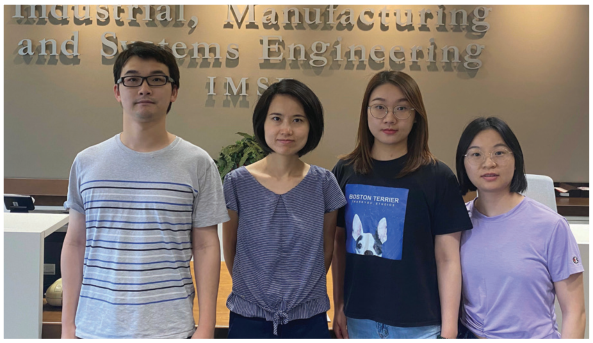
Handling high initial failure rates due to heterogeneity in degradation processes: Burn-in to the rescue

Many engineering devices are subject to complex multiple dependent degradation processes. Further complicating the failure behavior of these devices is the existence of substantial unit heterogeneity, caused by imperfection in manufacturing methods and variability in raw materials, particularly when the design and manufacturing processes of such devices are not yet mature. For example, the manufacturing process for micro-electromechanical system (MEMS) devices is still constantly evolving, and it is challenging to produce a uniform homogeneous population of products with minimal variability.

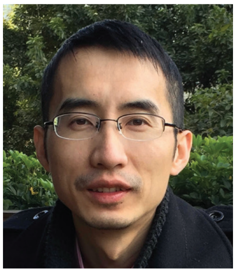
In the presence of this complex failure behavior, how can manufacturers identify and eliminate weak devices before they are sold to consumers or integrated into larger systems? Instituting a burn-in process could bring effective rescue. But the research of how to apply burn-in to devices that degrade is scarce. This is because devices subject to degradations become more prone to failure throughout their lifetime and typically do not benefit from burn-in. The situation is, however, different when there is a great degree of unit-level heterogeneity in the degradation processes because infant mortality may exist due to high initial failure rates of weak devices.

The study "Optimal Burn-in Policies for Multiple Dependent Degradation Processes," by doctoral students Yue Shi, Ying Liao, Zhicheng Zhu and E.L. Derr, assistant professor Yisha Xiang from Texas Tech University and professor Yili Hong from Virginia Tech, develops novel, degradation-based burn-in models to reduce unit-level heterogeneity for devices subject to multiple dependent degradation processes.

Their research studies two burn-in policies, one with a single screening point and the other with multiple screening points. Instead of pooling failure processes together and modeling a single overall failure rate, the authors considered different burn-in thresholds for individual degradation processes. At each screening point, a device is scrapped if any one of the degradation levels exceeds its respective burn-in threshold.



Texas Tech University authors and researchers, from left to right, Zhicheng Zhu, Yisha Xiang, Ying Liao and Yue Shi. Not pictured: E.L. Derr.



Yili Hong

The authors demonstrated the merit of the proposed models using experimental data from LED lamps. Their results show that the burn-in strategy is most effective for devices subject to multiple dependent degradation processes and that burn-in with multiple screening points outperforms burn-in with a single screening point.

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This month we highlight two articles from the September 2021 issue of *The Engineering Economist* (Volume 66, No. 3). The first involves levelized cost of energy in which the authors seek to modify the basic formula to account for probabilistic uncertainty in power plant lifetimes. They show how the lifetime uncertainty-corrected LCOE can produce significantly different results from the basic formula. The second involves optimal replacement, retrofit and management of a fleet of assets under regulations of an emissions system. The proposed model helps the firm simultaneously manage its assets' emissions and costs in a jurisdiction regulated by cap-and-trade.

The levelized cost of energy and regulatory uncertainty in plant lifetimes

As the world undergoes a radical transformation to electrify and decarbonize its economies, critical capital investment decisions must be made. In the electric power sector, many of those investment decisions are made using a metric commonly known as the levelized cost of energy (LCOE). This is a means of combining both fixed and variable costs into a single, unitized figure, generally expressed in dollars per megawatt-hour of electricity generated across a power plant's life.

One of the key risks facing many electric generators, however, is early retirement. For example, many fossil fuel power plants may be forced by regulators to retire early due to carbon emission constraints. The LCOE, however, presumes a fixed plant lifetime that is known with certainty. In practice, therefore, LCOE can be a biased metric in environments where the regulatory landscape is highly uncertain. Decisions made with this biased metric may give rise to costly losses for ratepayers and investors, known as "stranded costs."

In the article "The Levelized Cost of Energy and Regulatory Uncertainty in Plant Lifetimes," Carnegie Mellon University researchers David C. Rode and Paul S. Fischbeck modify the