Mechanical Unit Operations
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Lecture 04
Screening

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Welcome to the mooc course mechanical unit operations, the title of this lecture is screening. As the title indicates screening is about the separating, we are discussing about the particulate solids, particular solids may be having wide range of size distribution, so then how to them using the screens is about the screening in general. So we see the details of screening how to do, what are the analysis processes, how to handle uniform mixtures, how to the handle non-uniform mixtures etc. These things we are going to see in this and then coming couple of lectures.

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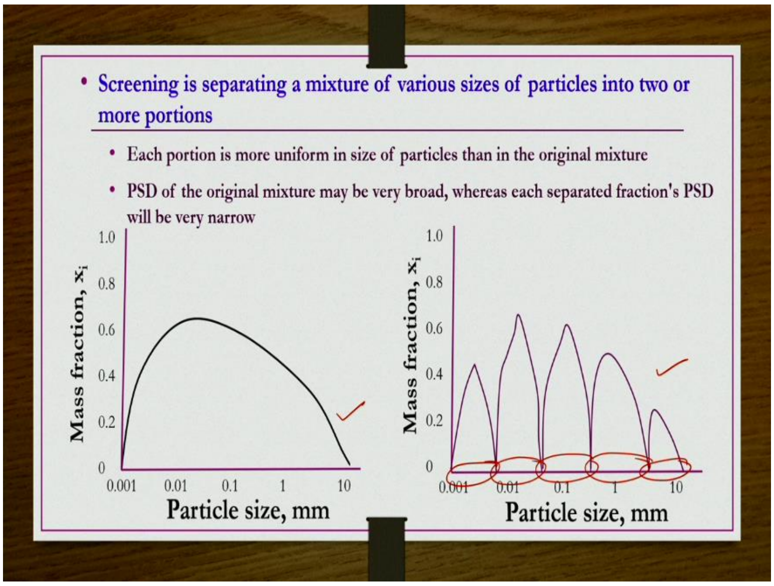

So the screening is separating a mixture of various sizes of particles into two or more fractions, what happens in general from the natural resources whatever the bulk material that you get, you what you need to do? You need to crush them into this smaller fraction so that you can comfortably use them in subsequent operations after pre-treatment unit operations, right. So one of the pre-treatment unit operation is a kind of size reduction, which is also accomplished by which is also followed by the screening, screening is one of the kind of important operation, right. That we have seen.

So here what happens whatever the natural resources or the crude raw material that you get from the natural resource, you crush them into the smaller fractions so that you can comfortably use them in their subsequent operations in unit operations or unit processes, right. that is what we do by size reduction, but when you do the size reduction or the reducing the size of this bulk material into the smaller fractions, you get the particles of very wide range of size distribution, some particles may be in a few microns size 1 micron or 10 micron smaller particles, some particles may be in some centimetres something like this.

So let us say I have a, drawn here mass fraction versus particles size in mm, you can see some particles are of around, you know 1 micron size and then whereas some particle are of 1 cm, so then distribution is very wide, very wide distribution, you can see but what we do if you do the screening, we can separate this crushed material into the several smaller, smaller fraction, so that we can have a separate fractions, individual fractions whose particle size distribution is much narrower compared to this initial mixture whatever we have taken.

So when we do the screening, the same sample we can separate into the several fractions, maybe one fraction of this range, another fraction of this range and another fraction of this range, another fraction of this range, another fraction of this range like this, what we have done. By using the screening we have separated the particles into several fractions and then each fraction now in having a kind of very narrow particle size distribution, so that you can assign one single average size for this fraction that is what by using screen we are going to do in general, for our applications.

So that it is each fraction whatever after the screening, we get that is more uniform in size of particles than in this whatever original mixture, that is what are going to do by screening, separating mixture of, you know particulate matter into various sizes are various fractions of having, you know different size fractions, right. So in other words, what we have, the particle size distribution of original mixture may be very broad as shown here in this picture and then whereas each separated fractions particle size distribution will be very narrow as shown in this subsequent figure like this.

So this is what basically the purpose of screening applied for a particulate matters that is what we are going to have. So now this is very crudely what about the screening, why should we do, but why should we do the suppression based and it size using the screens, is it all-important, so what we do, we see first few a generalize a kind of situations where the separation by size is required for this particulate matters and then we see some kind of specific applications examples as well.

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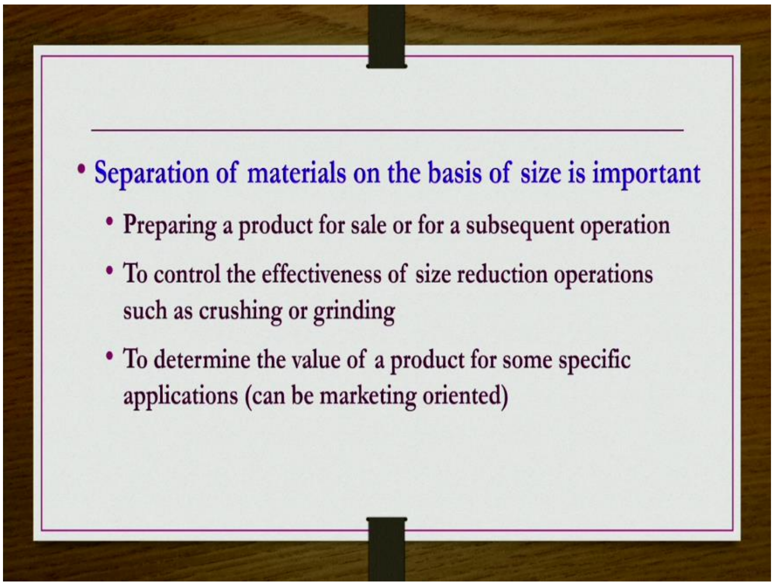

Separation of materials on the basis of size is important because preparing a product for sale or for a subsequent operation, for a subsequent operation, let us say after crushing you do the kind of separation into kind of smaller fractions and then you may be collecting only that fraction which is suitable for your subsequent operations, that is what those kind of generalise cases or sometimes you know, product that let us say you have fertilisers industries, whatever the fertilisers after, you know solidifying those chemical you get, you know pelleted forms or granulated forms, fertiliser that you get.

