Introduction to Abrasive Machining and Finishing processes

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Lecture - 20
Abrasive Flow Finishing: Part 1

Today we are going to study about Advanced Abrasive Finishing Processes, where in this is a particular sector of the abrasive processes where you will see the advance versions and you will do the finishing of a complex surfaces as well as the simple surfaces also, ok. So, what is the need of advanced finishing processes?

So, conventional finishing processes such as grinding, honing, super finishing, lapping, these are all you have seen and we move on to the advanced machining processes where the MRR or the material removal is the primary criteria. Now, we move on to the advanced finishing processes where our primary criteria is to finish to the nano level of simple to complex geometries.

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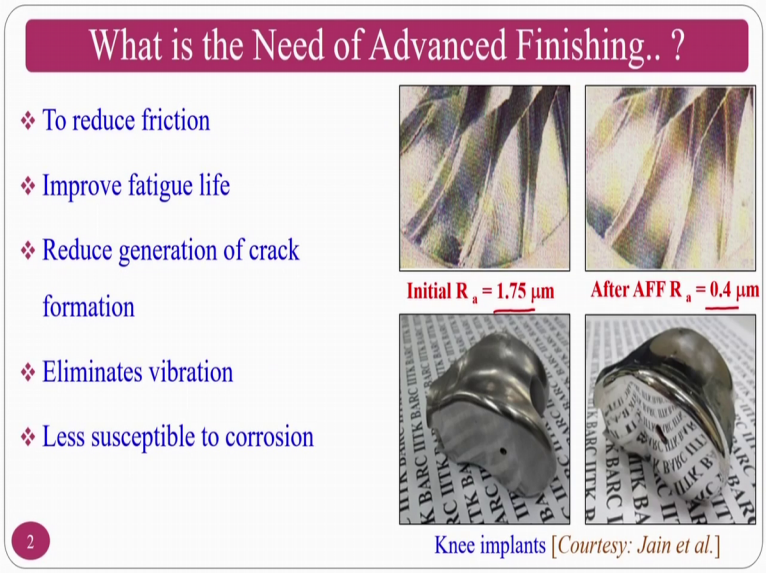

So, what is a need to reduce the friction it means that if you are going to get the micro to nano surface finish or you can reduce the friction improve the fatigue life.

If your surface is very rough, what will happen the fatigue life is very low because assume that you have a shaft and the bush. If your bush is too rough, what will happen

shaft will locate on the peaks of the bush surface roughness and whenever you are rotating with high speed, what will happen is these peaks will burn each or these peaks will shear off. Then, what will happen is there will be a eccentricity generation and the fatigue life or the other life of that system will collapse, reduce the generation of crack formation. If surface roughness is low, it can reduce the generation of the crack formation if the formation.

If you are using a some practical conditions, what will happen is the surface roughness will start initiating some other cracks. So, if you go for nano finishing, so this possibility will go down. So, it eliminates the vibration. If there is a rough, too rough surface, there will be always chances for some vibrations in the system less susceptible to corrosion. If the surface peaks is like this, what will happen whenever you have a flow of certain fluid what will happen the values will accumulate all the liquid. So, this will initiate the corrosion and other things, ok.

So, the advanced abrasive of finishing process what all the other advantages is that you can do the finishing for the complex surfaces also. This is a small turbine or impeller to be finished. So, initial surface roughness is 1.75 and final is 0.4 microns, ok. There is most important thing is that achieving, you can achieve by the hand lapping also, but at the same time automation is always good. So, advanced finishing processes with computer numerical control system and other things, it will be always be good, ok.

So, one can do also finish the neem plants by advanced finishing process. Not only abrasive finishing process, you can do this finishing process by MRF that is Magneto Rheological Finishing and other things. So, in particularly this particular section deals with polymer assisted abrasive flow finishing processes as well as magneto rheological finishing processes and their what are the advantages and limitations of the polymer rheological abrasive flow fluids as well as magnetic rheological abrasive flow fluids, we will see these things in deep in this particular section of the course.

So, we will move on to the first process that is called abrasive flow machining process or abrasive flow finishing process. Initially this particular process is called abrasive flow machining process because this particular process is used for deburring applications in complex features. Assume that there is a junction of 2 holes or multiple holes at the junction, where the internal holes 2 holes or 3 holes internally then if at all there is a burn

generation, it is too difficult for any particular person to remove that one. For that purpose the semi solid type of tools are developed and just extrude across that section.

So, it will deburr that that deburring is nothing, but the machining operation. That is why this particular process when it maintained in 1960s, so it is called as abrasive flow machining process. Gradually people are using it for the finishing application. That is why this process is also called as abrasive flow finishing process.

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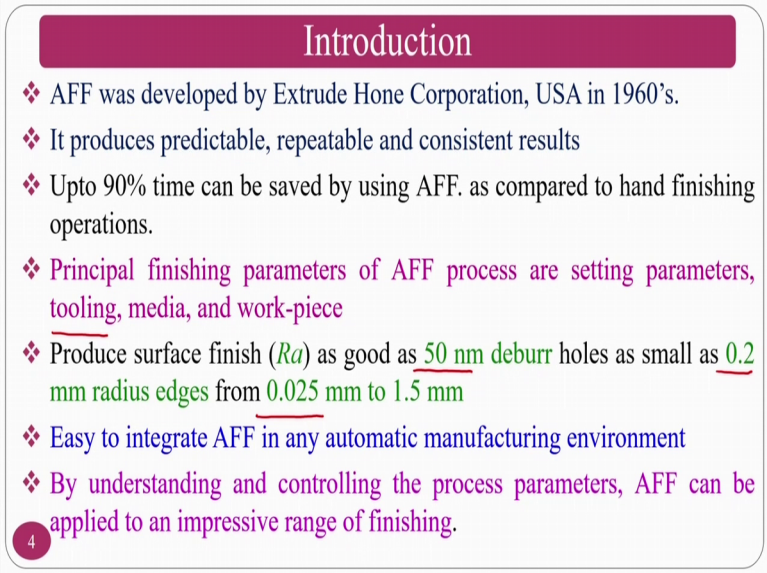

So, introduction to abrasive flow finishing process, abrasive flow finishing was developed by Extrude Hone Corporation in 1960s in USA. It produces the predictable, repeatable and consistent reasons because this has that ability to abrade across the sections uniformly.

So, up to 90 percent time can be saved by using AFF compared to the hand finishing operations. Hand finishing operations are not controlled by the automation. So, the same time to get the uniform surface finish, you need well equipped at the same time well experienced operators, but in abrasive flow finishing you can go ahead with the automation and you can do this particular process. Principle finishing parameters of AFF are setting parameters. That is nothing, but the input parameters like extrusion pressure, number of cycles and other things tooling. So, tooling is nothing, but how to hold the different work pieces medium, that is abrasive medium or media says that plural.

So, you can go for styling based polymers, you can go for silicone based polymers and work piece parameters such as initial surface, roughness produced surface, it can produce surface finish as good as 50 nano meter and deburr holes as small as 0.2 mm radius and edges of 0.25 mm to 1.5 mm. It can do the easy to navigate AFM to any Automatic Manufacturing Environment. At the same time understanding and controlling the process parameters AFF can be applied to impressive range of a finishing process. That means that you can apply based on your requirement to any particular finishing applications.

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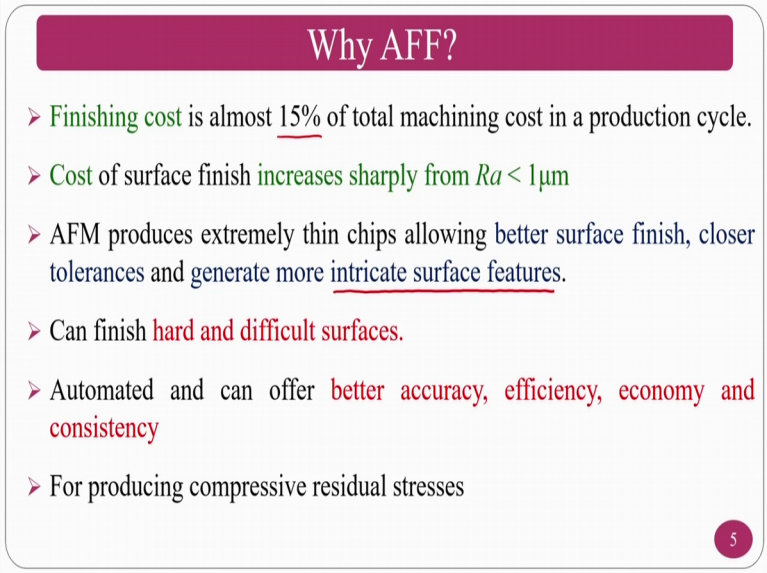

So, normally in a finishing operation, basically the finishing operation will be a final operation in particularly to any type of component manufacture. 15 percent of the production cost will always incurred in the finishing operation. The cost of surface finishing create sharply from less than 0.1 micron. That means that if for the requirement of surface finish is mandatory for a particular component, then the surface roughness is inversely proportional to the cost. That means that if your surface requirement is nano meters, your cost of the product escalate very high.

