Introduction to Machining and Machining Fluids
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Lecture – 08
Surface roughness in Machining

Now we are into the surface roughness in machining. Till now what we have studied is surface roughness, lubrication in machining and all those things.

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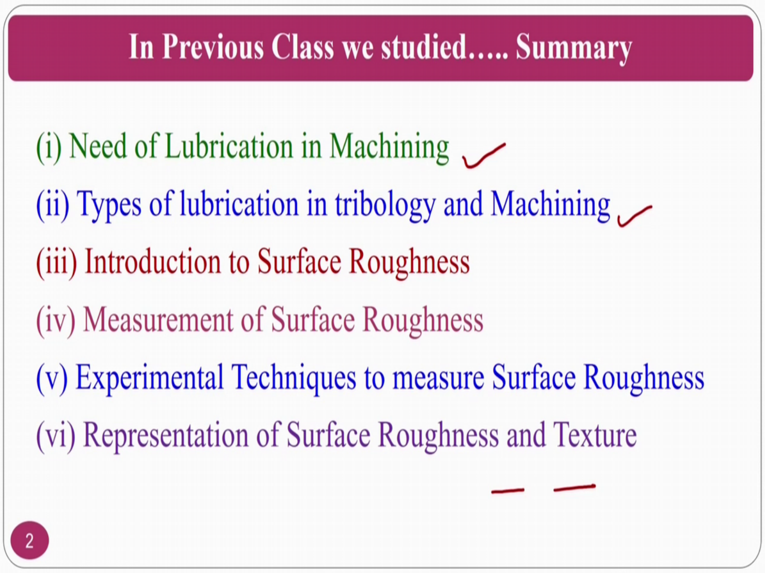

Whenever I am talking about surface roughness in material cutting, I am more inclined works what is the surface roughness in material cutting.

So, till now in the previous class, what we have studied is a, what is surface roughness? How do you define the surface roughness? What is center line average value? What is rms value? What is maximum peak to minimum value? And all these things this is the introduction to surface roughness, as the surface roughness is one of the most important responses that we take out from the machining experiments ok.

. So, we all study at the lubrication in machining, types of lubrication in tribology and machining introduction to surface that is what I was telling, how you measure the surface roughness, profilometers noncontact surface profilometers, and experimental techniques to and the representation of surface roughness and texture. These are all we have studied in the previous class ok.

So now we will move into exclusively what is the surface roughness in machining pertaining to this particular course ok.

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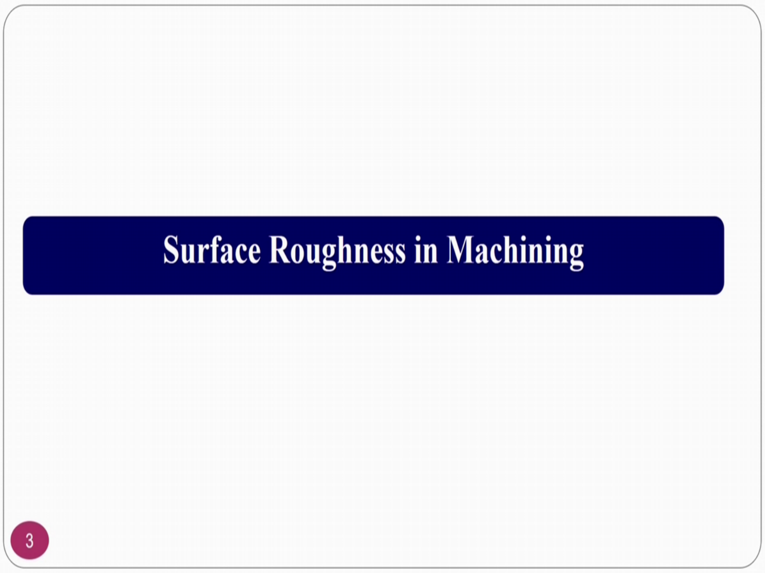

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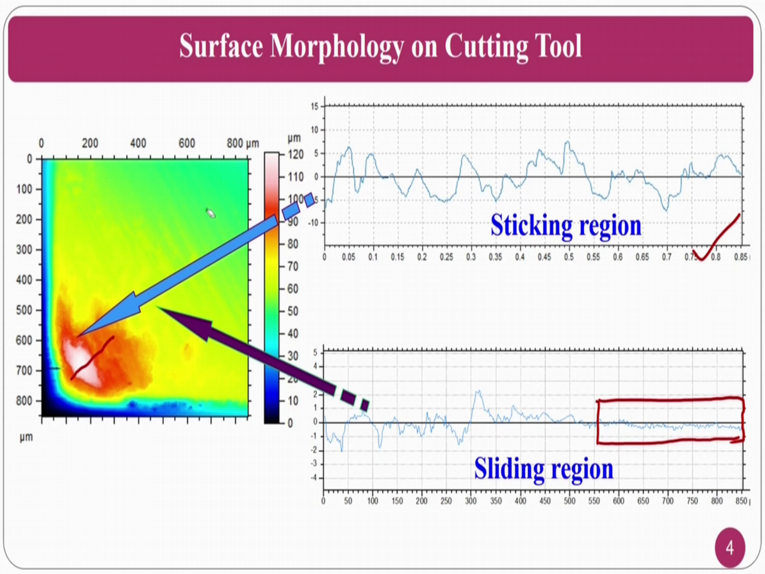

So, the surface morphology and the surface roughness is one parameter of the surface morphology. Morphology will tell you not only the surface roughness, there is any a waviness, there is any profile cr there and all those things.

So, for example, if you see the surface morphology of the cutting tool, one the machined, this is you have already seen, but from the angle of surface roughness. T previously you have seen this was a sticking region, and the sliding region as the tribological aspects. Now if you see, your perspective of looking. Now in the surface roughness, how do you represent the surface roughness, assume that I want to measure the surface roughness of the sticking zone, what I will do is I will just take the surface. Just I plot a line like this, and I will take the surface roughness or if I want to take across from the cutting edge. So, I will take like this.

So now that you will get in the form of surface roughness. So, similarly in this if you take in the region of this one, sliding region you will get the profile like this because if you see a flat region is there in this ok. So, gradually it is going to tending to the parent material. That is why, this is how we are looking from the surface roughness point of view.

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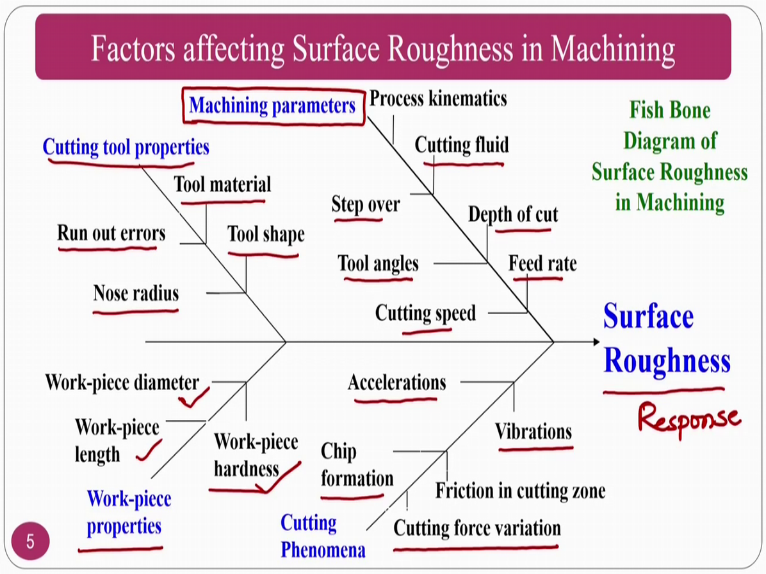

So now, what are the parameters are input conditions that will affect the surface roughness. So, what I am going to show you is a fishbone diagram of surface roughness in the machining. So, how the surface roughness will affect by various enormous input conditions that are there in the machining. So, if you can see the surface roughness, surface roughness is what my output response is ok, there is a difference between parameter and response. If I am seeing an input parameter; that means, that I can vary it because I am the person who is operating this machine, I can vary if the feed rate is the input parameter parameter means I can vary ok.

The responses when I talk about the surface roughness, surface roughness is a response; that means, that I cannot control it because it is an output response only I can pick it, I cannot change it; however, I can get different output by changing different input parameter ok. So, response is what I will get and input is what he will give. That is why whenever I speak about parameter; that means, that that are controllable things, and responses means what I am going to get ok. Surface roughness is for me a response.

If you see the machining parameters, the first I will take the machining parameters, the machining parameters are like cutting speed is one of the most important feed rate depth of cut, and the tool angles like rake angle flank angle and all those things step overs in the type of cutting fluids and process kinematics, whether you are holding it proper there. These are the major important input parameters, normally most of the researchers will.

So, the cutting phenomena, whether it is the acceleration phenomena is there, whether vibrations are there, the chip formation, you can see and friction cutting zone and cutting force variations. These are the other things that normally mostly people would not touch this; however, the design people who do design of these machine elements are the machine tools, normally thinks about if I am giving this input parameters they will measure the vibrations forces, and the chip formation as an output parameters ok.

However, the surface finish also varies with this intermediate responses. So, if you see the workpiece properties, the workpiece diameter workpiece length and workpiece hardness. So, these are the, another input parameters normally one can work is, how much diameter if my diameter increases, if the constant rpm if I am using if the diameter of workpiece increases what will happen? My cutting velocity goes up ok. Pi dn by 60, if you take that one de is, function and n is also a function. So, if my diameter increases my cutting velocity will increase.

So, workpiece hardness, if hardness goes up, I will take one some the glimpse of advanced in machining processes, where I will talk about the hard machining. So, hard machining means if you are working with much harder workpiece material that is called what; so, that is one of the studies that can takes place here.

Cutting fluid properties is another parameter that you can one can vary, that is a tool material whether it is a HSS CBM ceramic or something tool shape, whether the positive or negative, whether run outs are there are not on the tool, and nose radius whether I am going to use 0.4 or 0.8. For example, if you take a carbide tool, TPUN 16, 0, 3, 0, 8 so; that means, are the last one represents normally what is a nose radius ok.

So, in case of a one 16, 0, 3, 0, 4, 16, 0, 3, 0, 8 normally 0.4 is the nose radius in other case 0.8; where 8 is there if there is the most radius is about point nose radius. So, these are all the input parameters that will influence. So, this is the completely shows how these parameters influence my surface roughness. So, it is not so easy to control all these things. This is independent parameters, but in a machining system, these are all combined and that will be a combined effect also on the surface roughness. Not only this individual, will have a combined effect.

