Fundamentals Of Particle And Fluid Solid Processing
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Lecture - 01
Solid particle characterization

Hello everyone. Welcome to the very first class of this online certification course on Fundamentals of Particle and Fluid Solid Processing. Today we will be seeing that the first class on Solid particle characterization.

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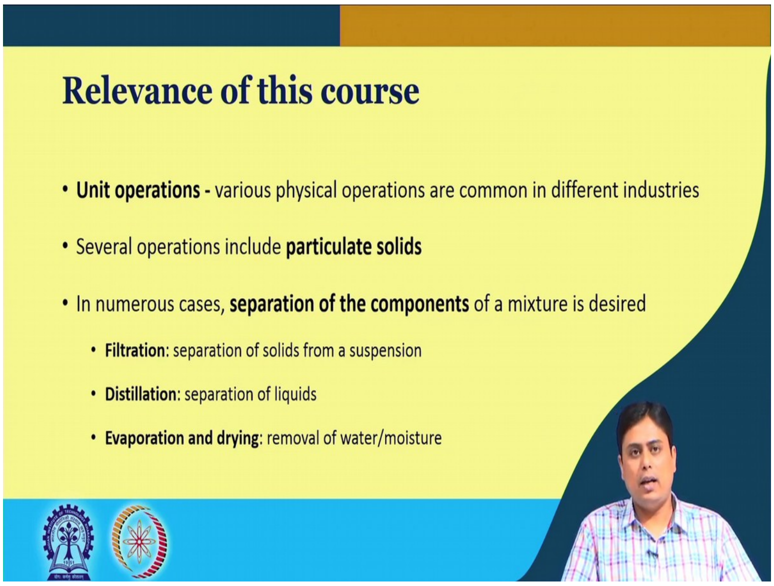

So, before I begin let me give you a introduction that why this course is important in case you have missed or you have not seen the introductory lecture of this course. So, the relevance of this course lies in understanding various processes that are common in various industries. We typically call them unit operations.

Now, several search operations include particulate solids and among them, several operations also include separation of components of a mixture that is highly desirable in several scenario. So, basically unit operations that we typically club various common physical operations together can also be broadly categorized in several processes. We will see that in the next slide, but let me give you an example that what are the unit operation processes.

For example, let us say in fermentation industry distillation happens similarly in petroleum refinery distillation happens. Now, both the processes are identical; the underlying principles are identical, but what matters is the detail in construction of those units in different sectors or different industries. Now as I said in numerous cases, this unit operation involves particulate solids which are actually is the focus of this course. So, here we will see that several to give an example that what are those operations, where the particulate solids are involved. Those are like filtration, sometimes distillation evaporations or drawing that involves this particulate solids.

Now, infiltration what happens? We separate solids from a suspension. In distillation typically two different liquids are separated; in evaporation or drying, we remove water or moisture from a solid surface.

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Now, as I said that based on this underline processes, this unit operations are broadly categorized in various several other processes that are the key features like fluid flow phenomena, heat transfer processes, mass transfer processes, mechanical processes and some thermodynamic processes.

So, any a typical industry with involve one or more of these processes. Now in fluid flow now this basically these sub categories eventually are taught as a separate subjects; core subjects in chemical engineering curriculum. For example, in fluid flow that is the preliminary basic course that is desired to know the subject in details where we study fluid transport or the suspension transport relevant to the particle solids, filtration, solid fluidizations that helps us to get the solids from a mixture.

Similarly there is heat transfer where we study evaporation, condensation, heat exchange. In mass transfer, we study gas absorption, distillation, extraction, adsorption, drying. In mechanical processes, we study separate solids transport separately. We also study particle size reduction as well as enlargement; we also study solid screenings. In thermodynamic processes, we study gas liquefaction, refrigeration its and such phenomena.

So, the point is that in any industry or industrial operations will involve or can involve more than one of these processes ok. But the focus of this course lies on this two aspects that is the fluid flow and the mechanical processes where we will see that the fundamentals of particles and how to separate or how to process a solid fluid mixture.

