Polymer Assisted Abrasive Finishing Processes
(Surface Morphology and Surface Metallurgy)
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Lecture – 08
Hydrodynamic Polishing, Elasto Abrasive Finishing

Welcome to the class and now we are going to deal with another process called Hydrodynamic Polishing.

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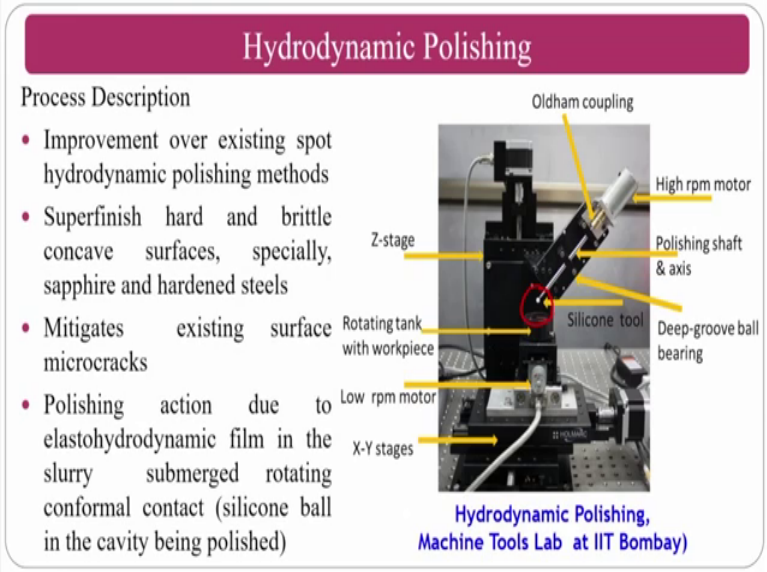

In hydrodynamic polishing; it is similar to the elastic commission machining, but here the contact will be there and you can see here, there will be a ball will be there and you can do the elastic ball. At this elastic ball will have against the work piece surface, there will be a finishing action will takes place.

Improvement over the existing spot hydrodynamic polishing method- normally what we will be there? There will be a polishing shaft will be there. Polishing shaft can rotate about any axis including sudden inclinations also. So, that you can do any types of blind holes also, this is normally a silicon tool; a silicon polymer will be there along with that you can blend the abrasive particle, that is why since the silicon polymer is there. Silicon polymer also processes elastic properties as well as partial viscous properties that is why

this is also comes under one of the finishing processes. And if you want more details you can go through the papers of Professor Ramesh Singh of IIT Bombay ok.

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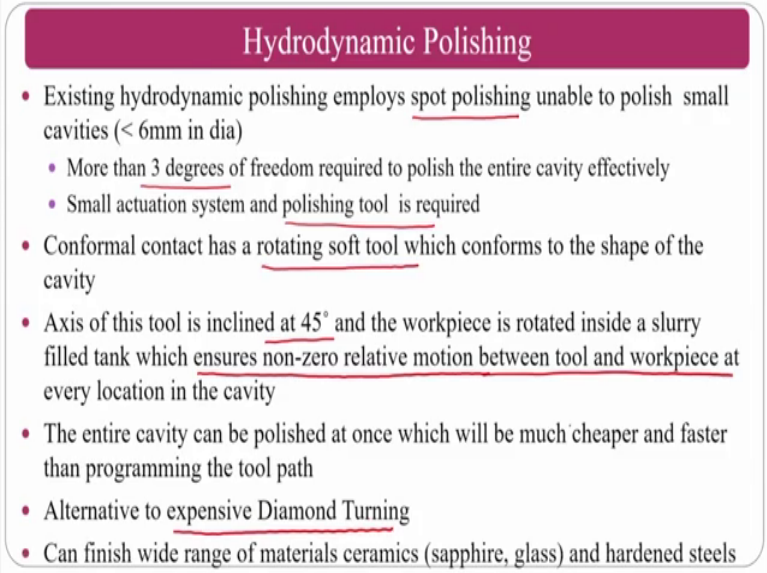

So, the existing hydrodynamic polishing employs the spot finishing unable to polish small cavities. Basically whenever the cavities are very small like less than 6 mm under the things, it will be very difficult. If have a hydrodynamic polishing, you can make your ball according to that or you can make your sphere according to that and you can do the finishing operation.

It has an more than 3 degrees and small actuation system for the polishing tool and other things. Conformal contact has a rotating soft tool which conforms the shape because of its viscous and elastic properties it can conforms the shape, then it will do the polishing ok. Axis can be inclined at 45 degrees and rotated inside the slurry so, that ensures a non-zero relative motion between the tool and the work piece. If there is a non - zero contact; that means, that all the contact is properly done with respect to the work piece by the tool and the finishing will do.

The entire cavity can be polished in only one go. So, alternative is diamond turning process which is slightly expensive.

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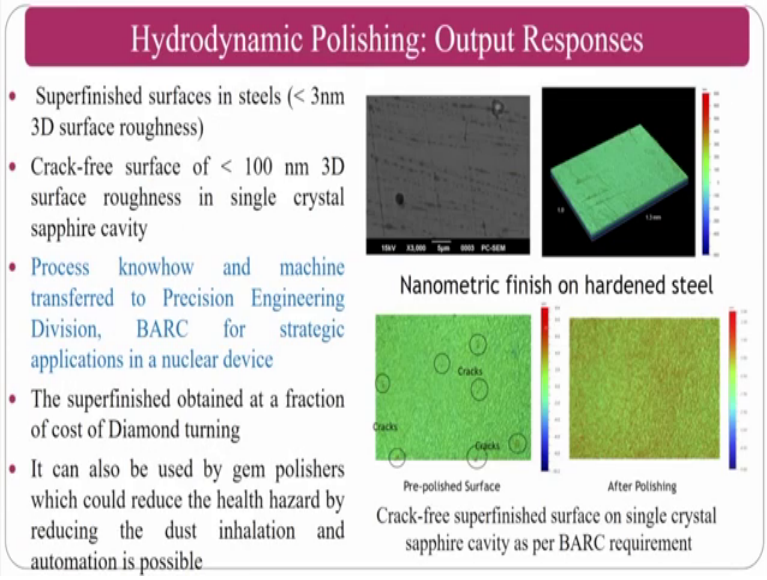

You can see the roughness variations in this one. The superfinished surfaces in steels approximately less than 2 nanometers on the 3D surface and crack free surfaces you can achieve and this is referred and Professor Ramesh Singh as a part of his project has been developed. And you can see the surfaces there is full crack free surfaces after finishing even though crakes are there before finishing process ok.

Now after completing Elasto-hydrodynamic finishing process, now we move on to another important process that is called Elasto-Abrasive Finishing process. The hydrodynamic polishing process I have not touch much because that is completely relevant or normally resembles like elastic commission machining process. However, there is some chemical action will be there in elastic commission machining, but here pure contact will be there in; but spherical ball and other mechanism is similar that is why you have only got some of the glimpse of hydrodynamic polishing.

However Elasto-Abrasive Finishing process is one of the process that is normally done for the finishing of internal features as well as external features. So, courtesy to professor Suraj who is there in IIST, Indian Institute of Space science and Technology; so, I have referred his papers and made the PPT for this one.

