Polymer Assisted Abrasive Finishing Processes
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Lecture – 14
Finishing of Biomedical implants

Welcome to the course on Polymer Assisted Abrasive Finishing Process. Today, we are going to have a important class where we understand what is the practical application of this particular course, how this polymer assisted abrasive finishing processes especially in terms of abrasive flow finishing process where you will use polymer assisted or polymer rheological abrasive fluids. So, moreover you also see some of the other applications also, but I am going to concentrate mostly on bio implants.

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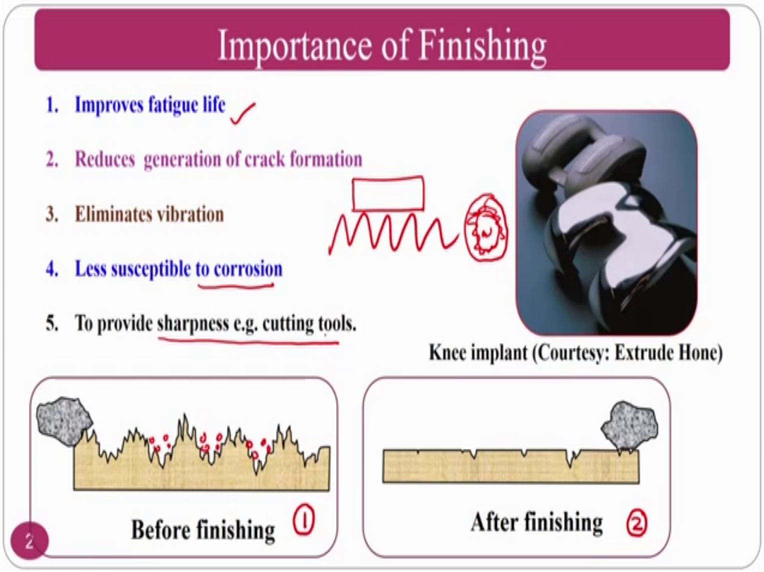

See importance of finishing you should also know what is the importance of machining. It will improve the fatigue life if the surface is roughness is less; that means, that your contact area or bearing area will be high.

Assume that figure 1 and figure 2 if you take, what will happen? Bearing area for figure 2 will be much high compared to figure 1. At the same time crack formation whenever you have the crack formation because of the surface roughness there may be always a crack formation will takes place wherever the valleys are there. At the same time, it can eliminate the vibration, means whenever you have the surface is too rough, figure 1 assume that my surface is too rough. And on top of it if you have any load if you are putting what will happen? It will be on the only peaks.

After some time, what will happen? This peaks base shear off and it will give some eccentricity. Assume that this is the practical application is in terms of a shaft that is there in a bore and this surface is very rough like this and your shaft is mounting on this one. So, what will happen is after some rotations this shaft will fail because of the rough peaks will shear off, then vibration will come into existence.

Then less susceptible to corrosion; that means, that if you surface is like this and fluid flows on top of it, what will happen? This the fluid can stay more in quantity whenever the surface roughness is high in this one compared to the low surface roughness. So, the corrosion will be also will be high to provide sharpness. To the cutting tools at the same time you can also give good aesthetic appeal. As you can see here the knee implant which we are going to talk mostly about the knee implants and hip implants, as well as cardiovascular applications and other things.

If you see the knee implant one and knee implant two what is happening here is if you are going to place the knee implant one the surface roughness is too high surface roughness may obstruct the body fluids. Assume that the body fluids flows on it, what will happen? It will abstract the flow. At the same time if you have the flow on this one then may be obstruction, but obstruction compared to the unfinished surface it will be less. So, the body fluids easily flows and body fluids will not stay in the surface valleys and corrosion will not take place, and the life of this knee implant will be enormous.

Now, we look in upcoming slides how the nano-surface finish improves the biomedical devices.

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Polymer assisted abrasive medium for macro to micro features; in this what are the few geometries that we are going to do? Practically speaking this is not exactly what we are going to finish the knee implants or hip implants or cardiovascular applications or something, but the preliminary study or preliminary experimentation that we have done at our laboratory is shown here, so that you can understand.

If my work piece is bio stainless steel or surgical steel if you want to finish this tubes you can go for high viscous medium. As the geometries are going down or the geometries are reducing, what will happen? You will have to use the low viscous medium. So, the medium development itself is a very very challenging task because you have to play with minimum 15 to 20 ingredients.

The basic problem comes like stickiness, self-deformability, self-upgrading ability and more over the sedimentation problems this all things are there. So, you will have to choose; obviously, a good base polymer rheological additives, which rheological additives you are choosing will decides what is your viscosity. At the same time your stickiness to the surface if the stickiness is very high, what will happen? It will stick on to the surface and other layers of the medium will flow on top of it.

So, in respective of how much sticking is there it just simply flows on surface rather than upgrading the surface. In that circumstances what the biggest problem is even though you are going for 100 cycles, 200 cycles, n number of cycles the finishing action will be much much less. Whenever you can take the implant out and you can cross check the surface finish may not be improved. For that purpose you should have good abrasive particles chemical compatibility and other physical compatibility between the all the ingredients should be good.

Suppose for example, you are using a silicon based with carbon based composition, normally the compatibility will not be very good. So, you will have to choose carbon based means carbon based, if you want to choose completely silicon based means silicon based.

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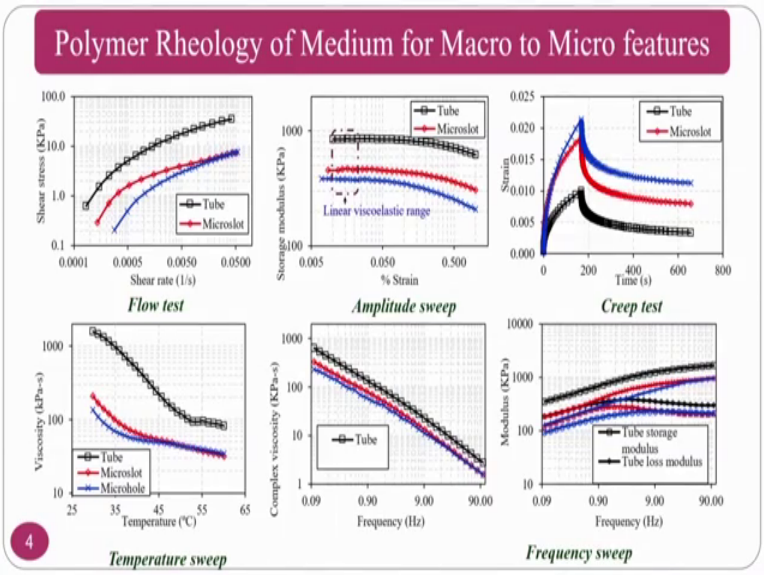

So, there are some terminologies and other things which covers in the medium development. For example, if you want to go through the medium and its rheological characteristics and other things it itself is a very big course. So, just I am giving you some of the glimpse if at all I want to go for a micro slot if at all I want to go to a tube, what are the various properties and other things.

So, these are the rheological properties which I have already discussed when I am teaching about the abrasive flow finishing process. So, these are the same thing, but medium compositions are slightly different, but the physics linear visco elastic region, creep recovery, elastic region, visco elastic region, elastic recovery and all these things are approximately same. And what is here we have shown is one is for macro applications another mediums are for micro applications, like micro hole, micro slot and other things.

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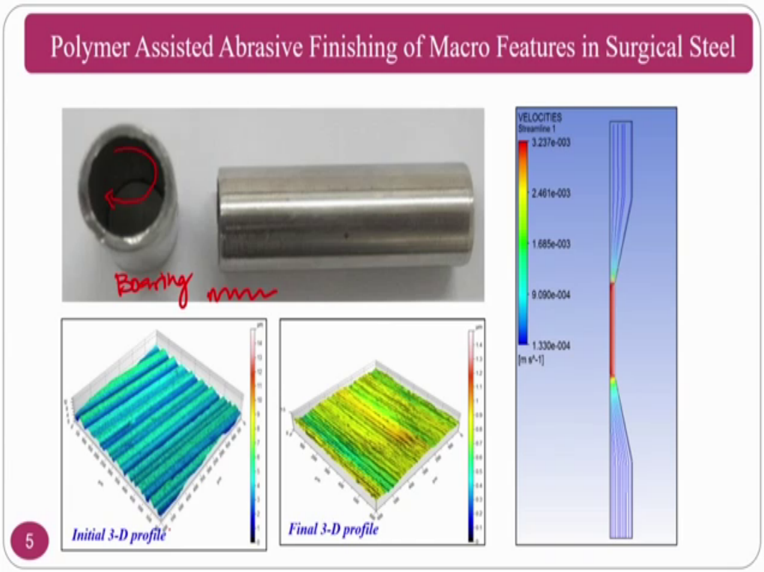

Now, you will understand in the upcoming slides why we want to finish the macro features and why we want to finish macro features. So, first we start with macro features, big features like a stainless steel tube or surgical stainless steel tube. This surgical stainless steel tubes are mostly important in various surgical aspects and other things.

If you see the initial surface roughness normally this is a boring surface there the boring will be done inside the work piece and the surface approximately looks like the turning process only, and then you do the polishing process using the medium that is given. So, you will get the initial profile and final profile.

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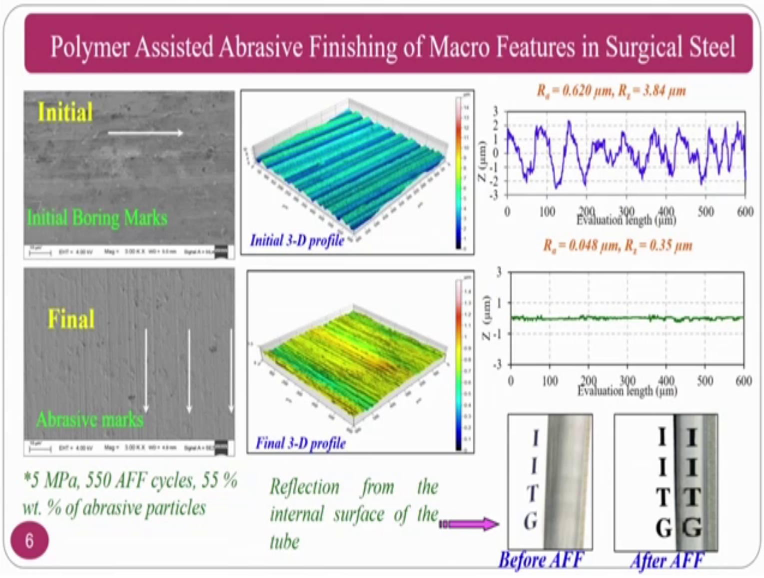

How this the finishing will take place and other things? It is same as abrasive flow finishing process in this particular class just I am going to explain you the applications because you should know why we you are studying this particular course. If you can understand why we studying this particular course, then you will get the essence of this particular course. So, initial boring masks you can see these are the dominating initial boring marks are there similarly the same 3-D graph is there as well as 2-D graphs is there.

