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A Study of Technology Used and Comparison Between Traditional and Hf120 (Advanced Aero Engine)

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Abstract- ***Paper includes detailed study of the HF120 turbofan engine, which is the first product from GE Honda Aero Engines. This paper is to showcase state of art technology involved in gas turbine engines and to bring out various aspects and future trends in field of propulsion technology. Paper also includes development in gas turbine engine that have helped to achieve great fuel efficiency and less noise, increased power, thrust and also advancements made in the field of materials have contributed in a major way in gas turbine in accordance to the future trends that have come up in recent years. The paper reviews the evolutionary process that has taken place over the years with reference to the different design concepts used for aero engines. At General Electric, the official corporate slogan is "Imagination at work." At Honda, it's "The power of dreams." Two of the world's respected names in propulsion have come together to design and manufacture engines for the next generation of very light jets. The joint venture, known as GE Honda Aero Engines, combines the strengths of two industry leaders recognized for delivering high performance and reliable engines. The HF120 is an advanced 2000lb thrust class turbofan propulsion system. It incorporates a development philosophy and operational features consistent with Honda's tradition of Innovation and GE's rigorous design and testing standards.***

Keyword HF120, Honda's, GE's, design and testing, "Imagination at work.", GE Honda, 2000lb

I. INTRODUCTION

1.1 GE HONDA AERO ENGINE

The forces associated with fluid movement are well known; we are all familiar with the power of strong winds, or waves crashing onto rocky shorelines. However, the ingenuity of mankind has enabled air and water flow, wind and wave energy to be successfully harnessed, to provide beneficial movement and power through the ages. The gas turbine is a machine that burns fuel to provide energy to create a moving flow of air, and to extract valuable power or generate useful thrust from that movement. The jet engine has revolutionized air transport over the last 50 years, a jet engine employs Newton's laws of motion to generate force, or thrust as it is normally called in aircraft applications.

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A GE Honda Aero Engines, is a 50/50 joint venture between GE Aviation and Honda Aero, Inc., and was formed in October 2004 to design, manufacture, sell, and support a family of innovative engines in the 1000 to 3500 pound thrust class for the business aviation industry.
The two companies began talks in 2003 with the goal of providing durable and economical engines for business aviation. The idea was to combine the strengths of each parent company in technology leadership, manufacturing expertise, and performance engine tradition to provide modern business aviation engines with the performance and availability of large commercial engines. A strategic alliance between the two companies lead to planning of 50/50 project intended to develop, certify and market the Honda engine. The **HF120**, product from GE Honda Aero Engines, utilizes Honda's world-renowned expertise in manufacturing, research and development and GE's experience in aerospace technology, durability, and certification. The HF120 comes from some of the most innovative people in the world and is designed to deliver performance, durability, and value to business aviation. The emergence of light, low-cost business jets creates considerable opportunity for highly reliable and durable jet engines. The GE Honda HF120 durability will be ideally suited for high-utilization aircraft, such as the emerging air taxi segment. Lightweight and efficient design enables the performance, range and comfort required of the business jet customer. This engine meets all future demands that is environment friendly, noise reduction, lower sfc, higher efficiency, light weight, increased thrust and more time before overhaul (TBO).

II. HISTORY

Honda began developing a small turbofan in 1988. The company began testing the first design, the HFX-01in 1995, followed by the HFX-20 in 2000. Experience with the earlier designs led to the development of the first production engine, the 1,700 lb thrust (7.6kN) HF118. A proposed joint venture with GE Aviation was approved and GE Honda Aero Engines was created in 2004, as a 50:50 joint company to design, manufacture, sell, and support a family of innovative engines in the 1,000-3,500 pound thrust (4.4-15.6kN) Class for the business aviation industry. Honda Aircraft Company, Inc. was created on 4 August 2006 and launched the Honda Jet on 17 October 2006. Full engine testing of the HF120 began in September 2007.

The HF120 features a one piece, 18.5-inch, wide-chord swept fan blisk, two-stage low-pressure (LP) compressor and Honda- developed counter-rotating high-pressure (HP) compressor based on a titanium impeller. Honda launched the HF120 at the 2006 NBAA show, as the power plant for two nascent business jet programmes; Honda's own 8-seat **Honda Jet** and **Spectrum Aerospace's Freedom** light jet. Certification and first customer delivery was subsequently set back again and rescheduled for the second half of 2012. In June 2011, flight testing of the FAA- conforming Honda Jet achieved new milestones, including a maximum speed of 425 knots (TAS)), a rate of climb of 3,990 feet per minute and reaching the aircraft's maximum operating altitude of 43,000 feet. Honda at the NBAA in Las Vegas announced a further 12-month slippage in certification and customer deliveries in October 2011, after it emerged that, following icing tests conducted in February 2011, a redesign had been required of the HF120s titanium fan blisk. The first Honda Jet test aircraft fitted with modified fan blisks joined the test programme in November 2011. The slippage results from the extra time needed for engine and aircraft-level retesting. Seven engines with the enhanced fan blisk design were to be used for the overall certification programme, which is now expected to be completed in the second quarter of 2012, followed by US Federal Aviation Administration certification of the engine in the second half of 2013.Honda reports over 100 orders for the $4.5 million Honda Jet and expects to sell at least 400 aircraft in the HF120's thrust class each year. In June 2011 GE Aviation confirmed that it was in talks with other airframes about the next applications for its Honda joint-venture engines beyond the HF120 for the Honda Jet. GE has confirmed that it wants the GE Honda brand to its company's brand in this size market. The joint venture agreement between GE and Honda currently covers a maximum thrust rating of 3,500lb-thrust (13.2kN), but a 5,000lb-thrust (22kN) class engine would be competitive with engines produced by rivals Pratt & Whitney.

2.2 STUDY OF BASIC GAS TURBINE ENGINE

Most of the gas turbine engines are internal combustion engines. A gas turbine engine extracts energy from the flow of a combustion gas. Energy is added to the gas stream in the combustor, where fuel is mixed with air and ignited. In the high-pressure environment of the combustor, combustion of the fuel increases the temperature. The products of the combustion are forced into the turbine section. There, the high velocity and volume of the gas flow is directed through a nozzle over the turbine's blades, spinning the turbine, which powers the compressor and, for some turbines, drives their mechanical output. The energy given up to the turbine comes from the reduction in the temperature and pressure of the exhaust gas. Gases passing through an ideal gas turbine undergo three thermodynamic processes. These are isentropic compression, isobaric (constant pressure) combustion and isentropic expansion. Together these make up the **Brayton cycle.**

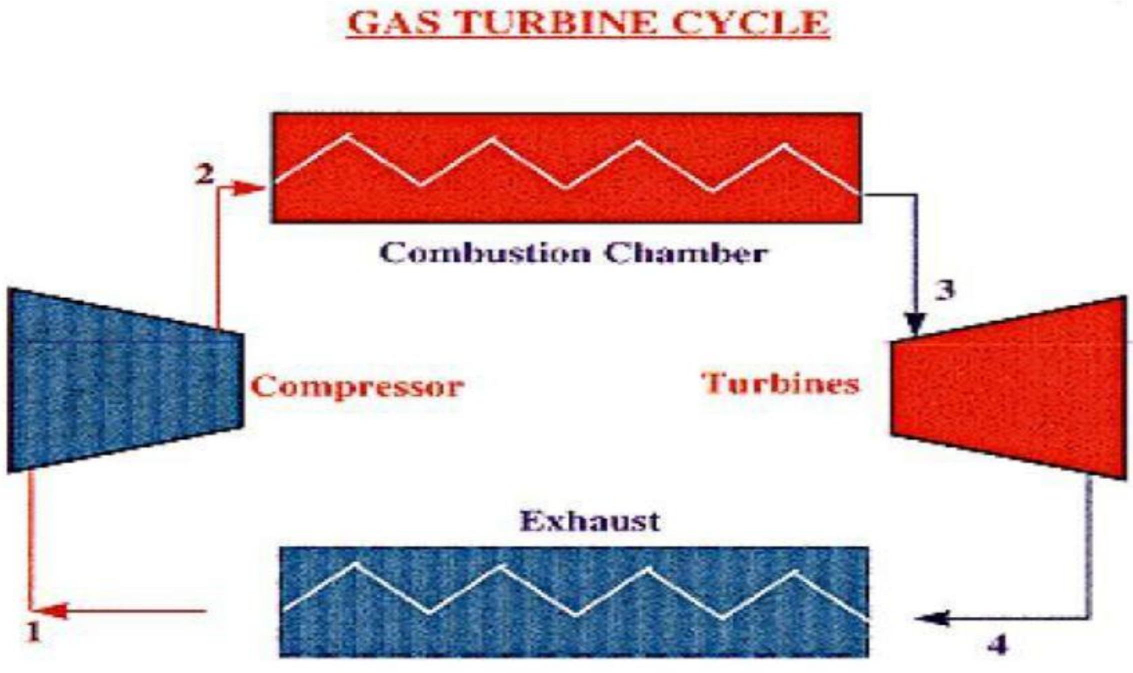

Figure 2 Gas Turbine Cycle

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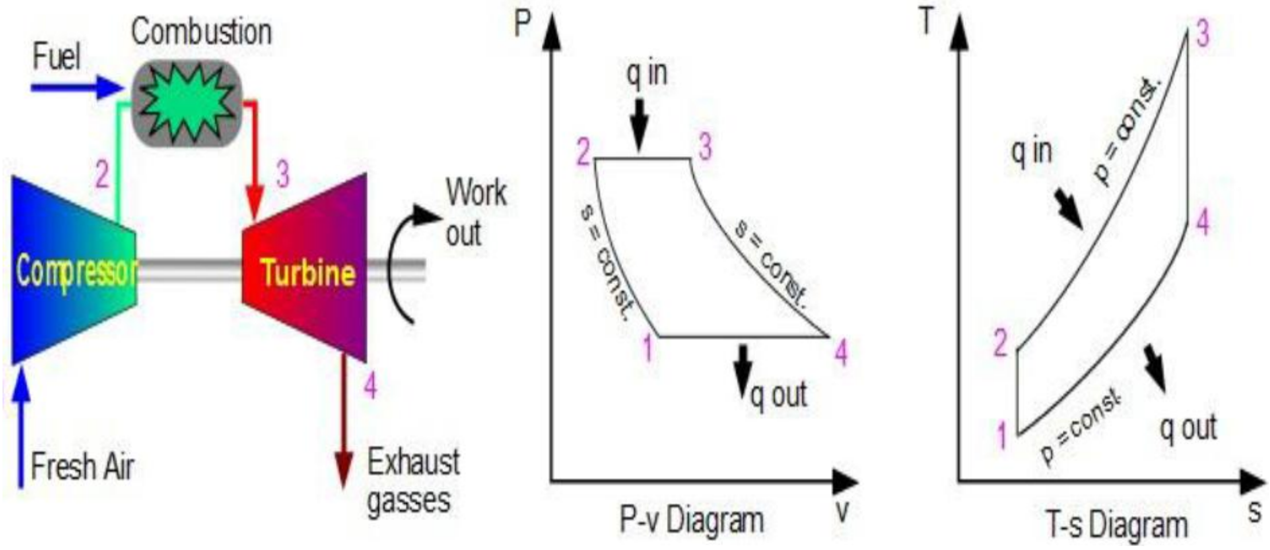

Figure 3. Brayton cycle

There are three main components of a simple a gas turbine engine, namely a compressor, a turbine and a combustion chamber and a nozzle.

