Introduction to Abrasive Machining and Finishing Processes
Dr. Mamilla Ravi Sankar
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture - 18
Elastic Emission Machining Process

So, now we move onto elastic emission machining. This is one of the advanced abrasive machining processes; also some people it is called as elastic emission finishing process also depend on your requirement. Mostly this particular process is of finishing process since it is named as elastic emission machining process that is why we are considering this particular process into the advanced abrasive machining processes.

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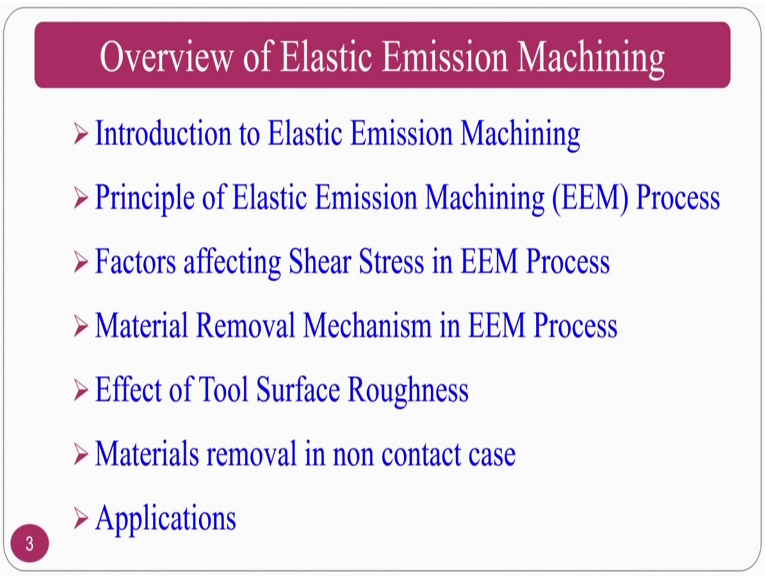

So, overview of this elastic emission machining process we just see into the introduction of elastic emission process, principle of elastic emission machining process, how the material removal rate will occur, at the same time how the material removal mechanism will takes place factors affecting the shear stress in elastic emission process, material removal mechanism. Effect of tool surface roughness, if the surface roughness of the tool is too high normally what will happen is the roughness that you are going to achieve is also high. The material removal in noncontact case what are the different, different phenomena how the material will remove in case of noncontact regime of elastic emission machine, then the applications of this one. Normally this particular process uses for the finishing of optical lenses, glasses and other things.

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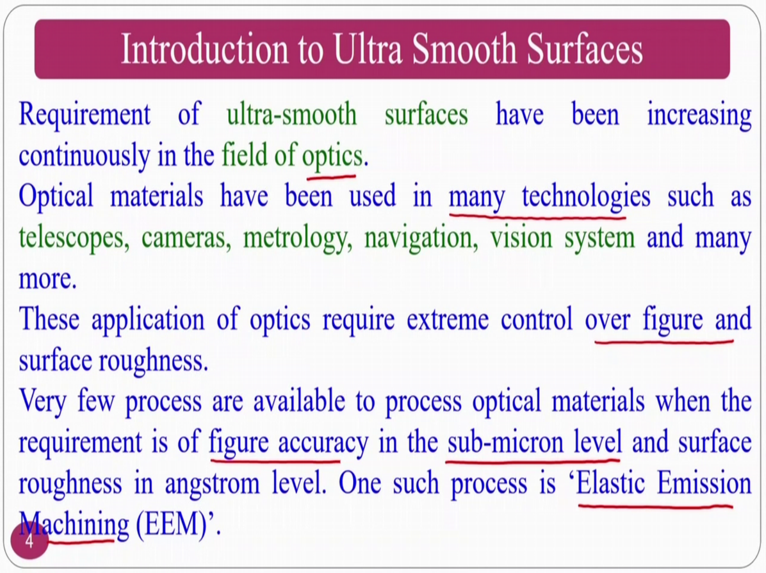

So, introduction to ultra-smooth surfaces, where you required ultra-smooth surfaces. Requirement of ultra-smooth surfaces basically have increase continuously in the field of optics basically ok. So, the optics means lens contact lenses to the lenses whatever the you are seeing on my face the lenses and all. These are the eye lenses or the x-ray lenses or if you are going to see the lenses different lenses in a telescope, different lenses in a microscope and other lenses as to be done ok. Optical materials have been a used in the technology such as telescopes, cameras, metrology equipments, navigation, vision system and many more; that means, that you are going to see this lenses in a huge applications and you do not want any scratch mark on it.

So, if at all I have a scratch mark on my eye specs what will happen, so always my vision will be disrupt. So, you should not have any type of the scratches on it. For that purpose normally people go for elastic emission machining process. These applications of optics require extreme control over the figure as well as the surface roughness that means that you require figure roughness is there at the roughness obviously, you know the centre line average value or RMS value or maximum peak to minimum value at the same time you require the figure

Big figure means you need to certain sculptures structures. Assume that if at all the people want on these particular specs you require a convex on one side concave on another side ok. This is always require along with the surface roughness also. If you are going to give better surface roughness, but you are not going to give proper figure, what will happen the vision system of that particular person will greatly affect.

Processes for optical materials processing which require the figure accuracy in submicron level surface roughness is required and even people require Armstrong level. Nowadays if you go to telescope SLR cameras are very high end cameras that are used in either Formula 1 racing or sports these are all high speed cameras these are the cameras where you require a very very good surface roughness like Armstrong surface roughness or if not some of the cases you can be happy with submicron level surface also. So, one of such process is elastic emission machining ok. Why is this particular process only that we will see in the upcoming slides?

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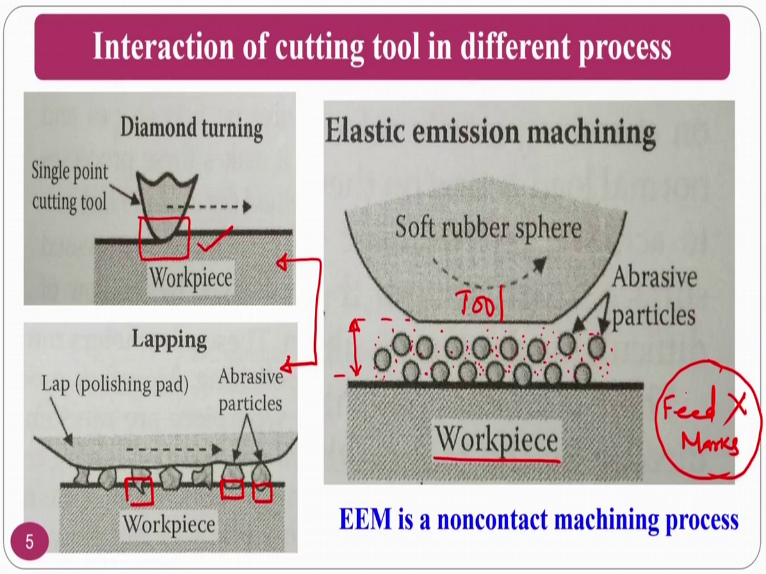

Interaction of cutting tool in different processes how the cutting tool will have the interaction you can generate the mirror surfaces using diamond turning process as well as you can also do by lapping process ok. The problem in this particular two techniques, these are the one technique these are the second technique. This is what the drawback of this one. You will get the feed marks on the surface because in both conditions you will have the contact of your tool with respect to work piece in the in the diamond turning process you can see the contact with respect to work piece because of this what will happen you will get always the feed marks ok, so that is a drawback.

