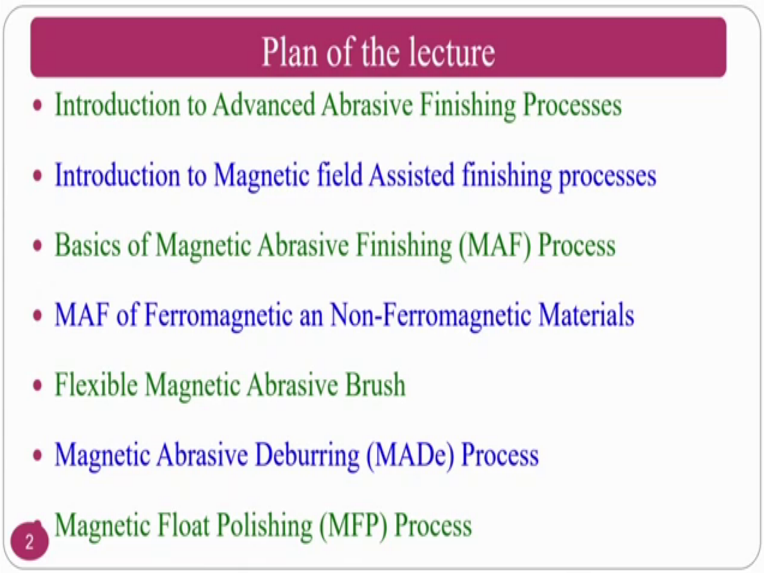
Introduction to Abrasive Machining and Finishing Processes
Dr. Mamilla Ravi Sankar
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture – 22
Advanced Abrasive Finishing Processes (Magnetic Field Assisted Abrasive Finishing)

So now we are moving to another set of Advanced Finishing Processes which uses abrasive particles that is called Magnetic Field Assisted Abrasive Finishing Processes. So, in this category they are varieties of processes ranging from magnetic abrasive finishing to magnetorheological finishing to magnetorheological abrasive flow finishing and so on. So, in this particular class what we are going to see is magnetic abrasive finishing, and some of the it is allied processes such as magnetic float polishing magnetic abrasive deburring and other things.

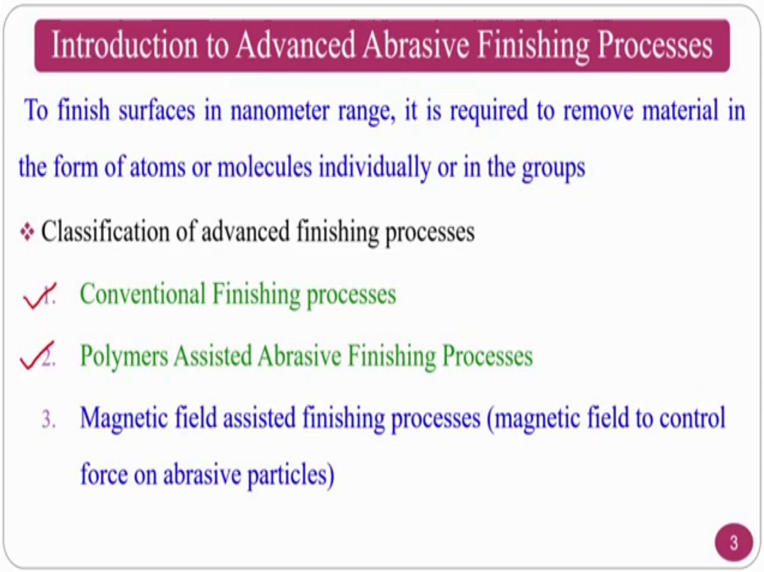
(Refer Slide Time: 01:08)



So, the plan of the lecture goes like this. So, Introduction to Advanced Abrasive Finishing Processes, what are the various abrasive finishing processes. Then Introduction to Magnetic field Assisted finishing process. Then basics of magnetic abrasive finishing process, how it will be working and what is it is mechanism, how about whether you are going to finish a magnetic material or a nonmagnetic material, how the field of lines will emerge, how the field of lines will emerge and other things and the magnetic abrasive finishing of ferromagnetic and non-ferromagnetic materials, where the mechanism of material removal how it will takes place how the flexible magnetic abrasive brush will form and other things. Flexible magnetic abrasive brush, how this particular brush is responsible for finishing.

So, magnetic abrasive deburring process as well as magnetic float polishing process. Just we will see the glimpse of this particular processes at the end, ok.

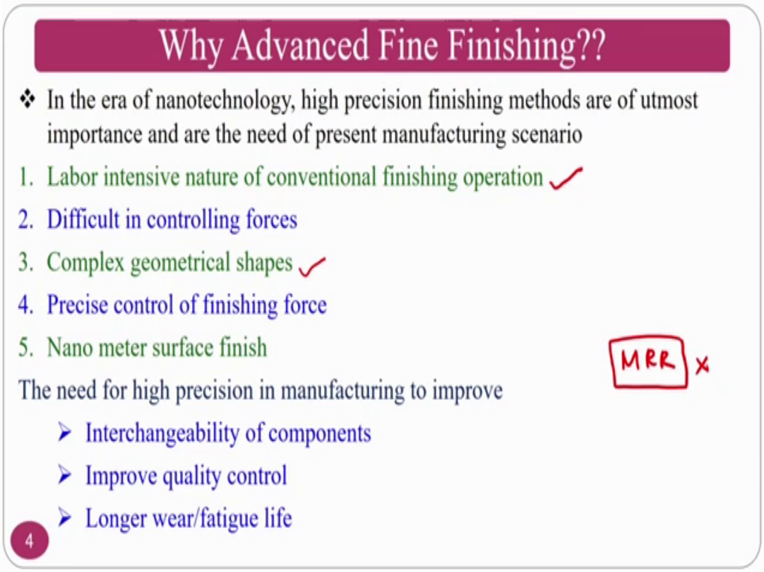
(Refer Slide Time: 02:12)



So, introduction to abrasive finishing processes, where 2 finish the surfaces in the nano metical range. It is required to remove the material in the form of atoms individually or in the molecules or in groups of this atoms or molecules we have to remove. The classification of advanced finishing processes or what we have seen in this one is the abrasive finishing processes. So, the conventional finishing processes followed by polymer assisted abrasive finishing processes which we have studied only very few material about this particular process like abrasive flow finishing process, polymer rheological abrasive fluids or medium and it is rheology and it is capabilities and all those things. Polymer rheological abrasive fluids and it is based finishing processes itself is a very vast course.

So, just I gave you glimpse in this particular course. However, if at all people are interested extensively in this particular course, there will be a advanced version of this course where polymer assisted abrasive flow finishing processes ok. So, it is a 10 hours course, where you can do this particular course and you can learn more and more. So, that particular course is mostly about the basics, plus advances also. So, that will be mostly useful for doing you are B-Tech project work M-Tech project work and PhD oriented work also ok. So, that is why I have not touched much upon on this polymer assisted abrasive flow finishing processes or polymer assisted abrasive finishing processes. However, I am going to give you some of the introductions about the magnetic field assisted finishing processes, where magnetic field is used to control the forces of this particular process.

(Refer Slide Time: 04:11)



So, why advanced fined finishing process is required? Normally, this process is labor intensive methods, because the final operation that one can do on particular component or particular workpiece is finishing operation in a mechanical spectrum. So, you have to acquire the tolerances, you have to acquire the finishing and many things.

For this purpose, what all you require is, you need to choose a very highly skilled labor; wherein, if you are going for the skilled labor or very high skilled labor; the salary of the skilled labor or very high skilled labor will goes up. So, the product cost goes up, difficult to controlling forces. Because as I said even though very experienced person operates with the hand or something what will happen today he will be fine. So, we will be finishing properly tomorrow assume that he has a quarrel with a family member like wife or something.

So, he may come I am just for example, I am giving do not take in a otherwise. So, he may show the anger on the component. So, it will be lot of problem for the surface finish and other things, because it is not controlled or automated by a mechanized way or a electronic controlled way it is a human. So, emotions also will be a part of finishing forces.

So, complex geometrical shapes, some of the conventional finishing process cannot do for the complex shapes like any neemplant hip implant and other things, because the conventional abrasive finishing processes uses the solid type of tools like grinding wheel, honing wheel and other things. So, precise control of the finishing forces is not achieved because the solid to solid contact. If you are going for a grinding wheel, it is a solid to solid contact between work piece in a grinding wheel; so, the forces will be enormous. So, you need minimum forces and you have to get the surface finish very good, but we do not bother about MRR. We are not at all interested in a finishing process about what is the material removal rate.

So, nanometer surface finish, because we want in a finishing process is the surface finish that one can achieve on the component, not the material removal rate. Need of high precision manufacturing is to improve interchangeability of component if you are finishing and everything is good so, interchangeability is good improve the quality control. So, some of the components in a conventional finishing processes may reject in the quality control examination.

So, if you are going for advanced finishing process, the surface finish levels will be enormously high in that circumstances what is going to happen is you are going to get the good quality product. So, it can pass the quality control test. Long wear and fatigue life, because your surface peaks are very less, I mean to say peaks and valleys are very less because of which what will happen is you are going to get good life.

(Refer Slide Time: 07:34)

Finishing Ability of Various Abrasive Processes

S.No	Finishing Process	Work piece	Ra value (nm)
1.	Grinding	-	25 - 6250
2.	Honing	-	25 - 1500
3.	Lapping	-	13 - 750
4.	Abrasive Flow Machining with SiC abrasives	Hardened steel	50
5.	Magnetic Abrasive finishing (MAF)	Stainless steel	7.6
6.	Magnetic Float Polishing (MFP) with CeO_2	Si_3N_4	4.0
7.	Magnetorheological Finishing (MRF)	Flat BK7 Glass	0.8
8.	Elastic Emission Machining	Silicon	<0.5
9.	Ion Beam Machining	Cemented carbide	0.1

5

So, finishing ability of various abrasive finishing processes; if you see the spectrum the serial number followed by the finishing process, work piece material and the surface roughness value ok.

So, the surface roughness value is given in the nanometers. So, if you are going for grinding, you can achieve this particular value like 25 nanometers if you are going for micro grinding or very super finished type of grinding under the sim honing and the lapping process. And if you see abrasive flow finishing process the best surface finish achieved by extrude one company is 50 nanometers. However, there are some reports that the people have done extensively in this one and they have achieved.

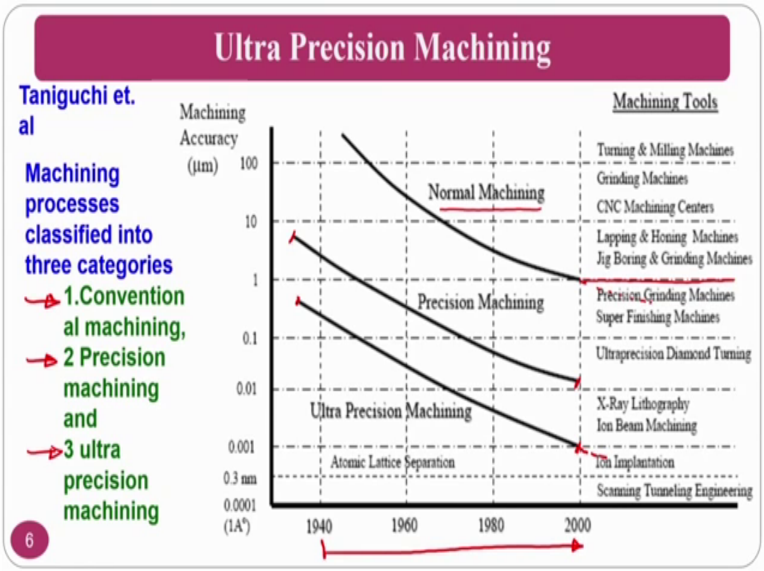
Below this on some of the common materials also magnetic abrasive finishing, which we are going to study in this particular class is this magnetic abrasive finishing process on stainless steel the people achieved 7.6 nanometers. Magnetic float polishing with cerium oxide as a abrasive particles, with a cerium oxide as abrasive particles achieved 4 nanometers, which is a very good this particular part also we will see in this particular process.

