

Development of HF120 Turbofan Engine

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ABSTRACT

General Electric Company and Honda have jointly developed the HF120 turbofan engine to be installed in the HondaJet. Both GE and Honda brought their leading technologies to the HF120 program and targeted top-class light weight, low fuel consumption, and low emissions as key design goals for the small turbofan engine. The HF120 improved specific fuel consumption by 3% and thrust-weight ratio by 17% compared with an earlier HF118 turbofan engine that Honda had developed independently. In addition, the HF120 complied with emissions regulations for larger turbofan engines that currently do not apply to small engines in its class. Notable features of the HF120 include wide chord swept fan, carbon composite fan stator vane, high-efficiency centrifugal compressor, effusion-cooled combustor, and air-blast fuel nozzle. The HF120, with these and other technologies, received a Type Certificate from the United States Federal Aviation Administration in December 2013.

1. Introduction

The HF120 turbofan engine (HF120) to be installed in the HondaJet (Fig. 1) was jointly developed with General Electric Company (GE), starting from 2006 and received a Type Certificate issued by the United States Federal Aviation Administration (FAA) in December 2013. This paper provides a brief overview of the HF120 featuring top-class technologies in a small turbofan engine. These include light weight, low fuel consumption and low emission.



Fig. 1 HondaJet

2. Development Goal

One basic goal for the GE Honda joint venture team was to upgrade the HF118 turbofan engine (HF118)^{(1), (2)} independently developed by Honda and to achieve top-class low fuel consumption and high thrust-weight ratio in

the engine class of comparable thrust. Although the small engine class to which the HF120 belongs is not subject to emissions regulations, one of the additional intentions was to conform to the regulations on NO_x, CO and THC applicable to engines with 6000 lbf or more of thrust (larger engine)⁽³⁾.

3. Engine Overview

Shown in Fig. 2 and Table 1 are the HF120's external appearance and major specifications, respectively^{(4), (5)}. This engine belongs to a thrust class intended for business jet aircraft such as the HondaJet with the capacity of 6 to 8 people and features a conventional dual-shaft turbofan engines.



Fig. 2 HF120 engine

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Table 1 HF120 engine specifications

Model	HF120
Takeoff thrust	2095 lbf
Length	59.5 inch
Width	25.8 inch
Height	30.5 inch
Weight	466 lbs
Low-pressure rotor speed	19055 rpm
High-pressure rotor speed	49200 rpm
Interstage turbine temperature	860°C

4. Engine Performance

4.1. Specific Fuel Consumption and Thrust-Weight Ratio

Shown in Figs. 3 and 4 are the trends of specific fuel consumption (SFC), and thrust-weight ratio with respect to engine takeoff thrust. Both SFC and thrust-weight ratio improve with increase in takeoff thrust.

Figure 5 shows the achieved fuel consumption and thrust-weight ratio for the HF120 in comparison to certain competing engines of 2500 lbf or less. The figure indicates respective improvement in fuel consumption and thrust-weight ratio by 3% and 17% compared to the HF118. The HF120 also secures a competitive edge over the reference competing engines.

4.2. Exhaust Emissions

Figure 6 shows the amount of emissions of the HF120, when the limit of each item in the regulation is considered to be at its allowed limit. The limit for each item is

calculated by engine thrust and cycle pressure ratio. Smoke is subject to emissions regulations for all turbofan engines, but there are no current regulations concerning NO_x, CO and THC for the small engine class including the HF120.