At the same time if you see here in the lapping process also, the lapping process there are three-dimensional or three body abrasion will takes place where in you will have a random surface roughness marks. So, this is another disadvantage because of this feed mark, the vision system that are used in optical so that may be destroyed ok. For that purpose what will be the solution the solution is in this particular thing we do not want feed marks, even though we are getting a very good surface roughness and the figure in terms of diamond turning as well as lapping, but the problem in this conditions is that you are going to get the physical feed marks which is nothing but the scratches or lines on the lenses.

You I said if you have scratches or the lens or the lines on the lenses, if you give the scratches and the lines are there on the lenses, then it will disturb the vision or it will disturb my vision. Because if at all I want to see a microbes in a microscope there is a clear scratch is there on the lens, then it will disturb at the same time you have to grab into the same into the computers and other things. So, complete vision systems will disturb.

For that purpose elastic emission machining is one of the solutions, because you do not have direct physical contact ok. If you see here in elastic emission machining, my tool is here, at the same time work piece is here, in between there is a submicron to micron gap will be there. If you see here there is a gap. In this gap you have abrasive particles, at the same time you have the carrier fluid also whatever the red dots that I am putting here in the carry along with the carrier fluid that is nothing but your carries fluid. Normally, carrier fluid will be a water or any other compatible liquids can be used in this particular thing.

So, in this particular case, as you see diamond turning as well as lapping which is complete contact is there, here there is no contact. If there is no contact what will happen is you may not get any feed marks ok. So, this feed marks will not be there in this one because of which the lenses or any optical things that are produced by elastic emission technique will be scratch free or it will have a good surface roughness along with the figure also ok. So, this is a one of the good process for producing the lenses.

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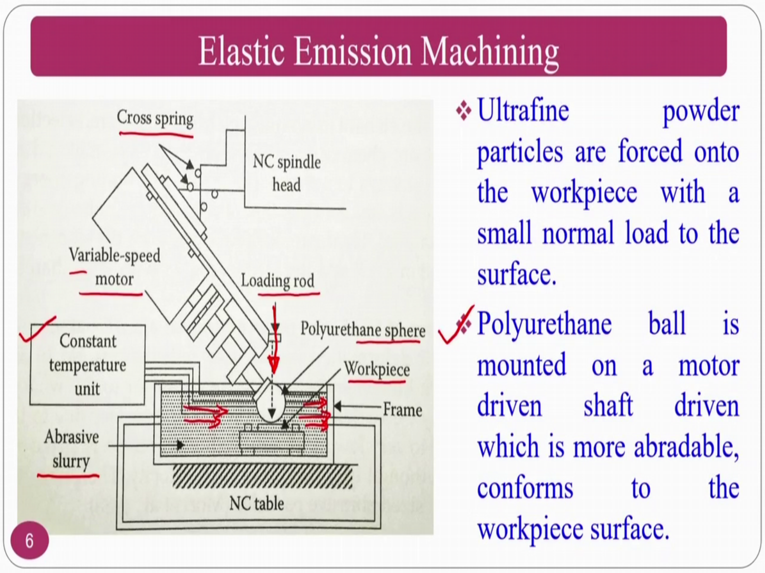

So, how the elastic emission works? If you see the elastic emission process, what will happen see, there will be a polyurethane ball here this is a polyurethane ball which is a tool basically on a work piece, and you can find there is a micron gap. There will be a micron gap with between your polyurethane sphere as well as a workpiece. This is flooded with abrasive particles which are very very fine in nature and along with the water or any other fluid ok.

What will happen here you have a loading rod. So, you can put the normal load whatever the load required; at the same time you have to make sure that the spherical ball of the polyurethane shear should not touch with a work piece ok. You have a NC spindle head, so that you can control the cross spinning; at the same time, variable speed motor, it will give you what are the speeds at which you are spherical ball has to rotate.

And you will should maintain the constant temperature unit, because you are going to finish the optical lenses; lenses are normally brittle materials. If you are not going to maintain the temperature or the temperature difference is there, then there will be a problem of brittle fracture. Normally, what are the temperature that you are maintaining here, it may not happen, but there may be because your focal point will vary if there is a thermal expansion and contraction and other. So, in order to maintain all these things you have to always go for constant temperature unit if there is a contraction and expansion in a sub-nano level or nano level also the focal points will drastically vary. So, for that purpose, you have to maintain the constant temperature.

Abrasive slurry says that it has a abrasive particles as well as a carrier medium ok. So, in a lapping process also you will have always a carrier medium which is water or oil or any type of thing along with a abrasive particles ok. At the same time some of the people they call it as a vehicle also ok. Some of the textbooks follows the vehicle because it is carrying the abrasive particles ok, do not confuse between carrier fluid, vehicle and other some slurry also the some people will say ok.

So, if you see here a polyurethane ball is mounted on a motor driven shaft which is driving a upgradable confirm to the work piece ok. So, there will be a sphere. Then what will happen there will be a ultra fine powder particles; that means, that the abrasive particles are forced into the work piece which with small normal to the surface. Normally, what will happen is your abrasive particles are moving like this ok. So, you are going to put a normal load on top of it, but make sure that work piece and you are polyurethane sphere are in no way contact. But because of this normal pressure at the same time flow ability what will happen abrasive particles and this fluid will go in touch with the work piece.

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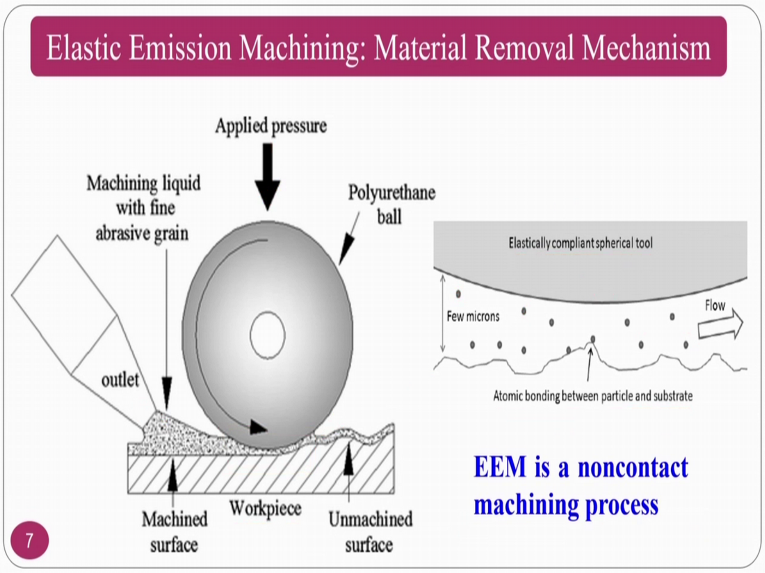

So, material removal mechanism if you see the zoomed version of the previous slide what will happen is this is how the outlet where the abrasive slurry is coming here, and there will be a microns gap between your sphere that is the polyurethane ball or the polythene sphere and the work piece ok. This is the normal load. And this is a rotation because of which what will happen is you will have the it will force the abrasive particles or the abrasive slurry towards the finishing region that is why the finishing will takes place. And this finishing is not by the virtue of shearing or something, but it might be the virtue of chemical reactions and other things.

