

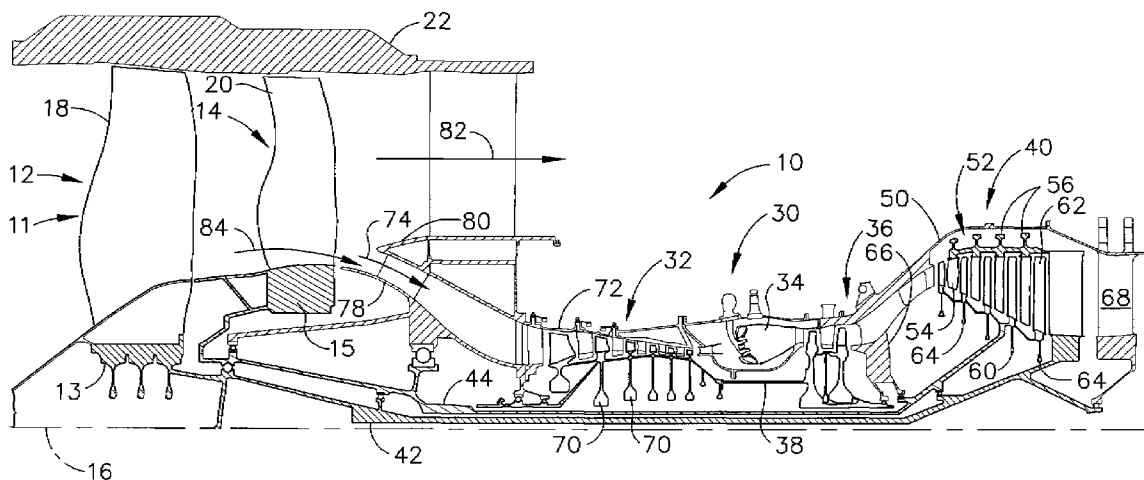


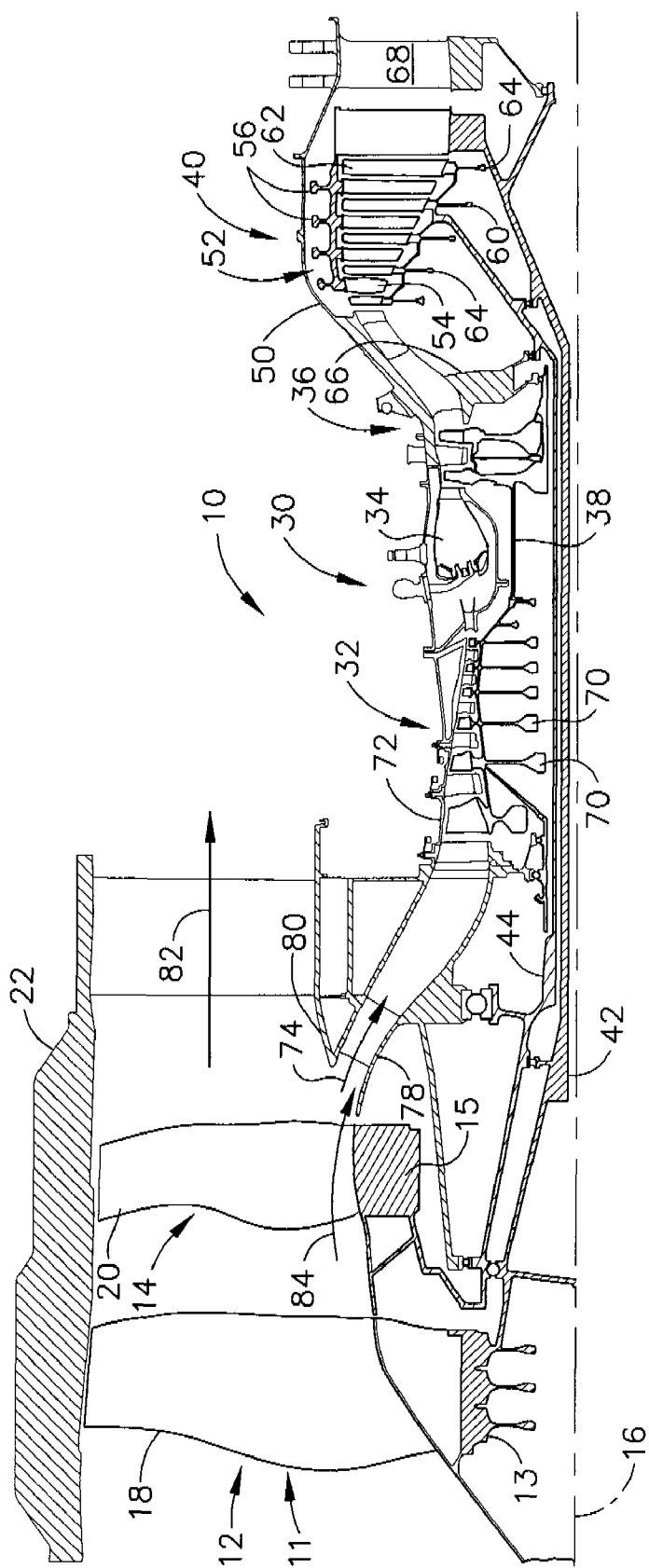
US 20070125066A1

(19) **United States**(12) **Patent Application Publication**
Orlando et al.(10) **Pub. No.: US 2007/0125066 A1**(43) **Pub. Date: Jun. 7, 2007**(54) **TURBOFAN ENGINE ASSEMBLY AND
METHOD OF ASSEMBLING SAME****Related U.S. Application Data**(63) Continuation-in-part of application No. 11/254,143,
filed on Oct. 19, 2005.(76) Inventors: **Robert Joseph Orlando**, West Chester,
OH (US); **Thomas Ory Moniz**,
Loveland, OH (US)**Publication Classification**(51) **Int. Cl.**
F02K 3/072 (2006.01)(52) **U.S. Cl.** **60/226.1; 60/268**(57) **ABSTRACT**

A method for assembling a gas turbine engine includes providing a core gas turbine engine including a high-pressure compressor, a combustor, and a turbine, coupling a counter-rotating fan assembly to the core gas turbine engine such that air discharged from the counter-rotating fan assembly is channeled directly into an inlet of the gas turbine engine compressor, and coupling a counter-rotating low-pressure turbine assembly to the counter-rotating fan assembly.

Correspondence Address:

JOHN S. BEULICK (12729)
C/O ARMSTRONG TEASDALE LLP
ONE METROPOLITAN SQUARE
SUITE 2600
ST. LOUIS, MO 63102-2740 (US)(21) Appl. No.: **11/469,187**(22) Filed: **Aug. 31, 2006**



TURBOFAN ENGINE ASSEMBLY AND METHOD OF ASSEMBLING SAME

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 11/254,143 filed Oct. 19, 2005.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to gas turbine engines, and more specifically to gas turbine engine assemblies and methods of assembling the same.

[0003] At least some known gas turbine engines include a forward fan, a core engine, and a power turbine. The core engine includes at least one compressor, a combustor, a high-pressure turbine and a low-pressure turbine coupled together in a serial flow relationship. More specifically, the compressor and high-pressure turbine are coupled through a shaft to define a high-pressure rotor assembly. Air entering the core engine is mixed with fuel and ignited to form a high energy gas stream. The high energy gas stream flows through the high-pressure turbine to rotatably drive the high-pressure turbine such that the shaft, in turn, rotatably drives the compressor.