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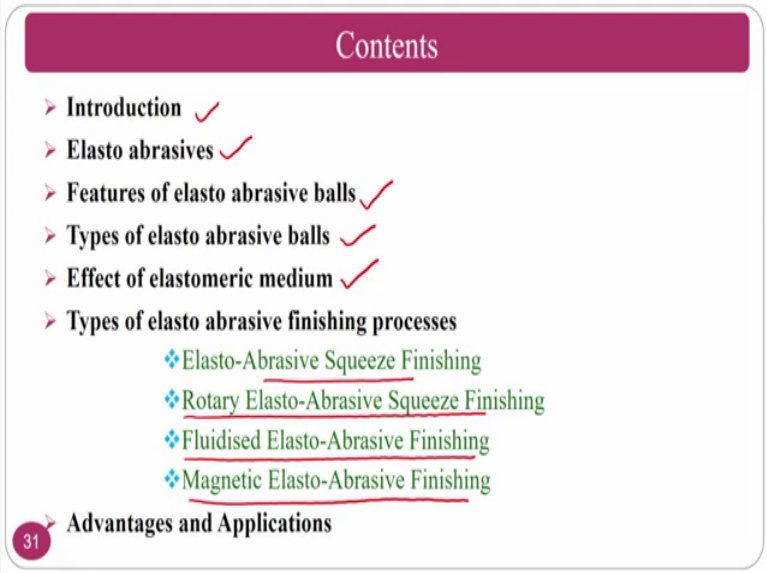

So, it includes introduction, elasto - abrasives features of elasto - abrasive balls, the beads whatever the thing, types of elasto - abrasive balls, elastomeric medium then there are 4 varieties of elasto abrasive finishing process is there. The first variety is elasto -abrasive squeeze finishing, second one is rotary elasto - abrasive squeeze finishing process, fluidized elasto-abrasive finishing process, magnetic elasto- abrasive finishing process. Then we will see what are the applications as well as advantages of elasto - abrasive finishing process compared to other finishing processes.

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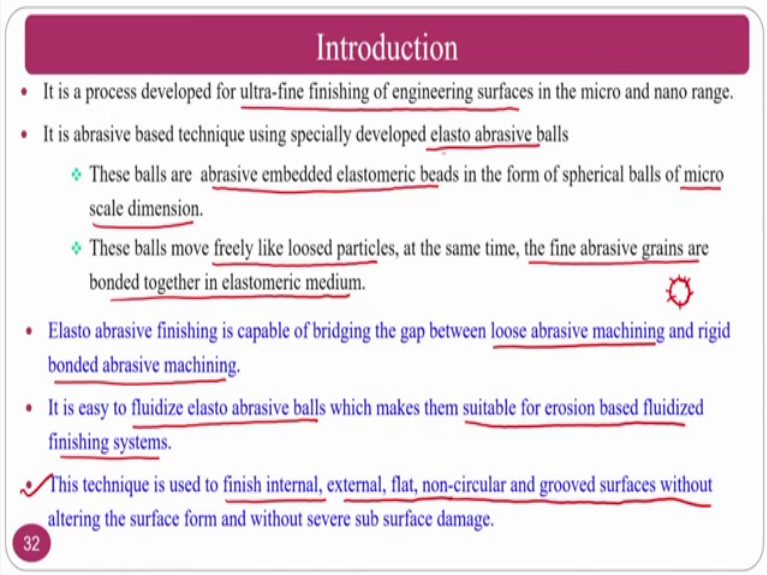

Introduction to this elasto - abrasive finishing process this is developed for ultra fine finishing of engineered surfaces from the micro to nano range depend on your ball that is fabricated. I mean to say elastomeric abrasive ball, how these elastomeric abrasive balls are developed and other things? We will see in the upcoming slides. These abrasive based techniques using the specially developed elasto - abrasive balls; these are specially made by using the temperature, by using some of the solvents along with the polymers.

These balls are abrasive embedded elastomeric beads in the form of spherical balls of micro scale dimension. These balls move freely like a loose particles; however, these all are bounded abrasives. At the same time fine abrasive grains are bounded together with elastomeric ball that is what I said these all are a bounded abrasive particles.

Elasto - abrasive finishing process is capable of bridging the gap between loose abrasive machining and rigid bonded abrasive machining processes. That means, that loose abrasive machining processes for example, if you see the lapping process and wherever the abrasive particle has freedom to move about it is own axis that is called normally loose abrasive process and grinding process is bonded. So, in between this elasto - abrasive finishing process comes where you will have a spherical polymer bead will be there on top of it you will have the abrasive particles.

So, it is easy to fluidize elasto - abrasive balls which makes them suitable for erosion based fluidized system that also we will see the one of the variety. And this technique is used to finish internal external flat non circular grooved surfaces without altering the surface form without severe sub surface damage; that means, that this is elastic balls will be there which are embedded with abrasive particles and these abrasive particles can finish any type of surfaces.

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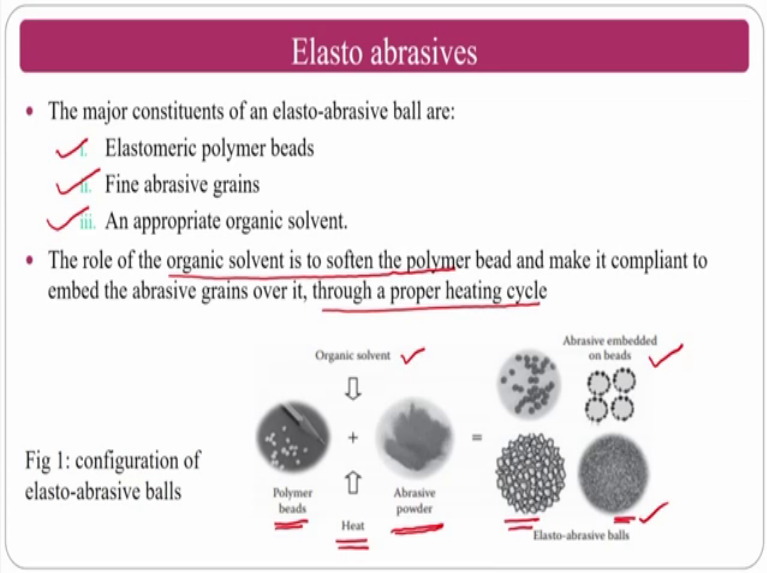

Fig 1: configuration of elasto-abrasive balls

Now, elasto- abrasive balls, elastomeric polymer beads is one of the major constituents fine abrasive grains an appropriate organic solvent. How this is fabricated? The role of organic solvent is soften the polymer bead and make it complaint to embed the abrasive grains on it, through the proper heating cycle ok. That means, that what the researcher is doing is first take the polymer beads, then you just mix with the organic solvent and you give a some heat for certain time that is why it is called as heating cycle.

Now to add the abrasive particles appropriately as per your requirement, your requirement may be the polymer some weight percentage, organic solvent certain percentage as well as heat you have to a certain degrees, then you mix along with these abrasive particles. Now you will get the abrasive embedded polymer beads.

And it looks like schematically like this, practically it looks like this. Some of the pictures, you will come across in this process in the upcoming slides how the abrasive particles look like and other things.