Magnetorheological finishing process achieves the surfaces roughness of 0.8 nanometer that mean that sub nanometers range can be achieved, elastic emission machining is less than 0.5 can be achieved using elastic emission machining and ion beam machining and other things can be achieved 0.1 nanometer other things. This is the beauty about the some of the processes that are given in the literature. So, this some of the slides is a combination or the study of many many research papers or and some of the books also. So, the slides comprises not only the reference books, but also it includes most of the research papers also.

So, people who are following this particular course should understand that they have to read the research papers also along with the books for your basic understanding and advanced understanding. However, what I want to tell at this particular point of time is that the questions that you are going to get from the examination, because keeping in mind of bachelor students masters students and PhD. Apart from this there are many faculties who are also doing this particular course.

Keeping all these people so, emphasis is given to the students that is why the question papers consist of mostly basics. So, keep the basics ready, at the time some of the advanced questions also will be there. So, if you are basics are proper then you can answer the advanced questions also ok.

(Refer Slide Time: 10:33)



So, ultra-piston machining if you see the Taniguchi et al, they has given a table where the machining processes are classified into 3 categories. One is the conventional machining, second one is the precision machining, and the third one is ultra-precision machining; if you see that machining accuracy versus number of years are the as the time passes.

So, the machining accuracy levels are coming down the surface requirements are coming down. So, new and new work piece materials are coming up the surface finish levels are enormously coming down ok. So, for that purpose what the people has to find is, we have to find a new type of abrasive finishing processes; where you can achieve very good surface finish on the advanced materials for any type of applications, ok.

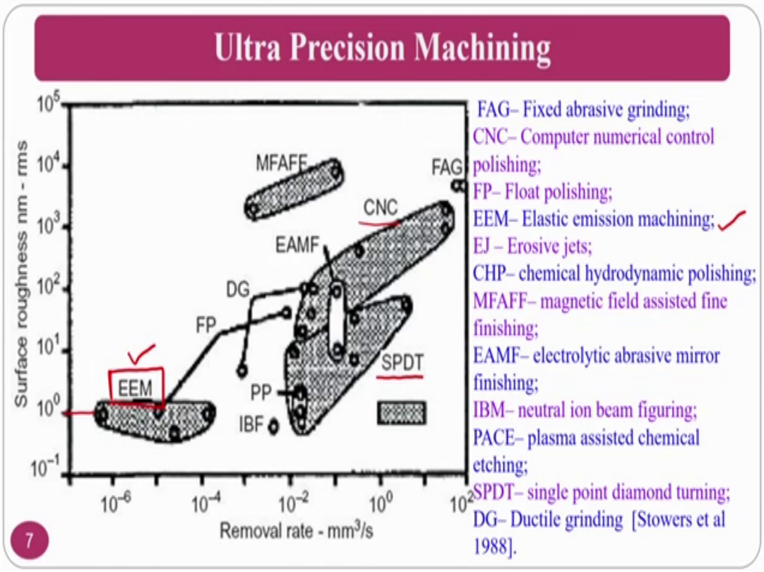
If you see the normal machining or the conventional machining the surface rangers is from 100 microns to the range of 1 micron as it progress from 1940 to 2000, ok. Currently we are in 2018. So, it will be still lower ok, if may go like this ok. So, in the precision machining processes, if you see the range is below 10 micrometers to approximately point above approximately slightly above 0.1 micrometer ok. So, as it reaches to 2000, if you are looking at 2020 and other things what will happen is, it may go below 0.1 microns also.

In ultra-precision machining processes if you see so, it is also starting from less than 1 micron, and it is approximately 0.001 a as per the year 2000 is concerned, if you are seen as per the current scenario what is going to be is it might have gone. But it may not you cannot extrapolate in the same tangential way because it is completely a randomized.

So, it will you can say qualitatively that it will be below than what it is in 2000 that ok. So, some of the normal machining processes like Turning Machining, Mill Turning, Milling, Grinding, CNC, Lapping, Honing, Jig Boring and other things will come under this category. And precision machining normally precision grinding, super finishing, ultra-precision diamond turning and other things; X-ray lithography, ion beam machining, ion improve implantation and other things all this will go for the ultra-precision machining ok.

So, some of the abrasive processes also will be in the range of the precision machining to ultra-precision machining processes ok; that means, that whatever you are going to study in the conventional way. That means, like grinding and other service which you have seen in the early part of this particular course, come under the conventional machining. The second part was to be are going to see like polymer assisted abrasive finishing processes, and magnetic field assistant abrasive finishing processes come under the category of precision machining to ultra-precision machining.

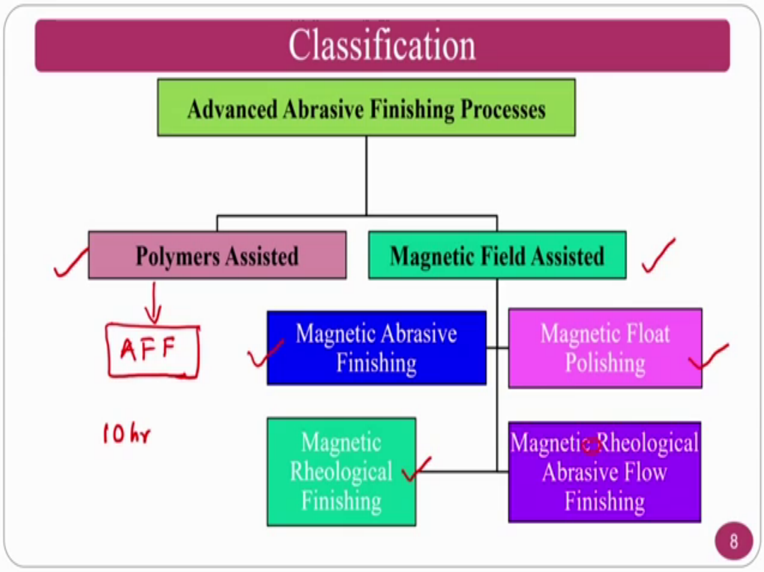
(Refer Slide Time: 14:05)



So, if we can see here elastic emission machining is what we have studied, and MRAFF we have we will studies. And so, many things like Elastic emission machining, the Electrolytic abrasive machining these are all which we have not studied. But however, some of the processes that we have studied is elastic emission machining this follow in the surface roughness range of 10 to the power 0 and so on.

So, we are not as most of the processes are not relevant to abrasive processes like a single point diamond turning, CNC metal cutting and other things which we will not come under the abrasive finishing processes, that is why we have not studied; ion beam machining and all those things. That is why what I can say is that among our processes, we have one process that comes is elastic emission machining and other things.

(Refer Slide Time: 15:12)



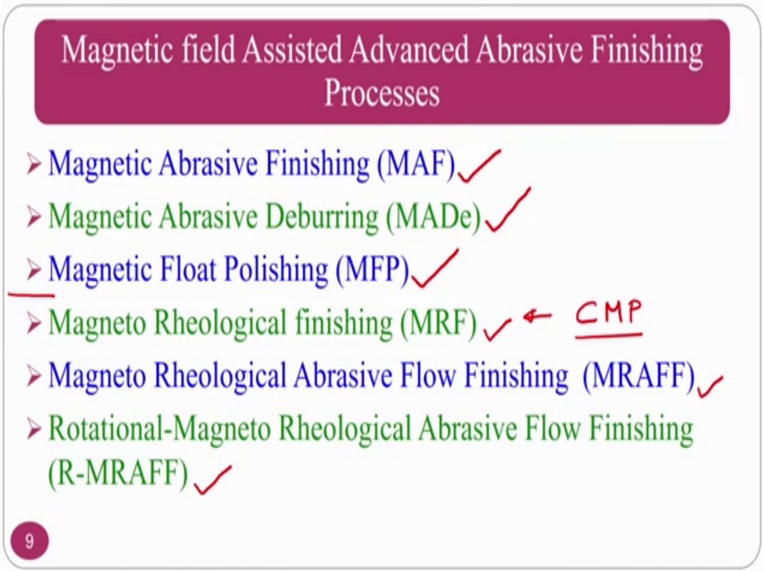
The classification of this polymer assisted finishing processes and magnetic field assisted finishing process, we have studied the abrasive flow finishing which is a main part of polymer assisted finishing process. And extensive to it, if at all anybody is interested as I already mentioned, there will be a new course which is floating for 10 hours that is polymer assisted abrasive finishing processes.

Where extensively people will study about the polymer rheological abrasive fluids, how the mechanism of material removal, what are these allied processes and etcetera will be studied in this particular course. So, do not think that abrasive flow finishing is the only process that we will be covered in that one. It will cover lot of processes like elastic emission machining that we have seen in the previous slide, and elasto abrasive finishing, micro AFF, orbital AFF so on. There will be a pitch polishing where the polymer oriented will be there.

There are abrasives that are made up of polymers so on you will study in 10 hours course that will be for one month and other things, ok. If anybody is interested they can register for which the course will be floated in the early part of 2000 19. So, what we are going to study in the particular section is called magnetic field assisted finishing processes; where we will see the first one is magnetic abrasive finishing. The second one: we will see the allied process that is called magnetic abrasive deburring followed by magnetic float polishing, then magnetorheological finishing. And we will also see chemo mechanical magnetorheological finishing process. And we move on to magnetorheological abrasive flow finishing process and rotational magnetorheological abrasive flow finishing processes.

These are the things that we will see in the category of magnetic field assisted finishing processes.

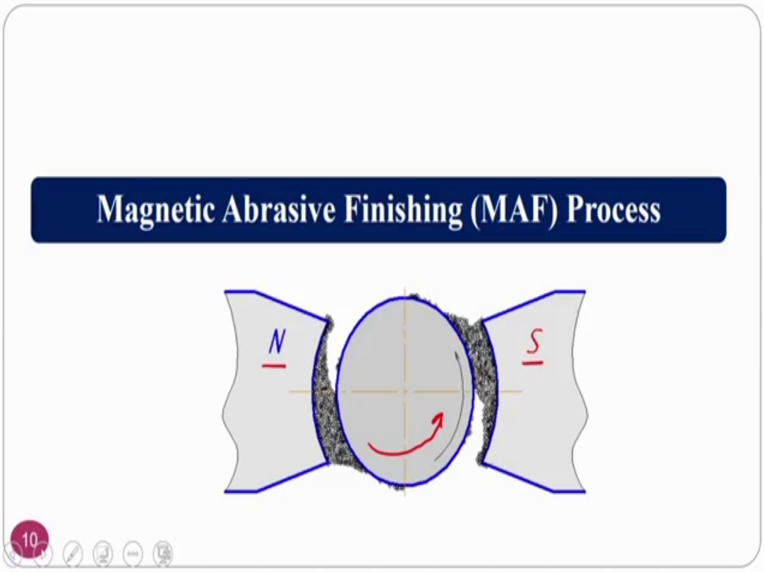
(Refer Slide Time: 17:23)



So, what we are going to study in this particular section of magnetic field assistant finishing process? We are going to study Magnetic Abrasive Finishing, Magneto Abrasive Deburring, Magnetic Float Polishing.

