INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Mechanical Operations

Lecture-07
Effectiveness of screen-1

With
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Welcome to the second lecture of week 2 of mechanical operations course and this lecture consists of effectiveness of a screen. T his particular topic that is effectiveness of screen I will cover in two parts. In part one I will cover the theory related to the effectiveness of screen, and in second part I will show some worked example how the effectiveness of screen will be calculated. So let us start the part 1 of it which consists of theory of effectiveness of a screen.

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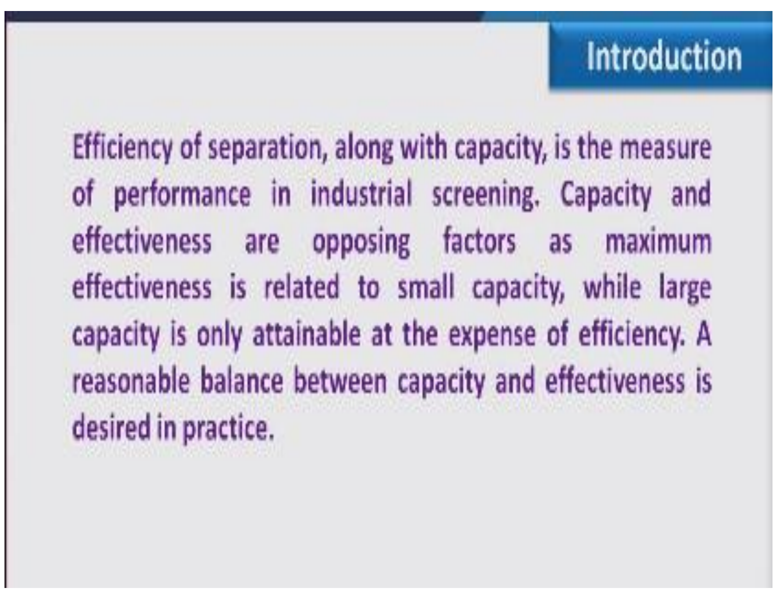

The efficiency we also called effectiveness of screen as the efficiency of screen. So efficiency of separation along with capacity is a major of performance in industrial screening. Capacity and effectiveness are opposing factors as maximum effectiveness is related to small capacity, while large capacity is only attainable at the expense of efficiency. A reasonable balance between capacity and effectiveness is desired in practice.

So if you see here I am considering two terms one is efficiency or effectiveness of screen and second is the capacity of screen.

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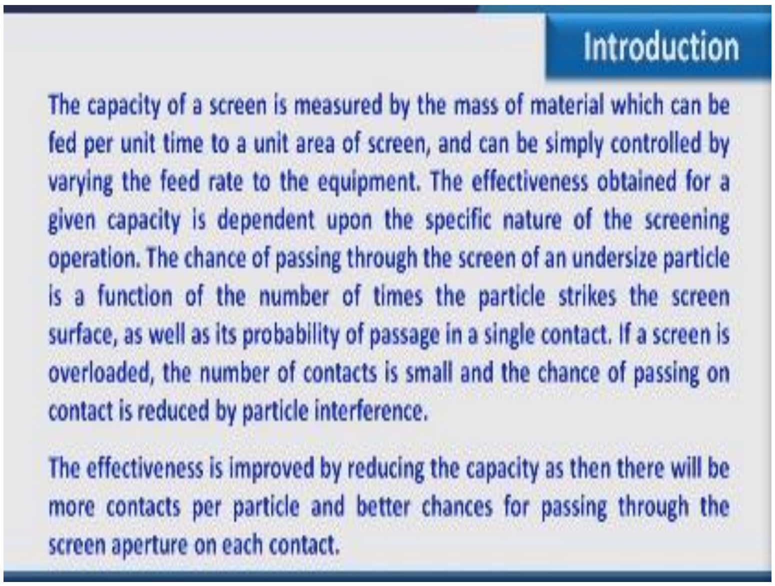

The capacity of a screen is measured by mass of material which can be fed per unit time to unit area of a screen. So what is capacity is the amount or mass taken by unit area of screen in a unit time that can be simply controlled by varying the feed rate to the equipment. The effectiveness obtained for a given capacity is dependent on the specific nature of screening operation. The chance of passing through the screen of an undersize particle is a function of number of times the particle strikes the screen surface.

As well as its probability of passage in a single contact. If a screen is overloaded the number of contacts is small and chance of passing on contact is reduced by particle interference, because as

I am having more number of particle one particle has less chance to reach to the screen. And therefore it has less chance to pass through the screen.

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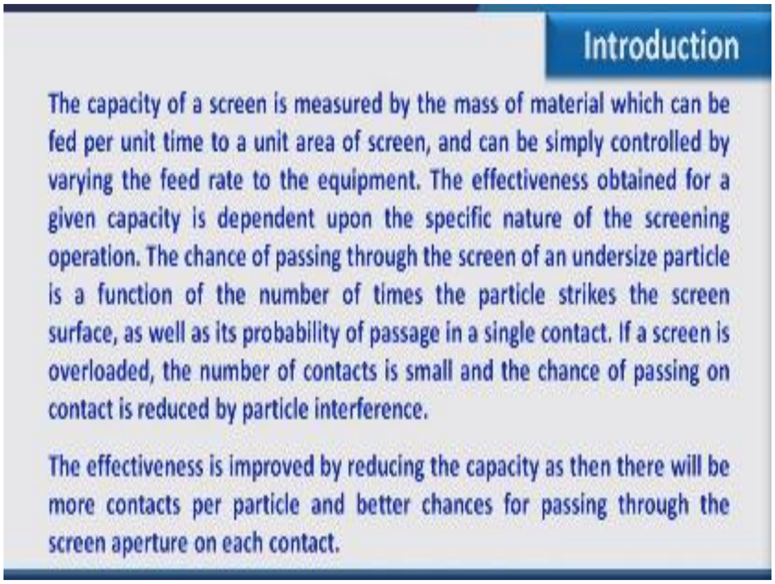

The effectiveness is improved by reducing the capacity as then there will be more contacts per particle and better chances for passing through the screen apertures on each contact. So here you see the effectiveness is basically when a particle passes through the screen. So at how it will pass in what time it will pass it will all be counted in terms of effectiveness of screen.

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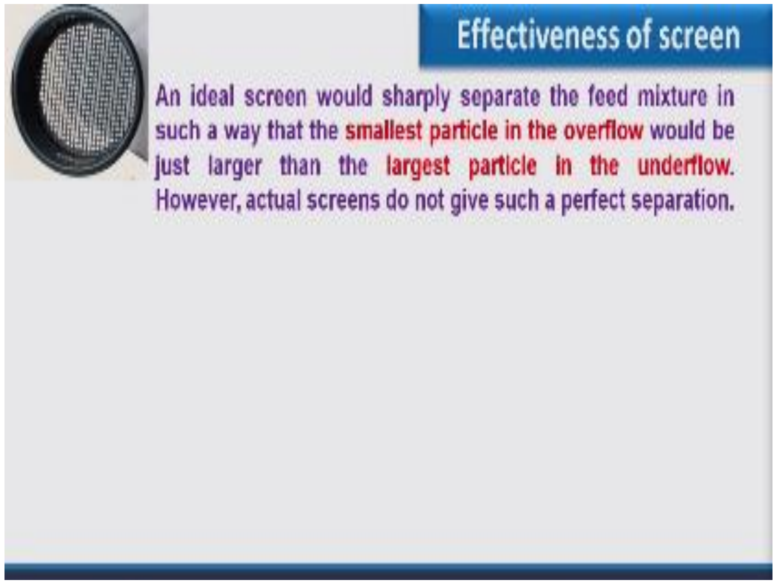

So here as far as effectiveness of screen is concerned here you are seeing an screen if I am considering as ideal screen what is the role of ideal screen and if it does not met then the concept of effectiveness of a screen comes. So an ideal screen would sharply separate the feed mixture in such a way that the smallest particle in oversize would be just larger than the largest particle in the underflow.

So what happens when I consider a particular screen so and when screening process is carried out some of the material is passed through the screen. So obviously the material which is smaller than the opening of the screen that would be passed and the material which is larger than the opening of the screen that will stay on the screen. So the separation should be in such a manner so that largest particle in underflow should be just smaller than the smallest particle in overflow. However in actual screen such kind of perfect separation does not meet.

