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(54) **GAS TURBINE ENGINE WITH HIGH LOW SPOOL POWER EXTRACTION RATIO**

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CPC ***F02C 3/06*** (2013.01); ***F02C 7/36*** (2013.01); *F05D 2220/32* (2013.01); *F05D 2260/4031* (2013.01)

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CPC F02C 3/06; F02C 7/36; F05D 2220/32; F05D 2260/4031; F05D 2260/40311
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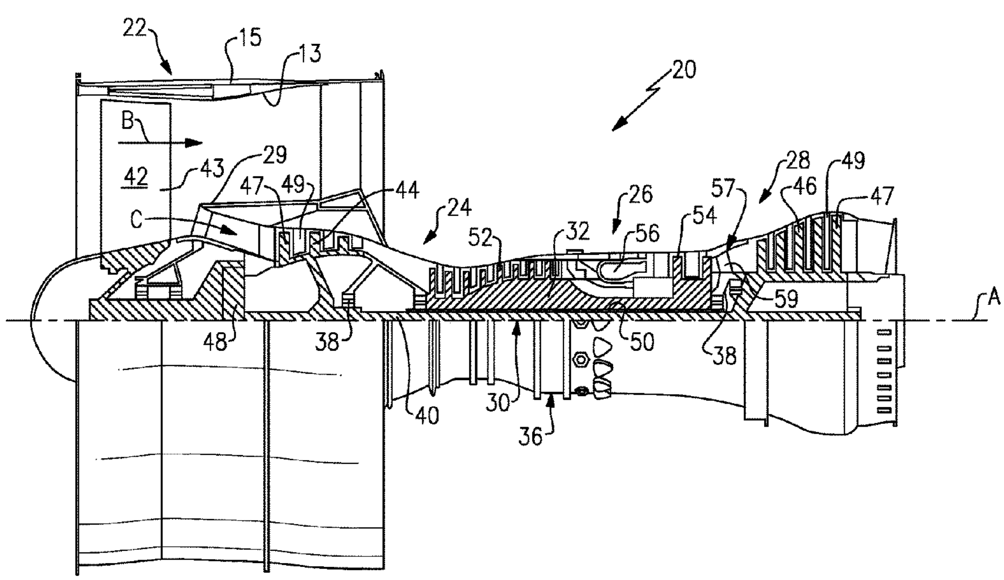
(57) **ABSTRACT**

A gear reduction drives a fan rotor at a speed slower than a fan drive turbine. The turbine section further includes a high pressure turbine driving a high pressure compressor. The fan drive turbine and low pressure compressor are connected by a shaft and the low pressure turbine. The shaft and the low pressure compressor define a low pressure spool, the low pressure spool has a torque at maximum takeoff defined in ft-lbs and also having a low pressure spool power defined in horsepower and at maximum takeoff, and a ratio of the low pressure spool torque to the low pressure spool power being defined, with the low pressure spool power being defined in horsepower, and the ratio of the low pressure spool torque to the low pressure spool power being greater than or equal to 0.6 ft-lb/hp and less than or equal to 1.2 ft-lb/hp.

