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GPMS continues to extend the range of aircraft on which its Foresight MX HUMS can be installed. So far this year, it has gained STCs for Bell's 429 (pictured), 212 and 412 types. (Photo: Bell)

A PICTURE OF HEALTH

Peter Donaldson talks to HUMS experts about the latest developments in health and usage monitoring technology and the progress being made towards condition-based maintenance.

Sometimes, the full promise of the best technologies takes far longer to come to fruition than anticipated. In the helicopter world, health and usage monitoring systems (HUMS) come into that category.

With its safety benefits long proven over decades in medium and heavy helicopters offshore and in the military, HUMS technology has taken longer to benefit lighter helicopters (although that is happening now), while the long-awaited shift from scheduled to condition-based maintenance (CBM) remains just that – long awaited. However, there is a path from here to some kind of CBM nirvana paved with stepping stones that add value in their own right.

The initial value proposition of HUMS was twofold. The first part was that by collecting and processing data from sensors that measure vibration in engines and transmissions, along with torque figures, temperatures, rotational speeds, control inputs and a host of other parameters, faults could be detected and corrected before they become dangerous. This is now well established, if not flawless.

The second was that HUMS information would enable the condition and remaining useful life of the monitored components to be calculated so accurately that rigid maintenance schedules could be set aside and parts replaced or overhauled only when the CBM system says it should happen. Unnecessary work would be eliminated, reducing maintenance costs and improving aircraft availability without increasing risk.

Burden of proof

Regulators demand schedule-based maintenance and rightly insist on high standards of proof before they will award credits that allow the time between overhauls (TBO) or an inspection interval to be extended, or a component or subsystem to be maintained on condition. For example, guidance from the US FAA to HUMS developers seeking a maintenance credit says that the system must provide the same level of assurance from fault detection to reporting action as the physical inspection it is intended to replace.

A technician installs the hardware for GPMS's Foresight MX system. (Photo: GPMS)

"That's a pretty tall order," notes Eric Bechhoefer, CEO and chief engineer at GPMS, developer of the Foresight prognostic HUMS for light helicopters. "It's a lot of work, and it's not going to happen without OEM participation."

RotorHub covered Foresight in some detail last summer, and since then GPMS has earned supplemental type certificates for the system on the Airbus AStar and Bell's 212, 412 and 429. Andrew Swayze, the company's head of marketing and strategy, reports extensive interest from North America and overseas, plus new projects with operators including Duke Energy and the Tennessee Valley Authority.

"We've been gratified to see the market respond to our lightweight system offered as a subscription service with pricing geared to produce a concrete return on investment from greater availability, cost savings and asset value protection," Swayze says. The last of these is a benefit of the information the system generates about the way the aircraft has been used, as well as the condition of key components.

Ready for action

Central to HUMS and CBM is dealing with data and presenting it to maintainers and operations managers as clear information they can act on. "It is the delivery of actionable information in which HUMS and CBM have seen most progress in recent years," says Chris Thomson, who recently retired as a vice-president of Curtiss-Wright and now acts as a consultant to the firm. "Data collection is the most complex part of any HUMS process because you require sensors and data acquisition, you require recording and data transfer, and so on."

Curtiss-Wright makes flight recorders, including crash-protected varieties, and data acquisition units (DAUs) to meet both accident/incident investigation and full HUMS requirements, and can link them to aircraft communication systems for in-flight downloading. Steve Leaper, product manager for flight recorders and bids and proposals manager for avionics at the company's Christchurch, UK facility, explains that its Fortress product line records flight data, voice and imagery, along with vibration and other HUMS data, and can be interfaced with Honeywell satcom equipment.

"Information comes into the recorder and is processed and can be put out either in short bursts or a constant stream so that not only can you track the flight path of the aircraft, but potentially you can also look at the performance," he says. "If you start to add HUMS into that data stream, you give operators a lot more information they can use."

Leaper adds that if a human expert or even an artificial intelligence system running in the cloud has eyes on the information as it comes in, it is possible to see if the aircraft is doing anything abnormal that could indicate a problem. "They could start monitoring it more closely to find out what's happening and, if something is detected, start communicating with the crew for safety," he notes. "It is a way of closing that loop, and it is work we are starting to do now with the flight recorders that we are introducing with Honeywell."

More prosaically, wireless data transmission eases the burden on flight crews and maintenance professionals when it comes to managing the data. "Cloud-based infrastructure and wireless communications are enabling technologies because getting data to the right place to do the analysis is the key to getting anywhere with this stuff," says GPMS's Bechhoefer.

Before data can be recorded and transferred off the aircraft, it has to be acquired from the sensors, which is the job of the DAU. Curtiss-Wright offers multiple DAU product lines that gather all kinds of data in any required format, in compact form factors and with additional capabilities including data processing.

Rapid results

Pat Quinn, product line manager for data acquisition at Curtiss-Wright, explains that the company is working on a new-generation member of the Axon DAU family that is to incorporate a processing module that will run the fast Fourier transform (FFT) algorithms on the data aboard the aircraft. He believes that airborne analysis will be an important driver of future HUMS and condition monitoring systems. "Results are gathered and the data analysed a lot faster than downloading raw data and spending ages processing it allows," he says.