- **Compressor**

A compressor compresses incoming air to high pressure. The pressure rise is achieved by converting the high kinetic energy of incoming air into pressure energy.

- **Combustion Chamber**

Inside a combustion chamber, the fuel mixed with oxidizer (air) is burned to produce high- pressure, high-velocity gas.

- **Turbine**

A turbine extracts the energy from the high-pressure, high-velocity gas, which is flowing through the combustion chamber.

- **Nozzle**

Nozzles lets hot exhaust gases to flow out at very high velocities producing much of the thrust.

There are various types of gas turbine engines but here we will be containing our discussion to aircraft gas turbine (air breathing) engines. Some of them are:

- Turbojet
- Turbofan
- Turboprop
- Ramjet
- Scramjet
- Pulseje

2.3 TURBOFAN ENGINE

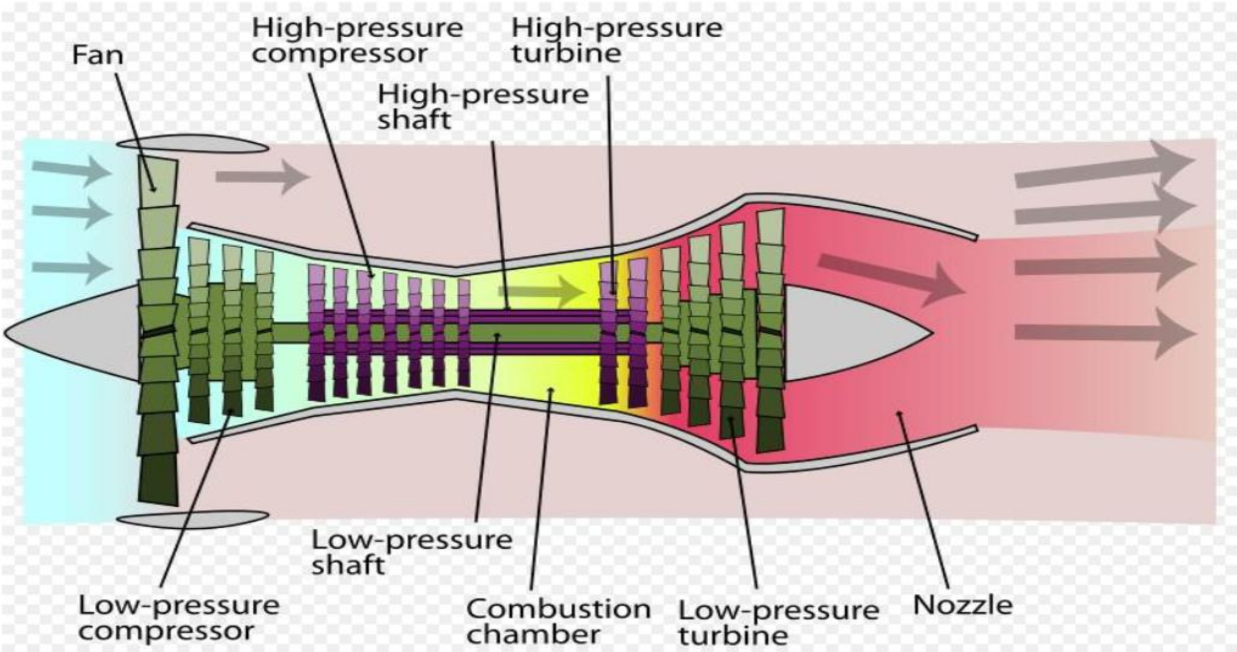

Figure 4 Turbofan Engine

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A turbofan engine is an air breathing gas turbine engine that uses a Gas Generator Core, comprising of a compressor, a combustor and a turbine to generate kinetic energy in the exhaust by means of converting the internal energy in the fuel into kinetic energy. Turbofans are generally more efficient than turbojets at subsonic speeds. The turbofan engine consists of an inlet, fan, compressor, combustor, turbine, and nozzle. a turbofan engine gets some of its thrust from the core and some of the thrust from the fan. The bypassed flow is at lower velocities than the flow through the gas generator core. But owing to its higher mass, the thrust produced by the fan is more efficient than the thrust produced by the core. Hence, turbofan engine is more efficient than turbojets at subsonic speeds. The ratio of the air that goes around the engine to the air the air that goes through the engine core is called **BYPASS RATIO**.

In the turbofan, a portion of the turbine work is used to supply power to the fan. The **thrust specific fuel consumption** (TSFC, fuel mass flow rate per unit thrust) is lower for turbofans and indicates a more economical operation. The turbofan also accelerates a large mass of air to a lower velocity than a turbojet for a higher propulsive efficiency. The frontal area of a turbofan is quite large compared to a turbojet and for this reason more drag and weight results. The fan diameter is also limited aerodynamically when compressibility effects occur. Since most of the air flow through a high-bypass turbofan is low-velocity bypass flow, even when combined with the much higher velocity engine exhaust, the net average exhaust velocity is considerably lower than in a pure turbojet. Engine noise is largely a function of exhaust velocity; therefore turbofan engines are significantly quieter than a pure-jet of the same thrust. Other factors include turbine blade and exhaust outlet geometries, such as noise-reducing "chevrons". Since the efficiency of propulsion is a function of the relative airspeed of the exhaust to the surrounding air, propellers are most efficient for low speed, pure jets for high speeds, and ducted fans in the middle. Turbofans are thus the most efficient engines in the range of speeds from about 500 to 1000 km/h (310 to 620 mph), the speed at which most commercial aircraft operate. Turbofans retain an efficiency edge over pure jets at low supersonic speeds up to roughly Mach 1.6.

2.3.1TURBOFAN CLASSIFICATION

* High bypass ratio * low bypass ratio
* mixed flow * unmixed flow
* Single spool * twin spool * multi spool

▪ **<u>Low Bypass Turbofan Engine</u>**

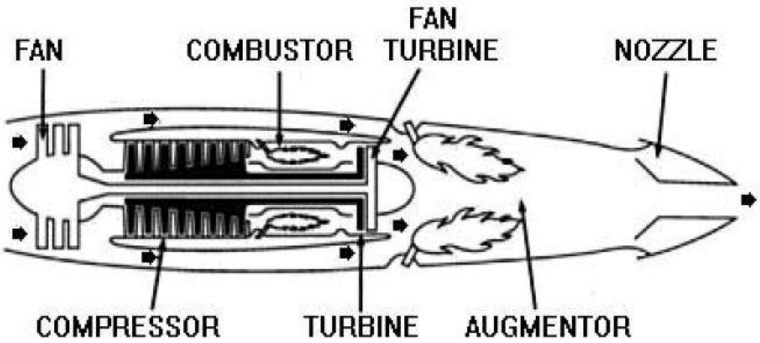

Figure 5 Low Bypass Turbofan Engine

Low bypass turbofan engines usually have a bypass ratio of 2:1 or even less than that. The bypass flow and the core flow can exit either through the same nozzle or separate nozzles. Generally, low bypass turbofan engines make use of a mixed exhaust nozzle i.e. the bypass flow and the core flow exit from the same nozzle.

▪ **<u>High Bypass Turbofan Engine</u>**

High bypass turbofan engines have a bypass ratio of the order of 5:1 or 6:1, which implies, they have larger bypass ratios. Since a large mass of air is accelerated by a fan in high bypass turbofan engines, these are much more fuel efficient and produce much more thrust as compared to a low bypass turbofan engine or a turbojet engine.

2.3.2TYPICAL TURBOFAN COMPONENTS

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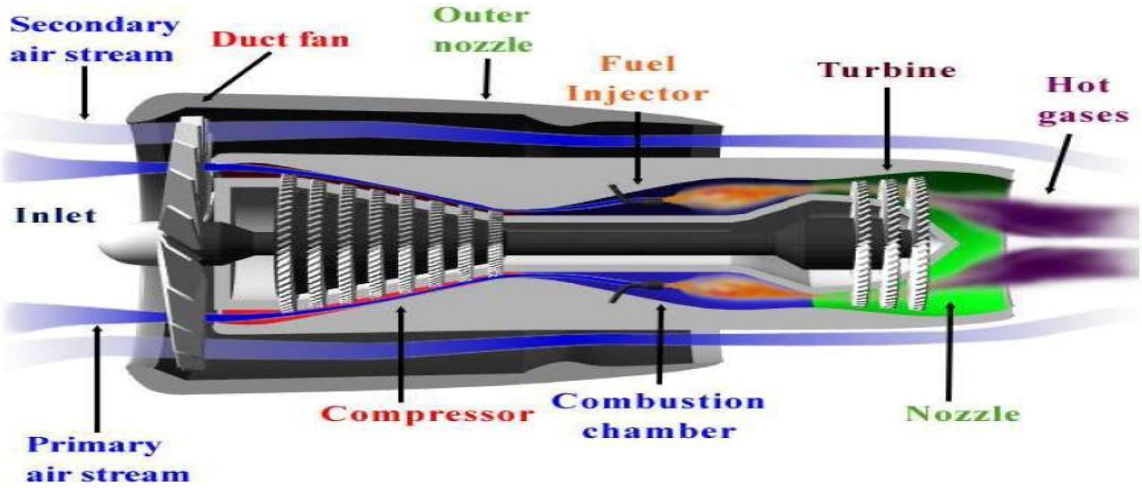

Figure 7 Turbofan Components

- **INLET:**

An inlet is used in all turbine engines for directing the free stream air into the engine. The inlets may be of various shapes and sizes. Depending upon the speed of the aircraft, these are classified as:

- Subsonic inlets
- Supersonic inlets
- hypersonic inlets

The inlet efficiency has a strong effect on the net thrust produced by the aircraft engine, both at low speeds and high speeds. Hence, an inlet must operate efficiently over the entire flight envelope of the aircraft. The front gap in the housing is used to guide the airflow into the engine. The distance between the first part of the engine (compressor) and the gap is called the inlet. The inlet is not a part from the engine itself; the inlet is a part of the front nacelle installation or housing. The inlet has an aerodynamically advantage, this is described. The inlet is used to provide the engine a straight airflow, even during different angels of attack, turbulence and all rational airspeeds. This is to prevent harmful effects in the compressor. The inlet also has another function. The shape of a modern turbofan inlet duct causes an air velocity decrease therefore a temperature and pressure increase, this phenomenon is called ram recovery and has a positive impact on the thrust without using more fuel, the pressure and temperature increasing occurs by flying faster than Mach 0.2. There are several formulas to calculate the inlet values of temperature, pressure and airspeed in contrast with the outside temperature, pressure and airspeed. The first aspect that has to be solved for proving that the inlet has a positive effect on the efficiency is the temperature in the inlet duct.

