Fundamentals of Food Process Engineering
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Lecture - 41
Mechanical Separation Techniques

Hello everyone welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. Today we will start a new chapter on Mechanical Separation Techniques. We know that in food processing, different phase of material or different kind of material we need to separate for example, sometime the liquid and gasses need to be separated, sometime liquid and vapour need to be separated or sometime different liquid samples need to be separated.

And all these separations are done based on certain principle for example, diffusional mechanism, molecular diffusion mechanism or some chemical based on certain chemical parameter, but there are certain requirement also there, in that case we used a mechanical means to separate different size fractions or different material.

So, these kind of separation that we perform by I mean that that we call the mechanical separation, that is being done based on the physical parameter or physical properties of food. And those are also very important in certain cases we will see them eventually. So, that is why we will start the topic of mechanical separation today.

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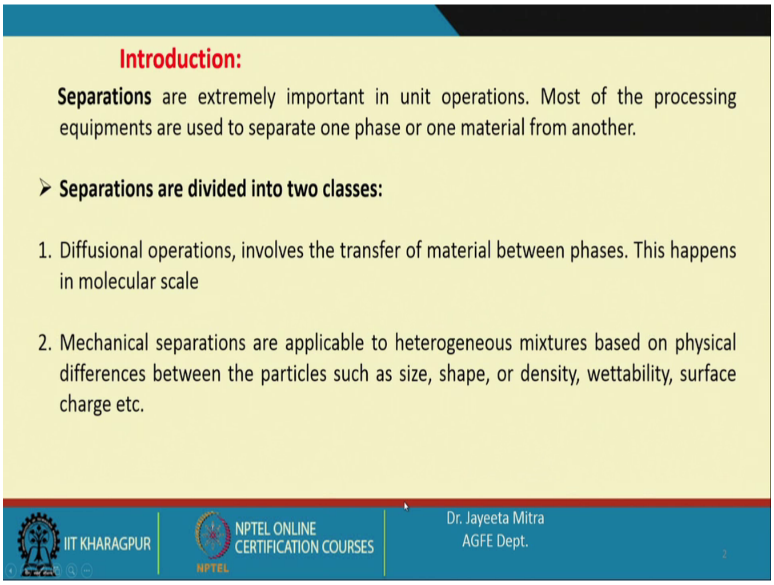

Separations are extremely important unit operation; basically in food and chemical this is very important. Most of the processing equipment are used to separate one phase or one material from the other. So, as I said that when we use the diffusion; that means, we want to separate in the molecular scale, that is maybe for separation of the gas and liquid or vapour and liquid etcetera.

But mechanical separation these are applicable to heterogeneous mixture based on physical differences between them. That means, physical differences between the particles that we want to separate and what are those physical difference maybe? They will be size, shape or density or surface property, surface charge, wettability all such may be the parameter on which we want to separate by using the mechanical force to separate these particles.

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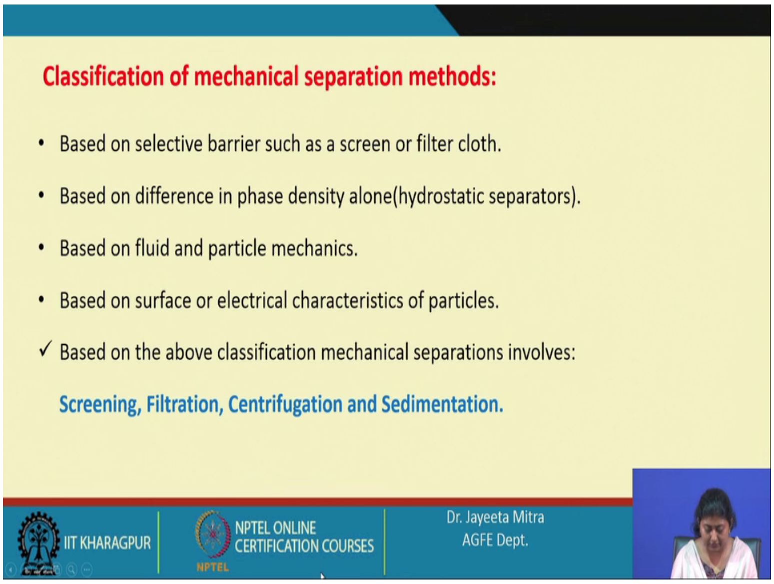

Classification of mechanical separation methods. So, for classification of mechanical separation, we need to see based on selective barrier such as screen or filter cloth. We call it selective barrier because we fox the shape or size of that so, that a particular fraction can pass through and all other can retain over there. So, filter cloth also or screen also we can select and other is based on the difference in phase density alone. That means the hydrostatic separated that when we use. So, that work based on the phase density difference between the two material or two different phases.