We are zooming this particular portion. And what here it is happening, if you see here, so there will be a few microns gap between elastically complaint spherical tool that is nothing but polyurethane ball or a polyurethane sphere. And you are putting a load normally in this direction, at the same time you are rotating it ok. Because of this what will happen these particles are forced towards the surface of the work piece; and at the same time, slurry is there this slurry is a liquid and it will remove the material.

How it will remove the material that we will see, what are the chemical reactions that is going to takes place; how the material removal takes place in the non-contact region is different. As a mechanical engineers what you can guess is shearing action as well as abrasion is a normally the material removal action in terms of grinding, in terms of lapping and other things, but in terms of elastic emission process this is not so, it is a noncontact type of machining process. So, even it is noncontact is there how the material removal is taking place that we will see in the upcoming slides.

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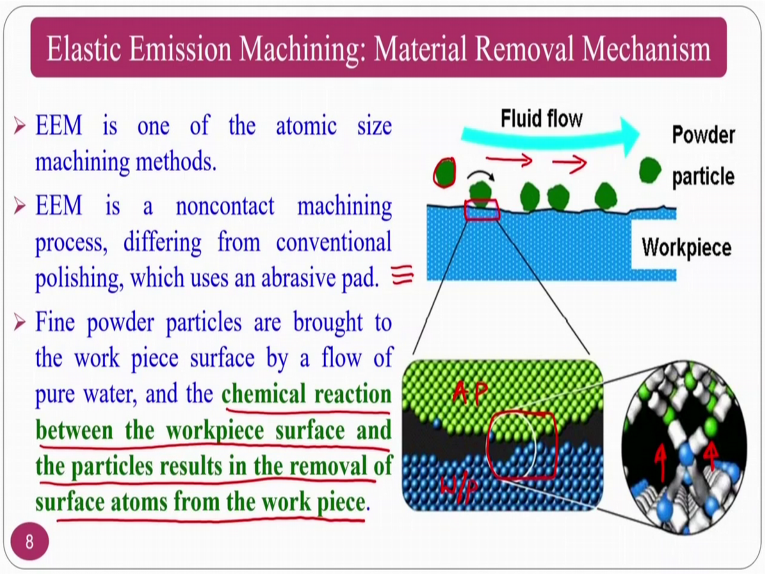

So, EEM is one of the atomic size machining methods where you can remove the material in terms of atom by atom. So, elastic emission machining is a noncontact type machining process differing from the conventional polishing which uses the abrasive pads because of this what will happen you will get a feed marks or the predominant direction of the surface roughness that is nothing but the lay. So, we ha[ve] which have seen in the grinding process and other things, whenever you see the grinding process where you will see a straight lines.

So, fine powder particles are brought into the work piece surface by the flow of pure water, and the chemical reaction between the workpiece surface and the particles results in the removal of surface atoms of the work piece. This is how the mechanism of material removal takes place. It is not by the virtue of the shearing action it is not by the virtue of abrasion or something. So, what will is happening is your spherical ball is rotating at the same time, you are giving a normal load on it because of which part will happen it is directing the slurry, the slurry is compressors of the carrier fluid as well as the abrasive particles, those are going near to the work piece and it is chemically reacting and taking by atom by atom that is how the mechanism works in the in case of this for the material removal.

The schematically if you can see what is happening is your fluid that is a carrier fluid is flowing like this and abrasive particles are also there in the carrier medium that is called the slurry. Slurry is a combination of your carrier fluid plus abrasive particles ok. So, this what is happening in whenever the abrasive particle is in contact with respect to the work piece. If you see here this is the abrasive particle and this is the work piece material and there will be a contract here, and this particular contact is making a chemical contact and it taking away the atom by atom.

In this circumstances what is happening here is that the material are removed by atom by atom by the chemical action not by the mechanical abrasion or scratching on the shearing action because of which you do not find any type of shearing marks or the feedback like this. So, you are going to get a better surface finish without the mechanical shearing action.

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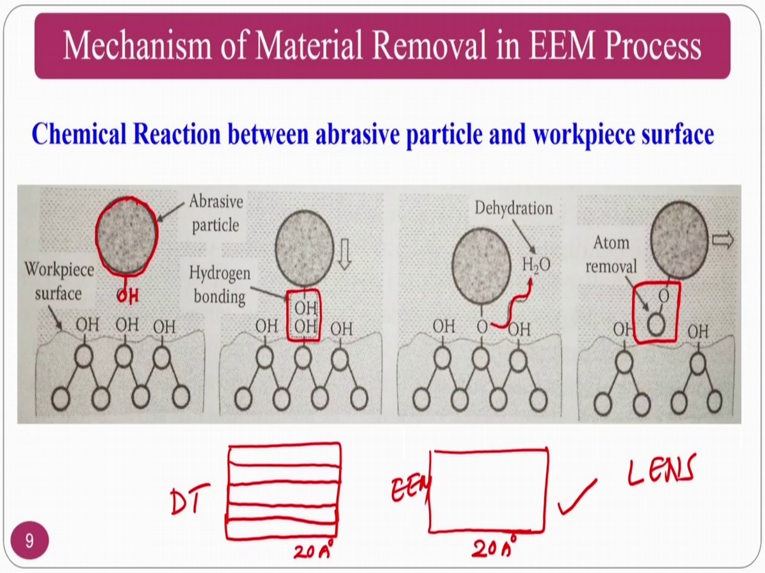

Mechanism of material removal, if you see the chemical reaction between abrasive particle, in the case one what is happening it has a water molecules which are there as a part of your abrasive slurry, this water molecule you have OH group and this OH at the same time work piece also on the surface of the work piece the abrasive slurry is moving.

So, it has which OH molecules are on the surface. This OH molecules OH molecules having a hydrogen bonding, and it will goes off as the water ok. Then it will re retain the oxygen bonding and this oxygen will remove one atom. So, this is how the material removes atom by atom not by mechanical action because of which what you are going to get if this is a surface in terms of grinding or the diamond turning, your tool will go you again it will come back your tool will go again it will come back. So, this type of scratch marks will be there even though you are going to get the surface roughness about 20 Armstrong or something.

But the same surface if you can get achieved by the elastic emission process, diamond turning process, elastic emission machining in the circumstances you get 20 Armstrong just I assuming, but there is no a scratch marks on this particular process. This you can use for the lens applications or mirrors applications or superfine mirrors. So, for example, synchrotron mirrors are made up of some of the synchrotron mirrors are made up of this particular process where you do not get any stretch marks ok. Not only you are getting a surface finish of 20 Armstrong's, you are also eliminating the feed marks that you predominantly see on the mechanical process that is why this particular process is much more efficient compared to mechanical processes.