This surface has to be finished. You have a viscoelastic medium where viscous component is there elastic component is there, you have a abrasive particle that is supported by your polymers and polymer will put your radial force here, and axial force, and axial velocity here and shearing will takes place. Assume that my abrasive is there it will go and shear the surfaces, and it will give me a good surface like this.

And at the same time this particular paper is already published. If somebody wants to know about this details and other things they can go through this is a paper published by Doctor Sachin Singh and Doctor Ravi Shankar from IIT, Guwahati. So, more details can be known from that particular paper. At the same time, you can see here. However, after polishing see; that means, that this particular is refers to this one or this is refers to this one and this particular surface is refers to this one and this is refers to this one that is what is a importance of finishing.

However, here I am not talking much about parameters and other things because macro is not that much a complicated that is why I will talk about some of the physics of finishing in terms of micro holes as well as micro slots, so that you can understand because in abrasive flow finishing already I conveyed you regarding the macro features and its finishing. So, in this particular class I will concentrate slightly more in micro features.

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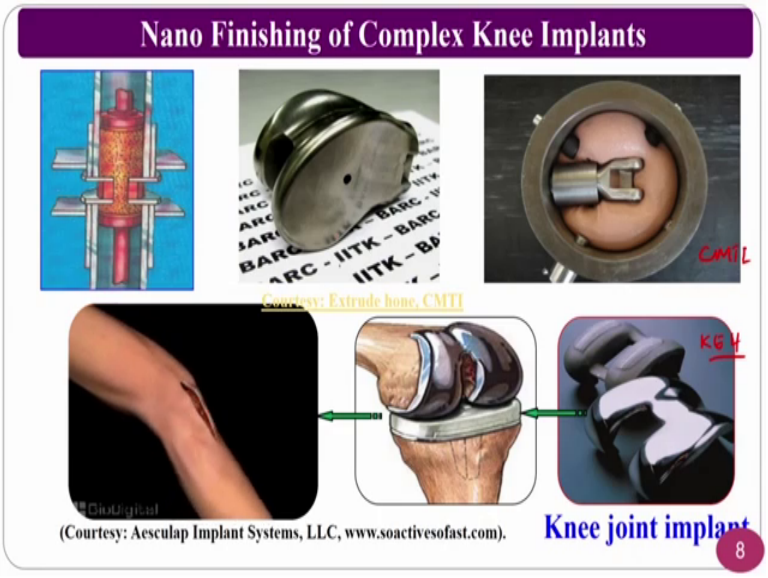

First, we start with macro features then we will go to micro features. And this is particular study is conducted at IIT, Kanpur and CMTI, Bangalore. So, some of the researches is also done by (Refer Time: 10:59), ok. This is done at CMTI, Bangalore and (Refer Time: 11:05) extrude hone. Not only abrasive flow finishing process can do the polishing it can also done by MRF process and other processes. This is knee implant initial surface which is too rough, that is why IITK word is not that much visible on this one.

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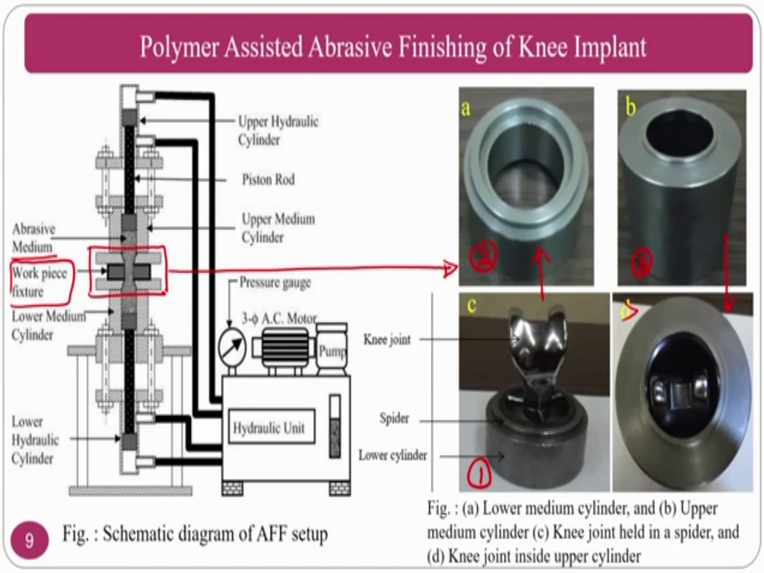

How to polish the knee implant? So, for that purpose we can use abrasive flow finishing process where in you have to play with polymer rheological abrasive medium and you have to design a special type of tooling. This picture is familiar to you because you are going through the abrasive flow finishing process, wherein you have abrasive medium is there workpiece fixture is there. This is the area where you are going to fix your fixture.

So, your fixture has male and female part, wherein your knee implant is mounted and it can be finished by using a polymer rheological abrasive medium. You can see this is a male part and this is a female part, so that this male part and female part can sit together and the polishing can be done. After putting this into this one, so you can also close with this one.

So, part 1, part 2 then you have these two combined will give raise to this. And when you place part 3, part 1 and 2 and 3 are placed to get a this surface and you can hold the workpiece intact and their main purpose of tooling is to hold the knee implant in position to allow the medium to, to allow the medium across the surface of the finishing, so that the finishing can be taken place properly, ok.

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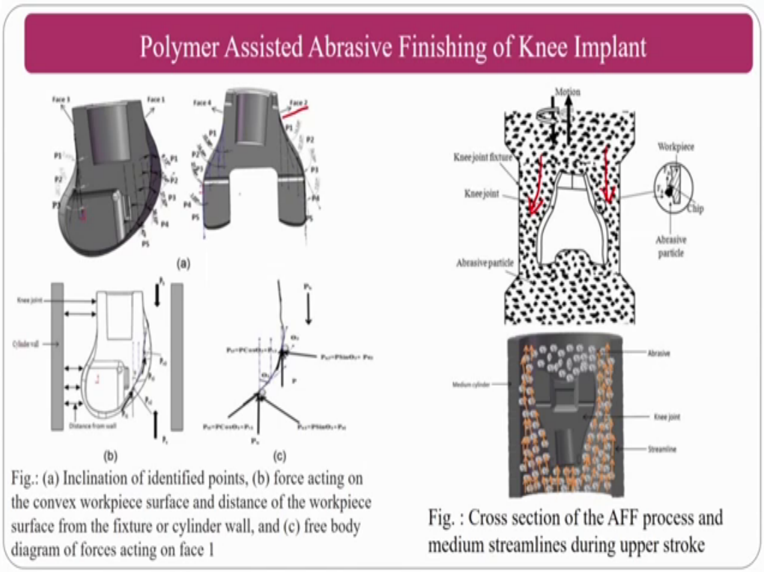

You can see here how the medium is flowing and other things. And the curvature is completely different from point to point for that purpose what you have to do is you have to measure the surface roughness at different different levels. That is why the author has given at a different different faces he is going to measure the surface roughness value. And, you can see how the polymer abrasive medium is flowing on the knee implant; this is how the knee implant it works. This is how the polymer rheological abrasive medium flows across the surface to be finished on the knee implant and the finishing can be taken place.

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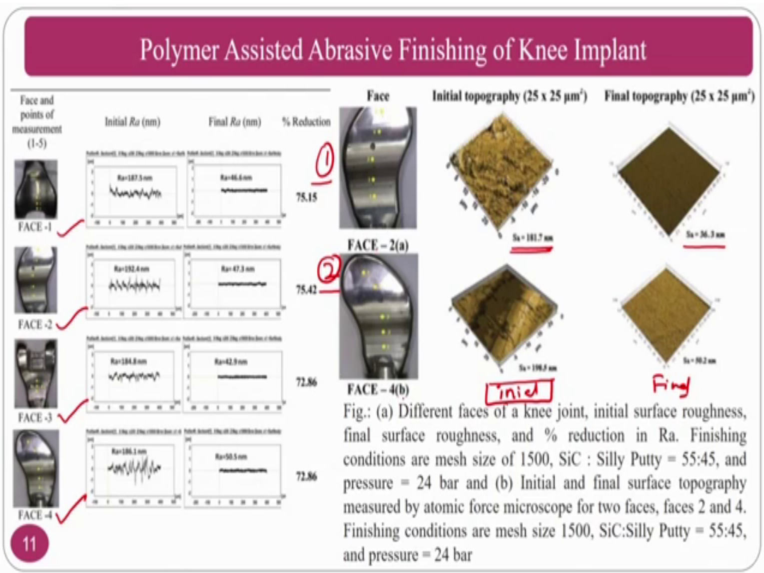

You can see the surface, it is a initial surface roughness which is considered in the normally area surface. It is approximately 182 nanometers, after finishing it is 36.3 nanometers. You can see again at on other side because I said that it has a changing of curvature is there at many many places because of which you have to measure at different locations that is why it is measured two locations here.

So, location 1 and location 2, initial and final, initial and final surfaces and at the same time it is also measured at different faces face 1, face 2, face 3, face 4, in face 2 a is given here and face 4 b also given the 3 dimensional surface. So, that you can measure at different different levels or you can measure at different different regions of a knee implant and you can give what is the average value of the surface roughness on the knee implant.

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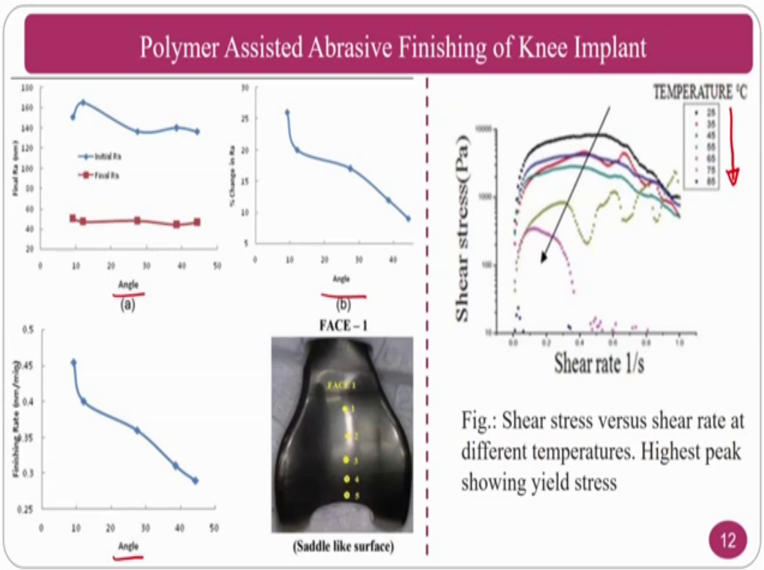

You can also see here the final here the final (Refer Time: 15:04) with respect to angle, what was the angular unchanging surface roughness. If you see at different different angles it is moving at the face and you can also require the surface roughness at this surfaces because this is the area where you have to have the relative motion and other things.

So, the medium which you have to prepare it should have good amount of shear space at the same time if you are going to put temperature as you see here if you are going to increase the temperature what will happen, the shear stress of the medium will decrease. Then polishing efficiency will slightly reduces.

Now, we move on to the hip implant especially we deal here with the acetabular socket, some people it they may call it as acetabular cup, some people they call it acetabular socket and other things.