Third one is based on the fluid and particle mechanics; also we can perform the mechanical separation based on the surface or electrical characteristics of the particle. And based on all these above classification mechanical separation can be categorised as screening, filtration, centrifugation and sedimentation. So, we will see them in a bit detail in our this particular class.

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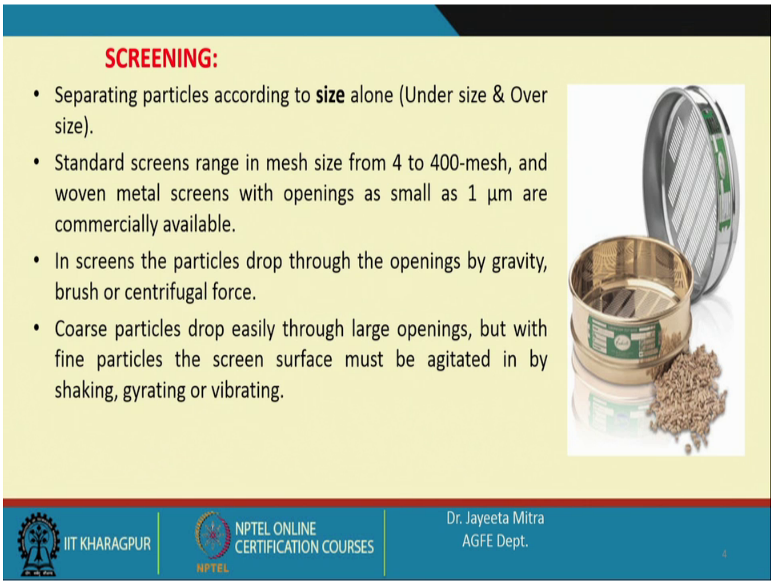

So, first is screening. So, in screening we mention about screening a bit when we dealt the different particle size analysis thing. So, the different fraction, the different size of the particle different mean size of the particle we have calculated a further for the size reduction and then for analysis of those different fraction, we use a screen there are many method, but screen is a one effective method.

So, like that here also for mechanical separation according to the size alone we need screens. Standard screens range in mesh size from 4 to 400 mesh and woven metal screen with opening as small as 1 micro meter are commercially available. In screens the particles drop to the opening by gravity, brush or centrifugal force. And coarse particles drop easily through the large opening, but with fine particles the screen surface must be agitated by shaking or gyrating or vibrating motion, otherwise what happen those fine particle may clog the force of the screens. So, to separate to get a particular size fraction we can use a screen, and the size opening or the mesh size of that screen can give us two fractions, one is retain over the screen and the other which is pass through the screen.

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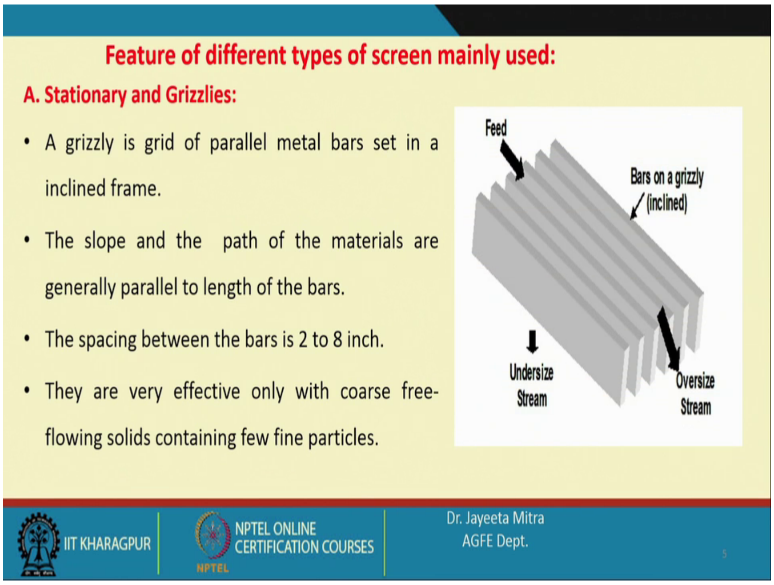

Now, feature of different types of screens mainly used that is first one stationery and grizzlies. A grizzly is grid of parallel metal bar set in a in client frame. As we can see here the parallel metal bars are there those are set on an inclined frame from one side series entering and the undersized which is passing through the screen that is come from the down section and the over size is moving with the stream.

