Accelerometers for Health & Usage Monitoring Systems (HUMS)

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Health and Usage Monitoring Systems (HUMS) are gaining wide acceptance as an effective predictive maintenance strategy in helicopters and some fixed wing aircraft. Due to the large number of critical flight safety systems on aircraft, particularly rotating systems on helicopters, vibration monitoring technology is effective in the detection and prevention of catastrophic mechanical failures. HUMS started more than 15 years ago, as a safety system and has evolved into a front-line strategy for reduction of aircraft maintenance costs. The key benefits associated with HUMS systems include:

- **Safety:** alerting maintenance personnel to drive train health and operation outside approved parameters.
- **Economic:** eliminate dedicated return to base flights; reduce non revenue flights, inspections and false removals; insurance savings.

More benefits are still to be realized, since HUMS technology continues to evolve. In the case of accelerometers and signal conditioning, instrumentation performance criteria and specifications continue to be optimized, to meet the stringent aircraft testing requirements of the aerospace and defense industry. Typical HUMS applications include rotor track and balance; shaft balance; monitoring (transmission vibration, engine vibration); gearbox (main, tail and intermediate); and rolling element bearing diagnostics. Furthermore HUMS enables the recording of flight conditions in excess of approved flight manual parameters, and to check aircraft health status after each flight.

Onboard aircraft HUMS systems are comprised of a basic data acquisition device and processor, pilot interface and display panel; rotor blade tracker; piezoelectric accelerometers, signal conditioners and tachometers; cockpit voice and flight data recorder; and Frequency Domain Reflectometry (FDR) sensors. Installed on-ground is a HUMS information management system, with data retrieval and memory cards.

Piezoelectric HUMS Accelerometers

Piezoelectric accelerometer technology is a standard widely accepted and used in HUMS; sensors typically have specialized requirements for performance, reliability, and packaging, depending on the particulars of the aircraft and standards. Piezoelectric HUMS accelerometer technology can be divided into charge output and ICP® (integrated circuit piezoelectric) sensors. PCB Piezotronics (PCB®) was the pioneer of ICP®, a technology which has grown to become an industry standard.

ICP® accelerometers incorporate built-in a microelectronic amplifier, which functions to convert the high impedance electrostatic charge from the piezoelectric sensing element into a low impedance voltage signal. In all-welded, hermetic designs, the high impedance circuitry is sealed and electrically shielded inside the accelerometer. ICP® accelerometers were first manufactured in the mid 1960's. Sensors operate from a low-cost, constant-current power source over a two-wire circuit, with signal/power carried over one wire and the other wire serving as ground.

The main advantage of this technology is the capability of ICP® accelerometers to operate continuously with low impedance in adverse environments via long, ordinary cables, without increase in noise or loss of signal quality. Cost per channel is less than using charge output sensors, since low noise cable and charge amplifiers are not required. This is especially applicable for the “particular” environment we find inside a helicopter’s transmission. Therefore, the HUMS accelerometer should be unaffected by electrical interference (and EMI), cable noise, harsh environments (eg, lubricant spray in transmission box). Historically, the only serious limitation for ICP® technology has been the temperature. Recent models are now available to withstand up to +150°C, well above the normal temperature of measurement points or locations inside the drive or transmission train of the helicopter.

HUMS charge output accelerometers generate a high-impedance, electrostatic charge output in response to mechanical stress applied to its piezoceramic, or crystal, sensing element. These accelerometers send a high-impendance signal and operate through low-noise cable into a charge amplifier, which converts the charge signal into a usable low-impedance voltage signal for data acquisition. The charge amplifier provides for signal impedance conversion, normalization, gain/range adjust and filter weight. The constant current power needed to operate an in-line charge converter comes from a separate unit or may be incorporated inside a readout instrument or the HUMS acquisition unit. Charge output accelerometers are typically used in environments where temperature is a consideration, such as turbine measurements.

HUMS accelerometer technical specifications can differ depending upon the user. Typical considerations include high resonant frequency for rotating part diagnostics, and accurate low frequency phase data for rotor track and balance. Sensors are electrically isolated from ground in order to rule out obvious electrical interference problems. They also feature low base strain and case strain sensitivity; a reliable and maintainable connector and cable system; and hermetic connector or integral cable versions for resistance to harsh environments. HUMS accelerometers also feature easy installation, especially in some part of the helicopter’s transmission, using a single center bolt mount, through bolt design.

All PCB Piezotronics HUMS sensors feature a robust element design, with ceramic and quartz sensing elements, and top or side exit electrical connectors, and in a variety of hermetically sealed physical configurations. High temperature versions operate up to +900 ºF (+482 ºC); with a 500 g measurement range; frequencies of up to 15k Hz; and a variety of sensitivites, including the most popular 10 and 100 pC/g. In addition to all above mentioned specifications, PCB sensors are available in electrical case isolated versions, to reduce EMI and ground loop interference, hermetically sealed in a stainless steel or titanium housing, and shear mode sensing geometry for best response to case strain. Also available is the new Model 495B10 differential charge converter for HUMS. Operating from aircraft power, the converter will condition the signal of a charge output accelerometer, enabling it to be used by standard data acquisition equipment. While this sensor family represents a sampling of solutions used for this critical application, advanced design capabilities permit PCB® to customize solutions specific to customer requirements, including compliance with any typical MIL standards. Some PCB® HUMS sensors have also passed parts of RTCA-160E testing.

For harsher aerospace applications, PCB® also manufactures high temperature aerospace accelerometers (+649 ºC) +1200 ºF to satisfy particular engine measurement requirements. This might include such applications as vibration measurement on gas turbine engines, in flight or in test cells; rocket motor vibration measurements; and thruster vibration. Accelerometer models are available that can function in nuclear radiation environments, and possibly in a combination of temperature extremes and radiation, for nuclear power generation or space vehicle applications. In addition, Series 3741 high sensitivity MEMS accelerometers, with response down to 0 Hz and full scale ranges from 2 to 200 g, and sensitivities of 1 V/g to 10 mV/g, respectively, are designed to provide accurate readings whilst subjected to severe vibrations over a wide temperature range.

For nearly 40 years, PCB® has manufactured a variety of aerospace sensors and signal conditioners for flight test and in-flight monitoring; flutter test; ground and vibration test; sound and vibration testing; load factor measurement; structural dynamics; acoustics and turbulent flow; engine health (vibration) monitoring; dynamic fatigue; environmental stress screening; control system input and response tests; wind tunnel and aerodynamic testing; active vibration control; engine/airframe and aircraft carrier qualification; and troubleshooting.

PCB® quality system is based on the requirements of AS9100:2004 and ISO9001:2000. In-house calibration is conducted with full traceability to NIST/PTB, and calibration methods are accredited by A2LA to the ISO 17025 standard.