Engineering Metrology
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Lecture – 26
Surface Metrology

Welcome back to this course on Metrology.

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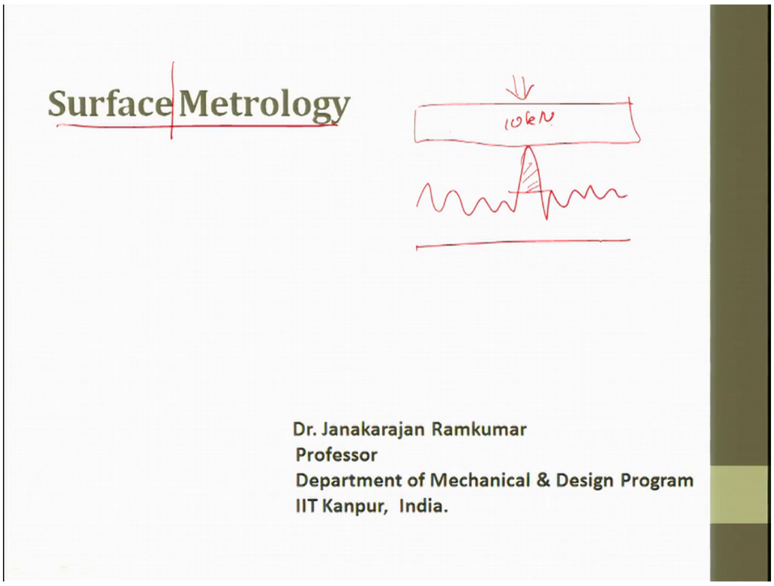

So, the topic of discussion will be Surface Metrology. So, it is very clear from the topic itself surface metrology means, measuring the surface. A science of measurement where and which you try to measure surfaces. Moment you say surfaces, these surfaces are 3 dimensional in existence and the surfaces can be flat, can be circular and it can have a combination of flat and circular, which leads to complex surfaces. Surfaces are very important because, when you have when you have several parts, when these parts are assembled, the surface of these two parts starts interacting. So, when it starts interacting, they always lead to wear and tear right.

And second thing, when you have surfaces which are very rough, something like this very rough ok, so then what happens, the load which is taken suppose let us assume, here is a load which is to be taken by a surface. Now you see the load is resting on one point only. So, the load if you wanted to distributed then, what we have to do is we have to break this peak and allow the load to be shifted to the bottom surface, so where the load is getting distributed.

So, here if you have rough surface then, this rough surface what happens, the load will be taken by few points that is point number one second thing is there will be lot of wear and tear because, the pressure is exerted on the load also at a certain point. The third thing is because of improper surface then, there will be lot of vibrations and charter also and the because wear and tear this wear and tear also to premature failure.

So, now, it is very clear that surface plays a very important role, the surface measuring is also very important. This will try to dictate or talk about the entire product. So, surfaces play a very very important role that is why today, we are talking about nanometer surface finish. When you talk about nanometer surface finish, the undulations are almost converted into a line.

Now when the load rests on the line, so the load is getting uniformly distributed, there will not be any wear and tear or there will not be any premature failure. So, because of this we are trying to understand the surface and we are trying to measure a surface and quantify a surface. This is what will be the discussion in this lecture.

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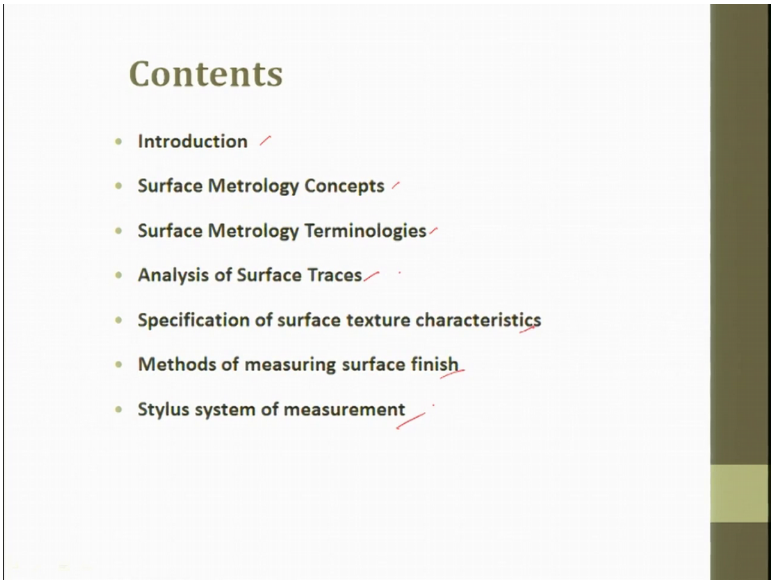

So, the content we will have introduction then, we will have to understand surface metrology concepts then, we will look into certain terminologies then, we will try to see like we studied about measurement, so we have we will try to measure a physical data and this physical data finally, gets converted into a voltage data, this voltage data intern gets converted into another physical output data. So, we will try to see how are the tracing happening, then specification of surface characteristics, what are the different methods of measuring surface finish and the last one will be stylus based measurement we will go through it.

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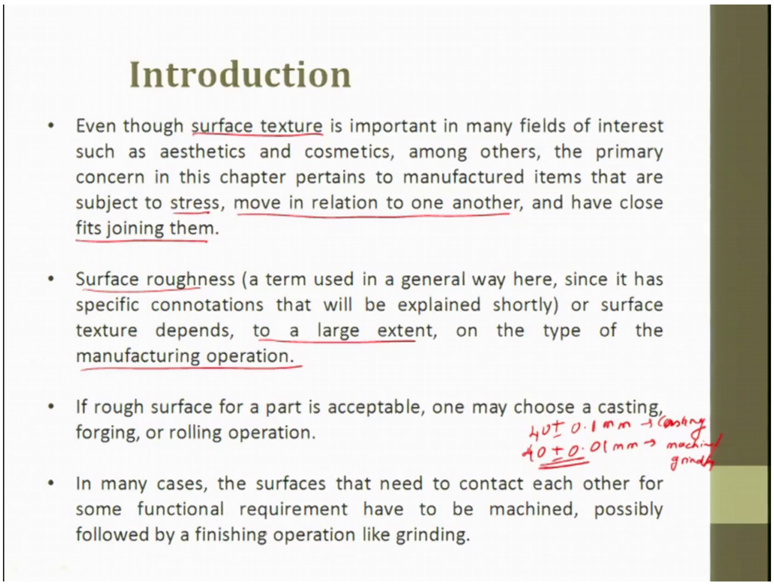

Even though, surface is important in many fields of interest such as, aesthetic and cosmetic amongst others, the primary concern in this particular lecture pertains to manufacturing items that are subjected to stress move in relation to one another and have a close fits of joining them. So, aesthetic, so why are we talk about aesthetic is, we have a glossy finish, you have a flat finish or a glossy finish, you also have something called as a matte finish. So, it tries to have a better aesthetic value and cosmetic value, but these 2 are secondary importance, the primary importance is when the manufactured item subject to stress, moving with one another and then, having close fits, it is very important for us to measure the surface texture.

The surface texture people when that sub texturing is very small, they call it as roughness. So, surface roughness or surface texture depends to a large extent on the type of manufacturing operation. So that means, to say there is a part, so we have to see, what was the previous step in the manufacturing process this part has undergone and that is what we try to look as a prime focus, when we try to do surface roughness or surface texturing. These two depends on the previous manufacturing process. If rough surface for a part is acceptable one may choose a casting, forging or rolling process.

