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Sheridan et al.

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(54) **GEARED TURBOFAN WITH OVERSPEED PROTECTION**

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F01D 5/02 (2006.01)
(Continued)

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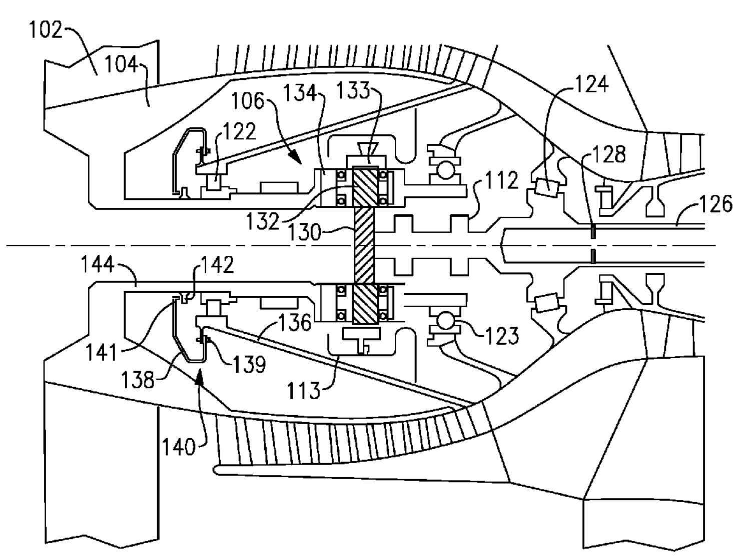
(57) **ABSTRACT**

A gas turbine engine has a fan drive turbine driving a gear reduction, the gear reduction, in turn, driving a fan rotor, the fan rotor delivering air into a bypass duct as bypass air and into a compressor section as core flow. A forward bearing is positioned between the gear reduction and the fan rotor and supports the gear reduction. A second bearing is positioned aft of the gear reduction and supports the gear reduction. The second bearing is a thrust bearing. A fan drive turbine drive shaft drives the gear reduction. The fan drive turbine drive shaft has a weakened link which is aft of the second bearing such that the fan drive turbine drive shaft will tend to fail at the weakened link, and at a location aft of the second bearing.

17 Claims, 4 Drawing Sheets



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F02C 7/36	(2006.01)
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F16H 1/28	(2006.01)
F16H 57/10	(2006.01)

