Introduction to Abrasive Machining and Finishing processes
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Lecture – 13
Representation of Surface Roughness

The Representation of Surface Roughness. Now, you have measured the surface roughness and you want to go further how to represent, assume that I want to have a milling surface to be represented. I want waviness representation, I want what type of lay that is predominant direction of surface roughness, whether it is a milling lay or a parallel lay a perpendicular lay a crosshatch pattern how to represent all these things that is most important for a abrasive processes, ok.

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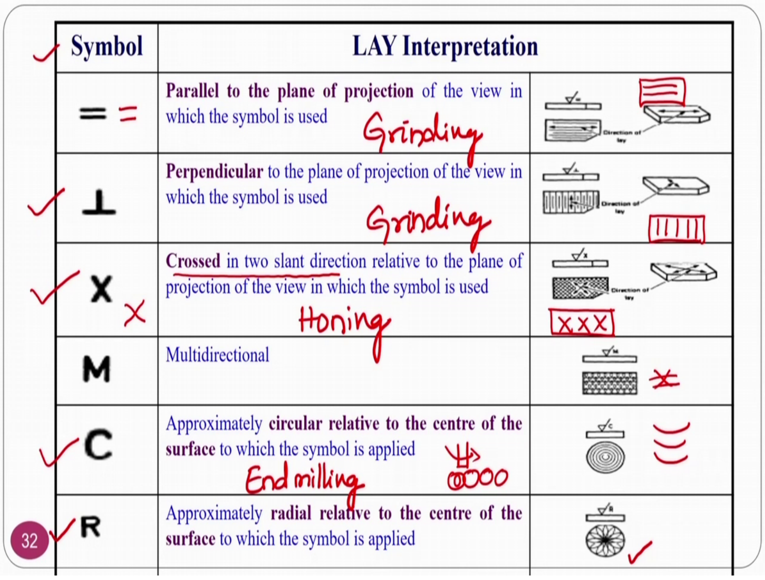

So, how do you represent? If you see the symbol here it represent by the symbol at the same time lay interpretation and corresponding picture. So, this lines of two parallel lines will represent parallel to the plane projection of the view which is symbol is used that means, that parallels lay that is a predominant surface direction is a lay is a parallel lay like I have a surface here and my surface roughness lay pattern is like this.

Now, you will get this type of surface pattern in grinding operation at particular location because the grinding will rotates and it will generates and your table moves to and fro, that will the table reciprocates for that purpose. As a result what will happen you will get a parallel surface along the direction of your table moment, ok. Assume that if you are rotating in the grinding wheel in one direction and if you over if you place your workpiece in a perpendicular direction then if you do and if your measurement is in perpendicular direction then it will be a perpendicular type of surface roughness.

Assume that now, I have this particular surface wherein I am getting a this type of things. If you can place you can assume that this is also a parallel also because, how you orient your workpiece will determine the surface pattern at the same time how you are going to measure also play determine the surface direction, ok. So, the crosshatch pattern, normally crosshatch pattern will represent by x type and this normally is the two salient directions related to the plane of projection of the overview.

Normally, this surface will have crosshatch patterns like this. This type of crosshatch patterns will be normally you will observe in honing process. In above case normally this is in grinding process this also you will observe in grinding process only, ok. So, this is what the honing process crosshatch pattern as I said there will be a helical motion forward direction and helical motion reverse direction when it is coming out because of this normally you will end up with crosshatch patterns. And a multidirectional, normally if you see the multidirectional you will have a many directions not only crosshatch you can also will have parallel perpendicular and other things.

Whenever you club 2 3 processes in some cases it is a harsh process like a surface roughness is very high whenever you are going for a secondary operation then the finishing is going to takes place. So, you will get a pattern which is there in a coarse grinding process. Then if you followed by the fine honing process, then you will get a multi directional surface pattern. Then you can go for a circular type normally circular type you will observe in terms of milling and other things is sometimes you will see this type of curves because in a end milling cutter and other things what will happen your milling cutter will rotate in. Assume that your milling cutter is like this and if you it is going to generate what will happen.

So, it will give you surface. So, this is called circular pattern. Normally end milling is one of the common example, ok. So, that is depend on your feed how much it is moving if it is too high then you can clearly see complete circle, if it is very very less in that circumstances normally you will observe very less amount of segment of a circle. So, R approximately radial relative to the center of the surface which is the symbol represent normally this is the type of the symbol that represent which refers to the lay size the shape is radial which is up represent by the symbol R.

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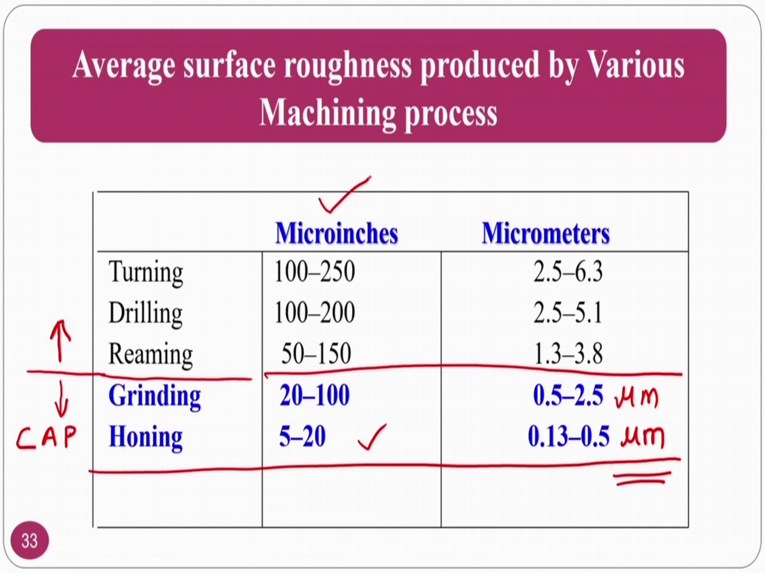

Average surface roughness produced by Various Machining process

	Microinches	Micrometers
Turning	100–250	2.5–6.3
Drilling	100–200	2.5–5.1
Reaming	50–150	1.3–3.8
Grinding	20–100	0.5–2.5
Honing	5–20	0.13–0.5

So, the average surface roughness produced by various machining processes. If you see here, so these are all comes under the normal machining processes and these are all like grinding and a honing process comes under conventional abrasive processes, ok. So, since we are talking about conventional abrasive processes just we will see the surface roughness values normally it will be 0.5 to 2.5 micrometers in grinding, honing normally it will be slightly lesser also. So, it will be 0.13 to 0.5 micron or micrometers. This is the in micro inches and this is micrometers. So, normally people represent mostly in the micro meters in India particularly. So, I am mostly emphasizing on micrometers. But some of the countries who are watching this from the online source you can also convert these particular values for that purpose I am just giving you the micro inches also.