- **COMPRESSOR:**

Gas turbine engines or the jet engines power most modern passenger and military aircraft. All types of gas turbine engines have a compressor to increase the pressure of the incoming air before it enters the combustor. The compression of the air is effected by one of two basic types of compressor; one giving axial flow and the other centrifugal flow. Both types are driven by the engine turbine and are usually coupled direct to the turbine shaft. The two types are:

- **Centrifugal flow compressor**

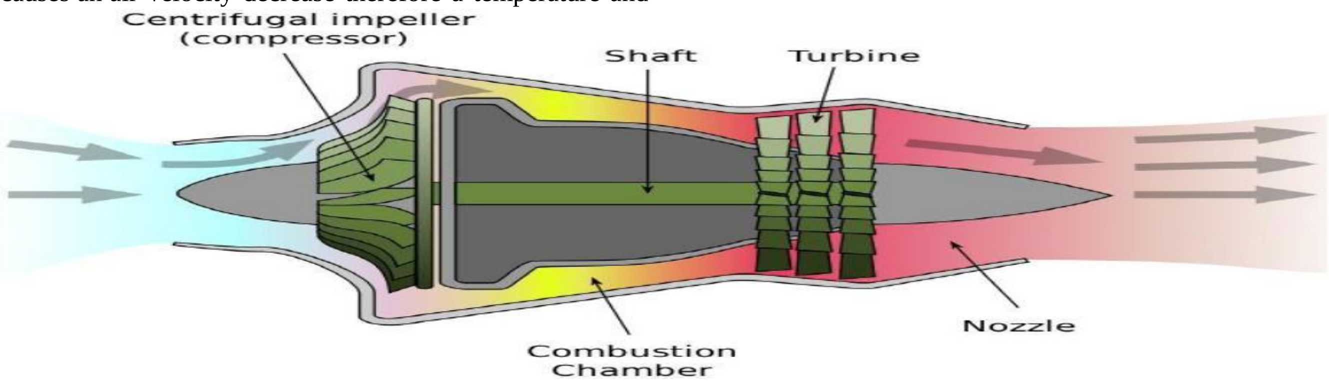

Figure 8 Centrifugal Compressor

A centrifugal compressor turns the flow through the compressor perpendicular to the axis of rotation i.e. the air enters axially and is delivered radically. It produces a high-pressure ratio of 4:1 or 5:1 in a single stage. The centrifugal flow compressor consists of several single or double-sided disk stages (impellers) mounted on one axle driven by a turbine. The air that is leaving the inlet duct collides to the center of these impellers. The rotating impeller increases the air velocity and pressure during the centrifugal action that moves the air from the center to the rim of the impeller. At the rim of the impeller a diffuser is captured the air. The diffuser leads the compressed air to the next impeller that is increasing the pressure once more.

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Also this diffuser has an divergent nozzle, this means an increasing of the pressure. In every stage 50% of the pressure the diffuser and 50% do rise by the impeller. In contrary to the high efficiency, the centrifugal flow compressor cannot be used for higher speeds, this because this compressor can convert less air in a higher pressure as the axial compressor with the same frontal surface.

- **Axial flow compressor**

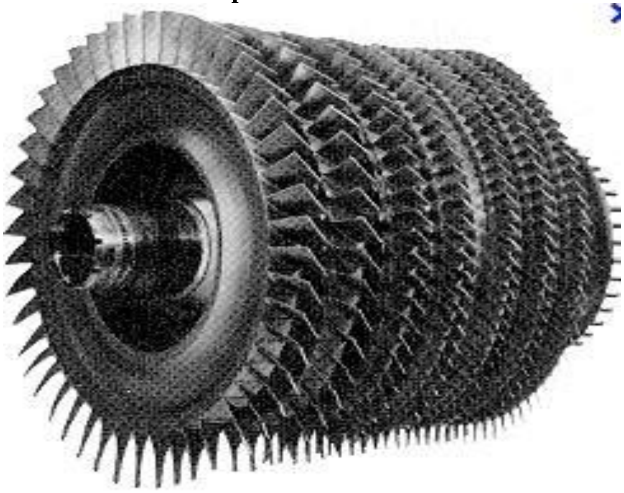

Figure 9 Axial Compressor

The most used compressor in the modern engines is the axial flow compressor. An axial flow compressor is in respect of all others an efficient compressor. However there are several types of axial flow compressors, from less efficient, like the straight engine, up to extremely efficient, like the high by-pass engine. In an axial compressor, the air enters axially and delivers axially. It is much more fuel-efficient than a centrifugal compressor. Moreover, it gives the turbofan engine a long, slim and streamlined appearance. The engine diameter is reduced which results in much low aircraft drag. A multistage axial compressor can develop a pressure ratio as high as 6:1 or more. The air handled by this is more than that handled by a centrifugal compressor of the same diameter. The thrust produced per unit diameter is more. It also ensures 6% to 8% less specific fuel consumption.

A compressor consists of rotating parts called rotors and stationary parts called stators. Rotors are attached to the central shaft rotating at high speed, while the stators remain fixed. Further the rotors may be drum type or disc type rotor. The compressor blades are airfoil shaped and produce pressure variation much like the airfoil of a spinning propeller. A stator increases the pressure and keeps the flow from spiraling around the axis by bringing the flow back parallel to the axis. The rotors and the stators are placed in alternating sequence such that the compressor is composed of several rows of airfoil cascades. One set of a stator and a rotor is called a stage. The number of stages used in a compressor depends upon the pressure ratio required.

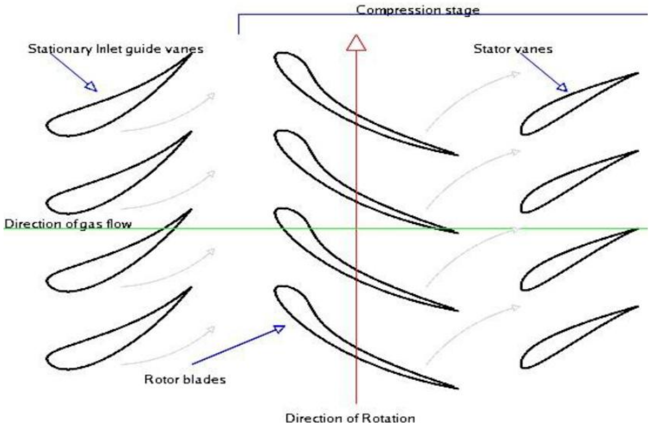

Figure 10 Compressor Blade Orientation

An axial flow compressor consists of one or more rotor blade assemblies mounted on its own axle. The turbine is rotating this axle. The rotor blades are fitted on the axle under an angle. The rotor blades are scooping the air and convert the kinetic energy of the air into a pressure and air velocity increases. Like the diffuser of the centrifugal flow compressor, fixed stator blades are fitted between each disk of rotor blades to lead the airflow to the next disk of rotor blades. The stator blades are necessary to maintain a constant air velocity as the density of the air increases. In the early years one turbine rotated one rotor blade assembly that compressed the air as long as needed for the combustion. This compressors where long installations and less efficient as a twin spool compressor. A twin spool compressor has for every rotor blade assembly an own axle with an own turbine. The front compressor turns with a low velocity and is called the Low Pressure Compressor [LPC]. The rear compressor turns with a high velocity and is called the High Pressure Compressor [HPC]. The velocity difference has a great impact on the efficiency of the engine. A higher velocity means a higher pressure increasing. Twin spool compressors can be used to design a by-pass engine. The airflow in the inlet of a by-pass engine is spited up in two directions. One part of the airflow enters the core engine for compression and combustion and another part of the airflow is passing the exterior of the engine but intern housing. The relation between the by-pass flow and the flow that entered the engine is called the **By-Pass Ratio** [BPR]. A high BPR means a higher efficiency and less noise. The pressure and temperature difference between the exhaust gasses and the outside temperature and pressure is high. Because a by-pass engine is increasing the pressure and temperature of the by-pass flow the difference between the variables at the exhaust the engine will be fewer when comparing with the engine exhaust variables.

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To give the by-pass flow a higher pressure and temperature a second rotor blade assembly must be required. In the LPC the air will be compressed and will be separated before entering the HPC into an engine flow and by-pass flow for even better results a multi spool compressor can be used.

- **COMBUSTOR:**

When the air comes out of the compressor it is ready to be ignited. To ignite the fuel in the engine a combustion chamber is needed. In combustion chamber or burner, the fuel is mixed with high-pressure air and burned. These must be designed to ensure stable combustion of the fuel injected and optimum fuel utilization within the limited space available and over a large range of 16 air to fuel ratios. The design of the combustion chamber depends upon the application and requirements in each case.

- **Annular type burner**

The liner of the annular combustion chamber consists of a continuous, circular, inner and outer shroud around the outside of the compressor drive shaft. The inner is often called a "burner basket" because of its shape and the many holes that allow cooling air inside. In this type of chamber, fuel is introduced through a series of nozzles. The configuration ensures better mixing of air-fuel, better use of available space and uniform heat distribution.

