INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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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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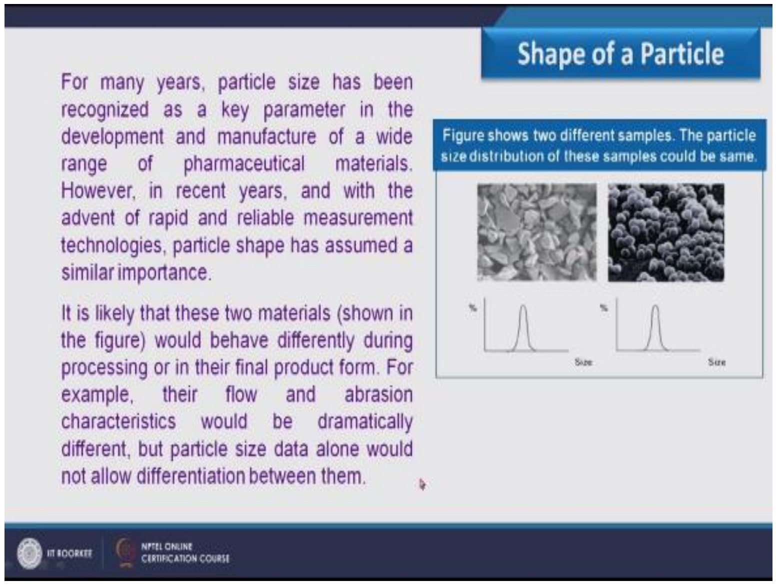

To define a particle size now this part two of lecture 2 I am going to discuss.

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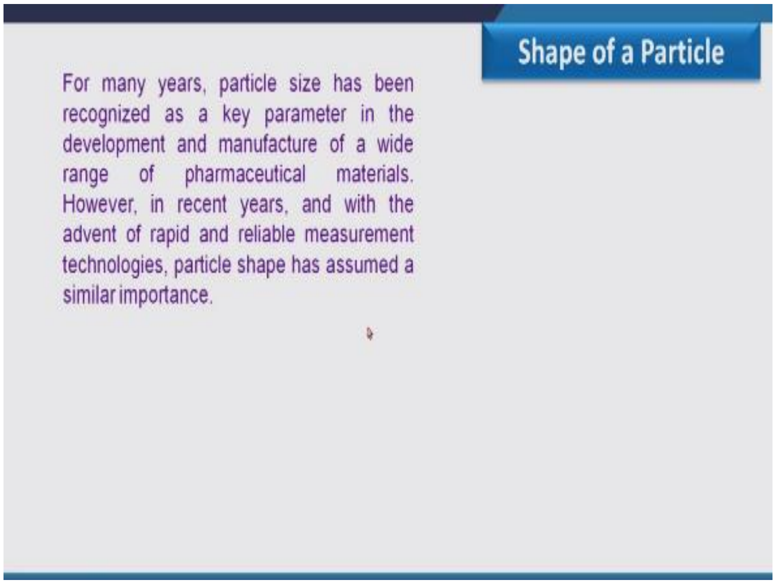

The shape of a particle for many years particle size has been recognized as a key parameter in the development and manufacture of a wide range of pharmaceutical materials. However in recent year and with the advent of rapid and reliable measurement technologies, particles shape has assumed a similar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

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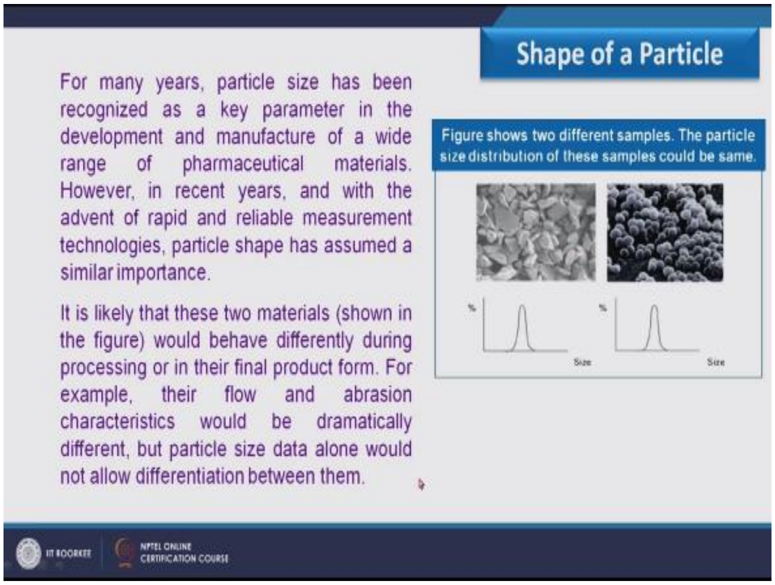

It has two images in images one the particle of very irregular shape our shown and here particle which are shown having a similar shape now if I consider both these particle it has same particle size distribution has you can see from this figure, now this particle size distribution says that if I consider 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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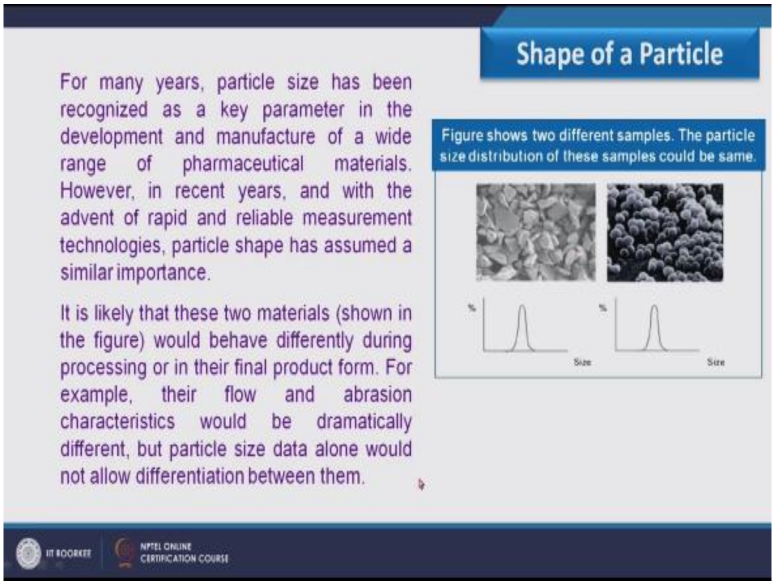

