Introduction to Abrasive Machining and Finishing processes

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Lecture - 21
Abrasive Flow Finishing- Part – II

So, we move on to the second part of Abrasive Flow Finishing process, where we deal with so many things. Till now we have studied abrasive flow finishing process.

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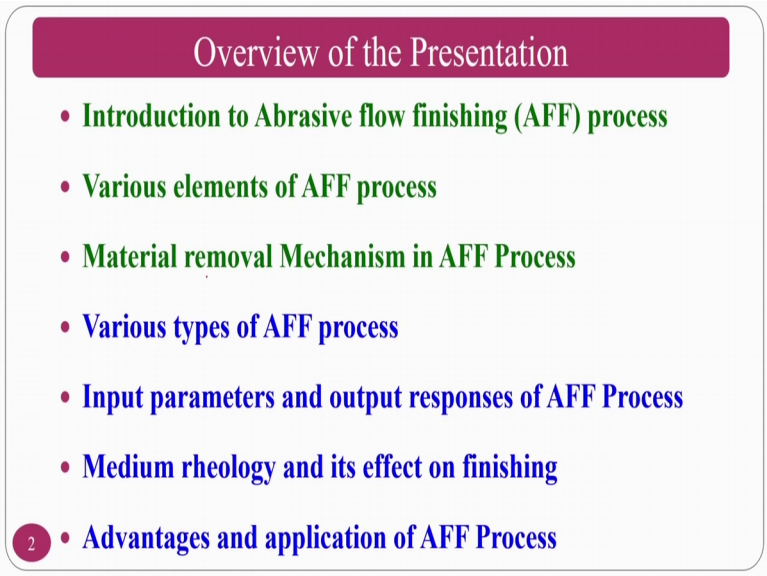

Introduction to abrasive flow finishing, we have studied various elements, that is machine setup, the tooling or fixturing as well as, we have seen the medium. So, these are the 3 main elements of abrasive flow finishing which we have seen. And at the same time material removal mechanism we just touched it about the viscoelastic nature and as well as, the abrasive particle how we can get and other things. So, we looked into this one from the point of shearing and other things slightly, in this particular class also.

Then we move on to various types of abrasive flow finishing processes and the blue ones, which in the slide are shows what I am going to talk about in this particular session. And, the input parameters and output responses of the abrasive flow finishing process, medium rheology and its effect on finishing because rheology of the polymer rheological abrasive medium is a main thing that one has to understand, if at all a person want to work in abrasive flow finishing process ok. So, the advantages and applications

of abrasive flow finishing process that we will see, apart from it we just see some of the material removal mechanisms also in this particular class ok.

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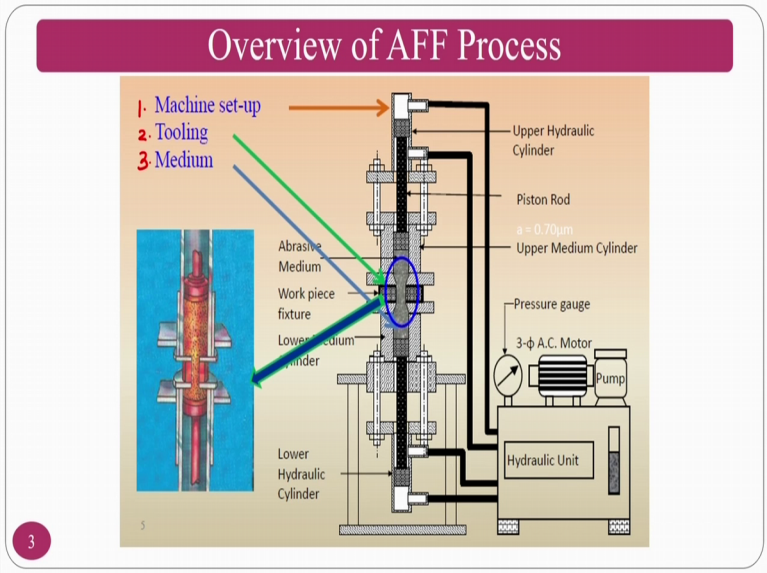

This is what we have seen, the abrasive flow finishing process where the setup is there as well as, tooling and medium or the main 3 main elements of the abrasive flow finishing process and we move on, so, that the finishing will takes place in the shearing zone.

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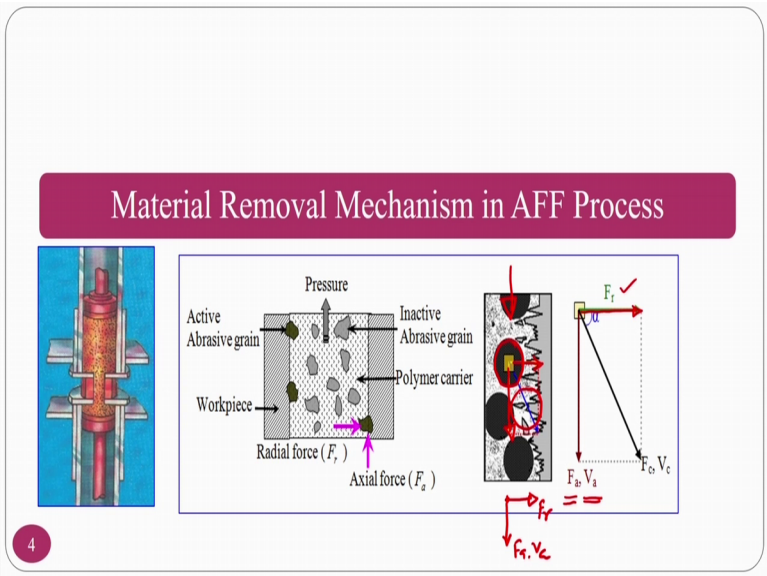

So, the material removal mechanism in the previous class I could able to explain you, but from the forces point of view and others point of view, I would like to explain here. If

you see the extrusion pressure is applied, if you are going to apply the extrusion pressure in the previous class we have seen the downwards arrow, in this one you have a upward arrow. Or, if you assume that you are going to apply the extrusion pressure in the same direction if you take here, so there are radial force and radial velocity, radial velocity is neglected because indentation velocity is negligible compared to axial velocity ok.

So, this is a axial velocity and axial force and radial force. So, because of the radial force, this abrasive particle will try to indent on the surface and because of the axial force and velocity it will try to move in this particular direction ok. This is F r and this is F a and V a and this is F r, so that the chips will be generated and this chips will accumulate in the medium. How it will accumulate in the all those things we will see.

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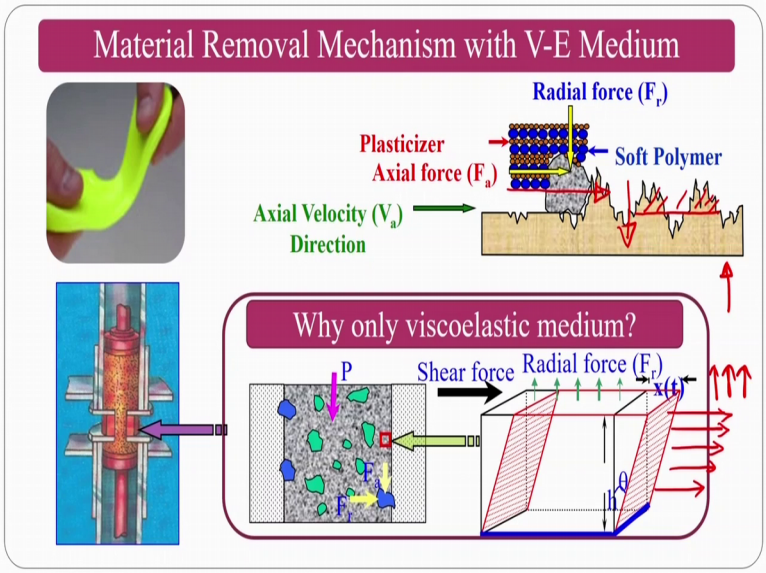

This is the mechanism that, we have seen and which we have not seen in the previous classes is, how the abrasive particle this particular abrasive particle is going to get the assistance of viscoelastic nature.

So, the visco elastic nature is explained in the previous class, the schematic is given again here. So, whenever you have a extrusion pressure, the visco elastic element viscous component tries to move in this direction. This is the direction of applied pressure and elastic component moves into perpendicular direction. Because of these two, the material removal will takes place. This viscous and elastic effect will support the abrasive particle; that is what we are seeing in the above picture. So, the viscous and elastic

components that is, axial force and axial velocity will move in this direction and radial force will move in this direction. Because of the radial force the indentation takes place and because of the axial force what will happen, these particular peaks will be sheared ok.

So, you will get the surface finish. That is what the material removal mechanism and how, the visco elastic effect came into picture. The viscoelastic nature of the medium is not that much easy to identify. So, once a researchers started their carrier with so many polymers and other things, but once they know the mechanism of visco elasticity and other things then only you could able to make the medium in a perfect way because, we need viscous effect as well as elastic effect. How the viscous effect is going to help the abrasive particle, how the elastic effect is going to help the abrasive particle. These signs should be understood before proceeding towards the abrasive flow finishing mechanism.

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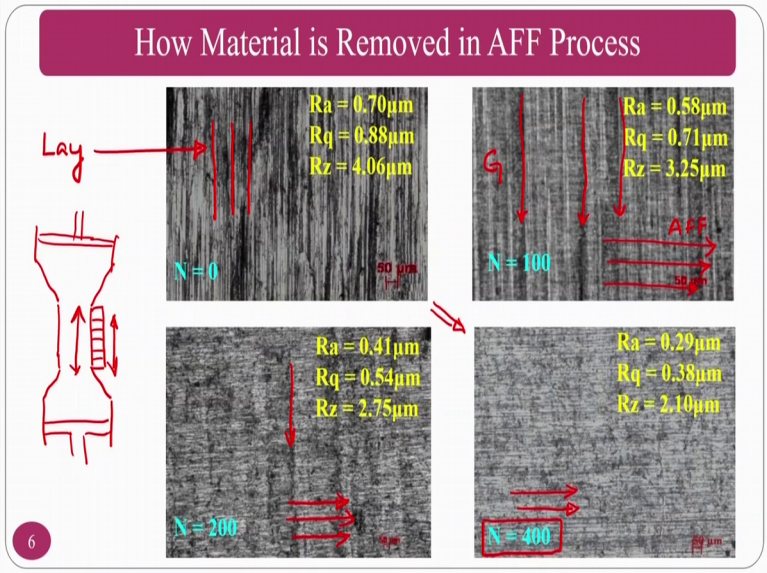

If you see the material removal mechanism in this particular process, so initially we have the grinding surface assume that, this particular surface is the aluminum alloy and silicon carbide metal matrix composite. This is the initial surface roughness where you are going to see the initial grinding marks. These are the grinding marks which you can call as a lay, this is called lay that is nothing, but predominant direction of surface roughness in a grinding operation. So, after 100 number of cycles because, always you place your work piece perpendicular to the medium flow direction ok.

So, what you have seen, you this is your fixture and this is your work piece and you are placing them again the fixture and your reciprocating. So, what will happen here is whenever you reciprocate the medium, the medium flow direction will be like this. So, always you place the grinding marks perpendicular to it so, that means, that your work piece if I just for example, understanding purpose, the grinding marks should be like this, on top of it the abrasive flow finishing medium will reciprocates like this. So, that you can see that dominating the marks of grinding process here and there will be small abrasion or the micro nano scratches also you can see on this surface in this direction. This is this directions are abrasive flow finishing directions and these directions are grinding directions ok.

So, this is how the finishing starts or shearing of the surface peaks so that are generated by the grinding process will be sheared. If you go on increase the number of cycles with the by keeping the extrusion pressure and medium composition constant, you are dominating shearing marks of the abrasive flow finishing process will gradually increase and your grinding process, lay directions which are small small they will goes off. So, dominating once only will be staying ok.

