A time-varying accelerated lifetime model for maintained reparable systems with dormant failure mode of cooling system

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One page Abstract before full paper

The effects of temperature on electronic device failure is well known and most of lifecycle reliability testing are carried out mainly through accelerated testing, during which the temperature and, in some cases, the power are substantially increased to make the test duration manageable. The Arrhenius or the Coffin Manson models may then be used to relate the reliability on test to the reliability prediction in the field. Depending of the failure mechanisms, the choice of an appropriate stress model is crucial since the failure may not be not due to a high steady-state temperature but also to temperature gradients, temperature cycle magnitude, or rate of change of temperature. Knowing that, taking into account the mission profile, the practitioner is thus able to design a system including a cooling part that maintains a desirable temperature. To do that, he must also consider maintenance aspects, such that inspection policies or testability of device's state, in order to fulfill an reliability objective, often given in terms of MTBF for repairable systems.

The aim of this paper is first to describe how the reliability characteristics of a component living in a environment with controlled temperature may be modified by taking into account of random cooling system failure. In a quite simple model, it reduces to a step-stress model where the unique time of temperature's switch is unknown and follows a given lifetime distribution. Then standard results obtained by applying parametric cumulative damage models (also known as Sedyakin models) are introduced in the repairable systems theory. To be precise, we model the failure times of a cooling system with a renewal-type counting process with non negligible repair times. The aim is to adapt the model to standard inspection policies for which the system state can only be known through periodic inspections.

The failure times of the principal component has an intensity process that depends on the cooling system's state through the variability of the temperature. In that model, the cooling system may be seen as an independent part, and the principal component as a dependant part because the failure intensity of the principal component depends on the cooling system's state, but not the contrary.

As results, we provide closed form expressions for reliability functions and mean time to first failure (MTTFF), and analyse with numerical simulations the Mean Time Between Failure for this non stationnary process. An exponential distribution for the cooling part and Arrhenius-Weibull distribution for the principal component are assumed.

As a by-product, we analyse the effect of the duration between inspections on the reliability of the principal component.

Keywords: recurrent events, stochastic intensity, Arrhenius Model, dynamic stress, repairable systems, MTBF