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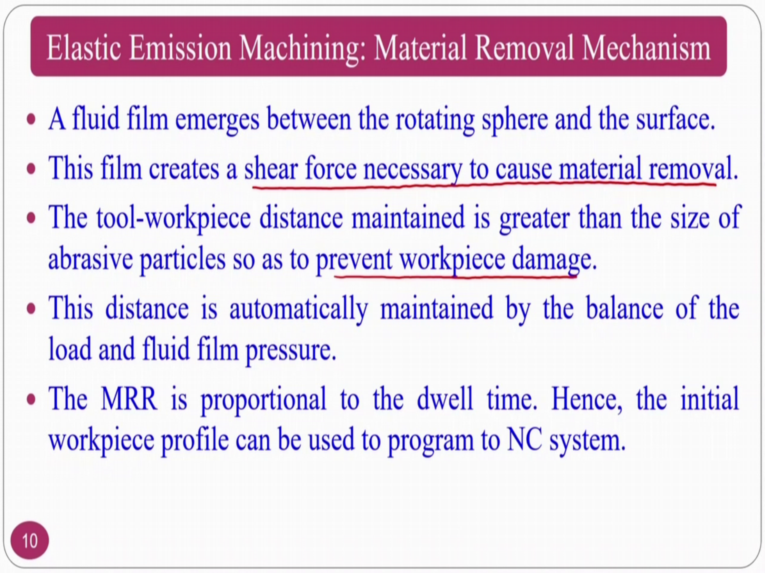

So, elastic emission in the material removal mechanism. A fluid film emerges between a rotating sphere and surface. This film create the shear force necessary to cause the material removal, that means that this particular sphere is rotating which it rotates tries to move the abrasive particles in the direction of their motion, tangent to the motion. Assume that my sphere will moving like this, what will happen, abrasive slurry is coming like this, what will happen it tries to give the motion along the tangential direction at that particular position ok. So, this will empower the abrasive particles to posses the shearing action.

The tool-work piece distance is maintained is greater than the size of the abrasive particle so that to prevent the workpiece damage that means, that always your abrasive particles are so fine that that the gap should be always much bigger than the abrasive particle. So, that there would not be any mechanical shearing action. This distance is automatically maintained by the balance of the load and fluid film pressure. So, this will be there will be a closed loop system will be there and always they will measure the forces and it will be maintained the pressures.

The MRR is proportional to the dwell time hence the initial work piece profile can be used to the program to NC system - numerical control system or computer numerical control system you can go hack. Assume that I want to finish a convex shape. Assume that this is a convex shape that I want to measure. So, just I measured with a CMM and all the points and I will make into M codes and normal other all the codes then you can feed this to the CNC system. When you are going to feed to the CNC system, the CNC system will take care of the x, y, z motion and other things.

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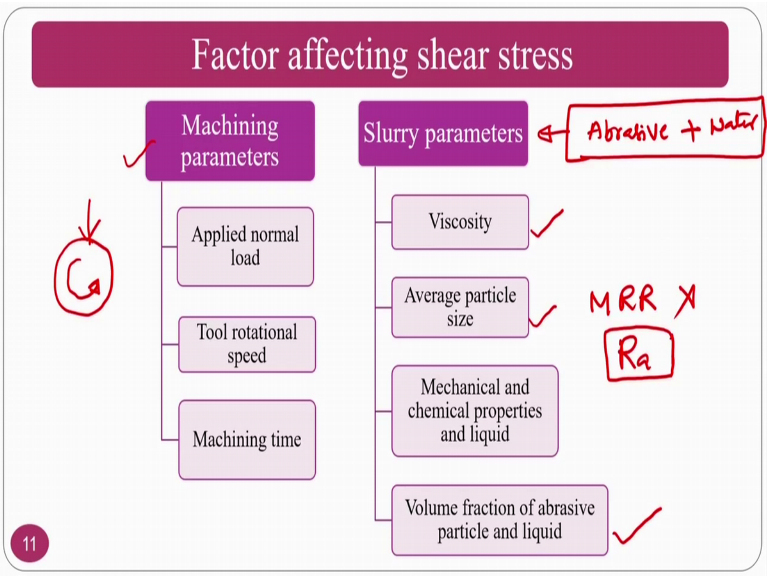

Though so factors affecting the shear stress normally the first one is a machining parameters that is nothing but the applied load. How much load that the machine is applying on the sphere, so that it will give some pressure on the fluid. The tool rotational speed that is nothing but how fast you are rotating the sphere, so that you will give the shearing action to this one. At the same time machine tell whether you are going to mission for 10 minutes or 10 hours or something depend on your work piece material condition and workpiece inside surface roughness condition, your time, your rotational speed your applied load all these things will vary. Where the slurry is nothing but abrasive particles at the same time you will have a water or any other fluid this is nothing but your abrasives slurry.

So, the viscosity of the abrasive slurry this is nothing but a suspension the viscosity if at all you want the high viscosity if at all low that is always is the function of what is the following characteristics that you required. You need very low flow rate then you can go for high viscous fluids if you want very high flow rate then you can go for low viscous fluids and other things.

Abrasives size of the particle whether you want to get a good surface finish, then you are to go for super fine or ultra fine particles. Whether you are material removal is a criteria then you can go for coarser size particles normally this particular process uses for the finishing of the lenses. So, in that circumstances material removal may not be a criteria in this condition consideration is the surface roughness on figure accuracy and other things.

Mechanical and chemical properties of the liquid, so the mechanical properties also required the abrasive particle should have some mechanical strength and other things. And the chemical properties whether OH bonds are performing easily or something.

So, volume fraction of abrasive particles if the abrasive particles are more what will happen as we have seen in the previous slide the abrasive particles OH group is reacting with the OH group of your work piece. In that circumstances what is happening O if you have more and more number of abrasive particles, OH to OH bonding will be very good; at the same time many places this OH-OH bonding will be there and it will be release as H 2 O and the remaining oxygen will bind to the surface atom and takes away in terms of oxide atom.

So, it will form the oxides and it will remove the material ok. So, as we have seen the oxide films are very easy for example, if you are putting a mild steel in a rain after few days if you see that will be rust formation you can scratch the rust with respect to you are nail also, but if you want to scratch on a mild steel, you cannot scratch that is the beauty about this particular process.