So, as you increase number of cycles what will happen is, surface lay that is generated in the grinding will goes off gradually and at last you will get a fully fledged abrasive finishing processes and you will get a very better surface on this one. And if, you see 400 number of cycles then you are going to get a very good surface marks of abrasive flow finishing process and you may not find many of the grinding marks and you may find two dominating scratch marks of the grinding process ok. So, that is how in 400 cycles, where it is a laboratory setup the medium flow is approximately can say, it is 200 to 250 grams is a maximum medium that you can place in a medium cylinders ok.

So, in a commercially way what is people will do, they were going to put few kg's also. In that way the number of cycles you are going to experience the surface finish will be very few. So, do not go by number of cycles many times, this is always depend on what is your medium cylinder capability. If your medium cylinder capability is too small, your number of cycles will go up; if your number of cycles will go up what will happen is your medium gains some temperature because, of shearing action at faster rates.

So, that is all some of the problems will be there in a laboratory scale for; however, this laboratory scale things that we have we used in this particular experiment are economic to produce. That is why this is done at the laboratory scale itself ok. This is how you can see that completely grinding marks are transformed into finishing marks of abrasive flow finishing process ok. This is how the material removal mechanism will takes place and whatever the physics that I spoke in the previous slide about the viscoelastic nature will shear the surface peaks of the grading marks, gradually disappears and only abrasive flow finishing marks will be appearing on the surface.

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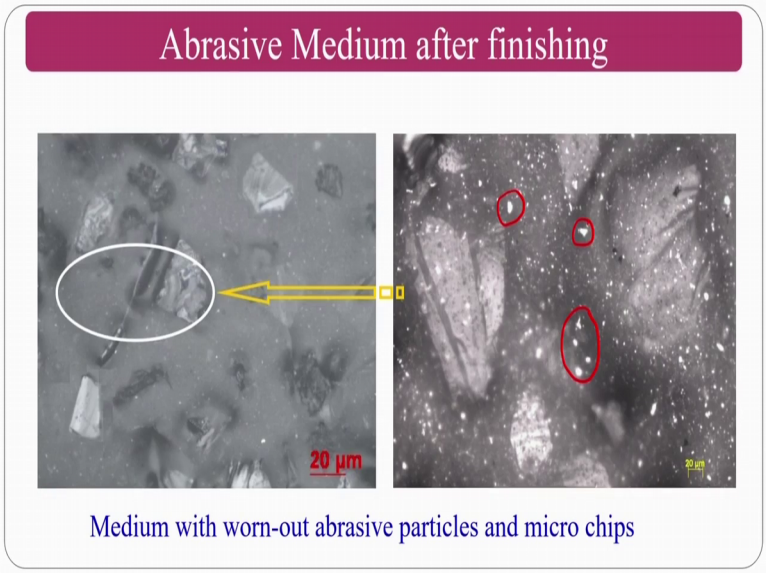

So, in the previous slide also you have seen, where these particles will go or the where this chips will go. As I discussed in the previous class this chips will embed into the medium and this medium slowly gains the bluntness of abrasive grains as well as, this will gains number of chips in to it. This number of chips as increases the weight of the medium goes up once the mediums weight gains to 10 percent of its own weight, that means, that 1 kg, that means, 1000 grams if you are going to measure your weight after few experiments if it is 1100 grams then, you have to discard the weight.

So, you can clearly see the chips of different sizes, these different sizes because of your shearing nature So, some of the abrasive particles may agglomerate and shear, so you will get a big chip, if you have are going to have is one abrasive gain shearing, you may get a small chip and all those things. Mechanism is complete a random because, your

particle location is random and particle shape is random and many randomness are there because, it is a two phase medium and it has to remove by the virtue of a polymer a polymer b, many things are there because, that medium compositions and all those things we will see in the next slides.

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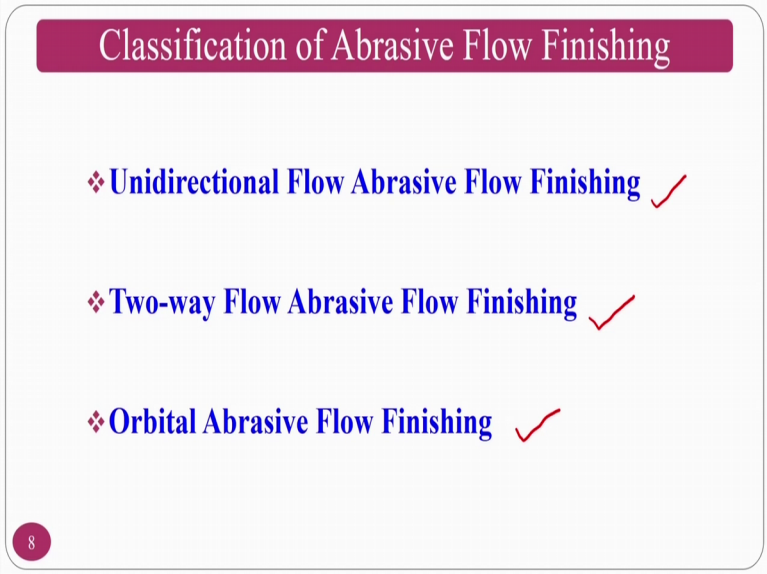

So, the classification of abrasive flow finishing process there are normally 3 varieties; one is unidirectional flow abrasive flow finishing process, two way abrasive flow finishing process and the orbital abrasive flow finishing process. Unidirectional abrasive flow finishing process also called as one way abrasive flow finishing process also ok.

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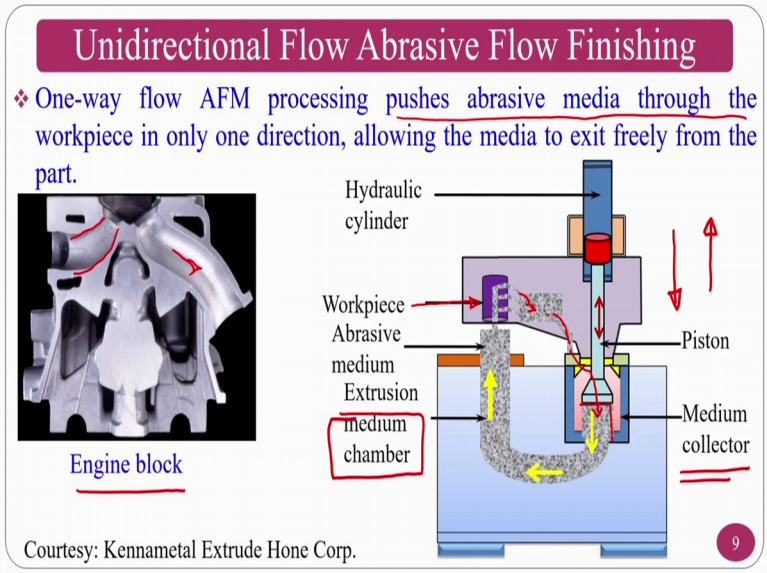

First we will see unidirectional abrasive flow finishing process where the medium is located in a medium collector. This one, this is a location and this is pressurized by using a hydraulic cylinder piston and the medium will pass through the extrusion medium chamber extrude through the workpiece ok.

You can see the workpiece is there and it will extrude into this area and this will come, there will be a lead which will open and this will enter into the medium cylinder, whenever the piston goes towards upside ok. This is how it will be the recycled. So, medium will be placed in the medium chamber and abrasives and medium are extruded through the workpiece to be finished. This is called one way abrasive flow finishing process. As you can see here one way abrasive flow finishing process pushes the abrasive media through the workpiece only one direction; that is why because it is pushing in only one direction ok.

Whenever, it is pushing in only one direction this is called one way abrasive flow finishing process or unidirectional finishing process. It is not pushing whenever it is re tracing the path towards back side ok. It is just goes because of to allow the medium that is excluded from the workpiece to comes into medium collector ok. So, the work pieces that are finished by using this particular process are like engine blocks.

So, whenever you have this type of blocks which are complicated to finish then, you just connect this with the proper tooling and then you just try to finish ok. You can see here unfinished one and you can see the finished one here, at the same time you can finish any

type of complex surfaces using the one way abrasive flow finishing process or unidirectional finishing process.

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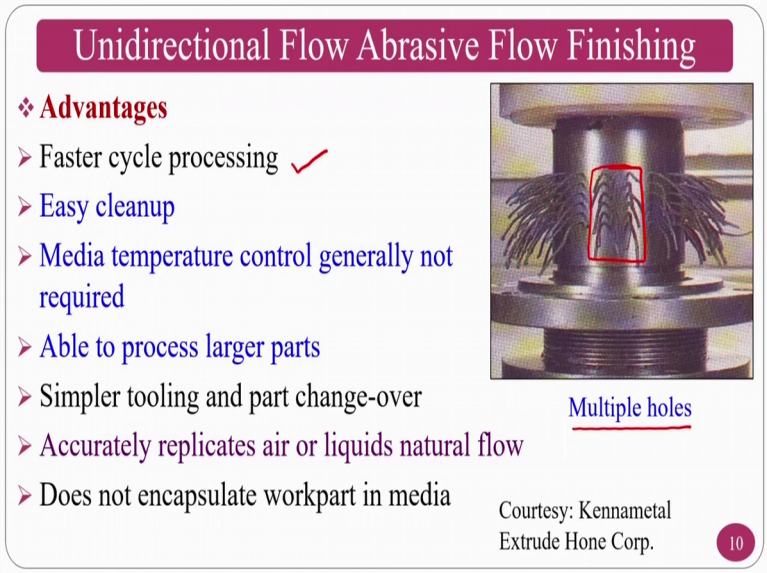

So, the another application of this particular process is, you do not require the medium collector and other things; that is called the multiple holes based work pieces can be finished. Multiple holes based workpieces where you will have a big medium cylinder wherein, the medium is filled and you are extruding through these holes. Whenever you try to extrude this one what will happen it is the one way so, the medium comes out through these holes and these holes will be finished properly.

And the medium will be collected, using some external source and then it can be reused again and again for similar type of work pieces. Only thing that you have to note in this particular picture is that there is no automatic medium collection unit here, only thing is that once it is pushed or extruded through the holes this medium comes out and the external people or external system will collect this medium and they will be using for again manually placing this particular medium inside the medium cylinder.

Advantages of this particular process is, faster cycle processing and easy to clean up because, this is external so, any un experienced person also can collect, there is no need of highly expertized person, whose payment will be very high. So, normal persons can easily clean up. Medium temperature control generally not required because, here in one

go the medium is coming out so, there will not be a requirement of any temperature control any indent.

As I said if you are going for many times of reciprocation as you have seen, the basic type of abrasive flow finishing process that is called two way abrasive flow finishing process that you have seen in the previous lecture, where the medium is reciprocated in a two way. So, that we will see in the next slide so, in that circumstances what will happen, the medium has to go through the narrow region of workpiece. Whenever it is going through narrow region of the workpiece, the temperature rises because of the friction that is experience by the medium.

So, you require to control the temperature for that purpose you always go for temperature controlling unit. So, able to process larger parts it does not matter, whether it is a small part or a big part. If this is a very big part whatever you are seeing in this picture and this can be accomplished in a one go. So, simpler tooling and part changing over that is required because here simple tooling is required because you are extruding from one direction and the finishing is taking place in a straight away.

So, accurate and duplicate air liquid natural flows and it does not encapsulate work part in the medium. These are the advantages of one way abrasive flow finishing process and then you move on to the two way abrasive flow finishing process, which is commonly used for explaining the physics of the abrasive flow finishing process.

