INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Mechanical Operations
Lecture-13
Examples of Laws of comminution-2

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Welcome to this second part of lecture 2 where we are discussing different examples to illustrate how to compute power consumption using three laws of comminution. Now in this part we will consider third example, example 1 and example 2 we have already covered in part 1 of this lecture. Now example 3 goes as Sphalerite having density of 4000 kg/h is fed to a crusher at 10,000 kg/h in closed circuit.

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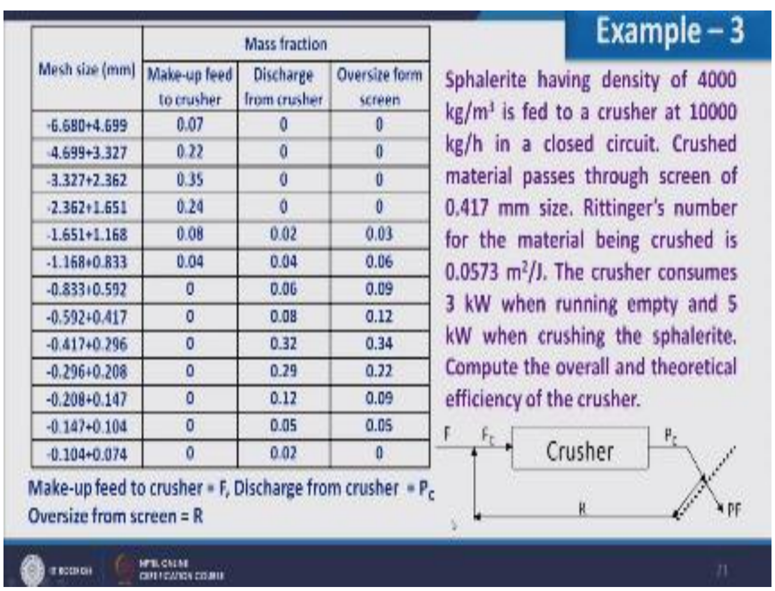

Mesh size (mm)	Mass fraction		
	Make-up feed to crusher	Discharge from crusher	Oversize form screen
-6.680+4.699	0.07	0	0
-4.699+3.327	0.22	0	0
-3.327+2.362	0.35	0	0
-2.362+1.651	0.24	0	0
-1.651+1.168	0.08	0.02	0.03
-1.168+0.833	0.04	0.04	0.06
-0.833+0.592	0	0.06	0.09
-0.592+0.417	0	0.08	0.12
-0.417+0.296	0	0.32	0.34
-0.296+0.208	0	0.29	0.22
-0.208+0.147	0	0.12	0.09
-0.147+0.104	0	0.05	0.05
-0.104+0.074	0	0.02	0

Now if you consider this diagram 10,000 is a feed to closed circuit. So when we consider the closed circuit obviously F would be the feed which we have considered as 10,000 kg/h. Crushed material passes through the screen of 0.417 mm size, so the screen size is 0.417 mm. Rittinger's number for the material being crushed is 0.0573 m^2/J and the crusher consumes 3 kW when running empty and 5 kW when crushing the sphalerite.

So that is the consumption of crusher, now what we have to compute is the overall as well as theoretical efficiency of crusher. Therefore, for this problem the associated data for particle size distribution is known to us. Here we have the F is basically the makeup to the crusher, its distribution is given.

Discharge from the crusher that is the P_C value it is given and oversize from screen that is the R value so fractions of R are also given over here. So in this particular problem number of screens we are considering where the size vary from 6.68 mm to 0.074 mm. For this problem we have to calculate overall as well as theoretical efficiency of the crusher. To calculate this first of all we should understand, we should calculate the power consumption for crushing the feed.

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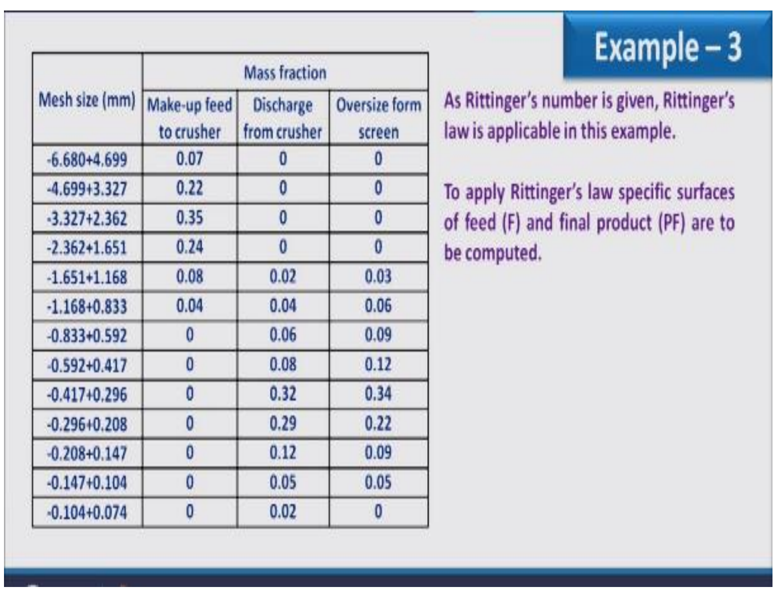

Mesh size (mm)	Mass fraction		
	Make-up feed to crusher	Discharge from crusher	Oversize form screen
-6.680+4.699	0.07	0	0
-4.699+3.327	0.22	0	0
-3.327+2.362	0.35	0	0
-2.362+1.651	0.24	0	0
-1.651+1.168	0.08	0.02	0.03
-1.168+0.833	0.04	0.04	0.06
-0.833+0.592	0	0.06	0.09
-0.592+0.417	0	0.08	0.12
-0.417+0.296	0	0.32	0.34
-0.296+0.208	0	0.29	0.22
-0.208+0.147	0	0.12	0.09
-0.147+0.104	0	0.05	0.05
-0.104+0.074	0	0.02	0

So this is the data for present problem. As in the present problem Rittinger's number is given, so Rittinger's law is applicable in this example to calculate power consumption. So to apply

Rittinger's law specific surfaces of feed as well as final product are to be computed. Now for feed we have selected F stream and for final product we have selected PF stream. Now why I have selected F as well as PF because we have to calculate power consumption for closed cycle, So F is the feed to closed cycle and PF is the product from the closed cycle.

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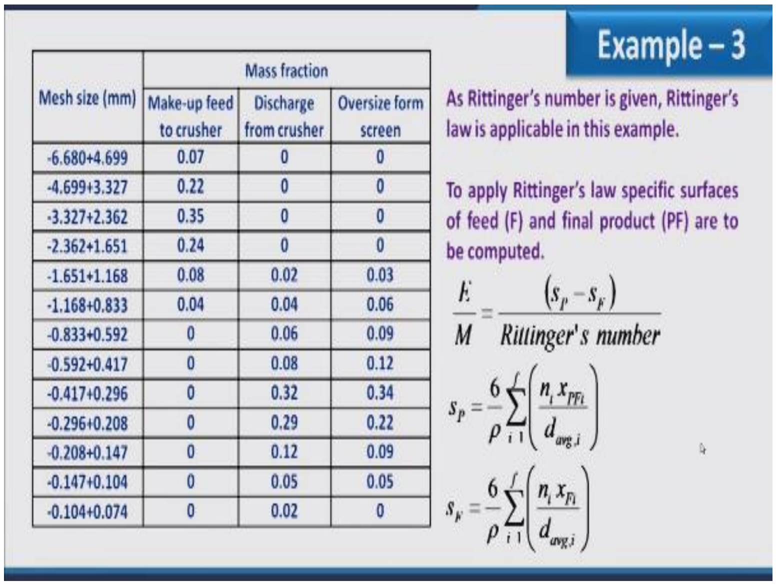

Example – 3

Mesh size (mm)	Mass fraction		
	Make-up feed to crusher	Discharge from crusher	Oversize form screen
-6.680+4.699	0.07	0	0
-4.699+3.327	0.22	0	0
-3.327+2.362	0.35	0	0
-2.362+1.651	0.24	0	0
-1.651+1.168	0.08	0.02	0.03
-1.168+0.833	0.04	0.04	0.06
-0.833+0.592	0	0.06	0.09
-0.592+0.417	0	0.08	0.12
-0.417+0.296	0	0.32	0.34
-0.296+0.208	0	0.29	0.22
-0.208+0.147	0	0.12	0.09
-0.147+0.104	0	0.05	0.05
-0.104+0.074	0	0.02	0

As Rittinger's number is given, Rittinger's law is applicable in this example.

