IT systems for all aspects of engine monitoring, management and maintenance planning have evolved in recent years. These provide airlines with greater insight and ability to manage engines than was previously possible. The next stage will be one integrated system for all tasks.

IT systems for engine maintenance management

There are many IT systems available for maintenance, including those designed to improve efficiency of engine maintenance, monitoring in operation and shop visits. This article analyses three of the more prominent systems involved in these processes.

Sulzer Innotech's Smart Monitor is a leading IT application in the process of engine conditioning monitoring, and is in addition to the various systems available from the original equipment manufacturers (OEMs).

One major system involved in the shop visit process is Spirent System's AuRA.

Overall engine management, maintenance planning and improvement in maintenance costs and ownership efficiency are covered by Total Engine Support's Engine Fleet Planning & Costing (EFPAC) system.

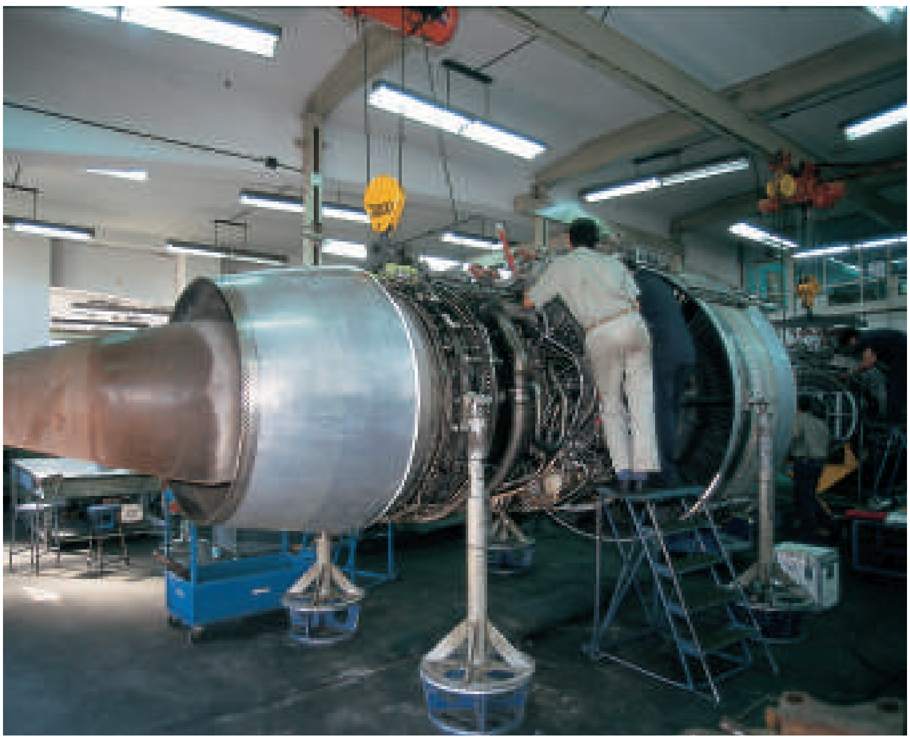
Condition monitoring

Engine condition monitoring has relied on monitoring or recording systems supplied by the OEMs on their respective engines, which means that an airline could be using up to five different recording systems. Recorded data from these monitors are then analysed by airline engineers. Engine performance parameters such as fuel flow, exhaust gas temperature (EGT) and vibration are tracked to indicate how an engine is behaving over a period of time on-wing. This process is carried out on-site at an airline's maintenance facility by engine management engineers.

Engineers analyse the raw data by plotting recorded data graphically so it can be compared to standard performance data provided by OEMs. William Gizzi, head of Smart Monitor at Sulzer Innotec, explains that recorded data is compared manually by engineers. Also, data for each measured parameter are standardised for standard operating conditions, such as atmospheric pressure and temperature at sea level. However, this provides those airlines which do not operate in standard conditions with a distorted picture of their engines' performance. "The OEM's systems are too basic and do not consider the more detailed aspects of an engine's operation. The analysis also does not provide an insight into why an engine is performing in a particular way, how good or bad its performance is compared to what would be a good or standard performance for the given operating conditions and what part of an engine is causing problems."

The manual comparison of data to standards requires extensive experience from engineers, who rely on their own judgement and analysis to remove engines for a shop visit when deviations from standard conditions appear excessive.

Smart Monitor makes no changes to



Traditional monitoring systems require airline engineers to manually analyse raw data. More sophisticated monitoring systems have been developed that analyse engine performance in terms of deviation from normal performance for the conditions in which it is operating.

