Polymer Assisted Abrasive Finishing Processes
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Lecture – 12
Advances in Abrasive Flow Finishing: Spiral Polishing, R-AFF

Now, we are seeing various Advancements in Abrasive Flow Finishing Process. So, in this particular class we extensively see about Rotational Abrasive Flow Finishing process. Why this particular process is important compared to other various advancements and other things we will see.

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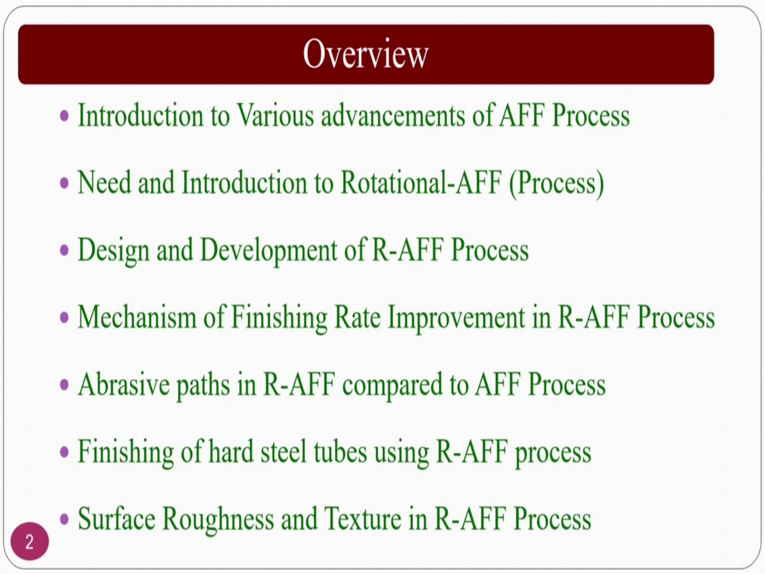

So, the overview of today's class, we will see about the introduction to various advancements that we have studied in the previous classes. What are those in a introduction way, at the same time what are the drawbacks of those processes, and how one can overcome in this particular process, need of rotational abrasive flow finishing process compared to other advancements. And, we also see the introduction about this one, then we will see what are the various designs, we do not want to go in deep analysis of the structural analysis and other things, but we just to see what is the design one, what is design two and what are the drawbacks of design one, why we have to go to design two and other things we will see.

Mechanism of material removal, it is similar to abrasive flow finishing process only , but how the finishing rate improves; that means, that material removal rate improves in this particular process. Abrasive paths, if you are giving different different rotational speeds how the path will change and the finishing of hard tubes also we will see and initially we will see the flat surfaces, then we will go initially we will see the flat surfaces, then we move on to the cylindrical surfaces..

Then at last we will see what are the surface roughness capabilities; that means, that what is the finishing capabilities of this rotational abrasive flow finishing process and this particular process not only for finishing applications, it can also applicable for texturing and other things. So, how this particular process is suitable for or capable of; how this process is capable of producing various textures also.

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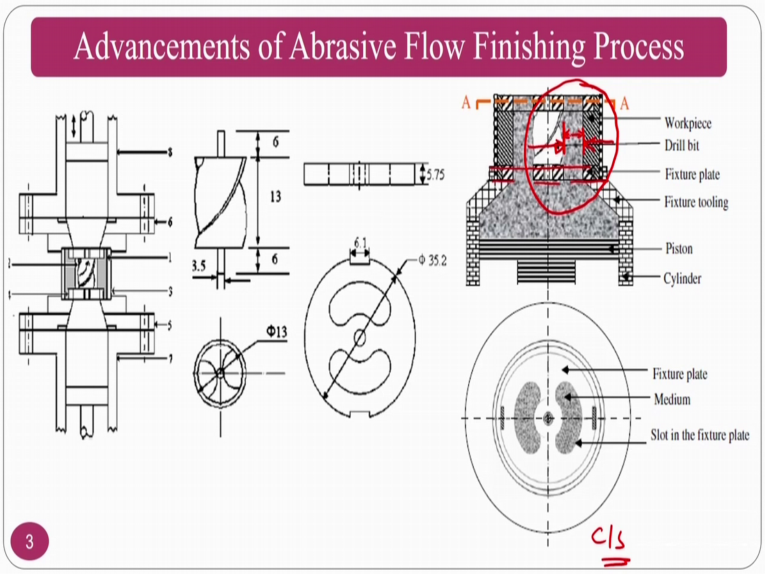

One of the advancement that we have seen is drill bit guided abrasive flow finishing process, wherein the drill bit is placed in between in order to reduce the abrasives to move at the centre of the medium slug. That we have seen and this can be held loosely or it can be held tightly; i mean to say that, drill bit can hold tightly in the fixture region normally the fixture region is here.

So, these are the vends are there through the vend it will go. So, that you can see in the bottom cross sectional view, only thing is that we are restricting the medium at the centre. So, that the number of active abrasive particles will go on increased ok, but the question is you are restricting here assume that a drill bit can be rotatable if it is freely there and because of the medium reciprocation it is rotating. And the abrasive particles are getting some random motion and other things, but because of viscous and elastic nature or the liquid nature of the medium, there is a loss from this region to this region; that means, this is much gap is there. If, you can see here this much gap is there, this gap the loss of the medium because of the liquid. So, dynamic motion may not be transferred ok; but, however the normal motions of this particular process will be there.

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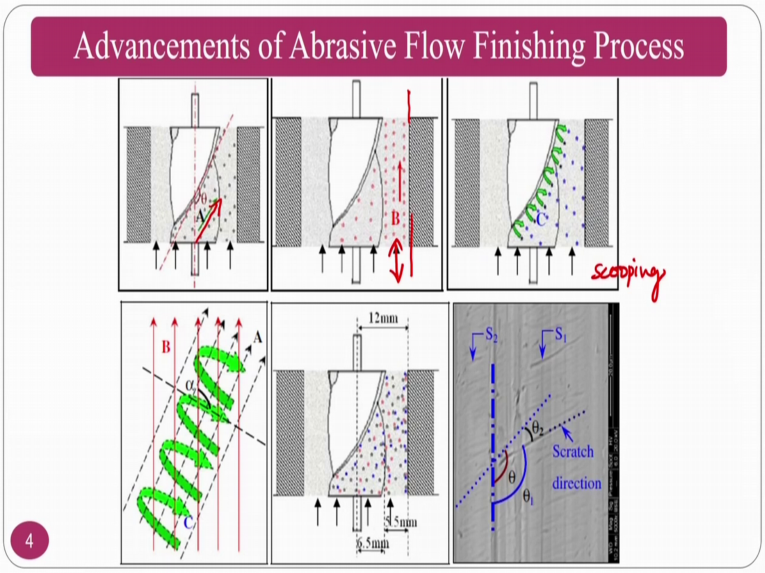

These are the common motions that or there in the drill bit guided abrasive flow finishing process one is because of the flute you will get a inclined motion and because of the reciprocation; you will get reciprocating motion, because of the flute 3 D curvature you will get a scooping flow ok.

This scooping flow along with a reciprocating as well as inclined flow, these are all leads to a dynamic motion of abrasive particles at the centre of the slug, but it may or may not improve the surface finish are randomized abrasive particles as we expect. Because, this is happening at the centre of the medium ok, but what is our main constraint is the medium has to be activated at the edge or in the finishing region of the work piece, but here it is not activating at the finishing region; i mean to say, the activation should be done on this work piece, but it is not on the work piece, but it will improve the finishing rate. What we can infer from this particular process is that, the active grains are having certain motion and this motion is causing some inclination ok.

