DECREASE PRODUCT RELIABILITY VALIDATION COSTS BY NONCONVENTIONAL TESTS

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ABSTRACT: Efficiency tests to check the reliability involves their organization so as to achieve the required results as well as lower costs. This can be achieved by reducing the number of products that are defective in these tests - tests even without fail. A further reduction of the sample used in the tests without failures is obtaining by extending the test time, but preserving terms of reliability required. This required in advance of a full test for one-parameter model Weibull -1P be applicable. Research conducted shows that when test time is extended, the number of products tested without is greatly reduced, which demonstrates the benefits of applying the nonconventional methods to validate the reliability of products.
KEY WORDS: reliability modeling, confiance level, complete test, failure, Weibull law.

3 INTRODUCTION

Product reliability has become lately a performance indicator, even a marketing feature: potential buyers are interested, in addition to the technical features of the product - constructive and functional, also on the overall cost of ownership of the product, where an important share is the maintenance cost, which is in direct relationship with the product reliability.

As a result, under the delivery contracts one of its important components is the demonstration of the level of reliability of the product (validation reliability).

For efficiency of the reliability of validation tests, it must be organized so as to obtain the required results (tests effectively) with the lowest costs.

Cost reduction validation test reliability can not be achieved by conventional methods, so it is necessary that the tests apply nonconventional methods by which this goal is achieved.

Reduce costs of validation test reliability can be achieved either by reducing the work - this way means shortening the time of trial and this can be achieved by practicing accelerated testing (severe regimes test) or by reducing the number of products that are defective in these tests - path that assumes the practice tests without failures.

Given that the products to be tested are expensive, most effective way is the second - attempts without fail. Therefore, in the present paper will be presented research done in order to improve the reliability of the validation test by practicing tests without failures.

4 RESEARCH UNDERTAKEN

It is envisaged that attempts to validate the reliability of running in terms of reliability based on specifying a number of elements:

- *The subject of the validation test reliability*: part or system;
- *Reliability objective R_0*: reliability required after a certain time for the product;
- *Confidence level* α: the probability that the reliability estimate to be true (1-α: the risk that the estimate is not true);
- *Failure criterion*: define possible defects and failure modes;
- *Mission Profile*: how to test, detailed in the test procedure.

The design of the test program without failure requires determining the number of products to be tested, and efficient test necessitates exploring the possibility of reducing the number of products, given that fully respected the terms of reliability required.

In this respect, the theoretical investigations were carried further and applied research in this specific case for validation of reliability presented in the end.

Sample size when tested without failure

Since the products were generally very reliable (for reasonable test time on who can afford a firm product development phase, F(t) is quite low) validation test requires large samples and long sufficient to damage the pieces, so as to ensure the required confidence level.

One of the ways that overcome these drawbacks is to practice tests without failures.

The question is to determine the number of products to be tested on predetermined length of time to demonstrate, with a minimum level of trust (or a maximum risk), a minimum level of reliability for the items tested.

For this, will apply binomial law which determines the probability that in the group of size n, k failures occur until such time as the reliability R is set to be demonstrated.

According to the binomial law, if R is the probability of proper operation, F - probability of failure, n - the number of products tested, k - the number of possible failures in the n trials, then the probability of k failures occur is [1]:

$$P_{k,n} = C_n^k F^k R^{n-k} = C_n^k (1-R)^k R^{n-k} = C_n^k F^k (1-F)^{n-k} \quad (1)$$