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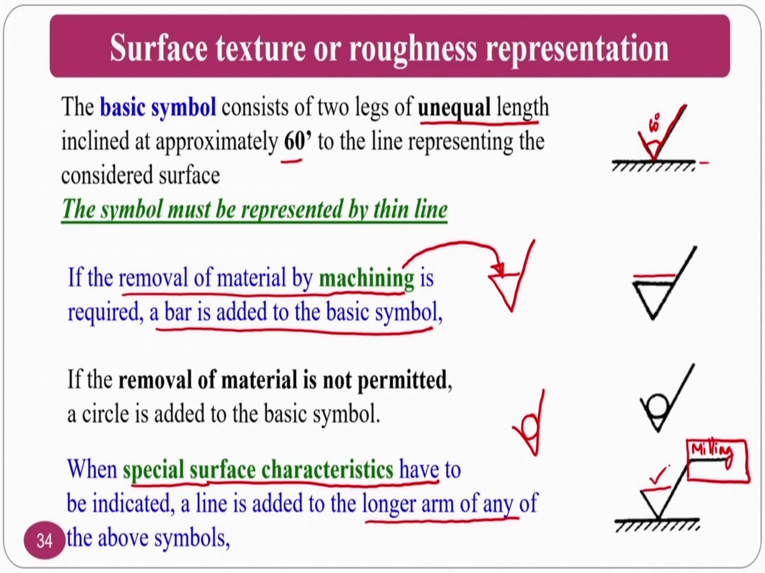

The surface texture or the roughness representation normally there are symbols to represent the surface roughness, ok. The basic symbol consists of two legs of unequal length, ok, so which is indicated approximately at 60 degrees to a line representing the consider, the symbol must be represented by a thin line that is this is a thick line that is represented here at the same time thin line represent in a unequal length which is at 60 degrees, ok.

So, this is how you represent the basic symbol, this is just a basic symbol that one can I represent how you can add on like you purchase a computer then. Now, you increase the ram you will increase the hard disk, you will increase some other thing, you purchase some other things and all those things like that you can add on this one. Assume that this particular surface I want to be produced by milling process I want to add what is the surface roughness value, I want to add the waviness value. So, I want to add the lay direction I want to add so many things, those are all to be added to a basic symbol, ok. You purchase a basic model.

Now, you add on things like as I said in like a computer, ok. So, in a surface roughness also you can add on the things. How do you add on things? Assume that if the material removal lease by the machining process. So, you will add a line like this to a basic symbol, and you will add a bar added to the basic symbol just you add a bar you have a the surface just you add this particular thing. So, that is nothing, but this represent machining process.

So, the material removal is not permitted I think does means that assume that I want a particular surface roughness without removing a material then you represent with a 0 assume that this 0 represent low material removal, but I want a surface of this one. Assume that I want a product wherein there is should not be any material removal, but I want a 5 micron surface roughness, then what is the thing? If it is a castable product just you cast it and you will just give it you need not do any move any machining process on top of it, that surface will be represented like this.

Special surface characteristics, when the special surface characteristics have to be indicated the line is added to the long arm of any of the above symbol that means, that you are going to add this particular arm. If you have a any special type of surface characteristics assume that I want to mention that it should be machined by milling process then I can write milling on top of it on this like that I can write. And it will also come in a upcoming slide, but for your better understanding I am just saying I can write its milling that. And you have to represent machining, beside because it is a material removal process, so you have to represent like this and you have to specify milling. That means, that you have to remove the material and you have to achieve the surface roughness that is specified it is not specified here and you have to represent the material removal symbol also, ok.

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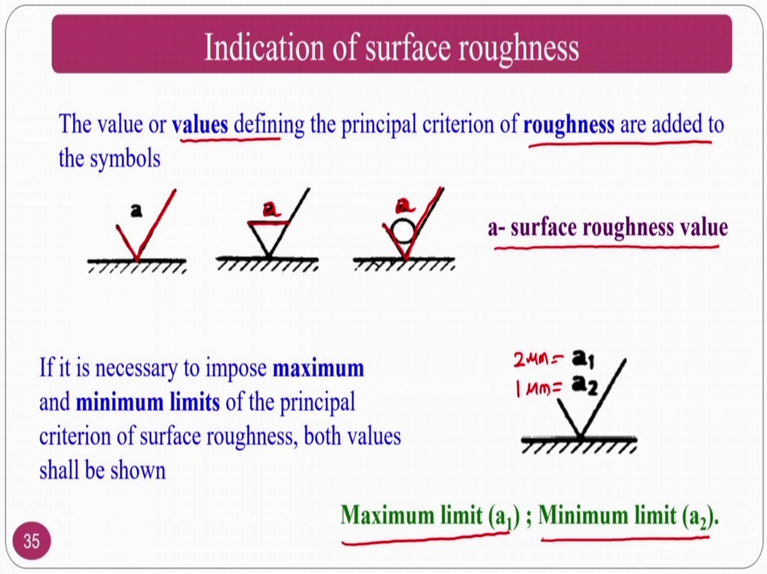

Indication the values or the values are defined by the principle creation of the roughness added to the symbols, assume that I have this surface roughness value is a, a is a surface roughness value and I am representing in 3 ways. One is I want a surface roughness like this, I want a surface roughness by using a machining process, I want a surface roughness a without removing any material, ok. So, this is how you can represent in a 3 ways.

At the same time if it is necessary to impose maximum and minimum limits of the principle criterions of surface roughness both value can be two. Normally a 1 represent the maximum limit and a 2 represent the minimum limit. Assume that I want a particular surface whose surface values can be within the range, assume that the surface roughness can be like in between 1 and 2. So, in that circumstances a 1 represents 2 micrometers and a 2 represent 1 micrometer; minimum and maximum values that you can specify on a particular component surface roughness symbol so that the supplier will give you as per your requirement.