[0004] The gas stream expands as it flows through the low-pressure turbine positioned forward of the high-pressure turbine. The low-pressure turbine includes a rotor assembly having a fan coupled to a drive shaft. The low-pressure turbine rotatably drives the fan through the drive shaft. To facilitate increasing engine efficiency, at least one known gas turbine engine includes a counter-rotating low-pressure turbine that is coupled to a counter-rotating fan and a booster compressor.

[0005] An outer rotating spool, a rotating frame, a mid-turbine frame, and two concentric shafts, are installed within the gas turbine engine to facilitate supporting the counter-rotating low-pressure turbine. The installation of the aforementioned components also enables a first fan assembly to be coupled to a first turbine and a second fan assembly to be coupled to a second turbine such that the first fan assembly and the second fan assembly each rotate in the same rotational direction as the first turbine and the second turbine, respectively. Accordingly, the overall weight, design complexity and/or manufacturing costs of such an engine are increased.

BRIEF DESCRIPTION OF THE INVENTION

[0006] In one aspect, a method of assembling a gas turbine engine is provided. The method includes providing a core gas turbine engine including a high-pressure compressor, a combustor, and a turbine, coupling a counter-rotating fan assembly to the core gas turbine engine such that air discharged from the counter-rotating fan assembly is channeled directly into an inlet of the gas turbine engine compressor, and coupling a counter-rotating low-pressure turbine assembly to the counter-rotating fan assembly.

[0007] In another aspect, a turbofan engine assembly is provided. The turbofan engine assembly includes a core gas turbine engine including a high-pressure compressor, a combustor, and a turbine, and a counter-rotating fan assembly coupled to the core gas turbine engine such that air

discharged from the counter-rotating fan assembly is channeled directly into an inlet of the gas turbine engine compressor, and a counter-rotating low-pressure turbine assembly coupled to the counter-rotating fan assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a cross-sectional view of a portion of an exemplary turbofan engine assembly.

