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Modeling and evaluation of reliability and availability of industrial systems

Applications to parallel series and series parallel systems

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Abstract— With today's highly reliable components, we are often unable to obtain a reasonable amount of test data under normal use condition. For this reason, accelerated tests method is the reasonable procedure to be applied. It is used to determine the reliability of a product in a short period of time by accelerating the use environment. Application of the method of accelerated tests can save cost that we used to pay for overcoming the dilemma of not being able to estimate failure rates by testing directly at use conditions.
In the method of accelerated tests, acceleration factor is known or there exists a mathematical model which specifies the relationship between lifetime and reliability or failure. This model proves its value not only as a way of a validation model for classical reliability models existing in the literature, but more, as a quantifier of reliability gain resulting when replacing or modifying parts (cost-benefit analysis).

Keywords—wire ropes; sudden failure; brutal damage; broken wires

I. INTRODUCTION

Two kinds of tests are widely used to assure product reliability; environmental tests and life tests. Environmental tests found out latent defects that can be eliminated or reduced prior to life tests. On the other hand, life tests predict the lifetime of products at normal use condition. As today's products become more reliable, it is getting more difficult to estimate their failure time distributions or reliabilities within an affordable amount of time and in an economic way.

The operation of industrial utility systems offer multiple degrees of freedom (e.g. equipment sizes, number of units, and their loads) that can be exploited to achieve large economic savings.

At the same time, since no equipment is one hundred percent reliable, it is necessary to account for the possibility of failure together with preventive and corrective maintenance periods of all the items of the plant.

In this way, reliability and availability issues not only have a major impact on the design and operation of a utility system, but also they considerably increase the number of options that should be assessed to reduce capital and/or operating costs. Hence, minimizing such expenditure represents a very challenging task due to the highly combinatorial computations involved and strong interrelations between the equipment.

Generally, reliability can be defined [1] as the probability that a device or system will perform a required function at a given point in time, when operated under specific conditions. In other words, reliability is a quantitative measure of non-failure operation over an (operational) time interval. It is important to note that this definition assumes that certain criteria have been previously established to clearly specify what is considered to be the intended function of the item.

In addition, failure normally implies a corrective maintenance action corresponding to the repair time needed to bring an element back to regular operation. Also, the equipment often requires preventive or scheduled maintenance to improve its reliability. Hence, the down time of a unit is comprised of both its corrective and preventive maintenance periods.

It is worth mentioning the concept of maintainability which might correspond to the probability of completing a repair action during a certain time interval [2] [3], or it can denote the probability of performing preventive maintenance during a certain time interval [4].

In any case, it must not be confused with the downtime or with the complement of availability. Thus, while reliability is a measure of non-failure operation of an item, maintainability is related to its capability of being repaired or to its need of receiving maintenance. Thereafter, both measures can be used

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to calculate the overall availability, representing the net operational time of an element or system.

In this paper, we present two methods, the reliability-classical method and the method of accelerated tests [5-7], implemented by a graphical calculation. We illustrate and compare these two approaches by using the rough estimate of gap that represents the gain in reliability between the two methods and estimating the relation reliability-maintainability and availability [8-10].

II. . Comparison of conventional and reliability model accelerated tests

A. Numerical part

A library to calculate the reliability of complex systems is developed, derived from systems whose functional description can be translated into a block diagram that combines, in series or in parallel, components (or failure modes) for which the law of reliability must be known a priori. The characteristics of the components (the law of reliability, hours of work already accomplished, the control component), are saved in a library (Fig. 1).

