Fundamentals of Food Process Engineering
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Lecture - 36
Size Reduction

Hello everyone, welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. We will start today a new topic on Size Reduction.

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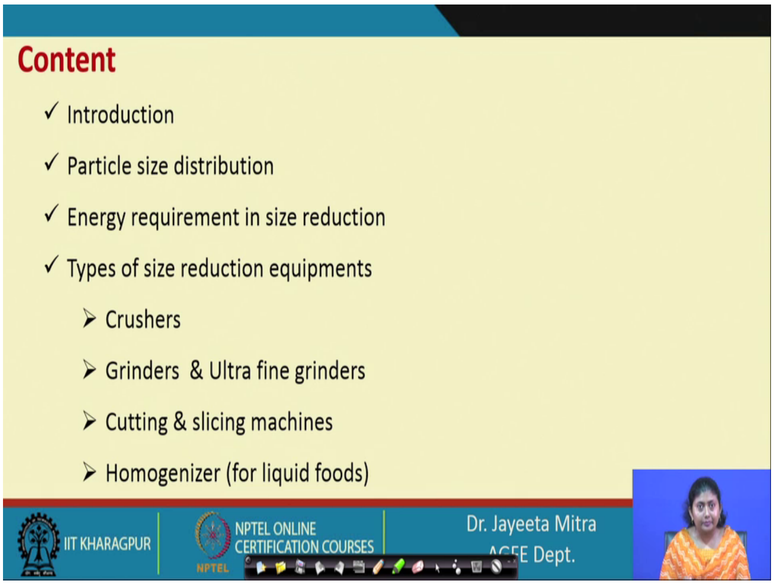

This is a very important unit operation in food as well as in the chemical engineering industries. We will cover the introduction about size reduction, particle size distribution, energy requirement in size reduction, types of size reduction equipments; crushers, grinders and ultrafine grinders, cutting and slicing machine, homogenizer for the liquid food.

So, since size reduction can be applied to both solid and liquid material, although we will cover in very much detail the size reduction related to solid particles. And also we will see the homogenizer which is specifically used for making fractions of liquid particles, when we try to mix try to prepare a liquid emulsion kind of operations. Those are also very important in some food application. So, let us see what are the, you know introduction or the requirement of size reduction unit operation in food industry.

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Size reduction or comminution is the unit operation in which; the average size of the solid pieces of the food is reduced by the application of grinding, compression or impact forces.

Now, there are different forces that we use to reduce the size of the particle from the bigger one to the smaller one. And we will see that in most of the time these different forces not alone works in a particular operation. The combination of more than one type of operation or forces may work on the particle. And there are different kind of operation like cutting, chopping, grinding, milling or all are used in certain kind of size reduction operation. Similarly, for the liquid and semi solid like, when we want to do atomizing or we want to do homogenizing applications meshing etcetera.

So, one such example we are we can observe here that is the coffee bean to coffee powder preparation. This is done by grinding to increase the surface area that is one operation and there are other operations that we will see.

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The basic objective of this if accelerating the heat and mass transfer. So, what happened that when we grind a particle for example, coffee bean here for preparation and extraction. Now what happened that in extraction what we are doing is when we when we have extraction we need a solvent and we need a solid (Refer Time: 03:55) or particles from which we want to extract the bioactive compounds. So, in that case we have a continuous solvent and in that we have you know different particle smaller or bigger.

Now, as much as the interface area; that means, the contact between a particle and the surrounding solvent we can increase so, the extraction will be faster. Similarly, if you want to you know perform certain drying operation where we finally, need some you know powdered form of material.

So, if we grind it and then it is exposed to the heat source, so what happened that; heat can penetrate faster into the, you know center of the of the material. And also the moisture can transform faster from the, you know inner core to the surface. So, grinding in a way is resulting the increase in the surface area and thereby helping certain other operation like heat transfer, mass transfer etcetera. Another is that to facilitate separation processes for example, milling wheat to obtain flour and bran separately or filleting of fish.

Now, what happened that when we want to separate the bran from the wheat kernel, for similarly we want we want this kind of operation in you know separation of the rice bran also. So, in this case we want to separate 2 different part of a grain which is having somehow different composition or they have different use. For example, we separate the rice bran to extract the oil from the rice bran. So, that is why we need the rice bran separated from the kernel. So, all this operation that is to facilitate the separation process sometimes we need to use the milling or size reduction operations.