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So, with this preamble, I guess it is now clear that what we are going to cover. Now when it comes to the particulate solids or let's say the bulk solids or sometimes, it is called the granular solids. Why this is important? The reason is that the solids; the concept of solids is difficult than the fluids because it has convoluted geometrical orientation and defining its physical state is sometimes difficult or most mostly it is difficult.

So, for example, general knowledge on fluid let us say liquid or gases, the concept if you know that and if you try to implement that in the case of solids, it will not help. And in fact, that perceptions are sometimes counterintuitive. For example, to mix two liquids, what you do? You mix, you take those two liquids put in some buckets or some places and then you vigorously mix them.

If you do that for the solids; if you take different types of solid particles, you mix them in a container and you shake it vigorously stir it, vibrate it. It can happen; eventually what will happen that there will be a particle agglomerations or particle size separation, instead of mixing that happened in liquid or the gas case.

Another example is that you take a steel ball or iron ball a heavy ball, you put that in a container, then you pour sands inside the container. So, basically the iron or the steel ball stays at the bottom of the container and it is filled with the sand particles. And then you shake it on a vertical plane. What will happen? The iron or the steel ball will come to the surface; open surface. So, it will rise through the small particles which is completely different from the liquid or the gas phases. And again somehow, if you can introduce some gaseous phase of the liquid phase though the bottom of that container immediately that steel ball will sink due to fluidization.

So, the point is that we need to study the solid classifications separately; its attributes are different than the fluid phases. So, what are the important attributes of an individual particle? So, individual particle if you state it composition, size and shape; then possibly you can define or understand its characteristic. Like composition it helps the properties like to understand the different properties; like density conductivity and all this things that can be determined if you know the compositions. But again that is helpful; this knowledge is helpful if the composition is homogeneous, but in most cases solid particles in solid particles that is not the case. So, that is why this solids are complicated than the fluid.

Similarly size and shapes, these are also important features. If it is a regular shape of the regular sized particle, then it is easy to define, but in most cases it does not have a particular size or shape.

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So, what happens; that if you define a particle size then several properties such as surface area, surface per unit volume; it settling rate in a fluid can possibly be determined. If you can define a particle shape, then it would be easier to understand what is the characteristic of a particulate solid.

So, it can be of regular shaped particle or irregular shape particle. Regular means like a spherical particle, cubic particle, cylindrical particle etcetera that you can define by several different types of dimensions. For example, a spherical particle if you define its diameter, then you can define that particle shape as well as a size.

For the cubic or the cuboid particles, you have to define the three dimensions; for the cylindrical also, you have to define its radius and the height. But in case of irregular particle; for example, of broken glass; broken wheels windshield of a car, if you see those shapes those are irregular shapes. So, how do you define the size of such particles.

In industrial scale bulk amount of particles are handled at a time. So, how do you define particle size of that complete system? So, in that case determination of size of a single particle does not help you, what helps is the particle size distribution. And then if you get the particle size distribution, statistical average mean sizes can be obtained which can give you one representative idea that what are the size is available that you have in the case of industrial scale sample.

So, like particle size shape and the composition has significant influence on the solids characteristics as well. Like in case of nanoparticles when the size goes around 10 to the power minus 9 meter that is the nanoscale. Particle size actually changes the colour of that substance.

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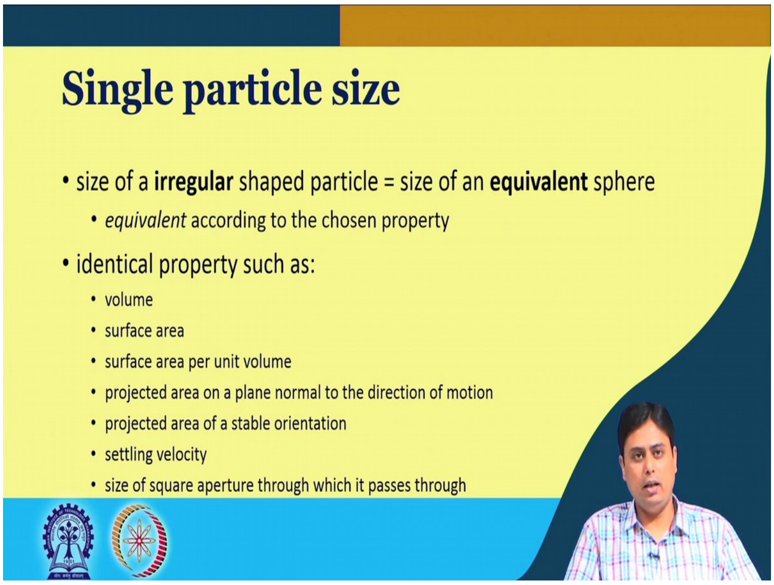

