Introduction to Mechanical Micro Machining
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Lecture – 20
Difference between macro and micro machining (Contd.)

Good morning, everybody and let us discuss about this surface roughness further in the lecture. In the last class we have seen that surface roughness play important role in the quality of the components and we have seen three different components; one is the profile another is a waviness and the third one is the surface roughness.

So, let us see then how these three parameters are affected by different-different process parameter, it may be the machine parameter or it may be the machine itself. So, let us continue in for the discussion.

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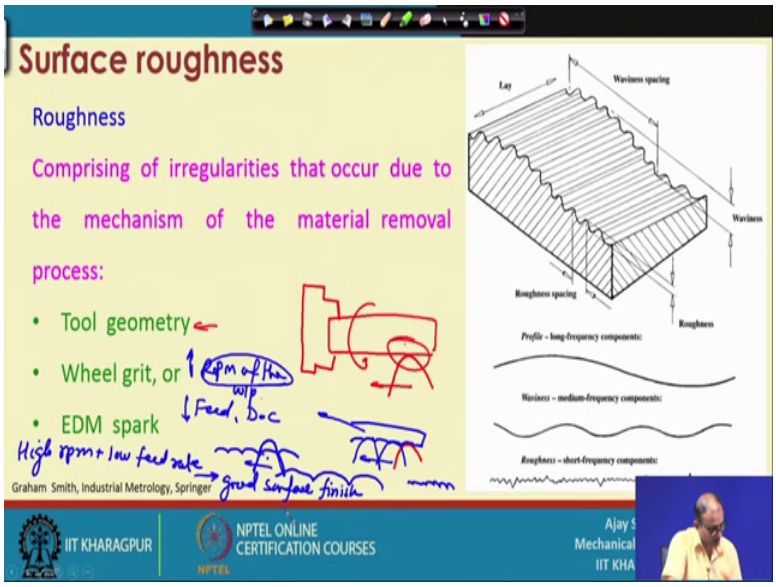

So, this is the surface roughness profile which we have seen in the last class and we have seen that it has three component; one is the profile component it is a very very long frequency component, waviness is something which is medium frequency and the roughness is a very very short frequency component.

So, let us see all the thing the one is the roughness; how the roughness? Roughness comprise of the irregularities that occurs due to the mechanism of the material removal of the process. First thing is a tool geometry, wheel grit; if it is a grinding process and if

it is a machining process then it is a EDM spark. So, now, how this tool geometry will affect here because we know that we have one something is called the nose radius. And now let us consider the that we are turning one work piece. So, this is the workpiece and we are turnings; so, we are rotating in this direction. So, if you zoom this particular thing what is going to happen? That we are moving this particular work is in this direction and we are; tool in this direction we are rotating work in this and the anticlockwise direction.

So, if you zoom this particular; what is going to happen? Your tool is actually penetrating inside and this is your work piece. So, these are the features; so, these are the different different condition of the or location of the tool with respect to time; it is going inside in inside. So, once you complete this machining what you are getting? You are getting a small small artefacts of the impression of the nose radius; whatever is there. That again depends on three parameter; that we all know that it is a cutting speed; let me we write it here. So, it is a RPM of the work piece.

Because now here our work piece RPM because if it is milling operation; then work piece RPM is the tool RPM; then it is a feed rate and depth of cut. Because now if you increase the depth of cut, what is going to happen? That your tool will penetrate more inside it and your waviness will be more. If your feed rate is very very high then what is going to happen that? You will get this type of impression; if your RPM is very very high what is going to happen? You will get a very very small in print; because high RPM and the low feed rate will give you the good surface finish; high RPM plus low feed rate equal to good surface finish.

So, you have to consider these particular things in such a way that you are getting a surface finish as low as possible. And then the wheel grit in the grinding operation; so this is related to machining.

