Problem Of The Month

December 2000—Screen Size Probability Plots From Pulverized Data

Large size particles are pulverized or crushed into smaller particles by rod mills, ball mills, hammer mills, ring-rolls, ball-race mills, and other brute force operations such as grizzly crushers. The pulverized materials are used for coal fired boilers, aggregate plants, powered metals plants, and chemical plants around the world as a first step for reducing materials to the proper sizes for subsequent use.

The principles of pulverization involve impact, attrition, and crushing and one or more of the principles are used in each type of equipment. Energy required for the operation depends upon hardness of the material, friability of the material, and fineness desired. Rittinger's law says "The work to produce material of a given size from a large size is proportioned to the new surface produced". Kick's law says "The energy required to effect crushing or pulverizing is proportional to the volume reduction of the particle". Rittinger's law is probably more accurate than Kick's law.

Large particles when crushed do not give two equal sized part—they give two smaller size parts plus many little particles. The size distribution from pulverization is described by placing the crushed materials onto vibrating screens to segregate the sizes. Typical mesh sizes are shown in the following table:

Standard Screen Sizes					
U.S. Standard Sieve			W.S. Tyler Sieve		
Mesh	Inches	Millimeters	Mesh	Inches	Millimeters
20	0.033	0.84	20	0.033	0.83
30	0.023	0.59	28	0.023	0.59
40	0.0165	0.42	35	0.016	0.42
50	0.0117	0.30	48	0.0116	0.30
60	0.0098	0.25	60	0.0097	0.25
100	0.0058	0.149	100	0.0058	0.15
140	0.0041	0.105	150	0.0041	0.10
200	0.0029	0.074	200	0.0029	0.074
325	0.0017	0.044	325	0.0017	0.043

ASTM-E1 lists typical screen sizes as 80, 100, 120, 140, 170, 200, 230, 270, 325, 400.

The vibrating screens at usually stacked with coarse screens on top and fine screens on the bottom. Mixtures of crushed particles are place on the top screen and descend by gravity/vibrations. When the screening test is over, the product retained by a specified screen size is calculated and often reported as a percent of the total charge weight to the top screen.

Most graphical plots show screen size by percent of total weight and frequently the data plots are curved when plotted on uniformly divided graph paper. Interpretation of curved lines is a little difficult. A better way to interpret the results is to convert the data into probability plot using WinSMITH Weibull **software. The method uses the Probit method #2 described in** The New Weibull Handbook**.**

The Problem

Consider the following screen data for pulverized coal:

- 99.5% of the material will pass through a 50 mesh screen,
- 96.5% of the material will pass through a 100 mesh screen, and
- 80.0% will pass through a 200 mesh screen.

This is the same as saying

- 0.5% of the material is held on a 50 mesh screen,
- 3% of the material is held on a 100 mesh screen, and
- 16.5% of the material is held on a 200 mesh screen.

Probability plots represent cumulative quantities versus screen size. The cumulative data from above is

- 0.5% will be 50 mesh screen or coarser,
- 3.5% (0.5% + 3% = 3.5%) will be 100 mesh or coarser, and
- 20% (0.5% + 3% + 16.5% = 20%) of the material will be 200 mesh or coarser.

Data input for WinSMITH Weibull (**using an X-datum and Y-percentage**) requires

1) clicking on the icon for “Method/Input” (bottom row, third from the left) and
2) selecting the icon for“**Probit 2**” (bottom row, seven from the left).

The data is correctly input as

(screen size)*(cumulative affected quantity)*(quantity sampled).