To apply Rittinger's law specific surfaces of feed (F) and final product (PF) are to be computed.

$$\frac{E}{M} = \frac{(s_P - s_F)}{Rittinger's\ number}$$

$$s_P = \frac{6}{\rho}\sum_{i=1}^{f}\left(\frac{n_i x_{PFi}}{d_{avg,i}}\right)$$

$$s_F = \frac{6}{\rho}\sum_{i=1}^{f}\left(\frac{n_i x_{Fi}}{d_{avg,i}}\right)$$

So when we apply the Rittinger's law the expression goes as $E/M = S_P - S_F /$ Rittinger's number. Rittinger's number is already given to us, S_P and S_F we have to calculate. So S_P and S_F we can calculate using these expressions. So before starting the computation of this we have to draw all data from this given particle size distribution data.

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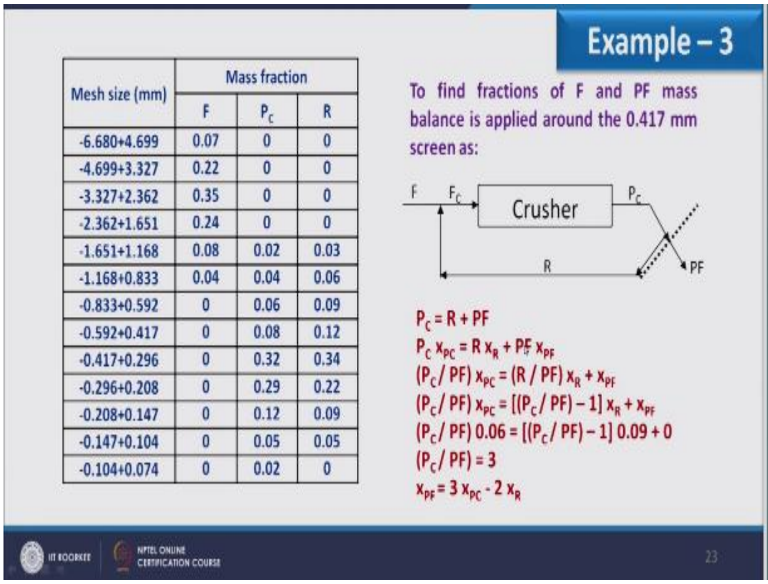

So to find fraction of F as well as PF mass balance is applied around 0.417 mm screen. Because F is given to us and fraction of F are already known to us we have to calculate fraction of PF. So we will make the balance over here where P_C is equal to PF=R. So P_C=R+PF, when we make the component balance P_C x X_{PC} = R X_R + PF $X_{PF,}$ we have to calculate X_{PF} for different fractions.

Further we can rewrite the expression as P_C/PF that is the ratio of P_C/PF x X_{PC} = R/PF x X_R + X_{PF}. Further this R/ PF we can replace using this expression where R/PF can be replaced with P_C/PF – 1. So if you see this particular expression we are getting in terms of ratio of P_C/PF. So finally we have P_C/PF x X_{PC} = P_C/PF -1 X_R + X_{PF}. We have to calculate X_{PF} from this expression.

To calculate X_{PF} at least we should know all these data. However, if you see the data which are given to us only F is given to us, not P_C or Pf. If we make the balance around closed cycle then F would be equal to PF. But along with PF we should know the value of P_C also, so how we can calculate the ratio of P_C over $P_{F,}$ for this we have used the analyses which goes as if this screen is having size 0.417mm and I want to calculate the particle size distribution of this then I can assume that the material which is available above to this would be 0 because if I am considering undersize it means I can assume that particle which are available above to these screens would be 0.

For example here if you see this table here on 417 this much fraction are retained so if I consider this screen it means above to this all x_{PF} value would be 0, considering this factor for example if I consider this particular interval so here we have a P_C value or x_{PC} value is 0.06 and x_R value 0.09 so these value we can use to calculate the ratio of P_C over P_F, so P_C over P_F x 0.06 is equal to P_C over P_F -1 x 0.09 and here we have considered x_{PF} as 0.

Now resolving it we can have the ratio of P_C over P_F as 3, this ratio we can put in this particular expression and finally we have $x_{PF} = 3x_{PC} - 2x_R$, considering this equation we can calculate fraction corresponding to P_F stream.

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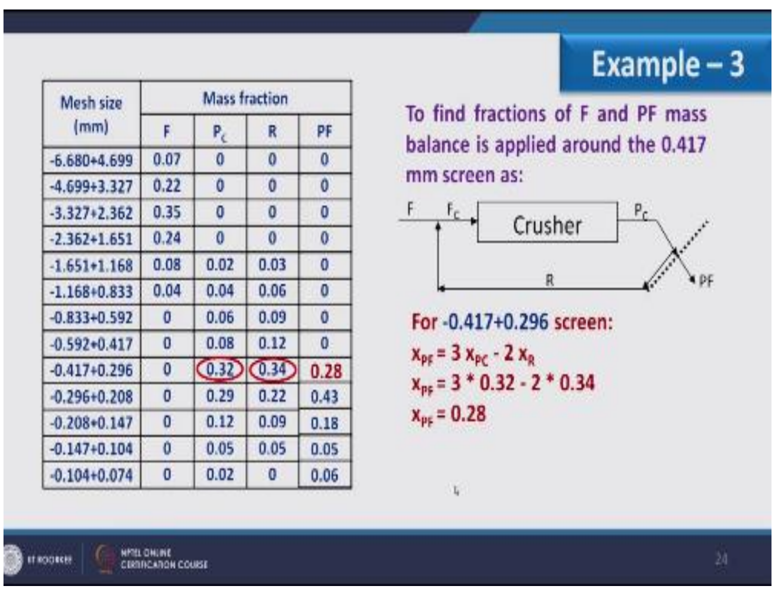

Mesh size (mm)	Mass fraction			
	F	P_C	R	PF
-6.680+4.699	0.07	0	0	0
-4.699+3.327	0.22	0	0	0
-3.327+2.362	0.35	0	0	0
-2.362+1.651	0.24	0	0	0
-1.651+1.168	0.08	0.02	0.03	0
-1.168+0.833	0.04	0.04	0.06	0
-0.833+0.592	0	0.06	0.09	0
-0.592+0.417	0	0.08	0.12	0
-0.417+0.296	0	0.32	0.34	0.28
-0.296+0.208	0	0.29	0.22	0.43
-0.208+0.147	0	0.12	0.09	0.18
-0.147+0.104	0	0.05	0.05	0.05
-0.104+0.074	0	0.02	0	0.06

Now here you see for this particular section where the size shows as -0.417+ 0.296 because above this we have assumed all value of x_{PF} as 0, so x_{PF} expression I am having in this form considering value of x_{PC} and x_R as 0.32 and 0.34 I can calculate value of x_{PF} which is 0.28, so 0.28 will lie over here, hence in the similar line following the same expression we can calculate value in other fractions also, so this is the complete fraction of x_{PF}. Now once I know the x_{PF} to calculate specific surface of feed and product we have to calculate d average because this d average is required in S_P expression as well as S_F expression.

How I can compute that d average by simply doing the arithmetic.