Another option is to process sensor data as close to the source as possible, which in practical terms means within the sensor itself. That is a capability that Dytran offers in its Controller Area Network – Machinery Diagnostics (CAN-MD) smart sensor technology.

Dytran describes CAN-MD as a bus-based, digital smart accelerometer network with configurable firmware. It offers the ability to collect vibration data, process spectral data and calculate condition indicators within the sensor itself and without the need for an external data processor. "It provides actionable outcomes to the user directly

Smart digital sensors can process the data they collect and use it to calculate HUMS condition indicators. (Photo: Dytran)

from the sensor and with no more data to be analysed," says the company.

The sensors incorporate digital signal processing, which is what makes them smart. Dytran says that smart sensing in general is one of the biggest innovations in machinery monitoring technology and that it will eventually "open the floodgates" for HUMS in all kinds of aircraft and even ground vehicles. "Also, the sensors and sensing systems going digital is a big deal," notes the company. "The reduction in cabling and weight in a digital system is very significant."

While CAN is a digital data bus standard most strongly associated with cars, it is increasingly applied to aircraft and formalised through ARINC 825.

Different approaches

The task faced by all HUMS data processing and condition monitoring systems, explains Bechhoefer, is to extract the fault signal from the noise, to identify the particular fault from the fault signal and to provide predictive estimates of the remaining useful life on the component in question.

There is a major division between approaches to this problem characterised by big data on one side and physics-based systems on the other, with a third based on measurement of complexity offering some intriguing possibilities.

Essentially, the big data approach aims to build libraries of known faults against which to compare information from the machine being monitored. While this works with simple machines such as electric motors, Bechhoefer argues, it doesn't work with complex ones such as gearboxes.

This, he says, is because faults occur infrequently, faults in different components happen with different modalities, each component has multiple fault modalities and the same component in different positions in a gearbox will have different signatures. This makes it practically impossible to build a comprehensive fault library for helicopter fleets.

GPMS's Foresight is physics-based. In this context, it means that the laws of physics applied to vibration data from a healthy gearbox, for example, dictate that the data will have a Nakagami probability distribution that when plotted on a graph has a quite different shape from the classic Gaussian bell curve. "Therefore, when the calculated result provides a distribution that is no longer Nakagami, we know the component is no longer good," states Bechhoefer.

The phrase "no longer good" is important because Foresight draws upon plentiful data from healthy machinery and looks for differences that imply that a fault is developing, which is more productive than trying to compare data with known faults that occur only rarely. A bonus here is that Foresight requires little training data, normally needing only about 10 minutes, he says.

An intriguing alternative to the detection of anomalies in data has recently been dubbed artificial intuition to distinguish it from artificial intelligence. Developed by Dr Jacek Marczyk, president of Ontonix, and used in the company's Complexity and Health Monitoring System (CAHMS), this approach takes raw, unprocessed data from multiple channels, discerns the relationships among them and detects changes that indicate developing faults. It does all of this without prior knowledge of the monitored system or training on the data, Marczyk emphasises.

Deteriorating relationships

CAHMS relies on the ability to measure the complexity in the system being monitored and to detect changes in it. Complexity is defined as structured information, he says, and the unit of complexity is the bit. Such structured information can be depicted in complexity maps that show the relationships and interdependencies between different data channels.

Some of these healthy relationships may be sharp and linear, such as that between the angle of the steering wheel and the corresponding angle of the front wheels of a car, for example, while others may be naturally fuzzier because there are more factors involved, such as that between the accelerator pedal displacement and the ▶

Curtiss-Wright is working with Honeywell to interface crash-protected HUMS data acquisition units with satellite communications to enable real-time monitoring and analysis of data. (Photo: Curtiss-Wright)

engine speed. However, when a previously sharp relationship starts to become fuzzier – in other words, there is more complexity in the system – it is likely to indicate wear in the steering rack or a track rod, for example.

CAHMS relies on the correct placement of sensors to provide reliable data streams from monitored components, so it might be challenged by the fact that each accelerometer on a helicopter gearbox picks up vibration signals from many components. The system has been used in armoured vehicles, where it has proved able to reveal imminent failures 20 to 30 minutes ahead of time.

"We haven't done this on helicopters as of today, but because our technology is application-independent, we don't need to prove it on every single piece of equipment to show that it works," states Marczyk.

However, the path from scheduled to condition-based maintenance is paved not with radical ideas, but with small but significant steps, and there are some low-hanging fruits to be picked, according to Bechhoefer. These include extending TBOs and inspection intervals, which is long-established practice, but can be accomplished more quickly with support from HUMS information. HUMS can also inform the scheduled maintenance process by providing condition indicators ahead of time about components that are due to undergo inspection, for example. This could help eliminate unscheduled maintenance by detecting developing issues far enough ahead for them to be scheduled in with upcoming planned work.

Taxi driver

Perhaps unexpectedly, progress towards the adoption of true CBM could be accelerated by the introduction of electric urban air taxis, Bechhoefer and Thomson independently note. A clue is in business plans that contain what Bechhoefer calls extremely aggressive usage rates of around 4,500 hours per year.

"To get there, you're not going to have many inspections or overhauls – there are just not enough hours in the day," he points out. "Those economic forces will energise thinking about how monitoring affects your TBO." ■