Introduction to Abrasive Machining and Finishing Processes

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Lecture – 23
Advanced Abrasive Finishing Processes (Magnetorheological Finishing)

Now, we are going to look into Magnetorheological Finishing Process and its allied processes ok.

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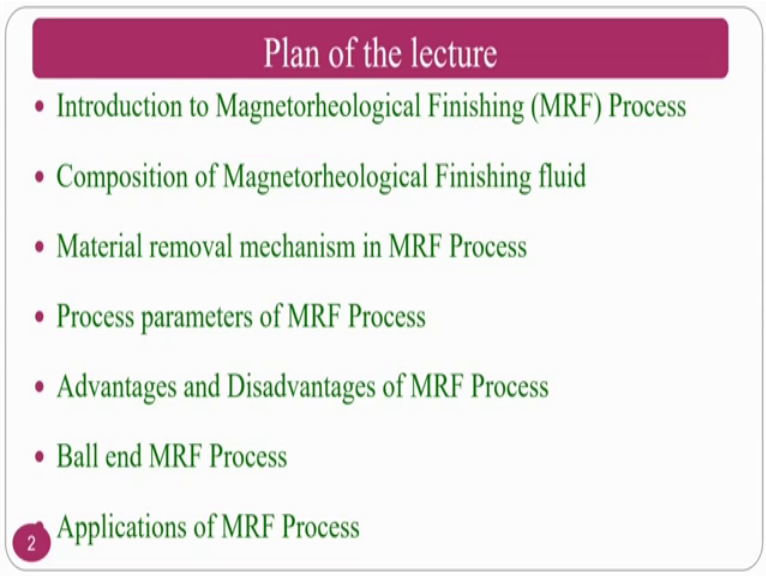

So, plan of the lecture goes like this; is Introduction to Magnetorheological Finishing Process, Composition of Magnetorheological Finishing Fluid. So, material removal mechanism in MRF Process and the process parameters, that is input parameter and output responses that one can study about MRF process, Advantages Disadvantages of MRF Process, what are the disadvantages of this one, how to overcome this type of a disadvantages.

See life is like to overcome the disadvantages and moving ahead ok. If there is some disadvantages of this MRF process so, how can we overcome? So, what are the alternatives and other things we will see. So, Ball end MRF process which is one of the alternative to overcome some of the disadvantages of MRF process and applications of MRF process.

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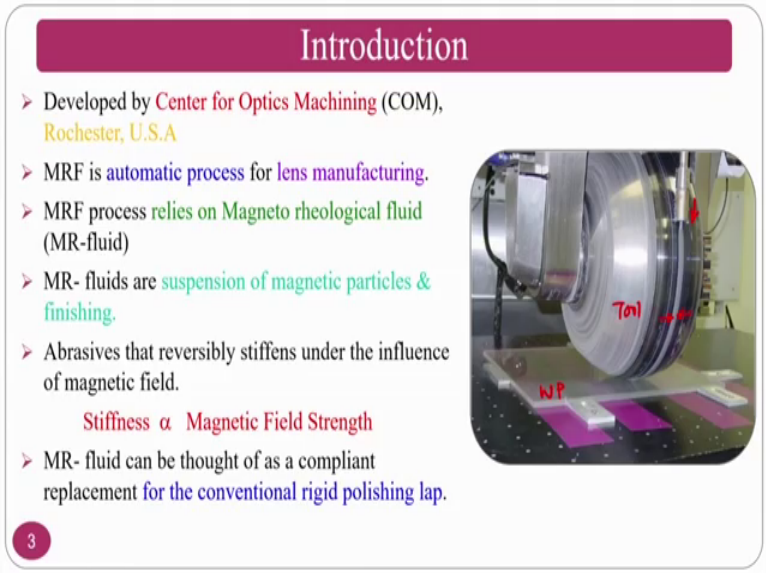

So, introduction to MRF process see this is how the MRF process works. This is the workpiece and this is the tool where the fluid is dispensed here. And because of the magnetic field that is there inside the grinding wheel, it becomes a thin ribbons type of structure and this is called a flexible polishing belt or you can say flexible polishing ribbon.

It is so thin that many people call it as a thin ribbon ok. So, it is developed by centre for optics machining in Rochester, U.S.A. And MRF is automatic process for lens manufacturing. Mostly, this particular process uses for lens polishing applications. And you can see overall where the lenses are used in defense sector and biomedical sector and other sectors we will see the lenses, and these lenses are to be precisely polished by one of the processes is MRF process. So, MRF process relies on magnetorheological fluid ok. So, magnetorheological fluid is the fluid that comprises of abrasive particles along with carbonyl iron particles and the carrier medium so on. Some people there may be using some rheological additives to enhance the performance of this particular fluid. So, MR-fluids are suspensions of magnetic particles and finishing particles.

So, abrasives that reversibly stiffens under this influence of magnetic field. Basically what is happening here is, the process of finishing you will see in the upcoming slides. So, wherever the magnetic field is there this particular polishing fluid becomes thin ribbon. And whenever the magnetic field is not there, assume that this ribbon crosses the

magnetic field, then it will become again the fluid. So, stiffness is the function of magnetic field strength. Normally, you can say stiffness so stiffness correspondings to the bonding strength, what you have studied in the grinding wheel, this is also a grinding wheel. But it is having a flexible fluid ok.

In your grinding process, the bonding is fixed ok, here what is happening is, particular cycle the bonding between the fluid as well as the abrasive particle is fixed. But once it goes to the sucking tank and it will reshuffle the abrasive particle. So, this particular process you will go and see that in the grinding region, this may be appearing like a 2 body abrasion, but once it crosses the grinding zone it will reshuffle. So, the abrasive particle is not sure that the same cutting edge will come for again the finishing action. So, the other cutting edge of same abrasive particle may also come ok. There you can also say that this process maybe following the 3 body abrasion ok. What I mean if you are not understanding, then I will explain in the upcoming slides also ok.

So, MR-fluid can be thought of the complaint replacement for the conventional grinding polishing lab; that means, what I would like to say is, that it looks like a conventional grinding process, but the bonding ability the stiffness is proportional to the magnetic field strength. That means, that the grade of the grinding wheel, the grade of the grinding wheel means how strongly the abrasive particle is held by the rest of the career fluid, or rest of the magnetorheological finishing fluid will depend on the magnetic field strength. So, normally in the conventional grinding process, the bonding ability between the bonding material and abrasive is function of the bonding material; whether you are using a clay, whether you are using a metal, whether you are using a any other like a rubber or shellac or something ok. That will be a function of your bonding material.

Here, the bonding strength between the abrasive particle as well as the other parts of magnetorheological finishing fluid will depend on the magnetic field strength. It is externally controlled, but in a conventional grinding the bonding strength is inbuilt in the grinding wheel.

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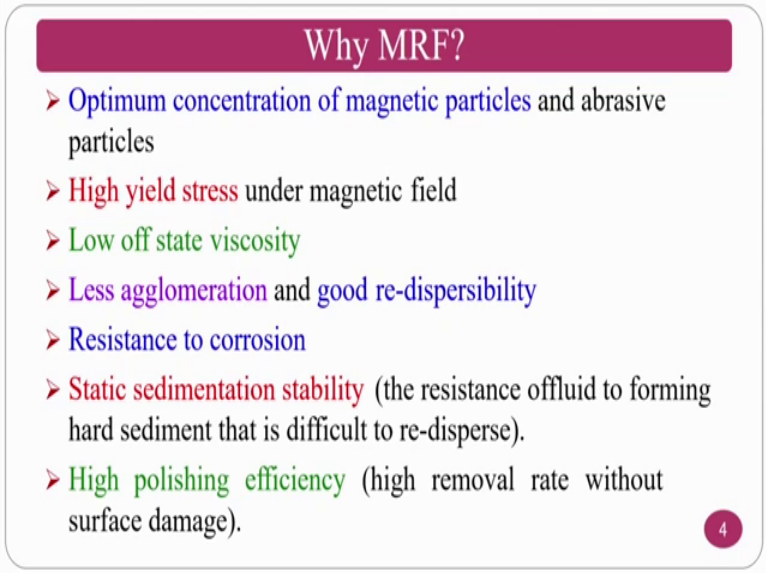

Why only MRF process for some of the applications? So, optimum concentration of magnetic particles and abrasive particles can be varied. High yield stress and magnetic field; so, low off state viscosity and less agglomeration and good re-dispersibility; that means, that your abrasive particles can redisperse. That is what I was saying in the previous slide; whenever you have a jet, this jet is giving the fluid, and this fluid whenever it enters in to the magnetic field the region, because of the magnetic field strength it will form a ribbon like structure. Once the magnetic field is completed, because it is rotating and the magnetic field is fixed at the bottom.

