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SPACE PROPULSION SYMPOSIUM (C4)
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FAILURE DETECTION OF LIQUID PROPELLANT ROCKET ENGINE USING SYSTEM INVARIANT ANALYSIS TECHNOLOGY

Abstract

Health monitoring of rocket engines is one of the key technologies to enhance safety and survivability of launch vehicles. A large amount of data for engine condition monitoring, such as pressures, temperatures, flow rates, and so on, can be collected from distributed sensors to analyze engine system behavior. If we can interpret the collected data effectively, a foretaste of engine failure can be detected and the engine can be shut down safely before a catastrophic failure for avoiding the loss of vehicle. In order to detect a foretaste of failure of liquid propellant rocket engines from a large amount of engine condition monitoring data, the System Invariant Analysis Technology (SIAT) is applied. The SIAT is a kind of analysis methods to handle big data for automatic system management, developed by NEC. In this method, a concept of flow intensity is introduced, and a large, dynamic, and complex system is modeled as aggregate of relationships between flow intensities measured at various points across the system. Auto Regressive models with eXogenous inputs (ARX) are used to learn linear relationships between two flow intensities from the measurement data. If the modeled relationships hold all the time, they are regarded as invariants of the system. By tracking any change of those invariants, the operational status of system can be detected in real time. In the demonstration for applying the SIAT to the health monitoring of liquid propellant rocket engines, the data sets of Reusable Sounding Rocket (RSR) engine firing tests are given as the real measurement data. The RSR engine was designed to have advanced features such as wide-range throttling, re-ignition in an atmospheric condition, sure abort capability, long lifetime over 100 flights, and so on. Those advanced features were verified through the engine firing tests on the ground. The test series includes not only normal ones without any trouble but also abnormal ones to simulate engine failures. Those data sets are used, respectively, to construct the model for health monitoring and to demonstrate the failure detection. This paper shows the results of demonstration to detect a foretaste of failure for liquid propellant rocket engine. Base on the demonstration results, we discuss the advantages of the SIAT for real-time health monitoring. Further we discuss the possibility to identify an engine component that causes a failure by extracting the broken invariants.