Polymer Assisted Abrasive Finishing Processes
(Surface Morphology and Surface Metallurgy)
Dr. Mamilla Ravi Sankar
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture - 03
Surface Integrity and Surface roughness representation-Part-II

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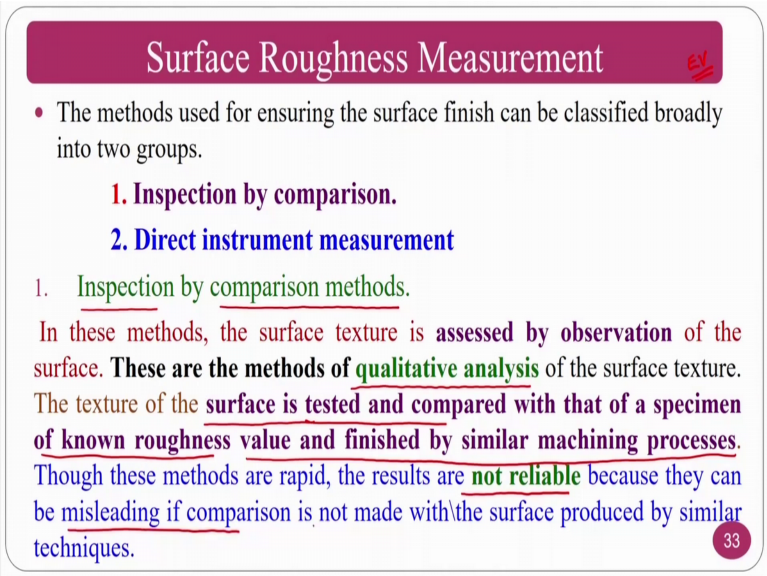

Now, we move onto the Surface Roughness Measurement. Normally, the surface roughness measurement methods used into the normally the finishing processes or the machining processes. One is by inspection and comparison or inspection by comparison; another one is direct instrument method.

Inspection by comparison method if you see here, what is normally will be done. These methods are assessed by the observation. Basically, just you see that product and you just tell whether it is finished or not finished, it is exclusively a comparison method, qualitatively comparison whether this is good or the another object is good like that ok. These are the methods of qualitative analysis. I said know these are the qualitative analysis that means, that only you can say that Ram is a good boy, you cannot say Ram is a 90 percent good or 80 percent good or 40 percent good ok.

So, for that purpose what I mean to say is that you can say whether the product is good or not good. You cannot say this is 80 percent good or 70 percent good or 50 percent good or something that means, that you can say that this is a qualitative hope. The undergraduate students might have understood that the difference between qualitative and quantitative is if you want to say this is 50 percent or 40 percent that is called quantitative; you are specifying the quantity ok. If you are saying whether good or bad, or quality is good, quality is not good that is called qualitative ok.

For now this inspection by comparison method is goes by qualitative method. The surface structure or the surface is treated by comparing with that of the specimen know of the known roughness value and finished by the similar machining method. Actually, if at all I want to check particular component, assume that I want to check a particular component by abrasive flow finishing process or any other polymer assisted abrasive finishing process. I will have a master sample by known input conditions and other things I have finished one.

Let me explain you in this way. So, I have a grinded sample or the ground sample, which is done by the grinding operation master sample, is there. And the customer gave me this sample is you have to achieve approximately this. Now, I have a master sample, and the company has produced some thousand samples, I just compare. I will take both into the hands and I will see ok, this is master and this is what we have done ok. If it is then, I am selecting. If it is not ok, I am not selecting like that that what is the finished by the similar machining operation or a finishing operation. Then you just say whether it is or not ok.

This though these methods are rapid, and results are not reliable, because you may get sometimes biased or you may get this is ok like that also, you can just keep it, so, that is why this is not reliable, because they are misleading if the comparison is not made with the surface produced by similar techniques, why I am saying is that assume that my master sample is procured from some agencies. And you are having a sample that is produced by grinding.

If you do not know, what is this master sample has prepared from which process. Assume that this is prepared from a lapping process, and whatever you have got that lot of the sample that is produced by the company is a grinding process. If surface finish is not matching or if it is matching it is if it is not matching, then see the surface lay directions will be different. Your application may be somewhat lapping oriented applications, but the surface roughness that you are going to get are the predominant surface roughness directions on the grinding sample will be a straight line type of, but in lapping it is not. It will be random and mostly, it is circular or something. So, sometimes the small small errors may mislead.

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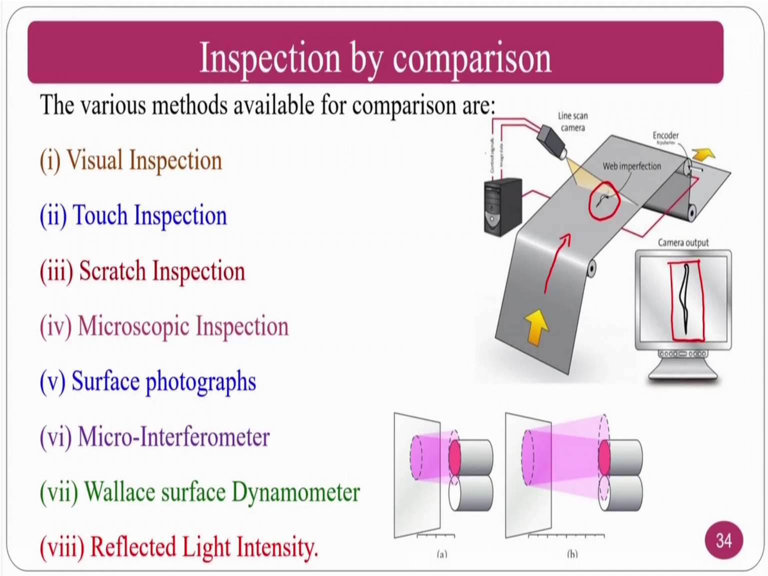

The inspection by comparison, these various methods are available. One is visual inspection method, then touch inspection method, and the scratch inspection method, and microscopic inspection method, surface photographs, and micro- interferometer and other thing, Wallace surface dynamometer and other things ok, reflected light intensity. These are the some of the methods ok.

One you can see here, how you can see using the lines scan camera and other things, what people can do is the parts are moving on this belt. And whenever the part will come into the picture to lapping, it will take the image, and it will give the inspection. And it will in inspect the surface whether the surface is or not and other things, and it will be decided. And the same thing camera output will be there, and you can see here what will be the image of that based on this the person who is sitting in the computer or automatically robot system or something. They will select whether the part is acceptable or not acceptable.

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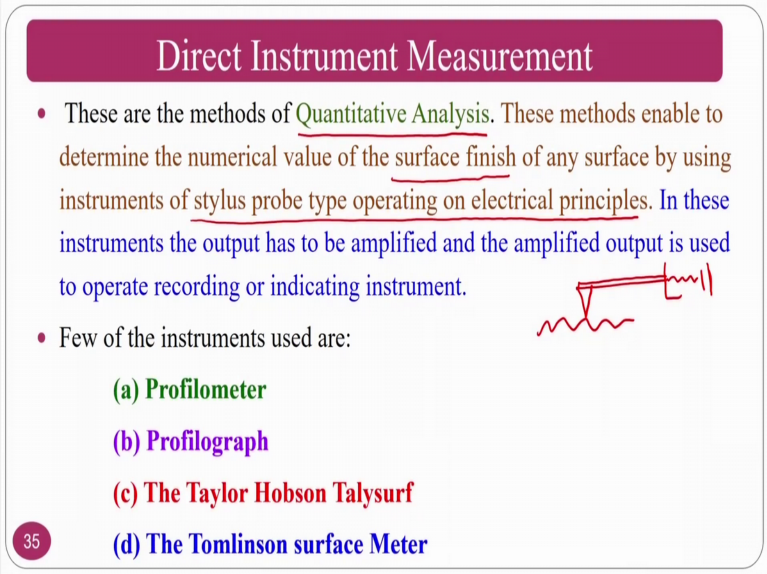

And another methods also are there. So, these are the so many methods, which one can follow. And another one is direct instrument method. Direct instrument method follows quantitative analysis. You have a instrument, and it will give you a definite value whether the roughness is 1 micron, whether the roughness is 0.5 micron or something that is the qualitatively it will convey.