That behavior of these two sample would be equal why it so because both our having different shape so what is the effect of this there flow and abrasion characteristic would be dramatically different but particle size data alone would not allow differentiation between them therefore alone with measuring 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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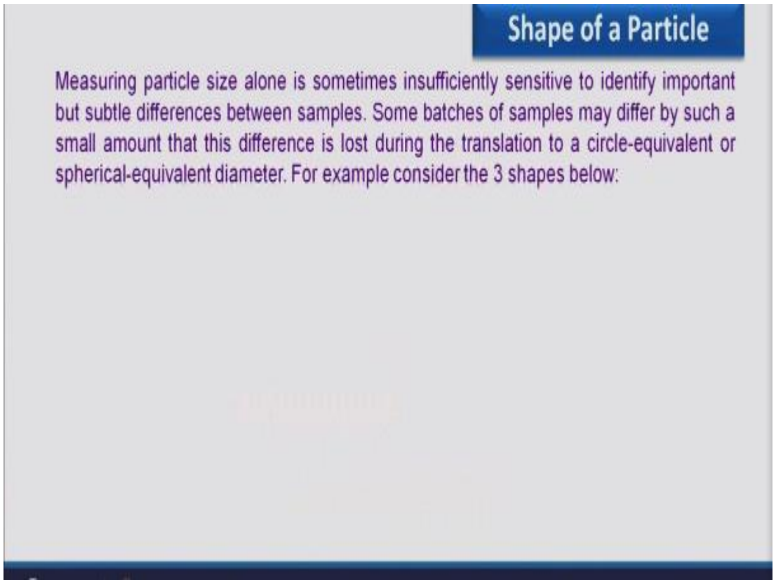

That this difference is lost during the translation to a circle equivalent or spherical equivalent diameter. For example consider the 3 shape which are given over here.

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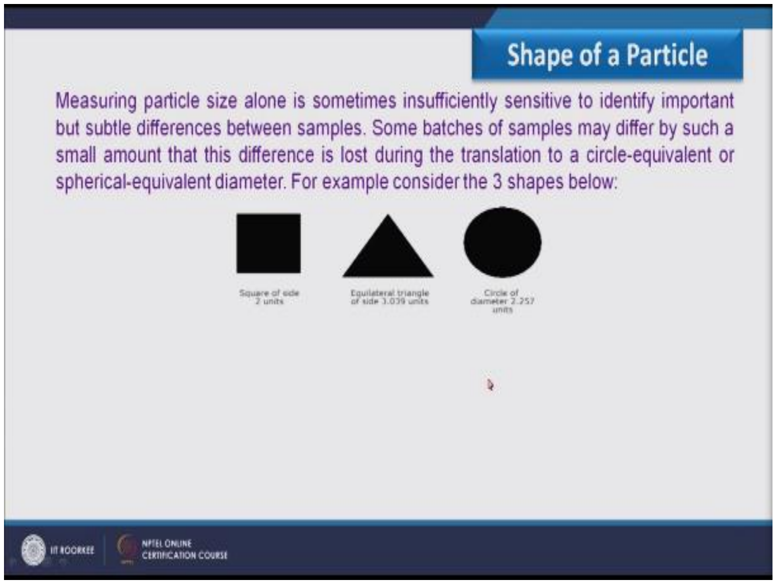

Here that I have already taken this example while discussing the size of particle here if I consider this as square this triangle and this circle both are having same circle equivalent diameter so what is the meaning of this that if I am having same equivalent diameter of different shape I assume that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

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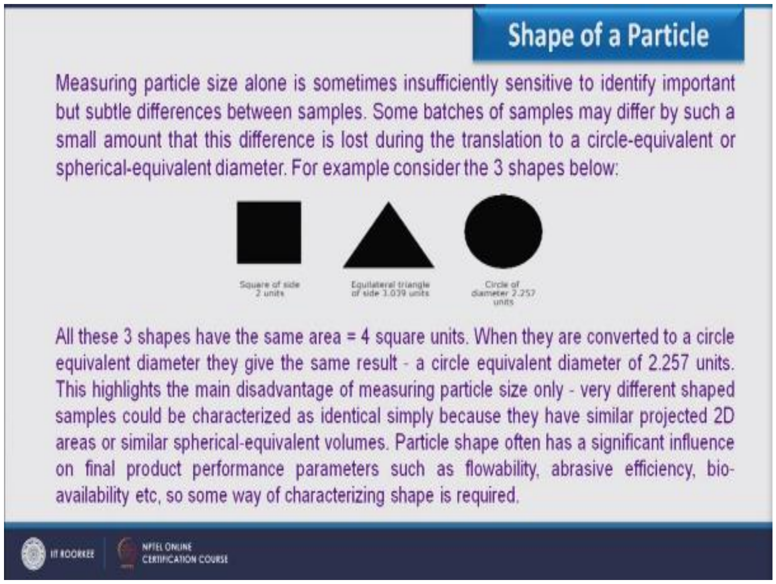

So this highlights the main disadvantage of measuring particle size only very different shape samples could be characterize has identical simply because they have similar projected 2D area or similar spherical equivalent volume. The particle shape often has a significant influence on final product for 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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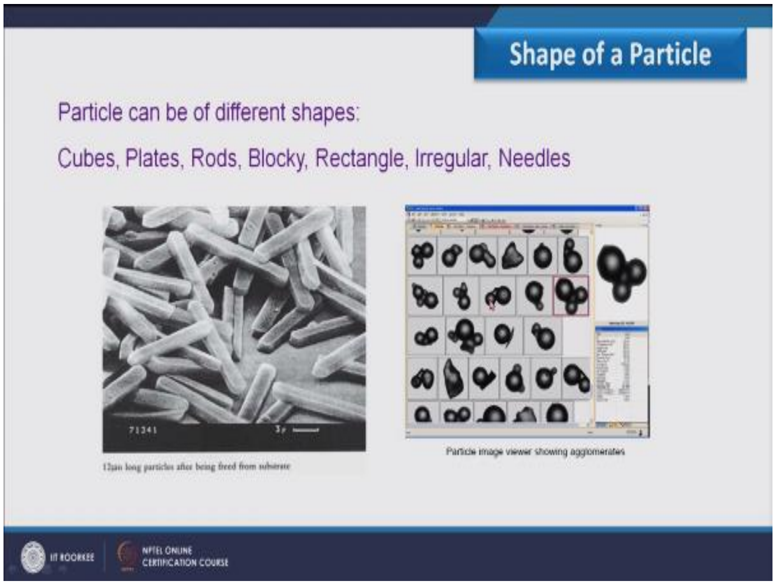

So particle can be of different shape like it may be cubes, plates, rods, blocky, rectangle, irregular, needles etc, so all these we are having different shape of a particle here we have these are the single and here due to agglomeration it acquired different shape during the process so alone with size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

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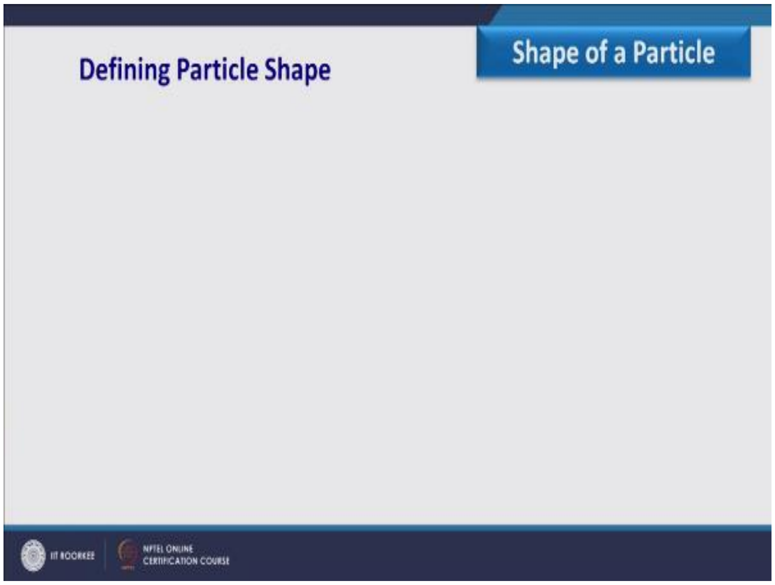