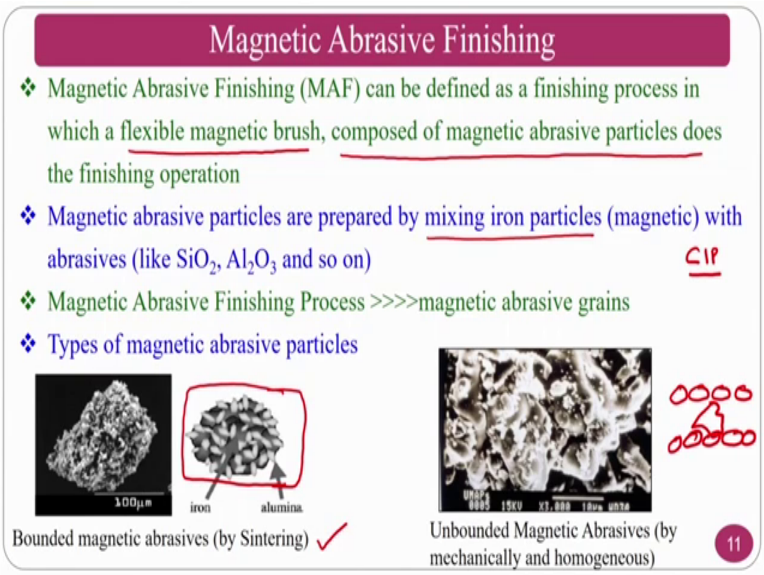
In this, we will study in this 3 in this particular section. Then followed by other processes where you will see magnetorheological finishing processes. And magnetorheological abrasive flow finishing process, and rotational magneto abrasive finishing processes, and there is some variety that will be clubbed along with magnetorheological finishing process is called CMP, that is called chemo mechanical polishing. And normally people uses the chemical to make a passivation layer, then remove by the magnetorheological finishing process. That claims we will see in the upcoming classes.

(Refer Slide Time: 18:15)



So, you can see here magnetic abrasive finishing process; where the workpiece is rotating continuously, and the abrasive particles are placed, where you have a North Pole and you have a South Pole. And the chains will form from North Pole to South Pole because of the rotation of the work piece. And other things the shearing action takes place and the material will be removed in a nanoscale or sub nanoscale and the surface finish is achieved in the nanometric range.

(Refer Slide Time: 18:48)

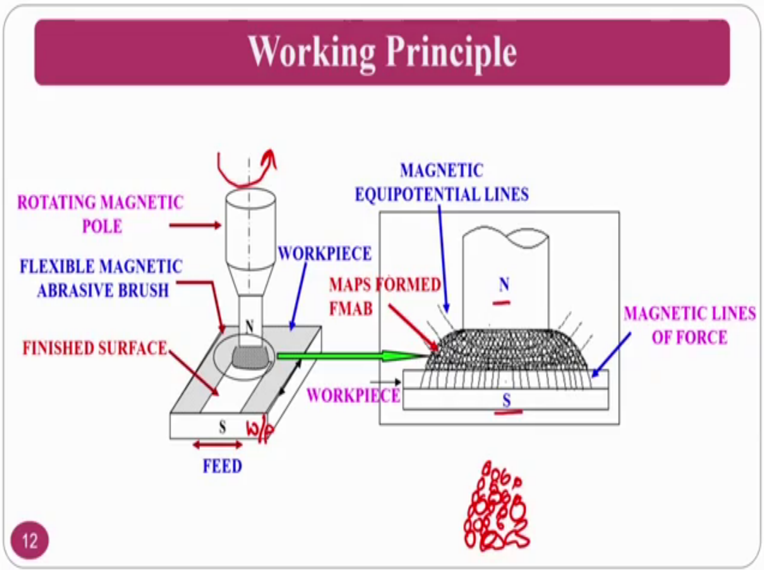


So, magnetic abrasive finishing can be defined as a finishing process with a flexible magnetic abrasive brush composed of magnetic abrasive particles for the magnetic abrasive particles along with the CIP particles and other things. So, magnetic abrasive particles are prepared by the mixing of iron particles. Normally, iron particles are called as CIP ok, carbonyl iron particles. These are normally very pure variety of iron particles ok. Whenever you have a magnetic field; so these CIP particles from the chain from North Pole to South Pole ok.

So, assume that this is a North Pole and this is the South Pole. So, you will form a chain. So, these 10 chains a multiple chains will form where in abrasives are held ok. This is the one variety. And another variety of the abrasive particles is that you can go for the bonded abrasive particles or in this aspect, we can go for bonded magnetic abrasives using the sintering. That means, that you have the iron particle where in you can sinter the abrasive particles, and you can make a single abrasive particle like this ok.

This can happen, and you can use this particular process for the finishing applications, ok. Normally un-bonded also you can use in that circumstances, you have to form the magnetic particles chain. That is CIP particles chain and you will have a abrasive particle, then you will have a another chain, this chain will entrap the abrasive particle and give support to remove the material.

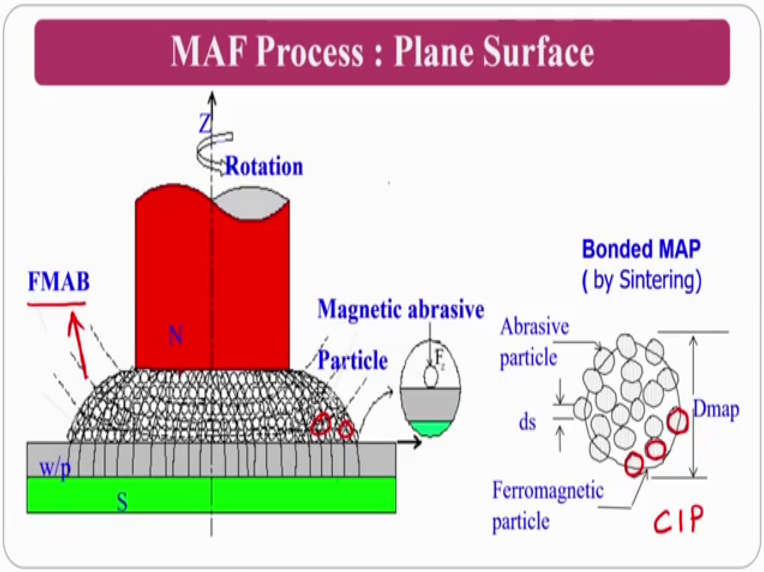
(Refer Slide Time: 20:47)



You can see the working principle, this is the feed is given to the workpiece, this is the workpiece, and the tool is there rotating magnetic pole plugs, and you have a flexible magnetic brush. You can see the North Pole is there, South Pole is there, where in your work piece is there. And you will form a magnetic field of lines that is not you nothing but you form the chains. So, these chains are formed and abrasive particles are entrapped, ok.

This abrasive particles are entrapped, this chains will support the abrasive particles, and since the motion is given to the work piece as well as rotary motion is given to the tool, what will happen? The shearing action will takes place, my workpiece is stationary and you are giving the tables feed ok. And your tool is like this and it is rotating. So, relative motion causes the material removal ok. That is how the magnetic materials will help the abrasive particles to remove the work piece material.

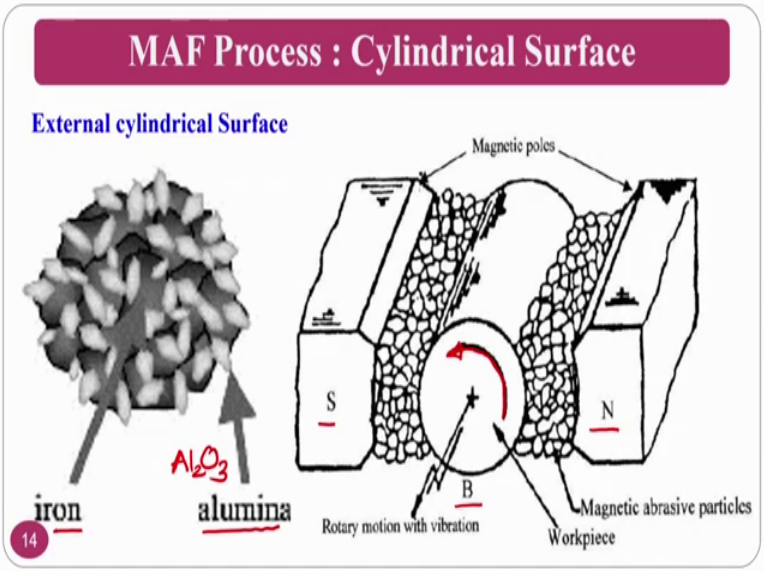
(Refer Slide Time: 22:02)



So, for planar surfaces whatever you have seen in the previous slide also is the planar surfaces, and workpiece is there, flexible magnetic abrasive brush is there, this is you can see clearly the North Pole and South Pole; where you have the magnetic abrasive particles are embedded. In this one and this field of lines will support the abrasive particles.

And we can see the schematic of the bonded abrasive particle. Where in ferromagnetic particle that is nothing but the CIP particle is big one, and wherein you are going to bind or you are going to sinter the abrasive particles, ok. This particular bonded abrasive will act as a single entity, ok.

(Refer Slide Time: 22:55)

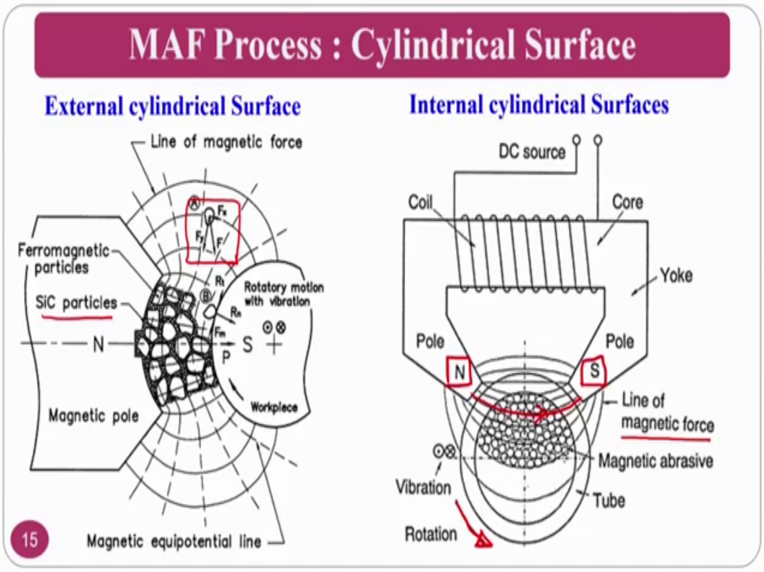


So, whenever you are going to use, the previously you have seen it is for the flat surfaces. Now if at all I want to see for a cylindrical surfaces. How it look like? So now, the cylindrical surface, you I have the South Pole, I have the North Pole, and field of lines will transfer always between North to South, ok. And you have the workpiece.

So, workpiece is given rotation and because of this chain formation; where the abrasive particles are there as well as yours CIP particles are there. Because of this relative motion what will happen? External surface of the cylinder will be finished. And you can see here enlarged version the same image, where you can see the abrasive particles which are the thing, but the alumina Al 2 O 3 is sintered on CIP particle, ok.

These abrasive particles will remove the material depend on the magnetic field strength, ok.

