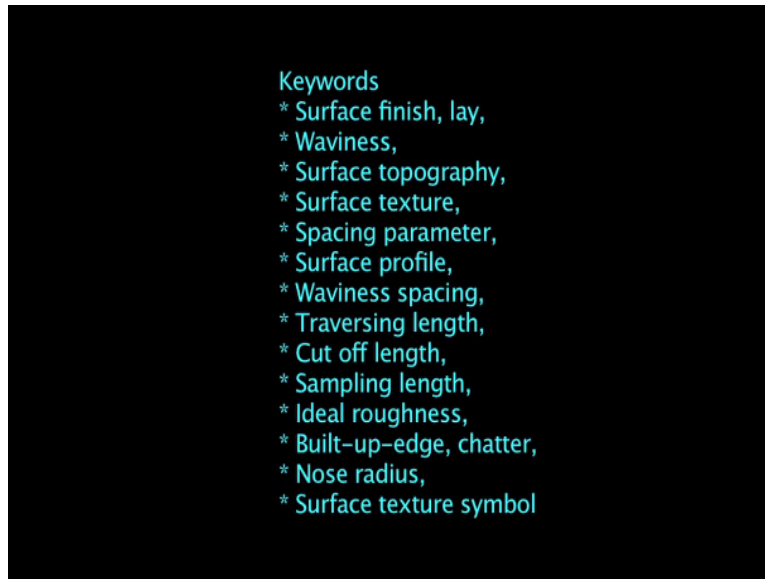


**Metrology**  
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**Module-5**  
**Lecture-1**  
**Basics of surface roughness**

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Welcome you all for the series of lecture on surface in the metrology. Now will start module number 5 lecture number 1.

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## Measurement of surface finish

- Basic understanding of surface roughness
- Indication of finish on drawings
- Parameters of surface finish
- Measurement methods: contact and non contact type
- Care of instruments

In this module we will be covering the following aspects of measurement of surface finish. We will learn about basic basics of surface finish and how the surface finish is indicated on technical drawings and what are the various parameters used in the measurement of surface finish and then we will move on to the different kinds of measurement of surface finish like contact method and non-contact method.

And we will also learn some offline methods and in-process gauging of surface finish and then we will care of instruments.

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### Why surface finish?

Surface finish, also known a surface texture or surface topography, is the nature of a surface as defined by the characteristics such as **lay, surface roughness, and waviness**.

Surface texture is one of the important factors that **control friction during sliding**.

- To improve look and feel of a product
- Fit between parts
- To control the process that results in the surface needed.



Now let us understand what is the meaning of the surface finish, if you take any engineering component it will have a surface which is open to atmosphere at there are some valleys and peaks on the outer boundary of the work piece. And the sometimes the surface will be very rough and sometimes it will be very smooth. In some cases where there are sliding parts for example machine tool guide ways or bearing surfaces.

We need to have very fine and smooth surface, so that the frictional forces are reduced and in some cases we need to have somewhat rough surface. For example in the cases of mating parts which are not to be moved, there is no sliding between 2 mating parts for example parts in interference fit. So, in such cases to prevent the relative motions between the 2 parts we need to have slightly rough surface.

This surface finish it is also known as surface texture or surface topography and in some cases we require very fine surface just to improve look of the component or the product and we need to measure the finish of the surface to control the machining process also. Now we can see here we have 2 mating parts, we can see the finish on the face of this cylindrical part and the roughness on the round cylindrical portion.

Also we can see this is the finish of this flat surface and here intentionally there made very rough to have a proper griping. And we another picture of a flat surface which is face turned component. We can see clearly see the rough surface and we can see the circular the concentric circles made by the cutting tool cutting action.

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## Importance of surface finish

- Surface roughness, is important from the point of view of fundamental problems such as friction and wear, surface contact, lubrication, fatigue strength, and tightness of joints.
- It affects conduction of heat and electrical current, cleanliness, reflectivity of the surface, sealing action.
- It also affects the positional accuracy of mating parts, load-carrying capacity, resistance to corrosion and adhesion of paint and coatings .
- The accuracy and surface-finish requirements for machined parts in modern industry are becoming more and more stringent.

The surface roughness is very important from the point of view of fundamental problems such as friction and wear, surface contact, lubrication, fatigue strength and tightness of joints. It affects the conduction of heat and electrical current, cleanliness, reflectivity of the surface and sealing action. It definitely affects the positional accuracy of mating parts, load-carrying capacity, resistance to corrosion and adhesion of paint and coatings.

And then the accuracy and surface finish requirements for machine parts in the modern industry are becoming more and more stringent.

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- If the machining imperfections exceed design specifications, the functionality of the product is affected.
- So, it is essential to check whether the design of the work piece complies with the functional requirements
- Hence , it is necessary to check the geometry and the surface characteristics of the work piece

In the machining imperfections exceed the design specifications, then the functionality of the product is definitely affected. So, it is very essential to check whether the design of the work piece complies with the functional requirements of the product. Hence it is necessary to check the geometry and the surface characteristics of the work piece.

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### Understanding Surface Texture

- To examine the deviation between points on a surface and other points on the same surface
- Every part's surface is made up of texture and roughness which varies due to manufacturing techniques.
- To understand a component's surface and to control the manufacturing process to the degree required in today's modern world, it is necessary to quantify the surface.
- Surface texture parameters can be grouped into these basic categories: Roughness, Waviness, Spacing, and Hybrid.



Say we have a component like this and then I am just showing the details of this particular surface. So, you can see it appears to be some wavy that means with respect to this point what is the height of this point, what is the height of this point like this. The relationship between various points on the same surface we will be studying and then every part surface every engineering component surface will have sort of texture.

