

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL
NPTEL ONLINE CERTIFICATION COURSE
Mechanical Operations

Lecture-03
Characterization of a single particle-2

With
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Welcome come to the part two of lecture 2 that is characterization of single particle, in the part one of this.

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Lecture I have told about the size of a particle what is the important what is the purpose to measure the size of a particle and what are the different ways.

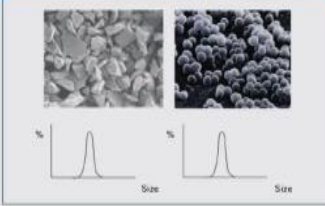
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Shape of a Particle

For many years, particle size has been recognized as a key parameter in the development and manufacture of a wide range of pharmaceutical materials. However, in recent years, and with the advent of rapid and reliable measurement technologies, particle shape has assumed a similar importance.

It is likely that these two materials (shown in the figure) would behave differently during processing or in their final product form. For example, their flow and abrasion characteristics would be dramatically different, but particle size data alone would not allow differentiation between them.

Figure shows two different samples. The particle size distribution of these samples could be same.

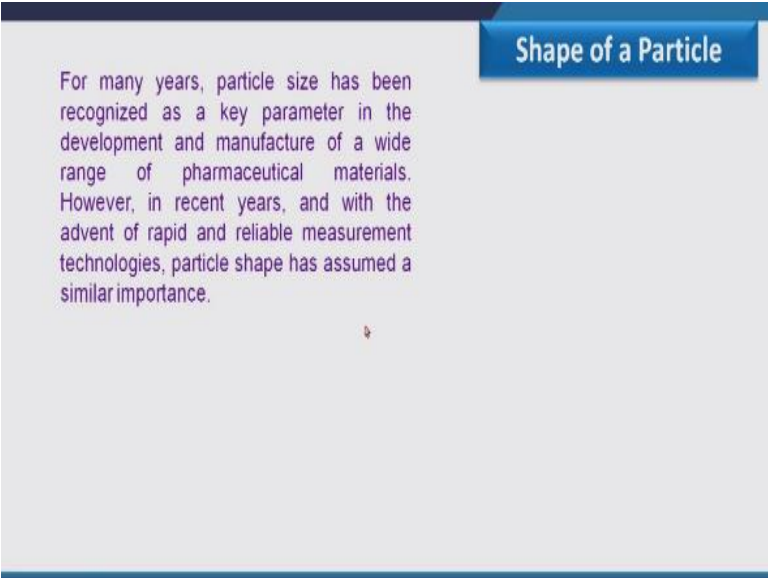


The figure illustrates two different particle samples. The left sample consists of angular, irregularly shaped particles, while the right sample consists of spherical particles. Below each SEM image is a graph showing a single, narrow peak representing the particle size distribution. The y-axis is labeled '%' and the x-axis is labeled 'Size'. The two graphs are identical, indicating that despite the difference in particle shape, the size distribution of both samples is the same.

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To define a particle size now this part two of lecture 2 I am going to discuss.

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Shape of a Particle

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The shape of a particle for many years particle size has been recognized as a key parameter in the development and manufacture of a wide range of pharmaceutical materials. However in recent year and with the advent of rapid and reliable measurement technologies, particles shape has assumed a similar importance. Now why particle shape is important that I can demonstrate by this figure if you consider this figure.

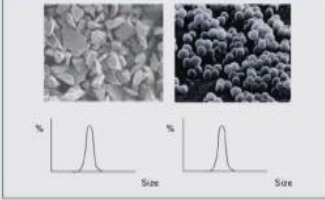
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Shape of a Particle

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It is likely that these two materials (shown in the figure) would behave differently during processing or in their final product form. For example, their flow and abrasion characteristics would be dramatically different, but particle size data alone would not allow differentiation between them.

Figure shows two different samples. The particle size distribution of these samples could be same.



The figure consists of two scanning electron microscope (SEM) images of particles. The left image shows particles with irregular, angular shapes. The right image shows particles that are more spherical and uniform in shape. Below each SEM image is a graph of particle size distribution, showing a single peak for each sample, indicating that despite their different shapes, their size distributions are similar.

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It has two images in images one the particle of very irregular shape our shown and here particle which are shown having a similar shape now if I consider both these particle it has same particle size distribution has you can see from this figure, now this particle size distribution says that if I consider size of particle only it behaves similarly in the process where it is used however it is very difficult to say this.

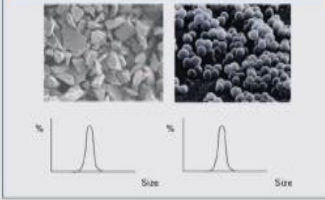
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Shape of a Particle

For many years, particle size has been recognized as a key parameter in the development and manufacture of a wide range of pharmaceutical materials. However, in recent years, and with the advent of rapid and reliable measurement technologies, particle shape has assumed a similar importance.

