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(54) **Turbine engine and load reduction device thereof**

(57) A fan rotor apparatus includes: a rotatable fan disk defining a central aperture and carrying an array of airfoil-shaped fan blades around its periphery, the disk having a forward end and an aft end; and an annular,

generally axially-extending forward fan shaft extending through the aperture and coupled to the fan disk for rotation therewith, where the forward fan shaft joins the fan disk at or near the forward end.

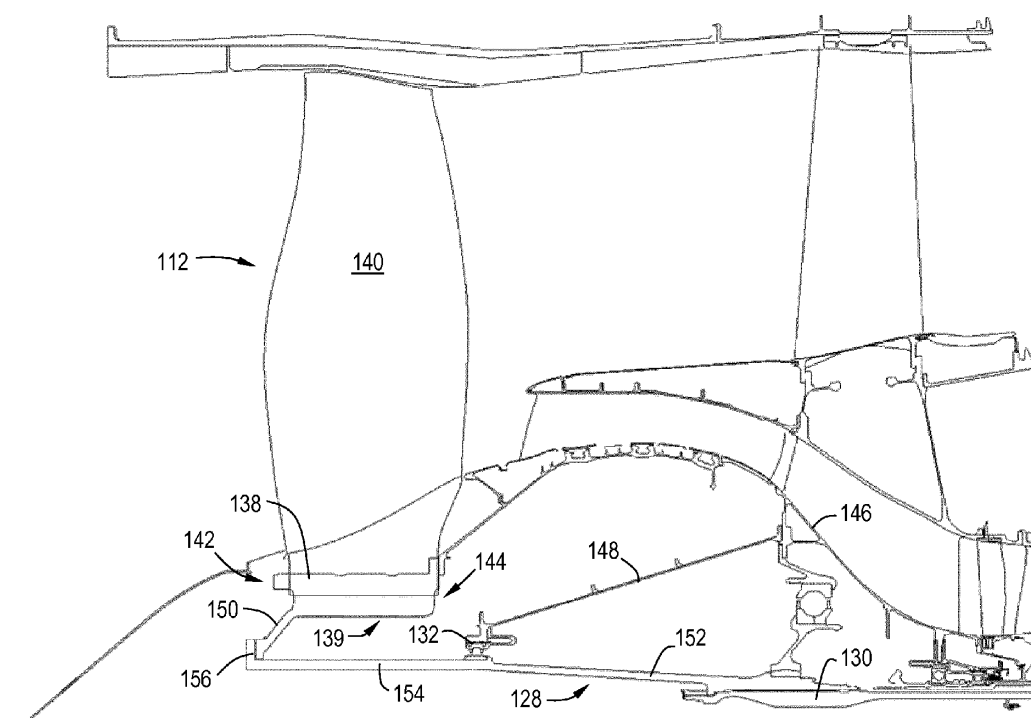


FIG. 2

Description

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to gas turbine engines and more specifically to bearing assemblies and load reduction devices for gas turbine engines.

[0002] A gas turbine engine includes a turbomachinery core having a high pressure compressor, combustor, and high pressure turbine in serial flow relationship. The core is operable in a known manner to generate a primary flow of propulsive gas. A typical turbofan engine adds a low pressure turbine driven by the core exhaust gases which in turn drives a fan rotor through a shaft to generate a bypass flow of propulsive gas. In the case of a high bypass engine this provides the majority of the total engine thrust.

[0003] The fan rotor includes a fan that includes an array of fan blades extending radially outward from a fan disk. The fan shaft transfers power and rotary motion from the low pressure turbine to the fan disk and is supported in several rolling-element bearing assemblies spaced along its length. The bearings are commonly referred to as no. 1, no. 2, and no. 5 bearings, identifying their sequential position in the engine.

[0004] During operation of the engine, a fragment of a fan blade may become separated from the remainder of the blade as a result of impact with a foreign object. Accordingly, a substantial rotary unbalance load may be created within the damaged fan and carried by the bearings, bearing supports, and the fan support frames.