So granulated fertilisers are not in a kind of uniform size and then you may be needing to have a kind of a specified size or fertilisers for a given kind of applications. So there are also you may need to use this kind of screening for the separation of this material as per their applications, okay, so it can be as a kind of requirement for the product or it can be kind of requirement for a, you know subsequent operation in the planned.

Likewise the effectiveness of the size reduction operations can also be controlled by using this size analysis by screening or to control the effectiveness of size reduction operation such as crushing or grinding, so whatever the crude raw material that we get from the natural resources, crude raw material that we get, that you reduce into the smaller fraction, smaller size particle by crushing or grinding.

Whether those equipment or properly grinding or doing the size reduction or not, that effectiveness of those equipment can also be studied using the screen analysis, we are going to do that one also by taking some example problems in next module, probably you may need that equipment are crushing material of, let us say 0.1 mm size, but either it may be doing very smaller, particle size much smaller or you know some micron size 0.001 mm or someone to 1 mm to 2 mm or bigger size also it may be doing, is it doing proper duty not or for a selection of, you know equipment also this kind of analysis is required.

Let us say if you are not sure which kind of size reduction equipment should you use for crushing the material, reduce size, reduce material of your requirement, right. Let us say you do not have information, then you try size reduction equipment and then you take the that sample and then do the screening and then subsequent size analysis of the individual fractions and then you can see which is going to be very beneficial for you, that way also for selection as well as the controlling the effectiveness of this size reducing equipments is also done by this separation based on the size using the screens.

Also to determine the value of a product for some specific applications, usually you know marketing oriented, for marketing purposes, let us say some food product or some kind of pharmaceutical product, you need to have the chemical, that final product or the chemical of specified size, in such cases also you may need to use the in separation by size using the screens. So these are some general kind of situation where we may need a kind of size, separation or the separation based on the size using the screens, but now we take a few examples, you know specific examples what way they are useful.

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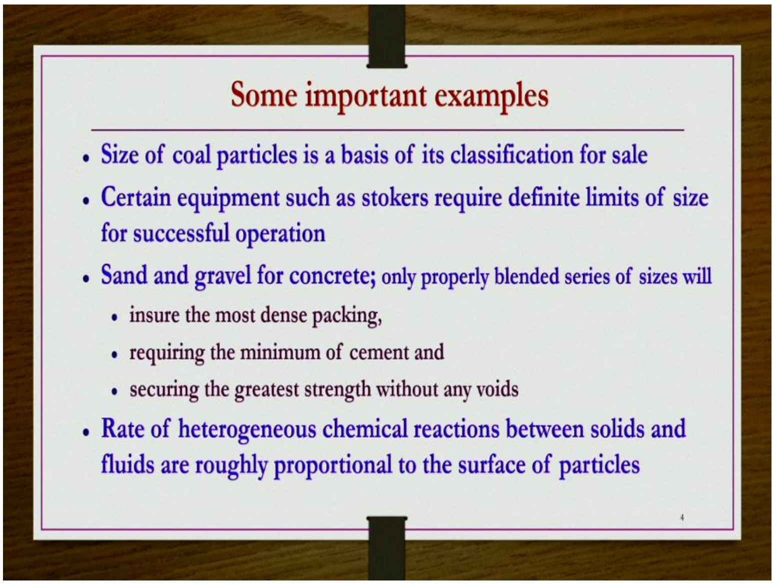

Let us say size of coal particles is a basis of its classification for sale, in general, coal is subtend by the mining, when you do the mining, open cast mining or underground mining you get the coal, that coal is an kind of big lumps or in a small particles size and entire things are there, usually those coal has been taken into a kind of a the transporting equipment like lorries or conveyors something like that, belt conveyers etc, there will be, from the mines, where using the belt conveyors there will be taken out and then once they reach the surface from the surface they taken to the industry, where they can be used by the trains or lorries etc. right.

So when it comes for use, let us say you are using for the coal combustion, so that you get the energy, so there are, you cannot have a kind of big size particles, you know for this kind of process, otherwise you know combustion may not be effective, you cannot all to have a kind of very fine coal dust particles, you know having the 1 mm or even smaller than some nanometres scale. So those kind of particle may also be not suitable for the combustion, probably you may expect to have a kind of particles something like you know 500 to 900 microns size that is going to be much suitable for you.

So there also you may need to do the size analyses or separation based and the size and the market value for that particular coal, which is having specified size maybe having more value, that could be one kind of applications and then certain equipment such as stokers etc. they need definite limits of size for successful operations, okay. Then also in concrete mixture making, so we have the cement, water and then sand gravel mixture we take in a kind of equipment we mix them in order to get the concrete mixture for construction purpose, right. So further, you might have seen the sand as well as the gravel particles are screened at the construction site, so that only a specified size are only taken into the this container where the concrete making is done by using the cement and then water.

So there you need to have a kind of specified size of the sand, specified size of the gravel, then only you can have a kind of a proper concrete which will provide a proper strength and which will required a less cement etc, that is possible, so you here also in this kind of construction purpose also the size, separation by side is also becomes, you know in kind of important component. So when you have this sand and gravel for concrete only properly blended series of sizes will provide you the most dense packing, requiring minimum amount of cement and then securing the greatest strength without any voids, okay. So here also screening is a kind of important applications.

Then coming to chemical engineering, most of the heterogeneous reaction, where the reactions is taking place between solid and fluid, the specified size of the solid particles are you know required because the rate of the heterogeneous reactions are general proportional to the surface of the particle, so then here you also you are supposed maintain kind of specified size of particles which is participating in reaction with a kind of fluid. So here also you may need to have a kind of size analyses or size separation based on the screening.