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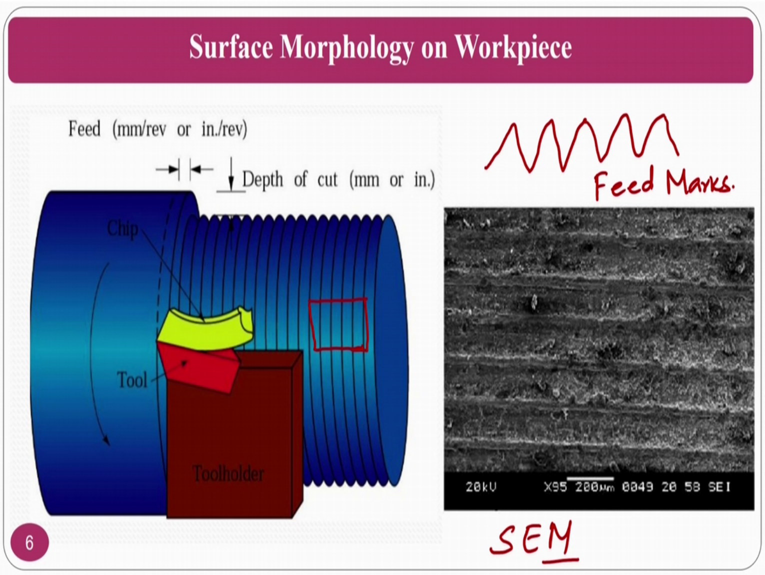

The surface morphology of the workpiece, if you see the surface morphology of the workpiece; so, if I am doing metal cutting, assume that this is a tool holder and this is the tool. If I am cutting my machining process, depth of cut is there and feed is there. Whatever we are seeing here, this if you if you see these things, anyhow you will show scanning electron microscope. This is the SEM image; I will explain you what is the SEM and all those things which will upcoming slides.

A SEM refers to scanning electron microscopy. If I take a part of this one, if I cut using the precisions and I place, in the scanning electron microscopy, being a metal there is no requirement of you for the gold coating and all those things. So, you will get this type of variation. If I want to represent normally for simplicity sake the surface roughness looks like this. In a turning process, these are nothing but the feed marks.

So, till now if I say after my statement that is the feed marks; that means, that most influencing input parameter, in the machining conditions are feed rate. Since these are the feed marks, this is feed is going to take part in a manager to decide the surface roughness.

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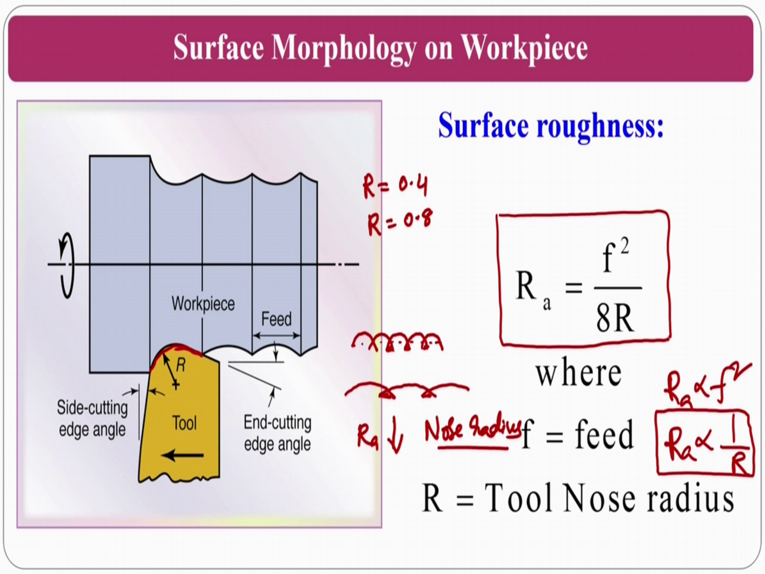

So, surface morphology, if you see nose radius is also a important parameter to decide surface roughness. Let me see.

So, this is the equation; where Ra is equivalent to f square by 8 R, where f is nothing but feed and tool nose radius. If you will see this picture, if my feed increases, what will happen? Surface roughness is proportional to feed, square R fee, surface roughness is inversely proportional to nose radius. How just now I was telling you that if there are 2 tools. Whose nose radius is one is 0.4 another one is 0.8, just time I was telling tpun 16 0 3 0 4, 16 0 3 0 8. Assume that a tool nose radius equivalent to 0.4, another case R equivalent to 0.8.

In these conditions, this is the nose radius, this is going to replicate on my workpiece. So, if my nose radius is low what will happen? It will come like this. So, what I am going to get I am going to get the surface finish of approximately, the if I remove all these things if I am going to get if my nose radius increases, what will happen? This is my nose radius ok. If I remove these things, what will happen? I will get a better surface roughness; that means that I am my surface roughness Ra value is going to decrease with respect to nose radius ok.

So, that is why I am telling, your Ra is inversely proportional to your nose radius. That does not mean that you have to go for very high nose radiuses. If you go for very high nose radiuses, there will be a problem of chattering and all those things. So, always you should strike a balance between your nose radius as well as your surface finish what you require ok.

Now, if you see the surface roughness always follows the equation. Just now I was telling you, that surface roughness Ra Equal to f square by 8 R.

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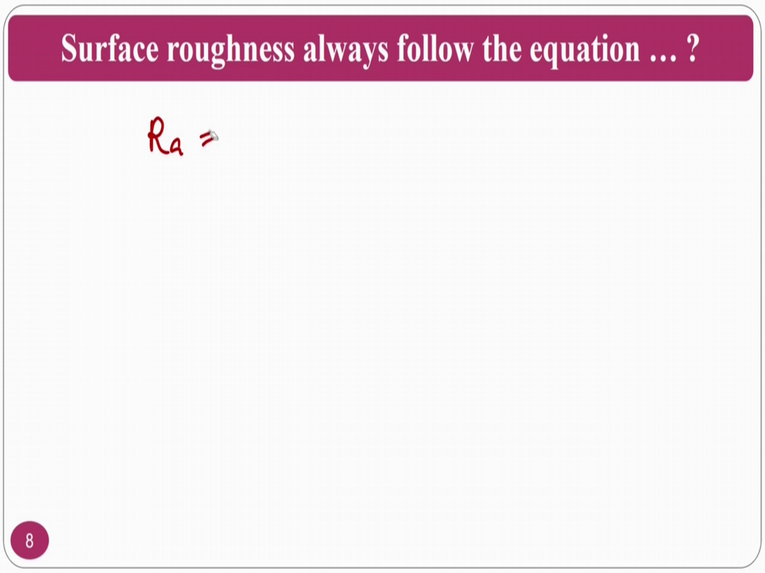

Do you think always is follows? Maybe, may not be, let us see what will happen. So, there will be conditions where this may not be 100 percent true, up to certain level it is true up to certain percent it may not true, in case of built up it is formation.

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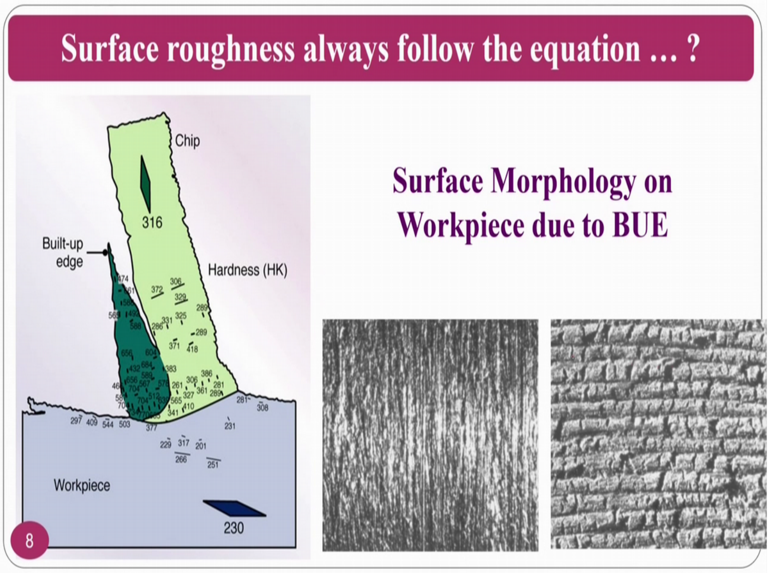

So, my f square by 8 R, normally stands when there is a assumption, that it is a continuous chip there is no built up edge formation and all those things. If the built-up edge formation is there, the surface roughness that you are going to get on the final product will be completely rough. So, your if you increase the feed; obviously, it little bit increase at the same time, your built-up edge that is forming on the surface is also influences the surface roughness ok.

So, these are the built-up edge fragments that are taking part on the workpiece. If that takes place, metallurgy will change, as well as surface morphology will change; that means, that R surface roughness will be changed.

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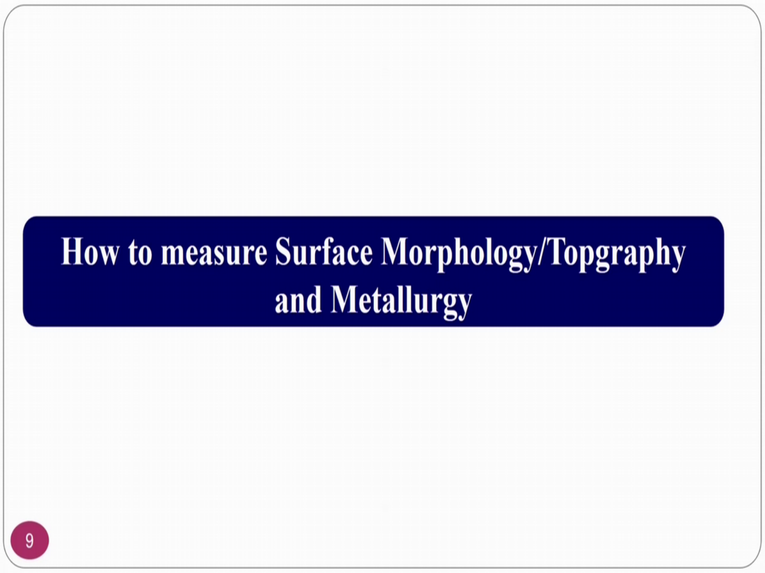

Now, I was talking about what is surface morphology, many times what is surface topography, what is surface metallurgy and all those things. In a metal cutting operation, you may be a PhD student. So, you are well acquainted with the machining process, but what is the quality of the product that you got it. That you have always characterized. For that purpose, I will just give you some introduction about, how to check the surface morphology.

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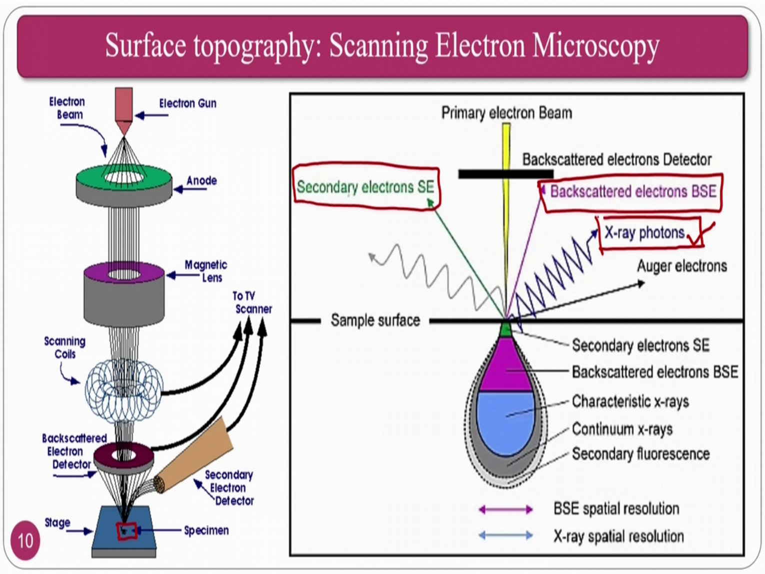

So, the first one is scanning electron microscopy, how the scanning electron microscopy a characterizes our the surface. So, if you see this one. You have a electron gun where electron beam in it is allowed will be there magnetic lens, will be there to focus. And it at last you will have a backscattered electron detector is there and the stage is there where you just place your workpiece, you just place your a workpiece on top of it normally you will get the electrons which will be detected basically. So, what are the electrons that are detected?