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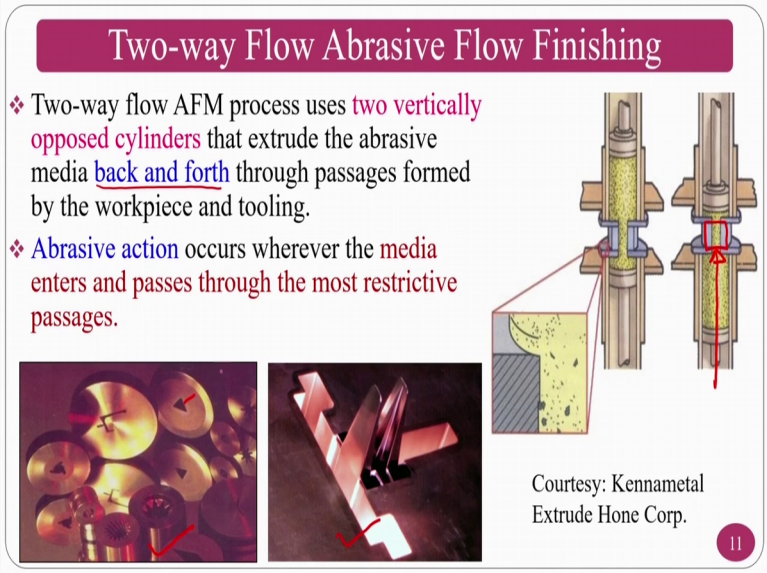

So, that is what the we have seen in the previous class, whenever I talk about abrasive flow finishing process normally, to make the science and the physics easy, we understand or by default we take two way abrasive flow finishing process. This is a process that we have seen in the previous class. However, we will see two way abrasive flow finishing process uses two vertically opposite cylinders that extrude the abrasive media back and forth. That means, that this abrasive medium is reciprocated back and forth.

Abrasive action occurred when the media enters and passes through the most restrictive passage. That means, that if you see in this picture, the most restrict to passage is this particular thing. So, this is particular part is the most restrict to region because of which the medium experiences more restriction so, that means that the abrasive spill abrade more in that particular area. The common type of work pieces that will be finished by using this one is through holes type of things ok.

In the previous case you can go for through holes, in a wall or some other places. If at all I have a dies like extrusion dies like this or like this, what is happening is this extrusion dies can be placed in the workpiece region and this can be finished in a straight away. So, the medium will try to reciprocate through this one and this will be finished.

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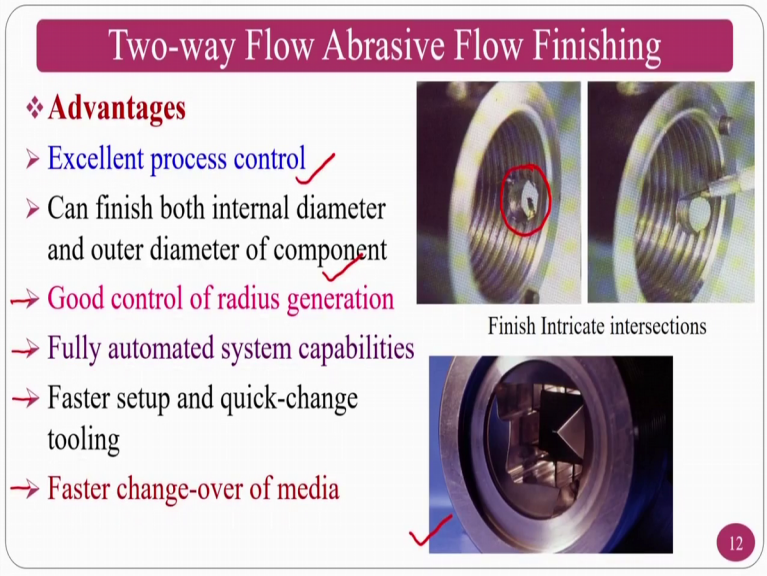

So, deburring action also can be taken place by using abrasive flow finishing So, the advantages is excellent process control will be there, can finish both internal diameter as well as outernal diameter. This will be depend on how you are going to develop the

tooling for the workpiece material. And good control of radius generation is there and fully automated system capabilities can be done and fast setup and quick change tooling and faster changeover of the medium and other things will be taken.

So, this type of deburring also can be done by the abrasive flow finishing process; however, this deburring also can be done by thermal based deburring process also ok. So, for that purpose if at all one has to go for this type of deburring process, what you have to do is you have to have proper tooling ok. So, this the bottom one, can be finished by abrasive flow finishing process. However, the top one normally people prefer thermal oriented finishing processes for the deburring applications and you have every chance to use the abrasive flow finishing process also if, you can maintain the proper tooling.

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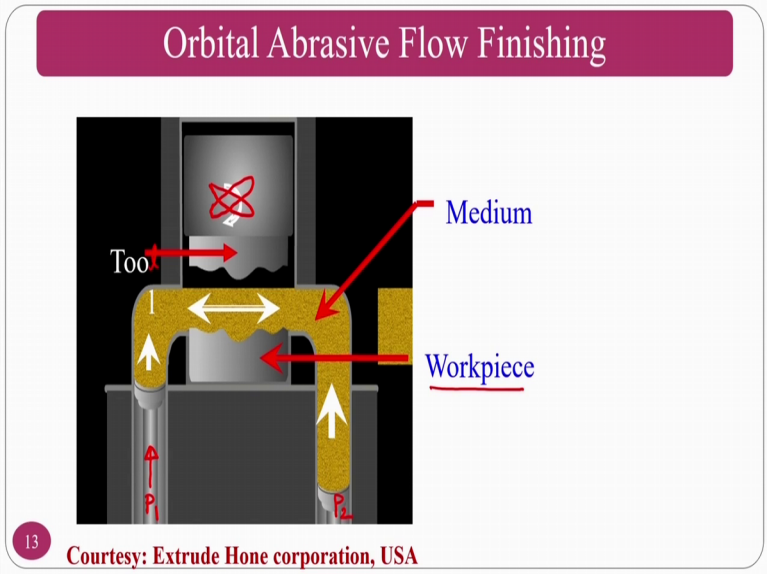

So, the third variety of abrasive flow finishing process is orbital abrasive flow finishing process. The orbital abrasive flow finishing process normally uses for the blind holes type of work pieces ok. So, for example; what you are going to see here is, the medium is there and this is the workpiece and this is the tool basically. So, the medium will reciprocate in the vicinity of or in between tooling and work piece. So, you can see here, this is a medium piston that is pushing here and another piston is here, the piston 2 piston 1 is there. So, this piston 2 and piston 1 tries to reciprocate the medium.

So, the orbital motion is given to the tooling. If, you are going to give this type of things what will happen is whenever due to the orbital motion of the tool, the medium will get

the narrow, the medium will try to finish the shape that is there in the workpiece region. That is how the medium will help in finishing the blind holes. Normally, finishing the blind holes is one of the difficult task.

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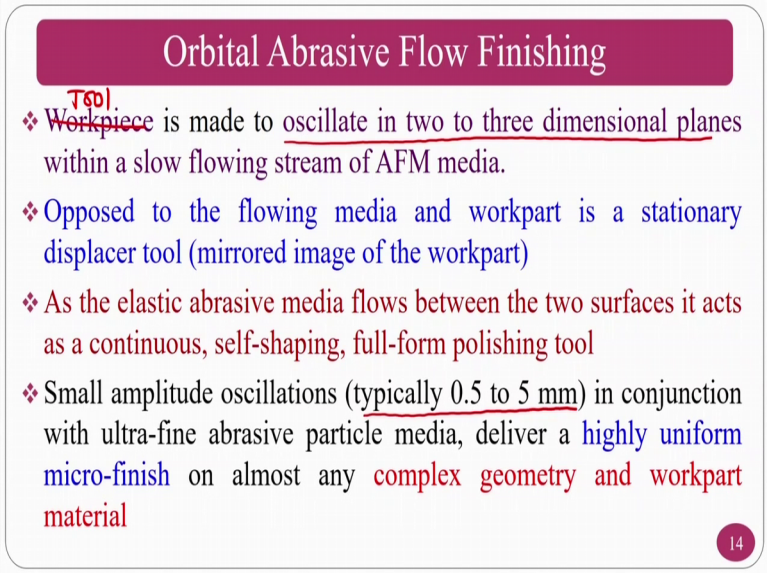

You see if you see the mechanism of orbital abrasive flow finishing process, workpiece is made to oscillate in two to three dimensional planes with a slow flowing stream of abrasive flow finishing media. Then, opposite to the flowing media work part is stationary and dispenser and as the elastic abrasive medium flows between the two surfaces act as continuous and self sharpening and fully forming polishing tool, the small amplitude oscillations normally typically 0.5 to 5 mm in conjugation with the ultrafine abrasive particle media, deliver high uniform micro finish on any complex geometry work part material ok.

Normally, tool is made to oscillate or given orbital motion. Then the workpiece is stationary in between the medium will try to reciprocate and because of this multiple actions of the tool, as well as the abrasive medium, the work piece will be finished into micro to nano level.

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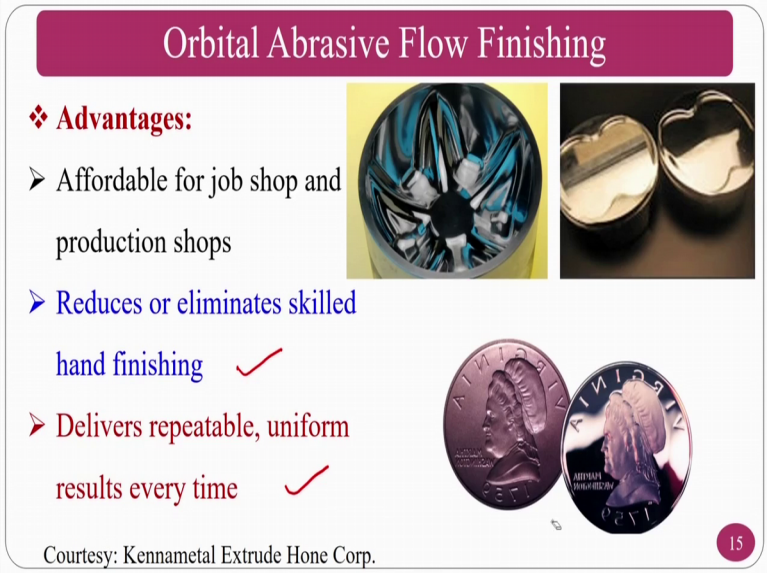

So, the simple to complex surfaces that one can finish using orbital abrasive flow finishing process is this. So, you can finish this type of dice you which are given, at the same time coins also you can do the finish ok.

So, the advantages affordable for the job shop and production shops, reduces and or eliminates the skilled hand finishing operations, delivers repeatable uniform results every time; that means, that if at all to be finished this type of blind surfaces for very good applications are high tech applications, you require the skilled labour. If at all you want to hire a skilled labour, the cost or in terms of the salary for the skilled labour will goes up.

So, if you can automate the system using orbital abrasive flow finishing process then, you can finish this type of surfaces easily and the production cost of these particular components will be always less ok. So, that is why this will be a good alternative to the skilled labour and you can sell the products at minimal cost also and the production rate also goes up, you can sell this particular product at a competitive price in the market. Possible input parameters of abrasive flow finishing process, whenever in the slides, I am talking about abrasive flow finishing process; that means, by default I am explaining about two way abrasive flow finishing process.

Kindly all the people who are watching the video should note it down or should understand that, I am clearly talking about the two way abrasive flow finishing process because, the physics of explanation will be easier for two way abrasive flow finishing

process rather than, one way or unidirectional abrasive flow finishing process and orbital flow finishing process. That is why, we always explain the finishing mechanism or the other things whatever, I am going to explain will be corresponding to two way abrasive flow finishing process.