And suppose in the filleting of fish; that means we want to develop certain special kind of product of fish muscle, where we want to separate the bones from the fish. So, we are doing the filleting so these are the special requirement of different food processing sections. Then facilitating, mixing and dispersion for example, milling or crushing ingredients for dry mixing. Now, if the bigger size of particle we are using and 2 different spice mix for example, we want to prepare. So, then if the particle size are bigger so mixing will not be proper and a non-homogeneous structure will be there. And when we want to use is that mixture into food so what happened that; we will have trouble in optimizing the quantity of the mixture.

So, you might have seen that nowadays very readymade, spice mix are coming different branded company for you know the noodles making company. So, they are they are giving that particular kind of spice mix. So, grind they are drying and grinding different 2 3 4 and more than that different spices. And then they mix them together, and then they use it in certain applications. And another is to obtain the pieces and particle of defined shapes and sizes also.

Now, what is that if we consider the different shapes then different operations are there where we need a particular kind of let us a spherical shape or a particular kind of structure, then we want to grind it and sieve it in those particular kind of you know predetermined perforated screens. So, that we can get the particular shape or else if we want to determine the different size fraction for example, in the wheat milling we want different fraction of it. For example, we want Suji which is one fraction and we want the whole wheat flour that is a more finer fraction. And also we sometime need Dalia which is a coarse fraction of that. So, different fraction of same grain sample when we want to use; so that we can get out of this size reduction operation.

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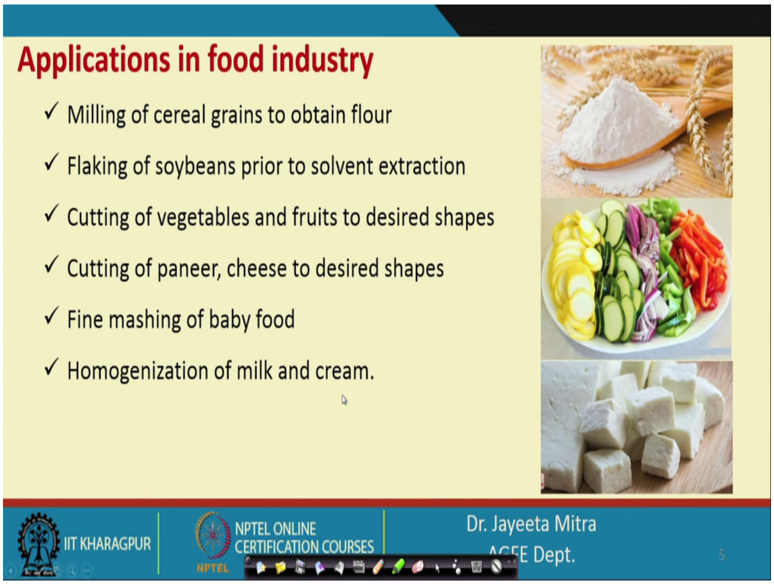

So, as I mentioned that in the food industry here are many application, cereal milling which is to obtain different kind of flour. In nowadays not only the one grain sample, but multigrain products are; you know becoming more and more important in terms of consumer preference, because many grain if we mix we are getting multivitamins and mineral rich products. For example, the multigrain flour is used for Chapatti making. They have they have different atta sample are prepared out of that bread sample are prepared out of that. So, cereal grains to obtain flour this is one of very important application. Then flaking of soya bean prior to solvent extraction.

So, not only soya bean if you want to extract you know any other for example, rice bran or any other oil extraction. So, some optimized size we need to prepare because if we make a bigger size flakes. So, extraction will not be efficient since the heat and mass transfer will not be that much efficient right. So, for that this flaking is done and after that the proper size reduction of those flakes is important.

So, this is one operation, then cutting of vegetable and fruit to desired shape. So, this is of course, done for the preparation of different recipe and cutting off paneer, cheese etcetera in desired shape. So, this is also one type of operation that we that in that we are reducing the size. Fine mashing of baby food because they do not have the you know that taste for chewing all those to reduce the size. So, we need to finely mash them and for preparation of that; the companies which are you know going to prepare baby food kind of product, they do it by proper size reduction.