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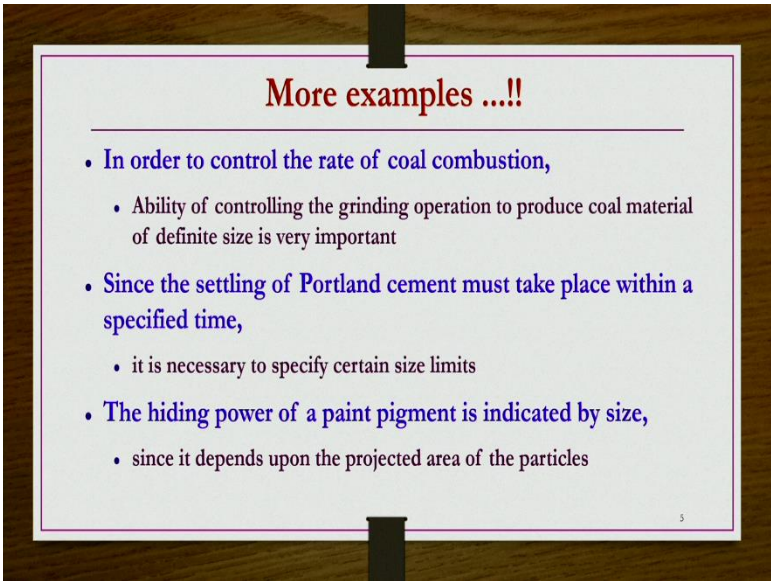

Likewise, if you see some more example as I already mention in order to control the rate of combustion, coal combustion, so where ability of controlling the grinding operation to produce coal material of definite size is very important, similarly we have a settling of Portland cement that must take place within a specified time, so accordingly, it is necessary to specify certain size limits for those kind of Portland cement also, then the hiding power of a paint pigment is indicated by size, which depends upon the projected area of the particles, so then, so here you may need to a kind of size analysis or separation based size. So if you see the application, the applications, specific applications also N number of applications are there, so few of them I have listed out here.

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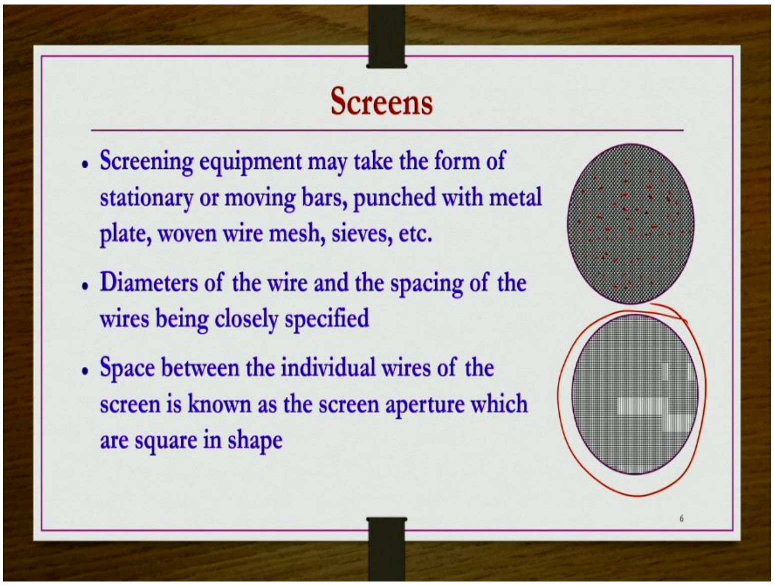

Then what equipment should be used for the screen analysis, so in general, the screens, it screens are used for this kind of screening operation, where the separation based on the size is taking place for a given particulate matter, right. So what are the screens? Screening equipment may take the form of stationary or moving bars, punched with metal plate, woven wire mesh, sieves etc. So we have in general metal plates like this so where they are punched with small, small kind of holes or holes of desired size and then the hole opening is almost uniform in the entire this plate and also the distance between these holes is also maintained uniform in general, right.

Then we also have a kind of woven wire mesh like shown here, you know, so what we do you take wires and then you do the woven wire meshing here as shown here, like you know kind of sieves. So here, you know the diameter is of wire and then opening of the wires are being very closely specified in general, also the spaces between the individual wires of the screen is known as the screen aperture which are square in the shape, the screen aperture shown here, you know they are square in the shape and then the that opening is known as the screen aperture okay.

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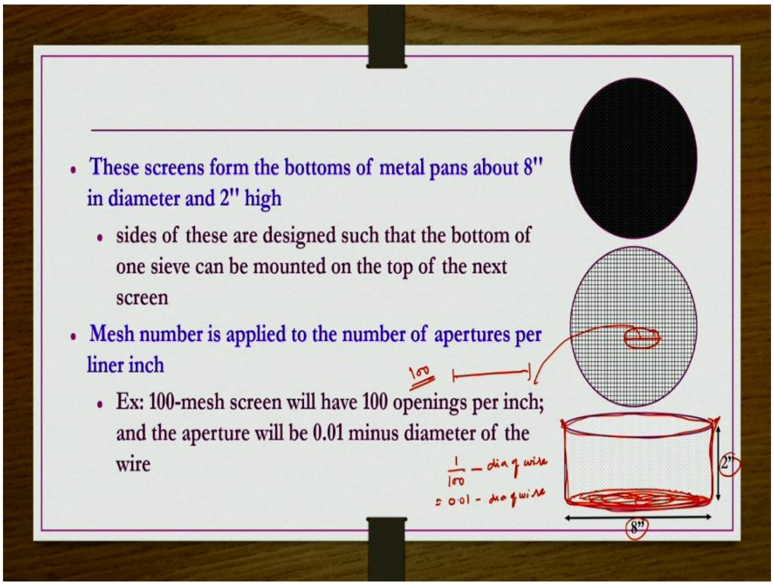

So we do this things, this screens usually form the bottom of metal pans about 8 inch diameter and then 2 inch height, they are something like this we have a kind of metal pans like this, as shown here this metal pans, right? So the diameter usually 8 inches then that depth or height is usually 2 inches, the screens whatever are there, they form bottom of this pans, here in this bottom usually we have the screens, right. So whatever the screens that are shown previous slide, like this, they are placed here like this, I have shown a kind of, you know 2-D image.