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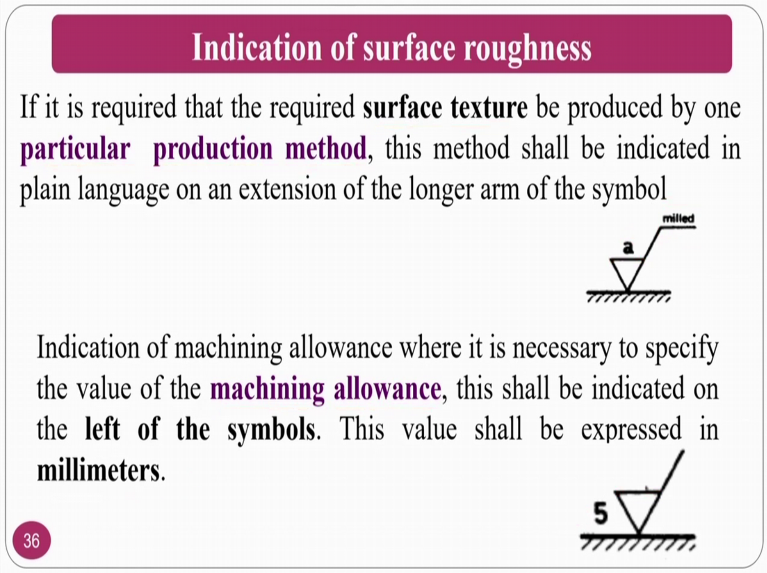

Indication of the surface roughness if you see as I said in the previous slide, so if the required surface texture to be produced by one of the particular production method that means, that this method shall be indicated in a plain gauge on a extension. That means, that what I was explaining you here if I want a texture like the texture of the milling will be like a circle, ok. This type of texture I want that means, that I have to do this by a end milling process and a this is a material removal process. So, you have a line and roughness value is represented by a, this is how you can represent this particular symbol of surface roughness.

Indication of machining allowance; where it is a necessary to specify a value of a machining allowance. And this shall be indicated at the left of the symbol, this value can be expressed in millimeters, ok, the 5 will represent the machining allowance. Why? The allowances are always to be mentioned because nothing or any particular manufacturing process cannot produce exact dimensions. Assume that I want a rod of 10 mm diameter, no process in this world can produce exactly 10 mm there will be a plus or minus 0.01, 0.1 mm or something. So, that is what the allowances is.

So, the customer has to specify because it is a constraint of a manufacturing engineer which he cannot produce exact values. For that purpose what the customer specify a certain allowance, that allowances are represented at this location of a particular symbol and this symbol represent you have to do the surface by machining process. But you can add certain allowances that is approximately 5 and the dimensions normally will be expressed in terms of millimeter that means, that I want to generate a assume that I want to fabricate a 100 mm diameter plus or minus 5 allowance is given. Assume that if it is 5 millimeters you can say 2.5 mm or something. So, that it can go plus a within the 5 diamond or diametrically.

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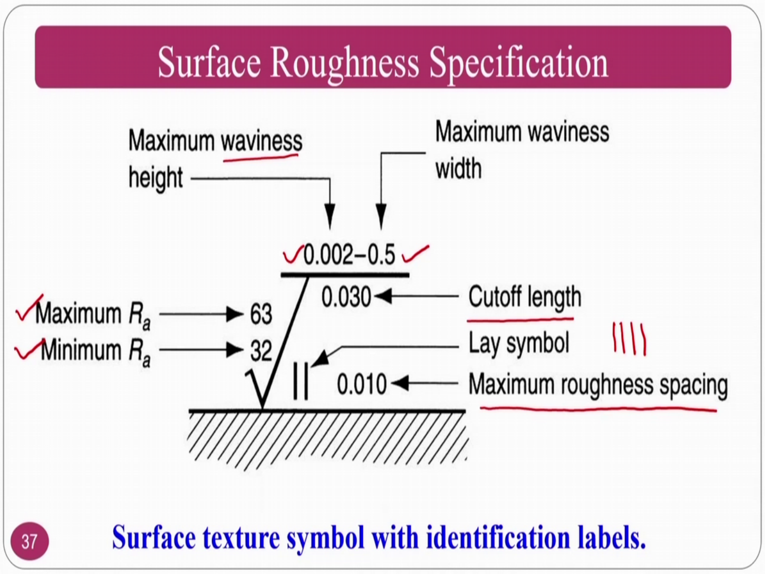

The surface roughness specification completely, how it will represent which will show this one. You clearly follow this particular slide so that you can understand how to represent the surface roughness, allowances, maximum limit, minimum limit of surface roughness, which type of process that you have to do, what is the type of lay that you have to achieve and all those things, ok. We will go by one by one this is a symbol the basic symbol which can praises of maximum roughness and a minimum roughness that is mentioned.

At the same time maximum waviness height and maximum waviness width is mentioned here, at the same time cutoff length. As I said cutoff length is most important to avoid the waviness so that is why here normally 0.03 mm is given as a cutoff length and a lay symbol that is nothing but I want a parallel surface ok. Parallel surface now, that means, that you can achieve like a parallel lines on the product, that the maximum roughness spacing is represented by 0.01.

This represent the complete symbol whereas, you have the maximum roughness to minimum roughness, maximum waviness to maximum waviness, maximum waviness height to maximum waviness width, cutoff length lay symbol as well as maximum roughness spacing. That means, that how much spacing is there between the roughness as the peaks and valleys and other things, or distance between two peaks or a distance between two valleys. This we can represent by this particular complete symbol.

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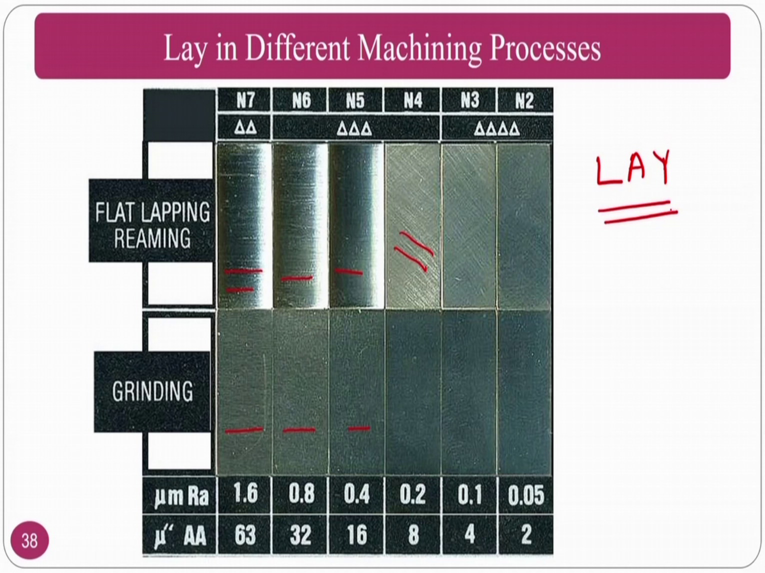

You can see the lay pattern here flat lapping normally you can achieve here. So, or you can also have some of the surfaces like a inclined surfaces, how you are holding your hand or how the people are place the abrasive pads automatic and other things. Grinding, normally grinding you will get a parallel and perpendicular type of a pattern depend on a which direction you are seeing the surface.