The slope and the path of the material are generally parallel to the length of the bar. Slope is generally parallel to the length of the bar and the spacing between the two bars is 2 to 8 inch they are very effective only with coarse free flowing solid containing few fine particles. So, grizzlies are not suitable for the fine particles, they are good at only handling the large size particles.

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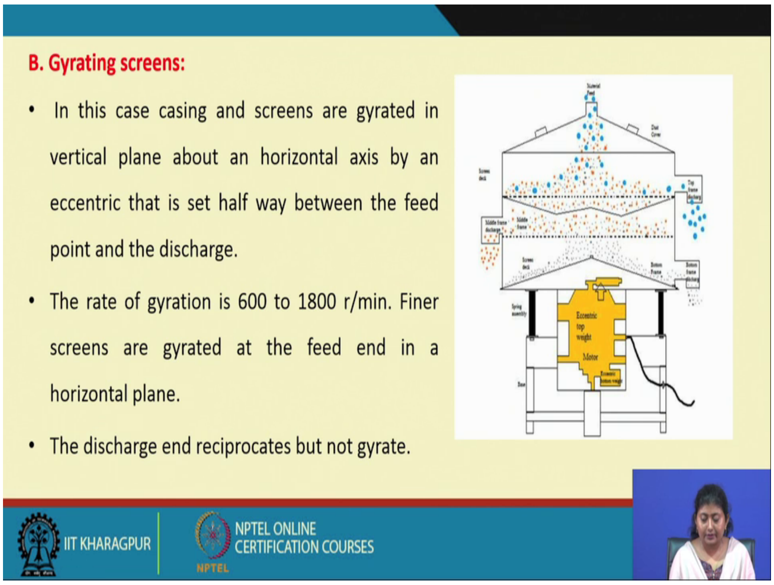

Now gyrating screens. So, gyrating screens in this case the casing and screens are gyrated in vertical plate, about the horizontal axis by an eccentric that is set halfway between the feed point and the discharge. And the rate of gyration is again varies from 600 to 800 revolution per minute. Finer screens are gyrated at a feed end in a horizontal plane and the discharge end reciprocate but not gyrate. So, gyratory arrangement we have seen when we have discussed the different size reduction equipment, here also gyrating screens are very common where we can use we can use this kind of screen to separate different fraction of material.

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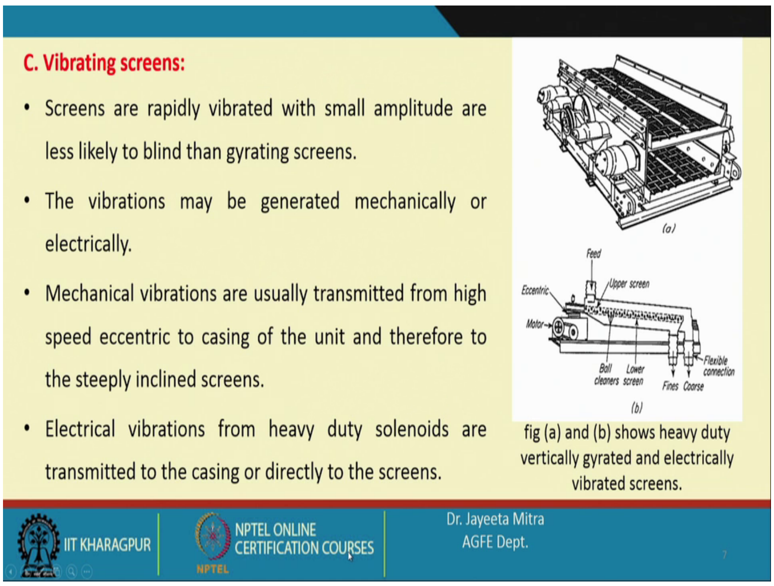

Now, vibrating screen; so, this is another screen layer which can be vibrated horizontally or vertically. So, this screens are rapidly vibrated with small amplitude and are less likely to blind the blind that gyrating screens. So, because of this vibration, small amplitude vibration that we are providing the screens are less likely to blind than the gyrating screen.

So, the particle small particle would not clog or fill the small fine particles in the screen. So, that is why it is beneficial compared to the gyrating screens. The vibration may be generated mechanically or electrically mechanical vibrations are usually transmitted from high speed eccentric to casing of the unit and therefore, to the steeply inclined screens.