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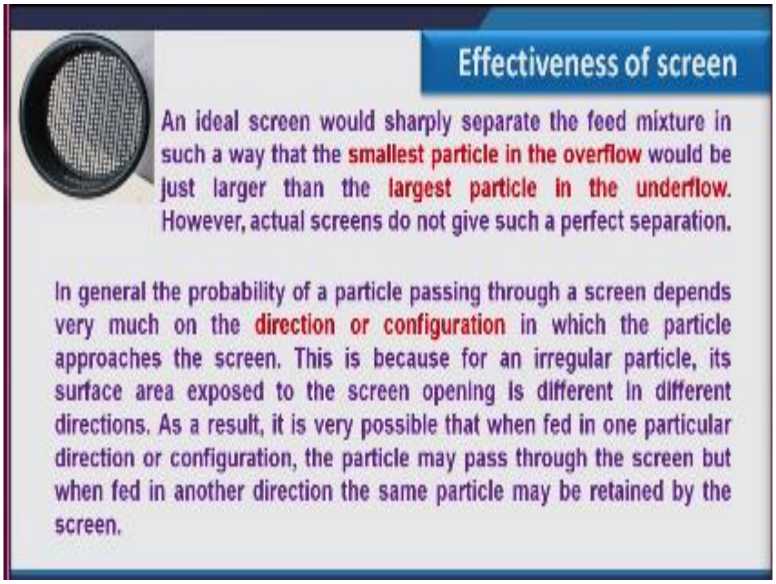

Now why it is so, in general the probability of particle passing through a screen depends very much on the direction or configuration in which the particle approaches the screen. This is because for an irregular particle its surface area exposed to the screen opening is different in different directions. As a result it is very possible that when fed in one particular direction or configuration the particle may pass through the screen, but when fed in another direction the same particle maybe retained by the screen.

For example, if I am having a particle of needle structure if that particle will fall horizontally on the screen it will be retained by the screen. However when it comes to the screen vertically it will pass through the screen.

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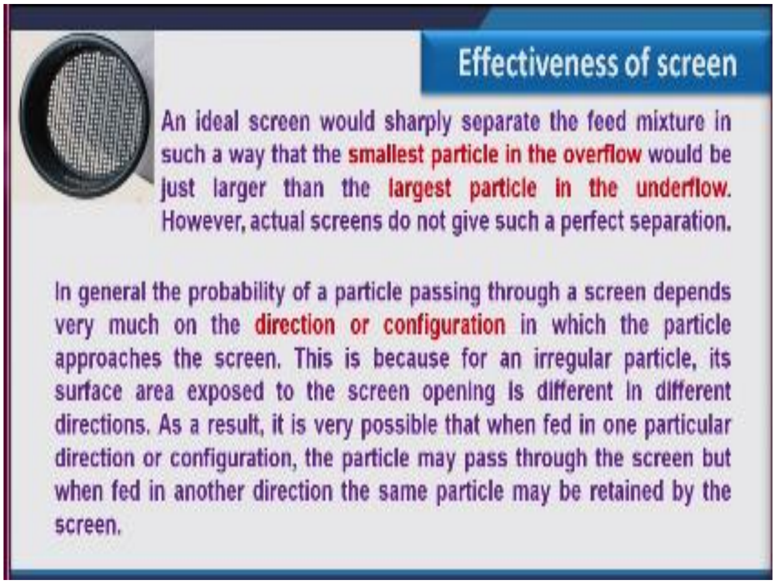

So same particle maybe passed through the screen or may be retained by the screen. It totally depends on which direction it will reach the screen.

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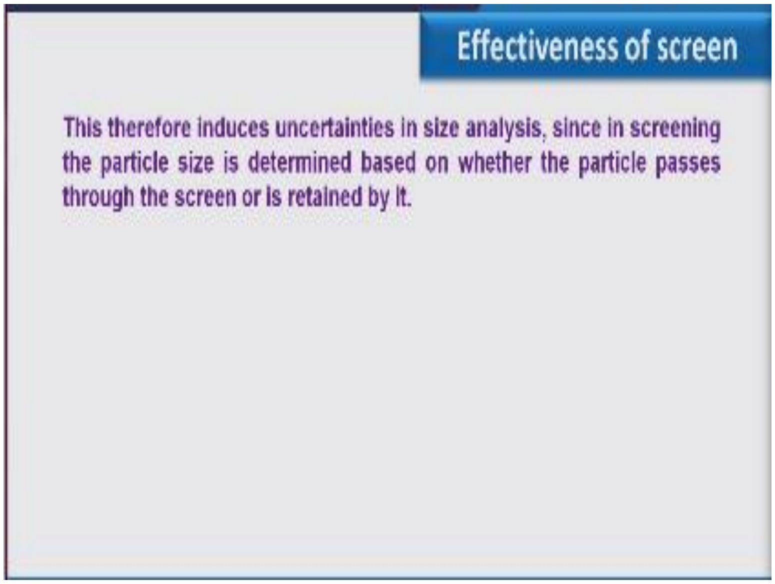

So this therefore induces uncertainties in screen analysis or size analysis. Since in screening the particle size is determined based on whether the particle passes through the screen or is retained by the screen. So if I am not having that perfect separation whatever particles should pass if they have not been passed then the separation will not be perfect. S it is therefore absolutely necessary that while performing a standard screen test on a mixture of particles the test is repeated three to four times until consistent results are obtained.

Also the screen must be subjected to a type of vibratory, oscillatory, gyratory motion so that each particle gets chances to approaching the screen in almost all possible directions or configuration.

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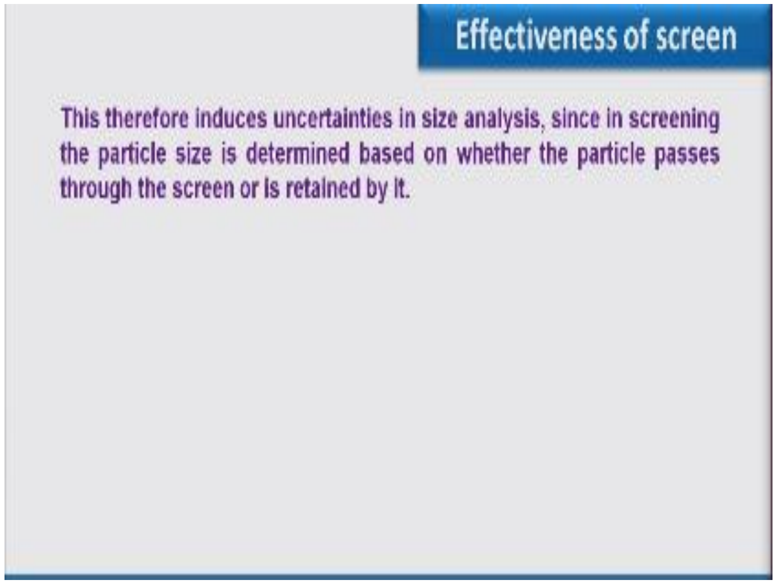

So when we carry out a screen analysis we have to repeat the test at least three to four times and along with this all type of motion should be generated in the screen set. So once it will be done then the chances of a uniform result will be more.

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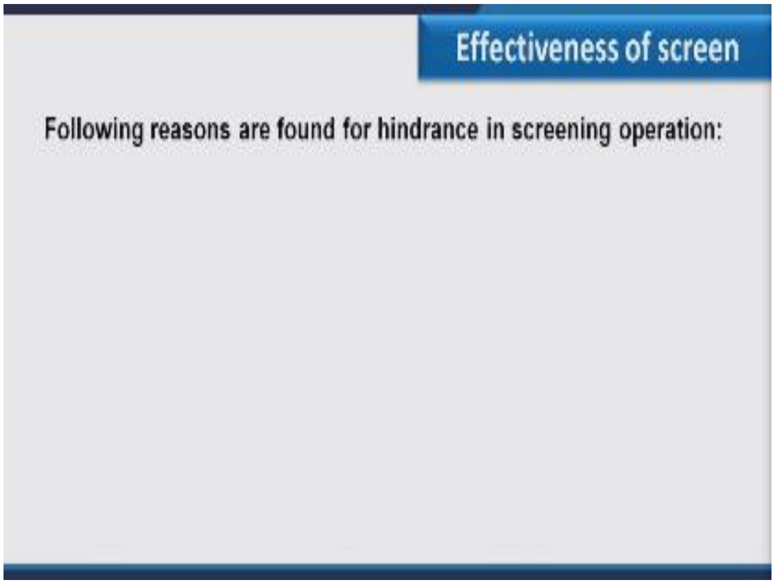

Now here I am having some of the reason for hindrance in screen operation why this separation is not perfect.