It can be rough texture or very smooth texture or it can have a very specific type of surface as shown in the previous picture. And then measurement of surface texture is very essential to understand a component's surface and to control the manufacturing process to the degree required in today's modern world. So, surface texture parameters are grouped into many categories like roughness parameters, waviness parameters and spacing parameters and also the combination of this termed as hybrid parameters.

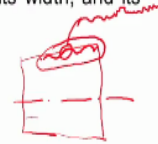
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## The principal elements of surfaces

**Surface:** The surface of an object is the boundary which separates that object from another substance. Its shape and extent are usually defined by a drawing or descriptive specifications.

**Profile:** It is the contour of any specified section through a surface.

**Roughness:** It is defined as closely spaced, irregular deviations on a scale smaller than that of waviness. Roughness may be superimposed on waviness. Roughness is expressed in terms of its height, its width, and its distance on the surface along which it is measured.



Now what are the various principle elements of a surface. Now you can see here the general term surface it is the boundary of any engineering component which is expose to the atmosphere or other kind of medium. And then we say a profile it is a contour of any specified section through a surface. For example say we have a component which is turned like this now you can see here if you take this particular portion.

Now it has a taper component maybe because of some error in the machine tool slide movement and also it will have some periodic shape like this which is termed as waviness. If you take if you consider this small portion of this wavy surface and enlarge it. It will have a surface like this which is turned as roughness that means profile it consists of all it consists all the elements like the form error of the work piece and then wavy surfaces and then roughness of the surface.

It is total contour of the surface is known as the profile and then the roughness is the closely spaced irregular deviations on smaller portion of waviness as considered here.

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**Waviness:** It is a recurrent deviation from a flat surface, much like waves on the surface of water. It is measured and described in terms of the space between adjacent crests of the waves (waviness width) and height between the crests and valleys of the waves (waviness height).

Waviness is caused by,

- Deflections of tools, dies, or the work piece,
- Forces or temperature sufficient to cause warping,
- Uneven lubrication,
- Vibration, or
- Any periodic mechanical or thermal variations in the system during manufacturing operations.



And then we have the waviness it is a recurrent deviation from a flat surface. It is a like wave on a surface of water. It is measured and described in terms of space between adjacent crests and peaks and valleys like this okay. It looks something like this, this is a peak and then this is the valley and we measure the distance between peaks and valleys and distance between 2 peaks and such parameters we study.

This waviness is caused due to deflection of tools and work pieces. For example we have the work piece mounted between 2 centres and when we using the cutting tool when we press. So, if it is slender it may bend like this, the work piece may bend like this because of this waviness may occur and also the cutting forces will cause the waviness and temperature variations cause the variations and if the lubrication is not proper.

Then also the waviness may occur and machine tool vibration, chatter of the cutting tool these are some of the reasons why the waviness occurs on the surface.

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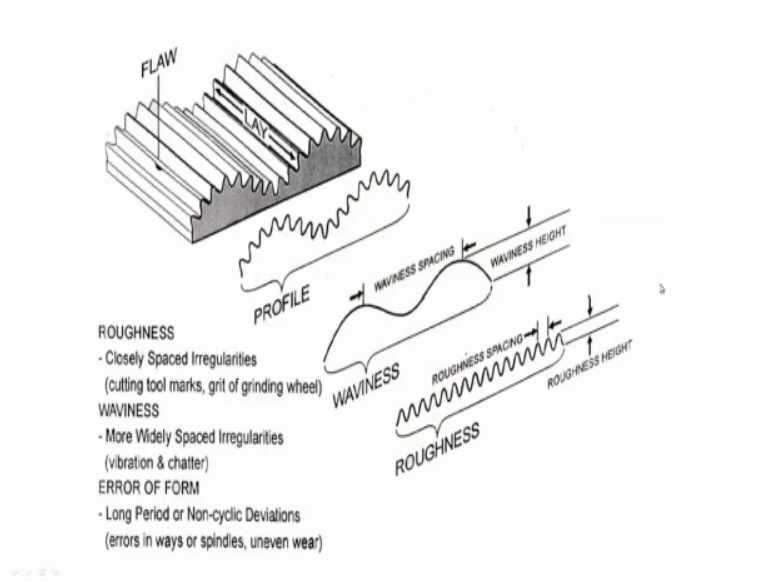
**Flaws:** Flaws, or defects, are random irregularities, such as scratches, cracks, holes, depressions, seams, tears, or inclusions.

**Lay:** Lay, or directionality, is the direction of the predominant surface pattern and is usually visible to the naked eye.



And then maybe there are some flaws like the blow hole on the surface. On the component surface maybe there is a blow hole or some scratch maybe there or a crack or some depression, so such things are known as flaws. And lay it is the direction of the predominant surface pattern which is visible to the naked eye. So, this appears on the because of the tool movement of the surface tool is like a tool mark on the machine component.