So, that means that if the roughness requirements are low, then your cost of the product will goes up. So, abrasive flow finishing or the abrasive flow machining produces extremely thin chips allowing the better surface, finish closer tolerances and generate more intricate surface features also. That means that predominant texting also people have observed, it can finish hard and difficult surfaces like whenever if you want to

finish the hard materials or hard steels, you can do it. At the same time automated can offer better accuracy, efficiency and economy and consistency for producing compressive residual stresses also.

This particle process will be used. That means that whenever you are using reciprocating the medium across the work piece, that picture you will see in upcoming slides. What will happen there will be a possibility of compressive residual stresses generation. Some of the papers on abrasive flow finishing also reported that the compressive residual stresses are observed. If the compressive residual stresses are there, it is always good to apply into the practical conditions.

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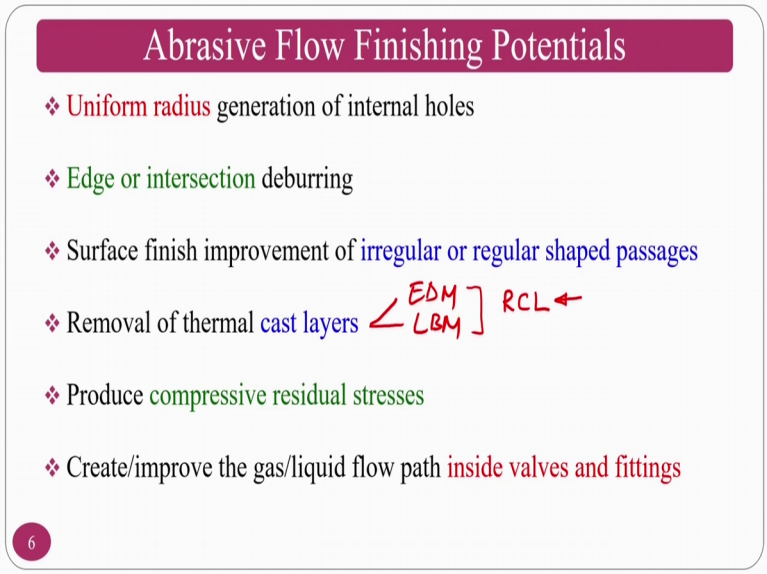

If you see the abrasive flow finishing process, potentials uniform radius generation on internal holes can be achieved edge or intersection deburring. That is what I said. Whenever you have an intersection of 2 holes internally, then deburring at that location is completely a difficult task for a conventional finishing process. For this particular process, it will be easy because you are going to use a liquid to semi-solid type of tool, ok. How to fabricate or how to design this type of a liquid based tool and other things, we will touch some of the introductions.

Surface improvement of irregular and regular shape passages can be achieved and removal of thermal cast layers that is whenever you have done the process like EDM or Laser Beam Machining, this type of thermal processing whenever you do what will

happen is re-cast layer will be formed. That we have seen in the previous classes. This re-cast layer is not good for practical application because it is a brittle layer at the same time thermal cracks will be there.

So, whenever you use into the practical condition, this particular re-cast layer will go off leaving the eccentricity and causing lot of noise and other things. That is why it has to be removed before you are going to put into the practical applications produces compressive residual stress which we have seen and this is good for the practical application at the same time create or improve liquid flow path inside the walls and fittings.

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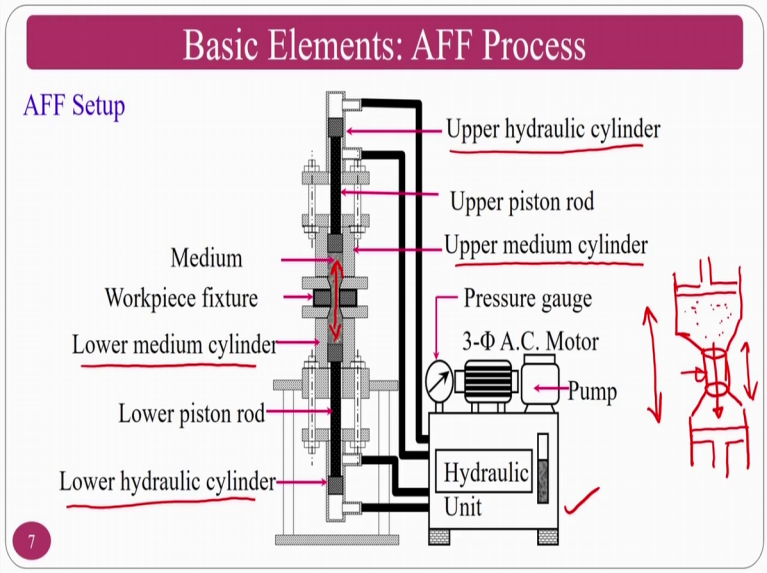

That means that it can we be used for fuel injector nozzles and others. Wherever the fluid flow is most important and fluid flow which is to be controlled or controlled fluid flow is required, there you can do the surfaces to the nano scale and you can achieve a better surface.

If you see AFF process as such you have lot of elements and individual elements, we will see in the upcoming slides this is how the AFF process looks like or abrasive flow finishing process looks like. Hydraulic unit basically hydraulic unit is connected to the lower hydraulic cylinder at the same time upper hydraulic cylinder because there will be a hydraulic fluid to actuate the upper and lower hydraulic cylinders, so that the pistons will move. You can see lower medium cylinder and upper medium cylinder. These are the most important things as you can see in the next slide also. What will happen is, you

have a medium cylinder like this, this is your workpiece. Assume that this is a workpiece, these are the piston. What it will do is this is a workpiece, this is a medium cylinder, you just have to fill the medium here and this will these two pistons will reciprocate like this. That means that the medium which is there in the upper medium cylinder will try to pass through this one and reaches to the lower medium cylinder. Whenever it is reaching the lower piston will go back to accommodate all the medium and to and fro. What will happen in this way if you start reciprocating the medium, what will happen the internal hole or the inner walls of this particular cylinder workpiece will be finished ok, so that you can see here this is the upper medium cylinder where the medium is there and lower medium cylinder. The main function is the medium has to reciprocate in this direction, this is the medium on which I am writing the arrow. This medium has to reciprocate, so that the workpiece friction which is there holding the workpiece will be finished, ok.

For that purpose hydraulics unit will supply the hydraulic power which is controlled by the solenoid wall. See this solenoid wall changes the direction once it reaches to the maximum limit of the piston moving to the top trade center to the bottom trade center. The other bottom cylinder piston will actuate, ok.

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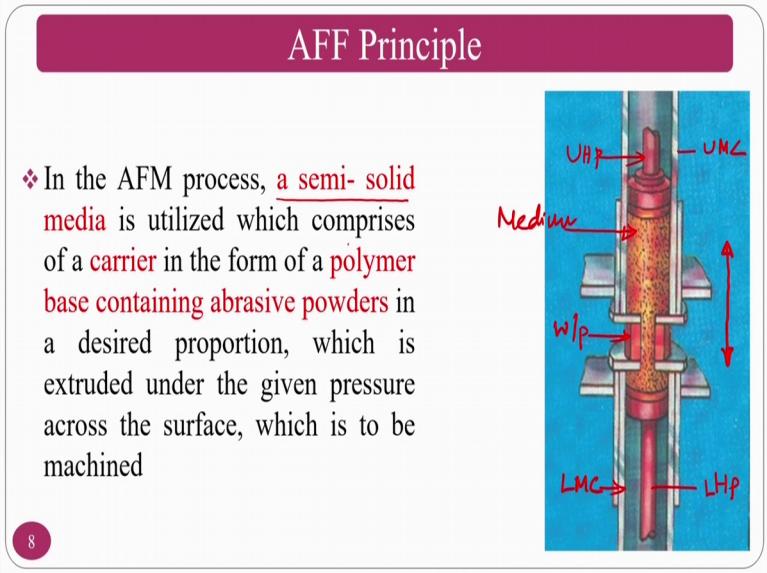

So, this in clear way I will show you the finishing region how it will take place. In this one, you can see here the medium is placed in the top medium cylinder. This is the medium and this is the upper medium cylinder, this is the lower medium cylinder.