DETAILED DESCRIPTION OF THE INVENTION

[0009] FIG. 1 is a cross-sectional view of a portion of an exemplary turbofan engine assembly 10 that includes a counter-rotating fan assembly 11 that includes a forward or upstream fan assembly 12 and an aft or downstream fan assembly 14 disposed about a longitudinal centerline axis 16. The terms “forward fan” and “aft fan” are used herein to indicate that fan assembly 12 is coupled axially upstream from fan assembly 14. In one embodiment, fan assemblies 12 and 14 are positioned at a forward end of turbofan engine assembly 10 as illustrated. In an alternative embodiment, fan assemblies 12 and 14 are positioned downstream from the core gas turbine engine. Fan assemblies 12 and 14 each include respective rotor disks 13 and 15 and a plurality of fan blades 18 and 20 that are coupled to each respective rotor disk. Fan assemblies 12 and 14 are each positioned within a nacelle 22.

[0010] Turbofan engine assembly 10 also includes a core gas turbine engine 30 that is coupled downstream from fan assemblies 12 and 14. Core gas turbine engine 30 includes a high-pressure compressor 32, a combustor 34, and a high-pressure turbine 36 that is coupled to high-pressure compressor 32 via a shaft 38. Core gas turbine engine 30 includes an outer casing 72 that defines an annular core engine inlet 74.

[0011] Turbofan engine assembly 10 also includes a counter-rotating low-pressure turbine 40. Low-pressure turbine 40 includes a stationary outer casing 50 that is coupled to core gas turbine engine 30 downstream from high-pressure turbine 36. Low-pressure turbine 40 also includes a radially outer rotor section 52 that is positioned radially inwardly of outer casing 50. Outer rotor section 52 has a generally frusto-conical shape and includes a plurality of circumferentially spaced rotor blades 54 that are coupled to, and extend radially inwardly from, a respective rotor disk 56. Although, the exemplary embodiment only illustrates four rotor disks 56, it should be realized that outer rotor 52 may have any quantity of rotor disks 56 without affecting the scope of the method and apparatus described herein.

[0012] Low-pressure turbine 40 also includes a radially inner rotor section 60 that is aligned substantially coaxially with respect to, and radially inward of, outer rotor section 52. Inner rotor 60 includes a plurality of circumferentially spaced rotor blades 62 that are coupled to, and extend radially outwardly from, a respective rotor disk 64. Although, the exemplary embodiment only illustrates five rotor disks 64, it should be realized that inner rotor 60 may have any quantity of rotor disks 64 without affecting the scope of the method and apparatus described herein. In the exemplary embodiment, inner rotor 60 is rotatably coupled to aft fan assembly 14 via shaft 44 and also to turbine midframe 66 which provides structural support for inner

rotor 60. Outer rotor 52 is rotatably coupled to a forward fan assembly 12 via shaft 42 and also to turbine rear-frame 68 which provides rotational support to outer rotor 52.

[0013] In the exemplary embodiment, inner rotor blades 62 extending from a respective rotor disk 64 are axially interdigitated with outer rotor blades 54 extending from a respective rotor disk 56 such that inner rotor blades 62 extend between respective outer rotor blades 54. The blades 54 and 62 are therefore configured for counter-rotation of the rotors 52 and 60. In one preferred embodiment, low-pressure turbine outer rotor 52 and forward fan assembly 12 are configured to rotate in a first rotational direction, and low-pressure turbine inner rotor 60 and aft fan assembly 14 are configured to rotate in a second opposite direction.

[0014] In operation, air flows through fan assemblies 12 and 14 supplying the high pressure compressor 32 wherein the airflow is further compressed and delivered to combustor 34. Fuel is added to the high pressure air in combustor 34 and ignited, expanding to drive high-pressure turbine 36, and low-pressure turbine 40 is utilized to drive fan assemblies 12 and 14 by way of shafts 42 and 44, respectively. Turbofan engine assembly 10 is operable at a range of operating conditions between design operating conditions and off-design operating conditions.

[0015] In the exemplary embodiment, the counter-rotating fan assembly 11 is sized to discharge a predetermined quantity of air based on the gas turbine engine compression ratio. More specifically, high-pressure compressor 32 includes a plurality of stages 70 wherein each stage further increases the pressure from the previous stage such that core gas turbine engine 30 has a compression ratio based on the quantity of stages 70 utilized within high-pressure compressor 32. Moreover, although a single core gas turbine is illustrated, it should be realized that the core gas turbine engine 30 may include a compressor having any quantity of compression stages, and thus a wide variety of compression ratios.