[0005] To minimize the effects of potentially damaging abnormal imbalance loads, known engines include support components for the fan rotor support system that are sized to provide additional strength for the fan support system. However, increasing the strength of the support components undesirably increases an overall weight of the engine and decreases an overall efficiency of the engine when the engine is operated without substantial rotor imbalances.

[0006] Other known engines include a bearing support that includes a mechanically weakened section, or primary fuse, that decouples the fan rotor from the fan support system. During such events, the fan shaft seeks a new center of rotation that approximates that of its unbalanced center of gravity. This fuse section, in combination with a rotor clearance allowance, is referred to as a load reduction device, or "LRD". The LRD reduces the rotating dynamic loads to the fan support system.

[0007] For the LRD to operate successfully, it is often desirable to have a specific ratio of the axial distance from the fan disk to the #5 bearing, divided by the axial distance from the #2 bearing to the #5 bearing. However, newer engine designs with long cores and short forward overhangs do not provide sufficient axial length for this configuration.

[0008] Accordingly, there is a need for a fan rotor load reduction device which is effective in a limited axial

space.

BRIEF DESCRIPTION OF THE INVENTION

[0009] These and other shortcomings of the prior art are addressed by the present invention, which provides a forward fan shaft with increased flexibility in a given space.

[0010] According to one aspect, the invention provides a fan rotor apparatus including: a rotatable fan disk defining a central aperture and carrying an array of airfoil-shaped fan blades around its periphery, the disk having a forward end and an aft end; an annular, generally axially-extending forward fan shaft extending through the aperture and coupled to the fan disk for rotation therewith, where the forward fan shaft joins the fan disk at or near the forward end.

[0011] According to another aspect of the invention, a turbofan engine includes: a turbomachinery core operable to produce a flow of pressurized combustion gases; a turbine disposed aft of the core; a rotatable fan disk mounted forward of the core, the fan disk defining a central aperture and carrying an array of airfoil-shaped fan blades around its periphery, the disk having a forward end and an aft end; and an annular, generally axially-extending forward fan shaft mechanically coupled to the turbine, the forward fan shaft extending through the aperture and coupled to the fan disk for rotation therewith, where the forward fan shaft joins the fan disk at or near the forward end.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The invention may be best understood by reference to the following description taken in conjunction with the accompanying drawing figures in which:

FIG. 1 is a schematic cross-sectional view of a prior art gas turbine engine;

FIG. 2 is an enlarged view of a portion of a gas turbine engine incorporating a load reduction device constructed according to an aspect of the present invention of ; and

FIG. 3 is a cross-sectional view of a portion of a gas turbine engine showing an alternative load reduction device.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Referring to the drawings wherein identical reference numerals denote the same elements throughout the various views, FIG. 1 schematically depicts a prior art gas turbine engine 10. The engine 10 has a longitudinal axis 11 and includes a fan 12, a low pressure compressor or "booster" 14 and a low pressure turbine ("LPT") 16 collectively referred to as a "low pressure sys-

tem". The LPT 16 drives the fan 12 and booster 14 through an inner shaft 18, also referred to as an "LP shaft". The engine 10 also includes a high pressure compressor ("HPC") 20, a combustor 22, and a high pressure turbine ("HPT") 24, collectively referred to as a "gas generator" or "core". Together, the high and low pressure systems are operable in a known manner to generate a primary or core flow as well as a fan flow or bypass flow. While the illustrated engine 10 is a high-bypass turbofan engine, the principles described herein are equally applicable to other types of turbine engines.

[0014] The inner shaft 18 comprises a forward fan shaft 28 and a rear fan shaft 30 coupled together and mounted for rotation in several rolling-element bearings. The forward fan shaft 28 is carried by a first bearing 32 (commonly referred to as a "no. 1 bearing") and a second bearing 34 (commonly referred to as a "no. 2 bearing"). The rear fan shaft 30 is carried by a bearing 36 (commonly referred to as a "#5 bearing").