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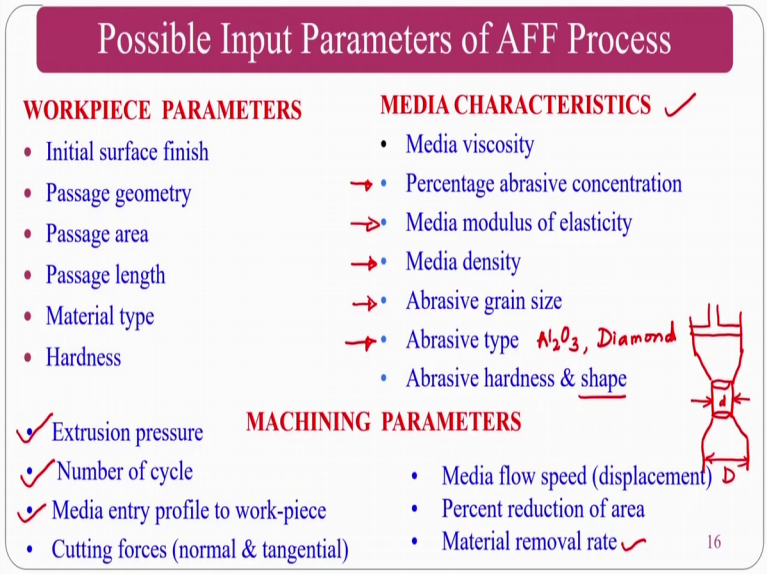

So, the work piece parameters initial surface roughness; initial surface roughness is very very important input parameter because, you cannot get a nano surface roughness, if your surface roughness is 100 microns or 200 microns. For example, if you are developed a hole using EDM process with carbon based dielectric fluid, it is damn difficult to finish into the nano. So, what you have to do is, your initial surface should be like 1 micron or less than 1 micron then, you can get the nano surface.

So, that means, that initial surface and initial surface texture, initial surface morphology, initial surface metallurgy will always plays a crucial role in abrasive flow finishing process to achieve the nano surface roughness. Passage geometry, if the passage geometry is too narrow then, the forces experience for the same extrusion pressure will be very high and it will you get the surface finish that is required in few cycles only. if the passage geometry is big then you need more and more cycles.

Passage area, so geometry and passage area cross sectional area also play a major role because, if you have sharp edges like a square or something then there will be a your medium may not reach to those surfaces. Passage length, as I said geometry covers

passage area and passage length. So, the length if it is too high, there will be always problem of aspect ratio.

If you are aspect ratio is bit high; that means, there will be a pressure drop at the centre of the workpiece region. So, you should go for the advanced mediums and there are some of the advanced mediums that can overtake this type of high aspect ratio holes to be finished. So, material type, if the material is ductile, material removal will be very good, if the metal is too hard it will take more and more number of abrasive cycles ok. So, if the hardness is more you have to go for high hard abrasive particles and you can get the surface roughness as per your requirement.

If you see the medium characteristics, media viscosity will play a major role because, the viscosity is high; that means, that medium flow will reduce, but the thing is that it will try to remove the as much material as possible ok. So, percentage of abrasive concentration, the abrasive concentration is very high. If the abrasive concentration is high; that means, that number of abrasive particles taking part in the finishing per unit time will increase so, the material removal always increases.

So, medium modulus of elasticity and medium density these all also will improve the abrasive action. At the same time abrasive grain size, if the abrasive grain size increases what will happen, the indentation will increase ok. If this is the abrasive size and this is the abrasive size what will happen is, for the same extrusion pressure and other things by indentation created by the higher abrasive particle will be more. So, the material removal will be more. Abrasive type, abrasive type is if you are going to have harder and harder abrasive particles like, in one case you are going to use Al 2 O 3, in another case you are going to use diamond, what will happen is that diamond will give you more material removal as well as better surface finish compared to alumina.

So, abrasive hardness and shape, because of abrasive hardness is a function of it is abrasive type because, Al 2 O 3 hardness is less compared to the diamond and abrasives shapes normally, abrasive shapes are completely random. No two abrasive particles will be similar in looking. So, machining parameters are the finishing parameters, if you see the most important one will be extrusion pressure.

If you are going to increase the extrusion pressure, what you are going to experience is your radial force and axial forces will increase, at the same time axial velocity also

increases. Because of which, what will happen the finishing action will takes place but up to certain limit if, you are going to increase beyond certain limit, what will happen it will not only shears the peaks but also it creates its own scratch marks. Number of cycles you required to optimize the number of cycles for each and every material with respect to the input conditions like initial surface roughness, type of work piece material, type of abrasive material and other input parameters you have to fix, then extrusion pressure and all those things you have to fix, then you have to optimize the number of cycles. For each and every material combination the number of cycles will be different. Media entry profile to the work piece, seen cutting forces this type of things you can measure.

Media flow speed; that means, that how the you can improve the flow speed and other things. Flow speed always will be function of your medium composition and extrusion pressure. If you are medium is to be low viscous and pressure is high; that means, that medium flow speed is very high, vice versa also if, the extrusion pressure is low at the same time if the medium viscosity is very high then, the medium flow speed will be very less. Material removal rate you can use as a output response and percentage reduction area; that means, that if you could realize this is my fixture and this is my work piece and normally, tapering will be given, so that the medium entry will be smooth enough. That is why always the tapering will be given before the workpiece starts ok.

So, what I mean to say that, area reduction is the diameter of the workpiece to the diameter of the medium cylinder. This is the medium cylinder diameter, capital D, this small d will be the diameter of the this one. Area friction normally, will be with respect to work piece and the medium cylinder ok. If you are medium cylinder is to big normally, what will happen you require very few number of cycles.

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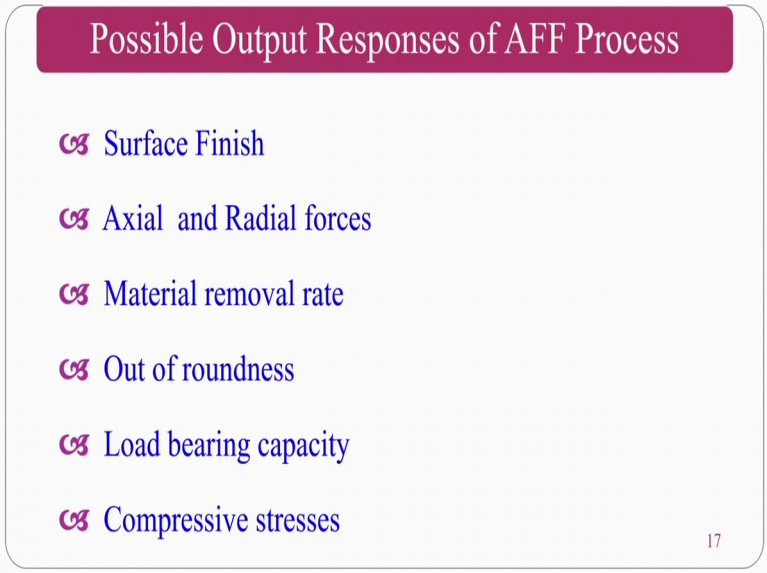

Possible output responses normally, the surface finish, axial and radial forces, normally if you want to see the surface finish measurement, you can see in most of the papers because abrasive flow finishing process is basically a finishing process. So, radial forces and axial forces these are all you can see in only few papers like Professor Gurana's paper you can see, but it is very difficult to measure the forces in abrasive flow finishing process. Because, in case of two way abrasive flow finishing process I am talking about, in that circumstances you have to go for ring type of parameters ok, or you can also go for acoustic emission based measurements and other things.

Professor Williams and Rajurkar also measured using online monitoring as done using acoustic emissions sensor, at the same time Professor Gurana and Professor VK Jain have done the force measurement with respect to ring type dynamometer and other things ok. Material removal rate, how much material is removed, this is a least bothered because abrasive flow finishing process is about the surface finish that you are getting. Whether you have achieved the nano surface finish or not, that is the question mark as per the current driven is concerned, but material removal rate also is one of the input parameters, if at all you are going for the deburring application.

So, out of roundness normally, out of holiness if you see the if at all you want to improve the out of roundness for a or cylindricity and other things, this can also be one of the input parameters and you can improve the out of roundness by reducing or by shearing of the surface peaks. Load bearing capacity, normally if at all you are going to reduce the surface roughness; obviously, the load bearing area will improve. So, compressive

residual stresses can be incorporated on the particular part, so that you can use in practical application and other things.

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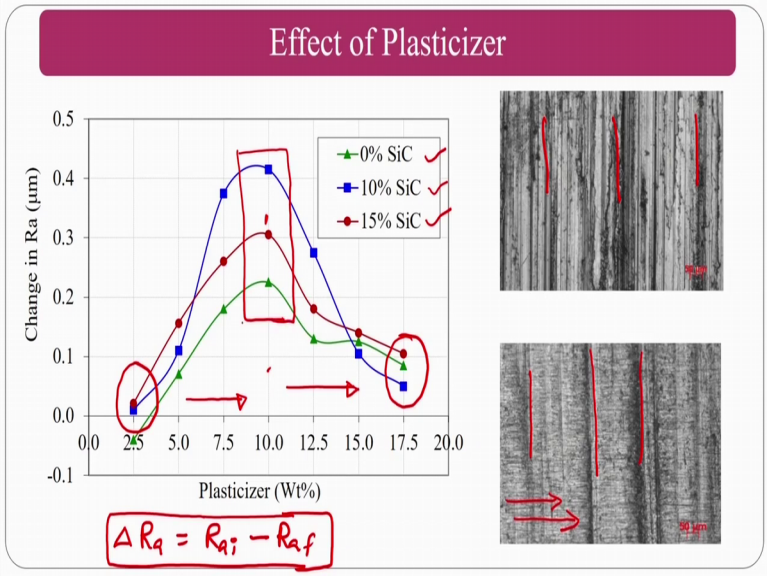

So, we move on to the effect of one of the medium parameters that is called plasticizer. We have taken here aluminium alloys, lykan carbide, metal matrix composite, one is a pure aluminium alloy, second one is 10 percent SiC third one is 15 percent SiC.

So, do not bother about all these things if you see the finishing mechanism with respect to plasticizers, you can consider any one curve because, we are interested to know about plasticizer. If you were going to increase from 2.5 to 17.5 the change in roughness change in roughness is nothing, but delta R a is nothing, but R a initial minus R a final, that is inertial roughness minus final roughness ok. If it is maximum that mean that the finishing is improved a lot ok. So, as you increase the plasticizer content what is happening here is, the medium gets better flow ability and abrasion and other things. That is why as you move on from 2.5 towards 10 the medium gets better flow ability and abrasion.

As you move again from 10 to 17.5, what is your going to see is it is decreasing. If you take three conditions one is the initial condition, another one is a final condition and the middle condition what it is going to do is, if you are going to have two less plasticizer; that means, that your polymers are dominating, normally polymers are dominating by elastic characteristics if it is elastic characteristics are more what will happen your radial

force will be very high, if the radial force is very high what will happen it will indent to more rather than the shearing. That is why the change in roughness is less. If the same thing happens in the on the other side the same if you were going to see here, at 17.5 you will have ample or the more amount of plasticizer softeners and other things are there.

So, your medium is so low viscous, it will simply flow on top of it. As you can see this is the grinding marks and the medium just flowing on top of it, rather than shearing and other things. That is why you can see dominating liners here and very very small marks of abrasive flow finishing are there here ok.

So, this flowing, instead of abrading the surface in just a simply flows because, you have too much amount of this particular plasticizers ok. So, if you are going to have the optimum amount, what is going to happen here is that you will get better flow ability, better abrasion and other things. That is why you will get optimum amount of radial force, optimum amount of axial force and axial velocity for which, the shearing action will be good and change in the roughness will be good.

