US010385868B2

(12) United States Patent
King et al.

(10) Patent No.: US 10,385,868 B2
(45) Date of Patent: Aug. 20, 2019

(54) **STRUT ASSEMBLY FOR AN AIRCRAFT ENGINE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 440 days.

(21) Appl. No.: **15/201,934**

(22) Filed: **Jul. 5, 2016**

(65) **Prior Publication Data**

US 2018/0010616 A1 Jan. 11, 2018

(51) **Int. Cl.**

F04D 29/52	(2006.01)
B64D 27/10	(2006.01)
F02C 3/04	(2006.01)
F02K 3/06	(2006.01)
F04D 29/02	(2006.01)
F01D 25/16	(2006.01)
F01D 25/24	(2006.01)
F01D 5/14	(2006.01)
F01D 17/16	(2006.01)

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

CPC ***F04D 29/522*** (2013.01); ***B64D 27/10*** (2013.01); ***F01D 25/162*** (2013.01); ***F01D 25/24*** (2013.01); ***F02C 3/04*** (2013.01); ***F02K 3/06*** (2013.01); ***F04D 29/023*** (2013.01); *F01D 5/146* (2013.01); *F01D 17/162* (2013.01); *F05D 2220/323* (2013.01); *F05D 2220/36* (2013.01); *F05D 2240/35* (2013.01); *F05D 2300/603* (2013.01); *Y02T 50/672* (2013.01)

(58) **Field of Classification Search**

CPC combination set(s) only.
See application file for complete search history.

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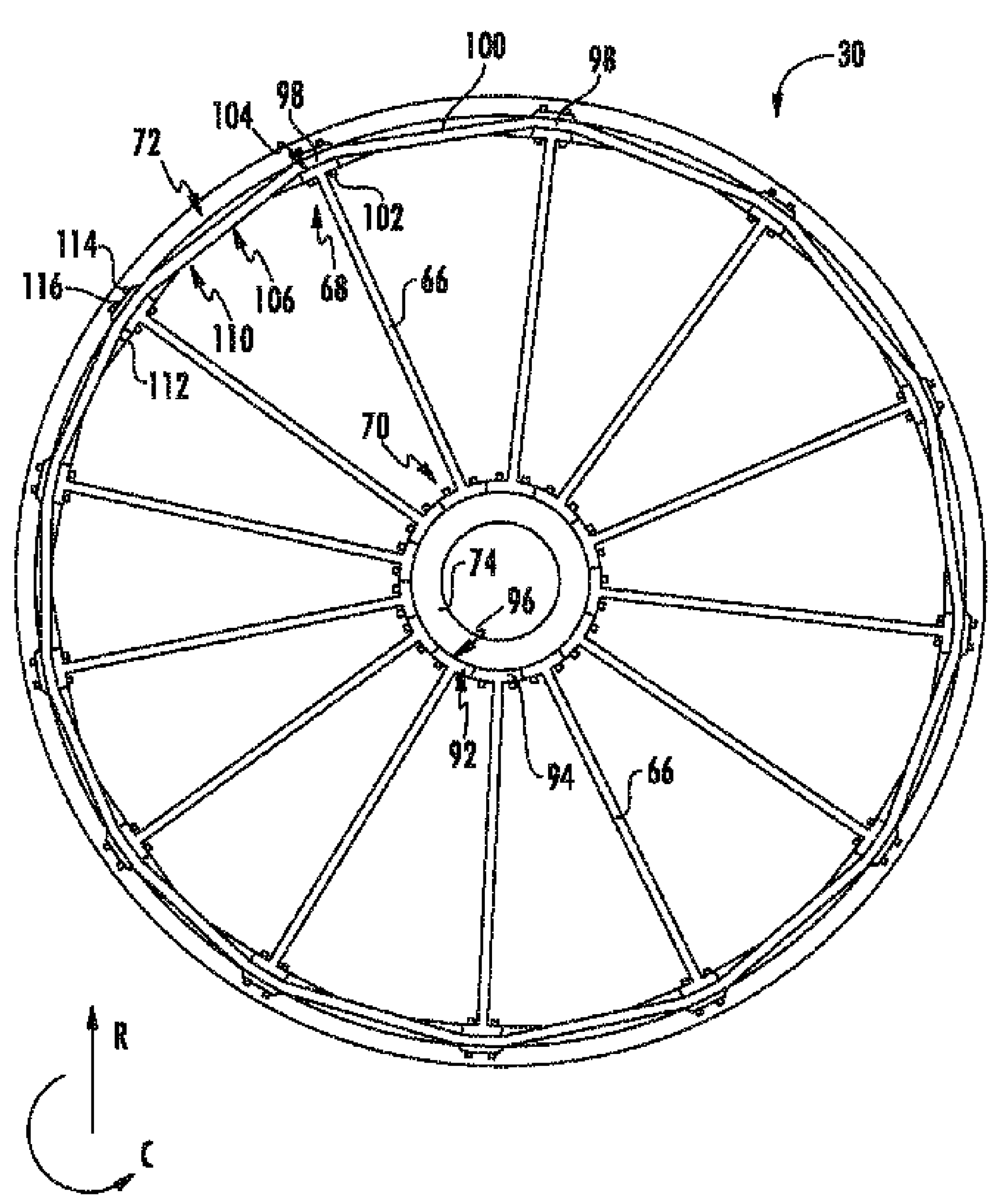
(57) **ABSTRACT**

A strut assembly for a gas turbine engine includes an outer structural case. The outer structural case includes a first mounting pad for mounting a first strut and a second mounting pad for mounting a second strut. The outer structural case further includes a case ligament extending between the first mounting pad and the second mounting pad in a substantially straight direction to reduce an amount of bending stress on the outer structural case.

