Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 100 (2016) 43400-43402

ISSN: 2229-712X

Technology Advancement in Gas Turbine Aero Engines

Mohana Rao R[1] and Dr. Manzoor Hussian [2]
[1]Cyient Ltd, Manikonda,Hyderabad, Telangana, 500032, India.
[2]JNTU Hyderabad, Hyderabad,Telangana, 500072, India.

ARTICLE INFO

Article history:
Received: 24 September 2016;
Received in revised form:
29 October 2016;
Accepted: 5 November 2016;

Keywords
Gas Turbines, Gear turbo fan (GTF),
Bypass ratio (BPR),
High pressure Compressor (HPC),
Low Pressure Compressor (LPC),
Low pressure Turbine (LPT),
High Pressure Turbine (HPT).

ABSTRACT

Crude oil price influence the economic conditions of world which will impact on the airlines operating of aero engines that lead to turbo machinery for future fuel conservation requirements. The continuing effort to improve performance has created in optimizing the efficiency of current and future gas turbine engines. The fuel efficiency of an aircraft is dependent upon the drag contributed by the airframe, engine and the efficiency of the engine itself. In this paper we discuss the latest advancement in gas turbine engines that improves efficiency of the engine from a unit mass of fuel that is burnt. Turbofan engines coupled with planetary gear increases speed of low pressure compressor by three to four folds of fan speed takes place inside the core of the engine, which includes the compressor, the combustion chamber, and the turbines that extract mechanical energy from the hot, expanding gases. By increasing the fan diameter & by improving the overall bypass ratios up to 12, the fuel efficiency of engine increases to double digit ~15% which is revolutionary in aero engine development history

Introduction

Current aero engine technologies are facing three issues

a) Fuel burn
b) Noise and
c) NOx emission

In the entire system of airplane 50% of fuel burn is contributed by engine and 50% by airframe structure, in case of noise 60% is contributed by engine & 40 % by airframe where as for NOx emission engines contribute majority of this problem. As per ACARE 2020 norms Fuel burn, Noise and NOx emissions are to be improved by +50%, reduction of -10db and -80% respectively. In this paper we are discussing on the fuel efficiency technologies that OEM Engine makers are adapted for future readiness. a) Increase the speed of low pressure spool that will directly improve fuel burn by coupling gear box called Gear Turbo Fan (GTF) b) Open rotor technologies that work on propellers counter rotate each other and c) Improve Thermal efficiency by material properties and new cooling system for high temperature in turbines.

1.1. Gear Turbo Fan Engine

Gear turbo fan engines are expected to be disruptive technology by employing the largest bypass ratio in the history of turbofan engines by adding planetary gear box to turbofan engine promising double digit fuel burn savings. Figure.1 depicts the architecture of conventional and GTF engines, the upper cross section show the conventional turbofan engine (V2500) whereas lower half of the cross section is Gear Turbo Fan engine. The slow speed of the fan which contribute to low noise directly can enhance passenger comfort and reduced flight related fatigue.

Tele: 990857172
E-mail address: mohan.ramanadham@gmail.com

The geared turbofan engine is standard twin spool turbofan design, in which fan is decoupled from low pressure compressor but coupled with planetary gear system by doing so the speed of the fan is reduced. This will reduce the noise and vibration of fan case, the planetary gear system increase the speed of the low pressure spool by approximately 3 times the speed of fan, and slightly increase the speed of high pressure spool because of reduced no. of stages thus engine now houses three shafts, all turning at different speeds. Due to less no. of stages life limited airfoil parts reduced in part count, thus less maintenance of engine.

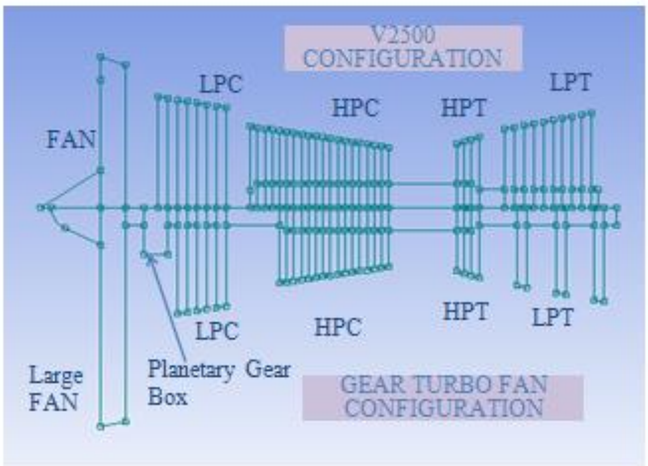

Figure 1. Cross section of Conventional Turbo Fan Engine vs Gear Turbo Fan Engine.