(52) **U.S. Cl.**

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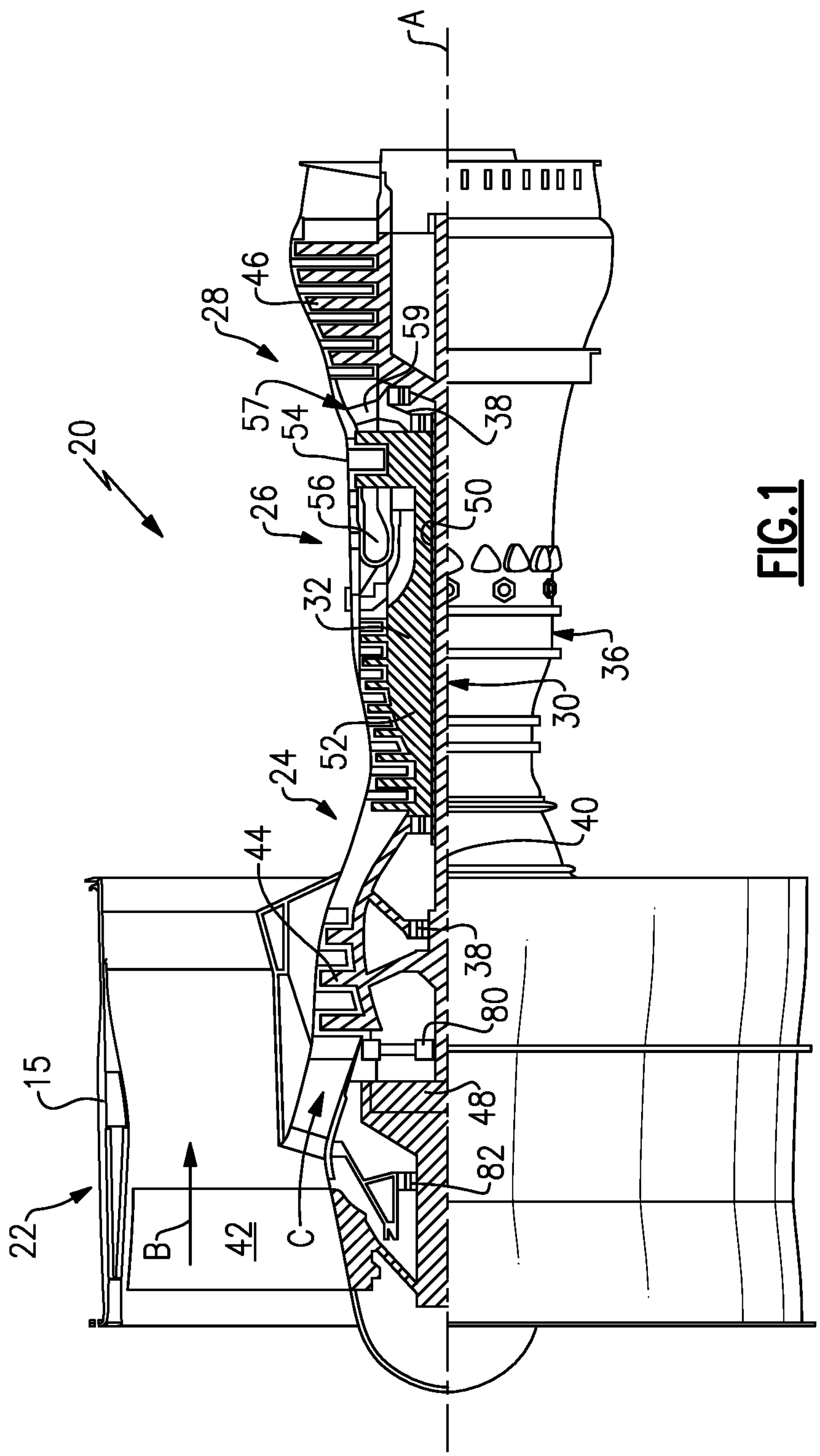
A
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80
15
48
82
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B
42
C