(Refer Slide Time: 23:57)

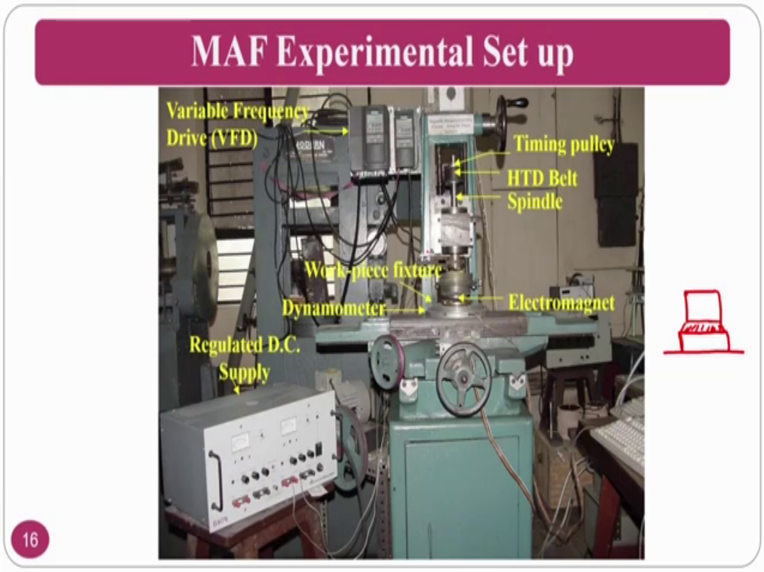


How to finish the internal cylinder? So, you can see the internal cylinder mechanism of material removal, as well as what you have seen in the previous one external cylinder. So, if you are seeing the external cylinder, what will happen is, SIC particles are there, at the same time magnetic particle like CIP particles are forming chain so that there will be a forces generation that is required F x and F y. That is in the radial direction, because of the magnetic field strength, at the same time because of the rotational effect, there will be a tangential force.

Because of this what will happen? The material will remove on a cylindrical surface. See, if you see in the hollow cylinder, if at all I want to finish the inner surface of the hollow cylinders, in the circumstances, what will happen? You have the North Pole you have the South Pole the field of lines will move always from North to South, that you can see here, and you have abrasive particles as well as you have the CIP particles.

So, this is line of magnetic force will form the chains, and this chains will entrap the abrasive particles and finish the surface. And here also you have to give the rotational motion to the workpiece, because of the relativeness what will happen? The material removal will takes place. So, after seeing the flat surfaces as well as internal and external cylindrical surfaces finishing mechanisms, or the schematic views, we now proceed to the experimental setup how to finish the simpler surfaces.

(Refer Slide Time: 25:43)



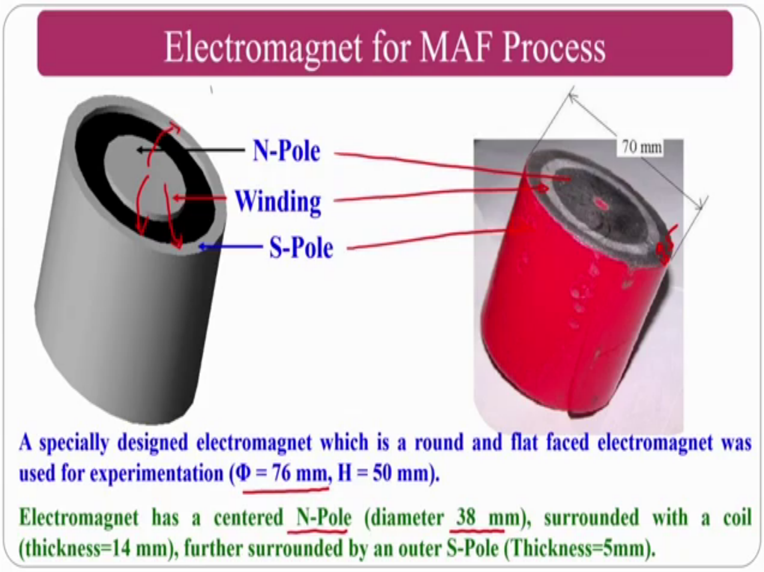
Because we fought all we want to understand the physics of the MAF process then we have to go for the simple surface to be finished. So, in this particular case, what we are going to see is the flat surface. How to finish is a flat surface where in the surface roughness is there. So, you can see here the electromagnet, the workpiece is there as well as the dynamometer is also there.

So, ring type thermometer is placed on which the work piece is phase; if you see this particular location, where the workpiece as well as the tool is placed ok. So, the dynamometer is placed like this, on top of it, there will be a workpiece, on top of it there will be the magnet; wherein you have the flexible magnetic abrasive brush will be there. So, that flexible magnetic abrasive will form.

Since, the rotation is given by the variable frequency drive, variable frequency drive rotates the flexible magnetic abrasive brush, the spindle that connects to the flexible magnetic brush that is called this one. So, it will be rotated by the variable frequency drive ok. So, the regulated DC supply is always given to the electromagnet; where in the end as well as South Pole and as well as North Pole is there in the same fixture ok. So, in the same tool you have North and South Poles, and the electromagnetic field of lines will transfer from North to South in between you just place the workpiece.

So, you can do the finishing operation. So, elaborative way about the electromagnet we will see in the next slide.

(Refer Slide Time: 27:47)



If you see the schematic diagram of the electromagnet; where which is act as a tool, what will happen is you have a South Pole at the surface, North Pole at the middle or the centre and you have the windings. Always, there is a difference between permanent magnet and electromagnet. The people like B-Tech students you may have some basic knowledge, you should have some basic knowledge about the difference between permanent magnet as well as the electromagnet. If you see a permanent magnet the magnetic field strength will be constant.

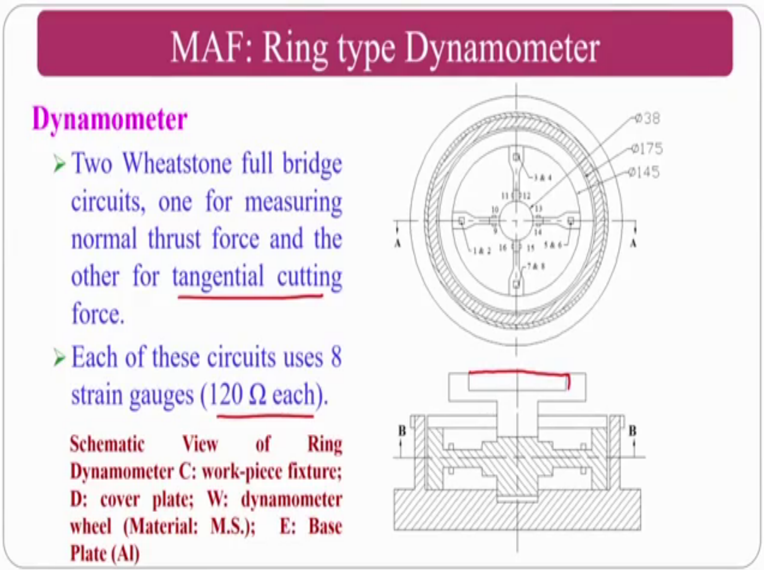
1 Tesla; assume that it is a the magnetic fields maximum strength is 1 Tesla means that is 1 Tesla completely ok, with respect to time that may decay also. But in a electromagnet what is the beauty about this one is, you can control the voltage the or the power supply so that the windings will generate the magnetic field. So, the magnetic field can be a variable. It can be 0.1 Tesla; it can be 1 Tesla or anything ok. So, the capacity will be defined by the input power as well as windings and many other things, ok.

The difference what I want to say at this particular moment of time is that, permanent magnet means you have a particular value of the magnetic field, and in a electromagnet you can vary the magnetic field. If you can vary the magnetic field that mean that your strength of your flexible magnetic abrasive brush can be improved. So, this is the North Pole and South Pole, and how it looks like in the practical way, you can see here, this is the South Pole again; the red portion, and the windings are there at the centre and the North Pole is at the core.

So, the specially designed electromagnet which is a round and flat phased electromagnet was used for the experimentation. And the dimensions are 76 mm diameter with a height of 50 mm; is fabricated and electromagnet as centre North Pole whose diameter is 38 mm and surrounded with a coil whose thickness is 14 mm, and further surrounded by a South Pole which is 5 mm thickness. So, you can see here, this is 5 mm thickness and the 14 mm thickness is the windings and again 36 38 mm is the North Pole.

So, for the 2 poles sandwiches the windings in this particular thing. This is a special design that is made for the magnetic abrasive finishing. So now, what will happen? Always the field of lines, we will transfer from North Pole to South Pole ok. North Pole to South Pole in that circumstances what will happen is, you can give the relative motion so that you can do the finishing operation; that how to do the finishing operation how the flexible magnetic abrasive brush will be formed and other things. We will see in the upcoming slide.

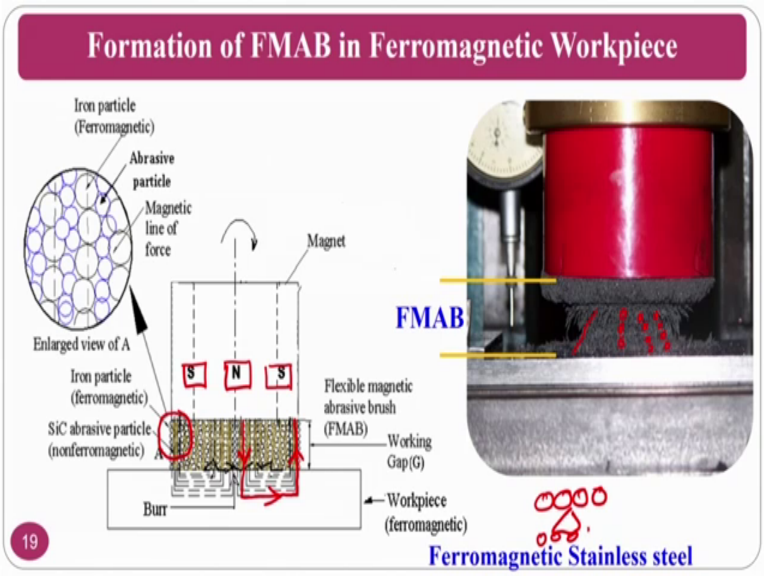
(Refer Slide Time: 31:02)



So, as I said dynamometer also used here; the dynamometer is a ring type dynamometer to wheat stone full bridge circuit one measuring the normal thrust force and another one measure the tangential cutting force. Each the circuit has 8 strain gauges. Normally, this as the strain gauge type of thing; so you can place the workpiece and you can measure the forces ok. This may be ring type may be normal strain gauges type also will be there ok.

So, there are some of the applications where you will use ring type dynamometer is like abrasive flow finishing process and other things. Here there are so in a ring type dynamometer. You will see a strain gauges, here also you can use a strain gauge based. So, the developments of this type of dynamometers are economic, and you can maintain this one because you can fabricate with a little knowledge and a little collaboration with the electronics people and other people. If at all you want to go for commercially available dynamometers normally it causes to few lakhs rupees.

(Refer Slide Time: 32:16)

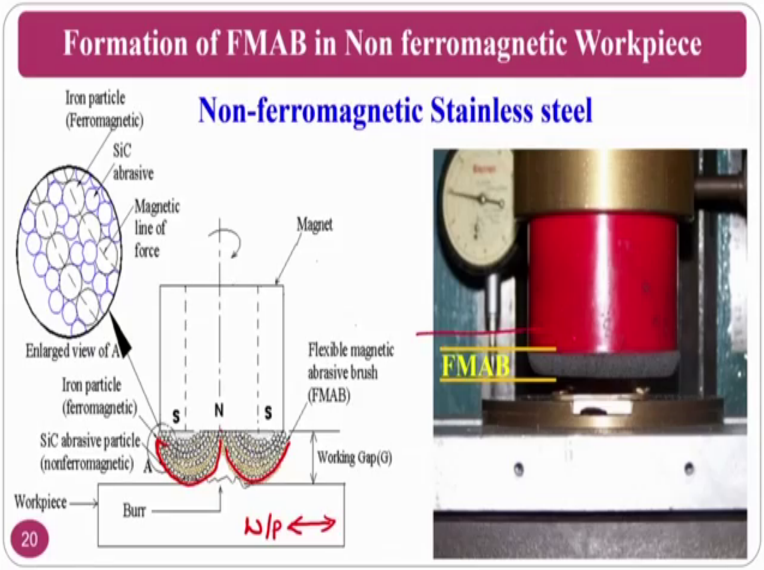


That is why people go for the strain gauged based measurements. If you see the flexible magnetic abrasive brush formation in ferromagnetic work price material, ferromagnetic work piece means it is a magnetic material, what will happen if you see the schematic diagram, the first one, the magnetic field of lines you have at the central portion n; that is North Pole on other sides you have the South Pole. Because of which what will happen is you can form the North to South Poles, North to South Poles ok.