In many cases, the surfaces that need to contact each other some functional requirement has to be machined, possibly followed by a finishing operation like grinding. So, if you go back and see if I give you a tolerance of 0.1 millimeter maybe this can be done by casting. If, I try to write 40 plus or minus 0.01 millimeter then, it is machining and sometimes grinding. So, you see depending upon the tolerance, the number of process increases right. So, when we go to a surface, this is tolerance right, but surface is another thing. Tolerance is the deviation, which we give or we accept some variation in the process is tolerance. The surface is talking about the surface, so here it is more of dimension, here it is more of surface, we talk about the surface.

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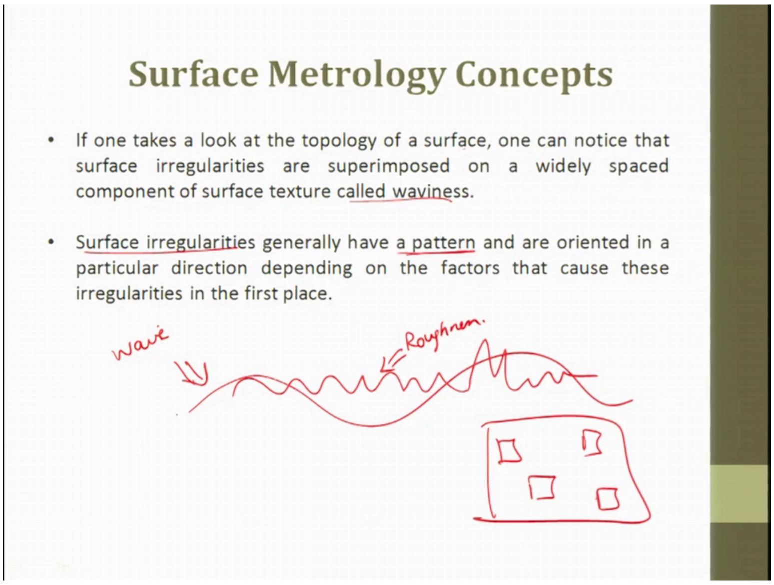

So, if one takes a look at the topology of a surface, one can notice that surface irregularities are superimposed on a widely spaced component of surface texture called waviness ok. So, when we try to see a surface closely, we will try to see lot of irregularities. These things are called a surface irregularities, these surface irregularities are superimposed ok. This is a wave and this parameter is called as waviness. The surface irregularities generally, have a pattern and are oriented in a particular direction depending on the factors that causes these irregularities in the first place ok. Surface irregularities generally, have a pattern. So, that is why what we do, if we have a large surface area we measure roughness at 3 4 points and we talk about the entire surface what is the roughness value generally has a pattern and are oriented in a particular direction.

Because your 2 load have moved in one particular direction, on the factor that causes these irregularities in the first place. So, these are called as roughness and this is called as waviness.

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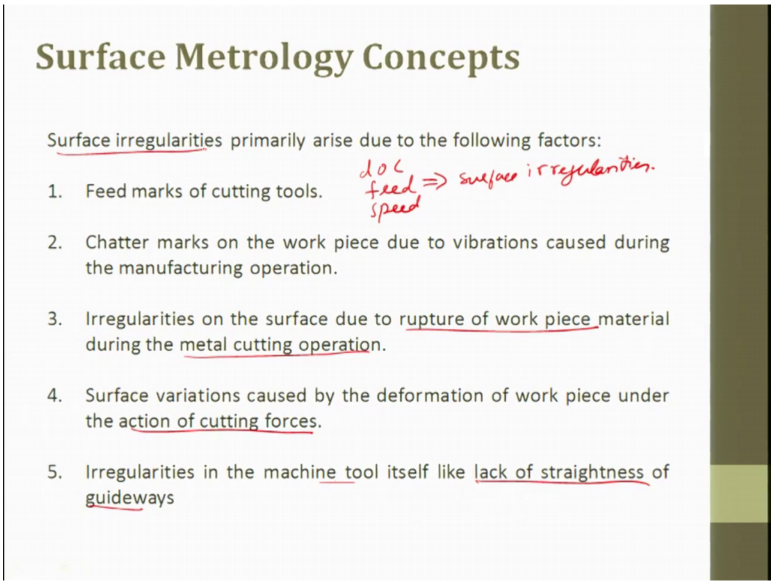

The surface irregularities primarily arise due to the following factors: Feed marks of the cutting tool. See the feed marks of the cutting tool whenever you do a contact machining, the tool is given depth of cut, depth of cut, feed and there is a speed. So, generally the surface irregularities are because of feed ok. Chatter marks, on the work piece due to vibration, can caused during the manufacturing process also leads to surface irregularities.

Surface irregularities on the surface due to rupture of work piece material, during metal cutting operation also leads to surface irregularities, for example; you try to when you are using a software work piece a hard tool it digs. So, when it digs, it ruptures the work piece. The surface variation caused by the deformations of the work piece under the action of cutting force; that means, to say you are taking a very soft material, this problem is very common when we do titanium baffle machining or titanium diaphragm machining.

So, in diaphragm they are all thin thickness, so when you try to put it in a fixture and start machining it, moment you load it in a fixture, the deflection happens. So, now, whatever you machine will be on a deflected surface. So, that is what the surface variation caused by deformation of the work piece, during the action of cutting force is also there. Irregularities in the machine tool itself like lack of straightness and guide and of guideways machine tool variation. So, this also leads to surface irregularities.

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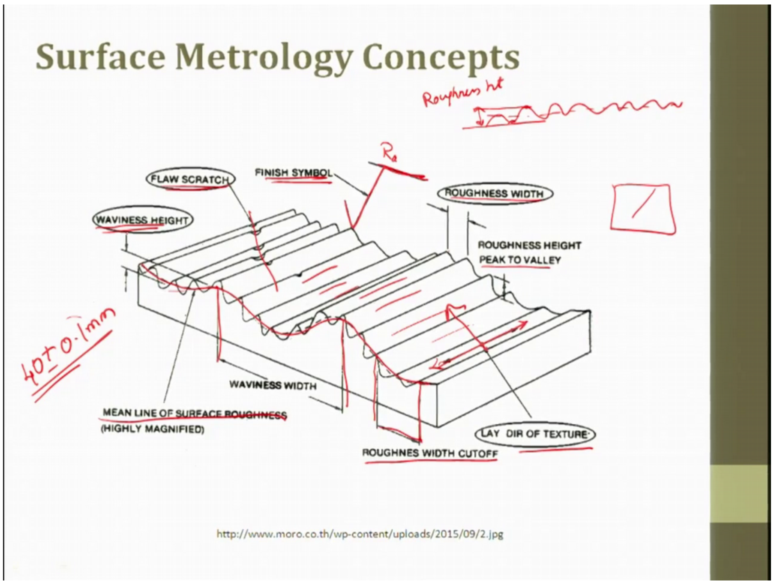

When we try to understand the surface metrology, these are some of the terminologies which are used. So, this is the 3 dimension way of looking on a surface right. So, if you look at it, so here is what is the first terminology which we have to know is waviness, this is a waviness ok. The height of this wave is called as waviness height. Predominantly this happens on a process before machining and during the process of machining, these surface irregularities happened on the surface. So, this is the wave and this is the wave height and you also have wave width to be measured. This is called as a waviness width ok.

So, now, let us look into roughness. So, within a wave you have some irregularities those things are called as surface roughness ok. So, the in a surface roughness, you also like waviness height, you also have surface height. So, that is nothing, but peak to valley. So, if you look at it, this is the two dimensional view of a surface irregularity and here what you take is only surface. So, this portion is called as roughness height. So, here we try to take peak to valley height ok. So, in the same way you also have something called as roughness width cutoff. So, here is a roughness width cutoff, which is within the wave you will have irregularities. So, this portion is called as the roughness width cutoff ok.

