CFM56-3 modification programmes

The CFM56-3 operates at four different thrust ratings, and in various operating climates and temperatures. Modification programmes are available to increase EGT margin, improve on-wing life and reduce maintenance costs.

There are three major upgrade kits for the CFM56-3: the advanced upgrade kit; and two sub-kits of the advanced upgrade. The first of the sub-kits comprises the enhanced performance upgrade, which is an improvement package for the compressor. The second is the enhanced durability kit for the turbine.

Upgrade package

In 1999 CFMI wanted to introduce the technology that was used in the -7B series to the -3 series. This involved the development of a 3-D aerodynamic package, where airfoils were redesigned for the high-pressure compressor (HPC).

The turbine's durability was improved by increasing the cooling of high-pressure turbine (HPT) blades and enhancing the design of the HPT blade tips.

The effect of the 3-D airfoils in the HPC was to increase exhaust gas temperature (EGT) margin by 20 degrees centigrade, compared to a target improvement of 15 degrees.

A new material, N5, was used in the HPT nozzle. CFMI claims that the effect of this, combined with better HPT blade cooling and an improved tip shelf, was to reduce the scrap rate of HPT blades by about 50%. The scrap and replacement rate for HPT blades is 30-40% at the first shop visit. Another 30% of blades are replaced at the subsequent shop visit. The upgrades to the turbine have therefore increased the life of HPT blades by 50%.

The advanced upgrade comprises the HPC and HPT improvements together as one package. These are known as the 'time on-wing' upgrade. CFMI claims that total maintenance and fuel costs are reduced by 20% when both the HPC and HPT improvements are incorporated in an engine. The effect of the 3-D aerodynamic blades is to improve fuel burn by 1.6-1.8%. A 737-300 operating on a route with a still air distance of about 550nm would burn about 1,400 US Gallons. The improvement in fuel burn would save about 24 US Gallons on the trip, and at an annual utilisation of 1,700 flight cycles per year would result in a total saving of about 41,000 US Gallons. At current full prices this would be equal to about $80,000 per year per aircraft.

Enhanced performance kit

The enhanced performance kit mainly relates to upgrades in the HPC. The 3-D aerodynamic blades deliver most of the increased EGT margin that is provided by the advanced upgrade package. The enhanced package increases EGT margin by 15 degrees centigrade. Given that EGT margin deterioration rates on the CFM56-3 are 3.0-4.0 degrees per 1,000EFC after the first 2,000EFC since shop visit, the additional EGT margin will allow the engine to stay on-wing for another 3,500-4,000EFC. This will be equal to 5,000-6,000EFH at most operators' engine flight cycle times, and so be an element in reducing maintenance costs per engine flight hour.

The increase in EGT margin will be particularly beneficial to airlines operating in hot climates. The EGT margins of engines rated at 23,500lbs thrust are only about 30 degrees after the first shop visit, and so the engines have a sea level outside temperature limit (SLOATL) of about 39.4 degrees *(see CFM56-3 specifications, page 10)*. The EGT margin also reduces by about 15 degrees during the first 2,000EFC on-wing, and the SLOATL goes down to about 34.7 degrees. Similarly, the EGT margin of engines rated at 22,000lbs thrust is only about 40 degrees, and the SLOATL is only 42.5 degrees. The EGT margin is reduced to about 25 degrees after the first 2,000EFC on-wing, and so the SLOATL is reduced to about 37.8 degrees.

This illustrates how engines with high thrust ratings can benefit from the HPC enhancement kit, which increases EGT

CFM56-3s rated at 22,000lbs & 23,500lbs thrust that operate in high temperatures have the most to gain from the performance upgrade modifications. These increase EGT margin and so improve on-wing life.

Southwest was one of the first airlines to install the full upgrade kit for the CFM56-3. It expects on-wing interval to increase by about 2,900EFC as a consequence.

margin by 15 degrees. This would allow these higher-rated engines to operate with fewer take-off power restrictions and achieve longer on-wing intervals.