- **Can type burner**

Can type combustion chambers are particularly suitable for engines with centrifugal flow compressors as the airflow is already divided by the compressor outlet diffusers. The separate flame tubes are all interconnected. The entire combustion system consists of 8 to 12 cans that are arranged around the engine. The disadvantage of this design comprises of the unfavorable inflow/outflow ratios and the associated large size. Ignition problems may also occur at high altitudes. The advantages include low development cost and good accessibility for servicing.

- **Can-Annular type burner**

It is a combination of can type and annular type combustion chamber. In this type of combustion chamber, all flame tubes have a common secondary air duct. The aerodynamic properties of this type are inferior to those of annular type combustion chamber. These are suitable for large engines (for mechanical reasons) and the ones with high-pressure ratios. Development costs are lower and volume smaller than with a can type combustion chamber.

- **Turbines:**

A turbine extracts energy from the hot flow and turns the compressor. The high pressure and temperature gases expand through the turbine to provide enough power output from the turbine. The turbine is directly connected to the compressor and all the The compressor and its auxiliaries absorb power developed by the turbine. A turbine, just like a compressor consists of rotors and stators. The stators prevent the flow from spiraling. Depending on the engine type, the turbine may be multi staged. A single turbine stage can be used to drive multiple compressor stages effectively. Turbofan engines generally employ a separate turbine and shaft to power the fan and the gearb o x respectively. This arrangement is called **two spool engines**. The turbine has the task of providing power to drive the compressor and accessories. It does this by extracting energy from the hot gases released from the combustion system and expanding them to a lower pressure and temperature. The continuous flow of gas to which the turbine is exposed may enter the turbine at a temperature between 850 and 1700 °C which is far above the melting point of current materials technology.

To produce the driving torque, the turbine may consist of several stages, each employing one row of stationary guide vanes, and one row of moving blades. The number of stages depends on the relationship between the power required from the gas flow, the rotational speed at which it must be produced, and the diameter of turbine permitted. The design of the nozzle guide vanes and turbine blade passages is broadly based on aerodynamic considerations, and to obtain optimum efficiency, compatible with compressor and combustor design, the nozzle guide vanes and turbine blades are of a basic aerofoil shape. The desire to produce high engine efficiency demands a high turbine inlet temperature, but this causes problems as the turbine blades would be required to perform and survive long operating periods at temperatures above their melting point. These blades, while glowing red hot, must be strong enough to carry the centrifugal loads due to rotation at high speed. To operate under these conditions, cool air is forced out of many small holes in the blade. This air remains close to the blade, preventing it from melting, but not detracting significantly from the engine's overall performance. Nickel alloys are used to construct the turbine blades and the nozzle guide vanes because these materials demonstrate good properties at high temperatures. Depending on the engine type, there may be multiple turbine stages present in the engine.

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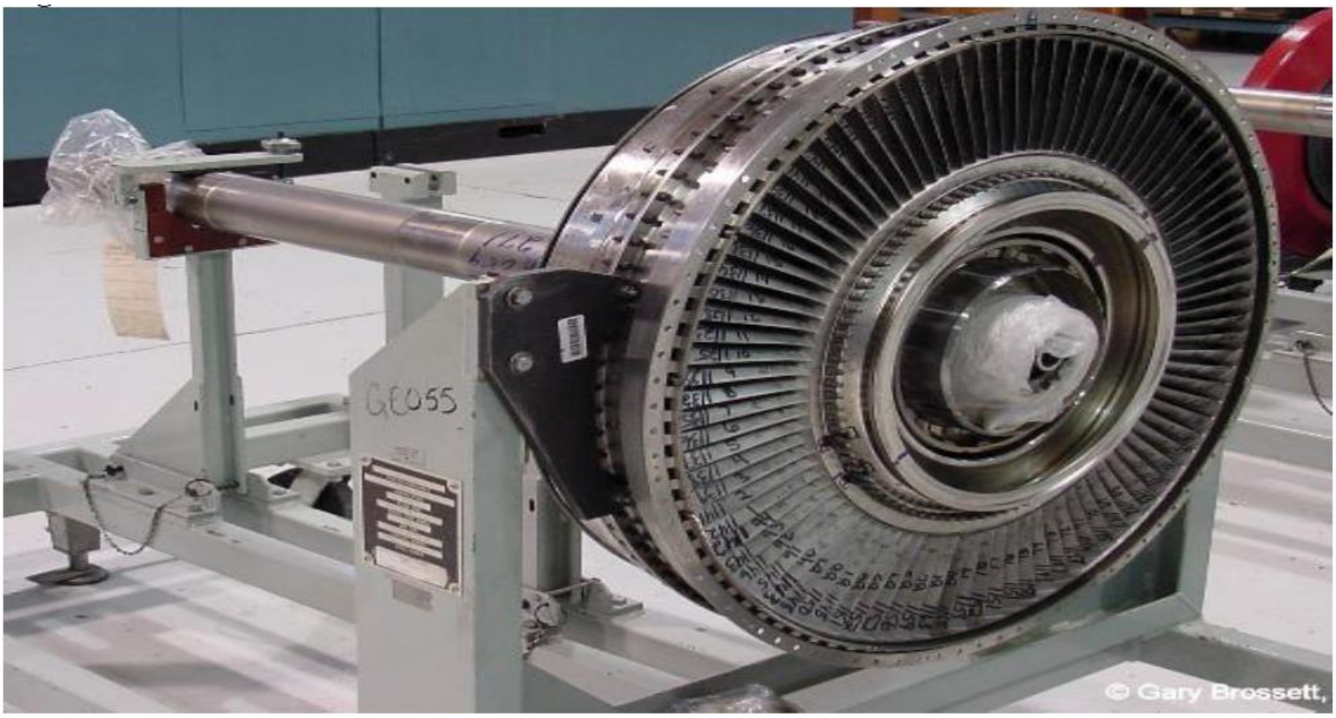

Figure 11 Turbine

The turbine blades exist in a much more hostile environment than compressor blades. Sitting just downstream of the burner, the blades experience flow temperatures of more than a thousand degrees Fahrenheit. Turbine blades must, therefore, be made of special materials that can withstand the heat. Or they must be actively cooled. Single, actively cooled turbine blade is hollow. And cool air, which is bled off the compressor, is pumped through the blade and out through the small holes on the surface to keep the surface cool.

- **NOZZLE**

After the gases leave the turbine they expand further in the exhaust nozzle and are ejected into the atmosphere with a velocity greater than the flight velocity, thereby producing thrust for propulsion. There are two types of nozzle.

- **Convergent nozzle**

These nozzles have a fixed geometry. The convergent nozzle is a simple convergent duct. When the nozzle pressure ratio (pe /po) is low (less than about 4), the convergent
nozzle is used. The convergent nozzle has generally been used in engines for subsonic aircrafts.pe = pressure at exit po = pressure at entry

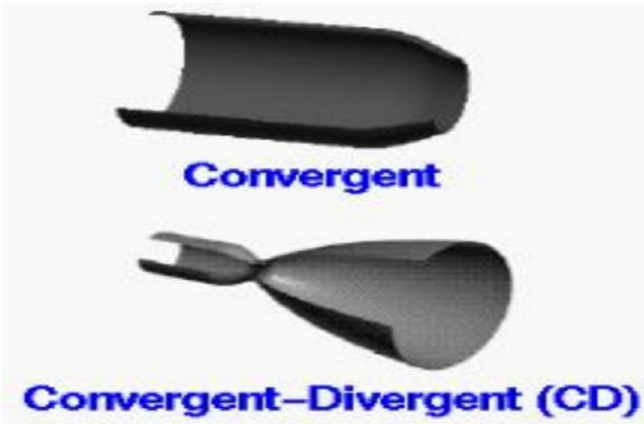

Figure 12 Convergent-Divergent Nozzle

- **Convergent – Divergent nozzle**

These are used in turbofan engines. It has both Convergent duct and divergent duct. Most convergent-divergent nozzles used in aircrafts are not simple ducts. They incorporate variable geometry and other aerodynamic features. It is used when the nozzle pressure ratio is high (greater than about 6). Variable geometry nozzles are also more efficient over a wider range of airflow, than fixed geometry nozzles. This is because the flow is first converged to a minimum area or throat and then expanded through the divergent section to the exit.

2.3.3 THRUST PRODUCED BY A TURBOFAN ENGINE

Thrust is a force produced by accelerating a mass of gas according to Newton's third law of motion.

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Also force equals the rate of change of momentum according to Newton's second law of motion. A gas is accelerated to rear through the engine due to which the aircraft is accelerated in opposite direction. In a turbofan engine some of the air bypasses the engine core and thus the thrust Equation is given as follows:

T= ma [(1+f) ue+ B uf - (1+B)u]

- Advantages of a Turbofan Engine
- Since a fan is used, more amount of air is sucked into the engine providing more thrust
- The fan is enclosed by the cowling and is thus protected and its aerodynamics can be easily controlled
- The extra amount of air, which bypasses the core of the engine, produces extra thrust than any the turboprop or turbojet engine.
- Due to presence of fan, the fuel consumption is increased only a little, the turbofan produces more thrust for same amount of fuel and is thus fuel-efficient.

 Disadvantages of a Turbofan Engine

 It is the most efficient at subsonic speeds only.

 It has a greater complexity due to addition of ducts and multiple shafts.