See there are various type of electrons that are detected. Among which there are 3 major things. One is x ray photons will be detected. Secondary electrons will be detected; which we are mostly worried about, and backscattered electrons we are worried about. These are the 3 things which normally we want as a mechanical engineer, but if the metallurgy people material science people they may go in deep of this knowledge. But; however, for the introduction of this course I guess this much is sufficient enough.

So, secondary electrons from here the secondary electrons are captured, and the detector will be there it will detect, backscattered electrons will come up to this one, this backscattered electrons are strictly bigger and if you just bombard it and it will go to the detector of the backscattered electrons. And x rays will be there to detect the elemental analysis.

So, most of the time mechanical engineers have a slight difference, because backscattered imaging as well as the secondary electrons imaging are the 2 types of imaging so, the difference; so, what will be the difference. So, for a be tech students are the basic people who are working on the characterization of the surfaces in the mechanical engineers you may have some of the doubts.

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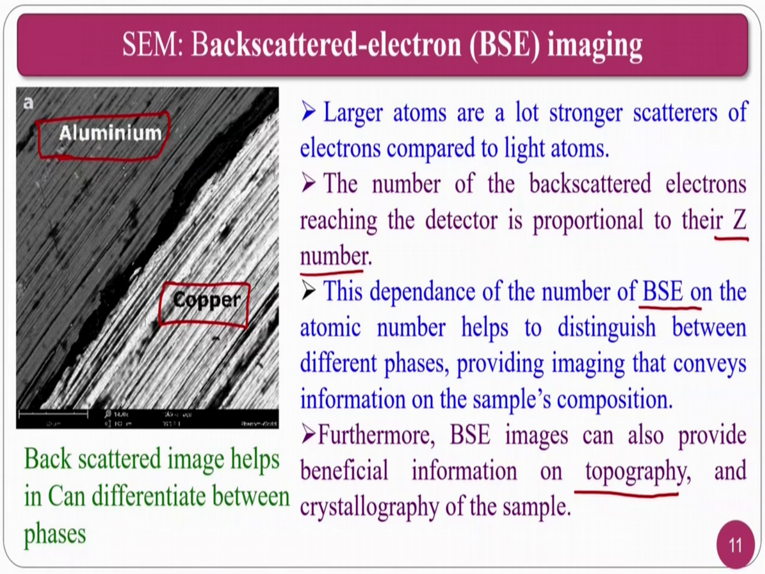

So, if one can understand between the backscatter image as well as secondary electrons image, you will be used this technology for choosing which type of image I want after doing my machining operation.

If you see the backscattered image, just I am if you see there are the aluminum and copper 2 faces are there in a alloy. Larger atoms are lot strongers and compare to the light atoms this number of backscattered electrons reaching to detector proportional to their z number that is valency number, depend on the number of backscattered electrons atomic number helps to distinguish within different faces providing the image. And what I want to tell is the back scattered image helps you in terms of differentiating the faces.

If I have an alloy ok, if I am doing a machining on an alloy where copper and aluminum is a part, if my surface is there, whenever I focus, if I want check the what are the faces are available on the surface, I should take the image which is back scattered image, so that you can differentiate aluminum you can differentiate copper ok.

My intention is to check the faces, then I have to, but back scattered image also give surface topography ok. It also give surface topography if, but conditions are the, quality of this may not be superior to the secondary electrons image. If you are thing is to find the element I mean to save the faces sorry, not the elements, it is the faces, then you should go for always back scattered image; when you are doing your characterization using scanning electron microscopy.

Now, various field enhanced scanning electron microscopies are also there which go beyond work the scanning electron microscope is nowadays are doing.

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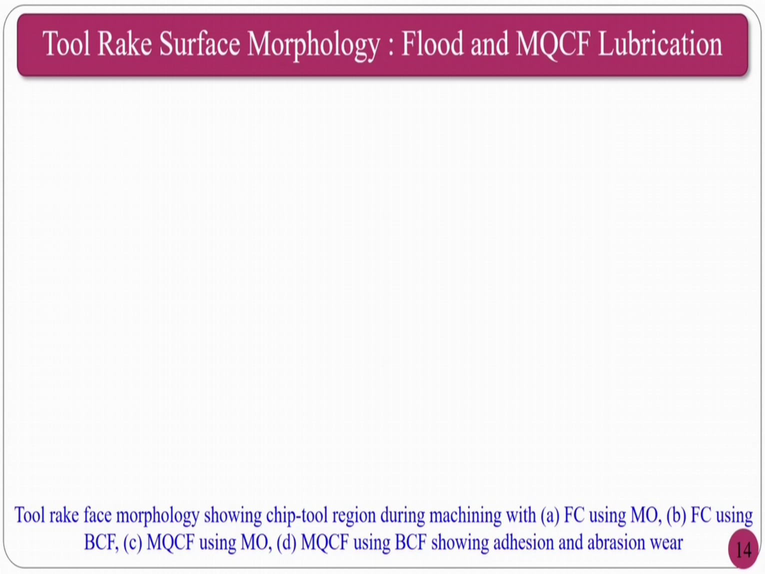

If at all, I want to know about the surface morphology. Then you should go for secondary electrons. They in contracts a secondary electrons originate from the surface, are near surface of the sample ok. These electrons are emitting if you would have seen clearly in the previous slide where I have shown the scanning electron microscopy, if you see here. So, the secondary electrons are coming from the surface. If you see the select, secondary electrons are coming from the top; that means, that surface topography will be the better one ok.

So, there are interaction between primary electron beam, and the sample have lower energy and the backscattered electron than the backscattered electrons. Just I will give you some glimpse. So, if you see figure a. This is the full backscattered image. I am talking about the image of particular location on a leaf. I it is a taken from the Wikipedia. Acknowledge to the Wikipedia. Just I want to differentiate between what is the backscattered image quality, what is the secondary electron image quality ok, for that purpose. The first this is the image which I have taken, which is a full backscattered image. If I want to convert this full backscattered image surface topographically, the final image that I am going to get is this one that is b.

But if I locate the same area and if I am taking the image from the same area using secondary electrons ok, electrons, this is a topography, you can clearly differentiate between the pictures between a b and c. That is why the understanding what a mechanical engineer, we may not be a very good metallurgical aspects, but whenever you are taking your pictures, you should be cautious to know what you want. If you know what you want half of the problem is solved. So, you can go ahead with this one and you can take ok.

So, what do you understood from this force lights of scanning electron microscopy is, if I want the faces, I should go for back scattered image. If I want the surface morphology are the topography which is there on the surface, I should go for secondary electrons imaging. Hope you understand ok.

Machined work piece surface morphology. If I want to see the machine surface morphology, this is the surface if you at all if I am taking a secondary electrons image and this is taken from a micro turning process.

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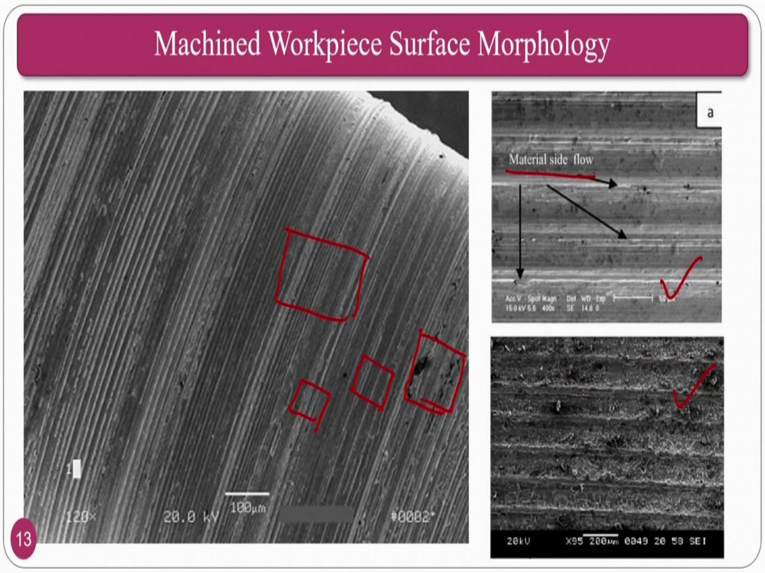

It is not normal turning process, it is it is taken from a micro turning, and you can also see the feed marks.

So, the feed marks are varied, if you see the feed mark here, if you see the feed marks here, it is slightly difference is there. So, this is all depend on your cutting-edge quality, if you are maintaining the cutting-edge quality you will get uniform; otherwise, you will get lot of problems, these problems may be because of material. Defects in the work piece may be the cutting-edge problems are if you are not supplying cutting fluid properly. These are type of problems will come.

So, you can also see the material side flow. Normally, whenever you see the merchant theorem you assume, that there is no side flow, but practically most of the times you will have the same flow in the ductile materials ok. So, you can see these are the feed marks, if at all I will take a cut from here and they just put a slab on it. But these pictures are different from this one. So, for you for the better understanding of the students, their pictures are taken from the Google source. And we are thankful for the authors who have posted it on the Google are publish there one ok.

So, the tool rake surface morphology. Just I want to say you that till now we have seen secondary electrons how it is affecting and backscattered affecting now x rays. So, I was telling you that x rays how it will help you.

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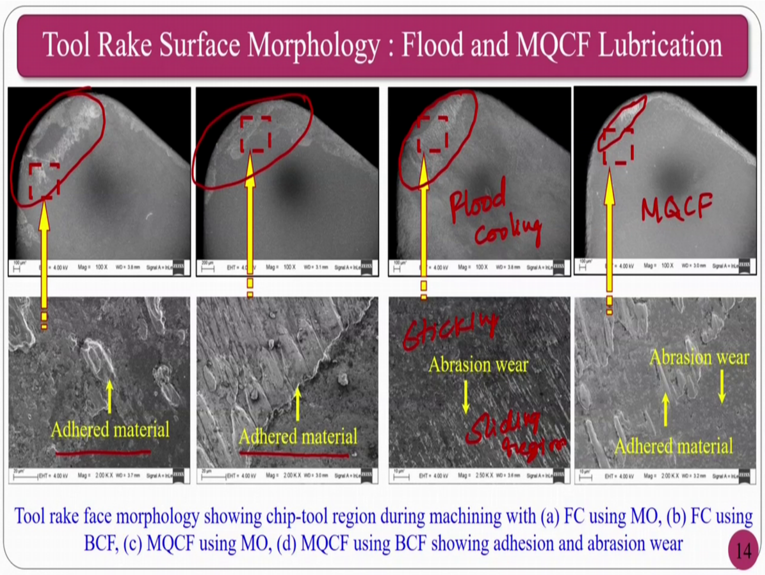

So, if at all I want to check, this analysis also I want to give you some glimpse of tribological aspects. For that purpose, flood cooling and minimum quality cutting field. That is called minimum quality lubrication type of things is tested at our laboratory; where in you can see that the secondary electrons image is taken here, and where you can see the sticking region and at the materials also.