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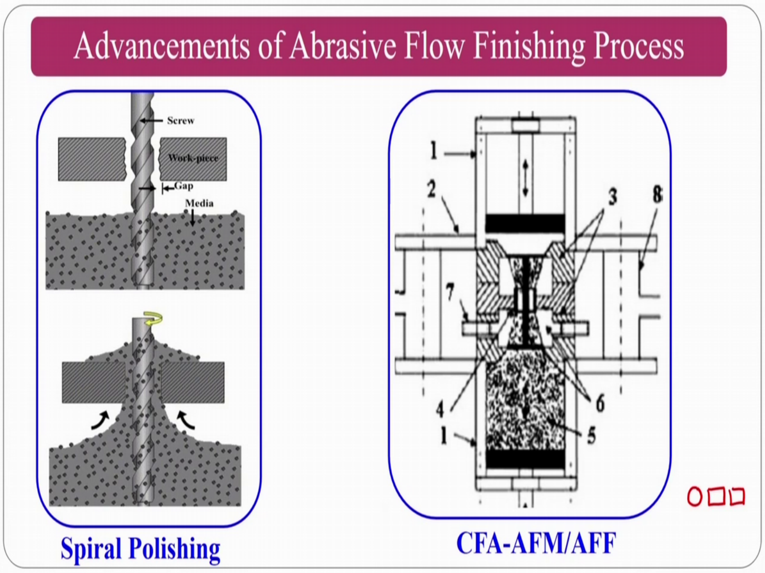

At the same time there are another two advancements, one is the spiral polishing process where you are giving a rotational motion to the screw which brings the medium up because of the flutes and similarly vice versa. So, that the finishing action can takes place, and in this condition the medium should be much much viscous. If, it is too low viscous what will happen, there is a heavy chance that medium may fall down, but in the condition of centrifugal force assisted abrasive flow finishing process, your medium should be low viscous; because, you are going to use as you have seen you are going to use a different different shapes like circular shape of rod, rectangular shape of rod, square type triangular type.

So, many types the author has used, but here if it is too viscous at from the centre or from this shape assume that it is a triangular shape or a rectangular shape. If, you want to give some centrifugal motion to the abrasive particle, it cannot reach to the work piece ok. These are the some of the drawbacks.

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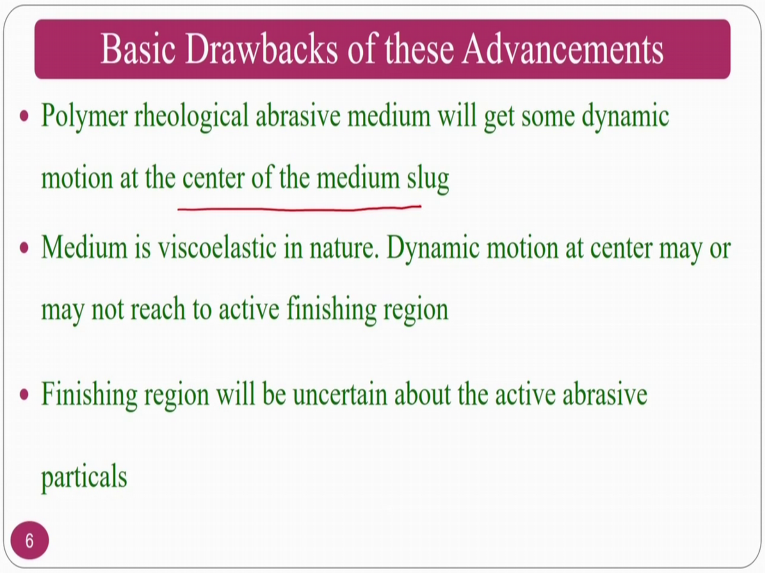

But on an average if you see all this processes, drill bit guided abrasive flow finishing process, spiral polishing process, as well as centrifugal force assisted abrasive flow finishing process. What is the common thing that one can observe is, medium or the polymer rheological abrasive medium gets an dynamic motion at the centre of the medium slug not at the finishing region, but as a mechanical engineer or as a manufacturing engineer. What I want is? I want to make the dynamics or abrasive particles active in the finishing region ok.

The medium is viscoelastic in nature dynamic motion at the centre may reach to the finishing surface; may not reach to the finishing surface ok. That is why finishing region will be uncertain about active particles in the finishing region.

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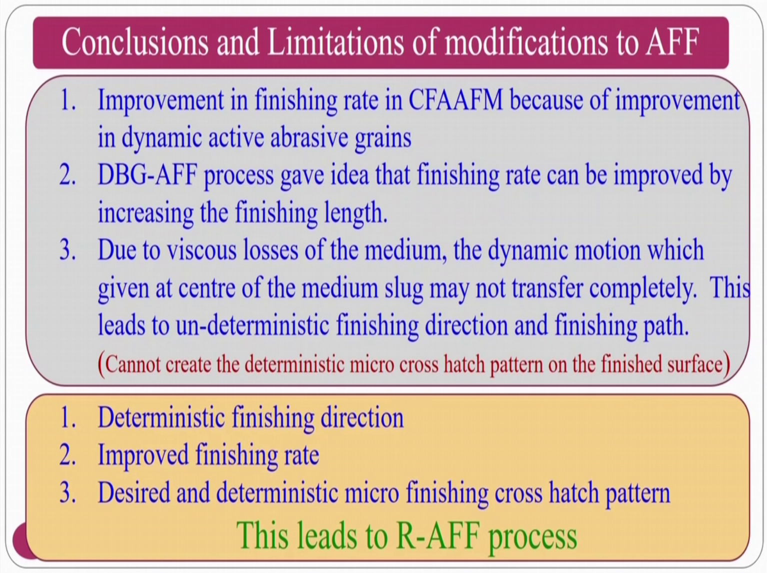

So, we will see in particular, what are the limitations and modifications with that we have to do. The first limitation of this one is, improvement of finishing rate in Centrifugal Force Assisted Abrasive Flow Finishing or Machining, because of the dynamic active abrasive grains, drill bit guided abrasive flow finishing process gave some idea of the finishing improvement because of the length of inc abrasive particle motion; that how much distance it is moving.

So, because of the inclination scanning electron microscope images that you have seen, can increase the finishing rate and due to viscous losses of the medium dynamic motion which gives at the centre of the medium slug may not transfer completely ok. This is the basic drawback of almost the three process that we have just seen the introduction that is, drill bit guided, centrifugal force assisted as well as spiral polishing ok.

So, this motion at the central's slug cannot give us deterministic micro cross section pattern; that means, that the surface pattern that I want at the same time surface finish also. So, if at all I want a deterministic pattern like a honing process, because the in honing process the abrasive particles are fixed on a hone. So, the cross edge pattern that you are going to get is in a deterministic way, but in this case if I can rotate the work piece; what will happen, the motion that you are giving is in the finishing region.

For that what we have done is deterministic finishing direction, improved finishing rate and desired micro finishing as well cross hatch pattern; that means that texture can be achieved by giving the motion to the work piece itself. In the previous condition the motion is given to the medium and medium may transfer may not transfer this dynamic motion to the work piece because of it is viscous losses and elastic losses ok. If I can give the dynamic motion to the work piece in that circumstances, the work piece will get the cross hatch patterns as well as dynamic motion it can create and the active abrasive particles will also take part in the finishing process.