If you are seeing in a parallel direction to a surface lay that is parallel, if you see the perpendicular then it will be perpendicular. So, the surface in one direction it is how you are seeing or how you are going to measure is whether it is parallel or perpendicular. One side it is parallel on other side if you see it is perpendicular, that is how the grinding and lapping surface lay. Lay always I was saying is nothing but predominant direction of surface roughness.

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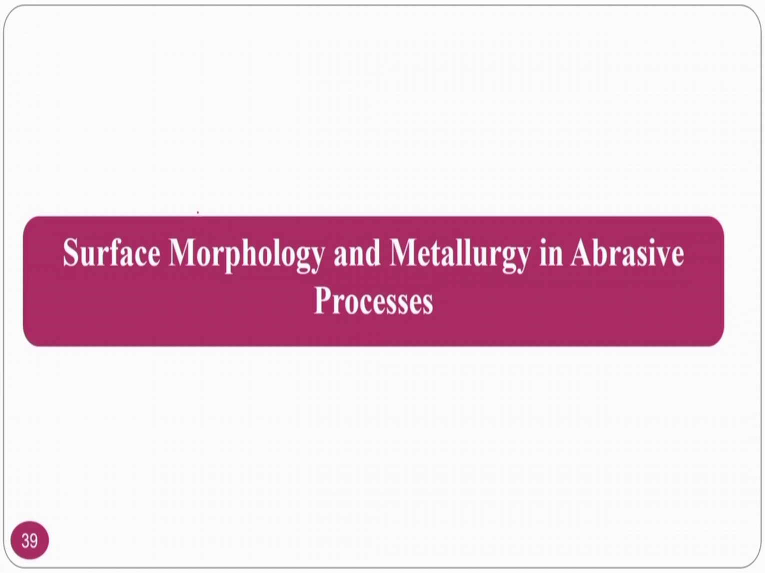

The surface morphology and metallurgic in abrasive processes, because the surface roughness that we have measured, but surface morphology will be a completely different aspect because there will be a chips clogged or the chips are burnt on a surface. This is cannot be measured sometimes because assume that I have a surface like this whenever you do some finishing process or something this particular thing can bend like this. So, this is, this will not be shown in the surface roughness because it will give you a less surface roughness value because of the bending or something burnishing action. But what will happen? This is not good from the practical point of view. So, the surface morphology you have to observe.

Assume that I am doing a burnishing operation that is a deformation process where you take a hard tool and roller burning deformation you just do it what will happen the peaks all deform. So, if you may get a better surface roughness if you are looking at a surface roughness value, but if you see the morphology you will understand whether that is deform, whether it is sheared or something, for that purpose you should understand the surface morphology at the same time any temperature rise which causes the burning action or metallurgical changes or something. Even though surface roughness is very good, but the surface practically burnt then it cannot be used because the cracks formation will be there and other adverse surfaces will be there on the top layer of the material.

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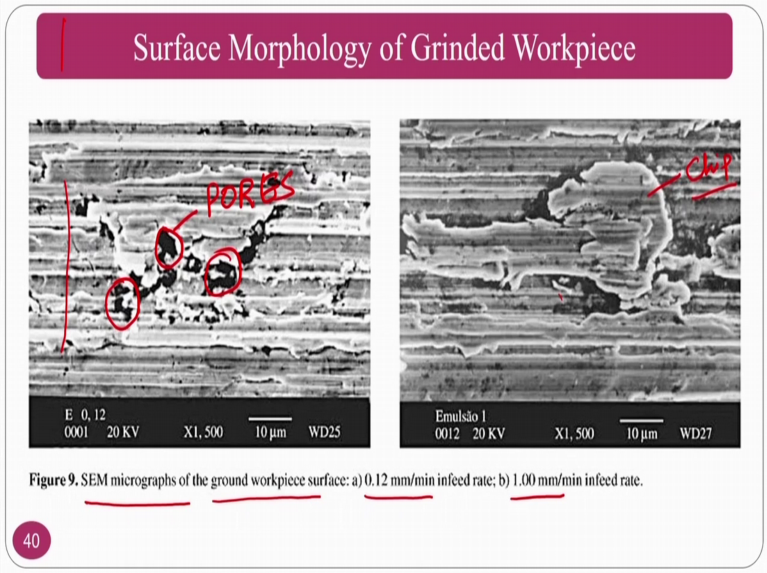

If you can see here the SEM image which is micrographs of the ground surface normally 12 mm per minute infeed and 1 mm per minute. Now, you can see the surface if you go and measure the surface roughness in a particular line what will like you will get a particular value, but from this particular you can see there is a defect or the material is gone there is are the pores are formed, ok.

So, this type of morphology which you may not see from the surface roughness. This is a pore basically singular and if you see many many these are things. So, these are called our pores basically. At the same time in the other way around you have the pores or the material is there at the same time you can also see a surface where chip is deformed again, ok. So, the ploughed material deform on a direction along the direction of the grinding wheel rotation, ok.

So, this chip which is has to be removed it is adhere to the surface and the next abrasives that are came just they put a lot of radial force. So, it is there smear there itself that means, these type of surfaces are there. Assume that if you are going to measure the surface roughness value here what will happen? You will get a very beautiful surface roughness value. But if you are going to put this particular surface in a practical application this particular is a undeformed chip, it is a un removable chip which is a burr what will happen, this goes off in a patterns. And then it will leave a void there or it will leave some eccentricity for that purpose not only surface roughness which you have to see you have to see the surface morphology or surface topography of that particular components.