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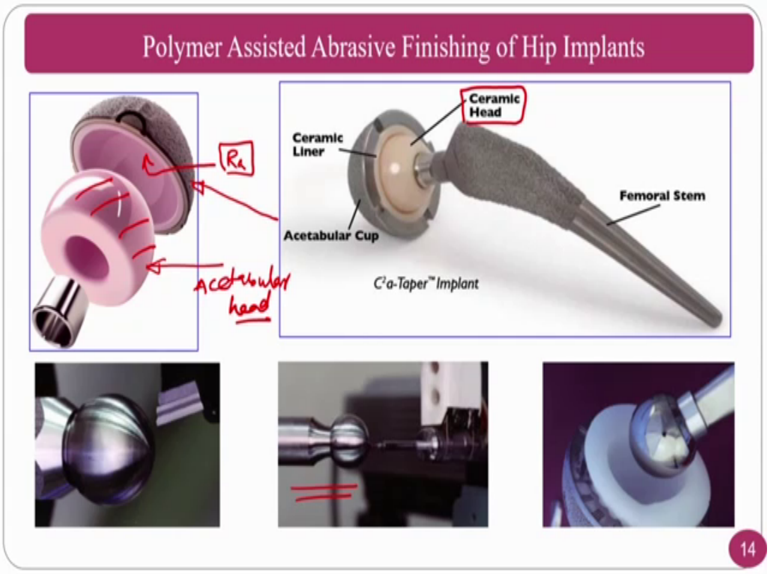

So, in a hip implant acetabular head as well as acetabular socket both are to be properly polished otherwise the relative motion will be not good for the patient. This is acetabular head or normally a it is made up of a ceramic material, at the same time this is as acetabular cup or acetabular socket also we can say. But in acetabular head we mostly bother about the external surface, in acetabular socket we bother about this internal surface, roughness value, so that the contact will be proper.

So, normally the head will be machined first and then it can be polished. So, the two important locations in a hip implant is acetabular head, top portion as well as acetabular socket region these have to be polished.

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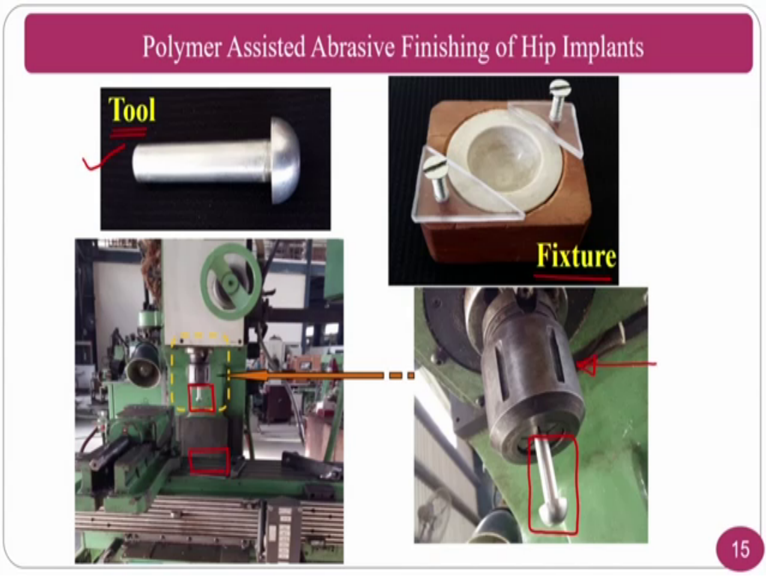

Very simple mechanism is found here and you just have a aluminum tool, and you have a fixture to hold the acetabular socket. Normally, we can design a simple wooden based fixture that can be placed on a milling machine and milling cutter can be replaced by the tool the you can design according to your requirement.

This tool is looks very simple, but recent works we are doing our complicated things because we want the tool to be more viscoelastic in nature. So, some of the recent works are unpublished. So, we are not showing here. However, the same principle is followed there also. You can see the n milling cutter collet. So, we can hold your tool here and you can hold the workpiece here.

You can see here assume that I am holding my workpiece here and my tool is here and the tool will need to have the polymer viscoelastic medium. For that purpose what we have done is we have taken sufficient amount of polymer rheological abrasive medium that is exclusively prepared with some of the advanced abrasive particles and polymer rheological additives and we have done the finishing operation.

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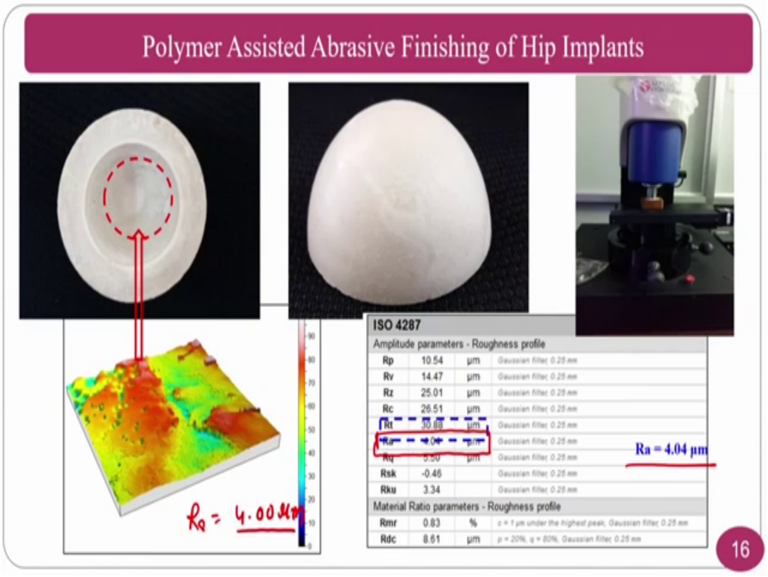

So, the initial surface roughness is measured normally initial roughness is approximately is 4.04 micrometers. This is measured using a noncontact interferometry based surface profilometer and this is the surface roughness; average surface roughness is approximately 4 micrometers. We want to find the surface roughness of the bottom side of the acetabular socket. So, this material itself is a very complicated material this is material we have procured from ISA, Bangalore and this is ternary composite where ceramics, polymers and bio-ceramics are involved in it.

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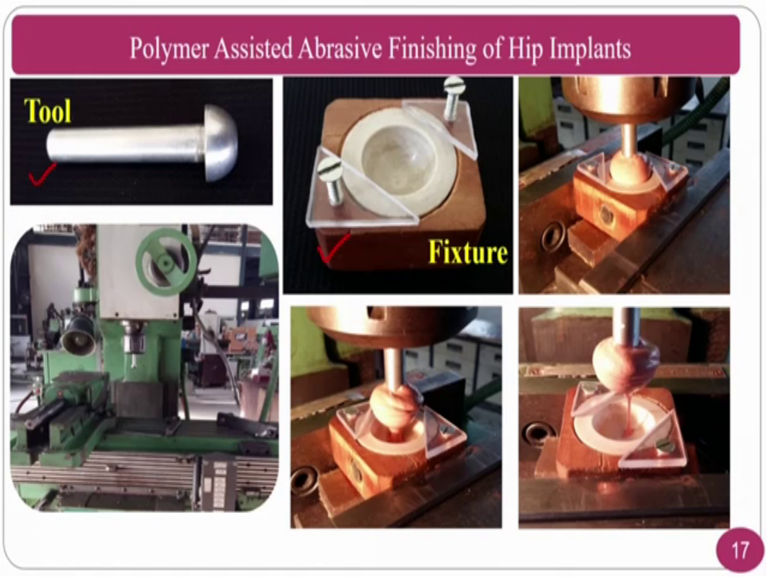

Now, you can see the tool and a workpiece, fixture and other things the tool is here, the workpiece is in the fixture. Now, workpiece is placed beneath the tool and it is filled with optimum amount of the medium that is already optimized its composition, ok. Simple medium is used here however; the people can go for complex mediums and other things.

The medium whatever here is a silicon based medium it is just a simple medium where we have used a very less amount of abrasive particles. However, this medium is not going to give very better results, but preliminary experimentation as per the analysis just we want to check whether the finishing action is going on or not. For that we have done, using the silicon based polymers along with the hybrid abrasive particles.

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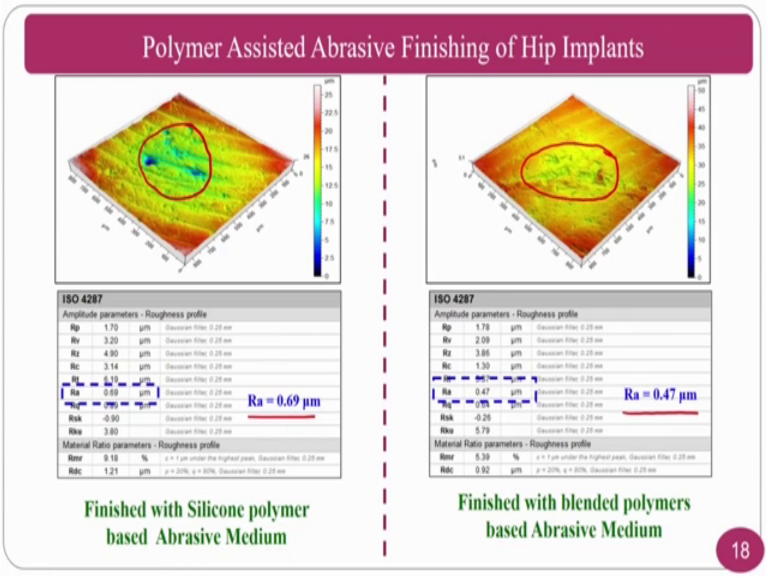

And the surface roughness you can see here from 4 microns are 4.04 microns, the surface roughness is reduced to approximately 0.47 micrometers; that means, the surface is enormously improved. But the pits are some delamination is another basic problem here that is why we need to go for the advanced polymers where you can make the polymer assisted abrasive medium.

As I said this is just a preliminary study where we can do or where we should understand that whether the process is working, whether the tool is working or not, for that purpose we have tested the surface roughness as enormously decreased, but this cannot be used directly into a practical application. However, the life of this particular component will be greatly enhanced because the surface roughness is drastically reduced or enormously reduced from 4 microns to 0.4 microns.

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Now, we move on to the micro components or micro features that are normally used in many many biomedical applications. The first one is micro slots. These micro slots are finished using polymer assisted abrasive finishing process where the medium is too low viscos. That mean that as you have seen in the first slide or second slide that there is a different different mediums are there and these are the mediums as your passages are small and small what you have to do is, you have to reduce the viscosity of medium and you have to go for the fine to super fine abrasive particles, then only these abrasive particles will pass through this narrow gaps.