Then, on the surface sometimes you can have a scratch. For example; you have a very flat surface there is a deep scratch. So, this is the flaws scratch which is there, so which runs along this direction ok. So, this is the between two roughness you what you measure is called as the roughness width. So, the mean line of roughness is going to be, so, you have a roughness, you have a surface regularity, you try to draw a mean line based upon the surface data. So, that is called as mean line of surface roughness ok.

Generally, when we try to talk about 40 plus or minus 0.1 millimeter, these are dimensions basic size and tolerance given. So, in a similar manner we always try to put a symbol like this and try to write what is the roughness we want on the surface to do. So, this is a finish symbol which is used wherein, you can see in a manufacturing drawing while referring to the surface irregularities. So, this is the symbol which is used.

And the last thing lay or direction of texture, so if you look at it there was a tool, which has moved in this direction to clear a straight line. This way it is called as the lay, the lay is the direction which is of when you try to measure roughness we always try to measure it in the perpendicular direction ok. If you measure along the lay direction the roughness whatever you get it will be within one trench alone that is not correct.

So, perpendicular, so this will be the feed which has been moved. So, this is you if you try to get the roughness along perpendicular to the lay, so then only you can try to talk about the roughness of this surface. So, that two important things are waviness and roughness; you have to contact waviness, you have to contact roughness. So, here we are more focused towards roughness parameter as compared to that of waviness parameter.

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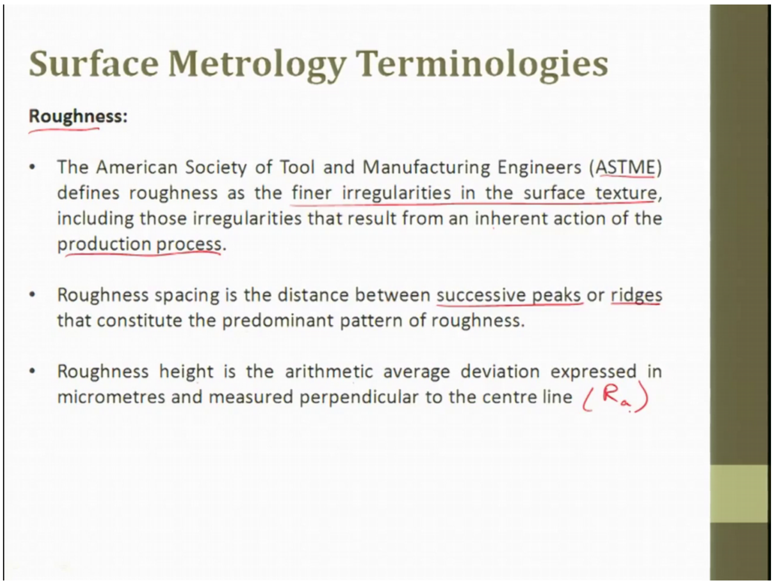

Roughness, how is roughness defined. American society of tool and manufacturing engineers ASTME defines roughness as a finer irregularities or in the surface texture, including those irregularities that results from an inherent action of a production process ok.

Waviness is before machining whatever does that leads to waviness, whatever happens during machining leads to roughness. Roughness spacing is the distance between successive peaks or ridges that constitute the predominant pattern of roughness Roughness height is the arithmetic average deviation expressed in micrometers and measured perpendicularity centre line. So, this is otherwise called as Ra.

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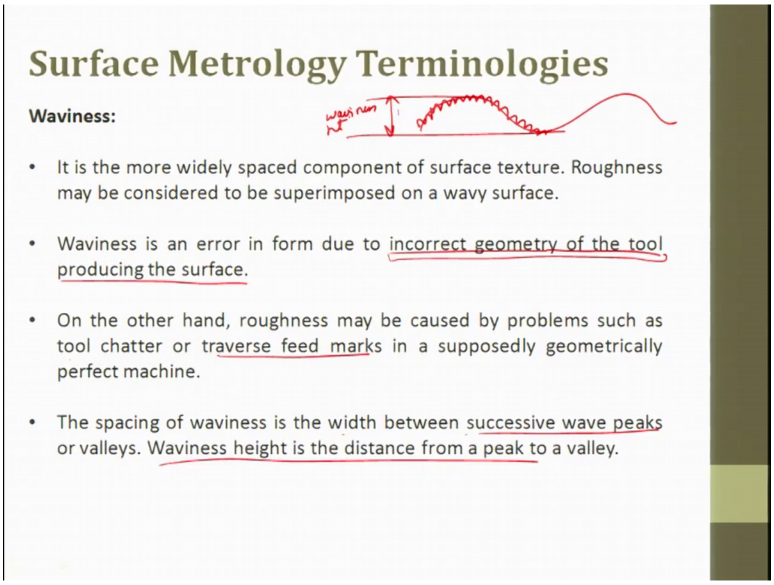

Waviness is the most widely spaced component of surface texture. Roughness may be considered to be superimposed on a wavy surface. So, this is a wave and here is the surface roughness ok. Waviness is an error in form due to irregular geometries of the tool producing the surface. On the other hand, roughness maybe caused by problems such as tool chatter or traverse feed marks in a supposedly geometrically perfect machine.

So, in correct geometry of the tool produces waviness and roughness maybe caused by the problem such as tool chatter or traverse feed marks in a supposedly geometrically perfect machine. The spacing of waviness is the width between two successive wave peaks. Roughness also it is the same. Waviness height is the distance between peak to valley, so this is waviness height.

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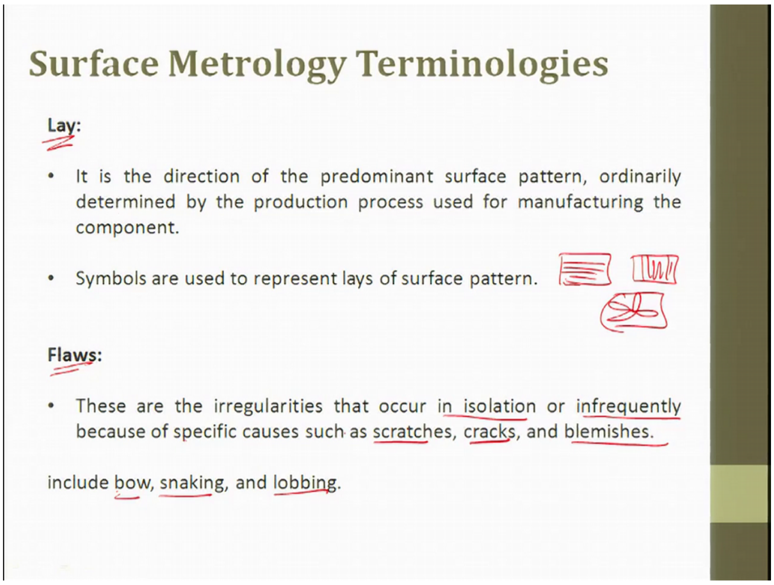

What is lay it, is the direction of the predominant surface pattern ordinarily determined by the production process used for manufacturing the component. The symbol are used to represent lay of the surface pattern. For example; you can have a lay pattern like this, you can have lay pattern like this, you can also have lay pattern something like this ok. By looking at the lay pattern, we can try to distinguish what is the machining process which is been used to generate the surface.

What is a flaw, they are irregularities that occur in isolation or infrequently because, of a specific cause such as a scratch crack or a blemishes including bow snaking and lobbing. So, these are basically defects in the work piece itself, we which cannot be avoided both by the process of initial generation and machining. So, those things are called as flaw.