It is likely that these two materials (shown in the figure) would behave differently during processing or in their final product form. For example, their flow and abrasion characteristics would be dramatically different, but particle size data alone would not allow differentiation between them.

Figure shows two different samples. The particle size distribution of these samples could be same.

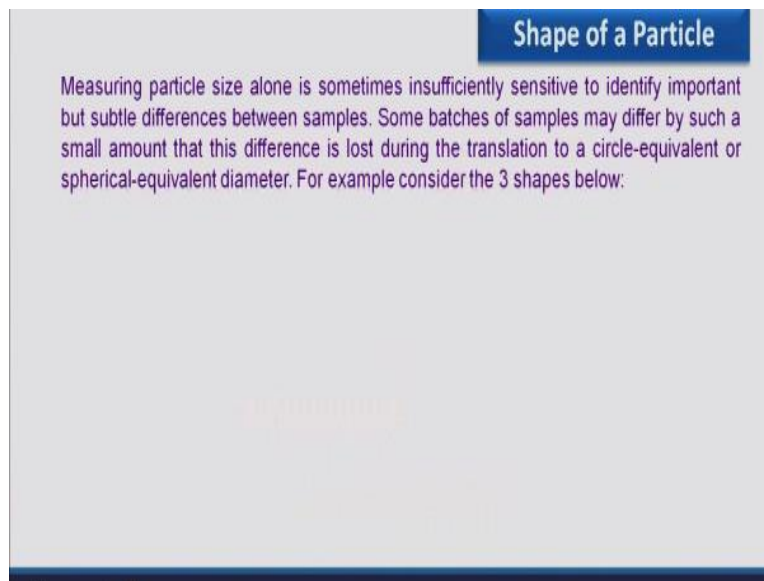


The figure illustrates two different particle samples. The left sample consists of angular, irregular particles, while the right sample consists of rounded, spherical particles. Below each SEM image is a graph showing the percentage of particles versus size. Both graphs show a single, narrow peak, indicating that despite their different shapes, the two samples have identical particle size distributions.

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That behavior of these two sample would be equal why it so because both our having different shape so what is the effect of this there flow and abrasion characteristic would be dramatically different but particle size data alone would not allow differentiation between them therefore alone with measuring the size of a particle to indentify the shape of particle is equally important so ,measuring particle size alone is sometimes insufficiently sensitive to identify important but shuttle difference between sample some batches of samples may differ by such a small amount.

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That this difference is lost during the translation to a circle equivalent or spherical equivalent diameter. For example consider the 3 shape which are given over here.

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Shape of a Particle

Measuring particle size alone is sometimes insufficiently sensitive to identify important but subtle differences between samples. Some batches of samples may differ by such a small amount that this difference is lost during the translation to a circle-equivalent or spherical-equivalent diameter. For example consider the 3 shapes below:

Square of side 2 units Equilateral triangle of side 3.039 units Circle of diameter 2.257 units


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Here that I have already taken this example while discussing the size of particle here if I consider this as square this triangle and this circle both are having same circle equivalent diameter so what is the meaning of this that if I am having same equivalent diameter of different shape I assume that they behave equally where ever there they are used in the process.

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Shape of a Particle

Measuring particle size alone is sometimes insufficiently sensitive to identify important but subtle differences between samples. Some batches of samples may differ by such a small amount that this difference is lost during the translation to a circle-equivalent or spherical-equivalent diameter. For example consider the 3 shapes below:



Square of side 2 units Equilateral triangle of side 1.039 units Circle of diameter 2.257 units

All these 3 shapes have the same area = 4 square units. When they are converted to a circle equivalent diameter they give the same result - a circle equivalent diameter of 2.257 units. This highlights the main disadvantage of measuring particle size only - very different shaped samples could be characterized as identical simply because they have similar projected 2D areas or similar spherical-equivalent volumes. Particle shape often has a significant influence on final product performance parameters such as flowability, abrasive efficiency, bio-availability etc, so some way of characterizing shape is required.

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So this highlights the main disadvantage of measuring particle size only very different shape samples could be characterize has identical simply because they have similar projected 2D area or similar spherical equivalent volume. The particle shape often has a significant influence on final product for performance parameters such has flow ability, abrasive efficiency, bio-availability etc, so some way of characterization shape is required therefore here I am going to discuss the way to defined the shape and to and techniques to compute the shape factor for a particle.