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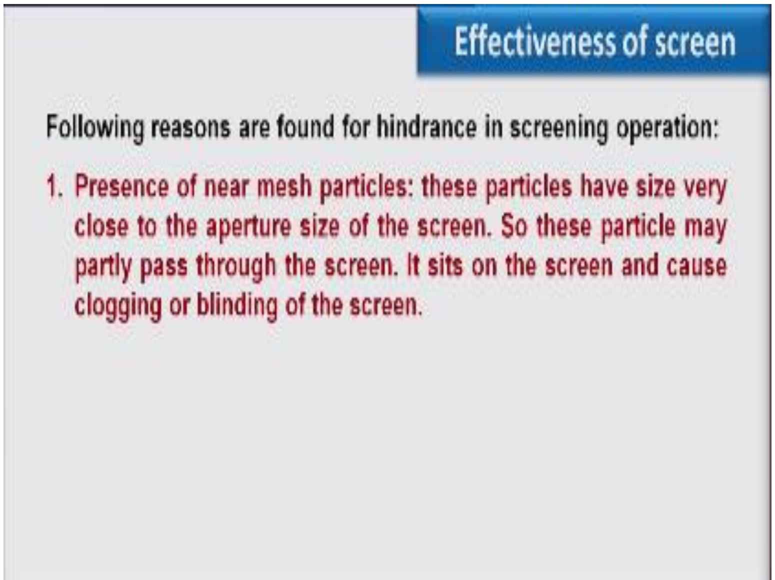

The first is presence of near mesh particles: these particles have size very close to the aperture size of the screen. So these particles may partly pass through the screen. It sits on the screen and cause clogging or blinding of the screen. So if particles are very close to the aperture size of the screen it will clog the screen and it will not allow the particle which are smaller in the size then the opening of the screen while passing through the screen.

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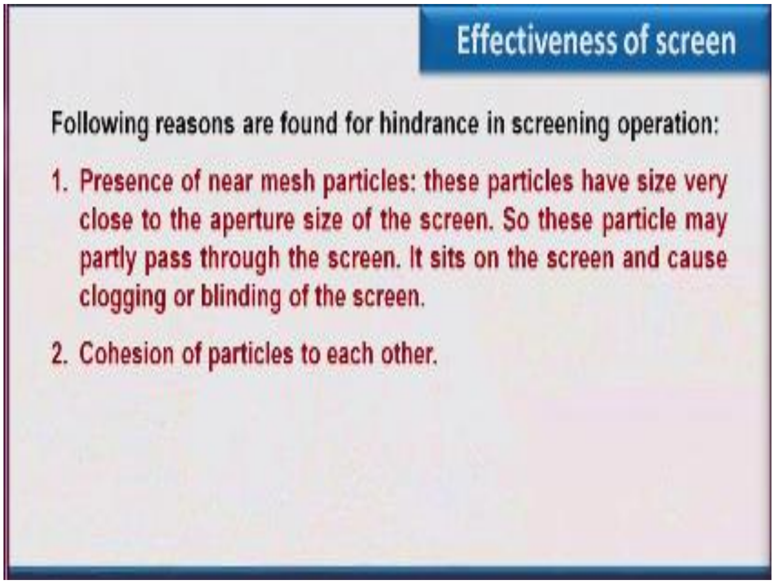

Second point is cohesion of particles to each other when we deal with a mixture of particle it usually happens the particle may clog with each other or may join the other particle and make a bigger particle, and instead of fine particle now it comes in a category of coarse particle. So instead of passing through the screen it will be retained on the screen.

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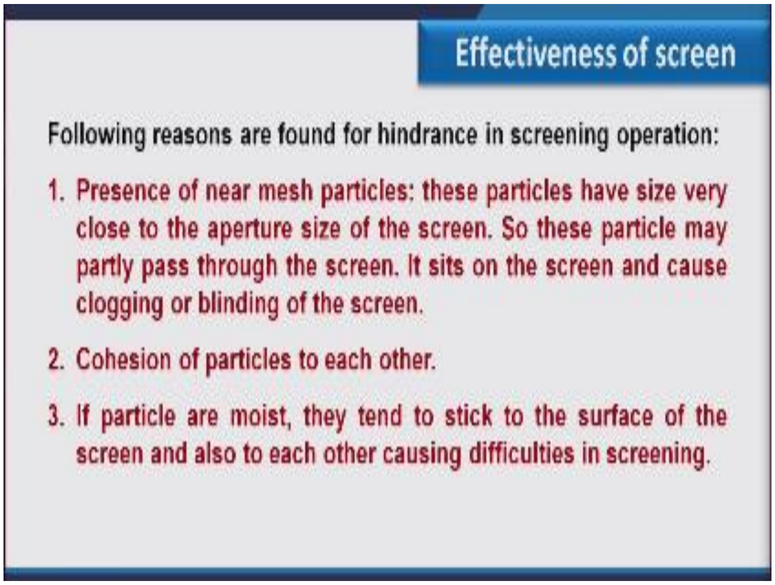

If particles are moist they tend to stick to the surface of the screen and also to each other causing difficulties in screening. So these are some of the points which create hindrance in screening operation.

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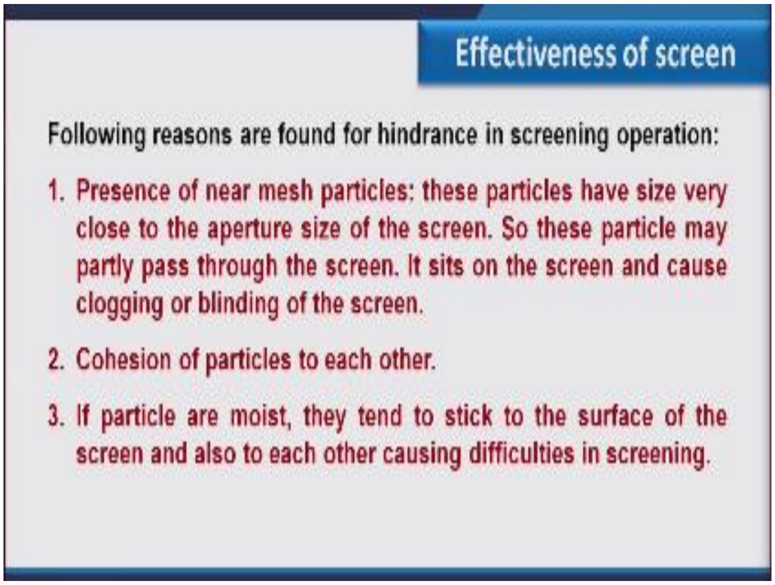

So till now we have discussed that how the effectiveness of a screen will be affected by passing or retaining of the material. Now in this slide we are going to define that how the effectiveness of screen is defined and how we can compute it. So the effectiveness of a screen we also called it screen efficiency is a measure of success of a screen in closely separating materials.

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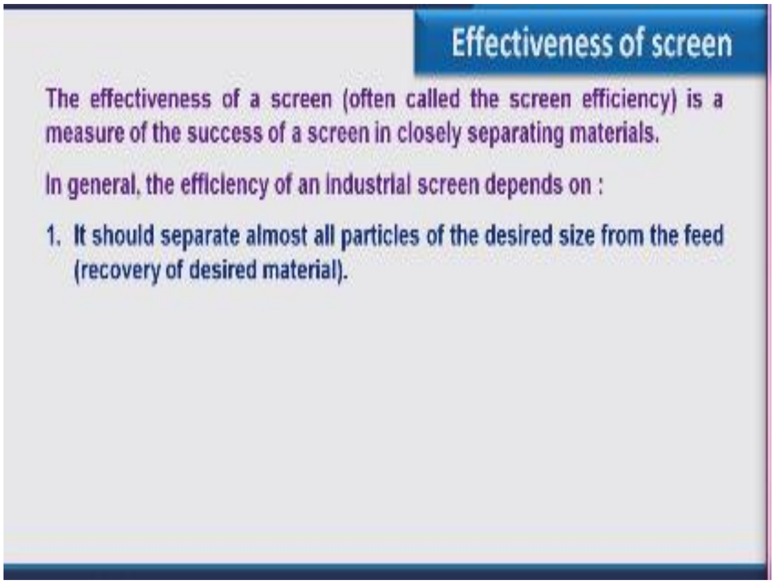

So in general efficiency of an industrial screen depends on first is, it should separate almost all particles of desired size from the feed. What is the meaning of this? Suppose I want to separate a particle of larger size then the screen should be operated in such away so that larger particles should always be retained by the screen. Therefore first point is as far as efficiency of screen is concerned it should separate almost all particles of desired size from the feed and we call it recovery of desired material.