Now, the point is that how do we define a single particle size. We will come to the sample of different particles when we will discuss the industrial scale samples. But let us at first focus that how do we single out a particle and how do we characterize a single particle size.

In case of regular case, we have understood that it can be defined very easily by any of these dimension that is in case of cuboid-three dimensions, in case of spherical the diameter, in case of cylindrical; the radius and the height. But in case of irregular shaped particles, what has been conventionally done is that the size of irregular shaped particles has been equated with the size of an equivalent sphere.

Now this, what is the equivalent sphere. Now this equivalent definition depends on the chosen property that with which property you want an equivalent sphere. For example, that identical property can be of equivalent volume that you calculate the volume of the irregular shaped particle and then the same volume of a sphere what would be its diameter of the sphere that you can easily calculate, and that gives size of a particle; irregular shaped particle.

Similarly, you can equate the surface area of irregular shaped particle with the equivalent sphere having same or identical surface area. There can be possibility that the surface area per unit volume may be same in both the cases and then you determine the sphere. Now, the point is that why we are sticking to that size of a equivalent sphere. The point is that the spherical particle definition is very easy. Sphere is symmetry in nature, it requires only one dimension to tell its size because shape is already spherical.

So, size can be easily determined by only a single dimension because of its symmetry in nature. So, it brings a great deal of simplicity. If we can find some kind of equivalence, the property equivalence with the sphere that we are looking for when we are looking into a particular solid particle.

Similarly, the projected area on a plane normal to the direction of motion because of irregular shape, it will have a different projection area. But if you can get the projected area on a plane normal to the direction of its motion and you equate that area with the area of a sphere and then calculate the spherical a diameter. Thus the diameter of the sphere, you can get another a particles in the size; I mean another size of the same particle.

So, basically all these criteria again; if you equate that with the projected area of a stable orientation; stable orientation means that irregular shaped particle. So, when you try to measure its dimension through a microscopy, it would not sit on the slide or on the plane on any direction or the orientation. It will sit on its stable orientation.

So, on that stable orientation, what is the projection for the projected area that you are looking or that you get from a microscopic image? You equate that area with the equivalent surface area of a sphere and if the and find out the dimension of the sphere or the radius or the diameter of the sphere, you get a characteristic dimension of the irregular shaped particle of the size of the particle.

Similarly settling velocity as I said in my introductory lecture of this class that a basic fluid mechanics knowledge is essential to understand this course. So, the settling velocity you may have heard about Stokes' law. We will again cover or refresh your memory in the later of this course; later stage of this course.

So, the point is that the settling velocity; that means, when particle is trying to settle through a pool of liquid, it attains a velocity; that velocity if you equate that with the equivalent sphere and then determine the diameter of that sphere. You can get dimension or a size of a irregular shape particle having identical settling velocity.

And finally, or the other possibility can be that size of a square aperture through which it passes through during the screening or the sieving operation, that how do we separate different size particles. We separate with take that on a screen, we shake it or vibrate it and then we separate different size of particle through the overflow and the underflow.

Now, the particles that go through that square aperture, it can be equated with the similar size sphere and then we find out its diameter. So, the point is all this now this is not that all the exhaustive list. There can be several other possibility of finding a dimension; a size dimension of a irregular shaped particles. These are the few representative and sometimes it is the mostly used ones.

Out of this very commonly used is the volume equivalent or equivalent volume spherical diameter for the irregular shaped particle. The point is that what I was trying to mention that even for single this irregular shaped particle by doing all these analysis, we can find different dimensions of size or different measurement of mean size.