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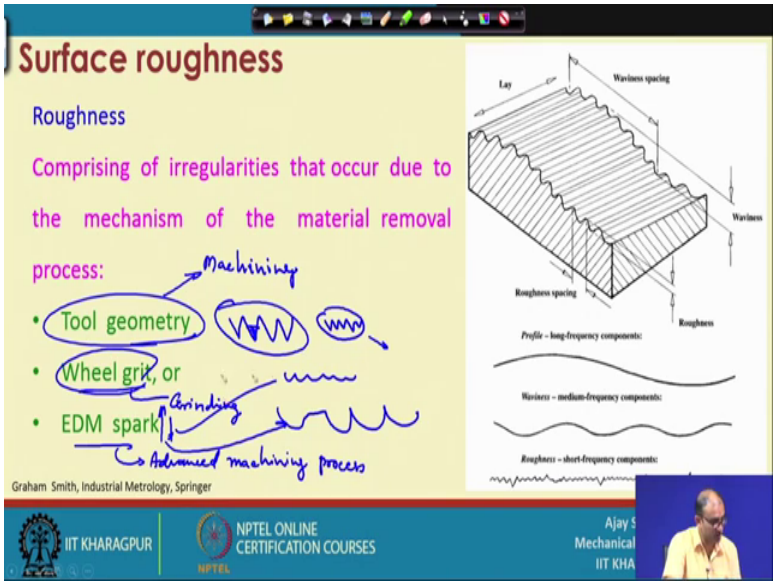

This is related to the grinding and this is related to advanced machining processes so that is called machining process. Because here we know that if this a spark size is very very large, it will remove more material. So, it will create this type of crater and if you are spark energy is very very low; at that time it will create a very very small character; if it is a very very high then it will create this particular thing.

Grit size is also important; what is the grit size? What is the spacing available between these two? Because if you have a grit size something like this and if you grit size something like this then here your roughness will be very very low roughnes. Because surface finish should be very very low; surface finish should be very very high and surface roughness should be very very low.

So, if it is the grit size of this one then it will penetrate more also and that the time it will damage or it will create more material removal. More material removal means more surface roughness; so, these are the three different processes by which you can create a different roughness and everything depends on this particular parts; so, this is about the roughness part.

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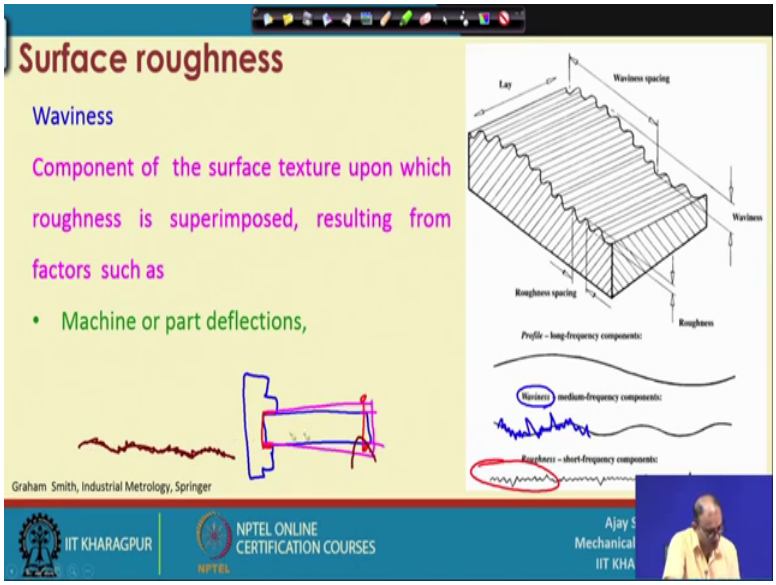

Now, coming to the same operation, but it is waviness. Now what is going to happen with the waviness? So, component the surface texture upon with the roughness is superimposed a resulting from the factor that we will see now. So, now, what is the roughness? Roughness is waviness is the component on where the roughness is superimposed; the roughness is located here.

So, softness roughness is superimposed over the waviness. So, that is the wave then you reduce that waviness then you will get the same thing here at this location. So, what are the components which will effect of this part? This is a machine part deflection. Now what will happen that if you have work piece here; again same thing let us discuss, turning operation and you have a problem with the holding this components. So, it has some deflection at this location; at this location.

So, what will happen? That this will vibrate with a very very high frequency but very very low amplitude. So, it will not be something like this but it will be also not like this; it is something in between these two. So, when this will vibrate; what is going to happen? That you will get some type of; this is the vibration say this is the total span of vibration; continue and your tool is located here.

So, this is your cutting tool; so, when it will vibrate then what is going to happen? That your work is it something like this, so it has some this type of components and on the top

you have a vibration also; that means, roughness component that is; obviously, by the cutting tool action.