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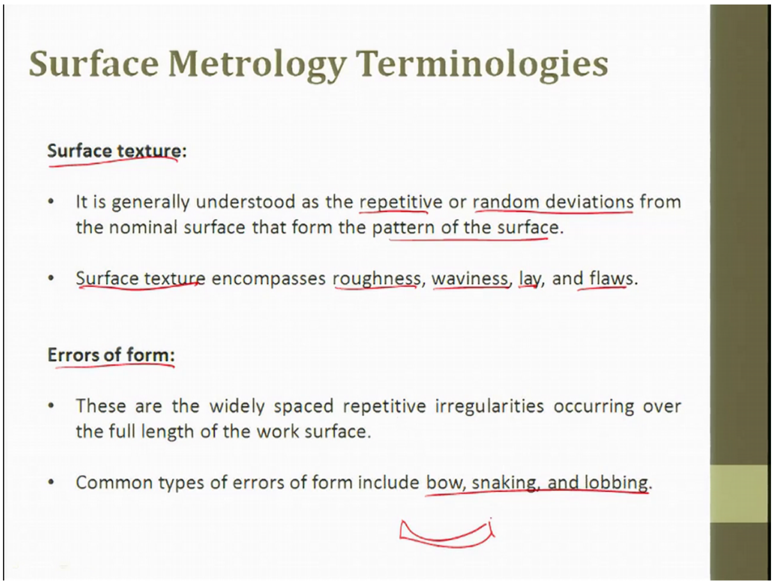

Surface texturing the it is generally, understood as a repetitive or random deviation from the nominal size that forms the pattern on a surface ok. Repetitive because, in machining operation what we do there is a relative motion between tool and the work piece and as when the tool moves, it is repeating the tool geometry when it starts moving in the contact machining. The surface texture encompasses wave roughness waviness lay and flaw is surface texture.

So, surface roughness is a subset of surface texture, waviness yes, lay is also an flaw is also. What are the errors of forms, they are widely spaced repetitive irregularities occurring over a full length of the work piece are some of the error of form. Common types of error which includes snaking, lobbing and bow, bow means it is something like this, so the deflection itself.

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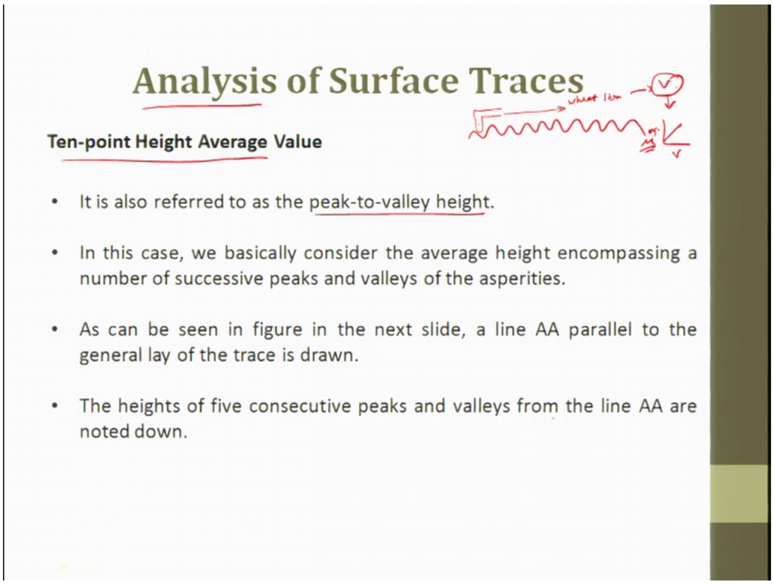

So, analysis of surface traces, so the irregularities whatever is there, now what we are trying to do is we are trying to somehow measure it and analyze the data ok, measure and analyze the data. Generally speaking, in a roughness how do you do it, you just have a stylus or you just have your finger, scribe it over the surface when you try to scribe it over a surface then, you see what are all the irregularities. So, you can have a mechanical way or you can have an electrical way.

So, generally we keep a stylus, the stylus intern is attached to the wheatstone bridge principle ok. And then finally, what we get is the output, this output is calibrated and then we try to get what is the voltage what is the magnitude, so this will be in microns. So, this data is finally, converted into voltage calibrated and displayed as microns. So, you remember last class, we last lecture we saw about the transducers, so in this is one of the example for it.

So, there are several parameters to measure, height 10, height average value is one method. So, it is also referred as peak to valley height. So, in this case we basically consider the average height, encompassing a number of successive peaks and valleys of the asperities. As can be seen in the figure in the next slide, which I will draw a line AA parallel to the general lay of the trace is drawn, the height of 5 consecutive peak and valleys from the line AA are noted.

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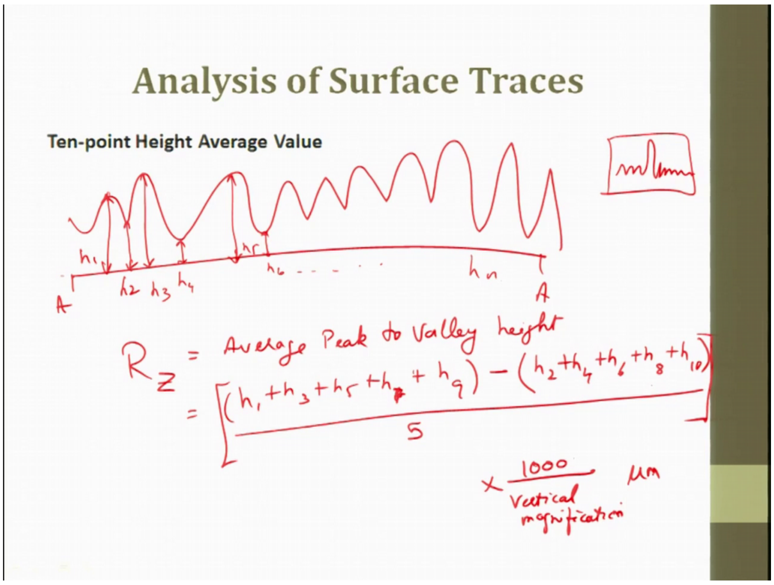

So, what they are trying to say is there is a line ok, which is AA and then what you have is you have a undulation on the surface ok. So, this is let us take, this is h 1, this is h 2. this is h 3, this is h 4, this is h 5, h 6 and so on right you can go up to h n.

So, what we write a formula is R z R z, which is nothing, but the average peak to valley, valley heights ok, this can be expressed as h 1 plus h 3 plus h 5 plus h 6 sorry plus h 7 plus h 9 minus h 2, h 4, h 6, h 8 and h 10, that divided by 5 and the entire thing will be multiplied with 100 divided by vertical magnification. This is nothing, but to make sure see this you measure the roughness which will be with a stylus and then finally, what you get will be stylus with a data like this.

So, now, you have to amplify, this is a surface undulate which will be very small. So, you amplify the signal and then you display, so that is why we talk about vertical magnification which will always be reported in terms of microns.

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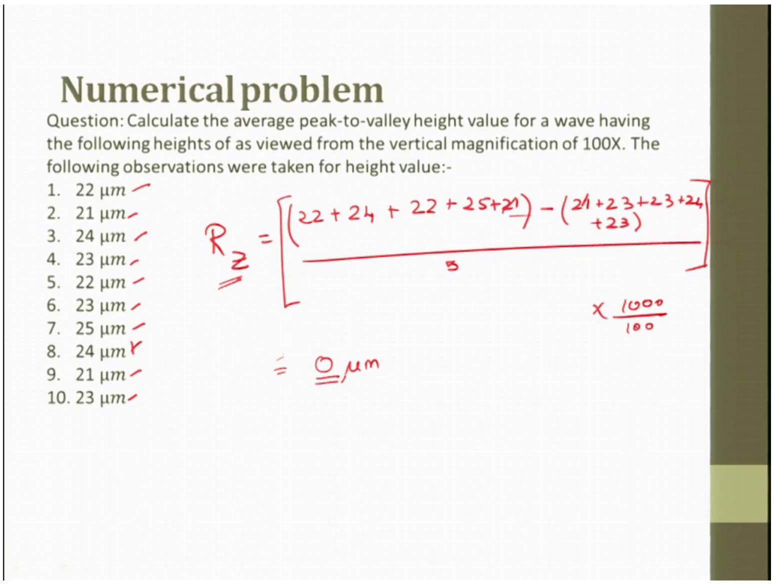

So, let us try to solve a problem. So, calculate the average peak to valley height value for a wave having the following height as of a viewed from a vertical magnification of 100 X. The following observations were taken for the height value ok. So, now, R z will be nothing, but 22 plus 24 24 maybe 20, 21, 22, 24, 22 plus 24 plus 21 minus 21, 23, 23, 24 and 23 ok, divided by 5 and this is vertical magnification is of 100 X, so into 100 divided by oh this is 1000 divided by vertical magnification 100.