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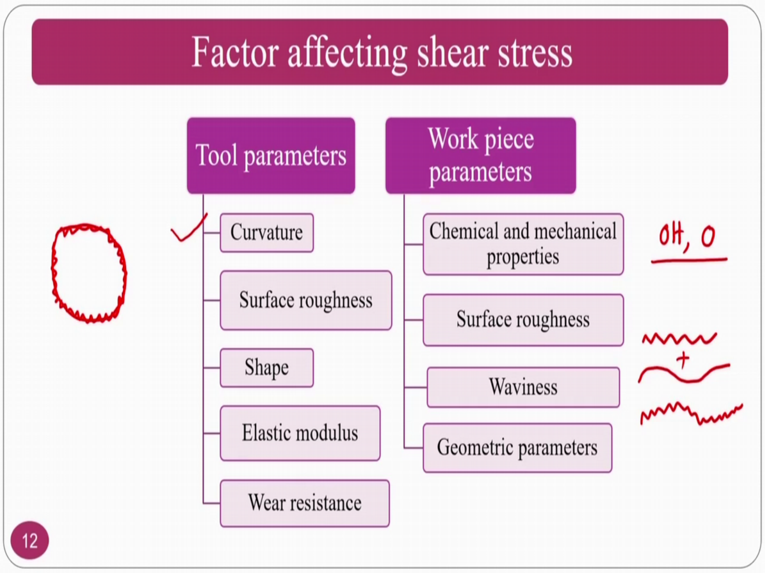

So, the next set of the factors that affecting the shear stress is tool parameters ok. The curvature normally spherical curvatures are the common curvature. If the surface is like this, what will happen, the workpiece also get the bad surface finish ok. The shape always you are shape to be maintained precisely and the elastic modulus you should have the appropriate elastic modulus that you require for that particular process and where is it should be wear resistant because if the way of this particular polyurethane sphere is too high what will happen your re changing time on the changing time between these two spheres will be high that is called as a nonproductive time and that nonproductive time should be reduced.

For that purpose, so you should always go for highway resistance, so that the wear will be very low. The workpiece parameters that you have to see is chemical and mechanical properties. Because it has to form OH bonds again oxygen bonding and other bonding it has to do. The surface roughness the initial surface roughness should be good, so that the final surface roughness can be achieved at earliest possible that mean that if you are having the surface roughness as 1 micron and your final surface roughness is 1 Armstrong, then it will be a very big trouble for to get that particular surface roughness ok.

The waviness as you have seen the surface roughness is like this and waviness is like this. So, both if you combine what will happen is this is the profile roughness ok. So, waviness also should be maintained properly because this particular sphere cannot correct waviness. It can correct to the surface roughness up to certain level, but form of which is nothing but the high amplitude thing is very difficult to correct. So, the geometric parameters and other things should be proper.

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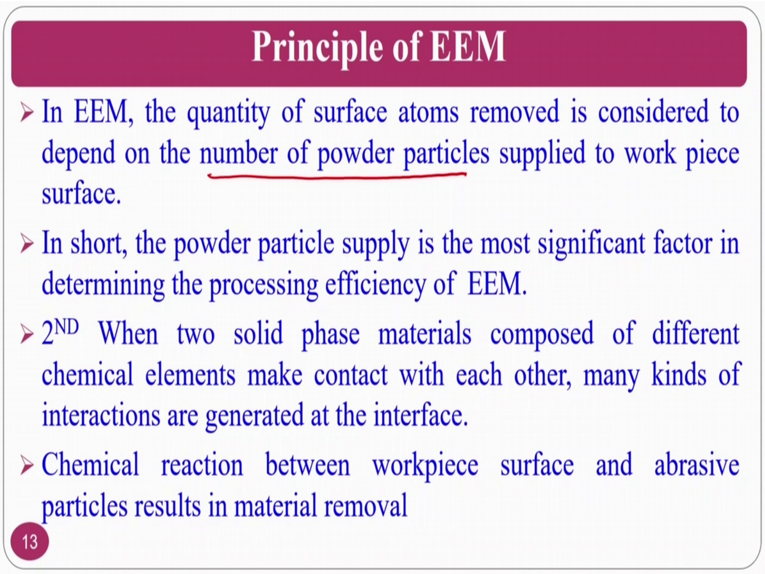

The principle of EEM. In the EEM, the quantity of surface atoms removed is considered to depend on the number of powder particles. As I said abrasive particles because the each abrasive particle will form OH bonding OH bonding of that work piece surface and it will remove. In short the powder particles supply is the most significant factor in determining the process efficiency; that means, abrasive particle will form OH bonding with respect to OH bonding of your work piece surface.

So, this will go as H 2 O and the remaining oxygen will bind to the atom of the surface and it will remove. So, this is always if you are sending maximum number of abrasives, then what will happen maximum number of OH bonding will be taking place. Second, when two solid phase materials composed of different chemical elements make the contact with each other, then interaction generated at the interface will be very good. At the same time chemical reaction between the workpiece surface and the abrasive particle results in material removal that is what I was saying that OH bonding and OH bonding will takes place.

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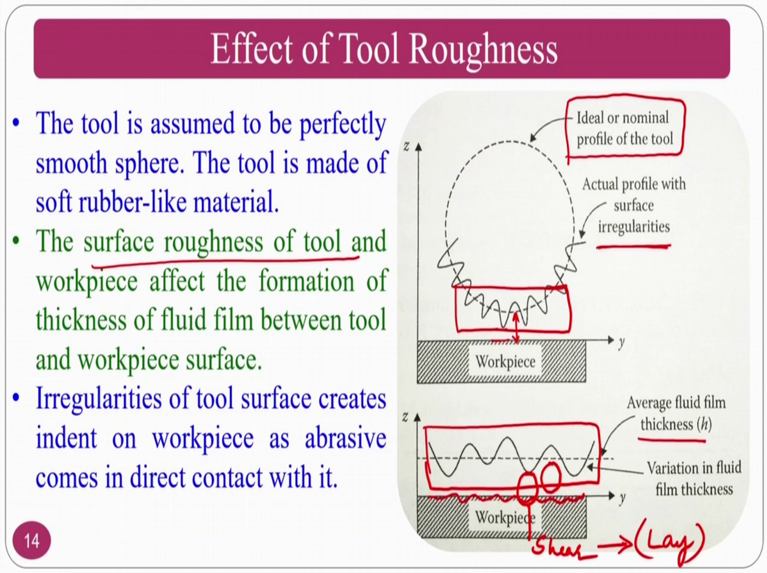

The so if you see the roughness of the tool that is a sphere, what will happen you are require ideal surface is this particular sphere. But normally if you want to see you will have always say actual profile will be lot of roughness will be there ok. This is assumed to be perfectly smooth sphere, but the normally tool will have soft rubber like material, the surface roughness of the tool work piece affect the formation of thickness of the fluid film between the work piece; that means, that if this is a surface what will happen this may be a thickness of the profile. If this is a surface then this thickness will vary. If the surface roughness is too high, what will happen it will affect greatly the film thickness and other things. So, if the film thickness is varying that the for location to location what will happen the surface roughness also will be very poor.

So, this is the actual fluid film thickness because the you if you see here, this is the variation because of this variation this is a fluid film thickness is generating. If because of this, what will happen your surface also will have wavy surface characteristics. So, irregularity of the tool surface create indent on the workpiece, and it will also create some indent.

Assume that the abrasive particle as I said the distance between the sphere and the workpiece should be higher than your of abrasive particle. If you see in this particular case it may be higher in this case, but it may be lower in this case because of which what will happen you will get a shear mask because the abrasive is completely in contact or it is squeezing between your spherical ball at the same time the work piece. So, it has chances to shear ok. So, then it will create a layer that is nothing but predominant surface roughness direction because of which what will happen the shear marks will be generated.