The above coal example is shown below in column format for easily copying into WinSMITH Weibull from this page:

50*0.5*100
100*3.5*100
200*20*100

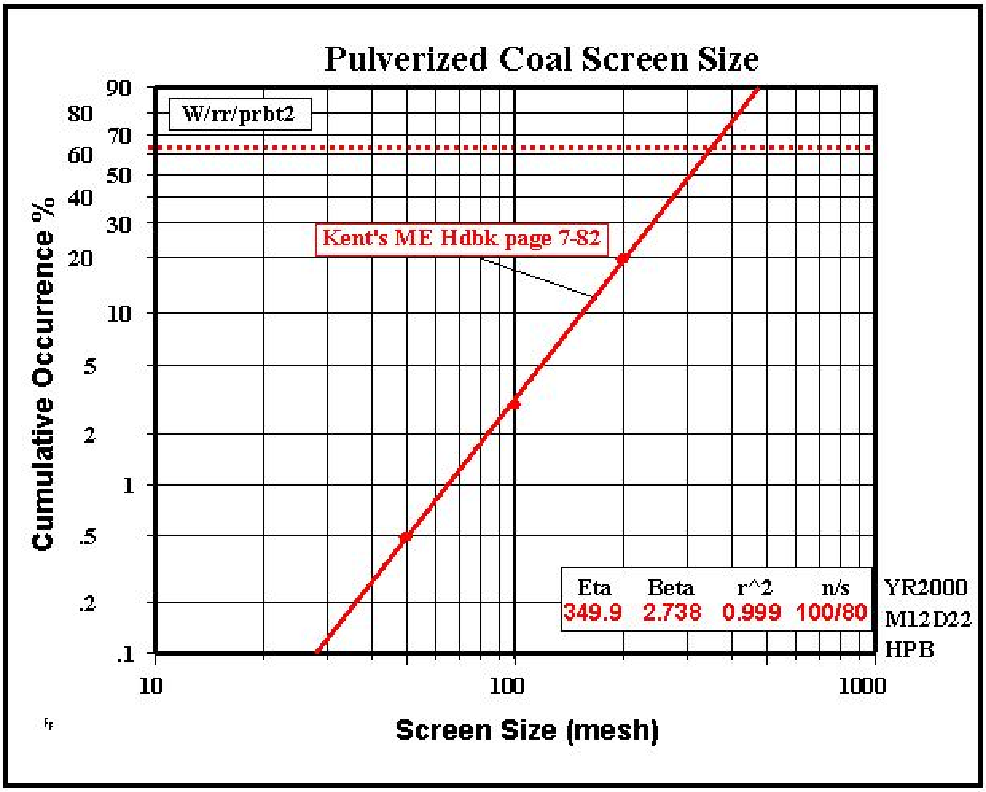
Again, as a reminder, it’s

- screen size (the X-value), then
- cumulative quantity (cumulative percentage), and finally the
- total quantity (if you’re working in percentages, then the total quantity is 100%).

Or (screen size * cumulative quantity * total quantity) as show above in the data file. Please note the data must be in rank order by screen size.

Since the data is represented in % of total weight, the data is easy to input. Did you notice that 80% of the total cumulative information **does not exist** from the sample?

The graph for the three data points is shown below as a Weibull plot.



Based on only three samples of data, the Weibull distribution says the characteristic particle size is ~350 mesh as described by the equation F(size) = 1-e^(size/349.9)^2.738.

Solving for the mesh size, the Weibull equation is (size) = eta*(ln(1/1-F(size)))^(1/beta). For example, if we wanted to know the particle size where 90% of the particles would be of larger screen size, we would calculate (size) = 349.9*(ln(1/(1-0.9)))^(1/2.738) = 474.5 mesh size. The same calculation for where 0.1% of the particles would be of larger screen size is 28.1 mesh size. You can use the "Predict" icon in WinSMITH Weibull to give you the facts from the Weibull plot.