So, if you look into it, this one this one goes off and if you try to subtract all those things what you get is going to be 0 microns only. So, here it is very clear, the R z value, after subtracting all these things what you get is going to be 0 microns. This is 1 parameter to characterize the surface.

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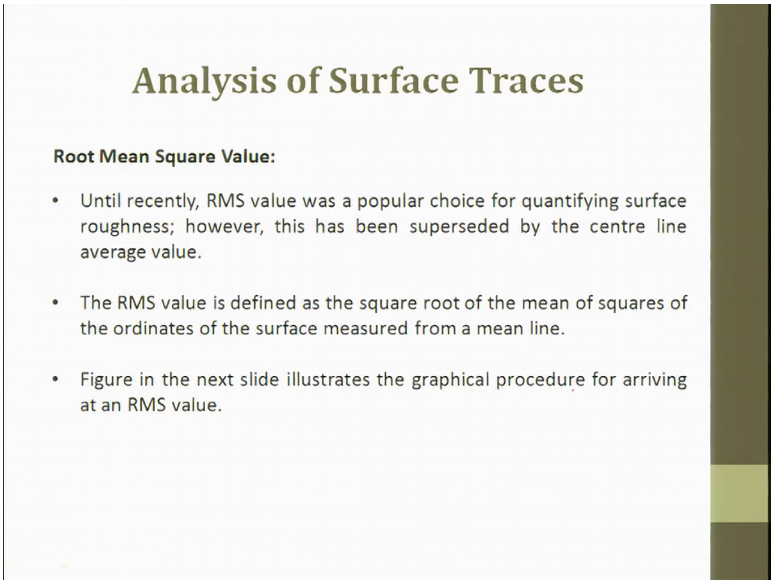

The next parameter to characterize a surface is going to be root mean square value. Until recently RMS values were very popular choice for quantifying surface roughness; however, this has been superseded by the centre line average method. We will see what is centre line next. The RMS value is defined as the square root of means of squares of the ordinates of the surface measured from a mean line. The figure which we will show in the next slide, illustrates the graphical procedure for arriving at the RMS value.

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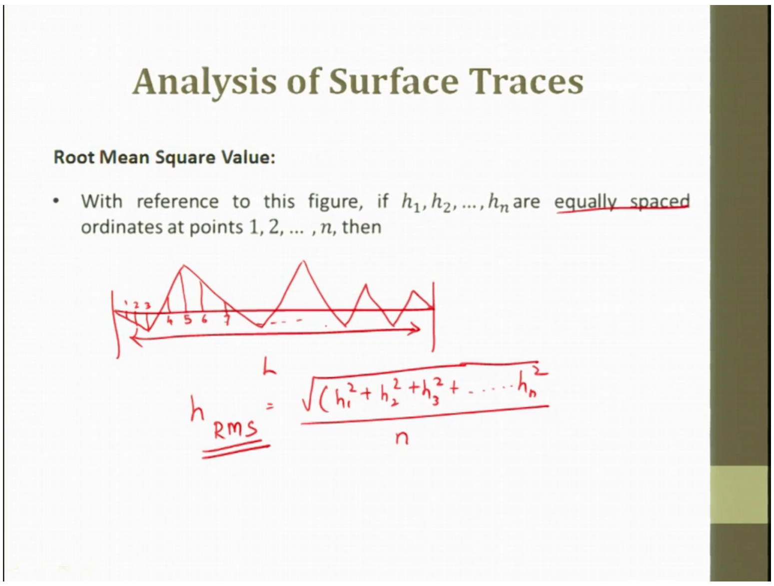

So, root mean square value, if you see the figure you have a length of span for which you take the measurement and then I am just converting this roughness value whatever you get ok. So, now, what we do is, we try to discretize, so this is 1, 2, 3, 4, 5, 6, 7 and so on. So, the root mean square value will be represented as h RMS which is nothing, but root of square root of h 1 square plus h 2 square plus h 3 square and then so on, h n square divided by n. So, this is called as root RMS value for the same surface you measure and try to get the irregularities. The only thing is they are all equally spaced ordinates at points 1, 2, 3 and so forth ok, this is RMS value.

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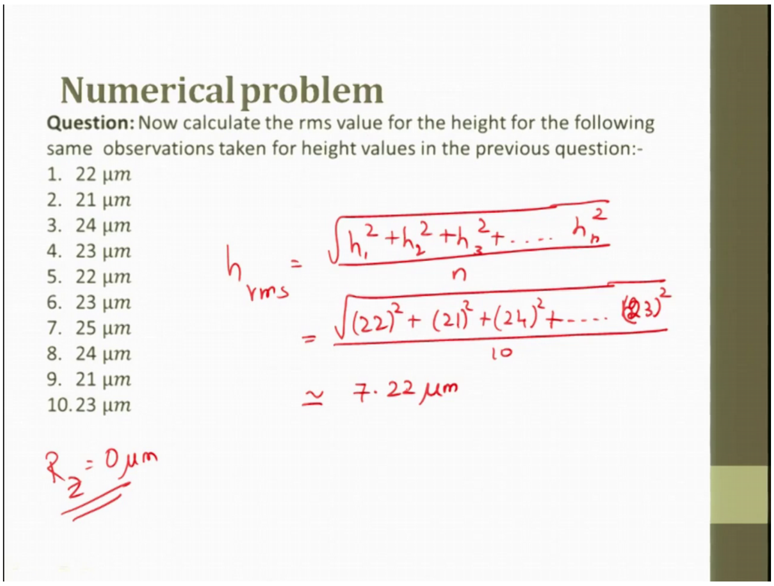

So, let us take the problem here. So, now, calculate the RMS value for a height for the following same observations taken for height values in the previous question. So, same thing where we got Rz is equal to 0 microns. So, we will try to get h RMS values here. So, how do we do it, we try to take h 1 square plus h 2 square plus h 3 square plus go on to h n square divided by n. So, here what we get is after calculation for the same for example, what we are trying to say is, take 22 square plus 21 square plus 24 square and go on up to h.

So, here it is going to be 10, so that will be 23 square right divided by 10. So, the answer is approximately 7.22 microns this is what you get. Say for the same surface, one of the parameters whatever you use you got 0 and the other parameter for measuring the surface you get is 7.22.