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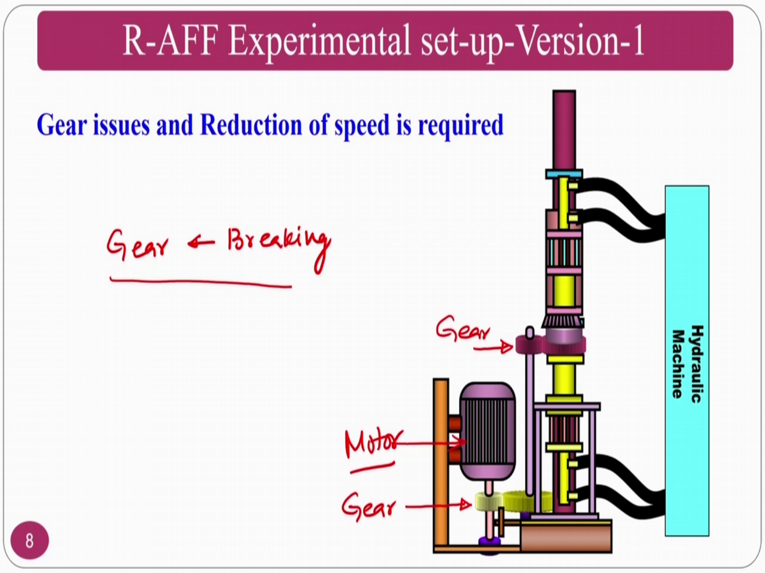

The version one; this is a design one, the basic thing that you can see is we have a motor and there is a gear reduction system multiple gears are there these are the gears these gears are connected to a big gear. So, that the gear reduction can be occurred and the same rod again we have another gear reduction system and this will rotate the work piece (Refer Time: 11:04) ok.

In this way the rotational abrasive flow finishing process is designed, but there is some problem when we design this was designed as a part of the PhD program at IIT Kanpur. So, there is a problem that if you are rotating at high speeds and your gear materials are not proper, if you do not have the proper gear reduction ratio, then the teeth's will break instantaneously; i mean that after few experiments itself.

So, if the setup is going bad in few experiments it will be very difficult to do. So, for that purpose, what is the drawback that we have to see. This is a lesson for the master student as well as a PhD students who want to design their setups and other things. Because, that is how you learn, you have to see what are the drawbacks? What are the things that is going bad? How to overcome it? In this condition the gear teeth's are breaking and because of which the system is not working properly ok.

So, we do not have anything with a medium and medium reciprocation and other thing, but rotational speed is given because of the gears, because of this gears breaking we cannot proceed further.

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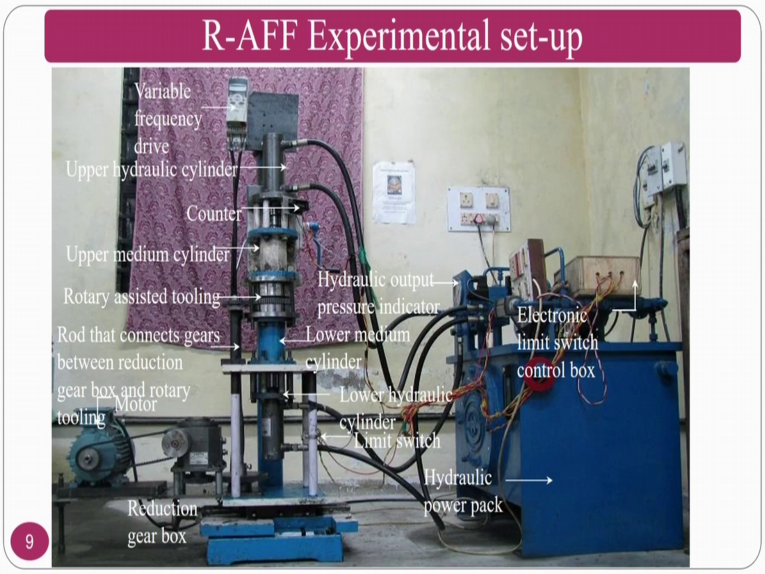

For that purpose we went on to a new abrasive flow finishing setup, where we have given rotational motion, in this one the new addition is we have taken a gear box and gear box can reduce the speed of the motor enormously ok. So, if at all I want a 10 RPM, if I if at all I want 20 RPM I can give. In the previous condition the motor RPM's are so high that if you give the gear reduction with respect to gears it is not possible.

So, how it is working in this condition is you can see here. So, the motor as you know abrasive flow finishing this is the lower hydraulic cylinder and upper hydraulic cylinder and upper medium cylinder and lower medium cylinder ok. So, these are all things are there and you reciprocate the medium in the working region; so, this much you have seen abrasive flow finishing process.

The rotational motion is given by a motor; the motor drives the reduction gear box, there is a high gear reduction ratio is there from where these are connected and from here this is the another gear which is enormously reduced and this imparts to this particular gear. And, this similarly this is connected here and this is imparted to the work piece ok; that is how the rotational motion is given. And, anyhow you have the hydraulic power pack to give the reciprocation motion using the hydraulic energy.

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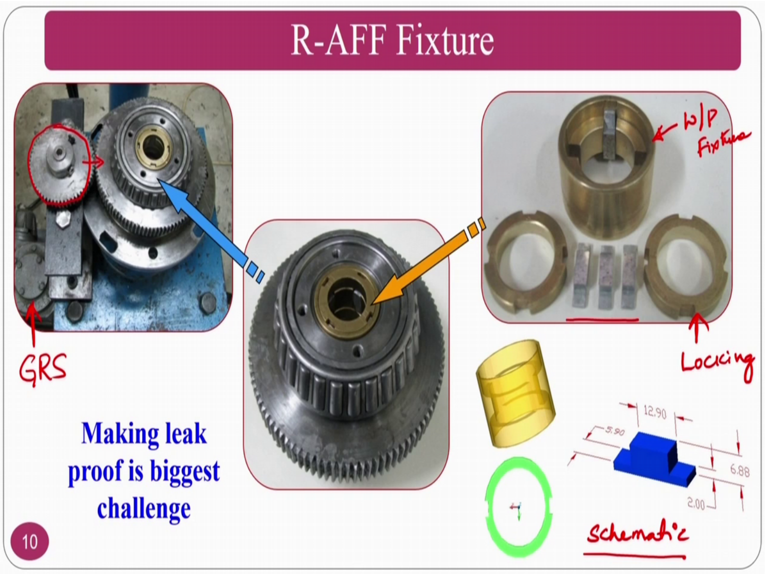

The most important thing compared to abrasive flow finishing process in this particular process is the fixture. How the fixture is designed and other things? If, you see here the gear reduction system is here gear reduction system ok, so that is connected to another gears and this is the gear that will be a driver gear, and this will be driven to the and wherein the work pieces are placed ok.

Wherein the work pieces are placed and you can see how the work pieces are placed and more over most important thing here is that leaking proof. Because, in the previous setup everything is under the static control only rotational motion is given to the work piece. That is why if there is a static region like medium cylinder and piston these are all in static as per the work piece is concerned ok, but your work piece has to be rotated whenever you have a work piece to be rotated, your static system and dynamic system in between you get a microns gap. In that microns gap the basic problem is since you are using a viscoelastic fluid there will be always chance of leakage.

So, in order to prevent the leakage, you should go for some of the things like multiple gear system and orrings as well as say some of the gaskets and other things we have used which are not shown here. So, orrings are used, so that it can be become leak proof then some of places we have used the gaskets. So, that it will completely become a leak proof system ok. You can see here the ball bearings are there, gears are there in between you have the work pieces and the fixtures.