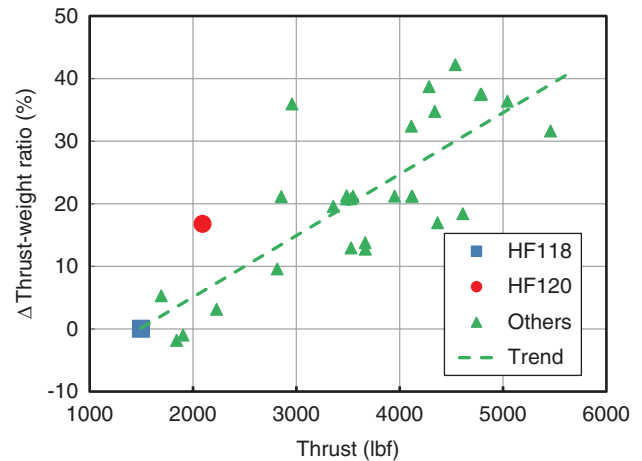


Fig. 4 Trend of thrust-weight ratio

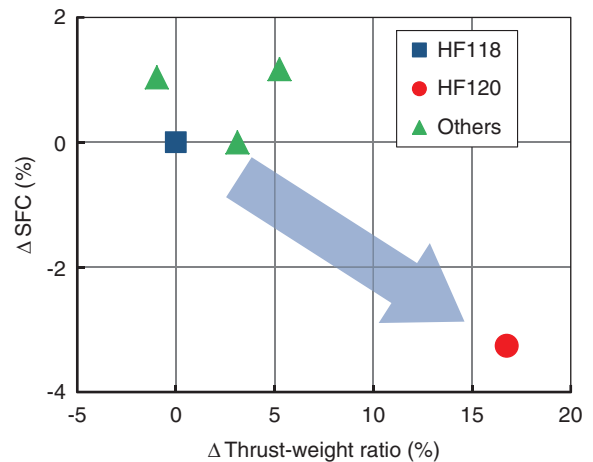


Fig. 5 Advantage of SFC and thrust-weight ratio

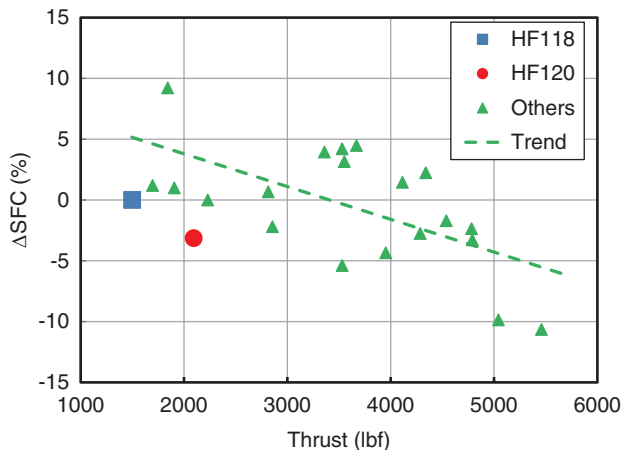


Fig. 3 Trend of SFC

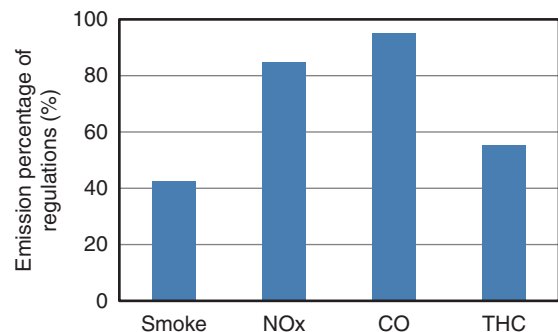


Fig. 6 Emission results

5. Engine Structure and Operating Principle

The HF120 engine's basic structure (Fig. 7) and the operating principle of many turbofan engines are illustrated below.

Air intake from the engine inlet is compressed by the fan and divided between the engine core and bypass duct.

Air taken into the engine core is compressed more by the low-pressure and high-pressure compressors and then sent to the combustor.

The high-pressure air is mixed with fuel sprayed from fuel nozzles within the combustor to generate high-temperature gas via steady combustion.

Energy is extracted from the high-temperature gas by the high-pressure and low-pressure turbines, and through a dual-structured rotating shaft, the high-pressure turbine drives the high-pressure compressor while the low-pressure turbine drives the low-pressure compressor and fan.

The air flowing through the bypass duct and the high-temperature gas after passing through the turbines are accelerated by the exhaust nozzle and emitted into aft area of the engine, which causes reactive force generating thrust.

For the HF120, a mixer blends the air and high-temperature gas upstream of the exhaust nozzle in an attempt to reduce exhaust noise and improve cruise fuel consumption.