Defining particle shape now here basically we want to define the particle shape so if you consider the particle shape it can be define how it can be define how it can computed that is very important however it is very easy in comparison to defining or in comparison to measure the size of a practical 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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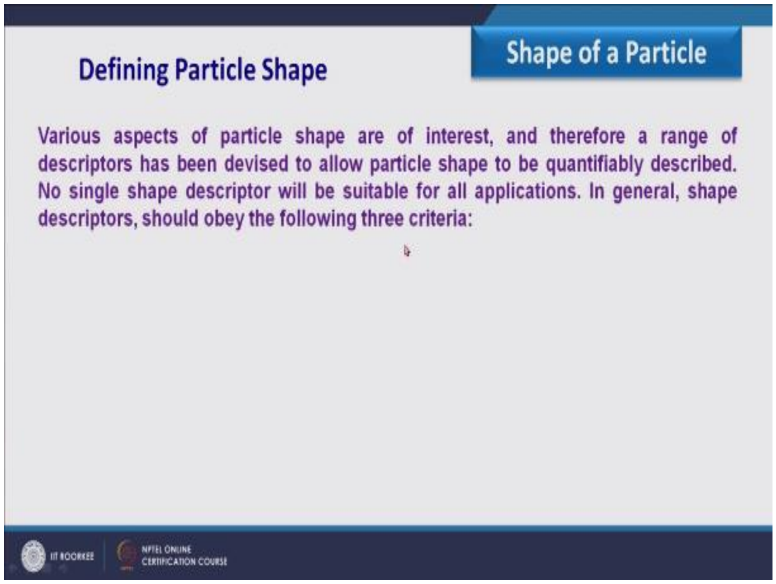

So various aspects of particle shape are of interest and therefore a range of descriptors has been devised to allow particle shape to be quantifiably described no single shape descriptor would be suitable for all purposes, so shape descriptor follow some criteria like some criteria we have defined based 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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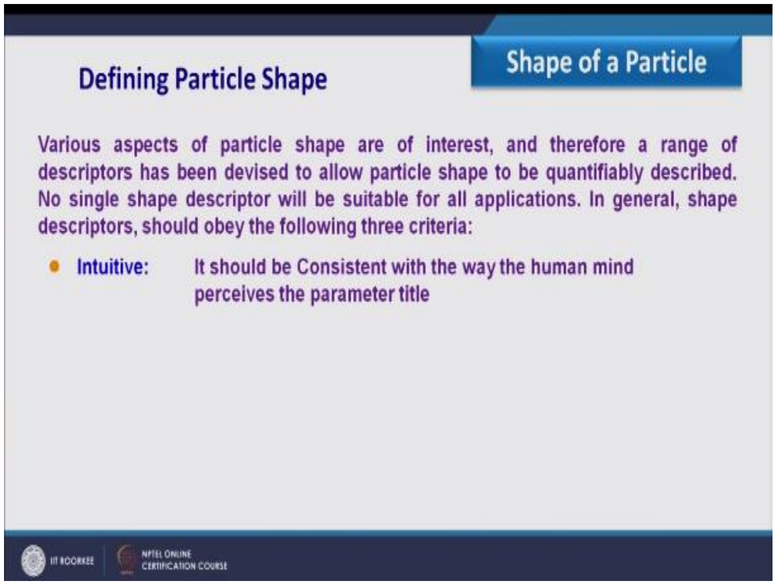

The parameter title for example if I am having the square shape of a smooth surface I am having the square shape of irregular surface so definitely I can say that their shape factor may differ because of this roughness of the surface, so how it comes from that the way I have identified the way I have 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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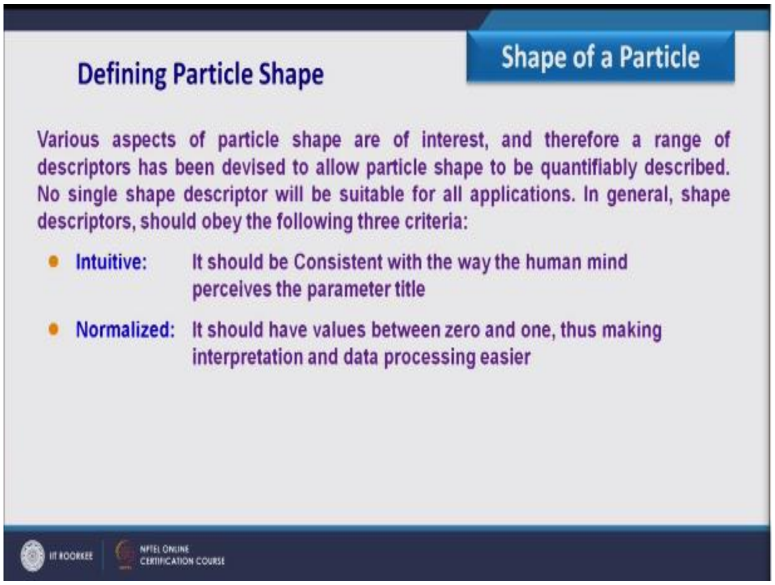

So that is due through intuitive we can define the descriptive another is normalized it should have the value between 0 and 1 thus making interpretation and data processing easier so whatever descriptors I'm having to define a particle shape all are falling in a range from 0 to 1though this is not the 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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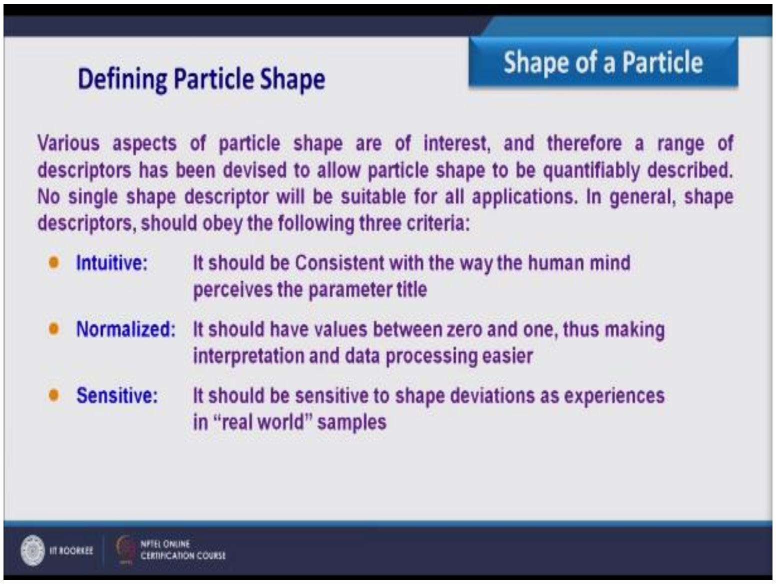