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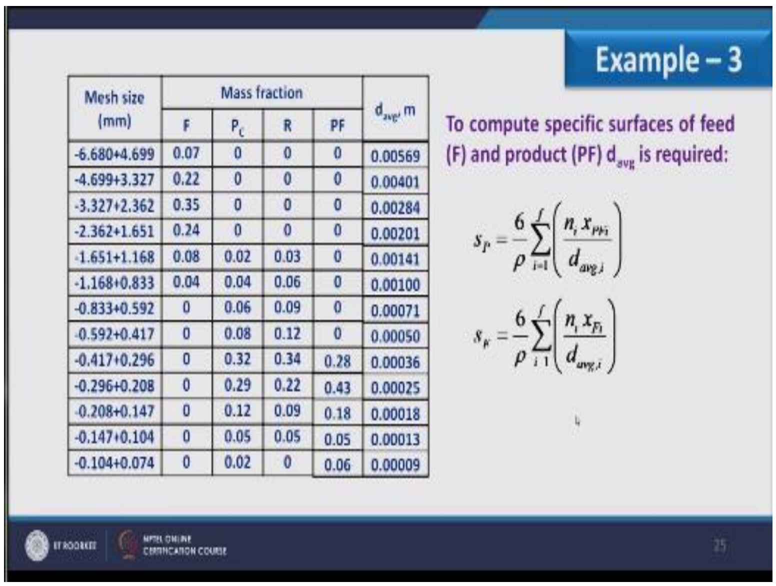

Mesh size (mm)	Mass fraction				d_{avg}, m
	F	P_C	R	PF	
-6.680+4.699	0.07	0	0	0	0.00569
-4.699+3.327	0.22	0	0	0	0.00401
-3.327+2.362	0.35	0	0	0	0.00284
-2.362+1.651	0.24	0	0	0	0.00201
-1.651+1.168	0.08	0.02	0.03	0	0.00141
-1.168+0.833	0.04	0.04	0.06	0	0.00100
-0.833+0.592	0	0.06	0.09	0	0.00071
-0.592+0.417	0	0.08	0.12	0	0.00050
-0.417+0.296	0	0.32	0.34	0.28	0.00036
-0.296+0.208	0	0.29	0.22	0.43	0.00025
-0.208+0.147	0	0.12	0.09	0.18	0.00018
-0.147+0.104	0	0.05	0.05	0.05	0.00013
-0.104+0.074	0	0.02	0	0.06	0.00009

Mean of these two value and we can calculate d_{avg} , for example in first case, in first interval the d_{avg} would be equal to 6.68 + 4.699/2 so value comes as 0.00569m. Following same expression arithmetic mean of these two value which are given over here we can calculate d_{avg} of each interval, so all $d_{avg\,i}$ for S_P as well as S_F are known to us, once I know the d_{avg}

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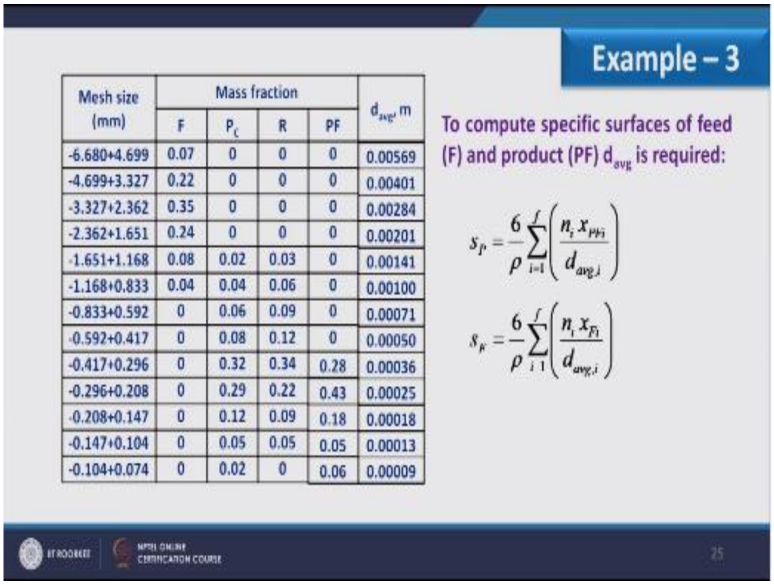

Mesh size (mm)	Mass fraction				d_{avg}, m
	F	P_C	R	PF	
-6.680+4.699	0.07	0	0	0	0.00569
-4.699+3.327	0.22	0	0	0	0.00401
-3.327+2.362	0.35	0	0	0	0.00284
-2.362+1.651	0.24	0	0	0	0.00201
-1.651+1.168	0.08	0.02	0.03	0	0.00141
-1.168+0.833	0.04	0.04	0.06	0	0.00100
-0.833+0.592	0	0.06	0.09	0	0.00071
-0.592+0.417	0	0.08	0.12	0	0.00050
-0.417+0.296	0	0.32	0.34	0.28	0.00036
-0.296+0.208	0	0.29	0.22	0.43	0.00025
-0.208+0.147	0	0.12	0.09	0.18	0.00018
-0.147+0.104	0	0.05	0.05	0.05	0.00013
-0.104+0.074	0	0.02	0	0.06	0.00009

Next value of n we have to calculate, once I know d_{avg} the value of n should be calculated next to it, how I can calculate value of n_i, the n_i is basically specific surface ratio for i^{th} intervals so for each interval I can calculate this, how I can calculate this using the value of.

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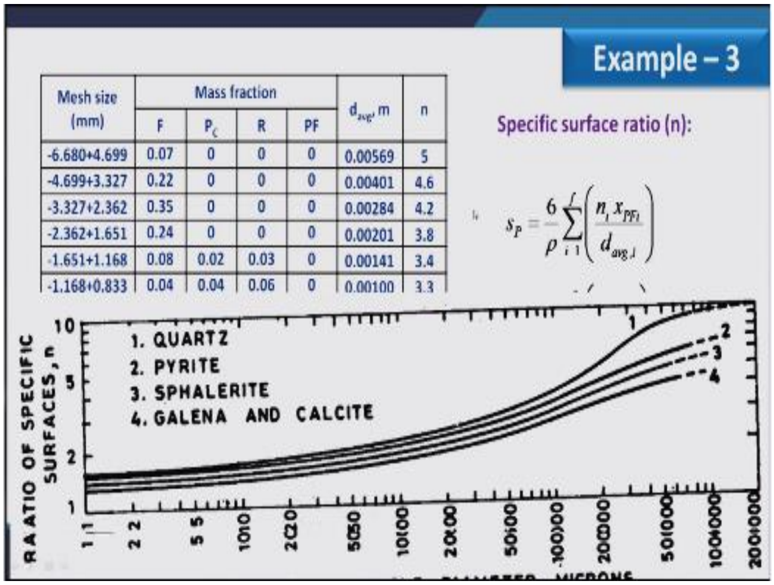

d_{avg} as well as this particular graph, this graph I guess you remember this, this we have disused when we where disusing the specific surface ratio, in this particular problem the feed is sphalerite and here corresponding to each d_{avg} value we can calculate, we can see the value of n from this graph. For example initially I am having 569 micrometer somewhere here the value will lie and curve three we will use to see the value of n for sphelerite, so once I draw the line corresponding to 5690 and corresponding to 3 I can see the value from this axis which comes out as 5.