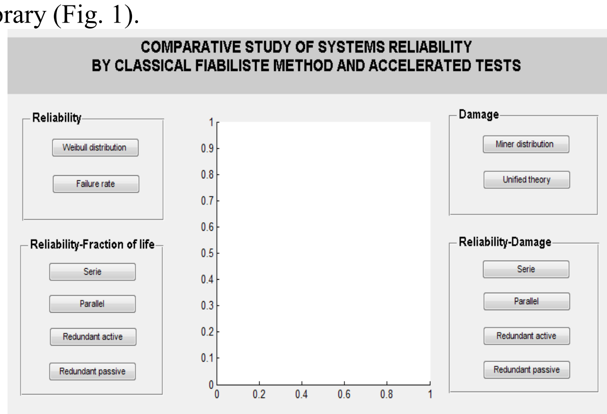

Figure 1. Interface library for comparative study of reliability systems

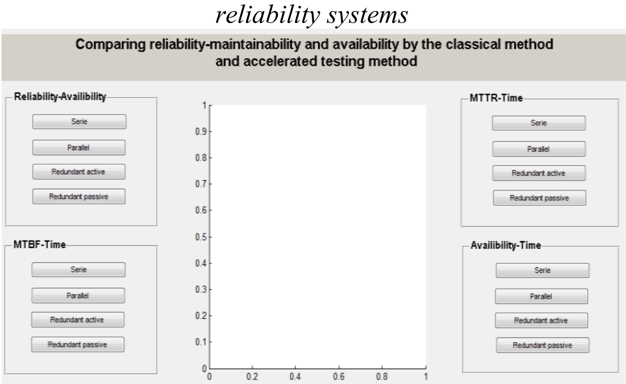

Figure 2. Interface library for comparative study of reliability-maintainability and availability

To treat the model, we uses an algorithm derived from graph theory, which generates digitally function of system reliability.

The interface module to load and present the results graphically is shown in fig. 2, the reliability function can be easily calculated classical compared with the reliability of accelerated testing, facilitating the search for greater reliability.

B. Weibull distribution

This is a law that can be adjusted correctly to all kinds of experimental results and operational cleverly choosing the parameter values. As it covers the case where the failure rate is variable and can therefore be easily adapted to periods of youth and various forms of aging systems.

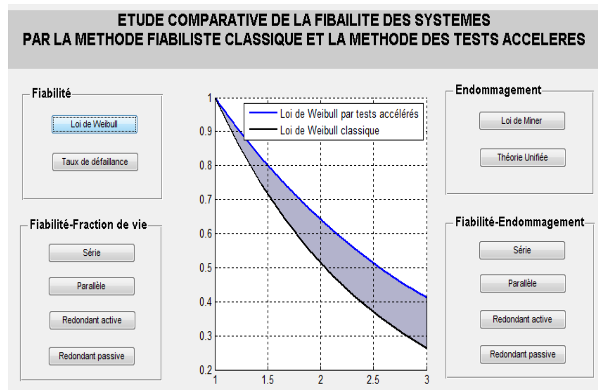

Figure 3. Comparison of Weibull distribution between the two methods

The fig. 3 shows a comparison of the Weibull distribution for reliability classical method and accelerated tests. There is a proportional improvement of reliability caused by the reliability of the accelerated testing method, which is about 15% to end of the observation period. The difference between the two methods is the gain of reliability to quantify the benefits (cost, quality) of a replacement or, similarly, any editing operation.

The reliability of the accelerated testing method represents an adjustment to the traditional reliability law, and it will allow a timely intervention for preventive maintenance of the system [11].

III. Parallel series system

For $\gamma = \Delta\sigma/\sigma_0 = (1.2)$; $\lambda=(1.5)$; $\gamma u = \sigma_u/\sigma_0 = 2$; S = 5 components ; P = 5 components.

Where γ is the position or origin parameter, $\Delta\sigma$ is the amplitude of solicitation, σ_0 the endurance limit of virgin material, σ_u the ultimate stress of virgin material and m is a parameter related to the material (m = 8 for steel).

S is the number of components in series and P represents the number of components in parallel.

We deduce clearly in fig. 4 that there is a rapid decrease of reliability for the two curves, and this decrease is greater for the reliability in accelerated testing, and thus leads to a gain of reliability and internal resistance component of 16%, which will keep longer system operation in service.

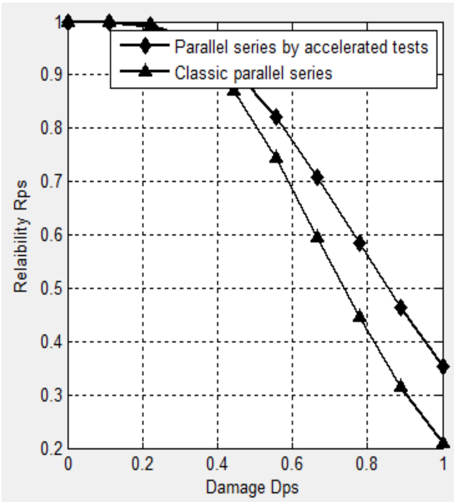

Figure 4. Comparison of the reliability depending on damage for a parallel series system

The superposition between curves of reliability and damage in fig. 5 diverges and has no point of intersection for classical reliability method. The method of accelerated testing shows an intersection that requires a critical maintenance to 82 % fraction of the system life.