So, the medium has to transfer or the medium has to push to the lower medium cylinder across the workpiece. This is the workpiece, ok. What will happen here is the medium is reciprocated like this first then comes back to the original position. This is the upper and lower hydraulic piston, ok. So, what will happen is if you are reciprocating the abrasive medium which consists of polymers plus abrasive and other things what will happen is, it will reciprocate and whatever the internal surface to be finished in the workpiece will be finished, ok. So, hope you understood.

I have an upper medium cylinder, I have a lower medium cylinder, in between I have a fixture where the workpiece is fixed. Now, my intention is to flow my liquid type of tool from top to bottom, bottom to up. For that purpose both the pistons will move up and down like that are reciprocate. Whenever this lower medium cylinders piston will push the medium, the medium flows across the surface finishing zone of the work piece and reaches to the top medium cylinder. Once the top medium piston or the hydraulic piston will push back, then it will come again to the lower medium cylinder across the work piece.

So, this reciprocating nature of the medium that consists of abrasive particles will shear of the surfaces to be finished in the work piece surface. So, in AFM process is semi solid media is utilized which comprises of the carrier fluid in the form of polymer based containing impressive powders and desired proportion and which is excluded if the given pressure that is what I have explained that it will move up and down and the material will be removed in the workpiece region wherever across the surface it is moving. Now, how the material will be removed, ok?

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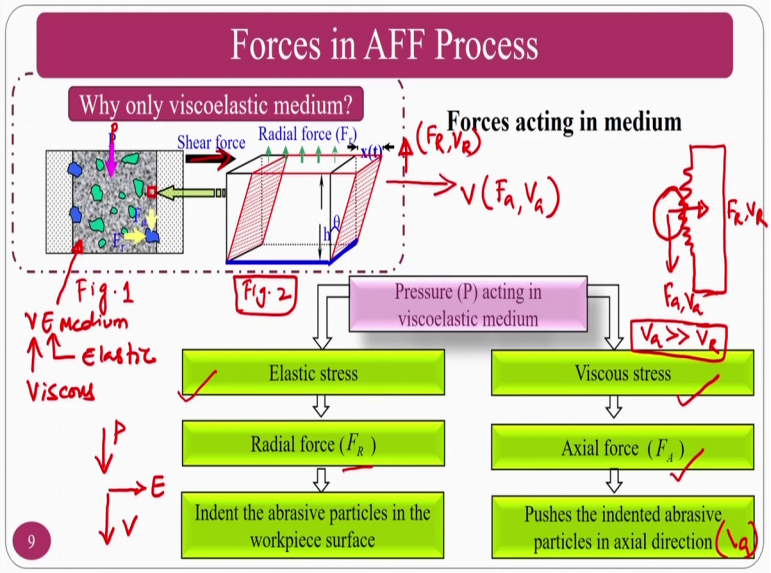

So, for that there will be physics behind it. So, the we what we are going to use here is assume that the finishing region is this particular figure, figure 1. What is here is happening is whenever extrusion pressure P is applied, you have a medium that is a viscoelastic medium ok. This particular ash color is nothing, but visco elastic medium. This is a viscoelastic medium. Visco elastic means it consists of viscous component and it consists of elastic component, ok. So, the viscous component tries to move along the direction of applied pressure. That means that the medium will be pressurized in this direction.

So, the viscous component moves in the direction of the pressure that is nothing, but viscous and elastic component moves perpendicular to it, whenever you take a honey or any viscous fluids like water or honey or something. Whenever you just throw it with a sudden pressure, what will happen the honey or water flow in the direction of applied pressure, but if you see the eraser which is made up of polymers normally erasers that you will use for erasing the pencil written errors and other things if you stress it that are normally visco elastic materials. Viscous component tries to move in the direction of applied pressure, but there will be a dimensional change in the eraser in the perpendicular direction if you might have seen that is called elastic component elastic component,.

So, if you see the analysis in the figure 2 what is here you are seeing here is viscous component tries to move. If I am applying a shear force in this direction, the viscous component moves in this direction and elastic component moves in this direction, ok. So, viscous component gives rise to axial force and axial velocity and here indentation will give the radial force and radial velocity, ok. So, if you see here what is the function of Fr Vr Fa and Va, so elastic stresses then you divide the pressure of visco elastic medium into two. One is elastic stress which causes the radial force and indentation of the risk particle in the workpiece surface, ok.

So, V r we are talking about the V r. V r is nothing, but velocity of radial velocity. That means that how much velocity the abrasive particle is indenting into the workpiece ok, let me explain with respect to a surface roughness profile. So, I have a surface roughness profile like this. I am having a abrasive particle here. So, my radial force and radial velocity directions are here. So, F r, V r and here is F a and V a these are the two things, ok. F r is required for us for indentation purposes, but if you see the radial velocity, the velocity at which the abrasive particle is indenting into the workpiece that will be too less compared to my axial velocity.

Axial velocity is nothing, but how fast the abrasive particle is moving along the direction of applied pressure. That means, that my V a axial velocity is much bigger than my V r. That is why V r is neglected. That means that the indentation velocity into the workpiece is always very negligible. That is why V r is neglected, but we considered the radial force along with the radial force, we consider the axial force, then the axial velocity also. So, viscous stresses if you see the viscous stresses, it will gives the axial force and face indented aggressive particle in the axial direction. At the same time, you will also get the axial velocity also.

So, you are getting in a abrasive flow finishing 3 things. One is the axial force, axial velocity and radial force, ok. So, these are the main components for finishing of this one. What is the main function of radial force? Radial force try to indent into the work piece surface or it will try to penetrate into the valley and try to shear the peak by the help of axial force and axial velocity. It will indent because of the radial force and it tries to move in this direction because of the axial force and axial velocity combination of this radial force. Axial force and axial velocity you are going to get a micro chip or the nano chip and the material removal will take place, ok.

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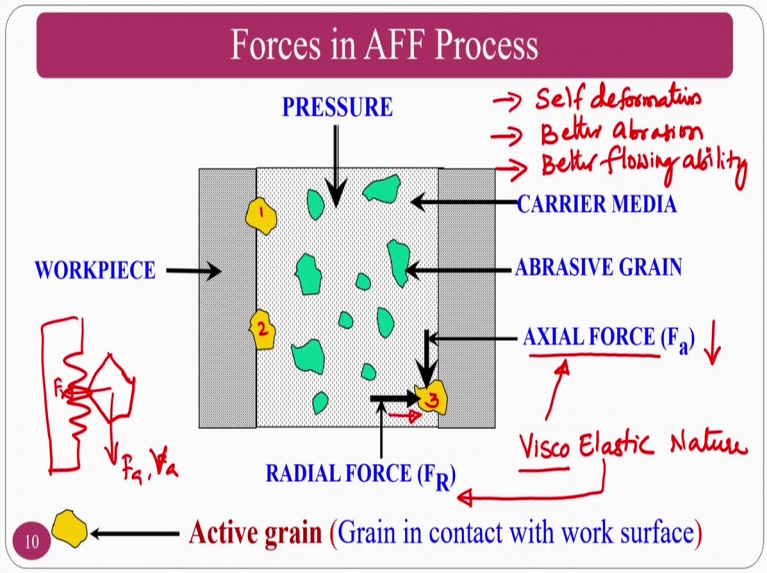

If you can see here, the forces which I am explaining here, so this particular slide will explain you about active abrasive particles. So, if your medium is there, at the same time medium will have lot of abrasive particles where in very few abrasive particles will take part in the finishing action because these are all coming in contact with respect to work piece. So, the yellow ones are active abrasive particles. That means that this is 1 2 and 3 are the active abrasive particles, ok. If you see here because of the visco elastic nature of the medium elastic nature, what is happening here is you can see the axial force along the direction of the applied pressure at the same time radial force because of elastic component in the medium, ok. In the previous slide, it was just congested. So, explanation might have not up to the mark.