Once it causes what will happen it will again becomes the liquid. So, what is the good thing about this one is, you are re-dispersibility will be very good, because once the magnetic field is gone it will become again a fluid this fluid will be sucked by the sucking pump. And it will be recirculated again ok. Resistance to corrosion because you will do not have any water based or something. There are magnetic fluids where you will follow the water based, but most of the magnetorheological fluids will not have the water content.

The static sedimentation stability that is nothing but the resistance to offluid to forming hard sediment that is difficult to this disperse and high polishing efficiency. Normally, this particular process will have good polishing efficiency because of high material removal rate without any surface damage on the workpiece.

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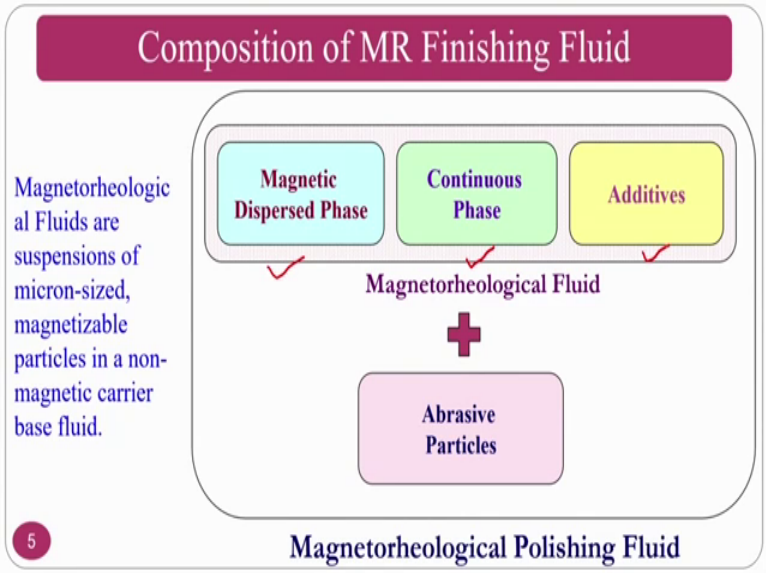

The composition, this is the most important thing for the MR-fluid, because you should know: what are the ingredients that are there. How the abrasive particles are getting assistance. As you have seen in the abrasive flow finishing process that the polymer chains along with the plasticizer softeners, this will support by giving the visco elastic nature to the abrasive particle, but how you are going to get that type of support in this one.

So, magnetorheological fluids are suspensions of micron sized magnetizable particles in a non-magnetic career based fluid ok. If you see here magnetic dispersed phase will be there. I will explain you what is there will be a continuous space and additives. These are the 3 things are available in the fluid along with that abrasive particles.

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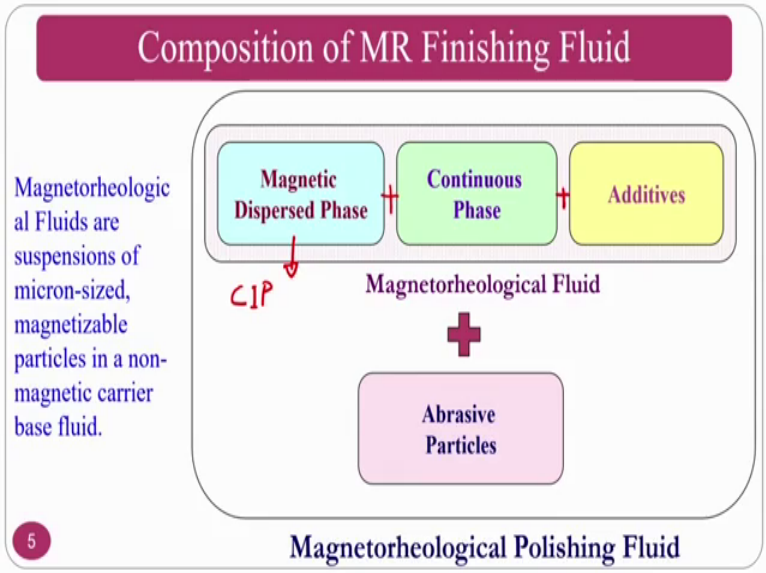

So, what is magnetic dispersed phase? This is nothing but normally what the people are going to use is CIP particles. That means carbonyl iron particles. These are the particles made up of pure iron, ok. Whenever you get a magnetic field, this will form a chain from north pole to south pole, that is what the beauty about this particular magnetic dispersed phase, particles is concerned. Then the continuous phase the people will use so many oils. One of the common oils will be silicone oil or silicon grease this type of the things is continuous phase.

What they are going to do here is, they club this 2, they take required amount of silicone fluid along with magnetic dispersed phase, that is CIP particles and mix along with the additives. Additives are required to hold the abrasive particle at locations. Normally, this may be like a functionalizes, it is will act as a functionalizes main function of this additives is to disperse the carbonyl iron particles as well as abrasive particles uniformly.

Some of the examples is like glycerin. So, people will use the glycerin and many other functionalizers to keep the 2 type of particles that is CIP particles as well as abrasive particles uniformly in a liquid; because whatever the thing that you are going to get here is a liquid or suspension type of thing ok.

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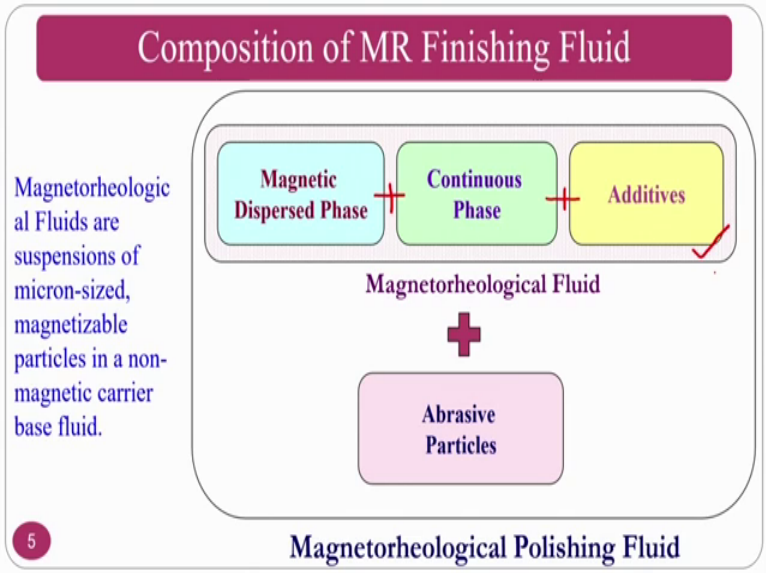

So, magnetic phase particles, plus continuous phase plus additives gives you a suspension; which is a liquid because you have to jet this liquid so that it will form the chains ok. So, in a liquid there will be a density difference. Once you add the abrasive particles ok, what you are going to add for this one is abrasive particles.

The density difference between a continuous phase, and additives as well as CIP particles and abrasive particles is huge, because of each what will happen there is always chance that the sedimentation will takes place. To avoid the sedimentation of abrasive particles as well as the magnetic dispersed phase, that is CIP particles, you have to choose right kind of additives. That is about the composition.