If after trying over the length of time t of n products were recorded k failures, the level of confidence with which it can be said that the product will meet the reliability target will be:

$$\gamma = 1 - P_{0,n} = 1 - C_n^k (1-R)^k R^{n-k} \quad (2)$$

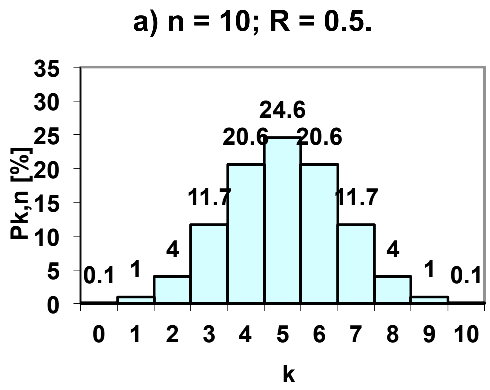
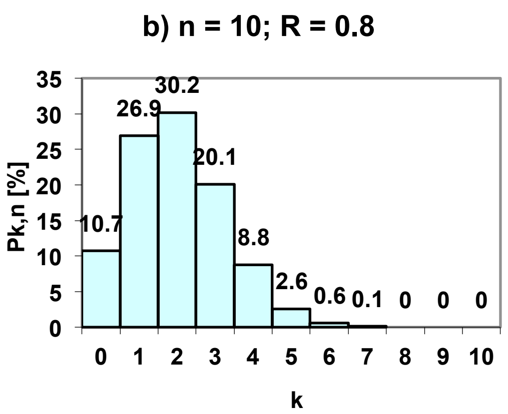


Figure 1. Binomial distributions for n = 10, k = 0, …, 1.

a) R = 0.5; b) R = 0.8



Analyzing previous relationships, is seen as a confidence level α will depend on the reliability R, as illustrated in Fig. 1 (where n = 10, R = 0.5 and 0.8) and on the volume of the sample in track.

In this respect, the theoretical investigations were carried further and have been applied to this research in this specific case for validation of reliability presented in the end.

If after trying n product during a period of time t, there has been no failure, the level of confidence with which it can be said that the product will meet the reliability target will be [2]:

$$\alpha = 1 - P_{0,n} = 1 - R^n \quad (3)$$

and sample volume required is determined by a simple relation:

$$n = \frac{\ln P_{o,n}}{\ln R} = \frac{\ln(1-\alpha)}{\ln R} \quad (4)$$

Analyzing the four previous relationships is evident and can simply demonstrate that only for k = n (full test) or k = 0 (tests without failures) solutions are unique and well-defined relationship between the three order parameters: the (minimum) demonstrated reliability R, the (minimum) α confidence and volume (minimum) of the sample to try n.

Therefore, to validate the reliability, an alternative method for the complete test can only be the test without failures.

Obs. According to relation (4), as the level of reliability to be demonstrated is higher and the degree of confidence is higher, the sample volume subjected to tests without failures will be higher.

Reducing the sample size by extending the time of test

One possibility to reduce the number of products tested n is the prolongation of the test method that provides efficient test because the cost of extending the test are lower than the savings resulting from the reduction in the number of parts tested.

The test duration increasing from t0 to t1, reliability validation test will become of verifying the reliability of R0 at time t0 in the verification of equivalent reliability R1 at time t1 - right Weibull values highlighted in Fig. 2 (where was done linearization function F(t) by double logarithms Weibull law).

But it is necessary to determine the new value R1 of reliability validated by testing. Thus, if the reliability is expressed by a Weibull law, there are relations:

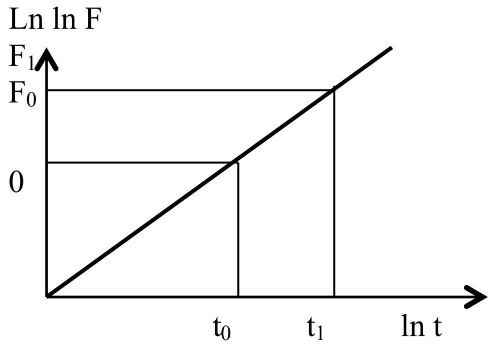


Figure 2. Linearized relationship between the unreliability function and the test time

$$R_0 = e^{-\left(\frac{t_0-\gamma}{\eta}\right)^{\beta}} \quad (5)$$

$$R_1 = e^{-\left(\frac{t_1-\gamma}{\eta}\right)^{\beta}} \quad (6)$$

After logarithms relations, obtained by dividing:

$$\frac{\ln R_1}{\ln R_0} = \left(\frac{t_1}{t_0}\right)^{\beta} \quad (7)$$

from which

$$\ln R_1 = \ln R_0 \cdot \left(\frac{t_1}{t_0}\right)^{\beta} \quad (8)$$

and then, by integration:

$$R_1 = e^{(\ln R_0)\cdot\left(\frac{t_1}{t_0}\right)^{\beta}} \quad (9)$$

It follows that to know the value of R_1 should be known shape parameter β, so we must know the law of reliability [3].