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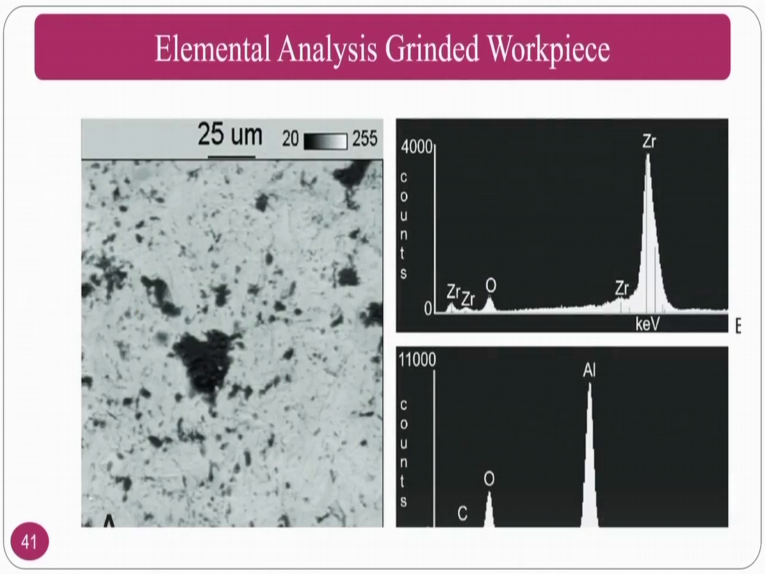

You also have to see the elemental analysis that means that if at all I want to understand particular surface, so you can go for line scan. This is that a grinding surface or something just to understand, to make you understand I have taken one particular surface and the surface is checked with the EDX analysis, ok.

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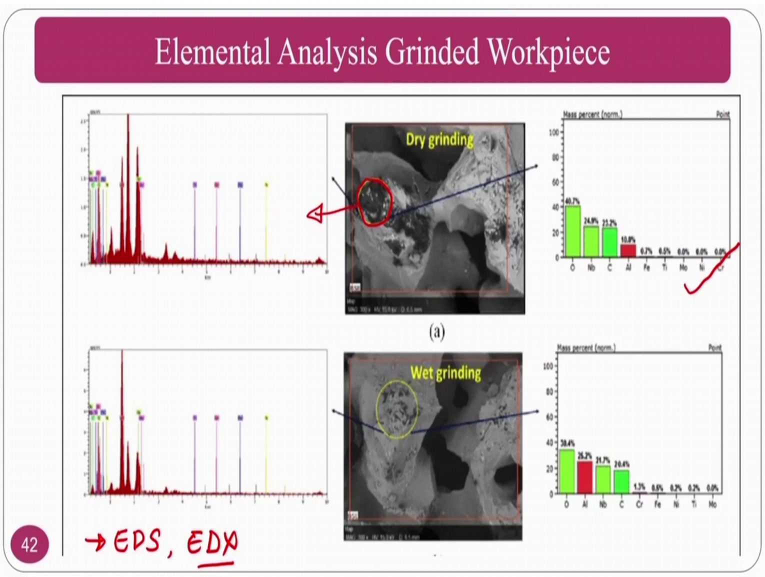

So, for your better understanding we have taken a grinded workpiece here and these things are tested from the elemental analysis, ok. Elemental analysis is done that is called EDS and some people they may also called as EDX also, Energy Dispersive Spectroscopy, this is EDS people commonly called as EDS. Some people they may also pronounce EDX also.

So, in this you can go for area, you can go for line, you can go for a point also, ok. So, in this particular the people gone for a particular area and measure and whenever you do the elements that are available here you will get a particular spectrum like this, and from the spectrum if the spectrum is not properly visible you can go and plot a bar chart like this, ok. So, measuring the surface roughness, then seeing surface morphology next you are going for metallurgical aspects.

Why the metallurgical aspects are important? As I said the burning is taking place or something then what will happen the elemental composition will change. Assume that the carbon percentage goes down, oxide film may form or the elements which are volatile or the elements with low melting point other things will goes off, because the grinding operation is a very fast process and the temperature generation is so high that low melting point materials will goes off giving a (Refer Time: 23:24). In that circumstances the element or the traces of that low melting point materials may not be present or it will be in very very less quantity, for that purpose which is not in terms of (Refer Time: 23:41) for that purpose you should understand the metallurgical aspects also.

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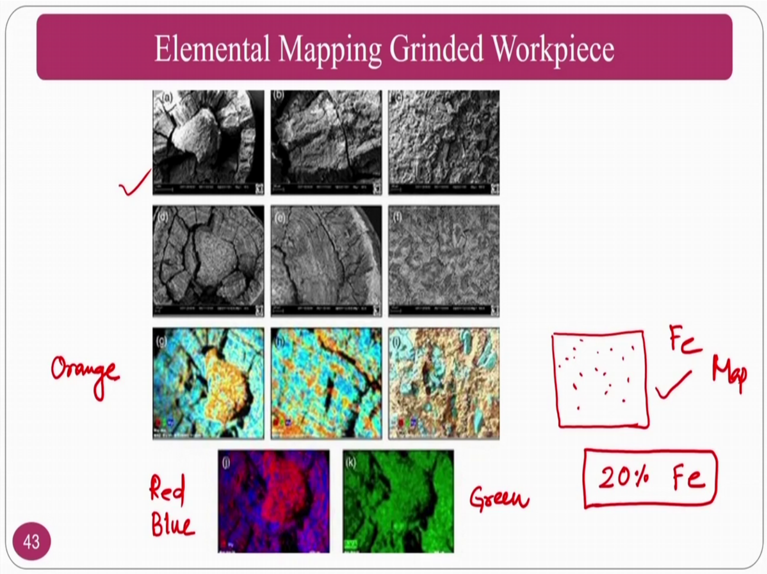

So, another one is elemental mapping. For the surface you can also map. Previously what you have done? You have done a point scan, you have done a line scan, you can go for a area scan, whatever you have seen is area scan just to draw a circle and you can find what are the elements in that area, ok. Similarly you if you want what are the elements in a particular picture, complete picture then you can map the elements, what how do you can map? This is the air surface and you can go for elemental mapping and the elemental mapping will give you different different colors one one color represent one one element.

Assume that if you give a red one represent some elements, blue represent some element, green represents some element, and orange represents some element and sky blue represents some other elements. So, you can represent different elements you can divide also you can get for each and every element you can get a spectrum or you can get a complete rectangle type of thing wherein you can show only one color points so that you can get what are the elements in that particular area. This is called elemental mapping.