FIG.1

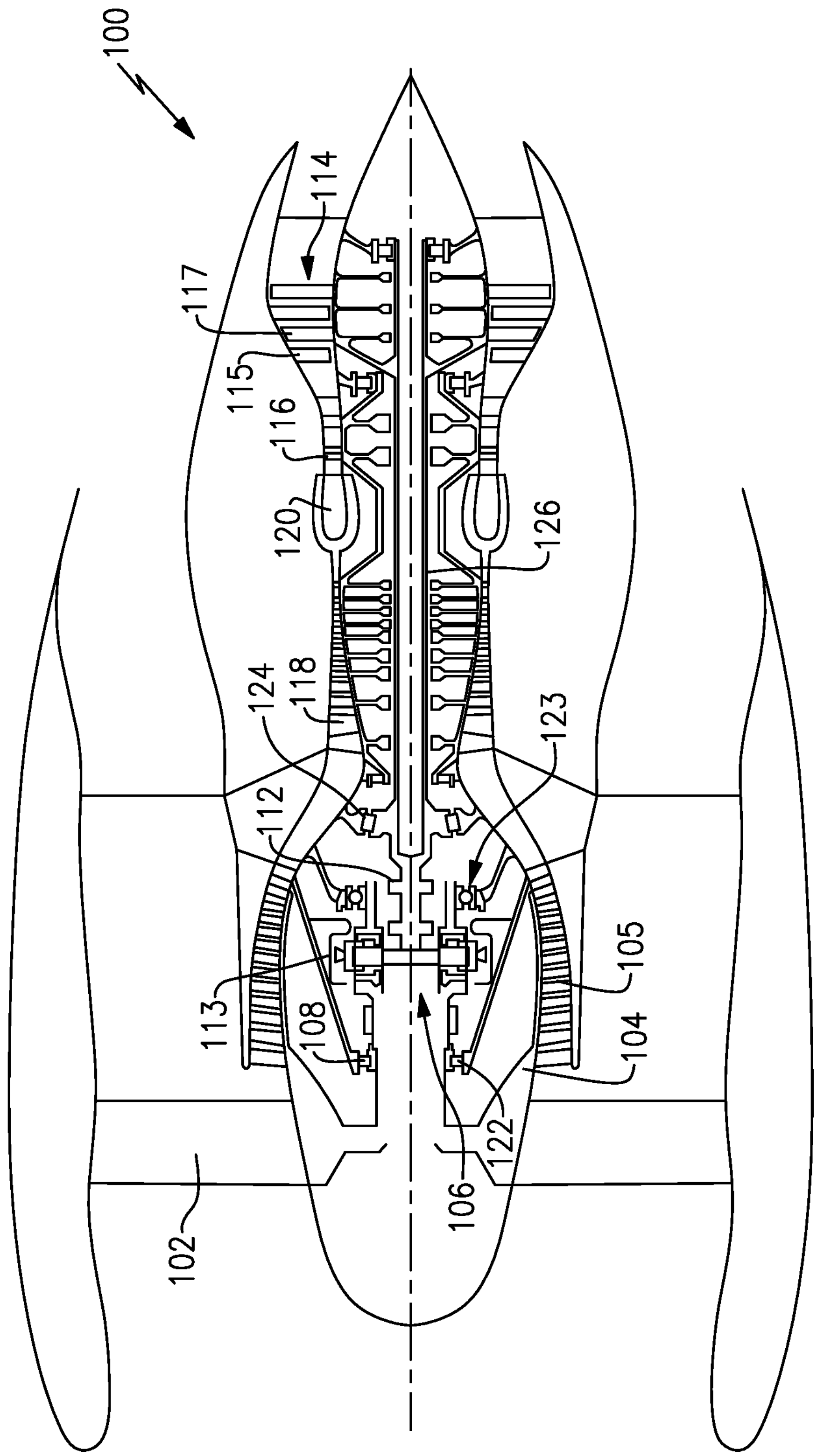
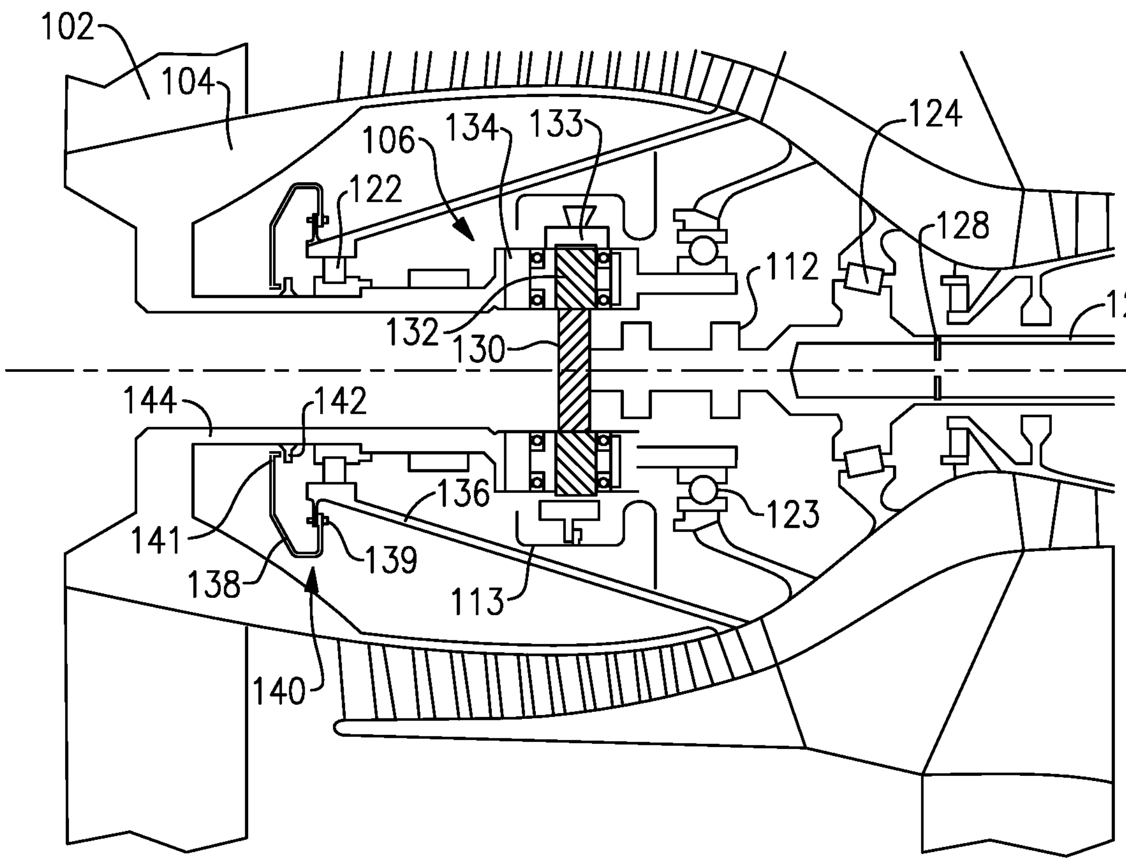
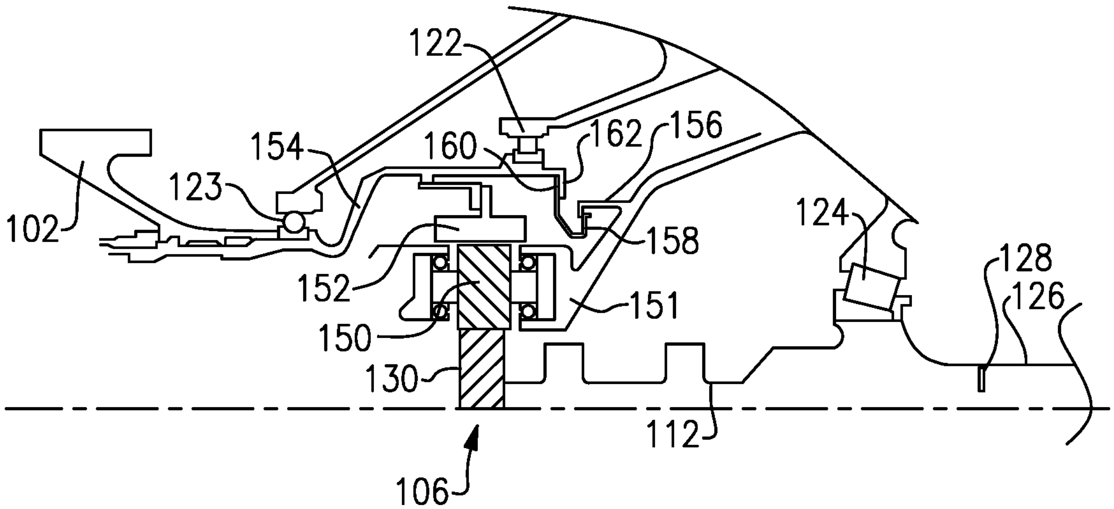