This methods enable to determine the numerical value of the surface finish or the surface roughness of any surface by using instrument of stylus probe type of operating based on the electrical principles ok. There is a contact method, where you will have a probe. Assume that this is my surface, I will have a probe. This probe is connected to some electrical sources, so lot of things are there which is less importance for the mechanical engineer just a stylus will be there, it will be moving on the surface and you will get the value. Similar things, you have also understood in the previous slides also. Few instruments, one is profilometer, profilograph, and Taylor Habson Talysurf, and surface meter and other things are the common methods.

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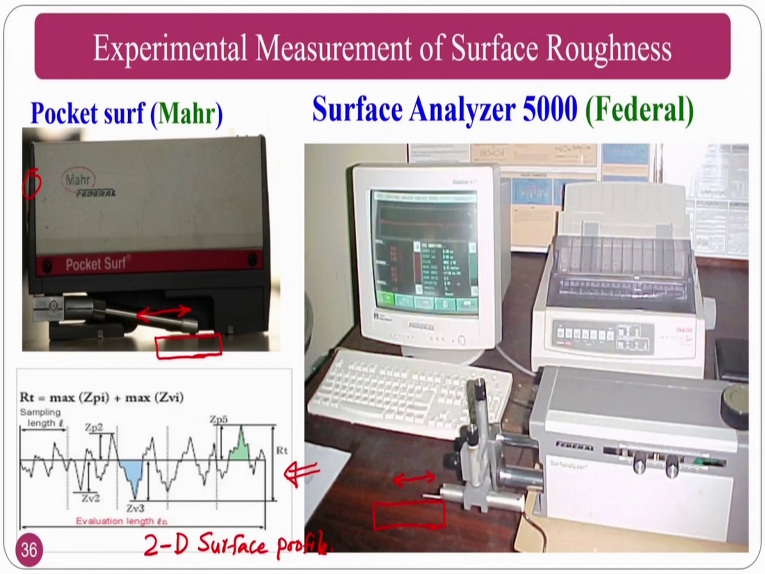

The pocket surf is there one method, and another is surface analyser. These are the two common methods, which normally we do at our laboratory. One is the pocket surf, the pocket surf normally what you can do is this is the probe which you can see here. And beneath that one what you have to do is you have to put your sample just you put your sample, and you just press a knob. Knob will be there on this side, you just press a knob, automatically what it will do. The probe will reciprocate like this and will give you a digital display ok, so that you will get the value.

Normally, this pocket surf is here rough method of estimating ok. To suppose I want to know what is the approximate value and other things, then you can go for it one or if at all I want to measure the surface roughness value of a cylindrical rod, which is mounted on the headstock of a late machine, you can go for pocket surf. And this will give you a rough idea about what will be the approximate surface roughness.

If at all I want to know more, then I will go for slightly upper side that is surface analyser 5000, where I will keep my sample here, this is my probe I will keep my sample here, and similarly I will operate. So, the probe will reciprocate, and will give you a roughness value. In this surface analyser 5000, it will give normally this type of profile. And this from the profile, you can give the value also and you can get the profile also that means, that it is a 2-D profile two surface profile you will get ok. So, now from this one how you are not only getting the value, but also you are getting what is the surface roughness along that particular line that is called 2-D surface profile.

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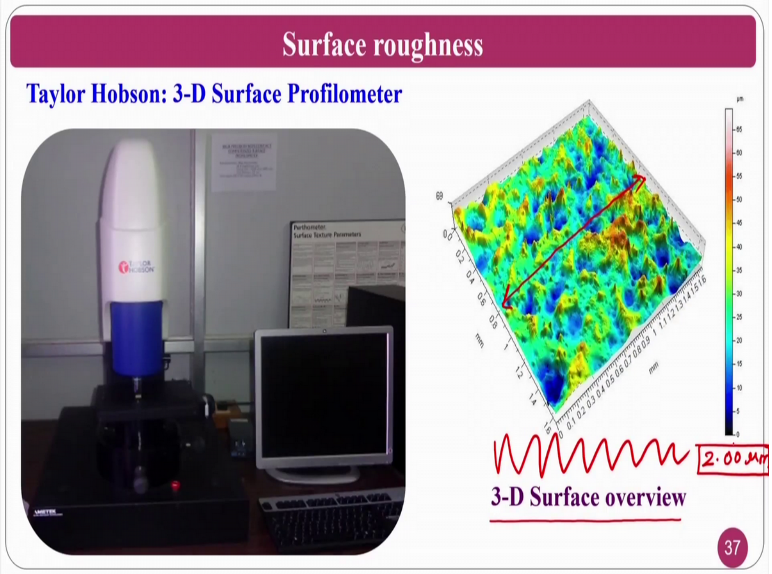

Now, what is the other way or more advanced way is non-contact interferometer surface interferometer and other things. This will give you a complete area wherever it can focus ok, from this you will get a 3-D surface view. What you have seen in the previous one, pocket surf is going to give you only the digital value. And the second one the surface profilometer, federal surface profilometer will give you a line scan.

Now, you have a Taylor Habson 3-D surface profilometer, which works are interferometer and other things which will give you a 3-D profiles. So, this is the advancement that is going from a digital value to a line, from a line to a plane. So, if at all I want the line, here I can get. If at all I want a digital value, if at all I want to measure a line surface roughness, just I plot line here. And this line will give me a surface profile like this ok. At the same time assume that this is 2 microns, it will also give you a digital value of 2 micrometres both it will give. So, this is slightly advanced compared to those two techniques.

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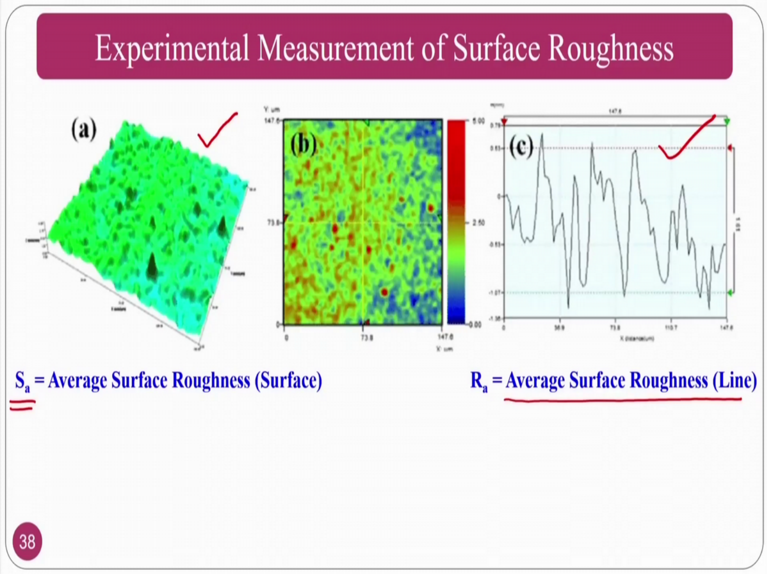

And now you can measure by the things also. So, once you got the 3-D surface profilometer, you can also get the average surface roughness value of that particular area also. In a 2-D surface profile, you can get only about that particular line ok. In the 3-D profilometer, you can get also the area surface roughness value that will be much more accurate.