[0016] Accordingly, in one embodiment, core gas turbine engine 30 includes a plurality of compression stages 70 that are predetermined based on the quantity and/or pressure of the compressed air discharged from the counter-rotating fan assembly 11. For example, a core gas turbine engine having a first compression ratio may be coupled to a counter-rotating fan assembly 11 having a first compression ratio. If the compression ratio of counter-rotating fan assembly 11 is increased, the fan assembly 11 may be utilized with a core gas turbine engine 30 having a reduced compression ratio. Optionally, if the compression ratio of the counter-rotating fan assembly 11 is reduced, fan assembly 11 may be utilized with a core gas turbine engine 30 that includes an increased quantity of stages and thus has an increased compression ratio. In the exemplary embodiment, high-pressure compressor 32 includes at least six compression stages 70. Therefore, counter-rotating fan assembly 11 may be selectively sized to be coupled to a wide variety of core gas turbine engines. Optionally, a single core gas turbine engine compressor may be modified by either increasing or decreasing the quantity of compression stages, i.e. greater or lesser than six stages, to facilitate coupling the core gas turbine engine to counter-rotating fan assembly 11.

[0017] In the exemplary embodiment, turbofan engine assembly 10 includes a gooseneck 78 that extends between

and facilitates coupling counter-rotating fan assembly 11 to core gas turbine engine 30. Moreover, gooseneck 78 includes a structural strut and/or aero strut 80 to facilitate channeling air discharged from aft fan assembly 14, through gooseneck 78, to core gas turbine engine 30. As such, the configuration of gooseneck 78 and the structural strut facilitate substantially reducing and/or eliminating ice and/or foreign particle ingestion into core gas turbine engine 30 since core inlet gooseneck 78 substantially "hides" the core gas turbine engine inlet from the main air flowstream that is channeled axially past the exterior surface of gooseneck 78 in an aftward or downstream direction. More specifically, during operation, gooseneck 78 is configured or oriented to divide the airstream discharged from the counter-rotating fan assembly into a first airstream 82 and a second airstream 84 to facilitate preventing particles having a predetermined mass from flowing in a radially inward direction and being ingested into the core gas turbine engine 30. Specifically, gooseneck 78 is configured to channel particles having a heavier mass, such as ice particles, or possible foreign object damage (FOD) type material from being ingested into the core gas turbine engine. As such, since the core gas turbine engine is "hidden" from the airstream, gooseneck 78 channels the heavier particles around the core engine to facilitate preventing damage to the core gas turbine engine.

[0018] The turbofan engine assembly described herein includes a counter-rotating fan assembly that is coupled to a counter-rotating low-pressure turbine assembly. The turbofan engine assembly described herein facilitates reducing at least some of the complexities associated with known counter-rotating low-pressure turbines. More specifically, the turbofan engine assembly described herein includes a front fan assembly that is rotatably coupled to a radially outer rotor section of the low-pressure turbine, and an aft fan assembly that is rotatably coupled to a radially inner rotor section of the low-pressure turbine.

[0019] Additionally, the above-described gas turbine engine does not include a booster compressor. As a result, eliminating the booster compressor results in a simpler, lower cost, and lower weight engine than at least one known counter-rotating engine. More specifically, the booster can be eliminated because a high-pressure ratio core is used in conjunction with the increased core stream pressure ratio that can be obtained with the two counter rotating fans. The systems described herein facilitate optimizing the speed ratio between the two counter-rotating fans to increase performance. Moreover, since no booster stage count issues exists, the interaction loss between the high-pressure turbine (HPT) and the low-pressure turbine (LPT) is substantially eliminated thus resulting in approximately 0.8% increase in LPT efficiency, the two-stage HPT is approximately 3% more efficient than the known single stage HPT thus increasing overall pressure ratio for additional thermodynamic improvements. Additionally, no variable bleed valves (VBV) bleed doors are utilized, and ice and foreign particle ingestion is substantially eliminated because the booster-less engine will allow the core inlet gooseneck to be hidden.

[0020] Further, the two-stage HPT facilitates increasing the capability of power extraction off the HP spool. The LPT power requirements (Aero Dynamic Loading) are reduced by about 10% resulting in either an improvement in efficiency and/or reduced weight, a simpler thrust reverser design can be utilized, additional space under the core cowl

may be available to locate the accessory gearbox and larger multiple generators, a shorter fan case, and a simpler, lighter, thinner inlet fan duct.