100
114
117
115
116
120
126
124
118
123
112
105
113
108
104
122
106
102

FIG.2



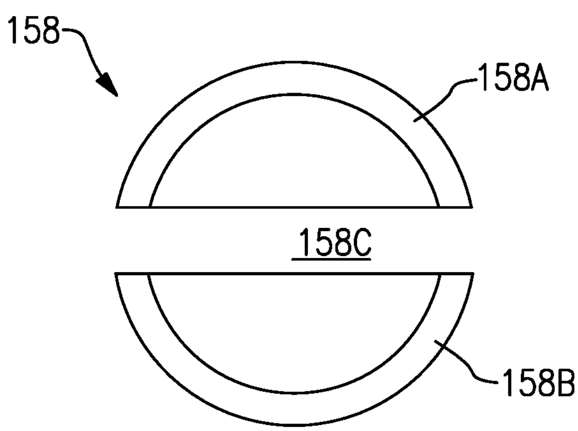
102
104
106
134
133
122
124
128
112
126
132
130
144
142
136
123
141
139
138
113
140

FIG.3



122
154
160
162
156
123
102
124
158
128
152
126
151
150
130
112
106

FIG.4



158
158A
158C
158B

FIG.5

GEARED TURBOFAN WITH OVERSPEED PROTECTION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 16/825,370 filed on Mar. 20, 2020, which is a continuation of U.S. patent application Ser. No. 15/625,144 filed Jun. 16, 2017, now U.S. Pat. No. 10,615,555 granted on Apr. 7, 2020.

