Advanced Machining Processes
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Module - 03
Lecture - 07
Abrasive Flow Finishing

Welcome to the course on advance machining processes. Today we are going to discuss on abrasive flow machining process. So this abrasive flow machining process is one of the fine super finishing process okay. So this is the outline of my presentation.

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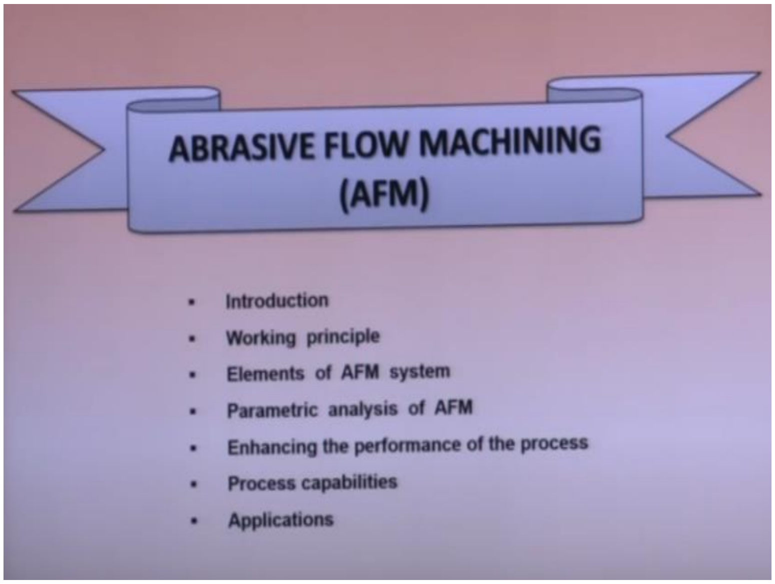

So this first I shall discuss about that introduction to the abrasive flow machining process. Then working principle of abrasive flow machining process. Then what are the different elements of abrasive flow machining experimental setup and then parametric analysis for controlling or for achieving better surface finish and then enhancing the performance of the process.

So these abrasive flow finishing process can be modified further for getting higher performance in terms of surface roughness material removal rate and then we shall discuss about the process capabilities okay and then we shall discuss about the application of this abrasive flow finishing process. So first thing comes why this abrasive flow finishing process comes? Why this super finishing processes comes?

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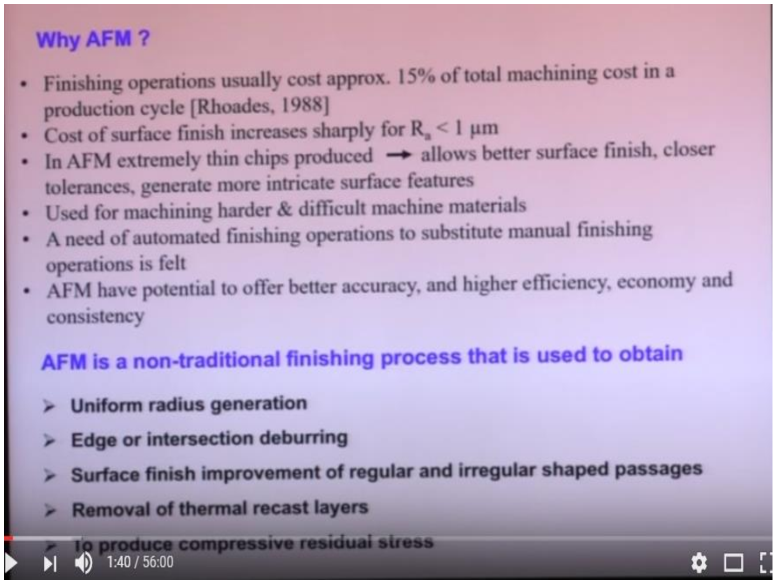

This super finishing processes is required in nowadays because nowadays this surface finish requirement is in the range of nanometer. So sometimes we need angstrom level surface roughnesses. Suppose we need the missile, in that missile the whatever lenses are used, in that lenses we need surface roughness in the range of nanometer or further in the range of angstrom level. Also the gyros used in aerospace gyros is used in aerospace applications, there also surface finish requirement is in the range of nanometer range.

Also there subsurface damages should not be there and it should be uniform throughout the workpiece surface. Also there are other things are there like nowadays most of the workpieces are very complicated oaky. So this complicated surfaces are very difficult to polish by conventional polishing process.

Also inaccessible areas are there. So these inaccessible are to be inaccessible areas in the workpiece have to be polished by this have to be polished by process or any finishing process okay and also nowadays this workpiece material are very harder. So you know that harder material polishing of harder material we need the tool should be harder than the workpiece material. So when your workpiece is high strength temperature resistant material in that case you have to go for nonconventional polishing process for polishing all these workpieces.

So in all these nonconventional polishing process loose abrasive particles are used while in conventional polishing process mostly like in grinding operation, there abrasive particles in their bonded form are used and in this bonded form in grinding operation this abrasive particles has a fixed path and it removes materials in so it any complicated surface it is very difficult to polish by this grinding operation.

So that is why people go for this nonconventional polishing process. So this AFM, why you are going for AFM process? Because nowadays this surface finish it consist of 15% it cost of this polishing of any component consist of 15% of total manufacturing cost. So it is very high, this polishing is very high. So cost of surface finish sharply increases when surface roughness less than 1 micron so when surface roughness is less than 1 micron this surface polishing cost surface finishing cost also increases tremendously.

So in AFM extremely thin chips are produced so this allows better surface finish, closer tolerances, and generate more intricate surface features. So this is used for machining hard and difficult to machine materials. A need for automated finishing operations to substitute manual finishing operations are felt. So these AFM process can be automated so we can automate this process this atomic abrasive flow finishing process okay.

So AFM have the potential of better accuracy, higher efficiency, economy, and consistency. So these are the requirement so requirement so that this abrasive flow machining process or abrasive flow finishing process had been evolved. So this AFM process it is developed by ex-student corporation of USA, so after that many researchers have contributed in this process. In Japan also many work have been done. In Soviet Russia also many works have been done in Soviet Russia and India also contributed many work on this abrasive flow finishing process.

So this AFM is a nontraditional finishing process that is used to obtain uniform radius generation. Suppose there is a intersection of 2 channels are there, 2 intersection of 2 channels are there. So in that intersection you need a uniform radius okay for uniform flow of gas or liquid. So that is why AFM process is very much helpful. So any accessible inaccessible areas, any complex geometrical shapes irrespective of their internal geometry or external geometry can be polished by this process.

So edge or intersection deburring. So deburring say is a very unwanted thing. So after drilling this divert deburring is there okay so this whatever deburring things are there so that that kind of unwanted component can be removed by abrasive flow finishing process. So surface finish improvement of regular or irregular shape passages can be can be done by this AFM process. Removal of recast layers. So it also very important. After doing EDM operation you see that in EDM operation you know there recast layers are generated. So these recast layer are nothing but whatever this moulded material it is deposited on the already machined surface. So this recast layer after deposition on the surface, already machined surface it becomes very brittle and very brittle and hard and porous okay. So these recast layer has to be removed before this recast layer has to be removed before this polishing before this holes can be used for further work okay.

So this recast layer can be removed by abrasive flow finishing process very successfully. So these process AFM process is also used for to generate compressive residual stress. So compressive residual stresses like in grinding operation you can see that because of this heat generated there okay and this tool is actually every time it is in contact with the workpiece surface this kind of compressive residual stress is generated. So that kind of compressive residual stress can be generated by using this abrasive flow machining process.

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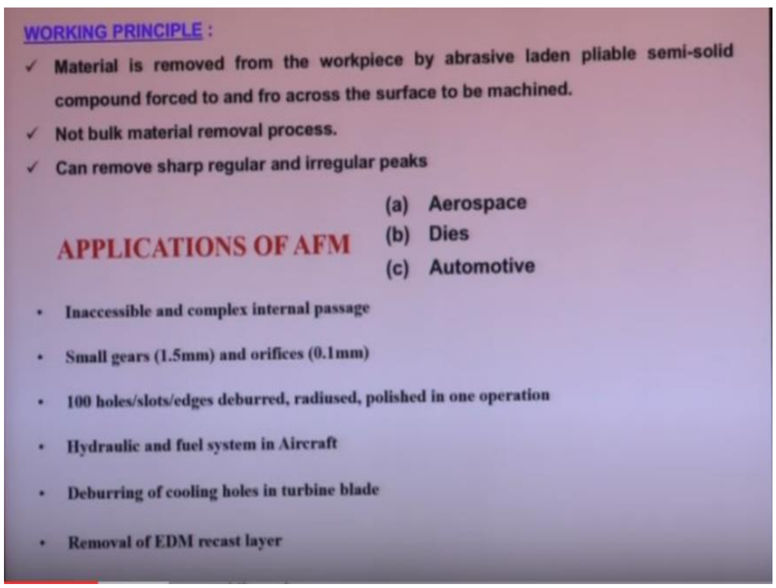

So what is the working principle, working principle of abrasive flow finishing process? Material is removed from the workpiece surface by abrasive laden pliable semi-solid compound forced to and fro across the surface to be machined. It is not a bulk material removal process. It is a selective material removal process. Can remove sharp regular, irregular peaks.

So applications are, it is very much used in aerospace, dies industries, automobile industries. So it can be used for inaccessible and complex internal passages. Small gears as small as 1.5 mm piece circle diameter, orifices as small as point 0.1 mm diameter can be easily polished by using this abrasive flow machining process.

So 100 holes per slots or edges can be deburred or radiused or polished by this process. Hydraulic and fuel systems in aircraft can be polished and deburring of cooling holes in turbine blades. So these turbine blades the deburred surface are generated after machining so that deburring operation after machining can be done by this abrasive flow finishing process.

So removal of EDM recast layer already we have discussed now and intake port of automobile engines okay. So this intake port if there some bursts are there if there are any irregularities are there that can be polished by abrasive flow finishing process.