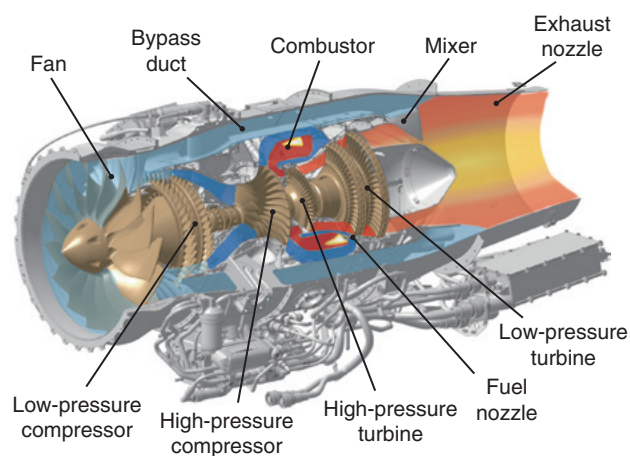


Fig. 7 HF120 engine features

6. Engine Characteristics

For overall component design, GE and Honda divided certain responsibilities. The high-pressure compressor, combustor and control system were assigned to Honda, while the low-pressure compressor, high-pressure turbine and mixer went to GE. The fan, low-pressure turbine and other components were jointly designed by GE and Honda. For example, Honda was mainly responsible for fan

aerodynamic design and GE was responsible for structural analysis for bird strike testing.

6.1. Fan

Shown in Fig. 8 are the fan's major components. A wide chord swept design was introduced into the fan rotor for enhanced aerodynamic performance, and the blades and disk were integrally machined from forged titanium material for light weight and strength. In addition for weight reduction, carbon composite material was incorporated in the fan stator vane with sheet metal bonded to its leading edge for stronger resistance to erosion.

6.2. Compressor

Shown in Fig. 9 are the compressor's major components. The low-pressure compressor adopted a two-stage axial-flow design to provide a better cycle pressure ratio and to downsize high-pressure components. The high-pressure compressor features a centrifugal rotor made from heat-resistant, high-strength titanium and a

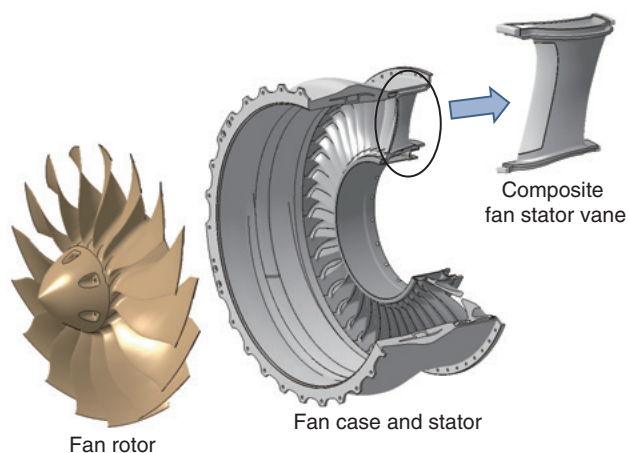


Fig. 8 Fan components

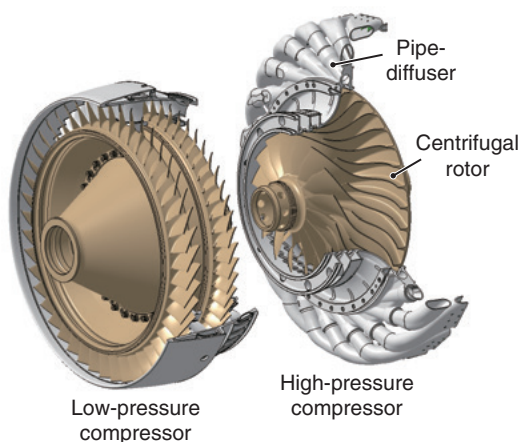


Fig. 9 Compressor components

pipe-diffuser structure that were highly streamlined by aerodynamic design using CFD in an attempt to improve fuel consumption.

6.3. Combustor

Shown in Fig. 10 are the major components of the combustor. A reverse annular layout was introduced in the combustor liner to reduce engine axial length. Effusion cooling by drilling a number of inclined narrow holes by laser beam (Fig. 11) was provided to cool the combustor liner wall and to simplify the structure. Typical fuel nozzles employ dual systems for the fuel lines in order to accommodate both the low flow rate and high flow rate regions. The HF120 utilizes a technology to consolidate them into a single system by using an air-blast fuel nozzle in an attempt to simplify and reduce weight. In addition, spray performance such as fuel atomization and flow pattern within the combustion chamber is adjusted accordingly to meet general emissions limits for larger engines.

