Abstract

Many modern engineering systems/processes are considered as hybrid dynamical systems. However, most of the existing diagnosis/prognosis approaches are intended for continuous dynamical systems and limited to single fault of unknown fixed degradation mode. In multi–component hybrid systems, discrete faults may be possible besides multiple parametric faults (abrupt or incipient), whose occurrence and degradation nature is unknown in advance. Multiple fault diagnosis is challenging due to the fact that the symptom of one fault effect may be masked or compensated by the other fault effects. In hybrid systems, component faults or degradations depend on the operating modes of the system which are activated by discrete events. Also, degradations are not observable from the measured variables in every working mode of the system for hybrid components. Thus, the existing techniques for continuous dynamical systems may not suffice for multi–component hybrid systems where discrete events along with the possibility of occurrence of multiple faults change the dynamics and degradation patterns of the system. Thus, more efficient and less resource intensive real time fault diagnosis and prognosis techniques have to be developed according to the present demands of critical machinery performance for maintaining system safety and reliability.

In this regard, a sequential multiple-fault diagnosis scheme is developed here for hybrid system based on decentralized architecture and bond graph modelling approach. The proposed method can diagnose any discrete or parametric fault whose effect may be masked due to pre–existing faults by introducing the new idea of dynamically updated model immediately after occurrence of each fault. Focused parameter estimation technique is proposed by using the information of fault directions obtained from the dynamic fault signature matrices for improving the online diagnosis of hybrid system. Moreover, this dissertation also considers the prognosis study of multi–component hybrid system and proposes the real time integrated prognosis scheme for degradation detection, degradation magnitude estimation and remaining useful life (RUL) prediction for multiple components degrading with different unknown rates. The fault indicator thresholds are used to trigger degradation detection as well as fault magnitude estimation, i.e., parameter estimation. With progressive parameter estimation, parameter deviation trends are identified and used for RUL evaluation for system prognosis. Parameter estimation can be done at fixed time intervals, but performing it only when a threshold violation occurs and then updating the model with estimated parameters is less resource intensive and more efficient approach to implement real–time health monitoring and prognosis. Besides, parameter estimation–based distributed prognosis scheme is proposed using bond graph model decomposition scheme. Utilization of multiple degradation models which include operational modes as additional control parameter and evolve through degradation model identification is suggested for system prognosis. The proposed approach is validated through both simulation and experimental work.

Key words: Hybrid system, Dynamic degradation patterns, Hybrid bond graph, Analytical redundancy relations, Sensitivity signatures, Multiple-fault diagnosis, Adaptive prognosis.