Now this particular screen is taking place at this bottom planes, so that will be occupying this bottom space here, so whatever the screens are there, they are taking the bottoms of this metal pans, so this metal pans are in general 8 inch diameter and then 2 inch height, okay. So we can have a different size, you know screens as a kind of bottom of different pans, so then we have n number of pans and then each pan is having screen at the bottom, right. So the opening of each screen is different from the other screens, so that we can do the size operations, right. Okay.

Then the sides of these pans, whatever drawn here metal pans are designed such a way that, you know we can place one on to the other, so that in the sides of these pans are designed such that the bottom of one sieve can be mounted on the top of the next screen, so that we can have this end number of screens one onto the other and then we can do the size analysis, fine. So for the screens the mesh number is also provided, usually the screen is designated by the screen aperture opening what is the opening size that is the one way and then other way in the mesh number, mesh number is, let us say this is one linear in space here, so this if I draw it here, this linear in space expand here.

So this is one linear in space, linear inch dimension in the screen, okay, I have expanded here, within this one linear inch or per one linear inch dimension if you have, let us say 10 opening like this 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 like this. Then what we say this particular mesh is given as 10 mesh number, let us say in the 1 linear inch dimensions, if you have a kind of 20 openings like this, then we can say, we can call it as 20 mesh number.

And then likewise if you have, let us say 100 mesh openings in a given linear inch like this, so than 100 opening are there then you can call them as a kind of 100 mesh. So what is the size of this square aperture, then that would be $1/_{100} - D_{wire}$ that has been used for constructing this a particular screen of 100 mesh numbers, so that would be $0.01 - D_{wire}$, that will give you the screen aperture opening, size of the screen, so the screens are in general that given by the mesh number or they are designated by the screen openings, so we can call them based on that, so and so let us say 3/4 inch screen opening 1/2 inch screen or you know 1/16 screen inch like that, you know by size also, we can say that size indicates the openings, screen aperture opening size indicated by that size 3/4 inch or you know 1/4 inch etc. right.

The same screens can also be designated by the mesh numbers, so that mesh number indicates the how many number of openings are there per linear inch dimensions, okay. So either way this screens are designated, labelled, this is about the individual screens, how to do screen analysis.

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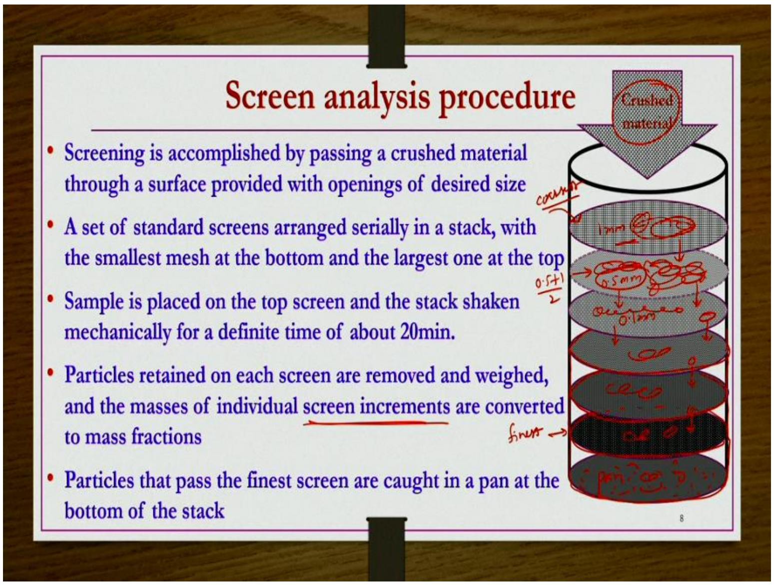

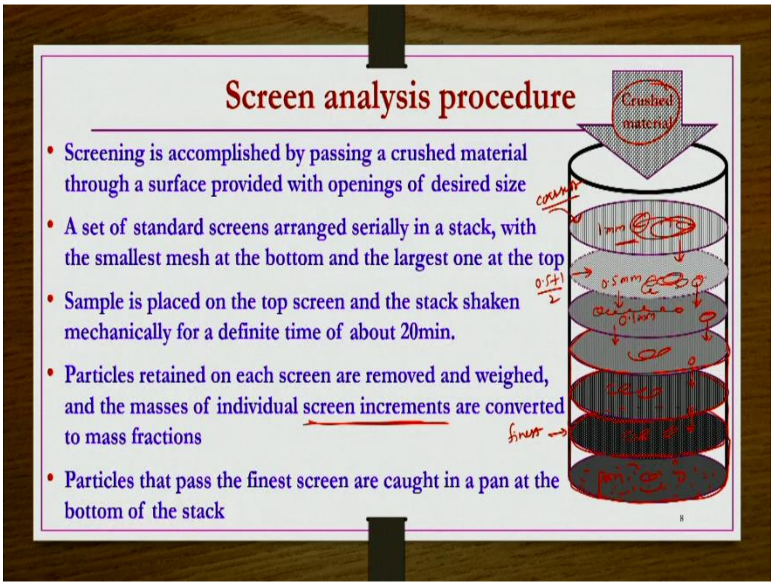

So in the screen analysis usually what we do, screening is accomplished by passing a crushed material through a surface provided with openings of desired size, that is what the screen about the in general. So in the screen analysis, a set of standards screen arranged serially in a stack, with the smallest mesh at the bottom and the largest one at the top, so that is something like this, so now this is the bottommost one is a kind of a pan, which is not having any kind of opening here right, so this is pan kind of thing, bottommost is a kind of a pan.

So here, so whatever the finest material is there, that will be collected here, so that will not pass through, so then on this pan, we will have a metal pan of having a kind of certain opening like this, that will be arranged, okay. So on this metal pan we can arrange, we can mount another metal pan of this, you know screen having this particular screen as a kind of opening, likewise one onto the other we can arrange these n number of metal pans, with a screen at the bottom or arranged or arranged on a metal stack like this, in a serially.