 The engine diameter is increased

III. GE HONDA AERO ENGINES

HF 120 TURBOFAN ENGINE FOR BUSINESS JETS

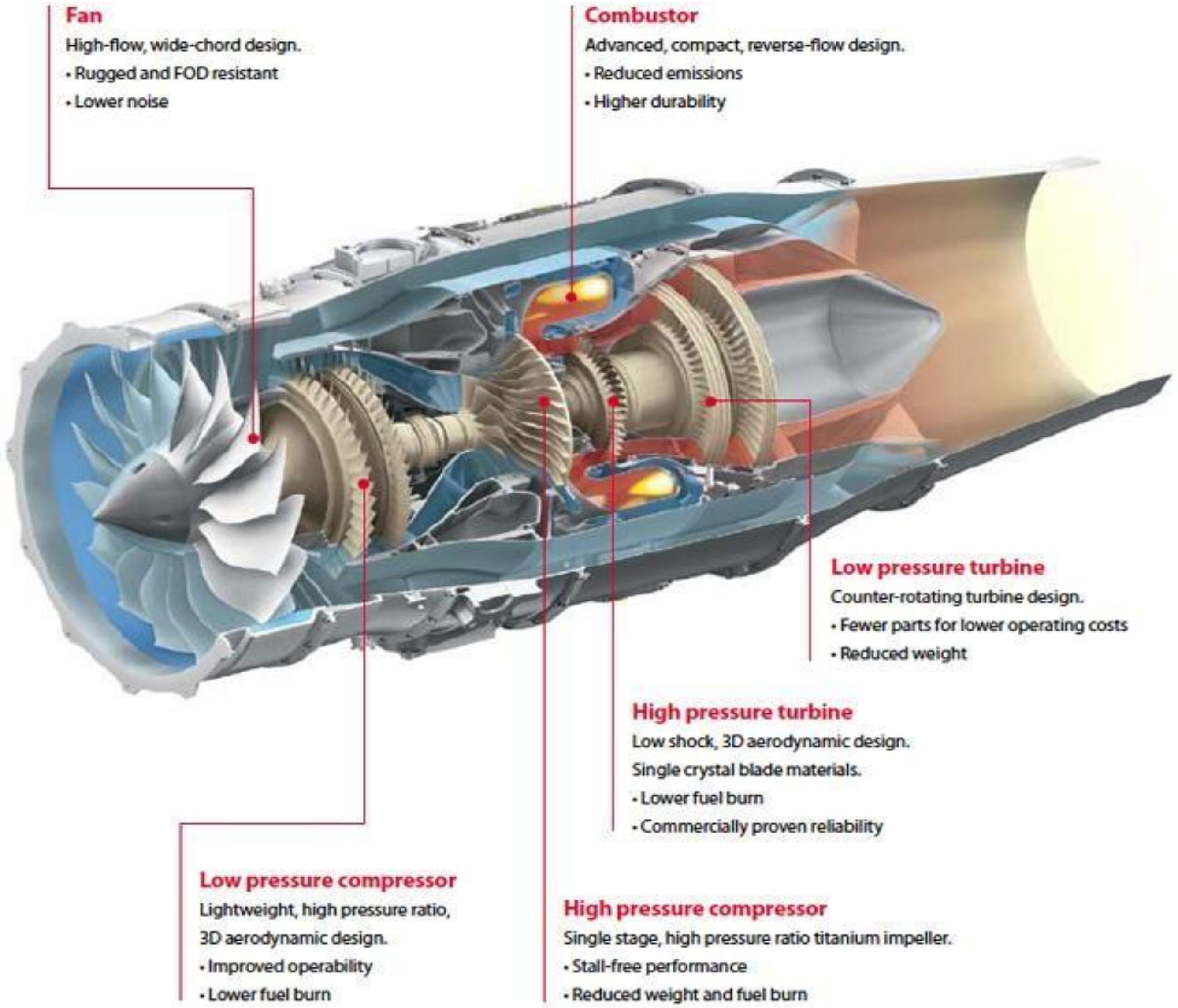

Figure 13 HF 120 Engine Details

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3.1ENGINEDISCRIPTION

The HF120 turbofan is the first engine to be produced by GE Honda Aero Engines. Developed from the Honda **HF118**, the HF120 is currently undergoing an extensive testing program, with formal certification testing scheduled to begin in late 2008.The engine has a wide-chord swept fan, two-stage low-pressure compressor and counter rotating high-pressure compressor based on a titanium impeller. Evolved from Honda's HF118, the engine demonstrates a 2,050 lbf takeoff thrust. The engine touts environmental performance, striving to meet and exceed future environmental standards for business jet engines. Greater fuel efficiency and reduced emissions are two of the results of the engine's lightweight design.

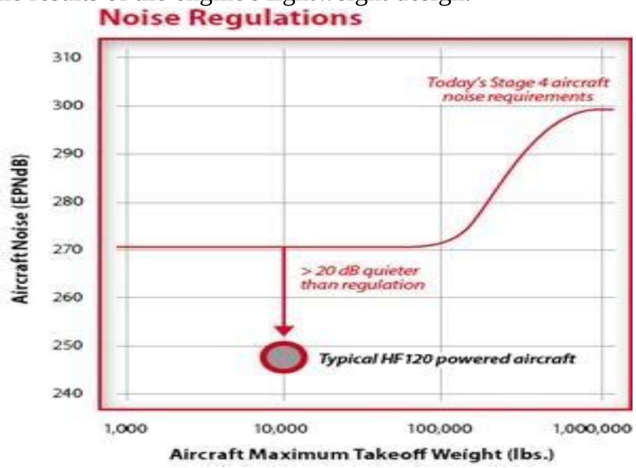

Figure 14 Noise Regulations Plot

The **HF120** technologies include:

Fan section: A 18.5-inch wide chord, compound-swept front fan and two-stage booster. The front fan and booster is GE Honda blisk designs with the latest 3D aerodynamics drawing from the same technology used to design GE's GEnx engines and Honda's Formula One experience for lower weight and efficiency. The outlet guide vanes are composite for weight reduction.

Compressor: Features a high temperature, titanium impellor developed by

Honda over the past 20 years designed to achieve maximum engine pressure ratio and stall-free performance.

Combustor: Based on the Honda HF118-design, it features, compact reverse- flow configuration, and single-stage air-blast fuel nozzles. The liner is made of Hastelloy material with laser-drilled, multi-hole cooling.

Turbine: For durability at high temperatures, powder metal disk and single-

crystal high-pressure (HP) turbine blade materials from the GEnx engine have been incorporated. The low-pressure turbine (LP) is a two-stage configuration. Also, a counter-rotating HP and LP system is being introduced to reduce weight.

3.2COMPONENT DISCRIPTION

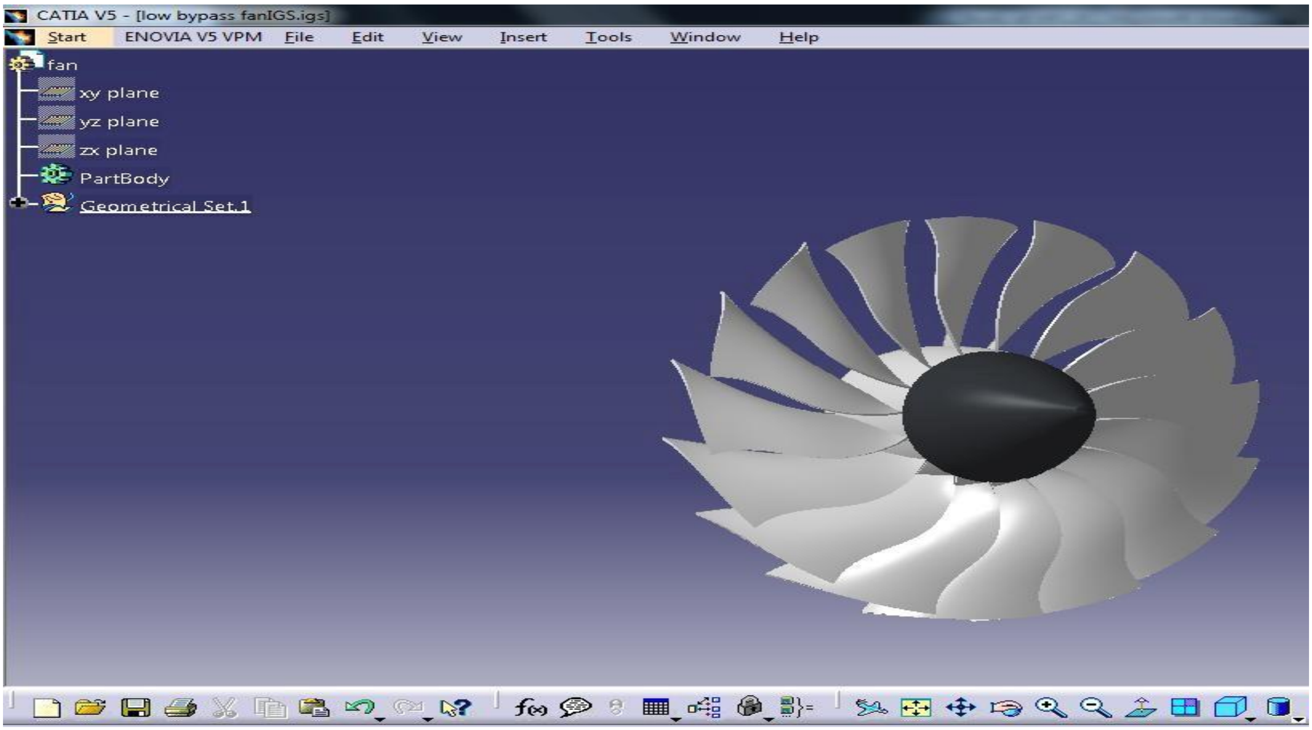

Figure 15 Wide Chord Fan Blade [Catia Model]

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3.2ENGINE SPECIFICATION

Type	Turbofan
Uninstalled Thrust	2095lbf
Thrust/weight [T/W] ratio	Greater than 5
Noise level	Stage 4 with margin
Time between overhaul [TBO]	5000hrs
Control	Dual channel FADEC
Specific fuel consumption [SFC] cruise (lb fuel/hr/lbf)	Less than 0.7
Dry weight	Less than 400 lbs (180 kg)
Length	44 inches (111.8cms)
Diameter	21.2 inches (53.8cm)
Pressure ratio [r]	24
Bypass ratio [B]	2.5

Table 2 Engine Specification

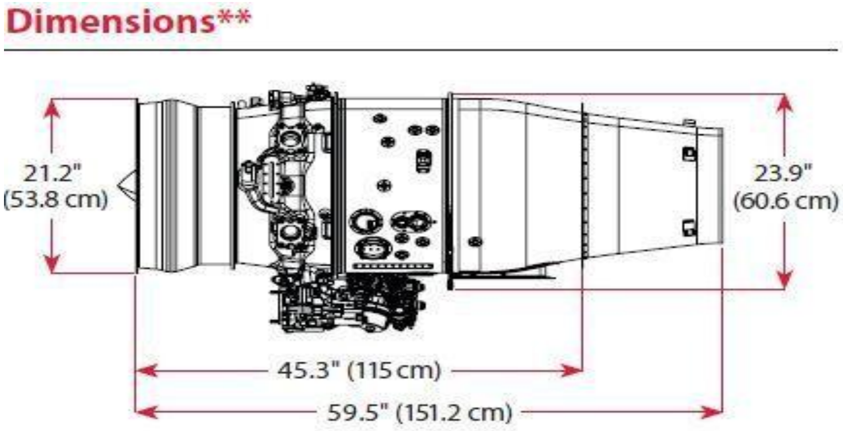

Figure 16 HF120 Engine Dimensions

3.3ENGINE TECHNOLOGY

❖ **DESIGN**

Integrating the technology and quality of GE and Honda, the HF120 turbofan from GE Honda Aero Engines has been developed with the future of business aviation in mind. A robust, simplified design delivers greater payload, longer range and outstanding durability. Greater fuel efficiency and reduced emissions are two of the results of the engine's lightweight design.