Since, you have the work piece material also a magnetic material, because of which what is happening here is it is moving like this. So, it is coming inside the work piece also and going; that means that the energy or the strength of these chains will be very high, ok. You can see the zoom up version of the chain here. So, it has abrasive particles as well as iron particles, and you have seen the field of lines. And if you see the good picture of this practical experimentation, you can see the field lines ok. These are the chains that are forming the magnetic CIP particles are forming the chains, and the wherein abrasive particles are held, ok.

So, this type of magnetic brush is generated which a embers the abrasive particles.

(Refer Slide Time: 33:55)

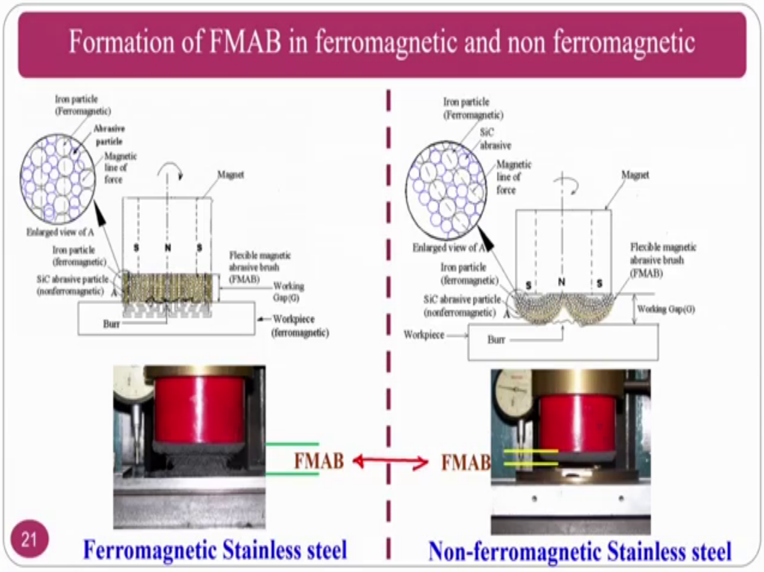


So, if you see for a non ferromagnetic workpiece in the circumstances what is happening here is, you can see the North to South Pole, since this work piece is a non magnetic workpiece so, the field of lines cannot pass inside. So that means, that the magnetic field strength is very low ok. So, that is why the surface, it has on the top itself, the field of lines magnetic lines of force that is on the surface only. So, there will be a slight problem that wherever that the central portion is there, the finishing may not occur, but by giving the table speed. So, this particular central portion can be varied and you can do the finishing operation.

If you see the flexible magnetic abrasive brush in the practical condition, you can see it is not touching. So, for that purpose it has to come. So, if you see the flexible magnetic abrasive brush this particular portion, for ferromagnetic material it is very big and magnetic field strength is very high. For non-ferromagnetic material it will be on the surface and the field strength is low; that there are some doubts that people will always get. If it is a magnetic material, there will be always chance that CIP particles may adhere to the surface.

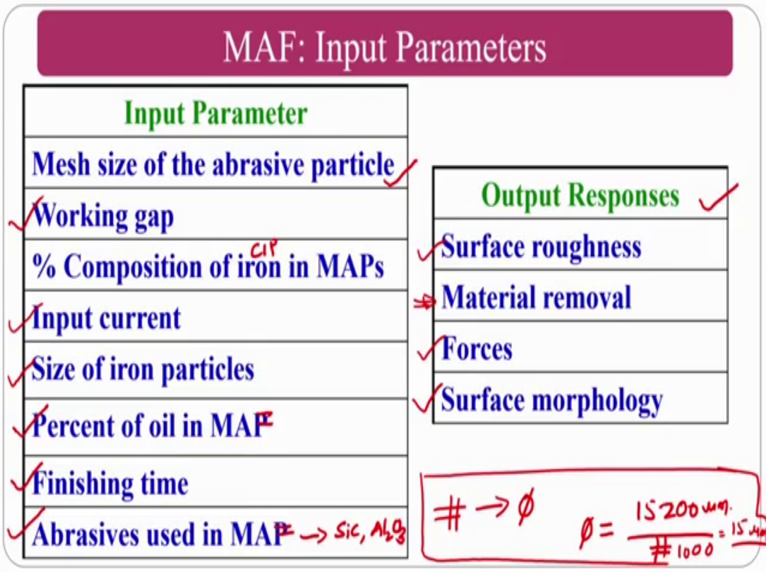
That type of drawbacks are there, but because of the relative motion of your tool that is which is compresses of North and South Pole along the windings, what will happen is that you can shear it off so that the finishing will takes place.

(Refer Slide Time: 35:40)



In the difference between ferromagnetic and ferromagnetic material, you can see here flexible magnetic abrasive brush is very strong in case of ferromagnetic, but not in case of non-ferromagnetic. And there will be adherence formation in the ferromagnetic, but it not in case of non ferromagnetic. But both the cases depend on your application you have to use this particular process.

(Refer Slide Time: 36:07)



So, input parameters mesh size of the abrasive particles; whether you want to go for thousand mesh size, as I already said you that to the mesh size conversion into the abrasive diameter. Normally, abrasive diameter is equal to 15.2 mm upon that mesh size. Assume that this is the thousand mesh size, what will happen if you are going to get approximately 15 micrometer. Because if you convert the mm into micrometers what will happen is, 15200 divided by thousands with approximately boils out to be like 15.2 micro meters. The working gap, the working gap has to be maintained because in the flexible magnetic abrasive brush in case of ferromagnetic is bigger, but in case of non-ferromagnetic it is smaller.

So, you have to play with the working gap. If you are working gap is too high, then the magnetic strength will be low. If you are going to have low, water lap and the compression will come into picture, not only finishing action will takes place, but also it will scratch enormously. So, you have to play with the working gap. At the same time percentage composition of iron particles that is nothing but the CIP particles, because you required the chains to be formed. So, chains to the abrasive particles ratio should be always maintained.

If your chains are more and abrasives are less, then also it will be a problem. So, your bonding strength will be very high; that means that the grade will be very high, ok. That if at all you are going to have number of abrasives more and number of CIP particles less, then it will be a soft grade.

So, with the energy required per a particular particle by the CIP particles will be very less; that means that you have to play neither less nor more. So, you to play with the experiments or you have to do the trial end errors forget the optimum values of CIP particles all as well as abrasive particles composition. And the next one is input current. So, you have to give input current so that the magnetic field strength will be varied.

Size of the iron particles so, you have multiple types of sizes of the particles, you can go for bigger particles if you can go for small particles, as all this will be depend on your application. Percentage of oil in magnetic abrasive fluid, what I mean to say is that, you have iron particles, you have the abrasive particles. If you want to mix, it still I want a powder form, I do not want like a liquid. Liquid type of magnetic fluids that we will see in the advanced version, that is called magnetorheological finishing processes and magnetorheological abrasive flow finishing process and other things, but here to make a consistent or to make the proper bonding or to make the integration.

For that purpose, very little amounts of oils to be used for this particular MAF process medium, ok. So, I have the CIP particles, I have the abrasive particles; where in I am going to mix a, very little amount of silicon oil or very little amount of grease or something, then it will be easy for me to make this particular particles type of fluid. Because whenever you do apply the magnetic field, what will happen is that you have to form a proper chain, if it is a in different in entity, then the chain formation may be a problem.

If we have some oil so that the connecting between the CIP and the abrasive particle is good; that means, that the chains formation will be very good. For that purpose, you have to use the optimum amount of oils. If the finishing time is high; so the more and more number of peaks will shear. So, you will achieve the critical surface roughness once you would achieve the critical surface roughness, then you can remove it. Abrasives used in this particular process.

So, abrasives normally one can use the abrasives can be used is silicon carbide Al 2 O 3 and so on you can use as per your requirement. So, output responses normally this particular process is a super finishing operation or a ultra-fine finishing process; where you always go for the surface roughness criteria; that means, that the first and foremost criteria that you are going to look is, what is the surface roughness or the surface finish that I am going to achieve.

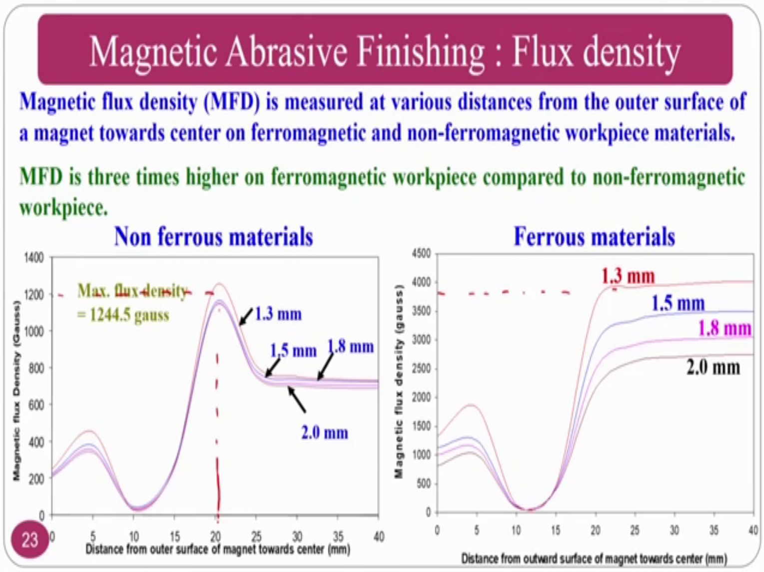
Second one is the material removal. So, we may not bother much about the how much material is removed from this particular surface, because our primary concern is surface roughness. The forces as we have the dynamometers, where the string gauges are fixed and it will give the forces and other things. If the forces are very high so the indentation will be very high. That means, that the surface roughness you may get is not up to the mark. So, if you can control the of interaction forces between abrasive particles and the workpiece surface; that means, it is always good.

So, surface morphology, many times people will think about the surface morphology and the surface roughness are similar or something. Many cases people think about the surface morphology and surface roughness are integrated. It is true that both are integral part of each other, but for the same surface roughness you may get different surface morphology, ok. So, this there are many examples for assume that I want to get 1-micron surface roughness, you may get the 1 micron by grinding process, 1 micron you by the fine boring process, 1 micron you may also get by fine turning process also, but the morphology will be different ok.

That means that the surface patterns; will be different you are lay pattern will be different. As I said a lay is nothing but the predominant surface direction or predominant surface roughness directions. This will be different so, you can also get 1 micron by honing process. So, you will get a cross hatch pattern in one case, you will get a triangular peaks in the termining process, you will get a straight lines in the grinding process ok.

That means that surface morphology also play a major role for your application. Application to application the surface morphology will be changing. You cannot use the grinding morphology or the turning morphology for the engine cylinder. There you have to use the surface morphology of honing process only ok.