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Now we can see all those terminologies in this diagram. So, you can see this is the total profile which consists of waviness of the surface and then micro irregularities, micro asperities valleys and peaks as also the taper and drum shaper, barrel shape. So, that total various parameters are

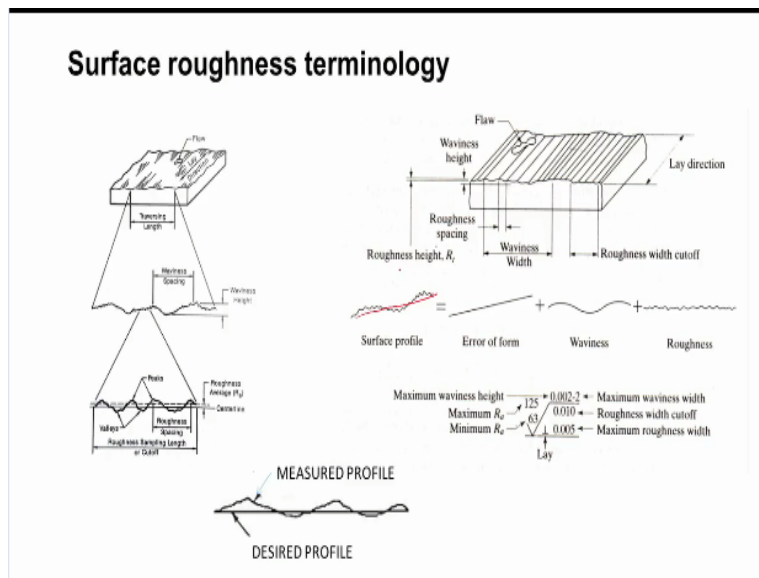


combined in this particular shape and which is termed as profile and here you can see there is a scratch in the or depression in this surface, this is known as flaw.

And we can also see the direction of tool mark which is termed as lay. Now when we remove this for micro irregularities or roughness then we will get the waviness like this and this is the waviness height and that is the distance between peak and valley and also the distance between 2 peaks or distance between 2 valleys is termed as waviness spacing and if we remove the waviness part of the profile. Then we will get only the micro irregularities which is termed as roughness.

And the distance between peak and valleys termed as roughness height and the pitch this pitch that is distance between 2 **peak** peaks is termed as roughness spacing.

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Now we will have another we have another diagram which will help us to understand the various terminologies. So, this is a flat surface and when we close the observe we can see the unevenness okay. this is the waviness we can observe and then direction tool mass we can observe and flaw also we can observe. And then when we measure the surface finish we will take we will move the instrument for example if you take the stylus type instrument.

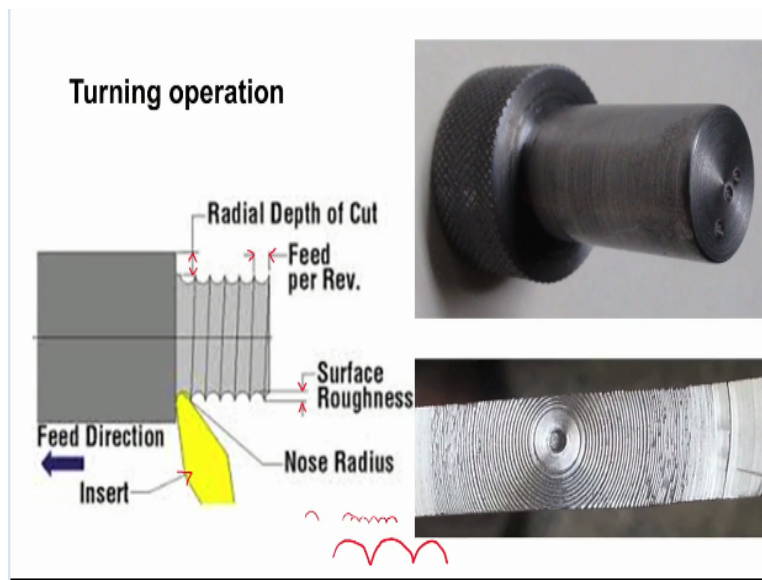
We move the stylus of the probe on a surface to a particular length which is termed as traversing length and this portion traversing length the profile is enlarged here. You can see the waviness and the waviness height and waviness spacing and again if you consider the small portion of the wavy waviness. Then it when we enlarge it we can see the micro irregularities we can see the peaks and valleys.

And the distance between 2 peaks of roughness is known roughness spacing and we consider a particular of the wavy profile and then we go for studying or the measuring the roughness. So, this particular length is known as roughness sampling length also it is known as cut-off length. And the actually when we mechanical engineers specifies the roughness we actually decide is specifies to have a desired profile like this which is almost flat and straight.

But when we actually cut the work piece using machine tool and cutting tool we get the profile like this when we measure it we get the profile like this. These variations are due to many reasons like the vibration of the machine tool and the shape of the cutting tool and then the use of various parameters, machining parameters like speed and feed etc., etc. And then here you can see the surface is tapered like this okay.

This is the surface profile and this is actually the combination of these 3 the error of the form, form error which is taper in this case and then we have waviness and then we have roughness. All these put together we get the profile like this.

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And now if we take the machining operation very simple very well known machining operation that is turning operation . Now you can see this is the work piece and then we have the cutting tool with some round nose, this is nose radius and then the cutting tool is fed in this particular direction, this is the feeding direction. And then because of this radius the tool mark appears on the machine surface like this okay, we get the shape, concave shapes like this.

So, this gap that is distance between peak and valleys known as the surface roughness. This is actually the radial depth of cut and then this is the feed rate per revolution. So, when we vary the feed rate then the roughness will change. So, if you have very fine feed then we get the surface roughness like this. So, and if the nose radius is more and then we get the surface roughness like this.

So, the geometry and the machining conditions do affect the roughness of the work piece. So, in this diagram you can see a turned component we have a turned component here you can see on the face, this is the faced portion you can see the concentric circles and then on the periphery also we see the tool mark. And this is another surface which is face turn we can see the concentric circles and then bur at the centre and then various the flaws burse on the surface. So, when we vary the feed rate this roughness will also vary.