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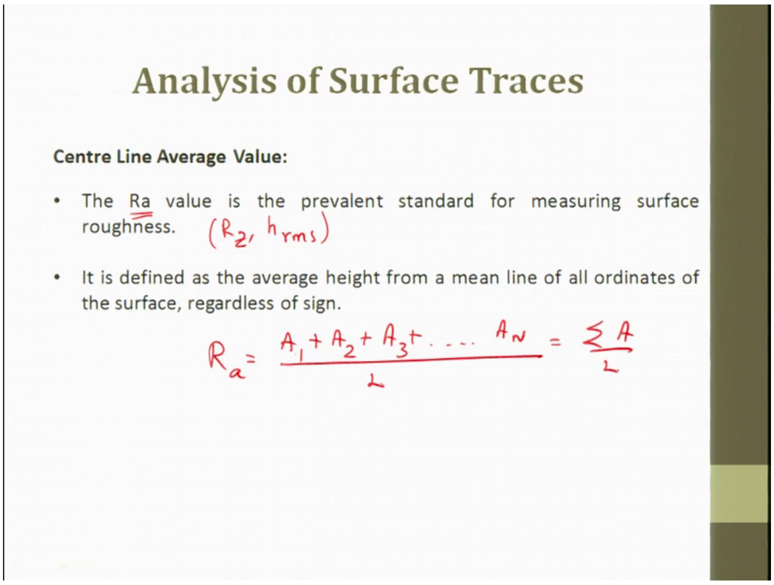

The third one is going to be the centre line average. So, in centre line average is Ra value is the most prevalent standard for measuring a surface. So, till now what we saw we saw R z and then we saw h RMS, two things we saw. But Ra is said to be most common, it is defined as the average height from the mean line of all ordinates of the surface, regardless of the sign we try to get here. So, what are we trying to say it is expressed as Ra equal to A 1 plus A 2 plus A 3 going on up to A n and then what we do is, we divided by length L which is nothing, but summation of A by L.

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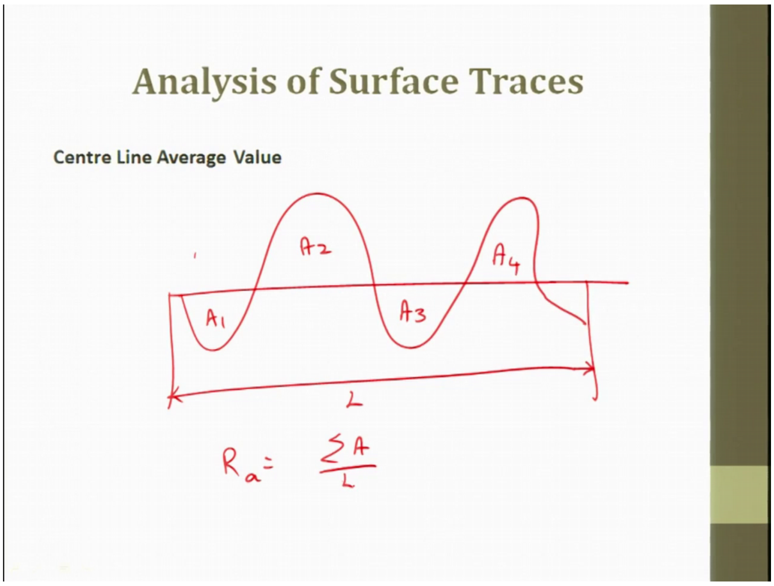

If you look at the figure, so it will be something like this. So, you have so this is your L, this is your A1, A2, A3 A4 ok. So, what you get is the summation of Ra is equal to summation of A by L.

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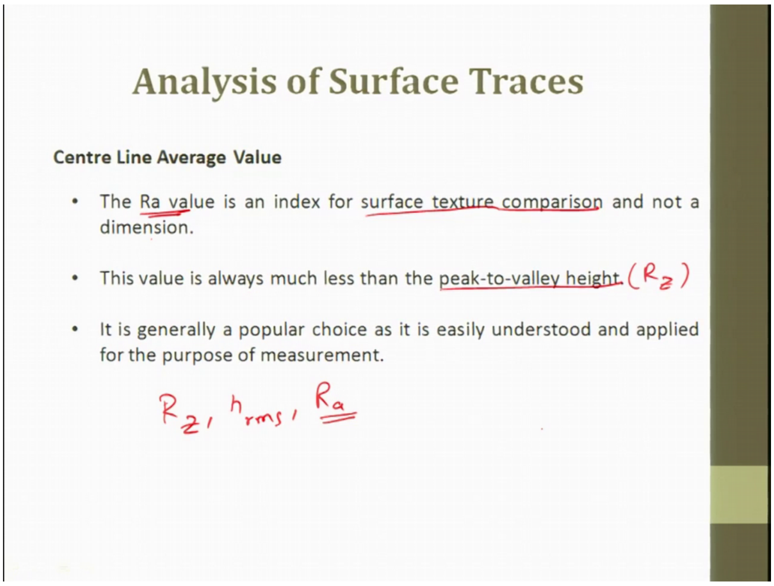

So, this Ra is an index of surface texture comparison and not a dimension. Ra value is a surface texture comparison. The valley is always the value is always much less than peak to height value. So, what is this, this is R z as compared to R z this values are less. It is generally a popular choice as it is easily understood and applied for the purpose of measurement.

So, this is very commonly used and the other thing you should also know is, you have measured three parameters R z, h RMS and Ra. All the 3 values need not give the same, all the three values need not be the same, you can use one in index to measure a surface and compare this with the other, other process or something, but for the same index ok. Ra is an index of surface texture comparison and not the dimensions.

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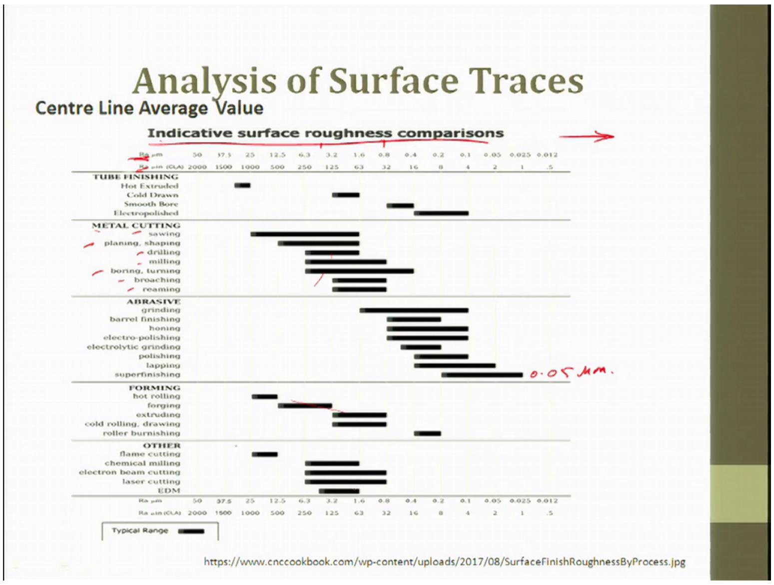

So, if you look at it for varying processes for varying processes, they have already predefined what will be the roughness generally we get. So, this is published in several hand books for example, you take metal cutting, sawing, planning, drilling, milling, boring, broaching, reaming you will see what should be the surface finish we can expect. So, this is Ra in terms of meters microns and you can also express in terms of inches. So, if you see here the values are decreasing when you move down.

So, when we take reaming operation, the value might be expected to fall from 4 microns it might go up to 0.8 microns. If you do not get it in this range then, it is basically we have to recheck the process and bring it under control. So, reaming is a process, now if you look at abrasive processes superfinishing, you can go up to 0.05 microns. When you look at forging you see that the dimensions fall above and the other operations, it is much more coarser.