So, those people who have some doubts, they can see here. What is happening is viscous component is generating the axial force and elastic component is generating the radial force, ok. So, because of which what will happen is assume that I have this particular surface. So, whenever my abrasive particle is like this in that circumstances, the radial force will indent like this and axial force will move, axial velocity will move here and F r will be there because of which the shearing action will take place, ok. Shearing or the chip will take place and the material removal will take place,. What about the inactive abrasive grains? This particular medium has 3 properties, ok. One it is self-deformability, second one is better aberration and better flow ability, ok.

So, these are 3 main components of this medium. One is self-deformability, better aberration and the 3rd one is better flow ability flowing ability, ok. These 3 requirements are there for this one what is happening here is if you have a self deformation, that means that if you make this particular medium a semi solid medium into a sphere and you put on a flat surface with respect to time, the atmospheric pressures can deform it.

A human is not a self-deformable body because you are not deforming by the atmospheric pressure. You are standing, you are walking, you are running, but there is no deformation because of the atmospheric pressure, but if a fluid or a semi solid that you are making into a sphere and placing on a flat surface after sometime, it is deformed by itself by the virtue of or by the assistance of atmospheric pressure that is nothing, but the self-deformation.

If it is deformed by the atmospheric pressure itself, what will happen if you are going to deform with respect to extrusion pressure or the external pressure. So, whenever you deform, whenever you want to deform with respect to some external pressures if this medium itself deformable, so if you are applying extra pressure, it will deform as per your requirement. That is a beauty about this process. The second thing is that it should better abrasion ability. That means that the abrasive particles that are there inside the medium or to be abraded against the surface to be finished or surface across which it will flow, so that the microchips or nano chips can be generated and the surface finish can occur and better flow ability.

So, it is having a self-deformability and now if you are going to put at certain pressure like 6 mega Pascal or 5 mega Pascal or 10 mega Pascal pressure, if you are putting through the hydraulic power pack what will happen is, it will flow to each nook and corners of the complex surfaces. That means that this particular medium can act as or can flow across the complex surfaces and can remove the material as per the requirement of the customer and you can generate or you can create the nano surface finish on that particular component. These are the 3 main properties of the medium. Whenever I will teach about the medium and its rheology, you may come across again.

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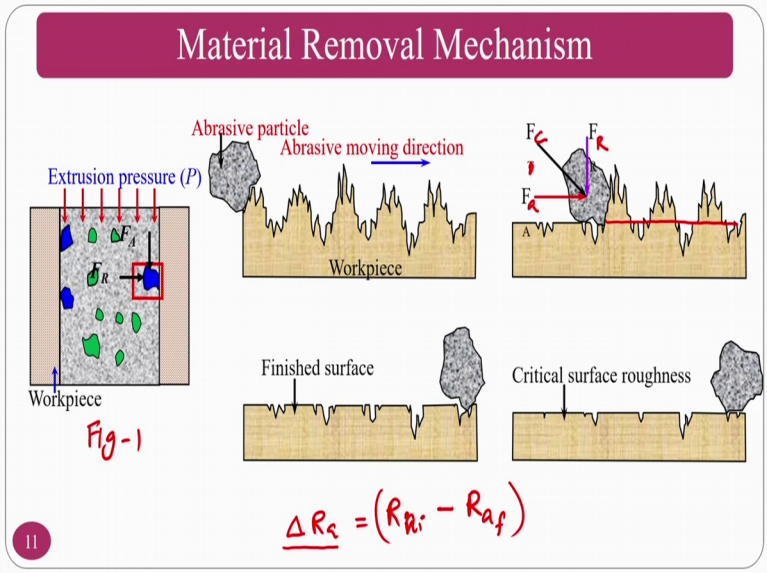

So, material removal mechanism which we have seen here, so viscoelastic nature is there and the abrasive particle as we have seen this is the abrasive particle where you are getting the assistance from the visco elastic polymers. So, visco elastic polymers if you see here, this is the axial force and this is the radial force and this is the resultant force,. Assume that I will say it is a cutting force or something, the resultant of this one, ok.

So, visco elastic effect is there because of which what will happen these peaks it will be sheared and you can get a good surface finish, ok. After getting a good surface finish, you will achieve a critical surface roughness value for any type of finishing applications whenever you play with respect to input parameters like number of cycles exclusion pressure medium variables and other things, with respect to number of cycles.

What do you mean by number of cycles? If you see the figure here, figure 1 what is means the medium is reciprocated like this. So, the medium from top cylinder, medium cylinder to the bottom medium cylinder is called one stroke and if it is reciprocated back, that mean that bottom medium cylinder to top medium cylinder this is called one cycle. That means, one bottom stroke and one top stroke it is nothing, but cycle. So, whenever assume that you are going to get the critical surface roughness at 100 cycles or 50 cycles, what will that means is, the change in surface roughness that mean that delta R a.

If you are talking about center line average, the change in R a will be a probe minimum or it is too less, then there is no meaning in going for more and more number of abrasive

cycles. That means that number of cycles if you are going to increase that is enhances your input power, but there is no change in roughness, ok. The change in roughness is nothing but initial roughness minus final roughness, ok. This if there is no much change in this value, then there is no meaning in putting extra energy into the system. That means that I am pressing R m extruding across the surface to be finished by the extrusion pressure. Extrusion pressure where it is coming you have to give input power to the hydraulic power pack.

So, that means that your input energy is there. If the change in roughness is good, you have to give extrusion pressure. If the change in roughness is not much, then there is no meaning in giving the extra or external energy. For that purpose whenever you achieve the critical surface roughness for any particular surface, then you can stop the finishing process.

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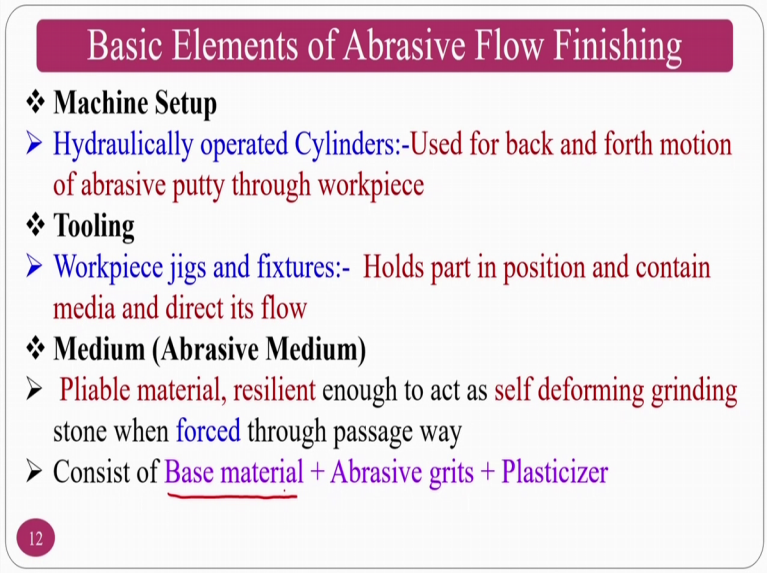

So, basic elements of abrasive flow finishing, one is a machine setup that is nothing, but the experimental setup which is hydraulically operated cylinders used for back and forth motion of abrasive putty and the pistons as well as medium cylinders and all these things will cover into the machine setup.

Then comes the tooling; So, tooling is nothing, but it is the work piece fixtures. Basically if at all I want to finish a neem plant my fixing devices are holding the neem plant, so that medium has to flow across the surface uniformly. So, this particular is nothing, but

the fixture or the tooling. Assume that I want to finish a hollow cylinder you required minimum tooling if at all I want to go for finishing of a neem plant or plant other things

So, what will happen is your fixture will be different that is nothing, but the tooling. So, tooling will vary from Component to the component. The medium, abrasive medium is a pliable material resilient enough to act as a self-deforming grinding stone. When forced through the passage way, it consists of basically base polymer materials, abrasive particles and rheological additives such as plasticizers hardness and so on.

