Spiral-Bevel-Gear Damage Detected Using Decision Fusion Analysis

Helicopter transmission integrity is critical to helicopter safety because helicopters depend on the power train for propulsion, lift, and flight maneuvering. To detect impending transmission failures, the ideal diagnostic tools used in the health-monitoring system would provide real-time health monitoring of the transmission, demonstrate a high level of reliable detection to minimize false alarms, and provide end users with clear information on the health of the system without requiring them to interpret large amounts of sensor data.

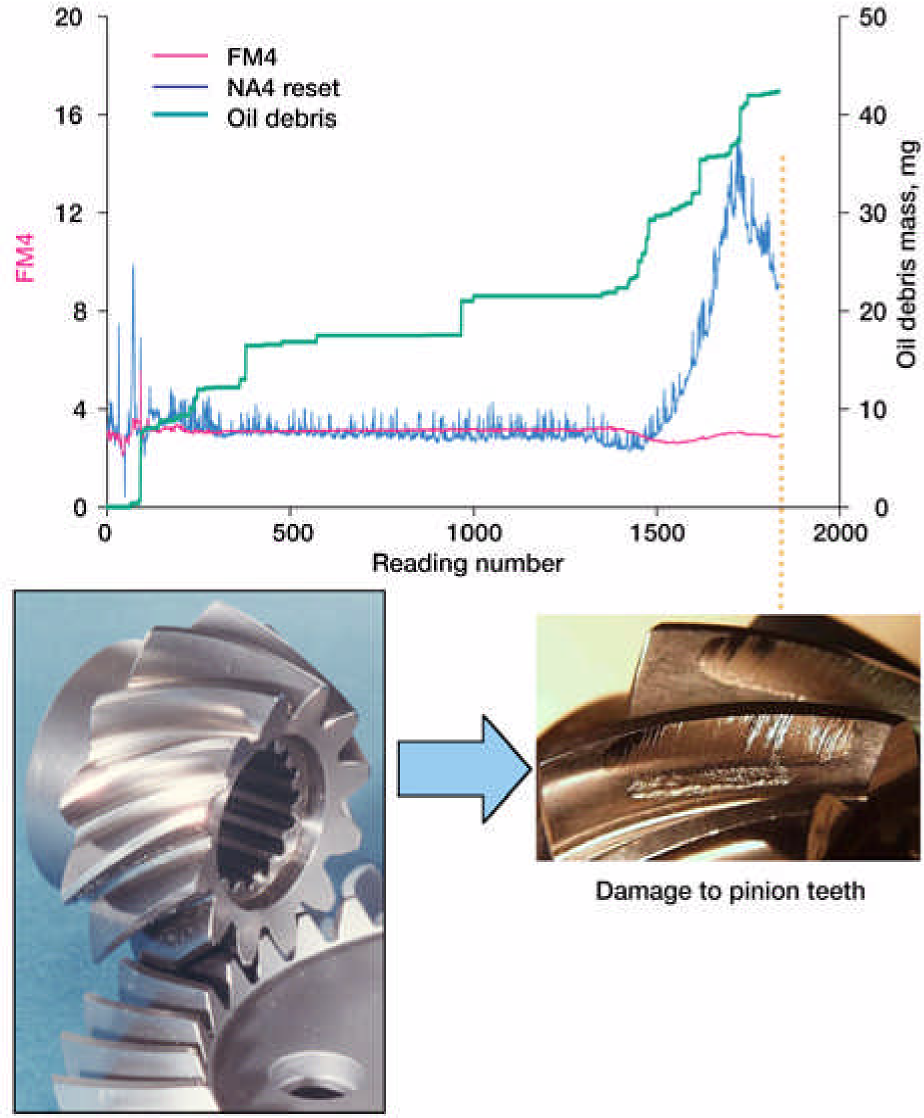
A diagnostic tool for detecting damage to spiral bevel gears was developed. (Spiral bevel gears are used in helicopter transmissions to transfer power between nonparallel intersecting shafts.) Data fusion was used to integrate two different monitoring technologies, oil debris analysis and vibration, into a health-monitoring system for detecting surface fatigue pitting damage on the gears.

The diagnostic tool was evaluated with vibration and oil debris data collected from fatigue tests performed in NASA Glenn Research Center’s Spiral Bevel Gear Test Facility. Data were collected from two accelerometers, an oil debris sensor, a speed sensor, and torque sensor installed on the test facility. The vibration and speed data were used to calculate two gear-vibration diagnostic algorithms-FM4 and NA4. The oil debris mass data were collected with a commercially available inline oil debris sensor.