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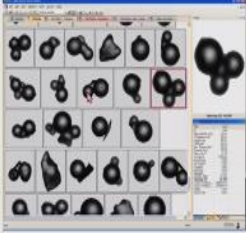
Shape of a Particle

Particle can be of different shapes:
Cubes, Plates, Rods, Blocky, Rectangle, Irregular, Needles



71341 3μm

120nm long particles after being fired from schroter

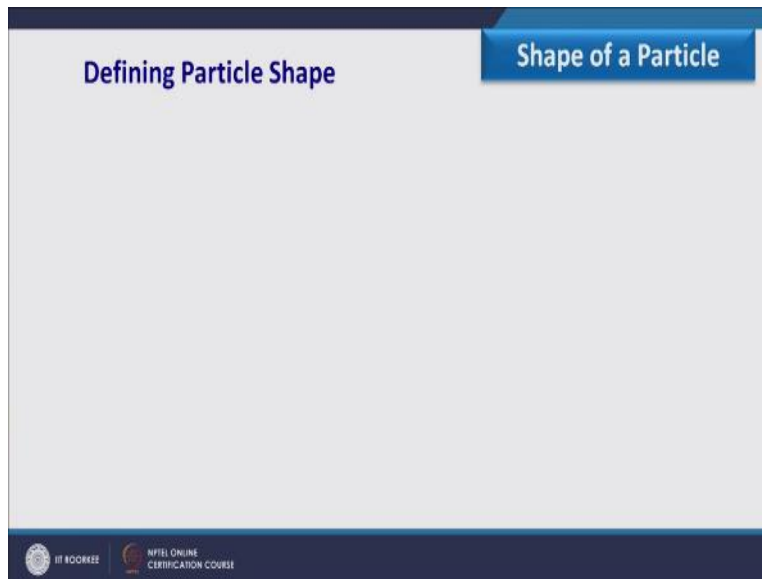


Particle shape viewer showing agglomerates

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So particle can be of different shape like it may be cubes, plates, rods, blocky, rectangle, irregular, needles etc, so all these we are having different shape of a particle here we have these are the single and here due to agglomeration it acquired different shape during the process so alone with size shape is also important.

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Defining particle shape now here basically we want to define the particle shape so if you consider the particle shape it can be define how it can be define how it can computed that is very important however it is very easy in comparison to defining or in comparison to measure the size of a practical because when we equate the size of a practical to some parameter to some property it has while equating this we can calculate the equivalent this we can calculate the equivalent diameter of a particle but how we can define the shape of it.

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Defining Particle Shape **Shape of a Particle**

Various aspects of particle shape are of interest, and therefore a range of descriptors has been devised to allow particle shape to be quantifiably described. No single shape descriptor will be suitable for all applications. In general, shape descriptors, should obey the following three criteria:

1.

2.

3.

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So various aspects of particle shape are of interest and therefore a range of descriptors has been devised to allow particle shape to be quantifiably described no single shape descriptor would be suitable for all purposes, so shape descriptor follow some criteria like some criteria we have defined based on that we have some descriptors or we have some definition of a particle shape. First criteria is intuitive it should be consistent with the way the human mind perceives.

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Defining Particle Shape **Shape of a Particle**

Various aspects of particle shape are of interest, and therefore a range of descriptors has been devised to allow particle shape to be quantifiably described. No single shape descriptor will be suitable for all applications. In general, shape descriptors, should obey the following three criteria:

- **Intuitive:** It should be Consistent with the way the human mind perceives the parameter title

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The parameter title for example if I am having the square shape of a smooth surface I am having the square shape of irregular surface so definitely I can say that their shape factor may differ because of this roughness of the surface, so how it comes from that the way I have identified the way I have seen the object accordingly I can say that their shape will would be slightly different though both are having the basic same shape that is a square but one is a square with the smooth surface another is a square with rough surface.

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Defining Particle Shape

Shape of a Particle

Various aspects of particle shape are of interest, and therefore a range of descriptors has been devised to allow particle shape to be quantifiably described. No single shape descriptor will be suitable for all applications. In general, shape descriptors, should obey the following three criteria:

- **Intuitive:** It should be Consistent with the way the human mind perceives the parameter title
- **Normalized:** It should have values between zero and one, thus making interpretation and data processing easier
- **Sensitive:** It should be sensitive to the shape of the particle

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So that is due through intuitive we can define the descriptive another is normalized it should have the value between 0 and 1 thus making interpretation and data processing easier so whatever descriptors I'm having to define a particle shape all are falling in a range from 0 to 1 though this is not the case with the particle size particle size we equate to the property and then we calculate whatever would be the magnitude of it that we say that his is the diameter however shape for shape I am sure that it should fall between 0 to 1. So that normalized is a criteria third criteria is sensitive.