These are some of the constituents of the medium that is used in the abrasive flow finishing process.

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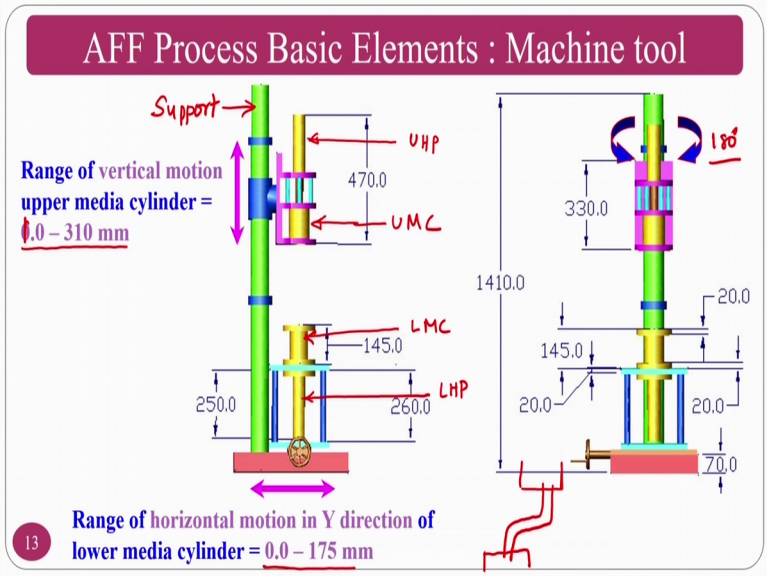

Abrasive flow finishing process basic elements, the first element is machine tool, ok. This is a machine tool drawing if you want to develop your own dimensions. Also given this is the laboratory scale development that is done and it has a various motions also, so that you can accommodate different size and shape component, ok.

So, this is the main support and which you are mounting basically this particular drawing that we have done for a radial drilling machine. So, this particular support came from the radial drilling machine. We have replaced the system, other systems with respect to the medium cylinders. This is an upper medium cylinder and upper piston, upper hydraulic piston, this is the lower medium cylinder and lower piston, lower hydraulic piston, then

you can connect this upper hydraulic piston and lower hydraulic piston to the hydraulic power pack which is not given in this particular picture and you can reciprocate it.

Whatever is missing here is the medium is not placed in the medium cylinders. These are the medium cylinders, two medium cylinders and the tooling has to be placed in this one, so that it can be finished. These are the different things that are not included, but if you see the various motions of this one, these motions are given vertical motion normally 1 2 3, 10 mm. So, that means that the maximum component you can hold with easily is 300 mm height component you can hold.

At the same time you can see the y axis and other axis motions and you can also see this particular upper medium cylinder set to 180 degrees because if at all I want to hold the abrasive medium, all I want to hold the workpiece with the offset. That means that assume that I want to hold this type of a tube to be finished, what will happen I need to rotate the upper medium cylinder here, so that it will come here. My lower medium cylinder is here, ok. So, that is the possibility of this particular motions that are given to this abrasive flow finishing process to make it as flexible to finish different, different kinds of work pieces.

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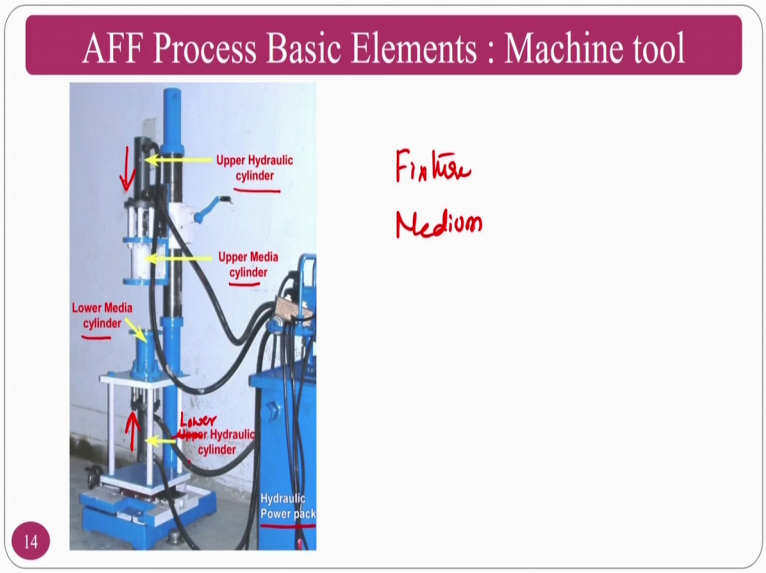

So, this is about the experimental original picture. Whatever you have seen in the previous slide is the schematic drawing. This is the experimental setup where you can see the lower medium cylinder, upper medium cylinder, upper hydraulic cylinder, lower

hydraulics, this is lower hydraulic cylinder and hydraulic power pack. Everything is there and these are the pistons which will try to push the medium and you can get the finish, ok. So, whatever is missing is here is the fixture and medium. Both are missing, ok. So, these two elements we will see in the upcoming slides. So, that second one is tooling or the fixturing.

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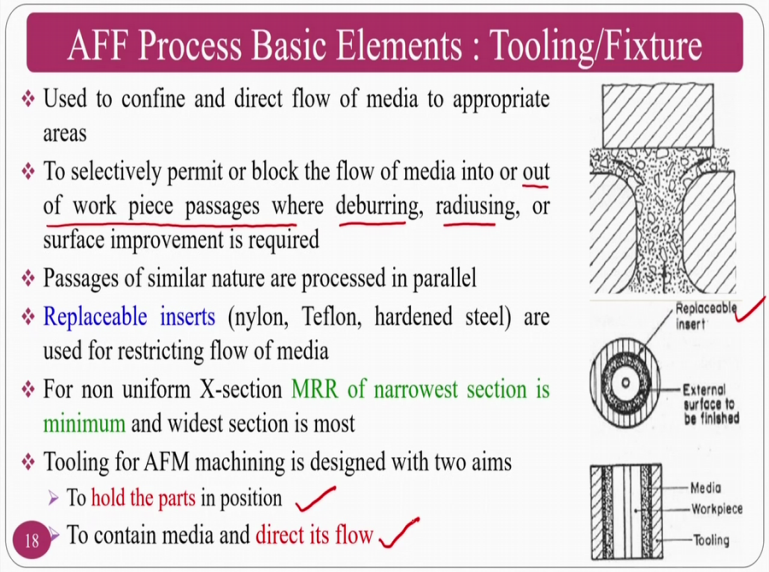

If you see here assume that I want to finish this particular component. So, I need to give the tooling as per the requirement, ok. So, used to confirm the direct flow of the medium appropriate area. That means that it has to guide the abrasive medium across the abrasive medium as I said this is semi-solid medium and it has to flow across the surface to be finished. When it will finish, if it can flow across the surface uniformly, then uniform surface finish can be generated, ok.

So, the tooling function is it has to guide across the surface to be finished, so that it can achieve the uniform surface finish to selectively permit or block the flow of media into out of workpiece passages, where the deburring radiusing and surface simple with required That mean that it has to permit to the regions where it has to finish, only it should not go into the other regions. The passage of similar nature are processed in parallel you can go for many things and replica replaceable inserts.

Now, we have seen the one of the element of abrasive flow finishing process that is a experimental setup or the AFM machine setup, ok. So, now we are going to see the

second element that is called a tooling or a fixturing. The basic function of the tooling or the fixture is to hold the workpiece in position and make the medium to flow across the cross-sections to be finished, ok. So, how it will do?