[0021] Exemplary embodiments of a turbofan engine assembly and method of assembling the turbofan engine assembly are described above in detail. The assembly and method are not limited to the specific embodiments described herein, but rather, components of the assembly and/or steps of the method may be utilized independently and separately from other components and/or steps described herein. Further, the described assembly components and/or the method steps can also be defined in, or used in combination with, other assemblies and/or methods, and are not limited to practice with only the assembly and/or method as described herein.

[0022] While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A method of assembling a turbofan engine assembly comprises:

providing a core gas turbine engine including a high-pressure compressor, a combustor, and a turbine;

coupling a counter-rotating fan assembly to the core gas turbine engine such that air discharged from the counter-rotating fan assembly is channeled directly into an inlet of the gas turbine engine compressor; and

coupling a counter-rotating low-pressure turbine assembly to the counter-rotating fan assembly.

2. A method in accordance with claim 1 wherein coupling further comprises coupling a counter-rotating fan assembly to the core gas turbine engine such that compressed air is discharged from the counter-rotating fan assembly at a first operating pressure and received at the core gas turbine high-pressure compressor at approximately the first operational pressure.

3. A method in accordance with claim 1 wherein coupling further comprises coupling a counter-rotating fan assembly including a first fan assembly and a second fan assembly to the core gas turbine engine such that the first fan assembly rotates in a first direction and the second fan assembly rotates in an opposite second direction.

4. A method in accordance with claim 3 further comprising:

coupling a first shaft between the first fan assembly and a first turbine rotor that is configured to rotate in a first rotational direction; and

coupling a second shaft between the second fan assembly and a second turbine rotor that is configured to rotate in a second rotational direction that is opposite the first rotational direction.

5. A method in accordance with claim 1 wherein coupling further comprises coupling a counter-rotating fan assembly that discharges a predetermined quantity of air based on the gas turbine engine compression ratio to the core gas turbine engine.

6. A method in accordance with claim 1 wherein providing a core gas turbine engine comprises providing a core gas turbine engine that includes a predetermined quantity of

compressor stages based on the quantity of compressed air discharged from the counter-rotating fan assembly.

7. A method in accordance with claim 1 further comprising coupling a gooseneck between the counter-rotating fan assembly and the core gas turbine engine to facilitate channeling air discharged from the counter-rotating fan assembly to the core gas turbine engine.

8. A method in accordance with claim 7 further comprising orienting the gooseneck within the turbofan engine assembly to facilitate preventing particles having a predetermined mass from being channeled in a radially inward direction into the core gas turbine engine.

9. A turbofan engine assembly comprising:

a core gas turbine engine including a high-pressure compressor, a combustor, and a high-pressure turbine;

a counter-rotating fan assembly coupled to said core gas turbine engine such that air discharged from said counter-rotating fan assembly is channeled directly into an inlet of said gas turbine engine compressor; and

a counter-rotating low-pressure turbine assembly coupled to said counter-rotating fan assembly.

10. A turbofan engine assembly in accordance with claim 9 wherein said counter-rotating fan assembly is selectively sized to discharge compressed air at a first operating pressure, said core gas turbine engine is configured to receive the compressed air at approximately the first operational pressure.

11. A turbofan engine assembly in accordance with claim 9 wherein said counter-rotating fan assembly comprises a first fan assembly that rotates in a first direction and a second fan assembly that rotates in an opposite second direction.

12. A turbofan engine assembly in accordance with claim 9 wherein said core gas turbine engine comprises a predetermined quantity of compressor stages based on the compression ratio of said counter-rotating fan assembly and the overall compression ratio of the gas turbofan engine assembly.

13. A turbofan engine assembly in accordance with claim 11 further comprising:

a first shaft coupled between said first fan assembly and a first turbine rotor that is configured to rotate in a first rotational direction; and

a second shaft coupled between said second fan assembly and a second turbine rotor that is configured to rotate in a second rotational direction that is opposite the first rotational direction.

14. A turbofan engine assembly in accordance with claim 9 wherein said core gas turbine engine comprises a predetermined quantity of high-pressure turbine stages based on the compression ratio of said counter-rotating fan assembly and the overall compression ratio of the gas turbofan engine assembly.

15. A turbofan engine assembly in accordance with claim 9 further comprising a gooseneck coupled between the counter-rotating fan assembly and the core gas turbine engine to facilitate channeling air discharged from the counter-rotating fan assembly to the core gas turbine engine.

16. A turbofan engine assembly in accordance with claim 16 wherein said gooseneck is configured to prevent particles having a predetermined mass from being channeled in a radially inward direction into said core gas turbine engine.