How they are arranged? The finest opening one is at the bottom just above the pan and then coarses to opening one at the top. So that is at the bottom you have to take a pan without any opening so that the finest material can be collected at the bottom, onto this pan you can have a kind of metal pan with a screen at the bottom that screen is having the finest opening of your requirement, then onto this one you can have the pan kind of thing which is having a kind of a opening the screen aperture opening larger than the bottom one, so this one we can another screen, whose opening in kind of a larger than this bottom one like that we can arrange one onto the other n number of screens we can arrange and then the top most one would be having a kind of largest opening screen aperture size.

So that means the screens has to be arranged such a way that the finest should be at the bottom and then gradually the screen opening should be in a increasing order and then largest opening would be at the top, right. Then sample is placed on the top screen and stake is shaken mechanically for a definite time of about 20 minutes and in general, so whatever the crushed material is there, that you take here and this set, whatever the setup is there you mechanically shake it, shake it for specify time 20 minutes or 30 minutes.

So that whatever the particles smaller than the this opening of the screen they will pass through, similarly particles smaller than this particular opening they will also pass through and then similarly particles whatever the things smaller than this screen opening they will also pass through here on this screen, like that, you know finer particles passing through and the larger particles are retaining. So that is whatever the, let us say the top screen it is having opening 1 mm let us say.

So particles which are having size more than 1 mm be retained on that one, particles having less than that size 1 mm that is 0.89 mm, 0.8 mm or even 1 microns, 2 microns all those things will passed through here, they will not be retained on the screen. Like that, you know on the second screen let us say it is opening its, let us say 0.5 mm, so whatever the material that is larger than 0.5 mm but smaller than 0.1 mm, they will be retained this second screen and then particles which are having size smaller than 0.5 mm they will be passed out through okay.

Like that, let us say if the next screen size is 0.1 mm, so here when the material comes here, while the shaking process is going on, whatever the material that is having size smaller than 0.1 mm that will be passing through the screen, but the whatever the material larger than 0.1 mm, but smaller than 0.5 mm would be retained on this particular screen. Like there is fraction, depending on the sample and depending on the size opening, each fraction there will be some material will be collected, sometimes it is possible that, you know, based on the sample one particular screen there will not be any material also.

So let us say this case itself, if you are sample, in the sample you do not have any particles more than 1 mm size, you know, it is possible that you know on the top screen you will not be having any material because your sample whatever has taken, that is having the size, you know that is not having any particles more than 1 mm, all the particles are having less than 1 mm only, so all the material pass through this screen, which is having 1 mm opening that is, so on the top there will not be any material.

Likewise, it is also possible for the intermediate screens also in between also, there may be some screens where there is no material present at all, so this is how we do it, right? Now the material that is passing through is known as the undersize material, so material that is retained on a screen is known as the oversize material and then in the screen arrangement, so each screen is given a title as screen increment, so on each screen increment we get some amount of material, that some amount maybe 0 in some cases and then we tabulate it.

And then let us say the material whatever the material that is collected on the second screen having opening 0.5 mm, so that material, the size of that material is expected to be between 0.5 mm to 1 mm only, right? So that is a kind of narrow size distribution, but not all particles will be having 0.5 mm, not all particles will be having 0.99 mm, because it has pass out through the previous one, the distribution may be between 0.5 to 1 mm. So we do not, there may be particles of you know different sizes, but what we see the distribution is very narrow, very narrow, so then the average size, we can assign the average size for this sample here on the second screen as 0.5+1÷2, so 1.5 that is 0.75 mm, we can say that is the average dimension of the sample retain on the second screen, like that for all the screens we can do, okay.

Now particles retained on each screen are removed and weighed and the masses of individual screen increments are converted to the mass fractions, so the screens arranged here, they are usually you know call as increment whatever the material that you collected on each screen after you know mechanically agitating it for our shaking this state for 20 minutes or 30 minutes you stop the operation, collect the material from each screen, weigh them and then convert them into the kind of mass fraction and then tabulate them against to their average particle size, against screen increment. So that is how the screen analysis procedure, that is the procedure that we should follow.

Then that data may be used for kind of, subsequent kind of analysis, analysis like, you know, separating fraction, each fraction having different factions, having average size, average dimension or average size any term can be used. Then what we can do, we can also calculate what is the total surface area of individual fraction as well as the total surface area of the entire sample that can also be calculated, so those things we are going to do in the subsequent lectures anyway. So but this is the screen analysis, this information would be used for those subsequent calculations like, you know obtaining the total surface area of sample or the surface area of the individual fractions.

Likewise, we have the volume mean diameters, surface mean diameter for the total samples, so how to obtain those different types of mean diameter, like volume mean diameter, surface mean diameter, surface to volume mean diameter or shorter mean diameter, these kind of things are there, so those can be calculated based on the results that you get from the screen analysis, okay.

So whatever the equivalent diameters in previous lectures that we have calculated, you know equivalent diameter or nominal diameter or sphericity, etc. they are with respect to the single particles, as I mention there also they are with respect to the single particles but now this is for the sample which is having several millions of particles, then for them, how to do analysis, how to fractionate them and then each fraction, how to assign a kind of equivalent diameter for that entire sample, equivalent like you know volume, equivalent diameter, surface equivalent diameter, those kind of things, in addition to the surface area of the individual fractions as well as the total surface area of the sample those things we are going to calculate in the subsequent lectures by using this result is that you get from this screen analysis.

So particles that pass the finest screen are caught in a pan at the bottom, so in the pan, whatever the particles you will get, you will expected to have the finest particles retain on this pan and then coarsest particle you are expected to be retain on the top screen in general, okay, depending on the size and the screen opening and then depending on the sample as well, okay, right? Then, is it true that let us say this 0.5 mm screen, whatever the sample is there, so that sample is it true that the entire sample within that range is going to have the size range only between 0.5 to

1 mm, but that is not true in general, that is not true in general because you take the solid sample so many of particles in general.