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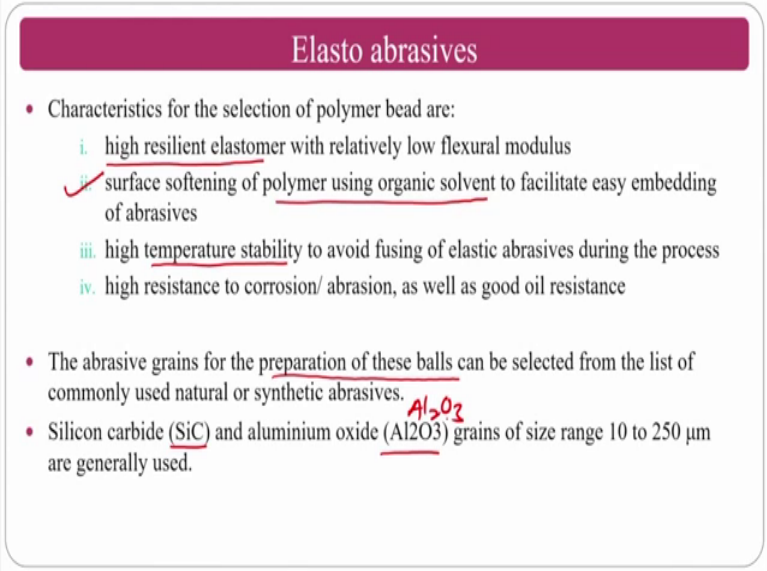

Characteristics for the selection of polymer beads are high resilient elastomer which is relatively low flexural modulus because it should have high resilience elastomer. So, that radial force can be applied whenever you are applying the axial force because the mechanism of elasto - abrasive finishing process is similar to the abrasive flow finishing process. However, in abrasive flow finishing process you have a continuous medium where in polymers, a plasticizers, abrasive particles and rheological reduce will be there. However here, the elastomeric beads will be there which are embedded with abrasive particles, but complete setup if you see the hydraulic power pack and other things will be approximately same.

Second one is surface softening of polymer using organic solvent to facilitate the embedding of abrasive particles; high temperature stability should be there. So, that this abrasive particles should not fuse during the finishing process or because of the temperature it should not go out also or dislodge; that means, that as a from the point of grinding it should not have soft grid. So, what I mean to say is there, if the temperature rises, what will happen? This elasto - abrasive balls may dislodge the abrasive particles also so, you should be bit careful.

High resistance to corrosion abrasion as well as good oil resistance. Abrasive grains for the preparation of these balls can be selected from a list of synthetic abrasives such as silicon carbide, alumina and many other abrasive particles ok.

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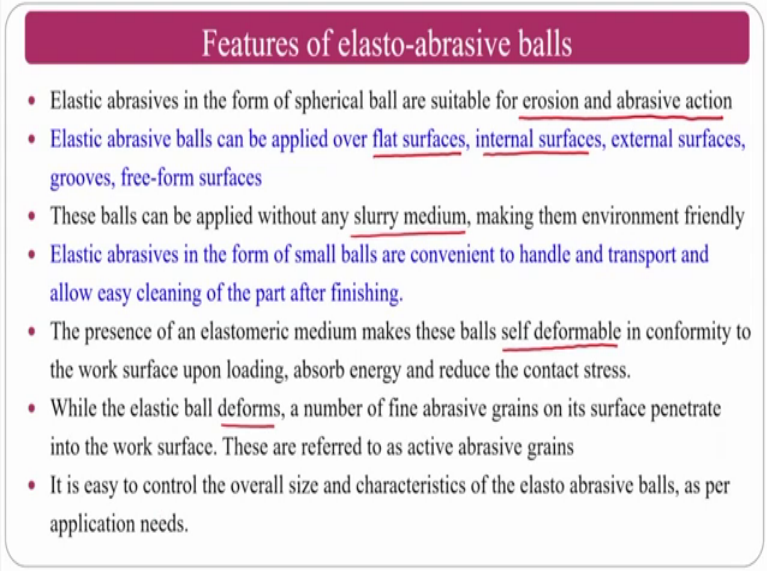

So, the features of elasto - abrasive balls because the major technology that Professor Suraj has done is developing of this elasto - abrasive balls. So, if you can develop this as elasto abrasive balls and if you can make as per your requirement, you can utilize for many many applications that was demonstrated by Professor Suraj. So, elastic abrasives in the form of spherical balls are suitable for erosion and the abrasive action and elastic abrasive balls can be applied over any surfaces that we have discussed like internal surface, external surface and other surfaces.

And you can apply without any slurry medium and that is why it can also called as environmental friendly, because if there is any slurry and other things, then there may be again a cleaning system will be there. If you do the cleaning system you have vary you have to dump that cleaning feed and other things will be a slightly worry. .

Elastic abrasives in the form of small balls convenient to handle and transport so, it is easy to clean. The presence of elastomeric medium makes the balls self deformable ok. This abrasives which are embedded on a polymer these are self deformable. Self deformable means with the atmospheric pressure if you put this ball under normal condition though so, if it is deforming with a atmospheric pressure conditions; that means, that it is self deformable. So, that if it is self deformable then what will happen whenever you load into medium cylinder and push what will happen is that the you can take to the nook end corners of complex surfaces also because if for the atmospheric

pressure itself it is deforming. If you put external pressure, what will happen? It will go to each nook and corner.

This elastic ball deforms number of fine abrasive grains on the surface penetrate into the work piece and the finishing action will be taken place. So, these can be easily controlled over the sizes if at all you want to finish small size holes or any features, you can go for small abrasive particles. If at all you want go for bigger one, you can go for bigger one.

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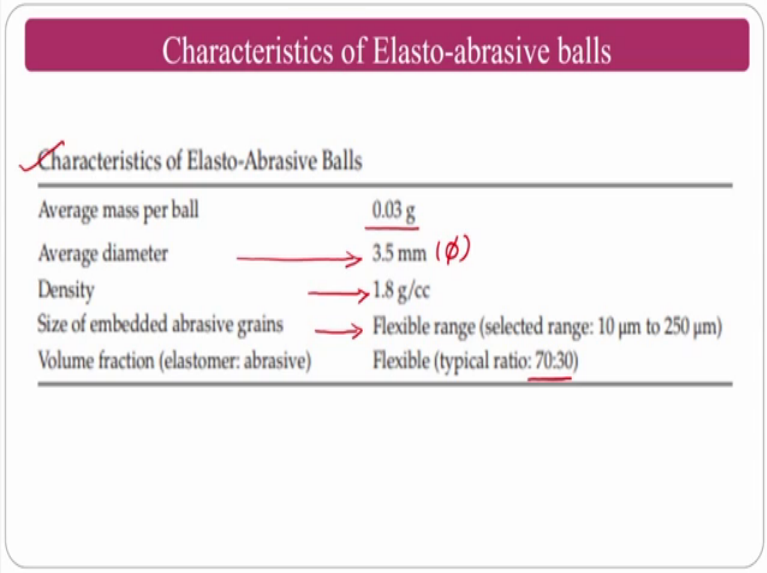

So, some of the characteristics that you can see of the elasto - abrasive balls is average mass per ball normally point not 0.03 grams, average diameter is 3.5 mm. So, that in this condition if you see you can use for macro applications and the density is 1.8 gram per cc, the size of embedded abrasive grains it can be ranged from 10 microns to 250 microns and it can be silicon carbide, alumina. And other things volume fraction of elastomer and abrasives normal typical ratio that is used is 70 percent to 30 percent; that means that 70 percent is elastomer and 30 percent is abrasive particles. However, depend on your application, you can vary all this concentration of abrasives and polymers.