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Defining Particle Shape **Shape of a Particle**

Various aspects of particle shape are of interest, and therefore a range of descriptors has been devised to allow particle shape to be quantifiably described. No single shape descriptor will be suitable for all applications. In general, shape descriptors, should obey the following three criteria:

- **Intuitive:** It should be Consistent with the way the human mind perceives the parameter title
- **Normalized:** It should have values between zero and one, thus making interpretation and data processing easier
- **Sensitive:** It should be sensitive to shape deviations as experiences in “real world” samples

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It should be sensitive to shape deviations as experiences in real world sample like previously I have given an example when square is having smooth surface when a square is having rough surface so though both, both object we are having of a square shape but I should be sensitive enough to identify that and that should be reflected in terms of the value which falls between 0 and 1 so based on these three criteria we have different descriptors first is we define as circularity.

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The slide is titled "Defining Particle Shape" and "Shape of a Particle". It states: "Based on these criteria following shape descriptors are devised." It shows two rows of shapes. The first row is labeled "Circularity" and shows a circle with "Circularity=1" and an ellipse with "Circularity=0.47". The second row is labeled "Convexity" and shows a circle with "Convexity=1" and an ellipse with "Convexity=1". To the right of the shapes, it says "Based on perimeter" and "Based on surface roughness". At the bottom, there are logos for BIT BODKEE and NPTEL ONLINE CERTIFICATION COURSE, and the number 20.

So circularity is basically how circular the shape is it defines that so which is defined based on the perimeter second descriptive I am having is the convexity and this is defined based on the surface roughness so if you see the convexity of this circular shape as well as this elliptical shape or elongated shape both are having convexity as one so it is defined based on surface roughness it has a smooth surface it has a smooth surface, so both are having convexity equal to 1 however when we define the circularity depending upon this circular nature of the particle the circularity vary but all value will fall between 0 and 1 third.

We are having the elongation how long the particle is like here if we consider this circle it has elongation 0 and if it is elliptical in shape it has elongation 0.82, so this is defined based on length over width ratio, so here we have three descriptive we are going to discuss these three descriptive in detail first is the circularity how the circularity is made is defined it is the ratio of perimeter.

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Circularity

Shape of a Particle

Circularity is a measurement of the ratio of the perimeter of a circle with the same area as the particle to the actual perimeter of a particle. Circularity also has values in the range of zero to one. A perfect circle has a circularity of one, while a very "spiky" or irregular object has a circularity closer to zero.

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Of a circle with this same area as the particle to the actual perimeter of a particle, so here we have to equate the perimeter of a circle of the same area as the particle to the actual perimeter of the particle circularity also has values in the range of 0 to 1 a perfect circle has a circularity of one while a very spiky or irregular object has a circularity closer to 0.


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Circularity

Shape of a Particle

Circularity is a measurement of the ratio of the perimeter of a circle with the same area as the particle to the actual perimeter of a particle. Circularity also has values in the range of zero to one. A perfect circle has a circularity of one, while a very "spiky" or irregular object has a circularity closer to zero.

Circularity = $\frac{\text{Circle circumference}}{\text{Perimeter of projected particle image}}$



For square of 1 unit side:
Diameter of circle = $\sqrt{\text{area of square} \times 4 / \pi} = 1.128$ unit
Circularity = $(\pi \times 1.128) / (4 \times 1) = 0.886$

Shapes	Circularity
Circle	1
Square	0.886
Triangle	0.777
Rectangle	0.668
Parallelogram	0.509
Thin Rectangle	0.4

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Here I am having one example how to define the circularity of an irregular particle if I am having this particle and this black section you are saying this is the projected area of the particle and this green line is basically the parameter if we consider this section it is defined as the perimeter of the particle and this red circle is the circle with same area as the particle, so considering this image we have defined circularity as circle circumference divided by the perimeter of projected particle image.

So if we consider this circle obviously it has circularity as one but what about this particle which is having a square shape so for a square shape I assume that it is a side is of one unit so diameter of circle because it is circularity is defined as circle circumference so circle circumference for this we have to calculate the diameter, so how we calculate the diameter while equating the circles are equal to the particle area so if I'm having a square shape the particle area would be one only.

So diameter of circle that is a square root of area of a square $\times 4 / \pi$ that is it should be $4 / \pi$ so 1.128 unit diameter we have found so circularity is the circle circumference that is $\pi \times 1.128 / 4 \times 1$

that is the perimeter of the particle if it is a square 1x4 similar value appears over here the circularity comes as 0.886.