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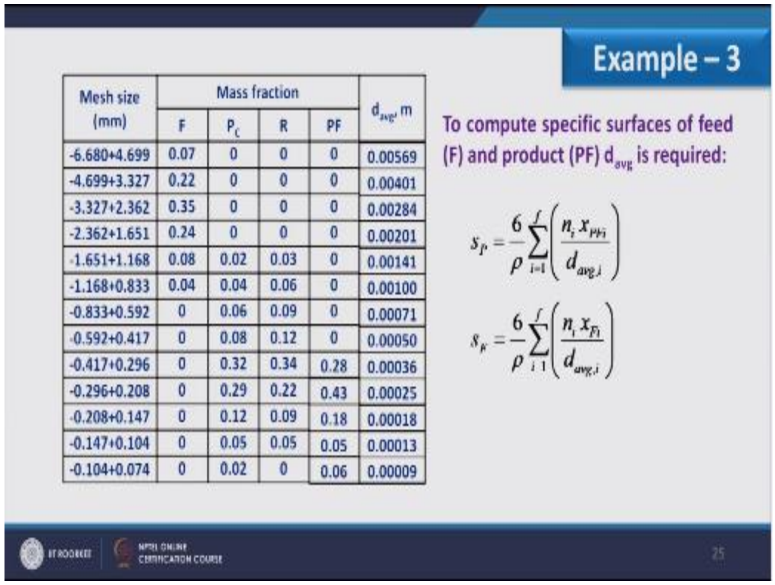

Mesh size (mm)	Mass fraction				d_{avg}, m
	F	P_C	R	PF	
-6.680+4.699	0.07	0	0	0	0.00569
-4.699+3.327	0.22	0	0	0	0.00401
-3.327+2.362	0.35	0	0	0	0.00284
-2.362+1.651	0.24	0	0	0	0.00201
-1.651+1.168	0.08	0.02	0.03	0	0.00141
-1.168+0.833	0.04	0.04	0.06	0	0.00100
-0.833+0.592	0	0.06	0.09	0	0.00071
-0.592+0.417	0	0.08	0.12	0	0.00050
-0.417+0.296	0	0.32	0.34	0.28	0.00036
-0.296+0.208	0	0.29	0.22	0.43	0.00025
-0.208+0.147	0	0.12	0.09	0.18	0.00018
-0.147+0.104	0	0.05	0.05	0.05	0.00013
-0.104+0.074	0	0.02	0	0.06	0.00009

And in similar line I can calculate I can see value of n for other intervals also, so here you see we already know $d_{avg\ i}$ and n_i for computation of SP as well as SF. Now I have to calculate the specific surfaces, these are the expression for SP as well as SF, so first of all we have to calculate n1 x x_{PF1}/d_{avg} 1 for first interval, so here you see the value n is given to us though x_{PFi} x_{PF1} is 0 so whole expression becomes 0, so here we can calculate the value of $nx_{PF}1/d_{avg1}$ for first interval and similarly for other intervals also. In the similar line we can calculate this for feed for each interval.

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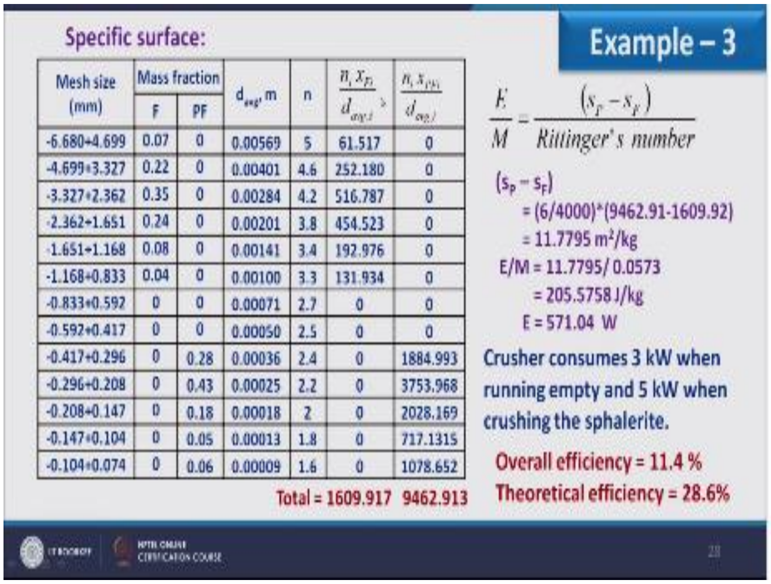

In this slide we have shown different value of ni x_{Fi} / d_{avgi} and its ∑ = 1609.9177 and similarly ni X_{PFi} /d_{avgi} its ∑ is = 9462.913. Considering these two value we can calculate $S_P – S_F$ and when we see the expression of S_P and S_F in this expression 6/ρ is common so $S_P – S_F$ we can calculate as 6/4000 which is the density of a sphalerite and value of ∑ is given as 9462 .91 – 1609.92, so after resolving it.

SP – SF we can found as, we can find as 11.7795m^2/kg so basically SP – SF is nothing but the new surface created which we have used in Rittinger's expression, using the value of SP – SF as well as Rittinger's number we can calculate E/M value which is the energy consumption per unit mass so here you see value which is coming to us is 205.5758J/kg, when we multiply this with the feed which is 10,000 kg per hour and here we are given Jul so we have to convert that in kg per second.

So once I do this and multiply with 205.5758 the energy consumption comes at 571.05 w, this is the energy consumption for new surface created. Our aim is to calculate the efficiency for overall crushing as well as theoretical efficiency so how I can compute this considering the initial energy consumption given to us.

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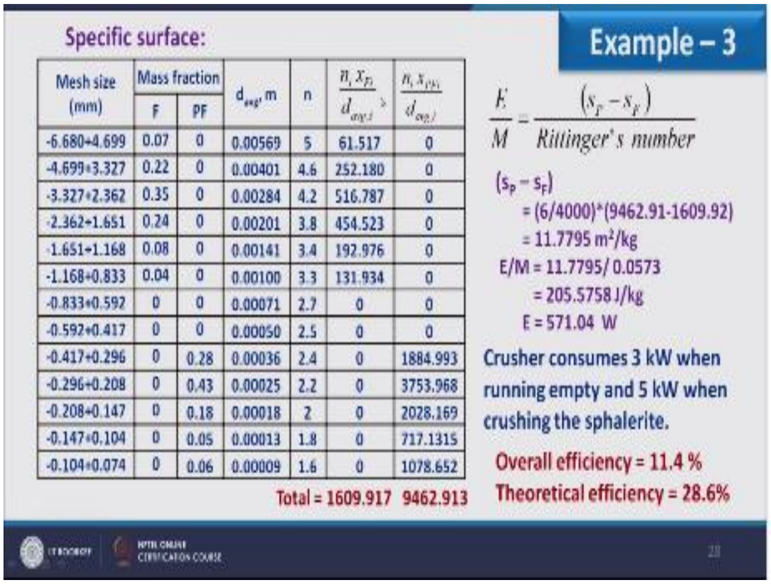

And these are crusher consumes 3kw when running empty and 5kw when crushing the sphalerite so you see the value of total 5kw is the total consumption of energy and 5 - 3 that is 2kw is used for creating of new surface so overall efficiency would be 11. 4, how we can compute this that 571.04/5000 x100, and similarly theoretical efficiency we have calculated as 571.04/2000 x 100 so that comes as 28.6%, so in this example we have used the Rittinger's number and specific surface of feed as well as product.

So that is all for example 3, now I am having example 4. In this example a grinder with 10% efficiency is used to crush.

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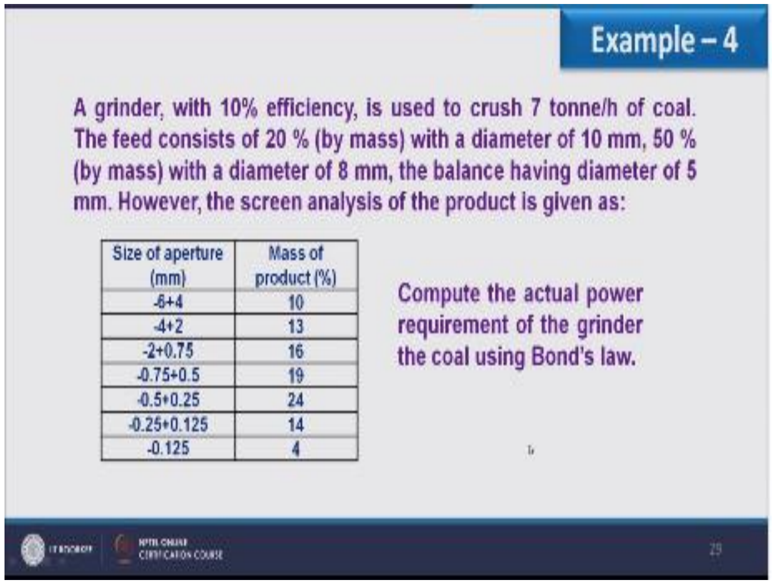

7 ton per hour of coal, the feed consists of 20% by mass with diameter of 10mm, 50% by mass with diameter of 8mm, and balance having the diameter of 5mm. However the screen analysis of the product is given in this table, what we have to compute is actual power consumption of the grinder using Bond’s law, so here you see the efficiency of grinding is given to us we have to calculate actual power consumption, so as far as.