So, this is called the complete fixturing system in which work pieces and work piece has it is own fixturing system, the schematic diagram also is given here and the original images is also provided here. This is the fixture work piece fixture and these are the locking plates; locking system or something these are the work pieces basically, that you can place the work pieces normally you have provided 4 slots ads you can provide 6 slots depend on your requirement and other thing as per. Here as per this particular design is concerned we have 4 slots; 4 slots are held by the 4 slotted the locking plates and other things. And, you can see the dimensions of your work piece in the schematic diagram ok.

The most important thing here is whenever this system is going to patent and other things the leak proof system, how you make a leak proof system is most important thing in this particular rotational abrasive flow finishing, because some most of the system is under static then only work piece region is in a dynamic condition. That is why most of the advancements if you see in the centrifugal force assisted as well as in the spiral polishing and other cases, the medium is given some of the dynamic motions not the work piece ok. That is why it is somewhat challenge to take, because whenever you rotate a external system the internal liquid system may also leak. So, you have to make the leak proof ok.

So, if at all you want to know about with the how the things are made leak proof and other things some of the research papers are there those things you can refer.

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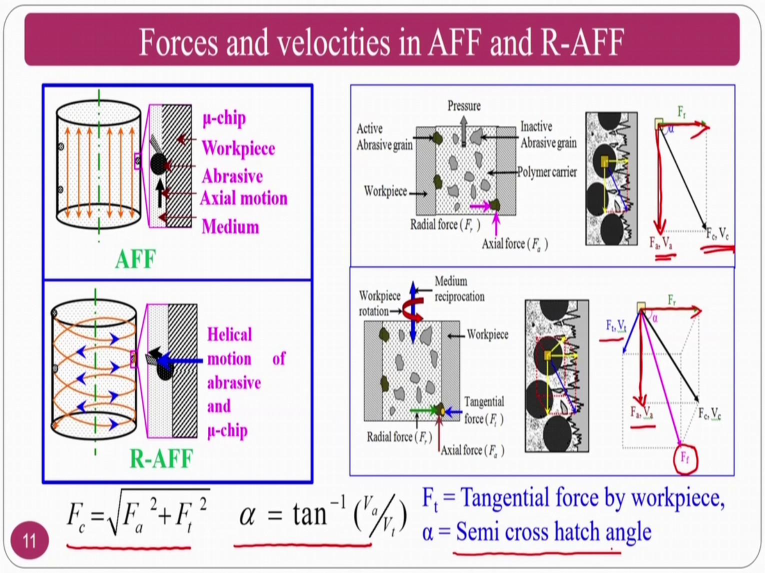

And, forces and velocities in abrasive flow finishing process and rotational abrasive flow finishing process; in abrasive flow finishing process the forces you have seen already like, you have axial force, and radial force, and axial velocity. So, this is the radial force and this is the axial force and you will have a axial velocity, because of which what will happen, you will get the cutting force and cutting velocity. But, in the rotational abrasive flow finishing process, the finishing will improve; why the finishing will improve? Because, you are giving a rotational motion, because of this rotational motion, you have already existing radial force; you have already existing axial force and axial velocity.

So, now additionally you are going to get tangential force and tangential velocity. And, your finishing force or the cutting forces got additional force and velocity that is why your finishing action will be much better in this condition compared to abrasive flow finishing process. Hope you understood, if not understood what is the benefit of rotational abrasive flow finishing process is in abrasive flow finishing process, you have axial force as well as radial force and axial velocity.

But in case of rotational abrasive flow finishing process, you have the 3 same additionally you have tangential force and tangential velocity; that means, that you have 3 forces and 2 velocities in a rotational abrasive flow finishing process, whenever you have another force extra force and extra velocity; that means, that shearing strength of that particular abrasive particle, that it is getting from the polymer rheological abrasive medium enormously high compared to abrasive flow finishing process. Because of which the shearing action will improve.

How the shearing action will improve and other things we will also see in the material removal mechanism of this particular process. And we can see the cutting force normally the cutting force is can be taken from the geometry like this and alpha also we can take from the ratio of velocities. And, alpha is the semi cross hatch angle at the same time F t is a new thing that is why it is written tangential force because of the work piece.

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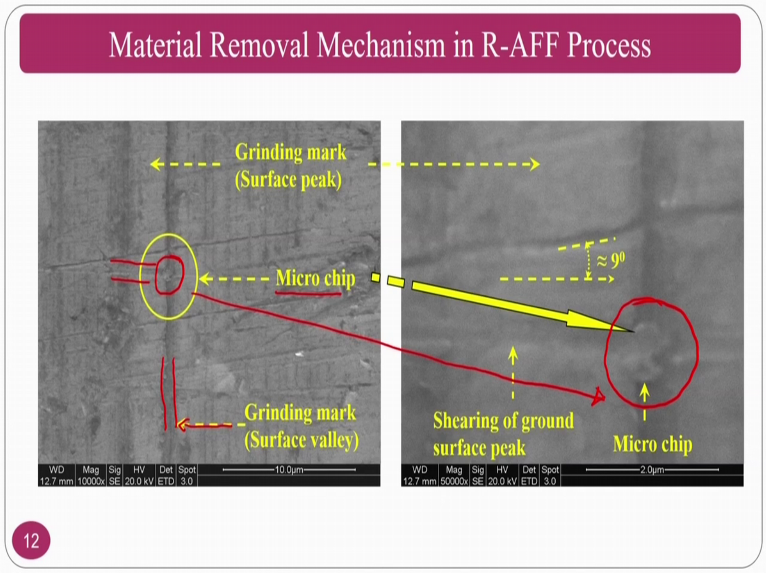

Material removal mechanism in abrasive flow finishing process as well as rotational abrasive flow finishing process is similar ok. So, how to prove that the material removal mechanism is by shearing and microchip formation and other thing? For this purpose what we have done is we have stopped the experiment after few number of cycles like 4, 5 cycles or something, I mean to say the reciprocating cycles ok.

So, you can see this is a grinding mark; this is a big one, this is the grinding mark that you can see here and the abrasive particles will move in perpendicular direction, if you are not going to any rotational motion ok. If you are giving rotational motion also some of the abrasive particles. I mean to say minimum number may also travel in a straight line, because this will have the viscous losses and elastic losses and other things. 100 percent may not listen to the rotational motion, because of which what you can see is some inclination is given here and the chip is formed here. This is called microchip; if you enlarge it, you can clearly see that this portion is sheared and formed a microchip here. The same thing is shown in this particular image also ok.

So, the normally the mechanism what I mean to say here is, it is shearing action only and this shearing action is improved, because of additional tangential force and tangential velocity along with the axial force and axial velocity and radial force. But, one thing you have note in the abrasive flow finishing also I told there is no radial velocity I mean to say that, I cannot say it is 0, but radial velocity is nothing but the indentative velocity, that I explained you that is much much less in comparison with axial velocity that is why we normally neglect it ok.

So, you should not note that radial velocity is 0 or something. It is much much less which can be neglected that is why, we always talk about the axial force and axial velocity and radial force only in abrasive flow finishing. In rotational abrasive flow finishing we add up tangential force and tangential velocity, because of which what will happen the shearing strength of the abrasive particle or the energy it gains from the medium, because of the dynamic motion of the work piece also we will enhance, that is why the shearing action and microchips will improve.

