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# JUDGING THE COMPLIANCE OF A DESIGN TO A SERVICE LIFE GOAL FROM LIFE TEST DATA OBTAINED IN AN ACCELERATED LIFE TEST AT STRESS LEVEL GREATER THAN THE STRESS WHICH THE SAME DESIGN WOULD EXPERIENCE IN SERVICE

## INTRODUCTION

In so many testing situations, where we are in a hurry to get product durability verification, we subject the product to a more severe test than what it would encounter in service. This is what is known as accelerated testing. The serious question this type of testing program raises may be expressed by the following quotation: "When you have tested a product under conditions more severe than service conditions, how do you judge whether or not it would be acceptable in service?" This is indeed a most critical question, which must be answered if we are to get anywhere by using accelerated testing techniques. As a matter of fact, it is an unanswerable question unless we know how much the durability life of the product is actually reduced by a more severe service load or stress. What is entails is an entire advance experimental program in which we establish the mathematical formula for what has become known as *"S-N Diagram"*. Without this mathematical relation, the so-called *"S-N Equation"*, we cannot ever truly judge a product's accelerated test results as to their acceptability for any intended service life. The most common type of *"S-N Equation"* which has been successfully employed over the years is what is known as an ***'INVERSE POWER FUNCTION'***, in which we express *Life* as being equal to

$$\frac{CONSTANT}{(STRESS)^m}$$

i.e., *Life* varies as the reciprocal of the $m^{th}$ power of the *Stress*. In this bulletin we shall show how to judge accelerated life test data by such an inverse power function of stress to predict the corresponding accelerated test life.

## A TYPICAL EXAMPLE OF EVALUATING AN ACCELERATED LIFE TEST

Suppose we are concerned with the durability of a certain new design of a machine component which is required to have a $B_{10}$ of at least 2,000,000 cycles in service at a standard service stress of 100,000 psi. In order to speed up the life test of this new design we subject the component to a stress of 125,000 psi, i.e., we increase the stress by 25%. From past experiments on this type of component and material we have found that the $B_{10}$ life varies inversely as the eighth power of stress. This means that the $B_{10}$ life at 125,000 psi would become divided by the factor $(1.25)^8$, which comes out to be a divisor of 5.96. Thus, in order to be an acceptable design for service, the component must have a $B_{10}$ life of at least 2,000,000/5.96 = 335,570 cycles at the higher stress of 125,000 psi used in the accelerated test. Now, suppose we test a random sample of 10 such components at stress 125,000 psi, with the following test life values, rearranged in numerical order:

401,152 cycles
429,340 cycles
461,678 cycles
490,908 cycles
518,240 cycles
549,200 cycles
581,347 cycles
607,345 cycles
636,901 cycles
668,112 cycles

Plotting these ten life values on Weibull probability paper with ordinates consisting of median ranks, we obtain the following values for the Weibull life parameters:

Weibull Slope = 6.45
Characteristic Life = 572,111 Cycles
Goodness of Fit = .98846
$B_{10}$ Life = 403,575 Cycles
(See Figure 1.)

(**NOTE:** These parameters were obtained from "LEASQ" in DRI's CARS Software Package)

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We are ready to calculate the confidence of meeting the design goal for $B_{10}$ life in the accelerated test by going to DRI's computer program called "GOALCNF" in the CARS Software Package, which is our abbreviation for *Goal Confidence*. The data from the Weibull parameter list which we determined from the accelerated life test data at 125,000 psi is entered into the "GOALCNF" program. The following printout is the result:

CONFIDENCE CALCULATION FOR THE DESIRED RELIABILITY

GOALCNF PROGRAM
QUANTILE LEVEL = .1
$B_Q$ GOAL AT QUANTILE LEVEL = 335570
SAMPLE WEIBULL SLOPE = 6.45
SAMPLE $B_Q$ LIFE = 403575
SAMPLE SIZE AT $B_Q$ LIFE =10
CONFIDENCE OF MEETING $B_Q$ GOAL = **.993788**
END

(The above answer came from the GOALCNF Program)

Thus, from the accelerated test results we conclude that the design will live up to the required $B_{10}$ life in service with a confidence of 99.4% (rounded to the nearest tenth of a percent).

## CONCLUSION

We have illustrated the straightforward and scientific way of judging accelerated life tests at stress levels above service stress by making a Weibull plot of the life test data in the accelerated test, and then judging these results with reference to the reduced life required due to increased stress by using the "GOALCNF" program with the accelerated test goal instead of the actual service life goal. The accelerated test goal can always be determined from the service goal when we have background data about the nature of the S-N Diagram and its S-N Exponent.

FIGURE 1
WEIBULL PLOT OF ACCELERATED LIFE TEST DATA