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Gas turbine engine with front support arrangement

Abstract

A gas turbine engine includes a propulsor section including a propulsor having blades extending from a propulsor hub, and a propulsor shaft that drives the propulsor hub. A compressor section includes a first compressor having a rotatable compressor hub. A speed reduction device drives the compressor hub and the propulsor through a connection established axially forward of the epicyclic gear system relative to an engine longitudinal axis. The epicyclic gear system is straddled by forward and aft bearings that engage a carrier of the speed reduction device.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This disclosure is a continuation of U.S. application Ser. No. 18/107,671 filed Feb. 9, 2023, which is a continuation of U.S. application Ser. No. 17/218,369 filed Mar. 31, 2021, which is a continuation of U.S. application Ser. No. 16/203,088 filed Nov. 28, 2018, which is a continuation of U.S. application Ser. No. 14/633,244 filed on Feb. 27, 2015, now US Granted U.S. Pat. No. 10,280,843 issued May 7, 2019, which claims priority to U.S. Provisional Application No. 61/949,331, which was filed on Mar. 7, 2014 and is incorporated herein by reference.

BACKGROUND
(1) A gas turbine engine typically includes a fan section, a compressor section, a combustor section and a turbine section. Air entering the compressor section is compressed and delivered into the combustion section where it is mixed with fuel and ignited to generate a high-energy exhaust gas flow. The high-energy exhaust gas flow expands through the turbine section to drive the compressor and the fan section. The compressor section typically includes low and high pressure compressors, and the turbine section includes low and high pressure turbines.
(2) A speed reduction device such as an epicyclical gear assembly may be utilized to drive the fan section such that the fan section may rotate at a speed different than the turbine section so as to increase the overall propulsive efficiency of the engine. In such engine architectures, a shaft driven by one of the turbine sections provides an input to the epicyclical gear assembly that drives the fan section at a reduced speed such that both the turbine section and the fan section can rotate at closer to optimal speeds.

(3) The epicyclical gear assembly includes bearings that support rotation of gears. Loads incurred during operation can disrupt a desired relative alignment between gears and therefore the gear assembly may be supported on structures designed to accommodate such loads.
(4) Although geared architectures improve propulsive efficiency, they present different challenges that can reduce any efficiency gains. Accordingly, turbine engine manufacturers continue to seek further improvements to engine performance including improvements to thermal, transfer and propulsive efficiencies.

SUMMARY

(5) In one exemplary embodiment, a gas turbine engine includes a nacelle, and a bypass flow path in a bypass duct within the nacelle of the turbofan engine. A fan section includes a fan with fan blades. The fan section drives air along the bypass flow path. A fan shaft drives a fan that has fan blades and the fan rotates about a central longitudinal axis of the turbofan engine. A speed reduction device includes an epicyclic gear system. A turbine section is connected to the fan section through the speed reduction device and the turbine section rotates about the central longitudinal axis. A first fan bearing for supporting rotation of the fan hub is located axially forward of the speed reduction device. A second fan bearing for supporting rotation of the fan hub is located axially aft of the speed reduction device. A first outer race of the first fan bearing is fixed relative to the fan hub.
(6) In a further embodiment of any of the above, the second fan bearing includes an outer race. The outer race of the first fan bearing and the outer race of the second fan bearing are fixed relative to the fan hub and rotate with the fan hub in the same direction.
(7) In a further embodiment of any of the above, an inner race of the first fan bearing is fixed from rotation relative to an engine static structure. An inner race of the second fan bearing is fixed from rotation relative to the engine static structure.
(8) In a further embodiment of any of the above, the epicyclic gear system includes a sun gear, star gears, a ring gear mechanically attached to the fan section, and a carrier. The carrier is fixed from rotation relative to the engine static structure.
(9) In a further embodiment of any of the above, the first fan bearing and the second fan bearing include at least one of roller bearings, ball bearings, or tapered bearings. Each of the star gears include a star gear bearing.
(10) In a further embodiment of any of the above, the carrier includes multiple flexible posts for mounting each of the star gears and the star gear bearing.
(11) In a further embodiment of any of the above, the first fan bearing is at least partially axially aligned with a fan blade of the fan section.
(12) In a further embodiment of any of the above, a carrier is fixed from rotation relative to an engine static structure without a static flexible mount.
(13) In a further embodiment of any of the above, an inner race of the first fan bearing is fixed from rotation relative to a carrier. The carrier is fixed from rotation relative to an engine static structure.
(14) In a further embodiment of any of the above, a high pressure compressor with a compression ratio of at least 20:1 and a fan bypass ratio greater than 10.
(15) In a further embodiment of any of the above, a compressor section is configured to rotate with the fan section. The compressor section includes a five stage low pressure compressor with a compression ratio of at least 2:1.
(16) In a further embodiment of any of the above, a rotating compartment wall is configured to rotate with the compressor section and form a seal with an engine static structure.
(17) In a further embodiment of any of the above, the speed reduction device is located radially inward from a first compressor. The speed reduction device is axially aligned with the first compressor.
(18) In another exemplary embodiment, a fan drive gear module includes a sun gear and a multitude of intermediate gears surrounding the sun gear. A carrier supports the multitude of