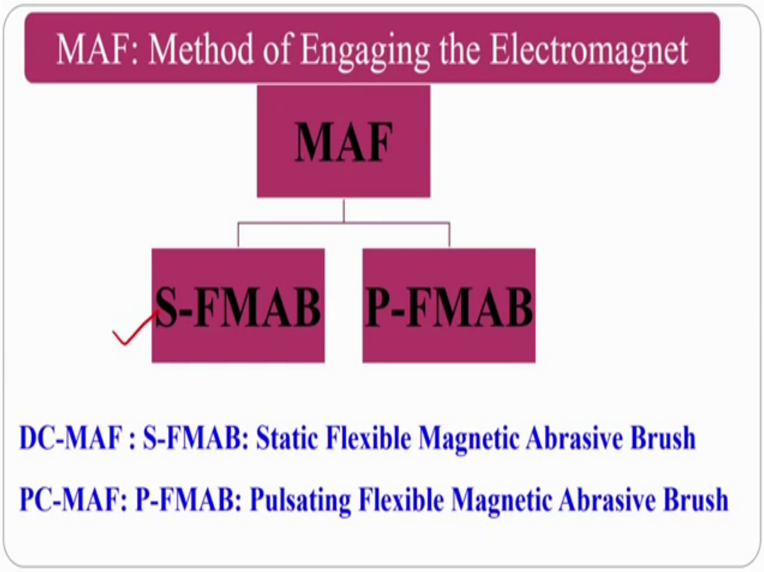
(Refer Slide Time: 43:45)



Magnetic abrasive finishing where you see the flux density magnetic, flux density is measured at various distances from the outer surface of the magnet, towards the centre of the ferromagnetic and non-ferromagnetic materials. So, magnetic flux density, 3 times higher in ferromagnetic work piece compare to non-ferromagnetic work piece.

If you see the non-ferromagnetic work piece, the maximum that is achieved is 1200, but in case of ferromagnetic material, it is approximately in between 3500 to 4000 ok. But at the same time you can see it is observed at the central portion, the distance from outer surface to towards the magnetic center ok. So, you can see the maximum the flux density is achieved in the ferromagnetic material; that means, that magnetic material. So that means that field strength is very high. You even though surface is very rough or slightly higher side also you can do the finishing operation.

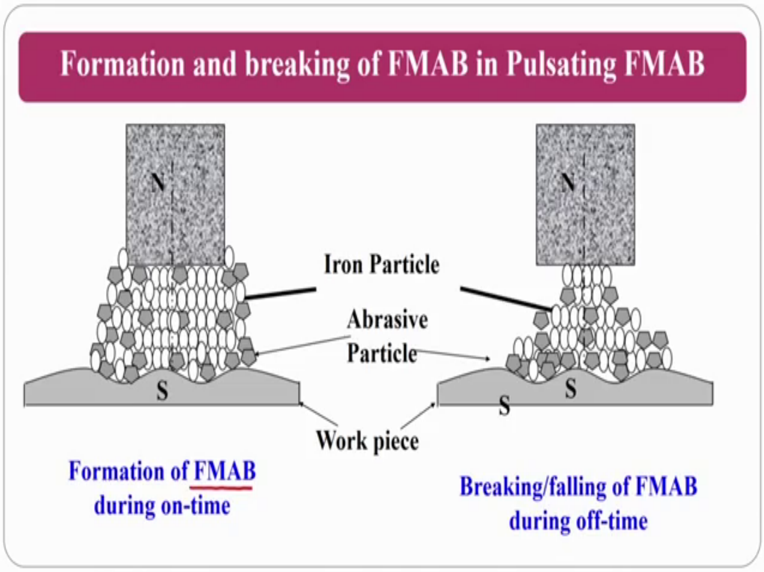
(Refer Slide Time: 44:59)



So, magnetic abrasive finishing process you have 2 varieties of flexible magnetic abrasive brush. One is static flexible magnetic abrasive brush; another one is pulsating flexible magnetic abrasive brush. In the static flexible abrasive brush what is happening is that whatever you have seen till now all will come under the category of static one ok. Because you are power supply, DC power supply is constant and you are going to get a static one.

So, you are chains are not leaving. So, that means, that whatever the pictures that you have seen in for a ferromagnetic for non-ferromagnetic your chains are formed, and your tool is rotating and the workpiece is giving the feed by the table. So, whatever you have seen is a static flexible magnetic abrasive brush and the pulsating type of flexible magnetic abrasive brush; you will see in the upcoming slides and what is the advantage of pulsating over the static we will also see ok.

(Refer Slide Time: 46:11)



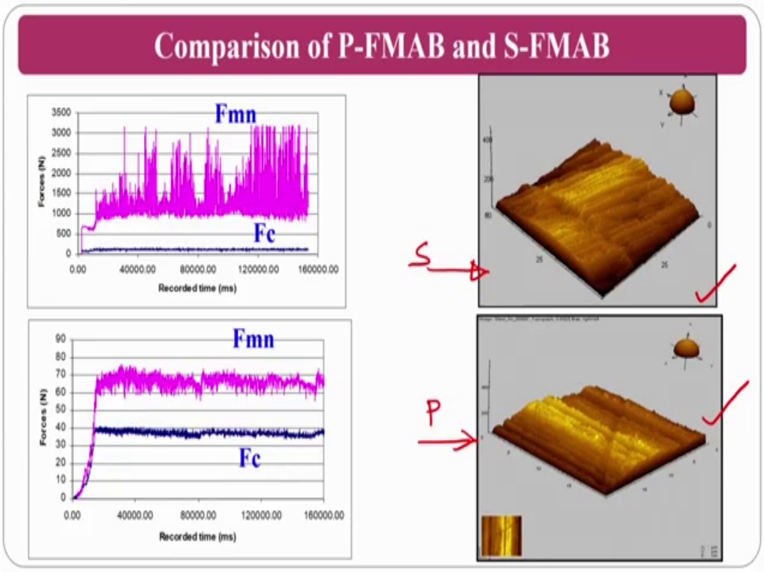
If you see here, the formation of flexible magnetic brush is constant in this one, but if you see the in terms of the static one, your chain is fix. That mean, that chain formation will be always there. So, that abrasive particles have or their embedded in the chains. But in the pulsating one what is the beauty about it one? You are giving a pulse then again you are giving a power.

In that circumstances when there is a lag between 2 pulses what will happen is, your flexible magnetic abrasive brush will collapse. So, if it collapses, you may think that it is a negative, but if it is collapses what is the beauty about it is, your abrasive particles can reshuffle; whenever it is forming a second chain. But this particular collapsing and forming the chain there will be a very very little gap.

That means, that you have a microseconds gap, as a nanoseconds gap in between what will happen there is a always chances that as soon as the chain collapses, the abrasive particles also will this orient or dismantle from the chain. Because of which what will going to happen is that you are abrasive cutting edges.

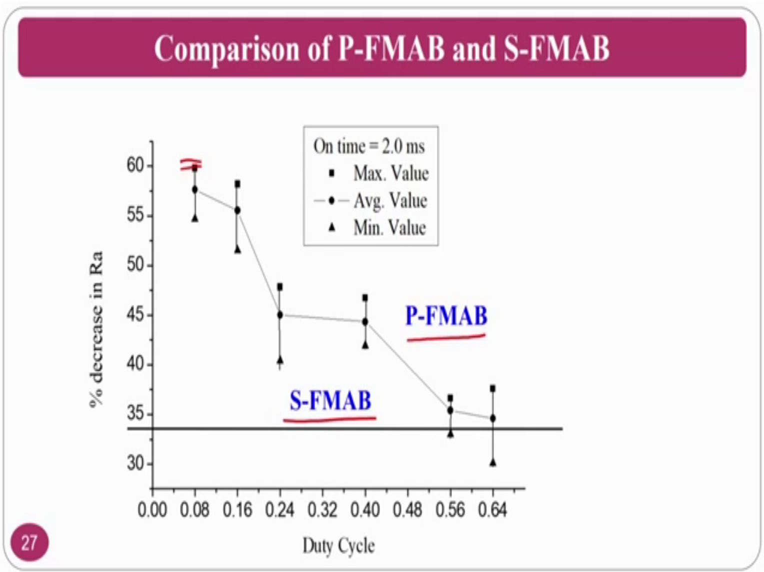
New cutting edges will may emerge for the finishing operation. That is the beauty about pulsating flexible magnetic abrasive brush.

(Refer Slide Time: 47:59)



If you see the comparison between pulsating and static, the surface roughness achieved in the static, and the pulsating are completely different, and this particular thing is achieved by the virtue of or the by application of the pulses. Whenever you are going to give the pulse current what is going to happen is, that your chain CIP chain is collapse and the abrasive particles are oriented or reoriented. According to that what will happen is new cutting edges or new abrasive particles will come into picture and the finishing will takes place.

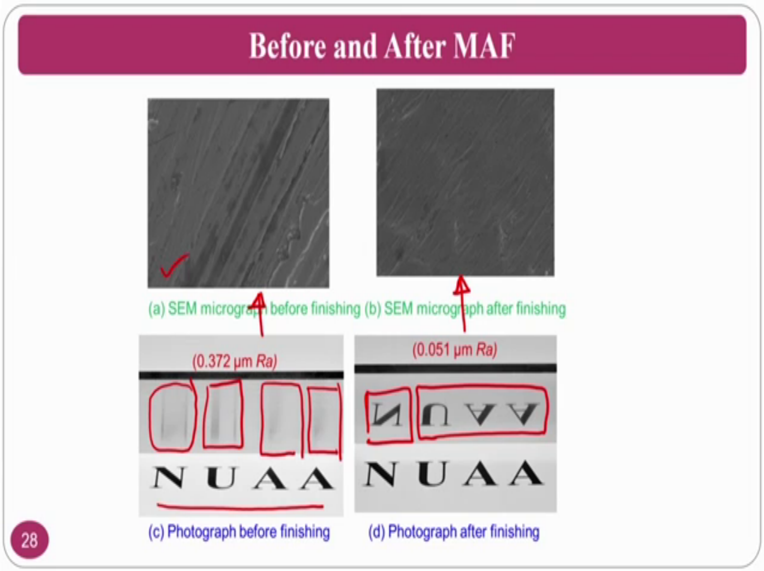
(Refer Slide Time: 48:46)



So, you can see here percentage decrease in R A for the static flexible magnetic abrasive brush is this approximately between 30 to 35 but if you see the flexible magnetic abrasive brush, the maximum it can go up to 60 percent also, ok. That is the beauty about this one that is the beauty about flexible magnetic abrasive brush, ok. So, why it is achieving: because the chain is collapsing and whenever it collapses the abrasive particles changes.

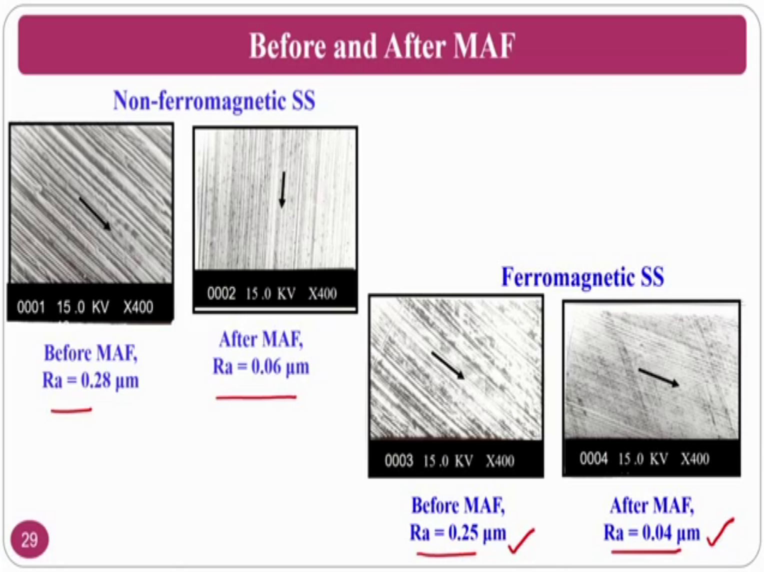
First point, abrasive particles may reorient and the chain in the second time formation maybe better chain or many possibilities are there in the pulsating type of flexible magnetic abrasive brush.

(Refer Slide Time: 49:38)



You can see the before and after the magnetic abrasive finishing process. Here it is not at all visible here. You can see NUAA, it is not at all visible, because your surface roughness is too high; however, after finishing you can see it is clearly visible all the words ok. So, that is the beauty about the surface, and you can also see this scanning electron microscopy image of these things. If this type of surface is there, what is going to happen is you cannot see the mirror image. If you are going to polish it, then you can see the mirror image after MAF process.