Table 1.0 provides the configuration of V2500 engine vs new GTF engine. The change in the GTF engine is higher fan diameter to whooping 2.057m (81inch) compared to 1.613m

(63.5inch) in the same class thrust range of turbo fan engine. By doing so the bypass pressure ratio is increased to 12 which significantly improve fuel efficiency.

Parameter	**Engine Type**	
	V2500	**GTF**
Thrust (Lbs)	27000	27000
By pass Ratio	4.8:1	12:1
Configuration	1-4-10-2-5	1-G-3-8-2-3
Fan Diameter (Inch)	63.5	81

As per table the GTFs low pressure spool has only 3 compressors and 3 turbines stages, as compared to larger and heavier 4 compressors and 5 turbines stages on the v2500, with this the number of airfoils reduced hence less maintenance of engine due to less life limited parts. A conventional engine in the same thrust range would normally have 21 ~ 23 stages of blading whereas the GTF engine, has only 17 stages. Also, the core engine parts that have been eliminated involve high cost materials, such as super alloys that can withstand high temperatures, while the gearbox materials are less exotic, providing a potential cost benefit. The planetary gearbox thoroughly tested at least 99.3 percent efficient for small inefficiencies such as gear tooth mismatch and bearing misalignment would generate enough heat to cook gearbox lubricating oil. The radius of the fan is 27% more than the v2500 engine fan, making the volume of the fan approximately 2 times the mass assuming the same material is used to make the blades. With double the mass the moment of inertia of the GTF fan is about 3.3 times that of the V2500. The overall equivalent moment of inertia of the low pressure spool of the GTF is at least 25% that of the v2500.

Gear Turbo Fan are designed and developed by Pratt & Whitney under the tag name of NGPF with PW1000G series of engines for Airbus, Bombardier, Mitsubishi, Irkut and Embraer; whereas Rolls Royce is working on wide body engines which are in the range of 50000- 90000 pound thrust scheduled to entire service by 2025.

1.2. Open Rotor Engine

Open Rotor Engine also known as Ultra High Bypass (UHD) Engine. In order to improve propulsive efficiency of gas turbines the open rotor configuration evaluated by using a second row of propeller blades rotating in opposition to the front row to provide a more direct thrust. There are two open rotor configurations have been designed and tested at low and high speeds, the expected fuels gains are confirmed but the challenge was increased noise with the two contra rotating fans are generating and there is no nacelle to absorb this noise.

Higher propulsive efficiencies are achievable for turbofans by increasing the bypass ratio through increases in fan diameter. Open rotor engines have no limitation by operating the propeller blades without a surrounding nacelle so that ultrahigh bypass ratios are easily achieved. Open rotor technologies offer the potential for significant reductions in fuel burn and CO2 emissions relative to turbofan engines of equivalent thrust.

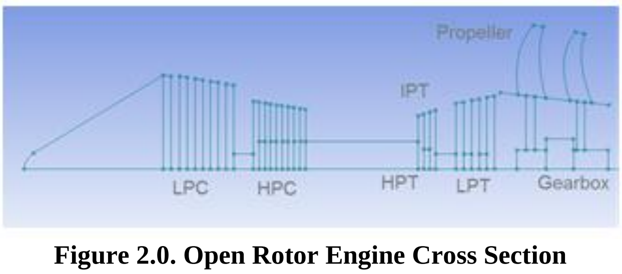

Figure 2.0. Open Rotor Engine Cross Section

The Open Rotor engine is comprised of the Propeller weights, Rear structures and Engine core consists of five stage LP compressor & five stage HP compressor, Combustor & single stage HP turbine & IP turbine, three stage low pressure turbine and planetary differential gear box with a gear ratio of 8. The open rotor engine comes out slightly heavier primarily due to the heavy propellers and rear weight structures.