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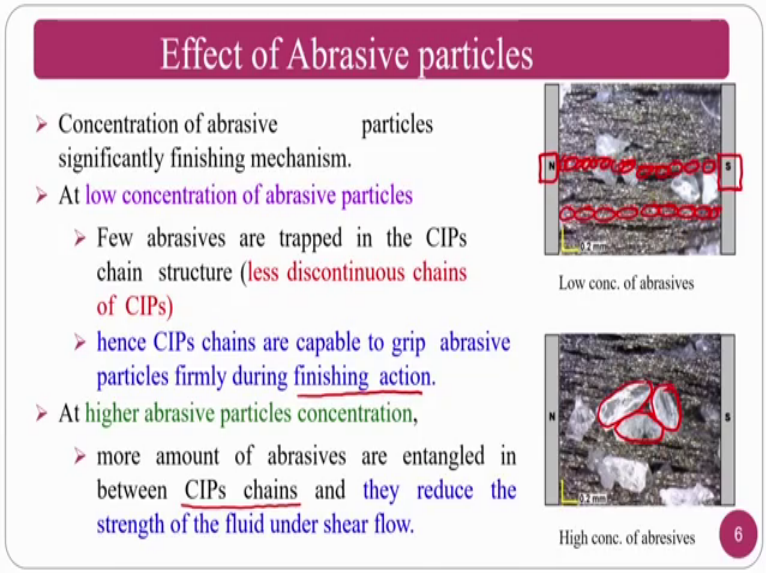

So, you can see here the effect of abrasive particles and other things. Concentration of abrasive particle significantly acts on the finishing mechanism. You can see low concentration of abrasives. Low concentration of abrasives few abrasives are trapped in the CIP chains that is less discontinuous chains are the same time hence CIP chains are capable of gripping the abrasive particles firmly in the finishing region ok; that means, that first what you have to understand in the figure one is that, whenever you have a north pole and south pole, you have your magnetic fluid or MR-fluid, magnetorheological fluid.

Magnetorheological fluid will have silicone oil or any dispersed oil plus CIP particles which are pure iron particles. Along with that you will have some additives to hold these particular particles uniformly. When particles means; I always mean that these are abrasive particles plus CIP particles ok.

Send this particular fluid in the magnetic field, magnetic field will have north to south pole this forms the chains. CIP particles will form chain from north pole to south pole like this. In between, you have the abrasive particles which are trapped ok. So, if this is the chain that is forming what will happen? The chains are trapped with abrasive particles, these abrasive particles will get the assistance from the CIP particles to finish, that is how the finishing action we will takes place in the MR finishing process.

If you look at the density of abrasive particles, if the abrasive particles are too less for the same amount of CIP particles the CIP particles will have good amount of strength to hold the abrasive particles ok. So, that mean that the bonding will be good; that means, that the grade is good in terms of conventional grinding process, the grade the bonding between the bonding material as well as abrasive will be very good. If you have higher concentration of abrasive particles, what is going to happen is the more amount of abrasive particles entangle between CIP chains that is carbon particles chains.

They reduce the strength of the fluid under the shear flow action; that means, that if you have more number of abrasive particles, there may be chance of formation of agglomeration, at the same time my magnetic field strength is constant, my CIP particles which are forming the chain is constant. And I am varying abrasive particles. In one condition my abrasive particles are less, in another condition my abrasive particles are high.

Whenever the abrasive particles are less, what will happen is my chains that CIP chains has sufficient amount of strength to hold the abrasive particles so that the abrasive particles can finish the work piece surfaces in a good way. The second thing, whenever I am going to add more amount of abrasive particles for the same magnetic field strength, and for the same CIP particles and other composition, what is happening here is, the my chain strength will go down; because it has to catch hold of many abrasive particles. At the same time if the density is very high, the abrasive particles are having tendency to agglomerate also. Because of each the strength of the polishing fluid to finish will go down. The capability of this fluid to finish the work surface will reduce.

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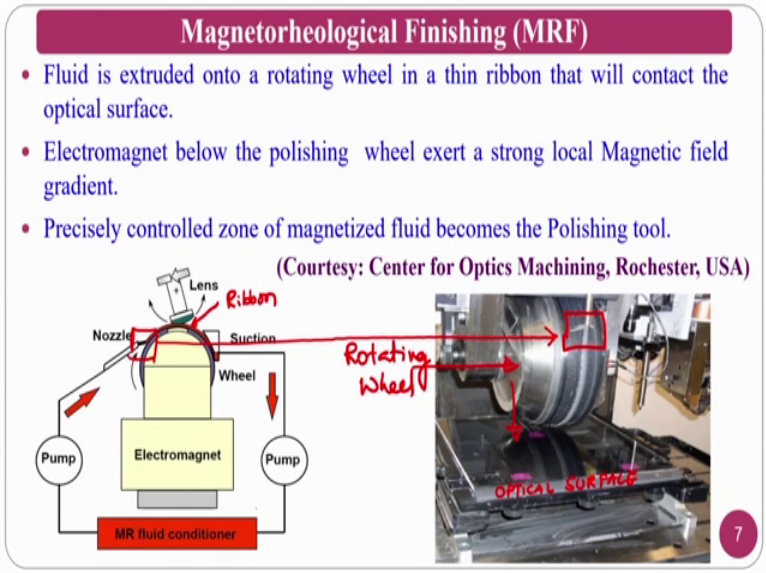

Magnetorheological finishing process; as you can see here, the schematic diagram and experimental setup both are there. So, fluid is extruded into the rotating wheel in a thin ribbon that will contact the optical surface; that means, that this is my optical surface, this is my optical surface and this is my rotating wheel ok.

So, when you are injecting the fluid here, what is it is farming? Is it is forming a thin ribbon, and then you just move down your wheel come to contact and your ribbon will be in contact. And the motion of XY you can give to your table where your work piece that is optical surface is provided so that it can be finished. The electromagnetic below the polishing wheel exert the strong local magnetic field gradient, and precisely control zone of magnetized fluids become a polishing tool ok.

So, a schematic diagram if you can see here, what is happening? You will have a magnetic fluid conditioner here, and you will have the MR-fluid in a MR-fluid conditioner, then you pump this to a nozzle, and a nozzle will dispense here ok. This is how it is dispensing, the same thing you can see here also, now practically how it is dispensing here ok. So, once it dispenses what is happening? It forms a thin ribbon in the schematic, this is thin ribbon is farming, and you have a lens, lens polishing is taking place, and the lens is abraded against this ribbon. Once the magnetic field is completed, how do you know the magnetic field is completed?

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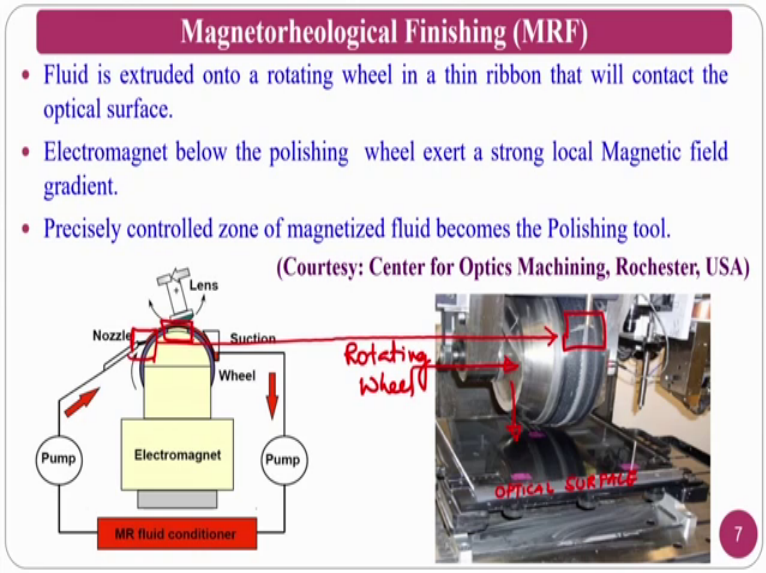

You can see here that you have a magnetic field, ok.