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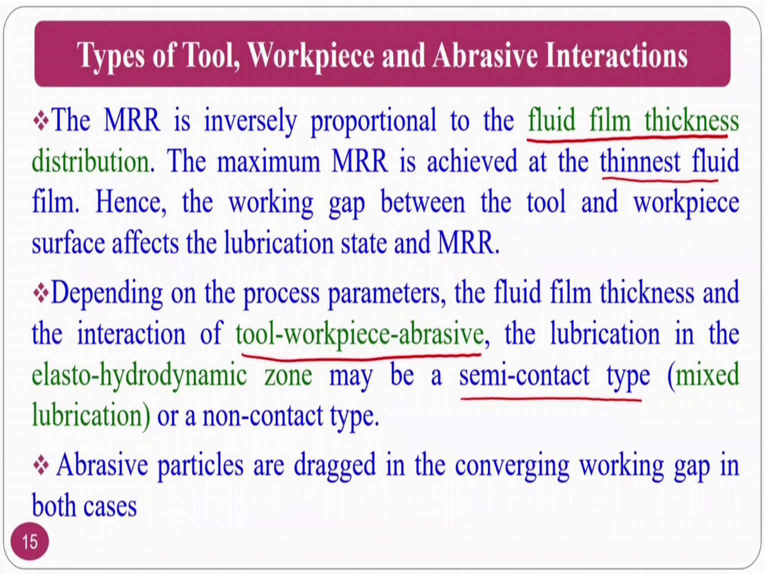

The types of tool work pieces and abrasive interactions, the MRR inversely proportional to the fluid film thickness that means, that if the MRR you want to be more what will happen is you have to use very less fluid film thickness. If you have very less fluid film thickness, if you have same number of abrasive particles and the fluid film thickness is low in one case and high in another case, in that circumstances what will happen is number of abrasive particles is coming in contact with respect to work piece will be high in terms of less fluid film thickness that is why it is always inversely proportional; that means that MRR will be very high if the fluid film thickness is low.

The maximum MRR is achieved at the thinnest fluid film,. And hence the working gap between the tool and workpiece surface affect the lubrication state and MRR. So, you need to have a proper lubrication, at the same time you need to have a proper material removal rate. Depending on the process parameters the fluid film thickness and the interactions of tool-workpiece and abrasive, and the lubrication in the elasto-hydrodynamic vision maybe semi contact type that is that nothing but the mix lubrication or noncontact type that means, that mix lubrication is nothing but you will have a very fine thin layer. A noncontact zone means you will have a hydro dynamically here So, the abrasive particles are dragged in the converging working gap in the both cases ok.

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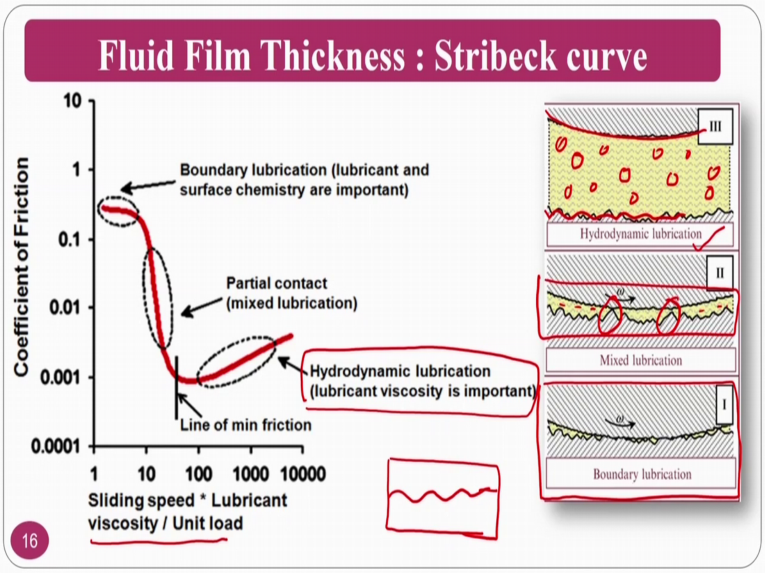

So, what is meant by this semi contact type or mixed type of lubrication or the noncontact type. So, if you see the basics of tribeca and other things, you can easily understand what is a boundary lubrication what is the mixed lubrication and hydrodynamic lubrication. If you plot between the sliding speed versus coefficient of friction, the first one is a boundary lubrication. Boundary lubrication means if you see here this particular image is shows the boundary lubrication that means, that it will have physical contact with respect to both surfaces.

Assume that if you have a having a abrasive grinding wheel at the same time you are having the workpiece, so the contact region between the abrasive particle and the work piece that is nothing but the boundary lubrication that means, that your abrasive particle is completely in contact with respect to the workpiece. So, for example, to for better understanding is chip tool interface, what will the happen is the sticking region and sliding region is there the sticking region is the boundary lubrication that where you have a chip as well as your cutting tool both are in contact that is nothing but the your boundary lubrication, where metal to metal contact or tool to chip contact will be there.

In the mixed lubrication; that means, the sliding zone where you will have partial cutting fluid also will fall or that means, that you have the tool at the same time chip, but in between you have a cutting fluid the film is very fine. That mean that some of the locations you will have the lubricant some of the locations it has a pure contact between the two metallic surfaces or I am assuming that HSS versus the mild steel, so that is why I am telling about metal to metal contact are something ok.

This is called sliding region you can say some of the locations, you will have contact and some of the locations you will have fluid in the hydrodynamic lubrication that is nothing but where you do not have contact no contact that means, that elastic emission machining works is in the hydrodynamic lubrication region, where your work piece is at the bottom and your tool is at the top, you do not have any contact where in you will place the abrasive particles ok.

So, these are the abrasive particles along with carrier fluid this is hydrodynamic lubrication zone is what you are going to use in terms of elastic emission machining because of your rotational effect of your tool as well as the normal load because of which what will happen your abrasive particles are guided, at the same time chemically reacted with the work piece and it will form the layer and the material removal will takes place. So, how the material removal will takes place in the hydrodynamic lubrication region or the noncontact region.

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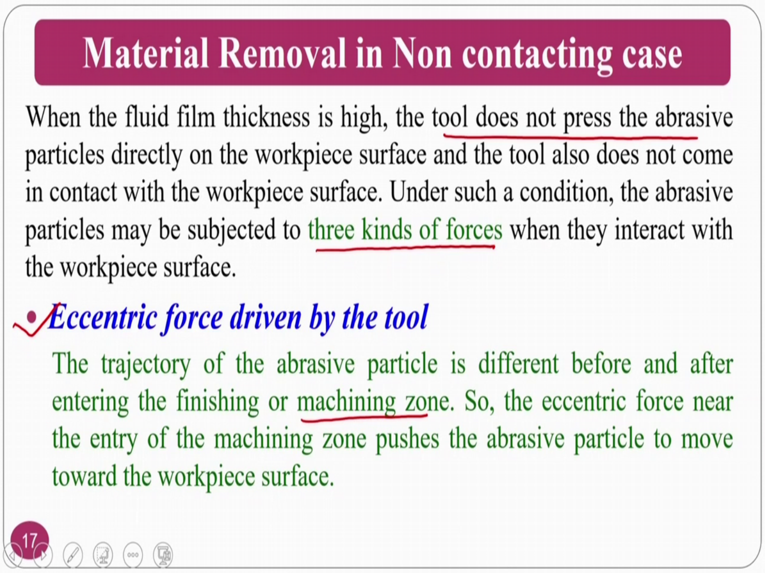

When the fluid film thickness is high the tool does not press the abrasive particles directly on the workpiece surface, and tool also does not come in contact with respect to work piece surface. Under such conditions, the abrasive particles may be subjected to three kind of forces. What are the forces? As I said in the previous slide you have a gap microns gap between your tool as well as your work piece. In that circumstances what are the three kinds of forces are generated which is nothing but eccentric forces driven by the tool that mean that the trajectory of the abrasive particle is different before and after entering the finishing and the machining region, so that the eccentric forces near the entry of the machining zone pushes the abrasive particles to move towards the work surface ok. This is one type of the forces that will pressurize the fluid towards the work piece.