Whenever you are going to showcase or whenever you want to sell your product, normally people may ask you overall area surface roughness. So, for that you have a sample, then you have to do at minimum at 5 to 10 places and you have to give the area surface profile, like the 3-D profile. This is average surface roughness of a surface that is scanned.

And you can also give the surface roughness value along the line particular line, so that you can understand which area the surface roughness is more, which area surface roughness is less, but on an average what is the average surface roughness of that particular surface ok. This is about the digital value is a single value, where you do not know the surface roughness profile.

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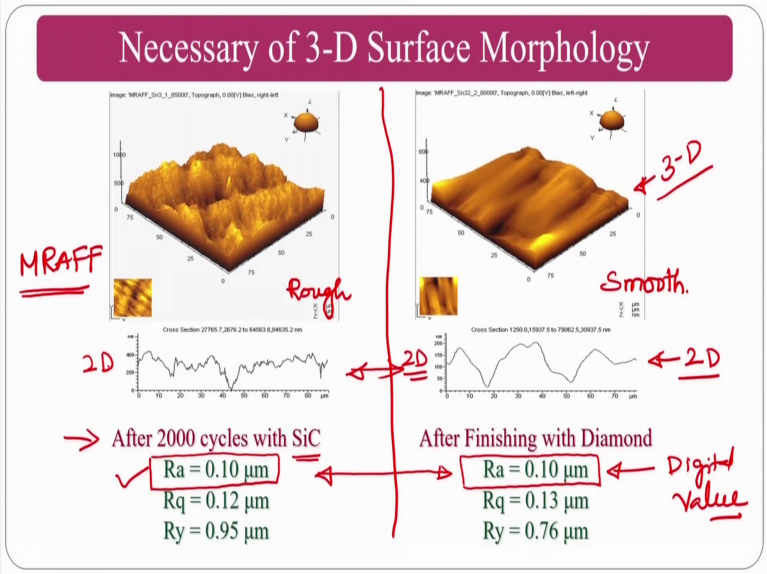

Next you will have a surface profile of two dimensions like this. And the furthermore, you will get a 3D surface profilometer, and this is what the surface roughness. Now, we will see what is the importance of taking a surface profile in a 3-D spectrum that means, that 3-D profile is required to for us that is what we will see here.

Assume that I have two surfaces of surface roughness x, then you can you use both the surfaces into the practical application may be may not be. For that purpose I will show you one example, which is finished by MRAFF process that process you will get in the upcoming classes where magneto rheological finishing, and abrasive flow finishing principles are clubbed ok. So, whenever you are going to study about magneto abrasive flow finishing process, you will get about magneto rheological abrasive flow finishing techniques. These are the two surfaces finished by magneto rheological abrasive flow finishing that means, MRAFF these are the finished by two techniques Magneto Rheological Abrasive Flow Finishing Process.

Now, we will see two surfaces, what is the difference. Here you see this is finished, we do not bother about how it is finished and other thing that we will see in the when other process is here. We bother about the surface. Normally, we bother about average surface roughness value of this particular surface. This is the atomic force microscopy image, where MRFF process has done for 2000 cycle with silicon carbide as its abrasive particle. And you are going to get a surface, but what you have to note here is the surface roughness value is 0.1 micron.

If you see same MRFA process, here also you are going to get approximately same value of 0.1 micrometre, here it is finished with diamond particles ok. You do not bother about the process and whether diamond or whether silicon carbide. What you have to bother is you can see the same value of surface roughness, but two surface morphologies or two surface profiles or two surface topographies. This topography is slightly rough surface compared to this one, but the value of both the surfaces is oh same.

Now, you can understand if you are not going to get the 3-D profiles or 3-D surfaces, then you would have thought assume that you would have taken only digital value, if you would have taken only a two-dimensional value like a two-dimension, this is 2-D profile 2-D profile you may mislead. If you take a 2-D profile; this profile is bit rough compared to this profile, this 2-D profiles you may mislead.

And assume that you are going to choose the rougher one, life of this component will be much less or slightly less compared to other component, which is smooth compared to the surface that is why, the people who are doing the research and other things, they should go for 3-D surface profiles, if you have the facilities available at your institute ok, so that you will get a good knowledge about the complete overview of the surface. This is a beauty about taking a 3-D surface profile, and analysing its 2-D surface and getting the digital value also ok. So, 3-D profile will give you 3-D image, it will give you 2-D image. And it is also give a digital value that is why, if we have a 3-D surface profilometer or atomic force microscopy, then you can get all other things also.

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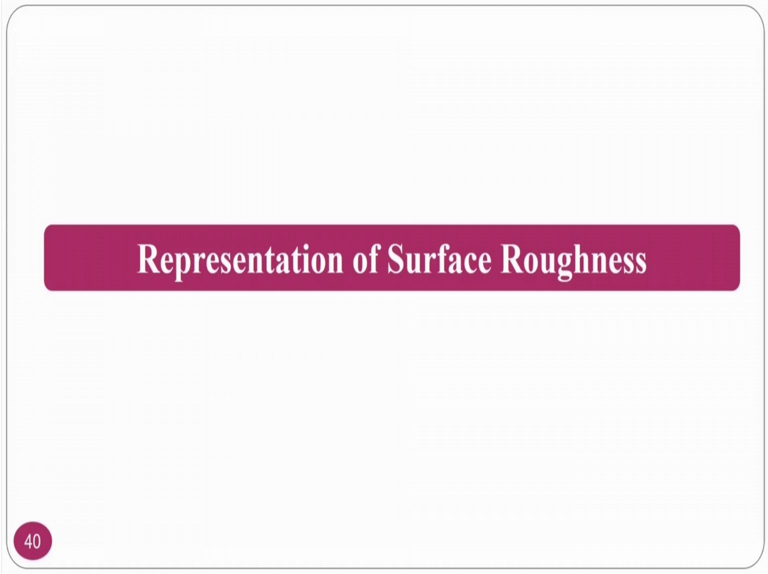

Now, we will see about surface roughness representation, how the surface roughness is represented.