To identify the Weibull law can hold a full test (all products will be failed). This additional number of products will be much lower than that the number which will reduce test volume, and costs occasioned by this additional testing will be outweighed by the financial savings.

Obs. It is recommended that the prolongation of the test should not exceed 30% (generally accepted limit extrapolation for Weibull law) because there are no guarantees that the failure mode (and therefore reliability model) is maintained.

4.1 Case study

It is considered that for a particular product is required next target validation reliabilities: *minimum R_0 = 0.99 after an operation in client t_0 = 1400 hours, for a confidence level guaranteed: α = 80%.*

1. For the tests *without failures* to normal regime, for the duration specified, the sample volume required is:

$$n = \frac{\ln(1-\alpha)}{\ln R} = \frac{\ln 0{,}20}{\ln 0{,}99} = 160 \quad (10)$$

which is a value too high because it requires tracking the 160 products in a real long time in operation (products are not used continuously) for a period of time that depends on the number of stands available:

$$T = n_{st} \cdot t_0 = n_{st} \cdot 1400[ore] \quad (11)$$

2. One possibility to reduce the number of products tested is extension test from t_0 to t_1 and reliability validation test will turn in verifying the reliability R_0 at time t_0 in the verification of equivalent reliability R_1 at the time t_2, according to relation (9) for Weibull model.

But it should be known shape parameter β, so we must identify the law of reliability.

Therefore, some products will be tested to failure (complete test): for example, 9 pieces to be tested (Failed = 9, Suspended = 0), and the results will be obtained from the following table:

Table 1. The failure times for a complete test

No	Failure time [hours]
1	1450
2	1800
3	2100
4	2350
5	2600
6	2850
7	3100
8	3450
9	3600

Identify model-3P Weibull distribution of failure times using special computer software Weibull ++7 (where the University of Pitesti holds educational license) created by the company Reliasoft [4].

Values follows: β = 3.4 (which indicates a phenomenon of wear); η = 2313 hours; g = 517.5 hours (Fig. 3).

It decided to extend the test by 30% (generally accepted limit extrapolation for Weibull law), so t1 = 2000 hours, resulting a new value of reliability will be validated in this case:

$$R_1 = e^{(\ln 0{,}99)\cdot\left(\frac{2000}{1400}\right)^{3{,}4}} = 0{,}96 \quad (12)$$