22 Claims, 6 Drawing Sheets



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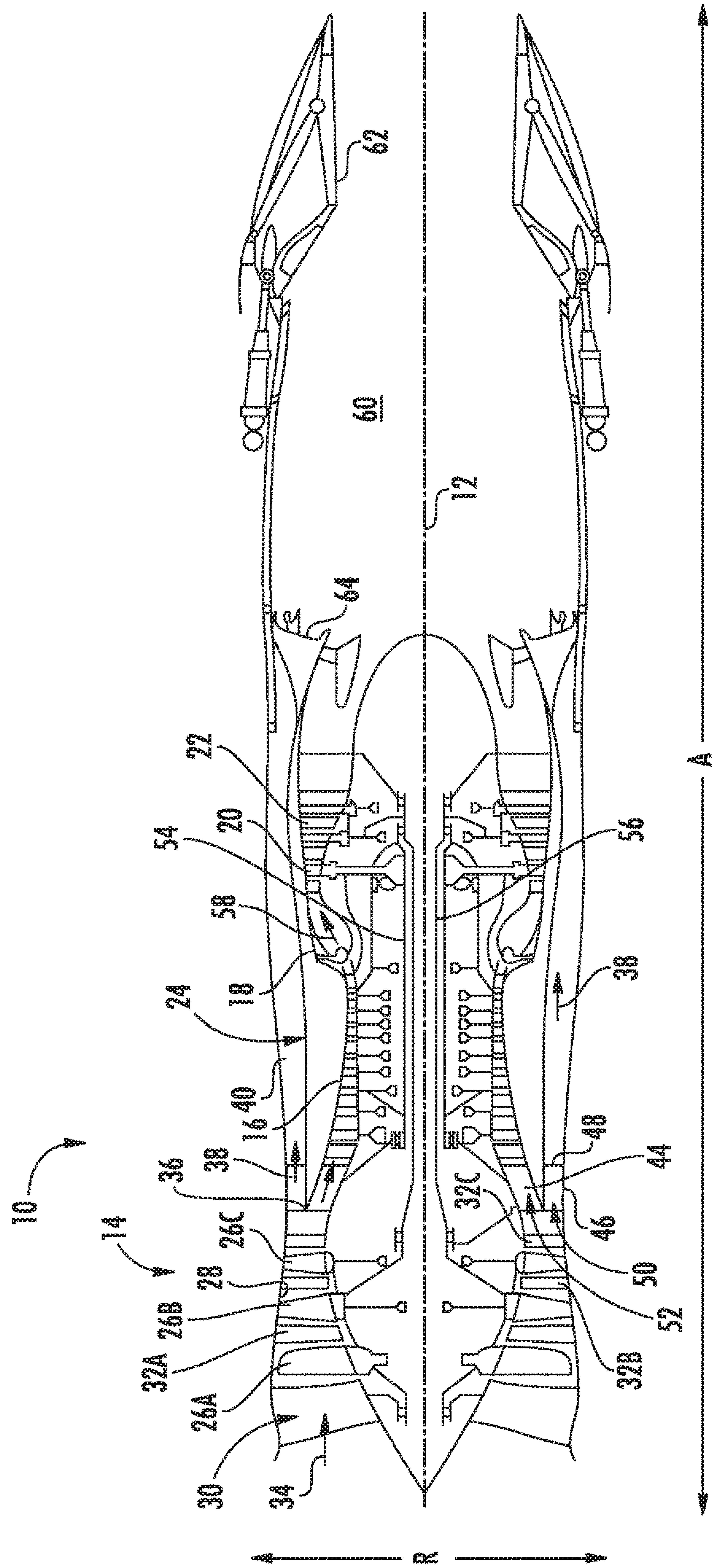
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26A
32A
26B
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26C
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60
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62
A
R
56
38
48
44
46
50
52
32C
32B