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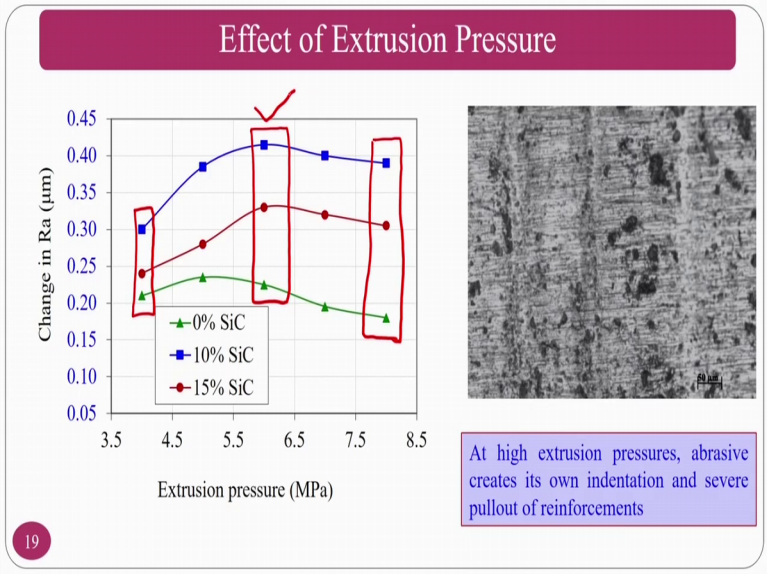

So, change in roughness with respect to extrusion pressure, if you are if the expression pressure is too low, what is going to happen is the medium start shearing. If you are going to have higher pressure what is going to happen is, it not only shears the workpiece, but also creates indentation, because if you are going to increase the expression pressure what is going to happen is the radial force will increase. If you see

the research papers what they clearly conveyed is at higher extrusion pressure, the force ratio will be high. The force ratio means, the F r to F a ratio that mean that you are radial force will be dominating compared to your axial force.

In that circumstances the indentation will be high because you are radial forces high, so the indents will be generated on the work piece surface. If you have optimum amount normally what you are going to get is good abrasion because, of low amount of indentation as well as proper shearing also because of which, what you are going to achieve is good change in roughness. So, medium and its rheology plays a major role that is what I was telling you.

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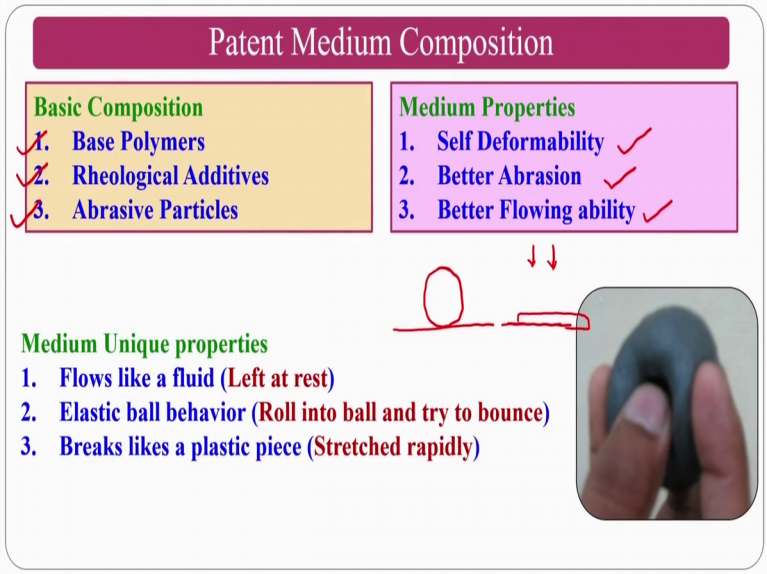

So, medium has patented by few of the researchers across the globe and our group also done the patent composition. So, some of the ingredients, all the ingredients which we cannot give, so one of the things are base polymers, rheological additives like softeners, hardeners, plasticizers, and antifungal agents, anti bacterial agents, and many more, so abrasive particles and other things. So, basic properties of the medium as I discussed that is self deformability, better abrasion and better flow ability, these are the minimum requirements for the medium, so that it can be used in the abrasive flow finishing process but this medium behaves uniquely.

So, what is if at all if you make a spear and put on a plate or a flat surface what will happen is after sometime it will become flat at the bottom ok. That means, that because

of the atmospheric pressure conditions it is becoming that, it is self deforming because of the atmospheric pressures, that is called self deformation ok. So, it is flows like a fluid, whenever you put like this for long time what will happen, it will become a flat and start flowing ok.

Elastic behavior or if you make a spear and just hit with certain height what will happen, the abrasive medium spear tries to jump ok. The third one is if you take it into hand and if you just pull it from your two hands what will happen, it is slowly deforms if you are going to pull it very fast but a higher shear rates it will break like a plastic material. So, with a science and deformation is unique here because, in one condition it is flowing in second condition it is behaving like a elastic ball and in the third condition it is behaving like a plastic material. So, the flow properties as well as de formation properties are completely unique that is why, this material has to be under stood from the flow and deformation studies.

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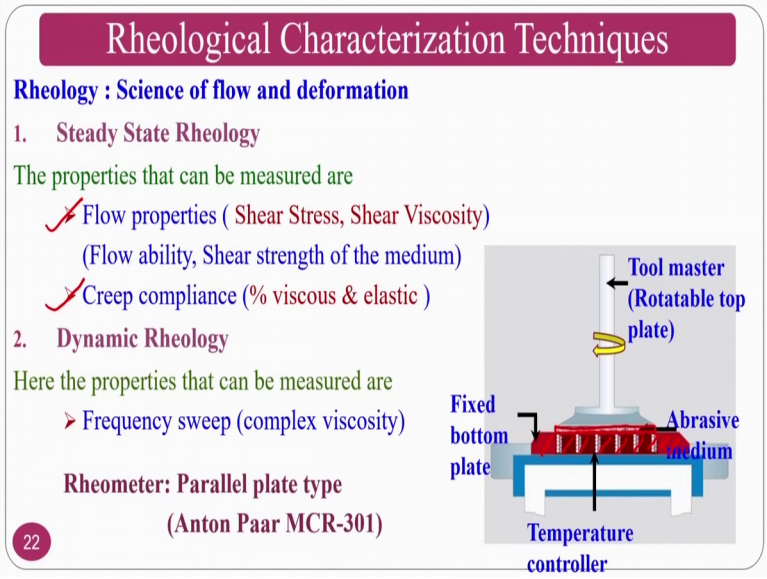

The science of flow and deformation is nothing, but rheology ok. So, the rheology can be understood for this particular medium by study state rheology, as well as, dynamic rheology. Study state rheology is nothing but, with respect to time we are not going to study in this. Study state rheology do not deal with with respect to time.

So, flow test, as well as creep recovery test, under other things can be studied in the study state rheology, at the same time the frequency sweep amplitude sweeps and other

things are studied in the dynamic rheology. If you see the schematic of the Anton Paar rheometer or tannel plate rheometers, you have a fixed plate here.

This is a red one is a fixed plate and a rotatable plate is there at the top and in between you have the medium, the red one which I have drawn is a medium, so whenever, you give the top plate a rotary motion so, it will shear from the periphery of the medium. You can have always a temperature controlling unit, so that if at all you want to check with respect to different-different temperatures and other things also you can check.

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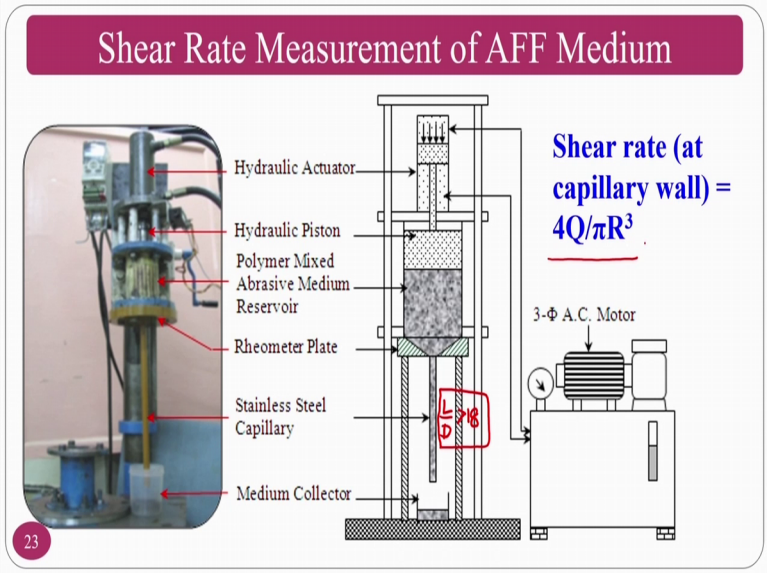

So, shear rate measurements. So, first at fore most thing that you want to measure is the flowing ability of a medium. So, if at all I want to understand the operant viscosity or the shear viscosity and a shear stress or medium, I should know: what is a shear rate at which I want to measure. For that purpose, one has to go for capillary rheometer. This capillary rheometer the medium normally, your L by D of this capillary should be greater than 18 ok. You can study the rheology basics where in this particular capillary rheometer and the parallel plate rheometer and other things will be given ok.

So, we have used the abrasive flow finishing setup itself because, we have to understand what are the shear rates that the abrasive flow finishing process is experiencing. For that purpose what we have done is, we have place the medium in a top medium cylinder and we have put a capillary to it and we have applied the extrusion pressure that, normally we apply in the abrasive flow finishing process. So, that we can collect the material and

shear rate can be calculated by measuring the flow rate as well as we know the radius of the capillary and other things.

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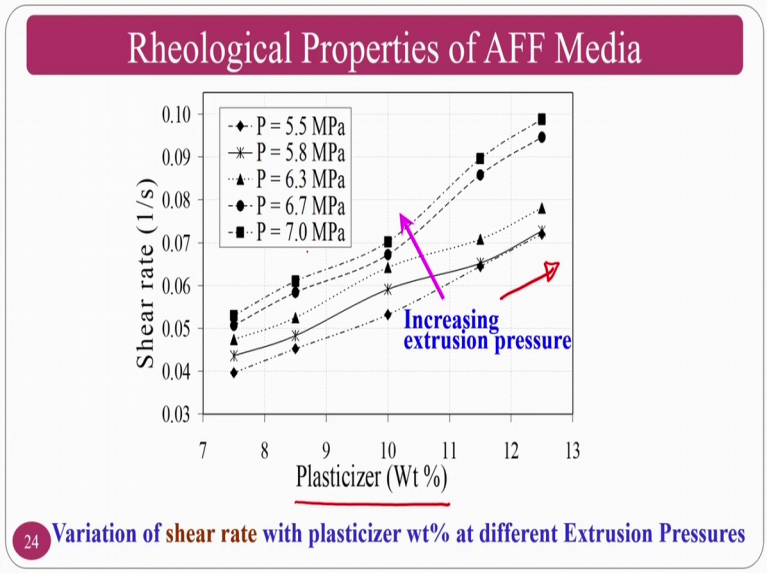

From here we can calculate the shear rates. So, the plasticizer content and extrusion pressures we have used the plasticizer content whatever we are using in a practical condition of the finishing at the same time extrusion pressures also. Now we calculated and plot the graph and you can see the shear rates ranging from 0.04 to 0.1 ok; that means, that my abrasive flow finishing process operates in this particular range. Now once I know the input range of this one then, I can go for the measure various rheological properties ok.

So, as you can see here, as the plasticizer content increases what will happen, the medium viscosity will go down, the flow ability of the medium will increase, that is why the curse or trending in a increasing trend with respect to the weight percentage as of the plastics. At the same time if you see here if you are going to increase the extrusion pressure, what you are going to experience is that medium flow rate will be increased because, you are putting more and more pressure on the medium. So, both the conditions are kept in this particular thing and we have measured the shear rates.

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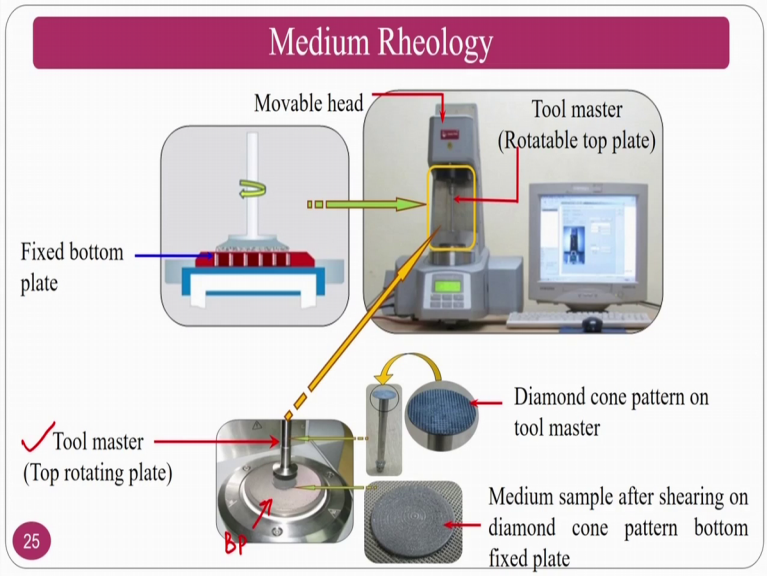

Once you measure the shear rates, now you have to give the shear rates to the rheometer, where you can measure using a parallel plate rheometry So, you can see this is a Anton Paar MCR 301 rheometer and where you can see this is a bottom plate and this is a top plate or the tool master and in between you are going to keep the medium ok. So, you are your bottom is fixed and the top will rotate whenever, you were talking about the shear rate; that means, that as you increase the shear rate means tool master will rotate at faster rate ok.

