Powder Metallurgy
Prof. Ranjit Bauri
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture - 21
Basis for particle size measurement

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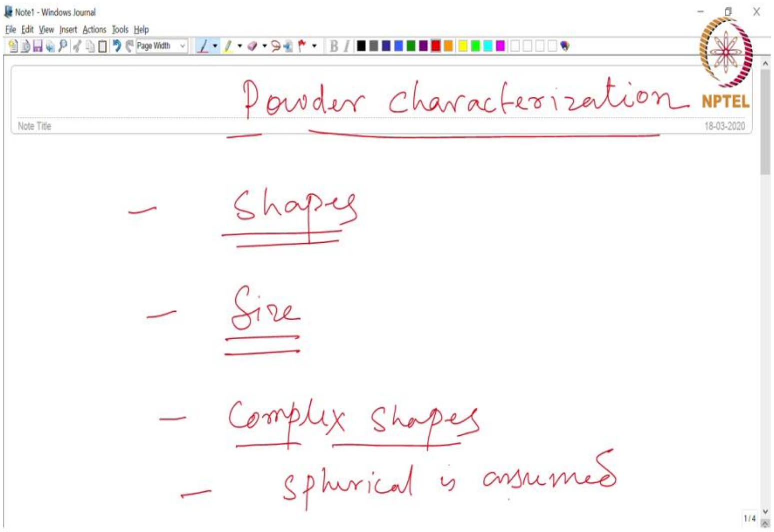

Hello and welcome back. So, right now we are on this topic of powder characterization, which is about evaluating the powder particles for their different properties like, size, shape and other characteristics. And, in the previous class we talked about the different kind of shapes and how they are defined. And we discussed about the characteristic dimension which can be used to define the particle size.

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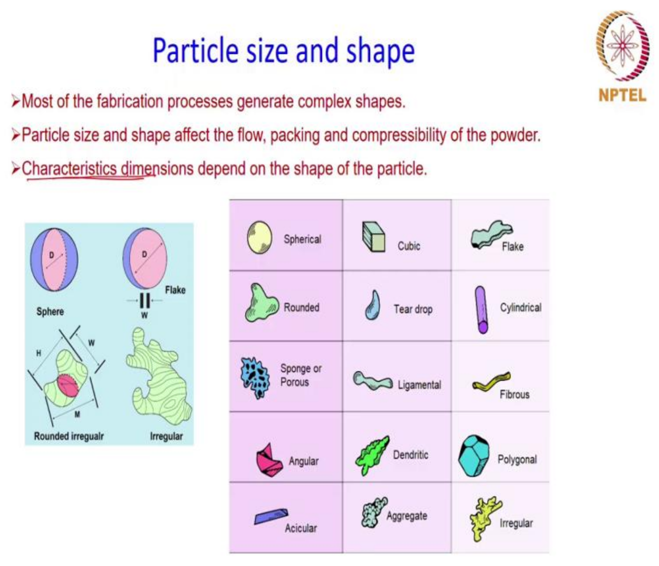

Most of the powders have complex shapes. And, therefore, it is difficult to define one single geometric parameter, which will give the size of the particle.

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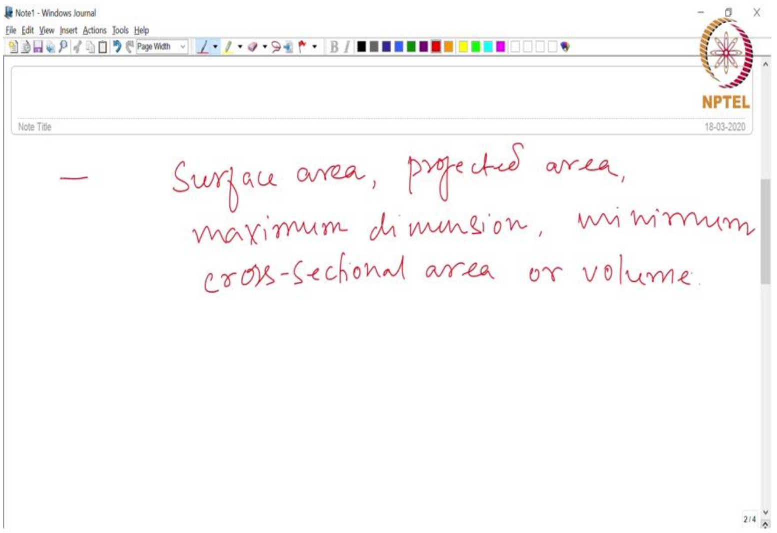

So, a spherical shape is assumed. And, the basis for this particular geometric parameter can be one of those geometric characteristics or geometric values like the surface area, projected area, the maximum dimension, or minimum cross sectional area or volume. And, this is explained here in this particular slide below.