hence

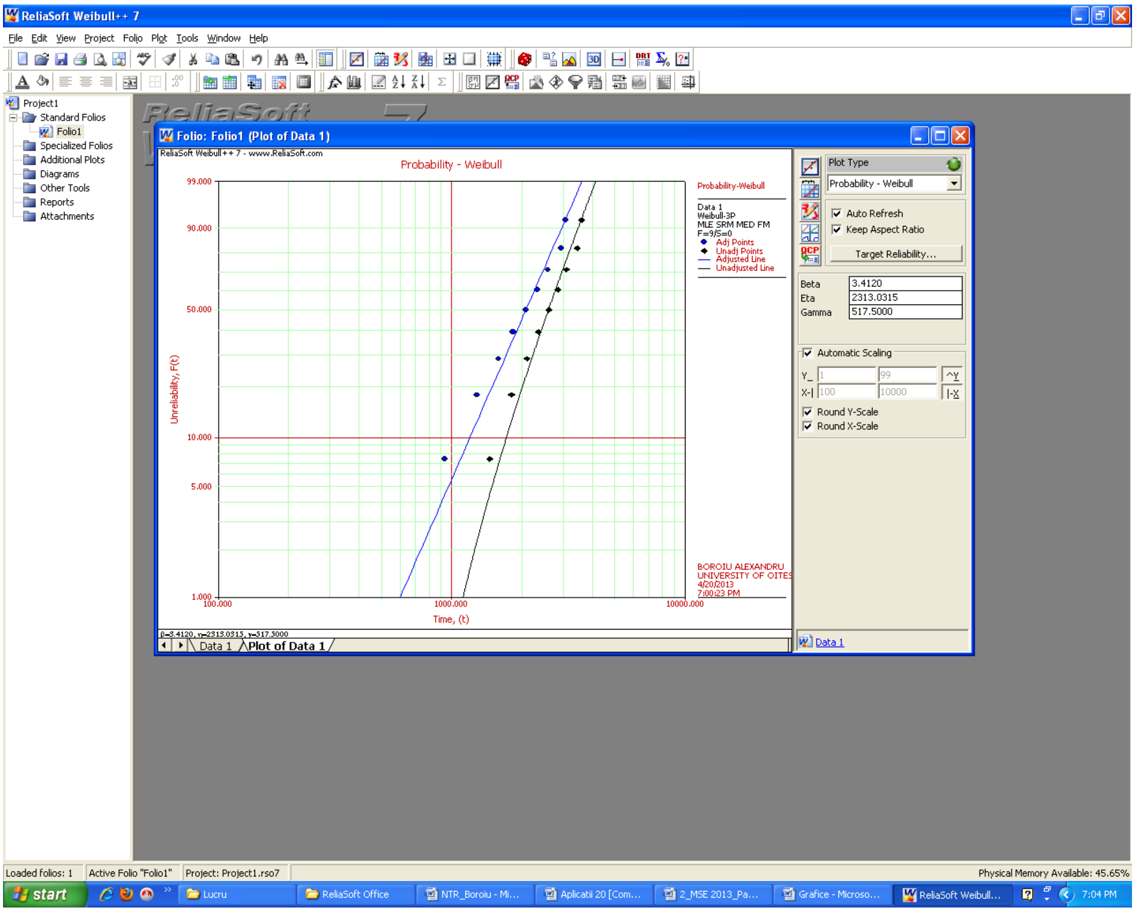


Figure 3. The graph Probability Weibull-3P for the complete test (F = 9, S = 0)

$$T = n_{st} \cdot t_0 = n_{st} \cdot 1400[ore] \qquad (13)$$

ie, trying 40 pieces to 2000 hours should not cause any damage.

It is found that by increasing the duration of the test with 30% achieved a reduction in the number of parts tested by about 75%.

Modeling reliability when tested without failures can be achieved only by models Weibull-1P or Exponential-1P, using Weibull ++7 software.

As a result, choose to operate Weibull-1P model, with the degree of confidence required (confidence level) of 80% and the parameter $\beta = 3.4$ (calculated by full test prior to 9 products).

Imposing the parameter of the form $\beta = 3.4$, for testing without failure of the 40 products (Failed = 0, Suspended = 40), obtain Weibull-1P model defined by the parameter $\eta = 5145.6$ hours.

We can get other useful results with QCP command:

- Mean life: 4622.7 hours;

- Reliability conditional on the last half of the time of the test: R (2000 / (2000 +2000)) = 0.68 (reduction of the reliability is only 32% on the second half of the interval);

- The time at which reliability decreases to R = 0.96 or: $t_{4\%}$ = 2008.5 hours (for testing extended BX information = 4%) - Fig. 4.

5 CONCLUSIONS

Following research carried out shows the following:

- asked for a confidence level of 80% to check if the product reliability t_0 = 1400 hours is 99%: in a test without failures would require 160 products.

- but expanding attempts to t_1 = 2000 hours and imposing any condition not failing product was obtained reliability target equivalent (96% with the same degree of confidence), which was determined based on the number of items needed: 40 products.