Now, this is the flood cooling, and this is the MQCF with the mineral oil. Normally, we also tested with some other advanced cutting fluids that is called bio cutting fluids; where we have done with bio cutting fluids of flood cooling as well as MQCF that is clearly shown. What I want to show here is the scanning electron microscopy, pictural image of cutting. So, you can see the sticking and sliding regions, if you are going to increase if you see these particular pictures, this is the sticking and sliding region, but if you are going to in a flood cooling.

in minimum quality, cutting fluid application where high pressure is there and forced convection is there which is better in terms of heat extraction. You will have a very less amount of tool wear ok. So, if you see from the tool wear, it is the picture is you are seeing at the tool wear, if I am seeing from the scanning electron microscopy perspective I can see from that both ok. This is a sticking region, and this is a sliding region.

Now, for this type of things, how to check the elemental mapping? Ok.

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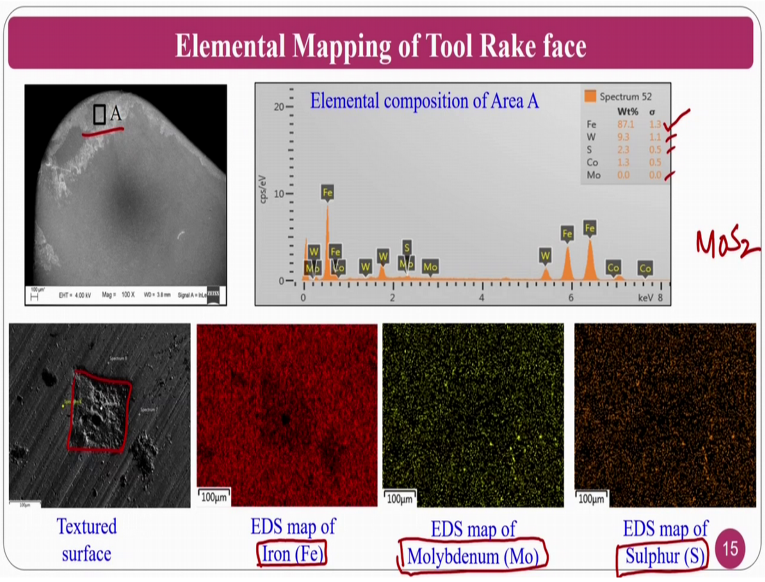

So, this is the area, for the same tool how my x rays, already you have seen backscattered and the secondary electrons now x rays. So, how the x rays will help me? X rays will help me in detecting what are the elements. Backscattered will give me the phases, here it will do me what are the elements.

For a example in this tool this is the tungsten carbide tool, where in the slightly tool adhered by the work piece material; that is called a slightly built up edge formation is there. And I want to check whether this particular, where white area is there is iron is there or not; that means, that if I am metal cutting with respect to the stainless steel are normally what we have done is ASS 3 1 6 L I think. So, if I am doing a stainless steel where F e based material is there or not.

So, you can check if I am doing a point analysis at this point, what where we have specified, it is shows maximum amount of iron; that means, this particular portion contains not of iron; that means, there is a adhesion by the chip material on the tool surface. So, I confirm by using electrons bombardment of scanning electron microscopy by edex analysis; that means, that elemental diagonal analysis, and tungsten carbide in how is there and molybdenum is a binder material will be there cobalt will be there.

And if et all I want to check a particular portion of any material. Normally this is the image that we have taken from the cutting tool, which is textured basically, where I we have a weakened hardness indentation is there; which is micro texturing is there where in the solid lubricant this filled. So, solid lubricant is a mos 2. So, you can clearly seen, elemental mapping tron always iron is there on the surface. At the same time molybdenum is there. Under the same time sulfur also is there.

So, this is how you can map the elements; where this red spots are there get those are belongs to iron. This is molybdenum, yellow parts are molybdenum and these orange ones are sulfur ok. So, this is how you can detect the elements. This is about the scanning electron microscopy.

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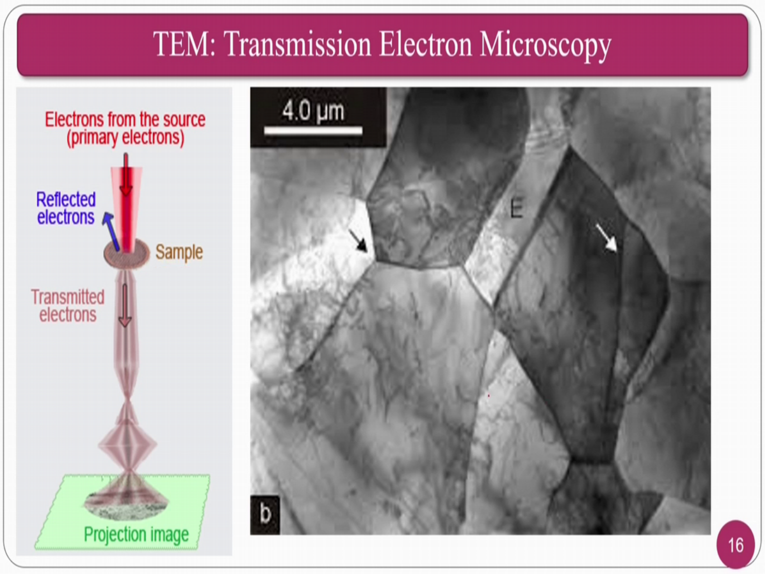

Now we are moving to transmission electron microscopy. This is another way of checking in depth analysis. Whenever I am doing the machining process, the machining process where the temperature is very high what will happen? The grain boundaries will change; that means that the particle of that material may enlarge.

How to check the grain boundaries and all those things? Because in scanning electron microscopy my sample is very big, and if I want to inject and want to check the grain boundaries it may not be possible. For this purpose, the first and foremost a difficulty situation are difficult work is that the sample preparation. You have to make the sample so thin so that the transmission will takes place across the sample ok.

So, the transmission electron microscopy, where the electron will be moved and transmitted through the sample I said the sample should be very thin sample. So, that the electrons will pass through and give the projected image. How the image look like. If it is just to see, this is also taken from the internet. So, you can see the grain boundaries and all those things grain structure and all those things. This you may not get in the scanning electron microscopy, because you have you need to pass to transmission, it has to transmit through the, if it can pass through the sample then only the it can give the image. It is what the transmission electronic microscopy gives.

So, the application of this one as I said if I want to do the machining where the temperature is very high, whether parent material grain is some excise whether the excise is still there are not after the machining on the surface. So, it may it have increased by some animators are Armstrong ok. Or it is not increased for that purpose transmission electron microscopy will be used, whether this still in the crystalline region or whether it is moved to amorphous region how the chip look like and all those things we will see, if you see the chip ok.

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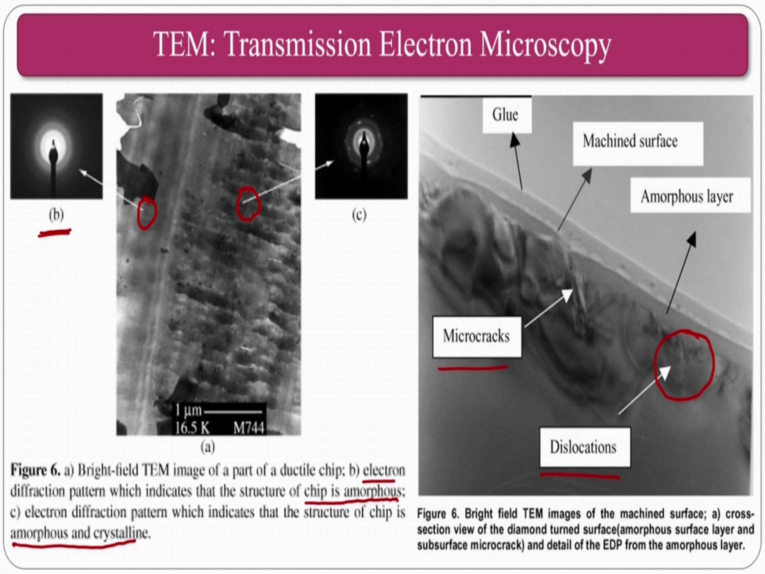

So, chip will have different zones. One is a free end another one is a machined end, if you see the both ends if you see this region where you do this is called the say seed graph. Normally, if you see the b, b show the amorphous nature, and the c shows crystalline as well as amorphous nature if I am looking at this one sad pattern of this one. So, you can check, one case is the machine region, or the machining side you will have the amorphous nature. On the free end side, you can see the crystalline plus amorphous nature.

So, this can be detected by sad images. And you can also see the machined surfaces. If at all, only thing is that I have to prepare the same thing accordingly. If I cannot prepare, where my beam cannot transmit across the sample you cannot take it. So, you have built the machine surface, and just to glue it and all those things, you can see the micro cracks dislocations and all those things if at all I want to check, the surface metallurgical aspects you have to go for the elemental analysis of SEM and partially you have to go for all the tem analysis also ok.

this is another area, being some of the students may be from bachelors from other schools may be starting of the masters. This will help you in a great way to characterize your BTP samples or MTech samples, which you are doing for your term projects, or MTP projects or this one in small small institution. So, if these facilities may not be there. So, this once you got this knowledge, you can search around your locality if this characterization facilities are there, you can utilize the services. And you can do good research work. That is what my motivation to explain to you for the manufacturing students ok.

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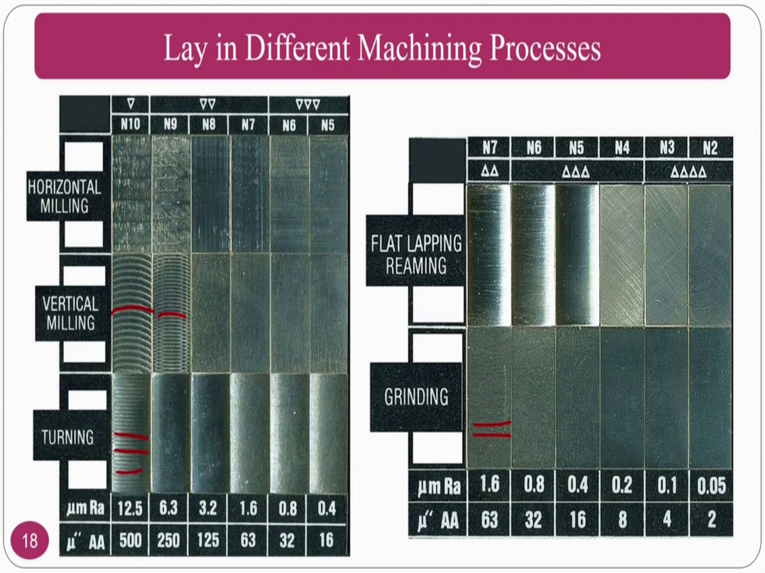

I was giving you the lay lays nothing but predominant direction of the surface roughness. So, if you see the horizontal, and anyhow I will come because the lay I am ending the surface roughness here itself. So, I am not coming into the next zone. So, milling, grinding, lapping and all those things the predominant direction horizontal milling you will have a particularly lay is anything, but predominant direction of vertical milling you will have a lay like this. Turning operations you will have a feed marks marks.