Engine management systems now available allow airlines to predict engine removal dates, taking into account all factors of on-wing performance. These systems can further use maintenance condition and on-wing performance to predict shop visit workscopes and costs, and thus engine maintenance reserves.

the acquisition of recorded data, so that equipment on the aircraft remains the same. It simply analyses all data from the various recording systems for the different engine types in an airline's fleet, and makes a difference to monitoring by determining what the performance of every parameter should be under each operator's actual operating conditions. This means that EGT will be different for two new engines operated on the same aircraft type at the same thrust rating and de-rate will be different on one aircraft operating in Saudi Arabia and the other in Iceland. Smart Monitor provides a standard pattern of EGT over time on wing for an engine operating in different environments. It does this for each parameter recorded, and thus generates a 'fingerprint' of performance for each engine type in a given set of operating conditions. "This transparency provides a better impression of an engine's performance. That is, it shows what each parameter should be compared to what it is for the particular operating conditions," explains Gizzi. "As an example, a bearing temperature might be recorded as being high. Regular condition monitoring systems do not explain whether this is high or normal for the given circumstances and conditions. A fingerprint provided by Smart Monitor would reveal if it is high or relatively normal for the particular phase of flight and operating conditions. The fingerprint for each set of operating conditions gives a better basis of comparison for normality. The fingerprint thus gives an airline the picture of a healthy engine."

Fingerprints are constantly updated with recorded data, which are added to the database of engine performance. Each parameter is compared against its fingerprint value for deviations. A zero deviation indicates a normally functioning engine. The use of the fingerprint and measure of deviation from it indicates when there is a significant difference between an operating parameter and standard performance. "This more accurate system of detecting deviations in performance means thresholds for removal can be smaller than with traditional systems. The more accurate monitoring also allows alarms to be set. These are triggered when large deviations arise," says Gizzi. "The additional advantages are that several parameters and their deviations can be monitored in parallel. Combinations of deviations indicate specific failures or problems." Gizzi explains that Smart Monitor's role in engine management pinpoints potential problems by indicating an engine's optimum removal time, so that removals can be scheduled to avoid high shop visit costs. This is achieved in the long term by comparing each parameter with the engine's maintenance at removal and subsequent shop visit cost.

Shop visit management

Shop visit workscopes vary significantly`in inputs and work required on each module and separate parts. Shop visit total turn times are also critical to total engine management costs, since they affect spare engine and inventory requirements and related costs. Engine turn times can be as long as 150 days in some cases, and as short as 50 days in others. Clearly there is room for eliminating inefficiencies in the shop visit process, and Spirent's AuRA is a system designed for this purpose.

An engine's workscope at removal is determined by several factors, including the time accumulated on-wing, performance of the engine while on-wing and maintenance condition at removal. The operation of the engine, particularly the flight hour (FH) to flight cycle (FC) ratio, will influence the workscope required on each module. There are three basic levels of workscope: repair; performance restoration; and overhaul, which involves a high level of parts replacement including life limited parts (LLPs). The required workscope can be estimated while on-wing, but a more detailed assessment cannot usually be made until the engine has been removed, disassembled and inspected in the shop. Decisions to replace or repair are made at this stage, and determine the labour and materials required.

In addition to altering the materials and labour used, changes to an expected workscope also affect the task card made for the shop visit and the tooling used.

Following removal, the number of processes involved in a shop visit increase as each module is disassembled into parts, inspections are made and repairs or replacements are carried out. The number of parallel processes in the middle of a shop visit is large, many of which are interdependent on ones. The number of parallel processes reduces again as repairs are completed and sub-modules and modules are re-assembled.

There is therefore plenty of scope for bottlenecks in the engine shop visit process to occur. AuRA is a system that uses critical path analysis to improve processes and stages in engine shop management. It can also be used to track an engine's configuration, which will include LLP life and previous maintenance actions on the engine, such as borescope timings and records, previous shop visits and workscopes and replacement of line replaceable units.

AuRA starts by producing task cards for an engine shop visit when an engine is removed. At this point, AuRA determines the tools, parts, materials, labour man-hours (MH), and total time required for these task cards. AuRA prevents unnecessary delays by ensuring that all the parts, tooling and labour are in place at the right time, and reduces the time each process takes by managing the logistics of each shop visit. Critical path analysis reduces the total time required for the complete shop visit.

However, AuRA does not determine the actual workscope of each engine, although it does identify and reduce the bottlenecks in the process.