intermediate gears. The carrier is configured to support a fan hub with a first fan bearing located on a first side of the carrier and a second fan bearing located on a second opposite side of the carrier. The carrier is configured to be fixed from rotation relative to an engine static structure without a static flexible mount. An outer race of the first fan bearing and an outer race of the second fan bearing are fixed relative to the fan hub and rotate with the fan hub in the same direction.
(19) In a further embodiment of any of the above, an inner race of the first fan bearing is fixed from rotation relative to a carrier. The carrier is fixed from rotation relative to the engine static structure.
(20) In a further embodiment of any of the above, each of the multitude of intermediate gears include an intermediate gear bearing. The carrier includes multiple flexible posts for mounting each of the multitude of intermediate gears and the intermediate gear bearing.
(21) In a further embodiment of any of the above, a ring gear is fixed relative to the fan hub and the first fan bearing and the second fan bearing include at least one of roller bearings, ball bearings, or tapered bearings.
(22) In another exemplary embodiment, a method of designing a gas turbine engine includes coupling a speed reduction device between a fan hub and a low pressure turbine drive shaft. A first fan bearing is positioned axially forward of the speed reduction device. An outer race of the first fan bearing is fixed relative to the fan hub and rotates with the fan hub relative to an engine static structure. A second fan bearing is positioned axially aft of the speed reduction device. An outer race of the second fan bearing is fixed relative to the fan hub and rotates in the same rotational direction as the outer race of the first fan bearing.
(23) In a further embodiment of any of the above, an inner race of the first fan bearing and an inner race of the second fan bearing is positioned fixed to a carrier and fixed from rotation relative to the engine static structure.
(24) In a further embodiment of any of the above, a ring gear of the speed reduction device relative to the fan hub is fixed to allow the ring gear to rotate with the fan hub. The first fan bearing and the second fan bearing include at least one of roller bearings, ball bearings, or tapered bearings.
(25) The various features and advantages of this disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a schematic view of an example gas turbine engine.
(2) FIG. **2** is a schematic view of an example geared architecture.
(3) FIG. **3** is a schematic view of another example geared architecture.
DETAILED DESCRIPTION
(4) FIG. **1** schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section **22** drives air along a bypass flow path B in a bypass duct defined within a nacelle **15**, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.
(5) The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static

structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.

(6) The low speed spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a first (or low) pressure compressor **44** and a first (or low) pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a second (or high) pressure compressor **52** and a second (or high) pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. A mid-turbine frame **57** of the engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The mid-turbine frame **57** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

(7) The core airflow is compressed by the low pressure compressor **44** with a compression ratio of at least 2:1 then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **57** includes airfoils **59** which are in the core airflow path C. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of combustor section **26** or even aft of turbine section **28**, and fan section **22** may be positioned forward or aft of the location of gear system **48**.

(8) The engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the engine **20** bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture **48** is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine **46** has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine **20** bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **44**, and the low pressure turbine **46** has a pressure ratio that is greater than about five 5:1. Low pressure turbine **46** pressure ratio is pressure measured prior to inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

(9) A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 ft (10,668 meters), with the engine at its best fuel consumption—also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC')"—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(Tram °R)/(518.7°R)].sup.0.5. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second (350.5 meters/second).