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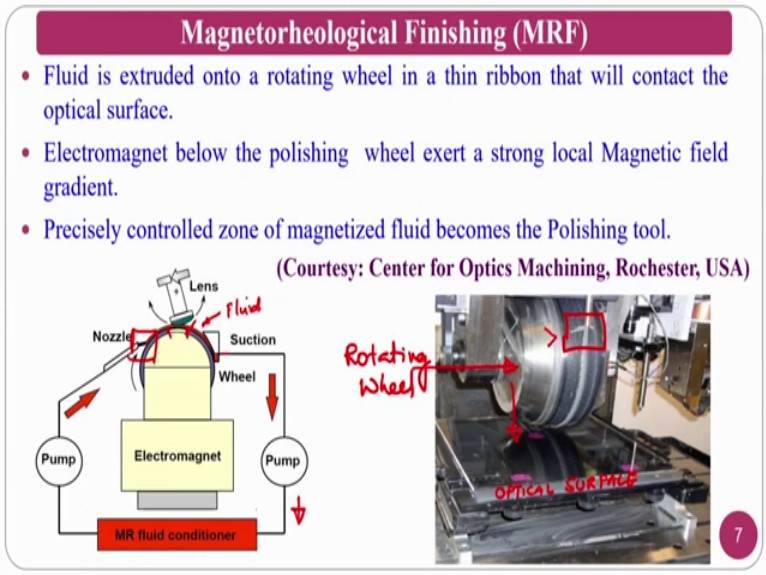

So, the yellow portion, here is the magnet that one can keep ok. Once it crosses that this particular location, again it will become a fluid. And this fluid will suck by sucking pump and it will supply to the magnetic fluid conditioner so that it can recycle ok. In the magnetic fluid conditioner, you can have some other magnet so that the chips all will be attracted towards that one, and whenever you are pumping again the chips will not be

there in the next go. If it is a metallic, if it is a non-metallic, then one has to go for some advanced type of filters and other things.

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So, this is what the magnetorheological finishing setup that is developed by a Professor VK Jain at IIT, Kanpur.

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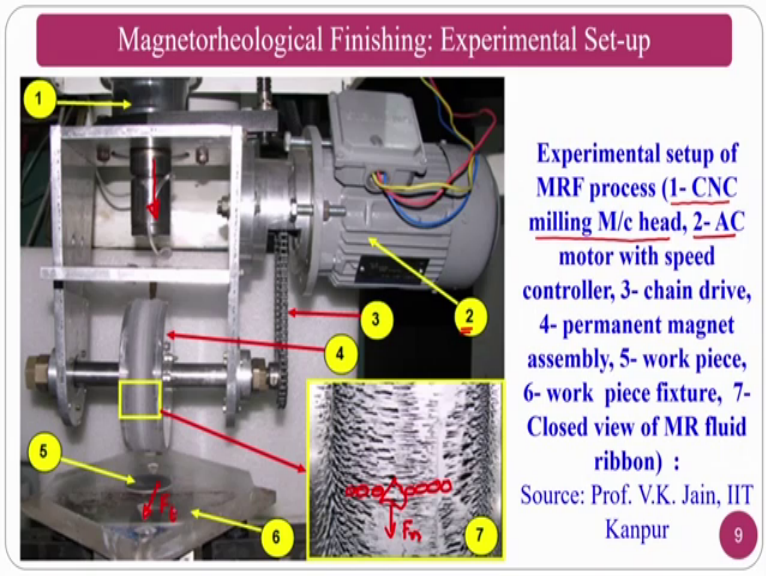

So, if you see the juned version of this particular process, where the work piece is there the 5 stands for work piece. So, the one is nothing but the CNC milling head, basically the experimental setup is developed on the end milling process ok. So, it is not too

expensive, also if you have a end milling process, just you have to change your head as per the requirements of your MR polishing process or MR finishing process.

Only thing is that here, this is the head of the end milling process where in your holding the MR finishing head. Second in one is AC motor with a speed controller. This one is a speed controller along with the motor, and the third one is chain drive system this is a chain drive system so that the flexible grinding wheel is mounted so that it will rotate. And 4th one is permanent magnet assembly. So, you can see the 4th one, there will be a magnetic assembly is there inside the grinding wheel and 5 is a workpiece.

This is a silicon workpiece, one has to finish a silicon workpiece. And the workpiece fixture is a 6; normally, perspex based work piece fixture is developed here, and the closed view of the MR-fluid ribbon. You can see here the MR-fluid is dispensed from the top and because of the magnet which is there it will form a ribbon ok. This particular ribbon is pressed again is the workpiece; which is number 5 and the finishing action will takes place.

Whenever, we have some fluid that is converting into a stiff ribbon. So, what is happening in the grinding process? We will see this abrasive particles that are there on this one which are held by the chains we will exerts a normal force or the radial force ok, or some people it is called as a normal force also. At the same time, because of the rotation that is given by the rotary chain. So, there will be a action of tangential force; that means that, the tangential force will be along the direction or at the contact point what is the tangent direction ok.

So, you will have a tangential force as well as the normal force. Because of the normal force what you are going to experience is the indentation of the abrasive particle into the work peace and because of the tangential force and the tangential velocity that is carried by the wheel. That is magnetorheological wheel the material removal will takes place. And the beauty about it what you have seen in the previous slides also, this particular fluid will enter become stiff then it will become again liquid.

So, in a liquid state, the abrasive particles are having a 3 body abrasion; if it is there in the contact, source is there is no contact, there will be a reshuffling of abrasive particles will be there. Whenever it enter into the finishing region, where the magnetic field is there it will become a stiff ribbon; where the 2 body abrasion will be there, and again it

will go into the fluid zone once the magnetic field is completed. And these fluid will the abrasive particles the CIP particles and all the composition will reshuffle.

So, the beauty about this process what you have already seen is, there is a tendency of abrasive particles orientation change. So, the new cutting edge may come into the finishing action in the next time. So, it is good the, it is good to have the reshuffling action. But on an average we consider about the finishing action in the workpiece and the wheel interface. There if the stiffness is too high, it will follow 2 body abrasion, if the stiffness is very low normally it may follow the 3 body abrasion.

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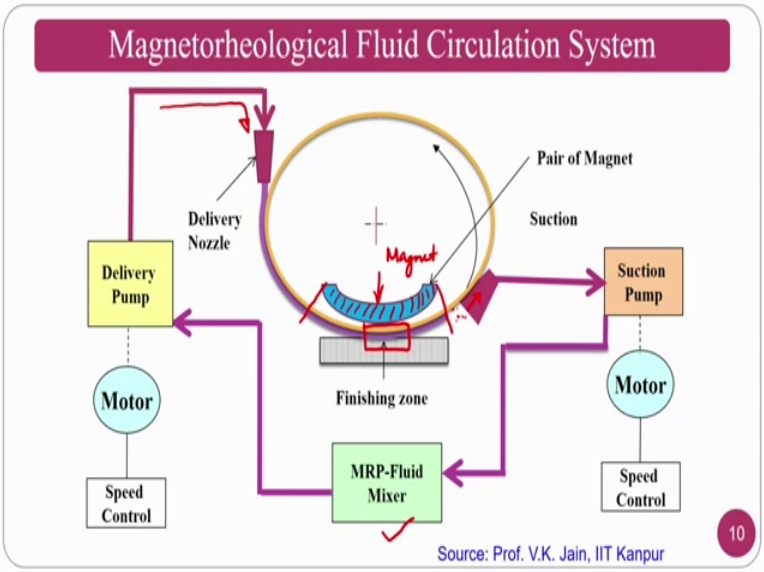

You can see here the magnetorheological fluid circulation system. You have a speed control motor will be there delivery pump; that means, that it will deliver the fluid from the conditioner tank like this, and it will enter into the finishing region. As you can see here this is a sky blue one is a magnet. From this region to this region, the fluid will act as a thin ribbon. Beyond which what is it is going to happen is that it will not act as a ribbon ok.

That is why once this ribbon is in contact with respect to work piece, and the finishing action will takes place in this region. Once the finishing action takes place by the flexible magnetized ribbon which consist of CIP particles fluid as well as the abrasive particles, it will comes out and it will form again the fluid here, and this will be sucked by the

sucking pump, and it will submit to the MR-fluid mixture or which is a conditioner tank ok.

So, this is how the circulation of MR-fluid will takes place ok. So, those people who have not understood how the fluid we will convert into ribbon, ribbon will convert into fluid can be explained by this particular sky blue colour magnet. What you are going to experience is the fluid is becoming a stiff ribbon wherever the action or the magnetic field is there. That is all; that means, that wherever this sky blue colour one is there, there only it will act as a stiff ribbon beyond which on either sides it will be a fluid. That is why delivery will be a fluid, sucking will be a fluid in between where the magnetic field is there, there it will be a solid.