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Circularity

Shape of a Particle

Circularity is a measurement of the ratio of the perimeter of a circle with the same area as the particle to the actual perimeter of a particle. Circularity also has values in the range of zero to one. A perfect circle has a circularity of one, while a very "spiky" or irregular object has a circularity closer to zero.

$$\text{Circularity} = \frac{\text{Circle circumference}}{\text{Perimeter of projected particle image}}$$

Legend:
■ area of the particle (A)
— diameter of circle of the same area
— perimeter of the particle (P)
○ circle with same area as particle

Shapes and their circularity values:
Circle: 1
Square: 0.886
Triangle: 0.777
Rectangle: 0.668
Tall rectangle: 0.509
Thin rectangle: 0.4

Illustration of circularity shape descriptor:
Circularity=1 (circle)
Circularity=0.89 (square)
Circularity=0.47 (circle)
Circularity=0.47 (elongated oval)
Circularity=0.52 (rectangle)
Circularity=0.21 (spiky irregular shape)

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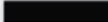


You can see the value over here and if you see this image we have circularity of circle 1 as it gets elongated it is circularity reduces for circular section for this rectangle section circularity vary and if you see this particular image it does not have any effect due to roughness of particle it has 0.47 and it has if I consider the roughness but due to this elongation due to this non circularity the value differs but all value will fall between 0 and 1.

Now we have the convexity the convexity is a measurement of surface roughness of a particle and is calculated by dividing the area of circle with the same area as the particle by total area, so you can see the definition it is the area of circle with same area as the particle.

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Convexity

Convexity is a measurement of the surface roughness of a particle and is calculated by dividing the area of a circle with the same area as the particle by a "total area". The easiest way to visualize the "total area" is to imagine the area enclosed by an elastic band placed around the particle. Convexity also has values in the range of zero to one. A smooth shape has a convexity closer to one. Figure given below illustrates how convexity is unaffected by overall form- a smooth needle has the same convexity as a smooth circle.

	Convexity=1		Convexity=1
	Convexity=1		Convexity=1
	Convexity=0.70		Convexity=0.73

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So we can equate the circle area with the particle area divided by total area so in other word the convexity can be defined as the particle area divided by total area how we can define the total area that I can illustrate by this example if you see this figure here we have the convexities of different shape now if I consider this rough surface it has convexity lesser than one, so if I'm having the smooth surface convexity should be closer to 1 or equal to 1 and as the roughness increases convexity reaches towards 0.

In this figure if I want to define the convexity that is the particle projected area that we can calculate very easily divided by total area, so what is the total area if I place a rubber band around this whatever would be the area of that rubber band that basically called as total area though convexity is defined as the particle area divided by total area, so as surface roughness increases the total area which is enclosed in the rubber that will increase then the particle area itself.

So that is the convexity next I'm having elongation.

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Elongation

Shape of a Particle

Elongation is a measurement of the length/width relationship and has values in the range of zero to one. Elongation is a comparison between the “strength” of the major axis (known as length) and the “strength” of the minor axis (known as width) of a particle.

Shapes that are symmetrical in all axes, such as circles or squares, have a length and width of similar values (elongation close to zero), whereas needle shaped particles have a length that is greater than their width (elongation closer to one). The actual calculation of elongation computes the center of gravity of a particle and defines the exact position of the major and minor axes.

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Elongation is a measurement of length over width ratio and has the value in the range of 0 to 1 elongation is a comparison between the strength of the major axis that is length and strength to of the minor axis that is width of the particle, so if we have elongation how we can define the elongation.

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Elongation







Shape of a Particle

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Shapes that are symmetrical in all axes, such as circles or squares, have a length and width of similar values (elongation close to zero), whereas needle shaped particles have a length that is greater than their width (elongation closer to one). The actual calculation of elongation computes the center of gravity of a particle and defines the exact position of the major and minor axes.

The elongation is defined as $(1 - \text{width}/\text{length})$ in order to obey the "intuitive rule" above.



	Elongation=0		Elongation=0.82
	Elongation=0		Elongation=0.79
	Elongation=0.24		Elongation=0.83

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It is $1 - \text{width}/\text{length}$ in order to obey the intuitive rule that is while seeing what should be the value of it like if I define the elongation we can very well identify that I against if the particle shape is of needle it must have the elongation equal to 1, so shapes that are symmetrical in all axis such as circles or squares have a length and width of similar value.

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



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The elongation is defined as $(1 - \text{width}/\text{length})$ in order to obey the “intuitive rule” above.

From the figure it can be seen that elongation is more an indication of overall form than surface roughness- a smooth ellipse has a similar elongation to a “spiky” ellipse.