So, grinding operation is always you have a straight line, because always you have a grinding will it will rotate, tangentially to the workpiece and. Normally the lapping process the particles are freely moving. In that circumstances the particles have independent to move in any direction; however, most of those times it will be in the direction of the motion of the lab. So, this is about the lay that is predominant direction of surface roughness. So, you are talking about the big spectrum of surface roughness, then it will be like this.

So now, we will move to the material removal rate. Say, many mathematical models are there out and all those things. I am not going into the complete mathematics. As I said there is a separate course noted by many other senior most faculty where you can study. The mathematics aspects and material removal, there are standard textbooks also it is very simple how do you calculate and all those thing just I will give you the some introduction and I will move on to the machinability aspects ok.

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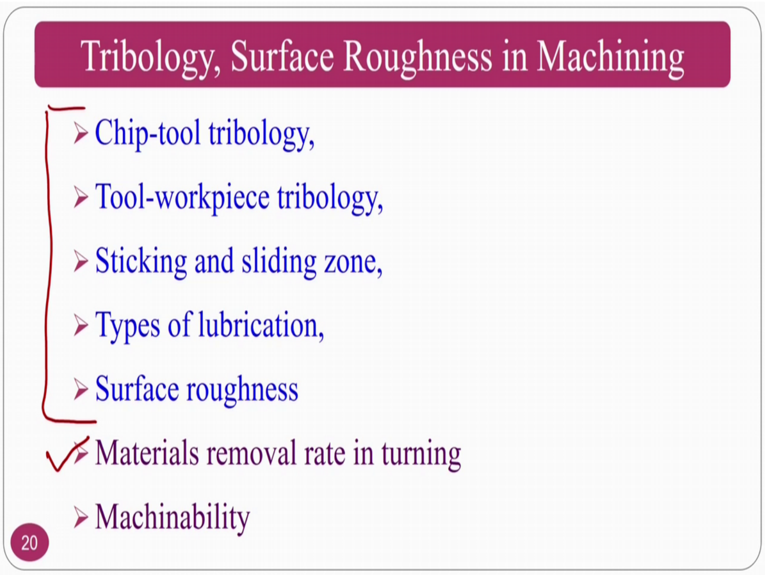

Till now we have studied all these things. And now we are going into the material removal rate in turning operation, single point cutting tool.

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So, then we followed by the machinability.

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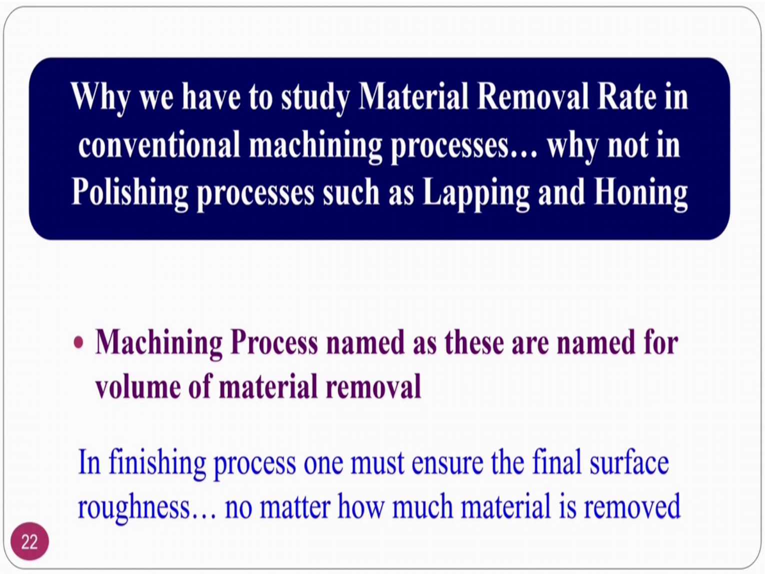

So, why we have to study the material removal rate in conventional machining why not in polishing process. Such as lapping, horning, some other advanced finishing processes and all those things ok.

Why we want to calculate? The process itself is called machining process, the machining process and the finishing process difference is my machining process means how much material I am removing. I am worried about what is the volume of the material that I am removing. In a polishing process I am not worried about how much material I am removing from the workpiece I should look at what is my final output in terms of surface finish ok. So, if my surface finish is 50 nanometers that is what my requirement is for the finishing or the polishing process, whether I remove one mm or one micron thickness or does not matter for being in a material removal process; that means, that conventional machining process, I worry about the material removal, because if I want to do the turning operation and bring a workpiece from 80 mm to 75 mm, I worry about the thickness material removal I do not worry about the surface finish.

Still, I worry about surface finish. But my major concern is material removal. That is a difference between a machining process, and the finishing process or a polishing process. Here in a machining process, how much materially I removed in a finishing process, what is the surface that I got. That is what I am telling here. That is how much material I am removing is a concern here what is the final surface roughness is a concern.

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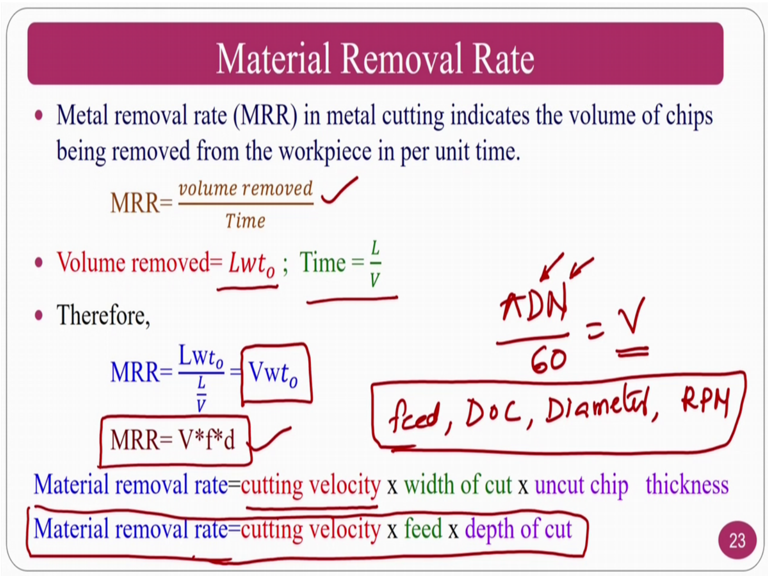

So, if you see it is very simple whatever the thing material removal in metal. Cutting indicates the volume of the chips being removed, volume removed per unit time. So, normally volume removed is Lw and t naught; where is t naught is nothing but my uncut thickness, w is nothing but my depth of cut, and L is nothing but my length. So, you can write time equal to length of cut by the velocity cutting velocity. So, if you can calculate this normally you will end up with this one ok.

 if you talk in terms of input parameters, it will be like this. So, where you know all the input parameters, which is cutting velocity in, but you know cutting velocity, you can calculate from the pi dn by 60. You can calculate the cutting velocity, where you the input parameter is rpm that is a rotational velocity of the workpiece, d is the diameter, and other things are kwon to you.

This is the only thing that you are calculating; however, these 2 are input conditions. Apart from your feed and the depth of cut ok. Just total input parameters is diameter, and the rpm rotations per minute. If you know all these things, you can calculate your material removal rate ok. So, that is what is given here ok. So, I just divided the cutting velocity also into input parameters.

Now, we will move to machinability.

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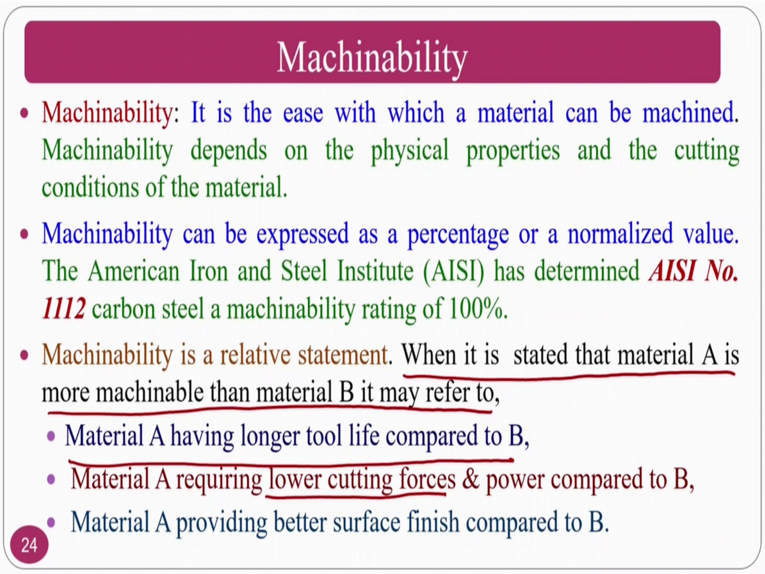

So, machinability is nothing but is nothing but ease of machining. How easily I am going to machine my workpiece is nothing but a machinability. Given material maybe anything to me, rather I have machined it with easy or not is what the machinability; that means, ease each material can be machined machinability depend on physical properties of the cutting conditions and the cutting conditions. Also, mission ability can be expressed in the percent of normalized value, these are the some of the standards that one can follow machinability is a relative statement ok.

So, what when it is stated that material A is more machinable than material B, it is a I said now it is a relative statement. Whether I have 2 materials assume that I have a mild steel in one hand and another side I have a silicon carbide. So, which is easy basically with the common if you are a machining engineer or basic metal cutting is known to you you can; obviously, say that mild steel is much easier to cut.

Why you say you are talking about the relative with respect to the silicon carbide ok. So, it is always relative. So, machinability is all squeezed, which material a having a longer tool life compared to b, then you can say that material a is more easy to machine. Material a require lower cutting forces, and power compared to b, then I can say material a is easily machinable or machinability of material A is good. Material A is providing better surface finish compared to B, to B in this condition also the 3 conditions are individual conditions if any one satisfies; that means, that my material A is much better machinability compared to material B ok.

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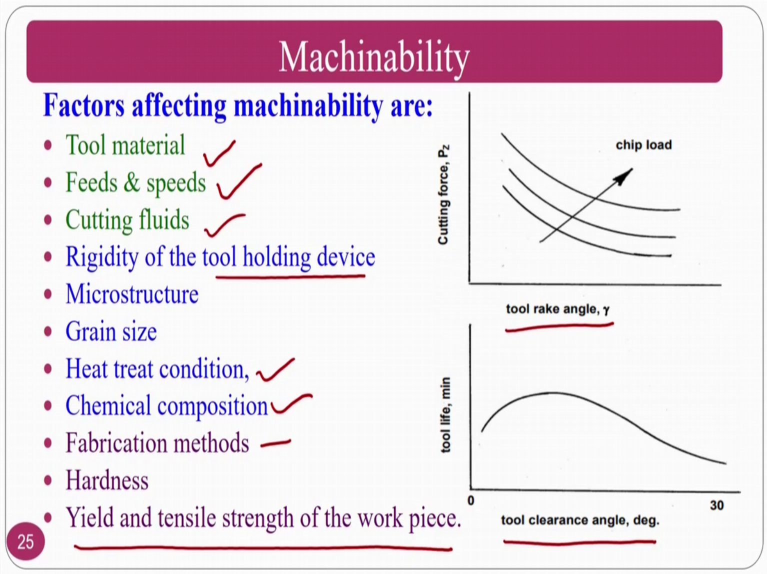

This is the relatively statement and the factors affecting the machinability are tool materials, feeds and speeds cutting fluids and the rigidity of the tool holding device how regidly I am holding. If it is not hold properly it may deflect. So, if deflect. So, the my machining conditions completely will destroy the microstructure. That I am going to get on the surface. Grain size of the machine surface heat condition chemical composition fabrication methods hardness yield and tensile strength of the workpiece. In many conditions will depend decides. In fact, of the machinability if it is very hard it is very difficult to machine ok. You have to find some alternative solution to make the machining of that particular material is easy. So, that is called machinability.