FIG. 1

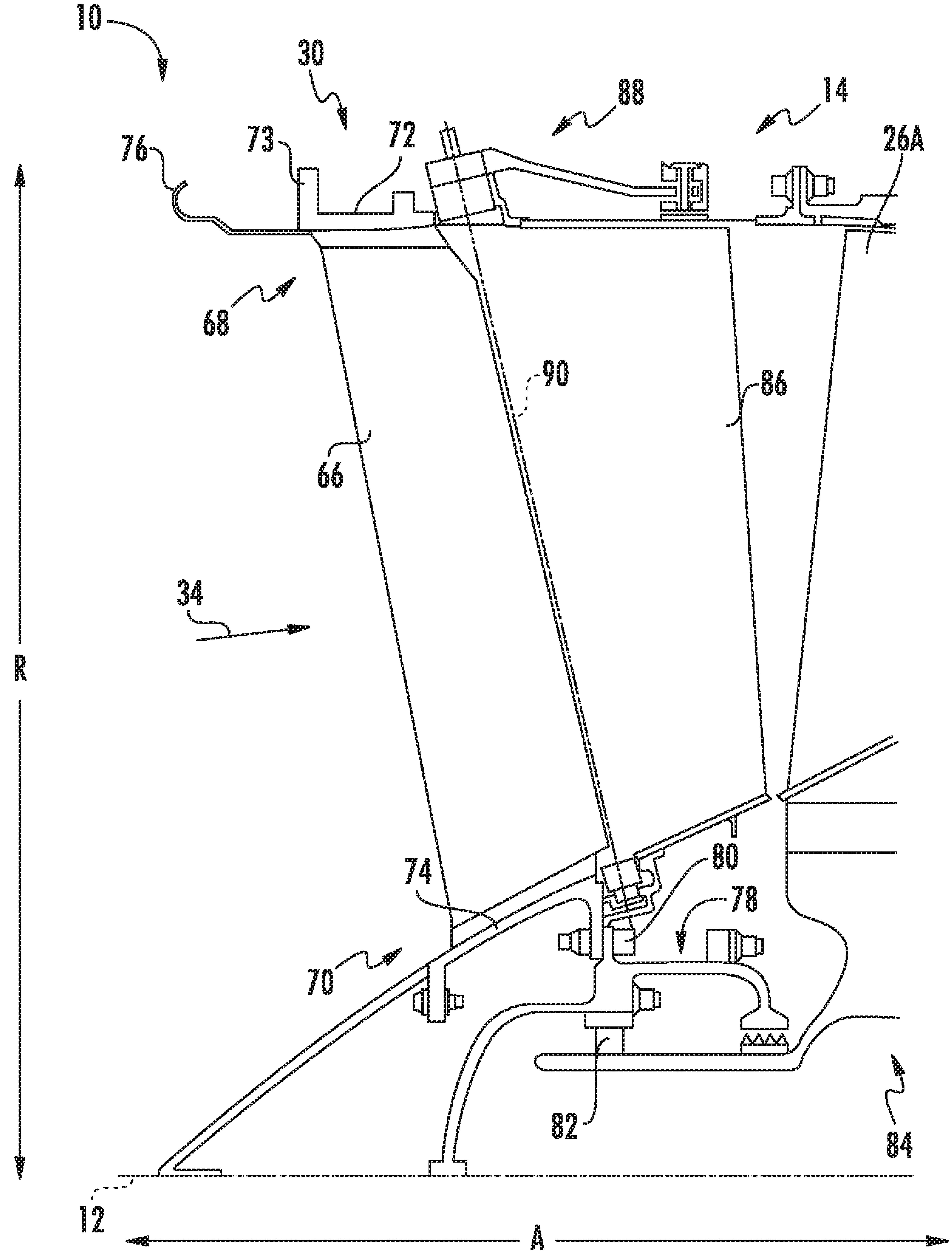
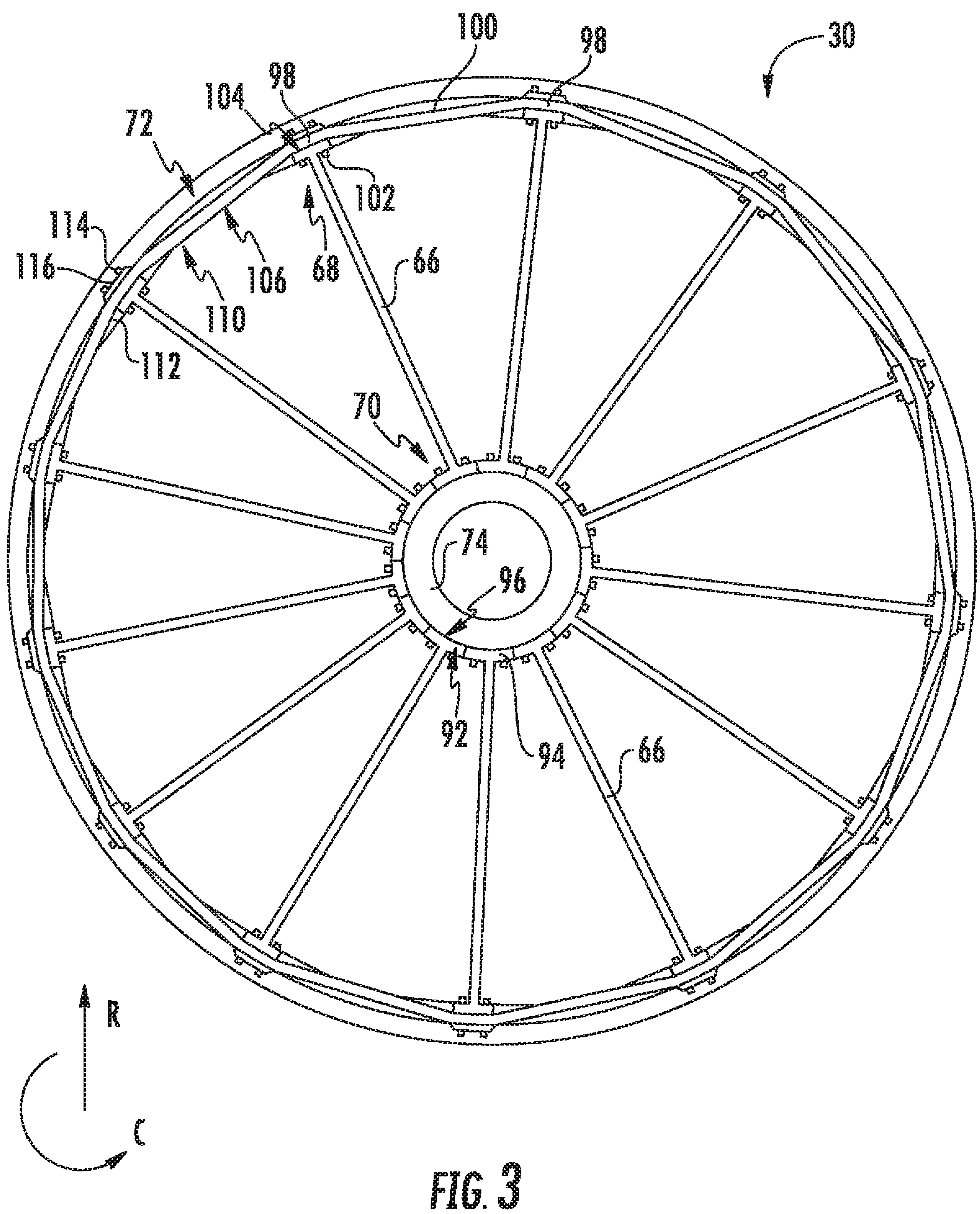