	Elongation=0		Elongation=0.82
	Elongation=0		Elongation=0.79
	Elongation=0.24		Elongation=0.83

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So elongation close to zero like in this case we have elongation close to zero whereas needle-shaped particles have a length that is greater than their width so elongation would be equal to 1. So the actual calculation of elongation computes the center of gravity of a particle and defines the exact position of major and minor axis, so from this figure you can say that elongation is more an indication of overall form than the surface roughness a smooth ellipse has the similar elongation as a spiky ellipse so if you see all this figure here we have this is smooth ellipsoidal surface here we have rough ellipsoid.

So both are having same elongation value so that that is basically based on the length and width not the surface.

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Defining Particle Shape		Shape of a Particle
Sphericity:		Based on Surface area per unit volume
Specific surface ratio:		Based on Surface area per unit mass
Volume shape factor:		Based on volume

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Here I am having three descriptive along with this we can define particle shape based on different factor the first shape is Sphericity and the factor is it based on surface area per unit volume second shape is specific surface ratio that is based on surface area per unit mass volume shape factor.

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Defining Particle Shape

Sphericity:	Based on Surface area per unit volume
Specific surface ratio:	Based on Surface area per unit mass
Volume shape factor:	Based on volume

Sphericity (ψ_s)
It is defined as the ratio of surface area of a spherical particle having same volume as the particle to the surface area of the particle. Since the diameter of a spherical particle having the same volume as the particle is d_v , $\psi_s = [\pi(d_v)^2]/S_p$

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That is based on volume so let us start with this Sphericity it is based on surface area per unit volume, so how it is defined is it is the ratio of surface area of a spherical particle having same volume as the particle to surface area of the particle since the diameter of a spherical particle having same volume as the particle is d_v because now in this case we are considering volume diameter instead of simple diameter. So Sphericity would be the.

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Defining Particle Shape

Sphericity:	Based on Surface area per unit volume
Specific surface ratio:	Based on Surface area per unit mass
Volume shape factor:	Based on volume

Sphericity (ψ_s)
It is defined as the ratio of surface area of a spherical particle having same volume as the particle to the surface area of the particle. Since the diameter of a spherical particle having the same volume as the particle is d_v , $\psi_s = \frac{[\pi(d_v)^2]}{S_p}$

It must be noted that since sphericity compares the surface area of the particle to that of the equivalent spherical particle, it defines only the particle shape and is independent of particle size. Sphericity of a spherical particle is obviously 1.0. The sphericity of a cylindrical particle having same length and diameter equal to 'l' is:

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Spherical particle area divided by the surface area of the particle, so it must be noted that since Sphericity compares the surface area of particle to that of equivalent spherical particle it defines only the particle shape and is independent of the particle size for example if I am having a particle of 1mm diameter or 10mm diameter when we equate the surface area of the particle and the equivalent surface area of a spherical both are having same value so that it will not affect it by the size of a particle it completely defines the shape of the particle.

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Defining Particle Shape

Sphericity: Based on Surface area per unit volume

Specific surface ratio: Based on Surface area per unit mass

Volume shape factor: Based on volume

Sphericity (ψ_s)
 It is defined as the ratio of surface area of a spherical particle having same volume as the particle to the surface area of the particle. Since the diameter of a spherical particle having the same volume as the particle is d_v , $\psi_s = [\pi(d_v)^2]/S_p$

It must be noted that since sphericity compares the surface area of the particle to that of the equivalent spherical particle, it defines only the particle shape and is independent of particle size. Sphericity of a spherical particle is obviously 1.0. The sphericity of a cylindrical particle having same length and diameter equal to 'l' is:

Shape of a Particle

$$d_v = \left[\frac{6V_{particle}}{\pi} \right]^{1/3} = \left[\frac{6 \left(\pi \times \frac{l^3}{4} \right)}{\pi} \right]^{1/3} = 1.143 \times l$$

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Here I have shown one example to calculate the Sphericity of a cylindrical particle which has length and diameter both are equal to 1 this d_v is defined as the diameter of a spherical having same volume as the particle, so that d_v would be equal to $6V_{particle} / \pi$ so that $V_{particle}$ is the volume of particle and $6\pi^{1/3}$ would be the d_v so if I am having cylindrical particle both its diameter as well as length equal to 1 so its volume would be πl^2 so πl^2 can be written as $\pi l^3 / 4$ because l is now equal to the diameter x l.

So $\pi l^3 / 4$ would be the total volume of the particle $6/\pi$ we have taken as it is and the power 1 over 3 we have considered so d_v we have calculated in terms of l as $1.143 \times l$. So we can define the Sphericity as $\pi d_v^2 / S_p$ that is the surface area of a spherical particle of d_v diameter divided by surface area of actual particle.