So, because of this particular things you are getting a different one on the signature other than the profile and the roughness that is called the waviness.

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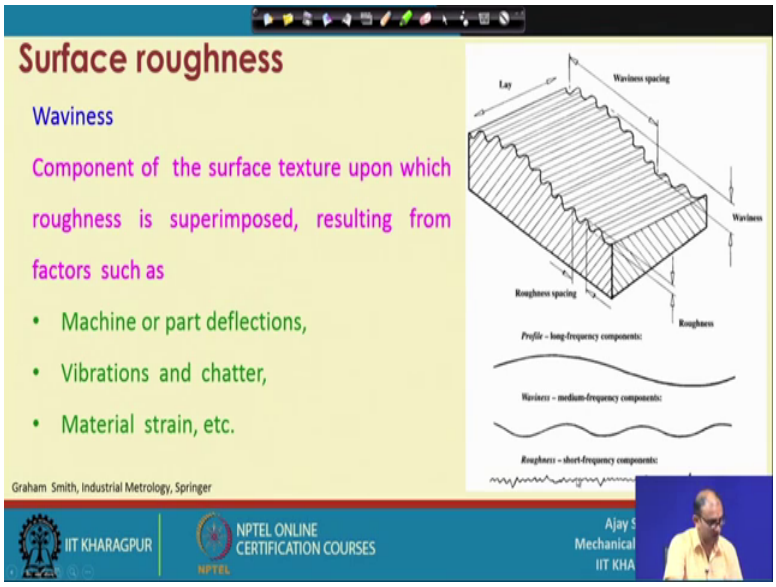

Then vibration the chatter that is also one of the thing; suppose you are you do not have any reflection from that, but your end up with the chatter and vibration because of many different reasons. So, if that will also create a waviness on the surface in the material strain because if you are material is very very strain; then what is going to happen? That you will get more elongated profile on the waviness direction. And on the top of that you are getting a surface roughness of the parts; so, this is about the waviness component.

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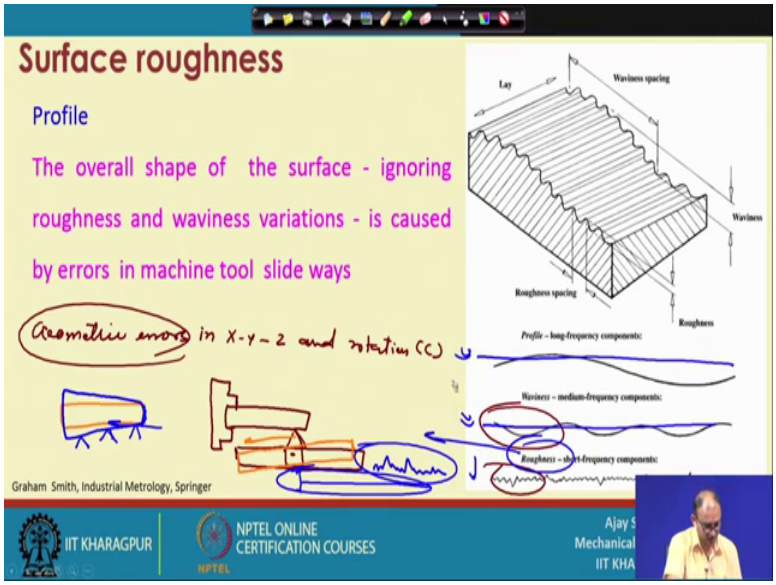

And third one is the profile compounds; so this is the profile. So, what is that the profile is a overall shape of the surface ignoring the roughness and waviness variation. So, it is mostly caused by the machine tool slide because this is very very long wave. So, you cannot get the same thing by this type of roughness or not by the waviness also.

Now, considered that we have seen that geometric errors in X, Y, Z and rotation that is C S E. We have seen some animation where your movement was in the X direction, but you are getting a rotation in the Y direction, translation in the Y direction, rotation in the Z direction, the translation in Z direction.

So, those are the geometric error; so, what are those things? That suppose your tool is moving with the tool post in this direction. So, it should be completed straight and your work piece is here. So, this is your work piece correct; so, now, what is going to happen? That suppose your tool is not; that means, your slide is not completely straight; then what is going to happen that. Suppose your slide is something like this; so, what is the tool will actually move in this direction.