You should there should B.Tech people you may slightly confused that is elemental analysis that means, that that will give you a quantitative value here it will give you the area where all the elements are there, it is called map, it is you are mapping the element. Assume that I want to map an iron I can map in a one particular rectangle, but in the previous slide what you can give is you can say assume that 20 percent is iron. In this picture you can map where all the points of Fe, this is called mapping, this is called ED, this also comes under the EDS this is called you can say that quantitative value, both will give you a correct analysis.

So, people you should understand the elemental mapping, as well as you should go for elemental analysis also. So, that you have a quantitative value as well as qualitatively good looking picture then only you can go for better publications in the good and reputed journals. Surface change just caused by various energies. Normally these surfaces are developed by many type of energies like mechanical energy, electrical energy, chemical energy and other, so on. So, how these surfaces are generated by this type of energies.

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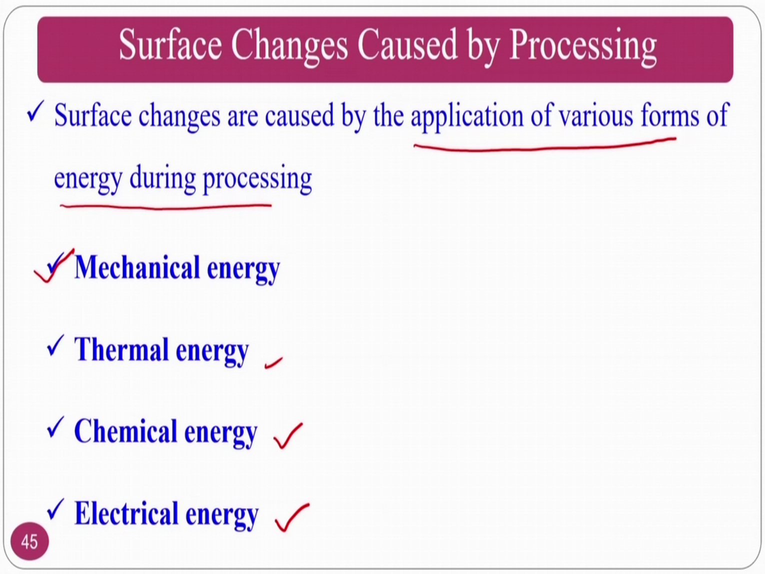

The surface changes caused by various processes, these are caused by the application of various forms of energy during the process so which pumps we will see here. First one is a mechanical energy, then the thermal energy then chemical energy and electrical energy. You have various energy forms, how this will affect the surface roughness that we will see here.

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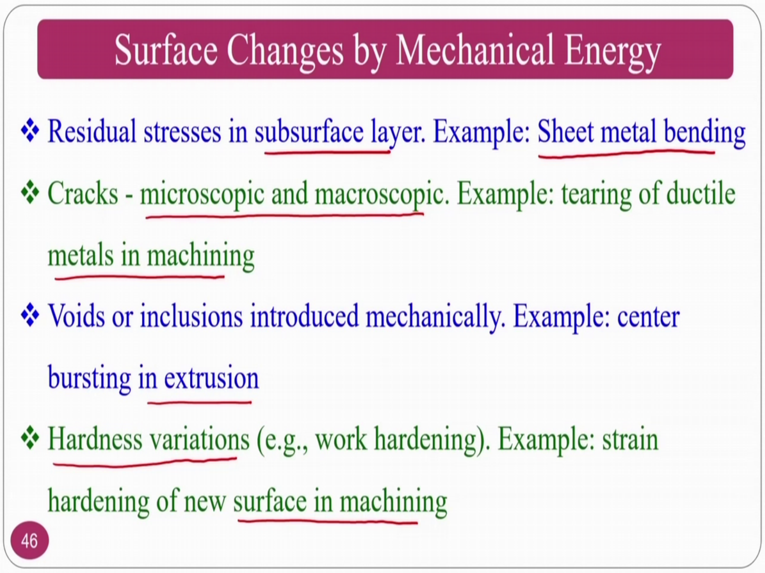

So, the first one we will see surface changes by mechanical energy residual stresses in subsurface layer example is sheet metal bending normally. Whenever you do the sheet metal bending process what will happen you will get always residual stresses and sheet metal bending is a mechanical type of energy that you are putting.

Cracks, microscopic and macroscopic example is tearing and ductile in the machining process. Machining process is also a mechanical process where you can remove the material. So, because of which normally the cracks and other things were generate.

Voids and inclusions introduced mechanically example center bursting are in extrusion. So, extrusion also just you have to push the material and you can extrude the material through a nozzle or through a vent that is available. So, you can have this type of things. So, that it will generate its own surface with voids or inclusions and other things. Hardness variations also creates by your mechanical, one of the processes is machining. So, whenever you do the machining operation the surface hardening will takes place on the surface.

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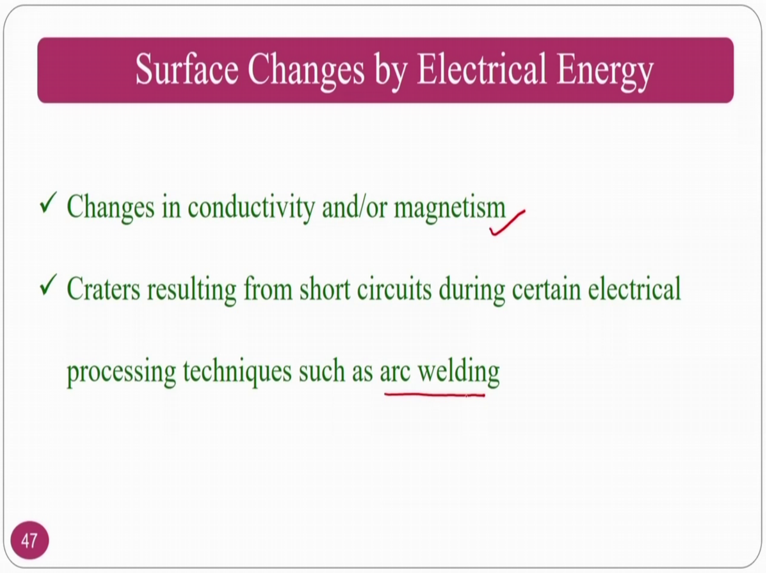

By the electrical energy the changes in the conductivity or the magnetism whenever you do certain process if there is a conductivity variation. Assume that in a particular process you have less conductivity, now the conductive because of the voids you have a less conductivity here the voids are reduced. So, you can increase the conductivity.