(Refer Slide Time: 18:40)


Defining Particle Shape **Shape of a Particle**

Sphericity:	Based on Surface area per unit volume
Specific surface ratio:	Based on Surface area per unit mass
Volume shape factor:	Based on volume

Sphericity (ψ_s)
It is defined as the ratio of surface area of a spherical particle having same volume as the particle to the surface area of the particle. Since the diameter of a spherical particle having the same volume as the particle is d_v , $\psi_s = [\pi(d_v)^2]/S_p$

It must be noted that since sphericity compares the surface area of the particle to that of the equivalent spherical particle, it defines only the particle shape and is independent of particle size. Sphericity of a spherical particle is obviously 1.0. The sphericity of a cylindrical particle having same length and diameter equal to 'l' is:

$$d_v = \left[\frac{6V_{\text{particle}}}{\pi} \right]^{1/3} = \left[\frac{6 \left(\pi \times \frac{l^3}{4} \right)}{\pi} \right]^{1/3} = 1.143 \times l$$
$$\psi_s = \frac{\pi(1.143 \times l)^2}{\pi(1.5 \times l^2)} = 0.871$$



So that $\pi(1.143 \times l)^2$ that is the surface area of a spherical particle and this $\pi 1.5l^2$ is the surface area of cylinder where length as well as diameter are equal to L so is Sphericity in this case is 0.871 so here if I am having more irregular shape this Sphericity would be close to zero if I'm having perfect is fair this Sphericity would have the value equal to 1, so here I am having some of the typical values of this Sphericity for depending.

(Refer Slide Time: 19:18)

Shape of a Particle

Sphericity (ψ_s)

Typical values of sphericities for some common materials are given here.

Material	Sphericity
Sand (rounded)	0.83
Fused flue dust	0.89
Fused flue dust (aggregates)	0.55
Tungsten powder	0.89
Sand (angular)	0.73
Pulverised coal	0.73
Coal dust	0.65
Flint sand (jagged flakes)	0.43
Mica flakes	0.28
Berl saddles	0.3 (average)
Raschig rings	0.3 (average)

The reciprocal of sphericity is commonly called the shape factor or more precisely, the surface shape factor (λ_s). Thus,

$$\lambda_s = (1/\psi_s)$$

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Upon different material likes sand pulverized coal, coal dust, Raschig rings etc, so these Sphericity is defined whatever would be the size of this irrespective of this we can consider this Sphericity equal to these values so reciprocal of Sphericity is commonly call the shape factor or more precisely the surface shape factor that is λ_s thus lambda is equal to $1/\psi_s$ another value or another shape factor we are having is the specific surface ratio.

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Shape of a Particle

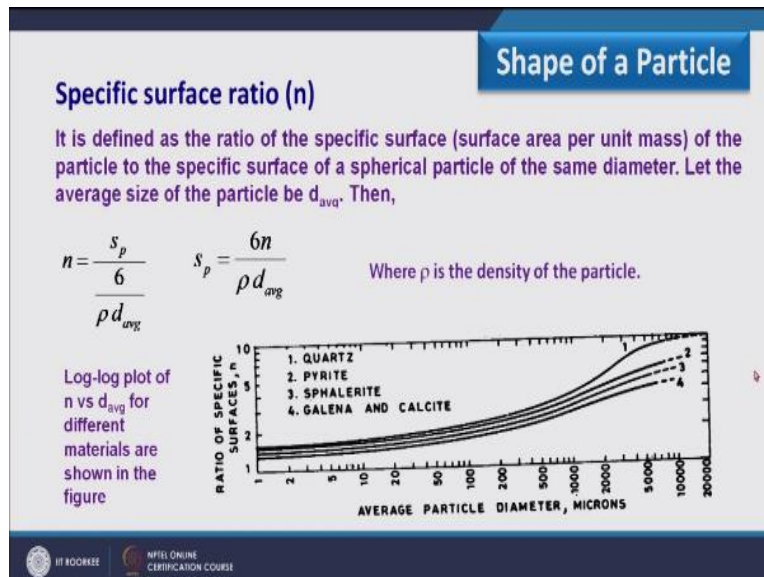
Specific surface ratio (n)

It is defined as the ratio of the specific surface (surface area per unit mass) of the particle to the specific surface of a spherical particle of the same diameter. Let the average size of the particle be d_{avg} . Then,

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That we denote by n it is defined as the ratio of the specific surface that is surface area per unit mass of the particle to the specific surface of the spherical particle of same diameter let the every size of the particle d average, so obviously when I consider the spherical particle that must have the diameter equal to d average.