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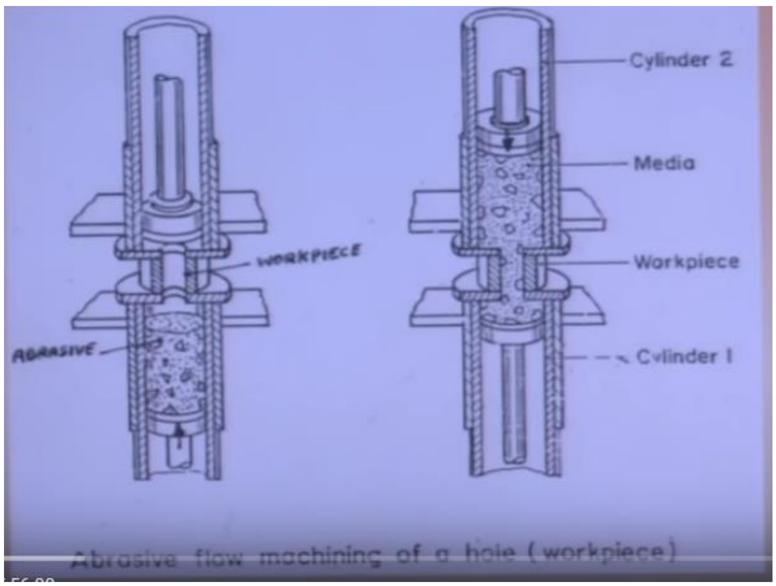

So this is the working this is the schematic diagram of abrasive flow finishing operation. Here you can see there are this is one piston, this is another piston, 2 pistons are there. So this is the 2 piston. This is called top piston. This is the bottom piston, bottom media piston, and in between you can see this is the media. So this is the viscoelastic polymeric media okay. So this viscoelastic media it is given to and fro motion.

So because this pistons actually it is moving up and down, so this pistons they are just simultaneous movement of this 2 pistons. So these 2 pistons actually move simultaneously so when this top media cylinder it is piston is coming in the downward direction this bottom media cylinder also it is going in the downward direction. So that is why whatever this media is there this media will flow through the workpiece. So this is the workpiece here. So this media will flow through this workpiece and it is means media is fiercely it is flown through the workpiece surface okay.

So you have to design this this zone this workpiece surface so that media will flow through the workpiece where you need a polishing okay. So because of this reciprocation motion of this pistons this media will flow to the workpiece surface from top media cylinder to the bottom media cylinder and while moving this one whatever this abrasive particles are there in the viscoelastic media it will remove the surface undulations from the workpiece surface okay.

So this viscoelastic media is the main rheological media which is used in abrasive flow finishing process which does the polishing. So we shall discuss further this working principle okay. So this is the schematic diagram of the process okay.

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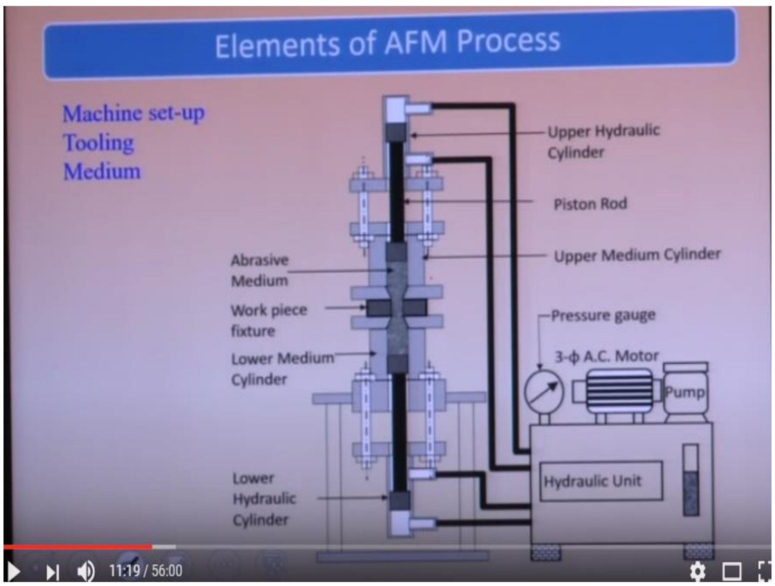

So you can see here there is a hydraulic system. So this is the hydraulic system here okay. So from this hydraulic system you can generate up to 100 bar pressure okay. So there are 2 inlets in that hydraulic system. So this is one inlet and this is another inlet here. So this is one inlet, this is another inlet. Through this inlet it is moving. So there are 2 pistons, 2 types of piston. This is the hydraulic piston and this is the media piston. So this is the hydraulic cylinder and this is the media cylinder here, 2 cylinders are there. Similarly at the bottom also there are 2 cylinders are there. So this is the media piston and this the hydraulic piston.

So this media piston and hydraulic piston they are connected by a connecting rod. So by this hydraulic unit you are giving this kind of reciprocating motion okay. So you are giving this one reciprocating motion and this is the means workpiece fixture here. So while you are giving this kind of reciprocating motion, so media is flown through the passages here in the fixture where you need a finishing okay.

So this media, viscoelastic media, it consists of abrasive particles so while this viscoelastic media is flowing through the passages where you need the polishing abrasive particles do the surface undulations by removing small chips from the workpiece surface, small small chips from the workpiece surfaces.

So this is the working principle of abrasive flow finishing process. So this is the hydraulic unit. It is the 3 phase motor is there in that hydraulic unit and there is a pump is there so it can generate from 0 to 100 bar pressure. So this much pressure is required okay to flow the media through the through the passages while you need the polishing.

So this viscoelastic media actually it holds the abrasive particles. So this media has a elastic property okay. So this media has a elastic property because when this abrasive particles will try to penetrate into the workpiece surface to remove the material so this media actually viscoelastic media actually holds the abrasive particles.

Otherwise what will happen this abrasive particle will come inside the media with a certain means with a small force. So this media has a viscoelastic property that is why it does not go inside very easily so it holds the abrasive particles. It gives the resistance to the abrasive particle to hold inside the media so that it can do the polishing operation okay. So this is the machining system.

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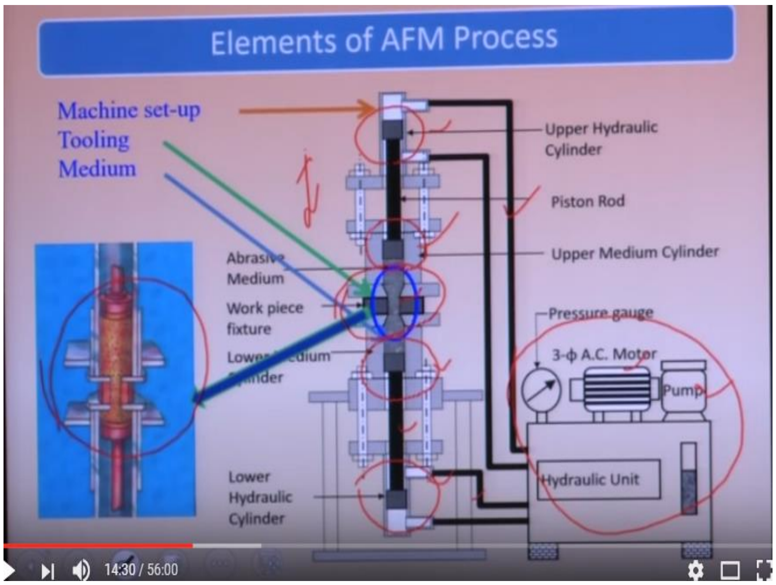

So this is the tooling medium. Here tool is there so tooling medium and this is the media here. So media is flowing from the top media cylinder to the bottom media cylinder and bottom media cylinder to the top media cylinder. So these 2 pistons media pistons are actually this is reciprocating like this and in between this abrasive this media actually it is flowing from top media cylinder to the bottom media cylinder and then bottom media cylinder to the top media cylinder. By flowing actually it will remove the surface undulations from the workpiece surface okay. So same so this is the fixture zone where you can see that how this machining is going on okay.

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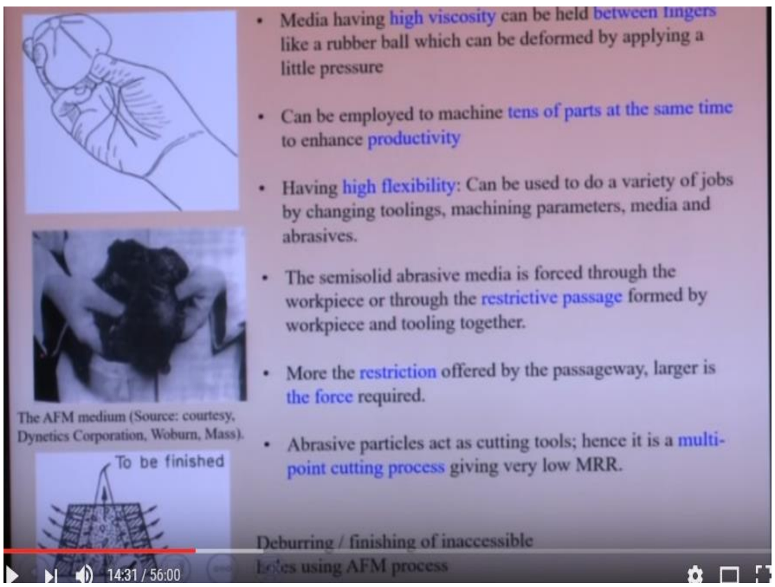

So this as I told that the main rheological media is the this polymeric media. So this media actually it does the machining operation by using this abrasive particles. It has certain property. It is a non-Newtonian fluid obviously okay so it is a non-Newtonian fluid. So media having high viscosity can be held between the fingers like a rubber you can see here, between the fingers like a rubber it can be held like a rubber ball which can be deformed by applying a little pressure.

So it is a very soft media. So this media can be deformed by using a very small pressure also you can deform the deform the shape. Means it can be it can take the shape of the workpiece where shape of the surface of the workpiece from where it is moving okay. So can be employed to machine tens of parts at the same time to enhance the productivity.

It has a high flexibility means it can be used to do a variety of jobs. Same media can be polished for a variety of jobs by changing the tooling operation. So tooling operation means just you have to flow the media in such a way that in between this workpiece or tooling or inside the workpiece you have to throw the media in such a way that only where you need the polishing so from there only this media will flow.

So we have to restrict the media where you need the polishing operation okay. So can be used to do a variety of jobs by changing the toolings, machining parameters, and media and abrasives. This semisolid media, abrasive media is forced through the workpiece or through the restrictive passage formed by the workpiece and tooling together. More the restrictions offered by the passageway, larger is the force required okay. For if you give more restriction so you need a very large force means very large means you have to consider higher pressure from the hydraulic unit okay.

So abrasive particles act as a cutting tools here hence it is a multipoint cutting operation okay and giving very low material removal rate so it is not a bulk material removal process, it is a low material removal process. So you can see here this kind of workpiece where small holes are there and media is flown through the at the internal surface and while we are giving restriction to the flow of media, so media will flow through this holes also. So while flowing this media through the holes as it contains the abrasive particles it will remove the surface undulations from the workpiece surface and whatever undulations are there into that hole so it will be removed. So it will be in firm hole okay.