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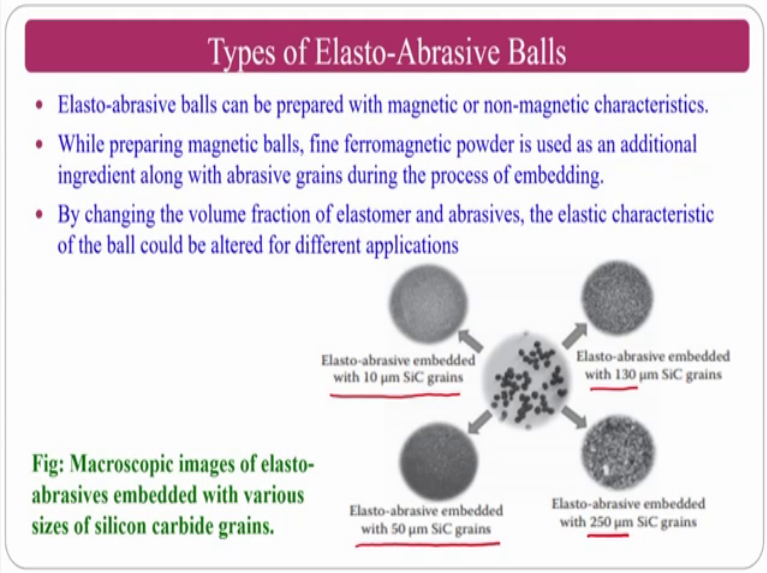

Elasto - abrasive balls can be prepared with magnetic or non magnetic characteristics. So, if you are going to make it magnetic characteristics, you can easily control from the magnetic field also. So, if you are not normal application like abrasive flow finishing you can utilize this one. While preparing the magnetic ball fine ferromagnetic powder should be used and this also we will see in the upcoming slides. Normally elasto - abrasive embedded grains are there, what will happen? This elasto - abrasive embedded these are all you can see 130, microns 250 microns, 50 microns and all these things are there. So, you can vary as per the your requirement.

So, macroscopic image of embedded with various size of silicon carbide grain; that means, that different abrasive particles sizes of same material that is silicon carbide is used in this particular context.

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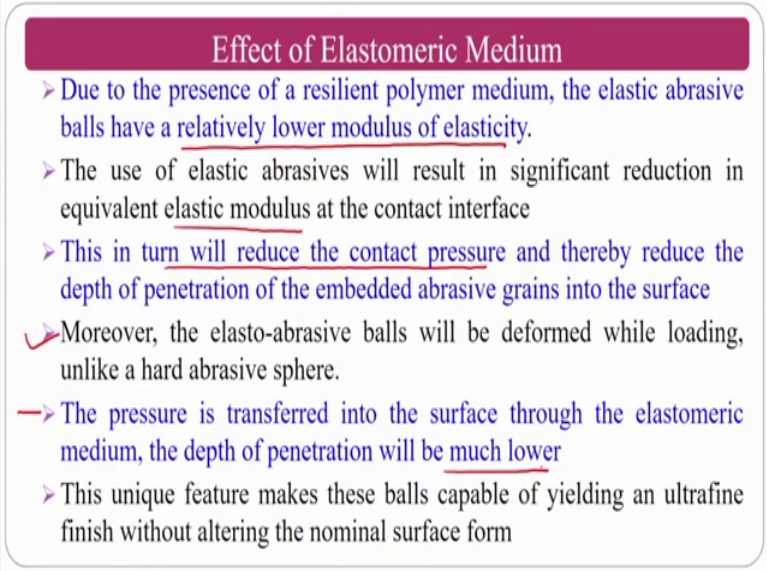

Now, the effect of elastomeric medium, due to the presence of resilient polymer medium the elastic abrasive is having relatively low modulus of elasticity that will be. So, that the finishing can be flexible and use of elastic abrasive balls will result in significant reduction of equivalent elastic modulus and contact interface; that means, that if your contact interface is very good. So, you can finish, as we have seen hydrodynamic polishing if there is a 0 non contact area; that means, that it is contacting all the areas so, the finishing will be better.

In turn, this will reduce the contact pressure and thereby reduce the depth of penetration the elasticity and viscous properties of this polymers used by the researchers have the visco elastic nature not like a direct ceramic direct ceramic particle. If there is a direct ceramic particle, if you are putting a load what will happen is it will do not have any elasticity; that means, that contact forces are enormously high in this case polymer is there. So, some questioning will be there and because of this what will happen depth of penetration will be less and you can do it for the polishing operation.

Moreover, elasto - abrasive balls will deform while loading and unlike the hard abrasive particles that is what I said that because of the questioning because of the elastic nature and other properties of the polymers what will happen whenever you apply certain pressure it will deform ok. The pressure is transformed into the surface through the

elastomeric medium and depth of penetration will be much low because of this elastic nature, this unique features make capable of yielding ultra fine surfaces.

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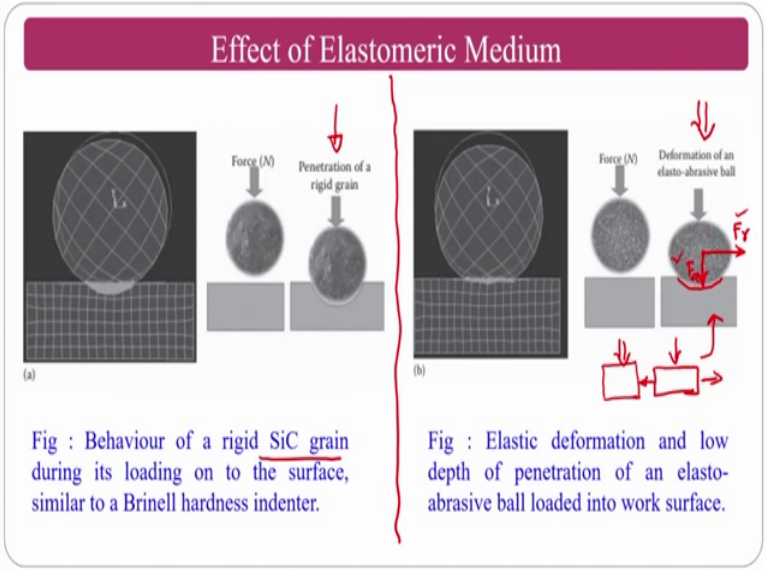

The effect of elastomeric medium if you see here the same thing is explained here in case of ceramic abrasive particle whenever you for going to give certain load what will happen? This do not have any questioning of task something because this is a ceramic particle it is a brittle material. So, depth of penetration will be more, but; however, if you are going to give some load to elastic abrasive what is made, because for the elasto -abrasive where the researcher has prepared with a polymer along with the temperature and solvent along with the abrasive particles. Because of the elastic nature and viscous nature whenever you apply depth of penetration will be there, but the depth of penetration will be less because whenever you are applying a load on a elastic what will happen the stresses will be there on the radial direction also that effect is called (Refer Time:17: 20) effect.

If you take an element you put some pressure on this one what will happen, it will expand like this; that means, that where the elasticity is going it is going into this direction this is called one of the common principle. So, what will happen your applying load here it is distributing and deforming in this direction, same thing is happening because of deformation in perpendicular direction along with that it is also acting in this direction. So, in the abrasive flow finishing you will understand much better way like

what is radial force, what is axial force and other things you will see in the abrasive flow finishing.

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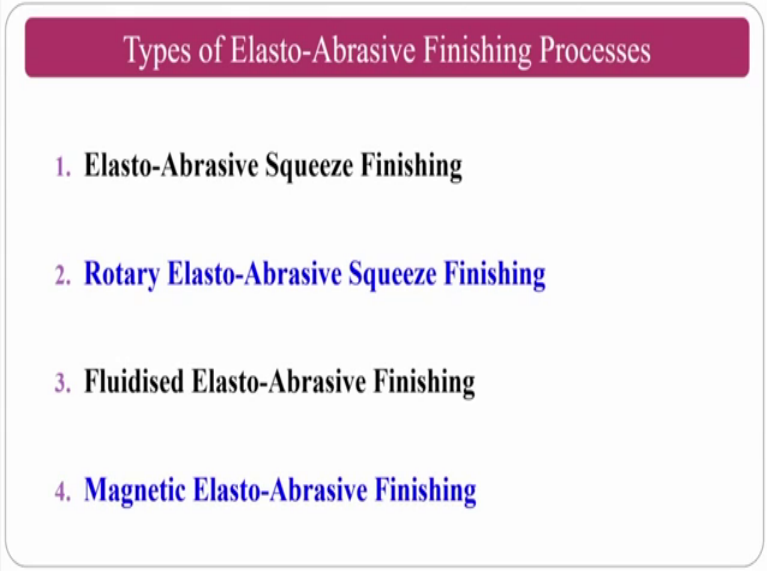

The same technology is here, but the basic difference between abrasive flow finishing process and elasto - abrasive finishing process is here these are the individual bodies and there is a continuous body, but in a individual what will happen , these all are a particles in a like a 3.5 mmr or 3 mmr particles. So, there will be a gap so, the finishing may be slightly interrupted. So, all the places that are that is a advantage of a abrasive flow finishing process over a elasto - abrasive finishing process because that is a continuous medium and you can make it low viscous medium also so, it will be better. So, there are 4 varieties one is elasto - abrasive squeeze finishing, rotary elasto - abrasive finishing and fluidized elasto - abrasive finishing and magnetic elasto - abrasive finishing process.