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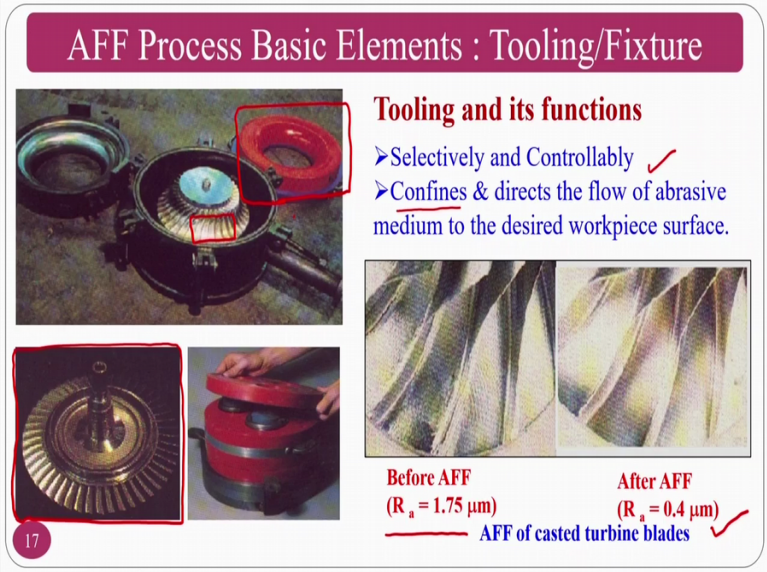

So, tooling and its functions if you see the selectively and controllability, that means that it has to select locations of the workpiece, so that the medium flow across that particular section only and controllability. So, it has to flow uniformly under the control of this particular friction and it should confine and direct a flow of abrasive medium across the cross-section to be finished, ok.

So, it has to be confined to that particular sections of the work piece only and it has to direct. So, how we will see in the picture? This is the small turbine or impeller blades that has to be finished. So, how to finish only the turbine blades and not the other particular parts? So, it has to finish this particular portion, not the other portions that are covered with a sky blue colour one, ok. So, that means it is masked to not to finish this particular portion and it has to finish only this particular part. For that purpose you need the proper tooling. At the same time you need to have proper radiusing on the tooling and other things, ok. If you can see here, there is a radiusing that is provided on the surface, so that the medium will freely flow on the surface and it will direct towards the finishing of these turbine blades or the impeller blades. These are the workpiece that is to be finished. Initially this is one that is to be finished and this is kept here.

So, you can keep it and you can put the fixturing and you can also place the medium initially and you can start the finishing process. This is nothing, but the tooling or fixturing, ok. This is major and you can see the before and after finishing. The before finishing, it is 1.75 microns and after finishing, it is 0.4 microns. This is how the casted blades can be finished, ok.

So, hope you understood now what is the function of the tooling or the fixturing is to hold the workpiece firmly and at the same time to direct the medium across the surface uniformly and controllably to finish that particular section only and not the other sections. If you see the other things of the tooling and fixturing, it is used to confine and direct the media flow to the appropriate areas of finishing selectively permit or block the flow of media into out of the work piece passages. That means that it should not pass the media out of the work piece passage. That means that it has to direct only to the surfaces and deburring radiusing or the surface improvement is required. That means that it can do.

So, it should not make the medium to move out of this, confined regions, the passage of the similar nature or processed in parallel. That means that you can pass, you can finish many holes or many comparts in a single go by using the proper fixturing replaceable, insert that mean that you can, then go for nylon teflon hardened steel. This type of replaceable insertion you can go, so that you can stop the media or restrict the media flow to not flow to the restricted regions for non-uniform X axis. MRR narrowest section is minimum and the widest section is most that you can see here and tooling for a abrasive flow finishing or abrasive flow machining is designed into aims to hold the workpiece in the position and to direct the medium flow. This is what I was discussing in a previous slide also, ok.

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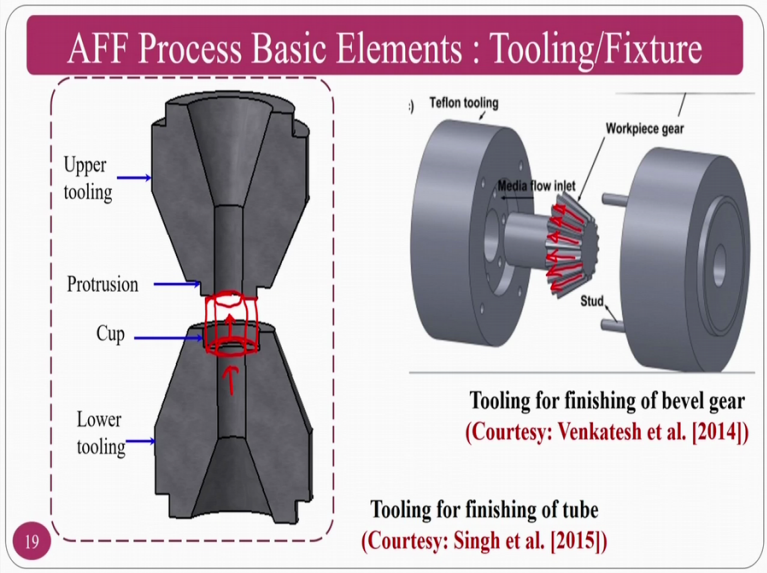

So, the tooling suppose I want to finish a cylindrical workpiece. For that purpose what normally you can do is, you can have a cylindrical workpiece and you can this can be a fixture and to understand make you to understand we have put this particular thing and this can be the outer diameter and this can be a inner diameter, ok.

So, that medium flows in the finishing region only ok, so that you can finish the internal surface of the hollow cylinder and you can use this particular cylinder in various applications. So, similarly the fixturing also can be done for the finishing of bevel gears and other things. So, the bevel gear you can hold the bevel gear in this direction and you can send the medium. So, the medium can flow across the tips and other surfaces, so that it can do the neighboring operation as well as finishing operation in the bevel on the bevel gear, ok.

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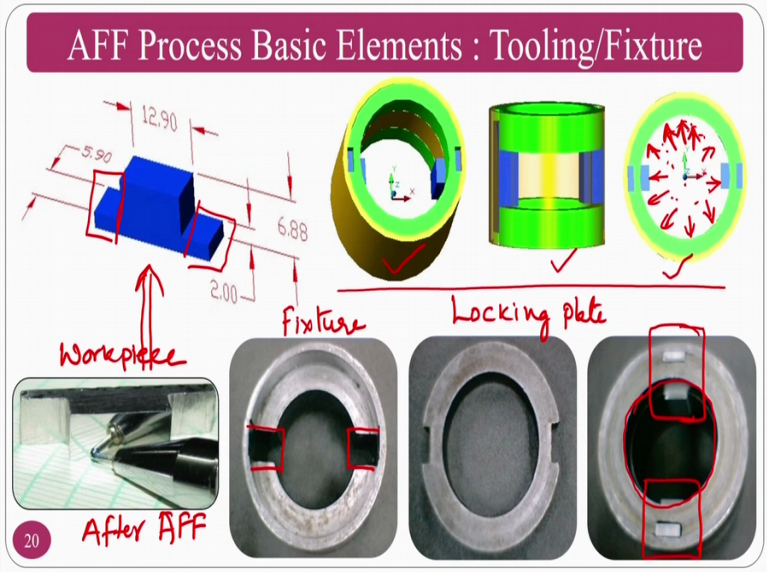

So, if at all I want to finish a flat surfaces, assume that this particular is my work piece and I want to finish it because see till now you have seen it is a cylinder and other bevel gears and other things what about the flat work pieces. You can also accommodate these things in a hollow cylinder. How to accommodate? If you see that you have the these type of work pieces.

So, you can see this is often after finished work piece after AFF process you can see the mirror surface finish on the work piece. The same thing is given here in a schematic way. So, how to hold this one? So, for that purpose you will have one is the fixture plate and the locking plate, ok. This is called the fixture. It is a part of the fixture that is nothing, but where the fixture you can say and this is a locking plate, ok.

So, this is the workpiece. So, you just place the workpiece in these regions, two pieces you can place, then you can put this locking plate, there will be two locking plates. One will fit at the bottom and another will fit at the top, so that these portions will be locked from both, bottom and top. So, the workpiece will stay there itself. As you can see here this is how the workpiece is engaged, ok.

So, sometimes you should make sure that both are on the same size. This particular picture is provided to make sure that to show how the workpiece look like. At the same time, you can have like this also or you can make the height of the workpiece, so that it will sit within the circle. Then, the uniform surface may also will take place if the

protrusion is there. It will still for the laboratory purposes, but if at all you want to go for commercial purposes and other things, you should have within the circle. So, the uniform surface finish will be occurred. The same thing explained in the schematic way and in the three dimensional and orthogonal views. Also shown this is the isometric view and these are the two front view as well as the top views, ok. So, this is how the tooling hold the workpiece. At the same time, it will allow the medium to pass through. This is the medium which will pass through across the surfaces, ok.