FIG. 2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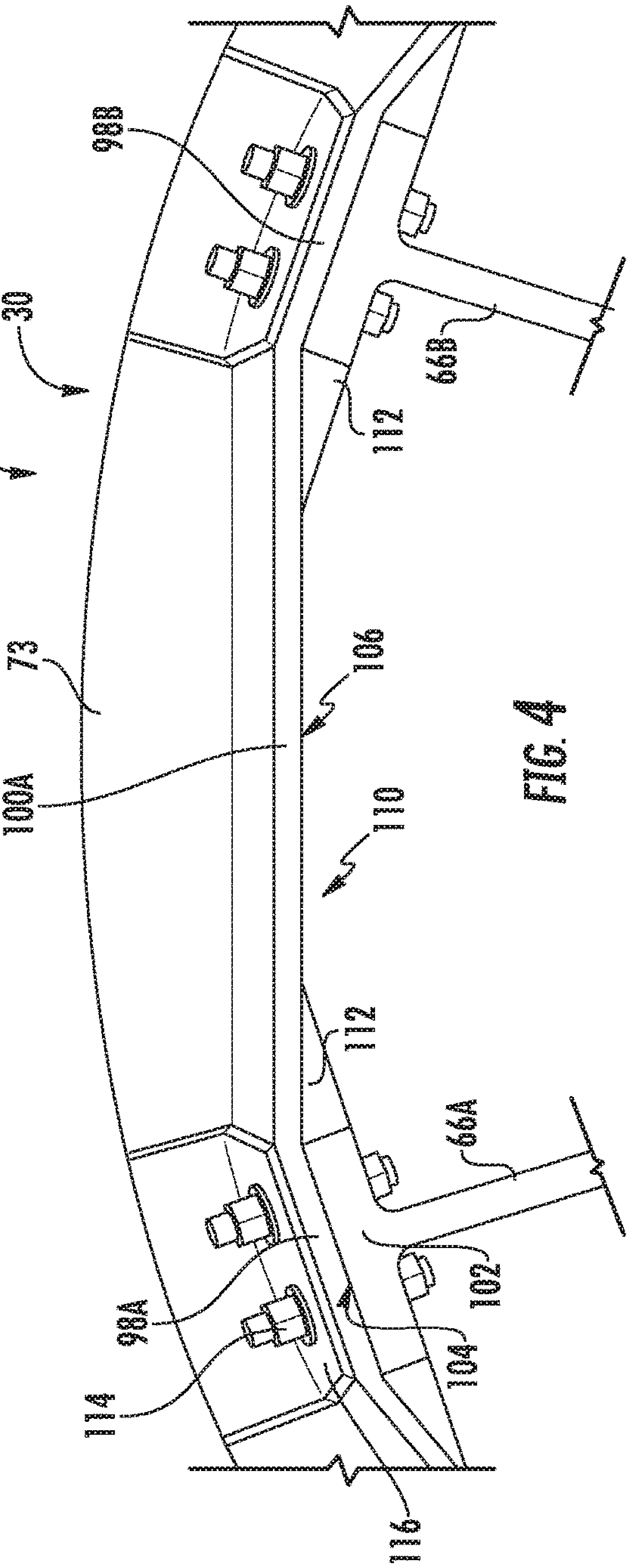
66
R
C

