Abstract

Reliability is one of the important parameters of the modern engineering systems. Practicing engineers and researchers have found a number of methods to increase system and component reliabilities. Increasing the safety margin, reinforcing redundancy, controlling the operating environment, employing more reliable components, and implementing a well designed maintenance policy are some of the important methods available for increasing the systems reliability. For productive systems, once they were installed, implementation of these methods except maintenance, are heavily constrained because of time, space restrictions, and economy. Number of break downs, amount of down time, size of the repair crew, fraction of nonconforming output, amount of investment, productivity and profitability of the production systems heavily depend on the maintenance. A properly balanced maintenance policy optimizes the benefits and costs of the maintenance.

Productivity is a key strategy for manufacturing companies to stay competitive in a continuously growing global market. For achieving higher productivity, industrial systems adapting more advanced technologies. These systems integrate mechanical elements, electrical circuits, electronic devices, computers and software programs as subsystems and components. Recent developments such as automated manufacturing systems (AMS), lean and agile manufacturing, just in time (JIT) management systems, etc., have significantly improved the productivity. But these increased sophistications results in increased investment (Collins and Hull, 1986), increased failure rate (Luce, 1999, Vineyard et al., 2000, and Holmberg, 2001), and increased mean downtime (Robinson, 1987, and Paz and Leigh, 1994). In short, these effects results into increased down time costs and should be minimized in order to improve the

return on investment (ROI). Implementation of a properly designed maintenance policy does the same.

Stochastic nature of the deterioration process is well represented using multi-stage deterioration models. Markov and semi-Markov models are best suited for modeling the deterioration process, inspection schedules, and the effects of maintenance actions.

Generalized time based maintenance policies for deteriorating systems is proposed in chapter 3. The term "generalize" is used in the sense that the models proposed in this thesis have no restrictions on the effectiveness of the maintenance. According to these policies the system undergoes periodic PM actions which make the system τ deterioration stages ($\tau \geq 1$) younger. The models consider both deterioration and random failures. The models differ mainly in the type of repair at random failures. In the Model 1: perfect repairs (as good as new repair) are performed, whereas in the Model 2: minimal repairs are performed. Model 3 is a combination of model 1 and 2, by considering threshold deterioration stage based perfect and minimal repairs at random failures.

A generalized condition based maintenance (CBM) policy is proposed in chapter 4. In addition to the maintenance actions considered in chapter 3, this policy also consider periodic perfect inspections to know deterioration stage of the system. If the observed condition at an inspection exceeds the threshold deterioration stage, preventive maintenance is performed. Otherwise no action takes place, continue to run the system. Random failures are treated as in the previous chapter.

In chapter 5, a generalized CBM policy with minor and major PM actions is proposed. According to this policy, based on the deterioration stage at an inspection, a minor PM, a major PM, or a preventive replacement (PR) is performed, or no action is taken. Major PM actions restore the system to "τ_2" deterioration stages younger (τ_2>1), while minor PM action restores the system to

"τ_1" deterioration stages younger ($\tau_1 \geq 1$), and $\tau_2 > \tau_1$. The PR brings the system to as good as new condition. The proposed model also considers an accumulated deterioration based increasing intensity for the random failures.

When applied to a specific problem, any one of the above policy can produce optimum results, which depends on the cost components, maintenance durations and effectiveness. For decision making, obtain results by executing the three policies independently, by comparing the results choose a maintenance policy that minimize the costs or maximize the availability.

In chapter 6, a CBM policy with perfect maintenance actions is proposed. The policy considers (i) condition based mean time between inspections and (ii) condition based repair activities. According to this maintenance policy, the mean time to next inspection depends on the condition of the system at last inspection or at last known condition. The condition at an inspection equal to or exceeds the threshold deterioration stage PR is taken. Otherwise continue to run the system till the next inspection time.

A methodology for application of joint-repair in machine interference problem is proposed in chapter 7. The methodology gives optimal solution using queueing theory basics and the suggested exhaustive enumeration procedure. With simple changes, the methodology can applicable to find (i) Optimum number of repair crews in a K-out-of-N:G repairable system with and without joint repair, and (ii) Optimum number of repair crews in a load sharing K-out-of-N:G repairable system with and without joint repair.

The maintenance policies proposed in this thesis either generalize the existing policies or propose new policies and concepts which contribute for the development of the maintenance theory. These generalizations improve the applicability of the discrete stage deterioration modeling for many production/industrial systems. The policies show improvement in availability, net benefits, or reduction in total costs. The models proposed in this thesis are illustrated with suitable examples, most of these examples deal with existing real world problems. The results of the illustrated examples show considerable improvement in availability and reduction in total cost.