It should be sensitive to shape deviations as experiences in real world sample like previously I have given an example when square is having smooth surface when a square is having rough surface so though both, both object we are having of a square shape but I should be sensitive enough to identify that 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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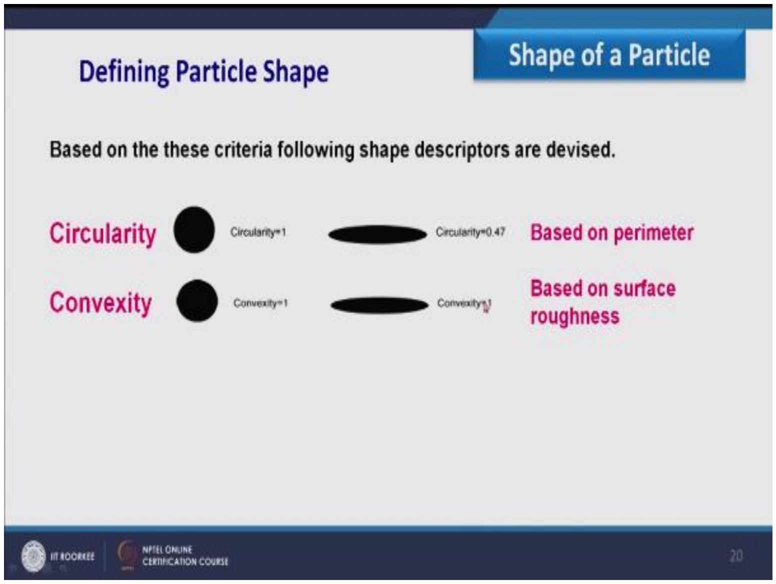

So circularity is basically how circular the shape is it defines that so which is defined based on the perimeter second descriptive I am having is the convexity and this is defined based on the surface roughness so if you see the convexity of this circular shape as well as this elliptical shape or elongated 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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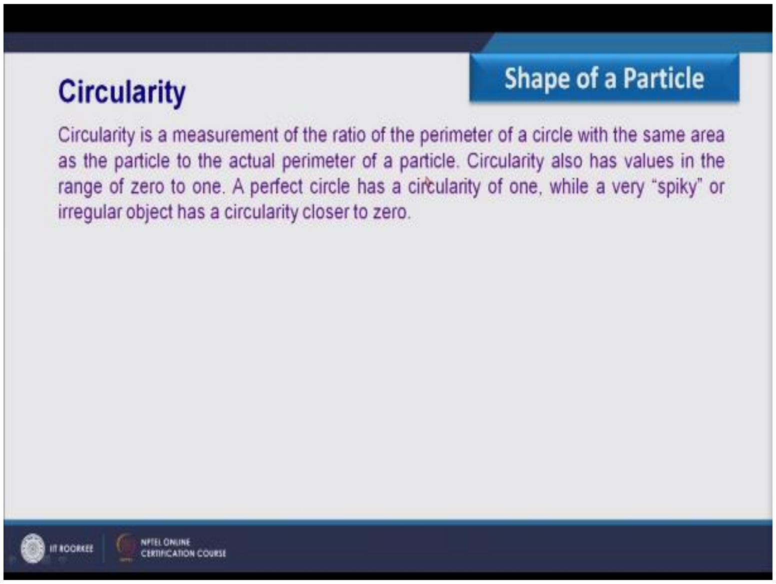

Of a circle with this same area as the particle to the actual perimeter of a particle, so here we have to equate the perimeter of a circle of the same area as the particle to the actual perimeter of the particle circularity also has values in the range of 0 to 1 a perfect circle has a circularity of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

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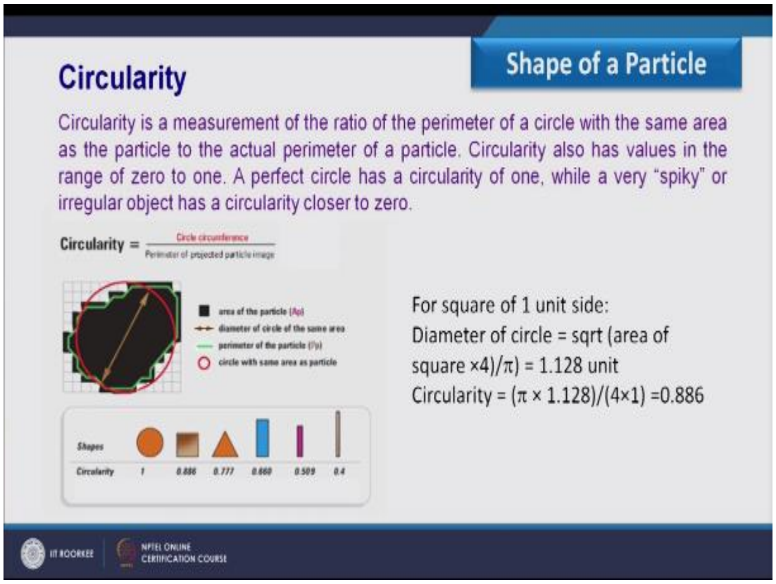

Here I am having one example how to define the circularity of an irregular particle if I am having this particle and this black section you are saying this is the projected area of the particle and this green line is basically the parameter if we consider this section it is defined as the perimeter of 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 x 4/ π that is it should be 4/ π so 1. 128 unit diameter we have found so circularity is the circle circumference that is π x 1.128/4 x 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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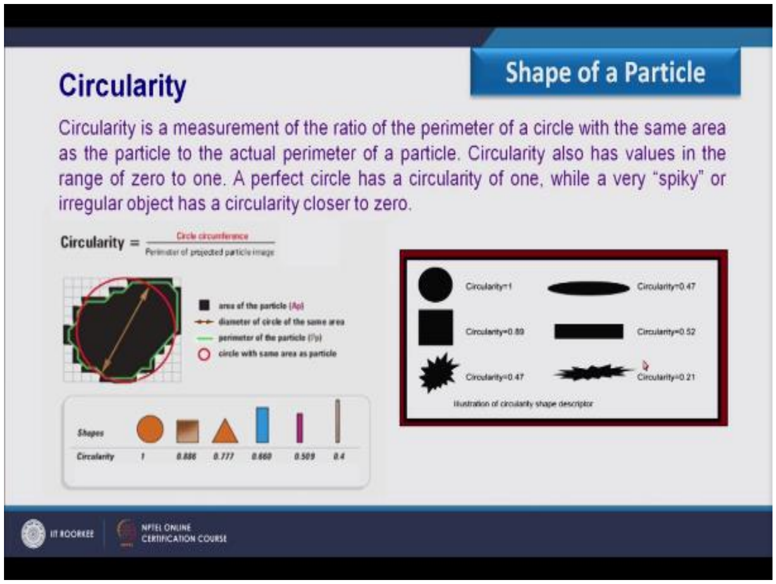