[0015] The fan 12 of the engine 10 shown in FIG. 1 is coupled to the forward fan shaft 28 in accordance with prior art principles. In contrast, FIG. 2 illustrates a fan 112 and surrounding structure which are constructed according to an aspect of the present invention, and which may be incorporated in the engine 10. The fan 112 comprises a fan disk 138 with a central aperture 139. The fan disk 138 has an annular array of airfoil-shaped fan blades 140 mounted around its periphery. The fan disk 138 has a forward end 142 and an aft end 144. An annular disk arm 150 extends at an angle axially forward and radially inward from the forward end 142 of the disk 138. A forward fan shaft 128 extends between the fan disk 138 and a rear fan shaft 130, and is coupled to the rear fan shaft 130 for rotation therewith, for example by a bolted joint or a splined connection. The forward fan shaft 128 comprises part of a load reduction device.

[0016] A no. 1 bearing 132 is mounted to a surrounding structural support frame 146 by an annular, generally axially-extending fuse 148. In accordance with known principles, the size, material, and mechanical design of the fuse 148 is selected to fail at a predetermined radial load, such as a load that might occur after separation of a fan blade 140. Failure of the fuse 148 allows the fan disk 138 to rotate about a new axis of rotation without imposing excessive radial loads on the surrounding structure. Other types of fuse structures are known, such as bolted joints or fuse pins designed to fail in tension or in shear, or collapsible member(s) in a frame designed to crush at designated loads. The specific type of fuse structure is not critical to the present invention.

[0017] In contrast with prior art designs, the forward fan shaft 128 extends axially forward past the aft end 144 of the fan disk 138, traversing the longitudinal extent of the fan disk 138, and is coupled to the fan disk 138 at a point at or near the forward end 142 of the fan disk 138. As used herein, the term "coupled to the fan disk at or near the forward end" means that torque is transferred from the forward fan shaft 128 to the fan disk 138 through

a load path passing at or through the disk's forward end. It does not necessarily imply any specific type of mechanical connection between the forward fan shaft 128 and the fan disk 138, or require any specific location of a mechanical joint between the two components. In the example shown in FIG. 2, the forward fan shaft 128 includes a tapered aft portion 152, a generally cylindrical axial portion 154, and a flange 156 which extends radially outward from the forward end of the axial portion 154. The flange 156 is coupled to the disk arm 150 for rotation therewith, for example using a bolted or splined connection. As a result, the forward fan shaft 128 is substantially less stiff in bending than the prior art design shown in FIG. 1).

[0018] The disk arm 150 shown in FIG. 2 could extend axially forward or aft of the forward end 142 of the fan disk 138. The angle and cross-sectional shape of the disk arm 150 may be varied to provide a bending stiffness suitable for each particular application. Also, while the forward fan shaft 128 is shown as being a single integral component, it could be built up from two or more sections joined together, for example using bolted joints.

[0019] FIG. 3 illustrates an alternative fan 212 and surrounding structure, including a frame 246, fuse 248, and bearing 232. A forward fan shaft 228 has a tapered aft portion 252 coupled to a rear fan shaft 230 and a generally cylindrical axial portion 254. An annular fan disk 238 carries fan blades 240 and has a forward end 242 and aft end 244. An annular disk arm 250 extends generally axially forward and radially inward from the forward end 242 of the disk 238. The disk arm 250 has a forward portion 256 which extends forward, then curves backward in a "C"-shape, and an aft portion 258 which extends generally axially aft. The aft portion 258 is coupled to the forward fan shaft 228 for rotation therewith, for example with a bolted or splined joint. The additional arc length of the curved portion of the disk arm 250 provides an opportunity to further increase and tune the flexibility of the forward fan shaft 228. Alternatively, the additional curve and arc length could be incorporated into the forward fan shaft 228 instead of the disk arm 250. Furthermore, any of the fan shafts described herein could be made all or partially integral with the fan disk.