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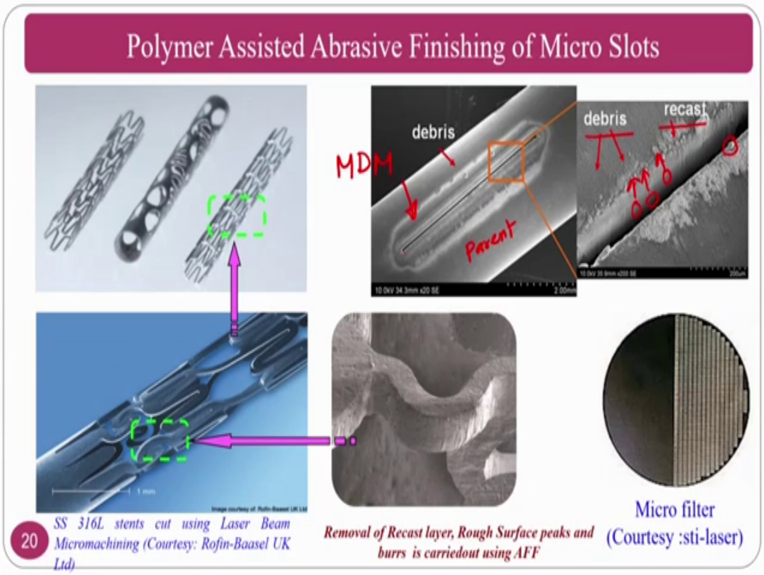

So, the applications of this micro slots, this micro slots can be in used in coronary stents and so on like micro filters and other applications. As you can see here these are done using the laser beam machining and electric discharge measuring. For example, if you see here what is happening is this is done by a advanced machining process; because of this what will happen? You can see the parent material and metallurgically destroyed material around. This material will have enormous recast layer heat effected zone and debris. As you can see here recast layer is there and debris is there.

For example, if you are going to use this particular component in a bio medical applications. For example, drug eluting stents what will happen? Your drug is going to elute from this position and your drug is one type of chemical and this will react with the debris that is there on the path through which it comes and it may also loosen, and these debris may also cause lot of problems to your heart. If this enters these are very hard materials and your heart or any other body parts are very soft, soft tissues and this will damage the human body, that is why we should be very careful in using this biomedical devices before that you have to do the proper polishing, so that you can remove the unwanted materials.

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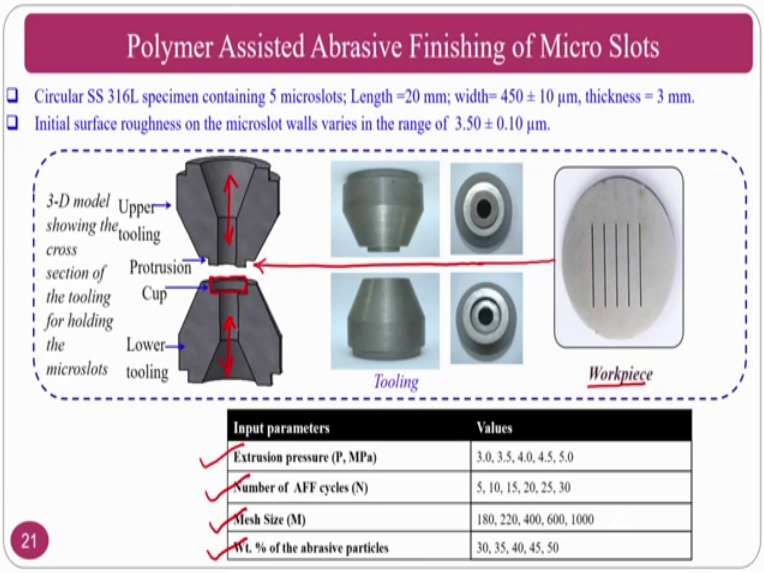

How this is finished? The micro slots are there, this micro slots, the extrusion pressure number of cycles, mesh, weight percentage of abrasives and other things are there, but however, much details are not given here about the medium because medium itself is very complicated as I said. Whenever you are moving towards liquid type of medium what will happen is sedimentation problems will come and this problems has to be overcome by choosing proper rheological additive into the medium, ok.

This is the fixture, this is the workpiece. This workpiece is placed in the fixture you can place your workpiece here and you can extrude the medium through and this one, so that the finishing action can be taken place and this micro slots can be finished.

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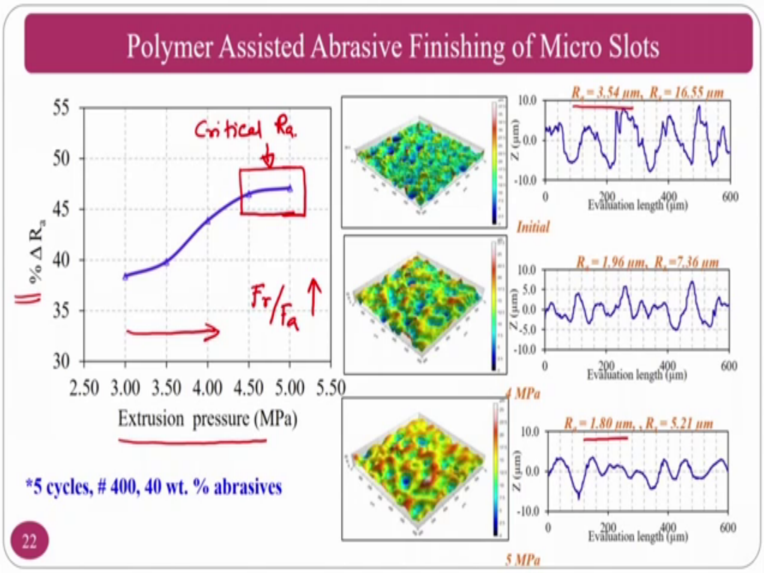

Now, we will see some of the mechanism basic mechanism because we have seen the mechanism for the macro applications in abrasive flow finishing process, here we will see similar to that one in micro abrasive flow finishing process. So, this particular class not only covers your biomedical devices finishing, but also covers micro abrasive flow finishing also.

Whatever you are seeing here polymer assisted abrasive finishing of micro slots and whatever you are going to see in micro holes in the next few slides this is a part of micro abrasive flow finishing process. So, do not think that micro abrasive flow finishing process is a different process and this is different. Whenever you are finishing the micro features then you can call it that particular process as micro abrasive flow finishing process also.

You can see here the extrusion pressure, as the extrusion pressure increases what will happen? Percentage change in R a gradually increases; that means, as you increase the extrusion pressure the holes that are fabricated using EDM process. So, in the EDM process you take very very thin sections in a in the die sinking EDM and you can do the machining of this slots. Then because of this thermal process EDM because EDM is a thermal process you will get recast layer heat effected zone and on all these thermally degraded layers. This layers are may be oxides, may be carbides. If you are going to use carbon based dielectric fluids you will get carbon carbide or the metal carbides, if you are going to use the deionized water or some other oxide based then you will get oxides.

Preferably, the persons who are doing research should do on oxide basis, so that oxides are soft enough, so that it can remove. However, being a constraint in this particular experiments, we have used carbon based dielectric fluids because of which what will happen, the hardness is much higher so the finishing ability is low. So, as you can see the percentage in R a, as you increase the extrusion pressure, what is going to happen? We know your radial force to axial force ratio will increase; that means, your indentation depth will increase and shearing also will improve.

That is why your change in delta R a will be good and you are attain a critical surface roughness beyond which if you are going to increase the extrusion pressure there will not be much change in the surface roughness. That is why this particular region or this particular value is called critical surface roughness, let me write R a. And at the same time corresponding 3-D profiles also you can see initial it is 3.54 microns after finishing it came to 1.8 microns.

Just this is a preliminary study, and if at you want to go through the main studies you can go through some of the papers of our group with Sachin Singh.

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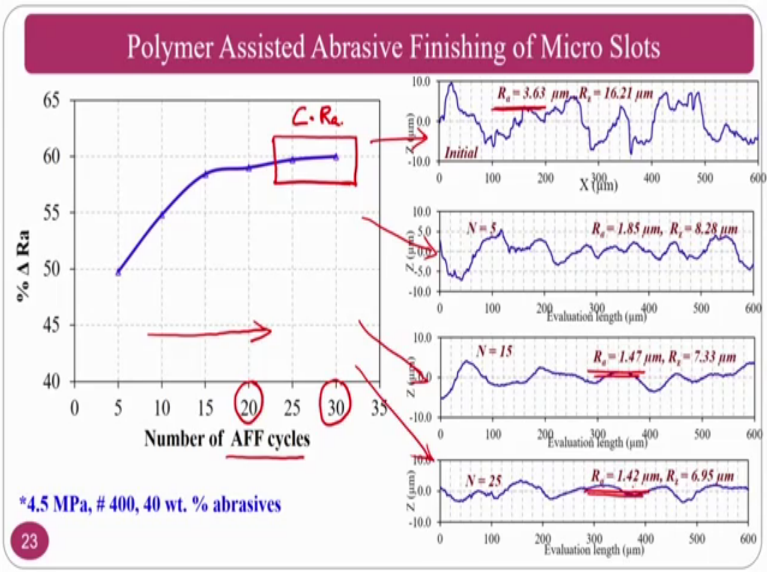

Now, we will move on to the number of abrasive flow finishing cycles. As the number of abrasive flow finishing cycles increases, what will happen? Number of times abrasive particle will shear the surface peaks because the surface peaks in a workpiece is constant. But if you are going to increase number of cycles what will happen? The new abrasive particles will come because of self-deformability as well as better followability.

Assume that the new abrasive particles every time will come and this abrasive particles will shear. If my number of cycles in one case it is 20, another case is it 30 assume. What will happen? In if the number of cycles is 20 the abrasive particle may touch 20 times for example, if it is 30 times. That means, that number of times abrasive particles which are involving in shearing action will increase. So, the finishing also improve.

At the same time, if you go beyond certain value what will happen? There also you will get some critical surface roughness value beyond which if you are going to increase the number of cycles. What will happen? You may not get much change in the surface finish, that is why you have to continue and you have to check.

The researcher might have stopped at 25 itself, but it is not so, because you have to go beyond certain level and you have to observe whether it is following the critical roughness; that means, that the change in surface roughness is very very minimal. That is how the critical roughness can be checked. And corresponding the 2-D profiles also provided here, so that you can see in this particular picture, so that the initial R a is 3.63 and final normally if you see R a is 1.47 and 1.42. These are the surface roughness values.

However, I am saying that this is the preliminary experimentation only the main experimentation is already there in the paper you can go through. And the surface roughness would have been still more better if we would have done this prefinishing experiments; that means, that EDM experiments with oxide based dielectric fluids, ok. So, because of the constraints or laboratory constraints and at that time we have done with the carbon based dielectric fluids.