2 Claims, 1 Drawing Sheet



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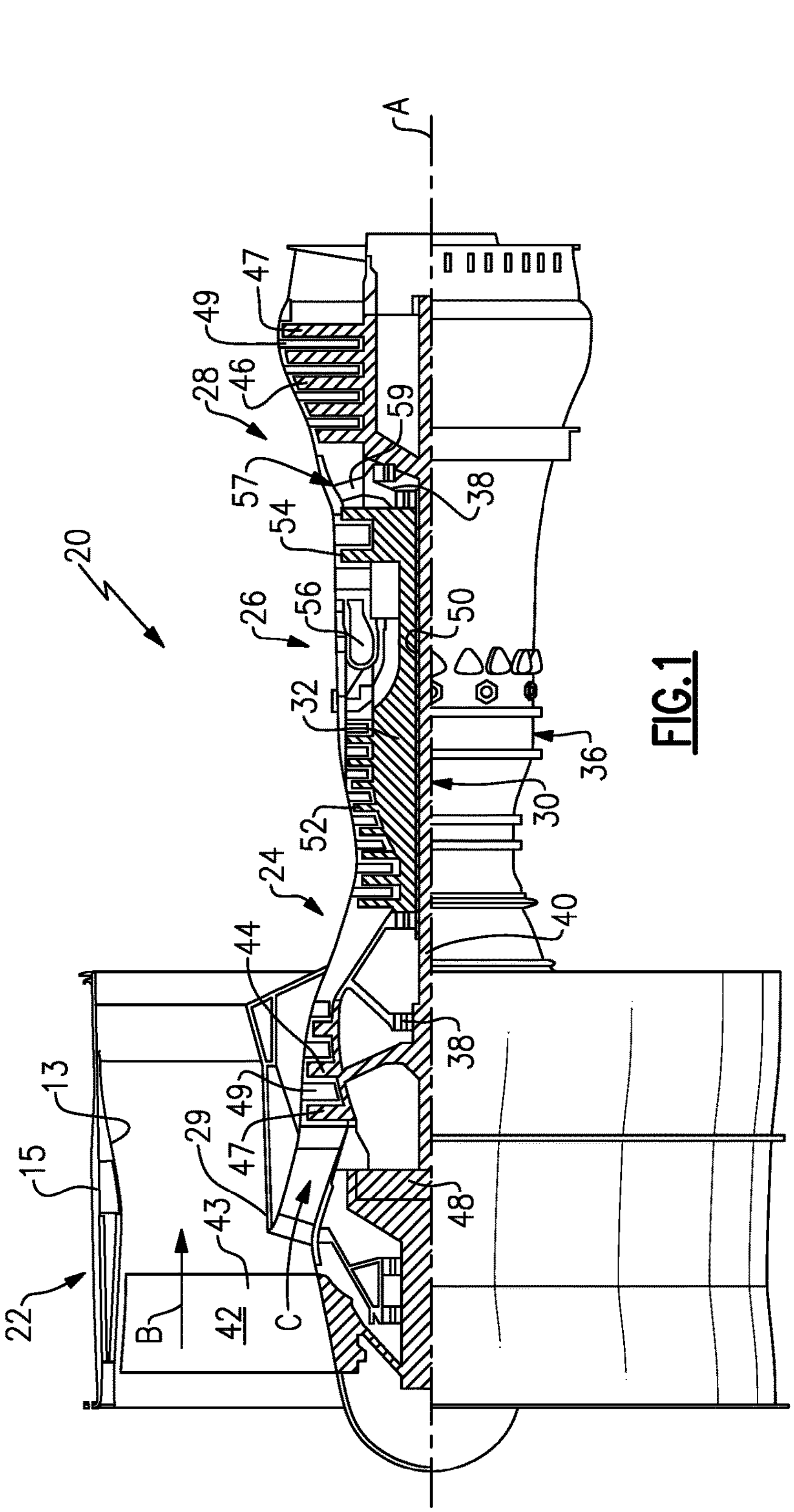
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FIG.1

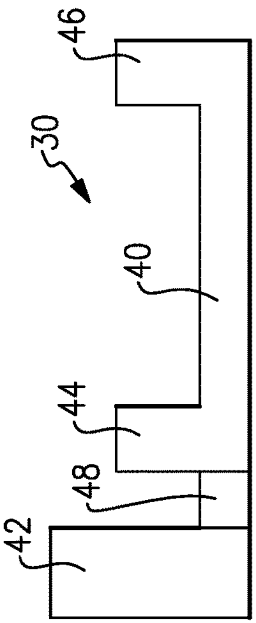
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FIG.2

GAS TURBINE ENGINE WITH HIGH LOW SPOOL POWER EXTRACTION RATIO

BACKGROUND

This application relates to a gas turbine engine with a gear reduction between a low pressure compressor and a fan, and where a ratio of low spool torque to low spool power is higher than has been the case in gas turbine engines with a gear reduction.

Gas turbine engines are known, and typically include a fan delivering air into a bypass duct as bypass air. The air is also delivered into a compressor. The compressed air is delivered into a combustor where it is mixed with fuel and ignited. Products of this combustion pass downstream over turbine rotors, driving them to rotate.