So deburring finishing of inaccessible areas you can see here can be done by using this abrasive flow machining process. So this is the media here you can see. It can be kept inside your in your hand. So it will take the shape of the workpiece surface so it here it can take the shape of shape of your hand, fingers okay. So it can it can take the shape of the workpiece surface. So it is a pliable okay. So it is a flexible pliable media okay. It can take the shape of the workpiece surface to be polished.

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So these are the different abrasive flow machining conditions it is shown here. So you can see here this media actually flowing through the holes perpendicular to the cylinder it is coming here in the first case and here we can see there are 2 platforms are used. One platform is for polishing another platform actually for removing the whatever media is there from the polished surface. So here they have used 2 platforms.

This is another schematic diagram of the abrasive flow media.

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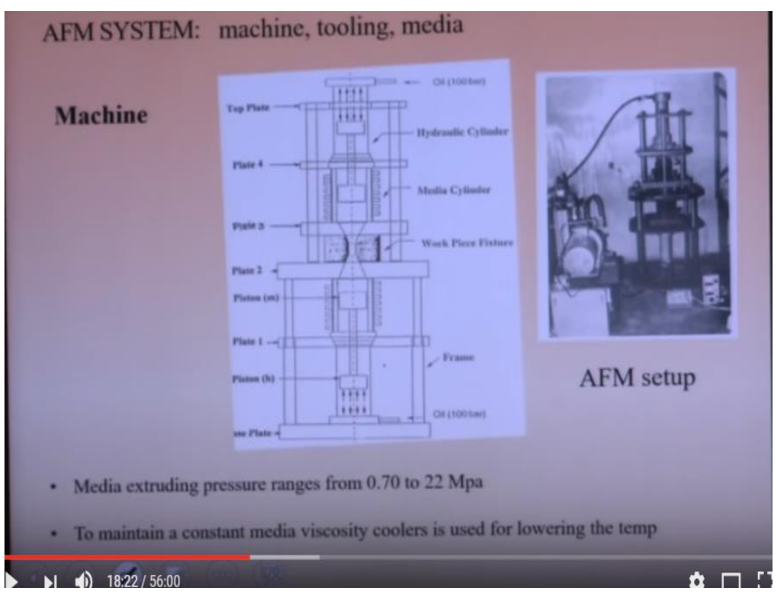

So in this setup you can see the machine, tooling, and media here okay. So media pressure here they have considered 0.7 to 22 MPa here. So to maintain the constant media viscosity coolers are used for lowering the temperature. So this media it its property actually dependent on the temperature of the media. So this rheological property of this media depends on the temperature okay. So with the increase in the temperature its property actually viscosity actually reduces. So we need the machining operation to be done at a constant viscosity okay.

So that is why during machining, during polishing itself we have to maintain the temperature of the temperature of the media so that viscosity remains constant so that is why some from external means you can use some coolant okay so this you can use some coolant to flow outside this media so that this temperature of the media can be maintained okay this temperature of the media can be maintained during machining operation okay.

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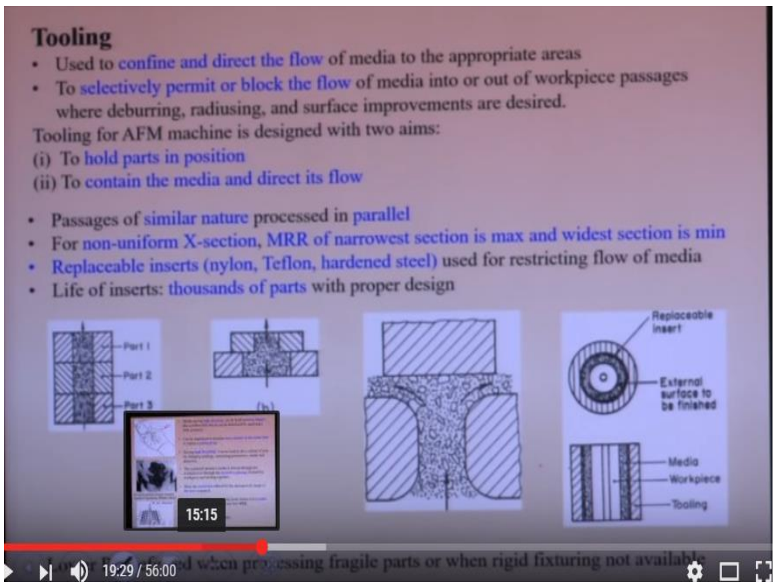

So tooling, this tooling is used I told that it is used to confine and direct the flow of media to the appropriate areas. To selectively permit or block the flow. So you have to selectively permit to flow or you can block the flow. Like you can see here so this media is flowing here so this portion you want to polish and this portion you want to do the radiusing operation. So for doing this radiusing operation you have to flow this media like this, you have to take a right turn. Here also you have to take a left turn. So that is why this is the block is kept, just exit of this hole so that this media can flow right hand or left hand side okay.

So here it can it can remove it can do the radiusing operation there at the corner of this block okay. So this is one of the operation here that can be done by using this AFM operation. So this is the radiusing operation okay. So that is why it is told to selectively permit or block the flow of media into or out of the workpiece passages where deburring, radiusing, and surface improvements are desired.

Tooling for AFM media machine is designed with 2 aims. So tooling for AFM machine is designed with 2 aims. To hold the parts in position okay. So here to hold the parts in position and to contain the media and direct its flow. So tooling is done to contain the media and to direct its flow. So here it is one of the tooling here. So this it is used to flow the media to direct its flow okay.

So passages of similar nature processed in parallel like here this passage this passage and these 3 workpieces, these passages are same. So it can be polished together okay. So that is why passages of similar nature can be polished parallel. For non-uniform cross-section, MRR of the narrowest so here you can see here cross-section is more, here cross-section is less okay.

So here you can expect that non-uniform polishing will be there where cross-section is less and lesser where lesser restriction is there restriction of the flow is there so you will get the lesser material removal rate. So material removal rate at the narrowest section will be less maximum and for the widest section it would be minimum.

So you can use the replaceable inserts like here you can use replaceable inserts are used here okay. So replaceable inserts can be used to restrict the flow of the media. So these inserts may be nylon, Teflon, or hardened steel for restricting the restricting the flow of this media. So life of this inserts can be increased by thousands of parts with proper design okay.

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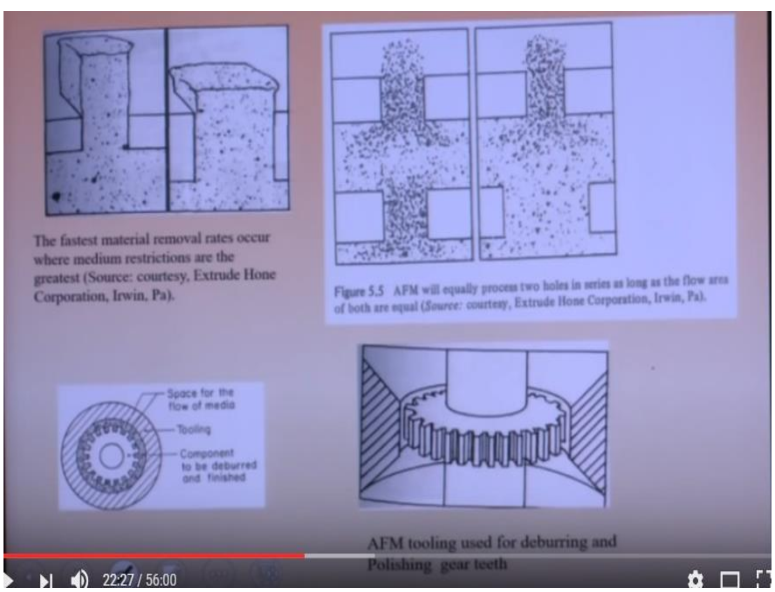

So now you can see this restrictions, so here this small cross-section, here it is the bigger cross-section okay. So we can expect that means higher material removal rate will be here than this material removal rate here okay. So here also lesser restriction here means maximum restrictions are here lesser restrictions are there.

So these kind of gears tooth can be polished by this abrasive flow machining process okay so here outside you have used a cylindrical fixture okay to restrict the flow of the media just outside this cylinder to restrict the flow of this media just outside this gear. So if you reduce the diameter of this cylinder outside this gear okay so in that case it will be more restricted, this flow will be more restricted here okay.

So if we increase the diameter of this cylinder so more lesser restrictions will be there okay. So these gears means outside at the outside you can use the this kind of nylon tooling okay to restrict the media.

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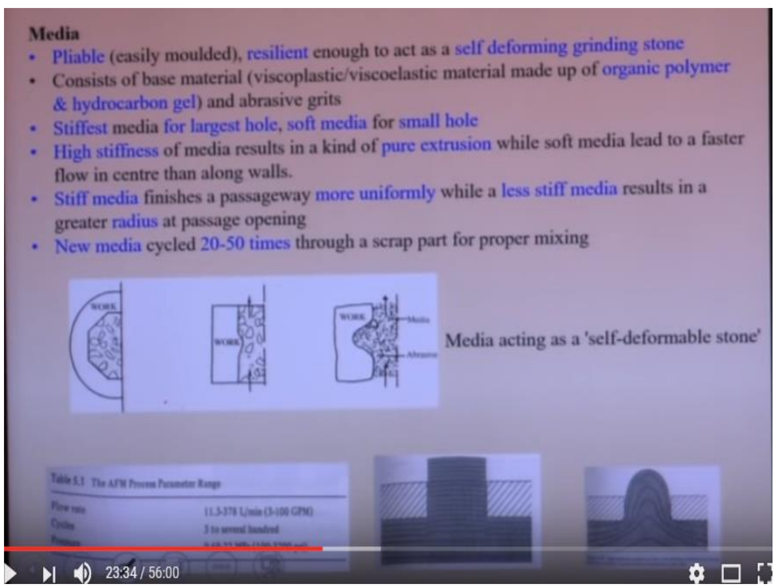

So any kind of complex surfaces can be polished by using this process, abrasive flow machining process. So another thing is that media. So another component of this abrasive flow machining process is the media. So this media is a pliable, easily moulded, it can be moulded easily, it can take the shape of the workpiece surface resilient enough to act as a self-deforming grinding stone. So grinding stone you see you know this grinding stone is used in grinding operation.