So, generally these screens are a bit incline to have a easy flow of the material; electrical vibrations from heavy duty solenoids are transmitted to the casing or directly to the screens. So, thereby the casing will vibrate with small magnitude. So, the first one, the first figure is shows the heavy duty vertically gyrated and the second one is the electrically vibrated screens.

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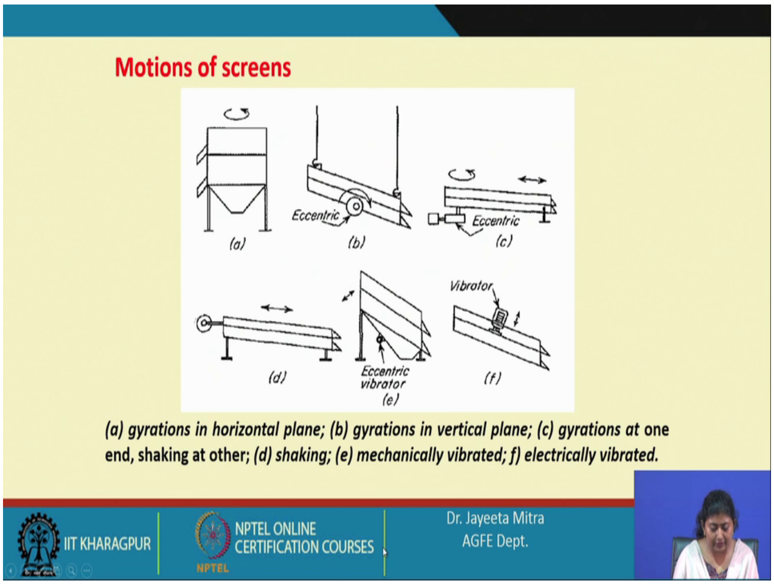

Now, motion of screen can be of many types; are the first one is the gyration in horizontal plane figure a, b is the gyration in particle plane, c the eccentric gyration. So, gyration at one end shaking at the other end; gyration at one end and shaking at the other end, d is shaking only and e is the mechanically vibrated screen and f is the electrically vibrated screen.

So, all are the different arrangement of the screen that we can use based on product to product or based on the efficiency. So, because inclination also is the flow of the grain forward direction, gyration and shaking both help in the you know proper screening, and they prevent the clogging of the mesh.

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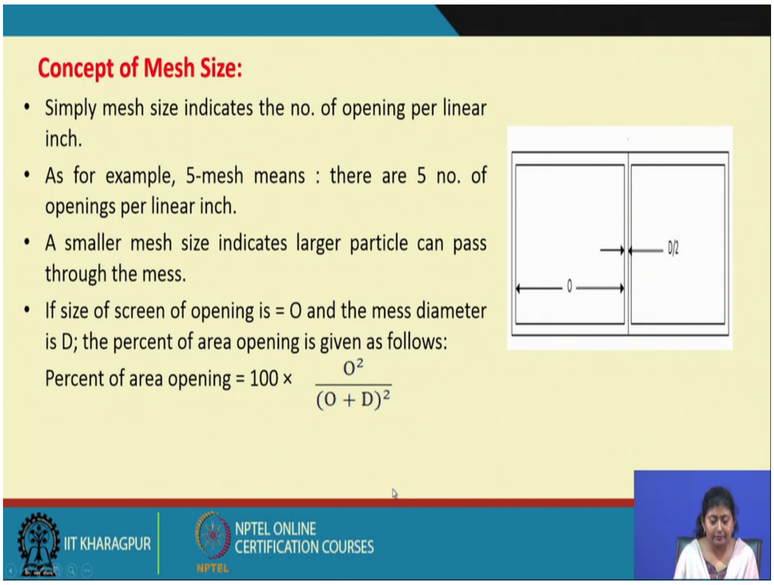

Now what is mesh size? We are since the last class we are we are talking about 400 mesh 20 mesh or 200 mesh like that. So, these are specification that we generally used for describing a particular kind of mesh. Simply mesh size indicate the number of opening per linear inch; as per example 5 mesh means there are 5 number of openings for linear inch.

A smaller mesh size indicate larger particle can pass through the mesh; that means, if I say that for mesh size; that means, per inch only for you know perforation or openings will be there and if I say 200 mesh size; that means, the 200 openings will be there per inch length so; obviously, that size fraction will be smaller one.