FIG. 3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66A
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98A
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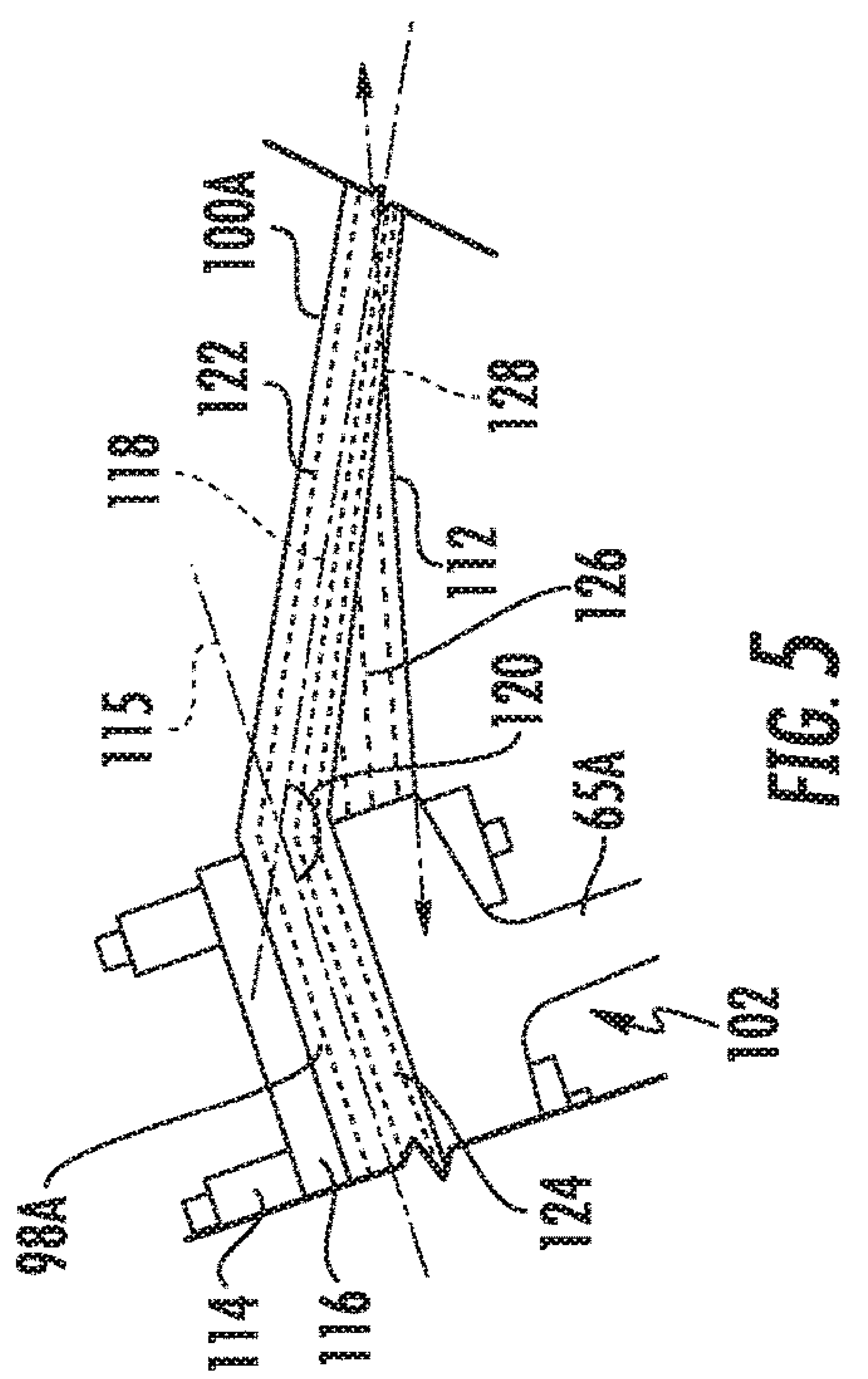
FIG. 4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112
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98A
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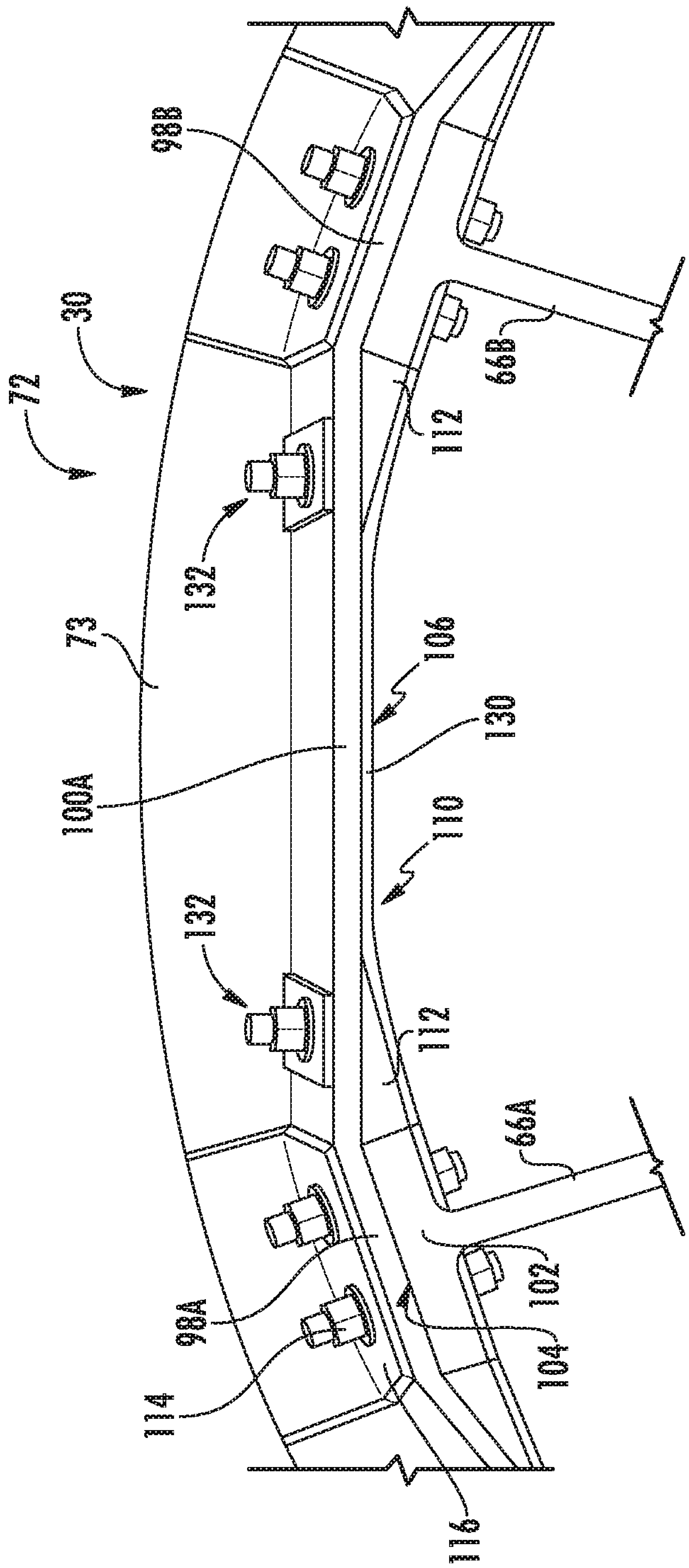
114
116

FIG. 5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100A
110
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112
66A
102
98A
104
114
116