[0020] In operation, the forward fan shaft design described herein permits the fan rotor to safely windmill after a blade release event while limiting the bending loads applied to the core. This can be achieved without the need for any specific engine length or bearing position requirements.

[0021] The foregoing has described load reduction device for a gas turbine engine. While specific embodiments of the present invention have been described, it will be apparent to those skilled in the art that various modifications thereto can be made without departing from the scope of the invention. Accordingly, the foregoing description of the preferred embodiment of the invention and the best mode for practicing the invention are provided for the purpose of illustration only and not for the

purpose of limitation, the invention being defined by the claims.

Claims

1. A fan rotor apparatus comprising:

a rotatable fan disk (138,238) defining a central aperture (139) and carrying an array of airfoil-shaped fan blades (140,240) around its periphery, the disk (138,238) having a forward end (142,242) and an aft end (144,244); and an annular, generally axially-extending forward fan shaft (128,228) extending through the aperture (139) and coupled to the fan disk (138,238) for rotation therewith, where the forward fan shaft (128,228) joins the fan disk (138,238) at or near the forward end (142,242) of the fan disk (138,238).

2. The apparatus of claim 1 wherein a forward end (154,156) of the forward fan shaft (142,242) is disposed axially forward of the forward end (142,242) of the fan disk (138,238).

3. The apparatus of claim 1 wherein the fan disk (138,238) comprises a disk arm (150,250) extending from the forward end (142,242) of the fan disk (138,238), the disk arm (150,250) coupled to the forward fan shaft (128,228).

4. The apparatus of claim 3 wherein the disk arm (250) comprises:

a forward portion (256) having a C-shaped cross-section, and an aft portion (258) extending axially between the forward portion (256) and the forward fan shaft (228).

5. The apparatus of claim 4 wherein a least a part of the forward portion (256) of the disk arm (250) is disposed axially forward of the forward end (242) of the fan disk (238).

6. The apparatus of any preceding claim wherein the forward fan shaft (128,228) is integrally-formed with the fan disk (138,238).

7. The apparatus of any preceding claim wherein:

the forward fan shaft (128,228) is coupled to a rear fan shaft (130,230), the two shafts collectively forming an inner shaft (18); and the inner shaft (18) is mounted for rotation in a plurality of rolling-element bearings (32,34,36,132,232) axially spaced apart along

the inner shaft (18).

8. The apparatus of claim 7 wherein at least one of the bearings is mounted to a structural support frame (146,246) by a fuse (148,248) which is configured to fail at a predetermined radial load.

9. A turbofan engine (10), comprising:

a turbomachinery core (20,22,24) operable to produce a flow of pressurized combustion gases; a turbine (16) disposed aft of the core; and the fan rotor apparatus of any of the preceding claims, wherein the fan disk (138,238) is mounted forward of the core; and the forward fan shaft (128,228) is mechanically coupled to the turbine.