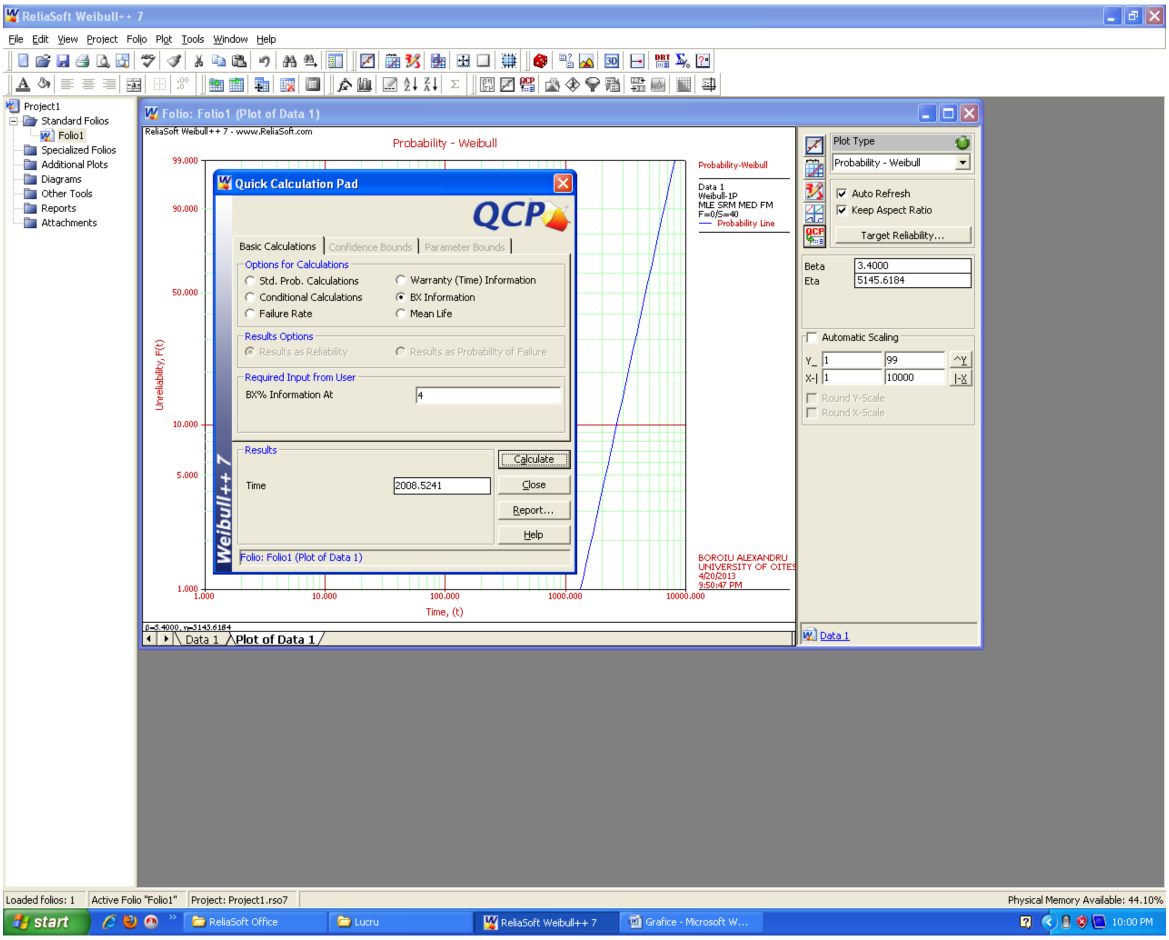


Figure 4. Useful results obtained by the Weibull model-1P determined (F = 0, S = 40)

In both cases we need in advance of a full test for one-parameter model Weibull-1P or Exponential-1P be applicable, so that the difference between the two tests is the number of products actually just watched the attempt without fail.

Therefore, one can conclude that the proposed tests are very competitive, because the number of defective products in preliminary tests was very small, and the number of products tested without failure is greatly reduced when extending the test time (only 40 produced over 160 products, ie 25 %), which demonstrates the benefits of applying unconventional methods to validate the reliability of products.

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