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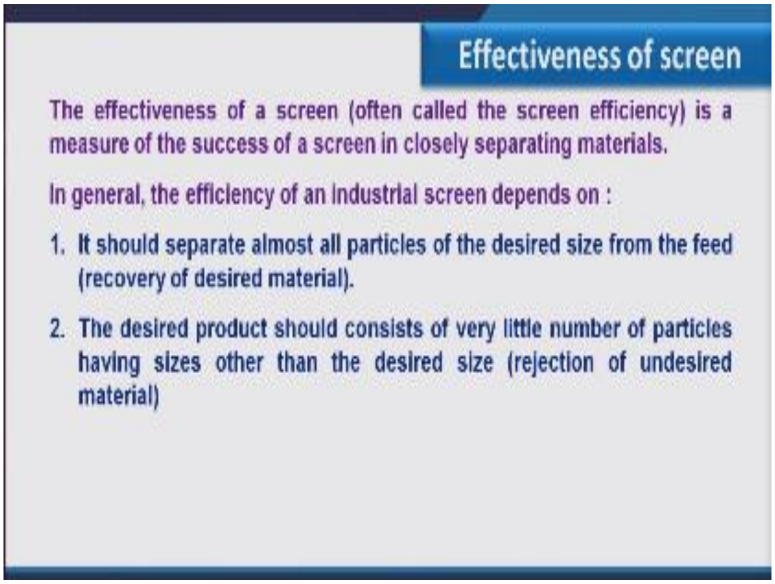

Second point I am having is the desired product should consist of very little number of particles having size other than the desired size. And that we also called rejection of undesired material. So if you considered the first point we call it recovery of desired material and second is rejection of undesired material what is the meaning of this.

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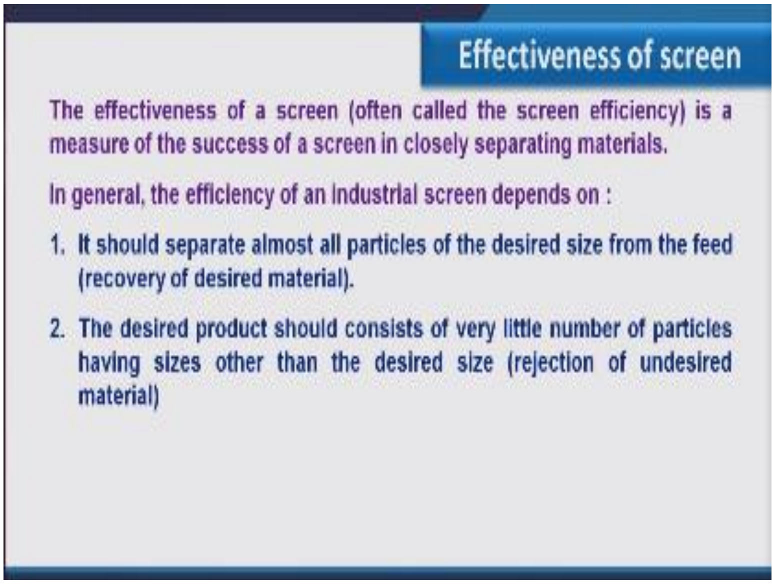

If I want to recover material for some size it should come to the either oversize or undersize in maximum portion, and it should have very little particle which are undesirable. So as far as effectiveness of a screen is concerned.

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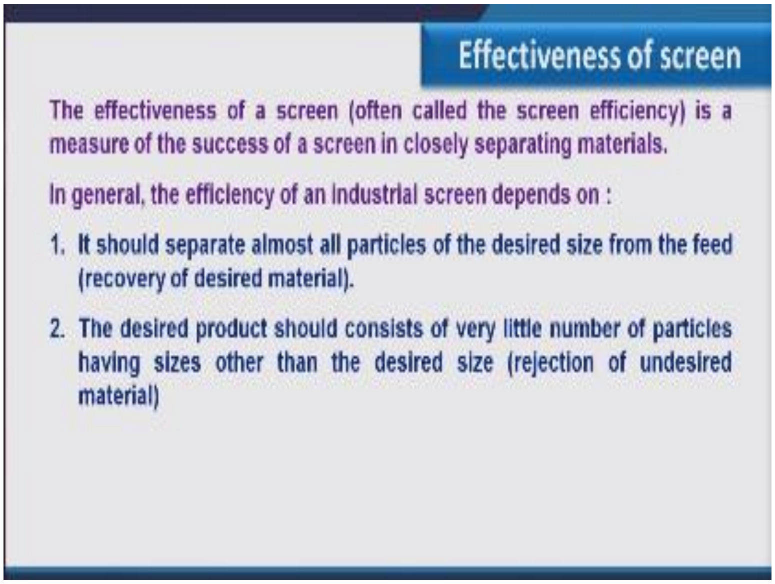

There are two factors first is recovery of desired material second is rejection of undesired material. So when I am having maximum recovery of desired material and maximum rejection of undesired material I can say the effectiveness of screen is maximum.

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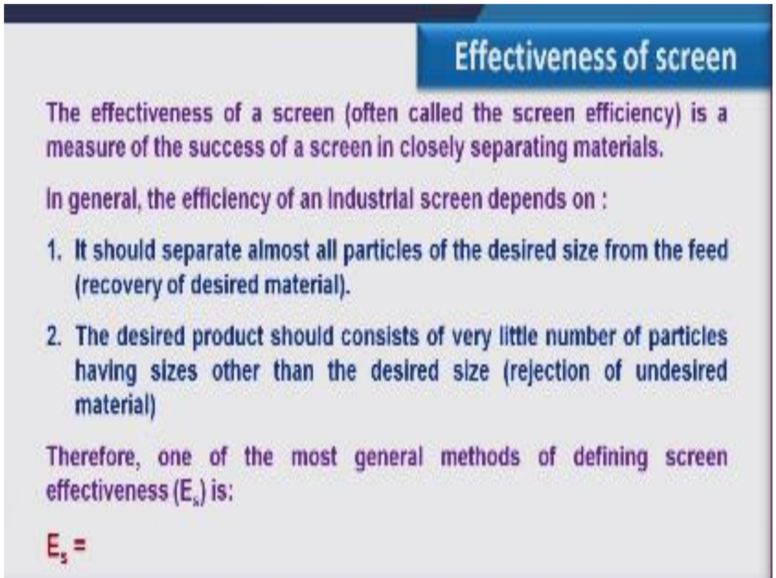

So as far as effectiveness of a screen is concerned mathematically we can define the, as far as its expression is concerned we can define E_s that is effectiveness of screen as recovery into rejection. So when I multiply recovery as well as rejection I can calculate the effectiveness of screen. Now here I am going to demonstrate how I can define desired material and how I can define undesired material.

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So here if Y_A is the mass fraction of desired material in feed. If you see I am having basically three section one is feed, another is whatever retained on the screen and third is whatever passed through the screen. So one is feed another is oversize and third is undersize. We have to define desired material in all these three and we have to define undesired material in all these three sections.

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Now if Y_A is the mass fraction of desired material in feed I can write Y_A separately as desired material.

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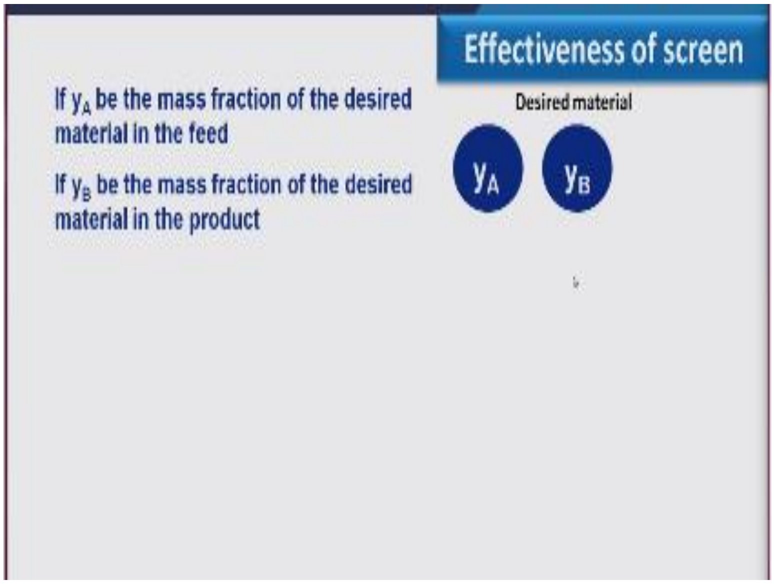

In the similar line if Y_B is the mass fraction of desired material in product. So we can separately show Y_B.