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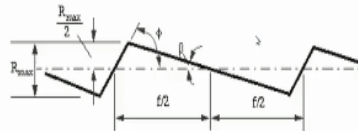
## SURFACE ROUGHNESS IN MACHINING

The resultant roughness produced by a machining process is a combination of two quantities:

- a. Ideal roughness
- b. Natural roughness

**Ideal roughness:** Ideal surface roughness is a function of feed and geometry of the tool. It represents the best possible finish which can be obtained for a given tool shape and feed. **It can be achieved only if the built-up-edge, chatter and inaccuracies in the machine tool movements are eliminated completely**

Idealized model of surface roughness



Now surface roughness in machining operation when we machine the work piece surface, so we get 2 kinds of surfaces one is the ideal surface and another one is natural surface. So, ideal roughness it is a function of feed and geometry of the tool, we discussed about this feed and geometry of the tool when we vary when we use very fine feed, the we get a better finish also when we have a sharp point we get a good finish.

It represents the best possible finish which can be obtain for a given tool shape and feed rate. It can be achieved only if build-up edge and chatter and inaccuracies in the machine tool movements are eliminated properly. So, this diagram shows that from valley to valley this gap is known as feed per revolution and these are the various angles on the cutting tool. So, because of this tool shape and feed rate we get the surface roughness.

This valley to peak distance is the  $R_{max}$  again the parameter use to designate the surface roughness.

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- For a sharp tool without nose radius, the maximum height of unevenness is given by:  $R_{max} = f / (\cot\phi \cot\beta)$
- Where,  $f$  is feed rate,  $\phi$  is major cutting edge angle and  $\beta$  is the minor cutting edge angle.
- The surface roughness value is given by,  $R_a = R_{max}/4$
- Practical cutting tools are usually provided with a rounded corner
- The roughness value is closely related to the feed and corner radius by the following expression:

$$R_a = (0.0321 f^2)/r, \text{ where } r \text{ is the corner radius.}$$

For a sharp tool without any nose radius, the maximum height of unevenness is given by this expression  $R_{max}$  is equal to  $f$  is the feed rate divided by these  $\cot\phi \cot\beta$  which are the cutting tools on the angles, of the cutting tool where  $f$  is the feed rate per revolution and surface roughness value is given by  $R_a$  is equal to  $R_{max}/4$ . Practical cutting tools are usually provided with a rounded corner.

So, if it is very sharp it will break easily and we get blunt corner on the tool. The roughness value is closely related to the feed and the corner radius by the following expression. We can use this if we know the radius corner radius of the tool nose radius and feed rate we can calculate what is the  $R_a$  value we are going to get.

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**Natural roughness:** Factors contributing to natural roughness are the occurrence of built-up edge and vibration of the machine tool.

Factors tending to reduce chip-tool friction and factors reducing the built-up edge would give improved surface finish.

And then other one is natural roughness, this natural roughness we get because of various inaccuracies in the machine tool and then vibration of the machine tool and cutting tool, chatter of the tool and then occurrence of the built-up edge on the cutting tool. Because of this we get a surface which is known as natural roughness which will be greater than the ideal surface finish.

So, if we can eliminate this built-up edge and vibration aspects of the machine tool then we get better finish.

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### **FACTORS AFFECTING THE SURFACE FINISH**

Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

A) The machining variables which include

- a) Cutting speed
- b) Feed, and
- c) Depth of cut.

And then what are the factors affecting the surface finish, see whenever 2 machine surfaces come in contact with one another the quality of the mating parts plays an important role in the

performance and wear the mating part. That is if 2 surfaces are very rough then the frictional force will more and the more wear will take place and if the surfaces are very smooth and if we can use some lubricant then the movement will be very smooth and friction will be less wear rate will also be less.

The height, shape, arrangement and direction of these surface irregularities on the work piece depend on a number of factors such as machining variables which include what is the cutting speed we higher the cutting speed and finer the feed rate we get better surface also what is the depth of cut, if you higher depth of cut then the cutting tool and work piece may vibrate and we get some roughness.

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B) The tool geometry

Some geometric factors which affect achieved surface finish include:

- a) Nose radius
- b) Rake angle
- c) Side cutting edge angle, and
- d) Cutting edge.

C) Work piece and tool material combination and their mechanical properties

D) Quality and type of the machine tool used,

E) Auxiliary tooling, and lubricant used, and

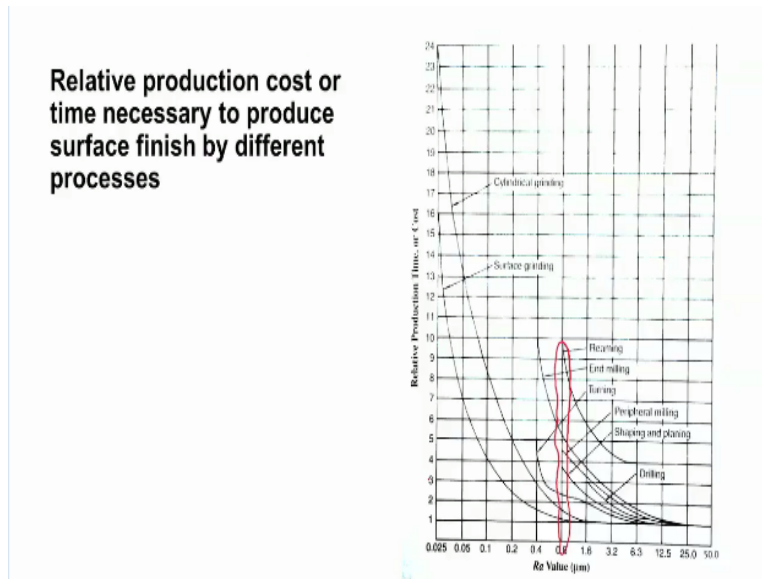
F) Vibrations between the work piece, machine tool and cutting tool.

