CHANGES OF FAILURE DISTRIBUTION AFTER A MAINTENANCE POLICY HAS BEEN IMPLEMENTED

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Abstract

In general the available literature on maintenance policies do not discuss the question of failure distribution under preventive maintenance. This is important because, maintenance planners may wish to know the degree of improvements that may be achieved by introducing a maintenance policy, which may enable them to modify the maintenance interval if necessary. In this paper an algorithm has been worked out in order to generate the failure distribution under a preventive maintenance policy.

1. Introduction

Day by day cost of maintenance resource is becoming higher and higher. In many situations, failure of a unit during actual operation is costly and/or dangerous. If the unit is characterized by an increasing failure rate, it is advisable to replace it before it has aged too greatly. On the other hand too frequent replacement means excessive cost. Thus, one of the most important questions is maintenance policy, which will balance the cost of failures against the cost of planned replacements and will maximize the company profitability. During the last two decades there has been a growing interest in maintenance policies for systems that are subject to stochastic failure.

2. Purpose of the study

Several maintenance policies are discussed in the literature on the subject [1, 2, 3, 4, etc.]. Most of them require, as inputs, information (for example cost of failure, failure distribution of the equipment, cost of preventive maintenance etc.) on the behaviour of the equipment. Generally, using this information preventive maintenance interval is calculated. After a maintenance policy has been worked out and applied for a given system, the failure distribution of the system under maintenance is expected to be changed. Maintenance planners may wish to know the degree of this change in advance such that if the improvement is not satisfactory he can modify the maintenance policy or the parameters of the model.

3. Methodology for the determination of the new failure distribution

We shall now consider the block replacement policy introduced by Barlow and Proschan [1] and we shall examine the failure distribution under preventive maintenance.

Algorithm

I. Data collected under the prevailing maintenance system is used to determine the parameters of the failure distribution.

II. The ratio of the $\frac{C_2}{C_1}$ (where C_2 is the total cost suffered due to exchange of non-failed items and C_1 is the cost suffered due to failure) is determined.

III. Optimum preventive maintenance interval is calculated using a simulation programme [5].

IV. The procedure discussed in section 4 is used to estimate the parameters of the new failure distribution under preventive maintenance.

4. Ascertaining of the new failure distribution after changing the maintenance policy

Let failure distribution be denoted by $F(T)$ and let

$$t(x)=F^{-1}(x) \tag{1}$$

Now the parameters of the failure distribution is assumed to be known. So, the optimum block replacement time can be determined by using the following equation [1]:

$$T\cdot m(T)-M(T)=\frac{C_2}{C_1} \tag{2}$$

where T is the value of the optimum block replacement interval, $M(T)$ is the expected number of failures in the interval $[0, T]$ is the derivative of $M(T)$. Mathematically $M(T)$ and $m(T)$ can be expressed as follows

$$M(T)=\int_0^T [1+M(T-x)]f(x)\,dx \tag{3}$$

and

$$m(T)=\int_0^T f(x)m(T-x)\,dx+f(T) \tag{4}$$

In case of block replacement, items of the same kind are replaced periodically, at time kT (where $k=1, 2, \ldots$) irrespective of the failure history. Block replacement is denoted in Fig. 1.

The value of $F(T)$, which randomly varies from 0 to 1, is generated using uniform distribution of a computer. This value is substituted in Eq. (1) in order to calculate the failure time t. The value of t thus calculated is compared with the value of block replacement time T. If t is smaller than the preventive

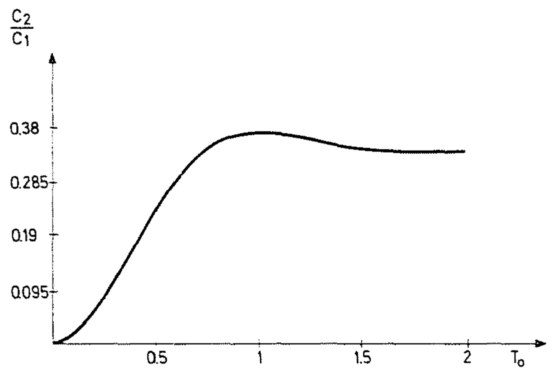

Fig. 1. Figure shows that not all the values of T derived with the help of the equation (2) are optimums.
$a=1.4$ and $b=1.9$

maintenance interval, then it means that the actual failure of the equipment could not be prevented and this value of t is recorded. In the program the possibilities of more than one failure within a block replacement interval is also taken into consideration. On the other hand if the generated failure time t is greater than the interval T then it is assumed that the failure is prevented. The process is continued until a given number of failures that could not be prevented are generated. This number depends on the minimum sample size required for calculating the parameters of a given failure distribution. This generated failure distribution is considered as the expected failure distribution after the implementation of the new preventive maintenance policy. The block diagram of the computer program used for the generation of the new failure distribution under preventive maintenance is shown in Fig. 2.

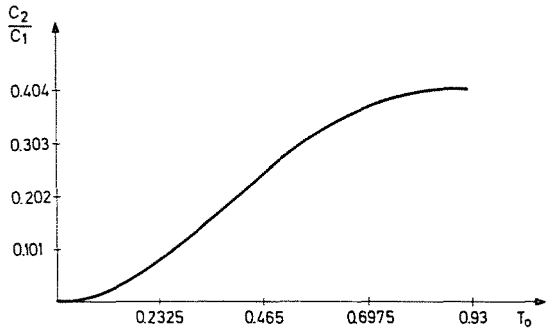

Fig. 2. The relation of C_2/C_1 in terms of block replacement interval. a = 1.5 and b = 2

Example

Let us assume that the equipment is subject to Weibull distribution, which is denoted as follows

$$F(t)=1-e^{-at^b} \tag{5}$$

where a, b are the scale and shape parameters of the Weibull distribution. From Eq. (5) t can be expressed as follows

$$t=\left[-\frac{1}{a}\ln(1-F(t))\right]^{\frac{1}{b}} \tag{6}$$

Let,

scale parameter $a=1, 5$;
shape parameter $b=2$;
total cost due to failure $C_1=1$;
total cost of preventive maintenance $C_2=0.26$;
mean time to repair = MTTR = 0.05;
using the values of a and b, mean time between failures = MTBF = 0.3939;
availability under the prevailing maintenance system $= A = \frac{\text{MTBF}}{\text{MTBF}+\text{MTTR}}$ $= 0.8874$.

Using Eq. (2) and a simulation program discussed in [5], optimum block time T is determined. $T=0{,}500066419$ and expected cost per unit time $\boldsymbol{B}(T)=1{,}1869005$.

Now using the value of a, b and optimum block time T, as input data in a computer program, block diagram of which is given in Fig. 2, the failure distribution under preventive maintenance is generated. The new MTBF is found to be equal to 1,64172 and the availability under the new maintenance policy is expected to be 0,9704.

5. Conclusion

A simulation model has been worked out that enables us to generate the failure distribution under preventive maintenance. This may help to determine the competence of a maintenance policy implemented and the improvement expected to be achieved with the help of the new maintenance policy.

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