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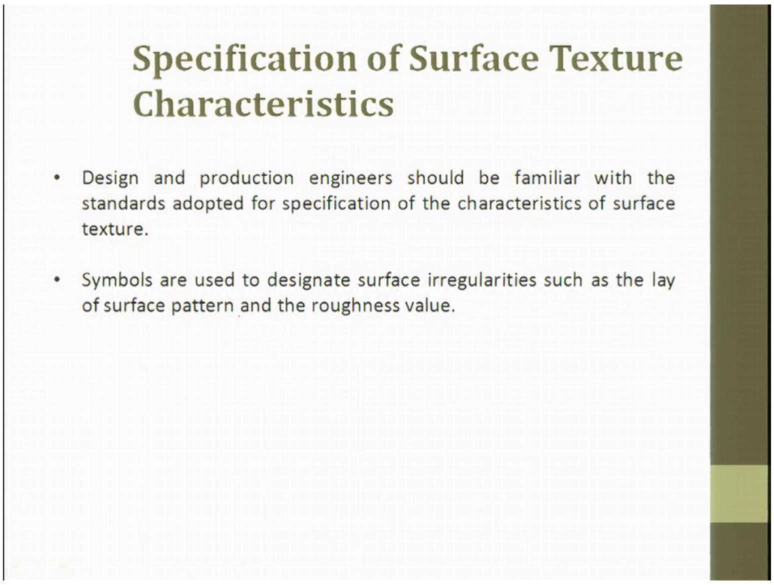

So, specification of surface texture characteristics, design and production engineers should be familiar with the standards adopted for specification of the characteristics of a surface texture. Symbols are used to designate surface irregularities such as, lay of the surface pattern and the roughness value. So, there are symbols which are used like, what we in the dimension measurement we saw symbols like roughness, we did saw straightness, flatness, runout, circularity, cylindricity same way we also have the symbols for surface texture.

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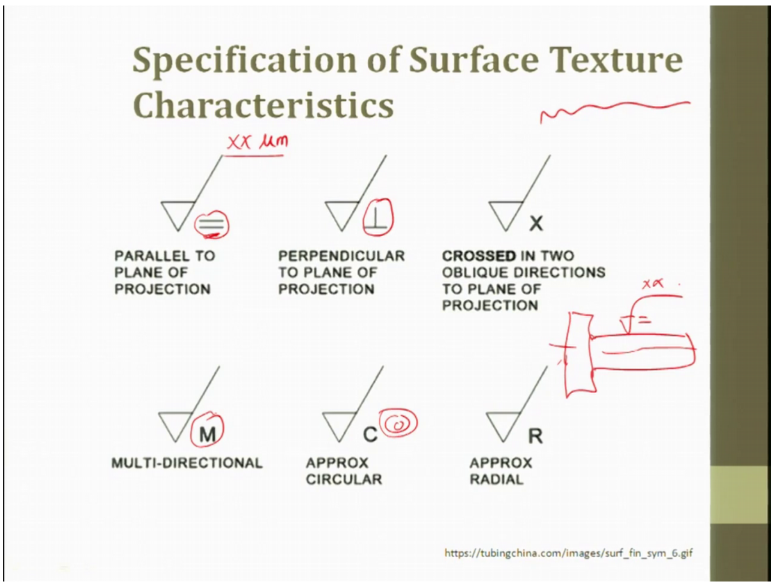

And this surface texture when we try to talk about the lay pattern is also very important to note. So, this is a typical symbol and here we write down the magnitude value whatever it is ok.

So, parallel to the plane of projection, this is perpendicular to the so, when we look at this we will should understand how is the roughness measured. Parallel to the plane of projection, perpendicular to the plane of projection crossed in 2 oblique directions to plane of projection will be X, multi direction then approximate circular for example; facing, then approximately radial ok.

So, here we it is random in nature so, it is called as multidirectional. So, these symbols are given on a surface. So, what they do is there is a surface or suppose if there is a shaft, so if the symbol is given like this, so they say Ra. So, here it can Ra equal to XX value. So, then by looking at the lay we will know what is the process done and what is the output taken and here is a symbol.

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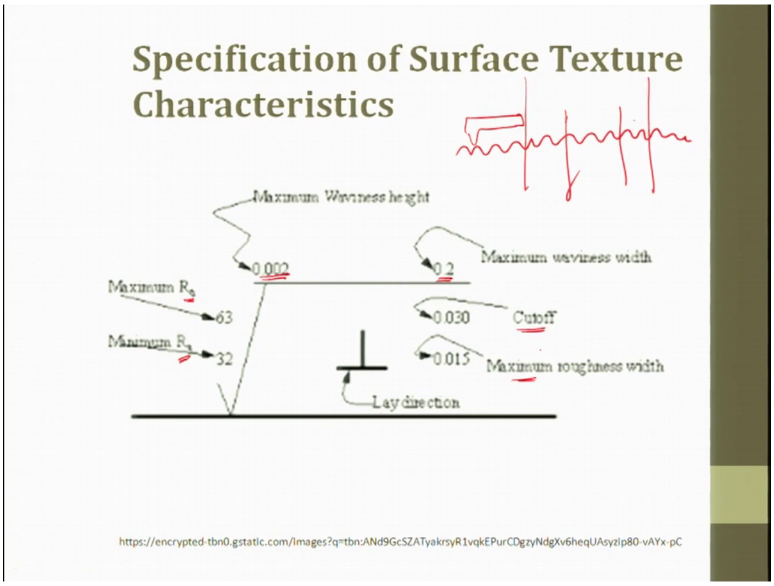

So, if you look at a specification of a texture characteristics, it will be here you will have maximum Ra, minimum Ra, maximum Ra, you will have what is the waviness height, what is the maximum waviness height, what is the maximum waviness width. And there is something called as cutoff and maximum roughness width and here is the direction. All these things are part of the game what is cutoff? For example; you have a surface right, this surface first as and when you start moving the stylus, it will have a running in weir or it will try to establish a surface and then you will try to have a measuring surface, maybe this is the measuring surface. So, in this measuring surface, we try to find out what are all the subsegments, so those things are called as cutoff lengths.

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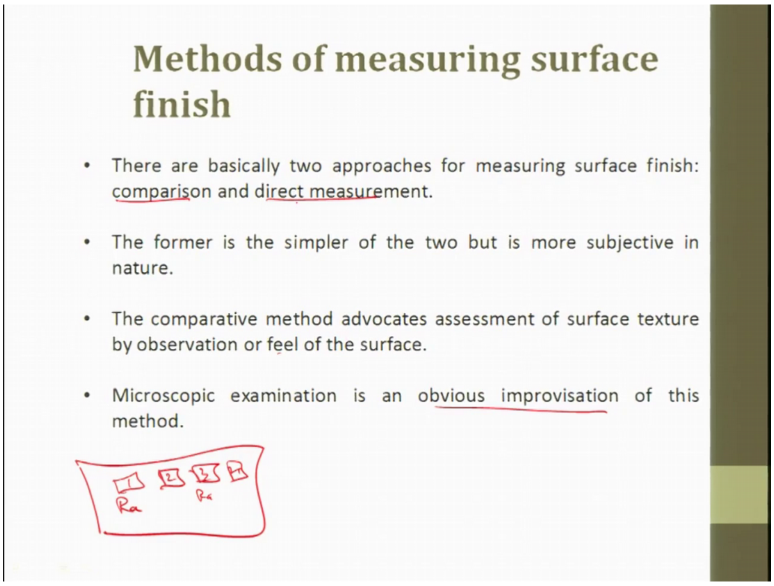

So, methods of measuring a surface finish, there are basically two approaches for measuring surface finish. One is by comparison the other one is my direct measurement. The former is simpler of both, but it is more subjective. The earlier days they used comparator. So, what they did was, they had they had a standard, so in that standard they had several samples and each sample they will have values.

So, the workshop operator or the superman used to scribe the surface, scribe the work piece surface, compare and say this is equal to this first grade, second grade, third greater or fourth grade, they used to say third grade then, correspondingly for this there will be a value which is given, so then, they compare it and see. So, or they have two surfaces looking at the surface, they try to do it. Comparative measurement advocates assessment of surface texture by observation or feel of the surface. Microscopic examination is the obvious improvisation of this method. So, put it under a microscope and look, but direct measurement is the best method to measure.

