How Healthy Is Your Engine?

Regular oil sampling, gas path performance trend monitoring and debris analysis can provide the data that let you answer the question correctly.

By Mike Gamauf

Unscheduled engine removals are about as welcome as a surprise tax audit. Turbine engine reliability has increased to the point where many simply assume the engine will always make power and never need to be removed prematurely. The truth is, even the most advanced turbine powerplants are still susceptible to the age-old nemesis of machinery: wear and erosion.

Turbine blades erode in the polluted air, bearings wear from heat and vibration, gear teeth and vanes inside pumps grind into each other hundreds of times per minute. When the turbine blades deteriorate, performance decreases in response to reduced efficiency. The oil inside the engine carries microscopic particles of the worn components that can lodge in other components, pitting the surfaces and, like road potholes, get bigger and bigger, leading to further wear.

In September 2004, a Beechjet 400A operating in Central America experienced an oil filter bypass indication in flight. The aircraft made a precautionary landing. The engine was removed and forwarded to an overhaul provider for investigation. Metal debris was collected from the filter and sent to a laboratory for analysis. The laboratory analysis determined that the debris was composed of chromium steel SAE 52100 and some SAE 4340 steel, a strong indication of a deteriorated bearing and that a steel gear was wearing. The analysis quickly led the engine overhauler to the oil pump assembly, which was found to have a deteriorated bearing and damage to the pump gears and housing. The Pratt & Whitney Canada JT15D-5 engine was repaired quickly, but had the flight been much longer, the engine would have been severely damaged.

Jet-Care International Inc.

Debris being prepared for analysis

Inflight shutdown (or worse) is something to be avoided at all costs. A prudent manager will ensure that all departmental powerplants are healthy and that if one is starting to deteriorate, the right treatment is applied before the engine needs to be removed from service. Three diagnostic tools that can help managers stay in tune with their engines are scheduled oil sampling, gas path trend monitoring and analysis of any debris collected by filters or chip detectors.

Oil Sampling and Debris Analysis

Oil is the lifeblood of any engine, and like human blood, it can be analyzed for signs of problems. Bearings, seals, liners and gears can wear and erode, introducing microscopic trace elements into the oil stream, samples of which can be analyzed in a laboratory to determine the specific material type making up the elements. Using a process called "Inductively Coupled Plasma," the oil is injected into high-temperature argon plasma, where it is vaporized. At that point the individual atoms are excited and emit light, which, in turn, is measured by a spectrometer that determines what metal is present, what type of alloy and in what volume.

The key to making oil sample analysis work is understanding how much of an element is normal for that type of engine at that point in its service life. By using a fleet's worth of data, the manufacturer can develop a baseline profile of oil samples throughout an engine's life cycle, and can make better recommendations to operators. So, while a new engine may normally produce only a few parts of iron per million parts of oil, an engine that has 3,000 hours may typically produce 100 parts per million, and that might be fine. Repetitive oil analyses can help alert operators to any spike or sudden increase in an element. Once such

an anomaly is identified, the manufacturer can recommend the appropriate action to be performed, such as replacing the oil, checking filters, or stepping up the frequency of oil sampling. Rarely will an engine be replaced based upon oil analysis alone, but regular checking helps eliminate bad surprises.

Many manufacturers encourage or mandate frequent oil analysis. Honeywell requires oil analysis for its TFE731 turbofan and TPE331 turboshaft series. Engines participating in the manufacturer's maintenance service plans have the analysis costs covered by the program.

"It really helps identify early on what is happening to an engine," said Robert Richardson, manager for aftermarket programs at Honeywell, Inc. in Phoenix. "We align the oil sample requirements with routine airframe maintenance to minimize downtime. It provides a sense of security when the analysis comes back clean. In the long run it helps lower the cost of ownership by catching potential problems early. Depending on the type of material, we have a service letter that helps identify possible source components. Then we may be able to repair 'on-wing' if possible, greatly reducing costs."