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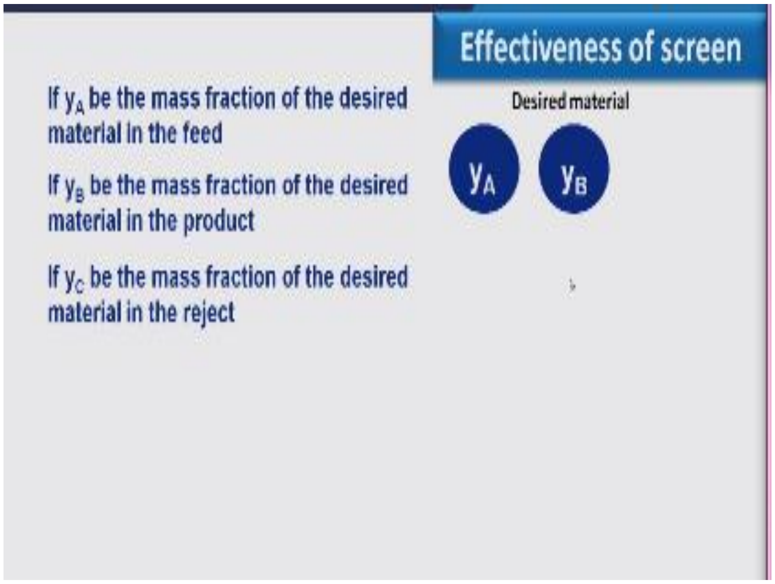

And if Y_C is the mass fraction of desired material in the reject, so here you see I am having three different fractions Y_A, Y_B and Y_C these are the desired material in feed product and reject, where ABC are resembling to feed product as well as rejection. So you can understand for if I am considering the mass fraction the maximum value of mass fraction could be one. So if Y_A would be the desired material in the feed then $1-Y_A$ would be the undesired material in the feed.

So in the similar line I can define undesirable material, so $1 - Y_A$ is undesired material in feed $1-Y_B$ is undesired material in product and $1 - Y_C$ is undesired material in reject. Now how I can define desired material as well as undesired material that purely depends on application for what I am computing the effectiveness of screen. In fact either the undersize that material has been passed through the screen.

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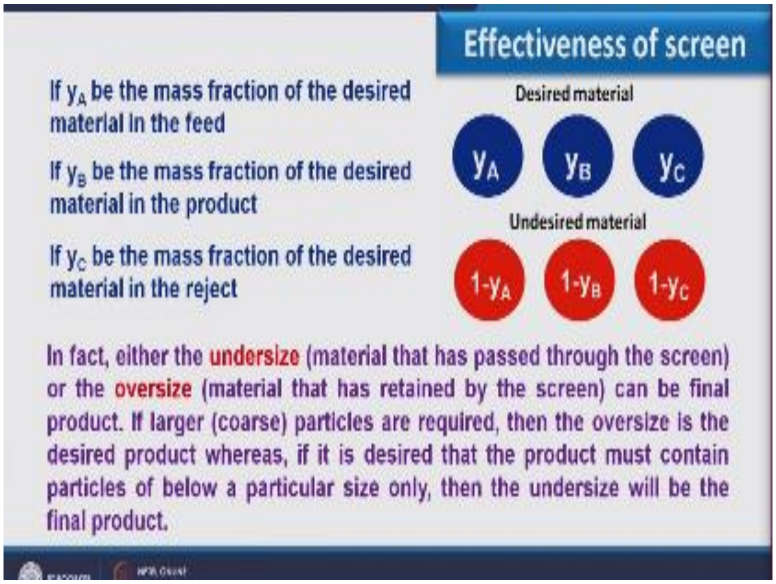

Or oversize that material has retained by the screen can be the final product, if larger particles are required then obviously oversize is a desired product. However if it is desired that the product must contain particles of below a particular size only then undersize would be the final product. So oversize and undersize purely depend on the purpose for what I am using the screen and for what I am calculating the effectiveness of a screen.

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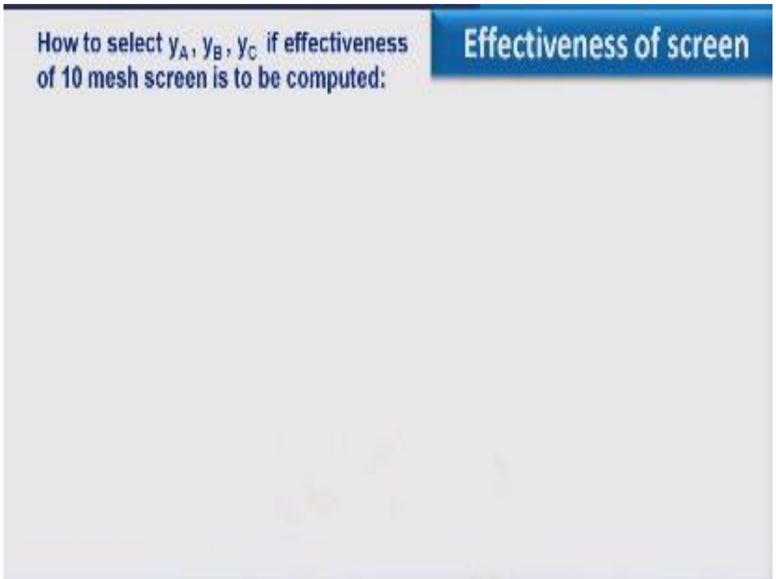

In this slide I am going to demonstrate how Y_A, Y_B and Y_C would be calculated, would be found if effectiveness of ten mesh screen is to be computed. So here ten mesh screen I am taking just for an example, how we have to find the value of Y_A, Y_B and Y_C.

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So here if you see here I am having a set of screen. Now what is the role of this set of screen if I am computing the effectiveness of a single screen that is of ten mesh. So how we perform the effectiveness of screen experiment. For example, if I have to use the feed on 10 mesh screen first of all I will select the screen which are larger in size then 10 mesh or smaller in size then 10 mesh.

To assume that 10 mesh screen is not as perfect as the size above to this should be retained all on the ten mesh screen. So if I am calculating the effectiveness of single screen then also I have to collect the set of screen which are smaller in size as well as is larger in size. I am speaking about size, so you should understand that I am speaking about the opening of screen. So complete feed which I have to use for computation of effectiveness of 10 mesh screen that feed I will put in this set.

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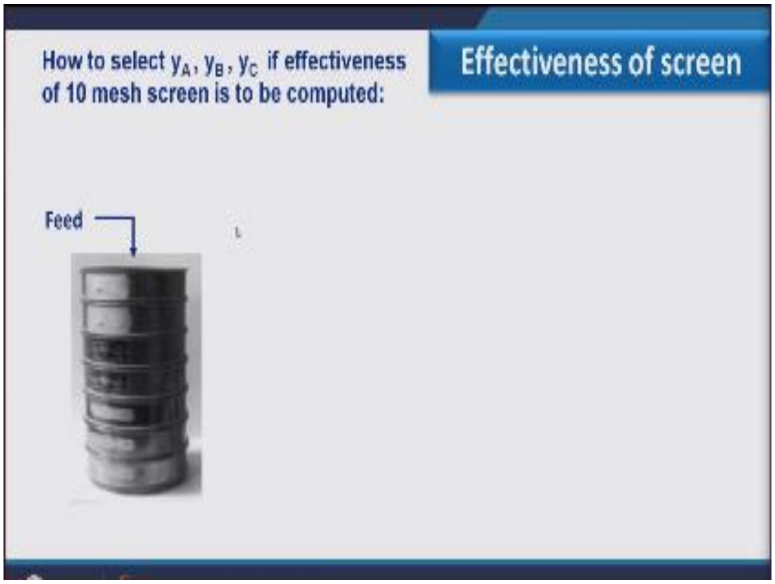

And at the bottom I will put the pan and at the top I will put the cover the complete set is fitted into the shaker, and then screen analysis will be done.

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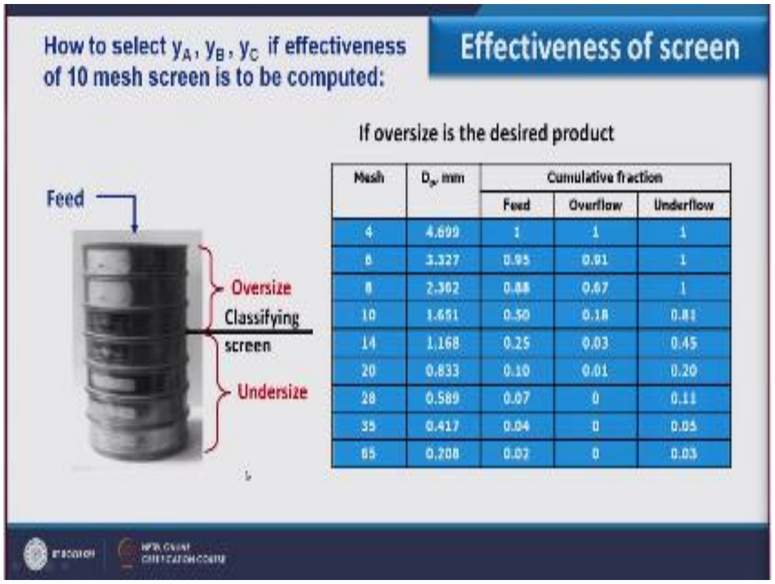

Mesh	D_p, mm	Cumulative fraction		
		Feed	Overflow	Underflow
4	4.699	1	1	1
6	3.327	0.95	0.91	1
8	2.362	0.88	0.67	1
10	1.651	0.50	0.18	0.81
14	1.168	0.25	0.03	0.45
20	0.833	0.10	0.01	0.20
28	0.589	0.07	0	0.11
35	0.417	0.04	0	0.05
65	0.208	0.02	0	0.03

So for example if this is ten mesh screen which I am calling as classifying screen above to this I am having oversize and below to this I am having undersize. Now if I am considering effectiveness of 10 mesh screen I have already collected the set of screen. So here if you see when we put the feed into the set of screen I am having the distribution of this feed indifferent set of screen which I can write the data in this table.