So, instead of a straight cutting; what you are getting here, you are getting something like a paper cutter. So, this is the surface which you are going to get; because your tool is moving in this direction. So, this is your tool motion; but your actual tool motion should be in the straight line. So, this is very very long variation or the long frequency

component this is happens because of the error what the geometric error of the machine to slide, where the axis orthogonality; so, those are things of the geometric errors.

So, these are the three different profiles; now what is our objective? Our objective is to reduce this particular things; if you are machining with the straight surface then the profile should be completely straight; that is also we do not want and we also do not want this particular things in this part right. So, these two things we can achieve here, but roughness is actually the stochastic; it is very random in this case that you are not able to control.

So, you will not get a straight line of the roughness; if you increase the magnification of any surface with a small scale, then you will get the roughness profile anyhow. Because this is very difficult to get or it is almost impossible to get the surface roughness in a straight line.

But this particular thing, we consider the perfect surface if it is fulfilling our requirement.

Because if you see the optical materials that optical materials when the light passes through it; if it is a mirror then it will translate and if it is a lens then it will pass through it. So, if the roughness is low to them whatever the lowest possible way then homogeneity of the light which is passing through or which is translated from the surface of the lens; optical material then it will have a very very perfectly required dimension but that will depend on this particular surface roughness.

So, smaller the roughness better is the performance in many many cases, but it is not always too many cases; you always need a surface roughness also, so that is different case.

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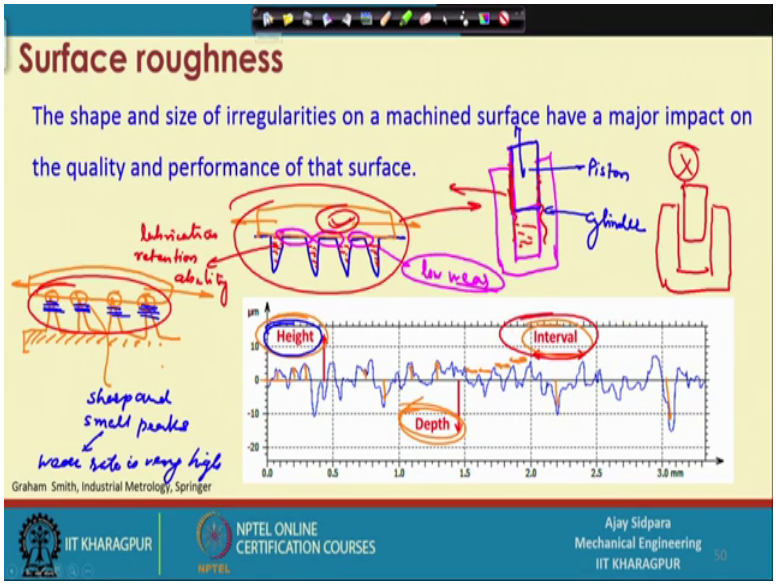

So, now let us go more detail about the roughness only; let us not talk about the waviness and profile because those two things can be actually controlled by the different different ways. If you remove all the variation or the errors among the machine tools and other parts you can actually maintain the waviness and the profile, but roughness is very very difficult to control.

So, let us know concentrate only on the surface roughness; so, what are the things that this is the one of the profiles which we can get by the different definitions to mention. This is measured by a contact profiler or the non contact profiler. So, what we are looking this particular part is the two or three different different things.

So, one thing is the highest; so these are the roughness and this is the 0 line; so that is called the mean line correct. At some part is above the mean line, some part is below the mean line. So, now how much is the height of this peaks from the mean line? So, that is called also from the centerline. Second thing is the depth; so, how much is this depth correct? So, this are the depth. These two important thing is that; third input thing in the what is the interval between these two correct?

So, these are the three different parameters of a roughness profile which play very very important role in performance of the component. So, size and the shape of irregularities on the machine surface a major impact on the quality and performance of that surface.

Now, how this will behave? Now suppose you consider that you have a surface which has only height; let us say this is the one surface. And now on the top of that you have one surface which is in relative motion. So, this is moving in this direction; this is stationery, consider this is stationery. Now this is a microscopically, we are not talking about it a very very large scale; it is very very small peaks.