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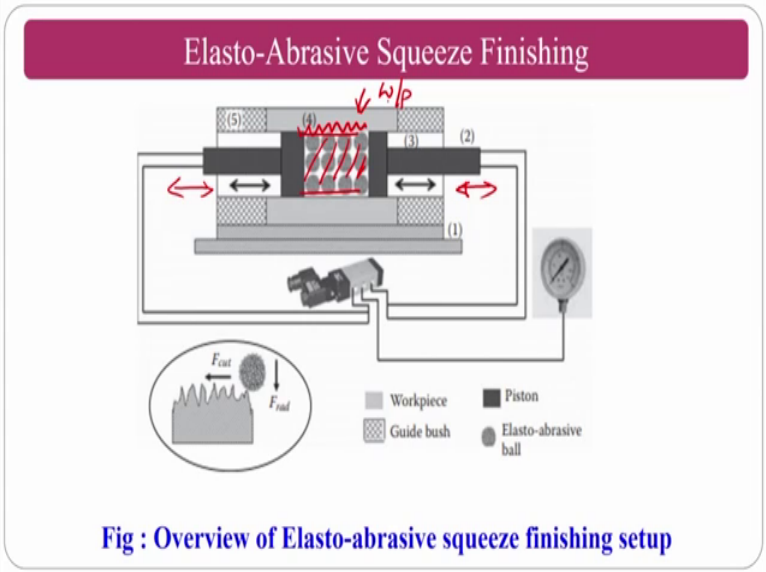

Fig : Overview of Elasto-abrasive squeeze finishing setup

So, this looks like similar to abrasive flow finishing process, as I said if your work piece is here and you will have always a empty zone in abrasive flow finishing process that you are going to study what will happen is it is a continuous body ok.

So, it is a continuous medium zero- non contact region will be there that is a advantage of abrasive flow finishing process and that is why the abrasive flow finishing process is much familiar and much industrial usage for the most of the companies. Here also it goes by the similar mechanism you will have a hydraulic power pack, pushes the medium and this will reciprocate into this one. So, that you have a work piece this work piece will be finished by the polymer elastic balls.

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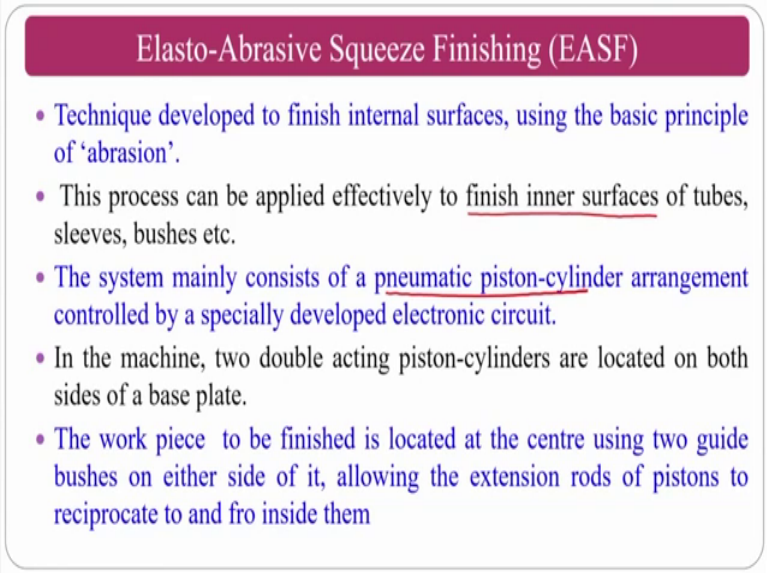

This technique is developed to finish internal and external surfaces and it is effectively for the internal surfaces like tubes and other things. The system mainly consists of pneumatic piston - cylinder arrangement and other things and you have a medium cylinders and you will do the reciprocation with respect to the medium that is there.

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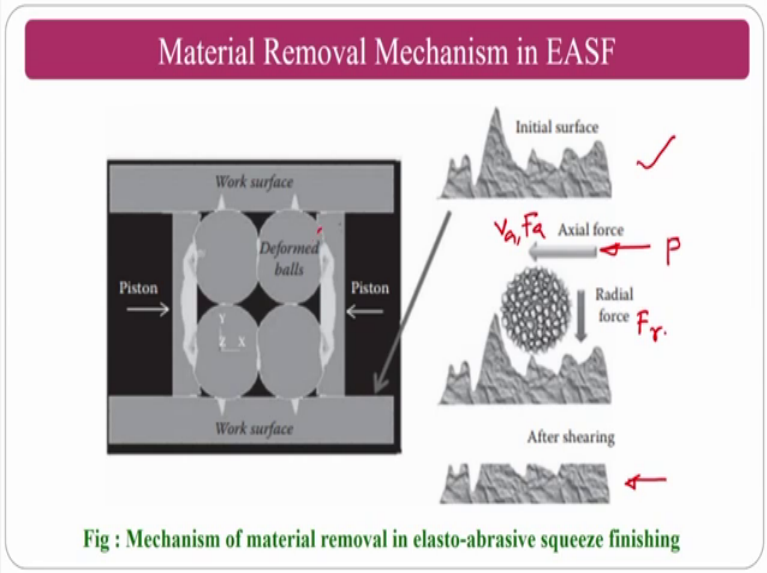

And because of this deformable ball are bonded abrasive particles what is happening is, this will try to finish and as I said whenever you apply a certain pressure axial force will act in this direction, radial force will act in this direction and axial velocity will also will

be act in this direction because your pushing. So, the initial surface will become finished and you will get a final surface of this. The same thing you can see here how the deformation and other things can be generated on the work piece.

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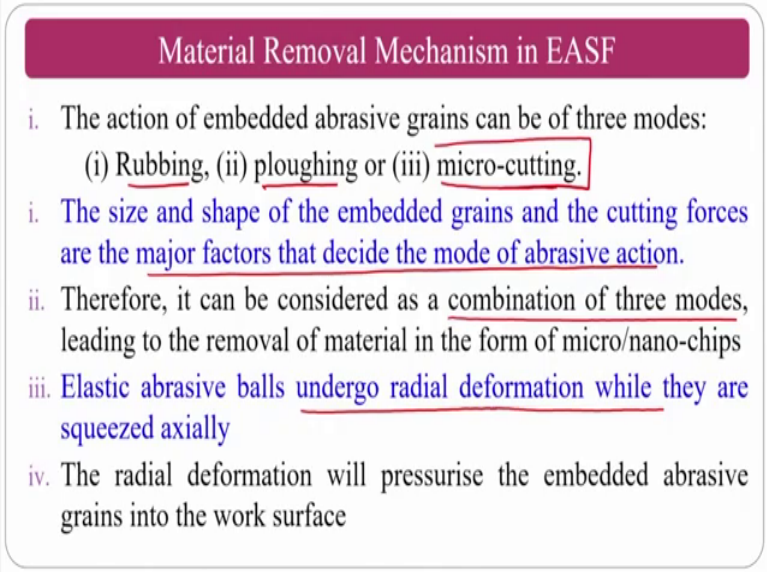

So, material removal mechanism normally the material removal mechanism will be 3 types, one is a rubbing action, ploughing action as well as micro cutting action. In this particular process normally the dominating is the micro cutting action if you are going to give sufficient amount of extrusion pressure. If you are not going to give sufficient extrusion pressure then there will be a slightly ploughing action and rubbing action, just it may move on the surface roughness that is already there on the work piece.