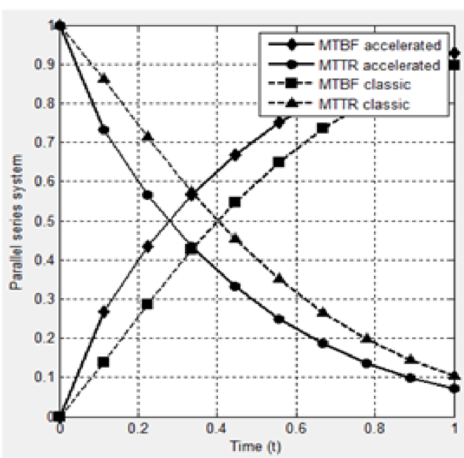

Figure 5. Superposition of curves of reliability and for a parallel series system

The fig. 6 shows the intersection curves of the MTBF and MTTR by the classical method and the method of accelerated tests for a parallel series system.

We deduce that the intersection curves of the conventional method is carried out at 40% fraction of the time and 50% of the total fraction, also the intersection curves of the method of accelerated testing is performed at 28% of the fraction of time and 50% of the total fraction, which requires an immediate and precise to avoid failures.

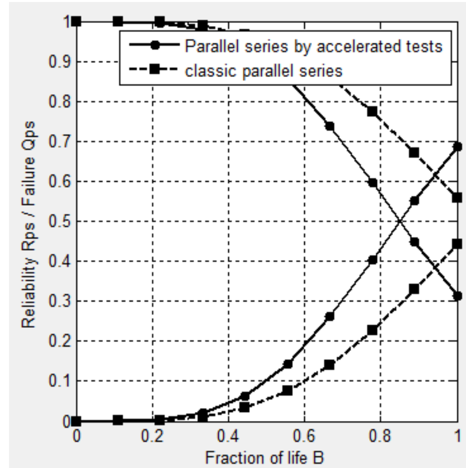

Figure 6. Superposition of curves of reliability-availability for parallel series system

The fig. 7 shows the intersection curves of availability by the conventional method and the method of accelerated tests. We deduce that the availability given by the theory of accelerated tests reached a large value at the beginning of operation compared to the conventional method. This reflects that the accelerated method is more efficient and accurate.

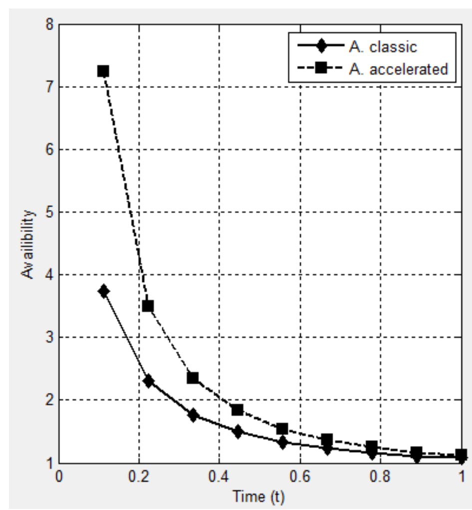

Figure 7. Superposition of curves of reliability-availability for parallel series system

IV. Series parallel system

For: $\gamma = \Delta\sigma/\sigma 0 = (1.2)$; $\lambda = (1.5)$; $\gamma u = \sigma u/\sigma 0 = 2$; S = 5 components; P = 5 components.

Where γ is the position or origin parameter, $\Delta\sigma$ is the amplitude of solicitation, $\sigma 0$ the endurance limit of virgin material, σu the ultimate stress of virgin material and m is a parameter related to the material (m = 8 for steel).

S is the number of components in series and P represents the number of components in parallel.