(Refer Slide Time: 50:23)



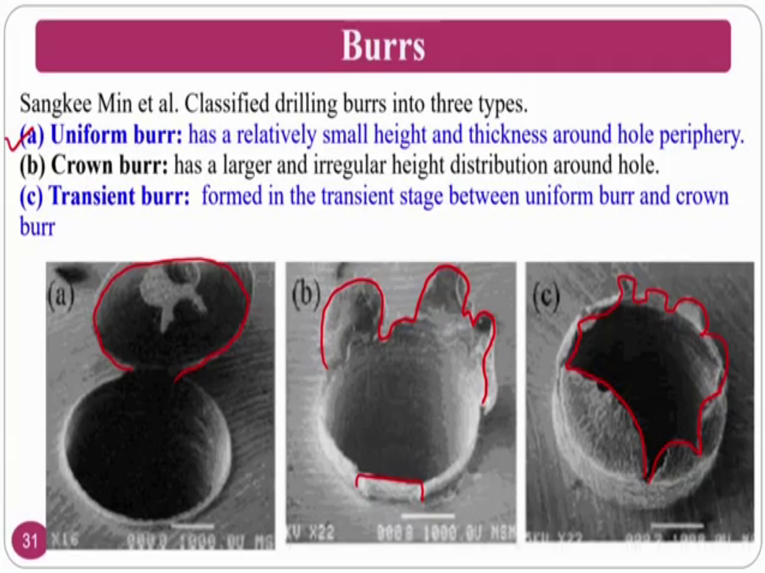
These are the reasons that are taken from Professor D K Singh, who is a student of the processor V K Jain; and you can see before and after for the ferromagnetic and non-ferromagnetic materials, and along and you can see the better surface finish that is achieved in the non-ferromagnetic is 0.6, but in case of ferromagnetic stainless steel, we can see it is 0.4 micro meters, ok.

So, you can see here for the non-ferromagnetic stainless steel and ferromagnetic stainless steel, that the before surface roughness and after surface roughness, what is you are going to achieve is, in case of non-ferromagnetic stainless steel, the initial surface roughness is 0.28 microns. After surface finish using magnetic abrasive finishing process, the surface finish is achieved is 0.6 microns in case of ferromagnetic stainless steel work piece: if you see it is 0.25 microns is the initial surface and after it is point bought force.

This is attributed to what is the strength of the chains, the strength of the chain that is formed during this process. As we have seen in the ferromagnetic the chains are embedding or it is also going inside the work piece material and forming a very strong force of magnetic force of lines, and this forms is strong chains and the abrasive particles are embedded and the finishing is proper. And not only in this condition non ferromagnetic also this will be very good.

So now we will see the application of this magnetic abrasive finishing for the deburring applications, ok. That is why some of the scientist it is called as a magnetic abrasive deburring process, but this is a similar to the magnetic abrasive finishing process, where in your application is different. In the previous in the previous case, you are major aim or the objective is to get the surface finish. In this case, your objective is to remove the burrs that are generated in conventional machining processes that are used before magnetic abrasive finishing process.

(Refer Slide Time: 52:53)



\

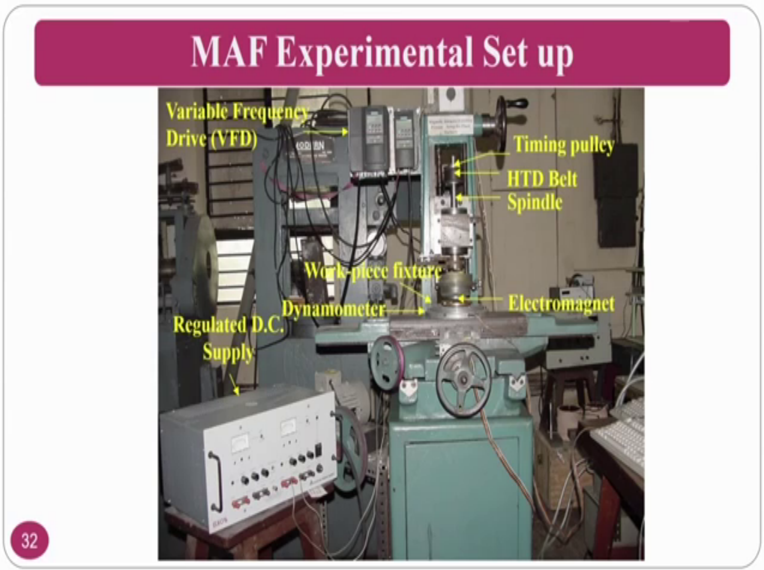
First as I explained in some of the slides burrs and other things, ok. Still some of the people may have the doubts how the burrs look like, what are the burrs and other things. So, that particular I want to clarify, for that purpose I have given you especially for the slide ok. It is normally seen in case of drilling operation. So, for that purpose we have taken from Sangkee Min et al classified the drilling burrs into 3 varieties. One is uniform burr and second one is a crown burr and the third one is a transient burr.

If you see the uniform burr, it has a relatively small height and thickness around the whole periphery you can see here. And the second one is a crown burr; it has a larger and irregular height distribution around the whole ok. You can see here and it has a irregular surfaces. So, at the same time you can have a small type also. The transient burr formed in the transient stage between uniform and the crown burr ok.

Crown burr is what we have seen here and in the transient burr, it is neither the transient, it is neither a crown nor a uniform burr so, it is like this. These are the burrs that you generally see in a drilling process on the back side of the workpiece. If you are going to drill a through hole and you may not remove the chip which is comes at the end properly. And this will hamper the operators, or this will hamper if you are not going to remove it this will hamper the customers who are handling this particular components.

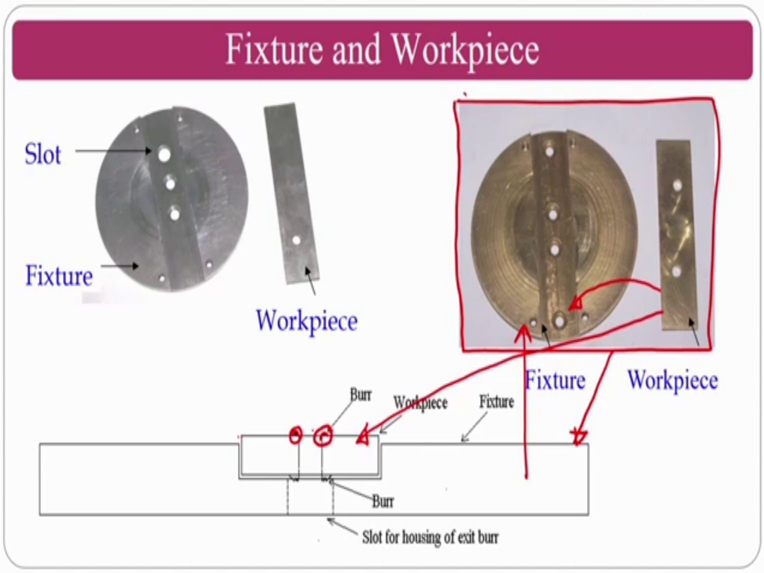
If you have this uniform burr crown burr and transient burrs, and if you are using this one with your hands what will happen? These materials which are made up of stainless steel or some other things, what will happen? This may cut the hand of the operator or hand of the customers, this also hurt various parts of the operators if it falls and other things. That is why you require, that is why you have to remove this burrs ok. That removing of the burrs from the sample are from the workpiece is nothing but the deburring operation ok; dehydration for some people if at all you want to remember in a good way. So, you can say like dehydration. So, water is removed or it is going out or something: so similarly deburring so that mean that burrs are removed.

(Refer Slide Time: 55:58)



For the same as I said we are going to use the same experimental setup that we have seen in the magnetic abrasive finishing process. And the slight change that we are going to do is that we are changing the fixture.

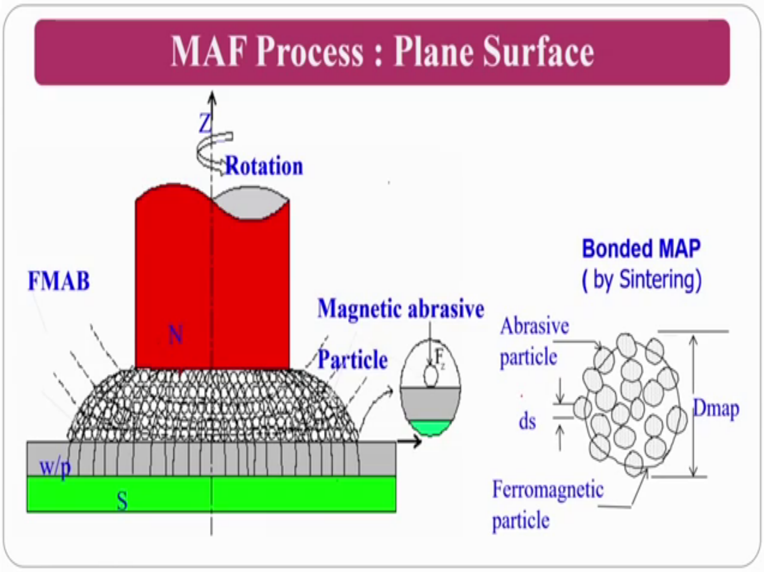
(Refer Slide Time: 56:05)



Instead of going for a big workpiece, we are making a slot in between, in case of magnetic abrasive finishing; we can finish this particular complete one ok. But if at all I want to remove the burrs on the flat surfaces, what I am going to do is that we are going to place the holes drilled surface. This is my work piece or this is my work piece, wherein I am going to drill a hole or setup holes I am going to drill, and this hoes will have the burrs ok.

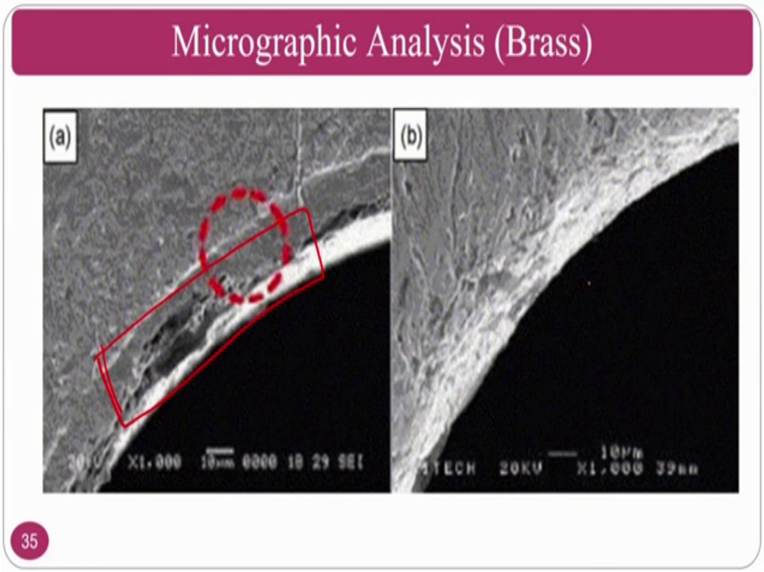
Assume that we are going to consider one work piece material, that is called brass workpiece, what you have to place this particular sample here, and tightening using proper screws. Then you are going to feed to the magnetic abrasive finishing process. So, that means, that you are going to have your work piece here, if you see this particular assembly that you have the fixture here, and you have the workpiece here ok. So, the burrs are there and these burrs are to be removed.

