Process Reliability

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Abstract: Daily production data from a production plant is used as a top down model in a Weibull probability plot to identify the reliability of a production process. Failures of the process are defined, identified, and quantified. Production losses for different categories are calculated. Lack of process performance is related to six-sigma concepts and the details are quantified in financial values for top management attention about the cost of unreliability.

Weibull Analysis For Process Data-
Traditional Weibull analysis is a bottom-up approach, often in a data-starved environment, with only a few age-to-failure data points for components. The component analysis tells about Weibull failure modes (beta values) and characteristic life (eta). [Abernethy 2000]

Process Weibull analysis is a top-down approach in a data-rich environment. Every production facility jealously gathers daily output of prime product as proprietary information because daily output is a precursor for money. Process Weibull analysis tells about reliability of the moneymaking process including consistency of production output (beta values). Process Weibull analysis also provides characteristic output values (eta), which give single point estimate for demonstrated daily output from the process. Gaps between the Weibull demonstrated production line and the actual data points, following loss of process reliability, quantify production losses from reliability problems.

Gaps between nameplate ratings of the process and the demonstrated production line defines an additional category of production losses related to efficiency and utilization, which are management driven issues. The nameplate line Weibull slope beta relates to 6-sigma concepts for excellence if the process is configured to perform to practical level of perfection. If the process is configured to perform haphazardly, then the nameplate beta can reflect poor performance with a single beta value. All losses (reliability losses plus efficiency/utilization losses) quantify the hidden factory which cost money, is nonproductive, and must be eliminated as explained in Chapter 8, Section 9 of Abernethy.

Most production data is a Weibull distribution based on plotting the data on a Weibull probability plot and observing the data makes a straight line. This is shown in a pragmatic manner by plotting the data on different probability papers and observing goodness of fit. Most Weibull demonstrated production lines have beta slopes larger than 5, which results in long tailed distributions toward the left-hand direction (the undesirable direction of lower production output). Most production data runs into a “wall” at larger outputs which is fixed by the “bricks and mortar” of the system. Tailed data conditions plus a maximum output-wall result in inferior predictive abilities using normal statistics to model the output from most processes.

Weibull Production Plots And Demonstrated Lines-
Most production process issues are traditionally viewed in a time sequence. Time sequences often suggest simplistic cause and effect drivers while disregarding that many things in production environments have probabilistic drivers. Weibull analysis disconnects the time sequence and plots data in a ranked sequence of production output, which clearly produces a different set of visual patterns for process performance.

Figure 1 shows a process, of only moderate capability, with a demonstrated production beta slope = 5.5. The upper right hand cusp on the Weibull demonstrated line represents failure of the process and defines reliability of the process = ~91%. Notice two line segments below the cusp, also give special information about how well the process functions. Gaps between the demonstrated Weibull line and the actual data points to the left of the upper right hand cusp are process reliability losses quantified by use of WinSMITH Weibull software utilizing the process reliability menu as a subset of the mixture analysis icon. [Fulton 2001] Days with zero output occur, and they are included in the analysis as two decades smaller than the least reported value so “zeros” can be plotted on the log scale of the Weibull plot. If special causes had not occurred, 99.8% of production output would vary between 284 tons/day and 1421 tons/day as a normal response curve—unfortunately in production, gaps happen!

Weibull Nameplate Lines-
Beta slope = 12.5 for the nameplate line in Figure 2 is defined by benchmark of similar processes, judgment, or experience—in this case the beta value is typical of 4th quartile producers with inferior

processes not optimized to reduce variability (but viewed by the process owners as their own beautiful children who make no errors). Notice the nameplate line cuts the demonstrated line at an altitude of the greatest data point (which often lies on the demonstrated trend line). WinSMITH Weibull also quantifies gaps between the nameplate line and the demonstrated line. The loss gap between the nameplate and demonstrated lines are motivated by different reasons than gaps between the demonstrated line and the actual data points. Also, notice the Pareto distribution of losses in Figure 2 has substantially altered the work priorities as shown by the priority bubbles over the losses.

Without nameplate lines, all losses appear as reliability issues associated with special causes; and other opportunities for improvements are never identified. When the nameplate line is identified, additional losses are quantified and more complete Pareto lists are established. If the demonstrated beta slope is flat (say less than 20), as often occurs with inferior operation production facilities, the larger losses are often efficiency and utilization problems due to common causes. Reliability engineers often solve special cause losses whereas six-sigma experts often solve common cause problems.

Well-designed and well-run operations with steep Weibull betas for demonstrated production lines result in reliability problems standing out as sore thumbs. Priorities for problem solving is not always easy to predict before the Weibull analysis is completed—so this makes the process reliability analysis fact driven rather than opinion driven. For mergers and acquisition efforts, the Weibull process reliability analysis technique is a quick and easy assessment of competing processes with fact driven information to supplement opinions and provide a reality check in the heat of a M&A battle.

Desirable Weibull Slopes-

Flat beta slopes are bad, steep betas are good for production Weibull plots. A rule of thumb for beta values flatter than 100 is simple: When beta is doubled, losses are roughly cut in half. Larger improvements occur by improving beta from 4 to 8 than from 50 to 100! Demonstrated beta values of ~100 represent world-class 6-sigma type operations carefully designed for minimum variation in process output. Demonstrated betas of 3-5 represent the bottom of the barrel. Few operations have betas larger than 200. More guidance on beta values are given in the hyperlink referenced below.