BACKGROUND OF THE INVENTION

This application relates to a geared turbofan wherein a gear reduction is straddle mounted with supporting bearings positioned both forward and aft of the gear reduction, and wherein overspeed protection is provided.

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

Historically, the fan rotor rotated as one with the fan drive turbine. This resulted in compromise in the design as it may be desirable to have the turbine rotate at a higher speed than the fan.

Thus, it has been proposed to include a gear reduction between the fan drive turbine and the fan rotor.

More recently, the assignee of the present application has developed a commercial gas turbine engine wherein a gear reduction is placed between a low pressure compressor and a fan, such that a fan drive turbine drives the low pressure compressor at one speed and drives the fan at a slower speed.

Such commercial engines have supported the gear reduction on two bearings forwardly of the gear reduction.

It has also been proposed to straddle mount a gear reduction. In a straddle mount gear reduction, bearings are placed on a forward side and on an aft side of the gear reduction. Such an arrangement raises challenges in the event of a failure of a component in the drivetrain of the fan.

SUMMARY OF THE INVENTION

In a featured embodiment, a gas turbine engine has a fan drive turbine driving a gear reduction, the gear reduction, in turn, driving a fan rotor, the fan rotor delivering air into a bypass duct as bypass air and into a compressor section as core flow. A forward bearing is positioned between the gear reduction and the fan rotor and supports the gear reduction. A second bearing is positioned aft of the gear reduction and supports the gear reduction. The second bearing is a thrust bearing. A fan drive turbine drive shaft drives the gear reduction. The fan drive turbine drive shaft has a weakened link which is aft of the second bearing such that the fan drive turbine drive shaft will tend to fail at the weakened link, and at a location aft of the second bearing.

In another embodiment according to the previous embodiment, the compressor section includes a low pressure compressor and a high pressure compressor and the low pressure compressor also is driven by the gear reduction to rotate with the fan.

In another embodiment according to any of the previous embodiments, the compressor section includes a low pressure compressor and a high pressure compressor. The low pressure compressor is driven at a common speed by the fan drive turbine drive shaft.

In another embodiment according to any of the previous embodiments, the compressor section includes a low pressure compressor and a high pressure compressor and the second bearing is positioned intermediate the low pressure compressor and the high pressure compressor.

In another embodiment according to any of the previous embodiments, a catcher is provided to resist movement of the gear reduction and the fan rotor in an outer direction in the event of a failure of a fan rotor bearing.

In another embodiment according to any of the previous embodiments, the gear reduction is an epicyclic gear reduction.

In another embodiment according to any of the previous embodiments, the epicyclic gear reduction includes a sun gear driving intermediate gears, a static ring gear, and a carrier rotating when driven by the sun gear, the carrier being attached to a fan drive shaft to drive the fan rotor, and the catcher includes a member attached to a static structure and having a radially inner end forward of a flange on the fan drive shaft, and the catcher being contacted by the flange should the gear reduction move in a forward direction, to resist movement of the gear reduction.

In another embodiment according to any of the previous embodiments, the epicyclic gear reduction includes a sun gear, intermediate gears driven by the sun gear, and a ring gear driven by the intermediate gears, with a static carrier, and the ring gear driving the fan drive shaft, the catcher including a member having a radially outer location positioned forwardly of a radially inwardly extending flange which rotates with the fan drive shaft, the catcher being controlled by the flange should the gear reduction move in a forward direction, the catcher to resist movement of the gear reduction.

In another embodiment according to any of the previous embodiments, the catcher is formed of two parts with an intermediate gap.

In another embodiment according to any of the previous embodiments, the gear reduction is an epicyclic gear reduction.

In another featured embodiment, a gas turbine engine has a fan drive turbine driving a gear reduction, the gear reduction, in turn, driving a fan rotor, the fan rotor delivering air into a bypass duct as bypass air and into a compressor section as core flow. A forward bearing is positioned between the gear reduction and the fan rotor and supports the gear reduction. A second bearing is positioned aft of the gear reduction and supports the gear reduction. The second bearing is a thrust bearing. A fan drive turbine drive shaft drives ng the gear reduction. A catcher is provided to resist movement of the gear reduction and the fan rotor in an outer direction in the event of a failure of the second bearing. The gear reduction is an epicyclic gear reduction.