And now when you are moving this surface here and there what is going to happen? This is actually the actual contact that is called apron contact area. But at macro scale what you think? That your whole surface is in contact with this particular; that is not the correct thing. So, these particular peaks are very very small and they are very very sharp also. So, let me write it sharp and small peaks.

So, when they will move in this reaction; what is going to happen? This will shear of from this part? So, it is wear will be very very high; so, is wear rate is very very high. So, height will play important role; now take the same surface. Now we let us just reverse it; so, we have not done anything just reverse the surface and let us put the same component on the top.

So, this is the same component then again we are moving a both directions. Now what is going to happen? Now what is our apron contact area? So, these are our contact area correct. So, our contact is very very large and they also not sharp. So, your wear rate will be very very low; low wearing this particular case. Other important thing advantage of this thing that; if you consider a piston and cylinder mechanism; so, this is the piston and this is a cylinder.

So, this is the cylinder and this is the piston; let me give different color; piston correct and this piston is moving up and down. Now, if you consider this is the surface of this particular because now interface is this location; so, this is the interface surface. So, this is the interface surface, if this interface surface is something like this; then wave rate will be very very high and after sometime what will happen? That you will have some type of opening between these two particularity; it will not be a completely smooth feed; there will be some type of opening between these two.

So, your cylindrical surface will be like this; that means your piston and then your cylinder will be something like this. Means we are giving very very large magnified you in this case; so after this what is going to? This is going to happen in this case. Other than

that the you always need a lubrication; so when it is moving up and down you fill up with this oils here and then this oil will be sprayed on this particular surface.

And if you use these particular surface here; then there are lot of advantages. Because one thing is that contact area is large; so, you will not get this particular thing. Another thing with you whatever this part is here of the whatever this values are here; this values are filled with the oil. So, your fiction will be very very low in this case.

So, this particular pattern whatever is there it will actually have the lubrication retention property; lubrication retention ability. So, here lubrication will be stayed here and when it is moving up and down; it will also provide one type of less friction in this case. So, what we need? We need this type of engineered surface and this surfaces are not correct way of doing this thing.

So, this is about the height and depth; coming to the interval, how interval play important role?

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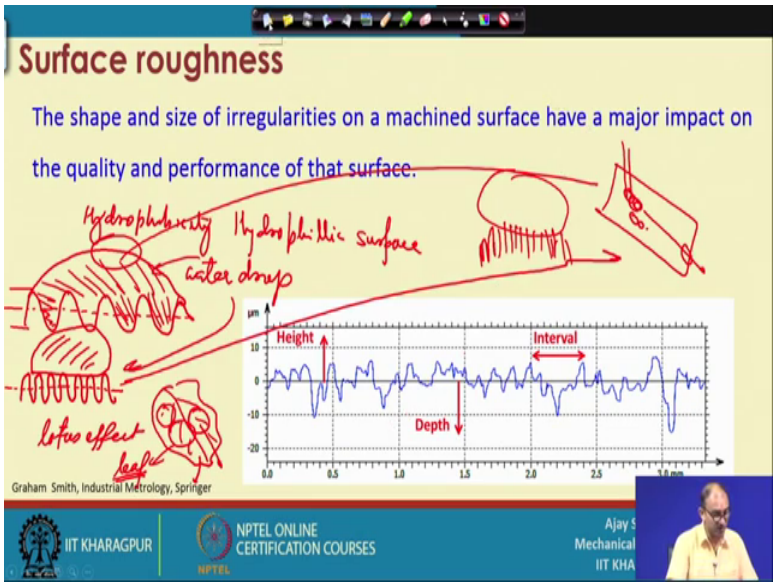

Now considered that we have one surface is something like this; so, this is the total height and this is central line. So consider the height and the surface of; height and depth both are same. Now this is the one thing; let us consider the same thing but it is at this level, again the same thing is here; so this is the part of this part.

Now how this thing will play important role here? Now it has a many things; now if you consider something like that hydrophobicity and hydrophilic surface correct. So, now what is happening here? That you put a water drop on the top surface of this.

Now, this is water drop; what will happen? The water drop will actually peel and cover all the things; this will be completely filled with the water drop; this is water drop. If you put the water drop here what will happen? The water drop will stay on the surface; why it is like that? Because now what happened? That if you see it if you have seen the lotus effect. So, that is called lotus effect; if you see any leaf, what happen?