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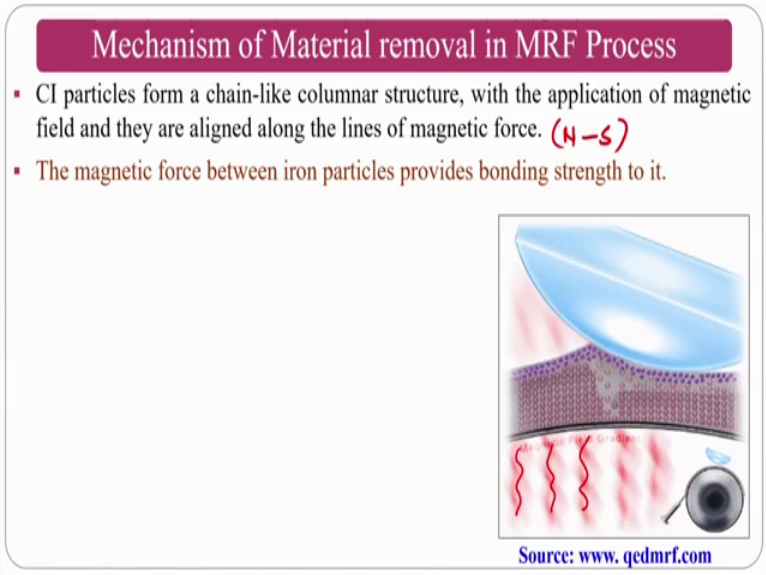

I mean to say the solid ribbon. So, mechanism of material removal in MR finishing process is carbonyl iron particles from the chain like columnar structures that you have seen in the previous slides; with application of the magnetic field they align along the lines of magnetic force from north pole to south pole. The magnetic force between iron particles provide the bonding strength to the MR-fluid. And you can see here the animation where the magnetic field is applied like this, ok.

So, CIP particles and abrasive particles are forming the chains, and abrasive particles are the pink ones which are experiencing the abrasion action against the lens ok.

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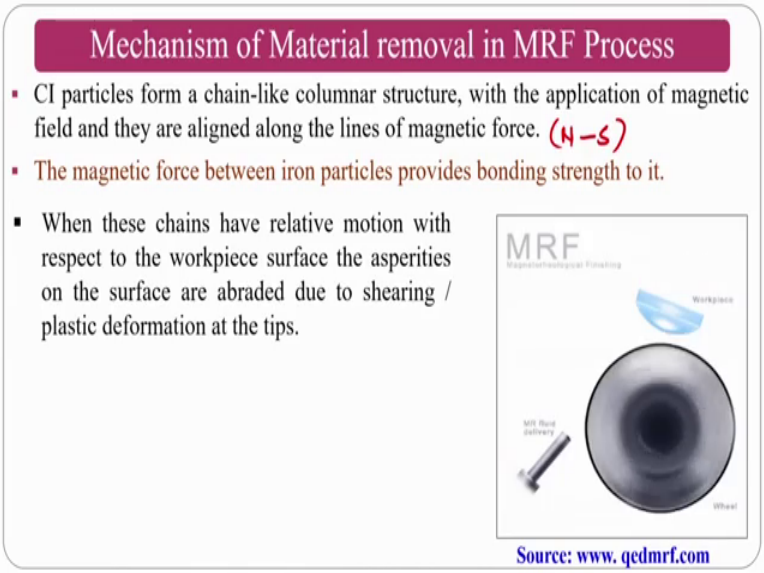

When these chains have relative motion with respect to the workpiece surface the asperities of the surface; that means, the workpiece surface abraded due to shearing or plastic deformation ok.

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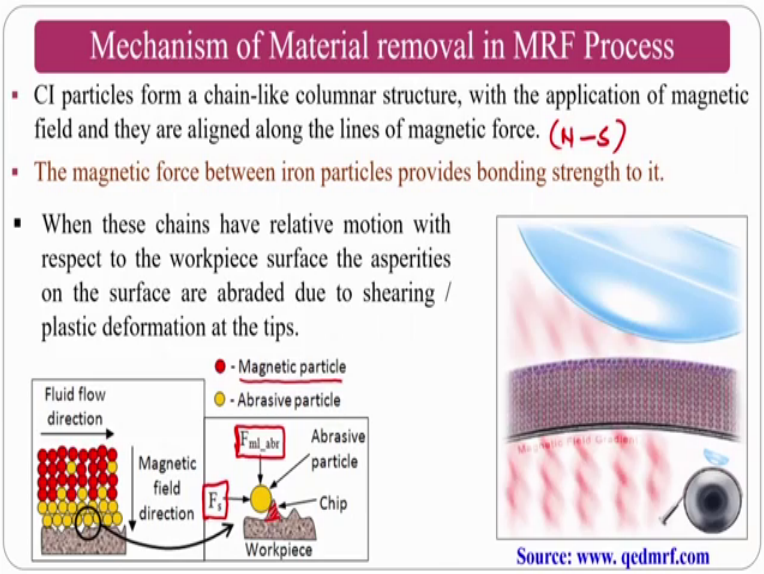

You can see here these are the carbonyl iron particles; which are nothing but the magnetic particles are the red ones, and the yellow ones are the abrasive particles. Abrasive particles are getting assistance by the chains of magnetic particles and because of the rotation it will experience the shear force, at the same time because of the depth of

cut off the grinding wheel as well as the magnetic field strength there will be a normal force. Because of which what will happen, the chip will be removed or the sheared. That is how the material removal mechanism will takes place.

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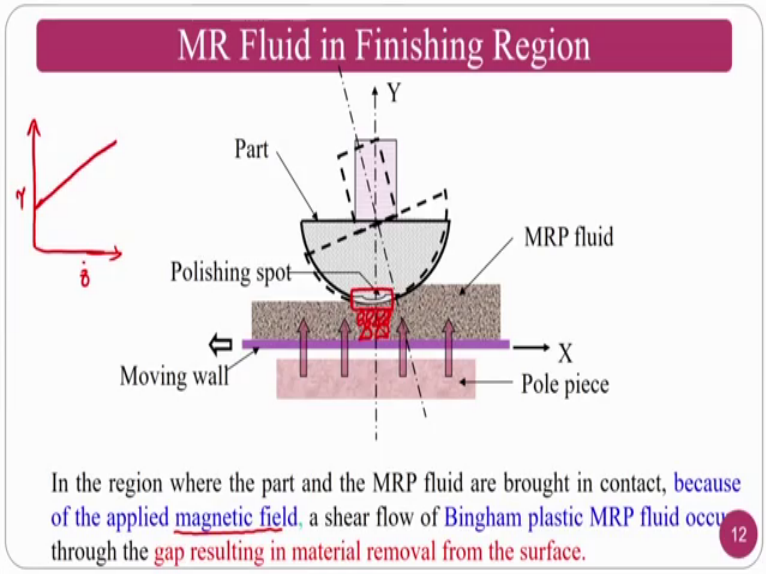

You can see here polishing sport, that is nothing but where the magnetic field is there this is a polishing spot. The MR-fluid is flowing here, and these MR-fluid forms a chain and the workpiece will get the finishing action ok; the region where the part and MR-fluid are brought in contact because of the applied magnetic field. And the shear flow of Bingham plastic MR-fluid occurs through the gap resulting in the material removal. So, normally Bingham plastic fluid is the one of the theoretical fluid that normally MR-fluid follow ok.

So, MR-fluid for the best example in the daily life is your toothpaste ok. What it will happen in Bingham plastic fluids? After certain stress it will not flow beyond which it starts flowing ok. So, this is how shear rate versus shear stress if you see what will happen. So, you have to apply certain stress, then only the thing will start moving ok. So, paste if you want to put the paste on your brush, if you put like this without pressing it may not come, you have to apply certain pressure. That is called minimum pressure that is required to push the paste out of the tube, that is in the common example.

The come so, daily life you have seen your toothpaste so that you if you can apply certain pressure, then only the motion of the fluid, we will start at the motion of the paste

we will start on to a brush, that is the example. Similarly, here also MR-fluid also follow Bingham plastic fluid.