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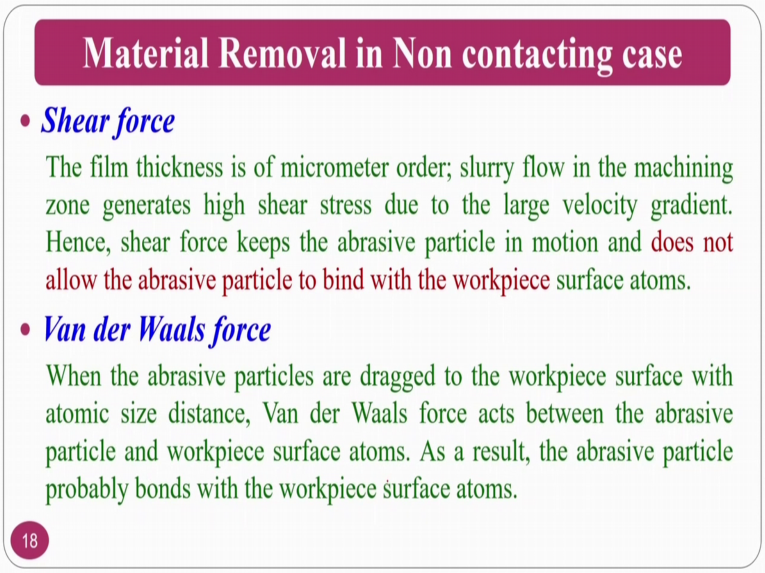

The second one is shear force. The film thickness of micro meter order; the slurry flow in the machining zone generate the high shear stresses due to which large velocity gradient will be there. Hence, the shear force gives the abrasive particle in motion does not allow the abrasive particles to bind with the work piece. That means that whenever you are giving a rotational motion to the sphere what will happen my abrasive particle having a chemical reaction with respect to the work piece at particular location.

It should not be stagnant at that particular position if it is stagnant what will happen the material removal may not takes place ok. For that purpose, it should be in a continuous dynamic motion. For that what will happen you are sphere is rotating this rotating sphere what will it will gives out the dynamic shear force to the abrasive particle, so that it will take away the material by forming OH-OH bonding and water will be released and move which is get the atom of the work piece material will get some shear force, so that it will be removed that is nothing but the shear force.

The Van der Waals forces, when the abrasive particles are dragged to the work piece surface with atomic size distance, Van der Waals force act between the abrasive particle and the work piece surface atoms as well as a result abrasive particle properly binds with the work piece surface atom.

Normally this will help the abrasive particles two bind between the abrasive particles bind with respect to the work piece and the shearing force will help in removing that binding of that O with respect to the atom of the work piece material, so that the material removal takes place by atom by atom.

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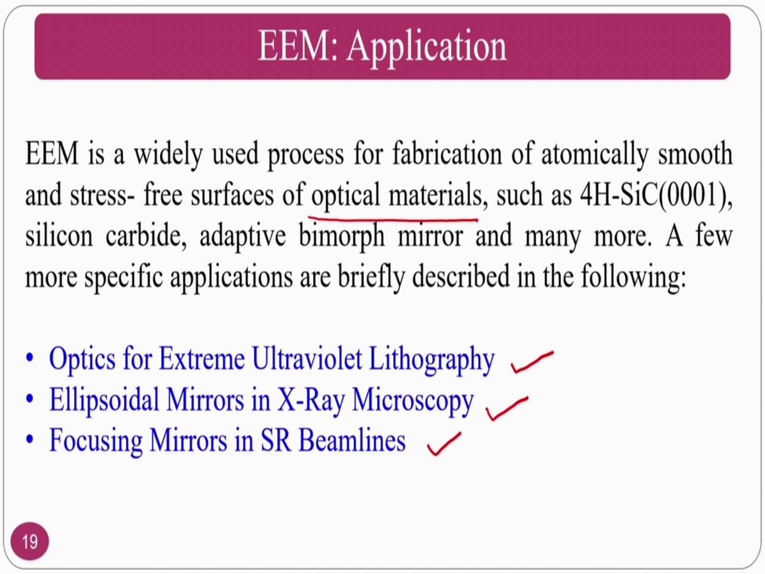

If you see the applications of elastic emission machining as in the first slide I said elastic emission is widely used process for fabrication of smooth stress free surfaces in the optical material such as 4 H-SiC silicon carbide, adaptive biomass mirrors many more a few specific applications are optics for extreme ultraviolet lithography this is one of the application, ellipsoidal mirrors for X-Ray microscopy at the same time focusing mirrors in the SR beam lines ok. These are the major applications of this particular elastic emission machining process

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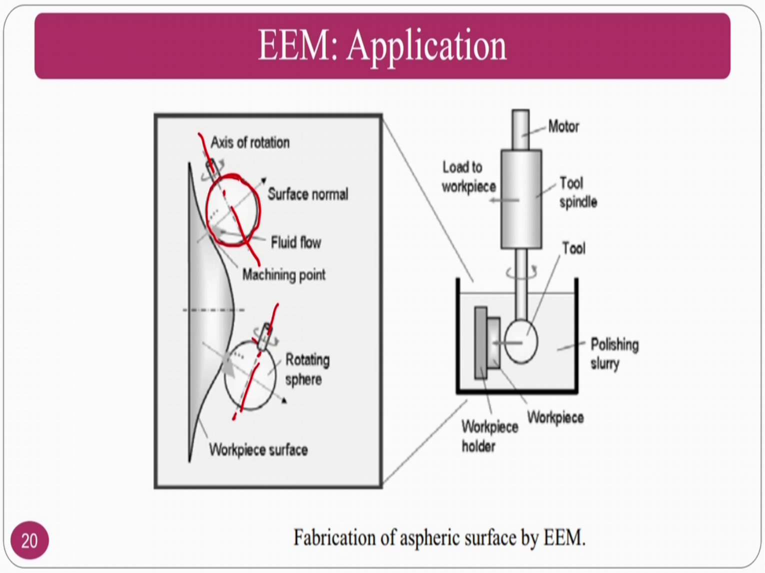

Fabrication of aspheric surface by EEM.