Size and shape of embedded grains and the cutting forces are the major factors for decide the mode of abrasive action; that means, that the forces this forces is a function of extrusion pressure and medium composition. So, if your medium composition and extrusion pressure applied properly then the; obviously, you will get the required micro cutting because micro cutting is nothing, but a shearing operation.

So, since this is particular process is a random process that is why abrasives also random, cutting edges also random and it has a viscous property it has a elastic property that is why the author considered it is the finishing is because of the 3 mechanisms that is rubbing, ploughing and micro cutting process. So, this abrasive process will undergo the radial deformation while there are squeezed axially that is called (Refer Time: 22: 19)

effect and other things that you can see much better way in the abrasive flow finishing process.

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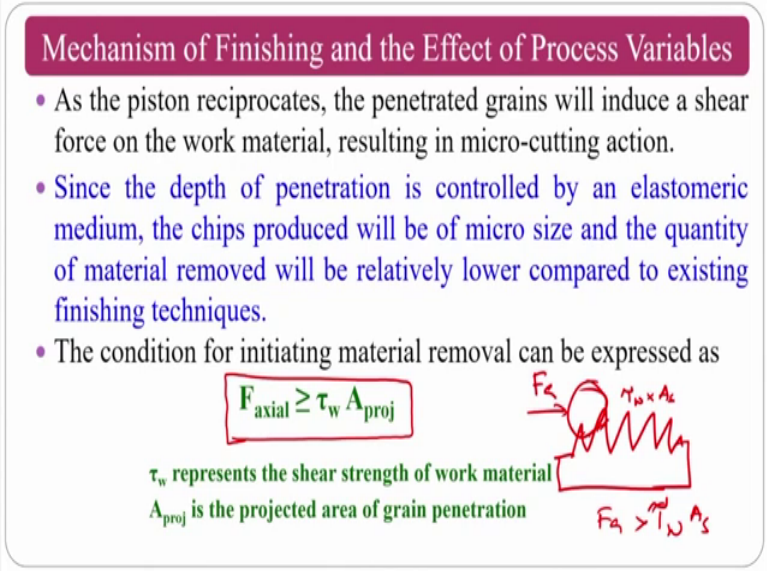

And the mechanism of material removal normally most of the micro cutting in case of any adverse finishing processes will go like this. iIf your axial force is higher than your penetration depth and the cross sectional area of the penetration depth and the shears strength of that work piece material, then what will happen? The micro chip will form if my surface is like this.

If abrasive particle is like this is my and my depth of penetration is this much and this depth of penetration cross sectional area and shear strength of the material work piece material into cross sectional area will give if your F a is greater than whatever the C s strength and cross sectional area, then what will happen? The shearing of the surface will takes place.

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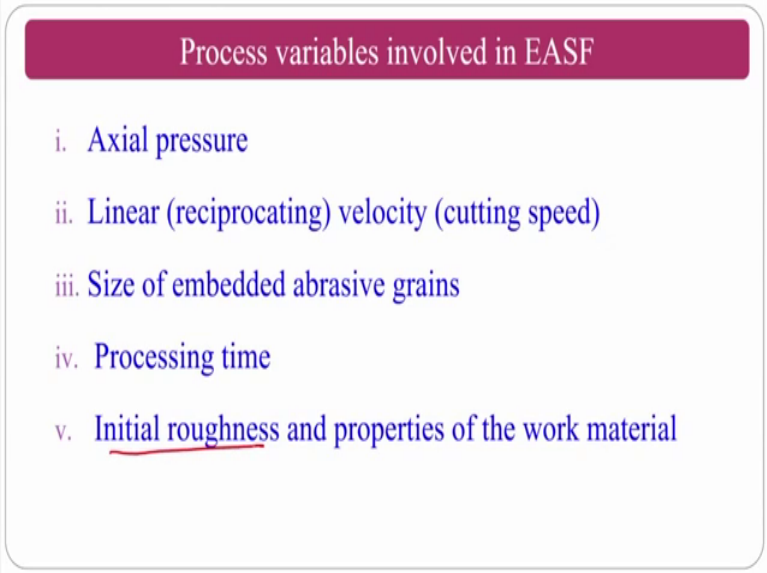

Process variables axial pressure, linear velocity that is nothing, but axial velocity size of the embedded abrasive, processing time, initial surface roughness normally initial surface roughness should be low so, that you will get a better final surface roughness.

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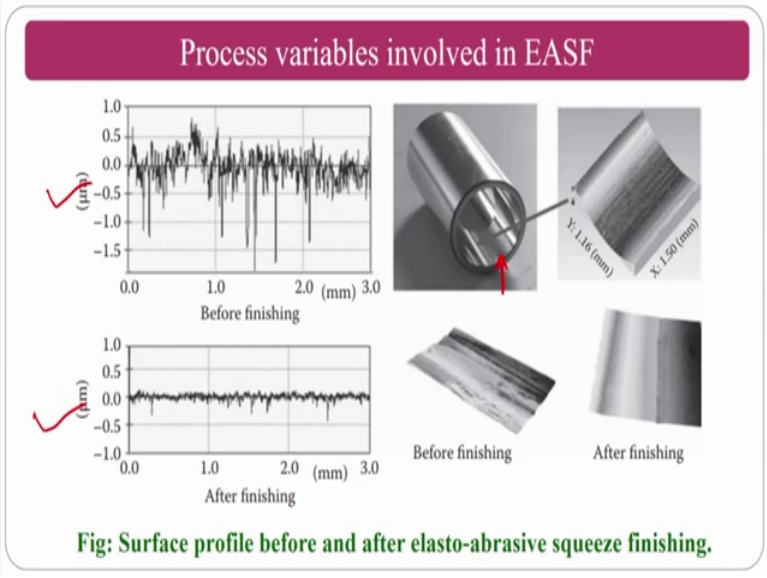

Fig: Surface profile before and after elasto-abrasive squeeze finishing.

The surface roughness is measured and it is shown that the tubes are better finished and you can see the surface roughness. This is the initial surface roughness and you can see the final surface roughness that at the same time mirror image of the surface is also

clearly visible. If at all you want to know about better details about this process, you can go through some of the papers of Professor Suraj.