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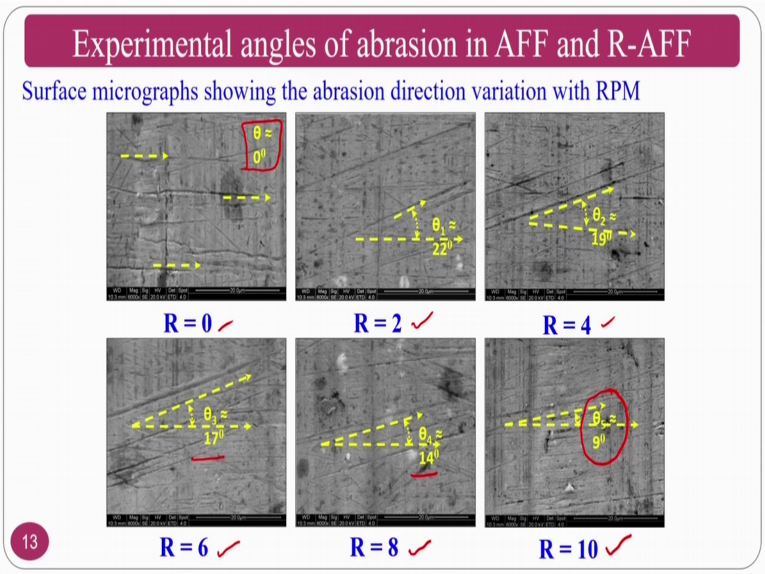

You can see here that, what is the affect of rotational speed? If you see there is theta equal to 0; that means, that angle is normally 0, because your rotational speed is 0 ok. So, whenever you are increasing to 2 rotational speed, now the angle is 22 degrees, if you are increasing to 4 angles go on decreasing; that means, that for a height of your cylindrical work piece where you have placed a work pieces. Those length per unit time will increase ok.

The 19 degrees then it is go on if you see here, rotational speed 6 you have 17 degrees, rotational speed 8 you have 14 degrees at 10 RPM rotational speed of your work piece the angle that you are going to get is 9 degrees. As you increase the rotational speed what will happen, the angle is coming down; so that means that, the length of cutting or the finishing length will improve. Since, your reciprocation speed is same at the same time work piece is rotating at very high speed. I mean to say not high speed as compared to 2 if you are using 10. So, it a speed is high compared to 2 in that way what will happen, the angle is less; that means, that it will form a high traverse length.

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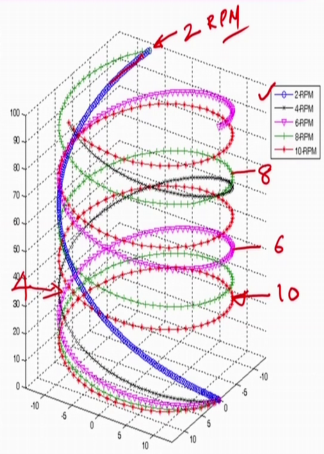
Helical path in R-AFF Process

Workpiece Rotational Speed (RPM)	Helical path length (Experimental from SEM Pictures)
2	66.74
4	76.79
6	85.51
8	103.34
10	159.81 ≈ 160



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That you can see in this one helical path. If you are see these helical path is calculated from the scanning electron microscope images, the surface micrographs that you have seen in the previous slide. So, if we know the work piece height ok, that theoretically and at the practically also we can know, because you know the work piece height and other things and you know the angle. From that you can calculate what is the experimental helical path length and helical path also we can generate in using this one.

So, you can just you need to do some mat lab programming which is very very simple mat lab programming you can do it and if you put 2 R P M, it is length is 66.744 slightly increased to 76.8, then 6, then 8, then 10, normally it is going to approximately 160. So, that is our 60 mm length you can increase and what I mean to say is if you are going to increase the work piece rotational speed, the length per unit time will increase and the finishing rate will improve ok.

The same thing you can see here, if your RPM is less, that is blue only one arc is there and if you are going to increase. So, you can see for a same unit time the red one is 10 RPM and the pink one is 6 RPM and the green one is 8 RPM and the black one is 4 RPM and the blue one as you know it is 2 RPM that is there already.

So, the helical path length will increase. Why the helical path is coming, because your work piece is rotating at the same time medium is reciprocating. It is resembling like a honing process, but it is not a honing process where you have a fix sticks are there here it is a flexible medium is there. That is why some of the papers they also name it as flexible honing process ok, but nowadays there are some other flexible honing processes also available that you have seen in the lectures, when I was discussing about the conventional abrasive based polymer finishing processes.

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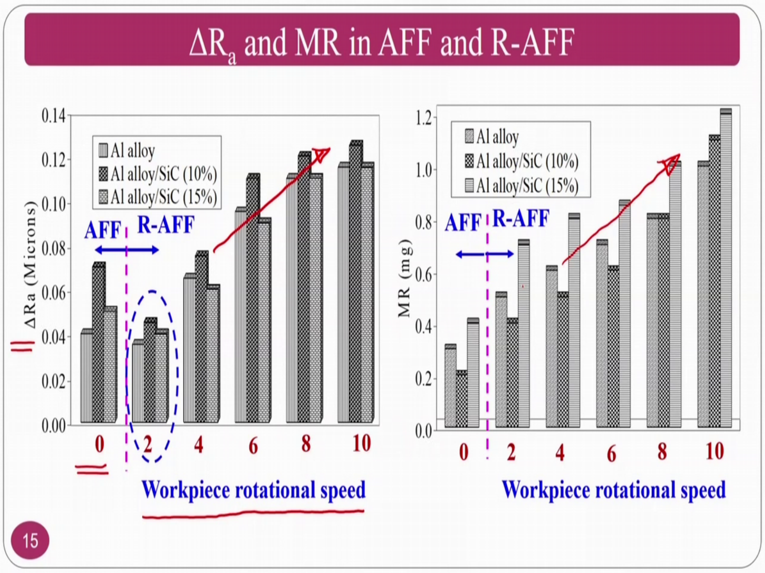

Now, we move on to the surface roughness or change in surface roughness and material removal in comparison to abrasive flow finishing process in case of rotational abrasive flow finishing process. First we will see the work piece rotational speed verses change in

R a; that means that if your change in R A is increasing; that means that initial minus final the gap is increasing or the amplitude is increasing.

So, you always require the increasing trend; that means that you always need a increasing trend as you have seen the arrow. So, what is the advantage of this one is, that means that your process is moving in a good direction, but if you see here at 0 RPM; that means that abrasive flow finishing process. What will happen, the change in R a is higher compared to 2 RPM, but after 2 RPM gradually it is increased, 4 RPM it is matching, 6 RPM it is increased.

The thing is at a 2 RPM that is 2 low speed; that means that your tangential force and tangential velocity will be much much less or you can say it is nearly minimum, that is why there is no much difference. But, why it is reduced even though it is less that part I will talk in the next slide, but as you increase the 6 RPM, 8 RPM and 10 RPM, the thing is that it is gradually increasing, because your amplitude of tangential force and tangential velocity is increasing, because of which what will happen, shearing takes place at faster rate and the change in Ra will be increased.

Similarly, in case of work piece rotational speed verses material removal also. In material removal you can see the material removal is increasing gradually as the work piece rotation increases, because tangential force and tangential velocity come into picture. So, there is very less change in surface roughness when respect to 2 RPM, but material removal is slightly increasing.