So, if you are going to get a good product with the less forces and better surface finish for a particular material, as you have seen with easy; that means, that that particular material is easy if you are a manufacturing engineer in certain company if you think if customer comes and ask you to machine this type of materials, you have to see this machinability whether it is easy, and whether it is capable for our existing machines and all those things ok.

If you see the tool rake angle versus cutting force, normally the tool rake angle if it increases, it is sharpness increases and the forces; obviously, will goes down. So, what is the rake angle that I have to use for particular cutting of this material? To clearance angle also not play much more it will rub again is the final product so obviously, you should take care I also say that clearance angle is nothing but the flank angle.

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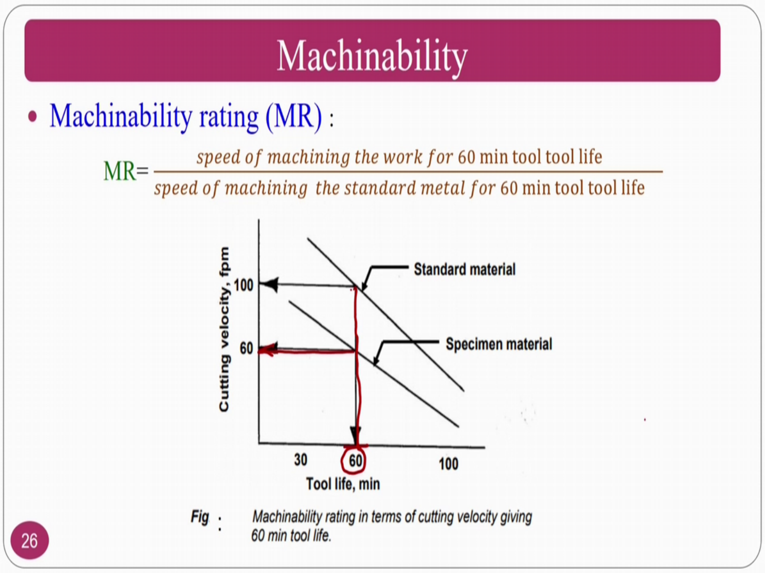

So, if you see the machinability rating, the speed of the machining of the work are 60 minutes of tool life to the speed of machining of a standard material for 60 minutes of tool life. Normally you decide machinability rating by this equation. At the same time, if you see particular material cutting velocity 60 and 100, if you are seeing standard material and specimen material is will have at 60 minutes.

So, my specimen material will have 60 to 60 for the same specimen, how about the standard, material it will have the you can go up to the cutting velocity 100 ok. So, for the 60 minutes as one hour is my tool life condition for this one ok.

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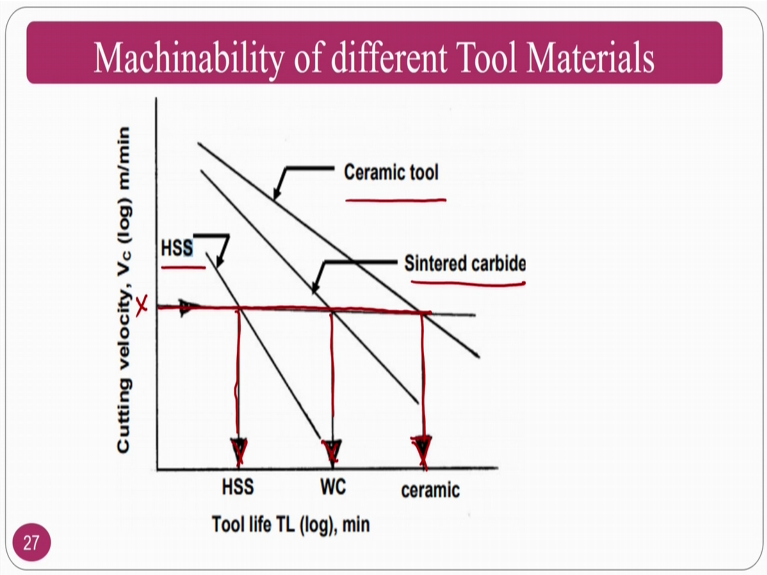

If you see the different materials, the ceramic tools sintered carbides and HSS, if I am taking the one hour as my tool life, or if I am want to check for the particular cutting velocity, I can say I can just drop this is what the cutting velocity, assume that this x is the cutting velocity that I want. So, HSS has it is own tool life and ceramic material and sintered carbide ceramic. So, you can draw here and you can show or you can identify what is the tool life. So, this will tell the machinability of my particular tools.

So, this is about the machinability.

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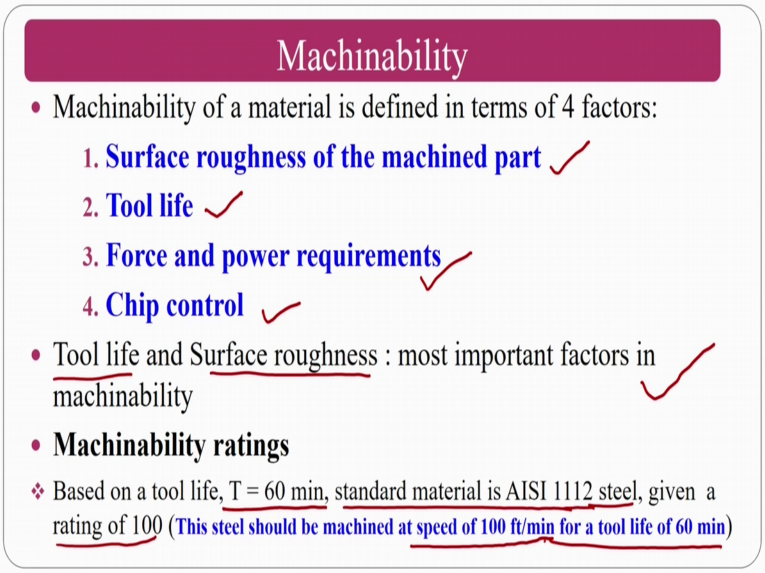

So, again if you see the machinability normally output responses how I will look at is surface roughness of the machine part; whether I am getting a good surface roughness, tool life for that particular material if I am having a better tool life; that is, that work piece material machining is machinability is easy force and power requirements power requirement should be low, if the forces are low. So, forces experiencing during machining of this material should be low and chip control, if I can control the chip easily like there is no entanglement there itself and all those things. If it is a discontinuous is there by using the chip breaker and others.

Machinability rating if you see the among all is full tool, life and surface roughness are the most important factors that will decide the machinability of that particular material. So, this is the condition for most of the companies are whenever you are taking a research should look into it. I should get on a product better surface roughness with high tool life; if I am getting you go for it.

And you choose that particular workpiece material tool material combination just machinability rating just you have seen, if there t 60-minute standard material AISI 1 1 1 2 steel given normally if the rating is 100 this steel should be machined at the speed of 100 feet per minute normally the textbook, which we followed is a American one. So, abroad one so, here it is taken feet for the tool life of 60 minutes this is what the machinability rating.

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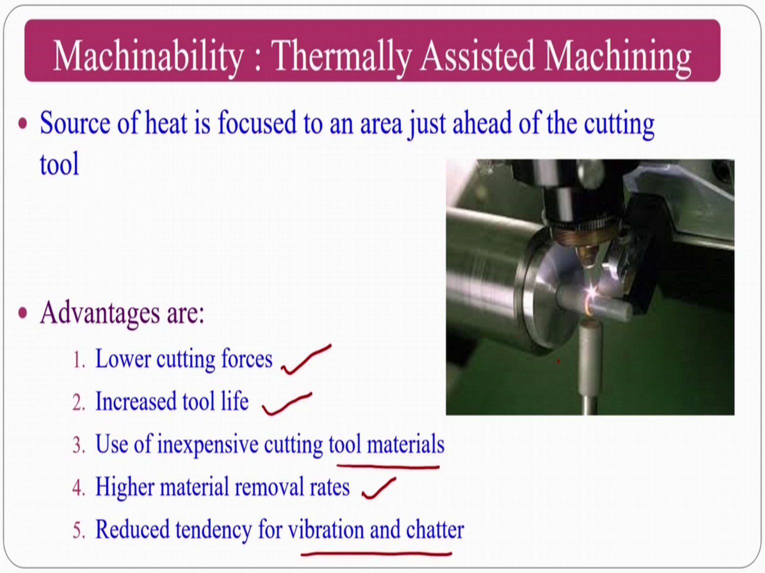

So, the final thing that I am going to talk about is a machinability, whenever you are talking about the ceramic materials. Ceramic materials are brittle metal a glass if I want to machining glass, what will happen if the forces are very high? It will break into pieces. So, how do you overcome it? So, the for the purpose there is called thermally assisted machining, which I have already talked to you and I am going to elaborately talk at the end where I am going to talk about advances in machining process processes. Just I will talk, if the ceramic is there, just I bombard a thermal that is means laser, I make the ceramic material softer. Then I will cut using a single point cutting tool ok.

. So, the laser is falling here, if you see here laser is falling. And the single point cutting tool is turning under. So, this is called ductile resume machining of brittle materials. What do you mean? Ductile resume machining of the brittle materials. Material is brittle, you are heating bringing into the ductile mode making it soft ductile mode means making soft now you are removing.

What are advantages that you are going to get. If you see the advantages, lower cutting force because it is softer material, tool life will increase because it is forces are very less. Inexpensive cutting tool materials you can go for normal tools. Because the material is in soft condition the higher material removal rate you can go for higher depth cut and feed also. And the reduces tendency for vibration. Because workpiece now no more a brittle and very hard it is ductile in nature.

That is why you understand now the machinability is improved, if I want to cut directly ceramic I need diamond tool, which is costly. At the same time hardness ratio is very low because if I want to cut a ceramic to the another CBN or diamond hardness ratio is very vary low. So, forces are very high, tool life is low, and the tool cost is very expensive and the material removal rate you cannot go for a very higher and vibrations and charter also comes.

So, if at all I have a simple solution like heating for example, if somebody want to do on soft some other small ceramics, you can go using there is some papers on hot machining like oxy acetylene gas flame you can use and you can cut with the carbide you can use, that technology also because your acetylene flame goes around 3000 degrees temperature. So, you can look into it is how you can make the process easy.

Thermal aspects of machining what I want to show you is, why we are going for the turbine aspects of machining. If you see the thermal aspects of machining already I have shown you.