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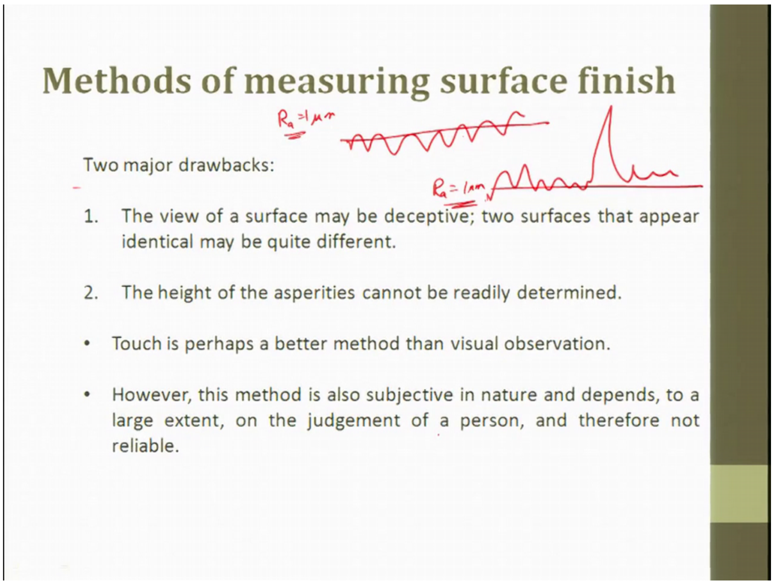

But the two major drawbacks are the view of the surface may be deceptive; two surfaces that appear identical might be quite difference, for example, these two surfaces can have a Ra value as 1 micron. The textures are completely different, the roughness are completely different, so you can have 2 different profiles, but have the same roughness value. So, if this is the case then, it becomes very difficult when we use this visual technique or comparison technique.

The height of the asperities cannot be readily determined, you can only touch and say this process is done by drilling, milling. But exactly if there is a peak then, you do not know when the load is applied, what is the load this peak is going to take how is this going to get damaged and other thing; however, this method is also subjective in nature and depends on large extent on the judgement of the person, which is touch.

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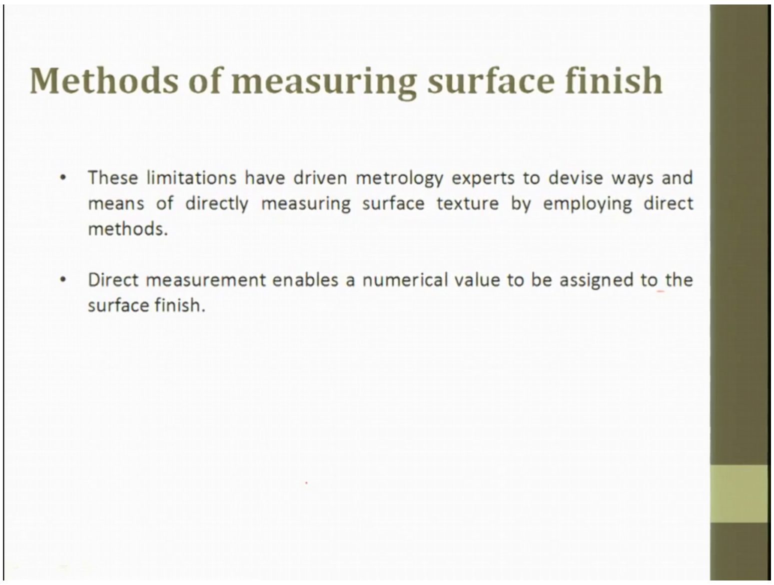

The limitation has driven metrology experts to device ways and means of direct measuring surface textures by employing direct methods. So, the direct measurement enables a numerical value to be assigned to the finished surface. So, rather than saying it is rough, it is slightly rough now, we would like to see what is the real magnitude value given to the generated surface. So, that is the direct measurement.

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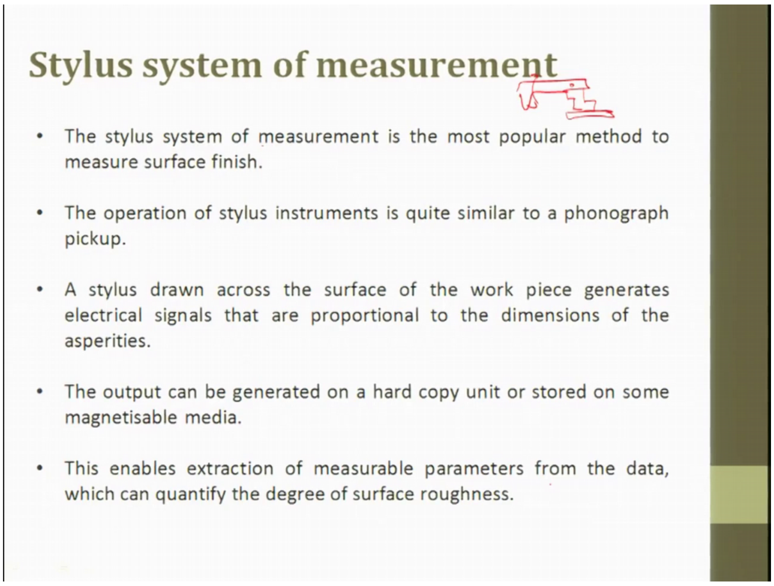

So, in indirect measurement, we always use a stylus system. You initially what you used as your hand now, replace the hand by a stylus. So, what happens in a stylus, this stylus will be something like you can have a stylus and this can be resting on a something on a fulcrum or something. So, this is pivoted here, when this fellow moves up or down, so you can start measuring what is a deviation.

So, stylus system of measurement is the most popular method of measuring surface finish. So, here is a mechanical thing which I draw, so you can go back and see in comparator how did we do, we had operating point then we had a fulcrum. So, in the same way, you can also try to change this pivoting point and other things with an electrical circuit.

The stylus draws across a surface of the work piece generates electrical signals that are proportional to the dimension of the asperities. So, here is mechanical, you can also have electrical. The output can be generated on a hard copy unit or stored in some magnetisable media. This enables the extraction of the measurable parameter from the data, which can quantify the degree of surface roughness.

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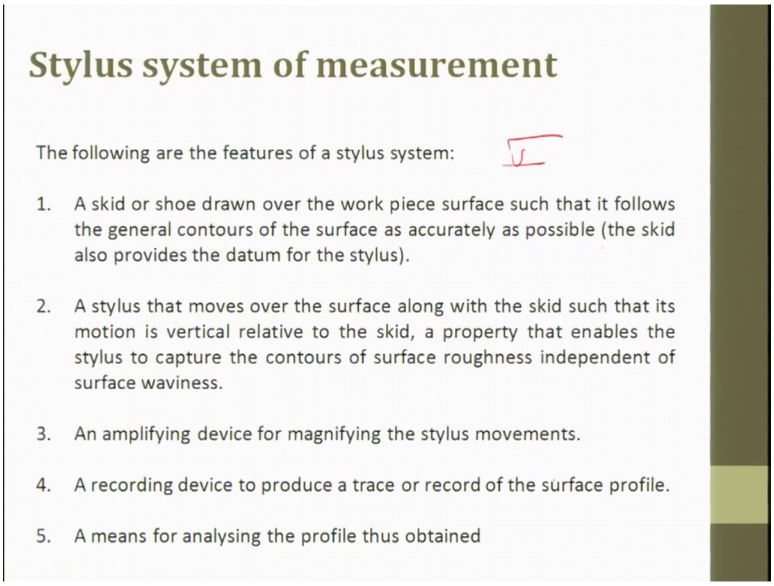

The following are the features of the stylus system. You will have a skid or a shoe drawn over a work piece surface such that, it follows the general contour of the surface as accurately as possible. A skid or a shoe stylus has a skid ok. The stylus that moves over the surface along the skid such that, its motion is vertical relative to the skid, a property that enables the stylus to capture the contour surface roughness independent of the surface waviness we use this. And amplifying device for magnifying the stylus moment and record it and finally, you try to measure the mean of it ok.

Thank you very much.