In some cases, if an accessory is suspect, it can be replaced on the wing. Keeping the engine in place is the primary goal.

"The value [of oil analysis] comes from preventing premature or unnecessary removals," Richardson said. "Typical costs for the analysis for an aircraft that flies 500 hours a year are less than $1,000. If you include trend monitoring, up to $4,000. But the cost for an unnecessary removal can be hundreds of thousands" of dollars.

For operators who fly less than 200 hours per year, an annual oil analysis determines whether water or internal corrosion is present. It can also catch other types of external contaminants heading into an engine.

"We had an operator who had a high content of zinc in the oil samples," said Josh Wagner, sales and marketing manager for Cedar Knolls, N.J.-based Jet-Care International Inc., a laboratory services provider specializing in oil sample analysis, debris analysis, engine trend monitoring, and aircraft fuel and fluid analysis. "They were placed on increased surveillance, but it turned out that there were no components in the engine that were made from zinc."

That mystery was solved when it was discovered that the operator was storing the oil samples in zinc containers, which were themselves deteriorating. With that concern set aside, it was determined that the engines were fine.

Maintenance alerts from engine monitoring systems can induce additional oil sampling analysis. Filter bypass indications from monitoring equipment will trigger an oil sample requirement. Even if nothing is found in the filter, a sample must be taken. However, in the long run, frequent oil sample analysis can be an enormous cost saver.

Similar to oil analysis, analysis of debris trapped in metallic filter elements and magnetic plug checks can help the manufacturer determine if immediate engine removal is necessary or if the component can continue in service. Recently a Midwestern Falcon 50EX operator experienced a chip warning light. The operator forwarded the debris from the chip detector for analysis and the material was determined to be gear and bearing material. (Bearings, gears, housings, liners and retainers are made from different materials that can easily be identified by a laboratory. Once the material type is identified, the manufacturer, again, can recommend the appropriate action to be taken: oil change, increased surveillance or possibly component removal.) In this case, the size of the debris and the material type indicated that the engine needed to be removed. Later teardown revealed a broken gear shaft in the planetary gear assembly, which was replaced at a cost of about $150,000 — not inexpensive, but far better than an inflight shutdown after a catastrophic failure. Collecting and sending the debris for analysis can reduce repair costs.

One note of caution to maintenance departments that perform scheduled oil sample analysis: Submit the material and trend data to your service provider as soon as possible. "We have several examples of operators not submitting samples promptly, only to experience a problem leading to an unscheduled removal," said Wagner. "Had we received it on time, we could have prevented a costly removal." Do not let samples sit in your toolbox.

Engine Performance Trend Monitoring

While routine performance measurement is a requirement for all turbine aircraft, keeping track of engine parameters over time can be a useful tool for detecting subtle performance degradation.

"We participate in the Honeywell Maintenance Service Plan for our engines and use both the oil sample analysis and the trend monitoring," said Bob Bruhn, maintenance manager at Motorola's flight de-

partment near Chicago. Not long ago, that practice paid off.

In November 2004, trend data indicated a subtle increase in the number two engine temperatures and fuel flow on Motorola's Falcon; a bleed air leak check was performed with no improvement. After several performance measurement runs to verify data, the engine was examined and a borescope inspection revealed significant turbine blade erosion and rub damage to the adjacent case.

"We had a long international trip on our schedule and it was certainly easier to deal with that at our home base. It was a textbook capture of an impending problem," Bruhn added.

The goal of most engine manufacturers is to provide low operating costs and low life cycle costs, without sacrificing performance. The days when a flight department could afford a spare engine sitting in the hangar are long gone. With improved engine design, trend analysis and eventually full-time engine condition monitoring, the completely "on-condition" engine is achievable. For now, trend monitoring will help detect degradation and give operators a heads-up on potential problems.

Pratt & Whitney Canada has an incentive for those who participate in trend monitoring programs.