In another embodiment according to the previous embodiment, the epicyclic gear reduction includes a sun gear driving intermediate gears, a static ring gear, and a carrier rotating when driven by the sun gear, the carrier being attached to a fan drive shaft to drive the fan rotor.

In another embodiment according to any of the previous embodiments, the catcher includes a member having a radially inner location positioned forwardly of a radially outwardly extending flange which rotates with the fan drive shaft, the catcher being contacted by the flange should the gear reduction move in a forward direction, the catcher to resist movement of the gear reduction.

In another embodiment according to any of the previous embodiments, the epicyclic gear reduction includes a sun gear, intermediate gears driven by the sun gear, and a ring gear driven by the intermediate gears, with a static carrier, and the ring gear driving the fan drive shaft.

In another embodiment according to any of the previous embodiments, the catcher includes a member having a radially outer location positioned forwardly of a radially inwardly extending flange which rotates with the fan drive shaft, the catcher being contacted by the flange should the gear reduction move in a forward direction, the catcher to resist movement of the gear reduction.

In another embodiment according to any of the previous embodiments, the catcher is formed of two parts with an intermediate gap.

In another embodiment according to any of the previous embodiments, the compressor section includes a low pressure compressor and a high pressure compressor and the low pressure compressor also being driven by the gear reduction to rotate with the fan.

In another embodiment according to any of the previous embodiments, the compressor section including a low pressure compressor and a high pressure compressor and the second bearing being positioned intermediate the low pressure compressor and the high pressure compressor.

In another embodiment according to any of the previous embodiments, the compressor section including a low pressure compressor and a high pressure compressor and the low pressure compressor being driven at a common speed by the fan drive turbine drive shaft.

In another embodiment according to any of the previous embodiments, the compressor section including a low pressure compressor and a high pressure compressor and the second bearing being positioned intermediate the low pressure compressor and the high pressure compressor.

These and other features may be best understood from the following drawings and specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically shows a first gas turbine engine.
FIG. **2** schematically shows a second gas turbine engine.
FIG. **3** shows a first embodiment safety feature.
FIG. **4** shows a second embodiment.
FIG. **5** shows a detail of the second embodiment.

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**. 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**, 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**. 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 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 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.

The core airflow 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 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**.

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) and less than twenty-five (25.0), with example embodiments being greater than about ten (10.0, or between fifteen (15.0) and twenty (20.0), 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 and less than 20.0:1, such as between about 10.0 and 15.0. 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 and less than 5.0, or equal to, or less than 4.0. 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.

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. "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 $[(\text{Tram}\ ^\circ\ \text{R})/(518.7^\circ\ \text{R})]^{0.5}$. 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).

As shown, a first bearing **82** is positioned forwardly of the gear reduction **48** and a second bearing **80** is positioned aft of the gear reduction **48**. While the bearings **80/82** are shown schematically, the bearing arrangement may be as shown in more detail in FIG. **2**.

FIG. **2** shows an engine embodiment 100 wherein a fan **102** rotates as one with a low pressure compressor hub **104** having compressor blades **105**. The gear reduction **106** thus reduces the speed of a fan driven by a fan drive turbine **114**, but the low pressure compressor hub **104** and fan **102** rotate at the same speed.

The quantities mentioned above with regard to FIG. **1** might also apply to the FIG. **2** engine.

A flexible drive connection **112** connects the fan drive turbine **114** to drive the gear reduction **106** as will be better explained below. While a flexible drive connection is shown, a more rigid connection may be utilized within the scope of this disclosure. Also, a flexible mount **113** is schematically shown for the gear reduction **106**.

The fan drive turbine **114** is shown to have rotating blades **117** and static vanes **115**.

A high pressure compressor **118** is driven by a high pressure turbine **116**. A combustor **120** is intermediate turbine **116** and compressor **118**.

Bearing **108** is forward of gear reduction **106** and thrust bearing **124** is aft of the gear reduction **106**. A low turbine shaft **126** is located between thrust bearing **124** and fan drive turbine **114** such that it drives flexible connection **112**.