You can see the value over here and if you see this image we have circularity of circle 1 as it gets elongated it is circularity reduces for circular section for this rectangle section circularity vary and if you see this particular image it does not have any effect due to roughness of particle it has 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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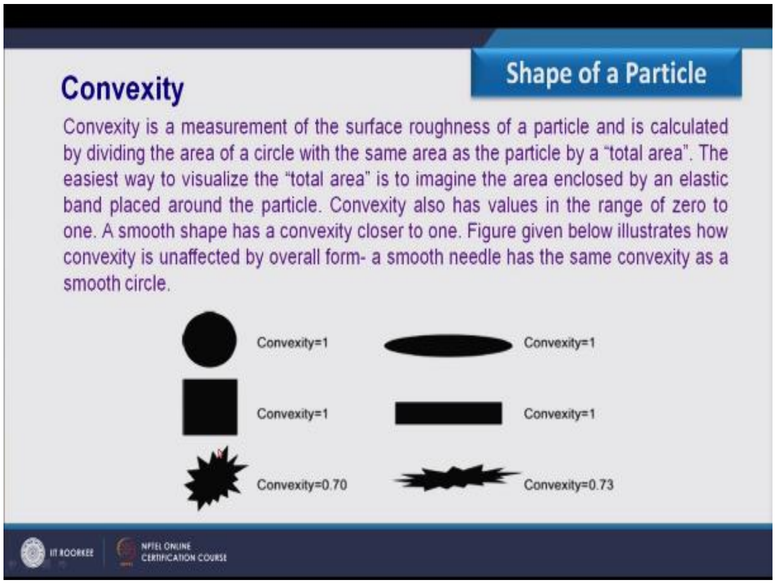

So we can equate the circle area with the particle area divided by total area so in other word the convexity can be defined as the particle area divided by total area how we can define the total area that I can illustrate by this example if you see this figure here we have the convexities of different 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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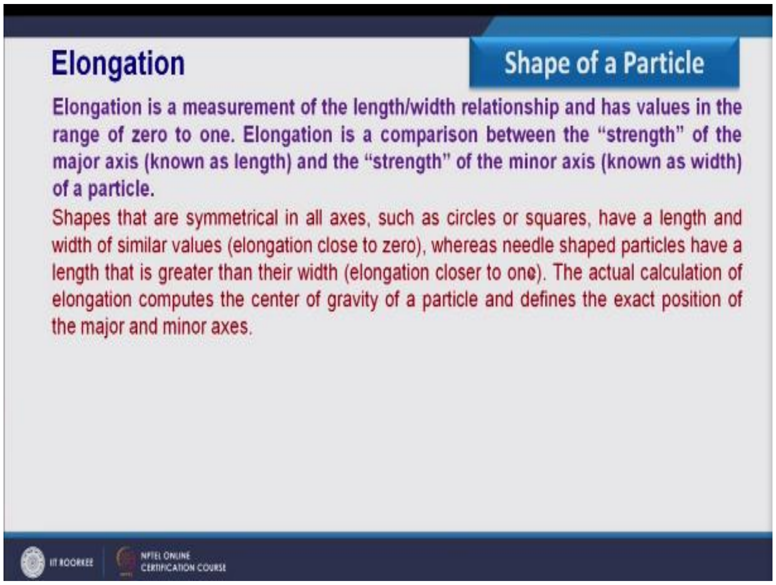

Elongation is a measurement of length over width ratio and has the value in the range of 0 to 1 elongation is a comparison between the strength of the major axis that is length and strength to of the minor axis that is width of the particle, so if we have elongation how we can define the elongation.

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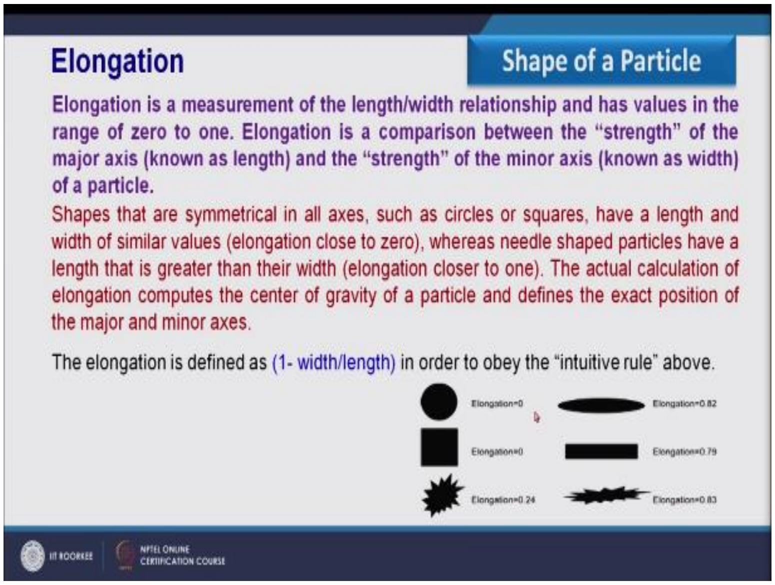

It is 1 minus width over length in order to obey the intuitive rule that is while seeing what should be the value of it like if I define the elongation we can very well identify that I against if the particle shape is of needle it must have the elongation equal to 1, so shapes that are symmetrical in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

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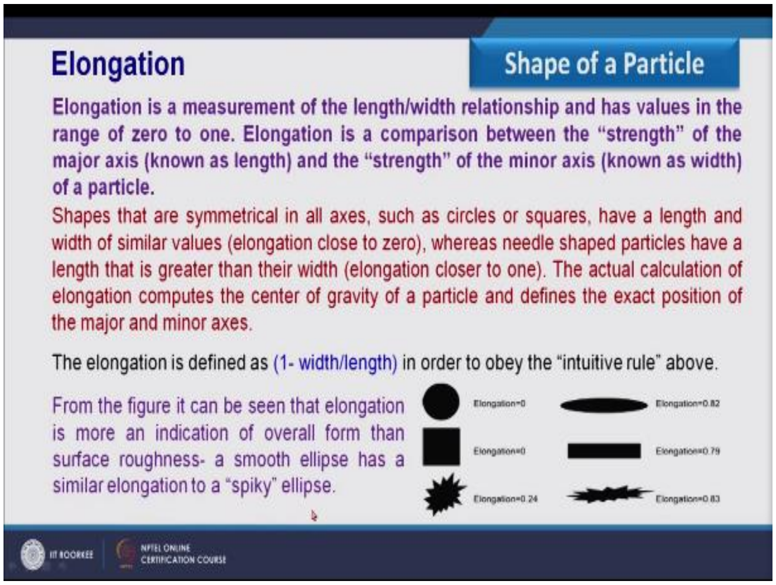