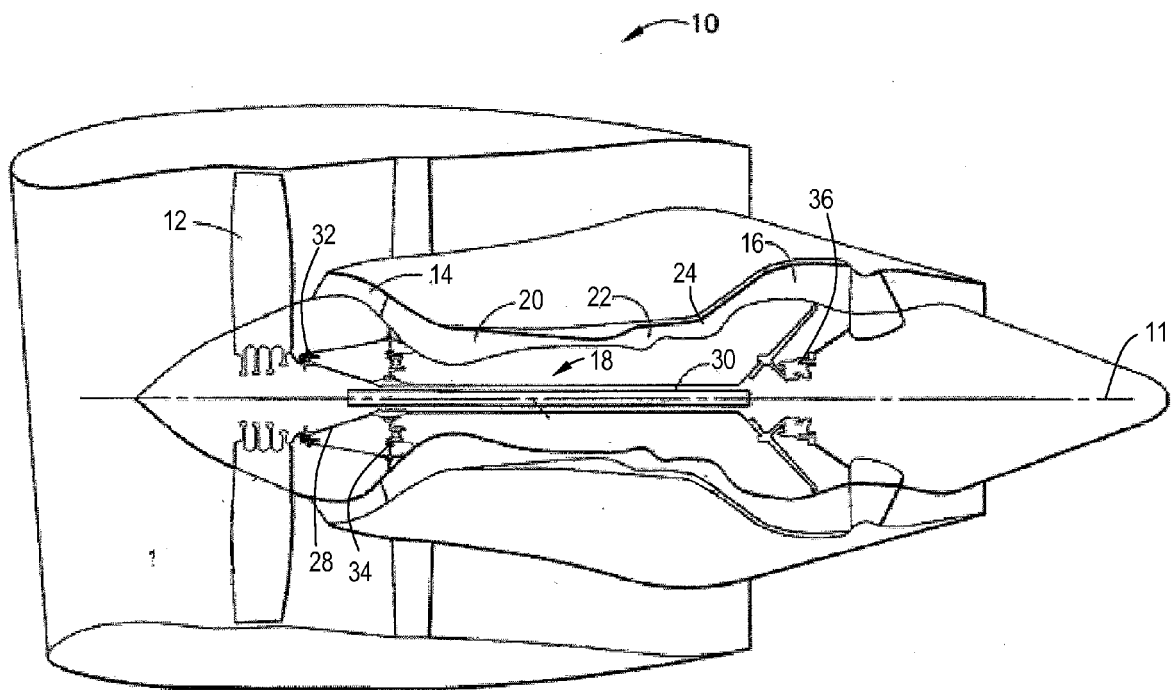


FIG. 1
(PRIOR ART)