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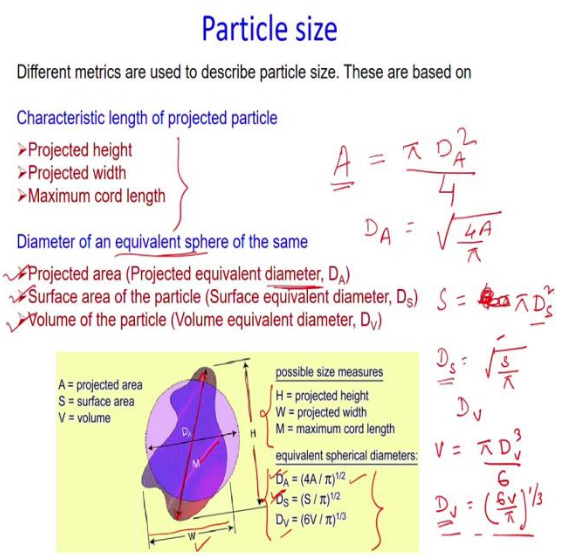

This is an example of a particle which is irregular in shape. We can define it in terms of an equivalent sphere, which is having the same projected area, same surface area, or same volume. Then, the size of the particle can be defined in terms of the diameter of a sphere, which is having a same projected area, same surface area, or same volume as the particle. These are the three parameters based on which we can define the particle size.

Consider the case of equivalent spherical diameter, which is based upon the projected area. So, here what is done is the area of the particle is equated with the area of an equivalent sphere. In this case, the equivalent diameter is based upon the area. So, it is written as D_A. So, that is the projected area of the sphere, which is set equal to the area of the particle. And, from here you get the projected equivalent diameter D_A as shown below:

$$A = \frac{\pi {D_A}^2}{4}$$

$$D_A = \sqrt{\frac{4A}{\pi}}$$

Similarly, when you set the surface area of the particle equal to the surface area of the equivalent sphere, then you have.

$$S = \pi D_S^2$$

So, in this case this is the surface equivalent diameter written as D_S which is given as

$$D_S = \sqrt{\frac{S}{\pi}}$$

Similarly, the volume equivalent diameter D_V is given as,

$$V = \frac{\pi D_V^3}{6}$$

$$D_V = \sqrt[3]{\frac{6V}{\pi}}$$

Thus by considering the particle as an equivalent sphere, the particle size can be defined using D_A, D_S or D_V. These are the different geometric parameters or geometric dimensions, which can be considered as a geometric parameter to define the dimensions of the particle, like the projected height H (slide above).

The projected width W or the maximum dimension for example, in this case the maximum dimension is the maximum chord length M. So, this is how first you need to define the characteristic dimension. And, then using the available instruments the particle size is measured.

Now, the particle size can be measured by different techniques using different instruments and each of these techniques use a particular basis for measurements. And, therefore, it is always good to mention what is the basis that was used for measuring the particle size, when the particle size data is presented.

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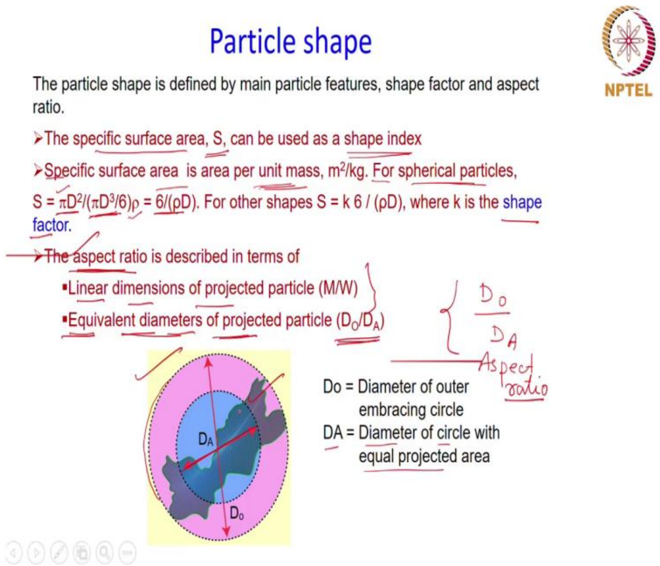

So, talking about the particle shape now like, how we have defined the particle size in terms of an equivalent sphere having similar projected area, similar surface area, or similar volume. The particle shape especially for the irregular particles can also be defined in a similar manner, wherein we use what is called a shape index. And, a geometric parameter again for example, the specific surface area, S, can be used as the shape index.