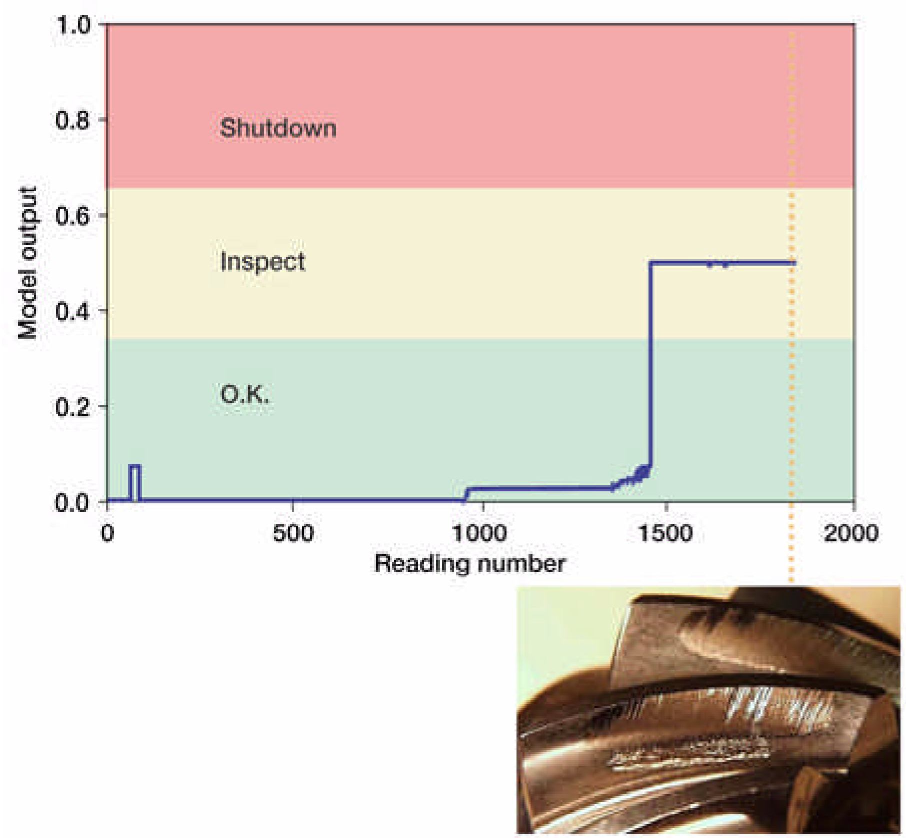
Multisensor data fusion analysis techniques were applied to the gear damage data collected from accelerometers and an oil debris sensor. This process is similar to methods humans use to integrate data from multiple sources and senses to make decisions. Data from multiple sensors were combined to make inferences that were not possible from a single sensor. Sensor data can be fused from the raw data level, feature level, or decision level. Decision-level fusion was chosen to integrate these features because it does not limit the fusion process to a specific feature or sensor. Vibration algorithms and accumulated mass of the debris were the features extracted and input into the data fusion system. Fuzzy logic was used to identify the damage level indicated by each feature and to perform decision-level fusion on the features. Then, the output of the data fusion model was given in the form of the possible actions end users could take and, in parentheses, the state of the gear. The possible actions and gear states were O.K. (no gear damage), inspect (initial pitting), and shutdown because of damage (severe destructive pitting).

Analysis of the data collected during these experiments demonstrated the advantage of fusing the features of different measurement technologies. The output gives clear, reliable information to end users making decisions about the health of the geared system. Results indicate that combining the two technologies greatly improves the detection of damage on spiral bevel gears.

The following two plots show the data collected from one experiment with pitting damage. The top figure shows the vibration algorithms FM4 and NA4 and the amount of debris measured by the oil debris sensor. The bottom figure is the output of the data fusion model used to integrate the oil and vibration data.



Input to data fusion model.



Output of data fusion model.

Bibliography

Dempsey, Paula J.: Gear Damage Detection Using Oil Debris Analysis. NASA/TM--2001-210936, 2001.

Dempsey, Paula J.: Integrating Oil Debris and Vibration Measurements for Intelligent Machine Health Monitoring. Ph.D. Thesis, Univ. of Toledo, 2002.

Dempsey, Paula J.; Handschuh, Robert F.; and Afjeh, Abdollah A.: Spiral Bevel Gear Damage Detection Using Decision Fusion Analysis. NASA/TM--2002-211814, 2002.

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