So, these are the commercial application, then homogenization of milk and cream because you know that if you take the raw milk and boil it. So, you will get the cream separated from the milk. So, the cream because of the lighter they come on come and float on the surface. Now, when we want to sell the milk or we want to pasteurize the milk so in the milk processing plant; we need to homogenize the milk and the cream properly. So, here the, you know this is a kind of liquid particle reduction and mixing properly. So, there we apply the homogenization.

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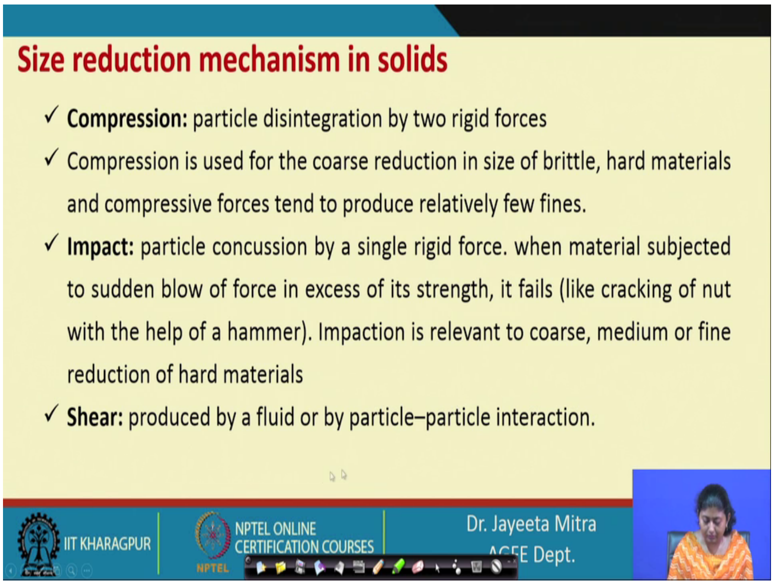

Now, size reduction mechanism in solids. So, definitely in the solid and liquid the method by which we or the mechanism by which we reduce the size will be different. So, first we will see the mechanism in the solid sample. One half one-fourth that we apply for reducing the size in the solid is compression, where particle disintegration by 2 rigid forces. Compression is used for the coarse reduction in size of brittle hard materials and compressive forces tend to produce relatively few fines. So, compressive generally we are getting a large particle bigger sized particle out of that.

Next is the impact force; so, particle concussion by a single rigid force is impact, in that we do by forcing a heavier impact on a particle. So, this is kind of a unidirectional force. When material subjected to a sudden blow of force in excess of it is strength then it will fail. So, like cracking of nut with the help of hammer, if you have seen that in cashew nut processing, also you know different research is going on to develop the sheller. Cashew nut sheller by mechanical means, but normally if you go to the villages where large scale cashew production is there.

You will see that they do the hammering at a particular angle and the junction of the 2 shell to break it. So, they will they will blow it in every blow they will break the shell of the cashew nuts. So, this is the mechanism by which they operate it. So, impaction is relevant to coarse, medium and fine reduction of the hard material. So, there are many application of this impact force we will discuss them. Then another is the shear so produced by a fluid or by particle interaction.

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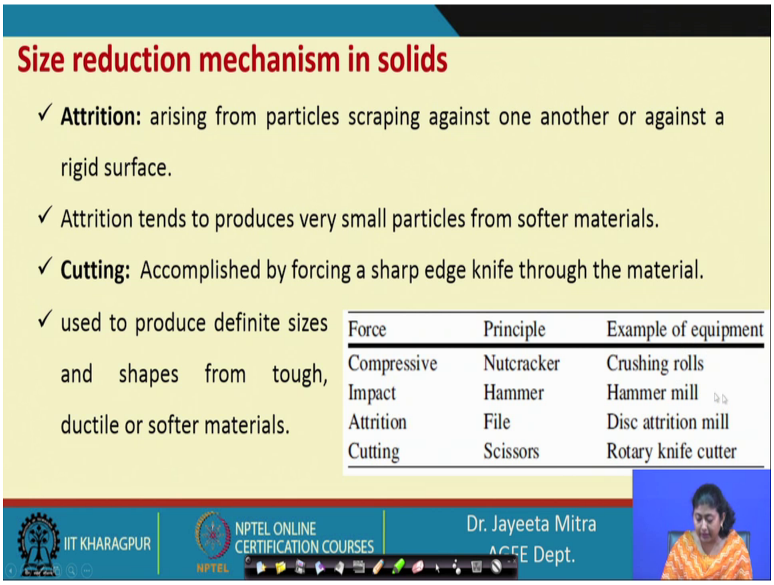

Then size reduction mechanism is Attrition; attrition arising from particle scrapping against one another or against a rigid surface. Attrition tends to produces very small particle from softer material. Cutting which is accomplished by forcing a sharp edge knife through the material. And this is used to produce definite size and shape from tough ductile and softer materials.