If you have seen in the motion that there are lot of drops which are staying on the surface and if you just inclined or till this part the water droplet would drop from the surface; it will not stay on the surface. Why it is like that? Because if magnify this particular profile of this leaf and what is happened here? That on the brief profile there a lot of small small fibers which are projected from the surface and it will actually limited this whole drop of the water and it will not spread the surface on the top surface.

So, these are the advantage; that if you have a very very high frequency component here and very very low frequency component here, then spreading of the water or any other things which will play important role. Suppose, you are using some components; some surface here and you are putting some drops here; chemical, oil whatever is there. If you have surface something like this; then what will happen? This particular drop will actually slide completely nothing will stay on the surface.

But if this is the condition that you have a large frequency component, small frequency component and then you are putting the drop drop will stay here only; it will not slide completely. So, there are different different; this is one of the applications only I am discussing, but other than that there are many applications where; if you do not change the height and depth but you change interval; then the surface will behave differently in different different conditions.

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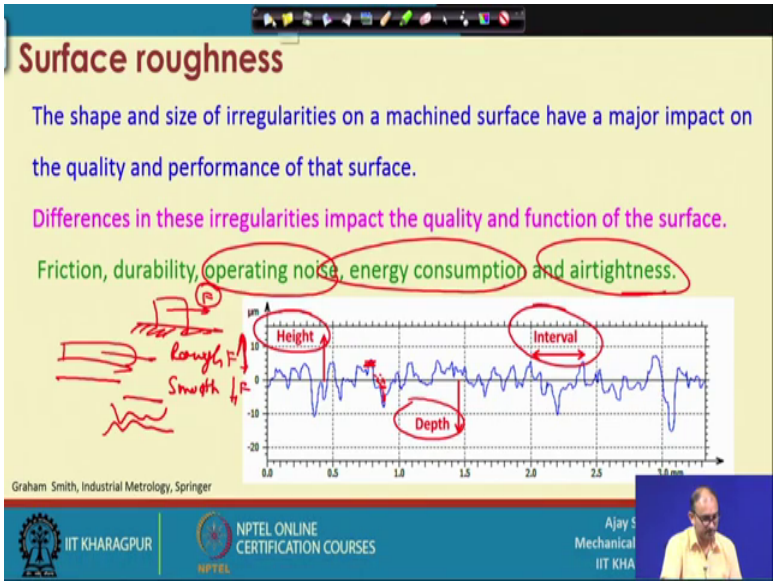

So, differences in these irregularities impact the quality and function of the surface. So, what is the friction? What we have seen earlier? That friction is very very high, if your height is very very high and you do not plate to surface. Durability is also important because if the roughness is very very high, your wear rate will be very high; wear (Refer Time: 21:44) and whatever the particles which are worn from this surface; whatever these particles are worn that will stay here. And then what is going to happen? That it will create further wear or the accelerated wear of this particular aspirities.

Because now these are considered the foreign particles and this particles, very difficult to remove because now sometimes, it will fill up this gap and it will reduce all retention properties also. Operating noise is also very very high because you know when the two smooth surfaces are in contact, you will not get ways.

But when there are two rough surfaces are in contact and then they are moving, then you will get more noise. Energy consumption is very very high because we know that if you are sliding one component on the smooth surface; then it is very easy to slide from the surface you do not required more force here. But it is on rough component F is very very small and rough component F is high.

And smooth component F is low because you do not; it slide very very slowly and air tightness is important because many location you do not require the air to flow from this; there is mostly gasket type of things, where you do not want to leakage also; air tightness

is one thing, leakage is another thing. So, at that time all these things roughness, height, depth and the interval all play important role in this type of different different characteristics of the component.