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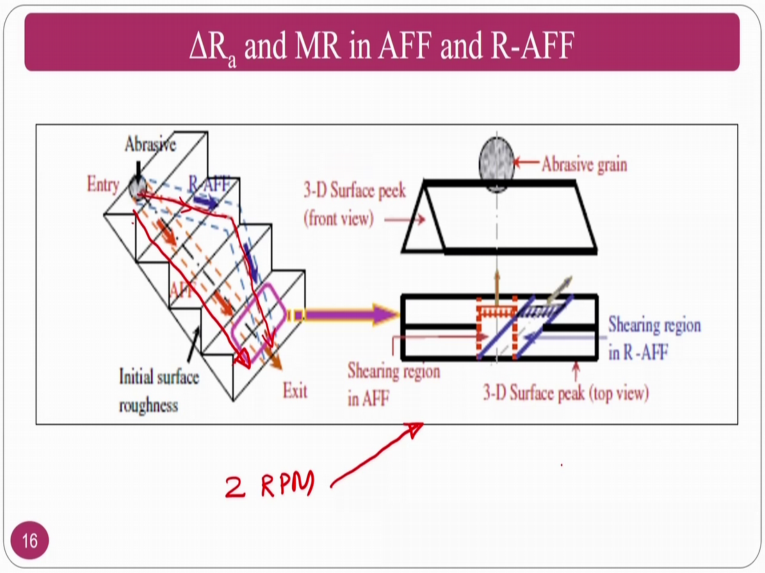

Now, the question is why it is increasing, at the same time why it is not up to the mark when 2 RPM is used. If, you see the abrasive flow finishing path; the abrasive flow finishing path will move in a straight line, but whenever you are going to increase the speed or whenever you are giving the work piece rotational speed, in that circumstances the abrasive particle will follow long distances ok.

So, because of the long distances and other thing, if you take 2 RP M and if you see here you are giving a rotational speed, because of which the length of cutting will increase ok. That is why if their forces and velocities are low and you have a cutting length is very high; obviously, you are change in R a will be reduced that is the main reason why at 2 RPM the change in surface roughness is low ok, but if you are go on increasing; obviously, the shearing strength will increase because of the abundant amount of tangential force as well as tangential velocity.

This is what we have seen about the flat surfaces, but we can now we will move on to the cylindrical surfaces.

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Finishing of Cylindrical Hard Steel Tubes

SiC wt% in medium composition	Workpiece Rotations(RPM)	Number of cycles	Extrusion Pressure (MPa)
20	2.0	400	4.5
30	4.0	500	5.0
40	6.0	600	5.5
50	8.0	700	6.0
60	10.0	800	6.5

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The cylindrical surfaces just I will give you the glimpse how the physics works, what is a reasons for the change in R a or the change in roughness at the same time material removal and other things. For which some of the experimental data is shown here.

So, the work piece is cylindrical hard steel tubes are used at the same time abrasive particles in R 20 weight percentage, 30 to 60 we have used work piece roughness is increased the number of cycles also increased from 400 cycles to 800 cycles and extrusion pressure; that means, that how much pressure you are exerting on the medium. That is also enhanced or increased from 4.5 to 6.5. These are all things are given to the experimental data. Now, we will see how the surface roughness will improve in case of cylindrical hard steel tubes ok.

Always looking at the applications and other things may not be good, because many of the PhD students and master students also require some of the experimental data, that is what the intention of us to put the experimental data, how the experiments can be done also can be understood from these particular slides, at the same time what is the preliminary experiments, what is the main experiments and other things. You require to do the pilot experiments or preliminary experiments, where you can change one parameter at a time. So, that you can get the feel what is that trends of the outputs because, output is a function of input so, input parameter; parameter is what you can change output response you cannot change that, only thing is that you can feel that or you can get the answer ok.

So, once you get the feel of the preliminary experimentation, then we move on to the main experimentation. If the material constraint is there then you can go for some of the design of experimental techniques like, CCRD technique, box bracken technique, tagoshi many many things are there ok. So, those will give you the complete idea, or if you have enormous material, enormous time and other things, then you can go for full factorial complete experimentation and you can plot that will be the best one ok.

So, you have to start with a preliminary experimentation you should get the trends now you should choose what is the optimum range of input parameters where I can do experiments, then you move on to the main experiments in that input ranges. So, preliminary experimentation is done then we found some of the ranges then we are doing some of the experiments here and effect of silicon carbide weight percentage. If you go on increase the weight percentage. The gradually the out of roundness is increasing; out of roundness is nothing but, how much it is deviating from a perfect circuit ok.

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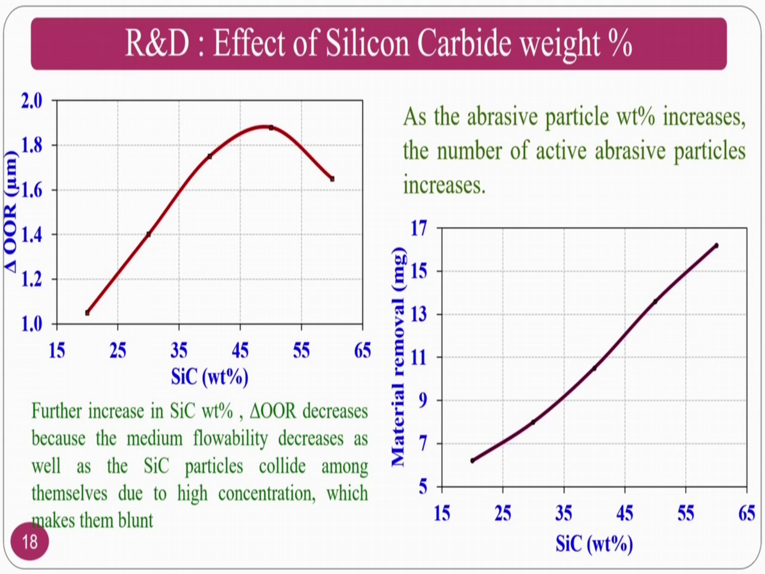

So, that you can measure using out of roundness measurement standard equipment's are there, which we have used in stellar Hobson, out of roundness measurement system we have used and you increase the number of abrasive particles what will happen, number of active abrasive particles that is those are involved in the finishing action will increase, but if you go on increase what will happen? The medium viscosity will enormously increase and you cannot add also. At the same time the problem is this abrasive particles will collide each other and it may become blunt also, but if you see if the number of active part abrasive particles will increase the material removal; obviously, will increase in this case.

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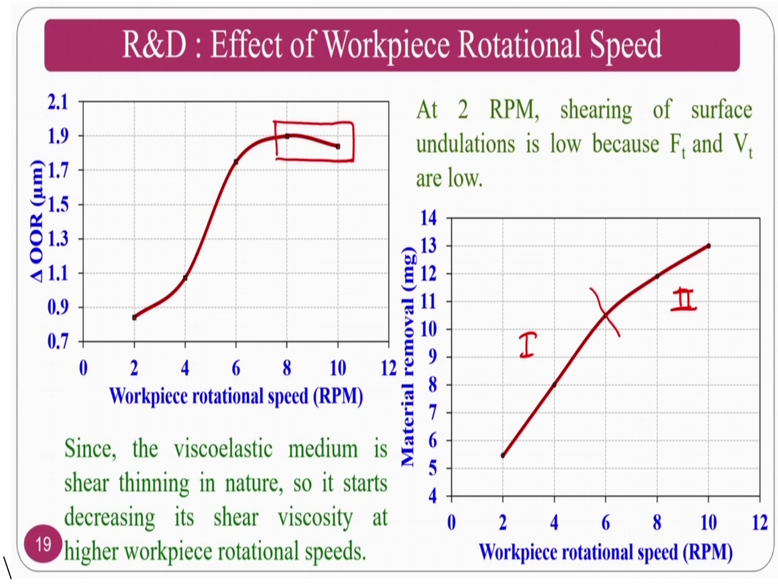

If you increase the rotational speed because the rotational speed is one of the new things compared to abrasive flow finishing process. In this one what is happening here is if you use low RPM as you have seen the material removal rate is also less. So, there will be very minimal change in out of roundness at the same time if you go on increase; obviously, it will increase and it will have such an saturated point beyond which there is no much change in out of roundness.