This not only finishes your workpiece, but also finishes your fixture also that is which is exposed to the finishing region. So, we have seen two elements; one is a machine setup as or the machine tool, then the fixturing or the tooling. Now, we move on to the third and main element of this abrasive flow finishing process is the abrasive medium. Normally some people it is called as the polymer rheological abrasive medium where you will have polymers rheological additives as well as abrasive particles. That is why this particular medium comprises of these 3 elements. That is why it is called polymer rheological abrasive medium or people if you are going to use very low viscous fluids then it is called as polymer rheological abrasive fluids also, ok.

So, this particular medium is a semi-solid to a liquid phase. That is why you can call it as a medium, you can call it as a fluid and at the same time the plural for medium is media. So, you can many people works on this particular area for their PhD research, masters research and other things, ok. So, those people who are interested to take up this abrasive medium as their research, it is well and good. So, our group also works extensively in this particular area.

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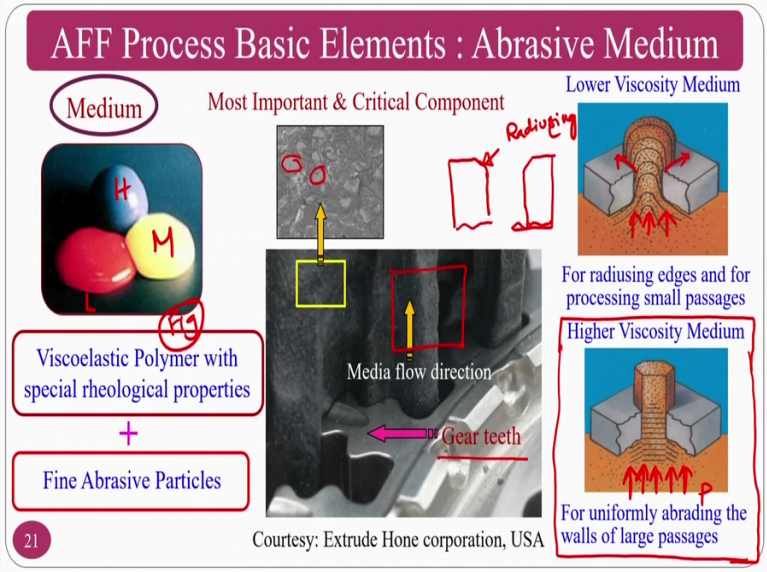

So, the medium, most important and critical component of this particular abrasive flow finishing process is nothing, but the medium, ok. So, the medium this is one what are the picture is taken from extrude hone which is now a days it is called Kennametal extrude hone. So, it will have the base polymers that is nothing, but visco elastic polymers with rheological properties and fine abrasive particles,.

So, what is the rheological additives that normally people will use in this particular thing is many types with plastic polymers are there, but commonly used is poly borosil are seen. So, many of the companies which commercially produces this particular polymer is one of the best example for visco elastic nature material and this particular material is blended along with so many rheological additives such as softeners, plasticizers, hardness functionalizes and so on.

If you are going for low viscous type of thing, then they are going to add the functionalizes for holding the abrasive particles in the location that is many additives are using. So, one can explore so many varieties of rheological additives. Apart from it people also uses some of the chemicals for having this particular material for long period without affecting the bacterial my or any type of microbes,.

So, as I said medium should possess majorly 3 things that we have discussed in the previous slides also. So, the deformation, self deformability, better abrasion and better flow ability and other things you can see here this is one of the complex thing that is

finished here. So, you can see the medium flow. How the medium is deforming itself in this particular section if you see how the medium is deforming as well as it is flowing across the section to be finished and the medium look like abrasive particles are blended with polymers, ok.

So, there are multiple varieties of the medium. Normally there are high viscous medium, medium viscous medium as well as low viscous medium. So, two examples that we are seeing here that is called low viscous medium and high viscous medium. So, if at all I want to abrade uniformly, then people has to go for the high viscous medium, ok. In high viscous medium, whenever you are extruding or that means that whenever you are applying the extrusion pressure from one direction what will happen is this medium is so high viscous that it will extrude through the hole. For example, I am telling it is a hole that is drilled by EDM process or laser beam machining process or any other process.

So, you are just putting the same pressure. This pressure extrudes the medium across the surface to be finished and comes out as a straight medium slug, ok. Medium slug is nothing, but it is a medium that is coming out as a single entity, ok. You are applying extrusion pressure. What will happen? The viscosity of the fluid is so low that it comes out as like this, ok. So, because of this what is happening is if you have sharp edges, you can do the radiusing. So, people you may know what is chamfering because chamfering will be normally given on the sharp edges to protect or to give safety to the operators, or the customers for the same thing you can give radiusing by using this one.

Because your medium is coming out like this, coming out like a flower, how the flower will come will show like that it is coming, then it is going. So, for example if you see water, if you switch on or if you just rotate if you on the tap what will happen, your water slightly comes in a divergent way. Similarly because your water is low viscous fluid, similarly if you are going for a low viscous medium, there will be a divergence and there will be a medium will come out like this and because of that if I have a hole like this, sharp edge and low viscous medium comes and it will become the radiusing.

So, this particular thing will become radiusing, ok. So, whenever you get a particular component like this and it will be always safe for the people, ok. So, this is called radiusing. So, that is a beauty about this particular process or especially whenever you are using low viscous medium for finishing as well as slight radiusing applications, you

can have a particular medium in this. In between there is no viscous and high viscous medium that is what you can see in the figure. This particular figure is this is high viscous medium, this is medium viscous medium and low viscous medium, ok.

So, let me write for your understanding this is a high viscous medium, this is medium viscous medium and this is low viscous medium. So, red on red, it may not be visible. That is why I am writing at the bottom. So, this is a low viscous medium. So, you can have 3 common varieties that is supplied by Kennametal extrude hone. You can purchase it, but the basic problem with this particular medium which I cannot say the basic problem or something what is the medium is too expensive for developing nation like India. At the same time, you have to discard this particular medium after whenever it reaches to 10 percent of its original weight that means that as you might have seen the tool life of a single point cutting tool.

Whenever you say that tool wear exceeds or the flank ware land exceeds 0.5 microns 0.5 mm or that means 500 microns, then you have to discard. Similarly the tool life or the medium life of this particular medium is whenever it exceeds 10 percent of its original weight, that mean I am purchasing 1 kg of the medium. That means that 1000 grams whenever it exceeds by 1100 grams, that means that you have to discard.

So, 100 grams of chips are the micro chips or the nano chips embedded inside the medium. So, you have to discard because of this. There may be scratches that one can generate on the surface. That is why the life of a medium can be expressed in these terms like whenever you have 1000 grams is weighing 1100 grams after 10 experiments or 200 experiments or any type of after finishing 10 samples or 100 samples whatever may be. So, if your weight is increased, that means that 10 percent of foreign elements are the foreign body materials are embedded inside the medium, then you have to discard that is about the life of the abrasive flow finishing medium.

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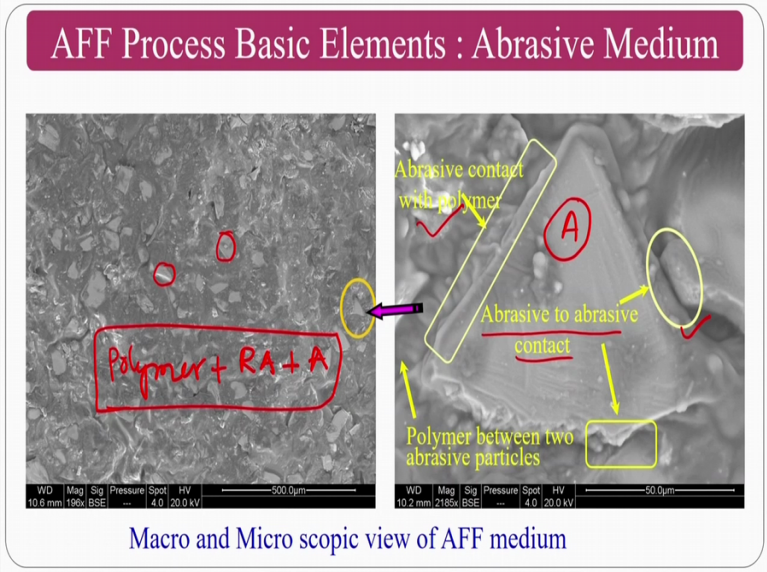

So, you can see the medium normally. So, the medium having lot of abrasive particles which are there in the polymer rheological abrasive medium, where you have polymer, where you have rheological additives and abrasive particles, ok.