This grinding wheel is called the grinding stone but this grinding wheel this whatever stone is used in grinding wheel it cannot be it cannot take the shape of the workpiece surface, but here it is also similar to the grinding stone here but it is self-deformable according to the workpiece surface okay. So that is why it is called self-deformable grinding stone. Same grinding stone polishing media can be it is used similar features but it can take the shape of the workpiece surface to be polished. So that is why it is called self-deforming grinding stone.

So it consists of a base material, this media consists of a base material. So this base media is the viscoelastic or viscoplastic media made up of organic polymer and hydrocarbon gel okay. So now this with this base media you have to add this abrasive particles okay. So you have a base media viscoplastic or viscoelastic base media is there that is hydrocarbon gel and organic polymer is there and with this you have to add within this base media you have to add the abrasive particles to make the media here.

So this abrasive particles has to homogeneously mixed with the media. So stiffest media is used for largest hole. So suppose you want to make the long holes, long holes you have to make, you have to polish okay. So in that case you have to use the stiffest media because stiffest media in that case you can see in this figure if you use the stiffest media so every or at every cross-section this media velocity will be uniform. Uniform media velocity will be there.

So you need a uniform you need a uniform polishing along the length of the hole, along the length of the hole you need a uniform polishing. So stiffest media is used for longer hole okay and soft media used for smaller diameter hole because smaller diameter hole you have to flow the media so you have to use the soft media. Also in that case here you can see at the center velocity is high, high velocity at the center and at the surface there are low velocity but for stiffest media everywhere this velocity profile is constant.

So for making small holes for polishing small holes small means less stiff media is used. So this less stiff media so it has a center velocity is high, at the surface its velocity is less. So this media can flow anywhere. So it can be used for radiusing also. So it can results in a greater radius at a passage opening okay. So whatever this passage opening is there if you generate a greater radius you have to do the radiusing operation, you have to use the soft media.

So you can see here this this kind of surface can be polished by this AFM media. Any kind of surface it will take the shape of the surface to be polished okay.

So high stiff stiffness of the media results in a kind of pure extrusion while soft media lead to a faster flow at the center than along the walls okay. Stiff media finishes the passageway more uniformly while the less stiff media results in a greater radius at the passageway. So now after for making the new media you have to you have to mix this viscoelastic polymeric media with the abrasive particles and you have to move this media over in a scrap, scrap workpieces for 20 to 30 times so that a homogeneous mixture of abrasive particles with the basic base media can be made okay.

So these abrasive particles are different types of abrasive particles are used like aluminium oxide, silicon carbide, then boron carbide, and diamond okay with 8 to 700 mesh size are used.

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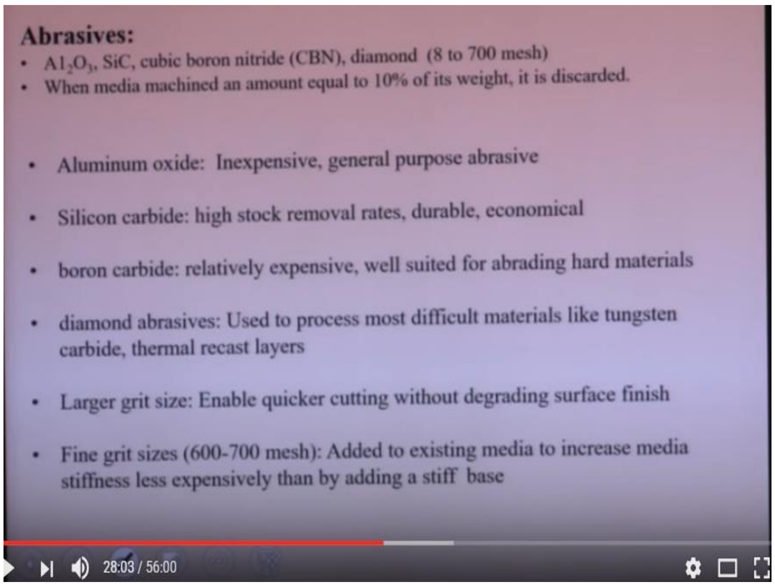

When media is machined an amount of 10% of its weight. Suppose you are doing the machining and your or initially your media weight of this media is suppose 1 kg. Now after machining whatever debris particles are there that will also come into the media okay. So after machining for many components you will see this media weight will increase because whatever debris particles that are also mixing with the media.

After sometime if it happens that this weight of the media has now increased to 1.1 kg now. So it is 10% increase in the weight of this media okay so now this media can be discarded. When this media machine by amount 10% of its weight okay so then in that case it can be discarded.

So other media is aluminium oxide. So this aluminium oxide is inexpensive general purpose abrasive particle it is okay. Silicon carbide it has a high stock removal rate, durable and economical. Boron carbide relatively expensive and well suited for abrading hard materials and diamond abrasives, diamond abrasives are used to process most difficult materials like tungsten carbide, thermal recast layer for because this thermal recast layer and tungsten carbide these are very hard materials, this hard materials can be machined by this diamond abrasive particles.

So larger grit size enable quicker cutting without degrading the surface finish and finer grit size 600 to 700 mesh are added to existing media to increase the media stiffness less expensively than by adding a stiff media okay.

So stiffest media can be machined with the same basic so means for making the stiffest media what is the concept is that you have to use the base media or viscoelastic media should be stiffer but if you have a same media there okay so in that case this in that case what you can do you can add more concentration of this abrasive particles in that case it can be considered as a stiffer media.

So this ex-student they have started this machining process, abrasive flow finishing process. It is extensively used in industry for polishing complex surfaces, complex geometries okay irrespective of their magnetic or nonmagnetic property of the workpieces, any kind of workpieces they are polishing okay.

So this media actually very costly because it is patented and it cost around 5 lakhs per kg. So it is a very costly media but you can use a in your own media so many researchers they developed then alternative solution for this AFM media okay so you can use that kind of media and it can give almost similar efficiency okay.

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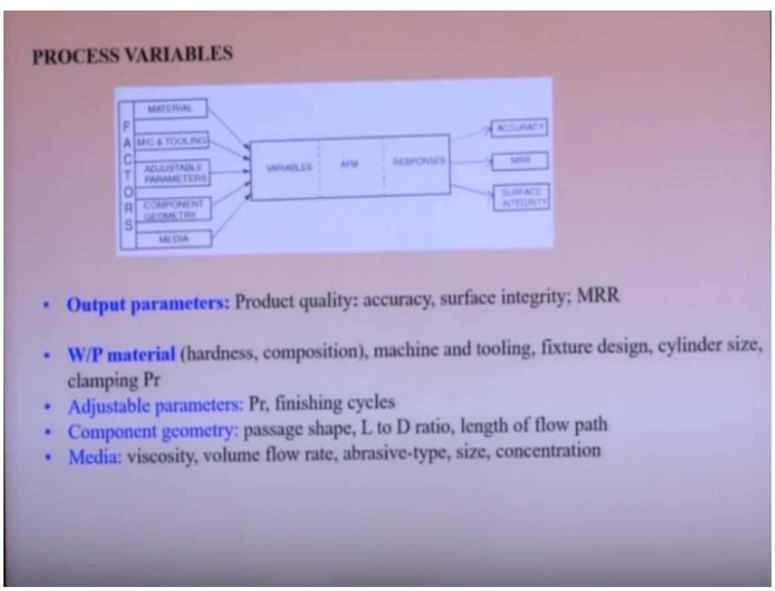

So these are the different process parameters of the abrasive flow machining process. So what are the output parameters? Output parameters obviously that is material removal rate, how much material removal you are getting and also surface integrity. So this surface integrity it consist of surface accuracy, tolerances, and then surface roughness, subsurface damage, all these things actually comes into the surface integrity. So these are the output parameters.

What are the different input parameters? Input parameters you can see workpiece hardness. So hardness and composition of this workpiece material okay now machining and tooling what kind of machining you are doing and what kind of tooling you are doing you are making and then fixture designs, cylinder size, clamping pressure all these are actually workpiece material input parameters for workpiece material.

Then adjustable parameters you can control the pressure so you can increase or decrease the pressure and you can control the finishing cycles or finishing stroke. So one cycle means top media cylinder to the bottom media cylinder and then from bottom media cylinder it will come to the top media cylinder then it will consist of a one cycle. One stroke means from top media cylinder to the bottom media cylinder it will consist of one stroke okay. So 2 strokes consist of 1 cycle. Now component geometry that passage shape l by d ratio length by length to diameter ratio and length of flow path all these are actually component geometry and media what are the different parameters of this media, medium viscosity.

You can use more viscose media, medium viscose media okay so different kinds of media or high viscose media also you can use, different kinds of media based on your requirement you can use different kinds of media. Volume flow rate of this media also one of the among another parameter. Then abrasive type is another parameter and abrasive concentrations also another parameter. So generally 60-66 % concentration of abrasive particles are used in case of abrasive flow machining process.

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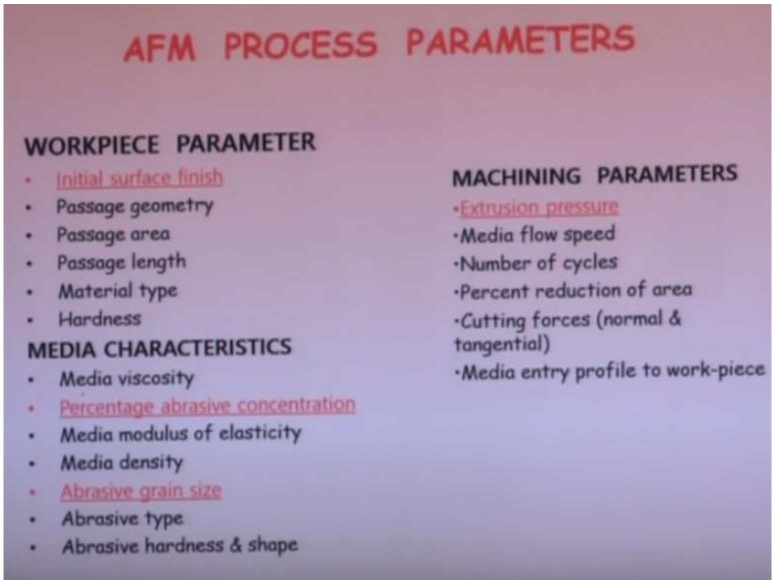

So these are the again different process parameters. Now you can see workpiece parameters are initial surface roughness of this workpiece, it also matters. So if it is very high highly rough surface okay so then you will not get that much efficiency because it is not a bulk material removal process. It is a polishing process and small small chips are generated okay. So initial surface roughness of the workpiece also matters. Passage geometry also matters. How this passage we have generated by using the tool. Passage area, passage length, material type, hardness all these are the workpiece parameters.