The turbine rotors drive the fan and compressor. Typically, there are two turbine rotors and two compressors. A lower pressure turbine rotor drives a lower pressure compressor. Historically the low pressure compressor was fixed to a fan shaft to drive the shaft. However, more recently a gear reduction has been placed between the low pressure compressor and the fan.

SUMMARY

In a featured embodiment, a gas turbine engine includes a fan rotor surrounded by a fan case and delivering air into a bypass duct defined between the fan and an inner core housing. The fan rotor also delivers air into the inner core housing and into a compressor section. The compressor section includes a low pressure compressor and a high pressure compressor. The high pressure compressor delivers air into a combustor where it is mixed with fuel and ignited, and products of the combustion pass downstream into a turbine section. The turbine section includes a fan drive turbine driving the low pressure compressor, and driving a gear reduction to in turn drive the fan rotor at a speed slower than the fan drive turbine. The turbine section further includes a high pressure turbine driving the high pressure compressor. The fan drive turbine and low pressure compressor are connected by a shaft and the fan drive turbine. The shaft and the low pressure compressor define a low pressure spool. The low pressure spool has a torque at maximum takeoff defined in ft-lbs and also having a low pressure spool power defined in horsepower and at maximum takeoff, and a ratio of the low pressure spool torque to the low pressure spool power being defined, with the low pressure spool power being defined in horsepower, and the ratio of the low pressure spool torque to the low pressure spool power being greater than or equal to 0.6 ft-lb/hp and less than or equal to 1.2 ft-lb/hp.

In another embodiment according to the previous embodiment, a gear ratio of the gear reduction is greater than or equal to 3.2 and less than or equal to 4.0.

In another embodiment according to any of the previous embodiments, the gear ratio of the gear ratio is greater than or equal to 3.4.

In another embodiment according to any of the previous embodiments, the power extraction ratio is greater than or equal to 0.70 ft-lb/hp.

In another embodiment according to any of the previous embodiments, the power extraction ratio is less than or equal to 1.0 ft-lb/hp.

In another embodiment according to any of the previous embodiments, the power extraction ratio is greater than or equal to 0.70 ft-lb/hp.

In another embodiment according to any of the previous embodiments, a pressure ratio at cruise condition can be defined across the fan rotor and the low pressure compressor. The pressure ratio is greater than or equal to 3.5 and less than or equal to 6.0.

In another embodiment according to any of the previous embodiments, the pressure ratio is greater than or equal to 4.0.

In another embodiment according to any of the previous embodiments, a pressure ratio at cruise condition can be defined across the fan rotor and the low pressure compressor. The pressure ratio is greater than or equal to 3.5 and less than or equal to 6.0.

In another embodiment according to any of the previous embodiments, the pressure ratio is greater than or equal to 4.0.

A gas turbine engine includes a fan rotor surrounded by a fan case and delivering air into a bypass duct defined between the fan and an inner core housing. The fan rotor also delivers air into the inner core housing and into a compressor section. The compressor section includes a low pressure compressor and a high pressure compressor. The high pressure compressor delivers air into a combustor where it is mixed with fuel and ignited, and products of the combustion passing downstream into a turbine section. The turbine section includes a fan drive turbine driving the low pressure compressor, and driving a gear reduction to in turn drive the fan rotor at a speed slower than the fan drive turbine. The turbine section further includes a high pressure turbine driving the high pressure compressor. The fan drive turbine and low pressure compressor are connected by a shaft and the fan drive turbine. The low pressure shaft and the low pressure compressor define a low pressure spool. The low pressure spool has a torque at maximum takeoff defined in ft-lbs and also has a low pressure spool power, and a ratio of the low pressure spool torque to the low pressure spool power being defined, with the low pressure spool power being defined in horsepower, and the ratio of the low pressure spool torque to the low pressure spool power being greater than or equal to 0.5 ft-lb/hp and less than or equal to 1.2 ft-lb/hp. A pressure ratio at cruise condition is defined across the fan and the low pressure compressor. The pressure ratio is greater than or equal to 3.5 and less than or equal to 6.0.

In another embodiment according to any of the previous embodiments, a gear ratio of the gear reduction is greater than or equal to 3.2 and less than or equal to 4.0.

In another embodiment according to any of the previous embodiments, the gear ratio of the gear ratio is greater than or equal to 3.4.