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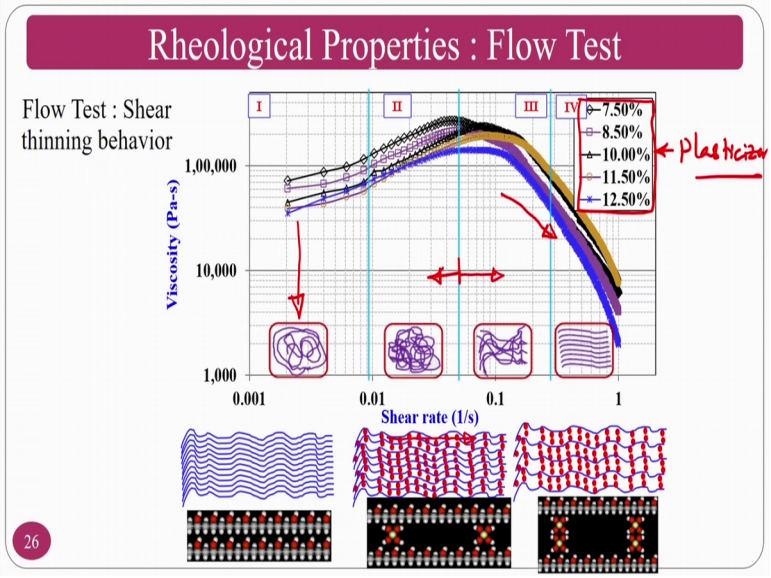

So, if you see the analysis, the shear rate as the shear rate increases means what is going to happen here is the abrasive medium will experience more rotational effect from the

tool master. If you are going to increase the shear rate; that means, if you see any curve, what is happening is if you are going to have the initial when the shear rate is low, that mean that your top rotating place is rotating at slower speeds because of which what will happen is, your polymer molecular changes climes one over each other and resists the flow.

Gradually, the viscosity of the fluid will increase because, unity of the polymer chains along with the other ingredients and the abrasive particles will increase, but any polymer chain or any material have their own strength beyond which, it starts breaking and it align in the direction of the motion of the top plate. That is why in the section one, it is increasing because of the unity of the polymer chains, in the other part what it is going to see is that it is shearing the polymer chains broke and align along the direction of the tool masters, so the down ward trend is observed ok. These are that labelling is given for the plasticizer ok.

So, if you are going to see the plasticizer as you increase the plasticizer content what is going to happen is the viscosity will reduce. That is what you can clearly see how it will reduce, if you are not going to have any plasticizer then, the viscosity of the fluid is very high. If you are going to impart the plasticizer, normally polymer is high molecular weight material, plasticizer is low molecular weight material, when you try to blend these two what will happen is low molecular weight material that is plasticizer softeners this will go and sit in between the high molecular weight materials and try to kick off.

That means, that the distance between intermolecular changes of are intermolecular distance between two polymer molecular chains will increase; that means, that intermolecular force of attraction between to chains will reduce. That is why the viscosity will reduce, that means, that you are going to impart viscous nature because the plasticizer softeners, all these rheological additives are dominating viscous characteristics. And the base polymers are dominating in elastic characteristics and partial viscous nature that is why the viscosity of the medium will reduce.

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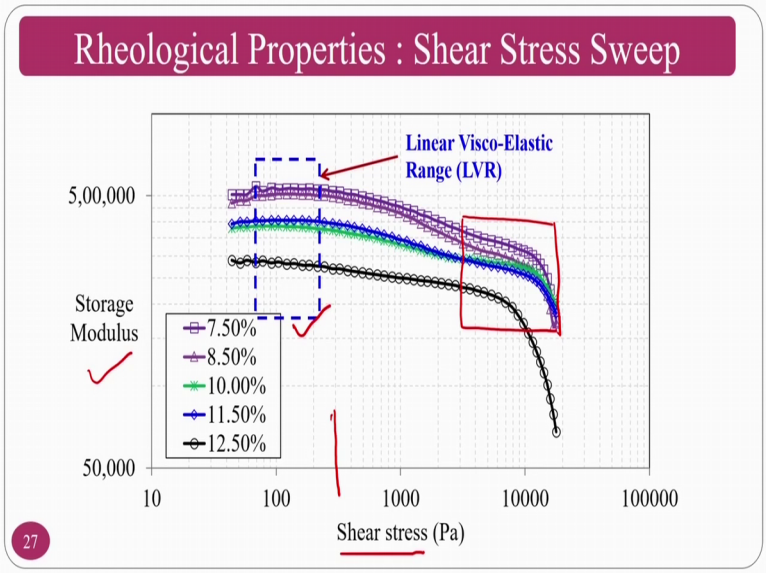

Normally shear stress piece required to measure the viscous and elastic components ok.

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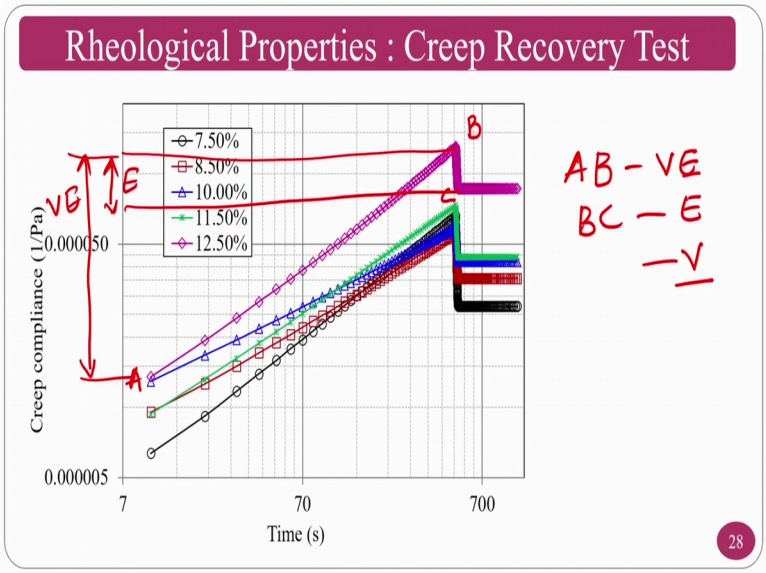

Normally I want to understand what is a viscous component and elastic component from this particular graph ok. I will go back to the previous slide to measure the linear viscoelastic region before that, you should understand why I require to measure the linear visco elastic region ok. So, in this one this is the creep recovery test what is happening is suddenly, in this one what you are going to put is you are going to put certain shear stress, then you are holding for the sometime and you will observe the creep compliance ok. Compliance is nothing but, inverse of your modulus, that means that stress by strain is modulus, if you are going to reverse is a strain by stress is nothing,

but your compliance ok. So, creep means sudden load you are applying and you are holding for sometime and you are observing the strain ok.

Since your stress is at the load is constant, so strain will continuously change with respect to time and you will want to observe the strain ok. That is what is done in this particular. The basic problem here in this curve is that, how much load one has to apply ok, for that purpose he people have to do the shear stress or the shear sweep curve. So, in this one I am going to increase the shear stress and I am observing the storage modulus. As I increase the shear stress there is no change in the storage modulus initially, but later on it is decreasing. That means, that even though I am changing the shear stress up to certain value, up to this particular value there is no change; that means, that my polymer molecules are at original state ok. So, if I can give any particular value of stress in this one and I can measure the viscous and elastic component.

In the next slide, that I am going to get original value of viscous and elastic component, assume that I a if at all I am going to give this particular region value what I am going to get here the polymer molecules are damaged or polymer molecular chains are broken, so I cannot give. So, if I can give the linear visco plastic region values; that means, that my polymer molecules are at original state and I can measure the original value of viscous and elastic nature. For that purpose I have given here 100 Pascal, which is taken from the previous slide, which is in the linear visco elastic region and I am observing the viscous and elastic component. A to B is visco elastic nature, B to C is plastic component. Once you know A to B is visco elastic nature and B to C is only elastic nature if you can subtract it in you will going to get the viscous nature ok.

This is about your elastic component and this is about your visco elastic component, this is your visco elastic component and this is your elastic component. So, you can get the viscous component from this particular ground. If you know the viscous component, if you know the elastic component then, it will be nice to understand about how much is the radial force because, radial force is a function of your elastic component, how much will be axial force and axial velocity, these things you can understand easily.

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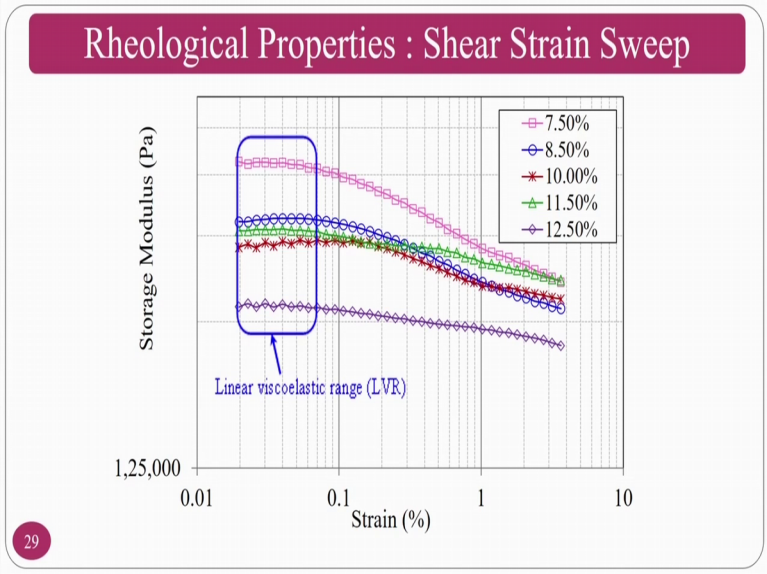

So, similarly you can do the strain sweep test also.

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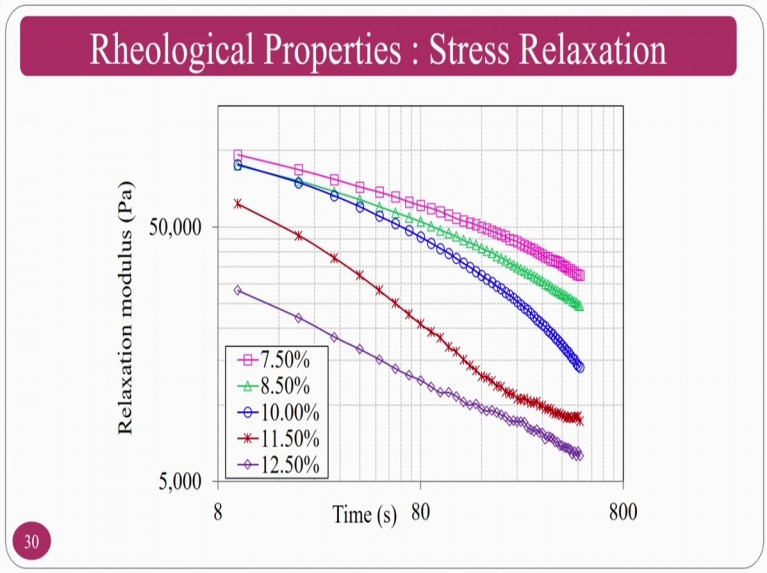

From the strain sweep test you can use that viscoelastic region in stress relaxation. Always stress relaxation should be faster because, the medium has to pass through your narrow region and it will go to medium. Because of the self deformation if it has to relax and self de formation will be fast if, your relaxing ability of the medium is very high. That is why you should always go for good relaxation. Since, these curves are following log log do not go by the bottom curve has the highest or the top one has highest or something ok. So, the best one normally will be the 10. So, you can see the curves and you can understand.

