Simple Accurate Approximations of the Two-Threshold Control Limit Policy in Condition Based Maintenance

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Abstract

With the technology advancement, equipment used in a number of important economic sectors such as discrete manufacturing, oil/gas production, defense, and health care, become more and more capital intensive. Condition based maintenance (CBM) is a promising approach to overcome the failures and the interruption of these equipment. CBM executes the necessary maintenance actions just-in-time and only when there is evidence of abnormal health condition. The maintenance decision making in CBM recommends cost and performance efficient policy based on the fitted degradation process. In this paper, we consider a component exhibiting a continuous monotone degradation. The degradation process is random and modelled as a Gamma process. The maintenance policy is of condition based type and follows the two threshold control limit policy with a preventive limit, a switching limit, and a given failure limit. The inspection cost is non-negligible. Therefore, the component monitoring is periodic. Our objective is to minimize the annual expected maintenance cost subject to a constraint on the minimum average availability. The decision variables are the preventive limit, the switching limit, and the time between inspections. We derive exact results for the key performance indicators but since they are numerically involved we propose a new simple (i.e., it involves basic spreadsheet calculations) and accurate approximation of the annual average maintenance cost and of the average availability. The empirical results show that the two threshold control policy achieves a yearly cost savings up to 9% compared the single threshold policy. Moreover, the optimization results show a balancing phenomenon, which stabilizes the optimal expected number of inspections per cycle as the degradation per unit of time increases. Moreover, we find that doubling the corrective maintenance cost increases the optimal annual average cost by a small factor of 13%. These results show the benefit of jointly considering the preventive limit, the switching limit, and the time between inspections in the maintenance optimization.

Keywords
Condition Based Maintenance, Control Limit Policy, Periodic Monitoring, Gamma Process, and Optimization.