FIG. 6

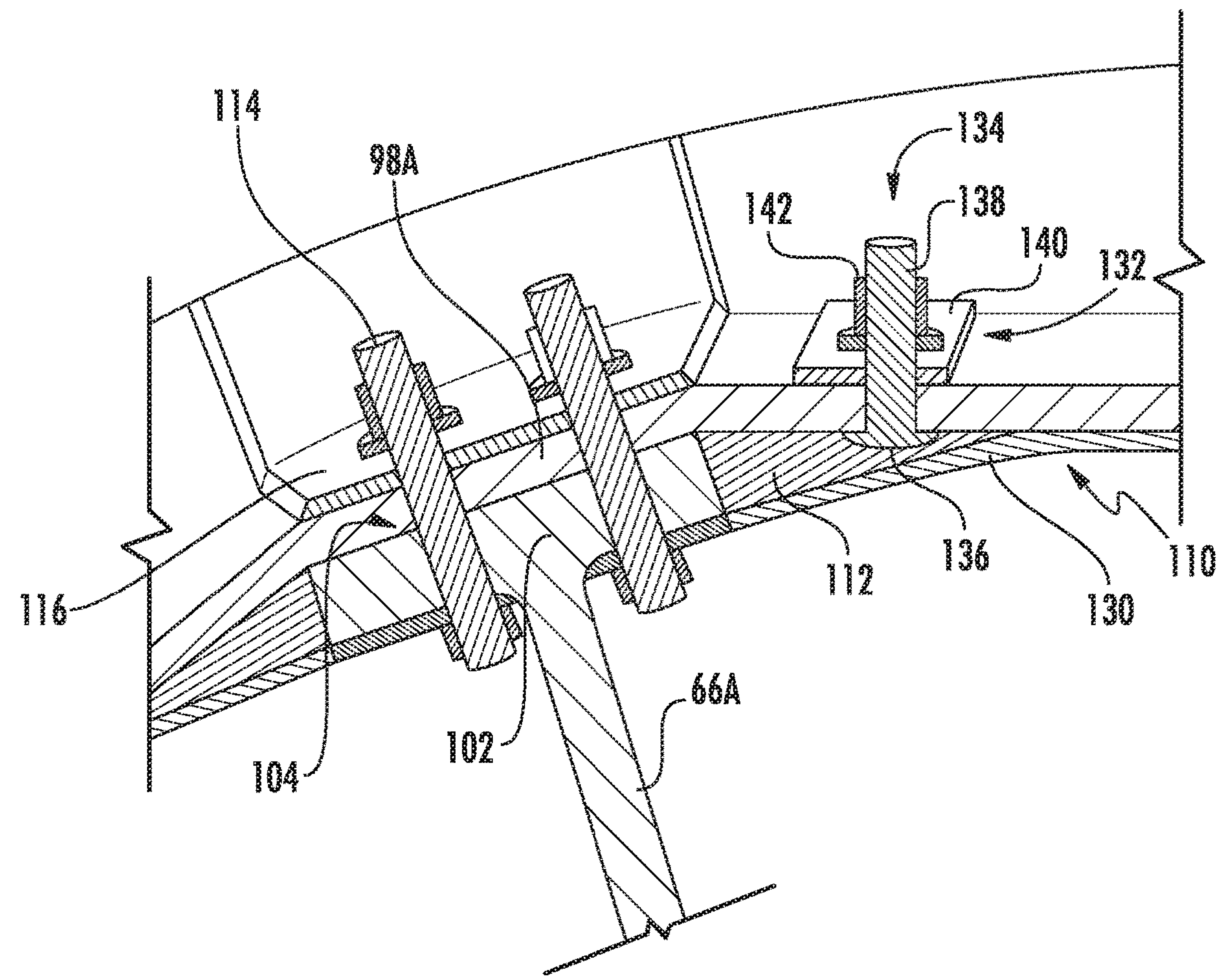

FIG. 7

STRUT ASSEMBLY FOR AN AIRCRAFT ENGINE

FEDERALLY SPONSORED RESEARCH

This invention was made with government support under contract number FA8650-09-D-2922 of the U.S. Air Force. The government may have certain rights in the invention.

FIELD OF THE INVENTION

The present subject matter relates generally to a strut assembly for an aircraft engine.

BACKGROUND OF THE INVENTION

A gas turbine engine includes a fan section and a core engine. The core engine includes serial axial flow relationship, a high pressure compressor to compress an airflow entering the core engine, a combustor in which a mixture of fuel and the compressed air is burned to generate a propulsive gas flow, and a high pressure turbine which is rotated by the propulsive gas flow and which is connected by a shaft to drive the high pressure compressor. A typical bypass turbofan engine adds a low pressure turbine aft of the high pressure turbine which drives a fan of the fan section located forward of the high pressure compressor. A splitter aft of the fan divides fan flow exiting the fan into core engine flow and bypass flow around the core engine.

The fan section includes one or more stages of fan rotor blades and a strut assembly. The strut assembly includes circumferentially spaced struts mounted to a hub at radially inner ends and to an outer case at radially outer ends. The outer case defines a circular shape, such that a circular flowpath surface is defined for a flowpath through the fan section. The case is typically circular in nature in order to withstand relatively high internal pressures. A circular case is known to be well-suited for withstanding these relatively high internal pressures (e.g., a delta pressure load of at least about fifty pounds per square inch).

The strut assembly must be capable of withstanding relatively large forces generated during operation of the gas turbine engine. These forces may include static forces from a weight of the various components of the gas turbine engine, as well as static forces generated during, e.g., in certain maneuvers of an aircraft including the gas turbine engine. Additionally, the strut assembly may be exposed to dynamic forced during, e.g., a fan blade out event, in which case a resulting asymmetrically balanced fan subjects the strut assembly to relatively large dynamic loads. The strut assembly is typically formed in a relatively robust manner in order to withstand the static and dynamic forces. However, such may lead to a relatively heavy strut assembly for the gas turbine engine.

Accordingly, a strut assembly better able to withstand the static and dynamic forces would be useful. Moreover, a strut assembly better able to withstand the static and dynamic forces, while reducing an overall weight of the strut assembly, would be particularly beneficial.

BRIEF DESCRIPTION OF THE INVENTION

Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

In one exemplary embodiment of the present disclosure, a strut assembly is provided for a gas turbine engine. The strut assembly includes an outer structural case. The outer structural case includes a first mounting pad for mounting a first strut, a second mounting pad for mounting a second strut, and a case ligament. The case ligament extends between the first mounting pad and the second mounting pad, the case ligament extending in a substantially straight direction from the first mounting pad to the second mounting pad.

In another exemplary embodiment of the present disclosure, a strut assembly is provided for a gas turbine engine defining a circumferential direction. The strut assembly includes a plurality of struts and an outer structural case. The outer structural case includes a plurality of mounting pads spaced generally along the circumferential direction, each mounting pad having a strut of the plurality of struts mounted thereto. The outer structural case additionally includes a plurality of case ligaments extending between adjacent mounting pads, each case ligament extending in a substantially straight direction between adjacent mounting pads.