So elongation close to zero like in this case we have elongation close to zero whereas needle-shaped particle have a length that is greater than their width so elongation would be equal to 1. So the actual calculation of elongation computes the center of gravity of a particle and defines the exact position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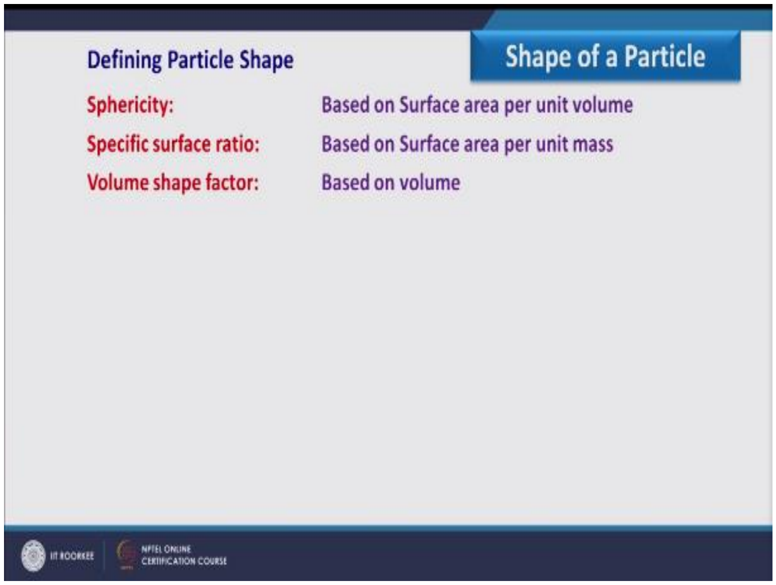

Here I am having three descriptive along with this we can define particle shape based on different factor the first shape is Sphericity and the factor is it based on surface area per unit volume second shape is specific surface ratio that is based on surface area per unit mass volume shape factor.

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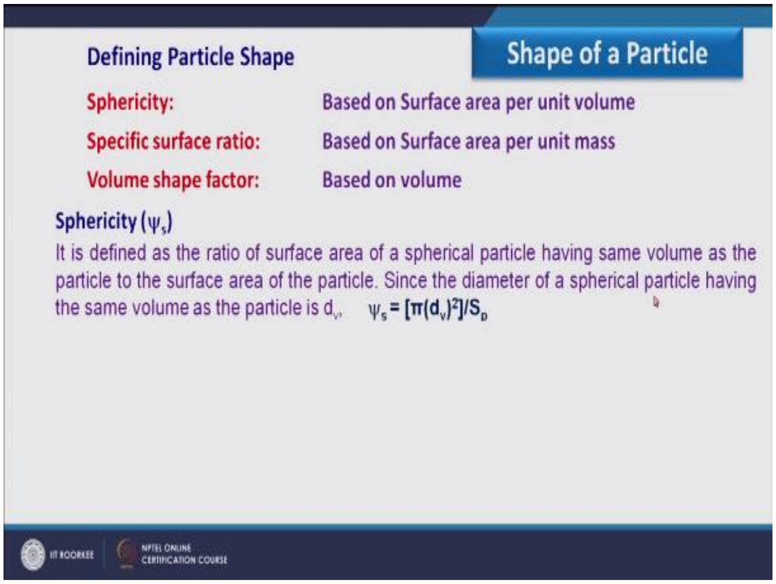

That is based on volume so let us start with this Sphericity it is based on surface area per unit volume, so how it is defined is it is the ratio of surface area of a spherical particle having same volume as the particle to surface area of the particle since the diameter of a spherical particle having 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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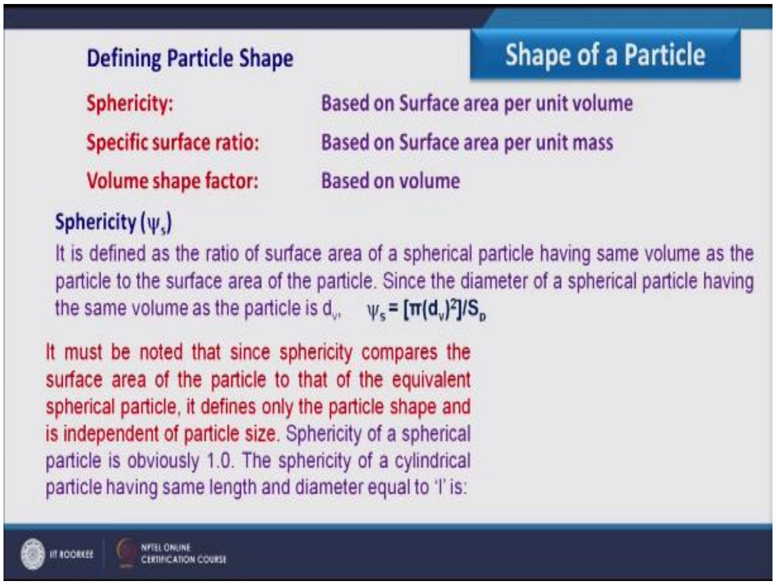

Spherical particle area divided by the surface area of the particle, so it must be noted that since Sphericity compares the surface area of particle to that of equivalent spherical particle it defines only the particle shape and is independent of the particle size for example if I am having a particle 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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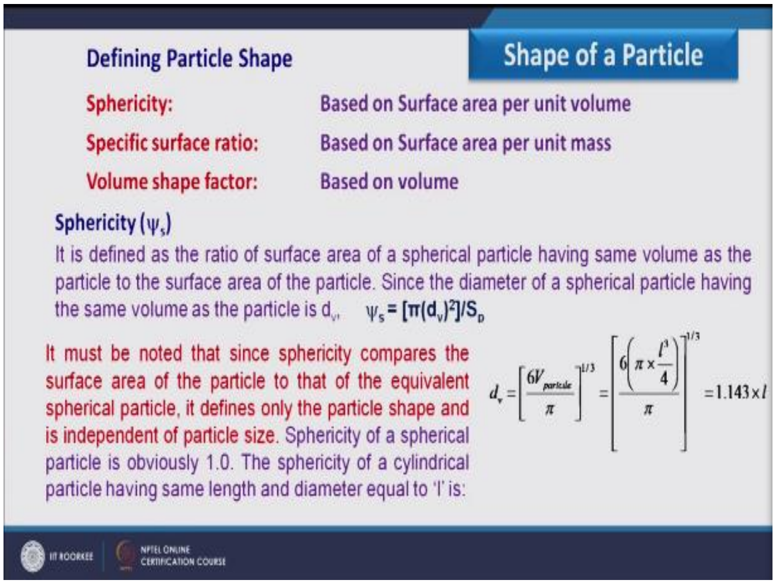

Here I have shown one example to calculate the Sphericity of a cylindrical particle which has length and diameter both are equal to l this d_v is defined as the diameter of a spherical having same volume as the particle, so that d_v would be equal to 6V particle by π so that V particle is the volume 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 l so its volume would be πl^2 so πl^2 can be written as πl/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/π we have taken as it is and the power 1 over 3 we have considered so dv we have calculated in terms of l as 1.143x l. So we can define the Sphericity as $\pi dv^2/sp$ that is the surface area of a spherical particle of dv diameter divided by surface area of actual particle.

