Track: 14. Safety Engineering, Risk and Reliability Analysis

Topic: System and structural health monitoring and prognostics using NDE/ SHM techniques

Authors and Affiliations:
Molly O'Connor, NASA Ames Research Center
Hanna Millares, San Jose State University
Portia Banerjee, [KBR] NASA Ames Research Center
George Gorospe, [KBR] NASA Ames Research Center
Naomi Endres, University of Michigan

Title: Vibration-based health characterization of multiple IMUs in UAV applications.

Molly O'Connor, Hanna Millares, Portia Banerjee, George Gorospe, Naomi Endres

Abstract

Inertial measurement units (IMUs) are vital in UAV navigation for vehicle attitude and position estimation, especially in the frequently-occurring case of temporary loss of GPS capabilities. Degradation in these units could yield inaccurate position estimates, resulting in incorrect input for vehicle control systems. A wide variety of these units exist to meet the needs of UAV operators, general aviation, and military vehicles. In recent decades, lightweight and inexpensive MEMS sensors have grown in popularity with respect to UAVs. Studies into the failure modes of MEMS devices suggest that vibration is one of the leading causes of MEMS degradation. MEMS sensors are generally encased in their own hermetic packaging, as their small size and sensitivity cause them to be particularly vulnerable to air damping and particulate contamination when exposed. Exposure to excessive vibration can cause cracking in this packaging as well as damage to connecting electronics, with recorded results that cause sensors to act outside of their specifications, potentially providing unreliable input to controllers. A prior study from the Politecnico di Torino looked into the degradation of MEMS IMUs, specifically the AXIS-AIS402, for aerospace and vibrating environments. In the study, the authors found that after exposing MEMS IMUs to simulated vibrations from working conditions of aerospace applications, the sensors showed increased noise and increased bias instability. At NASA Ames, several widely-used MEMS IMUs were selected for a new IMU degradation study, comparing accelerometer performance before and after exposure to similar levels of vibration simulating aerospace conditions. The IMUs were selected from the Pixhawk

autopilot systems, hobby sUAS, or prior experimental studies at NASA. Additionally, the industrial grade VectorNav-100 IMU was selected as a ground truth reference point to which the performance of the test sensors can be compared. In the study, each sensor is exposed to functional levels of UAV vibration as replicated on a single-frequency vibratory table in the NASA Ames SHARP Laboratory, and each accelerometer is characterized for bias, drift, and noise characteristics both before and after vibratory exposure. The focus of this study is to monitor the health of the IMU sensors and determine if sensor degradation can be detected from output error and frequency spectrum analysis, rather than from microscopic examination of the sensors. In this case, sensor degradation and faulty data can be more easily detectable by non-experts hoping to use these sensors as an important piece of an integrated package. In addition, specific sensor degradation modes potentially leading to in-flight hazards could be identified, such as accelerated levels of drift and altered temperature response. The overall goal of this work is to increase levels of safety for future users of these sensors and to provide a clear analysis of sensor limitations currently lacking in most sensor specification documentation.