Craters results from short circuit during the certain electrical process techniques such as welding and other things. So, craters also forms because of the some of the changes or fluctuations in the electrical processing or short circuit that are involved in the process.

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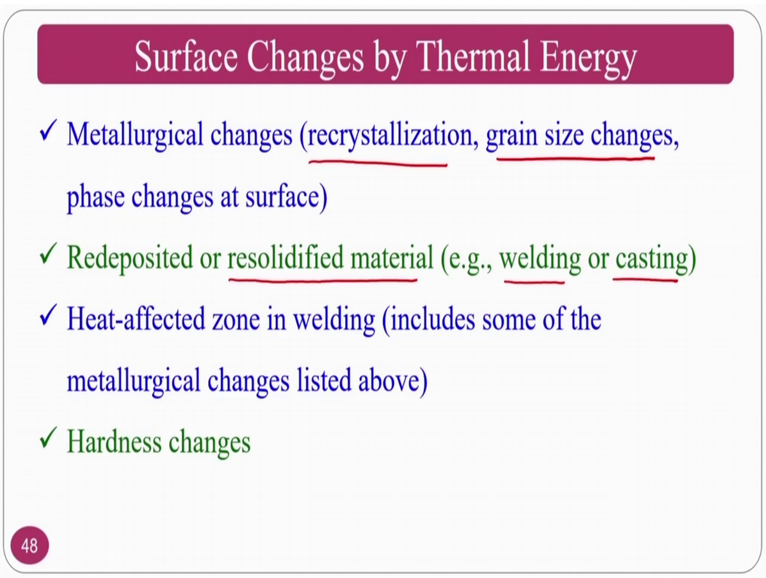

Surface changes by thermal energy the metallurgical changes as this is the most important because whenever you do the EDM process or machining process where the temperature goes up because of the chip will carry 80 to 85 percent, the tool will carry 10 to 15 percent and normally 2 to 5 percent will carry by the product that is the end product. So, temperature rise in the machining process will changes the metallurgical changes that is a recrystallization, grain size changes and phase changes on the surface and other things can be happen. Normally, if the temperature is up the grains start to enlarge that means that it will increase from the parental grain size. That is one type of a change in the structure of the surface due to thermal energy.

Redeposition or resolidified material like welding or casting; so, redeposited or resolidified material means because of the thermal energy if at all I want to do a casting process just you want to you have to melt that particular and you have to cast it. And a redeposit normally in a EDM process because of the spark melting and evaporation the material may not be removed completely. So, which is there under surroundings will redeposit, that is because of the thermal energy in the electric discharge machining process.

Heat-affected zone in welding normally done by the melt pool and other things whenever you want to do a melt pool in that circumstances you have to heat that means, that thermal energy is involved in this particular process. And this also causes the metallurgical changes. Hardness changes, so hardness changes also play major role because of the thermal energy if the heat affected zone resolidified layer these are the layers which if you are forming these are layer hard layers basically. Sometimes it may be a carbide layers and other things, ok. So, the hardness also will vary.

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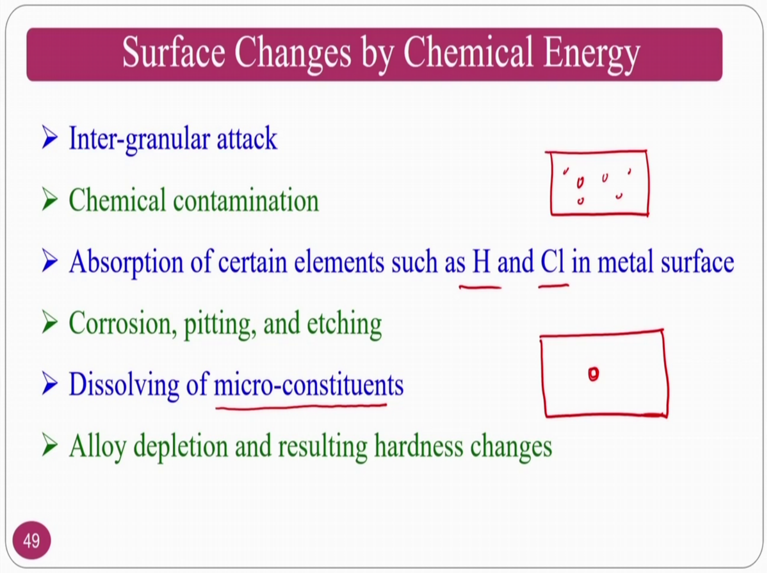

The surface changes by the chemical energy; inter granule crack, normally if there is a chemical energy there is a leaching process will be taking place and because of which there will be a inter granule crack. The chemical contamination normally if there is a surface if you do the chemical etching or electrochemical polishing process or something just you can have the contamination on the top surface. Assume that the stains, normally stains are done by a electro polishing. You cannot use the same thing in a human body, assume that it is a cardiovascular strength you can even put in a heart where the blockage is because it will have the traces of that particular chemical. So, you have to wash it. Why the traces are there? The traces are there because you are using certain chemical during this particular process. So, the traces will be there which is creates the contamination.

Absorption of certain elements such as hydrogen, chlorine in a metal surface normally whenever you have the electrochemical or chemical machining process you will always will have you hydrogen, chlorine. So, all some of the chemicals will be present on the traces on the surface.

Corrosion pitting and etching, normally if you are using on a iron based alloys if you see a acid etching or something if you do what will happen there will be a corrosion because these are highly affiliated towards a corrosion. Pitting that means, that there will be a holes will be formed assume that I have a surface like this there is a holes will be formed that is are the nothing, but the pits. And etching you can do the chemical etching process and other things.

Dissolving of micro constituents that means, that those particular regions assume that I have a particular surface this is an alloy, alloy has different elements. So, some of the elements are dissolved these are all some of the chemicals can dissolve, some of the elements. So, then this will leads to pits by going off that particular element from that particular location. Assume that I have a particular element which is affinity towards that particular chemical whenever I want to etch this particular surface what is going to do it will leave a hole here. So, because this particular thing is going off that is why it is leaving a bit there.

Alloy depletion and resulting in a hardness changes that means, that as I said some of the alloying elements will goes away and the hardness value will change. That is why in the conventional machining processes you have lot of problems, lot of advantages and other things.