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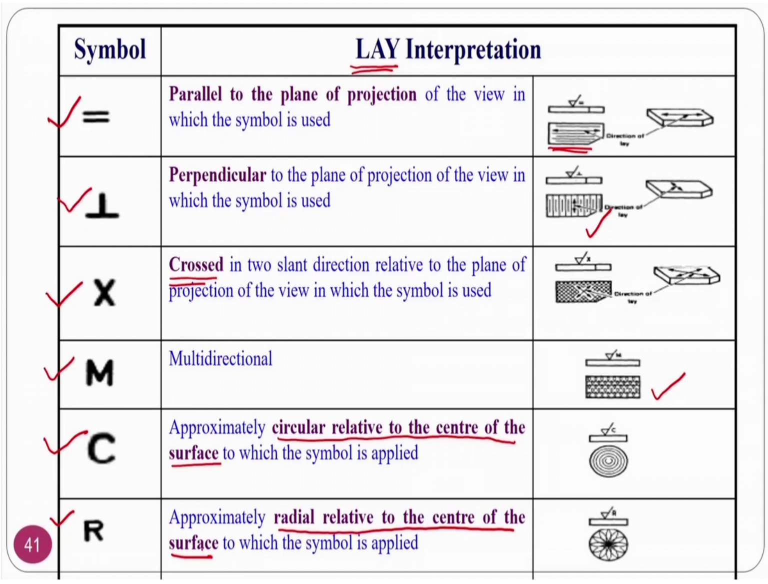

Symbol	LAY Interpretation	
=	Parallel to the plane of projection of the view in which the symbol is used	
⊥	Perpendicular to the plane of projection of the view in which the symbol is used	
X	Crossed in two slant direction relative to the plane of projection of the view in which the symbol is used	
M	Multidirectional	
C	Approximately circular relative to the centre of the surface to which the symbol is applied	
R	Approximately radial relative to the centre of the surface to which the symbol is applied	

As I said a lay, lay is nothing but predominant direction of the surface roughness. First is parallel to the plane projection. Normally, if you are getting the surface like this, it will be represented by like this. If it is perpendicular, it will be represented like this. If you are measuring a particular surface, and its representation you can see here. Crossed one you can see like a knurling operation and other processes, normally represent by x.

And multidirectional, if it is multidirectional by any other advanced finishing processes where the abrasives have free to move in that direction, you will get this type of thing. And the circular relative to the centre of the surface, the surfaces you can get like this. Normally, you will do one spacing operation and other operations, you will get this type of circular pattern or circular lay or represents the radial relative to the centre of the surface. These are the surface representations.

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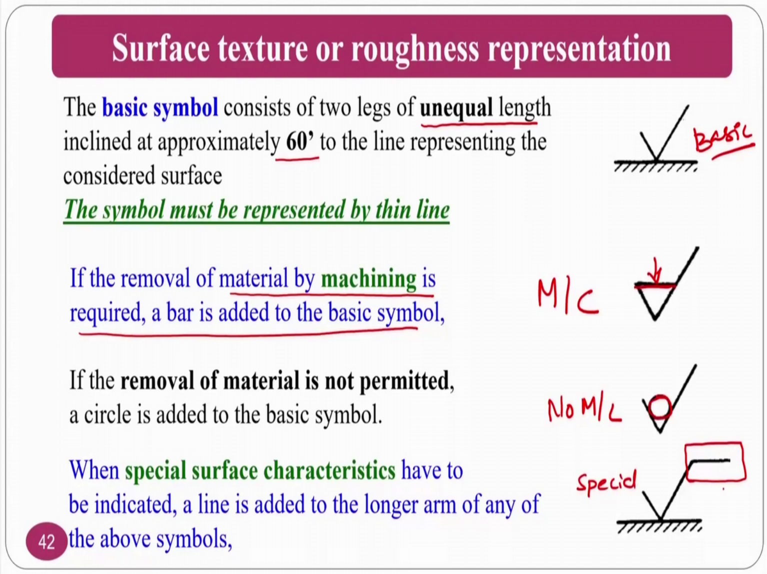

And the basics symbols, now how to represent? We know what are the lay patterns, whether it is parallel, perpendicular, circular, cross hatch pattern or multidirectional or radial directional, these are the surface patterns. Now, how I have to represent in the form of symbols. So, the basic symbol consist of two legs are unequal length, which is at 60 degrees, and the symbol must be represented by a thin line. If the material removal is by machining, then is required bar is added on a symbol that means, that this is the basic symbol. If at all I want to go for machining, then you have to add a line.

If the material removal is not permitted, then you have to represent by a circle here. And if the special surface characteristics has to be indicated, the line is longer arm any above symbol that means, that it if the any surface characteristics special surface characteristics has to be mentioned, then you will get a additional one ok, hope you got it. If it this is the basic one, if it is machining, if it is no machining or any special characteristics if you want, then you should have this type ok.

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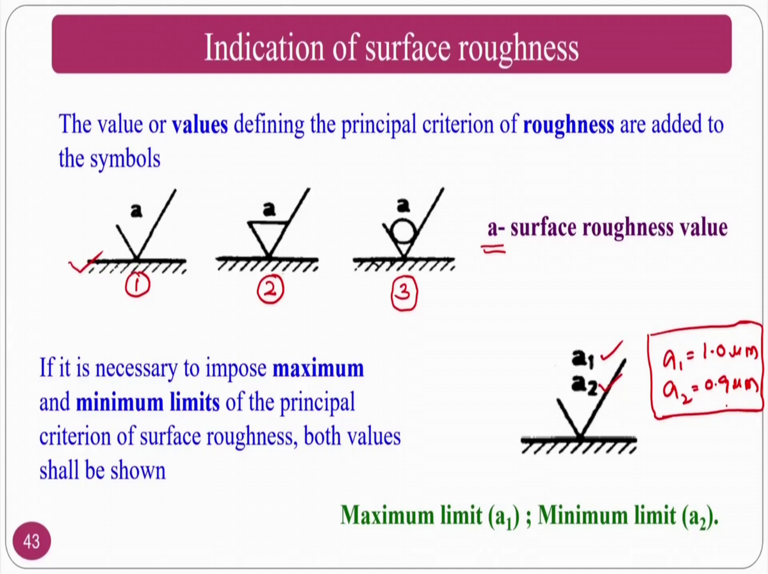

The values how you are going to represent? a is representing the surface roughness value, basic symbol with a that mean that this is the surface roughness that I want you use whatever the process that you want ok, this is one. In the second one, I want the surface roughness where you have to achieve the surface roughness by machining operation. In the third one, you have get the surface roughness not by machining process, you use any other process ok.

If necessary to impose maximum and minimum values of the surface roughness, both values also can be expressed. Like this one can be, maximum one can be minimum that means that a 1 is maximum limit, and a 2 is a minimum limit. For example, if I want to get 1 micron, so a 1 will be maximum 1.0 micrometres, and a 2 is 0.9 micrometre like that I can represent in the surface profile. And I can say that within this limit, you can get.

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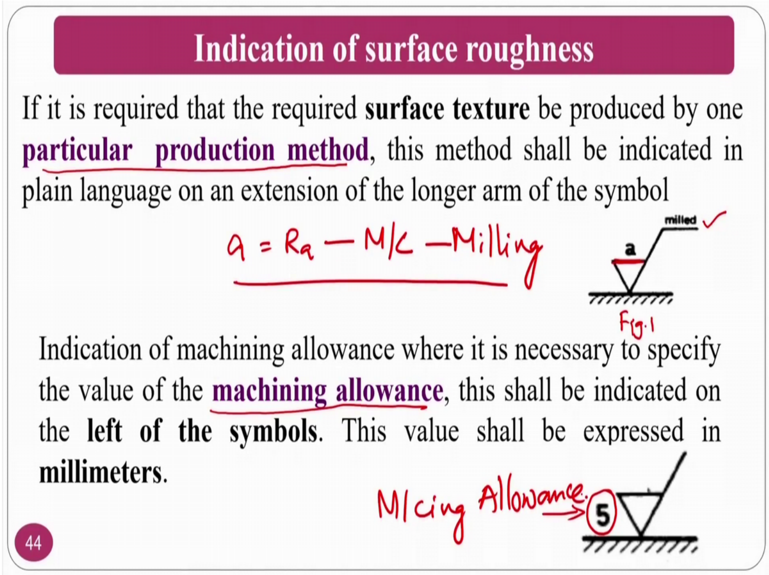

Indication of surface roughness, if you see that it is surface texture can be produced by anyone particular production method, this method shall be indicated also that means that if at all my this line, assume that I am talking about figure-1, this line represents machining process. It is if this portion is not mentioned that means, that you can use any method. If the special requirement is given by the customer, then you have to the do the machining and it is done by the milling process only or you have to perform the surface roughness a is a surface roughness have to be achieved by machining, and that to milling that is what the meaning of this.

