ABSTRACT

This thesis is concerned with model based online fault diagnosis of automotive spark ignition (SI) engine systems. Due to the forward and backward flow of different gas species, combustion process and reciprocating piston movements, the engine is a complex dynamical system. Malfunction of even a single component or subsystem of the engine can cause catastrophes and control anomalies leading to violation of emission regulations. The On-Board Diagnosis (OBD) standards demand the detection of various electrical and mechanical faults, but many times the diagnosis methods largely based on mean value engine models (MVMs) do not provide required sensitivity, isolability and identifiability for incipient faults. Further, Fault Detection and Diagnosis form an important building block of Integrated Vehicle Health Management (IVHM), which is being employed in increasingly many complex vehicular systems in recent times. The accuracy and performance requirements of diagnosis of automotive engines required in an IVHM again demand the use of accurate, quantitative models capturing dynamics of engine variables within the engine cycle. However, use of such models limit the online applicability of diagnosis schemes because of the limited on-board computational capabilities of the engine control units (ECU). Hence online fault diagnosis of engines based on models capturing the within-cycle dynamics, is a relevant area for research.

This thesis is an attempt to develop computationally attractive engine diagnosis schemes with improved fault sensitivity, isolability and identifiability as compared with MVM based existing fault diagnosers. This is achieved by examining every stage of model based diagnosis, namely, modelling, state/parameter estimation and fault diagnosis. This thesis adopts a hybrid state space modelling approach for the SI engine with appropriate choice of system state and fault parameters. For state/parameter estimation, an adaptive online estimation scheme based on Extended Kalman filter (EKF) is proposed, and is seen to be of comparable accuracy, at a much faster execution, to other nonlinear estimators. Online fault diagnosis schemes based on statistical change detection techniques, applied on predicted residuals from the EKF estimator under different fault scenarios, are proposed in this thesis. The online computational cost is greatly reduced by these techniques.

Keywords: Spark ignition engines, State space modelling, Nonlinear estimation, Adaptive Kalman filtering, Fault detection, Fault diagnosis, Fault tolerant control, Integrated Vehicle Health Management, Condition based Monitoring, Prognostics and Health Management, Likelihood ratio tests.