Some reliability assessment based on single degradation measurements

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Abstract

An important issue in the validation of mechanical parts for vehicles is reliability assessment for high mileages, by the means of tests. Since the tests should be as short as possible, and for parts subjected to degradation mechanism, such as wear or crack propagation, it would be appropriate using degradation measurements (such as mass loss or crack length) in order to estimate reliability [NIK07], [ME98]. In this study we deal with high mileage reliability estimation for a clutch washer subjected to wear process. The measure used is thickness loss, obtained by measurements in the end of each test.
We study three simple approaches for reliability assessment. The first one uses a linear model of the data, with confidence interval estimation by bootstrap. The second one is based upon a linear extrapolation, while the third approach is based upon a linear extrapolation with weighted data. Estimation results are then discussed in order to show the appropriation of these methods for analyzing this type of data.

1 Introduction

Nowadays, with the increase of mechanical components reliability, it is more and more difficult to assess reliability with traditional life tests that record only time to failure. For products exposed to degradation mechanisms, degradation measurements contain very useful information about product reliability. The purpose of this work is to develop data-analysis methods for reliability estimation using degradation measures.
The example used for this study is the wear process of a clutch washer. The thickness loss is measured on 10 used parts; we have thus one thickness loss measure for each part.

2 Linear regression

2.1 Method description

The linear regression on data is given by : $Y = a.X + b + \varepsilon$, where Y is wear (in mm of thickness loss), X is mileage (in km) and ε is random with Nomal distribution

The parameter a must be positive and b is defined as being equal to 0, since there is no wear at the beginning of use. We want to estimate reliability value for a mileage of 200000 km (X_c). The failure occurs when the thickness loss reaches $Y_l = 3,5mm$. With linear model, we can estimate the mean wear level (Y_c) for X_l: $Y_c^* = \hat{a}.X_c$. The wear distribution at X_c is approximated by a student distribution. Therefore the probability of failure can be expressed as :

$$P_{failure}(X_c) = P\{t_{n-2} > \frac{Y_l - Y_c^*}{\sigma(\varepsilon)\sqrt{1 + \frac{1}{n} + \frac{(x_0-\bar{x})^2}{\sum_i (x_i-\bar{x})^2}}}\}$$

The value obtained for $P_{failure}(X_c)$ is 0.026 %.

The confidence interval is computed using bootstrap [SAP06].

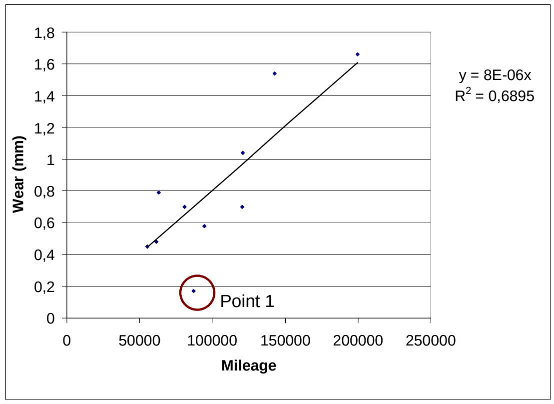

Figure 1: Linear regression

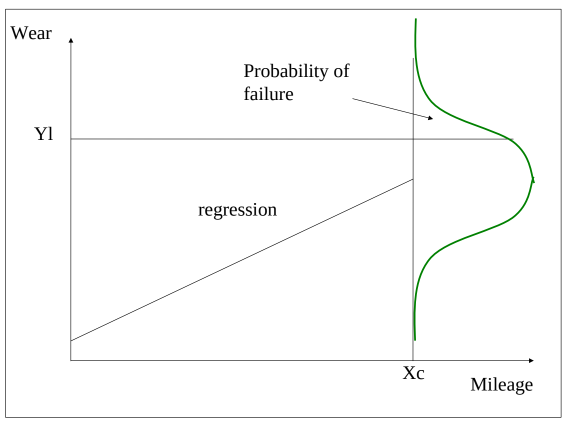

Figure 2: Probability of failure estimation

2.2 Results and discussion

This linear regression method allows reliability assessment, together with its confidence interval. In the example considered, $P_{failure}(X_c)$ is 0.026 % with an upper 90 % confidence bound of 0.2 %.