The open-rotor engine delivers almost the same aircraft speeds as a conventional turbofan engine expecting at least 25 ~30 percent lower fuel consumption but the economic viability will be the weight penalty incurred to protect the aircraft from damage caused by a rotor burst or blade release and drag increases as the diameter of nacelle increase. A turbofan can contain a released blade, but an open rotor will require shielding of the airframe and systems.

1.3. Improve Propulsive & Thermal efficiency

Many OEMs are betting for High Propulsive and Thermal efficiencies in the new technology eg., GE for its LEAP engine. i) 3D Woven carbon fiber composite fan blades of light weight and durability to improve propulsive efficiency & to increase high by pass ratio ii) new cooling methods & 3D aerodynamics in ceramic composites to improve thermal efficiencies. iii) Optimum aerodynamic design by CFD techniques in variable vane gaps, advanced transition models, Cavities and Casing treatments are areas to improve the efficiencies. iv) In terms of improved manufacturing technologies in erosion coatings to improve life, blade intergraded disk (BLISK) for low pressure disks, stator guide vane clusters manufacturing by metal injection molding (MIM) and near net precision casting for exit guide vane manufacturing. Linear Friction welding are new concept adapted for BLISK manufacture for new part production as well for repair, for outstanding welding quality to meet HCF and LCF strengths.

The LEAP engine is the first engine to use additive manufacturing for lighter parts of fuel nozzles which are 25% lighter than previous models and five times more durable than parts manufactured conventionally because nozzle pre-mixes these elements to provide lean burn combustion. 2nd generation Combustor consists of Twin-Annular, Pre-Mixing Swirler reduces NOx emissions by 50%* versus CAEP/6 standards having debris rejection system to prevent sand, dust and other harmful items from reaching the core. As a result the engine is highly durable, provides the best erosion protection. These are best useful in gulf streams where sand and dust prevail in the atmosphere.

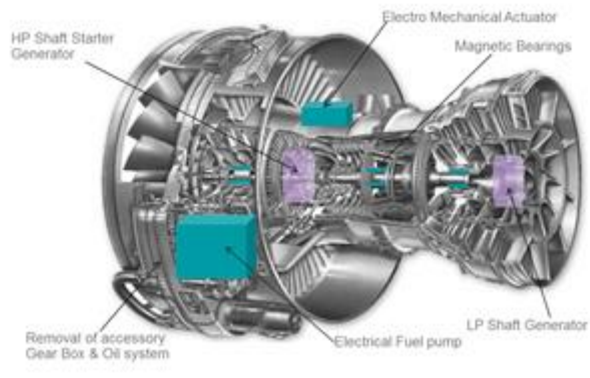

Figure 3.0 Electrical Engine Technologies

Electrical engine technologies are the new opportunity to replace hydro / pneumatic mechanism. Electric fuel pumps and metering units are new in place of accessory gear box and oil system. Electro mechanical actuators for variable vane mechanism in place hydro mechanical actuators. HP starter / generator and magnetic bearing are new technology advancements under developments.

Recuperative Gear Turbo Fan is advance concept to the GTF where the LPC air passes through the intercooler passes through HPC and goes to exhaust gas recuperator where the exhaust gas of the LPT goes out of the engine will be preheated the HPC gas, there by the temperature of gas increases further enters into combustor. This will improve combustion process thus increase in thermal efficiency and reduce NOx limits.

In order to enhance speed of the exhaust gases, optimizing thrust and fuel economy new system called variable area fan nozzle (VAFN) to ensure optimal efficiencies across the flight spectrum to adjust a flap assembly that would vary the fan exit area through which the fan air is discharged which is the first of its kind for high bypass turbofan engines. This simpler and inexpensive system of variable area nozzles, as compared to those seen in military jets.

Discussion and Conclusions

In this paper a comparative discussion on GTF, Open Rotor engine, LEAP engine technologies were carried out. Design constraints in the form of engine requirements thrust, time between overhaul etc. as well as technology limitations were taken into consideration.