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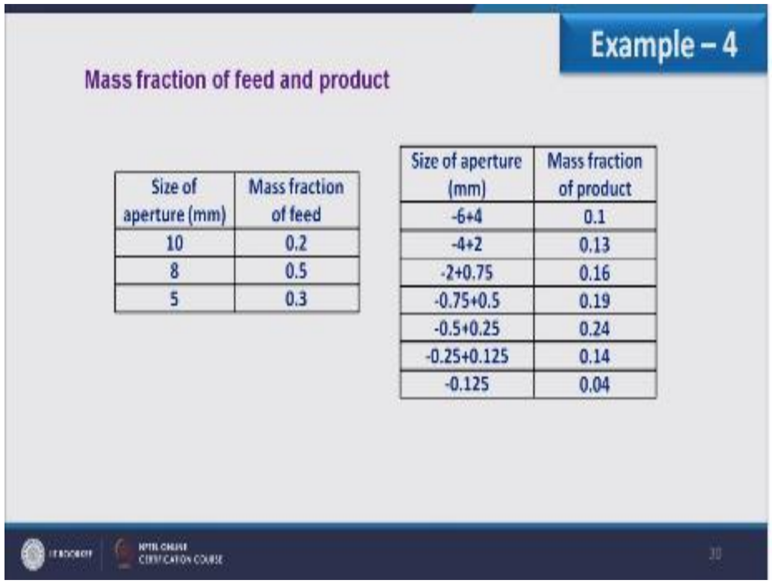

Size of aperture (mm)	Mass fraction of feed
10	0.2
8	0.5
5	0.3

Size of aperture (mm)	Mass fraction of product
-6+4	0.1
-4+2	0.13
-2+0.75	0.16
-0.75+0.5	0.19
-0.5+0.25	0.24
-0.25+0.125	0.14
-0.125	0.04

Data is concerned we can tabulate the data like mass fraction of feed and product, if you see the feed having 20% of 10 mm size, 50 mm of 8 mm size and rest 30 mm of 5 mm size and this is the distribution for product, we have to use the data given over here for feed as well as product to compute the energy consumption using Bond's law. When we apply the Bond's law, this is the expression for Bond's law we have to compute d_{pb} as well as.

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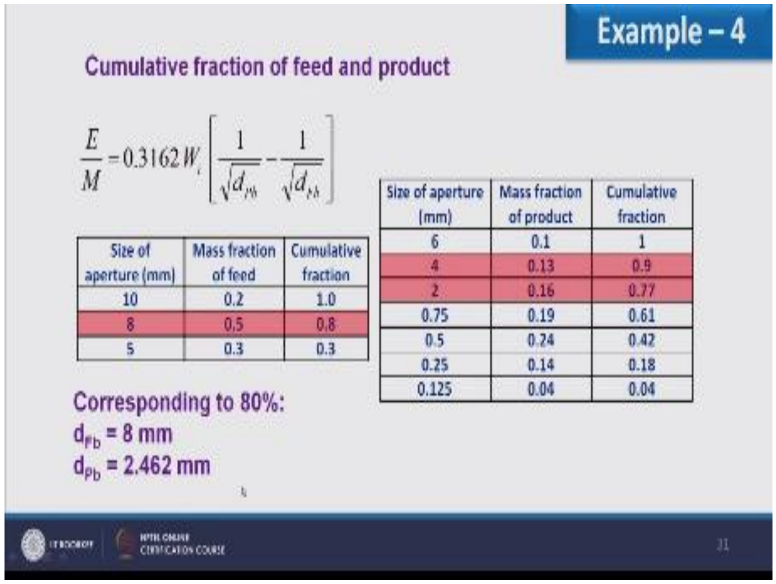

$d_{fb,}$ d_{fb} is the size correspond to 80% in feed so accordingly d_{pb} would be the size corresponding to 80% in product so if we see the mass fraction of feed over here that is 20.5 and 3 first of fall we have to make the cumulative of this so corresponding to 80% the value of diameter or aperture is given as 8 mm so that we can use directly over here, however for product these are the fractions we are given, first of fall we have to make the cumulative of it and you understand when we make the cumulative from bottom.

We use all minus signs of the aperture so in this product analysis we will lie somewhere here as far as 80% is concerned therefore the d_{pb} value will lie between 4 and 2. If we make the interpolation in between these two we can get d_{pb} value as 2.462mm, further the feed as coal is give to us and we have been asked to calculate using Bond's law so work index is required for this purpose, we can refer this table.

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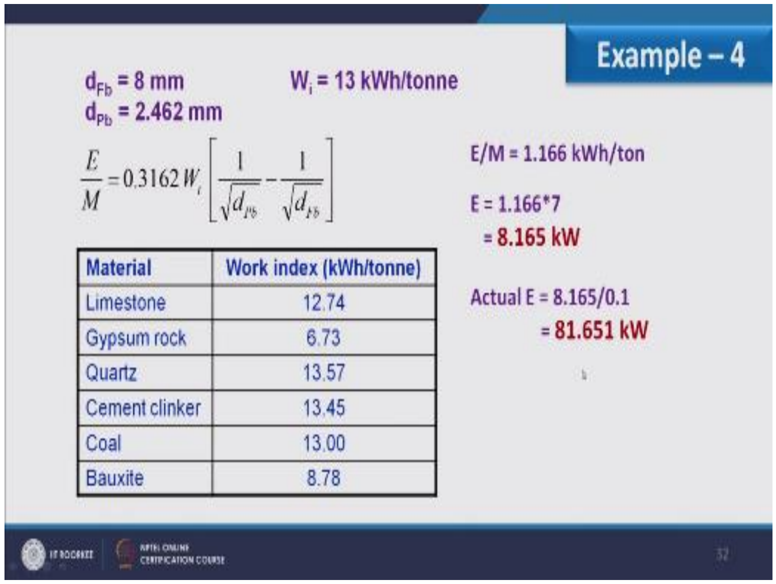

Where work index corresponding to coal is given as 13 kWh/ton, so using work index value d_{Fb} and d_{Pb} value we can calculate the power consumption using Bond's law and which comes out as E/M=1.166kWh/ton. Total feed which is entering to the crusher is 7 so that we can multiply with this so E that is power consumption is coming out as 1.166*7 which gives the value 8.165 kW. For this particular problem the crusher is having 10% efficiency so actual energy consumption would be 8.165/0.1 so 81.561kW is the energy consumption for this particular example.

So in this slide we have considered fifth example and this example goes as.