Now, if size of the screen of opening is equal to O, and the mass and the diameter mesh diameter is D, the percent of area opening is given by this equation that is percent area opening equal to 100 into O, there is the size of screen opening O square divided by O plus D whole square.

So, mesh diameter is D and size of screen opening is O. So, O square divided by O plus D square into 100 that gives us the percentage area opening.

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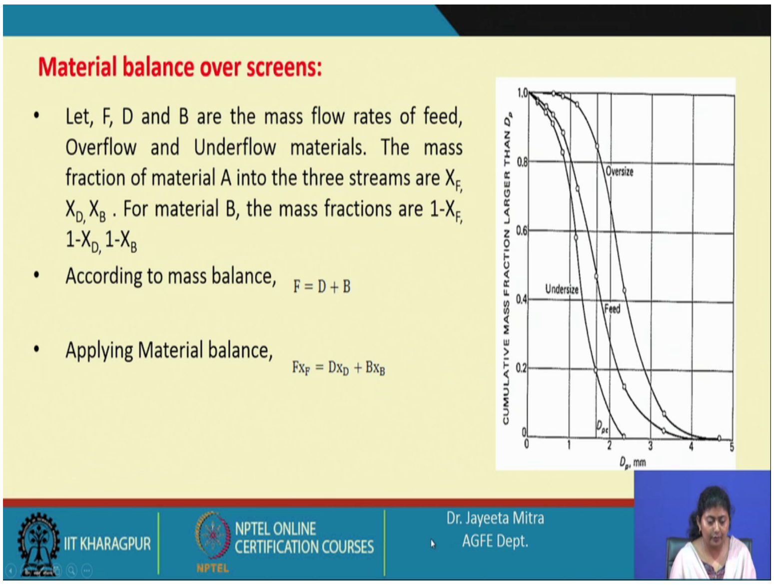

Now, material balance over screens; so, as I mentioned that whenever we run some material through a particular size of the perforation of a screen, so, some material will definitely retain over the screen and some will pass through.

So, if we want to categorise that, we can have three fraction one is the feed that is the size of the input that is coming on the on the screen, and another is the oversize that is retain on the screen, and the other is the undersized which is pass through the particular dimension or the particular mess size of that screen.

So, if we consider let us say F D and B are the mass flow rate of feed, respectively overflow D and underflow B of the material. So, feed radius F over flow rate is D and underflow flow rate is B. Now, the mass fraction of material A into three streams are X F, X D and X B.

So, let us say I am separating the mixture of A and B and the fraction of A in all three streams that is inlet stream or feed stream overflow stream, and underflow steam that I have categorised as X F, X D and X B. Then material B if you want to identify what will be the fraction of material B, in all the three streams that will be 1 minus X F that is in the feed then 1 minus X D that is in the overflow and 1 minus X B that is in the underflow. Because all the overflow and underflow or in the feed the total fraction will remain 1. So, 1 minus X F 1 minus X D and on minus X B will be the mass fraction of the material B in the feed overflow and underflow.

Now, according to the mass balance feed will be divided into or distributed into two sections, overflow D and underflow B. So, F equal to D plus B. Now applying natural balance we can write for a suppose if you want to do first F into X F that is equal to D into X D plus B into X B. So, here the cumulative mass fraction larger than a particular size B has been plotted with D. So, this kind of plot the cumulative mass distribution plot we have seen in the particle size reduction class also. So, here the undersize and the oversize and also the field has been plot in. So, we can get that if the critical diameter D pc we want to calculate that for D pc if it is the feed. So, what will be the oversize sample and what is the undersize sample of that.

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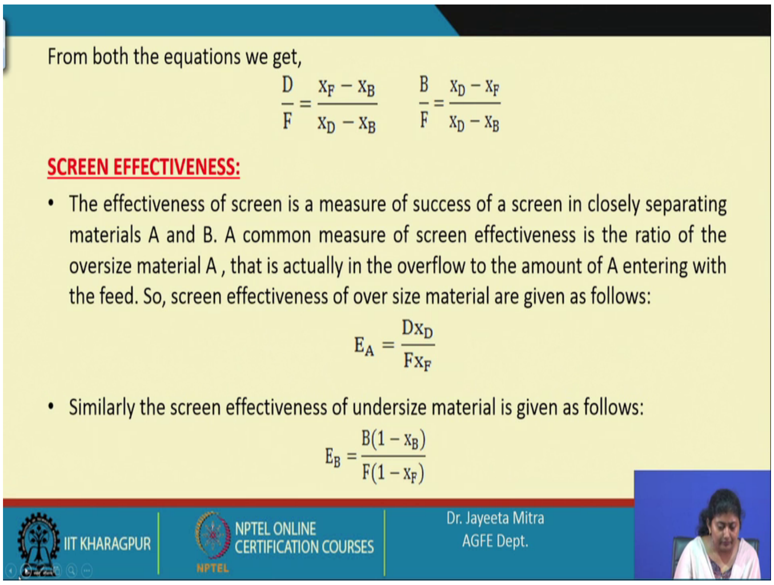