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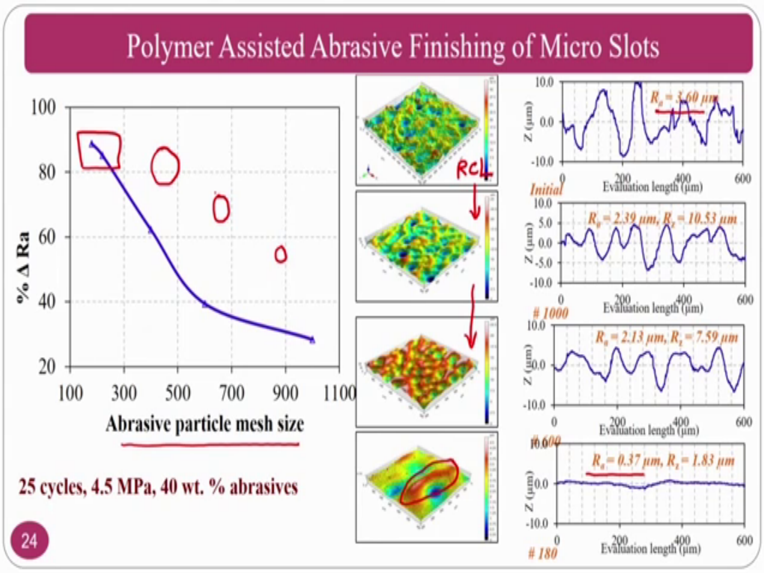

Now, you can see as the abrasive particle mesh size increases; that means, that my particle size is decreasing, this is my particle size, this is my particle size, this is my particle size like that. What is happening here? Your change in surface roughness is decreasing; that means, that you are not going to get much change; that means, that even if for that purpose the research says in this particular graph is if you are going to have a good size of particle.

Assume that you are going to have 2 (Refer Time: 31:29) size or something you are going to get a good surface finish 180 and 220, because what is happening there is if abrasive particle is too small whenever it comes into contact with the finishing region because of the radicalness, because of radial force, and opposite to radial force and other things this particles may penetrate inside the medium. That is why if you have a big sized particle it is not too big or something, but if it is 180, 220 or something, what will happen? This will happen multiple cutting edges and these cutting edges try to finish the surface peaks.

You can see here the surface roughness is 3.6 and it is improved to 0.37 surface roughness and you can see the gradual change of the surface. This is the surface recast layer surface. From the recast layer surface slightly reduced recast layer surface still there is recast layer surface, and predominant recast layer surfaces are there, apart from it most of the recast layer is removed in this process by the abrasive particles.

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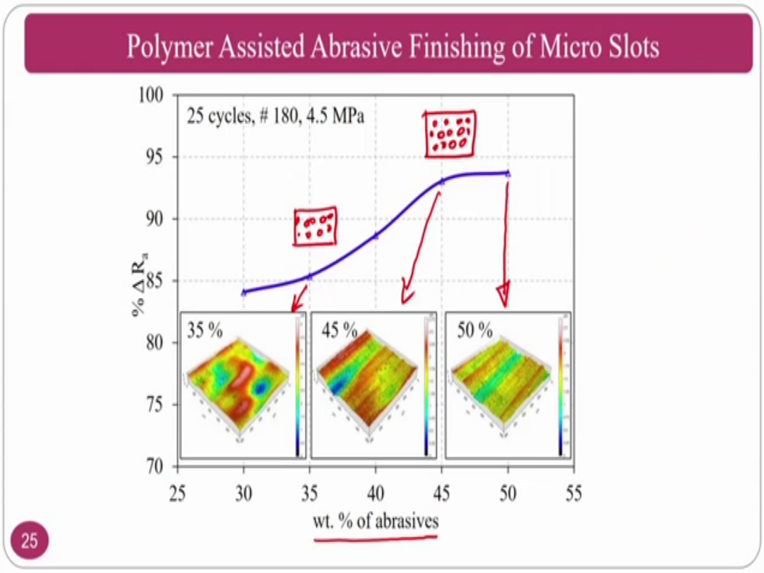

And you can see percentage weight of the abrasive particles. As percentage weight of abrasive particles increases your change in roughness also increasing; that means, that your surface roughness is getting good and good. What is happening here? If your percentage is assume that 35 for a unit area you will have this many number of particles. If you are going to have for 45, what is you are going to have?

The number of abrasive particles per unit area will increase; that means, that number of abrasive particles per unit area will increase; that means, that same surface roughness or same surface peaks will encounter with more number of abrasive particles. Whenever it is increased with more number of abrasive particles, what will happen? The low distribution will decrease at the same time smooth finishing can be taken place and good surface roughness can be achieved, that is evident from this particular graph.

If you are having a approximately same amount of surface roughness initially if you do with 0.35, 0.45 and 50 you can see the surface. So, the number of abrasive particles are going to increase if the number of abrasive particles are going to increase, what will happen? Number of abrasive particles that will hit the same surface roughness assume that this is my surface roughness if one case the abrasive particles are 10, in another case abrasive particles are 20, what will happen? The 20 abrasive particles will take part into the finishing action and the surface roughness; obviously, will be better; that means, surface finish will be better, surface roughness will reduce.

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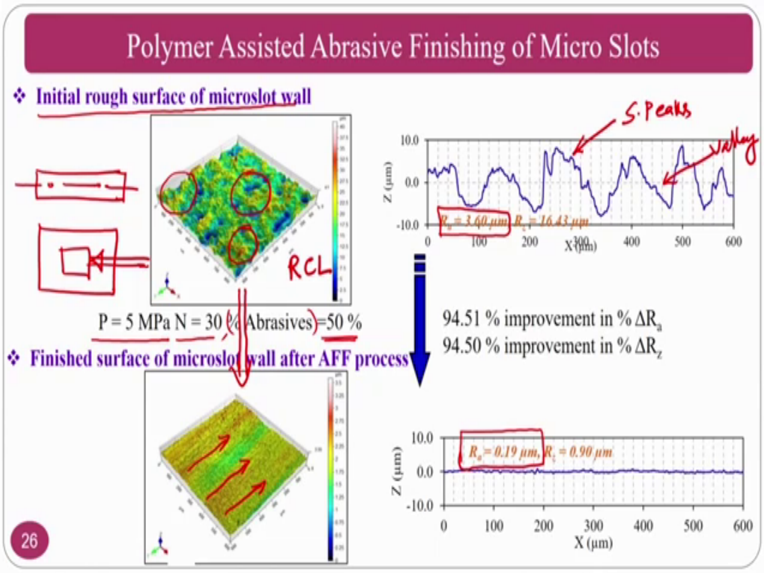

Now, you can see here the initial and final surface how this is achieved [vocalized-noise. Till now, we have seen how the extrusion pressure, number of cycles, weight percentage of abrasive particles place the major role. Once you do all these experiments you get some preliminary idea how much extrusion pressure I have to use, how much number of cycles I have to use, how much abrasive particles, concentration, we have to use in the medium that basic knowledge will come. Then, you can do the complete experimentation using design of experiments or full factorial experiments and you can get with a good surface.

That experimentation is carried out full experimentation using design of experiments is carried out and the initial surface roughness, you can see here of the micro slot wall. Assume that this is my micro slot we are going to cut this one about this axis and we are going to measure this particular wall surface roughness. Here we are going to find the surface roughness value.

Now, you can see the initial value surface roughness. Initial surface roughness consist of dominating recast layer and the surface is too rough. The surface value is approximately 3.6 micrometers. So, you see predominant, surface peaks and valleys. You cannot do much about valleys only thing that you can do is you can do the finishing of the surface peaks. At the same peaks recast layer will be hard and brittle in nature because it is a carbides.

So, sometimes delamination of this brittle layers also will takes place and goes along with the medium. Whenever the optimum conditions are used like pressure is 5 mega pascal that is 50 bar pressure number of cycles is 30 and percentage abrasives is 50 percentage, for this combination you can see the surface roughness improvement in terms of R a it has increased to 0.19 micrometer; that means, 190 nano meters.

And you can clearly see the transform from the recast layer to a approximately parental material, ok. You can see here the surface transformation by using the polymer assisted abrasive finishing process, this thermal layers whatever are formed because of the melting and resolidification are completely disappeared and you can have the shearing marks of your abrasive particles along the direction of the medium motion.

So, if you are going to put this two surfaces in a practical application the recast layer dominating initial surface roughness will enormously reduces its life and at the same time finished surface will improve the component life. So, at the same time this recast layer as I said cracks formation will be there because these are carbide formation, and other thing; because of these what will happen is this material will goes off by the action of brittle fracture. But here if it is finished that will be good.

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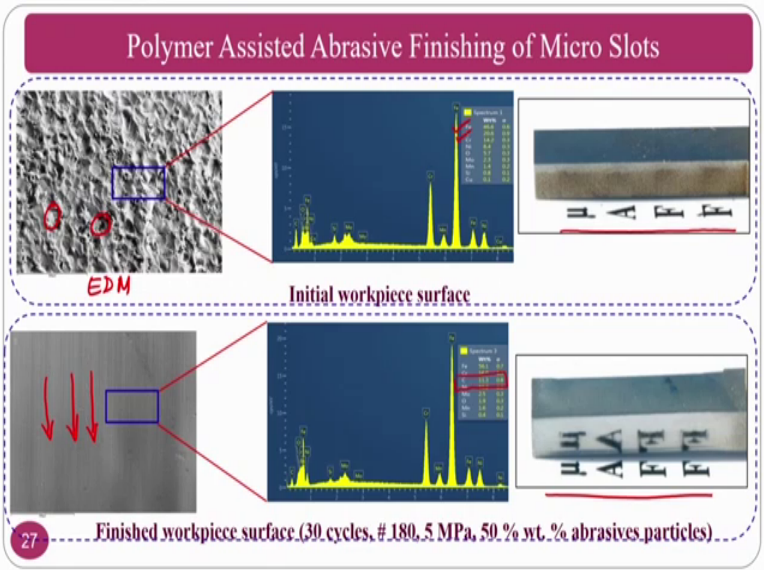

At the same time, you can also confirm this by using elemental analysis that is energy dispersive spectroscopy EDS, can see here the surface EDM surface. It is consist of mostly carbides and iron other things because of which you can see the surface finish also not good and as I said this if you are going to use in the practical application it is going to fail early. But if you are going to polish this surface and if you take what will happen? Your carbon content is enormously reduced.

However, normally speaking as a metallurgist, normally metallurgist people may not take the carbon content and oxygen content. However, to show the carbon content because we have used carbon based dielectric fluids in the initial or prefinishing state that is why we have shown and you can clearly see the crater formation. These are the crater formation; that means, that melting and evaporation is the mechanism of EDM, in that circumstances some of the material is stayed back and it is cooled by the dielectric fluid that is why this craters are formed and this craters are dominated by the recast layer. And recast layer is one type of carbide which is a brittle and fracture will also takes place.

Whenever you do the polishing action or the finishing action using the polymer assisted abrasive medium. What will happen? You are going to get a very good surface that polishing also will improve at the same time not only mechanically, it will give good results. Metallurgically also you are going to get a near parental material composition.

