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Reliability Modeling of Repairable Subsystems in Semiconductor Fabrication: A Virtual Age and General Repair Framework

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Abstract : In the semiconductor capital equipment industry, effective modeling of repairable system reliability is crucial for optimizing maintenance strategies and ensuring operational efficiency. However, repairable system reliability modeling using a renewal process is not as popular in the semiconductor equipment industry as it is in the locomotive and automotive industries. Utilization of this approach will help optimize maintenance practices. This paper presents a structured framework that leverages both parametric and non-parametric approaches to model the reliability of repairable subsystems based on operational data, maintenance schedules, and system-specific conditions. Data is organized at the equipment ID level, facilitating trend testing to uncover failure patterns and system degradation over time. For non-parametric modeling, the Mean Cumulative Function (Mean Cumulative Function) approach is applied, offering a flexible method to estimate the cumulative number of failures over time without assuming an underlying statistical distribution. This allows for empirical insights into subsystem failure behavior based on historical data. On the parametric side, virtual age modeling, along with Homogeneous and Non-Homogeneous Poisson Process (Homogeneous Poisson Process and Non-Homogeneous Poisson Process) models, is employed to quantify the effect of repairs and the aging process on subsystem reliability. These models allow for a more structured analysis by characterizing repair effectiveness and system wear-out trends over time. A comparison of various Generalized Renewal Process (GRP) approaches highlights their utility in modeling different repair effectiveness scenarios. These approaches provide a robust framework for assessing the impact of maintenance actions on system performance and reliability. By integrating both parametric and non-parametric methods, this framework offers a comprehensive toolset for reliability engineers to better understand equipment behavior, assess the effectiveness of maintenance activities, and make data-driven decisions that enhance system availability and operational performance in semiconductor fabrication facilities.

Keywords : reliability, maintainability, homegenous poission process, repairable system
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