V2500 family modification & upgrade programmes

The V2500 has been relatively free of major ADs that have impaired its economic performance. The engine has some major performance upgrades & minor modifications which are described here.

The original V2500-A1, delivering 25,000 pounds of thrust, entered service in 1989. It could achieve removal intervals of up to 8,000 flight hours (FH), but longer intervals were limited by turbine deterioration.

International Aero Engine's (IAE) first remedial action was a series of turbine durability improvements, including improved airfoil cooling and improved airseal materials. These were phased into production engines and offered as standard spare parts for installation during hot section refurbishment. The resulting '1992 standard' -A1 engine improved hot-section life by 50% over the original production standard.

V2500-A5 and -D5

IAE's partners developed higher thrust variants of the V2500: the -A5 for the A321, which entered service with Lufthansa in 1994; and the -D5 for the MD-90, which entered service with Delta Air Lines in 1995. The basic model could have been 'throttle-pushed' to deliver the 33,000lbs of thrust needed for the A321, but the higher temperatures required would have severely reduced exhaust gas temperature (EGT) margin, and had a negative impact on the engine's on-wing life. IAE increased the core flow instead to produce increased thrust at a similar temperature to the basic V2500-A1.

To achieve the necessary increase in airflow the fan diameter was increased by half an inch to 63.5 inches, although this did not require a new fan case. To increase the core flow, the core annulus line was adjusted and a fourth stage was added to the front of the low pressure compressor. The associated increase in fuel flow involved changing the fuel pump and the gear ratios within the engine gearbox.

The combustor and high pressure turbine (HPT) were refined to reduce nitrous oxides (NOx) emissions and extend the engine's life. Other design changes addressed emerging in-service issues, and parts that would experience significantly higher loading due to the increased engine rating were strengthened.

Efficiency improvements in the high pressure compressor (HPC) countered the potential adverse impact on fuel burn of the reduction in bypass ratio caused by increasing core airflow. Aerodynamic re-design of the HPC and re-matching of the stages within the compressor eliminated one row of variable stators, while an additional booster stage increased the engine-pressure ratio and improved overall cycle efficiency. Despite its lower bypass ratio, the engine's specific fuel consumption (sfc) remained unchanged.

The increased core flow also reduces combustor exit temperature (CET) by 75 degrees centigrade, while improved materials in the turbine airfoils allow them to run hotter for the same life, and improved cooling allows CET to be increased without increasing metal temperature. The 31,400lbs thrust V2530-A5 therefore runs cooler than the 25,000lbs -A1 did at service entry. The -A5's increased EGT margin due to the larger core increases the interval between overhauls: removal is driven by on-condition limits rather than EGT margin.

The V2500-D5 engine uses the same turbomachinery as the -A5, but the fan case and turbine exhaust case are modified for the fuselage side mounting.

V2500-A1 Phoenix Standard

In 1999 an improved 'Phoenix standard' version of the -A1 entered service. Incorporating the new features of the -A5, it was designed to increase the original version's on-wing life by 25% through improved performance retention.

As well as bringing the -A1's hot section up to the technological standards of the -A5, the Phoenix standard added the product introduced on later production -A1 engines. Its components supersede existing parts, so ultimately all 361 V2500-A1 engines will be upgraded as they are overhauled.

The V2500 has had relatively few problems with major ADs. The recently-certified SelectOne modification is a new build standard that is aimed at reducing fuel burn by about 1% and increase removal intervals by up to 20%.

There are numerous small modifications for the V2500 that have gradually improved its performance and reliability since being introduced into service.

SelectOne

The newest build standard of the V2500, SelectOne, was certified by the FAA in late 2007. It will become standard-build specification and enter service in the second half of 2008 on an IndiGo Airlines A320 following Airbus flight testing and certification.

The three-engine test programme suggests that SelectOne will: reduce fuel burn, and therefore carbon dioxide emissions, by 1%; improve time on-wing by 20%; add 12 degrees to the EGT margin; reduce miscellaneous shop visits by as much as 40%; and comply with the most stringent CAEP/6 NOx standards.

SelectOne modifications focus on the HPC, high pressure turbine (HPT) and low pressure turbine (LPT). The HPC has aerodynamic and mechanical modifications, elliptical leading edges on the blades and improved surface finish. The HPT has redistributed internal and film cooling, plus a minor restagger of the first stage for optimum cycle performance. There is a minor restagger of the LPT first stage.

Special ratings

IAE also offers two special ratings: the V2527E, which is an enhanced rating for the A320, providing additional thrust at high altitude airports; and the V2527M rating used on A319 airliners and the A319-based Airbus Corporate Jet to enhance payload and range capabilities.

Low noise bleed valve

In 2005 Dunlop Equipment, now a Meggitt subsidiary, announced that, under contract to IAE's partner Rolls-Royce, it had developed a replacement bleed valve for the V2500 capable of reducing overall noise output by 3dB. The valve controls the internal air pressure to reduce engine torque during starting and idling.

HPT duct segment repair

IAE's partner MTU has developed a repair for the HPT outer air seal duct segments, stages 1 and 2, to improve repair yield and durability, based on work with highly stressed military engines. IAE says it has developed a new multilayer, erosion-resistant, thermal-barrier coating with improved rub-in capabilities.

The repair starts by removing the coating from the outer duct segments and brazing the cooling holes. The air seal surface is restored, the abradable ceramic coating is applied, and the cooling holes are restored using the latest laser drilling process. Benefits of this repair include tailoring the thermal barrier coating for improved rub-in capability, and increased service life because of the better erosion resistance and improved thermal cycle resistance compared with competing repairs. Turnaround time is 28 days, including the final inspection.

HPT nozzle guide vane repair

In 2000 Lufthansa Technik (LHT) developed a repair for the HPT nozzle guide vanes, which are subject to more thermal stress than any other component. A ceramic thermal barrier coating protects the cobalt-alloy first-stage and nickel-alloy second-stage vanes, with a bonding coat to bind the brittle ceramic layer to the metal substrate. This process involves 53 steps, starting with grit blasting to remove the ceramic coating and chemically stripping the bonding coat. After cleaning and repair the bonding coat is applied by low-vacuum plasma spraying, then the zirconium oxide ceramic layer is applied using an air-plasma spray process, and a laser creates the cooling holes. The repair is one-eighth the cost of a replacement.

Fuel nozzle guide upgrade

Another LHT repair process enhances the original design of the V2500's combustion chamber fuel nozzle guide. The guide can exhibit cracking and severe oxidation as a result of its exposure to severe thermal stress during operation. If the protective thermal barrier coating bursts or spalls it can sustain heat damage. The LHT repair removes the damaged segment of the nozzle guide and replaces it with a new SPAD ring using electron beam or plasma arc welding. The repaired guide has the material properties of a new part.

To improve the outer ring's long-term reliability, laser cutting is used to apply multiple saw cuts to the ring to prevent future heat cracks from occurring, in combination with an improved thermal barrier coating. The thermal protection of the repaired nozzle guide is more comprehensive than the OEM coating. As well as reducing the scrap rate from 90% to 30%, the new repair extends the service life of the component beyond that of a new part.

Inlet cowl acoustic panel

The inlet cowl acoustic panels on the V2500-A1 and -A5 consist of a carbon composite sandwich structure covered by a fine wire mesh. LHT says problems with partial disbonds of the wire mesh started in 1998, and in 2002 the first 100% disbond occurred, effectively rendering the component non-airworthy. To avoid the high cost of replacement, LHT developed a method of replacing the installed wire mesh, a repair that it calculates can save an operator with just three aircraft more than $1 million. AC