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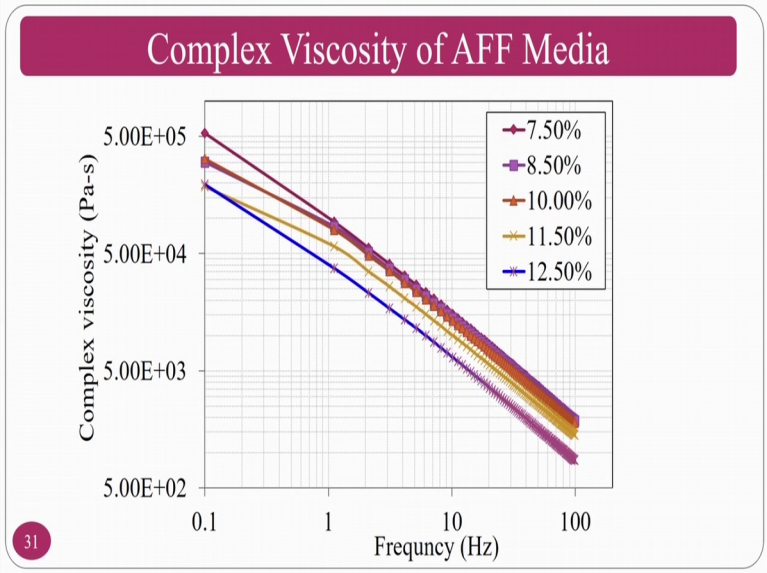

So, the complex viscosity of the medium if you are going to increase the frequency with respect to the time normally, this comes under dynamic. So, where the complex viscosity normal it can be measured or you can also measure storage modulus, loss modulus and tan delta other things also can be measured. If you are going to increase the frequency normally, the viscosity will gradually decreases because, the polymer chains will break and the viscosity will gradually decreases.

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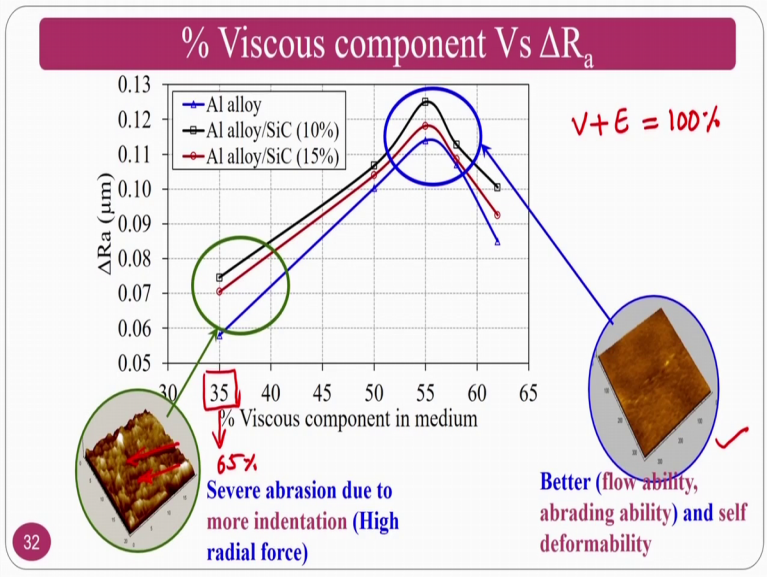

If you see the effect of rheology on the finishing of the medium if, you are going to measure your viscous component plus elastic component considered to be 100 percent in a visco elastic medium, if you are going to have 35 percent of viscous component. That means, that here so 65 percent will be your elastic component; that means, that elastic component is too high because of which it is not only shearing the peaks but also it is creating its own scratch marks.

That is why the change in roughness is less. If you see at 55 normally, what you are going to experience is a very good surface this is because you have a sufficient amount of elastic component, sufficient amount of viscous component and you are going to abrade uniformly across the surface, with a better flow ability better abrade ability. That is why you are going to get the better surface that is why you are going to get better surface finish.

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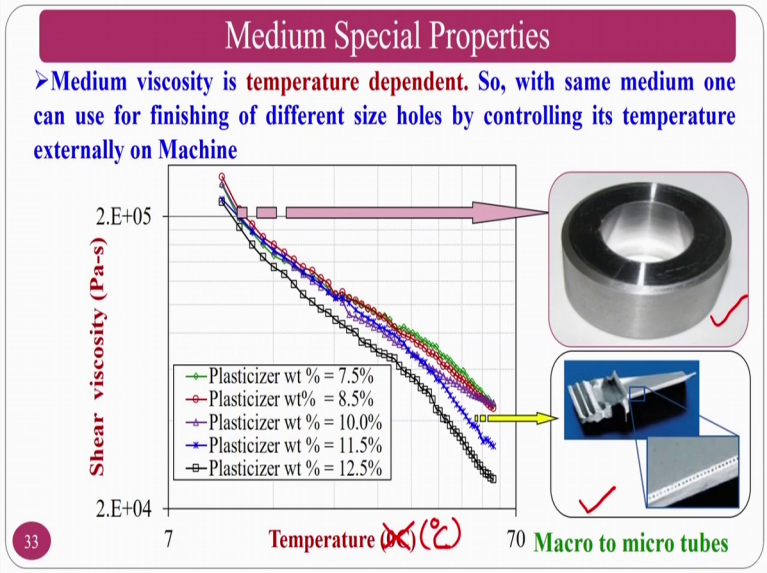

So, the other variable in the medium rheology is nothing, but temperature ok. So, temperature what you are going to see here is if, the medium temperature increases the medium viscosity will gradually decreases; because, if you are going to increase the temperature the medium polymer molecules gains energy and try to move apart. When the molecules are move moving apart, the distance between two polymer molecular chains will increase; that means, that polymer molecular attraction forces between two molecular chains will reduce. That is why always the viscosity will reduce.

The advantage of this one is if, the viscosity is high what will happen you can finish the bigger holes, if the viscosity is low then you can go for smaller also. Assume that I am going to have only one medium if at all if my abrasive flow finishing process has at temperature controlling unit, you can play with a temperature and reduces the viscosity of the medium. And, you can use for the small type of components or small geometrical features also can be finished ok. That is the beauty about the temperature dependent rheology of the medium also.

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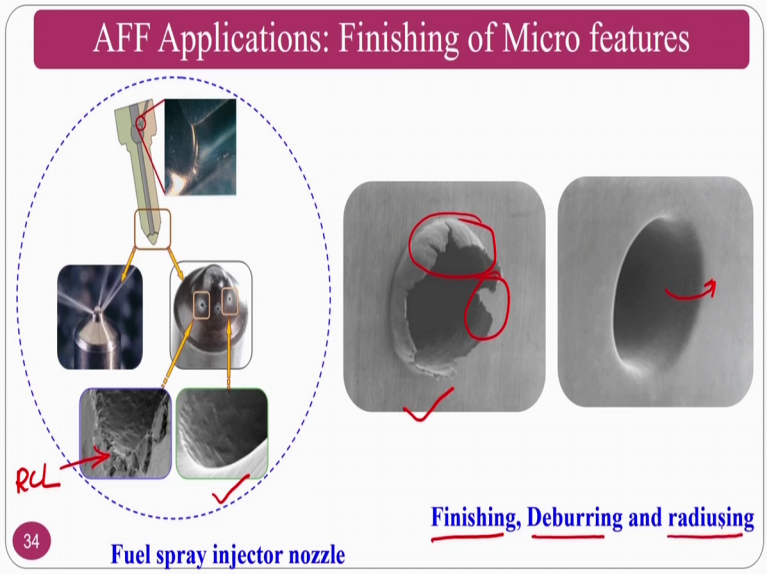

Normally, if you see the, you can do for the micro applications, the finishing of micro holes that are the fuel injector nozzles can be finished and this is the recast layer. This recast layer can be removed and it can be finished at the same time deburring. I was talking about in some of the cases deburring and other things exclusively I kept this particular slide for those people who could not understand: what is a deburring operation.

Whenever you do the drilling operation at the edge at the bottom side, you get this type of burrs. This is nothing, but a burr and if you are going to remove it by the abrasive flow finishing medium with a low viscous medium you will get you not only remove this burrs, but also you will get radiusing ok. So, two things one has to understand here is the finishing of the micro hole is done at the same time, deburring also done and a radiusing also done ok. This is the most beautiful thing about the abrasive flow finishing process.

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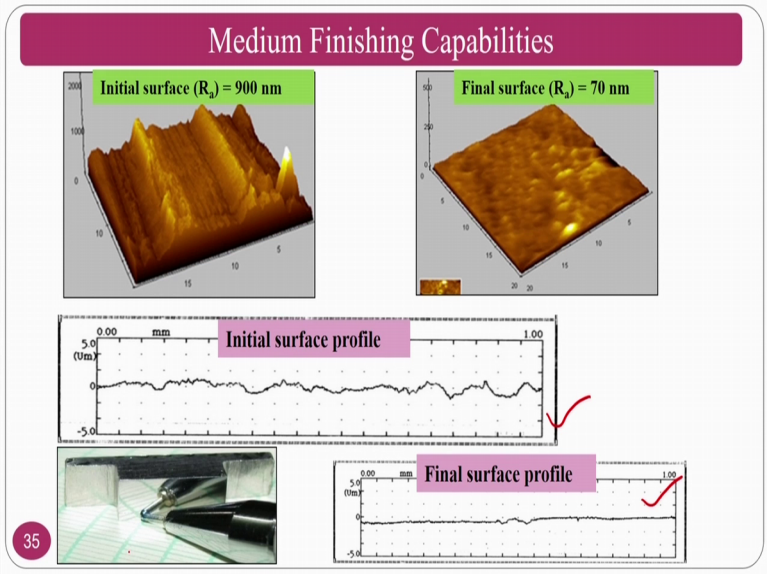

So, you can see the surface roughness as I said initial surface roughness is always important to understand and to get the nano surface finish in the later cases. So, initial surface roughness is 900 nanometers and the final surface roughness is 70 nano meters and the initial profile and the final profile you can see the mirror image of the pen tip in the workpiece ok. So, this is how you are going to finish these particular components.

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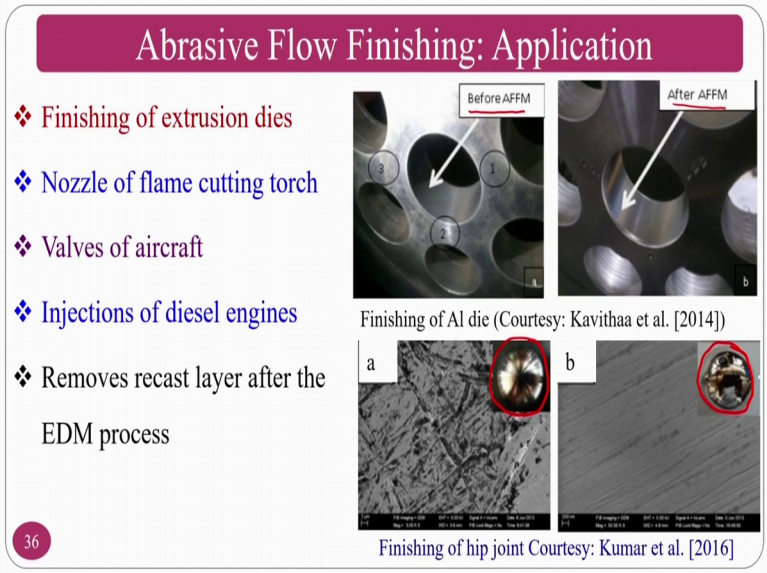

So, the applications finishing of extrusion dies, nozzle also can be done. Walls of the aircraft and it can remove the recast layers and other things, that can be done if you can see here before and after it is finished in a great level, at the same time you can see head

of the hip joint also can be finished ok. These are the things that can be done by the abrasive flow finishing.