So, then from both this equation that F equal to D plus B and F into X F equal to D into X B plus B into X B, but I can get is D by F equal to X F minus X B divide by X D minus X D. So, here over flow by feed we have expressed similarly we can express underflow by feed that is X D minus X F by X D minus X B.

So, what is it overflow D minus feed that is equal to amount of fraction of A in feed X F minus amount of fraction in B that is the underflow. So, X F minus X D divide by X D that is amount of fraction of A in the overflow minus amount of that that is going in the underflow similarly we can calculate B by F.

Now screen effectiveness; this is the effectiveness of a screen is a measure of success of a screen in closely separating the material A and B. So, it has been ideally separate A and B; completely the size has been define in such a way, a common measure of screen effectiveness is the ratio of the oversize material A that is actually in the overflow to the amount of A enduring with the feed.

So, screen effectiveness or oversize material are given as follows. So, E A based on the material A which is the oversize material, D in to X D that is the fraction of A that has gone into the, that has present in the overflow. So, D into X D divided by the that was present in the feed so, F into X F.

Similarly, the screen effectiveness of undersized material is given as well as follows E B that is call to B into 1 minus X B that means, the undersized fraction that has gone to the undersize, divided by the undersized fraction present in feed.

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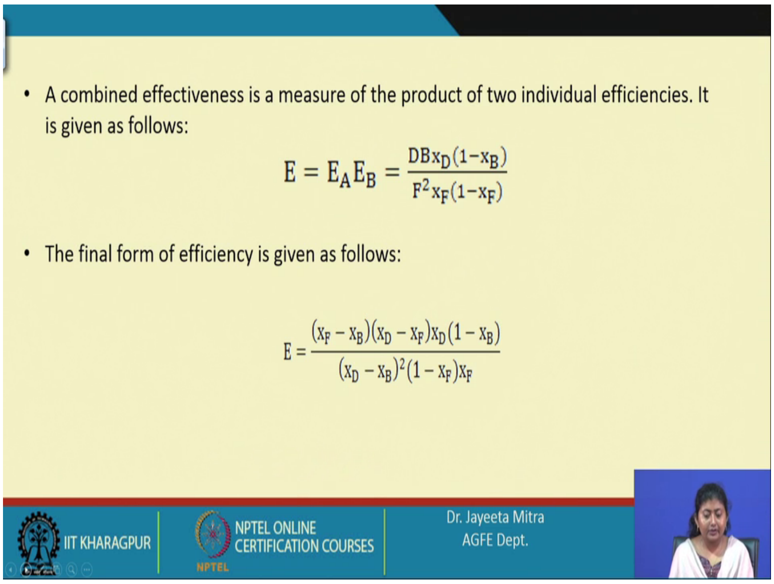

So, combining all those two efficiency based on oversize and undersize we can write E equal to D into B in to X D into 1 minus X D divided by F square that is feed rate square into X F into 1 minus X F.

And again if you want to change the value of that D and B and replace with the fraction so, D by F and B by F has been replaced by this two factor D by F and B by F. So, we are getting X F minus X D by X D minus X D multiplied with X D minus X F by X D minus X D. So, putting that into this equation we are getting an overall efficiency expression as E equal to X F minus X B into X D minus X F into X D into 1 minus X B divided by X D minus X B square into 1 minus X F into X F. So, this is the final expression of effectiveness, screen effectiveness.