Media characteristics like media viscosity. So viscosity of this polishing media is the main thing okay. So by changing this media you can use same means for different hardness of this workpiece material you have to change the rheological properties of this media okay. So you have to change the rheological properties of this media by changing the viscosity of this media okay means by changing the rheological properties of this media okay or that is by changing the viscosity of this media you can polish different hardness of the workpiece, different workpiece with different hardness okay.

So media characteristics, media viscosity, percentage of abrasive concentration, media modulus of elasticity, media density, abrasive grain size, abrasive type, abrasive hardness and shape. Machining parameters are main parameters, extrusion pressure, and finishing cycles. Media flow rate, percentage reduction in surface roughness, cutting force normal and tangential cutting forces, media entry profile to workpiece. These are the different machining parameters are there okay.

So William and Rajurkar in USA they did extensive research on this abrasive flow machining process. There they have used 3 kinds of media okay. So at the middle you can see that they have used 3 kinds of media. One is the low viscous media, second one is the medium viscose media, and third one is the medium high viscose media. So first one is the low viscose, medium viscose, and medium high viscose media, 3 types of media they have used and they had measured the mean material removal rate okay.

So what are the material removal rate there. So these material removal rate it is a linear material removal rate they have considered okay linear material removal rate it is not a volumetric material removal rate. This linear material removal rate is here inch per second okay inch per second they have considered as the output parameter.

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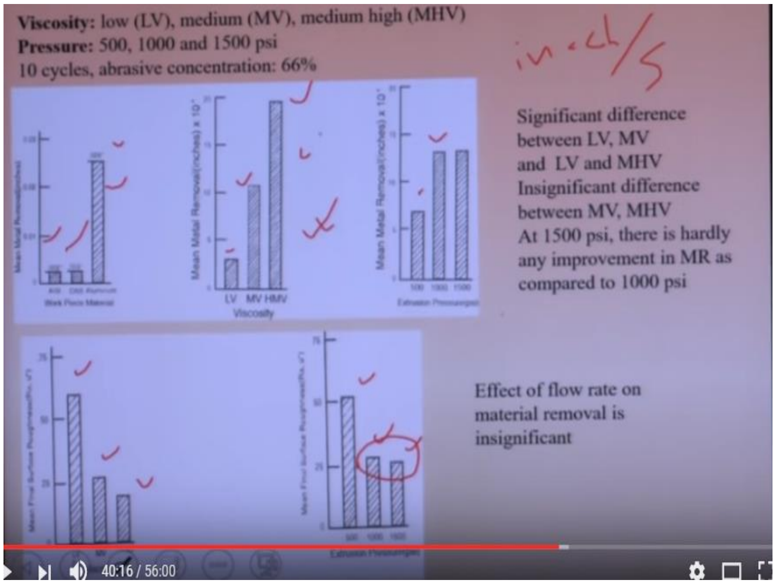

Now they have seen that there is a significant difference between linear low viscose media and medium viscose media and low viscose media and high viscose media. So you can see low viscose media there is a very less material removal rate but medium viscose media you can see when you are increasing the viscosity of this media your material removal rate increases and when you are going for high medium high viscose media still it is increasing. So you can conclude that with the increase in the viscosity of this media your material removal rate also increases, material removal rate increases okay.

So there is a significant difference between low viscose media and medium viscose media and low viscose media and medium high viscose media okay and there is hardly any improvement in medium viscose media and high viscose media okay. So as so all these experiments are conducted at or conducted at 1500 psi pressure okay so and this 10 cycles they are considered for this experiments and abrasive concentration is 66 percent they have considered and you can see they did experiments at different pressure 500 psi pascals per square inch, 1000 psi and 1500 psi they have considered, 3 pressures they have considered and you can see with the increase in pressure from 500 psi to 1000 psi you can see there is a significant increase in the material removal rate but when you are going for 1000 to 1500 psi pascals per square inch pressure psi pressure so there is hardly any improvement from 1000 psi to 1500 psi.

So you can con you can say that here this maximum or optimum pressure here is 1000 psi because beyond 1000 psi you are not getting any improvement into the material removal rate and here also they considered 3 different kinds of material okay, AISI, CRS, and aluminium so here from harder to, harder to softer material they have considered. So aluminium as it is a very soft material you can see its material removal rate is very high but for this AISI and CRS these 2 kinds of material you can see their material removal rate is not that much high okay. So now they have considered final surface finish or means final surface finish how much improvement in surface finish they have achieved.

So you can see with low viscose media you can see there is surface roughness final surface roughness is not that much good but with the increase in the medium viscosity they can see from medium viscosity to the high medium viscosity you can see final surface roughness of the workpiece actually decreases okay.

So this final surface roughness of the workpiece decreases. So this medium viscosity has a role on the surface finish as well as material removal rate okay. So now if you want to do the machine polishing on a harder material obviously we shall go for harder means we shall go for this higher viscosity of this media and when you are polishing the softer material like brass and aluminium then we shall go lower viscosity of this media and also you can see here with the 500 psi pressure with the 500 psi pascals per square inch pressure you can see here your final surface roughness is not that much good but at 1000 and 1500 pressure you can see your final surface roughness improves okay your final surface roughness improves with 1000 and 1500 pressure.

So also there is very hardly any improvement within this 1000 and 1500 psi pressure there is hardly any improvement but also effect of flow rate on material removal is insignificant. So now this active grain density is a very important parameter in case of abrasive flow finishing process.

So active grain density you have to see how many abrasive particles are there in a square millimeter area okay. So this active grain density counted over the surface of the media by bringing through the optical microscope you consider a 1 by 1 millimeter square area okay so this abrasive particles active grains these abrasive particles actually at the surface of the media it only takes part during the collision process. So you have to count this one for numerical simulation okay and we will get the idea from experience also how many active grains are there. Based on that your performance of the process will be improved.

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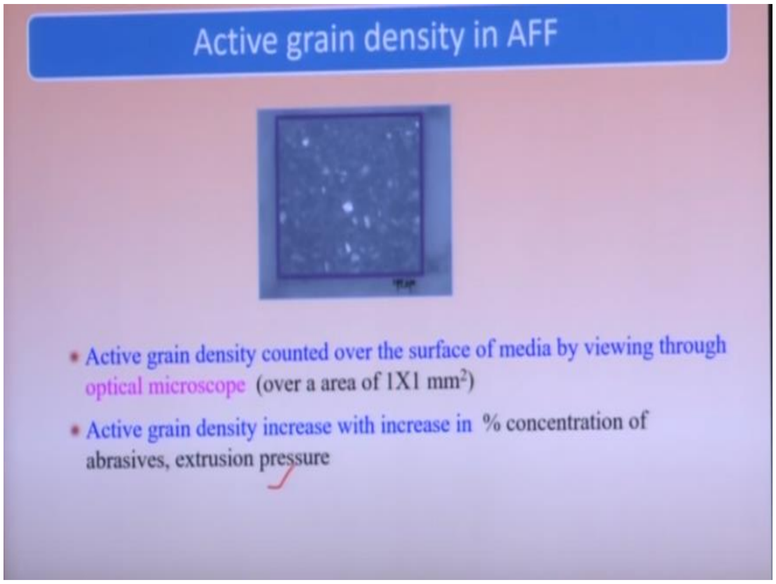

So if active grain density is less we have to increase the concentration of this abrasive particles so that this active grain density can be increased. So it can increase, this active grain density can be increased with the increase in the percentage concentration of the abrasive particles. Also increasing the extrusion pressure also your active grain density can be increased okay.

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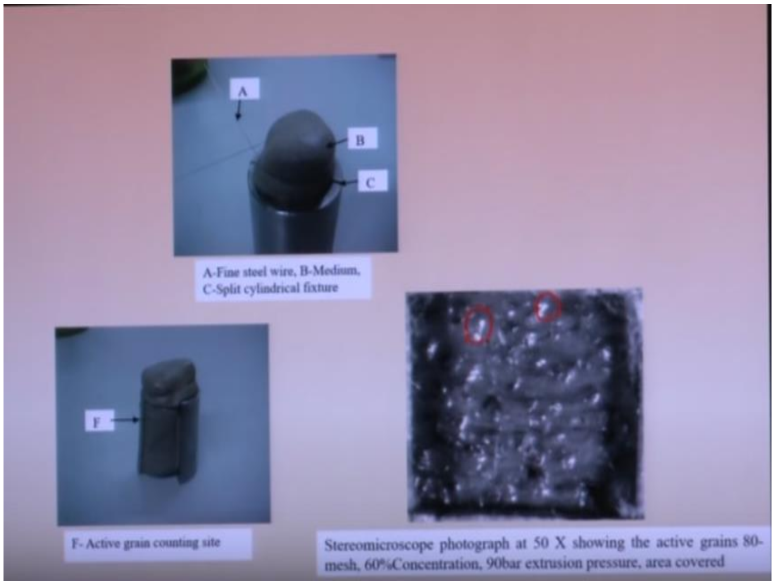

So here you can see this is the media here okay. So this media you can see under microscope. So these are the white spots. This white spots actually these are the abrasive particles okay. It is shown under 50 X optical microscope okay.

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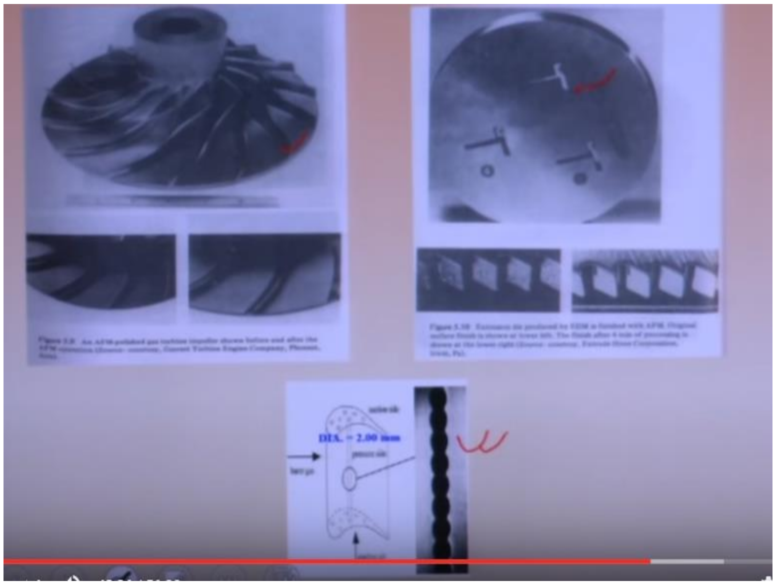

So now come to this applications parts. We can see this kind of turbine blades can be polished because after machining this turbine blades you will see different kinds of bars are there. Also machine because of machined by this different kinds of machining processes are used so you can see bars are there also you can see the non-uniform polishing.