In another embodiment according to any of the previous embodiments, the power extraction ratio is greater than or equal to 0.70 ft-lb/hp.

In another embodiment according to any of the previous embodiments, power extraction ratio is less than or equal to 1.0 ft-lb/hp.

In another embodiment according to any of the previous embodiments, the power extraction ratio is greater than or equal to 0.90 ft-lb/hp.

In another embodiment according to any of the previous embodiments, the pressure ratio is greater than or equal to 4.0.

In another embodiment according to any of the previous embodiments, the pressure ratio is greater than or equal to 4.0.

In another embodiment according to any of the previous embodiments, the power extraction ratio is greater than or equal to 0.70 ft-lb/hp.

In another embodiment according to any of the previous embodiments, the power extraction ratio is greater than or equal to 0.90 ft-lb/hp.

The present disclosure may include any one or more of the individual features disclosed above and/or below alone or in any combination thereof.

These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a gas turbine engine according to this disclosure.

FIG. **2** schematically shows a low spool.

DETAILED DESCRIPTION

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**. The fan section **22** may include a single-stage fan **42** having a plurality of fan blades **43**. The fan blades **43** may have a fixed stagger angle or may have a variable pitch to direct incoming airflow from an engine inlet. The fan **42** drives air along a bypass flow path B in a bypass duct **13** defined within a housing **15** such as a fan case or nacelle, and also drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. A splitter **29** aft of the fan **42** divides the air between the bypass flow path B and the core flow path C. The housing **15** may surround the fan **42** to establish an outer diameter of the bypass duct **13**. The splitter **29** may establish an inner diameter of the bypass duct **13**. 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. The engine **20** may incorporate a variable area nozzle for varying an exit area of the bypass flow path B and/or a thrust reverser for generating reverse thrust.

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.

The low speed spool **30** generally includes an inner shaft **40** that interconnects, 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 the 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 inner shaft **40** may interconnect the low pressure compressor **44** and low pressure turbine **46** such that the low pressure compressor **44** and low pressure turbine **46** are rotatable at a common speed and in a common direction. In other embodiments, the low pressure turbine **46** drives both the fan **42** and low pressure compressor **44** through the geared architecture **48** such that the fan **42** and low pressure compressor **44** are rotatable at a common speed. Although this application discloses geared architecture **48**, its teaching may benefit direct drive engines having no geared architecture. 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 the 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** may be 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.

Airflow in the core flow path C is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded through the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **57** includes airfoils **59** which are in the core flow 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 the low pressure compressor, or aft of the combustor section **26** or even aft of turbine section **28**, and fan **42** may be positioned forward or aft of the location of gear system **48**.

The fan **42** may have at least 10 fan blades **43** but no more than 20 or 24 fan blades **43**. In examples, the fan **42** may have between 12 and 18 fan blades **43**, such as 14 fan blades **43**. An exemplary fan size measurement is a maximum radius between the tips of the fan blades **43** and the engine central longitudinal axis A. The maximum radius of the fan blades **43** can be at least 38 inches, or more narrowly no more than 75 inches. For example, the maximum radius of the fan blades **43** can be between 45 inches and 60 inches, such as between 50 inches and 55 inches. Another exemplary fan size measurement is a hub radius, which is defined as distance between a hub of the fan **42** at a location of the leading edges of the fan blades **43** and the engine central longitudinal axis A. The fan blades **43** may establish a fan hub-to-tip ratio, which is defined as a ratio of the hub radius divided by the maximum radius of the fan **42**. The fan hub-to-tip ratio can be less than or equal to 0.35, or more narrowly greater than or equal to 0.20, such as between 0.25 and 0.30. The combination of fan blade counts and fan hub-to-tip ratios disclosed herein can provide the engine **20** with a relatively compact fan arrangement.

The low pressure compressor **44**, high pressure compressor **52**, high pressure turbine **54** and low pressure turbine **46** each include one or more stages having a row of rotatable airfoils. Each stage may include a row of vanes adjacent the rotatable airfoils. The rotatable airfoils are schematically indicated at **47**, and the vanes are schematically indicated at **49**.