So sometimes very fine particles which are having size smaller than 0.5 mm may be trapped between the other particle, bigger particle kind of thing, so that may not be passing through 0.5 mm, so it is possible that the material that is retained on this particular screen, that may be having size smaller than the 0.5 mm also that is also possible, sometimes it is also possible that particles which are having size larger than this 0.5 mm that may also pass through the screen, that is also possible if your screens are having a kind of, you know veering kind of thing, the mash is broken somewhere, something like that.

Those kind of things are also possible, anyway that will decide the effectiveness of the screen. So those effectiveness of the screen also we are going to see, there are several kind of parameters that are going to have influence for this kind of results where you know particles finer size are also being retained on a kind of screens and then particles bigger size may also be passing through, so there are several reasons we are going to see them also.

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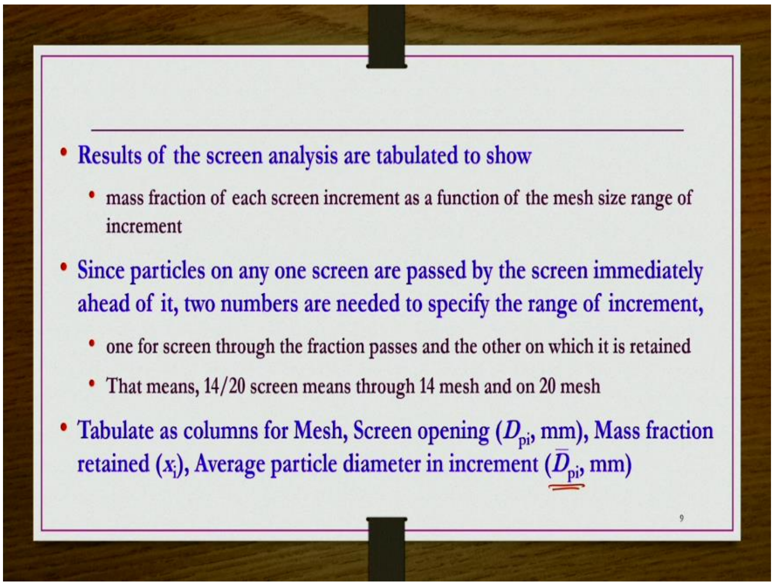

So these results what we do, the results of the screen analysis are tabulated to show the mass fraction of each screen increment as a function of mesh size range of increments. So let us say mesh size increment, 10 mesh what is the mass fraction you got, you can tabulate, then next row what you can have a 14 mesh what is the mass fraction, likewise 16 mesh what is the mass fraction, likewise in a kind of increment order, you can include 100 mesh what is the fraction of material that you retained, that you have to tabulate.

And then since the particles on anyone screen are passed by the screen immediately ahead of it, two numbers are needed to specify the range of increment range, right. So one for screen passing through or through the fraction passes and the other one on which it is retained, that means 14/20 screen means that is through 14 mesh and on 20 mesh, so different types of representations are there, this can also be represented as a -20+14 as I mention that also we are going to see in the next slide.

So this information what you do, tabulate as columns, one column for the mesh, next column for the screen opening that is the aperture opening for that particular screen, let us say 100 mesh what is the aperture screen opening, that you will be writing in screen opening D_{pi} column, next column is the mass fraction exile, let us say that is the what is the mass fraction that is the weight of the material retained on the 100 mesh, let us say if you are taking 100 mesh as example, weight of the material that is retained on 100 mesh divided by the total weight of the sample that should be retained as a kind of mass fraction retained on that one.

And then average particle diameter increment D_{pi} bar, let us say the material that is pass out through 50 mesh and then retained on 100 mesh, so whatever the clean aperture opening of 50 mesh plus whatever the screen aperture of 100 mesh divided by 2, that arithmetic average of these two screen openings there should be a kind of average particle diameter in that particular increment, that is given as D_{pi} bar like that you have to calculate, this information, now you can use for subsequent analysis further you know different types of size representation or for a surface area of individual fraction, as well as the surface area of the entire sample.

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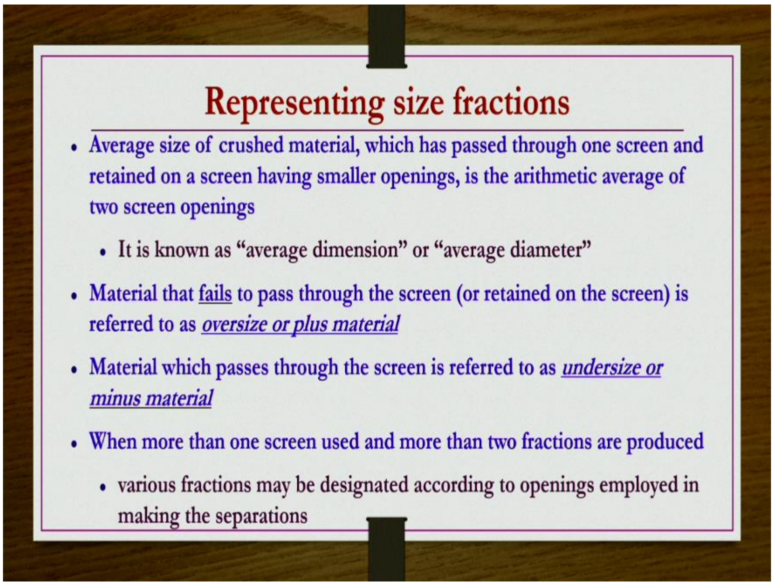