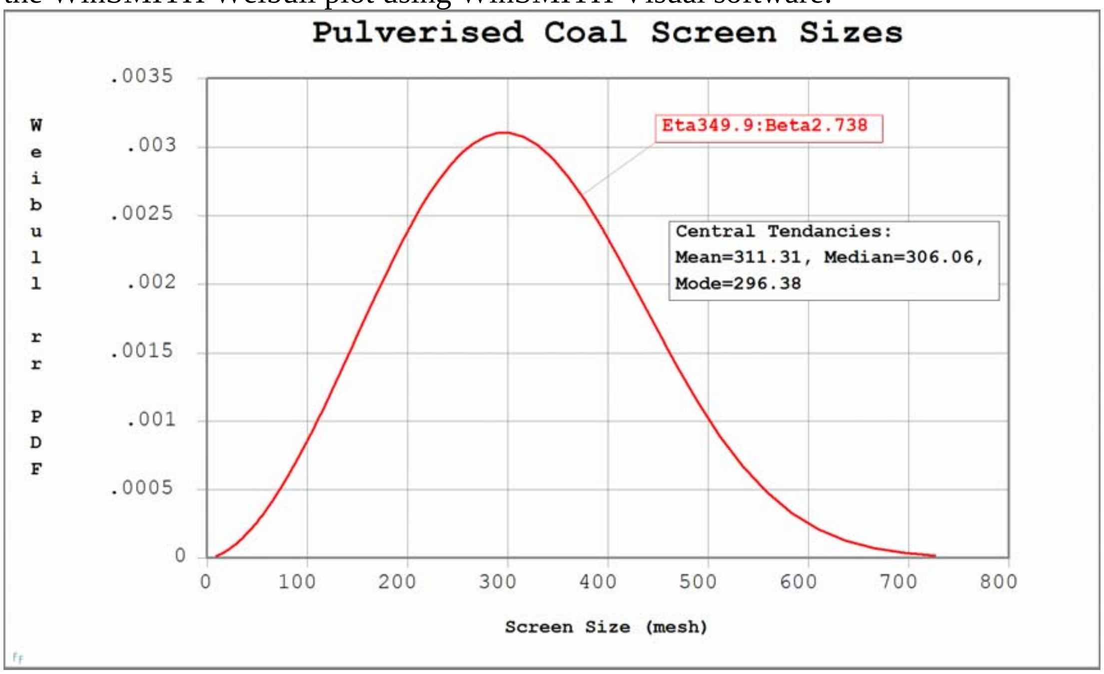
The values shown in the plot give the characteristic mesh size as 349.8 (eta), the shape factor 2.738 (beta) and the coefficient of determination 0.999 (r^2) says this straight line explains ~99.9% of the variation in the data, and for 100 percentage points 80 are suspended data (n/s). How much uncertainty exist in the statistical values?—of course with only three samples, you would expect large variances but some data is better than no data and you can fit confidence limits to the trend line by use of WinSMITH Weibull software.

When engineers have their results explained in straight lines on a X-Y plot, they can see the curve fit and comprehend the data. For engineers the relationship is simple: No cartoon, no comprehension.

Demonstration versions of WinSMITH Weibull are available at no cost by mouse click here.

The authentic WinSMITH Weibull data file for use with the demonstration version or authentic version is also available by mouse click here which can be imported into the demonstration software without randomizing the data (as occurs when you input data into the demo software). This COAL.W (2.3K) is a ZIP file COAL.ZIP so it very small (0.8K).

In case you'd like to see the probability density function (PDF), this plot was made from the WinSMITH Weibull plot using WinSMITH Visual software:



Notice how the plot has a slightly longer tail to the right. Also notice the variability in the typical central tendencies—this is why use of the Weibull characteristic value eta is so handy for describing the skewed metric with a single value.

You can download a copy of this December 2000 file as a PDF file by clicking here.

Refer to the caveats on the Problems Of The Month Page about the limitations of the solutions. Maybe you have a better idea on how to solve the problem. Maybe you'll find where I screwed-up the solution and you can point out my errors as you check my calculations. Email your comments, criticisms, and corrections to Paul Barringer. Return to top of page by clicking here.

Technical tools are only interesting toys for engineers until results are converted into a business solution involving money and time. Complete your analysis with a

bottom line converted into $'s and time so you have answers that will interest your management team!.

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