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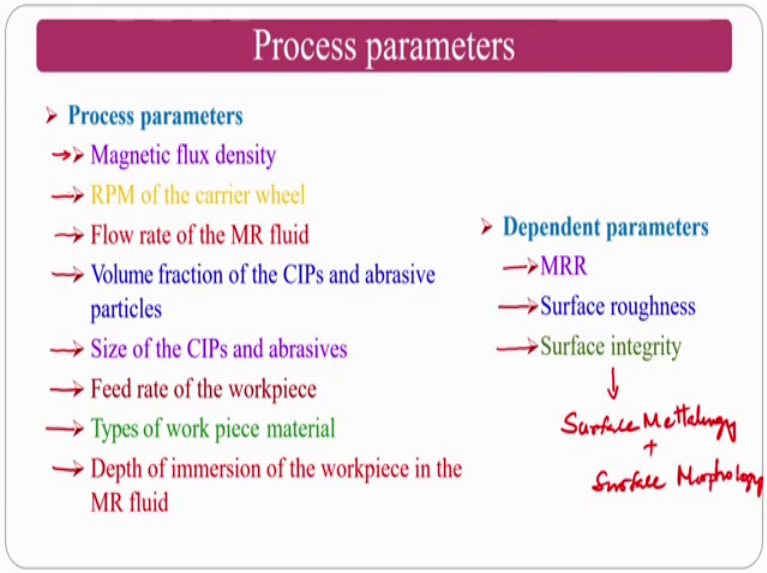

So, the process parameters input parameters are magnetic flux density is the first parameter. RPM of the wheel the if the RPM is very high what will happen your shearing forces will be very high. The flow rate of the MR-fluid, if the flow rate of the MR-fluid is very high, what will happen is, number of abrasive particles coming into finishing action will be more and more. So, the material removal rate will increase; volume fraction of CIP particles and abrasive particles. If the volume fraction of CIP particles increases, then bonding strength will increase.

If the volume fraction of the abrasive particles increases, then the bonding strength will decrease for a constant amount of CIP particles and magnetic field strength. The size of the CIP particles and the abrasive particles normally CIP particles are much smaller compare to the abrasive particles. If you are going for course type of abrasive particles; the course are abrasive particles means bigger abrasive particles. So, your material removal rate will be very good, but you may not achieve nano surface finish or sub nano surface finish. Feed rates of the table, the feed rate of the table should be optimum. Otherwise what will happen? That it will not get sufficient time to shear.

The type of workpiece material, if the workpiece material is harder, the material removal rate will be very less. If the workpiece is softer the material removal rate will be higher.

Depth of immersion of the workpiece in the MR-fluid; if the depth is high what will happen? The interaction forces are the finishing forces will be very high. The output responses that you can see here is MRR material removal rate, surface roughness will be another one and surface integrity. As I said surface integrity will be like the surface metallurgy and surface morphology. Surface morphology; surface morphology is always is a function of surface roughness also. So, it is additionally measured because some of the applications you require metallurgical aspects also.

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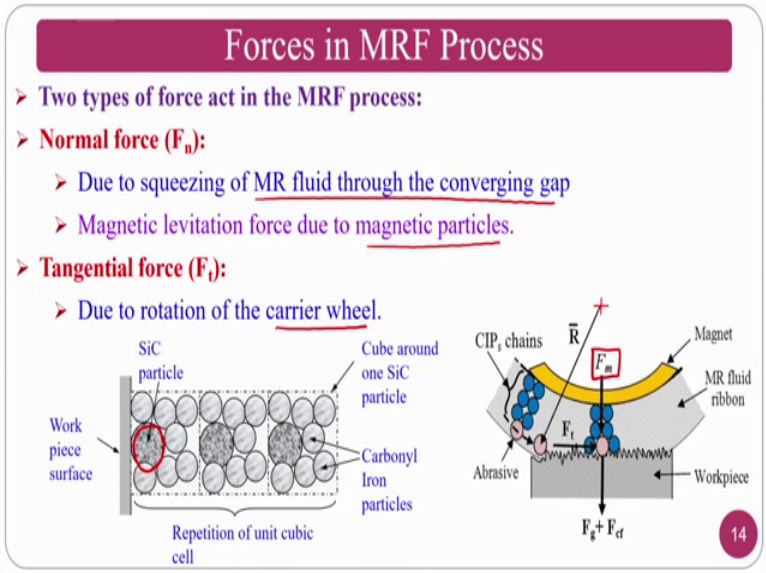

So, the forces in MR finishing process is the normal force that I already told you, and the tangential force these are the 2 forces. So, normal force the causes is due to squeezing action of MR-fluid though the converging gap; that means, that because of the magnetic field at the same time, because of the depth of cut that are going to give or by immersion of the workpiece into the MR-fluid you are going to get the normal force. Magnetic levitation force due to the magnetic particles CIP particles, these are the 2 things are responsible for normal force. At the same time tangential force due to rotation of the v; where in the ribbon is created. Because of this 2 what will is going to happen is, you are going to shear in our micro level nano level or sub nano level depend on various input parameters.

The schematic diagram shows how the abrasive particles are held, by the CIP particles against the workpiece surface. And this is how the strength of the abrasive particles

depends ok. So, number of CIP particles and other rheological additives that are using will hold along with the magnetic field strength ok. This is shows repetition unit of cubic cell where abrasive particles are held between the magnetized particles chains, that is CIP particle chains.

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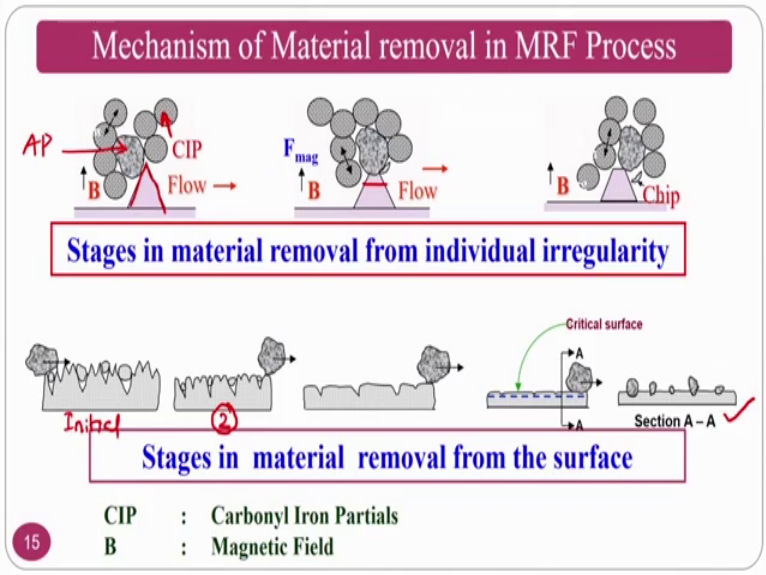

You can see the mechanism of material removal in MRF process; where this is the she peak, surface peak and this is the abrasive particle and this is the abrasive particle and this is the CIP particle ok. This CIP particles from the chain and this chain is entrapping the abrasive particle; that is why abrasive particle get some strength against the peak. And this peak is sheared in this one, and the sheared peak will go as a chip. That is how the finishing action will takes place in a ductile material. So, if you see in a gross spectrum, this is the initial surface or initial R a as you go on increase what will going to happen is that it will gradually shears of the peaks and gives the good surface ok.

What you can see here is, sometimes if you are going to measure the surface in the stage 2, you make it away good surface because you are particles are embedded in the valleys. But me you have to make sure that this particle should not be there. If you think that or if you assume that the surface roughness is very good now I can go ahead, then you are in the wrong notions. For that purpose, you have to increase the number of cycles and you have to improve the surface finish also ok. This particular concept, if time permit I will take in the magnetorheological abrasive flow finishing process ok.

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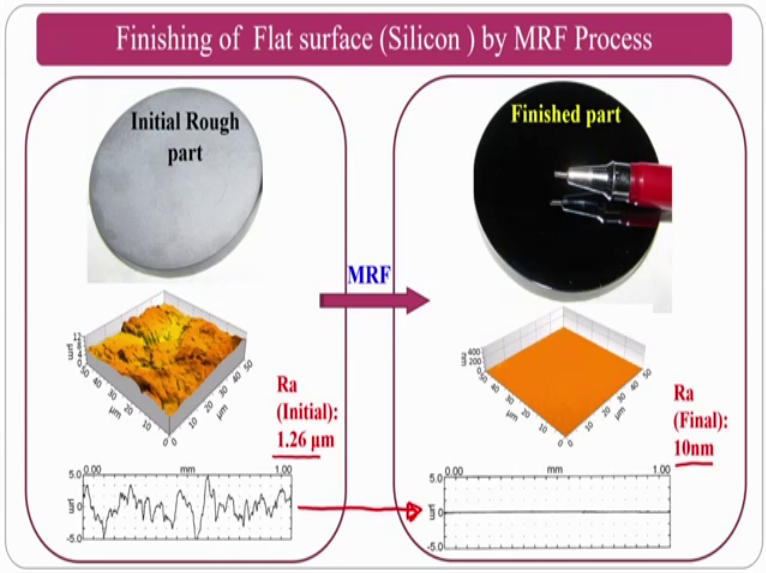

You can see the initial surface of the silicon blank, and this is the initial surface roughness 1.26 micro meters that mean that 260 nano meters. After MRF process if you can see this is a finished product ok. I am very thankful for Professor Ajay as well as Professor Vijay Kumar Jain who shared the slides. And after MR finishing this is how the initial surface roughness is converted, or this is the finished by MR forces and you can see the mirror surface finish.