So, if you see the force and the principle and also the equipment where this forces are being used. So, compressive force this is used in the nutcracker in the method is crushing rolls. Impact this is used in the hammer; hammer means attrition; attrition force is used in the disk attrition mill. Then there is cutting, this is used in rotary knife cutter the mechanism is like scissors. So, these are the different forces that is used for size reduction in the solid material.

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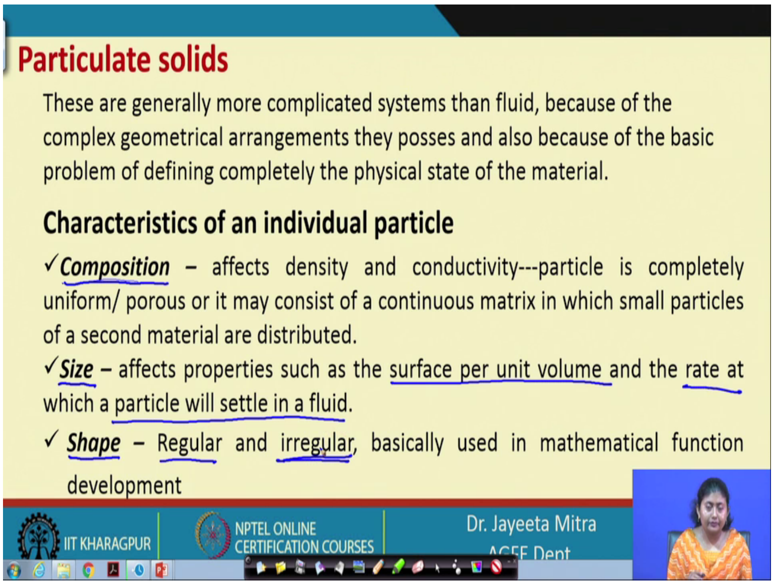

Now, when we discuss the particulate solid the problem is that; when we deal with the fluid material we consider them as a bulk fluid flow. And it is very you know little bit easy to understand the behavior we can categorize them in the Newtonian or non-Newtonian fluid. And then we can calculate easily the, what will be the velocity and what is the shear force acting at different location. So, when we use the bulk fluid we even can we even assume that the uniform, uniformity in the material is existing, but when we deal with the solid material particulate solid material specially.

So, these are you know having a very complicated system. So, to defining them in a uniform way is a challenge. And most of the cases if you look into the food industry where we handle the bulk particulate solid for example, any flour mill or any kind of processing where bulk material dry material flow is involved. For example, before extrusion also sometime we want mixing of different kind of raw grain sample or powdered sample. Then we mix it and then we send it to the some other channel. So, that time the challenges we face because the particulate solids are generally a complicated system than fluid.

As I mentioned because of the complex geometrical arrangements they possess and also because of the basic problem in defining them completely in terms of the physical state of the material.

The problem is that there are many irregularities in the particulate solids; in their shape, their sizes and their uniformity because sometime they may form a clump sometime there will be a porous structure, where lot many air pockets are there. And; obviously, there the size and shape non uniformity is a you know major concern. So, all this are there therefore, the characteristics of an individual particle. If we want to express based on certain criteria so that is important first.

So, once we see that how we can define a single particulate solid then we will move on to the different size reduction operation. So, first we will see now that how we can define the particulate solid in terms of what parameters. Then how those parameters are you know categorized and they will be classified in different category. And then we will see that what are the what are the actions on mechanism we can apply on them.

So, to characterize an individual particle first is composition so this is very essential. So, composition is the you know first important thing. So, this affects the density and conductivity of a material so composition if it is of one grain particle. So, it will have a uniform characteristics if it is a mixture of you know different grain. So, it is composition will vary so therefore, the composition is one important thing that affect the density of the product and also the conductivity of the product. Suppose you know in terms of thermal conductivity or heat transfer as well.

