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Imperfect diminishing maintenance modelling and reliability analysis for a multi-process degradation system

This work proposes a framework for analysing reliability and optimizing maintenance in a system subject to multiple degradation processes. Unlike models that assume perfect maintenance, this study incorporates an imperfect maintenance mechanism with diminishing efficiency, where the ability to reduce accumulated degradation decreases with each successive maintenance intervention.

Analytical survival functions and failure-time distributions for two distinct failure scenarios are derived. The first one is an aggregate-threshold scheme modelled via Wiener processes, where system failure is driven by a linear combination of all the degradation processes. In the second scenario, an aggregate-or-critical scheme modelled using Gamma processes is considered, where failure occurs if either the total degradation or a specific critical component exceeds its respective threshold. These mathematical derivations explicitly account for the discontinuities in degradation paths caused by imperfect repairs.

Building on these reliability models, our work develops two condition-based maintenance (CBM) strategies: one using the conditional Residual Useful Life (RUL), and another based on direct degradation thresholds. Numerical experiments show that optimizing the inspection intervals and decision thresholds of these policies provides significantly lower long-run average cost rates compared to traditional periodic maintenance strategies.

Primary authors: TORRES CASTRO, Inmaculada (University of Extremadura); BAUTISTA BÁRCENA, Lucia (Universidad de Extremadura); Mr MORENO MEJÍA, Emmanuel (University of Extremadura); AHMADI, Reza (Iran University of Science and Technology)

Presenter: BAUTISTA BÁRCENA, Lucia (Universidad de Extremadura)

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