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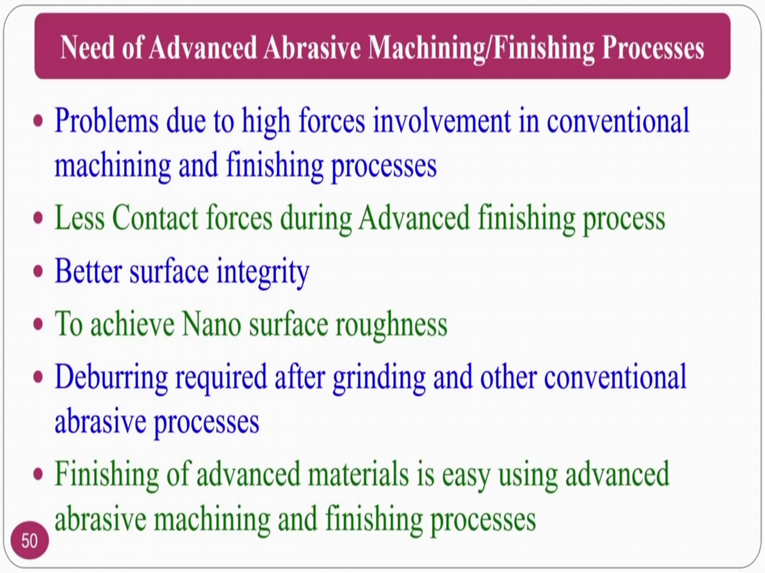

Most importantly for the surface roughness point of view, from the surface morphology point of view, surface metallurgical point of view, you have some constraints, but these processes are economic. Why the surface burning or surface roughness that you are generating during the grinding process is so high because the forces involvement between the grinding wheel abrasive particle as well as the plane surface or the workpiece surface. This is the most problem.

For that you can go at the same time this type of grinding processes because of the solid nature of the tool like a honing process, you cannot go and finish a complicate surfaces like a knee implant or a hip implant or some other things. For that purpose normally people will move towards advanced abrasive finishing processes which you come slightly later which you study slightly later. But you would require some of the advanced machining processes before you go to advanced finishing processes.

Conventional machining processes the forces involved are so high in advanced machining processes slightly less. If you see advanced finishing processes like abrasive flow finishing magneto logical finishing and other finishings, the forces are enormously low. So, that you can also finish this bio implants or complex surfaces because of this fluidic nature of the medium.

So, with the need of abrasive machining or finishing processes the problems due to high forces involvement in conventional finishing processes that is the one of the problem because of which surface roughness is very high, if the interacting forces are very high peak and valley height will be very high. So, this is the one problem.

Less contact forces during advanced finishing process. So, if you are going for abrasive flow finishing or a magneto logical finishing it is a fluid to the workpiece surface interaction. So, the forces are very less.

The better surface integrity that means, that you are going to get better surface roughness better metallurgical aspects, at the same time better surface morphology also you will get an advanced finishing processes. And achieve nano surface roughnesses, and deburring is required after grinding process because you have seen the burrs will be formed during honing process sometimes or the grinding process. But in abrasive flow finishing or some other process you may not require. And the finishing of advanced materials is easy using advanced finishing process like assume that I want to finish high temperature materials, if I want to finish bio materials then grinding is not a right solution or the conventional of the (Refer Time: 37:00) is not a right solution, but it may be a economic solution. But whenever you want to do particular component for aerospace sector or biological sector biomedical sector in the circumstances you do not want to take any risk because there is a direct involvement of human life that is why you can proceed for advanced finishing processes, ok.

So, as I am talking about grinding is a conventional finishing process I am taking into a next level of advanced finishing process, in between you come across with advanced machining processes in the upcoming classes then you come across abrasive finishing advanced abrasive finishing processes.

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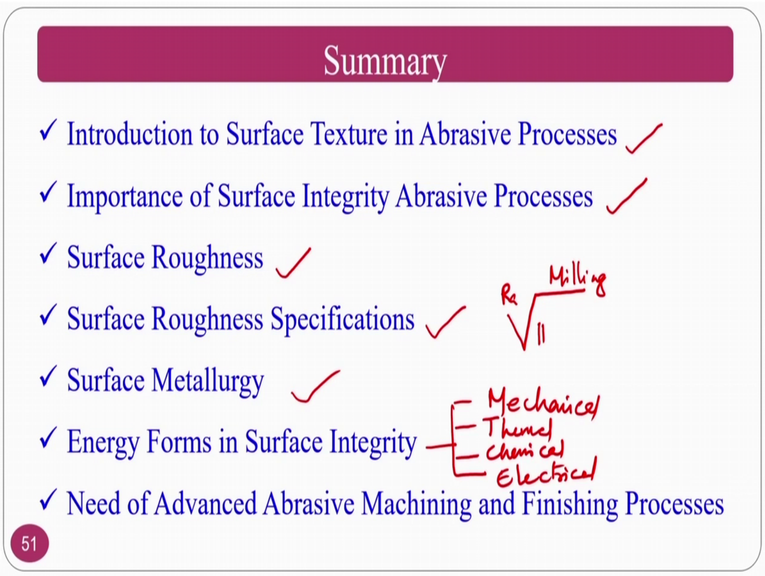

Summary of this particular class; you have seen introduction to surface texture in abrasive processes, importance of surface integrity which is nothing but surface metallurgy plus surface roughness that is nothing but surface morphology.

Then you have seen in a particular component of surface integrity that is called surface roughness, how do you represent the surface roughness, like this, you can represent you can represent the values you can represent the minimum Ra, maximum Ra and what is the process that you want to do and other things you have seen. And the surface metallurgy you have seen the elemental analysis using EDS energy dispersive spectroscopy, at the same time you can do a area scan line scan, and a point scan and other scans you can do.

And what are the energy sources that are causing all these things like mechanical, thermal, mechanical energy, thermal energy, chemical and so on you have seen.

Mechanical energy, thermal energy, chemical energy and electrical energy you have seen all these things, and need of advanced machining and finishing process that you have seen because I want in particular sector like bio and aerospace sector not much damage to the component is required. For that purpose you have to go for advanced finishing process, ok.

So, in next class we will see the advanced machining processes like abrasive jet machining, what abrasive water jet machining, ultrasonic machining, elastic emission machining and so on we will see in the upcoming classes. Till now, we have seen the conventional abrasive processes, now we move on to the second segment that is called advanced abrasive machining processes, then we will move on to advanced abrasive finishing processes. So, then we will see the final sector if time permits and other things. We will see the finishing of advanced materials using abrasive process and other things.

Thank you.