If you have a different kind of mixture and there are fat, protein, carbohydrate and different kind of material. So, then for each of the different kind of material the properties will be different right, so first this is important. So, the particle is completely uniform or porous or it may consist of a continuous matrix in which small particles of a second material is distributed. So, what is the characteristics that we need to know first. Second is the size, so size affects the property such as surface per unit volume. This is very important because the surface area if we are getting bigger surface area or larger surface area for a small unit volume then; obviously, the transfer processes will be increased.

So, therefore, surface per unit volume this we can get the idea from the size and the rate at which the particle will settle in a fluid. So, all such depend on the size of the particle. Now the last thing is shape. Now how this shape plays an important role, what happened that in a particulate solid you will get regular shape of the particle and irregular shape of the particle. Now, it is very easy for a scientist to identify what to categorize the regular size of particle. For example, if you take a crystal cube or if we take the spherical particle, round shape particle.

So, regular particle if it is there in the bulk solid. So, then to categorize them or to apply different forces or to analyze their behavior becomes a bit easy. Now, if those are irregular shape then to handle their irregularity becomes a challenge. And then what we do is we try to, try to define this irregularity with some kind of regular material. We replace this irregular material and we define certain kind of factor which correlates the irregular with the regular particle.

And we take those regular particle size and take them in you know modeling of the phenomena because any you know particle characteristic or bulk solid flow behavior when we want to analyze. So, we need the regular shape particle and then we use them in the modeling. So, all those irregularities are there we need to relate that how much they are close to a regular shaped particle. So, therefore, the shape of the particle is also very important. And once we know all this 3 it is easy then to identify the particle behavior.

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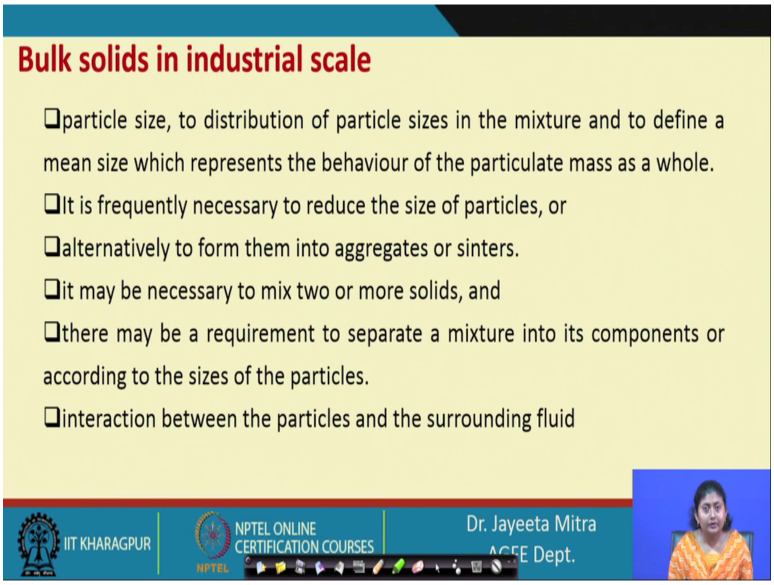

So, bulk solid in industrial scale when we want to analyze now. We have learnt that what is the basis of a characterization of a single particle; that we have learned now based on composition, their size and the shape. Now again the problem is we cannot get one size in a bulk mixture. So, we need to you know transform our analysis from the particle size to the distribution of particle sizes because when we try to handle the solids in the bulk scale or industrial scale we cannot get uniform particle size.

There are very rare operation where we can get this uniform particle size. Mostly a range of particle size we can get in that fraction of each size are present, and maybe they are dominated by 1 or 2 major size fractions.

So, particle size to distribution of particle size then we need to do in the mixture. And to define a mean size, which represent the behavior of the particulate mass on the whole. So, we need to develop a mean size out of all the lot of the bulk sample we need to identify this. And further this mean size we will we will take a representative of all this bulk solid and do the any kind of analysis; whether we want to analyze the energy requirement for the for the combination process or we want to do any kind of bulk flow modeling.

So, it is frequently necessary to reduce the size of the particle or alternatively to form them into aggregate or centers. So, these are the operation we made equal in industrial scale. It may be necessary to mix 2 or more solids and also their fraction size and shape is defined in most of the cases. For example, I have discussed the concept of instantization in the drying.