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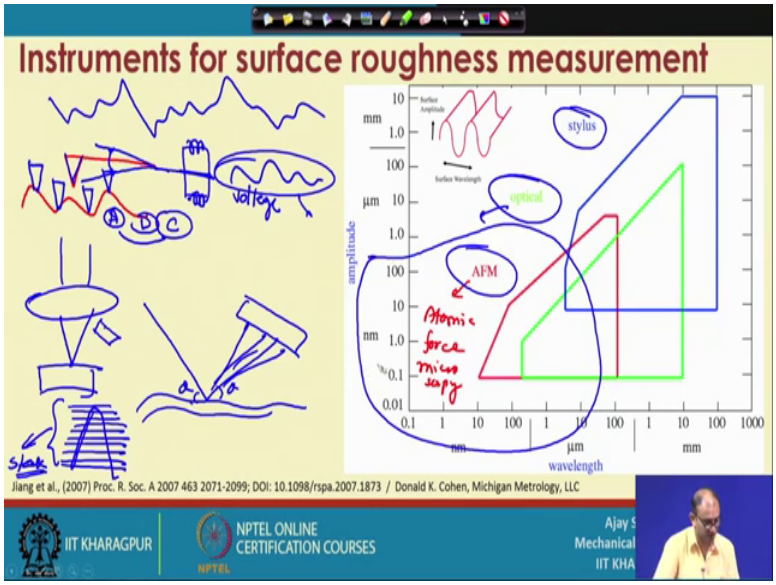

So, what are the instrument we can use for those things? So, there are many instruments; one is called the stylus type, another one is a optical type and this is called atomic force microscopy. So, let us see this thing this is called atomic force microscopy; so, here it is written wavelength and on this particular (Refer Time: 23:43) it is called the amplitude. So, what are these wavelength and amplitude?

So, this is what is that thing; so, this is the surface wavelength and this is called surface amplitude. Stylus type; that means, what is we are not going to discuss this component because this make we will cover at the end of this particular two processes micromachining process and PCN machining process; if time permits we will cover this process in the detail. Right now, let us discuss in a very very stylo way; so, this stylus way; that means, you have one stylus and you have one surface.

So, stylus will move on this particular surface. So, stylus is moving from here and then it is reaching this location, then reaching this location at this location. And because of that what will happen? This stylus will actually vibrate; in this way that way and because of this vibration what is going to happen? There is one coil available and this particular core is moving up and down because of this vibration and whatever is the up and down is this

motion; this is the coil. So, this distance will continuously change it will create one voltage signal.

So, depending on this up and down motion; you will get a same signal in terms of voltage. So, then you have a analogue to digital converter or digital analogue converter so that you can convert this particular mechanical motion; that is analogue signal to the digital signal.

So, you need ADC converter. So, ADC converter will convert this thing it will amplify also amplifies available at finally, the same thing will be plotted on to the graph. I work on in your computer screen, so this is called contact type; your stylus is moving on the top surface. Optical; that means, you do not have physical contact with the sample, you have a light and then you have a one particular lens and this particular light will strike to the surface and then there are some receiver of this light.

So, what is going to happen? That suppose you have a waviness and then light is passing here and then you have a one particular receiver. So, if you have flat surface then what is going to happen? This angle and this angles are same and if you have a waviness here then this angles and different. So, this particular location will be different to different, different locations and this way you can optically measure the roughness. Other way that there are many optical; there are many different methods available.

If you talk about the optical microscopy only then what it will do? That suppose you have this surface, then it will scan the surface in this way. Every time it will scan, your area will be increase and finally, it will take off this particular surface; then it will create a 3D surface measurement. So, that is one of the advantage of going with a optical and AFM; that you will get the 3D surface compared to stylus.

Stylus what you will get? You will get one line roughness only, but if you get a many line surface and then you coupled for take with each other, then you can get it 3D surface. All this instruments have a different different advantages and disadvantages. Now, coming to AFM; AFM you can see it that AFM is very very better or it will perform much better in this particular time because in a small scale. If you see the nanometer scale, AFM is more advantage of using at this process because it has a wavelength also in nanometer length and amplitude is also an nanometer length.