So if you see this table in first column I have put the mesh number where 10 mesh screen is falling in between. So whatever distribution of feed I am getting that I have put over here and here I have shown the cumulative values of this. Now how this oversize as well as undersize comes, the oversize which is shown over here it is not same as it is, but how this value is obtained to calculate the effectiveness of 10 mesh screen.

Now I will put the complete feed on 10 mesh screen only below the 10 mesh screen I will put the pan and on the 10 mesh screen I will put the cover. So this complete set which consists of cover 10 mesh screen and pan this I will put into the shaker, screen analysis will be done. So complete feed is divided in two part, first is oversize to 10 mesh and second is undersize to 10 mesh. Now that oversize to 10 mesh I will collect separately and then I will put that oversize into same set of screen in which I have put the feed initially.

So once I am having the oversize into this I will have the distribution of this and then I can write the values, I can fill the mass fraction retained on each screen and that value I can right over here. Similarly whatever material is collected in the pan that I will put in the same set of screen and then screen analysis will be done and then I can write the values over here. So here what you can see that if I consider 10 mesh screen if that 10 mesh screen would be perfect screen then it will not allow any fine particle to be retained.

I hope you are getting this the particle which are larger than 10 mesh screen will only be retained by the screen, but here if you carry out the screen analysis of oversize separately here I am having the value in below sectional also which has 14 as well as 20 mesh. And similarly if I consider the undersized, so if 10 mesh screen was the perfect screen it will not allow any undersize material to be retained on the screen, because if you see corresponding to 10 I am having this value which is retained on the screen.

It is not 0.81 but it has some value because we have done the cumulative analysis and so here larger value is appearing, but actually here this value as far as fraction is concerned is lesser. So if I consider the overflow the data shows that the lowest size screen have none of oversize and the larger size screen will not have any material from the underflow. So in this way though I am considering only effectiveness of single screen, but I have to test I have to do the screen analysis for feed oversize and undersize separately.

Once I am having this data now I am able to compute what is Y_A, Y_B and Y_C. Therefore if 10 mesh is the screen for which I am computing the effectiveness the desired size would be all material greater than 10 I hope you are understanding./

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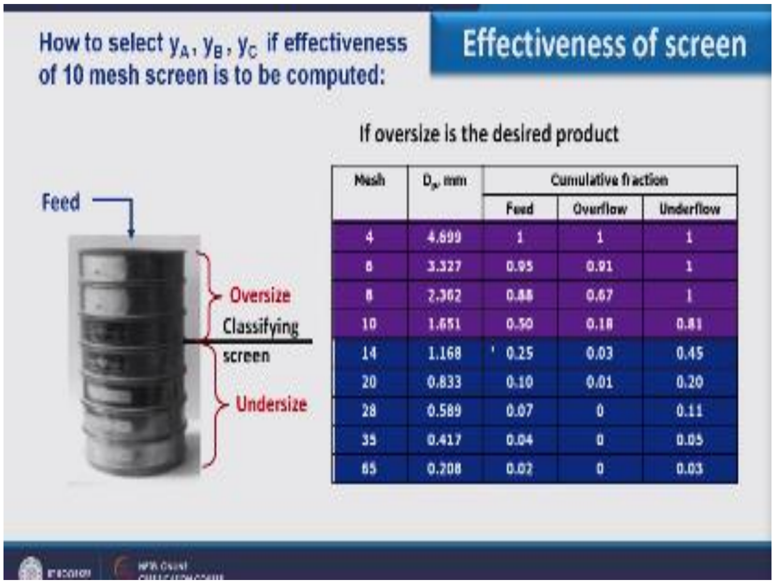

So here if you see all these are above whatever is available above 210 that is called the desired section and what is falling below 210 that comes under undesired material. So if I consider Y_A, Y_A is the desired material in feed, so if I consider this section that will consist of, that will speak about Y_A. Similarly Y_B is the desired material in the product why I am considering overflow, because now overflow or oversize is the desired product.

So obviously this section comes when I am considering the desired material present in product. Similarly this section will be considered as desired material available in reject. So Y_A, Y_B, Y_C can be computed in the similar line. For example, if I am considering that under flow is the desired material then I have to consider this below section where this particular section will speak about desired material in feed and this underflow would be desired material in product and this would be the desired material in reject.

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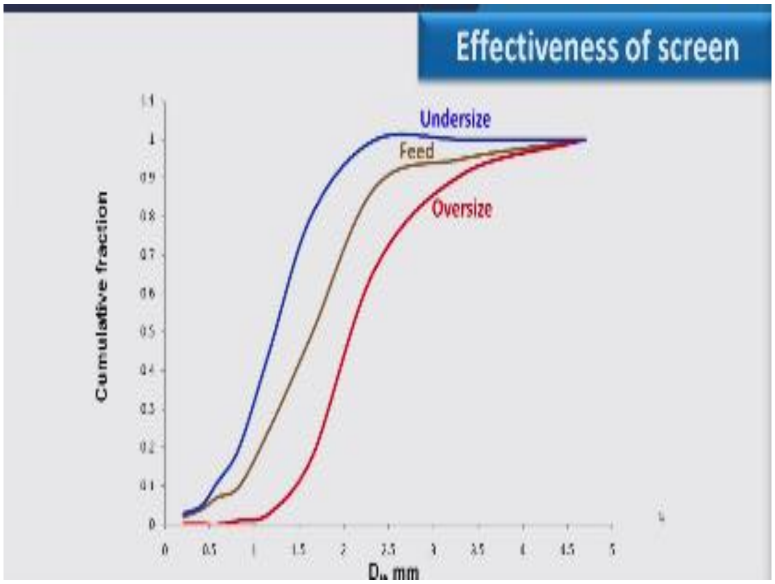

Graphically also we can discuss this here the cumulative of undersize feed and oversize we have calculated we have plotted over here and the graph is between cumulative fraction as well as the opening.

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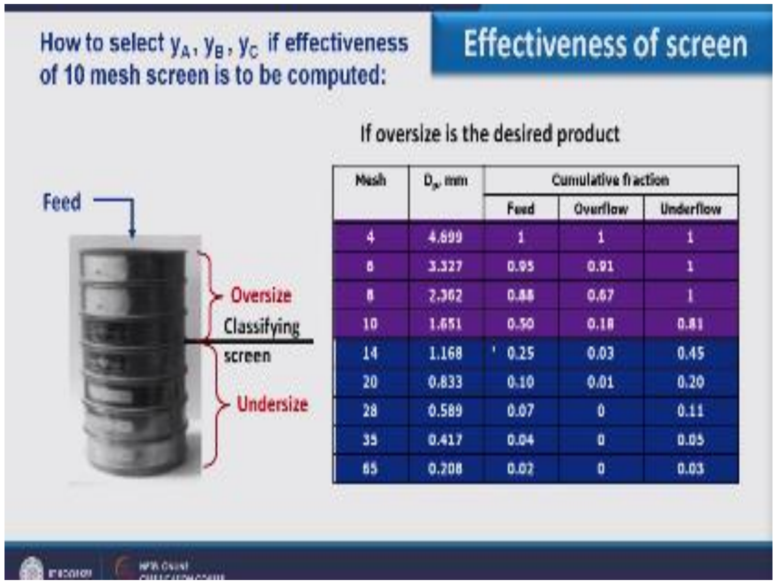

Mesh	D_p, mm	Cumulative fraction		
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14	1.168	0.25	0.03	0.45
20	0.833	0.10	0.01	0.20
28	0.589	0.07	0	0.11
35	0.417	0.04	0	0.05
65	0.208	0.02	0	0.03

Now if you see this table correspond to this tense mesh the size is 1.65.