The low pressure compressor **44** and low pressure turbine **46** can include an equal number of stages. For example, the engine **20** can include a three-stage low pressure compressor **44**, an eight-stage high pressure compressor **52**, a two-stage high pressure turbine **54**, and a three-stage low pressure turbine **46** to provide a total of sixteen stages. In other examples, the low pressure compressor **44** includes a different (e.g., greater) number of stages than the low pressure turbine **46**. For example, the engine **20** can include a five-stage low pressure compressor **44**, a nine-stage high pressure compressor **52**, a two-stage high pressure turbine **54**, and a four-stage low pressure turbine **46** to provide a total of twenty stages. In other embodiments, the engine **20** includes a four-stage low pressure compressor **44**, a nine-stage high pressure compressor **52**, a two-stage high pressure turbine **54**, and a three-stage low pressure turbine **46** to provide a total of eighteen stages. It should be understood that the engine **20** can incorporate other compressor and turbine stage counts, including any combination of stages disclosed herein.

The engine **20** may be a high-bypass geared aircraft engine. The bypass ratio can be greater than or equal to 10.0 and less than or equal to about 18.0, or more narrowly can be less than or equal to 16.0. The geared architecture **48** may be an epicyclic gear train, such as a planetary gear system or a star gear system. The epicyclic gear train may include a sun gear, a ring gear, a plurality of intermediate gears meshing with the sun gear and ring gear, and a carrier that supports the intermediate gears. The sun gear may provide an input to the gear train. The ring gear (e.g., star gear system) or carrier (e.g., planetary gear system) may provide an output of the gear train to drive the fan **42**. A gear reduction ratio may be greater than or equal to 2.3, or more narrowly greater than or equal to 3.0, and in some embodiments the gear reduction ratio is greater than or equal to 3.4. The gear reduction ratio may be less than or equal to 4.0. The fan diameter is significantly larger than that of the low pressure compressor **44**. The low pressure turbine **46** can have a pressure ratio that is greater than or equal to 8.0 and in some embodiments is greater than or equal to 10.0. The low pressure turbine pressure ratio can be less than or equal to 13.0, or more narrowly less than or equal to 12.0. Low pressure turbine **46** pressure ratio is pressure measured prior to an 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. 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. All of these parameters are measured at the cruise condition described below.

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 (10,668 meters). 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. The engine parameters described above, and those in the next paragraph are measured at this condition unless otherwise specified.

"Fan pressure ratio" is the pressure ratio across the fan blade **43** alone, without a Fan Exit Guide Vane ("FEGV") system. A distance is established in a radial direction between the inner and outer diameters of the bypass duct **13** at an axial position corresponding to a leading edge of the splitter **29** relative to the engine central longitudinal axis A. The fan pressure ratio is a spanwise average of the pressure ratios measured across the fan blade **43** alone over radial positions corresponding to the distance. The fan pressure ratio can be less than or equal to 1.45, or more narrowly greater than or equal to 1.25, such as between 1.30 and 1.40. "Corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(\text{Tram } ° \text{ R})/(518.7° \text{ R})]^{0.5}$. The corrected fan tip speed can be less than or equal to 1150.0 ft/second (350.5 meters/second), and can be greater than or equal to 1000.0 ft/second (304.8 meters/second).

The fan **42**, low pressure compressor **44** and high pressure compressor **52** can provide different amounts of compression of the incoming airflow that is delivered downstream to the turbine section **28** and cooperate to establish an overall pressure ratio (OPR). The OPR is a product of the fan pressure ratio across a root (i.e., 0% span) of the fan blade **43** alone, a pressure ratio across the low pressure compressor **44** and a pressure ratio across the high pressure compressor **52**. The pressure ratio of the low pressure compressor **44** is measured as the pressure at the exit of the low pressure compressor **44** divided by the pressure at the inlet of the low pressure compressor **44**. In examples, a product of the pressure ratio of the low pressure compressor **44** and the fan pressure ratio is between 3.0 and 6.0, or more narrowly is between 4.0 and 5.5. The pressure ratio of the high pressure compressor ratio **52** is measured as the pressure at the exit of the high pressure compressor **52** divided by the pressure at the inlet of the high pressure compressor **52**. In examples, the pressure ratio of the high pressure compressor **52** is between 7.0 and 12.0, or more narrowly is between 10.0 and 11.5. The OPR can be equal to or greater than 44.0, and can be less than or equal to 70.0, such as between 50.0 and 60.0. The overall and compressor pressure ratios disclosed herein are measured at the cruise condition described above, and can be utilized in two-spool architectures such as the engine **20** as well as three-spool engine architectures.