Warranty expenses, recalls, and other significant emotional events get attention in a large corporation because the details are quantified. Seldom are process losses identified on one-side of one-piece of paper as occurs with a Weibull process reliability analysis. Single sheets of paper get management's attention in dramatic fashion in a simple manner when production losses are multiplied by gross margin $'s to convert lost production into money---managers clearly understand money and time, so losses reported in $/year are attention getters! For example, Figure 2 shows significant production losses in three different categories. If gross margin/ton = $200, then the total losses are $18.5 million/yr of which $16.6 million/yr are in the category of efficiency and utilization losses—this magnitude of loss/yr will catch every manager's eye!

Process failures often have on-going greater losses than warranty expenses and other reliability issues. The high cost demands attacking the enemy within which functions as the silent saboteur ripping money from profits by hidden factories. If a one-year payback is required for justifying expenditures, remember the quantification of process losses gives a strong clue for the affordable amounts to spend for correcting losses by permanently removing the hidden factory. From the ~400-500 processes studied by Weibull process reliability analysis only one single operation has warranted a "Do Not Touch" designation—thus opportunities for improvement are great. Reduce process variability to reduce lost money and increase stockholder wealth--process reliability issues are all about money.

Further Reading-

For further reading on the subject, consult the May 2001 **Problem of the Month** at http://www.barringer1.com/may01prb.htm. Follow the hyperlinks to other pages and topics of interest about process reliability issues.

References:

Abernethy, Dr. Robert B., **The New Weibull Handbook**, 4th edition, published by the author who can be contacted at Weibull@worldnet.att.net, 2000.

Fulton, Wes, **WinSMITH Weibull**, version 4.0F software, published by the author who can be contacted at wes@weibullnews.com, 2001.

About the author:

Barringer is a reliability consultant with more than thirty-five years of engineering and manufacturing experience in design, production, quality, maintenance, and reliability of technical products from both a technical and bottom-line aspects of operating a business. He is author of training courses: **Reliability Engineering Principles, Process Reliability,** and **Life Cycle Cost**. He is also a registered Professional Engineer in Texas and named as inventor in six U.S.A. Patents and numerous foreign patents. He is a contributor to **The New Weibull Handbook**, a reliability text, published by Dr. Robert B. Abernethy. His education includes a MS and BS in Mechanical Engineering from North Carolina State University. Contact him by phone at 281-852-6810 or by email at hpaul@barringer1.com .

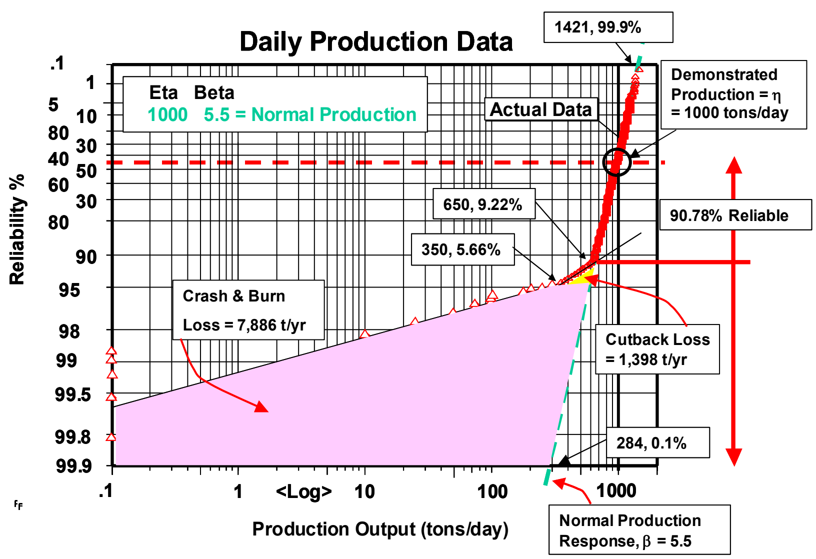

Figure 1

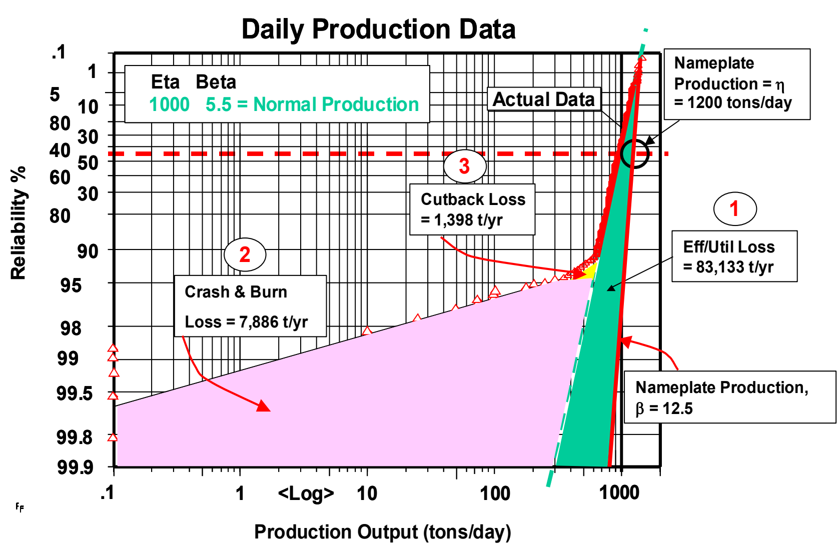

Figure 2