You can see here you have a lens with respect to the convex surface and you have to use your particular spear that is nothing but polyurethane sphere in different angles. So, you have a x, y, z motion caviling action and other things. Normally you might have seen the three axis machines, five axis machine and machines. So, you can use this type of motions to the spherical ball, then you can do at a different positions different accesses will be maintained. Here this is axes and this is another axes where you are maintaining at the different axes ok.

When you can get the smooth surface you should have always a perpendicular direction ok, a sphere will have always the perpendicular direction if you can go in proper. This is how you can do the aspirate surfaces by elastic emission machining process

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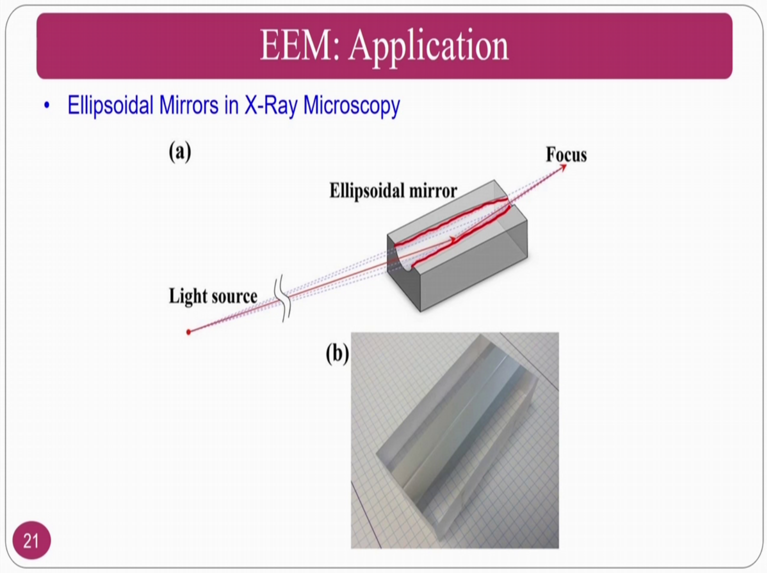

Ellipsoidal mirrors in X-Ray microscopy, you can do the finishing operation you can see there will be a gradual change in the curvature, and this curvatures can be machined by the elastic emission machining process.

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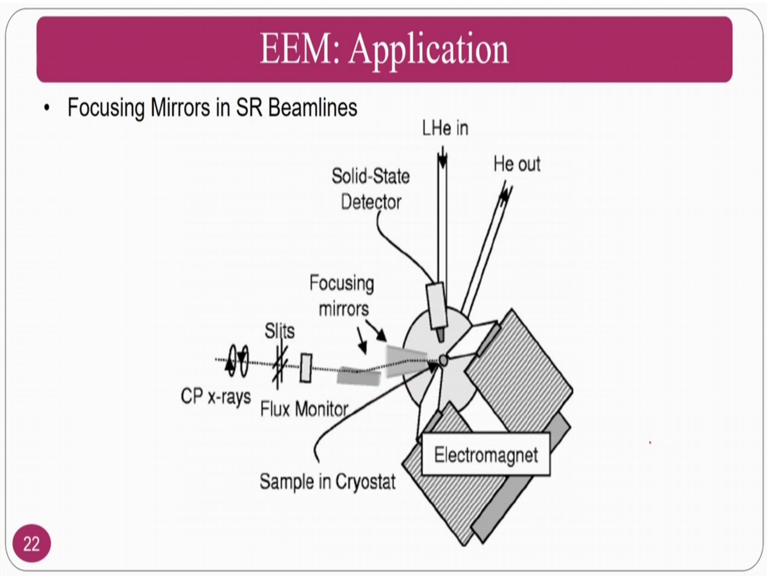

And the SR beam lines also if you see this SR beam lines are the mirrors focusing mirrors are machine by elastic emission machining process ok.

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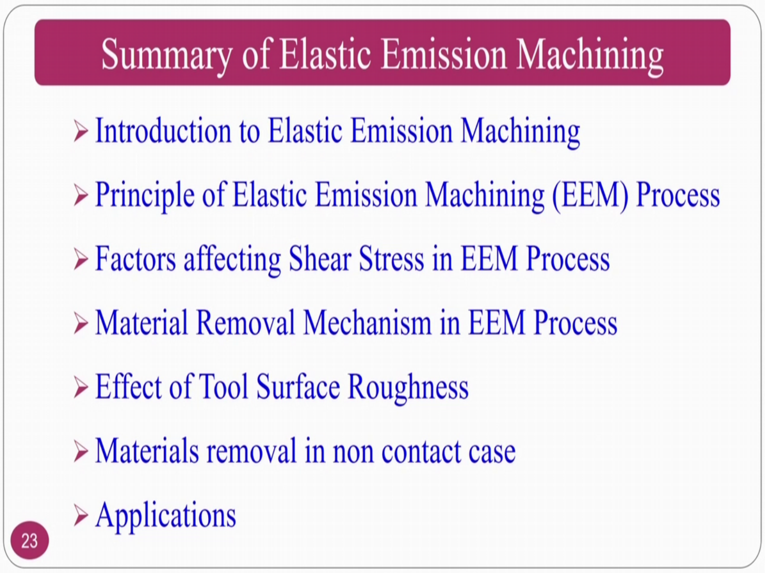

So, we will see the summary of this particular class. So, we have done introduction to elastic emission machining, then we have seen the principal, what are the factors affecting, what are the tool factors what are the input parameters, what are the workpiece parameters, what are the slurry characteristic, these are all we have seen how the material removal is taking place. We have seen that abrasive particles come near to the workpiece, but it would not touch the work piece.

And the OH bonds on the abrasive particles OH bonds on the workpiece will interact and H 2 O will release the remaining oxygen will bind to the workpiece material and it will take away the atom, so that is how the material removal mechanism atom by atom will take place without contacting the workpiece because of which you do not get any feed marks that normally you will achieve in terms of the mechanical processes.

So, effect of tool surface roughness. If the surface roughness of the tool is very high what will happen assume that this is my work piece surface. If roughness is like this always you should maintain the abrasive particle gap should be more than abrasive particle size. If this is abrasive particle what will happen at this particular location it may not touch, but if you come to this position what will happen, it will touch.

So, what will happen you should always have a smooth surface if you have a smooth surface like this and like this if you have a particle size like this there would not be any interaction. For that purpose the surface roughness of the tool plays a major role in determining the surface roughness of the work piece. If your surface roughness is poor what will happen some of the places it can scratch the surface. This particular location it will scratch the surface. So, you may get lines or the scratch marks on the surface. So, material removal in noncontact type you have seen the three modes of material removal in the noncontact types. And applications you have seen the lot of beam lines, lenses and other things, and other places you will use this elastic emission machining process ok.

I am very thankful for your kind attention. And you should note that not only a mechanical processes can do the machining and finishing, you should also look into this type of advanced machining processes, where the abrasive particles are not in contact with respect to the work pieces, but it can remove the materials. And the beauty about this particular process is you do not get a single scratch on the surface or single feed marks on the surface because there is known depth of indentation as because of the abrasive particles are slightly ahead or the above the contact of the workpiece. Because of this noncontactness, there would not be any mechanical action, only the chemical action will be there

Thank you.