Note, thrust bearing **124** is forward of combustor **120** and axially between the low and high pressure compressors **104/118**.

With the engine shown in FIG. **2**, should there be a failure of the drivetrain forward of thrust bearing **124**, the low turbine **114** could over-speed since there is no resisting torsional load to slow it down. Thrust bearing **124** will enable the turbine to maintain an axial running position with hot gases and fuel from the combustor attempting to accelerate the turbine without having the resistive force from the fan and low compressor to slow it down. This is an undesirable condition.

Thus, FIG. **3** shows a detail wherein a weakened link **128** is formed in a turbine drive shaft **126** aft of the thrust bearing **124**. The gear reduction is a so-called planetary system. Now, should there be a failure in the drivetrain, it will tend to be at the weakened link **128**. When this failure occurs, rather than the turbine section overspeeding, the turbine will disengage from its axial position and move aft since thrust bearing **124** will no longer hold it, and the rotating blades **117** will contact the static vanes **115**. The rotation of the fan drive turbine **114** will be stopped or at least prevented from accelerating to an unsafe speed avoiding the undesired condition previously mentioned

Similar undesirable conditions can happen with the fan rotor **102** as shown in FIG. **3** when it experiences bearing failure. FIG. **3** depicts a gear drive **106** that is straddle mounted by two bearings **122** and **123**. Bearing **122** is a radial bearing that can react radial loads but not axial loads. Bearing **123** is a thrust bearing that can react both radial loads and axial thrust loads. Bearing **123** reacts the axial thrust load from fan **102**. As further shown, there is a catcher or retainer feature **140**. The input drive **112** drives the sun gear **130** in this embodiment, which, in turn, engages intermediate gears **132**. A ring gear **133** in this embodiment is static. Thus, a carrier **134** rotates to, in turn, drive a fan driveshaft **144** that rotates with the fan shaft. It should be understood this arrangement can be utilized with the engines of FIG. **1** or **2**.

A catcher **140** includes a frame **138** bolted at **139** to a static frame **136**. In the event of failure of thrust bearing **123**, the gear reduction **106** and the fan **102** may be urged forwardly or to the left in FIG. **3**. However, the catcher **140** has a radially inner portion **141** which is radially inward of a flange **142** on shaft the **144**. The catcher **140** is formed of sufficiently strong material that it can contact, catch and hold the flange **142**, and hence resist movement of the gear reduction **106** and fan **102** to the left or outwardly of the engine.

FIG. **4** shows an embodiment wherein the gear reduction is a so-called "star gear" system. Structure, which is similar to that of FIG. **3**, is identified by the same reference numeral. Here, however, the carrier **151** is static. The intermediate gears **150** still rotate with the sun gear **130** and drive a ring gear **152**. Ring gear **152** drives a shaft **154** to, in turn, rotate the fan. In FIG. **4**, the gear drive **106** is also straddle mounted by two bearings **123** and **122**, but their positions are reversed such that thrust bearing **123** is forward of gear drive **106**. This embodiment may also be used with the engines of FIG. **1** or **2**.

In this embodiment, a catcher **158** has a radially outermost edge **160**, which is forward of a flange **162** associated with the shaft **154**. The catcher **158** is again bolted to a frame structure **156**, which is illustrated as associated with the carrier **151**.

Now, should thrust bearing **123** fail, the catcher **160** will catch the flange **162** and resist movement of the gear reduction and fan forwardly and outwardly of the engine.

FIG. **5** shows a detail of the catcher **158** having two halves **158**A and **158**B with an intermediate space **158**C. This will facilitate assembly of the catcher, which may otherwise be complex in the environment as illustrated in FIG. **4**.

The thrust bearings as disclosed and claimed may be any type thrust bearing, including ball bearings, tapered roller bearings and spherical roller bearings, among others.

Although an embodiment of this invention has 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.