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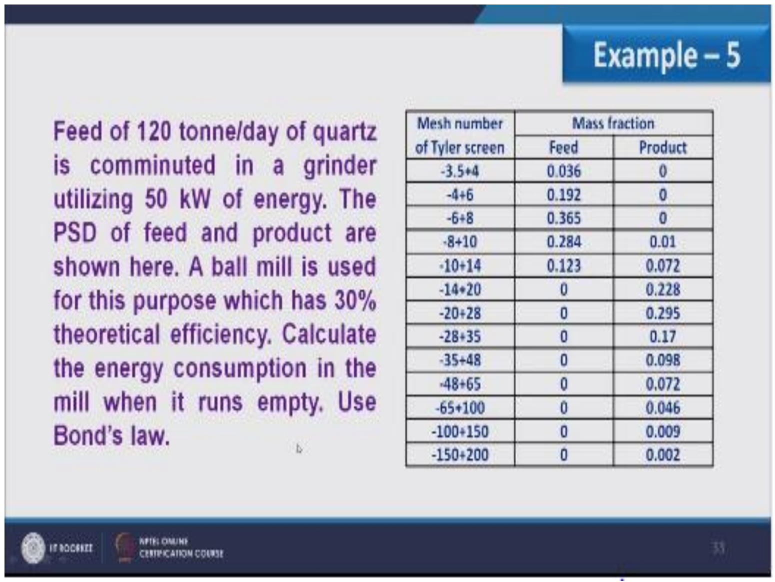

Mesh number of Tyler screen	Mass fraction Feed	Mass fraction Product
-3.5+4	0.036	0
-4+6	0.192	0
-6+8	0.365	0
-8+10	0.284	0.01
-10+14	0.123	0.072
-14+20	0	0.228
-20+28	0	0.295
-28+35	0	0.17
-35+48	0	0.098
-48+65	0	0.072
-65+100	0	0.046
-100+150	0	0.009
-150+200	0	0.002

Feed of 120 tons/day of quartz is comminuted in a grinder which utilizes 50kW of energy. The particle size distribution of feed as well as product are shown here, a ball mill is used for this purpose which has 30% theoretical efficiency. So total energy consumption of 50 kW is given to us and theoretical efficiency of 30 kW is known for ball mill, what we have to calculate is the energy consumption in the mill when it runs empty. So to calculate this again we have to calculate the power consumption for crushing the material and using expression of theoretical efficiency we can calculate the energy consumption while running the mill empty.

So in this problem we have to use Bond's law, so the data which are given to us that is for feed distribution.

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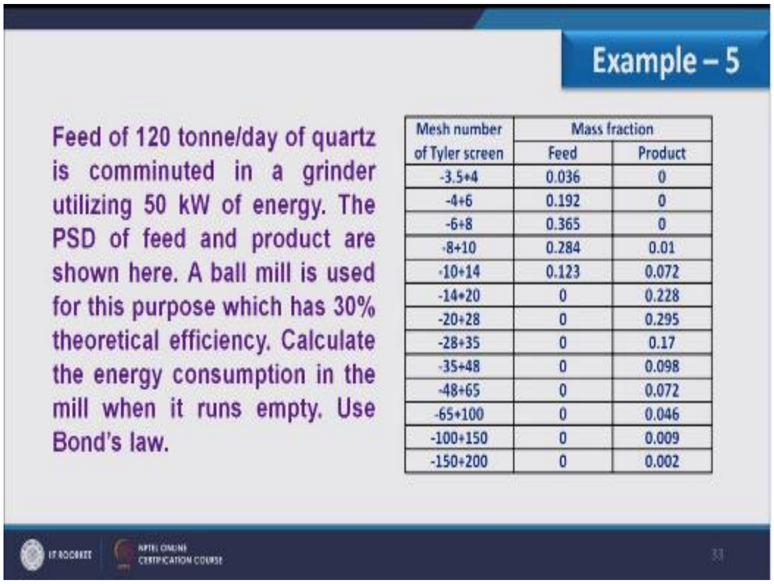
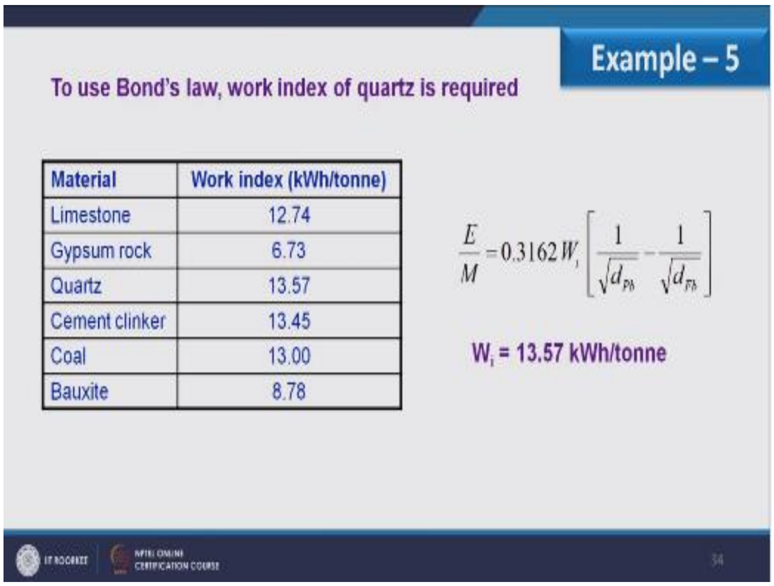


Mesh number of Tyler screen	Mass fraction	
	Feed	Product
-3.5+4	0.036	0
-4+6	0.192	0
-6+8	0.365	0
-8+10	0.284	0.01
-10+14	0.123	0.072
-14+20	0	0.228
-20+28	0	0.295
-28+35	0	0.17
-35+48	0	0.098
-48+65	0	0.072
-65+100	0	0.046
-100+150	0	0.009
-150+200	0	0.002

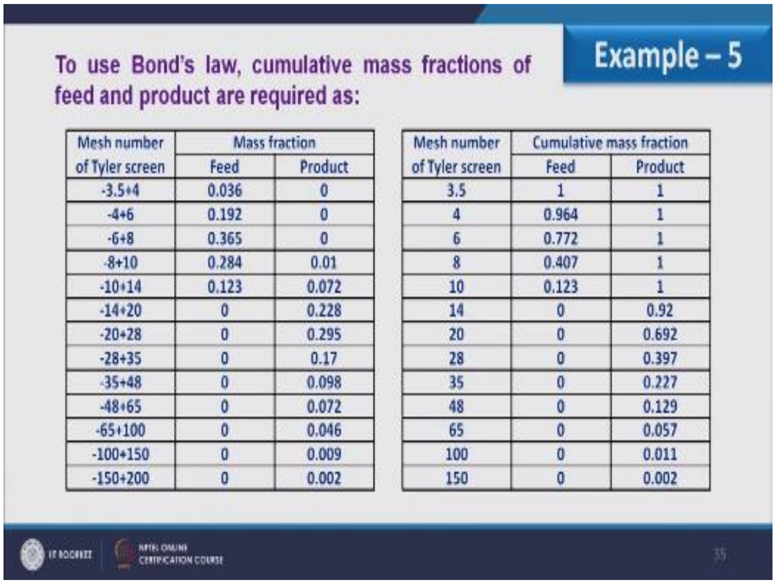
As well as product distribution and here if you see the first column of this, here we are given mesh number of Tyler screens and here mesh number are given to us not the opening of aperture, so let us start solving this problem.

(Refer Slide Time: 20:34)



To use Bond's law work index of quartz is required from this table we can see the value of work index of quartz that is 13.57 kWh/ton, and this is the expression of Bond's law where we have to compute diameter where 80% product is passed through the screen and here we have to calculate diameter where 80% of feed is passed through the screen. So here to use Bond's law cumulative mass fraction of feed and product are required to calculate the sizes.