Gear Turbo Fan (GTF) Engine entry into service that disrupted current aviation industry is a new paradigm shift by employing the largest bypass ratio in the history of turbofan engine provides double digit fuel burn savings. The slow speed of the fan, contribute to low noise, promising an enhanced passenger experience, and reduced flight-related fatigue while the first Open Rotor engine is expected to fly in commercial service around 2020. In any new Engine, the reliability of such a huge geared turbofan engine unknown, doubted on dispatch reliability for airlines. Further, the PW1100G series focus primarily on propulsive efficiency, forcing the engine to take on a large fan diameter of 81 inches, which will offer more drag than the competing LEAP 1A engine, which features a fan of diameter 3 inches smaller. The side effort towards better fuel savings increases drag, and may cost the Airbus A320's takeoff, climb, and cruise performance, especially at areas that have short runways, and/or challenged by terrain. Although the spool up time of the GTF engine is expected to be lower, allowing the airplane to respond faster to a terrain alert, a penalty on climb performance is expected to exist, reducing, safety margins related to obstacle clearance. The CFM LEAP 1A, on the other hand, with the reduced drag footprint, increased thermal efficiency, and optimized propulsive efficiency (not to the extent of PW1100G's) may lead to similar fuel burn savings, with a lesser penalty on performance. However, the spool up time may be considerably longer than the PW1100G's. Either engine option will affect the 320's performance, and may not be able to match up to the climb performance, safety and statistical reliability offered by today's sharklet equipped A320 with either the V2500-A5, or the CFM 56-5B4. P&W GTF engines are in the range of 15000 – 33000 pound thrust whereas Rolls Royce is working on wide body engines which are in the range of 50000- 90000 pound thrust of 118 inch diameter of bypass ratio 9.3:1 and can go up to 13 comfortably scheduled to entire service by 2025.

Although the open rotor engine is somewhat heavier, the reduced SFC and nacelle drag makes up for this and the resulting mission fuel burn is improved by approximately 15% compared to the geared turbofan engine. It can also be observed that for the open rotor configuration the location of the mid cruise operating point is not at the bottom of the SFC loop. Sizing the engine and choosing an appropriate design point for the propeller involves complex trade-offs, since for short haul aircraft large parts of the business case mission is spent climbing to cruise altitude, rather than cruising.

Many OEMs are investing R&D spend by improving aerodynamic efficiency , improve reliability or life cycles , reduce maintenance, reduce development and manufacturing cost, weight & operation stability . New technologies on these improvements are not too far for a better sky with green gases emits from these engines with extra comfort cabins for mankind.

Acknowledgment

The authors wish to thank Lachanna A & Hari A for their review and support.

References

1.Hans De Ryck "Turbofan design for the commercial aircraft", Warsaw University of technology, Faculty of Power and Aeronautical Engineering, Nowowiejska 21/25, 00-665 Warsaw, Poland, May 2008.

2.Lee S Langston "Not So Simple Machines" 46_51_ASME_Turbofans_F3_P4., 2013.

3.Linda Larsson, Tomas Grönstedt, Konstantinos G. Kyprianidis "Conceptual Design and mission analysis for a geared turbofan and open rotor configuration" ASME Turbo Expo 2011 , GT2011-46451

4.Wictoria Mellgren "Volvo Research and Technology- Open rotor the aircraft engine of the future" Advanced Engineering Communications.

5.S. Arif Khalid, David Lurie, Andrew Breeze-Stringfellow Trevor Wood, Kishore Ramakrishnan, Umesh Paliath John Wojno, Bangalore Janardan, Trevor Goerig Anthony Opalski "FAA Cleen Program Open Rotor Aeroacoustic Technology" May 2013.

6.Eric S. Hendricks and Michael T. Tong Glenn Research Center, Cleveland, Ohio "Performance and Weight Estimates for an Advanced Open Rotor Engine" July 30–August 1, 2012.

7. www.popularmechanics.com/flight/a17813/purepower-gtf-coming-to-market/

8. www.eurekamagazine.co.uk/design-engineering-features/technology/rolls-commits-to-geared-turbofan/65879/

9. www.pw.utc.com/Content/PurePowerPW1000G_Engine/