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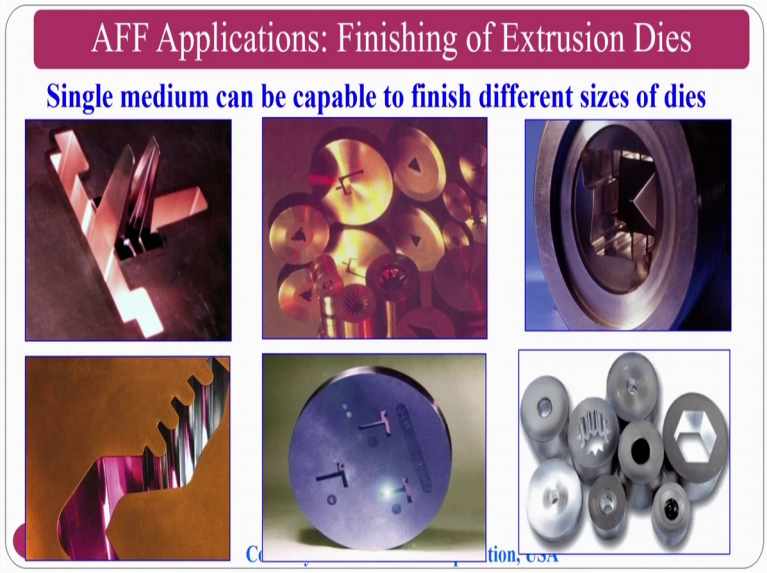

These are the extrusion dies various type of extrusion dies can be finished by the abrasive flow finishing process and you can also do the finishing of multiple holes in a die also that also is possible.

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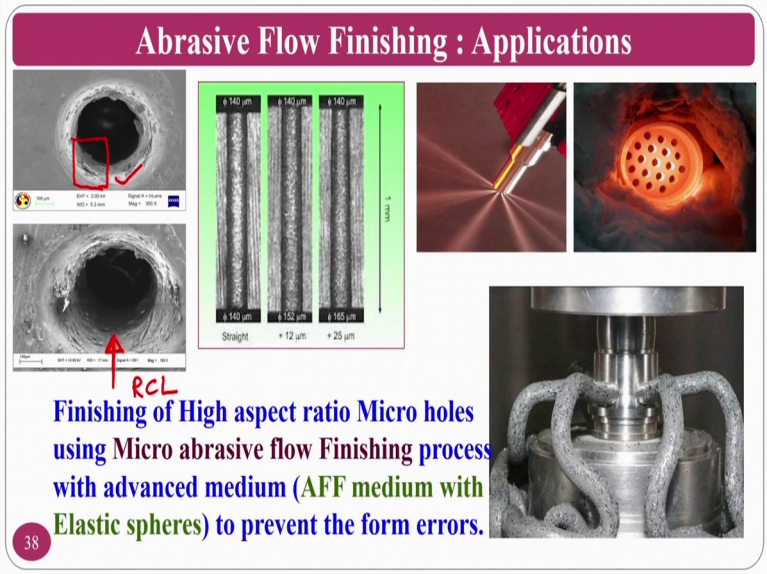

So, this is what I am talking about the recast layer. So, this is a laser beam machine surface, you can see the recast layer; that means, in a laser beam machining melting and

evaporation is normal phenomena if, you are if the material is not gone or that mean that if the material is unable to remove or if by the virtue of the gases or atmospheric gases are the normally some of the laser assisted machining processes or like air assistance are will also will be there. If the metal is not removed, this will be stay like a recast layer, melting molten material will stay there in the form of a layer that is called a recast layer.

As I said casting means melting then you just put into the mould. So, here there is no mould, but melt molten material will solidify again, that is why this is also resembles make a casting technique. That is why the layer formed here is a recast layer. You can see here, how the recast layer is there if you are going to put this particular component in a practical application it is going to fail as early as possible. For that purpose you should always try to finish this surface, so that you will remove the recast layer and the life of the component will increase. You can also do for the filters and other things and you can see the how the holes are finished using abrasive medium here.

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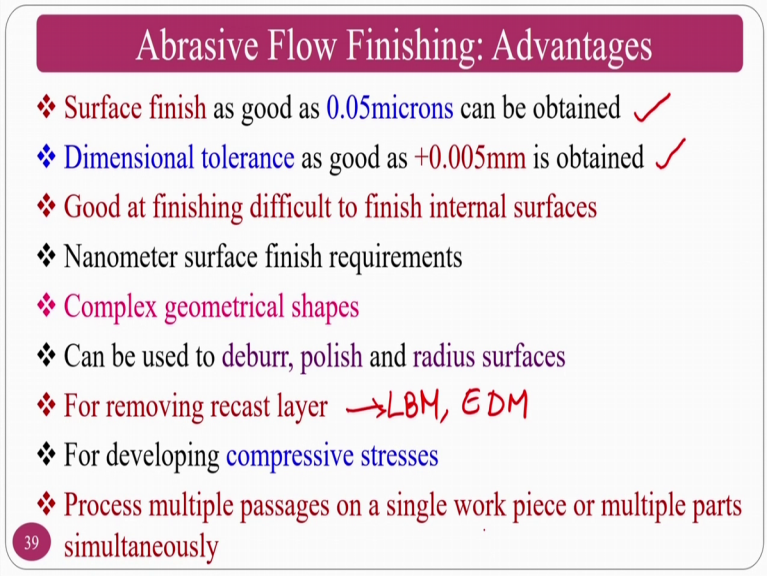

So, the other advantages surface finish you can get up to 50 nanometers, dimensional tolerances you can get up to 0.005 mm, other good finishing on the difficult to finish internal shapes also can be done, nano metrical surface finish can be achieved, complex geometry shapes can be finished, can be used and deburr polish radius, that we have seen in the previous slides for removing the recast layers, that are formed in laser beam machining and electric discharge machining and other processes, can be done using the

abrasive flow finishing process. So, for developing the compressive stresses, that is residual compressive stress is also can be developed and process multiple passages in a single go also can be done.

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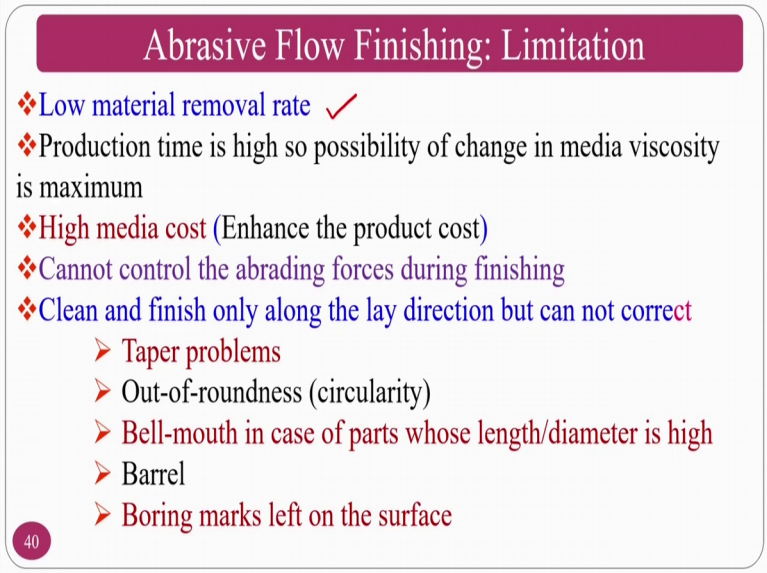

This is the advantages of this particular process. This process has limitation like low material removal rate. Production time is very high because, as you are going to increase the finishing time high the viscosity of the medium will go down. And medium cost is very high if, you at all you want to go for a commercial medium normally, the medium is too expensive. So, the production cost of your finishing component will goes up.

Cannot control abrading process during the finishing because, the medium is a one an along with explosion pressure will decide this one. It cannot correct some of the problems like taper problems, out of roundness, bell mouth, barrel and boring marks and other things cannot be done by this particular process. This particular process only can finish the surface, but not change the shapes because, the material removal in this abrasive flow finishing processes too less.

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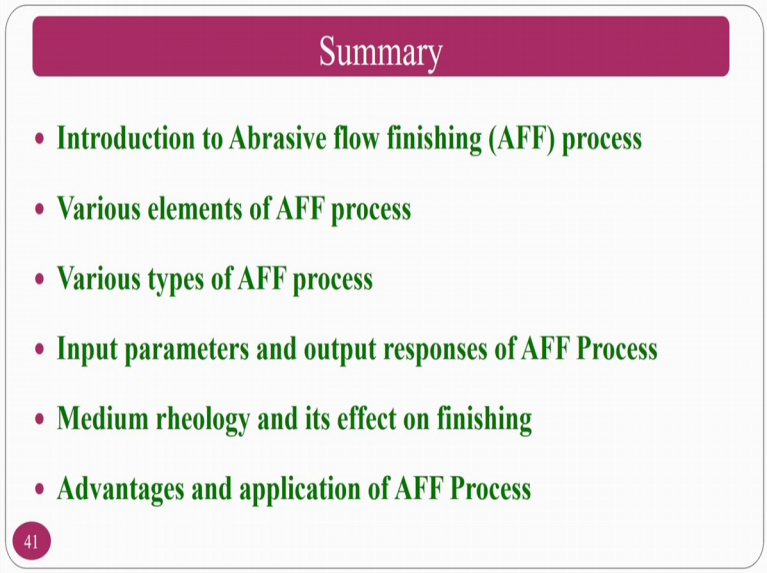

So, summary of this class we have seen the introduction to abrasive flow finishing, various elements of abrasive flow finishing, various types of abrasive flow finishing, input parameters and output responses, medium rheology and its effects on finishing, advantages and applications of abrasive flow finishing process. Effectively we have seen about the conventional abrasive flow finishing process and we move on.

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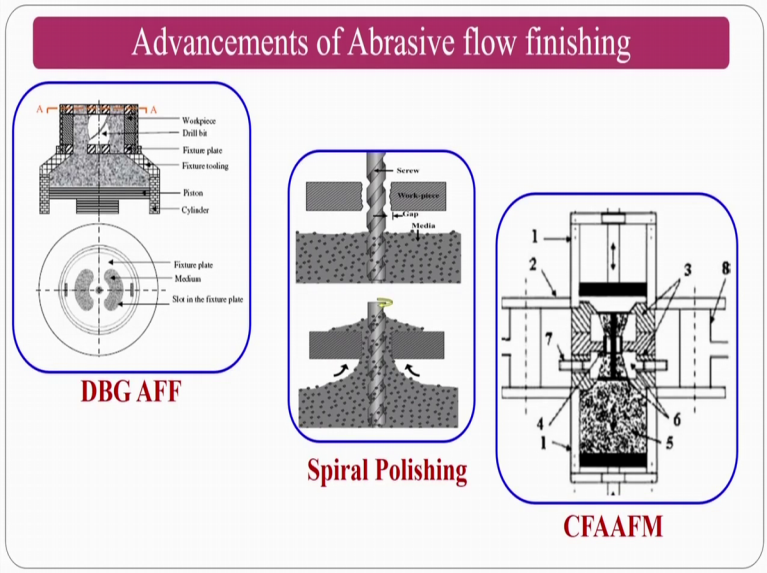

If time permits, we will see the advance versions of abrasive flow finishing process like drill bit guided, spiral polishing, centrifugal forces abrasion for from shearing process and other things also in upcoming classes subjected to if, the time permits ok. Thank you

for your kind attention for this particular class and I am very thankful for various researchers for their figures and other things in the area of abrasive flow of finishing.

Thank you.