So, it is; if you increase the rotational speed what will happen the finishing length will increase and the interaction frictions are very high. So, the polymer may get heat and other things because of which viscosity of the fluid may be slightly goes down ok, but the machining if you that the same thing can be attributed here in the section I and section II, the improvement rate if you see in the section I it is going very fast, but in section II because of the viscosity of the medium slightly going, because of the heat that is generated in because of the rotational speed of the work piece.

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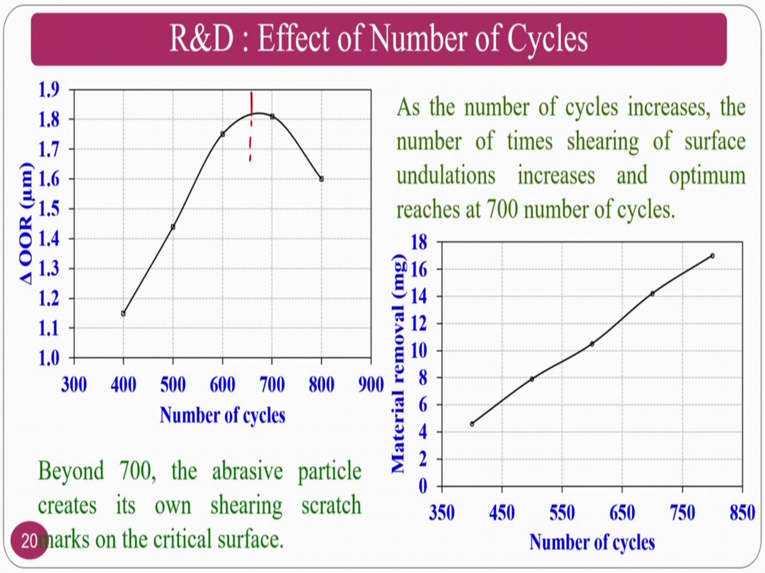

Number of cycles if you are increasing the number of cycles the same problem. The medium is constant and you are going for 400 cycles it is 500 it is ok, beyond certainly meet if you are going what is happening here is that, the abrasive medium also get the chips inside. So, chips are there along with the medium and abrasive particles.

So, abstraction will be there at the same time if the number of cycles are more and more what is the problem is, medium gains the temperature and viscosity will go down. If the viscosity will go down the abrasive holding ability, what we talk in the grinding process is the grade will change from hard grade to soft grade. In that circumstances the abrasive particle will only slide on the surface rather than the finishing, but cumulatively you can see that never the material rate removal can come down ok. Because, if you are increasing the number of cycles; obviously, the material removal rate may go down, but cumulative value of material removal will go on increase.

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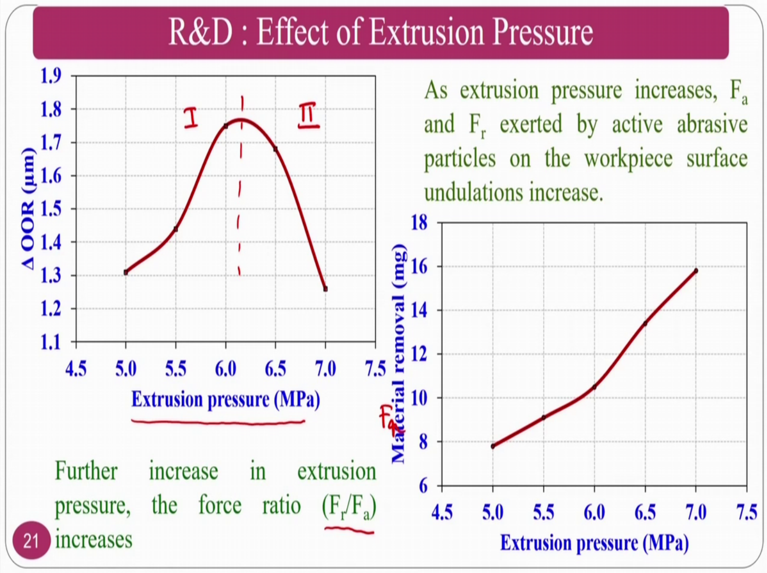

So, extrusion pressure; extrusion pressure if you are going to increase what will happen is force ratio will increase. So, that what we will see, here if you are going to increase extrusion pressure; that means, that the force ratio that is radial force to axial force will increase; that means, that if you are increasing the extrusion pressure the elastic component will gain more compared to viscous component and you can see in the part I and part II ok.

If you are increasing the radial force as the literature says that force ratio will increase this is measured by Professor Gorana and Professor V K Jain, that is explained with a experiments, that the force ratio is increased and other things ok. So, they have used a ring type dynamometer for the work piece and they have given the extrusion pressure. If the extrusion pressure is increasing the force ratio is increasing, if the force ratio is increasing what is happening here, F r is increasing; that means that your indentation force is increasing.

If your indentation force is increasing then it can create lot of indentations rather than shearing’s, that is why in the second region the material removal is less; that means that shearing is less ok, because of which the out of roundness is less. However, you can see the cumulative material removal will be an gradually increased.

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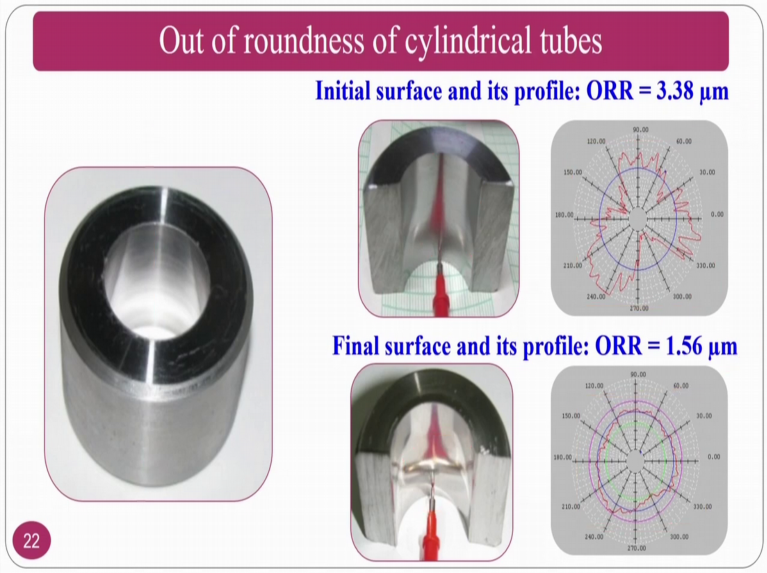

Out of roundness of the cylindrical tubes, now we will see. So, this is the initial surface where the out of roundness is 3.38 micrometers and you can see the pen tip image it is completely blur, how this is done is we have taken the work piece. Now, we have done the partition using a (Refer Time: 40:37) and we have checked the for the images, but this cylinder is used previously for the measuring of out of roundness then only it is made the parts ok.

So, that one has to understand in the after finishing you can see the image of your pen tip and other things are very much clear compared to the previous one. And, out of roundness is improved from 3.38 to 1.56 and you can clearly see the out of roundness profiles also compared to the initial one ok. That is how you can improve the surface finish; you can improve the out of roundness and other things.