And then tool geometry will also affect the surface finish, some geometric factors which affect the finish on nose radius and then various angles like rake angle and then side cutting edge angle, cutting edge. These are the cutting tool geometry will definitely affect the surface finish on the work piece. And then the combination of work piece material and tool material and then mechanical properties will also affect the finish of the work piece.

And what type of machine tool we use very robust and well built machine tool if we use. Naturally we get good finish. And then the use of auxiliary tooling like work rest and then proper loading of the work piece between centres and the use of coolant those things will also definitely

affect the finish what we get. So, vibrations between work piece machine tool and cutting tool this is also very important factor which will definitely the finish. If we reduce these aspects then we get good finish.

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And then this diagram will show the relative production cost or time necessary to produce surface finish by different processes we can see here x axis is it shows the  $R_a$  value in micrometers, range is 0.025 micrometer to 50 micrometer. And in the y axis we have 1 to 24 that is it is relative production time or relative production cost. In this picture we have considered various machining operations like the cylindrical grinding, surface grinding.

And then reaming operation, end milling, turning, peripheral milling operation, sheering and planing operation and drilling, very commonly used the machining operations. Now we can understand that whenever we want very fine surfaces naturally we go for grinding and then polishing operations. Now here we have cylindrical grinding and surface grinding which are able to give very fine surfaces with surface finish of less than 0.4 micrometer  $R_a$ .

So, naturally the production time is more and production cost is more compare to the other processes. Now whenever we want a a roughness value of 0.8 micrometer  $R_a$ , now we can see this is possible to produce by various machining operations if it is hole making operation we can





Now this picture shows surface roughness values for common production processes and these are roughness average or Ra value in terms of micrometer you can see the range is 0.025 micrometer to 50 micrometer Ra value. And these this row shows the ISO grades N1 grade, N2 grade up to N12 grade the N1, N2, N3 they are fine they provide finishes and then we use N10, N11 L N12 grades whenever we want to specify rough surfaces .

We have considered the various production processes like sand casting, hot rolling and then extruding operation cleaning, drilling, EDM process, milling. So, and then fine finishing operations like grinding, honing, electro polishing. Now you can see here these finishing processes like grinding, honing, lapping, super finishing their able to give very fine finishes you can see here the range is from 0.05 up to 0.8 micrometer Ra.

Super finishing can provide even the finer finish of up to 0.025 micrometer Ra. Now depending upon the availability where which facility is available we can appropriately select the machining operation and then for rough surfaces we can always go for these the milling, drilling, planning operations which are able to provide the finish in the range of 0.8 to 6.3 micrometer Ra.

Now we can this is sand cast process. In the case of sand cast surface the finish will be very rough like 12.5 to 25 micrometer Ra. So, if machining is require then if finer finish is require, because of the movement of other sliding surfaces. Then we can go for machining operations to produce required finish. Now recently some newer machining processes have come up and one such thing is plain glass cutting by hot air jet.

The hot air jet was used to cut the glass plain glass plates. So, there are other methods like laser cutting, water jet cutting and then diamond cutting most commonly use. But they provide very rough surface whereas this hot air jet cutting is able to give very fine finish of some 0.3 micrometer Ra to 0.8 micrometer Ra.

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## INDICATION OF SURFACE TEXTURE

- The **basic symbol** consists of two legs of **unequal** length inclined at approximately **60 degrees** to the line representing the considered surface
- The symbol must be represented by thin line



- If the removal of material by **machining** is required, a bar is added to the basic symbol



Now after understanding this the basics of surface finish and how to produce the finish. We will understand how the finish surface texture is indicated on technical drawings. Now you can see here this we have 2 lines separated by 60 degree one longer line and one shorter line. This is the basic symbol which is use to indicate the surface roughness on technical drawings and you can see the lens are unequal and they are separated by 60 degree.

And the symbol this symbol must be represented by thin line. This is the basic symbol used to indicate the roughness on the in the technical drawings. If it is required to machine the surface, if the surface is to be made by some machining operation or by **ss** some removal of material then you can see here a bar is added. So, this indicates that machining is required, that means we have to remove the material by machining operation like maybe turning operation or milling operation or the shaping operation something like that.

Now if removal of material is not permitted then a circle is added, bar is removed and circle is added. So, this indicates that no removal is permitted, we should be left as like cast surface, so further machining is to be made. And then when special surface characteristic are to be indicated, for example maybe electroplating or the surface should be electroplating or painting then a bar is added here to the longer line.

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- If the **removal of material is not permitted**, a circle is added to the basic symbol.



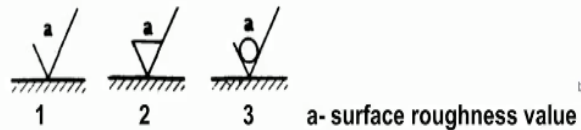
- When **special surface characteristics** have to be indicated, a line is added to the longer arm of basic symbol.



And then what is the how that special characteristic is to be produce should be return on this horizontal line.