So, instantization in that we need to have a particular side. So, that when that you know the particles are dipped into the liquid, where they where they should mix properly. So, they will not form a clump they are or agglomerate and they will uniformly dissolve in that. So, for that in instantization it happened that after spreading also we form certain kind of size increasing operation or a little bit of clump formation. So, that the particular size that optimized size that we want can be can be you know produced.

So, those are the different operations that we need. Now there may be a requirement to separate a mixture into its components or according to the size of the particle. And finally, the interaction between the particle and the surrounding fluid so, that is a case of extraction as I mentioned. So, extraction is very much important nowadays we try to extract many important bioactive and compound or heat sensitive compound out of the you know out of the matrix. So, therefore, we can use them.

And one more thing I think we will mention it somewhere; that I would like to tell at this point that all the grinding operation that we perform has different requirement. Now if we try to produce the particle which are very much heat sensitive, where we are producing some kind of particle fractions or want to extract certain component, which is very much heat sensitive. So, in that there are different operation to perform this size reduction under different temperature condition as well.

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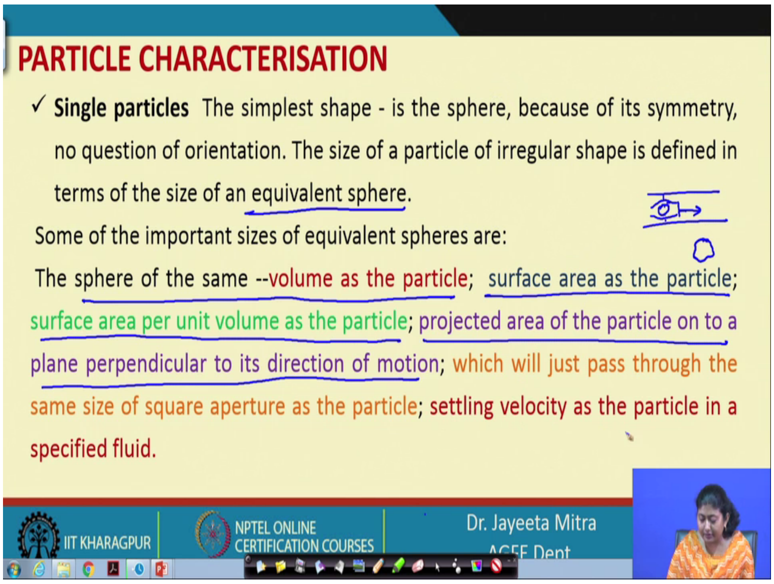

So, particle characterization, single particle we want to you know make it into the most common and most useful shape so that is the sphere right. So, why we use sphere most commonly because of it is symmetrical structure. Sphere is from the all side it is same so there is no problem of orientation in the bulk fluid, or in the you know heat ambient or in the liquid mixture. So, that from the every side the analysis can be uniformly done.

So, sphere is the most common shape we try to assume in this kind of bulk fluid material. And the size of a particle of irregular shape is defined in terms of the size of an equivalent sphere. So, whatever irregularities we found as I mentioned that we relate them with the known regular shape that is the sphere; some important size of the equivalent sphere. So, these are you know these are represented as the sphere; the sphere of the same volume as that of the particle or the sphere of the same surface area as that of the particle.

That means we are having an irregular particle; we are having an irregular particle. We measure the surface area of the irregular shape particle. And then the same area sphere we take a sphere which is having the same area. And the diameter of that we will take as the equivalent diameter. Similarly, there maybe you know certain sphere of the same surface area per unit volume of the particle or may be the projected area of the particle to a plane perpendicular to its direction of motion.

So, suppose there is a there is a flow and there is a particle. So, flow past this particle is going so in the direction of the flow, we take the projected area of this. And then that we will take as a that diameter of that, we will take or the distance between the 2 point in that the tangential point we will take and then we will measure the diameter. Or else we will also do that the particle should pass through the same size of the square aperture as the particle. And also settling velocity as a particle in a specific specified fluid so all such are different expression of the equivalent diameter.