The engine **20** establishes a turbine entry temperature (TET). The TET is defined as a maximum temperature of combustion products communicated to an inlet of the turbine section **28** at a maximum takeoff (MTO) condition. The inlet is established at the leading edges of the axially forwardmost row of airfoils of the turbine section **28**, and MTO is measured at maximum thrust of the engine **20** at static sea-level and 86 degrees Fahrenheit (° F.). The TET may be greater than or equal to 2700.0° F., or more narrowly less than or equal to 3500.0° F., such as between 2750.0° F. and 3350.0° F. The relatively high TET can be utilized in combination with the other techniques disclosed herein to provide a compact turbine arrangement.

The engine **20** establishes an exhaust gas temperature (EGT). The EGT is defined as a maximum temperature of combustion products in the core flow path C communicated to at the trailing edges of the axially aftmost row of airfoils of the turbine section **28** at the MTO condition. The EGT may be less than or equal to 1000.0° F., or more narrowly greater than or equal to 800.0° F., such as between 900.0° F. and 975.0° F. The relatively low EGT can be utilized in combination with the other techniques disclosed herein to reduce fuel consumption.

Applicant previously designed, manufactured and flew a gas turbine engine with a gear reduction between the low pressure compressor and the fan rotor. A gear ratio of the gear reduction in those engines was 3.06, or lower. This disclosure relates to gas turbine engines with a gear reduction, but also in embodiments with a gear ratio greater than or equal to 3.2, and also in embodiments greater than or equal to 3.4, and less than 4.0.

The low spool **30** is illustrated in FIG. **2** including a low pressure (or fan drive) turbine **46**, and a shaft **40** driving a low pressure compressor **44**. A gear reduction **48** drives the fan rotor **42**. The low spool is defined as turbine **46**, shaft **40** and compressor **44**.

In this disclosure, the low speed spool **30** has its torque reduced and speed is increased. This will enable a smaller shaft **40** to transfer the required torque. This is at least partially due to the higher gear ratio. Even so, a ratio of low speed spool torque at maximum takeoff to maximum takeoff thrust is higher than has been the case in the prior art. As an example, the following example engines would come within the scope of this disclosure.

	Engine 1	Engine 2	Engine 3	Engine 4
Low spool torque	89512 ft-lb	21027 ft-lb	19727 ft-lb	21061 ft-lb
MTO thrust	94027 lbf	25360 lbf	24240 lbf	32980 lbf
LST/MTO thrust	0.95 ft-lb/lbf	0.83 ft-lb/lbf	0.81 ft-lb/lbf	0.64 ft-lb/lbf

The ratios as disclosed above could be called a low spool torque-to-thrust ratio.

In the first generation gas turbine engines with a gear reduction developed by Applicant, the ratios were on the order of 0.18 ft-lb/lbf in one engine, 0.52 ft-lb/lbf in another engine, 0.61 ft-lb/lbf in yet another engine, and 0.65 ft-lb/lbf in yet another engine.

The disclosed low spool thrust ratios being higher provides more efficient operation by providing greater energy via the highly efficient low pressure turbine. In embodiments, the ratio may be greater than or equal 0.60 ft-lb/lbf, and in other embodiments greater than or equal to 0.70 ft-lb/lbf, 0.8 ft-lb/lbf and greater than or equal to 0.9 ft-lb/lbf in other embodiments. The ratio is preferably less than 1.2 ft-lb/lbf, and in embodiments less than or equal to 1.0 ft-lb/lbf.