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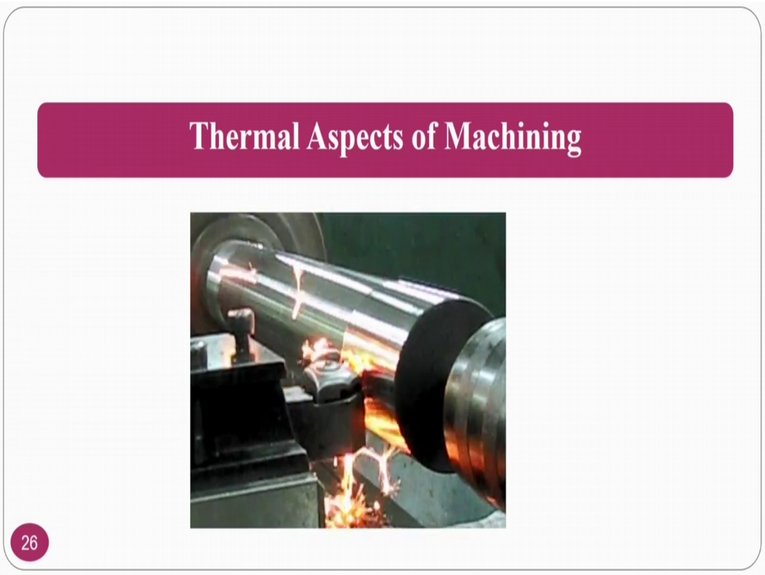

Just watch the video. If you watch the video; see lot of fire or chips with the red red color chips are moving in the machining region that is just going away. So, you can understand how much heat is generated. What are the thermal aspects are going on during the machining operation if you see the chip; red red chip is accumulating there ok. You can see in this area, you clearly see the chips are accumulating in the machining region which are very red red hot hot chips. So, the thermal aspects plays a major role. Now you can see that chip the continuous chip in red color is accumulating there and going off after some time.

. So now, you can understand what is the temperature generation, how the heat is affected there, and all those things. You can see now the.

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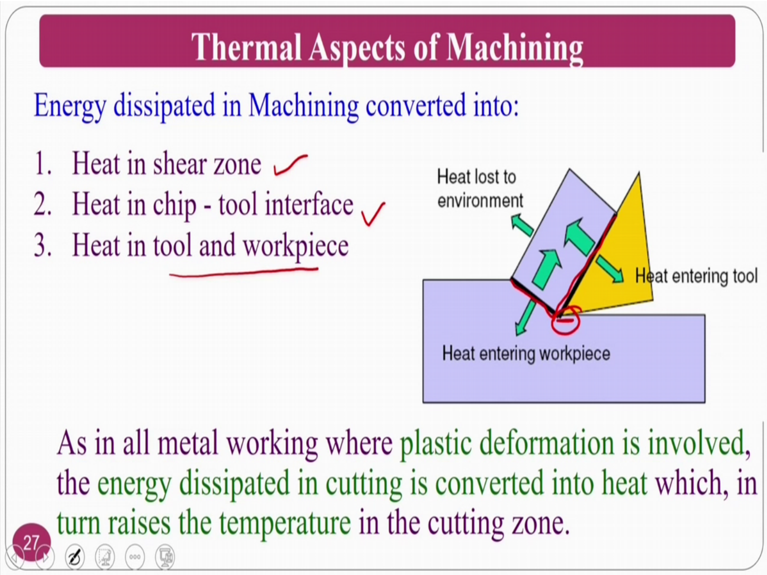

Energy dissipated in the machining is converted into the 3 zones; that is called the heat in shearing zone. And heat in chip tool interface that is this region. This is called a shearing zone. This is called chip tool interface. Another one is tool work piece this region.

As in all material working where the plastic deformation in energy dissipated in the cutting tool converted to heat, which in turns raises the temperature. So, because of the severe plastic deformation, normally the heat is generated now heat dissipated which is in terms of which raises the heat, raises the temperature with the machining region.

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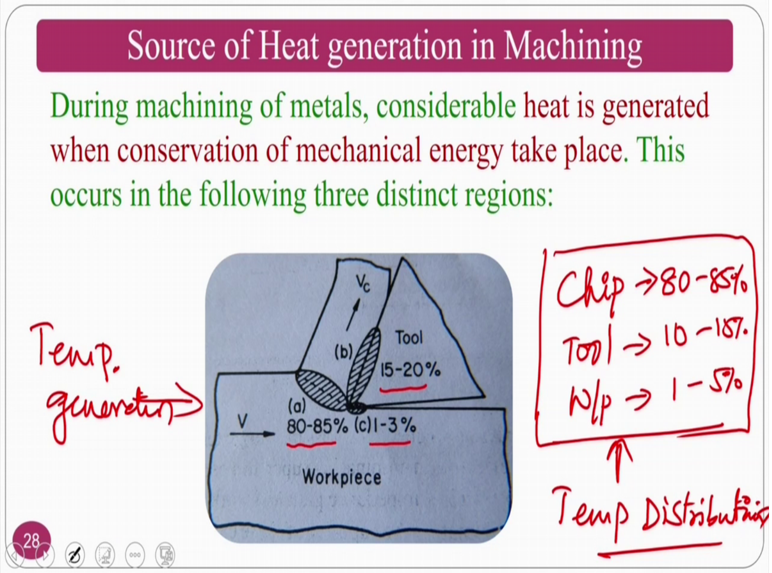

There is 2 things, one is heat generation, at the same time heat distribution. During the machining of material considerable heat is generated, which converts mechanical energy takes place this occurs in the following distict region. So, normally the heat is generated 80 to 85 percent in the primary shear zone. And 15 to 20 percent in the chip tool interface and one to 3 percent. Sometimes, it will be 5 percent also in that tool work piece interfaces ok, this is the generation of the heat.

So, normally the distribution; if you see the distribution and all those things so, here it is not there, but; however, I will explain you the distribution. Normally, 80 to 85 percent will be taken by the chip. This is the whatever you are showing the figure is temperature generation of the heat generation. So, how the distribution normally chip will take 80 to 85 percent. The tool or cutting will take around 10 to 15 percent. So, the workpiece takes around the one to 5 percent ok. This is the combination of these things will takes place. This is nothing but temperature distribution. This is temperature generation, this is temperature distribution ok.

So, there is a slightly difference is there. In temperature generation, it is the interfaces are the shearing zones. Here distribution, normally distribution I have given apple to ramu; that means, that I am giving to individual entity, that is nothing but this one. So, I am saying individually how the distribution even distribute the aspects.

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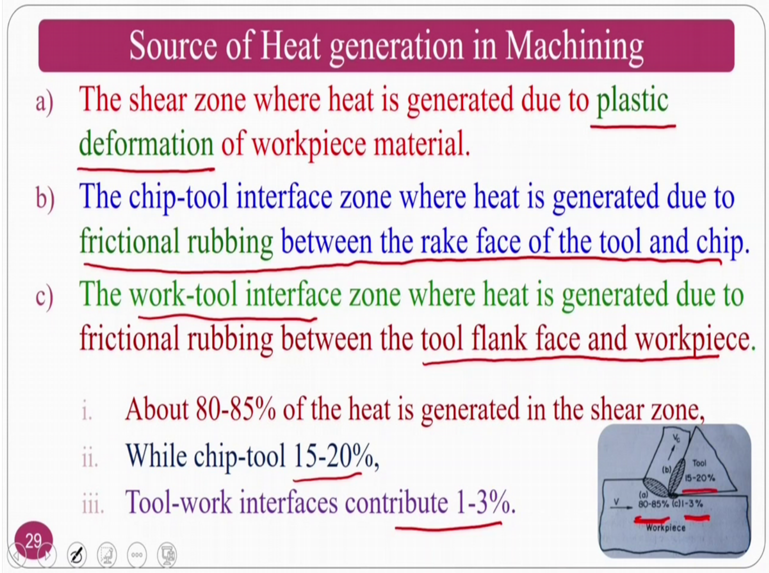

The sources of heat generation in the machining the shear zone where the heat is generated due to plastic deformation, this is about the plastic deformation, where I said 80 to 85 percent is generated. Chip tool interface where the heat is generated due to frictional rubbing between the rake face and the tool chip ok.

Though the are second one which is because of the frictional rubbing the third one tool work interface where the flank surface will rub against the workpiece, which leads to one to 3 percent. Normally, I said already it is fine about. 80 to 85 percent of the heat is generated in the shearing zone while 15 to 20 percent and about this one already have seen this one.

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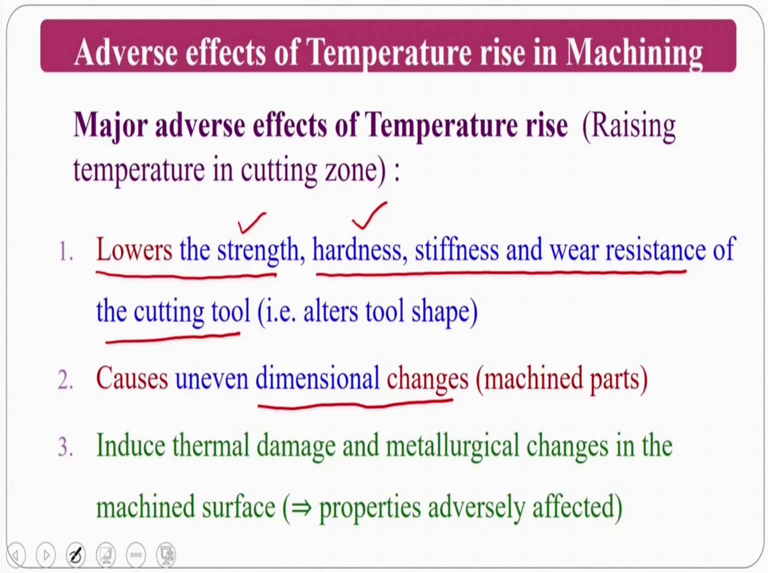

Adverse effect of temperature rise, normally the major disadvantages are what are the affecting things, whenever this is the temperature rise, that is lowers the strength hardness and stiffness and wear resistance of the tool; that means, that thermal softening of tool takes place, because whenever I am cutting. So, the my chip is continuously moving; however, my tool is static; that means, that continuously the heat is going in. Because of it is thermal aspects of will takes place, and the thermal softening of the tool takes place that increases the temperature within the 2 which lowers the strength of the tool, hardness of the pool also and stiffness of the tool and wear resistance and will all go down ok causes uneven dimensional changes.

Whenever the temperature as very high, what will happen? Workpieces also may have tendency to increase it is dimensions by nanometers are sometimes micro meters also. Whenever the thermal conductivity of the workpiece material is very high induce thermal damage and metallurgical changes to the mission surface normally, whenever the cutting tool machining region is very high, what will happen as you see the thermal layers will form.

There are thermal layers there are 3 thermal layers one is if you see in EDM process or laser beam process, where is thermal machining processes, heat effector zone recast layer and the conversion layers. I am not saying that all these layers will inform, but there is a chances of these layers that is. Recast layer or heat affected zone and conversion layer. There is a chance very less chance is there, but because the temperature is going up.