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- The value of **roughness** is added to the symbols



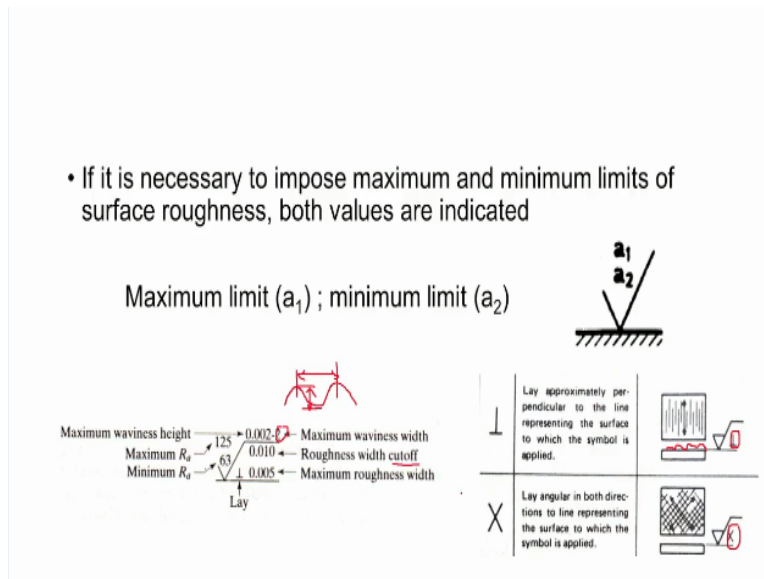
1. Roughness **a** obtained by any production process
2. Roughness **a** obtained by machining
3. Roughness **a** obtained without removal of material

Now sometimes we specify what is the roughness that is needed. Now you can see here we have 3 symbols here. So, indicates the surface roughness value, so if no parameter is specified, then it is understood that the value represents Ra value in terms of micrometer. If other parameters are required then Rt value or Rp value are max value then that should be clearly mention.

Now here the symbol number 1, roughness is obtained by production some production process. It will be which is not mention which production method is not mention okay like maybe it is cast

surface or a forged surface or a studied surface and in the symbol 2 we have a bar is added it indicates that some machining operation has been done. And the symbol 3 has circle here, it indicates that surface is obtain without the removal of material.

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Now sometimes it is necessary to mention the 2 values upper limit of the roughness and then lower limit of the roughness. In that case we use this symbol when is we have  $a_1$  and  $a_2$ ,  $a_1$  indicates the maximum surface finish and  $a_2$  indicates the minimum surface finish. We can see here we have used this basic symbol this is the surface on which the symbol is mention and then here we have 2 Ra values are mention this is maximum Ra value that is  $a_1$ .

And then minimum Ra value, so 125 and 63, so it is in microns Ra values 125 microns and it varies from 63 micrometer to 125 micrometer. And then you can see there is another symbol mention here inverted T, so this is to indicate the lay. So, now this is the surface okay surface under quotient and then now we have use this symbol this indicates that some machining operation is required.


And it also shows the lay direction that means to the surface that is mention to this particular surface lay is perpendicular. That means perpendicular to the direction of lay we have to measure the surface roughness. And this shows that the lay is it is angle lay angular in both directions

okay to if the surface is like this then we use X shape here. And we can also see on the horizontal line we have mention maximum waviness height okay like R.


So, distance between peak to valley what is the maximum waviness height that is mention here. So, it is 0.002 micrometer or 0.002 millimetre or 2 micrometer and maximum waviness width is also mention here it is 2 millimetre. That means so this gap is 2 millimetre and then roughness width cut-off is also mentioned here. We will learn about this cut-off in greater detail after sometime and maximum roughness width this is maximum roughness width 0.005 millimetre.

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- If it is required that the **surface texture** be produced by a **particular production method**, this method is indicated in plain language on the extension of the longer arm of the symbol



- **Indication of machining allowance:** Where it is necessary to specify the value of the machining allowance, this is indicated on the **left of the symbol**. This value shall be expressed in **millimeters**.



Now you can see here if it is required to produce the surface with a particular production method like shaping operation or turning operation or grinding operation. Then that is mentioned on the horizontal line. So, you can see here this is the symbol we have a bar here it indicates that surface is to be machine by some operation what is that operation is mentioned here, turning operation and what is the roughness value that is also mentioned here.

And sometimes what is the allowance, machining allowance that is provided on the work piece is also indicated in the symbol okay. This is 5 millimetre machining allowance is provided on the work piece.

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Symbol			
Removal of Material by machining is			
	optional	obligatory	prohibited
14.6.2.1	3.2 N8 or	3.2 N8 or	3.2 N8 or
14.6.2.2	6.3 N9 1.6 N7 or	6.3 N9 1.6 N7 or	6.3 N9 1.6 N7 or

And these are the some other types of indication as per the ANSI standards you can see here the removal of material by machining is optional we can remove by machining or otherwise. And here it is obligatory since we have this bar and then the machining preparation surface is required by machining operation. So, here grade is mention and here the roughness value is mention, since no parameter is mention it is understood that this is Ra value in micrometer.

And here no machining is required we need N8 grade or 3.2 micrometer surface finish Ra without the removal of material and here the limits are mention maximum roughness and minimum roughness values are mention.