Engines coming under this disclosure may shift more of the work from the high speed spool and compressor to the low speed spool and compressor compared to the first generation engines. As an example, in the first generation engine mentioned above where the low spool thrust ratio is 0.65, the corresponding low pressure compressor pressure ratio including the fan pressure ratio was 3.0. In the engine designed under this disclosure having the low spool thrust ratio of 0.64, the corresponding low pressure compressor pressure ratio with the fan was 4.1. Engines coming under this disclosure could also be said to include the pressure ratio across the low pressure compressor including the fan pressure ratio is greater than or equal to 3.5, and in embodiments greater than or equal to 4.0, and less than or equal to 6.5. Further details of the low spool thrust ratio may found in co-pending U.S. patent application Ser. No. 17/379,233, filed on even date herewith, and entitled "GAS TURBINE ENGINE WITH HIGHER LOW SPOOL TORQUE-TO-THRUST RATIO." The disclosure of which is incorporated by reference here.

The disclosed engine may also benefit from a power extraction ratio that relates the low spool torque to the low spool power, both measured at maximum takeoff. Low spool power is measured in horsepower.

	Engine 1	Engine 2	Engine 3	Engine 4
Low spool torque	89512 ft-lb	21027 ft-lb	19727 ft-lb	21061 ft-lb
Low spool power	98190 hp	37639 hp	35924 hp	34834 hp
LST/MTO thrust	0.912 ft-lb/hp	0.559 ft-lb/hp	0.549 ft-lb/hp	0.605 ft-lb/hp

In engines made according to Applicant's first generation gas turbine engine with a gear reduction the corresponding ratios were 0.558 ft-lb/hp, 0.551 ft-lb/hp, 0.534 ft-lb/hp, and 0.449 ft-lb/hp.

Engines according to this disclosure benefit from higher power extraction ratios by providing greater energy via the highly efficient low pressure turbine. In embodiments the power extraction ratio may be greater than or equal to 0.50 ft-lb/hp, and in other embodiments greater than or equal to 0.60 ft-lb/hp, and in further embodiments greater than or equal to 0.70 ft-lb/hp, in further embodiments it may be greater than or equal to 0.80 ft-lb/hp, and in further embodiments it may be greater than or equal to 0.90 ft-lb/hp. In embodiments it is preferably less than or equal 1.2 ft-lb/hp, and in further embodiments less than or equal to 1.1 ft-lb/hp, in other embodiments it may be less than or equal to 1.0 ft-lb/hp.

Engines coming under this disclosure may shift more of the work from a high speed spool and compressor to the low speed spool and compressor compared to the first generation engine. As an example, in the first generation engines mentioned above wherein the power extraction ratio was 0.558, 0.551 and 0.534, the corresponding low pressure compressor ratio including the fan pressure ratio was 2.9, 3.1 and 3.1, respectively. In the engines designed under this disclosure having the power extraction ratio of 0.559 and 0.549, the corresponding pressure ratio across the low pressure compressor including the fan pressure ratio was 5.0 for both. Engines coming under this disclosure could also be said to include the pressure ratio across the low pressure compressor including the fan is greater than or equal to 3.5, and embodiments greater than or equal to 4.0, and less than or equal to 6.5.

The combination of the two ratios disclosed above also results in a synergistic benefit with regard to the efficient operation of the associated engine.

The disclosures here can be said to provide efficient operation, with each disclosed ratio, but the combination of the two is particularly powerful. As the gear ratio goes up, the necessary torque on the low spool drops. Power has a relationship with thrust, and for a given thrust there is a given power. However, since this disclosure relates to gas turbine engines wherein a speed increase is provided to the low spool, one can reach the given power and thrust with less torque on the low spool.

A gas turbine engine under this disclosure could be said to include a fan rotor surrounded by a fan case and delivering air into a bypass duct defined between the fan and an inner core housing. The fan rotor also delivering air into the inner core housing and into a compressor section. The compressor section includes a low pressure compressor and a high pressure compressor. The high pressure compressor delivers air into a combustor where it is mixed with fuel and ignited, and products of the combustion pass downstream into a turbine section. The turbine section includes a low pressure turbine driving the low pressure compressor, and driving a gear reduction to in turn drive the fan rotor at a speed slower than the fan drive turbine. The turbine section further includes a high pressure turbine driving the high pressure compressor. The low pressure turbine and low pressure compressor are connected by a shaft. The low pressure turbine, the shaft and the low pressure compressor define a low pressure spool. The low pressure spool has a torque at maximum takeoff defined in ft-lbs and also having a low pressure spool power defined in horsepower and at maximum takeoff. The low pressure spool power is defined in horsepower. A ratio of the low pressure spool torque to the low pressure spool power being greater than or equal to 0.6 ft-lb/hp and less than or equal to 1.2 ft-lb/hp.