And, for spherical particles, specific surface area per unit mass can be used as the shape factor. And, the shape factor for the spherical particle from the equation below:

$$S = \frac{\pi D^2}{\rho(\frac{\pi D^3}{6})} = \frac{6}{\rho D}$$

The numerator in the above equation represents the surface area of the sphere and the denominator represents the mass (volume × density (ρ)).

Now, for irregular shaped particle, there are many dimensions that have to be considered. Many a times, the aspect ratio is taken as a parameter to define the shape. Aspect ratio is the ratio between the smallest and the largest dimension of the particle.

Aspect ratio using equivalent diameter is shown below:

$$Equivalent\ Diameter = \frac{D_0}{D_A},$$

where D_0 is the diameter of the outer embracing circle (slide above) and D_A is the diameter of the circle with equal projected area which is this one ok.

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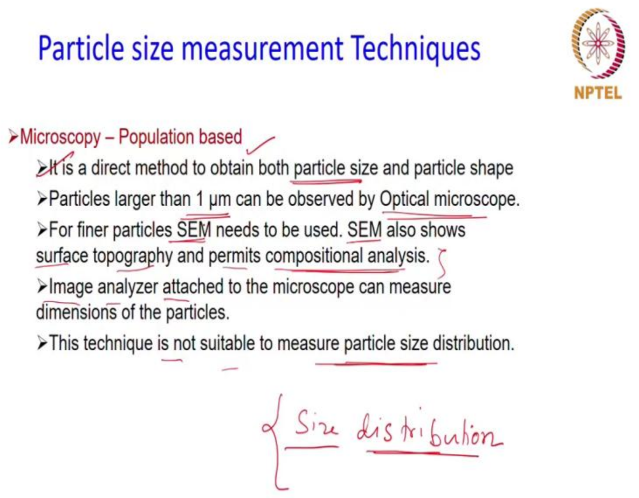

Now, if you talk about the measurement techniques for the particle size, there are different approaches and different instruments are available. And, as I would have said before each of these techniques or the instruments which are used, uses a particular basis for measuring the particle size.

In Microscopy, you actually see the particles under a microscope. It is a population based technique, because here you can capture the image of the particles and then calculate the number of particles in a given area or so on. And, therefore, it is a direct method to obtain both particle size and particle shape. Using certain analysis, you can easily derive the particle size from the images, which are captured on a microscope.

The kind of microscope that can be used will depend on the size of the particles. If, you have larger particles which are bigger than one micrometer, then optical microscope can be used. But, we all know that the optical microscopes have their own limitations in terms of the highest magnification that can be achieved.

When the particle size is smaller, then we will have to go for electron microscopy techniques, for example, the scanning electron microscope or SEM. And, the other advantage that you have in the SEM technique is that, it will also show the surface topography and it also permits compositional analysis of the particles. And, the particle size can be easily obtained by the image analyzer, which many times come with the microscope itself.

And, this kind of technique is not suitable to measure particle size distribution. So, there are two things, when you talk about particle size, one is the size itself. And, another is how the size distribution is. That means how the powder is in terms of a different mix of sizes.

Because, most of the time it will be, generally a mix of different size of particles in a powder. And, therefore, it is also important to know the different sizes present in a powder and that is what is known as the size distribution.

In order to get this distribution, it is recommended that other techniques are used, because microscopy as I said is not really suitable for measuring the particle size distribution. But, here the advantage is you actually see the particles directly and we can physically measure their size and get to know the actual size of the particles.