The invention claimed is:

1. A gas turbine engine comprises:

a fan drive turbine driving a gear reduction, said gear reduction, in turn, driving a fan rotor, said fan rotor delivering air into a bypass duct as bypass air and into a compressor section as core flow;

a forward bearing positioned between said gear reduction and said fan rotor and supporting said gear reduction, and a second bearing positioned aft of said gear reduction and supporting said gear reduction, and said second bearing being a thrust bearing;

a fan drive turbine drive shaft driving said gear reduction;

a catcher provided to resist movement of said gear reduction and said fan rotor in an outer direction of said second bearing, said catcher being fixed to static structure, said static structure being radially outward of said forward bearing, and said catcher including a member having a radially inner location positioned forwardly of a radially outwardly extending flange which rotates with said fan drive shaft, said catcher being contacted by said flange should said gear reduction move in a forward direction, to resist said movement of said gear reduction, and said member being axially intermediate said forward bearing and said fan rotor;

said gear reduction is an epicyclic gear reduction, said epicyclic gear reduction includes a sun gear driving intermediate gears, a static ring gear, and a carrier rotating when driven by said sun gear, said carrier being attached to a fan drive shaft to drive said fan rotor; and

said compressor section includes a low pressure compressor and a high pressure compressor and said low pressure compressor also being driven by said gear reduction to rotate with said fan rotor.

2. The gas turbine engine as set forth in claim **1**, wherein said catcher being between said gear reduction and said fan rotor.

3. The gas turbine engine as set forth in claim **1**, wherein said catcher is bolted to said static structure.

4. The gas turbine engine as set forth in claim **1**, wherein a bypass ratio is defined as a volume of air delivered into said bypass duct compared to a volume of air delivered into said compressor section, and said bypass ratio being greater than 6 and less than 25.

5. The gas turbine engine as set forth in claim **4**, wherein said bypass ratio being greater than 10.

6. The gas turbine engine as set forth in claim **1**, wherein said fan drive turbine having a pressure ratio greater than 5.

7. The gas turbine engine as set forth in claim **1**, wherein said fan rotor having a plurality of fan blades, and a fan pressure ratio measured across the fan blades alone being less than 1.45.

8. The gas turbine engine as set forth in claim **1**, wherein said static structure supports said forward bearing.

9. A gas turbine engine comprises:

a fan drive turbine driving a gear reduction, said gear reduction, in turn, driving a fan rotor, said fan rotor delivering air into a bypass duct as bypass air and into a compressor section as core flow;

a forward bearing positioned between said gear reduction and said fan rotor and supporting said gear reduction, and a second bearing positioned aft of said gear reduction and supporting said gear reduction, and said second bearing being a thrust bearing;

a fan drive turbine drive shaft driving said gear reduction;

a catcher provided to resist movement of said gear reduction and said fan rotor in an outer direction in the event of a failure;

said gear reduction is an epicyclic gear reduction;

said epicyclic gear reduction includes a sun gear driving intermediate gears, a static ring gear, and a carrier rotating when driven by said sun gear, said carrier being attached to a fan drive shaft to drive said fan rotor;

said catcher includes a member having a radially inner location positioned forwardly of a radially outwardly extending flange which rotates with said fan drive shaft, said catcher being contacted by said flange should said gear reduction move in a forward direction, said catcher to resist movement of said gear reduction; and

wherein said catcher being between said gear reduction and said fan rotor and between said forward bearing and said fan rotor.

10. The gas turbine engine as set forth in claim **9**, wherein said compressor section includes a low pressure compressor and a high pressure compressor and said low pressure compressor also being driven by said gear reduction to rotate with said fan rotor.

11. The gas turbine engine as set forth in claim **9**, wherein said catcher is bolted to a static structure.

12. The gas turbine engine as set forth in claim **11**, wherein said static structure supports said forward bearing.

13. The gas turbine engine as set forth in claim **9**, wherein said catcher is fixed to static structure.

14. The gas turbine engine as set forth in claim **9**, wherein a bypass ratio is defined as a volume of air delivered into said bypass duct compared to a volume of air delivered into said compressor section, and said bypass ratio being greater than 6 and less than 25.

15. The gas turbine engine as set forth in claim **14**, wherein said bypass ratio being greater than 10.

16. The gas turbine engine as set forth in claim **9**, wherein said fan drive turbine having a pressure ratio greater than 5.

17. The gas turbine engine as set forth in claim **16**, wherein said fan rotor having a plurality of fan blades, and a fan pressure ratio measured across the fan blades alone being less than 1.45.

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