AIRFINANCE GLOBAL

Engines: a matter of thrust ?

01/09/2001

Engines represent the largest cost element of modern airliners. With over 10,000 current and future generation engines on firm or conditional order, the present backlog reflects some $60 billion of orders.

Here we look at the current and future offerings of the major engine manufacturers spanning the range from 6,070 lb thrust regional engines to the 115,000 lb thrust GE90-115B monster required to take the new 777-300LR over distances of 10,000 mile (or more).

Main characteristics and applications

All modern ?jet? engines are in reality turbofans. That is they utilise a split flow system with separate high-pressure and low-pressure air streams.

The high-pressure stream is burnt with fuel to provide the power to drive the main fan.

This coupled with a high overall compression ratio ensures efficient fuel combustion and the high bypass ratios used provide efficient thrust at low exhaust velocity to provide quiet and efficient thrust. The usual arrange is to provide two shaft, one carrying the low pressure system of fan, initial compressor stages and power turbine, the other more compact shaft carrying the high pressure ?core? of the engine.

The exception to this is Rolls-Royces use of a three-shaft system, with an intermediate pressure section. Arguably this provides a more efficient and compact engine that comes into its own at higher thrust ratings, although GE and Pratt will undoubtedly make rival claims for their own two-shaft engines.

Most modern jet engines may be placed in three main groups according to their thrust, which we will consider in turn.

There are the large turbofans that power wide-body aircraft typified by the latest GE90, PW4000 and Rolls-Royce Trent engines. These typically range in take-off thrust from 50,000 lb to approaching 100,000 lb. At the highest available thrusts these power the widebody twins from the smaller A310 and 767s through the A330/777 models the four-engined 747-400 and Airbus A340-500/600 series and soon the double-deck A380. Older model engines like the CF6-80 series and RB211 still appear on certain models, but these are beginning to fade as the new generation of engines takeover with the development of wide-ranging families like the Trent, which is available in version ranging from 53,000 lb to 98,000 lb thrust.

There is little doubt that this class of engine is the main battleground for the ?big-three? manufacturers. Most current wide-body types offer a choice of at least one engine from each of their ranges and increasingly this focuses on the latest GE90, PW4000 and Trent engines.

The competition for the next major market segments is likely to differ from this as two manufacturers have secured exclusive position for their engines. GE engines will provide the sole power source for developed ER and LR versions of the 777-300 and Rolls-Royce for the stretched A340-500 and 600 series aircraft. Neither of these types is yet in service and as yet orders are quite modest with 49 firm and 51 conditional orders for the new 777s and 71 firm and 53 conditional orders for the new A340 models. Early days yet, but it may be that the limited choice of engines is being reflected in a limited range of customers. Certainly a number of key potential 777 customers are holding of ordering in part due to the lack of engine choice.

The situation on the A380 between the Trent and the GE/Pratt Engine Alliance company is not yet clear in market share terms, but both manufacturers? engines have been selected, the Trent by Qantas, SIA and Virgin Atlantic the GP7200 by Air France. Rolls are taking an early lead with 80% of the 75 announced orders of options where an engine has been selected.

Medium Fan Narrowbody Engines

The medium turbofans are those that power single-aisle narrowbody aircraft typically ranging from 20,000 to 35,000 lb in thrust. They include the CFM56 family, the IAE V2500 range, as well as smaller engines like the BR715 and PW6000 that power those aircraft of around 100 seats capacity like the 717-200 and A318-100 that represent the crossover point from regional to mainline aircraft.

One engine type, Rolls-Royce?s RB211 bridges the gap between these two main classes, ranging in thrust from the 37,000 to 43,000 lb RB211-

535 engine, at which level it competes with the PW2000 series engines to power 757-200 and 300 aircraft. In its most powerful variant it reaches 59,500 lb thrust in its latest -524 ?Hybrid Trent? version installed on some of the most recent 747-400 series aircraft. There are two main battlefields here, between the RB211-535 and the PW2000 series to power the 757, and between the CFM56 and IAE V2500 to power the Airbus single-aisle family.

With orders now tailing of, the RB211 is maintaining a significant lead over the PW4000 on the 757. However, Pratt?s V2500 is now running neck and neck with the CFM56 on new orders, although it has never managed to overtake the CFM56, which established a significant early lead, partly by virtue of being first into the market.