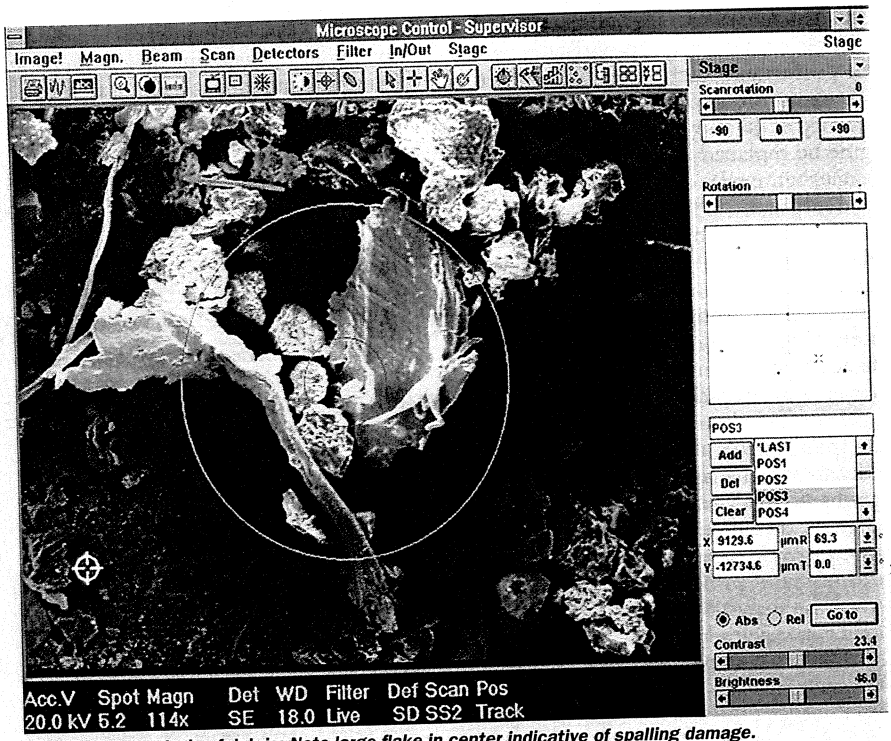
"We have two types of overhaul interval or HSI — a so-called 'hard time' interval, which is the basic minimum maintenance interval, and an 'on-condition' program," said Octavian Mocanu, P&WC's JT15D fleet management program engineering representative. "If you want to operate on an on-condition program, trend monitoring and oil sample analysis are mandatory. While not mandatory for hard time, operators who wish to increase their overhaul interval must participate. The TBO is in the process of escalating to 6,000 hours and operators who wish to participate need to perform both oil sample analysis and trend monitoring."

Another benefit of trend monitoring is potential increase in resale value. Nobody wants to buy an aircraft with a tired engine, but if your engine is still running strong, having years' worth of data could increase resale price.

Are These Programs Right for You?

In addition to engines, helicopter gearboxes also can benefit from oil sample analysis. Considering the size, complexity and cost of a modern helicopter transmission, it is prudent to monitor the condition of these valuable components. Most engine manufacturers endorse some form of oil analysis and trend monitoring. If you participate in a manufacturer's maintenance cost control programs, most will require some type of monitoring surveillance program.

Typical costs for a year's worth of oil sample analysis and engine trend monitoring fall between $3,000 and $4,000. Some operators regard that cost and program participation as unnecessarily burdensome, but considering that a premature engine removal requiring overhaul can cost hundreds of thousands of dollars, it seems to many others a small price to pay for peace of mind. **B&CA**



Microscopic analysis of debris: Note large flake in center indicative of spalling damage.

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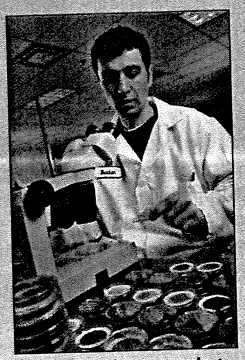

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