Then if you see the machining allowances, where necessary to specify value of machining allowance, this shall be indicated on the left of the symbol this is called machining allowance ok. What are the allowances that you have to give that can be represented at the left side of the symbol.

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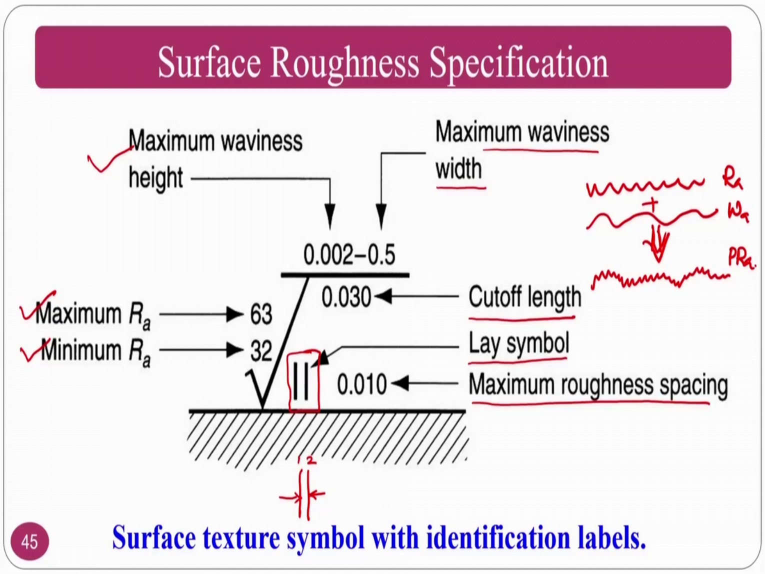

And overall what we can see here is complete representation. You can see here a 1, a 2 you al ready know that is the maximum value of the roughness, minimum value of the roughness value. And the lay pattern what type of lay, I want whether in this case I want a parallel surface that you can achieve by any process, because there is no line here. So, if would have been there, then you have to do by over the machining. If it is not there, you can do any whether you can do the machining process, whether you can do another process also. So, but the pattern they have mentioned is parallel that is mean that you have to mostly you have to do like grinding process, and the maximum roughness spacing also they have mentioned ok.

This is roughness is there, and the spacing between 1 and 2 also mentioned. At the same time waviness height, you can give your maximum waviness width also you can mention special requirements. And you can also mentioned the cut off length that mean that you have seen the cut off length. Cut off length normally have to be less than your waviness ok. If it is normally less than, then what will happen? The waviness cannot be into the roughness.

If it is embedded, then what you are going to get is a profile roughness. As you already know this is my surface roughness, and this is my waviness. If you club both, what you are going to get is the profiles roughness. This is Ra, this is Wa, and this is profile average roughness PRa ok. This is how you can represent the complete things basically, if at all you want still more complex, you can go ahead.

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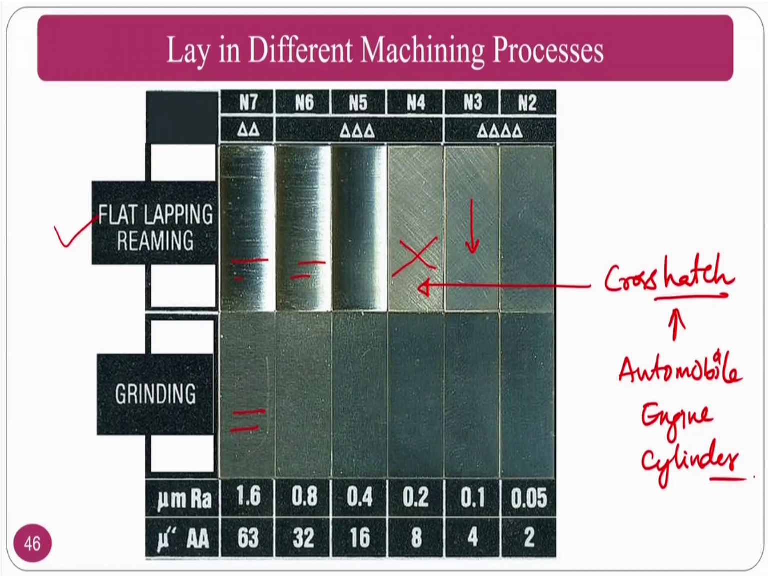

And you can see here, what is the flat lapping and reaming surfaces, normally you can see the lay pattern like this. Crosshatch patterns also will be there, and the grinding surfaces also will be there, you can get many types of surfaces. And these are nothing but the lay; you know the value that is called only roughness value. If you measure in the surface like a line, you will get a digital value.

But, sometimes people will specify the lay, like crosshatch pattern. This is crosshatch pattern; normally this is required for your automobile engine cylinders ok. Why you require it, because your lubrication and other things will be taken care, and this lubricant will stay in this crosshatch patterns. And we will have the smooth piston movement and for that purpose normally people do the honing process ok.

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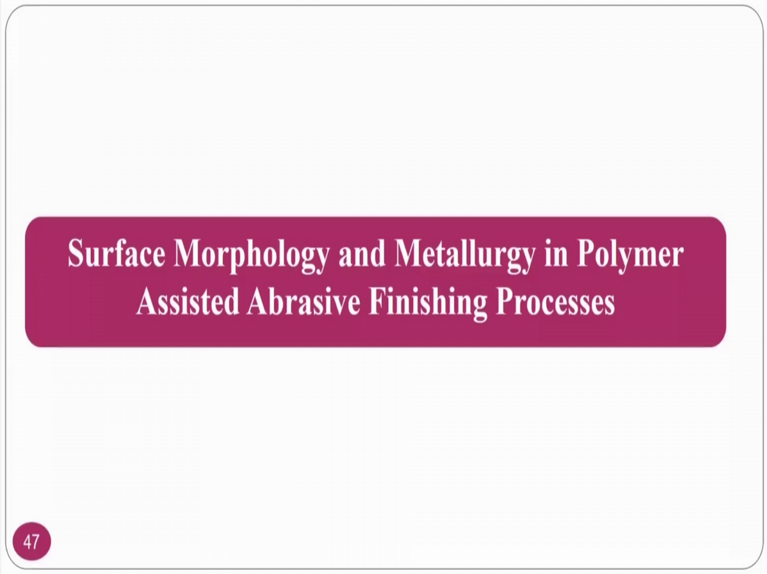

The surface morphology and metallurgy in polymer assisted abrasive finishing processes, if you see here. We have to understand, why we go for polymer assisted abrasive finishing processes.

