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«Condition-based Maintenance Optimization of Degrading Systems»

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CONDITION-BASED MAINTENANCE OPTIMIZATION OF DEGRADING SYSTEMS

Abstract

The main objective of this thesis is to analyze and optimize the condition-based maintenance strategies to be adopted for production systems that can operate in degradation mode. First, we consider a production system composed of one machine/component and then extend it to more complex production systems. The machine is modeled as a multi-state system ranging from perfect functioning to total failure and each degraded operating state is characterized by its own production rate, fraction of nonconforming items produced and level of side effects such as the amount of carbon dioxide emitted and the level of energy consumption. When the last acceptable state of the component/machine is reached, preventive maintenance actions are deployed to bring the machine back to one of the previous higher levels of performance. In this context, three various types of common manufacturing systems are considered in this thesis: a serial system without intermediate buffers, two-machine/component manufacturing system with an intermediate buffer and a serial-parallel system without intermediate buffers. In the first type of configuration (i.e., a serial system), the objective of the optimization is to maximize the production rate of the system. The numerical results showed that the optimal preventive maintenance policies should be selected from the perspective of the whole system and major maintenance actions should be applied to the bottleneck machine of the system. In the second type of configuration (i.e., a system with two machines and an intermediate buffer), the objective of the optimization is to minimize the sum of the costs associated with maintenance, inventory level, nonconforming items and side effects caused by the degradation of machine's performance, while keeping the production rate at a high level. An analytical evaluation method is thus developed to evaluate the production rate. The effect of preventive maintenance and buffer level is analyzed, and the obtained results clearly show that a minimum cost can be reached when preventive maintenance is optimized for the whole system. In the case of the third type of configuration (i.e., a multi-state series-parallel system), a new model integrating condition-based maintenance and redundancy optimization is proposed. The objective is to jointly optimize, under availability constraints, the structure of the system and the conditional maintenance actions at a minimum cost. To estimate the availability of the system, a new model combining Markov chains and the universal moment generating function technique is developed. Moreover, a genetic algorithm is proposed to solve the formulated combinatorial optimization problem. The results obtained showed that the integration of operating costs in the optimization model gives better results, compared to the model considering only design and maintenance costs.