(10) FIG. **2** illustrates the inner shaft **40** driving the geared architecture **48** to turn the fan **42** and the low pressure compressor **44** together at the same rotational speed. The inner shaft **40** is connected with a sun gear **60** in the geared architecture **48**. The sun gear **60** is surrounded by star gears **62** mounted on star gear bearing assemblies **64** attached to a static carrier **66**. The static carrier **66** allows the star gears **62** to rotate around an axis of each star gear **62** but not around and engine axis A. The static carrier **66** is fixed relative to the engine static structure **36** on the gas turbine engine **20**.
(11) The geared architecture **48** is located radially inward and axially aligned with the low pressure compressor **44** to shorten the overall length of the gas turbine engine **20**.
(12) A fan hub **68** is supported by a forward fan bearing **70** and an aft fan bearing **72**. The forward fan bearing **70** includes an inner race **74** fixed to the static carrier **66** and an outer race **76** fixed to the fan hub **68**. The forward fan bearing **70** supports radial and thrust loads from a forward end of the fan hub **68**.
(13) The aft fan bearing **72** includes an inner race **78** attached to the static carrier **66**, which is connected with the engine static structure **36**, and an outer race **80** is attached to a rotating aft support **82**. The aft fan bearing **72** supports an aft end of the fan hub **68** and carries radial loads from the fan **42**.
(14) A rotatable ring gear **84** turns the fan hub **68** and the low pressure compressor **44** at the same rotational speed. A rotating compartment wall **86** extends from the rotating aft support **82** and is sealed against the engine static structure **36** with an oil seal **88**.
(15) Scavenged oil passes through holes **90** extending through the ring gear **84**, the rotating aft support **82**, and the engine static structure **36** to direct oil towards the forward and aft fan bearing **70** and **72** and the geared architecture **48**. A rotating cover **92** aids in retaining and directing the oil towards the forward fan bearing **70**, the aft fan bearing **72**, and the geared architecture **48** and to prevent the need for carbon seals.
(16) FIG. **3** illustrates another example geared architecture **148**. The geared architecture **148** is similar to the geared architecture **48** shown in FIG. **2** except where shown in FIG. **3** or described below.
(17) A static carrier **110** includes an oil baffle **100** extending from a forward end and a cylindrical support **102** for supporting the forward fan bearing **70**. An oil feed tube **106** supplies oil to the static carrier **110** and the rest of geared architecture **148**. A multitude of flexible shafts **112** extend from the static carrier **110** to support the star gears **62** and the respective star gear bearing assemblies **64**. The flexibility of the shafts **112** support torsional loads from the star gears **62** and star gear bearing assemblies **64** and allow the star gears **62** to be isolated from the engine static structure **36** such that a static flexible mount is not necessary to mount the geared architecture **148**.
(18) The forward fan bearing **70** in this example includes a roller bearing with the inner race **74** mounted to the cylindrical support **102** and the outer race **76** rotatably attached to the fan hub **68** through a hub support **104**. Although a roller bearing is illustrated in this example for the forward fan bearing **70**, a ball bearing or a tapered bearing could also be utilized.
(19) The aft fan bearing **72**, such as a ball bearing, is mounted on an aft side of the geared architecture **148** opposite from the forward bearing **70**. Although a ball bearing is illustrated in this example for the aft fan bearing **72**, a roller bearing or a tapered bearing could also be utilized.
(20) The forward fan bearing **70** and the aft fan bearing **72** straddle the geared architecture **148** to greatly reduce misalignment imparted on the geared architecture **148**. This eliminates the need for a flexible coupling on the geared architecture **148** to combat misalignment forces acting on the gears.
(21) An inner shaft bearing **114** attached to the engine static structure **36** supports a forward end of the inner shaft **40** and carries both radial and thrust loads. Since the fan **42** imparts a forward thrust load and low pressure turbine **46** imparts an aft thrust load on the inner shaft **40**, the opposing loads are generally cancelled out by the aft fan bearing **72** and the inner shaft bearing **114** both being attached to the engine static structure **36**.

(22) The gas turbine engine **20** is designed by attaching the geared architecture **48** or **148** device to the fan hub **68** and the inner shaft **40**. The forward fan bearing **70** is positioned forward of the geared architecture **48** or **148** with the first outer race **76** connected to the fan hub **68**. The aft fan bearing **72** is positioned aft of the geared architecture **48** or **148**. The inner race **74** and the inner race **78** are attached to the static carrier (**66** or **110**). The ring gear **85** from the geared architecture **48** or **148** is connected to the fan hub **68**.
(23) The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