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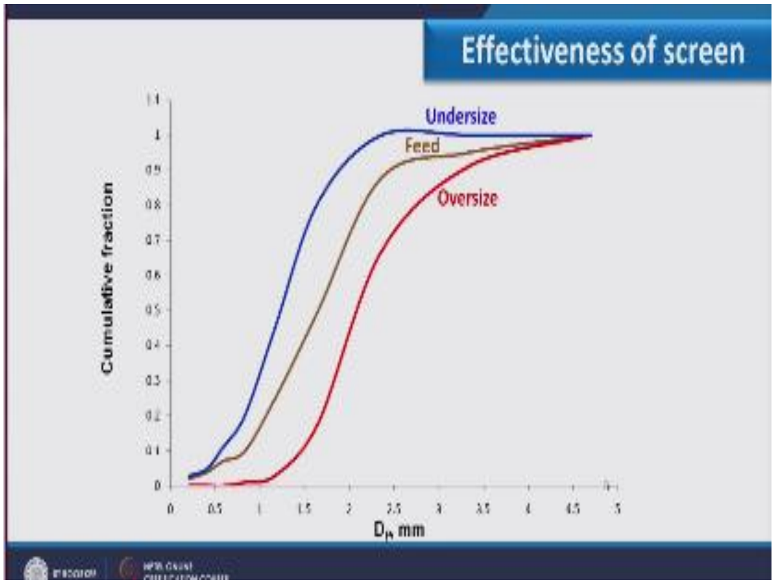

So in this graph correspond to 1.65 I can draw the line and then I can make a cut over here as oversize is a desired product so all these section which are falling below this line would be nothing but the undesired material. So what would be the Y_A is the desired material in feed. So if u see here I am having the cut at 0.5 so whatever present above to this that we have the desired material in feed. So Y_A would be 1-0.5 that is 0.5.

Similarly Y_B is the desired material in overflow or oversize, so that is Y_B = 1-0.18 that is 0.82, 0.18 comes from here and similarly I can calculate Y_C that is 1-0.81, 0.81 is available over here, so this would be the desired material in undersize. So in this way we can calculate Y_A, Y_B, Y_C, it will be more clear when we will discuss the worked example on effectiveness of screen. Now as far as expression of effectiveness of a screen is concerned.

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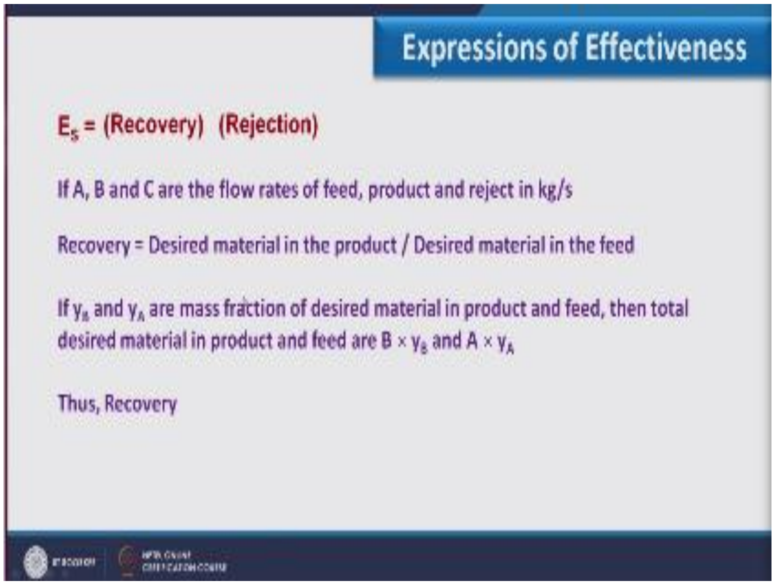

As you remember here it has two terms first is recovery as well as rejection. If A, B and C are the flow rates of feed, product and reject in kg per second so how I can define the recovery. Recovery is basically defined as the desired material in product / desired material in feed. So if Y_B and Y_A are mass fraction of desired material in product and feed, then total desired material in product and feed are B x Y_B and A x Y_A.

So how we can define the recovery which is nothing but the desired material in the product /desired material in the feed. So here you see this is the desired material in product and this is the desired material in feed. So recovery is BY_B / AY_A. So in this way we can define the recovery. Now as far as rejection is concerned.

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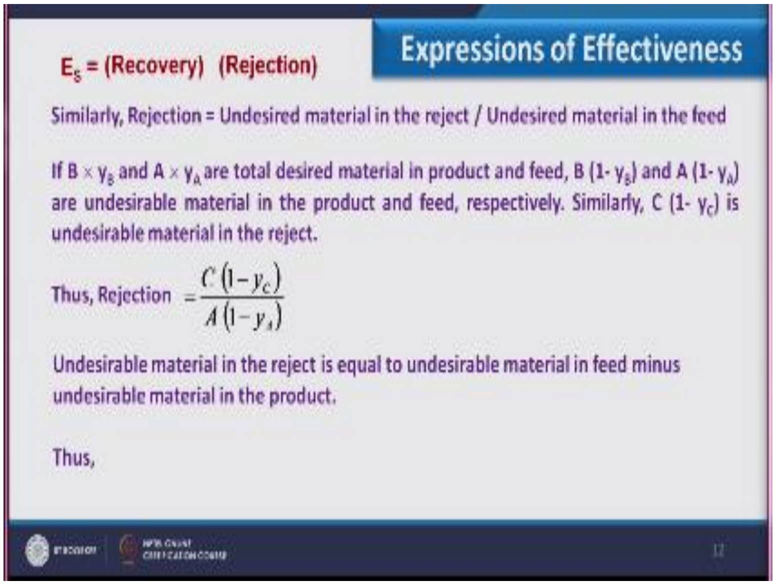

Rejection is basically defined based on undesirable material, so rejection we can define as undesired material in reject /undesired material in feed. So if BY_B and A x Y_A are total desired material in product and feed then definitely $B(1-Y_B)$ and $A(1-Y_A)$ are undesired material in product and feed respectively. Similarly $C(1-Y_C)$ is undesired material in reject. So rejection is undesired material in reject that is $C(1-Y_C)$ / undesired material in feed that is $A(1-Y_A)$. So $C(1-Y_C) / A(1-Y_A)$ is the rejection.

And if I want to elaborate this $C(1-Y_C)$ that is the undesired material in reject which would be equal to undesired material in feed- undesired material in product.

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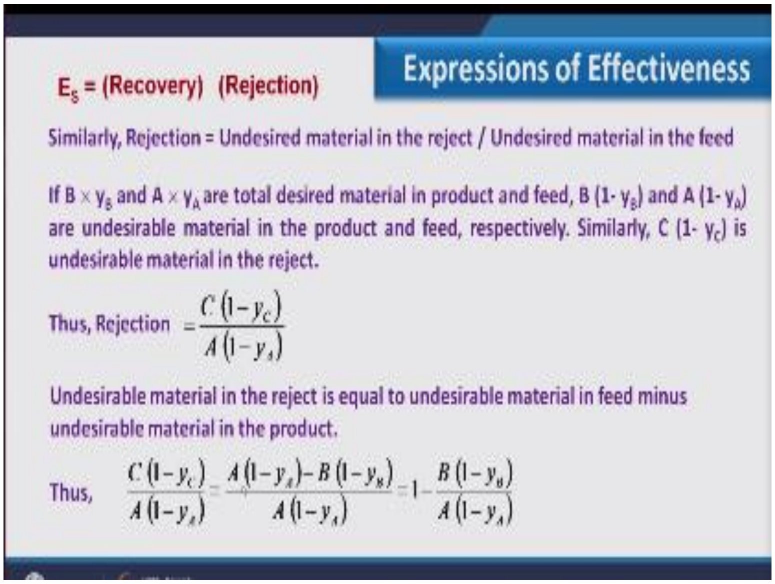

So we can write $C(1-Y_C)$ as $A(1-Y_A)$ that is undesired material in feed – $B(1-Y_B)$ that undesirable material in product. After resolving it I can have the equation as 1-B, $1-Y_B/A(1-Y_A)$, so considering the rejection as well as a recovery expression we can have the expression for effectiveness.

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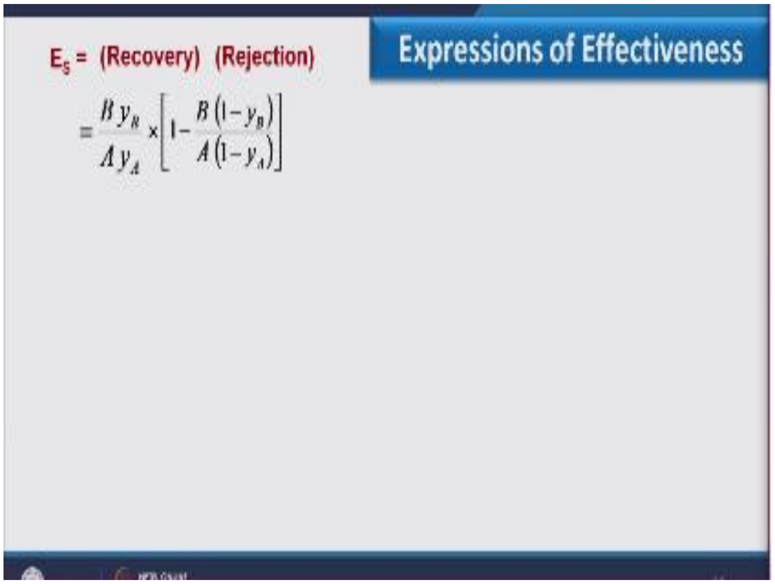

So that BY_B / AY_A is the expression of recovery and this is the expression of rejection. So here you see I am having another parameter that is B as well as A. However if we carry out the screen analysis we just have seen that from that screen analysis only Y_A, Y_B and Y_C can be computed.