So after doing this after machining by other process you can do the polishing operation by abrasive flow finishing process this kind of complex shapes can be polished by AFM process okay. So extrusion dye you can see here extrusion dye, these dies can be polished by AFM process and in turbine blades there are cooling channels are there so these cooling channels are non-uniform cross-sections and this kind of cooling channels are there. So these cooling channels also can be polished by abrasive flow finishing process.

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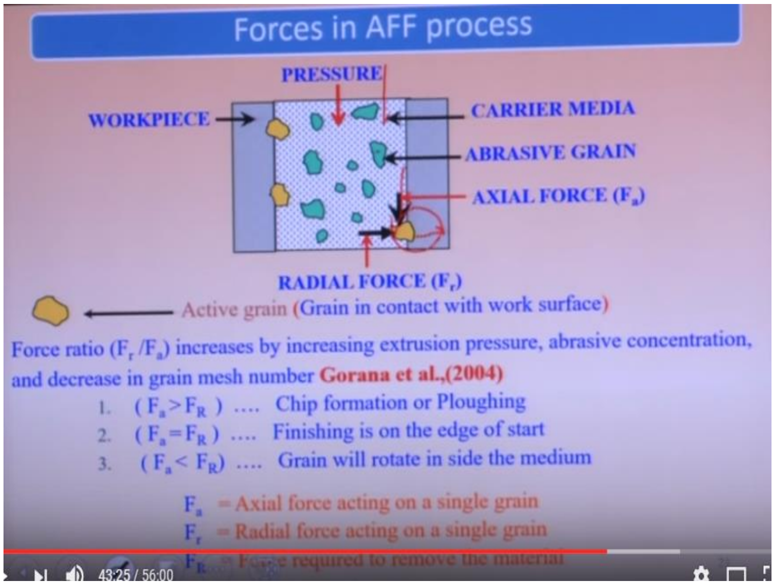

So what are the different forces are there in abrasive flow finishing process? So you can see that this media is flowing through this cylinder okay. So these are the abrasive particles are there. These abrasive particles it is indented into the workpiece surface and this indented workpiece it is moving towards the because of this axial force these indented abrasive particles are doing surface undulations from the workpiece surface okay.

So there are 2 forces are there, one is the radial force. This is the radial force Fr okay F small r radial force and this is axial force. This is the reciprocating motion. This is the axial force Fa is there okay and also there is a resistant force F R capital F suffix capital R okay. This resistance force is there. So it is based on the hardness of the workpiece material okay.

So when this abrasive particles is indented because of this indentation force this axial force actually it will try to remove the surface undulations okay. So this force ratio of Fr by Fa increases by increasing the extrusion pressure abrasive concentration and it decreases in grain mesh number okay. So it is proposed by Khurana et al in 2004 and there are 3 different conditions are there.

When axial force is greater than this axial force is greater than this resistance offered by the process by the media resistance offered by the workpiece okay then there is a chip formation or ploughing operation is going on and when this axial force is just equal to the resistance offered by the material in that case just finishing is at the edge of to start and when this axial force is less than your resistance offered by the offered by the workpiece material grain will rotate inside the medium okay. So there will not be any polishing in that case.

So classification of AFM process there are 3 different classifications are there. One-way AFM process, two-way AFM process, and orbital AFM process. So this is one-way AFM. We shall discuss later in the next slide. It is partially through cavity. Two-way AFM, it is through cavity and orbital AFM it is for used for blind cavity.

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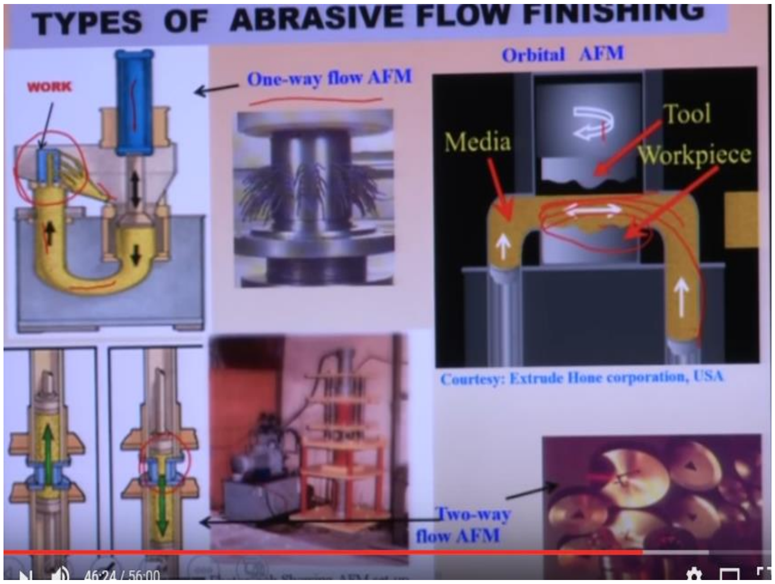

So types of AFM you can see here this is this is the zone of the workpiece here. So here small holes are there okay. So you can do the you cannot do the reciprocating motion here. So this media is flown through this media cylinder. Now it is flowing through this kind of fixturing arrangement. Now it is this media is going outside here.

So this is the one-way AFM process. Like this kind of holes, small holes on the cylindrical surface. So you can polish by this one-way AFM process. This top surface actually it is blocked. So one entry one exit is there for the media to flow through this small holes. So this kind of holes can be polished by one-way AFM process.

So this is the two-way AFM process. There is a through hole is there in this workpiece. By two-way AFM process it can be polished and this is the orbital polishing process. Here you can see this is the workpiece surface. Top of the workpiece surface there is a complex shape is there. So this complex shape can be polished by this kind of orbital polishing process.

So here this is the media cylinder, media piston, another media piston is here. So it will move here. So this kind of reciprocating, this kind of motions are given. So this kind of motions are given so that this media can polish the top surface of this workpiece. So this is called orbital polishing process and here at the top surface actually one tool actually it is rotated. This tool surface is actually it is the shape of the workpiece surface similar to the shape of the workpiece surface so that uniform pressure can be generated on the media okay.

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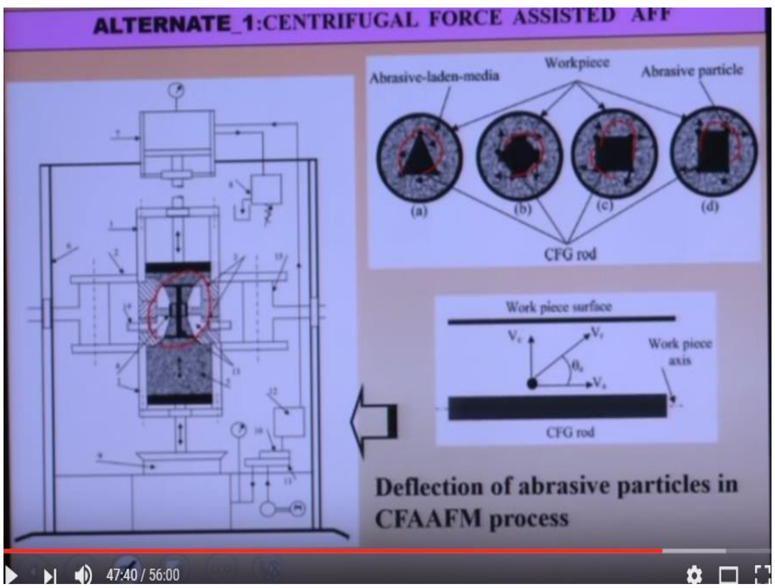

So how to enhance the performance of this abrasive flow finishing process? To enhance the different researchers actually they developed different process to enhance the performance of this abrasive flow finishing process. So this is actually centrifugal assisted abrasive flow finishing process here okay. So here you can see this is the workpiece here. At this workpiece at the center actually there is a centrifugal rod. So here you can see cross-section of this workpiece here.

So this kind of triangular rod, this is the (()) (47:01) rod, this kind of square rod, this kind of rectangular rod actually they are they are kept there. This is the cross-section of this rod and these rods actually it rotates with a certain rpm. So this CFT centrifugal force rods actually rotates with a certain rpm and media at the same time this kind of reciprocating motions are given. So because of this actually the centrifugal force of this rod what happens this tangential force are generated. This tangential force actually acts to remove the surface to enhance the surface to enhance to remove the surface undulations from the workpiece surface okay.

So you can see this tangential force is generated which helps in removing surface undulations.

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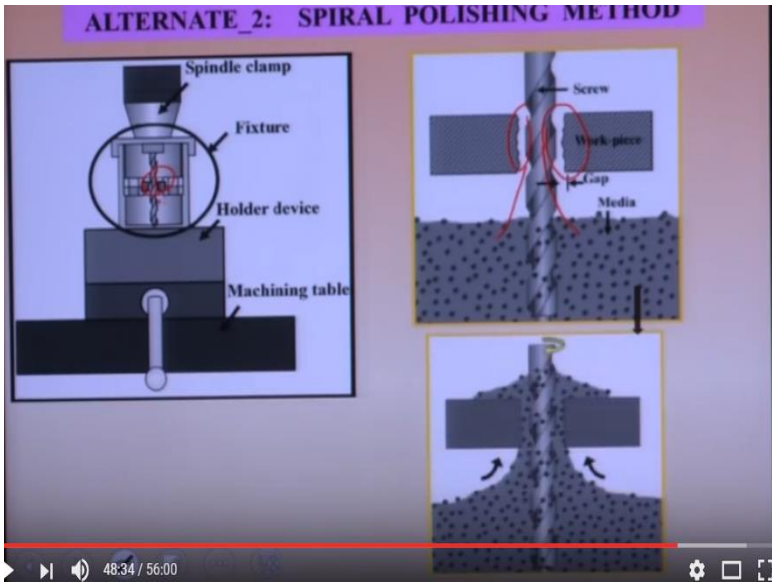

This is the one kind of spiral polishing process here. You can see this is the workpiece here and one spiral tool is actually used like our drilling tool where this spiral grooves are there. So first this bottom media, bottom cylinder actually it is filled up with the media. When you are rotating, this media will flow through the spiral grooves in between this workpiece fixture and the tool. So this is the workpiece here. In between the gap it will flow and it will come to the top media then again you can move to the bottom media by rotating in reverse direction.