So, these are 3 varieties of things are there polymers. Normally these are solids, are semi-solid. Rheological additives will be liquids mostly as well as some of the solid particles and abrasives will be solid or the ceramic particles, ok. This particular thing is a combination of liquids and solids mostly. So, this is a two phase medium, where you can have interaction between the different things.

So, if you can see here, if you can enlarge the medium to see how the abrasive particles are held in the polymer networks, if you see here, this is an abrasive particle. How it is blended at the same time, how it is staying inside the medium, it can have many possibilities like polymer under abrasive contact can be one of the at the same time abrasive to abrasive contact is another thing and it also can have many other things. Agglomeration is also some of the problems. You can also see there will be an agglomeration of this particular thing in some locations at the same time, there will be voids also.

If your medium viscosity is slightly higher side, then there will be a chance of voids in the medium also, ok. So, if you see the grinding wheel, grinding wheel also unit structure, so structure means you should have closed or open structure. So, if at all you

want to go for an open structure that means that your void should be present and at the same time the abrasive to abrasive distance will be slightly higher. So, you can designate this abrasive flow finishing. Somebody want they can do this particular also how to specify an abrasive flow finishing medium and other things you can also work on it. So, many people thinks about how the abrasive particles which are the solid particles will stay inside the abrasive.

Polymer rheological complex medium, ok. Polymer is a semi solid to liquid or rheological additives mostly liquids. At the same time, you have semi-solids also or the powders also in a this particular complex where the abrasive particles are sitting. That is one of the biggest challenges to understand for that purpose. So, the common thing is that that polymer networks or dimensions are approximately nanometers, but at the same time your abrasive particles are in approximately like 50 microns, 200 microns like that, ok.

So, how it will work? So, normally your polymer networks will be there which are blinded and at the same time, you are going to use rheological additives to hold it. So, this particular thing is a big chemistry to understand. If you can see how the polymers as well as rheological additives are blended and which part of the chemical of this polymer is attaching to the rheological additives, now which part of chemical bonds of the rheological additives, then how these things are attaching to the silicon carbide or I2 O3 or these type of abrasive particles and all those things can be a good study.

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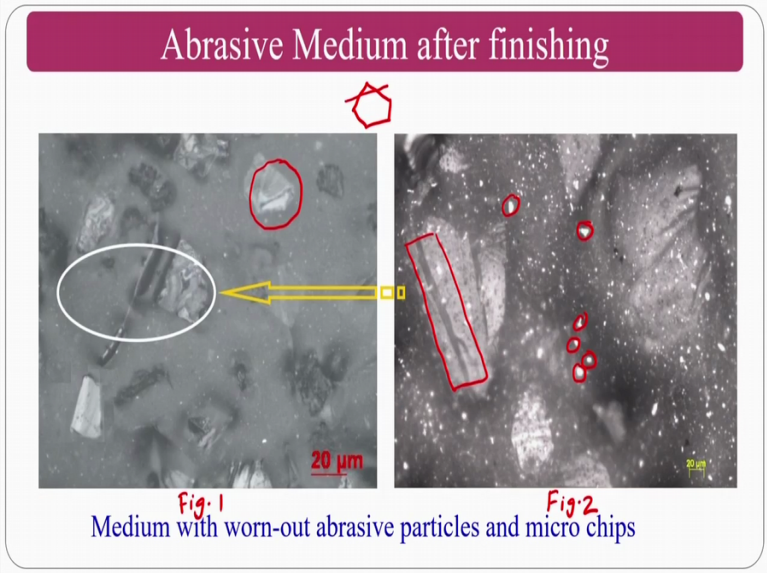

So, you can see here the medium and a grow spectrum. At the same time, you can see in the close up also in the second slide figure, one shows the abrasive particles as well as the chips, and if you zoom it up, you can see the figure 2, where you can see small fragments of the work piece. This particular medium having lot of polymers, plasticizers rheological, other rheological additives along with the silicon carbide particles, ok. This silicon carbide particles are getting help visco elastically from the various rheological additives and they finish the work piece material. The workpiece material here is pure aluminum material. That is why you can see the chips in a shining way, ok.

So, not only that if you can see clearly the abrasives also if you are going to use multiple times, the abrasive particles also become blunt, ok. This is another phenomena Sharp edges of the abrasive particles will become blunt because you are going to use this particular abrasive particles for hundreds and hundreds of cycles like 200 cycles or 300 cycles or 400 cycles. You depend on your requirement and depend upon your initial surface roughness and other things,

Not only that, you can also see some of the brittle fractures on the abrasive particles and you can clearly see these are the microchips or the nano chips that are evolved from the finishing region and these can go and blend with respect to the polymer rheological abrasive medium and if you are going to increase again and again, what is going to happen is the medium weight will increase. As I said in the previous slide that if the

medium weight which is assumed that you are going to have 1 kg that means that 1000 grams if it is going to be 1100 grams, you have to discard. This is how the medium weight will increase, ok.

So, at the same time one has to note here also is that the sharp edges of the abrasive particles will also become blunt, ok. This is the literature that says is that when it is increased by 10 percent, you have to discard this also is one of the thing from the point of blunting of abrasive particles.

So, the researchers might have seen that the abrasive particles might have blunt by the time, because it is already removed so much material that mean the summary of this particular class what we have seen is advance. We have entered into the advanced abrasive finishing processes and we took the first and foremost and highly important process that is called Abrasive Flow Mqchining and Abrasive Flow Finishing process.

Why it is called as Abrasive Flow Machining Process and Abrasive Flow Finishing Process? Since this abrasive flow finishing process used as a semi-solid to liquid type of cutting tool, this is mostly used for those internal holes where the intersection is there and burrs are there; for mostly, it is used in 1960s to 70s to 80s for deburring applications because your solid cutting tools cannot penetrate into those complex regions.

For that purpose liquid tools or the semi-solid tools are fabricated and these are used for deburring application. That means that the removal of burrs that are formed in an internal complex regions that is why this particular process in initial stage is called as abrasive flow machining process. Later on people are using it for the nano finishing applications. That is why this name is amended again to abrasive flow finishing process, ok.

So, the abrasive flow finishing process we have seen the name material removal mechanism initially with respect to visco elastic medium. How the forces are generated? Whenever the extrusion pressure is applied, what is happening here is you have axial force and axial velocity because both are in the same direction of applied extrusion pressure and the radial force and radial velocity perpendicular to that axial directions, but since the indentation velocity is so low compared to axial velocity, that is why indentation velocity will be neglected. Then, we move on to the various elements of the abrasive flow finishing process.

The first element is machine set up, where you have a lower medium cylinder, upper medium cylinder, lower hydraulic piston, upper hydraulic piston which is connected to a hydraulic power pack that supplies the hydraulic fluid. So, the medium can be reciprocated using this hydraulic system. Then, we move on to the second one that is called tooling and or tooling on the fixturing. That main function of the tooling and fixturing is to hold the abrasive particle intact in that particular location and to direct the medium across the surface to be finished and it has to direct uniformly uncontrollably and the third and most important thing is abrasive flow finishing medium or polymer rheological abrasive medium, where you have polymers, where you have rheological additives, where you have abrasive particles. The combination of polymers, combination of rheological additives, combination of abrasives use the name polymer rheological abrasive fluids or polymer rheological abrasive media. So, media stands for plural of the medium, ok.

So, the medium is a most crucial and when you have to discard because you are familiar about the tool wear, so what is the you are familiar with respect tool life. So, what is the life of this abrasive flow finishing media is that you have to discard whenever the medium exceeds 10 percent of his weight by having lot of chips in the medium, ok. These 3 elements we have seen and we will see in the next class about the few more details about abrasive flow finishing process. We enter into the types of abrasive flow finishing process and material removal mechanism in detail and applications, advantages and some of the rheological characterization for the abrasive flow finishing medium. These all we will see in the next class and the second part of abrasive flow finishing process.

Thank you for your kind attention.