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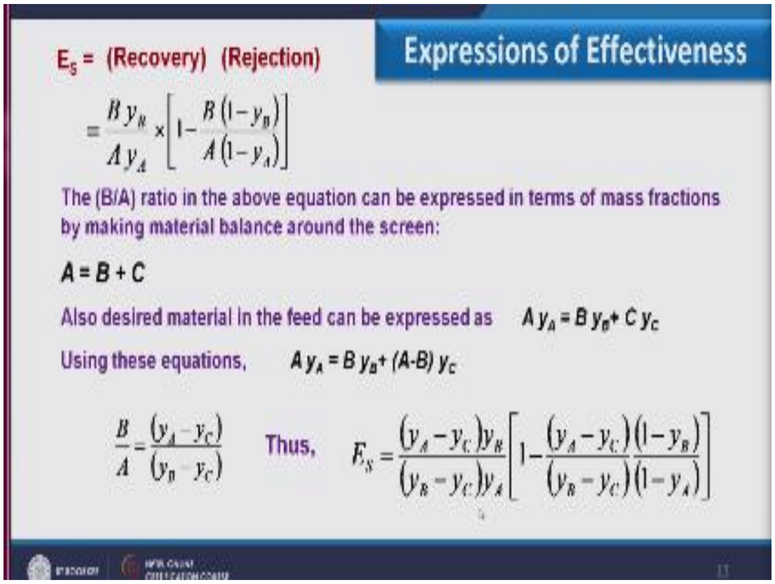

So this B and A we have to replace in terms of mass fraction also. So B/A ratio in the above equation can be expressed in terms of mass fractions by making material balance around the screen. So here you can understand very well that total feed is equal to total product and total rejection. So A is equal to B + C and desired material in feed can be expressed as AY_A equal to BY_B+CY_C.

So this is the mass balance and this is the component balance considering desired material as a component. Using this equation we can replace the C/A-B and after resolving this we can have the expression of B/A in terms of mass fractions. So that B/A we can put over here in above equation and then finally I am having the expression of effectiveness of screen in terms of Y_A, Y_B and Y_C.

So here you can see the, in terms of mass fraction only we can calculate the effectiveness of screen along with mass fraction if I know the flow rates of feed and product then also I can calculate the effectiveness of screen. Considering these two factors we will discuss the, we will calculate the effectiveness of screen when we solve the work example. Here I want to show the effect of feed rate on screen effectiveness.

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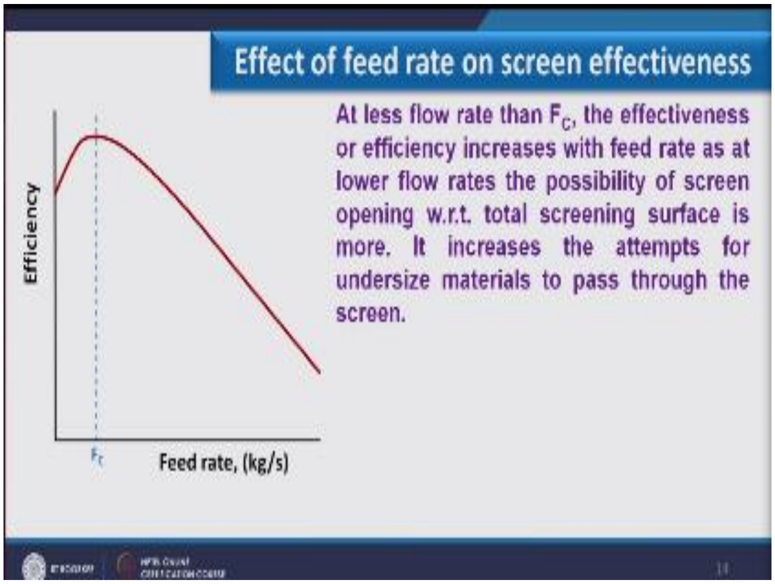

So if you see this curve here this curve is basically plotted between effectiveness or efficiency of a screen and feed rate, and the curve goes like this it increases up to certain level and then decreases sharply. So here if the maximum efficiency where I am finding I call it as F_C that is the critical feed rate. So at lower flow rate then F_C the effectiveness or efficiency increases with feed rate as at lower flow rates the possibility of a screen opening with respect to total screening surface is more.

Because at that time when I am having less feed rate I have less material so each particle has more chance to reach to the screen and then to pass to the screen. So when I am having lower flow rate it increases the attempts for undersize material to pass through the screen.

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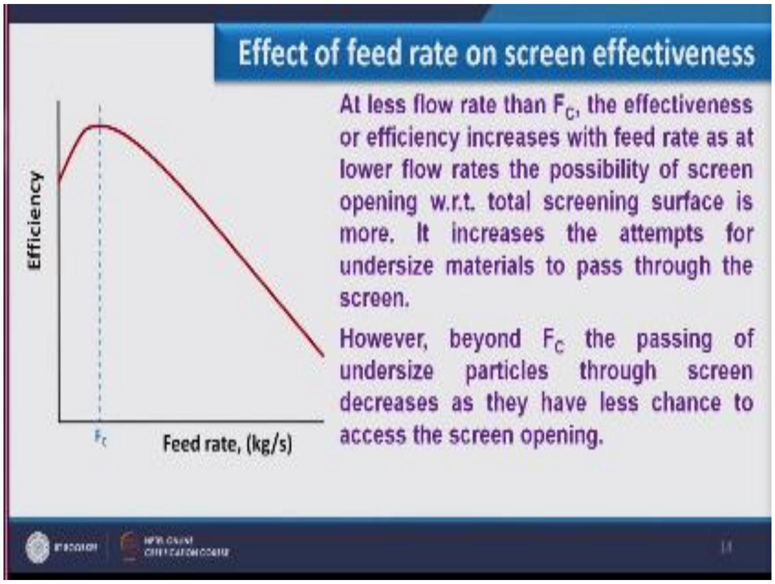

However if we increase the feed rate beyond F_C the passing of undersize particle through the screen decreases as they have less chance to access the screen opening. And hence the effectiveness of a screen decreases sharply. So here you see when I consider the effectiveness decrement ineffectiveness it means I am considering. I am feeding more material into the screen or in other word I am increasing the capacity of the screen.

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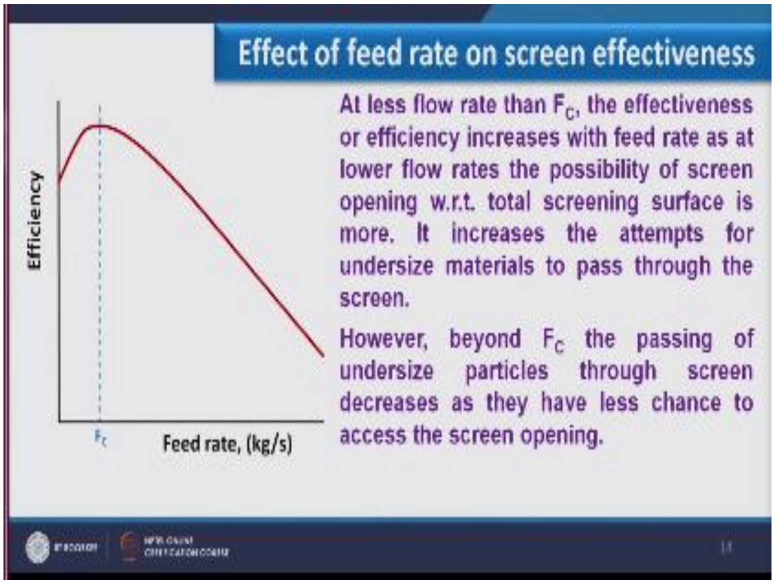

Therefore the effectiveness as well as a capacity moves opposite to each other which we have discussed earlier and that can also be demonstrated from this graph. So here I am stopping this but part of effectiveness of a screen and I will continue the example in second part of the same topic that is effectiveness of screen so that's all for now, thank you.

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