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A Finite-Time Prescriptive Maintenance Policy for Systems Exhibiting Bathtub-Shaped Degradation Rates

Real-world degradation processes often exhibit three distinct phases, namely a running-in (accommodation) phase, a steady-state (normal) phase, and a catastrophic wear phase. As a consequence, the degradation rate function, here intended as the first derivative of the mean degradation function, is typically bathtub-shaped: it decreases during the first phase, remains approximately constant during the normal phase, and increases again during the last phase. In such settings, maintenance policies should explicitly account for this behavior, since model misspecification can lead to systematically suboptimal decisions and, in turn, increased expected costs. Motivated by these considerations, we introduce a non-homogeneous gamma degradation process inspired by Giorgio et al. (2023) that accounts for a bathtub-shaped degradation-rate function, and we use it to develop a prescriptive maintenance policy. In this work, we consider a prescriptive maintenance policy for a degrading system in which degradation is influenced by a usage rate, that represents the operating intensity of the system, and where prescriptive actions include its adjustment.
We consider a nominal usage level corresponding to standard operating conditions. At each inspection, the usage rate is selected from a finite set for the next interval, where reductions slow degradation but incur a per-unit-time cost that increases with the deviation from nominal. The system is planned over a finite operating mission with periodic, perfect inspections and non-self-announcing failures. At each inspection, the policy selects the next usage rate and may perform preventive or corrective replacement.
The problem is formulated as a finite-time Markov decision process and solved via backward recursion. Numerical studies vary the number of available usage rate levels and the length of the operating mission. Results, compared to those obtained by adopting a simpler policy that allows for corrective and preventive replacements only, show that within the considered experimental scenarios, allowing for usage rate reductions significantly reduces the expected cost. Moreover, the results suggest that the optimal action at each inspection strongly depends on the degradation phase experienced by the system at that time.

Keywords: *prescriptive maintenance, non-homogeneous Gamma process, bathtub-shaped degradation rate, finite-horizon maintenance policy, average total cost.*

Esposito, N., A. Piscopo, B. Castanier, and M. Giorgio (2024). Adaptive Maintenance Policy For Gamma Degrading Units With Bathtub-Shaped Degradation Rate Function In The Presence Of Random Effect. In Advances in Reliability Safety and Security, Cracow (PL), 29–37.
Gertsbakh, I. B., and Kh. B. Kordonskiy (1969). Models of Failure. Springer.
Giorgio, M., A. Piscopo, and G. Pulcini (2023). A new Wiener process with bathtub-shaped degradation rate in the presence of random effects. Applied Stochastic Models in Business and Industry 40, 574–597.
Meissner, R., A. Rahn, and K. Wicke (2021). Developing prescriptive maintenance strategies in the aviation industry based on a discrete-event simulation framework for post-prognostics decision making. Reliability Engineering & System Safety 214, 107812.
Sun, Q., P. Chen, X. Wang, and Z. Ye (2023). Robust condition-based production and maintenance planning for degradation management. Production and Operations Management 32, 3951–3967.

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