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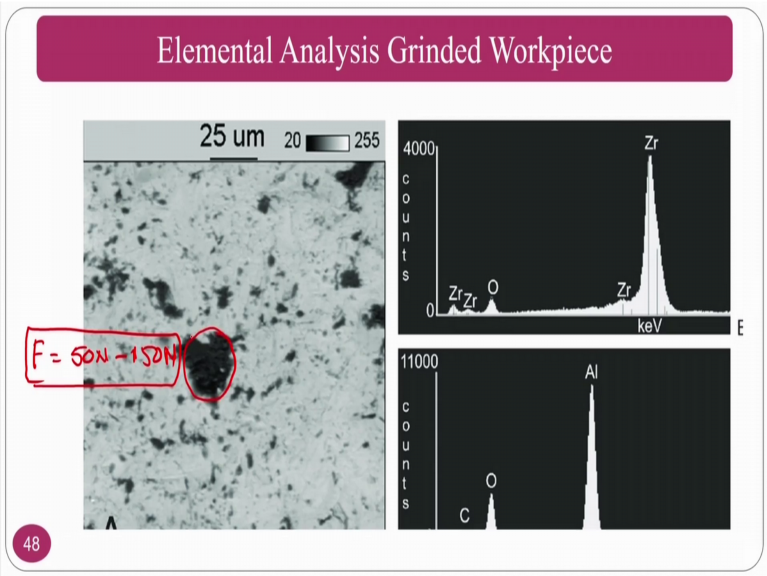

For example, if you are going for grinding process, whenever you do the grinding process, what will happen your forces normally your radial force and other forces will be approximately 50 Newton to 150 Newton’s normally because of this high amount of forces, the surface roughness you are going to get is rough.

At the same time, what you are going to experience is that damage of the work piece by burning and other things, you can see here. The burning or there will be a pit formation is there, and these are all observed whenever there is a forces that is why in polymer assisted abrasive finishing processes, you are going to experience the finishing with respect to a liquid type of tools polymers will be there, rheological additives will be there, some liquids, then some solids will be there, and abrasive particles will be there ok.

A grinding wheel is a solid body, polymer rheological abrasive fluids. These are all a liquid or a semisolid. Obviously, whenever you hit with a semisolid and whenever you hit with the solid, the forces will be much higher than the experience that you will do with respect to liquid or semisolid because of which you can also observe there is a change in the metallurgical properties also.

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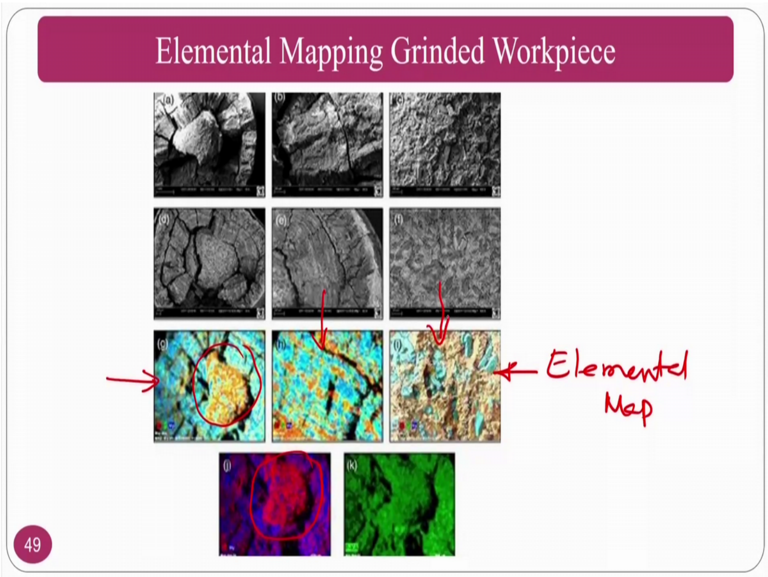

The surface roughness and elemental analysis if you can see here, lot of damages will be there for the grinding surfaces. And you can also see the elemental mapping also you can see there will be a change in the surface morphology the parental material. Whenever you see the parental material, then this is called elemental mapping ok. You can you can map the elements for the same pictures, you can see how the elements can be mapped and you can check.

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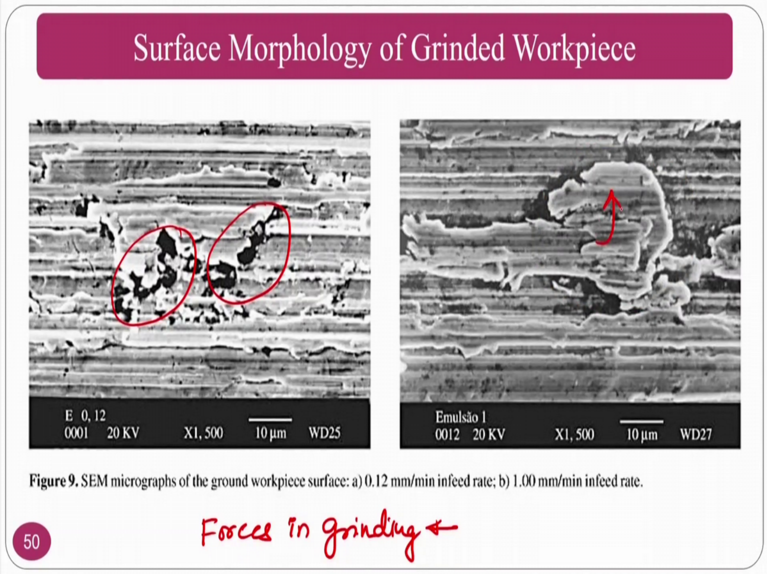

And you can see the grinding surfaces. The grinding surfaces I said the forces are very high forces in grinding are very high because of which what will happen, the surfaces damage will be very high, and you can see the surface damages ploughing ok. The mechanism of grinding material removal is abrasion is there ploughing and rubbing.

Three mechanisms are there. If there is a abrasion or shearing, there would not be much problem. If there is a ploughing, normally the material that removed from one place will just smear in to the other place that is called the ploughing and rubbing. Anyhow if you give insufficient depth of cut what will happen, the grinding wheel rub against and it will burn. All these things are because the interaction forces of grinding process or solid based tool, like lathe, turning process also the forces are very high. Whenever you talk about the finishing process, your forces should be as minimum as possible, so that the depth of indentation will be very less, so that you can get the microchips or nanochips, and you get a good surface finish.

What is I want to convey from this slide is that why we are going towards polymer rheological fluids or polymer assisted abrasive finishing processes that this finishing processes are confined to finishing processes. And the force experiences during this processes is normally 5 Newton’s to 10 Newton’s, so that mean that the finishing is very smooth. Whenever your requirement is finishing, then you have to go mostly for either polymer rheological abrasive finishing processes or magneto rheological finishing processes and so on wherever there is a liquid type or semi-solid type is there, you can choose a rather than the solid based tools.

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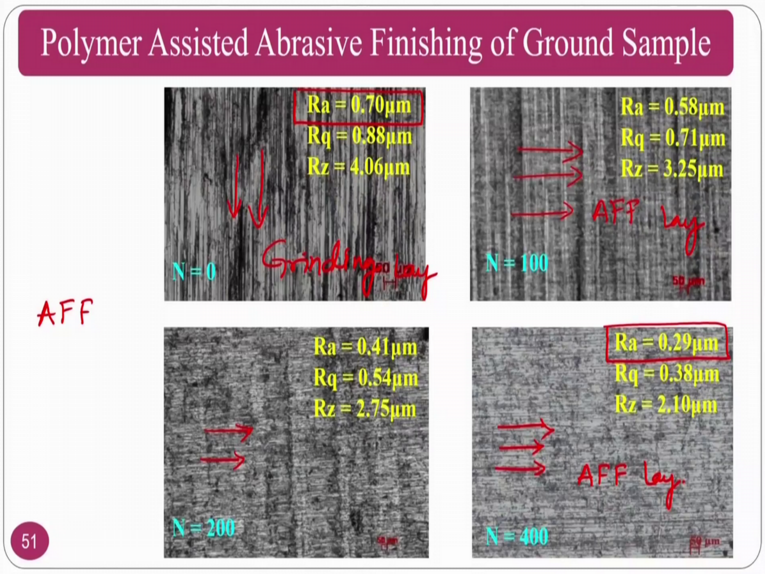

As you can see here, how the grinding surfaces also can be polished. This is some of the example of abrasive flow finishing, where you can see these are the grinding marks. These grinding marks also can be polished by this polymer rheological abrasive medium, you can see small small scratches that are there on this which is moving perpendicular to the grinding lay pattern. This is the grinding lay pattern, this is the AFF lay ok, this is grinding lay.