So in that way internal surface of the workpiece can be polished okay. So this is the actual exxagerated view. Here in this zone when media is flowing here so flowing here at the internal surface of this workpiece can be polished okay. So this is you can see here.

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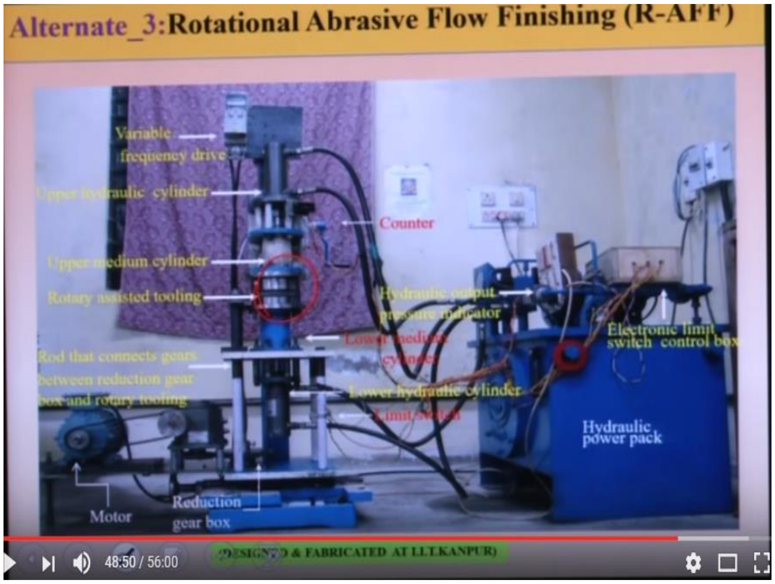

Another thing is that actually you can rotate the media here by an external means. So this is called rotational abrasive flow finishing process. You can rotate this media itself. So here whatever workpiece fixture workpiece tool is there that can be rotated by an external means okay.

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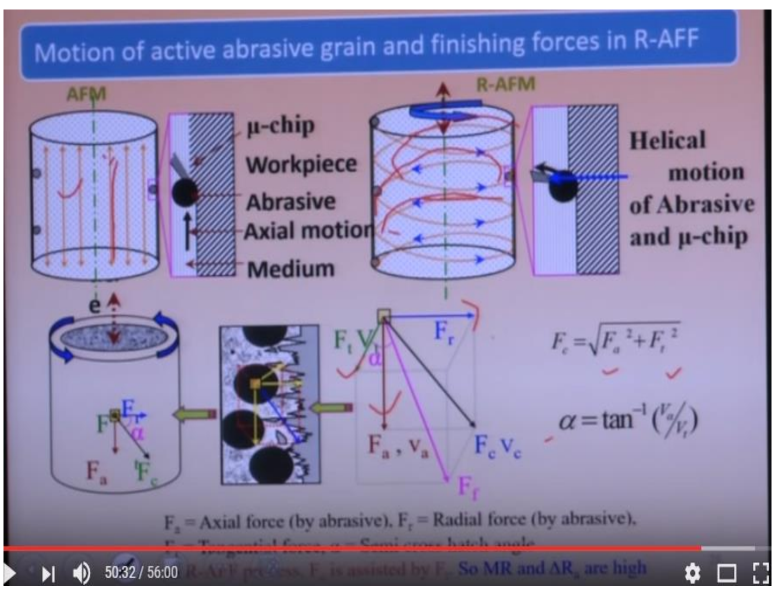

You can see what are the forces are there. This radial force is there because you are flowing you are giving reciprocal motion radial force is there and this axial force is there and this tangential force or coriolis tangential or coriolis force is added here. This coriolis force actually this coriolis force it is generated because of this rotation of this media okay. So this tangential force will helps in cutting the surface undulations.

So now you can see in normal AFM process this media will flow in the linear direction, but here in this case of rotational AFM process this media flows in a spiral path this kind of it flows in a spiral path okay. So as it is flowing through a spiral path okay so it will generate crosses as pattern into the workpiece surface.

So this crosses patterns are generated on the workpiece surface so this is actually helpful to retain the oil during this is helpful to retain the oil during your during your actual polishing of this cylinder, cylinder piston cylinders or cylinders of the engine or the engine cylinder and also it is taking more path.

So it is traversing more path okay so that is why more area are actually covered. So it is not covered because this abrasive particles are covered in a straight line path so it is not covered more area but in this case in R-AFM process it is covering more path okay.

So now we can see total cutting force is the axial force and (()) (50:28) force and tangential force and it is the alpha is the helix angle here.

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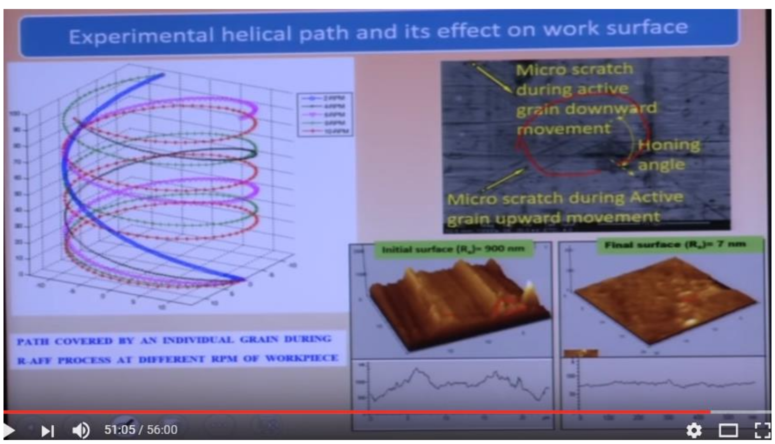

So it can it can move a so based on your actually rotational speed and also axial motion of this media so this helical path can be varied okay. So this kind of process patterns you can see here, these kind of process patterns are generated on the workpiece surface. So AFM picture also you can see. Before polishing actually this kind of surface undulations which is grinded surface, surface undulations are there. After AFM process whatever this surface undulations are there actually it is totally removed.

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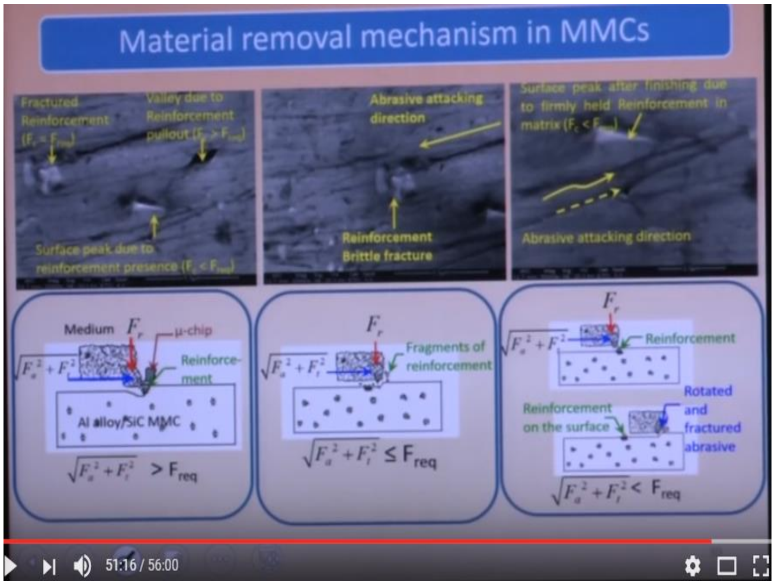

So AFM by MMC means metal matrix composites also can be polished by abrasive flow finishing process okay.

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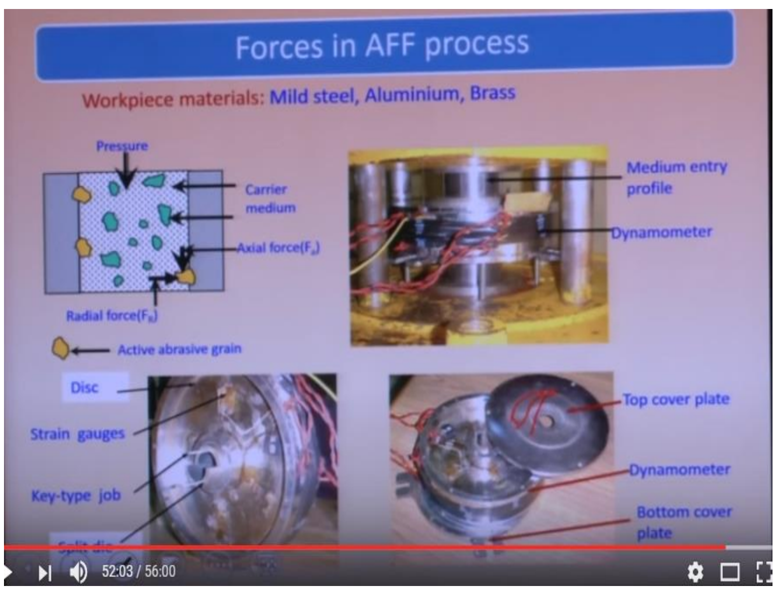

Okay so forces also you can measure, what are the forces are there. So you can use the strain gauges. So this plate actually attached in the fixture okay. At the top surface actually we can use 8 strain gauges at the top and bottom surface we can use the 8 strain gauges so by the deflection of this strain gauges you can measure the how much force in the how much how much this axial force is there and also at the surface also we can put the strain gauges okay like in drilling operation okay so by this movement or by tension and compression of this strain gauges okay you can calculate the what are the radial forces are there. So it can be measured experimentally, this forces, radial force and axial forces.

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So you can see here one applications this at the surface of the cylinder you can see so many holes are there. That holes can be polished by this AFM media okay.