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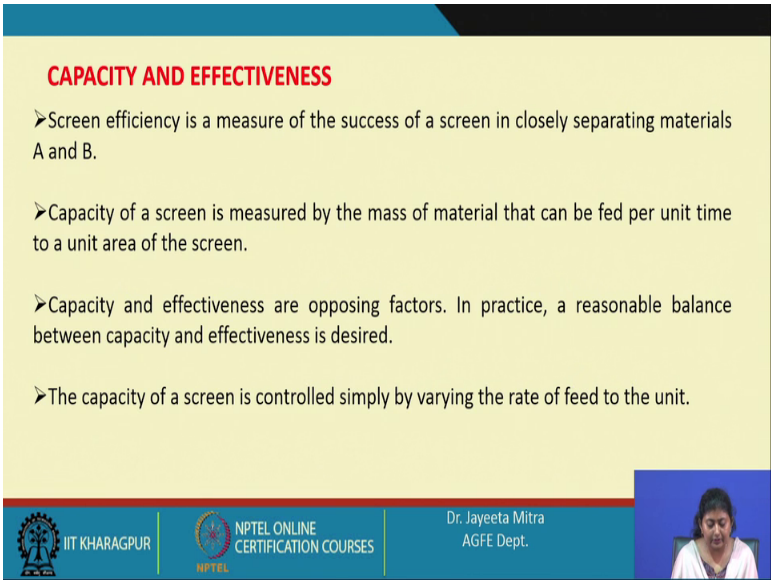

Now, capacity and effectiveness, screen efficiency is a measure of as I said that how closely we can separate A and B, and capacity of a screen is measured by the mass of material that can be fed per unit time to a unit area of the screen, and capacity and effectiveness are opposing factor in practice a reasonable balance between capacity and effectiveness is desired. The capacity of a screen is controlled by simply wearing the rate of feed to the unit. So, that is how we can change the capacity.

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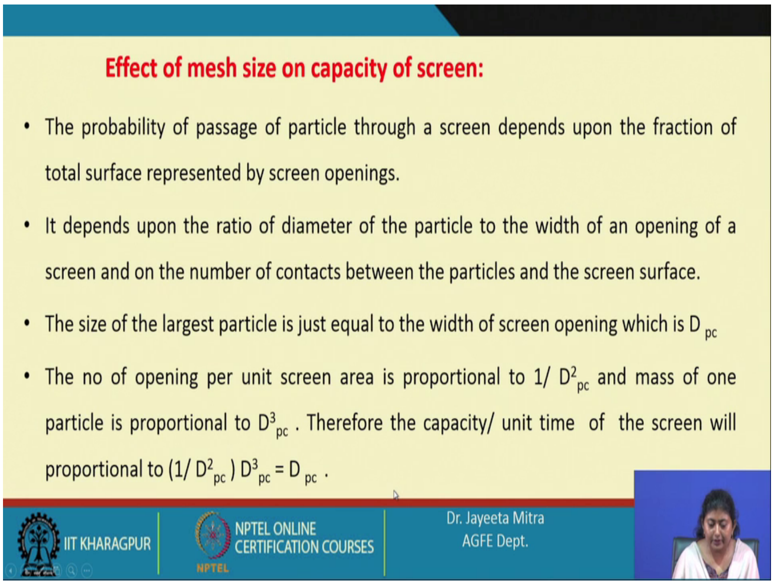

Effect of mesh size on capacity of the screen; the probability of passage of a particle through a screen depends upon diffraction of the total surface represented by screen opening. It depends upon the ratio of diameter of the particle to the width of an opening of the screen on the number of contact between the particle and the screen surface. So, many factors are there.

First is the ratio of the diameter of the particle to the width of opening of the screen and on the number of contact between the particle and the screen surface. So, the size of the largest particle is just equal to the width of the screen opening which is D pc critical diameter the larger size and the largest particle, and the number of opening per unit screen area is proportional to 1 by D pc square. Because we have mention that the particle that has been retained in a time, the you know the number of opening per unit screen should be proportional to the 1 by D p square.

So, the particle size that has been retained on that; that means it is having a bigger size particle and perforation size or the screen mesh size is lower than that. So, mass of one particle is proportional to D p the linear dimension q because volume that is d p q into density therefore, the capacity is again based on the area and area is here proportional to 1 by D p square. So, capacity width unit time of the screen will proportional to 1 by D pc square into D pc cube; that means it will vary directly with the D pc that is the critical diameter which is the size just above just little above the mesh opening size of a particular screen.

