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Test and Reliability Guidelines

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Test and Reliability Guidelines

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Keywords: Reliability, Test

1 Purpose and Scope

1.1 This Engineering Practice shows how product life can be specified in probabilistic terms, how life data should be analyzed, and presents the statistical realities of life testing.

1.2 Life tests are required to be conducted on a representative sample to estimate the expected life of the population. Analysis of the results is essentially a statistical problem. Life test planning should include these four specifications: 1) test environment, 2) number of test units, 3) life goals, 4) definition of failure, that is, what failure modes constitute the end of life. Calendar test time and cost may affect the priority of these specifications.

1.3 This Engineering Practice is not intended to be a comprehensive study on the large variety of subjects encompassed in the analysis of life testing, but rather a guide to demonstrate the power, usefulness and methodology of reliability analysis.

2 Background

2.1 A key characteristic of a product is its life. In the agricultural equipment industry a great deal of testing is conducted on materials, components and complete machines to determine expected life. Life tests are conducted under controlled environments in the laboratories and in the more variable environments of the field. When tests on several nearly identical parts are replicated under even the most carefully controlled conditions, variability or scatter in the cycles or time to failure is observed.

2.2 For example, extreme care is taken to insure dimensional and metallurgical control during manufacture of precision ball or roller bearings, so virtually no discernible difference can be found between bearings. However, when several “identical” bearings are tested to failure under the same carefully controlled test conditions, variations in life of 10 to 1 are not uncommon. As a result of the inevitable variations, product life needs to be specified in probabilistic terms. This mandates that test programs require enough replications to minimize the risk of erroneous test conclusions. The designer and test engineer must establish a test program to balance test time and cost against risk of a product failure. Figure 1 shows a histogram for 100 ball bearings tested to failure under identical laboratory conditions. Note that the individual bearing lives varied from 1000 to 5000 h. This variability is a fundamental reason for planning life tests and interpreting the results.

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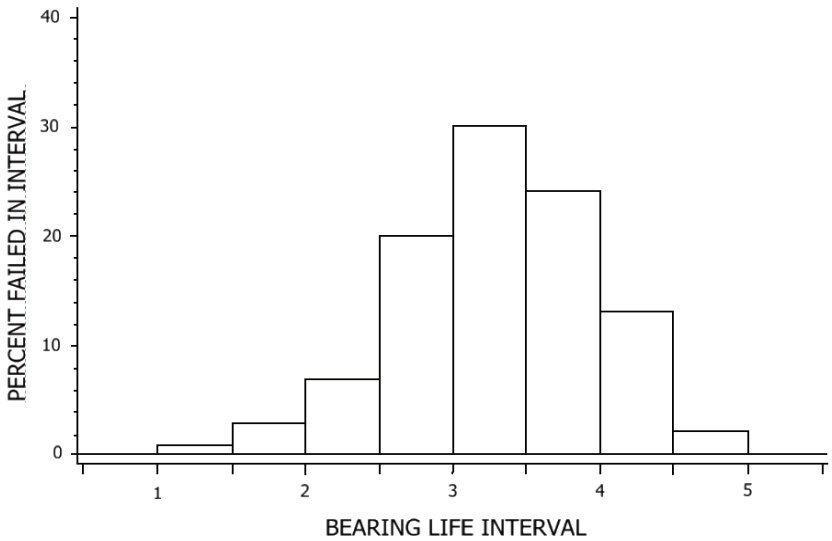

Figure 1 – Histogram of 100 bearings tested in a constant environment

2.3 The results of repetitive life tests conducted on the bearings at three different environmental or stress levels are shown in Figure 2. At each of the three levels, bearing life would be distributed as shown by the dotted lines. Connecting the point on each dotted distribution line at which 5% of the bearings failed, establishes a 5% failure line. Similarly the 50 to 95% failure lines can be drawn. The diagram of Figure 2 defines the life characteristics of the bearings for these test conditions. Due to variability, statistical tests must be performed to estimate the products probability of success or reliability.