The catalogue price for the parts for the enhanced performance kit is $485,000, and discounts are provided for volume purchases. The kit is installed during a shop visit, and usually when HPC parts are expected to be scrapped. The net cost is thus less than the list price of $485,000 when the cost of installing the regular HPC airfoils is considered. CFMI claims that the incremental cost of installing the new 3-D aerodynamic blades is about $300,000. Moreover, this cost is only incurred once by the operator, because the catalogue price of the 3-D aerodynamic HPC blades is the same as the price of the 2-D aerodynamic blades. The costs of replacing 2-D and 3-D blades at subsequent shop visits are the same.

Turbine upgrade

The turbine upgrade kit only includes the use of N5 material on the HPT nozzles, unlike the full upgrade kit, which also includes improved HPT blade shrouds, as well as the full upgrades on the HPC.

The catalogue price for the turbine upgrade kit is $370,000. Like the enhanced performance kit, the new turbine nozzles will be installed at a shop visit when the old material is due for replacement and so the kit will have an incremental cost over the replacement of the original nozzle materials. The new materials can extend the on-wing life of the engine, and they have the same catalogue price as the original nozzle materials.

Full upgrade kit

The catalogue price of the full upgrade kit is $1.4 million, which includes the full HPC upgrade, the HPT blade shroud upgrade and new HPT nozzle material.

As with the two smaller upgrade kits, CFMI claims that the full kit has a lower incremental cost than the list price of $1.4 million, since the parts being installed are replacing worn parts. CFMI puts this incremental cost at about $400,000.

The benefit of the upgrade is that on-wing removal intervals are extended. CFMI reports that some operators are achieving increases in the order of 4,000EFC, while others are recording increases of up to 8,000EFC. At average EFC times of about 1.5EFH, the installation of the full kit is increasing intervals by 6,000-12,000EFH.

This has to be considered against typical shop visit costs and on-wing intervals of unmodified engines. A mature engine rated at 22,000lbs thrust has a relatively low EGT margin of 45 degrees centigrade following a shop visit, and can be expected to have an on-wing life of 6,000-7,500EFC. A typical core performance restoration has a cost of $900,000, while a shop visit that also includes a workscope on the low-pressure turbine (LPT) or fan/booster section will cost in the region of $1.15 million *(see CFM56-3 maintenance analysis & budget, page 18)*. An unmodified engine therefore has a shop visit reserve of $120-176 per EFC, depending on the workscope performed and the interval.

Extending the interval by about 4,000EFC, through increasing EGT margin, would reduce the reserves to $80-110 per EFC on the basis that the costs of the shop visit were unchanged. This does not take into account the initial cost of installing the kit. If the net cost is taken at $400,000 and amortised over the first two shop visits, which is the probable interval that the new parts would require replacement, it would have an amortisation rate of $27-33 per EFC. The net saving would therefore be $13-33 per EFC over these first two shop visit intervals. This would be equal to a six or seven year period. The saving after this would be up to $55 per EFC. Fuel savings should also be considered.

Operator experience

Southwest Airlines was one of the first airlines to install the full upgrade kit in its fleet. All of its aircraft are rated at 20,000lbs thrust, and the unmodified engines achieve a mature interval of 14,000EFC between shop visits. This interval is one of the highest achieved by all CFM56-3 operators, despite the high temperatures in which Southwest operates. The interval is partially attributed to the high level of take-off derates used by Southwest's pilots.

Southwest started modifying its first -3C1 engines about two years ago with the full upgrade kit, and has so far modified about half its fleet. "Prior to the kit we were installing the 'new core' kit, which was a previous modification programme being offered by CFMI," explains Johnny Holley, manager of powerplant engineering at Southwest. "The full upgrade kit has increased EGT margins by 12-15 degrees Fahrenheit (about 5-7 degrees centigrade) compared to unmodified 2-D engines.

"Even though we have been achieving about 14,000EFC on-wing with the engines prior to the modification, we have found that the modified 3-D engines have been losing EGT margin at a slightly lower rate," continues Holley. "Combined with the increased EGT margin this means that we are predicting engines will remain on-wing for about 16 months longer than unmodified engines. This is equal to about 2,900EFC at our rates of utilisation."

Holley also explains that Southwest conducted an analysis on the upgrade kit, and found that it predicted no net increase in the cost of engine material and parts between modified and unmodified engines when the annual rise of list prices was considered. AC