In yet another exemplary embodiment of the present disclosure, a gas turbine engine is provided. The gas turbine engine includes a core turbine engine and a fan section in flow communication with the core turbine engine. The fan section includes a strut assembly having an outer structural case. The outer structural case includes a first mounting pad for mounting a first strut, a second mounting pad for mounting a second strut, and a case ligament. The case ligament extends between the first mounting pad and the second mounting pad, the case ligament extending in a substantially straight direction from the first mounting pad to the second mounting pad.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

FIG. **1** is a schematic cross-sectional view of an exemplary gas turbine engine according to various embodiments of the present subject matter.

FIG. **2** is a close-up, schematic, cross-sectional view of a forward strut assembly of the exemplary gas turbine engine of FIG. **1**.

FIG. **3** is an isolated, axial view of the exemplary forward strut assembly of FIG. **2**.

FIG. **4** is a close-up, isometric view of an outer structural frame of the exemplary strut assembly of FIG. **3**.

FIG. **5** is another close-up view of the exemplary strut assembly of FIG. **3** depicting a strut attached to an outer structural case in accordance with an exemplary aspect of the present disclosure.

FIG. **6** is a close-up, isometric view of an outer structural frame of a strut assembly in accordance with another exemplary embodiment.

FIG. **7** is a close-up, cross-sectional view of the exemplary strut assembly of FIG. **6**.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention. As used herein, the terms “first”, “second”, and “third” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms “upstream” and “downstream” refer to the relative direction with respect to fluid flow in a fluid pathway. For example, “upstream” refers to the direction from which the fluid flows, and “downstream” refers to the direction to which the fluid flows.

FIG. **1** is a schematic representation of an aircraft gas turbine engine **10** in accordance with one embodiment of the present disclosure. The gas turbine engine **10** defines an axial direction A, a radial direction R, and a circumferential direction C (i.e., a direction extending about the axial direction A, see FIG. **3**). The gas turbine engine **10** includes an engine centerline **12** extending along the axial direction A depicted in phantom for reference and has, in serial flow relationship, a fan section **14**, a high pressure compressor **16**, a combustion section **18**, a high pressure turbine **20**, and a low pressure turbine **22**. The high pressure compressor **16**, the combustion section **18** and high pressure turbine **20** are often referred to as a core engine **24**.

The fan section **14** is illustrated as a multi-stage fan section having first, second, and third stage fan blades **26**A, **26**B, and **26**C, respectively, disposed within an annular fan duct **28**. The fan section **14** additionally includes a strut assembly supporting at least in part the fan section **14**. Specifically, for the embodiment depicted, the fan section **14** includes a forward strut assembly **30** located forward of the first stage fan blades **26**A. Additionally, disposed adjacent to each of the first, second, and third stage fan blades **26**A, **26**B, and **26**C, the fan section **14** includes stages of guide vanes. Specifically, the exemplary fan section **14** depicted includes first stage guide vanes **32**A located aft of the first stage fan blades **26**A, second stage guide vanes **32**B located aft of the second stage fan blades **26**B, and third stage guide vanes **32**C located aft of the third stage fan blades **26**C. The first, second, and third stage guide vanes **32**A, **32**B, **32**C are each disposed around the engine centerline **12**, along the circumferential direction C. In certain embodiments, the third stage guide vanes **32**C may further be configured as struts.

Fan air **34** exits the fan section **14** and an annular splitter **36** splits the fan air **34** into a bypass air portion **38** bypassed around the core engine **24** through a bypass duct **40** and into a core engine air portion **42** passed through a diffusion duct **44** into the core engine **24**. At the aft end of the fan section **14** is a fan frame **46** including a circumferentially disposed plurality of structural struts **48**. The struts **48** extend radially across a fan bypass inlet **50** of the bypass duct **40** and a core engine inlet **52** of diffusion duct **44**. The splitter **36** is sectioned and attached to the struts **48** and splitter **36** extends axially between the fan bypass inlet **50** and the core engine inlet **52**.

Within the core engine **24**, a high pressure rotor shaft **54** connects, in driving relationship, the high pressure turbine **20** to the high pressure compressor **16** and a low pressure rotor shaft **56** drivingly connects the low pressure turbine **22** to the fan section **14**. Fuel is burned in the combustion section **18** producing a hot gas flow **58** which is directed through the high pressure and low pressure turbines **20** and **22**, respectively, to power the engine **10**. The hot gas flow **58** is discharged into an exhaust section **60** of the engine **10** where it is mixed with the bypass air portion **38** from the bypass duct **40** and exhausted through a variable nozzle **62** at the aft end of the engine **10**. An afterburner **64** may be used for thrust augmentation. The exemplary engine **10** illustrated in FIG. **1** is typical of a military gas turbine aircraft engine **10**, such as the General Electric F-110.

It should be appreciated, however, that the exemplary gas turbine engine **10** depicted in FIG. **1** is provided by way of example only, and in other embodiments of the present disclosure, the gas turbine engine **10** may have any other suitable form or configuration. For example, in other exemplary embodiments, the gas turbine engine **10** may additionally include a low pressure compressor forward of the HP compressor **16** and aft of the fan section **14**. Further, in still other embodiments, the gas turbine engine may instead be configured as any other suitable turbofan engine, a turboshaft engine, a turboprop engine, etc.

Referring now to FIGS. **2** and **3**, views are provided of the fan section **14**, or more particularly, of the forward strut assembly **30** of the fan section **14** of the exemplary engine **10** of FIG. **1**. Specifically, FIG. **2** provides a close-up, side, cross-sectional view of the forward strut assembly **30** of the exemplary fan section **14** depicted in FIG. **1** installed in the engine **10**, and FIG. **3** provides an isolated, axial view of the forward strut assembly **30** of the exemplary fan section **14** depicted in FIG. **1**.

