Mini-Symposium on Advancement in Probabilistic Mechanics and Uncertainty Quantification
15th U.S. National Congress of Theoretical and Applied Mechanics (USNCTAM'06)
University of Colorado at Boulder, June 25-30, 2006

Uncertainty Modeling and Analysis for Structural Health Monitoring and Prognosis of Aircraft Component and System

Jack Z. Zhao[1*], Sharayu Tulpule[2], Robert Morrris[3], and Jay Littles[4]
[1]Structural Methods and Prognosis
Sikorsky Aircraft Company
6900 Main Street, Stratford, CT 06615
e-mail: jack.z.zhaojz@pw.utc.com

[2] Propulsion System Analysis
[3]High Cycle Fatigue and Stage Vibration
[4]Engine Health Management and Sustainment

*Previously, Fatigue and Fracture Mechanics
Pratt and Whitney Aircraft
400 Main Stress, East Hartford, CT 06108

The life of a structural component is limited by its ability to resist the effects of its usage history and material aging process. In the past two decades, structural health monitoring techniques, via diagnostics and prognostics, have been extensively developed and widely utilized in aerospace and mechanical component and systems to provide state-of awareness of structure usage and material damage accumulation. For aircraft propulsion system, diagnostics and prognostics provide an unprecedented improvement in aircraft readiness and safety. By integrating real-time sensors data for engine usage parameters and static/dynamic response characteristics with physics based models of material degradation and damage accumulation, a new generation of structural health monitoring system will provide more efficient, affordable, and reliable techniques capable of assessing structural integrity, predicting useful remaining life, and recognizing the onset of structural failure early enough for better maintenance scheduling and actions planning for life-cycle fleet management.

Development of new generation of structural health monitoring for aircraft propulsion system needs multi-discipline efforts from various technical areas, including sensor network optimization, data collection and communication, signal processing and feature extraction, pattern recognition and reasoner, physics based material characterization and damage accumulation modeling, and remaining life prediction. Uncertainty modeling and propagation, as one of the technical challenges and hurdles, impacts almost each of the aforementioned technical areas and needs to be addressed exclusively. This paper addresses the technical challenges of structural health monitoring and presents a probabilistic approach for uncertainty modeling, propagation, and updating of diagnostics and prognostics algorithms used in structural health monitoring. Techniques to evaluate uncertainty associated with sensor measurements and engine diagnostic unit (EDU) and errors in signal processing and feature extraction will be presented. The technical requirements for development of a generic framework with numerical efficient and accurate algorithms for uncertainty propagation and updating will be discussed. The

probabilistic uncertainty modeling and analysis framework under the development will have a far-reaching impact on addressing sensor uncertainty propagation on part-specific life prognosis algorithms, and integrating the inherent part specific lifing variability into the reasoner uncertainties to enable better strategic mission planning for optimal fleet deployment and management. This material is based partially upon work supported by the Defense Advanced Research Projects Agency Defense Sciences Office (DARPA DSO) Engine Systems Prognosis program under Contract No. HR0011-04-C-0001.

Keywords: Damage, Prognosis, Sensor, Strutrual Health Monitoring, Uncertainty, Updating