❖ **The next advancement in business jet power.**

Born from the combined experience and technological excellence of GE and Honda, the new HF120 turbofan from GE Honda Aero Engines sets the stage for advanced business jet power. From concept to reality, the HF120 was engineered with a determined and well-defined goal: anticipate and fulfill the future needs of business jets. Welcome to the new dawn of flight

❖ **Light and powerful. Simplified for greater efficiency.**

From spinner to exhaust nozzle, the HF120 integrates innovative, proven technologies in an elegant, simplified approach. By reducing weight and introducing state-of-the-art

3D aerodynamic design, components are designed to interact with greater efficiency while optimizing power. With features like high-flow, wide-chord fan blades and advanced materials, the HF120 is expected to deliver the highest thrust-to weight ratio in its class. And that will help improve payload, provide greater range and lower operating costs.

❖ **Entry into service is a rite of passage.**

Through a rigorous testing and maturation program, the HF120 will enter into service as one of the most tested power plants for business jets. With a target of over 10,000 total hours in testing, the HF120 is designed to demonstrate an extremely high level of durability.

❖ **More haul. Fewer overhauls.**

The HF120 is designed for sustained performance and productivity for both business jet and high utilization applications. For example, the high-pressure turbine features a low shock loss design composed of rugged, commercially proven materials for maximum combustor firing temperature. Weight is reduced, durability is enhanced, and, combined with high-efficiency compressors, fuel burn is lower and range is extended. In fact, the HF120 is expected to have the lowest specific fuel consumption in its class. In addition, the HF120 will require significantly less scheduled maintenance, with time between overhaul of 5,000 hours and no need to open the engine for interim hot-section

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inspections. Compared to the competition, the HF120 is expected to stay on-wing 40%
longer than typical business jet engines.

❖ **Performance & Durability**

High-flow, wide-chord fan blades, high-temperature materials and advanced compressor design features provide reduced fuel burn and increased durability. The engine's simple, robust design delivers best-in-class durability, enabling Time Between Overhaul (TBO) that is 40% longer than other comparable business jet engines.

❖ **Environment.**

By reducing weight and incorporating innovative 3D aerodynamic designs, the engine components are designed to interact with greater efficiency while optimizing operability. The HF120 uses a sophisticated combustor and fuel nozzles designed to reduce NOx, CO, HC and smoke emissions. The HF120 is designed to meet noise levels quieter than Stage 4.

❖ **Maturation**

The HF120 builds upon five generations of research and development and integrates commercially proven designs and materials. It enters service fully mature from over10,000 hours in testing.

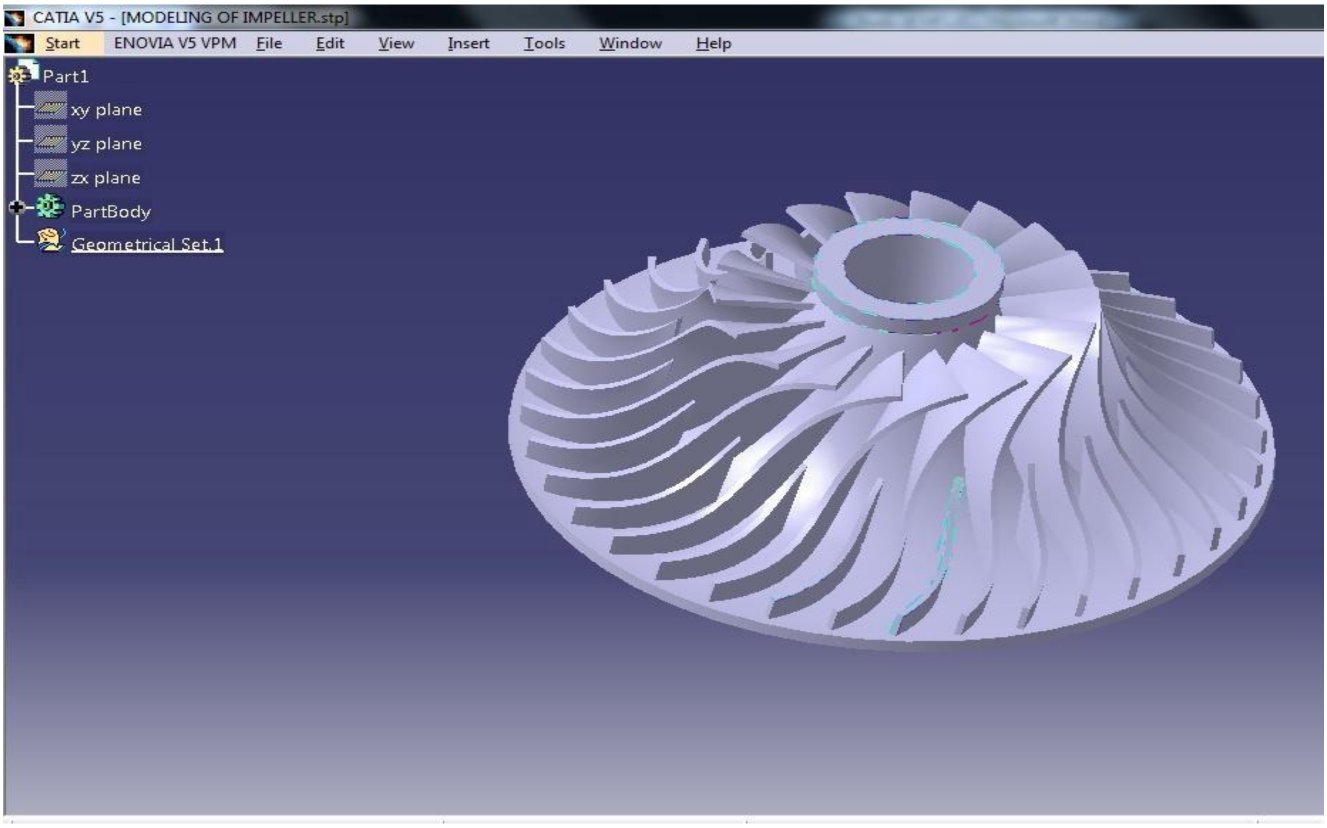

Figure 17 Titanium Impeller [Catia Model]

IV. GE HONDA AERO ENGINE [HF 118 VS HF 120]

4.1HF118 TURBOFAN ENGINE DISCRIPTION

The HF118 is a twin-spool turbofan, one-stage fan, two-stage compressor, two-stage turbine engine intended for the light business jet market. General Electric (GE) and Honda developed it in partnership. The HF118 reliable and durable turbofan propulsion system is targeted at small, less expensive business jets accommodating four to eight passengers such as the Honda Jet. Honda and GE forecast more than 200 of small business jets being sold each year. As of late 2006, the HF118 had accumulated more than 4,000 hours in ground tests and more than 450 hours in flight tests demonstrating the engine's reliability, long maintenance interval and fuel economy. In October 2006, GE Honda Aero Engines officially launched the HF120 as the successor to HF118 powering the production Honda Jet projected to enter service by 2010. Therefore, the HF118 was push into a developmental engine role for the Honda Jet prototype. The HF120's combustor is based on the HF118 design.

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Figure 18 HF-118 Engines

Several recent enhancements to the performance of the HF118 turbofan include:

- The cooperative design and testing effort in recent months on the HF118 engine has already resulted in an improvement in specific fuel consumption of approximately 4 percent and a weight reduction of approximately 8 percent.
- Honda's enhancements to its state-of-the-art high-pressure compressor (HPC) have increased airflow and improved efficiency. Improvements in the high pressure turbine (HPT) includes new blades using GE's advanced, single-crystal material and that were designed using 3-dimensional aerodynamic (3-D aero) design technology.
- The HPT durability and performance enhancements were validated in March during rig tests held at Honda's test facility in Japan. Further tests this summer at Honda will be run on an HF118 engine core. The HF118 is being designed to operate in service for an industry record-setting 5,000 hours before the first major overhaul with no interim hot-section inspection - a key cost-of-ownership feature.
- The HF118 fan is being enhanced with high-flow, wide-chord swept aerodynamic technology already service-proven on the GE90-115B, the world's most powerful engine, and on the GEnx engine currently being developed.
- In anticipation of future testing, an HF118 engine was successfully run this month at GE's outdoor test operation in Peebles, Ohio. Additional tests this year at both Honda and GE will further demonstrate engine performance and durability, as well as improvements in the compressor and turbine areas.

4.2 CURRENT STATUS OF HF 120 ENGINE

During Part 33 engine certification testing in February, the HF120 failed an "ice slab" test in which 0.25in-thick slabs of ice are injected into the engine at full power during ground tests at GE's Peebles, Ohio facility. The test simulates airframe ice breaking off and entering the engine. The 1,950lb take-off thrust (8.7kN) HF120, which features a one-piece titanium fan (also known as a blisk), experienced a "minor" power loss after the ingestion due to blade damage. The level of power loss apparently exceeded the test criteria of minimal or no-loss of power.