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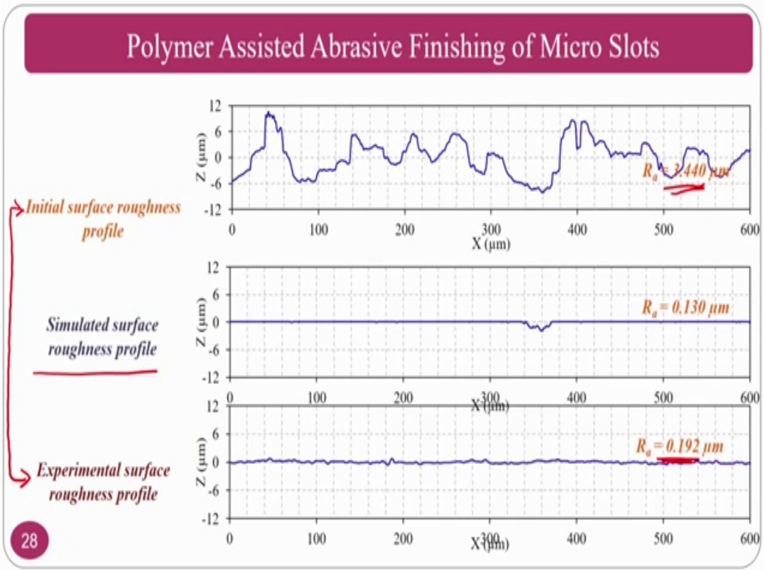

And you can see the surface finish 3.4 microns, from 3.4 microns to it is increasing to 0.1 micron. This is a two dimensional profile, so it will improve basically. And be the author have also done about the simulation studies, if at all you want to know about a simulation studies and experimental comparison and other things you can go through the paper. And for now, I am just comparing this with this because this is the initial and this is the final experimental graphs or experimental surface roughness values.

So, it gives the good surface roughness at the same time good metallurgical properties also. That is how the micro slots can be polished, knee implants can be polished, at the same time surgical stainless steel tubes can be polished. So, this particular medium is good for micro applications as well as macro applications.

Now, we move on to another biomedical devices where we use the polymer assisted abrasive flow finishing process. So, now, we are moving to the micro holes finishing. Till now, as you have seen in the previous ones what we have seen is micro slots, surgical tubes and other things knee implant macro aspects as well as one of the micro aspects such as micro slots finishing we have seen. Now, we move on to still more smaller size micro aspects that is called micro holes.

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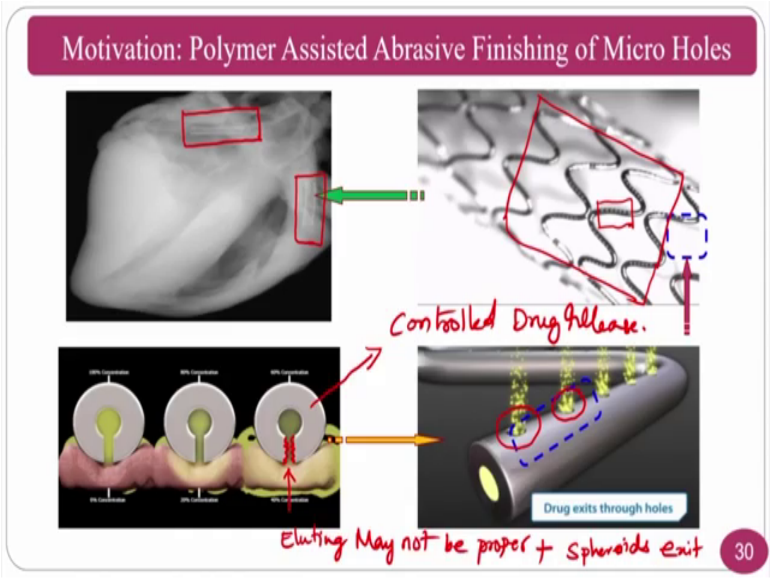

This micro holes, all most important for many many medical applications or medical devices, such as coronary stents which is especially drug eluting coronary stents. As you can see here the stents that are placed inside the human this is the stent, one you can see in the heart. There is another stent is also visible. Most of the time this stents are made up of (Refer Time: 42:09) and some of the times this also will be made up of biodegradable polymers also.

So, currently what you are seeing here is a metallic based stents and this has the core inside as a medicine that you can see if I take overview of the stent. The stent some of the portion if you just check what is you are seeing here is micro holes. These are the micro holes that are there in a stent, and this micro holes will support the drug that will be coming out.

Now, you can see here the drug is coming out from the holes. In case as you have seen in the previous slots also some of the applications they also use a slots for drug eluting applications and other things. If you have a recast layer heat, effected zone and other things where some spheroids are still there on the surface, in that circumstances what will happen?

Whenever the drug is coming out what will happen is it will come along with the drug because the chemical reaction will takes place, at the same time the drug is flowing and the spheroids which are enable to evaporate are remelted by the dielectric fluid and stays there itself, because of which this spheroids are loosely bonded and these may come out along with the drug and may cause lot of problem to the health.

That is why if you do not have proper surface roughness, at the same if you see the laser surface or if you see the EDM surface what you normally see is the whole will be very rough. This surface is rough the biggest problem is the drug eluting may not be proper. At the same time, plus this spheroids which are formed will also exist from the surface. This two will damage the tissues which are there in the heart.

Apart from it what is happening here is that controlled drug release. You can see another concept called controlled drug release will not be there. Assume that 1 ml per one hour you require, in that circumstances if the surface roughness is two high; that means, that what will happen? It will obstruct the flow. If it is too low what will happen? Properly drug will elute from there, so that your tissues or your fat that is there in the heart and other things will dissolve and it will rectify. For that purpose what you require is you have to make sure that is should be properly finished micro holes is required. This is the motivation of what we are going to see in the upcoming slides.

Upcoming slides you may not be seeing drug release and other things, but how to polish or how to finish this micro holes, so that the drug will be eluting. As a mechanical engineer our main purpose is to take care of the mechanical structure. In the mechanical structure of a stent it is a stent structure or manufacturing of the stent. We do not deal with the chemical and other things, ok. As a group if somebody is interested they can obviously, go along with the collaborations and they can do that work also.

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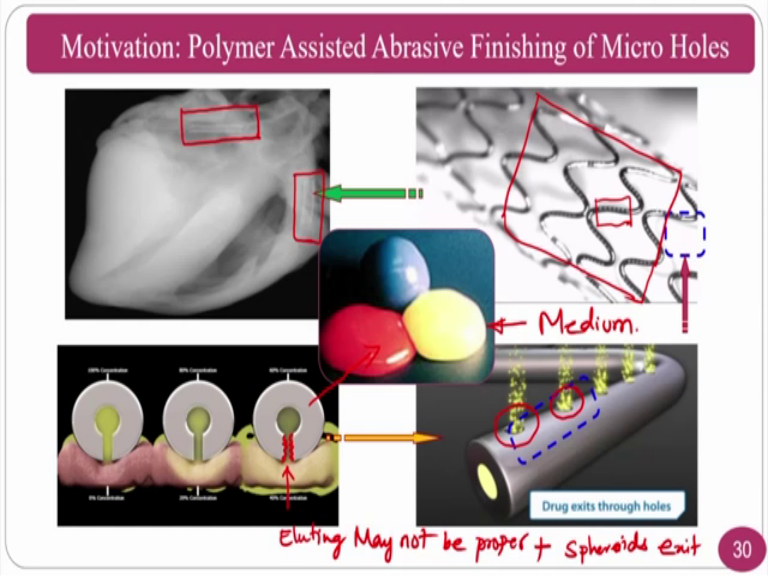

These are all can be done or these are all can be polished using abrasive flow finishing process wherein you have the medium. This particular medium is commercially available by extrude hone company or you can prepare your own medium if you have some polymer technology and other collaborations relevant to this polymer chemistry and other things, ok. This is the polymer medium.

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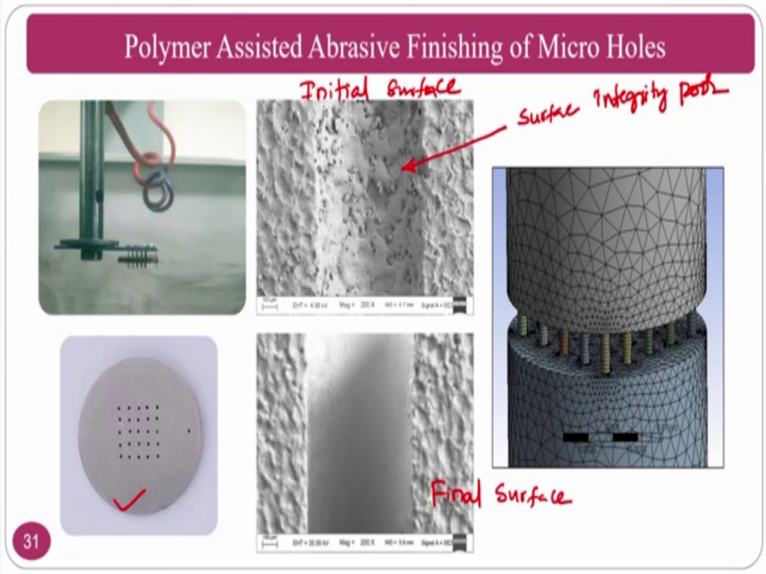

You can see here how the polymer assisted finishing is giving. These are the micro holes a array of micro holes are drilled using EDM process. There is a array tool is there and you are going to generate the array of holes on the surface, that is clearly visible in the bottom picture.

If you see the surface by just doing a cross section of one of the holes this is the initial surface and this is the final surface. But how we achieve the final surface and other things? Initial surface can you see the spheroids, if these spheroids are generated because of improper melting and evaporation. The molten metal that is evaporating is stopped by many other reasons like one of the reasons is flowing of dielectric fluid, and more amount of metal is melted and some is only evaporated, some is staying back these all will stay back on the surface.

Now, through this whatever the drug is going to be elute assume that this is the surface and it has to come through the surface the drug, what will happen? This drug will carry this spheroid particles and at the same time this is metallurgically contaminated. You have seen, the surface integrity of any particular surface is most important because surface roughness along with surface metallurgy is important. Neither surface roughness is good in the initial surface nor surface metallurgy is good in this particular surface, so completely surface integrity is poor. So, our intention is to reduce the surface roughness and to remove these metallurgical destroyed thermal layers that we are going to do.

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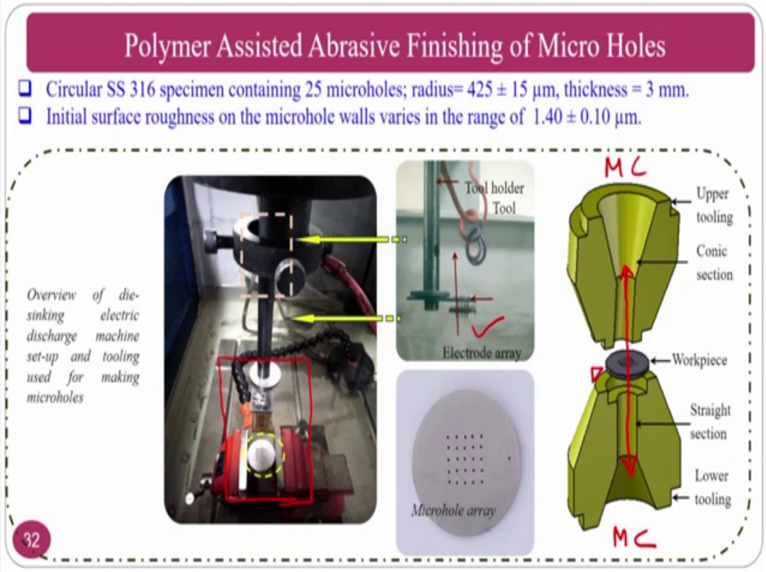

The first thing, how we have generated? The generated using a EDM process that you can see di sinking EDM. A array of micro holes are generated using a array based tool that is clearly visible here. And second thing is you can generate this one, this generated work piece is carried or placed in the fixture and this fixture will be placed in the abrasive flow finishing process.