(Refer Slide Time: 21:10)



Example – 5

To use Bond's law, cumulative mass fractions of feed and product are required as:

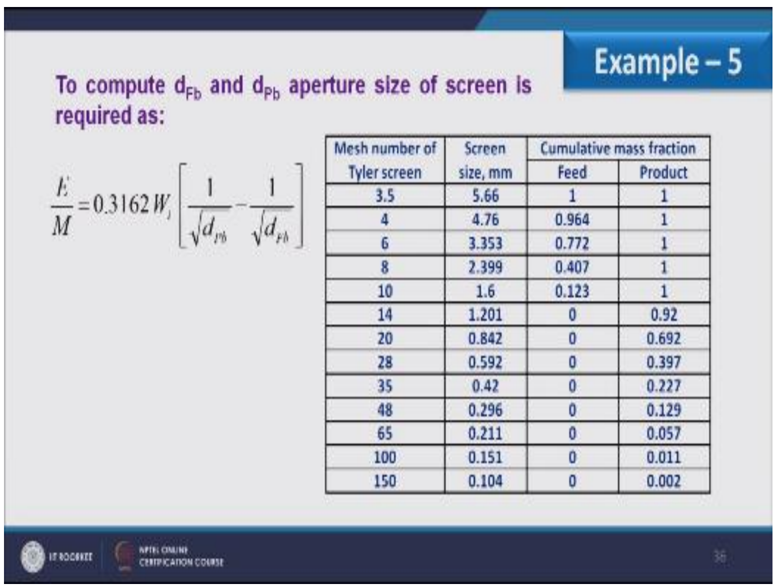
Mesh number of Tyler screen	Mass fraction	
	Feed	Product
-3.5+4	0.036	0
-4+6	0.192	0
-6+8	0.365	0
-8+10	0.284	0.01
-10+14	0.123	0.072
-14+20	0	0.228
-20+28	0	0.295
-28+35	0	0.17
-35+48	0	0.098
-48+65	0	0.072
-65+100	0	0.046
-100+150	0	0.009
-150+200	0	0.002

Mesh number of Tyler screen	Cumulative mass fraction	
	Feed	Product
3.5	1	1
4	0.964	1
6	0.772	1
8	0.407	1
10	0.123	1
14	0	0.92
20	0	0.692
28	0	0.397
35	0	0.227
48	0	0.129
65	0	0.057
100	0	0.011
150	0	0.002

Corresponding to 80%, for this purpose we do the cumulative and if you see we have done the cumulative from bottom. This table is basically the initial table where feed and product retained on each screen are given and in this table we have given the cumulative data, cumulative we have done from bottom so obviously the mesh number of negative screen are shown as we have shown the cumulative from bottom we are showing the screen with negative signs over here and the concept behind this I guess you understand that, that we have already discussed. So this is the cumulative mass fraction for feed as well as product.

Now what is the problem with this data, that here we are given the mesh number however correspond to it, corresponding to 80% we have to know the aperture size. So corresponding to these mesh number.

(Refer Slide Time: 22:17)

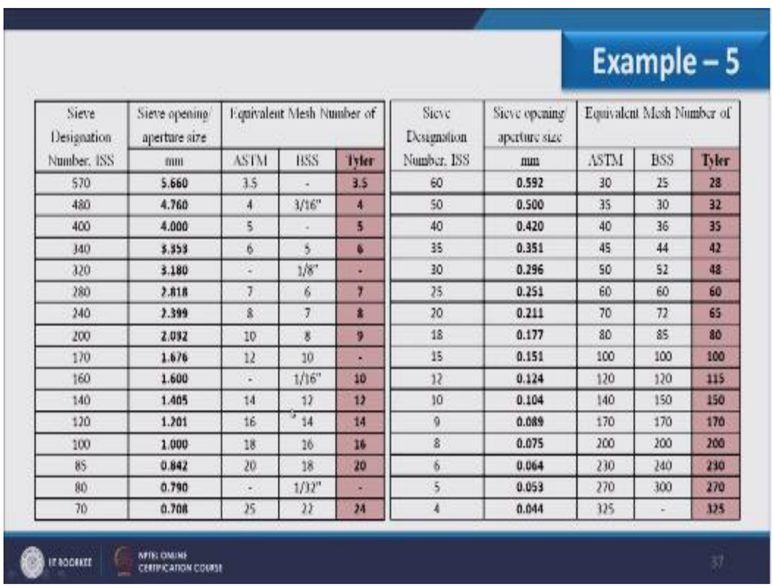


$$\frac{E}{M} = 0.3162\, W_i \left[\frac{1}{\sqrt{d_{Pb}}} - \frac{1}{\sqrt{d_{Fb}}} \right]$$

Mesh number of Tyler screen	Screen size, mm	Cumulative mass fraction	
		Feed	Product
3.5	5.66	1	1
4	4.76	0.964	1
6	3.353	0.772	1
8	2.399	0.407	1
10	1.6	0.123	1
14	1.201	0	0.92
20	0.842	0	0.692
28	0.592	0	0.397
35	0.42	0	0.227
48	0.296	0	0.129
65	0.211	0	0.057
100	0.151	0	0.011
150	0.104	0	0.002

For Tyler screen we should know the aperture of screens, so if you see in this table the mesh number of Tyler screens are given and corresponding value of screen size are also given, so from where I can note down these value for this purpose I have to refer the sieve chart which is the standard chart.

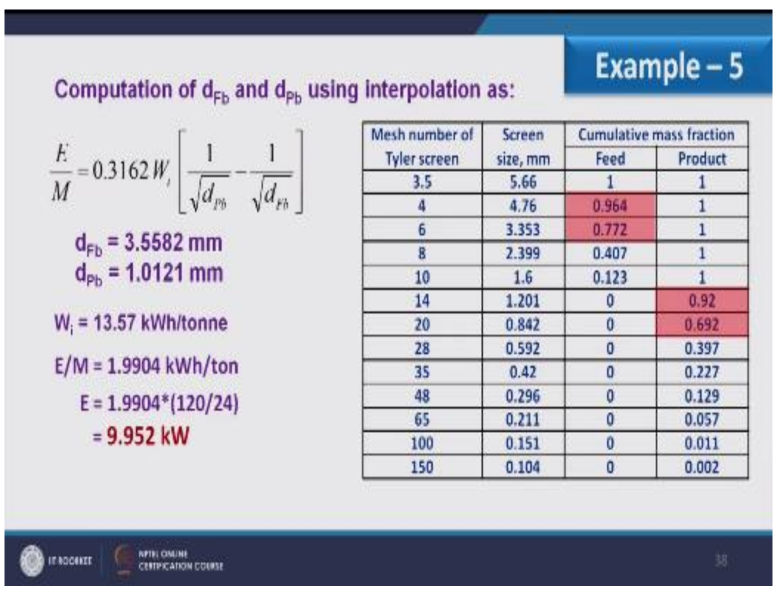
(Refer Slide Time: 22:41)



Sieve Designation Number, ISS	Sieve opening/ aperture size mm	Equivalent Mesh Number of ASTM	BSS	Tyler	Sieve Designation Number, ISS	Sieve opening/ aperture size mm	Equivalent Mesh Number of ASTM	BSS	Tyler
570	**5.660**	3.5	-	**3.5**	60	**0.592**	30	25	**28**
480	**4.760**	4	3/16"	**4**	50	**0.500**	35	30	**32**
400	**4.000**	5	-	**5**	40	**0.420**	40	36	**35**
340	**3.353**	6	5	**6**	35	**0.351**	45	44	**42**
320	**3.180**	-	1/8"	**-**	30	**0.296**	50	52	**48**
280	**2.818**	7	6	**7**	25	**0.251**	60	60	**60**
240	**2.399**	8	7	**8**	20	**0.211**	70	72	**65**
200	**2.032**	10	8	**9**	18	**0.177**	80	85	**80**
170	**1.676**	12	10	**-**	15	**0.151**	100	100	**100**
160	**1.600**	-	1/16"	**10**	12	**0.124**	120	120	**115**
140	**1.405**	14	12	**12**	10	**0.104**	140	150	**150**
120	**1.201**	16	14	**14**	9	**0.089**	170	170	**170**
100	**1.000**	18	16	**16**	8	**0.075**	200	200	**200**
85	**0.842**	20	18	**20**	6	**0.064**	230	240	**230**
80	**0.790**	-	1/32"	**-**	5	**0.053**	270	300	**270**
70	**0.708**	25	22	**24**	4	**0.044**	325	-	**325**