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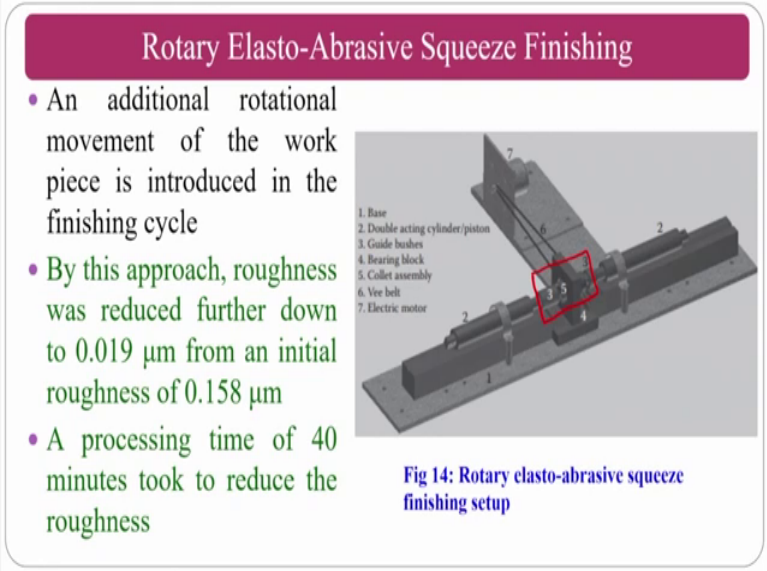

Then we come to the second category that is called Rotary Elasto- Abrasive Finishing process, the only mechanism change here is that work piece is rotated. So, the work piece here it is rotated rest all the things is approximately same ok. So, if you are going to give the work piece rotation, what will happen? Finishing action will be in a dynamic state and it will be done and centrifugal forces and other forces also involve because of the dynamic action of the rotary work piece ok. So, you have axial force, axial velocity, radial force, because of the rotation what will happen tangential force and tangential velocity also occur. So, one force and one velocity will be adding to the existing force and velocity because of which what will happen your shearing will be slightly dominate compared to the conventional type of elasto abrasive squeeze finishing process.

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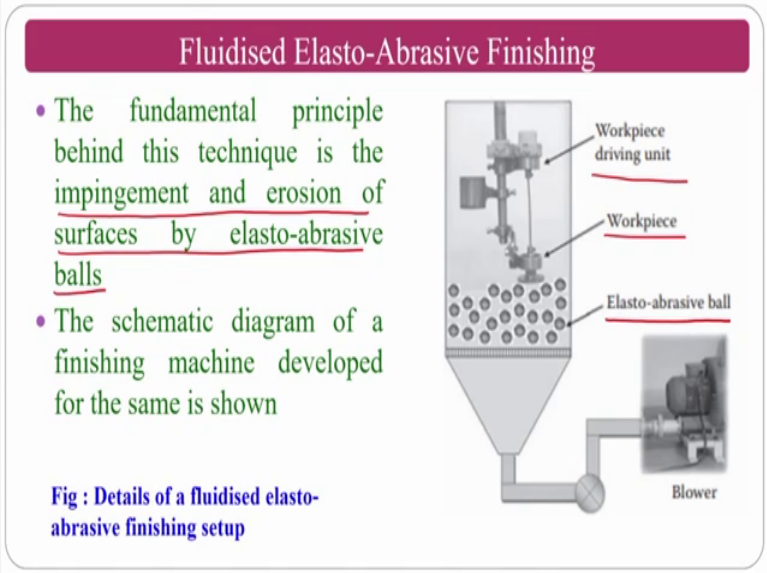

The third variety is Fluidized Elasto - Abrasive Finishing process where in the fundamental principle of this technique is to impingement of erosion of the surfaces by elasto -abrasive balls ok. Schematic diagram is there just, what is elasto - abrasive balls will be there and the work piece is there and work piece driving unit is there so, that the erosion will takes place with respect to the abrasive processes.

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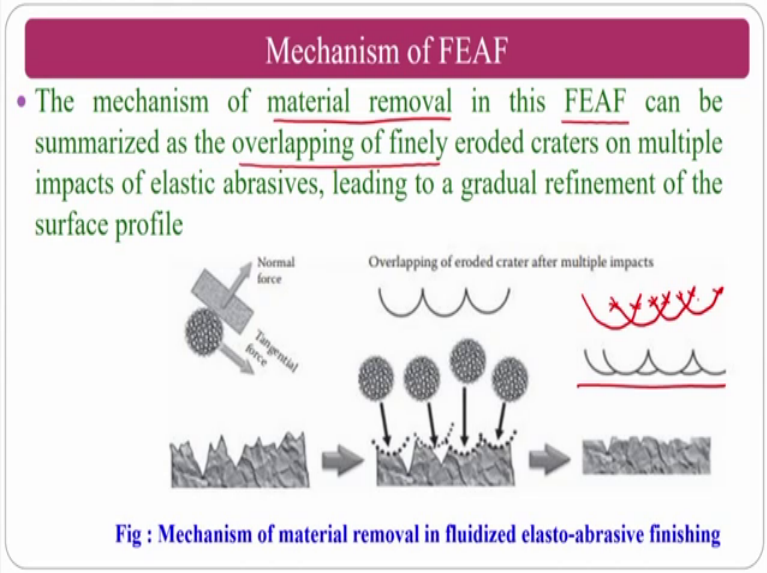

And you can see the mechanism also the elasto - abrasive ball will go and hit the surface and it is like a abrasive water jet machining abrasive jet machining and other things

instead of simple abrasive particle here. It is a elastomeric abrasive particle so, that the finishing action will be taken in a nano scale to the micro scale.

The mechanism of material removal in fluidized elasto - abrasive finishing process can be summarized as overlapping of finely eroded craters like this you have a crater. So, this intersects will goes off and generate the surface that is what the author convey it.

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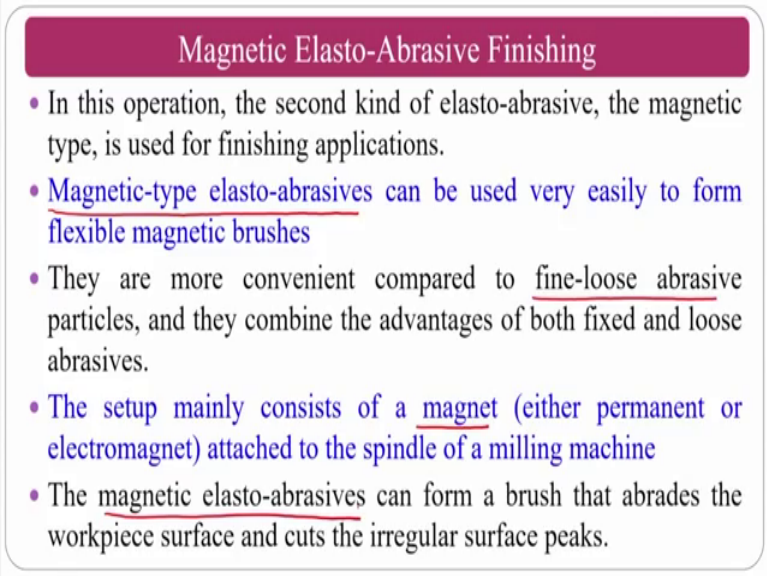

The last variety of this particular elasto - abrasive finishing process is Magneto Elastic -Abrasive Finishing process. So, in this operation the similar to elasto -abrasive is using, but one type of magnetic particles are also added to the medium. So, magnetic type elasto - abrasive particles can be used for this one; that means, that the author might have used iron based particles along with the abrasive particles and the polymer along with the solvent and heating process. They are more convenient compared to the fine loose abrasive particles, they are combine the advantages of both fixed and loose.

The setup will have additional magnet either it can be a permanent magnet or electromagnet, if you have electro magnet you will have a advantage that you can control the magnetic field and so, that you can control the finishing forces also. That is why recommended those people who want to do research they are requested to go for electromagnet so, that you can control the electromagnetic field of intensity so, that you can control the finishing forces.