Smooth surface gradually increasing, and the final AFF lay you can clearly see here that is predominant surface roughness directions, and it is polished. And you can see the surface roughness improvement from 0.7 micrometres to 0.3 micrometres, where the dominating surface roughness characteristics of grinding process is finished using abrasive flow finishing process. This is the beauty about polymer assisted abrasive finishing process that is why you are going to study about this processes.

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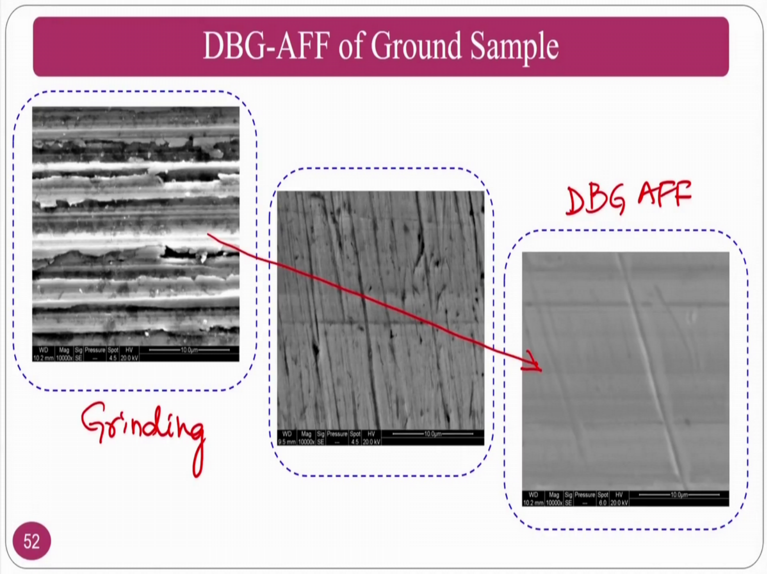

Some of the processes also you will study about drill bit guided abrasive finishing process. This is the grindingly lay grinding surface, and this is the drill bit guided abrasive flow finishing process ok. You can see the transformation, how the surface is transforming. This transforming is required, whenever you want mirror like surface roughness and other things.

Grinding process as per current scenario is considered to be one of the machining processes only, because we are moving towards advanced finishing processes and other so on. And you can also see the surface morphology lot of debris are there, these debris. And you can also see the bars, which are unremoved ok. These bars are there, and some of the debrises are there, some ploughing is there. Because, whenever the abrasive particle is moving here, there is a smearing of the material or deforming the material towards the next one or the previous one ok.

From this slide what I mean to say is that the importance of polymer assisted abrasive finishing processes, which is this particular course ok. Those people who want to do the research, in this area is enormous. Many people have already done, and still there is a scope for developing the abrasive flow finishing process, and various advancements in abrasive flow finishing processes, hybrid abrasive flow finishing process, and other things. These are all I will cover in upcoming classes also ok.

So, the grinding process is not the final finishing process that is what I want to convey as per the nano surface is concerned. If at all you are you are happy with the micro surfaces 2 microns, 1 micron or you are happy with 1.5 micron, then grinding is a very good process. If at all you want like 50 nanometers, 100 nanometers, 75 nanometers, then you have to obviously go to the advanced finishing processes. And one of them is polymer assisted abrasive finishing process, which is the course that I am dealing with the spiral polishing method also.

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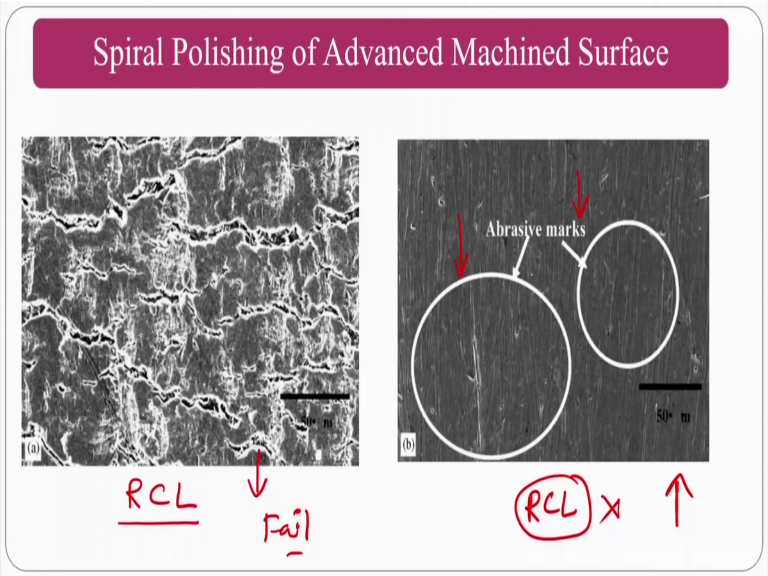

Some of the methods we will use idiom process, electric discharge machining. As I said that recast layer recast layer will have a re-solidified layer. This re-solidified layer whenever it is solidifying, there will be a cracks. And if at all you want to put this into practical application, then what will happen, it will fail. For the purpose you have to go for finishing of this one, and you can finish using spiral polishing method. And you can get the good pattern of the surface. And moreover you can remove the recast layer entirely, and you can expose to the parent material.

Now, if you put this into the practical condition, then what you are going to get is the good life of that particular component compared to the previous one that is why, you have to understand the applications. And some of the applications of the surfaces, these all you may get again also.

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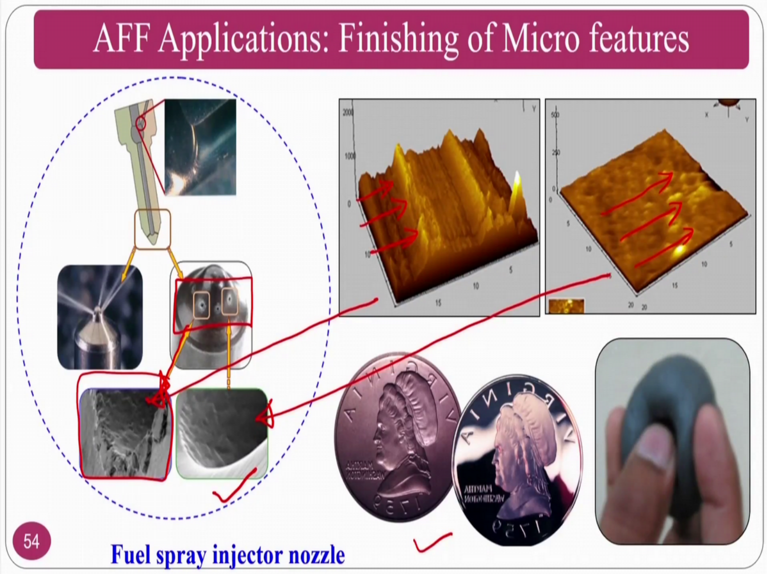

Whenever you see abrasive flow finishing process, the fuel injector nozzles that you have to finish in these are the, a extrude cone company they have specified. If you do not finish, it will be like this. And the fuel has to be ejected for the combustion and other things. If at all I want to eject x amount, if the surface is like this very rough surface, what I cannot eject perfectly. In that circumstances, what will happen that improper combustion will be there. For that purpose you have to finish this, and better combustion can be taken place, and carbon monoxide, and other dangerous gases would not evolve. So, this may refer to this one. I am not saying the same, just refer, and this will refer to this one so, that if at all I have the smooth, the fuel flow very smoothly.