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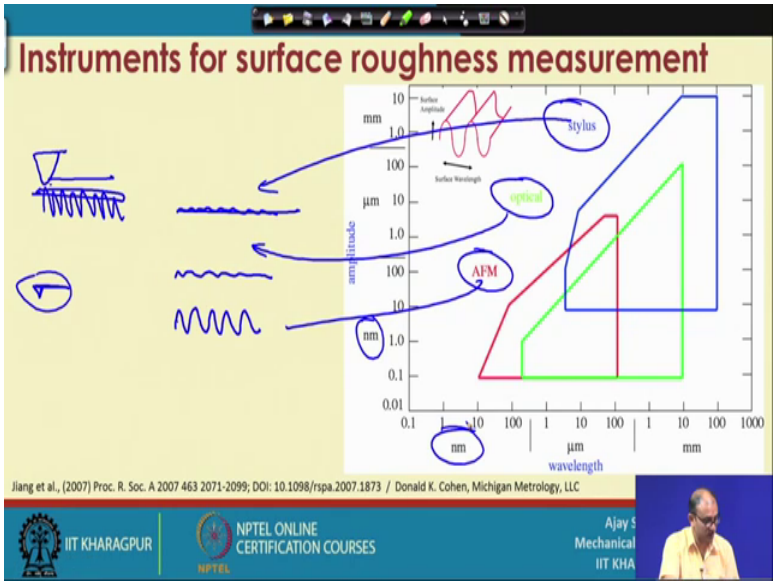

How this thing is important? Because now we see that if you have a surface is something like this. And if you are using with a stylus with a; where radius of something like this, then what is going to happen? That this stylus will simply move on the surface because it is not able to penetrate inside the surface

So, what you are getting the graph? You are getting a graph something like this. So, you will get a graph or something like this. In optical also what is going to happen? What wavelength you are using; white light you are using, white light into ferometer; what you are using green light that everything depends on there.

At that time also that performance of this particular this is the stylus part; if you go with the optical path then what is going to happen? You may get something like this; that is mostly it will cover the top surface correct. So, that is what is going to happen here; if you go with AFM; AFM also one type of contact type or the noncontact type; depending on the mode which we are using; frequency mode is there, taping mode is there contact modes are there.

So, here what is going to happen? That mostly it will give some more realistic idea because here the contact point of this particular AFM tip is very very small and very very sharp also and it has a very very high load amplitude variation measurement capability and the wavelength is also very less. So, this is more actually connected with this particular part; so, how you have to decide those things?

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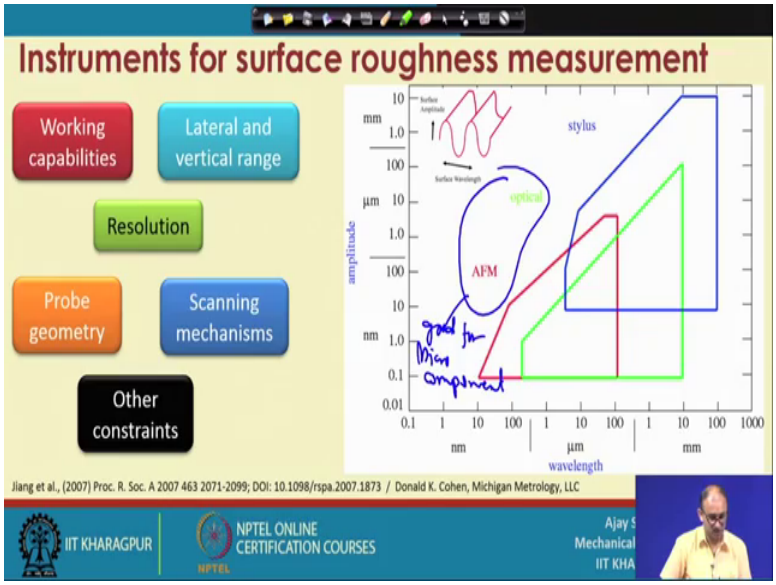

The one is the working capacity of the instrument, first; finally you have to decide which instrument is used for that. Resolution is important; what is the smallest measurement you can use for that? So, optical and the AFM's are more better in the measurement of the micro components; micro component good for micro components.

That vertical and the lateral line; that means, we have seen that what we want to measure; we want to measure height and depth only or we want to measure the spacing or the difference between the two heights also. Probe geometry because small are the prob geometry, more realistic things you can captured by that. Scanning mechanism because we know optical there are many a confocal microscopy is there, that intro for metric base optical measurements are there. So, those are the different mechanism by which you can get the different type of results

And there are other constraints what are the temperature requirement because in stylus mostly you do not need the lot of temperature sensitive things. But optical in AFM, you have to maintain the temperature also because most of the things it has based on the laser type of things. So, those things are very very important. So, these are the different ways you can select the component, but mostly people prefer optical in the AFM measurement for the micro component; surface of the measurement.

So, let me finish this class here and we will continue this for the discussing in the next class.

Thank you very much.