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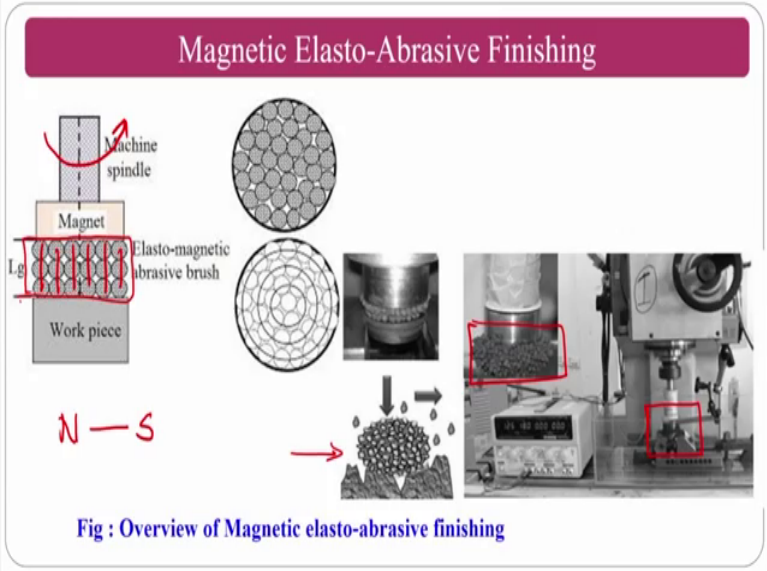

This magnetic elasto - abrasive finishing can form a magneto abrasive brush, this is similar to the magnetic abrasive finishing process some of the people they can go through the papers of Professor D K Singh and Professor Vijay Kumar Jain from IIT Kanpur. So, you can see this particular process also similar to the MAF process, magnetic abrasive finishing process and where you can also see like magnetic abrasive flexible brush can be generated. This is a schematic diagram where a magnetic particles which are embedded on the elastomer along with abrasive particle will be there, then you have a magnet so, that normally North to South Pole the chains will form. So, that these chains will do the polishing operation whenever you try to give certain relative motion with respect to the work piece surface. That is clearly evident from here also and the flexible magnetic abrasive brush is generated and the finishing operation.

So, the people who want to do research in this area it is as simple as that just take the enameling machine and you modify the tooling wherever you are just putting a cutting tool just if you have a common knowledge about this particular processes just you get a permanent magnet if you are not going to get a electromagnet. So, get a permanent magnet you make a polymer elastic abrasive balls along with the magnetic field particles like iron particles in specific you can go with carbon iron particles. So, that you will efficiency will be better because of more purity into iron in the carbo iron particles, then you use some of the a magnetic field and you can do the finishing process.

Similarly, you can do the MEAF process and you can compare, now it can be a good research so, that you can compare MEAF process along with magnetic elasto - abrasive finishing process. So, that you can say which process is better for which type of applications which process is better for which type of applications.

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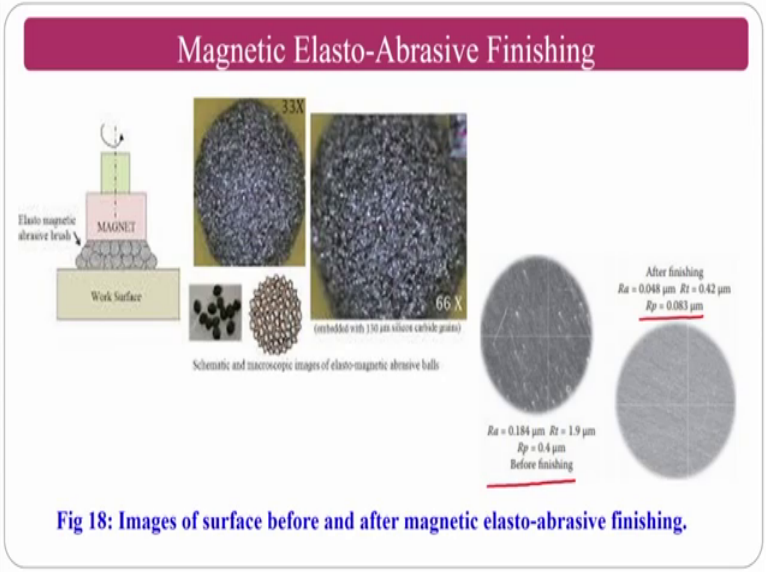

Fig 18: Images of surface before and after magnetic elasto-abrasive finishing.

So, you can see here how the abrasive particles are embedded along with the iron particles and the polymer. So, you can see the schematically on a polymer bead the abrasives as well as iron particles are embedded and you can see the finishing normally the initial surface roughness 0.184 and after finishing point naught 8 3 surfaces. So, the author got the good surface only thing is that here the technology is the how to make the magneto elasto - abrasive medium. The simple technology if you have medium you can do it like if you have wheat flour you can make chapathi, dosa, puri whatever you want ok. So, you can first be master into the medium preparation of any type of process like MRAF process or abrasive flow finishing process or magneto elasto - abrasive finishing any process only the technology lies is how you can make the medium then you can pass on you can apply to various sectors.

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So, some of the applications this is finished using elasto - abrasive finishing process and you can see before and after so much clarity is not there, but if you could have seen the original research paper; then the things may be much clear and fixture for the this type of work pieces are given.

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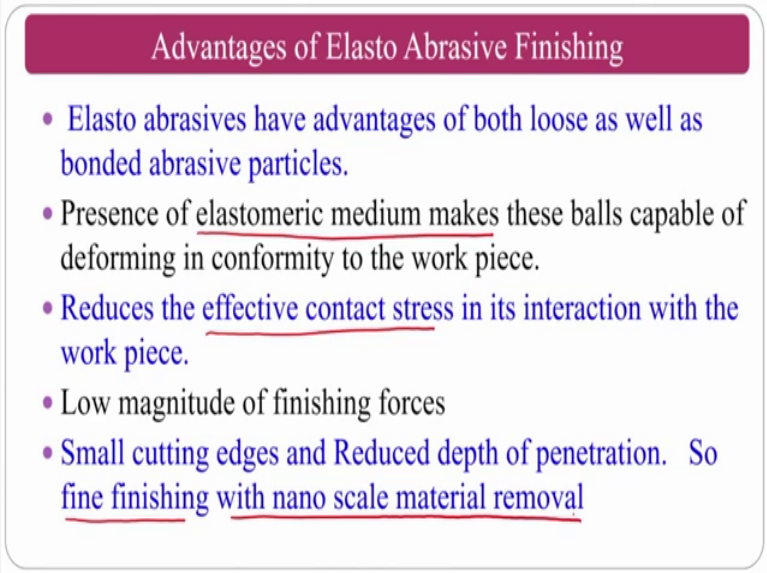

So, now we will see the advantages of this process. Elasto - abrasive processes have advantages compared to the loose as well as bonded presence of elastomeric medium makes these balls capable of deforming conformably to any type of surface to be

finished. Reduces the effective contact stresses because of elastic deformation along the literal direction and low magnitude of finishing forces, whenever you want to get the good surface finish as minimum forces as been if you can maintained and if you can make your fluid, if you can make your medium, then the finishing action can be done, but only thing is that it will be a time consuming. If finishing process are less, if your initial surface roughness is very high then finishing time will takes place, finishing time your finishing time requirement will be very large so, normally you take low initial surface roughness then you can go for finishing.

The small cutting edges reduce depth of penetrations. So, fine finishing can be achieved using this particular elasto - abrasive finishing process in particular. So, thank you for your kind attention. We have gone through the processes like elastic commission machining and hydrodynamic polishing and elasto - abrasive finishing. In elasto - abrasive finishing we have 4 varieties, one is elasto - abrasive squeeze finishing , rotary elasto - squeeze finishing, fluidized elasto - abrasive finishing and magnetic elasto abrasive finishing. These are the 4 varieties which we have gone through since all the processes has relation between polymer as well as abrasive in finishing the any type of complex features that is why this is a part of polymer assistant abrasive finishing processes.

Thank you.