Periodic inspection strategy for systems subject to competing failure modes sharing a common risk source

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ABSTRACT

Most of the systems suffer a physical degradation before they fail. This degradation is due to the irreversible accumulation of damage through life and may involve corrosion, material fatigue, wearing out and fracturing [1]. Since degradation is a complex random mechanism, it is best represented by a stochastic process frequently stationary and with independent increments. Under this stochastic-process approach, the system is regarded as failed when its degradation first reaches a critical threshold level. In the literature on degradation-based stochastic failure models, frequently, the degradation process is considered the only cause of failure (see, e.g., [2], [3] and [4]). However, in many practical situations, systems are not only subject to internal degradation, but also are exposed to catastrophic failures that can provoke a sudden failure.

A system subject to different competing risks is the setting of this paper. We assume the system is subject to two causes of failure (degradation and catastrophic failure). Both types of failure share an initial common source: an external shock process. So, the system is functioning under a random external shock process $\{N(t), t \geq 0\}$. We assume that each shock instantly initiates a degradation process in the system. As soon as a degradation process first reaches a critical failure threshold, namely ξ_c, the system is regarded as failed. Also, after each external shock, the system is more prone to suffer a catastrophic failure since each shock increases the failure rate function of the time to a catastrophic failure.

The system is not continuously monitored. Since it is generally less costly to replace a system before it has failed, a condition-based maintenance is proposed. This maintenance strategy is the following: the system is inspected each T units of time to check its status and, in these inspection times, different maintenance actions are performed. If the system is failed in an inspection time, a corrective replacement is performed and the system is replaced by a new one. If the system is functioning in an inspection time, the deterioration level of the degradation process is measured. If the deterioration level of any degradation process exceeds a maintenance threshold, namely, ξ_p ($0 < \xi_p < \xi_c$) a preventive replacement is performed and the system is replaced by a new one. Otherwise, no maintenance task is performed. We assume that the time to perform a maintenance task is negligible. Costs are associated with the different maintenance actions and the objective is to determine an optimal time between inspections and an optimal maintenance threshold. By optimal, we mean the pair of values (T, ξ_p) that minimize the expected cost rate.

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