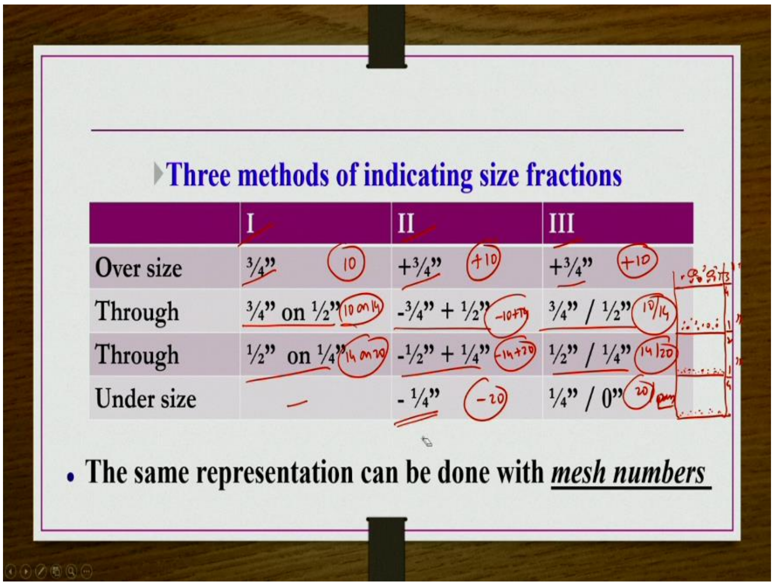

So how to represent the size fractions, there are three different ways of representing the size fractions, so first average size of crushed material, whatever it is said, which is passed out through one screen and retained on a screen having smaller openings, is the arithmetic average of two screen openings and it is known as the average dimension or average diameter or average size of the sample, different terminologies has been used for this kind of representation.

Then material that fails to pass through the screen retained on the screen is refer to as oversize or plus material. Similarly material that passes through the screen is refer to as undersized or minus material, okay. Based on the sample, you know some material may be passing through, some maybe retaining based on the size of the screen, as well as the best on the sample that you have, right. Whichever has pass through that we call as undersized or minus material, whichever has been retained on the screen that we call it as a kind of oversize or plus material.

When more than one screen used and more than two fractions are produced, then various fractions may be designated according to openings employed in making the separations and then these designations there are three different types of indicating size fractions are there, let us say you have a three screens, right. So one is the size 3/4 inch another one is kind of 1/2 inch, another one is 1/4 inch and there is a pan something like that.

So oversize material is the one that is retained on the 3/4 that is the coarsest opening screen, under sizes that is the collected below that 1/4 inch, whatever the pan is, that is the undersized one, okay. There is a representation for this one, let us say whatever the material retained here, so you can there are three methods 1, 2 and 3 ways of representing is there, so oversize you can simply the write 3/4 inch or plus 3/4 inch like this, right.

So whatever the material that is retained pass out through 3/4 inch and then retained on 1/2 inch, that you can be presented in three different ways, that is 3/4 inch or 1/2 inch or minus 3/4 inch, plus 1/2 inch or 3/4 inch by 1/2 inch, so that is that indicates that material pass out through 3/4 inch, but retained on the 1/2 inch. So there is another, whatever the material that has pass out through 1/2 inch and then retained 1/4 inch, similarly that through fractions intermediates one, we can call him as a through fractions.

So now here the finer particles are there, so that we can write it is 1/2 inch on 1/4 inch, minus 1/2 inch plus 1/4 inch, 1/2 inch / 1/4 inch, this three different ways we can represent, okay? So like ways finest, whatever the things they are pass out through 1/4 inch screen also they will be much smaller and they will be retained on a kind of pan like this. So for them, since it is under size, so here there is no representation and in the second one minus 1/4 inch or 1/4 inch / 0 inch, 0 inch stands for the pan without any openings.

So this three ways of representing is also, is there. So the same representation, the similar way of representation you can do using the mesh number as well, let us say you have a kind of a 10 mesh, 14 mesh and then 20 mesh in place of like inches, then you can write here, in the first case, let us say this should be simply 10, this should be +10, this should be +10 say I do not mean that the this 10 mesh is having her 3/4 inch opening, just a kind of representation only the same representation I wanted to show in terms of mesh number so then I am using this roughly the other numbers, okay. They do not indicate the same opening as kind of 3/4 inch, 1/4 inch or 1/2 inch as written here, okay?

So now here what we write 10 on 14 something like that, here -10 +14, here 10 on 14, then here, 14 on 20, then here -14 +20, then here, 14/20, then here -20 or 20 by 0 or 20 by pan something like that you can represents, this 0 indicates for the pan. So if the same representation you can do using this mesh numbers also, either you can do the, using the openings, mesh screen openings in terms of inches or centimetres or you can show them, represent them in terms of the mesh numbers, like 10 on 14 or -10 +14 like that, so these are the different types of indicating of size fractions are there, as I already explained, the same representation can be done with mesh numbers also.

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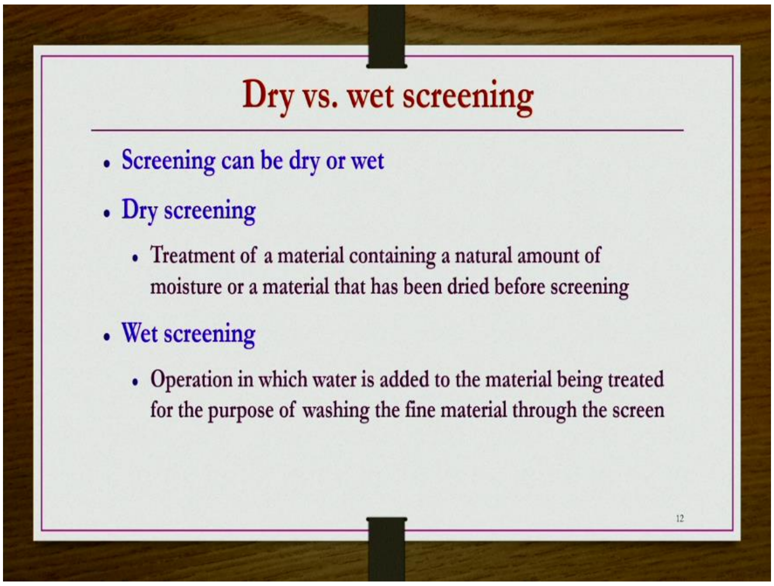

So can the screening be different, dry screening or wet screening something like that? Yes it is, so the materials screening can be dry or wet, dry screening is the one where the treatment of material containing a natural amount of moisture is treated as it is, so whatever the raw material that, crude raw material from the nature you get, you crushed them and then you do the size analysis, using the screen as it is or you can dry them, then you do the screen analysis using the screens, that is also possible, so if you use them as it is, including the natural amount of moisture that material is having or after proper drying also you can do this screening.