(Refer Slide Time: 20:20)



Because here we have equated in terms of diameter then how we can define n is the specific surface that is surface area of a particle per unit mass divided by the surface area of the spherical particle per unit mass, so how the surface area per unit mass of a spherical particle is defined like if I consider $6/d$ average that would be the surface area per unit volume if you remember the sorter diameter definition and when we multiply this with the density factor.

So that would be surface area per unit mass, so considering this we can also calculate surface area of particle in terms of specific surface ratio where ρ is the density of the particle bring the graph of log, log plot which is plotted n versus d average for different material for example here I'm having different material like quartz, pyrite, sphalerite galena and calcite so on this axis we have a specific surface ratio here I am having average particle diameter. So if I know the diameter that is shown over here we can calculate the value of n and then we can calculate specific surface per unit mass of particle.

So that is about the specific surface ratio next we have the volume shape factor.

(Refer Slide Time: 21:45)

Shape of a Particle

Volume shape factor (a)

This factor is sometimes used for calculating the volume of an irregular particle. We know that the volume of a spherical particle is proportional to the cube of its diameter. If we assume the same is true for irregular particle as well, then

$$V_p \propto (d_{avg})^3$$

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That is (a) so this factor is sometimes used for calculating the volume of an irregular particle we know that volume of a spherical particle is proportional to the cube of its diameter like I have shown over here V_p is proportional to $(d_{avg})^3$ now once I remove this is proportionality constant this would be equal to $V_p a (d_{avg})^3$ so that (a) is basically defined as volume shape factor.

(Refer Slide Time: 22:19)

Shape of a Particle

Volume shape factor (a)

This factor is sometimes used for calculating the volume of an irregular particle. We know that the volume of a spherical particle is proportional to the cube of its diameter. If we assume the same is true for irregular particle as well, then

$$V_p \propto (d_{svr})^3$$
$$V_p = a (d_{svr})^3$$

Where a is the constant of proportionality and is called the volume shape factor. Its value is $(\pi/6)$ for spherical particles.

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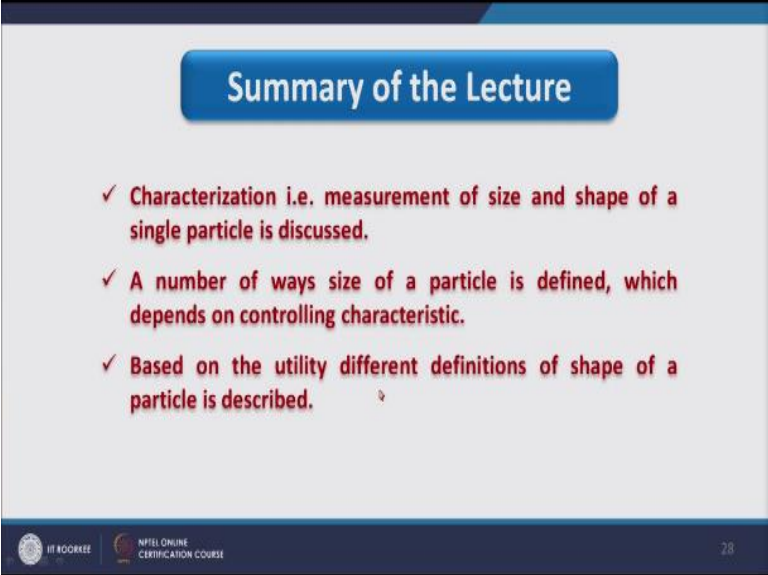
Where (a) is the constant of proportionality and for a spherical surface (a) the value of (a) is $\pi/6$ so accordingly we can define the volume shape factor.

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So here I am having the summary of lecture 2 which combines the summary of part 1 and part 2 of lecture 2 that is characterization of single particle, so summary goes as characterization that is measurement of.

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The slide features a blue header with the title "Summary of the Lecture" in white text. Below the header, three bullet points are listed in red text, each preceded by a checkmark. The first bullet point discusses the characterization of a single particle. The second bullet point discusses the definition of particle size based on controlling characteristics. The third bullet point discusses the utility-based definitions of particle shape. At the bottom of the slide, there are logos for "BT BODKEE" and "NFISL ONLINE CERTIFICATION COURSE", along with the page number "28".

Summary of the Lecture

- ✓ Characterization i.e. measurement of size and shape of a single particle is discussed.
- ✓ A number of ways size of a particle is defined, which depends on controlling characteristic.
- ✓ Based on the utility different definitions of shape of a particle is described.

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Size and shape of a part single particle is discussed in lecture 2 secondly we have discussed a number of ways size of a particle is defined which depends on controlling characteristic and finally based on the utility different definitions of shape of a particle is described.

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References

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These are the references you can refer so that is all for lecture 2 and thank you.

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