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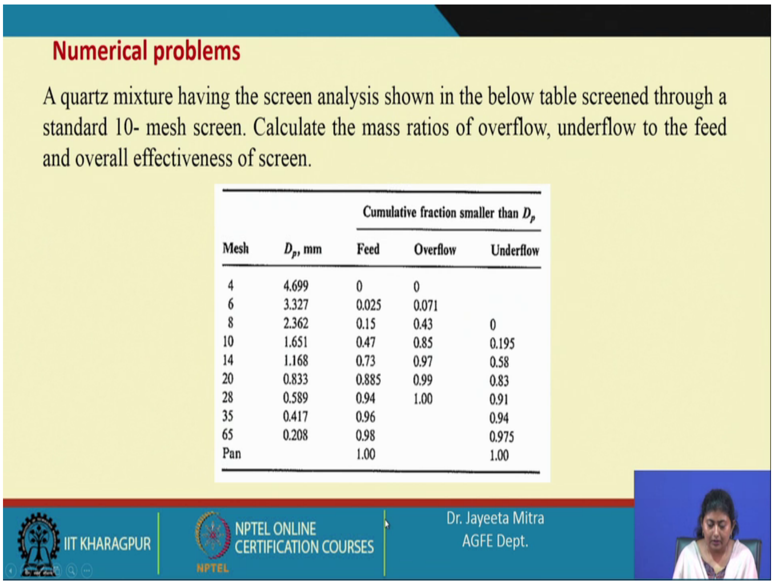

Now, here one problem is given where a quartz mixture having the screen analysis shown in the below table, screen to a standard ten mesh screen, calculate the mesh mass ratio of overflow or underflow to the feed and over a effectiveness of the screen.

Now, the similar kind of analysis you can do by any grain sample as well any mixture of the grain particle or other different size fraction you take and do the you know see the analysis in a similar way. We have taken this data from book that is why this distribution has been given on the quartz, but same principle we can use for food material for any ground flow distribution as well. So, mesh size has been given and particle diameter D p is given, feed rate overflow and underflow rate is also given. Now, what we need to see? We need to see the critical diameter, what is the critical diameter?

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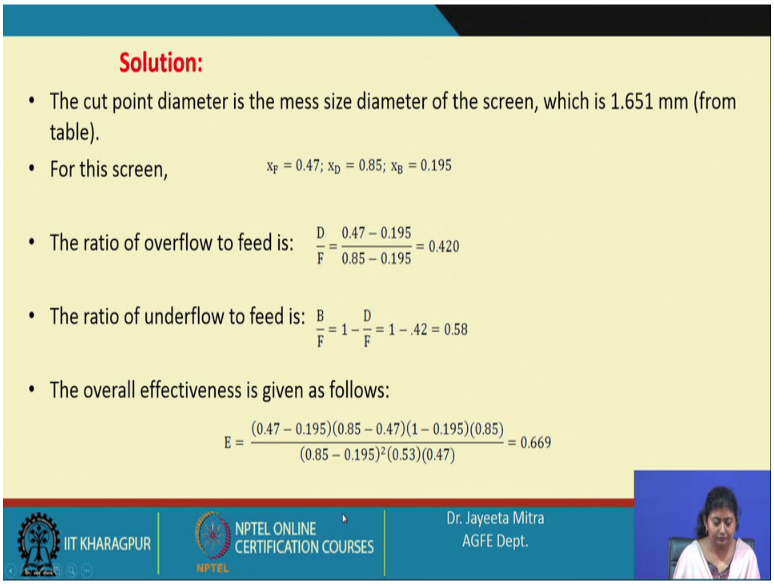

So, the cut point diameter is the mesh size diameter of the screen, which is 1.651 mm. So, this has been taken from the tabulated data, for this screen that is 1.651 this particular size for this particular set of screen that we have use we have calculated the X F, X D and X B.

So, D p size 1.651 for this size see the feed is 0.47 overflow is 0.85 and underflow is 0.195. So, we are expecting that maximum fraction of they should come in the overflow. So, if that happens once we have got this value of X F, X D and X D the ratio of overflow to feed that is D by F we will calculate and underflow to feed that is B by F that we will calculate. So, that is coming respect respectively 0.420 divided 0.420 and 0.58.

Now, we will use the effectiveness formula which is overall effectiveness based on oversize and undersize and put all such values that is value of the X F minus X B 0.47 minus 0.195 into X D minus X F that is 0.85 minus 0.47 into 1 minus X B that is 1 minus 0.195 into X D divided by X D minus X B square. So, 0.85 minus 0.195 square into this into this factor 0.47 that is X F and 0.58 that is the value of B by F.

So, if we just checking with the equation, this was our equation X F into 1 minus X F. So, that thing we will just put it here all the values, and then we can get the overall effectiveness of the screen. So, this is how we can solve the, we can calculate the effectiveness of a screen and also we can find out from what will be the oversize fraction and undersize fraction and capacity of the screen also. So, in the next class we will move on to the other different mechanical separation techniques in this chapter.

Thank you.