Here if fuel has to flow, there will be abstraction that is why you have to polish the surfaces. And one of the techniques people uses is abrasive flow finishing. Abrasive flow finishing uses polymer rheological abrasive medium. And exclusively about abrasive flow finishing processes and advancements and other things, we will see upcoming classes. And you can also see the polishing of some of the dice, and these are all can be achieved by this polymer rheological abrasive medium ok.

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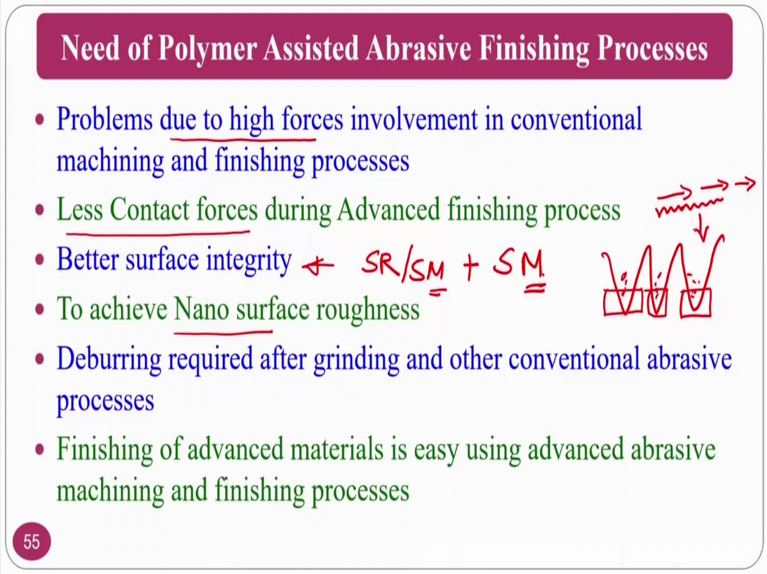

So, why we need the polymer assisted abrasive finishing process? Problem due to high forces involved in conventional machining and finishing processes. And less contact forces during advanced finishing processes. And better surface integrity, as I said surface integrity means surface roughness or surface morphology plus surface metallurgy ok. M stands for Metallurgy, here also morphology. To achieve nano surfaces or the surface roughness in the nano scale that means, that 1 nanometre to 100 nanometres like that.

And deburring is required after grinding have you have already seen the surfaces are very rough, and deburring is required as well as some other materials that are deposited on the neighbouring valleys, how is to be removed that the material that is loaded in the valleys has to be removed. The finishing of advanced materials have deburring, because the world is growing. As the world grows what is thing new materials are coming ceramics are coming, glass ceramics are coming, biomaterials are coming. You have to polish or we you have to finish.

Whenever a component is there like acetabular socket in a hip joint or a knee joint or any other application like cardiovascular stents, these are all to be polished up to a nano surfaces, because these are all directly going into a human. And if there is a high roughness is there, body fluids flow will be obstructed. And the this body fluids will stagnate in the valleys.

Assume that my I my surface is like this, this body fluids will stagnate here and nothing in this world is uncorrodible. And it will damage the material in this regions. And these will cause lot of other problems, whenever you have a neem plant or hip implant or many other biomedical implant that is why, you need to polish in to a near nano surfaces, so that body fluids can easily flow on this one, and there would not be much obstruction. And if there is stagnation of some fluid, it will be much less compared to the high rough surfaces ok.

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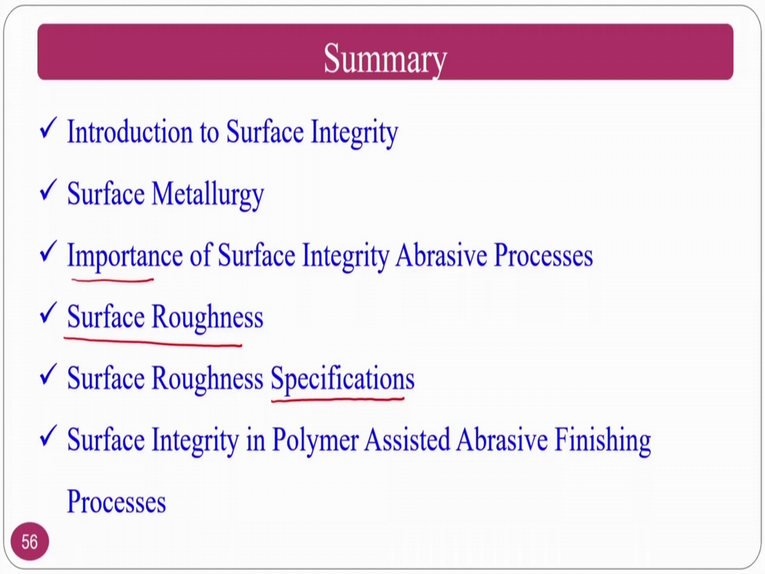

Summary of this one. So, introduction to surface integrity, we have seen. Why surface integrity is required, why not only surface morphology, then we have understood what is surface morphology for and we have gone to the first one that is called among the surface integrity, the first one which we have seen in surface metallurgy, since we are mechanical engineers.

We have just saw some of the glimpse and importance of the surface metallurgy, and if at all the people who are watching this may not be a good at metallurgy, many of you may be convenient with metallurgy. But, some people if you are not comfortable, then you have to collaborate with the material science and metallurgy guys, and you can get the collaborative work.

Then we have seen to the importance of surface integrity in abrasive processes, and we have got surface roughness, and surface roughness specifications, and how to represent the surface roughness, then at last we have seen the surface integrity in polymer assisted abrasive finishing processes such as abrasive flow finishing process, drilled bit guided abrasive flow finishing process, spiral process and so on ok.

Why I am telling the importance of this particular class of surface integrity is the surface integrity, you will get in polymer assisted abrasive finishing processes is much better compared to your grinding process or any other conventional finishing processes that is why, you are going to study a good course where you learn about the fluids that are going to polish or that are going to finish the components.

At the same time there are some plastics, there are some polymers that are directly going to finish the work pieces instead of ceramics directly. If the ceramic is indented to a metal, assume that I have a neem plant that has to be polished or the finished in that circumstances if you are putting a ceramic abrasive particles, then the interaction forces is very high, because one side it is a metal on another side it is ceramic. So, interaction forces are very high. If I put the plastic abrasive particles, which are embedded with the abrasives small abrasives, then interaction forces will be much less. So, you will go through some of the mass finishing processes where polymers are also have role, you will also go through some of the advanced finishing processes, where polymers play a major role.

Thank you for your kind attention for this particular class.