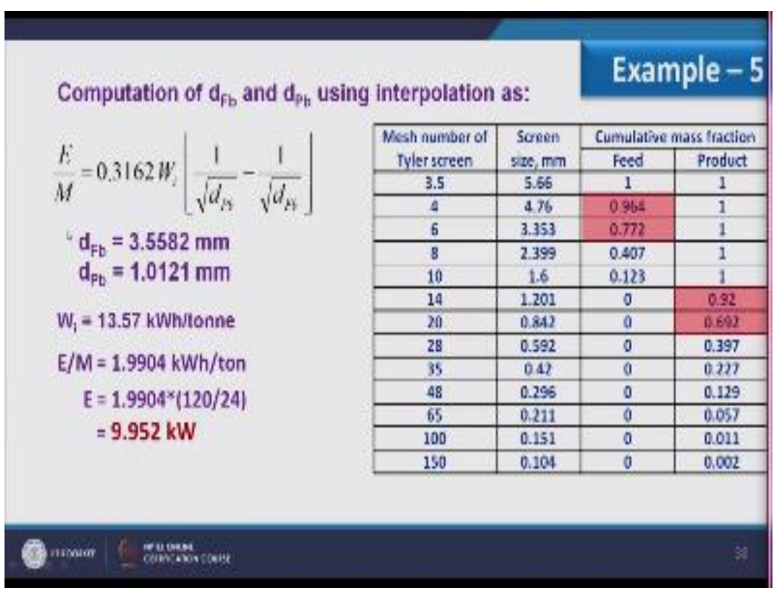
This is the sieve mesh chart where corresponding to Tyler screen the opening are already given, so if I consider Tyler screen of 3.5 mesh I can simply note down aperture as 5.66mm and corresponding to other values also we can note down the aperture size.

(Refer Slide Time: 23:06)



Once I know the aperture size then these value would be noted down over here, now I can calculate the power consumption using Bond's law. Further, to calculate the d_{Fb} value as well as d_{Pb} I have to see where 80% will lie so if I consider feed 80% will lie over here and for product 80% will lie over here, corresponding to 80% we can calculate the screen size by interpolation for feed as well as for product. Once I do this we can have the value as d_{Fb}=3.5582 and d_{Pb}=1.0121. Work index we have already noted down so energy consumption per unit mass is calculated as 1.9904 kWh/ ton, total feed if you remember that is 120 ton per day so obviously 120/24 we will use over here so total energy consumption is 9.952 kW.

(Refer Slide Time: 24:15)



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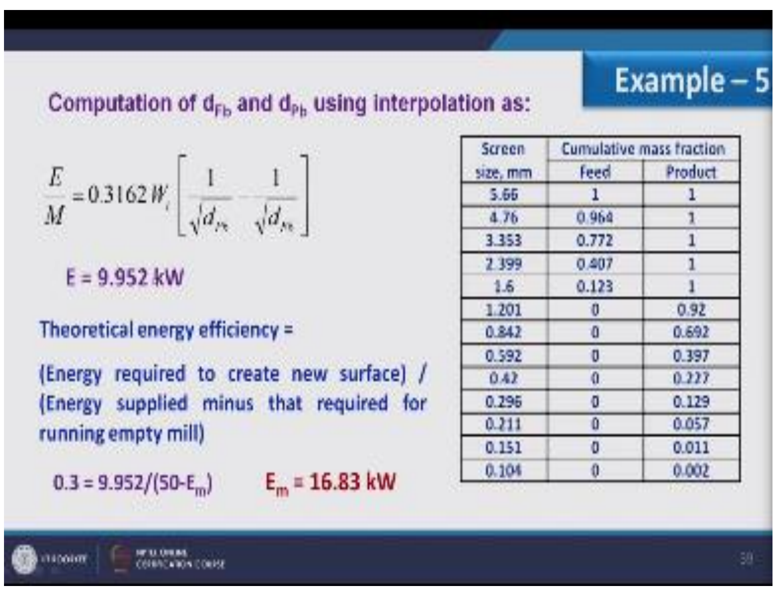

In this problem total energy consumption has come, theoretical energy efficiency is given to us which is defined as energy required to create new surface / energy supplied minus that required for running empty mill, so expression goes as 0.3 = 9.952 that is energy required to create the new surface/ 50 that is total energy consumption – E_m that is energy consumption to run the machine empty, so from here we can calculate value of E_m which comes out as 16.83kW, so that is all for example 5 so summary of this lecture is shown over here where total five examples

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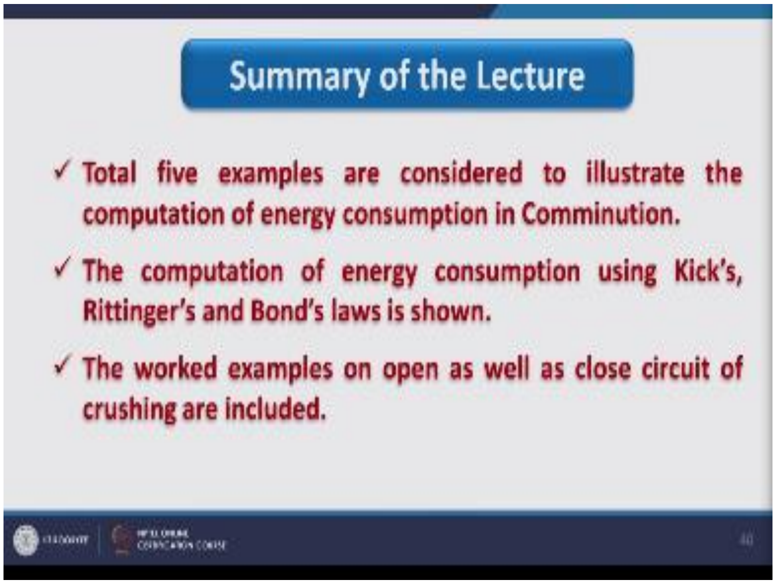

Are considered to illustrate the computation of energy consumption in comminution, so if you have seen this lecture, this lecture having, this lecture was having two part, in first part we have considered two example, in second part we have solved three different example, along with this the computation of energy

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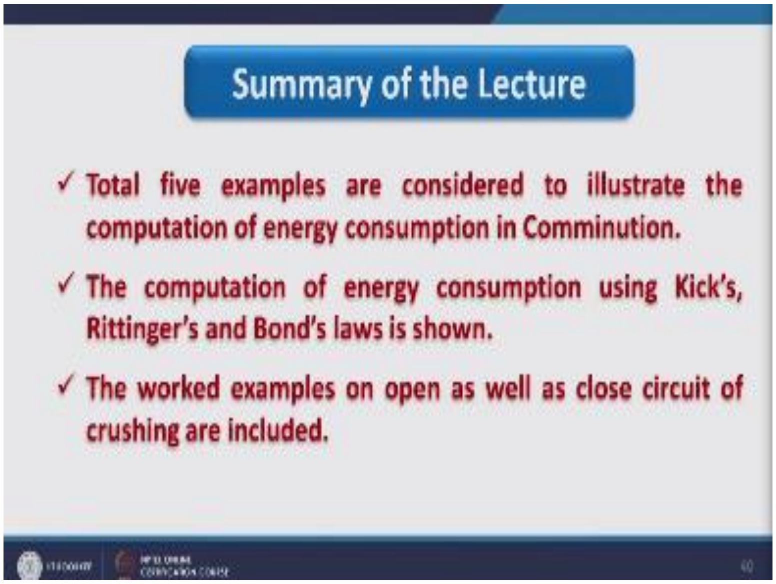

Consumption using Kicks, Rittinger's, and Bonds law is shown in this lecture and the work example on open as well as closed circuit of crushing are included. So here we have discussed five different examples using different comminution laws as well as different mode of operations, so that is all for now, thank you.

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