The benefits of this are reduced MH, because time is not wasted in the shop waiting for one process to start because another has not been completed, thereby causing a bottleneck. It also reduces materials. The reduction in bottlenecks has the consequent benefit of reducing turn-time and ultimately the inventory of spare engines required. It also reduces the materials used.

AuRA can also be used in managing the incorporation of airworthiness directives (ADs) and service bulletins (SBs).

As well as recording task cards and assisting in their logistics, AuRA also records the work done for each task card. Labour used during the shop visit can thus be plotted against time, which can be used to indicate peaks and troughs in labour requirements.

AuRA can be programmed to take into account inefficiencies in the shop visit to accommodate realistic working scenarios and breaks, which can be used to estimate the start and finish dates of a shop visit and turn time. This can be compared with the date an airline requires the engine to be returned, so advance warning can be provided for delays to implement contingencies.

Engine management

Effective engine management not only requires experience of an engine type, but also the ability to track a large number of engines and understand the factors that influence time on wing. The condition of each engine must be considered in respect of removal, and subsequent shop visit workscope and cost.

The objective of engine management is to reduce overall engine maintenance cost per FH, by aiming for the lowest point of the cost per FH U-curve.

Factors that influence engine removal are EGT and EGT margin, engine condition, accumulated life of LLPs, stub life policy of LLPs, FH:FC ratio, ADs and SBs and their status. Engines sometimes must be returned to lessors in a given or predetermined maintenance status, so this must also be monitored.

TES is a third-party engine management provider. Many small airlines sub-contracting engine maintenance also require an engine management service and use TES for this purpose. EFPAC is TES' tool for engine management.

EFPAC is designed to be comprehensive, in that it tracks and manages each engine, but it also aims to calculate maintenance reserves and locate the lowest cost per FH. Thereby combining the technical and financial aspects of engine management.

EFPAC monitors the engine's functions against time, and plots the information on screen for the user. Each engine's technical records are kept in

EFPAC's database, which includes information on engine configuration, maintenance status, LLP lives and remaining life, limits with respect to EGT and LLPs, and AD and SB status. Time on-wing is also tracked for the whole engine and for its parts.

Each engine's time on wing is recorded and EFPAC uses predicted utilisation to estimate the expected time on-wing, taking into account operating conditions and condition recorded parameters.

EFPAC can then be programmed to highlight time-on-wing limiting factors, such as LLPs or ADs. These different causes are colour-coded, and detailed information can be examined by the user if required.

Vertical lines are imposed on the time-on-wing progress of each engine to indicate removal for a shop visit. These removal times can be programmed to indicate the time for removal as determined by modules as well as the whole engine. EFPAC can even do this at part level. EFPAC can be programmed to highlight factors that will limit an on-wing run, so that these can be dealt with at earlier shop visits.

Frequent causes of early removals are LLPs, since individual parts with short lives can limit the on-wing time of an engine. With records of all LLPs and their accumulated time since new, EFPAC can be programmed to set a stub life for all LLPs. LLPs are often replaced with significant stub life remaining, so if time on-wing can be predicted accurately, their stub life can be reduced. Even though LLPs with stub life can theoretically be sold, they are rarely required by other carriers. Utilising a larger portion of LLP lives has a significant impact on engine reserves, since they are expensive parts. It will also extend on-wing life, further contributing to a lowering of maintenance reserves.

EFPAC enables the user to determine and input the shop visit workscope for modules and engines, and their consequent cost. It then further predicts the subsequent time on-wing according to different levels of workscope, maintenance condition and engine deterioration following the subsequent on-wing run and workscope required at the second shop visit. Taking the cost of labour, materials and parts into consideration, the cost of each workscope and resulting maintenance reserves can be calculated.

The effects of different workscopes on maintenance reserves can therefore be analysed. As EFPAC tracks engines in respect of time, engine shop visits can also be planned and changed to smooth removal rates, thereby minimising the number of shop visits and inventory requirements.

With this tracking ability in place, EFPAC can also be used to analyse the maintenance condition of an engine or several engines at any particular date. This is a useful tool when selling or leasing an engine is under consideration. It also facilitates prediction of a leased engine's return conditions, and calculation of any penalties that may arise.

Summary

These systems are independent of each other, but improve previous systems for monitoring and managing engine maintenance by providing managers with data and the ability to make decisions with more predictable consequences. These new systems also compliment each other.

The future evolution of engine maintenance management systems will involve integrating these systems or others like them, or developing a single system to manage all processes of engine monitoring and maintenance management.

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