Claims

1. A gas turbine engine comprising: a propulsor section including a propulsor having blades extending from a propulsor hub; a propulsor shaft that drives the propulsor hub, the propulsor rotatable about an engine longitudinal axis; a compressor section including a first compressor and a second compressor, the first compressor including a plurality of stages and a rotatable compressor hub, and the second compressor having a greater number of stages than the first compressor; a speed reduction device including an epicyclic gear system, wherein the epicyclic gear system includes a gear reduction ratio greater than 2.3, wherein the epicyclic gear system includes a sun gear, a plurality of intermediate gears, a carrier supporting the intermediate gears and the propulsor hub, and a ring gear, and wherein the speed reduction device drives the rotatable compressor hub and the propulsor through a connection established axially forward of the epicyclic gear system relative to the engine longitudinal axis; and a turbine section including a first turbine and a second turbine, wherein the second turbine drives the propulsor through the epicyclic gear system; wherein the epicyclic gear system is straddled by forward and aft bearings that engage the carrier.
2. The gas turbine engine as recited in claim 1, wherein: the second turbine includes a greater number of stages than the first turbine; and the first turbine drives the second compressor.
3. The gas turbine engine as recited in claim 2, wherein the second turbine includes an inlet, an outlet and a turbine pressure ratio of greater than 5:1, and the turbine pressure ratio is pressure measured prior to the inlet as related to pressure at the outlet prior to an exhaust nozzle.
4. The gas turbine engine as recited in claim 3, wherein: the first compressor includes three stages; and a portion of the rotatable compressor hub extends axially forward of the epicyclic gear system to the connection.
5. The gas turbine engine as recited in claim 4, wherein: the first compressor includes a compression ratio of at least 2:1; and the second compressor includes a compression ratio of at least 20:1.
6. The gas turbine engine as recited in claim 4, wherein the speed reduction device turns the propulsor and the first compressor at a common rotational speed.
7. The gas turbine engine as recited in claim 2, wherein: the carrier is fixed relative to an engine static structure; the ring gear establishes an output of the speed reduction device that drives the propulsor hub through the connection; and the forward and aft bearings support rotation of the propulsor hub.
8. The gas turbine engine as recited in claim 7, wherein: the carrier includes an oil baffle extending from a forward portion of the carrier; an oil feed tube is adapted to supply oil to the carrier, and the oil feed tube extends from the carrier to a position axially aft of the aft bearing relative to the engine longitudinal axis; and the aft bearing is radially aligned with the ring gear relative to the engine longitudinal axis, and the aft bearing is situated on an outer periphery of the carrier.
9. The gas turbine engine as recited in claim 7, wherein: the ring gear drives the propulsor hub and the first compressor through the connection; a shaft interconnects the second turbine and an input

of the sun gear; and the forward bearing is axially forward of the shaft relative to the engine longitudinal axis.

10. The gas turbine engine as recited in claim 7, wherein the speed reduction device turns the propulsor and the first compressor at a common rotational speed.

11. The gas turbine engine as recited in claim 7, wherein: the first compressor abuts the propulsor hub at an interface, and the connection is established at the interface; and the forward bearing is axially aligned with the propulsor hub relative to the engine longitudinal axis.

12. The gas turbine engine as recited in claim 7, wherein the ring gear includes a first ring gear portion and a second ring gear portion having respective radially extending flanges connected to the propulsor shaft.

13. The gas turbine engine as recited in claim 1, wherein the propulsor section is a fan section, the propulsor is a fan, and an outer housing surrounds the fan to define a bypass duct.

14. The gas turbine engine as recited in claim 13, wherein: the fan section delivers a portion of air into the compressor section, and a portion of air into the bypass duct, and a bypass ratio, which is defined as a volume of air passing to the bypass duct compared to a volume of air passing into the compressor section, is greater than 10 at cruise at 0.8 Mach and 35,000 feet; and the fan has a fan pressure ratio of less than 1.45 across the blades alone at cruise at 0.8 Mach and 35,000 feet.

15. The gas turbine engine as recited in claim 1, wherein: the turbine section includes a mid-turbine frame arranged between the first turbine and the second turbine with respect to the engine longitudinal axis, the mid-turbine frame supports a bearing, and the mid-turbine frame includes airfoils in a core airflow path.

16. A gas turbine engine comprising: a propulsor section including a propulsor having blades extending from a propulsor hub; a propulsor shaft that drives the propulsor, the propulsor rotatable about an engine longitudinal axis; a compressor section including a first compressor and a second compressor, wherein the first compressor includes a plurality of stages; a speed reduction device including an epicyclic gear system, wherein the epicyclic gear system includes a gear reduction ratio greater than 2.3, and wherein the epicyclic gear system includes a sun gear, a plurality of intermediate gears, a carrier supporting the intermediate gears and the propulsor hub, and a ring gear; and a turbine section including a first turbine and a second turbine, wherein the second turbine drives the propulsor through the epicyclic gear system; wherein the epicyclic gear system is straddled by forward and aft bearings that engage the carrier; wherein the speed reduction device turns the propulsor and the first compressor at a common rotational speed; wherein the propulsor section is a fan section, the propulsor is a fan, an outer housing surrounds the fan to define a bypass duct; and wherein the fan section delivers a portion of air into the compressor section, and a portion of air into the bypass duct, and a bypass ratio, which is defined as a volume of air passing to the bypass duct compared to a volume of air passing into the compressor section, is greater than 10 at cruise at 0.8 Mach and 35,000 feet.

17. The gas turbine engine as recited in claim 16, wherein: the first compressor includes three stages, and the second compressor includes a greater number of stages than the first compressor; the first compressor includes a compression ratio of at least 2:1; the second compressor includes a compression ratio of at least 20:1; and the second turbine includes a greater number of stages than the first turbine.

18. The gas turbine engine as recited in claim 16, wherein: the carrier is fixed relative to an engine static structure; the ring gear drives the propulsor hub through the propulsor shaft; and the forward and aft bearings support rotation of the propulsor hub.