(Refer Slide Time: 57:38)



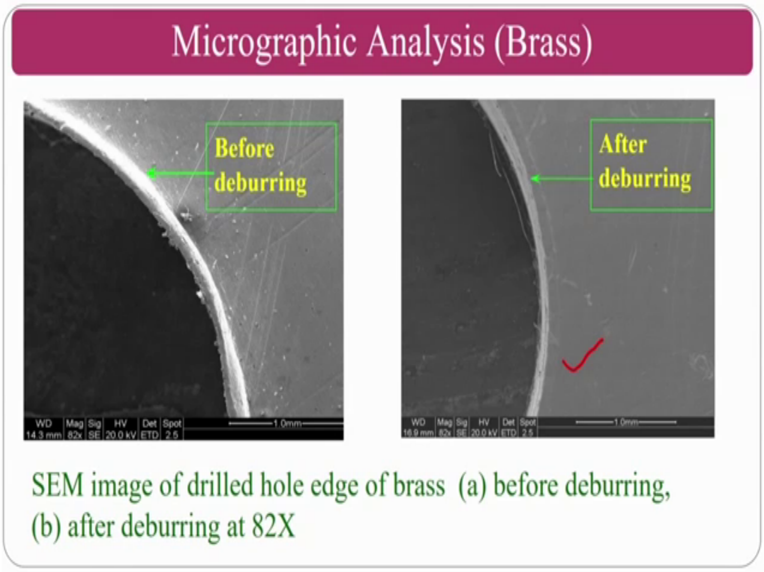
So we will use the similar setup. That is, MAF process for the plane surfaces only we will use, because we want a plane surface for that only requirement is that you have to remove the burrs so that you will get a flat surface.

(Refer Slide Time: 57:56)



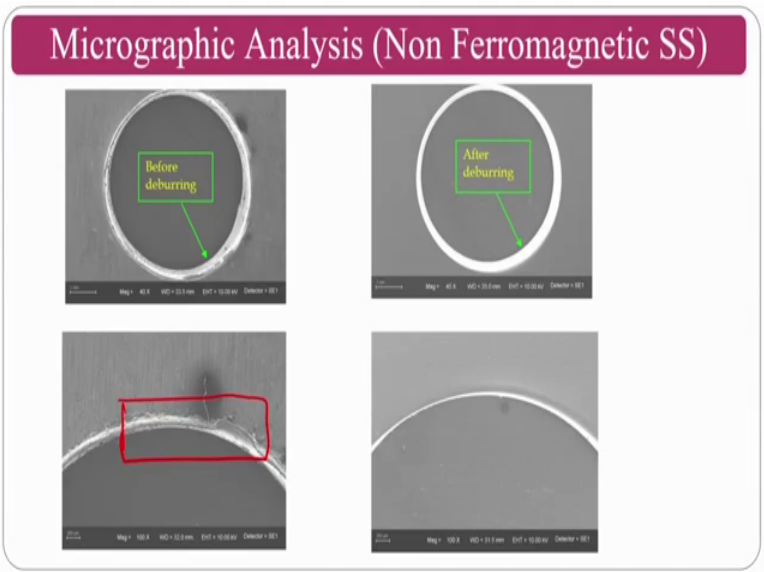
And you are going to give the rotational speed, as well as feed rotational speed to the magnetic tool and the workpiece will be given feed so that you can remove the burrs. So, you can see the burrs, these are the burrs which are removed in the case of second case.

(Refer Slide Time: 58:20)



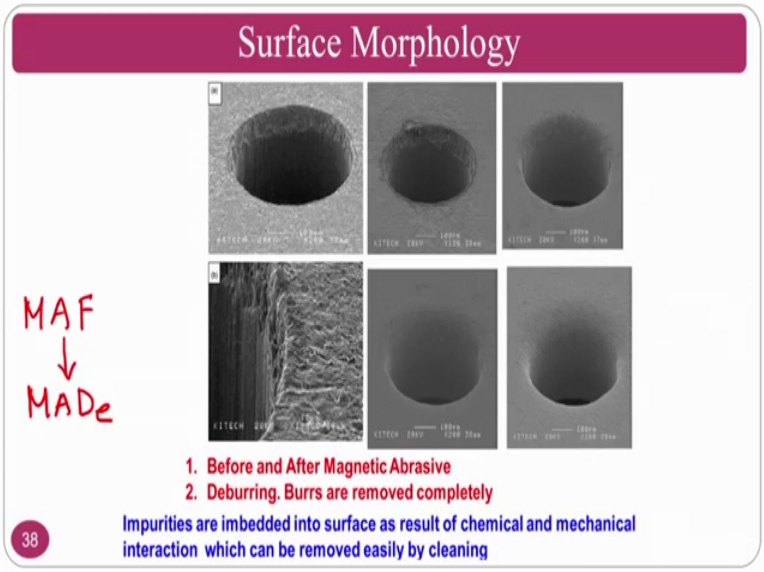
You can see some of the burs that are not removed from the drilling hole. These are the burrs before deburring operation. And after deburring operation you can see the there is no burrs on the flat surface ok.

(Refer Slide Time: 58:43)



You can see the complete hole after drilling process, and you can have the burrs on the surface. The drilling can be done by idiom process also, and idiom also can create a recast layer and the corresponding burrs also ok. It is not only the burr formation is not only specified for the conventional, it is also for the advanced machining processes also.

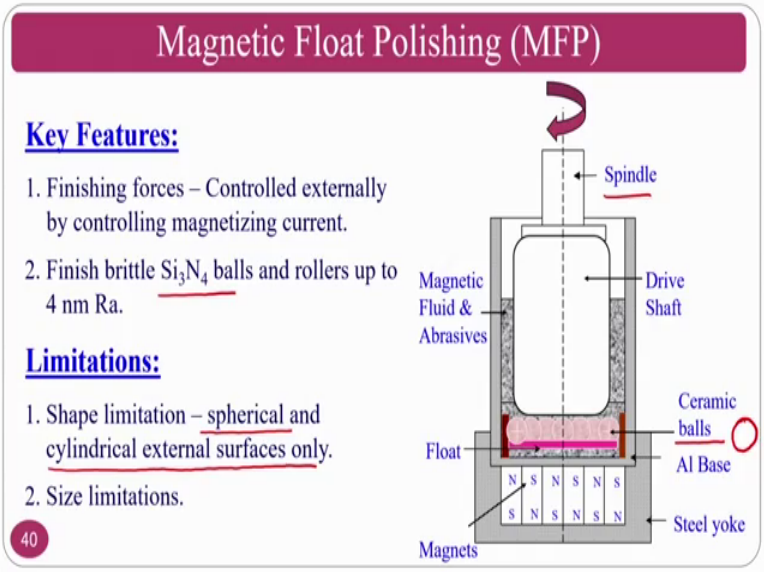
(Refer Slide Time: 59:13)



And you can see clearly the surface, the burrs formation and later it can be removed by the magnetic abrasive finishing process and particularly, it is for the deburring application. What I mean to say is magnetic abrasive finishing is used in this case for the magnetic abrasive deburring operation that is why this particular process is called magnetic abrasive deburring ok. Another process that we are going to see in a introductory way is magnetic float polishing ok.

Many of the people may not be acquainted with this particular process, because this particular process is not much done research. So, some people who want to do into these particular processes the research, they can take up and they can do a very good job.

(Refer Slide Time: 60:10)



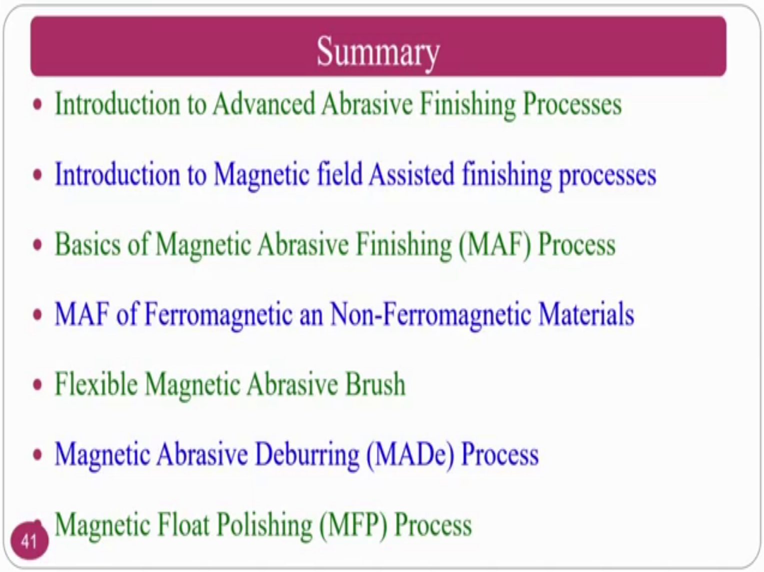
So, magnetic float polishing process, if you see the magnetic float polishing process, the magnetic poles arranged into North-South South-North like this. At the same time, you have the workpiece materials is a ceramic balls, and you have the magnetic fluid. You are going to have the spindle and these are the ceramic balls these are the spherical balls.

The spindle is given the pressure, and rotaration motion, and because of the North and South what will happen? The chains will form and these chains will press against the work pieces; that is a ceramic balls, and you have limitational forces and other magnetic forces so that the finishing will takes place. Key features of this particular process is finishing process which are controlled externally by the controlling the magnetizing current. That means, that your chains are controlled by the magnetic field, at the same time S I 3 N 4 balls are roller.

These are the ceramic balls which are non magnetic work piece materials, and this can be finished using this particular process. What I mean to say is that, if at all you want to finish a spherical surfaces, you have to opt are the best process to finish into a nano surface level like 4 nanometer average surface roughness value, then you have to choose magnetic float polishing process. But it has it is own limitations that is a shape limitation. Basically, it can do for spherical and cylindrical as external surfaces only, and it has a size limitation. You cannot go for very, very big work pieces and other things.

But this particular process is least explored, and people who want to do their PhD or masters and other things they can work on this process. And if you can develop this process, and if you can do that will be a good research work.

(Refer Slide Time: 62:20)



So, the summary of this particular class, we have seen introduction to advanced abrasive finishing processes. Then we move on to the introduction to magnetic field assisted finishing process, what are the finishing process that comes under this particular, in the category of magnetic field assisted finishing processes.

And basics of magnetic abrasive finishing process, then how the magnetic abrasive finishing process is applied for ferromagnetic workpieces as well as non ferromagnetic work pieces. In ferromagnetic workpieces how the magnetic field of lines or the magnetic force lines will be formed, and a in case of non-ferromagnetic material, how the magnetic field of lines are formed. These are we have seen and what is the finishing capabilities we have seen. And the how the flexible magnetic abrasive brush is formed in case of the non ferromagnetic workpiece material. How the flexible magnetic abrasive brush is formed in case of ferromagnetic work piece material we have seen. And the magnetic abrasive deburring just it is a variant of magnetic abrasive finishing process; where in just you are going to add a another dimension to remove the burrs.

That are generated during the conventional as well as unconventional drilling processes. So, some of the people they are also using this magnetic abrasive finishing using that chemo mechanical also. That is called chemo mechanical magnetic abrasive finishing process. In chemo mechanical process what is going to takes place is you are going to add some chemical that are going to make a passivation layer on the workpiece surface, so that the surface will become smooth, and then you can remove that smooth layer.

So, people are working on this one. So, some of the people who are interested for doing research and other things, they can go and they can take up this challenge like a chemo mechanical magnetic abrasive finishing; which is slightly advanced version of magnetic abrasive finishing process ok. That is another variant of magnetic abrasive finishing process apart from magnetic abrasive deburring. If you can also do the chemomechanical magnetic abrasive deburring that will also will be fine.

And at last we have seen the glimpse of magnetic float polishing, as I said magnetic float polishing is not much explored. So, people can follow Professor Ranga Komanduris papers; who extensively used magnetic float polishing. And the if at all the people want to study about magnetic abrasive finishing process, magnetic would deburring process you can follow many papers of Professor Vijay Kumar Jain of IIT, Kanpur ok.

Thank you for your kind attention.