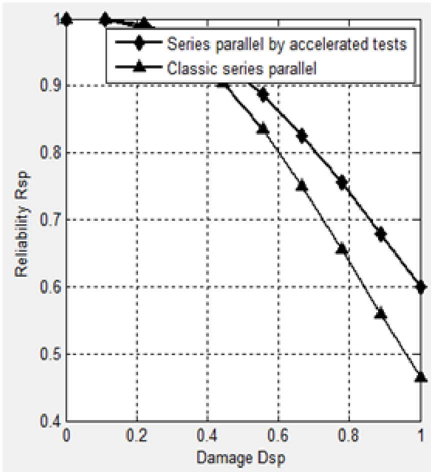

Figure 8. Comparison of the reliability depending on damage to a series parallel system

The series-parallel reflects the same trends as the redundant passive system (Fig. 8 and fig. 9). It is noted here that the system keeps a significant reliability, even at break (β = 1), and decreasing the reliability is not really important for a classical system as for an accelerated testing method.

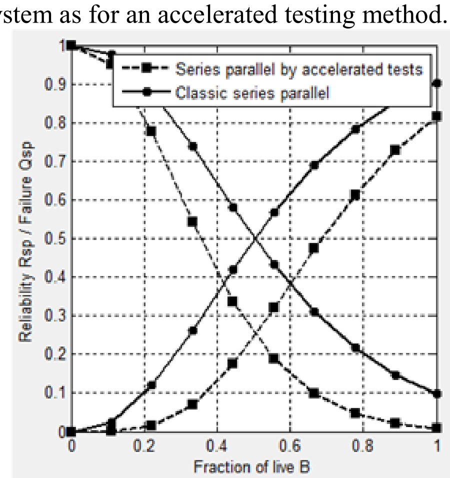

Figure 9. Superposition of curves of reliability and failure to a series parallel system

The fig. 10 shows the intersection curves of the MTBF and MTTR by the classical method and the method of accelerated tests.

We deduce that the intersection curves of the conventional method is carried out at 60% fraction of the time and 50% of the total fraction, also the intersection curves of the method of accelerated testing is performed at 43% of the fraction of time and 50% of the total fraction, which requires an immediate and precise to avoid failures.

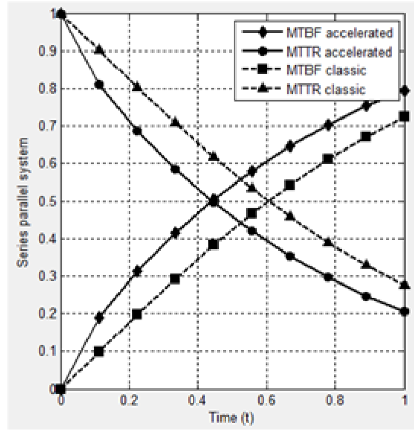

Figure 10. Superposition of curves of reliability-availability for series parallel system

Availability according to time (Fig. 11), ensure that there is a rapid decrease of reliability for the two curves, and this decrease is accentuated by faster method reliability of accelerated test.

Reliability is always important and less influenced by the trend series of components, beyond the point of intersection of the curves. The fall of the reliability is outstanding and the risk of default is increasing in both methods.

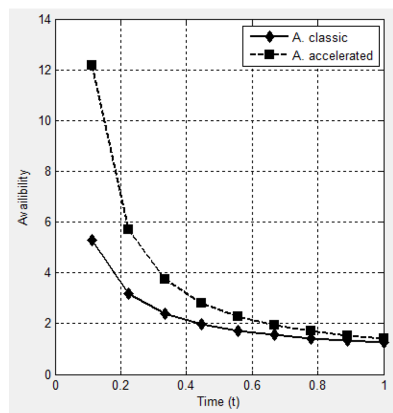

Figure 11. Superposition of curves of reliability-availability for parallel series system

V. Conclusion

Regarding availability and reliability issues, due to the complexities of handling these concerns within a systematic methodology, in most cases the redundant elements of utility plants are pre-specified according to heuristics or rules of thumb.

Our goal is to determine the reliability of complex multi component services. The theory enables accelerated testing, initially, to determine the reliability of system components through the acceleration factor. This parameter depends on the positional parameter Weibull, failure mode and associated stress.

With the increasing complexity of systems that results in costs of operation and maintenance costs. We therefore sought to reduce maintenance and improve reliability by using a numerical methodology that allowed us to illustrate a comparison based on two methods. The results show that the reliability of the accelerated testing method represents an adjustment to traditional reliability law, so it can provide support predictive maintenance for the determination of optimal periods between interventions and quantify the benefits of reliability as a result of replacement or modification.

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