So this method of doing this screening is known as the dry screening. Sometimes what happens in your samples too many of, you know finest particles are there, that you do not want in your case, in your representation or sometimes what happens based on the samples those finest particles are very much higher value, so as I mentioned, sometimes you know even the finer particles may not pass through the coarse openings because they are being retained between the particles or whatsoever means by the or sometimes because of the blocking of the screen openings of coarser screen apertures etc, because of those reasons sometimes it happens the fine particles may not pass through the bigger openings or the openings whose opening sizes bigger than the particle size under those conditions, also those particles may not pass through, but those particles are having higher value for you.

So then what you do, you can use water operation, the screen operation, in which water is added to the material being treated for the purpose of washing the fine material through the screen is known as the wet screen, either it may be of obscuring the process it is not usual for the process or those fine particles are having much more valued than the other particles there also this wet screening is kind of important one.

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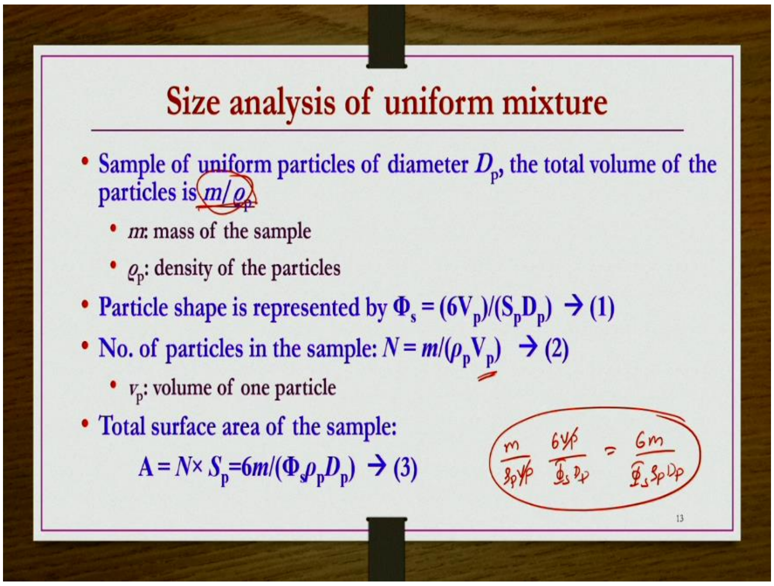

Then size analysis of uniform mixtures. So let us say if you have a mixture of uniform size, the particles, all the particles in the sample you have a particle sizes uniform or almost uniform that is D_P bar something like that or D_P, then, you know, it is easy to do the size analysis. So first we do the size analysis for uniform mixtures, then we go for the size analysis of the non-uniform mixtures subsequently. So what we have sample of uniform particles of diameter D_p, then the total volume of the particle should be m/ρ_P.

Because of the particles in this uniform mixtures the particle size is uniform, all the particles are having the same size or almost equal size okay, if not exactly the same size, they are very much close to each other. So then under such conditions if the mass of the particles, if the mass of the sample, you know and then you know the density of the particles, then you can know the total volume of the particles by m/ρ_P, so m is mass of the sample, ρ_P is the density of the particles. So for this particles, they may be uniform size, but you may not be knowing there sphericity.

So then particle shapes sphericity, you can calculate using the $\varphi_s = (6V_p)/(S_p D_p)$, this is already we have done, you need to do only for one particle only because now all particles are having same size, so then you take one particle, you measure the surface area, you measure its volume, then you get the D_P is anyway know this particle shape you can calculate by $(6V_p)/(S_p D_p)$,.

Now can you have a kind of method to find out the total number of particles in this particular uniform mixture, it is quite possible because for you now the total volume of the sample is known m/ρ_P, is the total volume of the sample, m is the mass of the sample, now you know the volume of one single particle, so what you do total volume of the uniform mixture the total volume of the sample which is having the uniform particles divided by the volume of one single particle if you do you get the total number of particle present in that sample.

m/ρ_P, is the total volume of the sample and then V_P is the volume of the single particle, right. So then you can get the number of particles present in that particular sample. Then total surface area of the particle how can you know, once you know the total number of particle? You can measure the surface area of one single particle and then you multiply that number by the total number of particles that you already got it, so then you will get the total surface area of the sample.

So that is $A = N \times S_p$, N is nothing but $m/\rho_p V_p$ and then from the sphericity definition S_p is nothing but $6V_p/\varphi_s D_p$, so this V_P, V_P is cancelled out, so we have $6m/\varphi_s \rho_p D_p$ is the total surface area of the sample for that uniform mixture, this is true only for the uniform mixture, but for non-uniform mixture we are going to use it as a kind of basis for each individual fraction because now after doing the screening onto each screen increment and whatever the sample that you have, that is having a kind of uniform size, that is what you assumption, right.

So that uniform size, so then you can say that the individual fraction that you get on each screens that is a kind of individual uniform mixture then you apply this principle and then add them together to get the total surface area of the sample. So the size analysis of uniform mixture that we have done today, in the next lecture, subsequent lecture will be doing the size analysis of non-uniform mixtures.

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The references used for this particular lecture are given here the unit operation of chemical engineering by McCabe, Smith and Harriot, then unit operations particulate solids, theory and practice by Ortega-Rivas, then Coulson and Richardson's chemical engineering, 2nd volume by Richardson and Harker, transport processes and unit operations by C.J. Geankoplis, unit operations by Brown et al and then introduction to chemical engineering by Badger and Banchero. These are the reference books that I have referred for this lecture preparation, but primarily the sources are given in this 3 and then 4th book. Thank you.