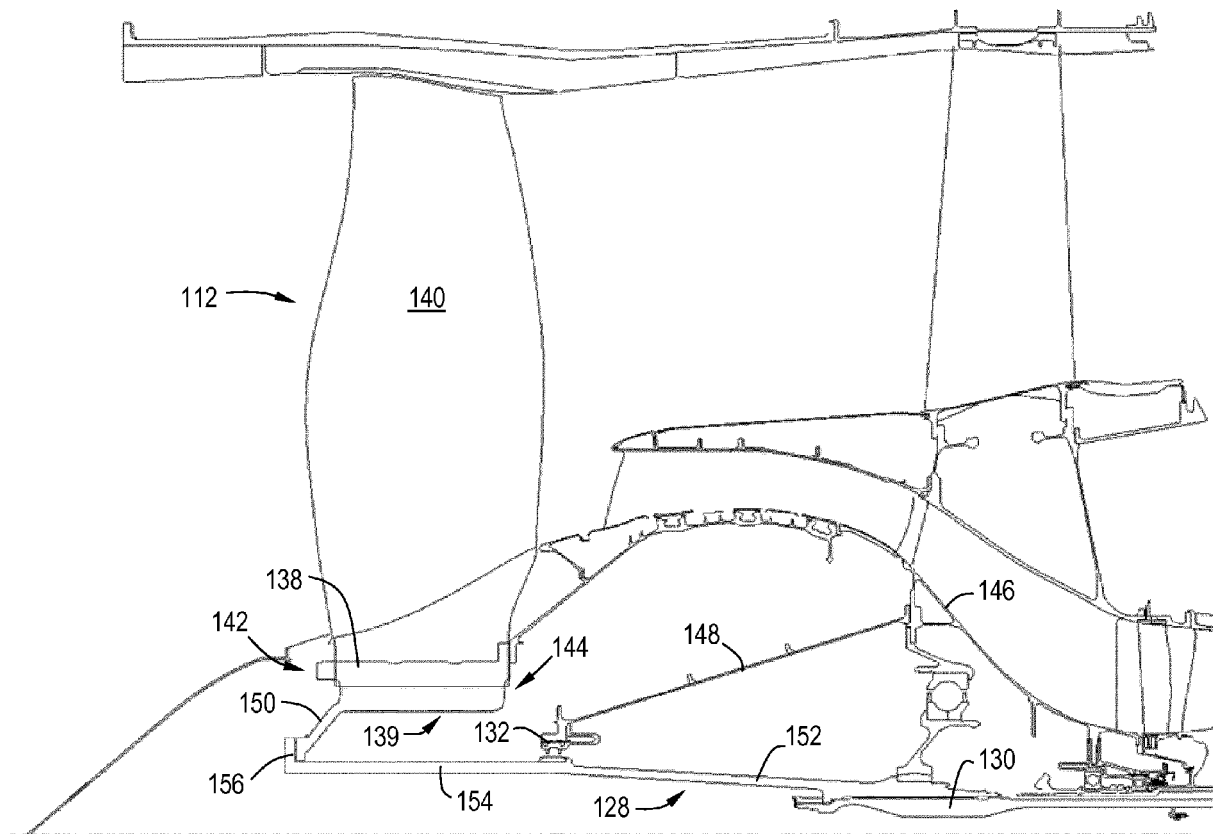


FIG. 2

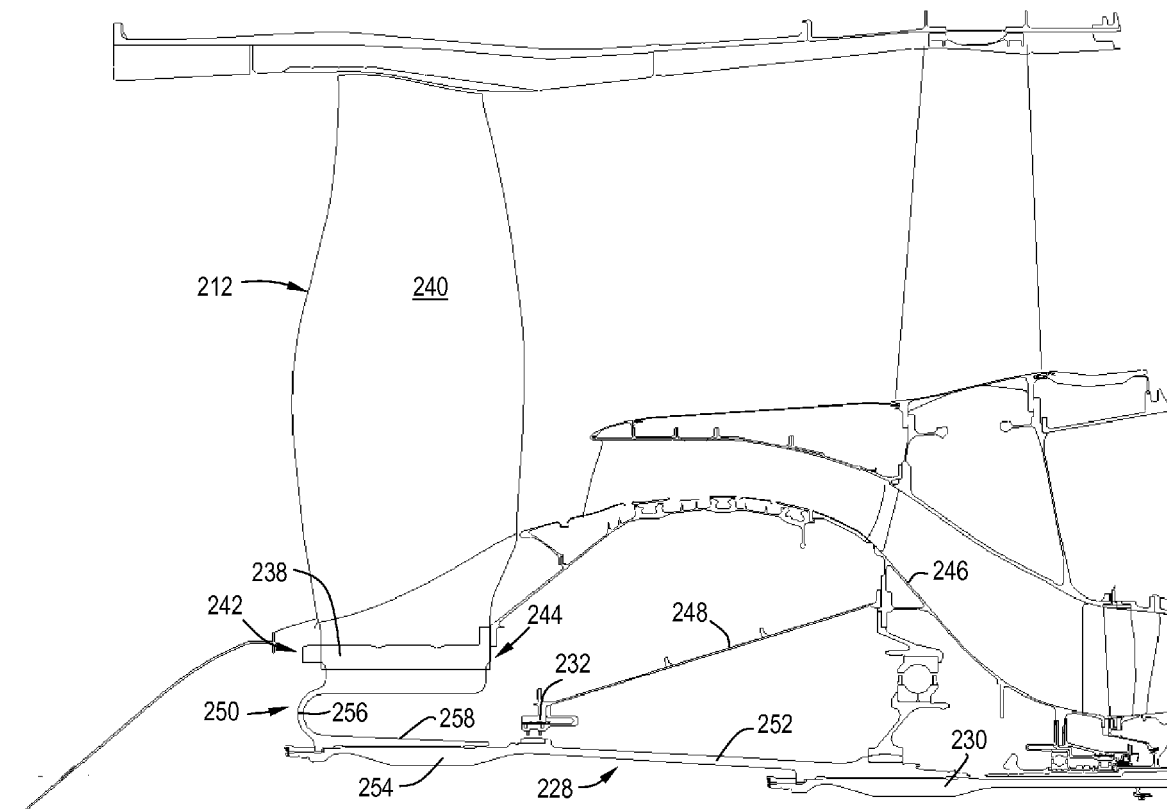


FIG. 3