Engineers then redesigned the fan blade, increasing the thickness of the leading edge of the 16 fan blades on the blisk and changing the manufacturing process for the component. The redesigned fan has passed the ice slab test, but a series of other tests, such as blade-out demonstrations and a 150h endurance block test, must be rerun for the new design. GE Honda Aero engines will use seven engines with the enhanced fan design for the overall Part 33 engine certification programme, which it expects to complete in the second quarter of 2012, followed by US Federal Aviation Administration certification of the engine in the second half of 2012

4.3 ENGINE SPECIFICATION

- **HF 118 ENGINE**

Engine Type	Two-spool turbofan
Components	1F+1LPC+1HPC+1HPT+1LPT
Take-off thrust	757 kgf (1,670 lbf)
Cruise thrust	191 kgf (420 lbf)
Take-off SFC	0.49 kg/hr/kgf
Cruise SFC	0.75 kg/hr/kgf
Bypass ratio	2.9
Dry weight	178 kg (392 lb)
Fan diameter	441 mm (17.36 inch)
Total length	1,384 mm (54.5 inch)

Table 3 HF118 Engine Specification

- **HF 120 ENGINE**

Table 4 HF120 Engine Specification

Type	Turbofan
Uninstalled Thrust	2095lbf
Thrust/weight [T/W]	Greater than 5
Noise level	Stage 4 with margin
Time before overhaul	5000hrs
Control	Dual channel
Specific fuel cruise (lb fuel/hr/lbf)	Less than 0.7
Dry weight	Less than 400 lbs
Length	44 inches
Diameter	21.2 inches
Pressure ratio [r]	24
Bypass ratio [B]	2.5

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V. ADVANCE GAS TURBINE

5.1GAS TURBINE ENGINES FUTURE TRENDS

- There will be higher compressor airflows, pressure ratio and efficiencies with fewer compressor stages, fewer parts and lower cost. Variable pitch fan or compressor blades will provide reverse thrust for braking.
- Engines will be developed to have lower specific fuel consumption (SFC)

resulting from component design improvements and other changes.

- Increased turbine efficiencies with fewer stages to do the necessary work, less weight, lower cost, and decreased cooling requirements will be developed.
- Increased turbine temperatures using better materials and improved cooling along with new manufacturing techniques will be used.
- Less use of magnesium, aluminum, and iron alloys but more of nickel and cobalt- based alloys plus increased use of composite materials.
- Burning fuel more cleanly with less pollution, which will run more quietly. It will make this type of power plant less hostile to environment.
- More airborne and ground engine condition monitoring equipment will be used, such as vibration and oil analyzers, and radiometer sensors to measure turbine blade temperature while engine is operating.

5.2ADVANCED COMPOSITE MATERIALS

- Composite materials are widely used in the Aircraft Industry and have allowed engineers to overcome obstacles that have been met when using the materials individually. The constituent materials retain their identities in the composites and do not dissolve or otherwise merge completely into each other. Together, the materials create a 'hybrid' material that has improved structural properties.
- The development of light-weight, high-temperature resistant composite materials will allow the next generation of high-performance, economical aircraft designs to materialize. Usage of such materials will reduce fuel consumption,

improve efficiency and reduce direct operating costs of aircrafts.

- Composite materials can be formed into various shapes and, if desired, the fibers can be wound tightly to increase strength. A useful feature of composites is that they can be layered, with the fibers in each layer running in a different direction.

This allows an engineer to design structures with unique properties. For example, a structure can be designed so that it will bend in one direction, but not another.

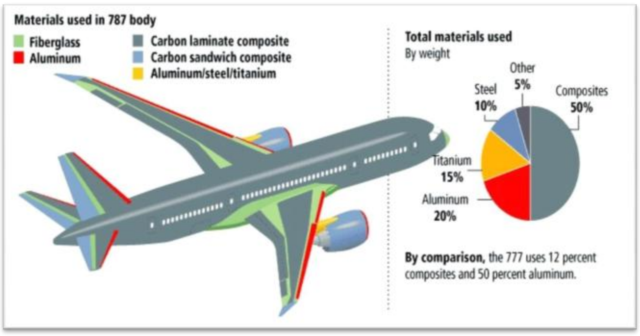

Figure 19 Composites on Aircraft

BENIFITS

- Light weight
- High strength-to-weight ratio
- Directional strength
- Corrosion resistance
- Weather resistance
- Dimensional stability
- low thermal conductivity
- low coefficient of thermal expansion
- Radar transparency
- Non-magnetic
- High impact strength
- High dielectric strength (insulator)
- Low maintenance
- Long term durability
- Part consolidation
- Small to large part geometry possible
- Tailored surface finish

5.2.1 ROLE OF COMPOSITE IN AIRCRAFT INDUSTRY

- A composite, in the present context, is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as a consequence of natural phenomena.
- In designing composite materials, scientists and engineers have ingeniously combined various metals, ceramics, and polymers to produce a new generation of extraordinary materials. Most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness, and ambient and high-temperature strength. Many composite materials are composed of just two phases; one is termed the matrix, which is continuous and surrounds the other phase, often called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phase." Dispersed phase geometry" in this context means the shape of the particles and the particle size, distribution, and orientation.

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- Weight reduction is the greatest advantage of composite material usage and is one of the key factors in decisions regarding its selection. Other advantages include its high corrosion resistance and its resistance to damage from fatigue.

These factors play a role in reducing operating costs of the aircraft in the long run, further improving its efficiency. Composites have the advantage that they can be formed into almost any shape using the molding process, but this compounds the already difficult modeling problem.

- A major disadvantage about use of composites is that they are a relatively new material, and as such have a high cost. The high cost is also attributed to the labor intensive and often complex fabrication process. Composites are hard to inspect for flaws, while some of them absorb moisture.
- Even though it is heavier, aluminum, by contrast, is easy to manufacture and repair. It can be dented or punctured and still hold together. Composites are not like this; if they are damaged, they require immediate repair, which is difficult and expensive.

5.2.2 MAJORLY USED COMPOSITES IN AIRCRAFTS

- Polymer Matrix Composites (PMCs)
- Titanium Based Metal Matrix Composites (MMCs)
- Ceramic Matrix Composites (CMCs)

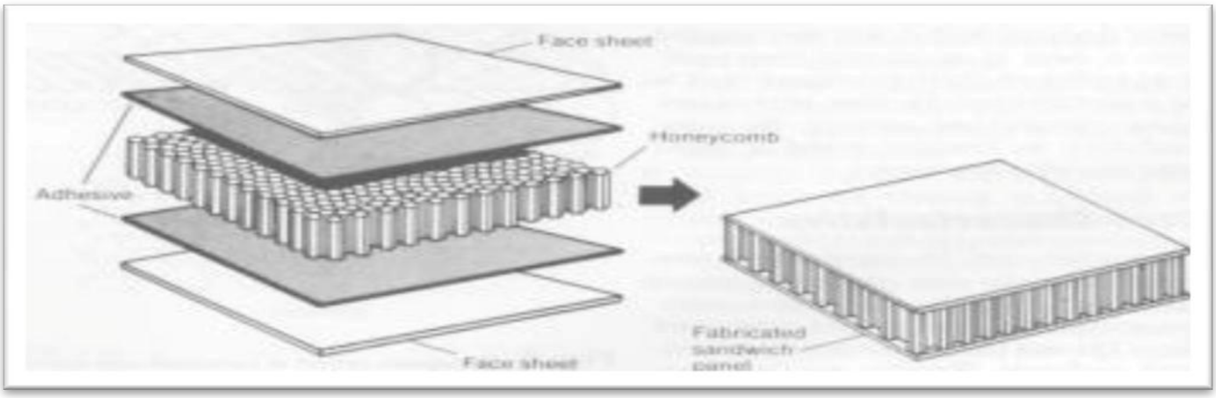

Figure 20 Sandwich Structure

5.3 WIDE FAN BLADES CONCEPT

- The fan draws air into the engine, compressing the bypass stream to produce 80 per cent of the engine's thrust, and feeding air to the gas turbine core. The hollow, titanium wide-chord fan blade, pioneered by Rolls-Royce and introduced into airline service in the 1980s, set new standards in aerodynamic efficiency and resistance to foreign object damage. Since that time it is continued to innovate and improve on our design of wide-chord fan blades. Designed specifically for high-bypass turbofans, the breadth of these blades sets them apart from the narrow and less efficient earlier equivalents. Rolls-Royce has designed and developed highly efficient lightweight titanium fans for civil engine applications in the thrust range 22000 lbs to over 100000 lbs.
- These wide chord fan designs are hollow and snubberless, and their fabrication has required the development of joining and forming technologies as well as a thorough understanding of material behavior. In the race to achieve better fuel economy, more thrust and less weight & noise from jet engines, designers have refined the blade design and materials to extract more thrust for any given fan disk area. One significant improvement is to make blade chords wider and, more recently, alter the blade geometry to give it a scimitar-like shape. Further refinements include making the blades from a light material such as titanium and to manufacture them with a hollow cross-section.

Figure 21 Wide Fan Blade

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5.3.1 Wide Chord Hollow Blade Characteristics

Rolls-Royce has designed wide-chord fan blades to be hollow in order to save weight. This employs a unique manufacturing process developed by the Group. First generation wide-chord fan blades, used on the RB211 and V2500 engine families, use a titanium honeycomb sandwich structure, where the honeycomb is diffusion bonded between two solid sheets. The next generation of fan blades, for the Trent range of engines, features an internal structure that is created during a process that diffusion bonds and super-plastically forms three sheets of titanium.

Hollow design allows significant weight savings to be made in the fan blade, especially at larger sizes, and a follow-on weight saving in the fan disc, structure and containment features. The Rolls-Royce wide chord fan blade is perhaps the best example of the application of titanium, coupled with advanced processing techniques, to give a significant service advantage. Modern blades are manufactured from three sheets of titanium representing the two outer skins and the internal corrugated structure. An inhibitor is applied, to define the internal structure, and then the three pieces are bonded in a high temperature pressure vessel. The blade is twisted and the cavity inflated at very high temperature using an inert gas in a shaped die to yield its final aerofoil shape. The total process results in bonds with properties equivalent to the parent material and an internal stiffening structure, which bears its share of the centrifugal load. Compared to the original solid clapper design this gives a fan module which is 24 per cent lighter, an overall engine weight benefit of 7 per cent, with a significant increase in foreign object damage (FOD) resistance over competitor designs.

5.4 AIRCRAFT NOISE

Aircraft noise is noise pollution produced by any aircraft or its components, during various phases of a flight: on the ground while parked such as auxiliary power units, while taxiing, on run-up from propeller and jet exhaust, during takeoff, underneath and lateral to departure and arrival paths, over-flying while en route, or during landing.