At the same time, you can see the 10 nanometers. And clearly you can see the transformation in the 2 dimensional surface profile; where the rough peaks are gradually converted into a very, very smooth surface. These type of surfaces are required for (Refer Time: 36:32) mirrors application and various other applications in the various industries.

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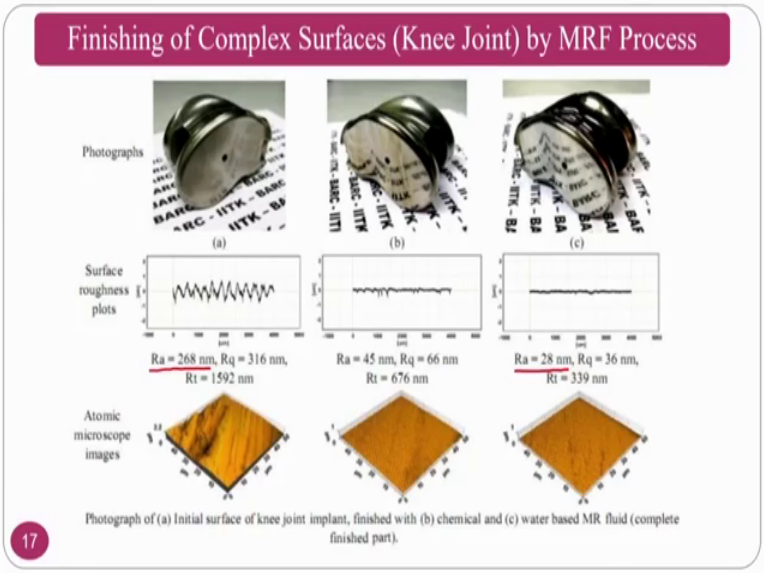

Apart from this Professor VK Jain's lab they have also done experiments on finishing of knee implants for biomedical applications. The initial surface roughness if you see the R a is 268 nanometers, but after finishing it is enormously reduced to 28 nanometers. And if the surface roughness is too low, what will happen? The wear and tear of the mating surfaces in a knee joint will be greatly reduced, and the life of knee joint will goes up. That is the beauty about this particular work. That is done by Professor Vijay Kumar Jain from IIT, Kanpur ok.

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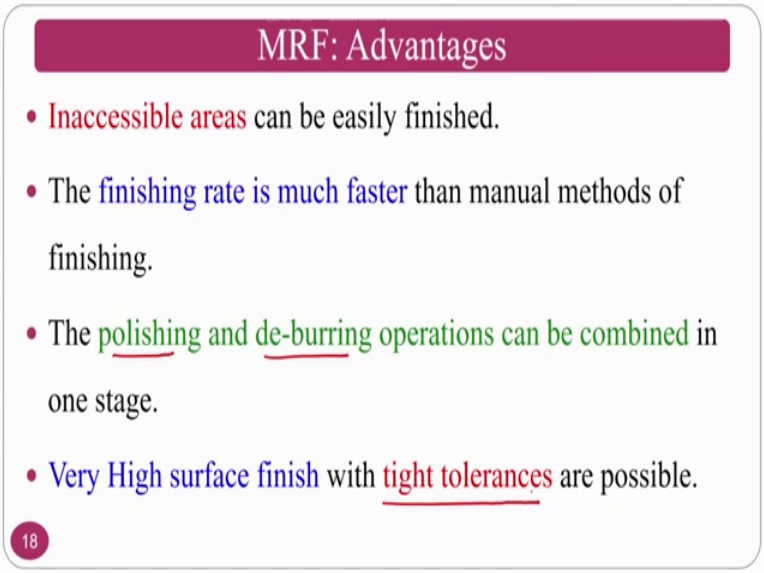

The advantages, inaccessible areas can be easily finished by this particular process. The finishing rate is much faster. The polishing and deburring options can be combined in this process. Both the polishing as well as deburring can be done. At the same time very high surface finish and tight tolerances is possible.

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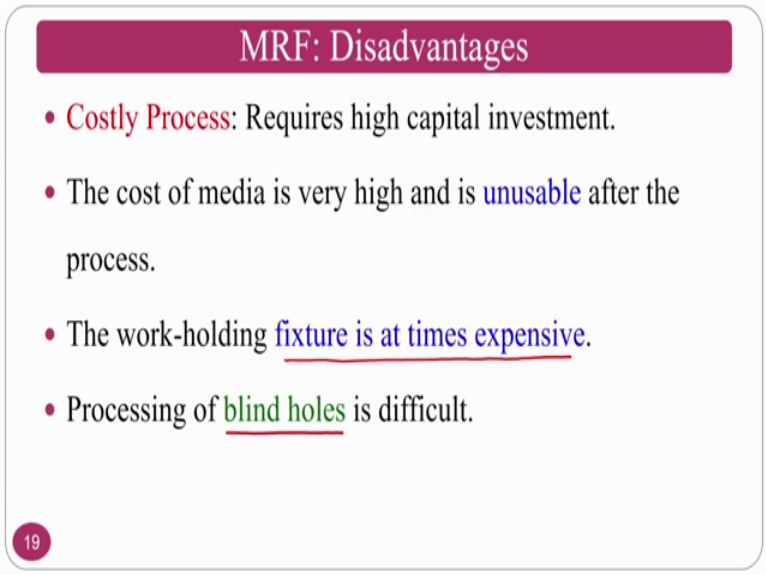

But the disadvantages, is this is a costly process, and the cost of the media is very high and unusable after the process, and work fixture sometimes it is expensive. And it cannot be used for the blind holds. That is a basic drawback of this particular process.

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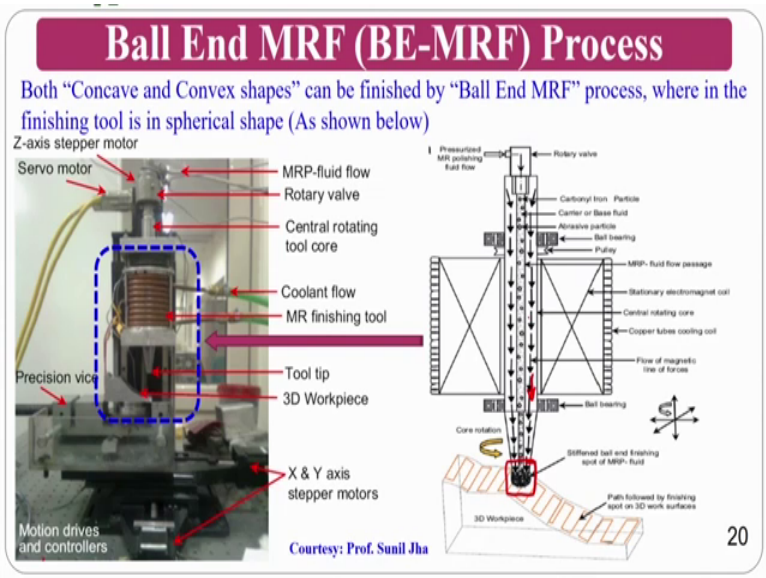

However, it can be overcome by some of the advancements of MR finishing process, that is called ball end MR finishing process; where this is a allied process or this is a advanced version of the basic MR finishing process, where you have a ball end at the is formed. And the magnetic field of lines is showed by the arrows, these arrows, and the fluid is coming from the centre. Because of these what will happen? There will be a strong magnetic field of strength will be generated at this one and which forms a spherical ball.