For example if you take a irregular shaped particle and equate with all these varieties of different property, you get different numbers in dimension. So, which means a simple irregular shaped particle can be represented by various numbers depending on the property that you choose to make it equivalent with the sphere. So, how do we define? That is why whenever we define a size of a irregular a shape particle; we have to tell what is it is either it is a mean volume equivalent volume diameter of a sphere or its a, identical surface area of a equivalent sphere.

The analogy you can draw that when you go for shopping that is say you have to buy a pair of jeans, what you tell to the shopkeeper? You tell your waist size or the circumference of your waist ok. But if you try to buy or if you are going to buy let us say a bed ok, then you have to tell your height. So; that means, that based on your requirement you have to define your measurement property ok.

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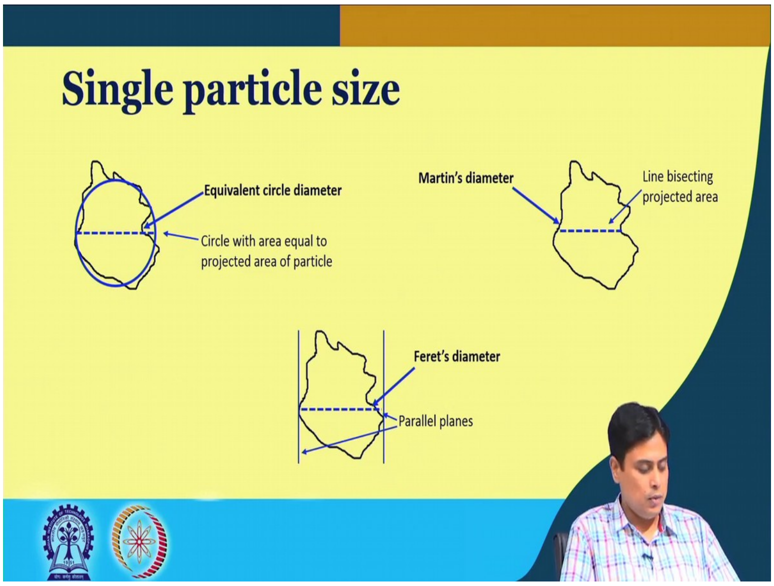

So, let us take this irregular shaped particles. Now what are the types or what are the common variety that we can have to define its size. So, for this irregular shaped particle, what can happen? One of the possibilities that we can draw a equal area circle that is exactly equal to the projected area of this particle and then we find out the circle diameter. So, this will be its equivalent size. The other possibility can be that we draw a line bisecting that projected area and that line or that dimension would be our diameter which typically calls the Martin's diameter.

The third possibility can be that we draw two parallel planes or the parallel tangents and find out what is the distance between the two parallel planes which is again a representative diameter call the Feret's diameter. Now this is quite common because sometimes we measure a substance or a particulates size or a single particle size by caliper.

So, caliper measurement typically gives this Feret's diameter for the irregular shaped particles. So, the point is that as again this slide shows that for any irregular shaped particle, you can have different diameters. So, which one you need that is based on your requirement or the focus of your study that. For example, if you are looking through the microscopy, you can get this equivalent circle diameter or Martin's diameter.

Again let me go back to the previous slide and if we see that when it is important to understand the settling or the sedimentation part, we will be possibly looking at the identical property equated with the settling velocity because it is more relevant to that applications. So, based on the application or based on your application in hand, you choose your measurement method to find out what is the equivalent irregular shaped particle size.

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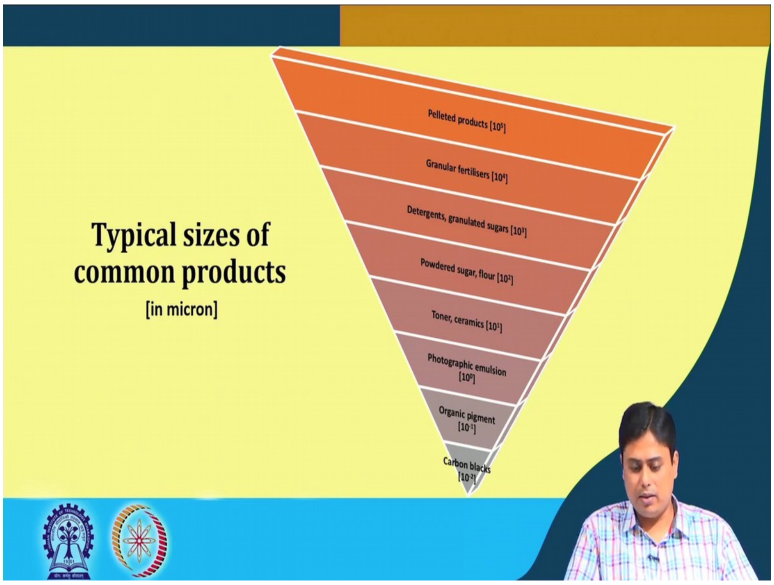

