PW1000G tests confirm performance predictions

Pratt & Whitney has developed the geared turbofan to take turbofan engine design to a new level. Recent testing on an A340-600 confirms the predicted fuel burn performance & noise emissions.

Lufthansa Group has confirmed its launch order for the Bombardier C Series. A significant feature of this order is that the aircraft is exclusively powered by Pratt & Whitney's (PW) new geared fan engine, the PurePowerTM PW1000G. The C Series is the second aircraft to utilise this new generation of turbofan technology.

The PurePower PW1000G engine will also be available on the Mitsubishi Regional Jet (MRJ), for which All Nippon Airways is the launch customer. This aircraft and the C Series are due to enter service in 2013.

PW has introduced the geared fan engine to achieve higher bypass ratios, lower fuel burn, and lower noise emissions than conventional turbofans. Fuel burn performance and noise emissions of conventional turbofans have generally improved as bypass ratios have been increased with successive engines over the past 40 years through the use of wider diameter intake fans. Wider fans and higher bypass ratios result in improved propulsive efficiency and lower average exit speed of exhaust gases from the engine. The bypass ratios of the earliest turbofans, such as PW's JT8D, were in the order of 1:1. They have reached up to 11:1 with the Rolls-Royce Trent 1000, and 9:1 with the General Electric GEnx.

PW has developed the geared turbofan by inserting a fan drive gear system (FDGS) between the fan and the low pressure compressor (LPC). In a conventional turbofan, the fan speed has been limited by the fan blade tip speeds being unable to exceed the speed of sound. Wider fan diameters have meant that to keep fan blade tip speeds below supersonic, revolutions per minute (RPMs) have had to be reduced. Since the fan is mounted on the same low pressure (LP) shaft as the LPC and low pressure turbine (LPT) in conventional engines, their RPMs have been limited by each other.

The LPC and LPT are more efficient at higher RPMs, but the desire to increase fan diameters has actually reduced their RPMs. Wider fans are also heavier. The LPC and LPT have had to add stages as a consequence of these two factors. The GEnx's LPT, for example, has seven LPT stages. This compares with the CF6-80C2's five LPT stages, and an engine with a bypass ratio of about 5:1. Additional LPT stages add weight. Increased fan diameters and larger LPTs ultimately limit the development potential of conventional turbofans.

PW's utilisation of the FDGS between the fan and LP shaft allows the LPC and LPT to turn at higher RPMs, and operate more efficiently at their optimum speeds. Smaller LPCs and LPTs, with fewer stages, are therefore required to drive the same size fan, and wider fan diameters and higher bypass ratios are consequently possible. The PW1000G powering the C Series will be rated at 24,000lbs thrust. Its most notable features are that it will have a fan diameter of 73 inches, a bypass ratio of 10:1, and three LPT stages. This compares to the CFM56-5C, with a thrust rating of 31,200-34,000lbs, a fan diameter of 72 inches, a bypass ratio of 6.4:1, and five LPT stages. This illustrates that the PW1000G uses a smaller core and LPT to drive the same size fan.

In the case of the PW1000G powering the C Series, the LPC and LPT require five fewer stages than a conventional engine of the same thrust rating. This is equal to 1,500 fewer blades and stators, which are some of the most expensive parts in the engine *(see New offerings: the latest turbofan programme developments, Aircraft Commerce, June/July 2008, page 40)*.

PW has also developed the technology in the high pressure turbine (HPT), high pressure compressor (HPC) and LPT, and has made the fan case of composite materials. This results in a lighter and shorter (due to fewer stages) engine, which in turn means a more durable engine that will flex less.

It is claimed that the benefits of the geared turbofan engine to operators and those that live near airports are massive, with reductions in fuel burn, operating costs, emissions and engine noise.

Testing

The design of the geared turbofan has been a work in progress at PW for over 20 years. In 2007 it commenced the testing and assessment of a full scale demonstrator engine.

PW has separated the design and testing of the PW1000G into nine technology readiness levels (TRLs). It has already completed TRL 1-6, which comprised the paper technology, parts testing and rig testing. TRL6 was completed in June 2008, with an engine demo prototype. PW will now undertake TRL 7 (flight test) with the relevant aircraft that it will go into service with.

Among many other tests, the demo engines were assessed on a ground test bed and two flying test beds (747SP and A340-600). The engine completed 250 hours of ground testing in Florida where engine performance and acoustic predictions were on target. Then the engine was fitted on to PW's 747SP for 44 hours of testing in 12 flights. This again proved the performance predictions. The engine was then transferred on to Airbus's A340-600 flying test bed for further assessment. This took 76 hours and 27 flights.

Overall, throughout its testing, the new engine design has met its performance predictions, and PW is confident that the PW1000G will be certified by the Federal Aviation Administration (FAA) in 2011 ready for service entry on the MRJ and C Series in 2013.

Fuel burn

The PW1000G's design is such that PW says all its components will operate to their optimal efficiency. "This will result in a 12-15% reduction in fuel burn compared to alternative engines," says Bob Saia, vice president next generation product family at PW. "If you were to take an aircraft's average use as 2,200 flight cycles (FC) per year, averaging 500nm, the engine would generate a saving of 140 US gallons (USG) of fuel per trip, 840USG per day and 305,000USG per year. If the average fuel price was $2.50 per USG, the annual saving for an operator would be more than $750,000 per aircraft." This implies that Lufthansa could save $22.5million per year in fuel alone after it has taken delivery of its 30 new C Series aircraft.

These fuel savings come about mainly because of the engine's higher bypass ratio, but also due to the new designs and higher operating efficiency of the LPC, HPC, HPT and LPT.

In addition to lower fuel burn, PW says that the PW1000G will produce 55% less NO_x and 12-15% less CO_2 than other engines. The PW1000G is also expected to have a Stage 4 noise emissions margin of 20dB. AC