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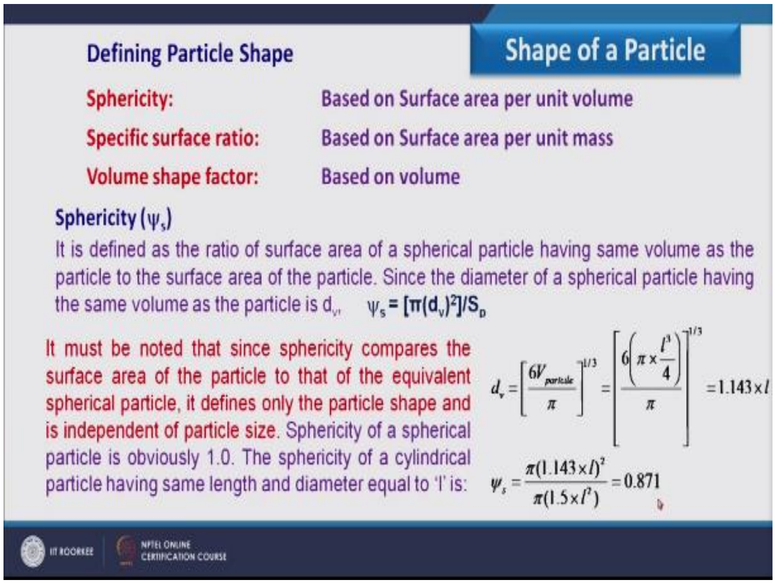

So that $\pi(1.143 \text{ X } l)^2$ that is the surface area of a spherical particle and this $\pi\ 1.5l^2$ is the surface area of cylinder where length as well as diameter are equal to L so is Sphericity in this case is 0.871 so here if I am having more irregular shape this Sphericity would be close 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 Sphercity for depending.

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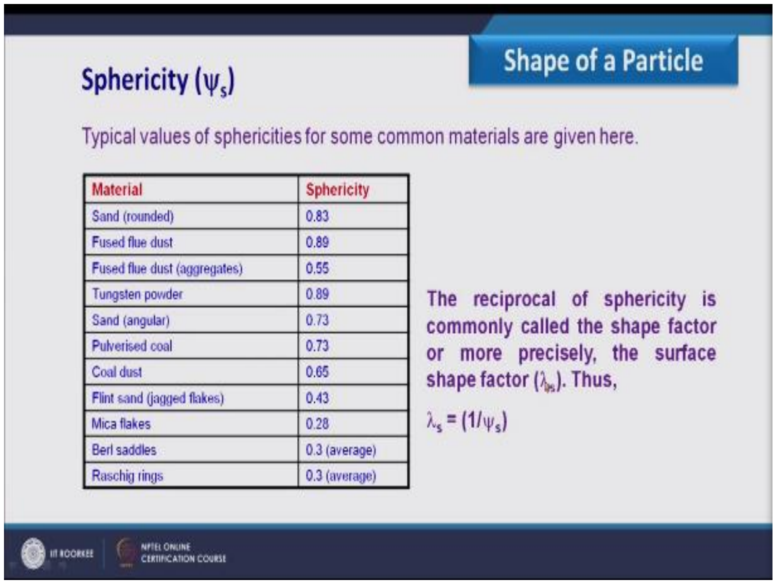

Upon different material likes sand pulverized coal, coal dust, Raschig rings etc, so these Sphericity is defined whatever would be the size of this irrespective of this we can consider this Sphericity equal to these values so reciprocal of Sphericity is commonly call the shape factor or more precisely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

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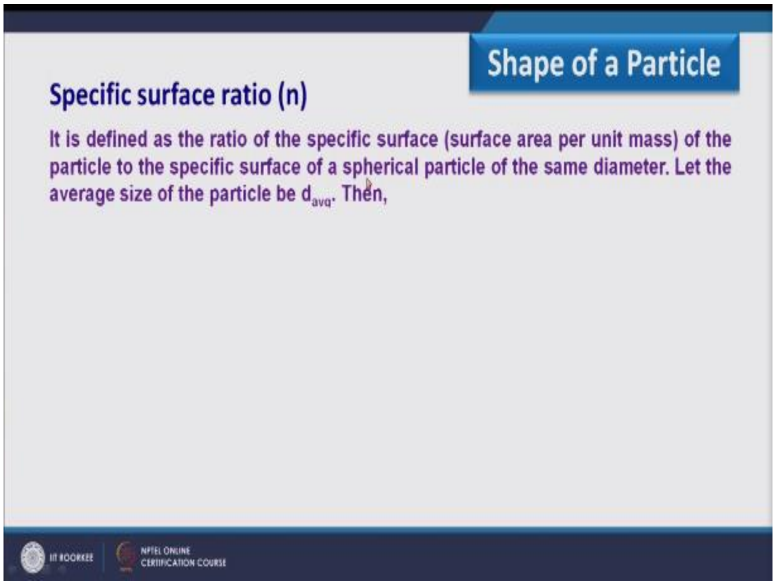

That we denote by n it is defined as the ratio of the specific surface that is surface area per unit mass of the particle to the specific surface of the spherical particle of same diameter let the every size of the particle d average, so obviously when I consider the spherical particle that must have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

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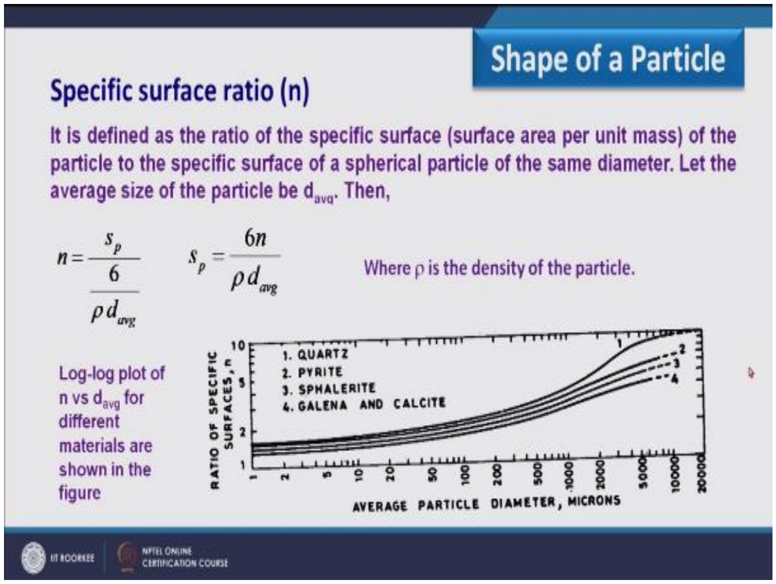

Because here we have equated in terms of diameter then how we can define n is the specific surface that is surface area of a particle per unit mass divided by the surface area of the spherical particle per unit mass, so how the surface area per unit mass of a spherical particle is defined like if I consider 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 quarts, 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.