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### Surface texture symbols

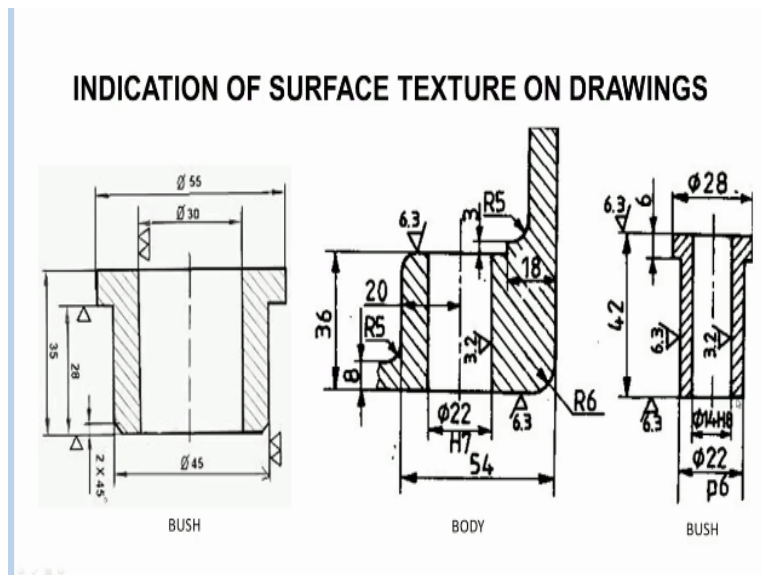
Lay Symbol	Meaning	Example Showing Direction of Tool Marks
—	Lay approximately parallel to the line representing the surface to which the symbol is applied.	
⊥	Lay approximately perpendicular to the line representing the surface to which the symbol is applied.	
X	Lay angular in both directions to line representing the surface to which the symbol is applied.	
M	Lay multidirectional.	

Lay Symbol	Meaning	Example Showing Direction of Tool Marks
C	Lay approximately circular relative to the center of the surface to which the symbol is applied.	
R	Lay approximately radial relative to the center of the surface to which the symbol is applied.	
P <sup>3</sup>	Lay particulate, non-directional, or protuberant.	

Now these are various kinds of surface texture symbols, now you can see here if inverted T is use then the lay is perpendicular to the direction in which the measurement is made. And here the cross hatch type texture is there and lay is multidirectional then we say M and if the lay is parallel to the measurement of surface finish and then we use this particular symbol parallel okay.

And then if the surface texture is concentric like this then we use this particular symbol this happens when we turn the work piece in the face turning operation okay. And then we have a particulate non directional texture then we use this P3 and then when the have the texture like this radial relative to the centre of the surface, then we use this particular symbol R.

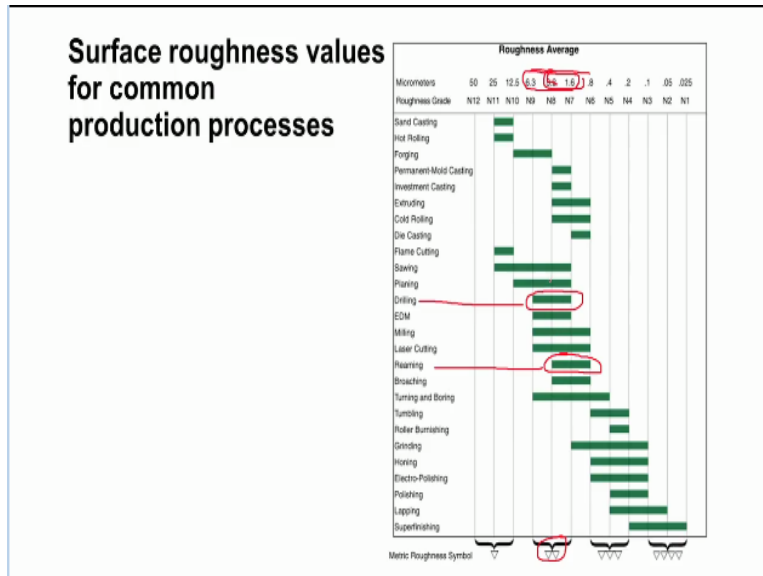
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Now you can see here these diagram show how the surface texture or surface finish is indicated on drawings. Now we can see here we have a hole here machined hole you can see the symbol here. So, we have this symbol with bar it indicates that the surface is to be produced by machining operation normally drilling operation.

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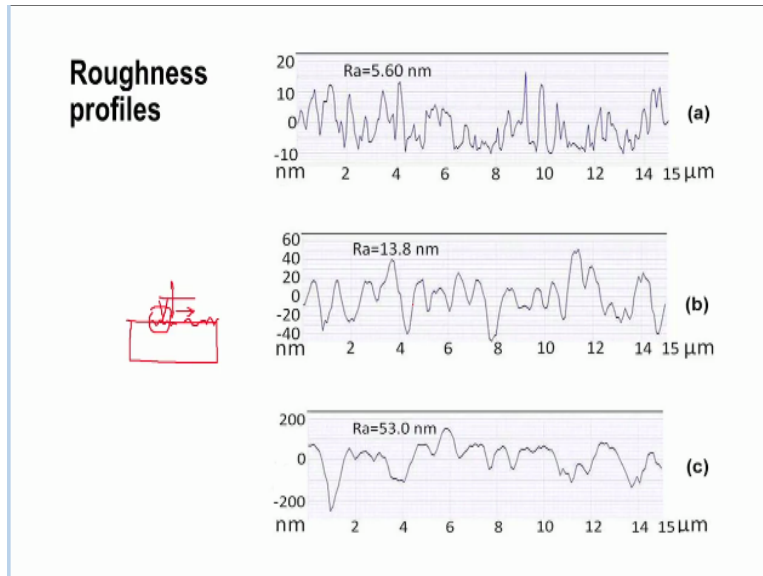


You can see here drilling operation can provide us with roughness varying from 1.6 to 6.3, 1.6 micrometer Ra to 6.3. So, here we have mention 3.2 micrometer Ra, so this hole can be produced by drilling operation and here it is 3.2 micrometer Ra. Now if required we can go for reaming operation. So, reaming can provide us the finish of 0.8 to 3.2 micrometer Ra.