Small general aviation aircraft produce localized aircraft noise. Helicopter main and tail rotors produce aerodynamic noise. A moving aircraft including the jet engine or propeller causes compression and rarefaction of the air, producing motion of air molecules. This movement propagates through the air as pressure waves. If these pressure waves are strong enough and within the audible frequency spectrum, a sensation of hearing is produced. Different aircraft types have different noise levels and frequencies. The noise originates from three main sources:

- Aerodynamic noise
- Engine and other mechanical noise
- Noise from aircraft systems

5.4.1 Turbofan Engine Noise Generation

There are many sources of noise from current aircraft. Turbofan engines work on the principle of sucking air into the front of the nacelle duct and pushing that same air out the back at a higher velocity. This change in momentum provides the thrust. The diameter of the engine is determined by the fan, which pulls air into the duct. This fan is a source of noise, similar to the noise caused by a propeller. The fan blades, by pushing through the air, cause noise by themselves. Once past the fan, the air is split down two different paths, the fan duct and the core duct.

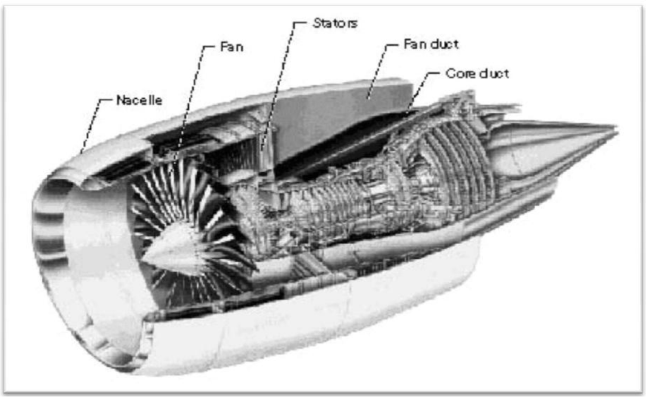

Figure 22 Turbofan Engine Noise

Consider first the flow in the fan duct. Downstream of the fan, the flow is swirling because of the spinning fan. This swirl causes loss of momentum before the air exits the nozzle so it is straightened out with a set of vanes called stators. These stators are a large source of noise as the wakes of air from fan flow slap against the stators like waves on a beach. This regular slapping takes place at the rate of blades passing by and generates a tone at what is called the blade passage frequency, or BPF. Non uniformities and nonlinearities result in many higher frequency tones being produced at 2 times BPF, 3 times BPF, and so on. Fan/ Stator interaction creates more than specific tones. The unsteadiness in the fan flow (often in the form of turbulence) interacts with the stators to create broadband noise. This is often heard as a rumbling sound.

In the core duct, the air taking this path is further compressed through a series of smaller fans called rotors. Each of these rotor stages is separated by a set of stators to straighten the flow. This is another source of rotor/stator interaction noise. The compressed air is then mixed with fuel and burned. This combustion is another source of noise. The hot, high-pressure combusted air is sent downstream into a turbine, which drives the fan and the compressor rotors. Since the turbine tends to look and acts like a set of stators, this is another source of noise. Finally, the core duct and the fan duct flows are exhausted into the air outside the back of the aircraft. The interaction of these jet exhausts with the surrounding air generates broadband noise called jet noise.

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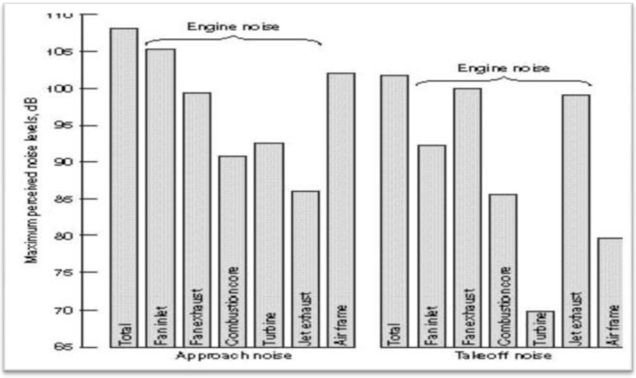

Figure 23 Engine Component Noise

5.4.2 Jet Exhaust Noise Reduction

Jet exhaust consists of the fan stream and the core/combustion stream. The core flow stream is typically at a higher speed than the fan stream. As the two flow streams mix with each other, noise is created in the surrounding air. Of particular difficulty, the jet exhaust noise is actually created after the exhaust leaves the engine. This means that jet noise cannot be reduced where it is created, but must be addressed before the exhaust leaves the engine. The theory of noise generation is being studied and computer codes that can simulate the theory are being developed. The final goal of this effort is to have a computer model for jet noise that will predict the source of the noise and how it is sent into the surrounding air. Theoretical understanding of jet noise is used to develop ideas for noise reduction concepts that are tested in model scale. Ideas that have already been tested or will be tested include mixer devices to combine the flows quickly, which reduce the noise generation area. Recently, test data have shown that a 3-dB reduction in jet noise can be achieved. The final goal is to demonstrate a 6-dB reduction

5.4.3 Fan Noise Reduction

In order to make progress on fan noise reduction, it is necessary to understand and be able to predict that noise. Therefore, as with jet exhaust noise, effort is being put into learning the theory of fan noise generation and developing computer codes that simulate that theory. The final goal of this effort is to have a computer code for fan noise prediction that can be verified. A second approach uses the theoretical understanding of fan noise to develop a succession of ideas for testing, with each test providing both data upon which the computer codes are verified and results upon which the next test might be built. Fortunately, the fan thrust provides many options to explore and there are many components to vary. Besides basic geometry, there are blade-wake tailoring, boundary-layer (a thin layer of air along the duct wall that moves slower than the rest of the flow) effects, fan speed, number of blades and stators, and many more. Recently, model test data showed that a 3-dB reduction in fan noise can be achieved. As with jet exhaust noise, the final goal is to demonstrate a 6-dB reduction.

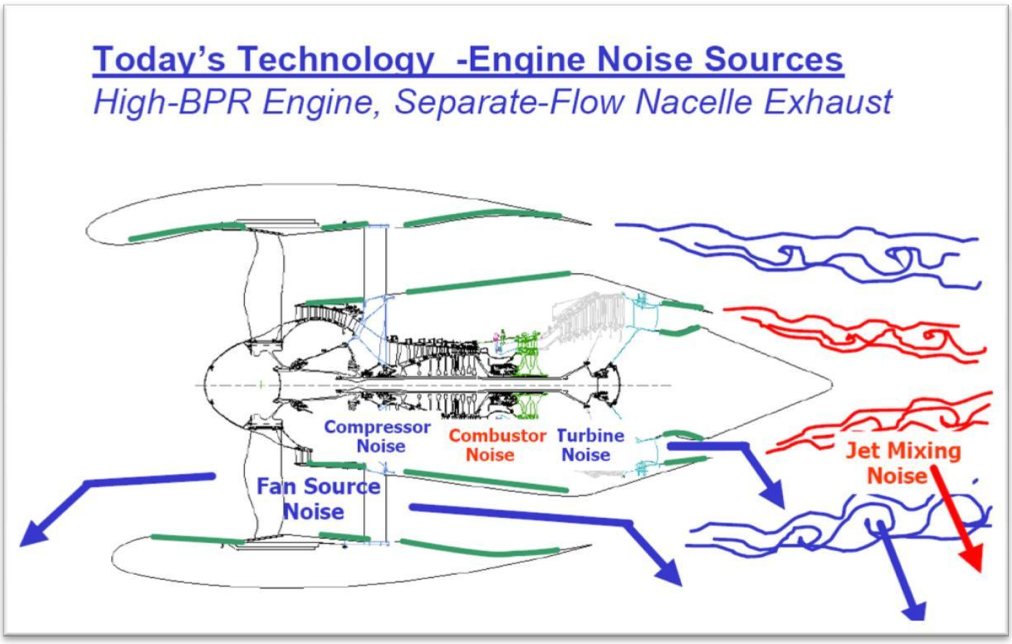

Figure 24 Engine Noise Source

VI. CONCLUSION

Several novel engine cycles and technologies currently under research were identified. It was shown that there is a great potential to reduce fuel consumption for the different concepts identified, and consequently decrease the CO2 emissions, Noise reduction. Furthermore, this can be achieved with a sufficient margin from the NO*x* certification limits, and in line with the medium term and long term goals set by FAA and other certification programs. It must be noted however that aero engine design is primarily driven by economic considerations. As fuel prices increase, the impact of fuel consumption on direct operating costs also increases. Joint Venture of multinational companies has led to rapid growth in field of aviation.

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With HF118 as power plant in business jets, it was difficult for pilots to attain cruise altitude because of low thrust [1670lbf] causing higher specific fuel consumption (SFC). So, there was a need a better advanced power plant that could resolve the problem. GE HONDA AERO ENGINES developed a new advanced engine that is HF120 twin spool turbofan engine for business jets. With increased thrust [2095lbf], lower SFC, noise reduction, better performance characteristics this engine will be further used in business jets. HF 120 has everything a power plant of business jet requires. HF 118 is no longer operational was pushed into a developmental engine role. HF 120 awaits certification as it failed blade out test. With few updates in HF120 engine, it will be operational by 2012.

Figure 25 HF 120 Turbofan Engin

REFRENCES

1. http://www.gehonda.com/products/hf120
2. http://en.wikipedia.org/wiki/GE_Honda_HF120
3. http://www.gehonda.com/products/hf120/pdf/hf120_datasheet.pdf
4. http://www.flysunairlines.com/hondajet-ha-420/hondajet-engine-ge-honda- hf120
5. http://www.stanford.edu/~cantwell/AA283_Course_Material/AA283_ Course_N
6. otes/Ch_05_Turbofan_Cycle.pdf
7. http://en.wikipedia.org/wiki/Geared_turbofan
8. http://www.sae.org/aeromag/techinnovations/1298t10.htm
9. http://www.volvoaero.com/volvoaero/global/en-gb/aboutus/Corporate%20values/Environmental%20care/vac_environment/gr een_engines/advancedturbofan/Pages/default.aspx
10. http://www.mtu.de/en/technologies/engineering_news/others/Riegler_ Geared
11. _turbofan_technology.pdf
12. http://en.wikipedia.org/wiki/Contra-rotating_propellers
13. J. B. Catlin, W. H. Day, and K. Goom, "The Pratt & Whitney Industrial Gas Turbine Product Line", Power Gen Conference, New Orleans, LA, December 1, 1999.
14. W. Layne, "Developing the Next Generation of Gas Turbine Power Systems – A
15. National Partnership", Dept. of Energy Workshop Next Generation Gas Turbine
16. Power Systems, Austin, TX Feb. 9-10, 1999.
17. S. Ashley, "Fuel-Saving Warship Drives", "Mechanical Engineering" magazine,
18. Report TR-102156, Research Project 3251-05, September 1993