So, this is a slide that shows the typical sizes of various common products that are typically available commercially. This is the size range that is given in micron. For example, the topmost is the bigger particle which is in the order of 10 to the power 5 micron which means in the order of meter scale that is a pelleted product. For example, you can have let us say the coal from its mining stage some chunk of big chunks of coals or maybe pelleted products, some catalyst; pelleted catalyst in this range; in the meter submeter range.

The granular fertilizers, it comes in the range of 10 to the power 4 micron. Again to refresh your memory, 1 micron is 10 to the power minus 6 meter. Detergent, granulated sugars comes in the range of 10 to the power 3 micron; that means, a 1000 micron level, then we have powdered sugar or the flour that we use regularly that is in the order of 100 micron; one particle size in the order of 100 micron The toner cartridges, a ceramics that we use in the order of 10 micron. The photographic emulsions is now in the order of micron. Then there are submicron particles like organic pigments and carbon blacks.

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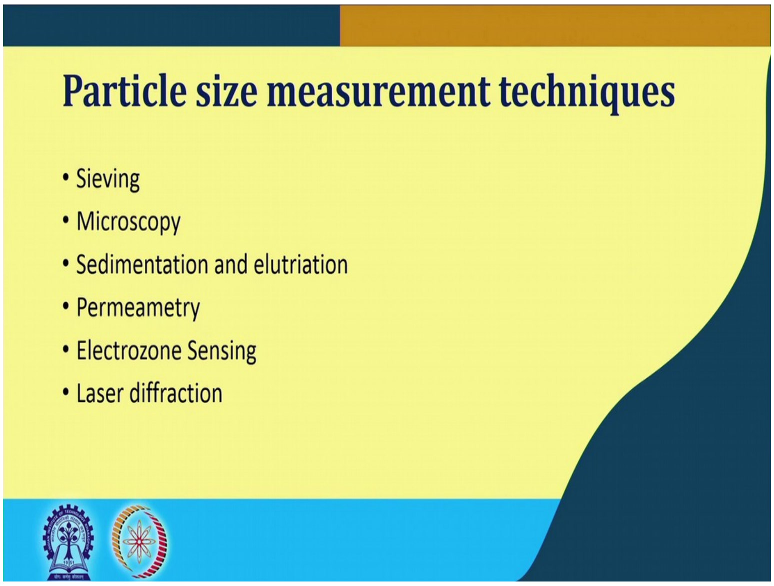

So, the point is that how do we measure a particle size. So, this particle size measurement techniques, we will be discussing in detail in the next lecture. But let me give you an overview that what will be covering in the next lecture is that different methods by which we typically characterize a single particle which are the sieving; which are the sieving microscopy, sedimentation and elutriation, permeametry, electrozone sensing, laser diffraction method. So, most popular method is a sieving or the screenings, then it comes by looking through microscopy. There are other methods as I have mentioned here are the sedimentation elutriation.

So, these classifications or these measurement techniques are not arbitrary. These measurement techniques cannot be applied for all the range of particle or the size range of particles; these are limited to a particular size range. For example, sieving or screening can be done for the size range more than 50 micron also, beyond that you cannot sieve that there is no standard sieve that can help you to identify a particle size below 50 micron. In that case, we have to go to either microscopy or sedimentation or permeametry methods or the other methods.

So, similarly based on the particle range we have to use our size measurement techniques that we will be cover in the next lecture. So, with this, I thank you for your kind attention and will interact with you in the next lecture.

Thank you.