3 Linear path extrapolation

In this section, the application of a linear path extrapolation method is described and its results are compared to those obtained by using the linear regression method previously presented.

3.1 Method description

At first the time to failure is computed for each part. The origin is defined in $(X_0; Y_0) = (0; 0)$ since there is no wear at the beginning of use. A linear path is then extrapolated from each measure until wear exceeds the critical level (Y_l). Next step consist in finding the lognormal distribution fitted for these times to failure. It is possible afterwards to estimate the failure probablity for 200000 km. This method is illustrated *Figure 3*

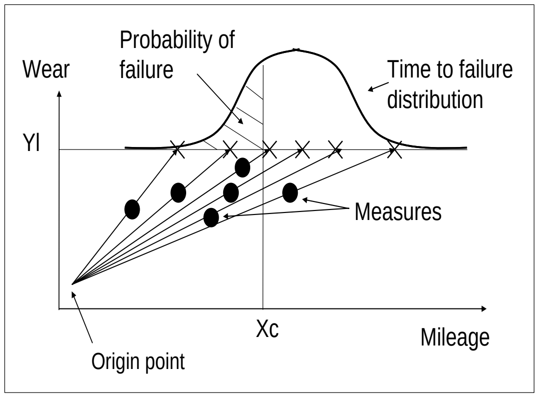

Figure 3: Linear extrapolation method

3.2 Results and discussion

This method, based on linear extrapolation, allows reliability assessment with confidence interval. In the considered example, $P_{failure}(X_l)$ is 6.6 % with a 90 % confidence interval of [0.4 %; 18.8 %] obtained by simulation. One may see that these results are very different from those obtained by a simple linear regression. This can be explain by the evolution of standard deviation : in the method 1, standard deviation is constant and in the method 2, standard deviation increases with mileage. A weakness of this method is the not consideration of incertainty introduced by extrapolation.

4 Linear path extrapolation with a system of weight

In order to improve the previous linear extrapolation method, all measures are differently weighted in order to lessen the influence of strongly censored measures.

4.1 Method description

The failure times are obtained as in the second method, previously presented (*3.1*). The failure times are then weighted before fitting with a probability distribution. The weights associated with times to failure (p_i) depend on extrapolation length :

$$p_i = k.\frac{Y_i}{Y_l}$$

where k is a normalization constant (the weights sum is equal to the number of observations)

$$k = \frac{n.Y_l}{\sum_i Y_i}$$

4.2 Results and discussion

For the same application example, the failure probability $P_{failure}(X_l)$ is 2.8 % with a 90 % confidence interval of [0.03 %; 9.8 %] obtained by simulation. The failure probability is smaller than the value obtained by the second method (*3.1*). This result is due to lesser influence of the point 1 (*Figure 1*) which artificially increases dispersion of failure times in the second method.

5 Conclusion and future work

In this paper, we studied three different methods for using degradation measures in reliability estimation of a clutch washer subjected to wear process. The first method, based on a simple linear regression gives the smallest value for the failure probability, since it estimates wear dsitribution with small dispersion. The two other methods are both based on a linear path extrapolation. The last one, using weighted data seems to give more accurate results, because it is less sensitive to strongly censored data. Simulations will be discussed in order to choose the most appropriate statistical analysis.
More generally, future work consists in defining criteria for choosing the most appropriate method for reliability estimation using degradation measurements for a specific type of available data.

References

Gnedenko, B.V. and Khinchin, A.Ya. *An elementary introduction to the theory of probability.* San Francisco-London: W. H. Freeman & Company. (1961).

Meeker, W.Q. and Escobar, L.A.: *Statistical methods for reliability data.* Wiley Series in Probability and Statistics, New York, (1998).

Nikulin, M., Gerville Reache, L. and Coualier, V. *Statistiques des essais accélérés.* Lavoisier. (2007).

Saporta, G. *Probabilités, analyse de données et statistique.* Technip. (2006).