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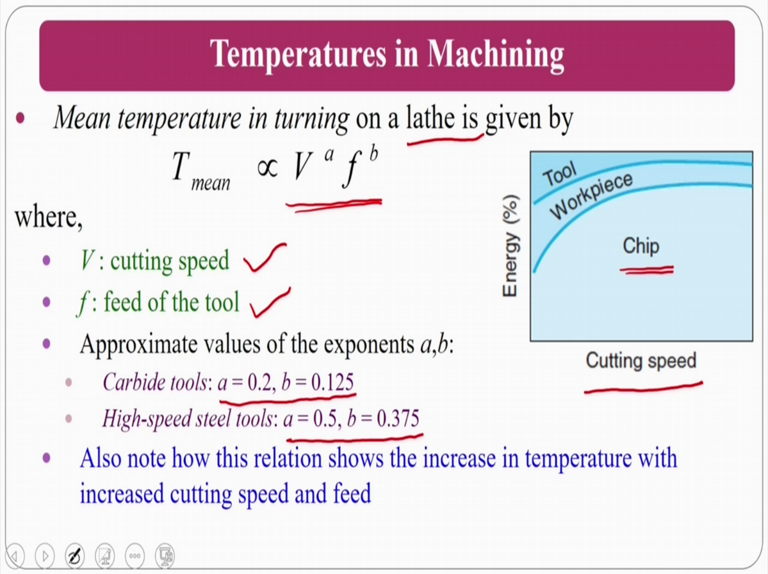

So, the mean temperature in the turning process is normally in the planning process are the lathe is a function of cutting velocity. And feed and a and b are the co efficients. So, the cutting velocity v and tool feed is nothing but this one. For the carbides approximately, a and b values are point 2 and, b is 0.125 high speed steel normally these values goes up. Because soft thermal softening of this material is faster than compared to the hard carbide tool that is why points 5 and b.

So, also not that the relation shows the increase in temperature with the increase in cutting speed and feed so, if the cutting speed increases, and the feed increases. If the workpiece is softer and that circumstances my temperature goes up ok if you see the cutting speed, and the energy percentage normally tool is upper side the work piece and the chip. So, this is the dissipation.

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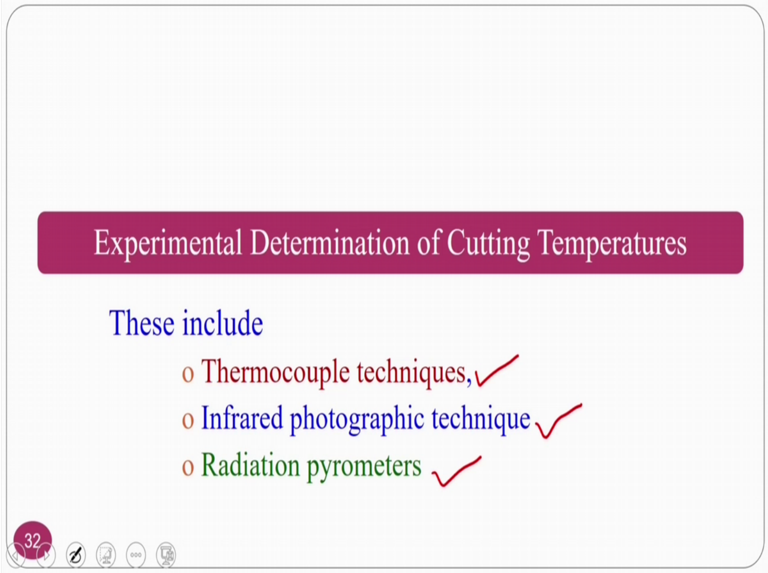

So now you measure this temperature. How to tem measure the temperature? That is called one is the thermocouple techniques, infrared spectroscopy radiation pyrometers and those things; however, just I will tell you processes how experimentally we can measure.

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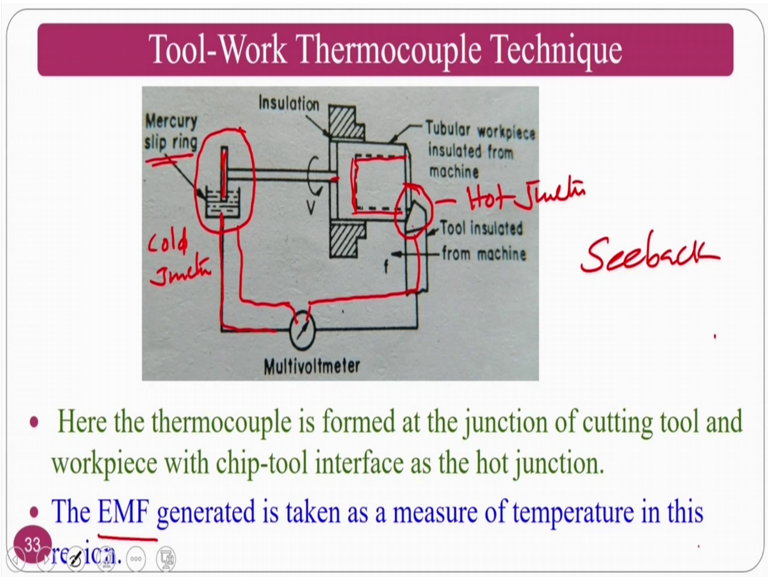

Now thermocouple techniques normally a thermocouple from the junction see if you see, if I tell I want to cut the orthogonal cutting, normally the best thing is just you take it you and you take the perfectly the tool and you cut it ok.

. So, here you can take the tube is taken. This is the hollow one. So, tube and I am cutting here. Now I am having a junction here because connection is not showing property. So, this is one connection. Another one connection is given here ok. So, this is also connected.

So, what I mean to say is I am cutting orthogonal machining process; where one junction is on the tool, another junction is here. So, there is whenever I am cutting this will become hard junction, and this is the cold junction; where I am having a disc here, which is connected basically the head stock will have a hollow structure; where I can put a rod which is connecting to the work piece, and I am connecting this rod with a disc. This is a disc basically; this is disc which is dipped in a mercury. This is we can see here, this is the mercury this is called my hot junction. This is called my cold junction; which is connected to this one.

So, using the seebeck effect if there is a temperature difference, then EMF will produce, what is called EMF is generated which is measured at the temperature. Normally EMF is generated because of there is a difference in temperature. This is called cold junction, this is called hot junction. When there is a cold junction hot junction is con converted, then EMF will produce from the EMF, you can calculate the by using some relations, you can calculate the temperature measured and all those things.

So, the see beck effect back effect, back effect will be there. So, hot junction and cold junction, you can connect and you can get it. This is what the thermocouples technique.

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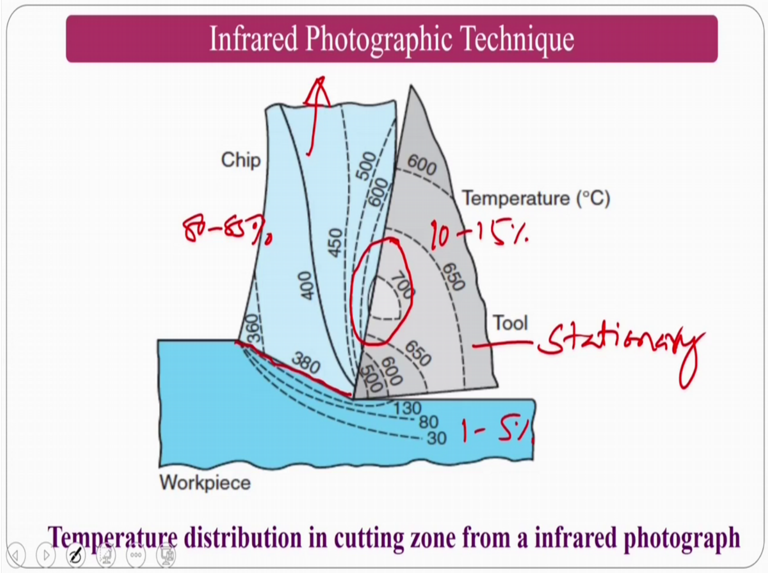

Temperature distribution in cutting zone from a infrared photograph

And another one is infrared photography techniques; where the if you are machining, infrared using this one. So, you can see the temperature regions using the colors that are captured in the infrared ok temperature distribution cutting zone from the infrared. So, normally the temperature highest temperature will be recorded in the chip tool interface.

Even though the highest energy heat is generated in the shearing zone, temperature highest region recorded here. Because the chip is taking 80 80 to 85 percent of heat, and the tool is taking 10 to 15 percent. Here what we see is taken one to 5 percent. At the same time the noting point that you have to see my chip is continuously moving body. So, it continuously moving body at the same time my workpiece is stationary ok.

That means, that my continuously chip what is taking the heat is moving on the red surface of my tool. At the same time it is imparting continuously. So, it is imparting continuously the heat. And it is also rubbing here. Because of normally the temperature recorded in this region will be very high. That is why the tempareture in this region is very high, because of the friction at the same thing because of the chip that is having highest temperature moving on the rake surface.

The another technique is this is the technique which employed by the Boothroyd. These are the some of the things. So, these are the 2 techniques which I am discuss; that is, thermocouple technique infrared pyrometers also used some other techniques also used so that about the temperature measurements in the machining operation.

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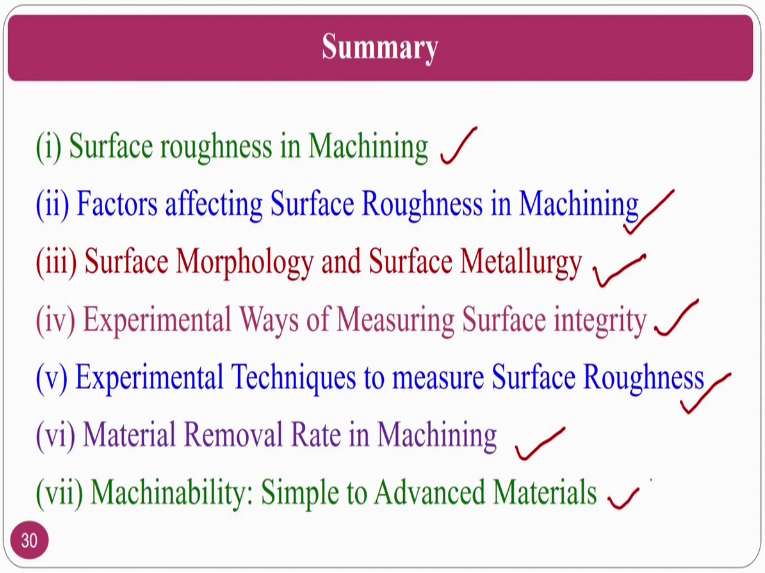

Summary of this class, if you see the surface roughness in machining we have study factors effecting surface roughness, we have seen a fishbone diagram, where lot of conditions are there. Surface morphology and surface metallurgy how to check scanning electron microscopy, where backscattered image is there, secondary electron image is there. X rays are their 2-elemental diagnosis what are the elements and backscattered is used for phase analysis.

Experimental ways of measuring the surface integrity, what just now I told techniques to measure the surface roughness, we have seen in the previous class profilometers and all those things. Material removal rate in machining we have seen now MRR equal to what are the equation and all those things Machinability simple to complex materials ductile material. And machining immobility rating then we has seen the laser assisted machining, that is called thermal, assisted machining and all those things.

That is all about today's class, pictures are taken from internet I am always say is that from my first class to the last class. It is for the teaching purpose only, for better understanding of the students I am taking these pictures. So, acknowledgement goes to the Google from where I am taking these pictures.

Thank you.