Regional engines

Regional aircraft have smaller, dedicated, short-haul engines like the PW306, AS977 and AE3007, and most ubiquitous of all the regional engines, General Electric?s CF34. The CF34 an engine was designed originally as the military TF34, progressing to business jets before finding favour as the engine of choice on most of the new generation of regional jets, including the latest offerings from Bombardier, Embraer and Fairchild Dornier. Unlike the with the larger aircraft types there is no choice of basic engine type with any of the new breed of regional jets.

Engine values

Engine first cost varies widely in the range $2 to 15 million depending first and foremost on rated thrust. This may represent anything between 20 and 33% of the aircraft total cost depending on installed thrust to weight ratio and number of engines.

While engine first cost is included in the quoted sticker prices of aircraft, it is common for airlines to negotiate separately over the engine, particularly where there is a choice of engines on a particular type. Key engine contracts are fought over fiercely by the manufacturers where there is a choice such as on the current crop of widebody twins. The installed engines are also depreciated with the aircraft from an airline-accountancy point of view. The reality, however, is that aircraft engines exhibit quite different depreciation characteristics from the aircraft they are installed in. In the first instance their value when new contains are large element of cost reflecting the maintenance status of the engine

Engine residual values

The model for engines values reflects relatively little depreciation, depending instead on the reality of its condition, mainly defined by the time since its last shop visit, usually measured in hours, and the life remaining on the life limited components measured in cycles. Typically values are measured in terms of a half-life engine. This largely mythical beast is one where the expected remaining time to the next shop visit equals the time run since the last one and where overall half the engine component lives have been consumed. However, as we have already indicated it is difficult to realistically to determine when the next shop visit will occur until the operator has determined a statistically sound operating database.

Half-life residual values do vary amongst engines due to their different stages in their overall life cycle. However, for most current engine ranges, they have stabilised at around 67% to 75% of their cost new. As the engine type goes out of production and the population ages, values begin to decline to a point where the value comprises almost entirely of the value of the remaining repair and component lives, with only a nominal value attaching to the engine carcass.

Maintenance cost issues

As well as being the largest installed cost item on the aircraft, the engine is also the largest generator of operating costs. Life cycle costs over thirty years operation can amount to three times the original installed cost, with each aircraft going through several complete maintenance repair cycles as well as having its critical lifed components replaced typically every 20,000 to 25,000 flights. Some key components will have lower lives than this and it is the lowest lifed items that tend to drive the eventual engine shop visits.

Maintenance is no longer a matter of overhauling the engine at regular intervals, but instead involves continuous condition monitoring of engine parameters to determine the performance of the engine and to identify the point when maintenance action is needed. Engine condition monitoring of parameters such as turbine inlet temperatures, levels of vibration and recording of over-speeding engines and high thrust excursions, together with regular boroscope inspection of the engine?s internal components obviate the risk of in-flight failure or precautionary shutdowns. Thus all engine heavy maintenance actions effectively become unscheduled ones and it is no longer possible to precisely plan the loading of engine shops until lifed component replacements become due. Typically these components are controlled by cycles, so hours per cycle is a critical factor in determining engine costs. Apart from primary engine removal causes, there are always other mainly environmental factors to consider. Bird strikes and other foreign objects, typically runway debris can seriously damage the early engine stages, while maintenance induced faults due to personnel leaving tools and materials in the engine can cause serious damage throughout the engine.

Although not all operators avail themselves of its potential advantages, the modular construction of modern engines enables airlines to break down the maintenance work into smaller packages corresponding to the major elements of the engine, each of which has different maintenance characteristics. This is particularly valuable if modules can be changed on the wing, so minimising down time.

The author has seen LLPs cost varying from $600,000 for a small regional fan engine to $2.0 to $ 2.5 million for previous to current generation CF6-80 engines. This suggest that engine stacks for the latest engine generation may well be as high as $ 5.0 million for 90,000 to 100,000 lb thrust engines.

We have also seen engine repair costs, excluding lifed components ranging from a third of a million dollars to about $1.8 million. This suggest that that typically LLP stack costs are greater by some 33 to 50% than the cost of an average engine shop visit. Depending on the time between shop visits and the extent of the replacements needed, typically one third of the disk stack may be replaced once the limiting component is reached as it is usually necessary to re-build the engine to an acceptable standard to the next limiter. The ratio of hours to cycles is a key factor in determining this ratio, with shorter haul aircraft using up their component lives quicker and needing more frequent shop visits.