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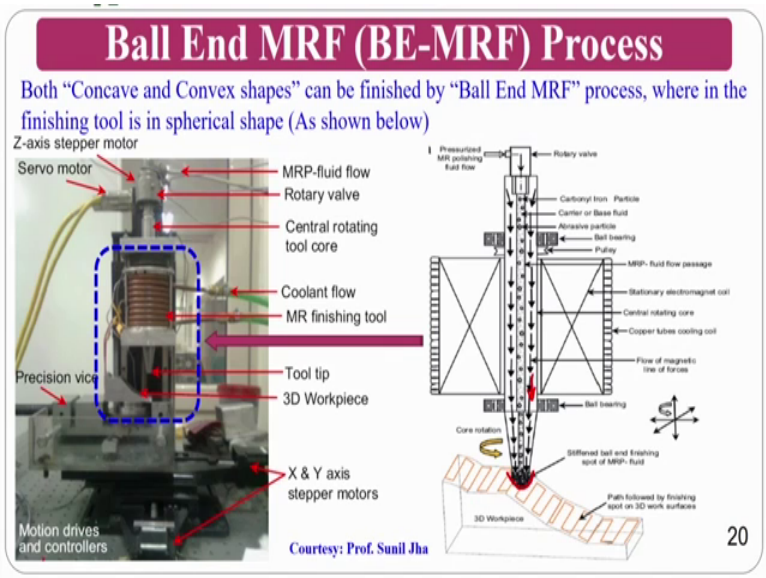

And this spherical ball is like a your helical cutter. Now you got a helical cutter which is having a flexible tool. Now you can move your x axis, y axis and z axis along with caviling and other things. So, Professor Sunil Jha of IIT, Delhi works extensively in this area, if at all you want more details about ball end MR finishing processes, his group is doing enormously good work. And, you can if the participants are from companies, Professor Jha has developed the commercial products; so, you can also contact him for supply of this type of machines ok.

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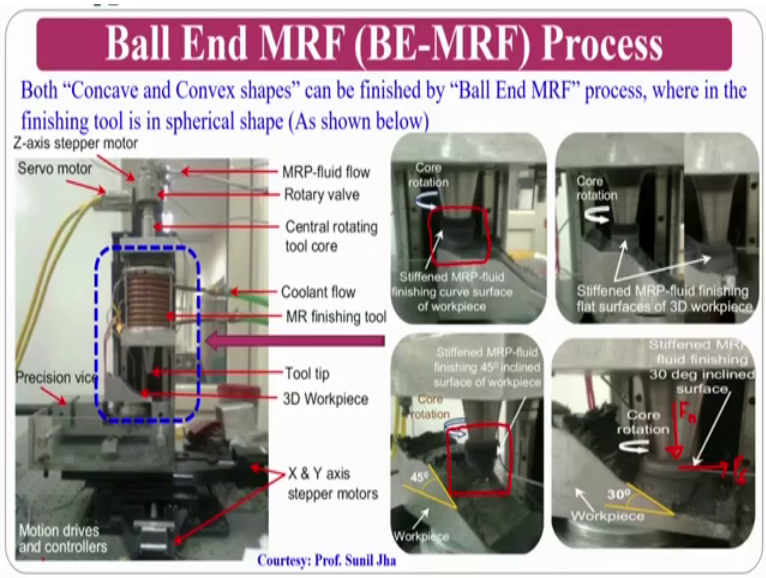

So, you can see here that it is forming a Stephen part of this MR finishing fluid and you can give some rotation so that finishing action will takes place, because of the magnetic field strength and depth of cut what will happen is you are going to get F n and because of the rotation you are going to get the shearing force. This how you are going to remove the material or the shearing the material in the finishing region; you can clearly see how the magnetic field top chains are forming before it is coming in contact with respect to workpiece. So, you can have x y and z motions so that you can finish any type of surfaces.

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So, the applications of MRF in broad spectrum you can use for the lens finishing applications.

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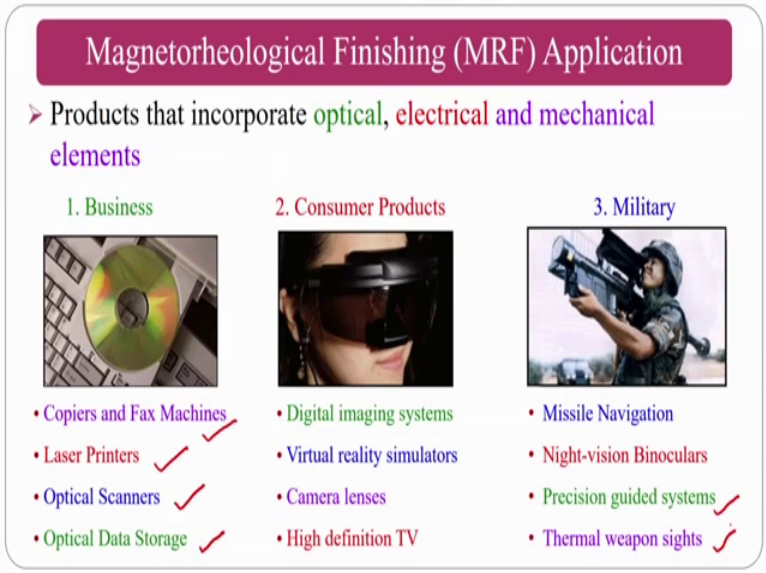

At the same time, these are the business applications like copier fax machines, laser printers, optical scanners, optical data storages, these are the one of the applications. If you see the consumer products like virtual reality simulator, camera lenses, these are all the applications where the lens polishing is required, or the super polishing of the lenses is required ok. So, like missile navigation system précised guided system thermal weapon sights, and these are the requirements in the military applications.

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In the operational applications like, optical sensor, laser diode optics optical telecom x rays and laser lithography these are the operations required. And industrial productions like laser be machines you require precise lenses, for laser welding options optical instruments nano precision grinding applications and other things. And a medical like endoscopes laser surgery intracellular imaging, laser scanning microscopy, these are the many applications in the medical field also ok.

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So, MR finishing process uses for many type of lens finishing applications as you can see very small lens to big lens where are finished using MR finishing process.

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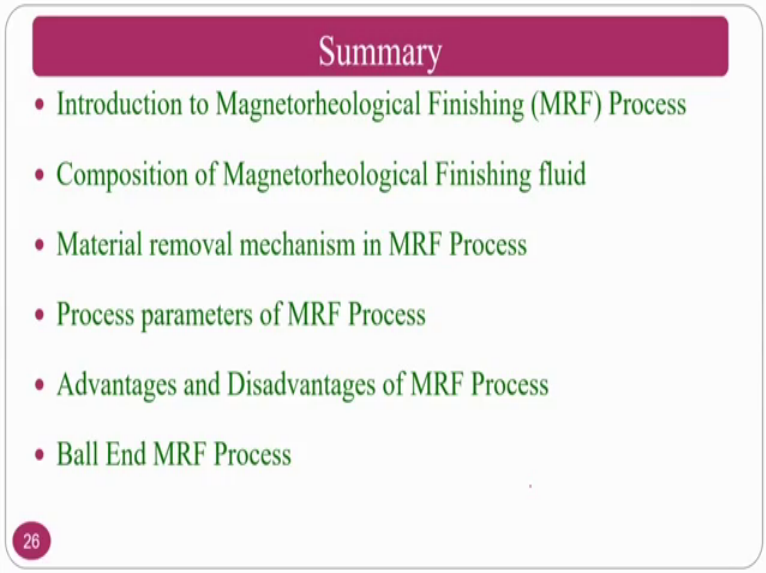

The summary of this particular class, we have seen the introduction to magnetorheological finishing process. Then the composition of this one, consist of CIP particles, carrier medium, additives along with the abrasive particles. So, you have seen the material removal mechanism in the MR process. And process parameters what are the input parameters that you can control and to achieve the output responses.

And advantages and disadvantages of MR finishing process, if you have if you are unable to finish the blind holes using MR finishing process, then we move on to one of the process that is called ball end MR finishing process; where you can achieve the blind holes finishing and other things and applications of MR finishing process as whole. It includes, ball end as well as normal or conventional magnetorheological finishing process. I am very thankful for your kind attention.

Thank you.