Now, your reciprocation of the medium will takes place in abrasive flow finishing process. This is above this you have a medium cylinder and below this you have a medium cylinder and this is a piston through which medium reciprocate. This reciprocating medium will try to finish the micro holes, that are generated by EDM process, so that thermal layers which are deteriorated will goes off along with that you will get a good surface roughness also.

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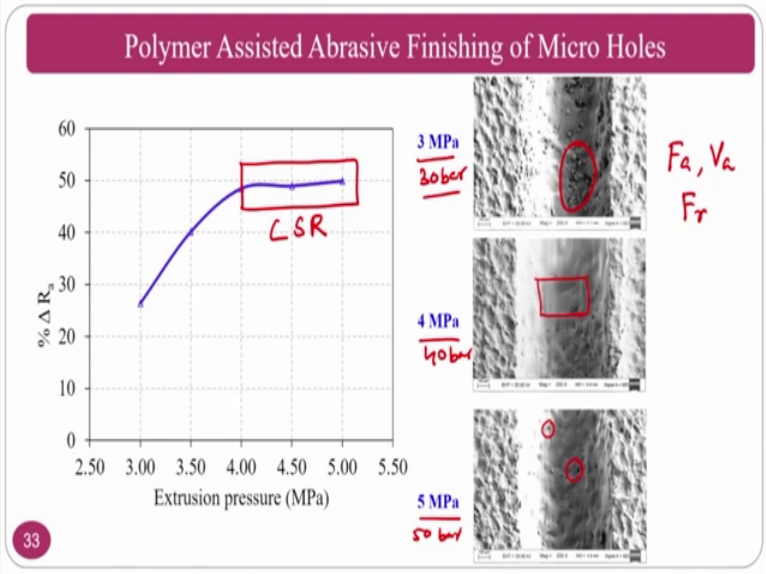

Now, we can see the extrusion pressure effect on the micro hole finishing. If you have the 3 mega Pascal 4 mega Pascal and 5 mega Pascal, the thing is that at low pressures; that means, that your axial force and axial velocity, radial force approximately small compared to your 5 mega pixel. That means, that here 5 mega pixel means 50 bar, 40 bar, 30 bar, in terms of you may see that only it is a difference of 1 mega pixel, but in terms of bar it is slightly higher side.

That is why your values of F a 1, F a 2, radial force and other things are approximately small because of which what will happen; partial indentation and partial axial motion will be there because of which what will happen? The medium is enable to remove the most of the spheroids that are there in the finishing region. If you increase further what will happen? The surface roughness has improved and you can see most of the spheroids are clearly removed from the surface. However, any processor will have some of the defects at the same time this is particular a preliminary experimentation is carried out at which pressure the finishing action is going to takes place in a better way.

Then what we will do? We take the experimental range and we will do the complete experimentation later, ok. For that purpose you can refer Sachin Singh, as well as Doctor Ravishankar, myself papers for the abrasive flow finishing of micro holes. And if you still further increase what will happen is finishing is approximately same, but the thing is that indentations are taking place because of high extrusion pressure and other things. That same thing is reflecting here.

The critical surface roughness is achieved here and beyond which if you are going to increase the extrusion pressure there may not be a substantial improvement of change in roughness surface. Even though you are going to increase the extrusion pressure, what will happen? Your force ratio will increase, if your force ratio will increase; that means, that increment of radial force is increasing because of which indentation will be predominant, not only the surface finish will takes place but also it can create the deep scratches.

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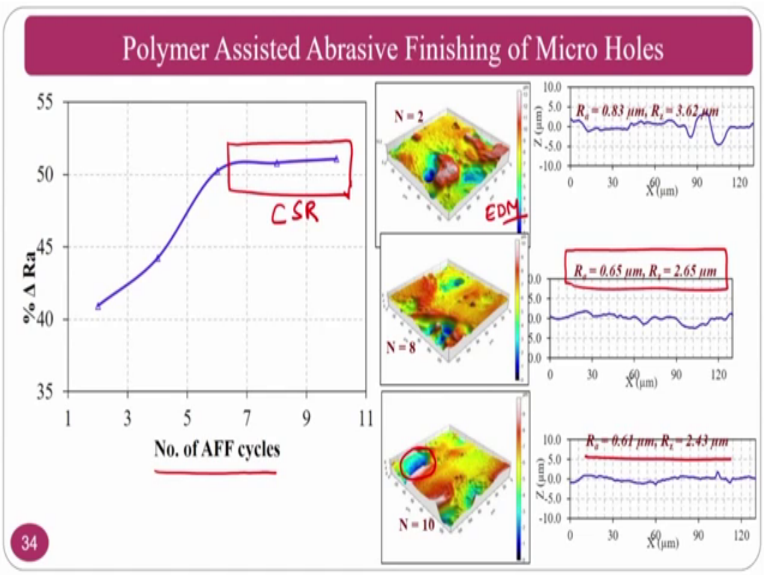

Now, we will see with respect to number of cycles as the number of cycles increases; obviously, the surface roughness will improve that is evident from the graph, and here also it is achieving approximately the critical surface value. Approximately is achieving the critical surface value after 6 number of cycles. So, you can see here the surface is predominantly by EDM surface because the prefinishing process is EDM. Here also you can see some of the EDM marks as well as some of the finishing marks. But if you go for 10 number of cycles and beyond, what will happen? There will be change, but indentation is also taking place here. The some of the materials is removing and the indentation also may be taking in the because of which you can see there is a good change, but sufficient amount of change is not there beyond certain value.

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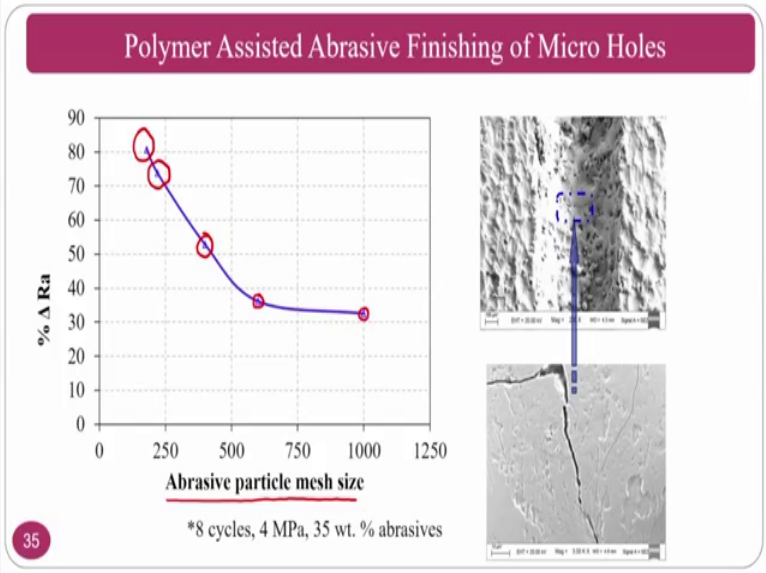

Now, we will see with respect to abrasive particle mesh size; that means, that whether you are going to use 220, whether you are going to use 180 or 400, 600 or 1000 like that the values are used. These are the mesh sizes. As you know the mesh size values increases the abrasive particle size will decrease. At the same time percentage delta R a change in surface roughness is decreasing; that means, that roughness value is also decreasing as you are increasing the mesh size; that means, that particle size you are going to reduce.

If you see in this particular context here abrasive size is like this gradually it is decreasing. So, like this. If you have bigger abrasive particle at least in a medium you have a medium slug you have a bigger abrasive particle, in that circumstances, what will happen?

Some of the edge may in contact with other surface roughness. If you are going to use two small abrasive particles what will happen is because of the radial effect which is it has to indent it may sometimes push back also, that problem is there because the medium is viscous elastic in nature that is why proper finishing is not done. If you are going to use very high super finished abrasive particles; whenever you are going to use low viscous abrasive flow finishing medium or low viscous polymer assisted abrasive medium.

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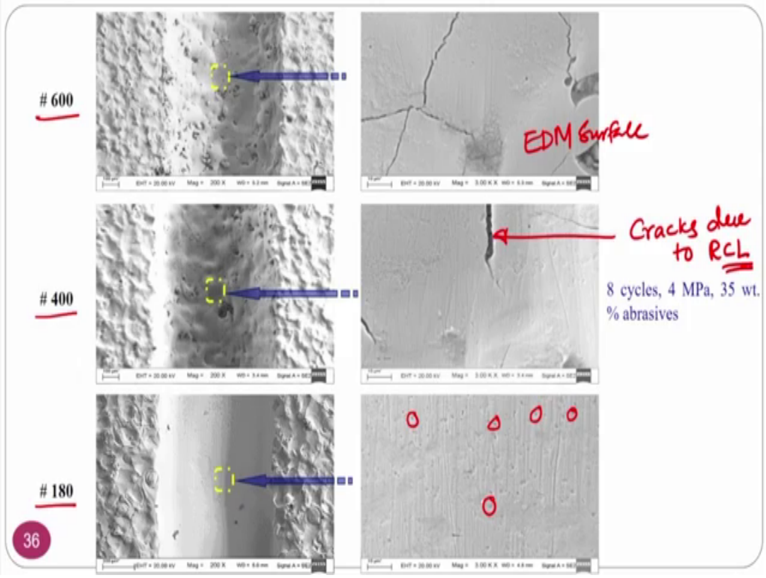

The same thing you can see hash 1600, hash 180, 400 and other things. If you are using 180 normally you have a good surface roughness, but here the same time you will have some of the indentations also. But however, indentations are much much smaller compared to your other thermal layers. You can see here this is EDM surface because the EDM recast layer, it is a bruited layer that is EDM surface. Here also cracks are enormously there.

If you are going to increase what will happen? This cracks are gradually goes off, cracks due to recast layer of EDM process. This cracks should be removed that can be only removed if you are going to use bigger sizes abrasive particles and however, as I said know bigger sizes abrasive particle means small size mesh sizes that is 180 mesh size or 220 mesh size, if you are going to use what happen the finishing action will takes place. However, 180 may cause some of the indentation because of its bigger sizes.