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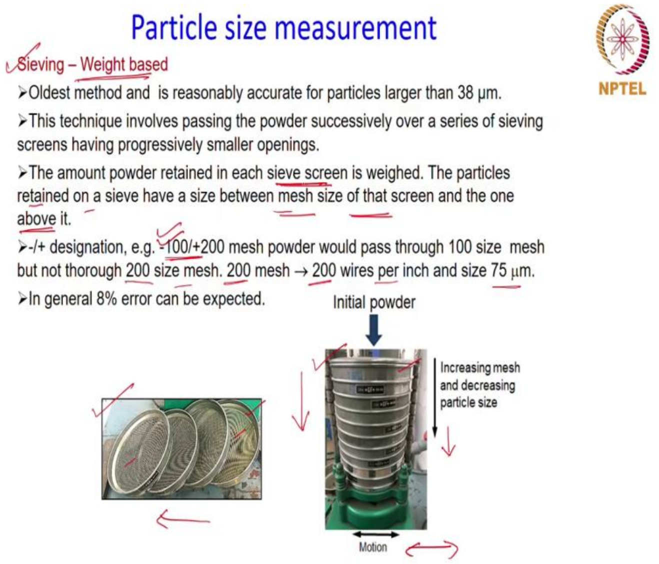

And, the other method or the other basis is the weight basis. And, this is one such technique which is one of the oldest methods that is the sieving process, wherein you use a series of sieves having a different mesh size like what you can see over here (slide above).

So, each of the sieves have a different size of mesh, starting from top to bottom the mesh size is decreasing. So, what is done is in this case, it is basically passing the powder successively over a series of sieving screens having progressively smaller openings.

So, when the mesh size increases; that means, the particle size is decreasing from top to bottom. So, that means, the topmost screen that you have is having the largest opening and the bottom one that you have has the smallest opening. And, mesh is the number of wires per inch. And, therefore, 200 mesh is actually 200 wires per inch. There are standard charts available, where you can see for each mesh size, there is a corresponding size in terms of the micrometer. For example, for 200 mesh, it is 75 microns. Similarly, for other mesh sizes we can get the corresponding size in micrometers. A plus minus designation is used to define the particle size in this case. For example, if you say -100/ +200 mesh powder, it means that this kind of powder particles will pass through a 100 size mesh, but not through 200 size mesh. So, the particle size is between 100 and 200 mesh size. And, as I said this is a weight based technique.

So, the powder is first loaded on the topmost screen; then it is given a shaking motion and as you shake it these particles depending on their size will pass through these different screens.

And, after a certain time once you stop it, the particles retained on each of the sieve will be collected and their weight will be measured. So, that is how for each size, how much weight is retained on each of these screens will be measured and that is why, this technique is weight based. So, when you see a particular size of particle being retained on a particular sieve, the size would be between the mesh size of that screen on which it is retained and the one above it.

So, that is how this plus minus sign or the plus minus designation comes into picture to define the size between these two screens, one which is having the powder and the other which is just above it.

So, before we finish today's class let us take a summary. We talked about the basis for particle size measurement and we have seen that a particular geometric parameter can be chosen to define the size of a particular particle. If, it is a regular shaped particle like a spherical particle it is easy to define that geometric parameter.

For example, the diameter of the sphere can be simply taken as the size of spherical particles, but for other kind of particles you have to take a particular basis to define the size. And, these are the different geometric parameters, which can be considered to define the size of the particles.

And, when you make an assumption of a spherical particle, then the equivalent diameter of the particle is taken to be the equivalent diameter of the sphere. And, the basis for that equivalent sphere could be a similar projected area, similar surface area or similar volume, as the particle which is being measured.

And, there are the three different equivalent diameters, based upon the projected area, surface area or volume. Similarly, we talked about the particle shape and how it can be defined based upon the equivalent diameter like, what we have seen for the particle size.

So, here for irregular shaped particles generally a ratio between the linear dimensions of the particle is taken. The ratio is called the aspect ratio and that can be also calculated based upon the equivalent diameters like, what you can see in the case for the particular particle which is irregular.

And, then we had seen that there are different basis of particle size determination. For example, if you are using a microscopic technique it is population based, where you actually see the particles in a microscopy, and you can see their actual size, and morphology, and you calculate the number of particles having a particular size and so on.

And, the other one is weight based where you actually calculate the weight which is remained on a particular screen, which is being used to separate the particles in terms of their sizes. So, these are the things that we have learned today in terms of the shape and size of powder particles and with that we come to the end of this class.

Thank you for your attention.