

High Performance Sensors for Rolling Element Bearing Health Monitoring

Pushing the Boundaries of Machinery Prognostics

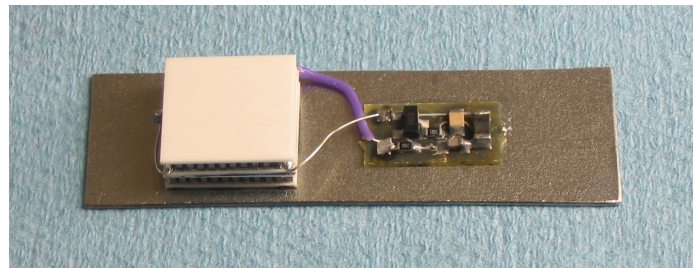
Problem Statement

Rolling element bearings in aircraft are critical to aircraft operation and safety. These bearings operate in extreme conditions, transmitting high loads, spinning at high speeds, and enduring harsh environments. Bearings and gears in the JSF lift fan drive system, for example, must endure high loads and accelerations, temperatures of 150 °C, and pitch velocities up to 25,000 ft/min. Bearings in the engine hot path must operate up to 300 °C. Future engines are expected to operate at even higher temperatures.

Turbine engine bearings are critical to aircraft operation and safety because their failure can lead to complete engine failure. Bearing failures in the turbine engine are the leading mechanical cause of class-A failures (loss of aircraft or > 1M\$ damage). The current maintenance paradigm for turbine engines is preventative maintenance; the engine is overhauled on a conservative usage-hour or take-off-and-landing-cycle basis. This maintenance schedule is inefficient, neglecting the remaining useful life of components and causing long periods of asset downtime. Condition Based Maintenance (CBM) shifts the maintenance paradigm from a sub-optimal time-based schedule to a maintenance schedule based on machine health; meaning maintenance is performed only when components are faulted.

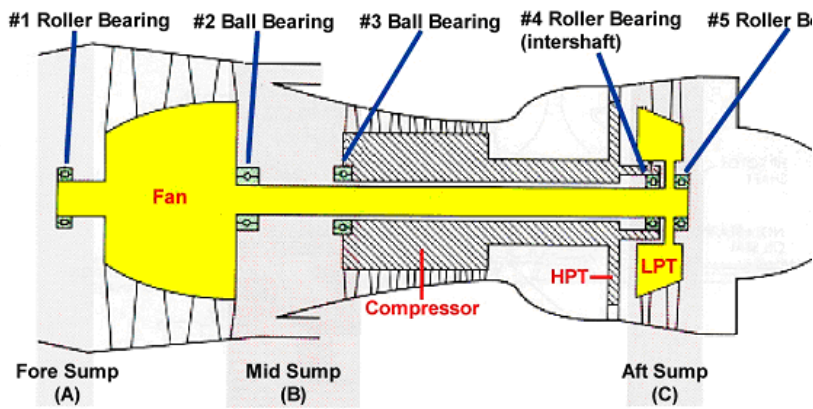
The Solution

To implement CBM practices, accurate and continuous knowledge of bearing health is essential. Sentient's bearing sensors provide means to continuously monitor the health of such critical, inaccessible, harsh-environment bearings and, consequently, prevent turbine engine failure.



The figures shows a bearing sensor prototype (right) and a sensor representation prior to enclosing the sensor with high temperature potting compound (bottom). The bearing and sensor, or "smart bearing", is designed to be a drop-in replacement for existing bearings, providing wireless temperature and vibration information to a receiver outside the





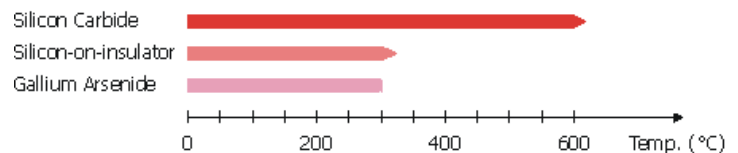
engine. The temperature and vibration information can then be used in maintenance scheduling, ultimately reducing maintenance costs. Such a bearing minimizes the impact to on-board electronics, and eliminates the need to modify the turbine engine.

With sensors at the point of failure and autonomous operation, this technology has the potential to provide diagnostic information for

bearings previously considered inaccessible and to provide earlier and better diagnostic information than existing sensors. For example, the #4 roller bearing, an inter-shaft bearing, on General Electric’s F136 turbine engine is inaccessible, vibrationally isolated, and exposed to high temperatures. Conventional diagnostic approaches, including vibration or oil debris monitoring, are ineffective. However, the smart bearing can provide diagnostic capability for the #4 roller bearing.

Sensor Details

The sensor monitors bearing health by providing measurements of bearing temperature and vibration. This data is provided via wireless transmission. Power for the sensor is harvested from the environment



using thermo-electric generators. High-temperature semiconductor materials enable operation in harsh environments. Sentient’s sensor is designed to be small, lightweight, and rugged. It has few parts, some of which are dual-use components that function both as sensors and standard electronic components. The sensor also has no moving parts, which further contributes to its ruggedness. Miniature thermo-electric generators (TEGs) directly convert waste heat to D.C. electricity, eliminating the need for power conditioning circuitry. The sensor encodes and transmits temperature and vibration information using frequency modulation. Sentient’s sensor utilizes existing technologies and as many off-the-shelf components as possible, equating to low technical risk; multiple sources exist for all of the components and development is not hindered by a need for exotic technologies or technological breakthroughs.

The bearing sensor, although initially targeted for turbine engines, can provide diagnostic information for bearings in a variety of other applications. For example, naval vessels, ground combat vehicles, commercial aircraft, and industrial machinery are promising applications for the same sensor technology.

Contact Sentient Corporation for more information on high performance bearing sensors and a discussion about how this technology can improve your maintenance capability.

850 Energy Drive
 Suite 307, Room 428
 Idaho Falls, ID 83401
 208-522-8560
 info@sentientscience.com