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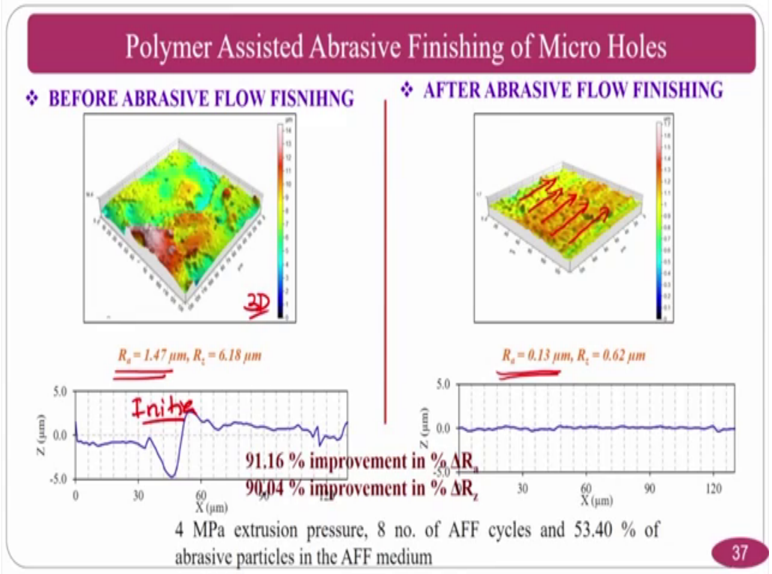

Before abrasive flow finishing and after abrasive flow finishing, if you know what is a extrusion pressure that we have to apply from the preliminary experimentation, number of cycles and abrasive mesh size. Once you do all these things then you have to do from that ranges you will get assume that I get a extrusion pressure some range number of cycles some range then abrasive particle, size some range, then you do complete experimentation. After complete experimentation, that experimentation is not shown because of the time constraint if I start teaching that it will take lot of time.

So, the optimum conditions ranges can be get, optimum conditions will be known from the preliminary experimentation followed by you do the complete experimentation using design of experiments or full factorial and other things then you will get a good surface that is what here shown. So, after full experimentations we have shown here. If at all you want to know about full experimentation you can go through the paper of micro hole finishing. You can see the initial surface 2-D and 3-D surface and the final surface.

Normally, 1.47 is the initial surface and 0.13 is the final surface. So, EDM surface is removed enormously at the same time you can also see some of the scratch marks by the abrasive particles. These will show that it is removed the surface that is randomly generated by the EDM process and later on the finishing is taken place.

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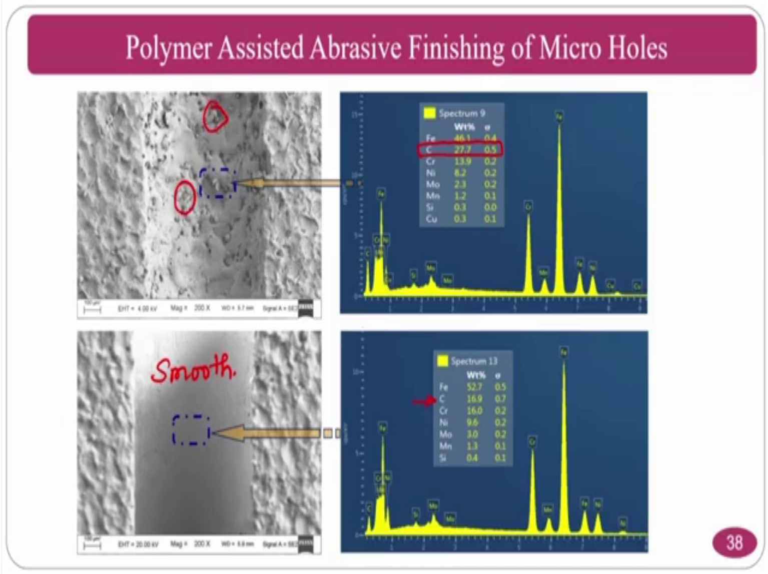

Not only that, we have to cross check the metallurgical aspects also we. If you can say that oxide layers are there or carbide layers are there then it will be a problem. That is why the metallurgical aspects before finishing and after finishing we have seen, and the carbon content normally this shows that carbides are high in the initial stated. And however, you should not take the carbon in a EDAX analysis, but if there is a carbon change what we assumed is that there may be iron carbides forming in the workpiece.

So, you can see here the carbon percentage is less. At the same time what as a mechanical engineer what you can infer from the surface morphology is a smooth surface is achieved by abrasive flow finishing medium which is having a polymer that is assisting the abrasive particle. This abrasive particles which gets a assistance from the polymer will try to shear off this recast layer and the spheroids that are formed on the workpiece surfaces.

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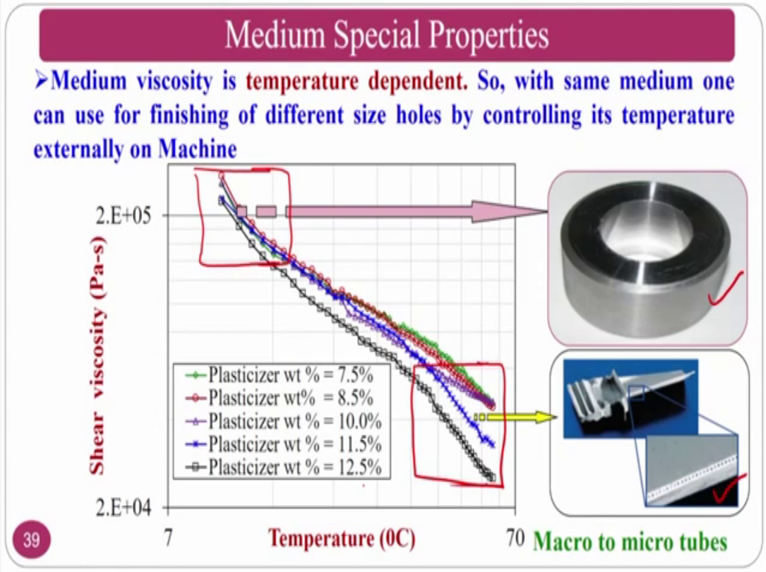

Now, medium special properties, this medium can finish the bigger holes, this medium can finish the smaller holes also because it is temperature sensitive in nature and this particular graph if you have seen in the abrasive flow finishing process that will be well explained there and at the same time what I mean want to say is that this medium is temperature sensitive medium. And if you can use this medium for bigger holes this one and if you can have a temperature control run medium cylinders, you can manipulate the temperature, same medium with temperature effect you can utilize for micro holes also.

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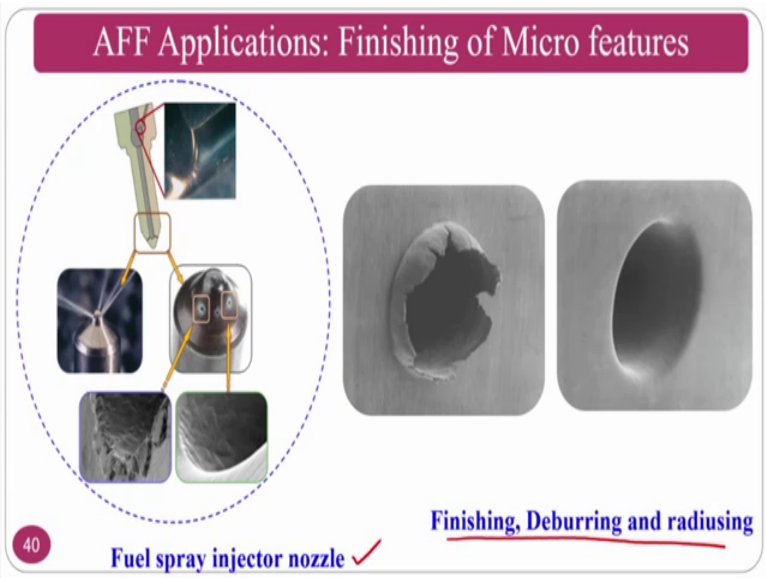

So, the applications, some of the applications not only biomedical applications you can also use for automobile that is fuel injector nozzles, at the same time deburring, radiusing and finishing also we can see. These are all explained in the abrasive flow finishing process itself. Still what I want show here is that you can do the polishing of the micro holes in automobile industry also.

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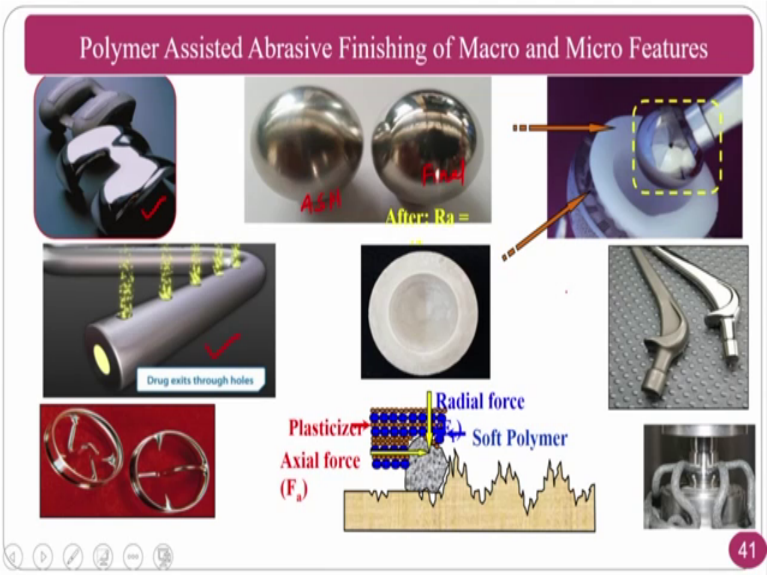

And some of the implants that are finished across the globe you can see here. This is the knee implant which you have seen drug eluting stents. These are the pictures are taken, however, finishing process is under the preliminary conditions; at the same time acetabular socket head, initial surface and final surface.

Acetabular socket head is obviously, required for the medical application that the same time this acetabular socket also should be finished, because so that both will have proper motion with respect to the hip. If you have a proper surface finish of the acetabular head and acetabular socket then your hip joint will be in good condition, so that the life of the hip joint will be very good. And hip joint itself the stem itself also can be polished using abrasive flow finishing process and in abrasive flow finishing process people regularly uses the polymer rheological abrasive medium.

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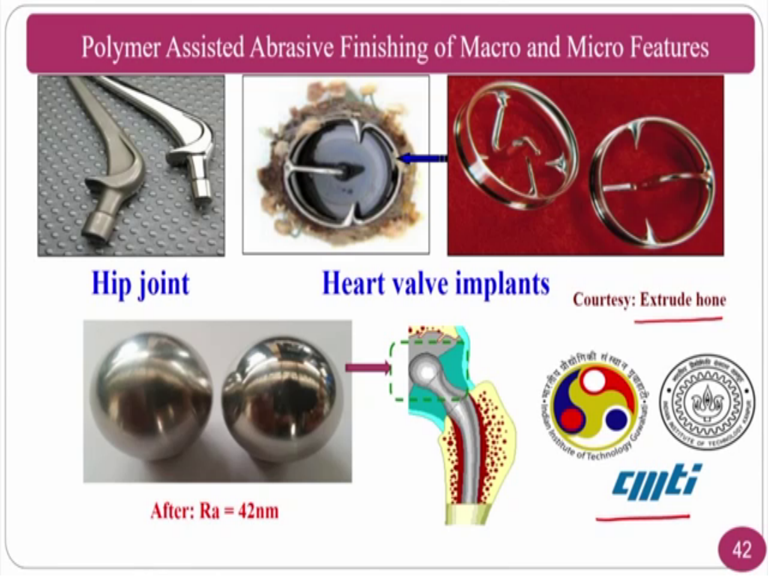

And this is another acknowledgement. This is done in collaboration with CMTI, Bangalore, extrude hone is the company that finishes extensively into abrasive flow finishing, where they develop the very sophisticated the polymer rheological abrasive medium.

Thank you for your kind attention for this particular class.