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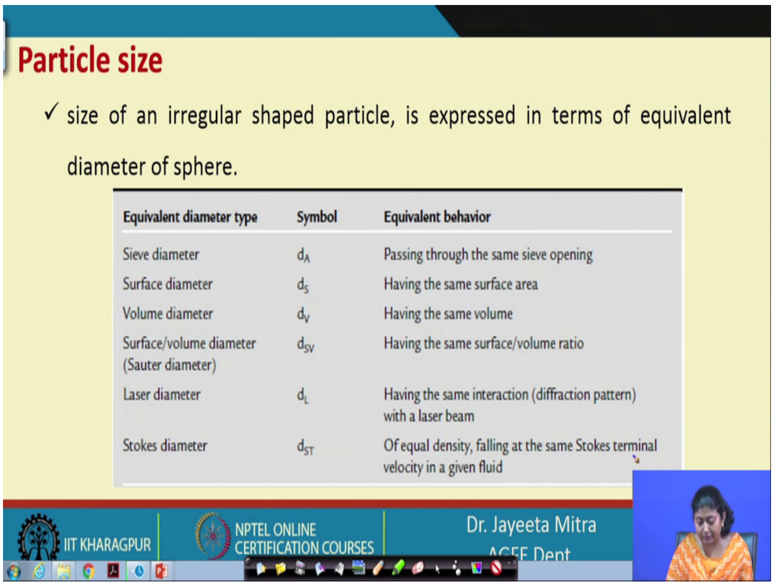

And the size of an irregular shape is also expressed, this is kind of a tabulated form all those things that we have just discussed that based on surface area, based on sieve opening, based on projected area. This can be categorize under different category like sieve diameter, surface diameter having the same surface area. Surface to volume diameter, which is also called the Sauter diameter having the same surface to volume ratio; lesser diameter like having the same interaction or the diffraction pattern with the lesser beam.

So, irregular shape particle which his having the diffraction pattern. Similar diffraction pattern having a spherical shape is taken here and the equivalent diameter is taken. Stokes diameter which is of equal density falling at the same stokes terminal velocity of a in a given fluid. So, all such diameters are used for analysis of the particle size.

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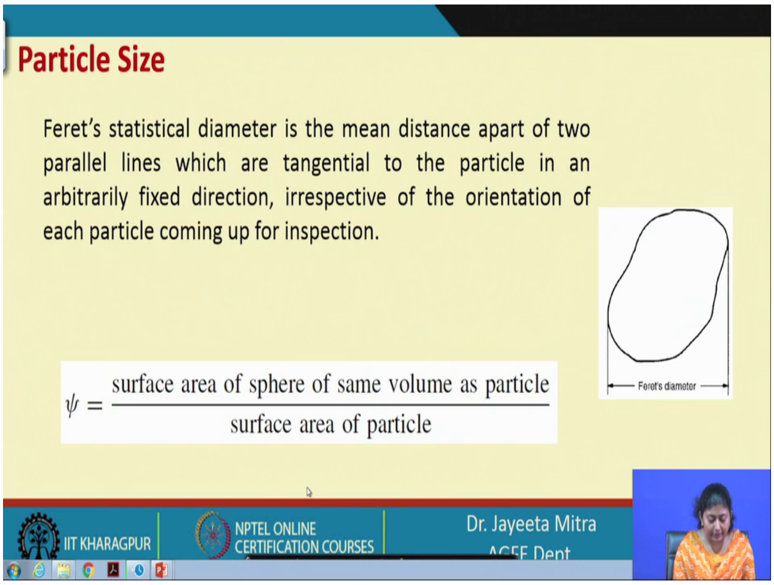

Now, one common expression is sometime use that is called the Ferets statistical diameter, which is the mean distance a part of 2 parallel lines which are tangential to the particle in an arbitrary fixed direction. So, these are the 2 parallel line which are tangential to the particle. And this is irrespective of orientation of each particle coming up in the inspection.

So, the orientation may change at any time, but we will take the 2 tangential parallel lines and take the diameter which is called the Ferrets diameter. Now, as I have mentioned that we take the you know common shape of a sphere and try relate the particle with that, try to relate the irregular shape particle with that.

So, that relation is developed by serricity. That relation is developed by the wise serricity that is nothing but the surface area of a sphere of same volume of a particle to the surface area of the particle. Surface area of a sphere having the same volume as of the particle divided by the surface area of the actual particle that we are taking so, this will define the serricity of the particle. So, we will stop here and we will continue in the next class.

Thank you.