So, if better drilled hole is required, better finish in the hole is required then we can go for reaming and here we can see the grades are used okay. This is the single triangle and double triangles are use, now form this diagram we can understand single triangle means it is a very rough surface maybe it is as cast surface is as **ca** cast and no machining is needed. And here we have a hole in which 2 grades, 2 triangle grade is used.

So, 2 triangle grade means we can use machining operations like milling, drilling operation, cleaning operation. So, such machining operation can be use to produce 2 triangle finish . So, like this we can indicate the surface finish on technical drawings.

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Now these picture show some roughness profile when we actually use some measuring instrument and when we measure the surface finish we get the surface profiles like this. We should understand that the see this is the work piece surface and say we have a stylus like this. So, this stylus is moved, so because of the roughness, waviness and form error, this stylus will move up and down when we draw the stylus on the surface, because of these variations this stylus will move up and down.

So, this up and down movement is amplified and then we get the roughness profiles like this. So, normally these peaks and valleys asperity heights are very small in terms of microns. So, very large magnification is used to amplify this vertical movement and the horizontal magnification is normally less. So, horizontal magnification maybe some 100 times or 200 times whereas the vertical magnification will be few thousands maybe like 1000, 5000, 10000.

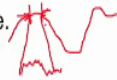
So, if it is very fine surface produced by grinding, lapping, supervision process, then we have to use very high magnification like 50000 or 1 lakh. If it is very surface produced by turning operation or shaping or planning operation, in that case it will be very rough surface will be very rough and we can use the lesser magnification like 1000, 2000, 3000.

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## Roughness parameters



- **Mean Line** - A straight line that is generated on the profile resulting in equal areas above and below the line. Also known as **centre line**.
- **Profile** - A two dimensional slice through an area.
- **Roughness Parameters** - The non-periodic finer irregularities in the surface texture which are inherent in the production process. These are a measure of the vertical characteristics of the surface.
- **Sampling Length** - The area selected for assessment and evaluation of the roughness parameter having the cutoff wavelength. Any surface irregularities spaced farther apart than the sampling length are considered waviness. Also known as **cutoff length**.



Now let us try to understand what are the various parameters used to specify the surface finish. So, we should understand some of the terminologies like mean line, so this is a straight line that is generated on the profile resulting in equal areas above and below the line. For example we have say we have profile like this, now we have to draw a line a straight line like this okay, such that equal areas above and below the line we get equal.

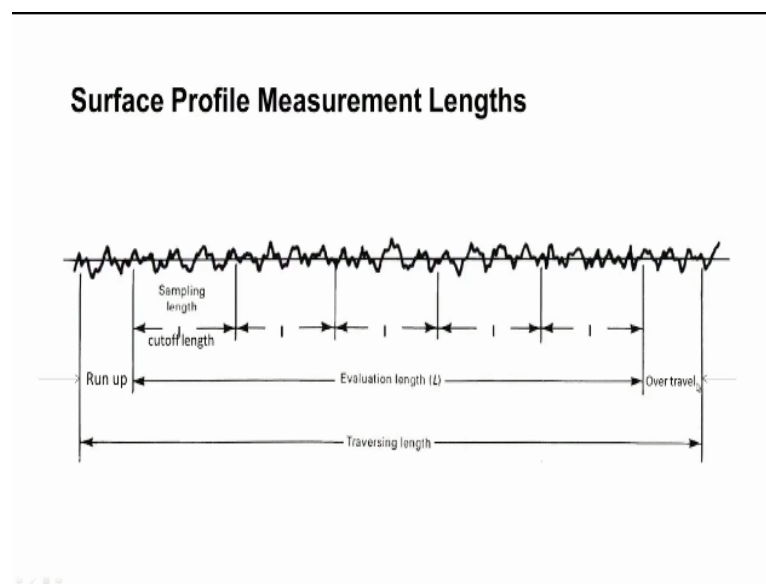
So, we have area here area above the mean line and then area below the mean line. So, we should draw the straight line maybe by trail and error method. So, that area above the area between the straight line and the profile above this means line and area below the mean line they are equal or we can always use some software to establish this straight line. So, this mean line is also known as centre line and then profile we understood it is a combination of form error and then roughness.

And roughness parameters, non periodic finer irregularities in the surface texture which are inherent in the production process, because of various reasons. So, these are a measure of vertical characteristic of the surface and then we should understand what is the meaning of sampling length. This is area selected or the length selected for assessment and evaluation of roughness parameter having the cut-off wavelength.

Any surface irregularities faced further apart than this something length are considered means waviness. So, the sampling length is also known as cut-off length, it is something less say we have some wavy profile like this. So, we consider we take a small portion of this and then we enlarge this to get the roughness profile. So, this length that is selected is known as cut-off length, so this cut-off length selection depends upon what is the machining process used.

And yeah depending upon the process that is used, machining process that is used we select the sampling length.

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Now this shows a surface profile measurement lengths, so this is the total length which is known as traversing length which traversed by the stylus of the instrument. Out of this, so initially we have some run up length and then over travel length which is not consider to evaluate the length the surface and this distance is known as evaluation length  $L$  and normally the it consists of 5 sampling lengths.

So, evaluation length is divided into 5 lengths each length is called sampling length or cut-off length indicated by small  $l$ . Now let me conclude this lecture, in this lecture we discussed about the basic aspects of surface roughness we try to understand what is waviness, what is roughness, what is form error and what is the meaning of profile. And what are the various production processes and what type of the roughness value they are able to give.

And then what is the meaning of centre line, mean line and what is the meaning of sampling length, cut-off length those things we studied. And also we studied how to indicate the surface roughness on technical drawings. So, with this we will conclude this lecture, in the next class we will continue the discussion on measurement of surface finish thank you.