6.4. Turbine

Shown in Fig. 12 are the turbine's major components. The high-pressure turbine featuring axial-flow and a single-stage uses a third-generation single-crystal alloy for the blade material to elevate permissible gas temperature at the turbine inlet in an attempt to reduce engine size and weight.

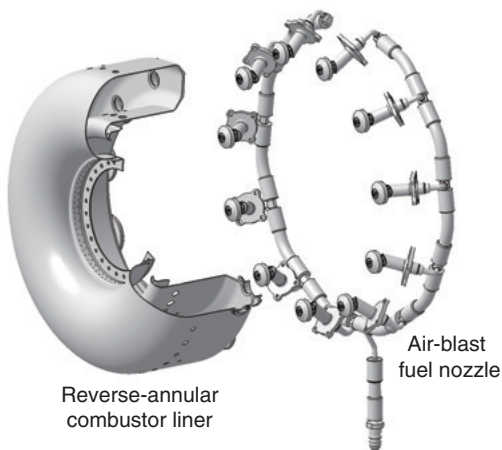


Fig. 10 Combustor components

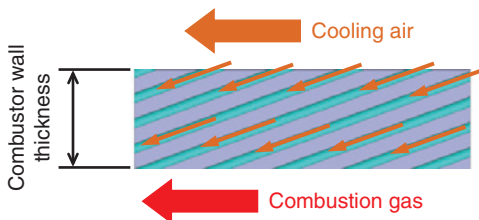


Fig. 11 Effusion cooling schematic

A low-pressure turbine (featuring a two-stage axial-flow layout) is designed to counter-rotate relative to the high-pressure turbine in an attempt to utilize swirl flow at the exit of high-pressure turbine and raise turbine efficiency.

6.5. Shaft System

Shown in Fig. 13 is the HF120's main-shaft cross-section. The low-pressure shaft's initial bending mode was set below idle speed and its secondary bending mode was set above redline to avoid any shaft resonance point within the engine's operating range. This setting was enabled by selecting a shaft structure that provides support for an overhung fan side. Shown in Fig. 14 is the Campbell diagram of the low-pressure shaft. Support of the high-pressure shaft turbine side was provided by a differential bearing that is held by the rotating low-pressure shaft, in an attempt to simplify bearing support of the structural members, the lubrication system, and the engine's design.

6.6. Control

A Full Authority Digital Engine Control (FADEC) regulates the engine by redundant digital electronic control

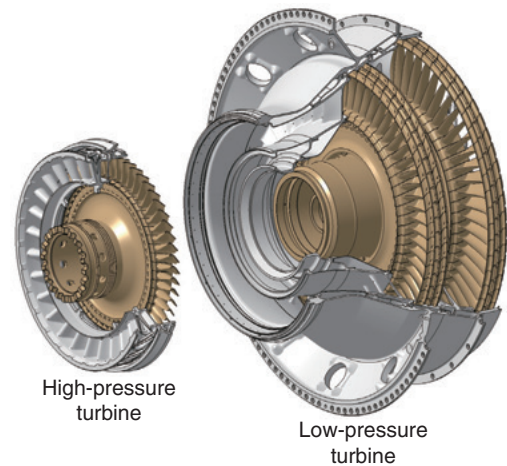


Fig. 12 Turbine components

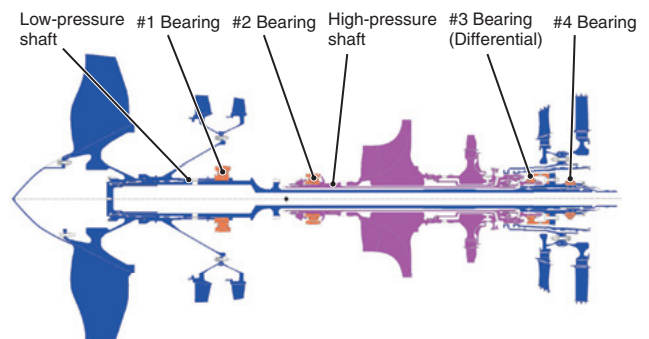


Fig. 13 Main-shaft cross-section

equipment. The major regulated items include fuel flow and bleed valve opening, providing thrust control to accommodate various flight conditions and pilot operations as well as adequate control to help prevent engine stall and lean blowout during acceleration and deceleration (Fig. 15).