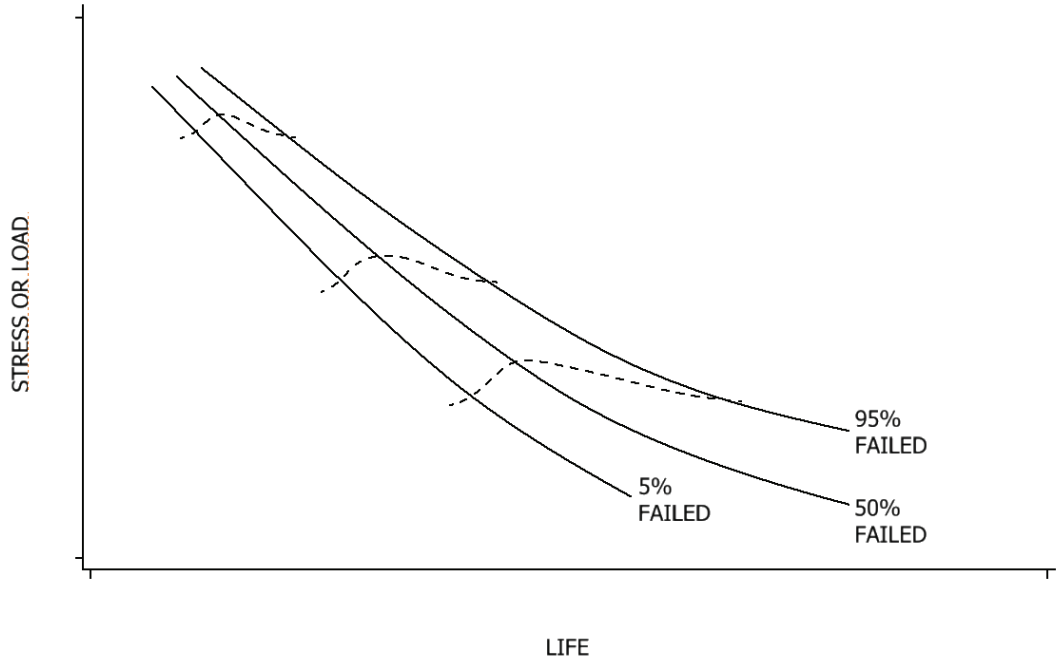

Figure 2 – Effect of varying stress on bearing life

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3 Definitions

3.1 confidence: Relative frequency that the statistically derived interval contains the true value being estimated

3.2 distribution: A mathematical function giving the cumulative probability that a random quantity, such as a component's life, will be less than or equal to any given value

3.3 failure mode: An accurate description of the type of failure, i.e., seal ball bearing typical failure modes are 1) spalled inner race, 2) spalled outer race, 3) spalled ball, 4) seal failure, 5) etc.

3.4 histogram: A graphical representation of a frequency distribution by a series of rectangles where the width of the rectangle represents the range of the variable and the height represents the frequency of occurrence

3.5 life goals: Desired cycles or hours to (x)% failure in a specific operating environment

3.6 population: The total quantity of parts to be produced and put into service

3.7 probability: Likelihood of occurrence based on significant tests

3.8 reliability: The probability that a part, assembly or system will perform satisfactorily for a specified period of time under specified operating conditions

3.9 sample: A small number of parts which will be considered as representative of the total population

3.10 suspension: A test or operational unit that has not failed by the mode under consideration at the time of the life data analysis

4 Reliability Figures of Merit

4.1 Two easily determined reliability figures of merit are failure rate, X, and mean time between failure (MTBF). The failure rate is the number of failures of an item per unit time. For example, the failure rate for a tractor experiencing 5 failures after 500 h of operation would be determined as follows:

Failure rate = number failures/units of cumulative time

= 5 failures/500 h

= 0.01 failures per hour

4.2 The other reliability figure of merit is mean time between failures (MTBF). MTBF is the total operating time of a population of a product divided by the total number of failures. Using the same values as the tractor in the previous example we have:

MTBF = units of cumulative time/number failures

= 500 h/5 failures

= 100 h

4.3 The MTBF is the inverse of the failure rate. Which figure of merit is utilized depends on the point of view that is taken.

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5 Series and Parallel Reliability

5.1 Any system can be modeled by combining its elements. Reliability modeling allows the designer to determine the effect of a component on the system.

5.2 The series model is more typical of mechanical agricultural machinery, in which a failure will disable the function of the unit. In this case the failure rate of the system comprising *n* components is the sum of the component failure rates.

$$\lambda_{system} = \lambda_1 + \lambda_2 \text{---} \lambda_n$$

5.3 As a simple example of the impact of component failure rates on a system, consider a hydraulic cylinder. The cylinder is composed of four components with corresponding failure rates as illustrated in Figure 3.

$$\Lambda_{cylinder} = \lambda_{barrel} + \lambda_{piston} + \lambda_{rod} + \lambda_{seal}$$

$$= 0.000002 + 0.000001 + 0.000001 + 0.000004$$

$$= 0.000008$$

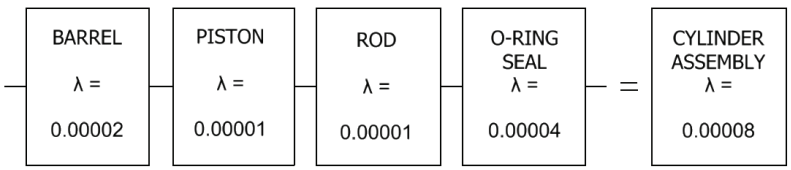

Figure 3 – Series failure model

5.4 On agricultural equipment a parallel reliability system model is likely to be utilized where redundancy is required. A parallel system assures that a system failure does not occur as a result of a single component failure. The system failure rate for a two component parallel system is determined from the following equation:

$$\lambda_{system} = \frac{1}{\frac{1}{\lambda_1} + \frac{1}{\lambda_2} - \frac{1}{(\lambda_1 + \lambda_2)}}$$

5.5 As an example of the parallel system failure rate as impacted by the component rates, consider an engine air cleaner system consisting of a primary filter and a secondary filter. If the failure rate for the primary and secondary filters is 0.000008, we have a system as illustrated in Figure 4.

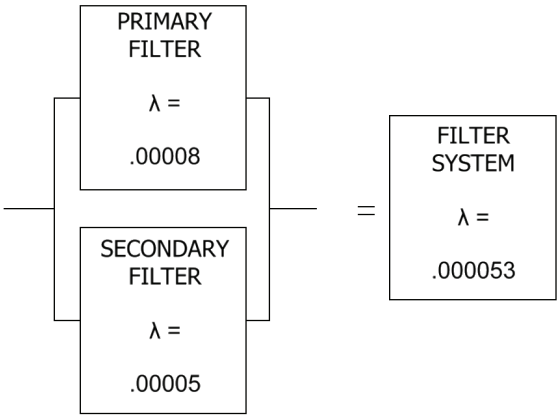

Figure 4 – Parallel failure model

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