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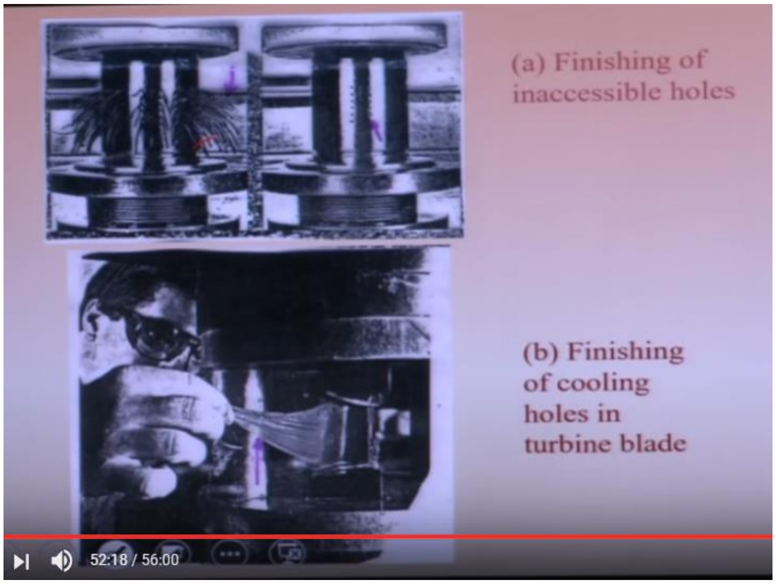

So same thing here. So many holes, thousands of holes can be polished, external holes can be polished by this AFM media.

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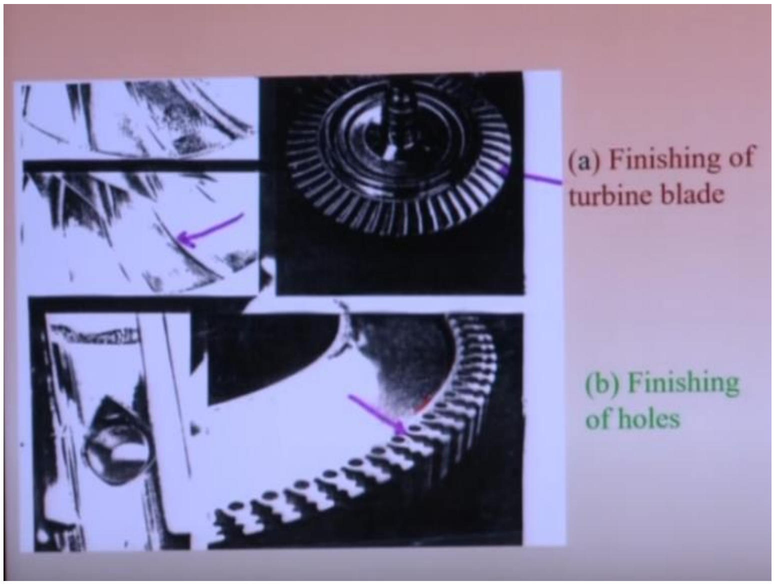

So this kind of turbine blades can be polished by this AFM media. This kind of small holes can be polished by this finishing holes can be polished by AFM media.

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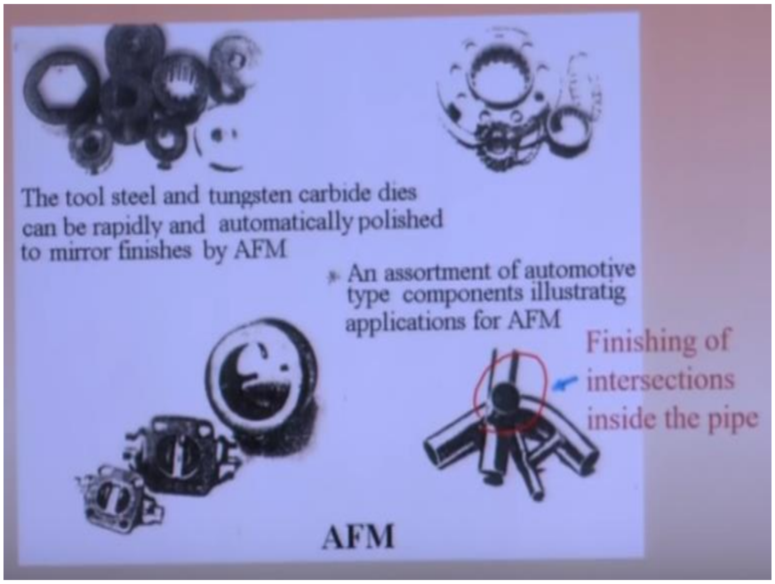

So I told initially that this kind of intersections of this holes here so many holes are actually pipes are actually connected here. Here you can see it is not a smooth at the intersection of this tools. Thus intersection of this tools can be polished by the abrasive flow finishing process, this kind of small components can be polished by AFM process.

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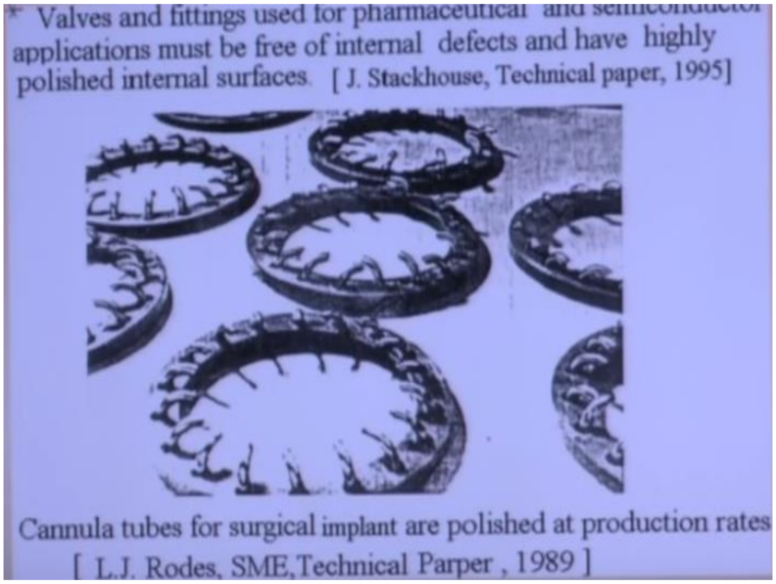

So this medical parts also should be bars free it should be highly polished, this medical parts. So this heart valves actually it is polished by abrasive flow finishing process okay.

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So like this so many applications are there for this abrasive flow finishing process.

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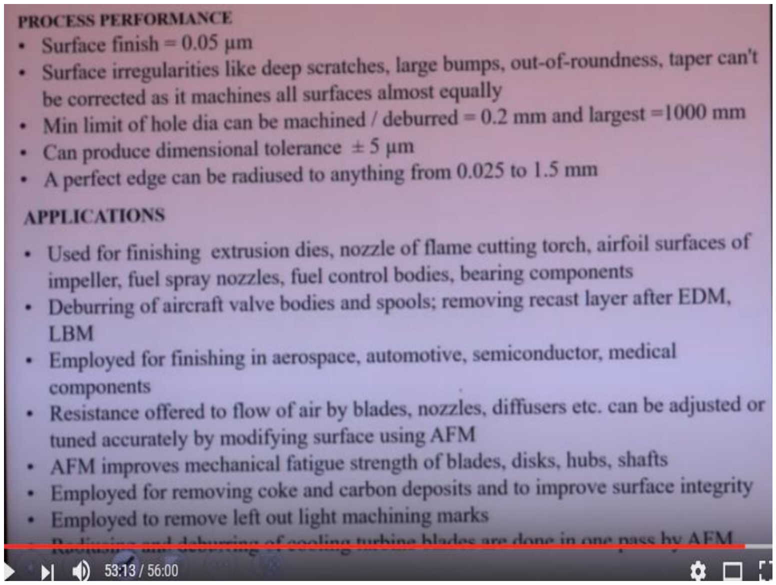

So what is the process performance? As much as actually nanometer level surface finish can be achieved you can see 50 nanometer up to 50 nanometer surface roughness can be achieved. Surface irregularities like deep scratches, large bumps, out-of-roundness cannot be taper cannot be polished by this process because here polishing is done uniformly everywhere so that is why out-of-roundness all these things can be corrected properly by this AFM process.

Maximum limit diameter of the hole that can be polished, minimum diameter of the hole that can be polished is 0.2 mm and largest diameter is 1000 mm. Can produce dimensional tolerance plus minus 5 micron. A perfect edge can be radiused to anything from 0.25 - 1.5 mm.

So applications used for finishing extrusion dies, nozzle or flame cutting torch, airfoil surfaces of impeller, fuel spray nozzles, fuel control bodies, bearing components. Deburring of aircraft valve bodies, spools, removing of recast layer after EDM, LBM. Employed for finishing in aerospace, automobile, semiconductor, medical components. Resistance offered to flow the air by blades, nozzles, diffusers, etc. can be adjusted or tuned accurately by modifying surface using AFM process.

AFM improves mechanical fatigue strength of blades, disks, hubs, and shafts. Employed for removing coke and carbon deposition and to improve the surface integrity. Employed for remove for removing left out light machining marks and for radiusing and deburring of the cooling turbine blades are done by one pass of abrasive flow finishing process okay.

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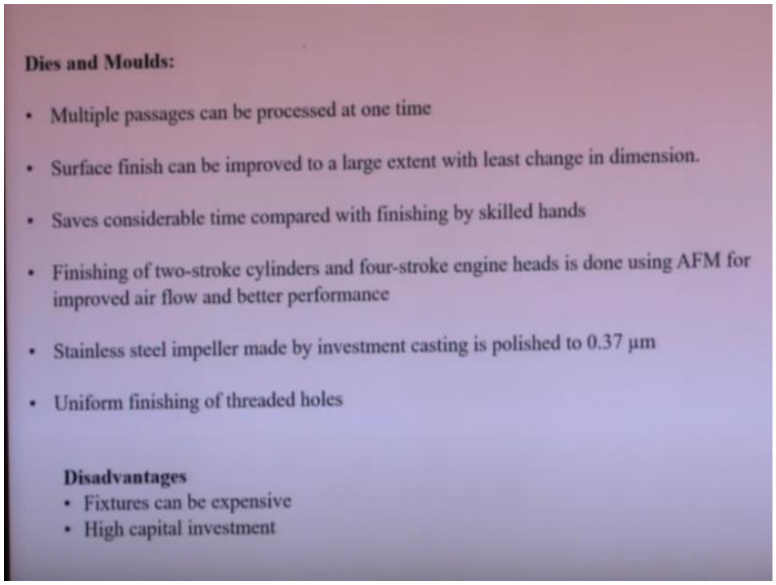

So dies and it is mostly used in dies and mould industries. Multiple passages can be processed at one time. Surface finish can be improved to a large extent with least change in dimension. Saves considerable time compared with the finishing with skilled hands. Finishing of two-stroke cylinders and four-stroke engine heads is done using AFM for improving air flow and better performance. Stainless steel impeller made by investment casting is polished by up to 0.37 micron. Uniform finishing of threaded holes are there. Disadvantage, fixtures can be expensive and high capital investment is there okay. So thank you.

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