Actuator Systems Prognostics

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Overview

Introduction

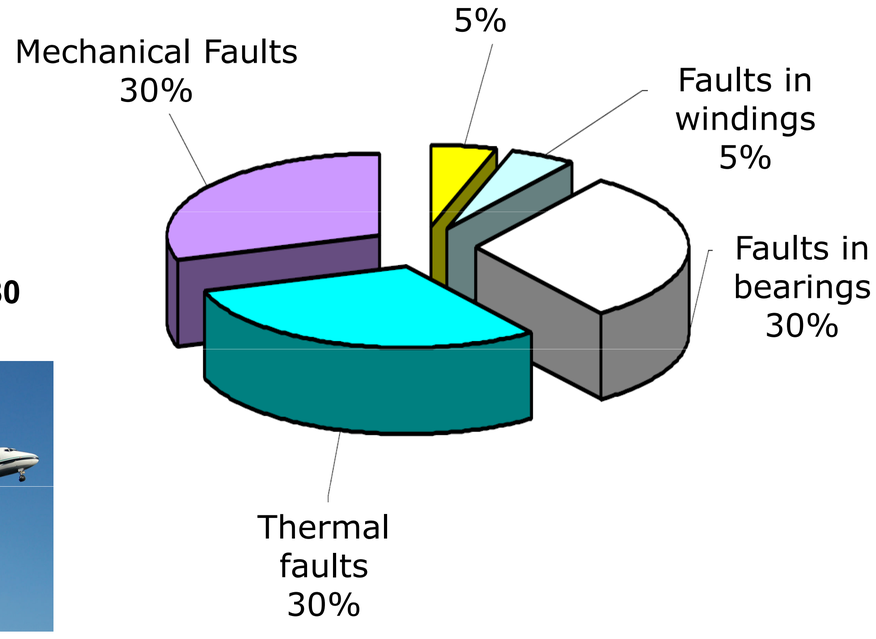
- Actuators are mechanical, pneumatic, hydraulic, electrical, or hybrid devices that perform a mechanical motion in response to an input signal
- Actuator failures in complex systems, such as aircraft or spacecraft, can lead to catastrophic consequences

Select Case Studies

Scaled Composites SpaceShipOne

Alaska Airlines MD-80 flight 261

Potential Fault Modes



Challenges

- Non-invasive prognostic methods requirement
- Limited built-in sensor suites
- Restricted on-board computational resources

Objectives

- Detect and classify incipient faults
- Estimate Remaining Useful Life (RUL) given a degraded mode
- Provide an accurate picture of EMA component health
- Generate real-time actions or recommendations for extension of RUL

Methodology

Test Article

- Linear electro-mechanical actuators (EMA) selected
- Moog MaxForce is a ballscrew, direct-drive design

Data Collection

- Initial data collected at Moog Inc
- EMA test stand constructed at NASA Ames
- Capabilities include: 5 metric ton load capacity, accommodation of test actuators of various sizes and configurations, and custom motion and load profiles

Sensor Suite

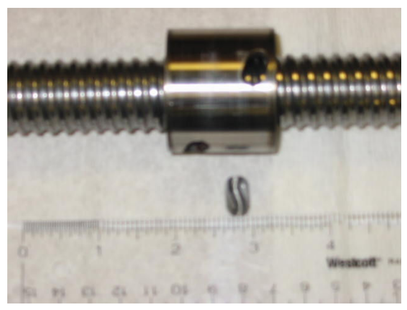
- Vibration, load, and temperatures sensors
- High-precision position sensors
- Current sensors

Electro-mechanical actuator test stand

Initial Set of Fault Modes

Mechanical faults

- Ball screw return channel jam
- Lubricant deterioration
- Backlash



Extracted actuator return channel

Motor faults

- Air gap eccentricity
- Insulation and conductor degradation

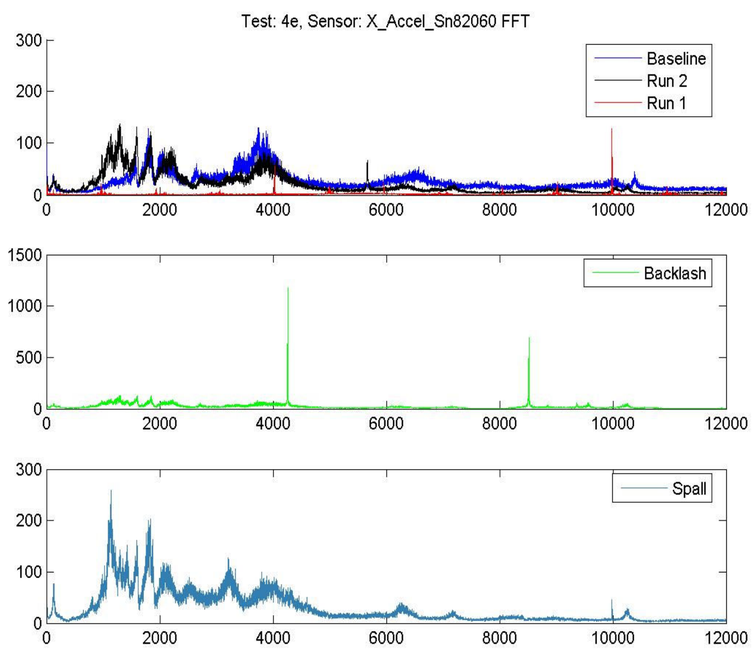
Implementation

Diagnostic System Development

- A neural network based diagnostic system developed and tested for mechanical (return channel jam, spalling) and sensor faults (bias, drift, scaling, loss-of-signal)
- Various motion profiles, load levels, and load types (spring or constant) were used in testing
- Results show the following overall rates: 3.46% false positive, 1.21% false negative, 0.29% misclassification, 3.8% unidentified

Prognostic System Development

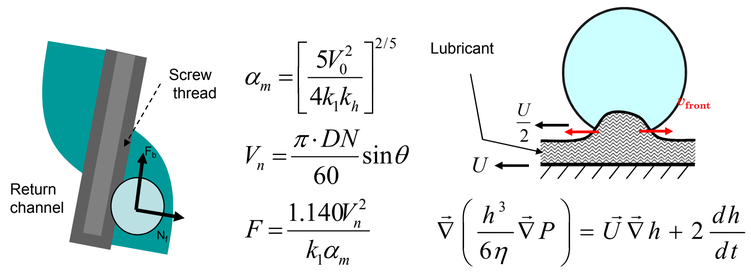
- The PHM system will employ a variety of algorithms (Kalman filters, Particle filters, neural networks)
- The influence of sensor noise and operational environment is being incorporated



Vibration data collected on Moog 883-023 actuator

Modeling

- Physical models: return channel wear, ball collisions, jam formation, vibration signatures, backlash, and lubrication deterioration
- Simulink models: T200 controller



Testing

- A Boeing 727 aileron wing section is being used as a developmental test bed
- Flight test planning being initiated on C-17, F-18, S-3, as well as on UH-60 helicopters and several unmanned aircraft

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