In another embodiment, the ratio is greater than or equal to 0.5 ft-lb/hp and less than or equal to 1.2 ft-lb/hp and a power ratio at cruise condition is defined across the fan and the low pressure compressor. The pressure ratio being greater than or equal to 3.5 and less than or equal to 6.0.

Although preferred embodiments of this invention have been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A gas turbine engine comprising:

a fan rotor surrounded by a fan case and delivering air into a bypass duct defined between said fan and an inner core housing, said fan rotor also delivering air into said inner core housing and into a compressor section, and a bypass ratio being defined as a volume of air delivered into said bypass duct divided by a volume of air delivered into said inner core housing, and said bypass ratio being greater than or equal to 10.0 and less than or equal to 16.0, said compressor section including a low pressure compressor and a high pressure compressor, said high pressure compressor delivering air into a combustor where it is mixed with fuel and ignited, and products of the combustion passing downstream into a turbine section, said turbine section including a fan drive turbine driving said low pressure compressor, and driving a gear reduction to in turn drive said fan rotor at a speed slower than said fan drive turbine, said turbine section further including a high pressure turbine driving said high pressure compressor, said fan drive turbine and low pressure compressor connected by a shaft and said fan drive turbine, said shaft and said low pressure compressor defining a low pressure spool;

wherein said low pressure spool has a torque at maximum takeoff defined in ft-lbs and also having a low pressure spool power defined in horsepower and at maximum takeoff, and a ratio of said low pressure spool torque to said low pressure spool power being defined, and said ratio of said low pressure spool torque to said low pressure spool power being greater than or equal to 0.9 ft-lb/hp and less than or equal to 1.2 ft-lb/hp;

wherein a pressure ratio at cruise condition is defined across said fan rotor and said low pressure compressor, and said pressure ratio being greater than or equal to 3.5 and less than or equal to 6.0; and

wherein a low pressure turbine pressure ratio is defined as a pressure measured prior to an inlet of the low pressure turbine as related to the pressure at the outlet of the low pressure turbine prior to any exhaust nozzle, and said low pressure turbine pressure ratio being greater than or equal to 8.0 and less than or equal to 13.0.

2. A gas turbine engine comprising:

a fan rotor surrounded by a fan case and delivering air into a bypass duct defined between said fan and an inner core housing, said fan rotor also delivering air into said inner core housing and into a compressor section, and a bypass ratio being defined as a volume of air delivered into said bypass duct divided by a volume of air delivered into said inner core housing, and said bypass ratio being greater than or equal to 10.0 and less than or equal to 16.0, said compressor section including a low pressure compressor and a high pressure compressor, said high pressure compressor delivering air into a combustor where it is mixed with fuel and ignited, and products of the combustion passing downstream into a turbine section, said turbine section including a fan drive turbine driving said low pressure compressor, and driving a gear reduction to in turn drive said fan rotor at a speed slower than said fan drive turbine, a gear ratio of said gear reduction being greater than or equal to 3.4 and less than or equal to 4.0, said turbine section further including a high pressure turbine driving said high pressure compressor, said fan drive turbine and low pressure compressor connected by a shaft and said fan drive turbine, said low pressure shaft and said low pressure compressor defining a low pressure spool;

wherein said low pressure spool has a torque at maximum takeoff defined in ft-lbs and also having a low pressure spool power, and a ratio of said low pressure spool torque to said low pressure spool power being defined, with said low pressure spool power being defined in horsepower, and said ratio of said low pressure spool torque to said low pressure spool power being greater than or equal to 0.6 ft-lb/hp and less than or equal to 1.2 ft-lb/hp;

a pressure ratio at cruise condition defined across said fan and said low pressure compressor, and said pressure ratio being greater than or equal to 3.5 and less than or equal to 6.0; and

wherein a low pressure turbine pressure ratio is defined as a pressure measured prior to an inlet of the low pressure turbine as related to the pressure at the outlet of the low pressure turbine prior to any exhaust nozzle, and said low pressure turbine pressure ratio being greater than or equal to 8.0 and less than or equal to 13.0.

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