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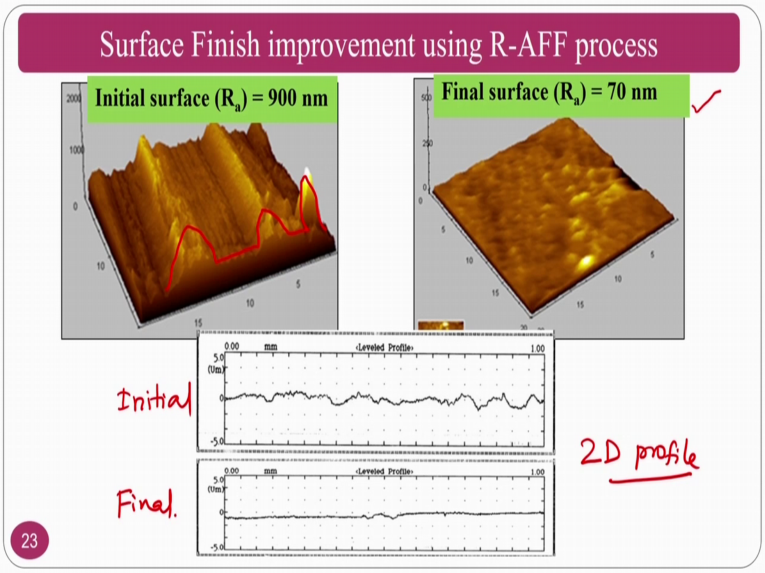

So, surface improvement also we have observed in this particular process compared to the abrasive flow finishing process. This is the atomic force microscopical image of the initial surface that is the work piece is prepared by the grinding process. And you can see, the surface peaks; the initial surface roughness is approximately 900 nanometres, in a small area of atomic force microscope measured area. And, after finishing you can see it is improved to 70 nanometres; that means, enormous improvement is there, at the same time you can also see the 2 dimensional profiles this is the initial surface and this is the final surface ok.

This is for long distances, the 2 D profiles or for the long distances and that means that it is for like 5 to 10 mm and other things and in case of atomic force microscope you can feel, how the surface peaks are sheared off from the work piece surface and you can get the Nano surface. So, as I said that the abrasive flow finishing process; finishing rate is less, in rotational abrasive flow finishing process, you can improve the surface finishing rate; that means that with the same time the finishing that you can achieve will be better.

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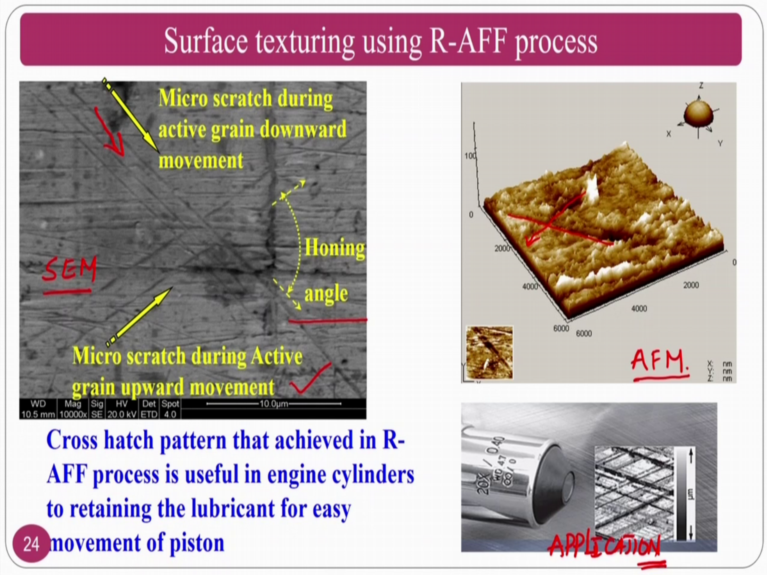

In abrasive flow finishing process you will get approximately the same pattern. As, if you are moving the abrasive particle perpendicular to your grinding surface then you will get a normal surface, but in a rotational abrasive flow finishing process you can see the micro scratch direction during the active abrasive particle movement. So, this is while the abrasive particle is moving; that means that your motion of abrasive medium is upwards ok.

So, the downward motion this motion whenever you are pushing down the medium down. So, because of this what will happen you will get a cross hatch patterns that is the honing's type of surface you can achieve. So, similar surface that you can also see using atomic force microscope, this is atomic force microscope image some of the B.Tech students will be there. So, they should understand that this is the scanning electron microscope image and this is atomic force microscope image ok.

So, in a scanning electron microscope you will see the top view and you can see complete surface profile or surface morphology in the atomic force microscope. So, here also we can see a part of cross hatch pattern here and that is most important for the pistons and other cases. That is what the application is shown here. So, cross hatch patterns can be generated along with a surface finish, that is why this process we will be slightly better compared to abrasive flow finishing process.

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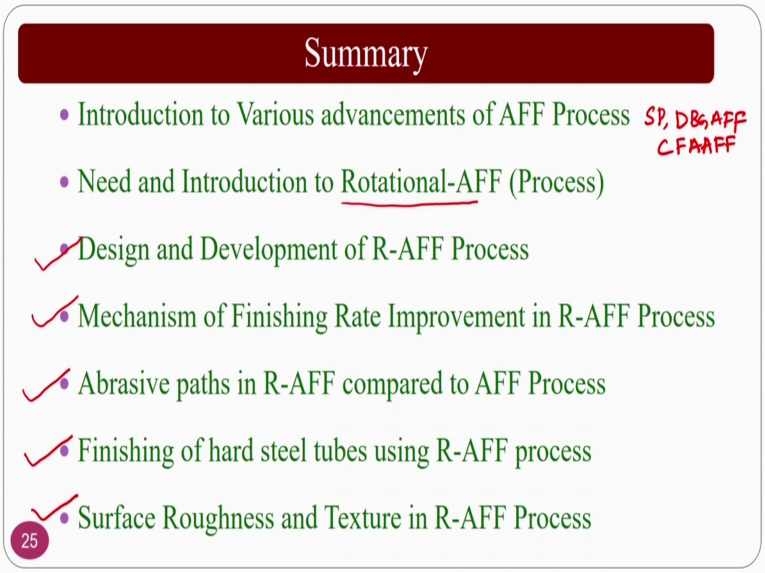

Summary of this class what we have done is, we have seen the introduction to various advancements that is spiral polishing process, drill bit guided, abrasive flow finishing process and centrifugal force assisted abrasive flow finishing process are and then we move on to the rotational abrasive flow finishing process. The need is in the process in the above processes, what is the problem is medium is given active motion, which is may not be carried to the work piece finishing region. That is why we try to rotate the work piece by having a leak proof system and then we have designed 2 designs and one design has some problem of a gear.

So, we move on to a gear reduction system and we can do the design and development of rotational abrasive flow finishing process. Then mechanism we have seen, how the material removal rate is improved at the same time finishing rate is improved, because of the additional tangential motion and tangential velocity, for additional tangential force and tangential velocity along with the axial force, axial velocity and radial force and abrasive paths we have seen.

The abrasive paths are angular motion is reduced and this can increase the contact path or the finishing paths. So, that the finishing rate will be improved and not only the flat surfaces we can also finish the hard steel tubes also in this particular process and we have also seen the surface roughness and texture that is generated. And, that we have seen is that it is not only for the application of the surface finishing process, you can also generate the surface textures like cross hatch patterns, that are normally used in I C engines at the same time you can also improve the out of roundness ok.

This is a beauty about rotational abrasive flow finishing process and the advantages of rotational abrasive flow finishing process over the conventional abrasive flow finishing process is it will improve the out of roundness, it will improve the finishing rate and finishing rate improvement means, your production time will reduce; that means that time is money in manufacturing's that is the motive of going to rotational abrasive flow finishing process compared to the abrasive flow finishing process at the same time you can also improve the out of roundness ok.

So, out of roundness may not that much improved in a normal abrasive flow finishing process, because of the rotational motion you can improve uniformly at the each and nook and corner of the cylindrical surface.

Thank you for your kind attention.