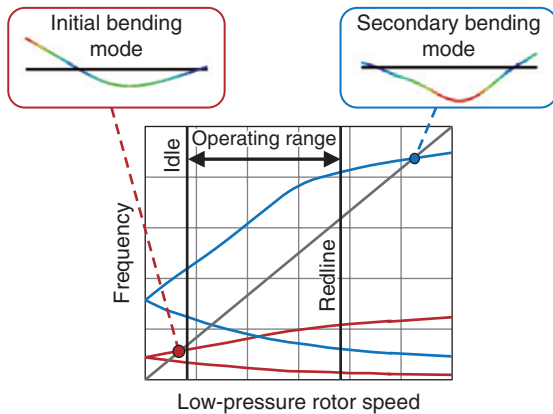


Fig. 14 Campbell diagram

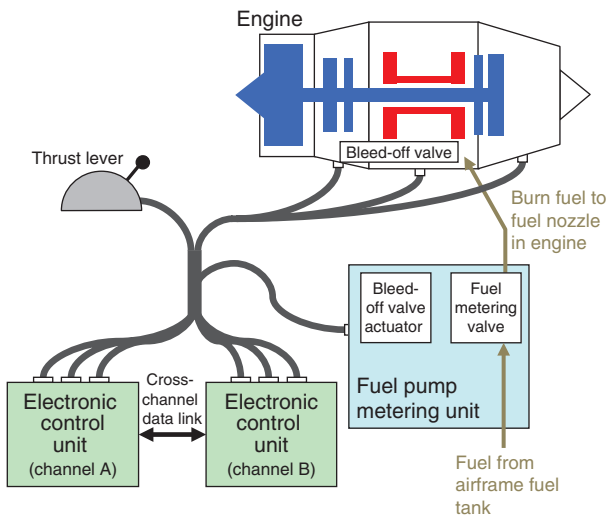


Fig. 15 FADEC system overview

7. Engine Type Certificate

Initial application for the HF120's FAA Type Certificate was made in February 2007 in parallel with developing the engine's detailed design, manufacturing all parts, and completing overall engine assembly. Ground testing for the first engine was initiated in October 2009, and flight testing and certification testing started in earnest in 2010. The engine certification process included various

types of tests, such as endurance, foreign object ingestion, and icing. For component testing, endurance, fire, environment and other tests were performed. Certification reports (totaling 190) were submitted to the FAA. The FAA Type Certificate was issued on December 13, 2013 (Fig. 16). The European Aviation Safety Agency (EASA) Type Certificate is expected to be received at the end of 2014.

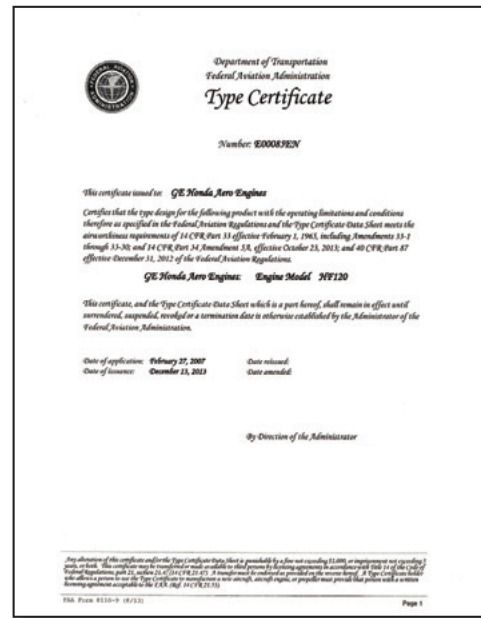


Fig. 16 FAA Type Certificate for HF120

8. Conclusion

Joint development with GE of the HF120 turbofan engine has been completed. The engine's FAA Type Certificate was issued in December 2013. Fuel consumption and thrust-weight ratio have been improved by 3% and 17%, respectively. For emissions, the HF120 satisfied the emissions regulations for NO_x, CO and THC that currently only cover larger turbine aircraft engines.

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