand. For that purpose why I am explaining this two is that you come across another process called rotational abrasive flow finishing, that I have intimated you during drill bit guided abrasive flow finishing process. Because, if you can rotate the work piece your finishing region or active finishing region will be active ok.

If, you start rotating the medium; medium is a liquid type of medium or semi-solid type of medium, lot of losses will be there and abrasive particles are random. So, randomness is generated and which may not give you a deterministic surface patron on the work piece, that is the drawback of drill bit guided process and centrifugal force assisted process, that is evident from this figure ok. You do not have proper direction of shearing.

Similarly, in case of drill bit guided abrasive flow finishing also, that is why you need to go for the work piece rotation that we will see in the next class.

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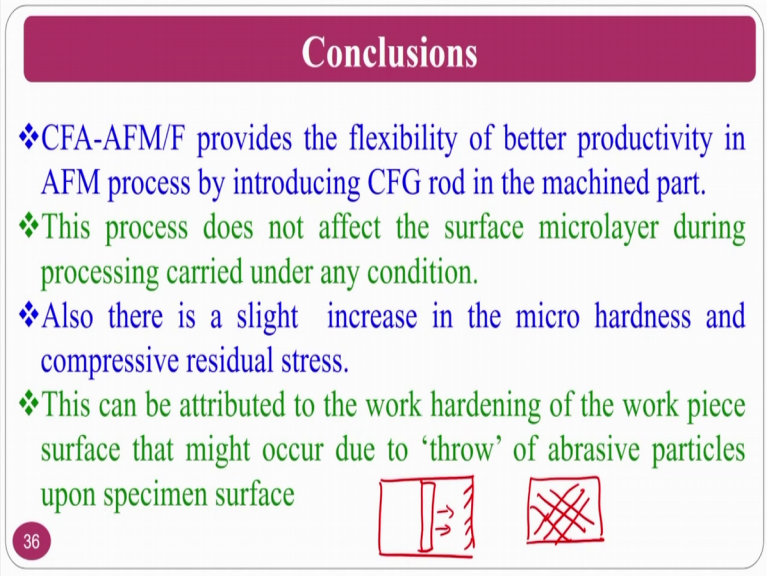

So, from these two we can see the centrifugal force assisted provides the flexibility and better productivity, and this process does not affect the surface micro layer; that means, metallurgical changes will not be there, and there is a slight increase in the micro hardness, and residual stresses also will be generated.

And, this can be attributed to the work hardening of the work piece and might occur because of the "throw" action of abrasive particle ok. This is about the 2 advancements; one is drill bit guided abrasive flow finishing process, another one is centrifugal force assisted abrasive flow finishing process. But, both the processes have the drawback that assume, that I want a certain patron like a honing process, I want a cross hatch patron. Assume that this is my surface I want a cross hatch pattern I cannot get ok.

So, how to get? So, this 2 processes are inside the medium and the medium is completely random, because your cutting edges are random your distribution of abrasive particles are random and it is a liquid nature. So, it is rotating. So, you do not have control at the away from the centrifugal rod, away from the drill bit, which is a finishing region finishing region is far away assume that this is my work piece, my rod is here this is my finishing region. So, it is far away. So, there will be a losses and other things will be there ok, that is the drawback of these 2 processes ok. We will come across some of the advancements in the upcoming class.

Thank you.