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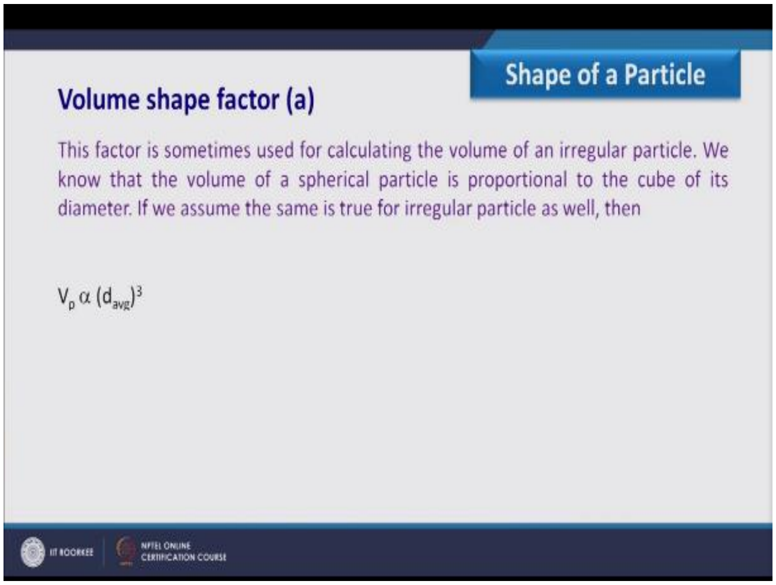

That is (a) so this factor is sometimes used for calculating the volume of an irregular particle we know that volume of a spherical particle is proportional to the cube of it is diameter like I have shown over here Vp is proportional to $(d_{avg})^3$ now once I remove this is proportionality constant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

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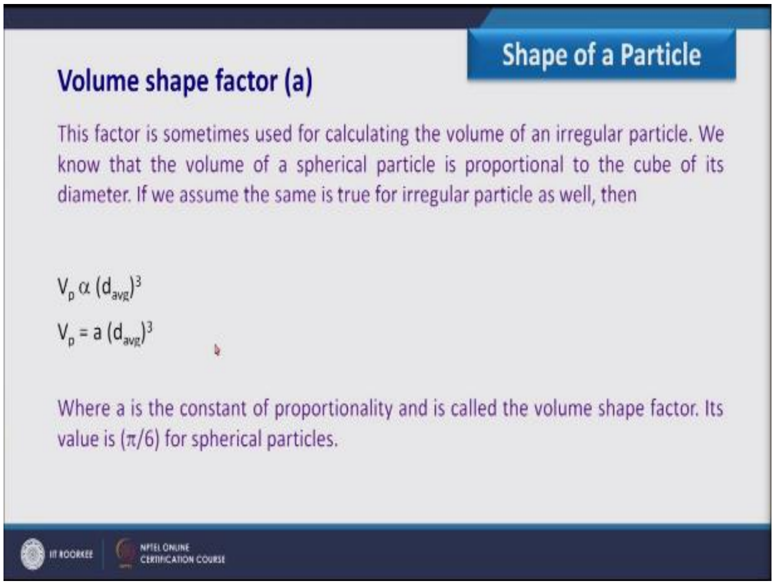

Where (a) is the constant of proportionality and for a spherical surface (a) the value of (a) is π/ 6 so accordingly we can define the volume shape factor.

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

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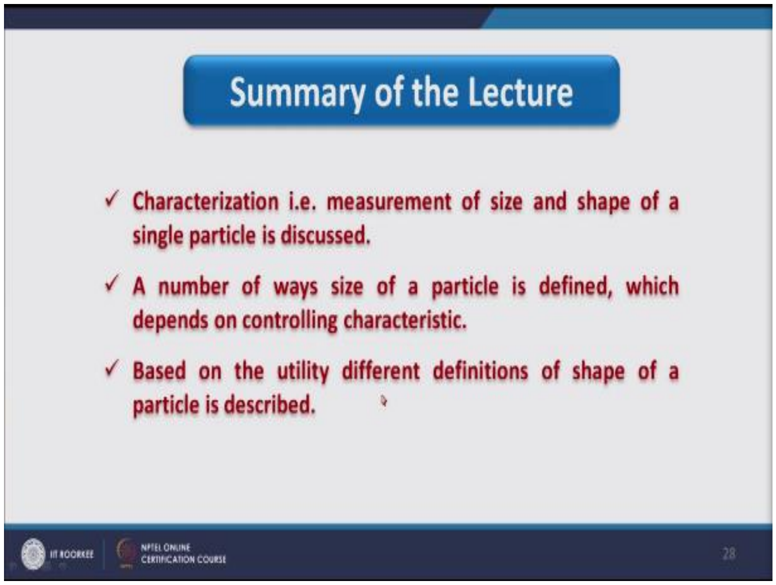

Size and shape of a part single particle is discussed in lecture 2 secondly we have discussed a number of ways size of a particle is defined which depends on controlling characteristic and finally based on the utility different definitions of shape of a particle is described.

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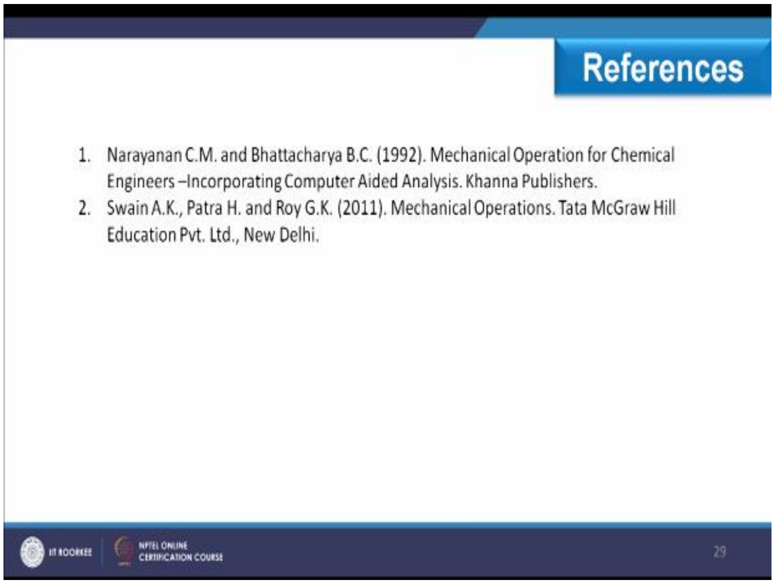

These are the references you can refer so that is all for lecture 2 and thank you.

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Acknowledgment

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Director, IIT Roorkee

Subject Expert & Script

Dr. Shabina Khanam

Dept. of Chemical Engineering

IIT Roorkee

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