As is depicted most clearly in FIG. **2**, the forward strut assembly **30** supports rotation of the plurality of stages of fan blades **26**A, **26**B, **26**C of the exemplary fan section **14**. More particularly, the forward strut assembly **30** includes a plurality of struts **66** extending generally along the radial direction R, i.e., between an outer end **68** along the radial direction R and an inner end **70** along the radial direction R. The outer ends **68** of each of the plurality of struts **66** are attached to an outer structural case **72** of the forward strut assembly **30** and the inner ends **70** of each of the plurality of struts **66** are attached to an inner hub **74** of the forward strut assembly **30**. The outer structural case **72** of the forward strut assembly **30** is configured for attachment to a frame or nacelle (not depicted) of the engine **10**. Additionally, as is depicted, the outer structural case **72** includes an annular forward flange **73** at a forward end. Notably, the exemplary engine **10** depicted also includes a forward seal member **76** for forming a seal with the frame or nacelle of the engine **10**.

Additionally, the inner hub **74** of the forward strut assembly **30** is attached to a bearing housing **78**. For the embodiment depicted, the inner hub **74** is bolted to the bearing housing **78** through a plurality of bolts **80**. The bearing housing **78** encloses a forward fan bearing **82** for supporting a rotor assembly **84** of the fan section **14**. As discussed above, the rotor assembly **84** of the fan section **14** may be attached to, or may be an extension of, the LP shaft **56** of the engine **10**. In certain embodiments, the forward fan bearing **82** may be configured as a ball bearing, a roller bearing, or any other suitable bearing.

Moreover, each of the plurality of struts **66** of the forward strut assembly **30** are configured with a guide vane **86**. Each of the guide vanes **86** are positioned directly aft of a respective strut **66** and operable with a variable guide vane system **88**. The variable guide vane system **88** is configured to rotate each of the plurality of guide vanes **86** about a guide vane axis **90**, such that the plurality of guide vanes **86** may direct an airflow entering into the fan section **14** over the forward strut assembly **30** in a desired manner.

Referring now particularly to FIG. **3**, the exemplary forward strut assembly **30** includes between thirteen (13) and twenty-one (21) struts **66** spaced along the circumferential direction C. Specifically for the embodiment depicted, the forward strut assembly **30** includes thirteen (13) struts **66**. However, in other embodiments, the forward strut assembly **30** may instead include any other suitable number of struts **66**. In certain embodiments, the plurality of struts **66** may be spaced substantially evenly along the circumferential direction C. However, in other embodiments, the plurality of struts **66** may be asymmetrically spaced along the circumferential direction C.

Further, as is depicted, the inner hub **74** of the forward strut assembly **30** defines a substantially circular shape with a substantially circular mounting surface **92**. Additionally, each of the plurality of struts **66** includes an inner mounting bracket **94** at the inner ends **70**, with each inner mounting bracket **94** including a curved mounting surface **96** matching a curve of the mounting surface **92** of the inner hub **74**. Moreover, the outer structural case **72** of the forward strut assembly **30** includes a plurality of mounting pads **98** and a plurality of case ligaments **100**. Each of the plurality of case ligaments **100** extends between adjacent mounting pads **98**, connecting the adjacent mounting pads **98**. For the embodiment depicted, the plurality of mounting pads **98** and case ligaments **100** are formed integrally of a composite material. For example, in certain embodiments, each of the plurality of mounting pads **98** and case ligaments **100** may be formed of a carbon fiber reinforced composite material. The carbon fiber reinforced composite material may include a plurality of arranged plies or layers, e.g., configured as a unidirectional tape, assembled around a frame. In other embodiments, the composite material may additionally, or alternatively include any other suitable composite material, such as a carbon or glass fiber reinforced composite material, or any suitable weave or braid of tape fiber architecture bonded using an epoxy or resin system (such as a bismalimide (BMI) or polyimide resin system). Additionally, the composite material may be used to form the plurality of mounting pads **98** and case ligaments **100** using a closed-mold strut tooling manufacturing process to provide a relatively high level of control of a final geometry of such components.

Further, the plurality of mounting pads **98** are spaced generally along the circumferential direction C, with each mounting pad **98** having a strut **66** of the plurality of struts **66** mounted thereto. Notably, for the embodiment depicted, the plurality of struts **66** each include an outer mounting flange **102** at the outer end of the respective strut **66**. However, for the embodiment depicted, the mounting pads **98** of the outer structural case **72** extend in a substantially straight direction. Accordingly, the outer mounting flanges **102** of the plurality of struts **66** each include a straight mounting surface **104**. Specifically, for the embodiment depicted, each of the outer mounting flanges **102** of the plurality of struts **66** are configured as a T-shaped flange.

Moreover, as is depicted, each of the plurality of case ligaments **100** extend in a substantially straight direction between adjacent mounting pads **98**. It should be appreciated, that as used herein, the term "substantially straight" with reference to the plurality of case ligaments **100** refers to the particular case ligament **100** defining a radius of curvature greater than at least two times a radial length of one or more of the plurality of struts **66** of the forward strut assembly **30**. Further, the term "substantially straight" may also refer to a case ligament **100** defining a straight neutral axis **118** (i.e., an axis through the ligament **100** where stress is zero; see FIG. **5**) extending in a straight direction between the adjacent mounting pads **98** (between which the case ligament **100** extends).

Notably, as each of the plurality of mounting pads **98** also extend in a substantially straight direction (each defining a straight neutral axis **115** therethrough; see FIG. **5**), each of the plurality of mounting pads **98** defines an angle with an adjacent case ligament **100** attached thereto. For the embodiment depicted, and as will be described in greater detail below, each of the angles defined between the mounting pads **98** and case ligaments **100** is less than one hundred and eighty degrees (180°) and within a ten percent (10%) margin of variation of each other (see FIG. **5**).

Referring still to FIG. **3**, each of the plurality of case ligaments **100** defines an inner surface **106** along the radial direction R. Given that each of the plurality of case ligaments **100** extend in a substantially straight direction between adjacent mounting pads **98**, the radially inner surfaces **106** of the case ligaments **100** together define a non-circular shape as viewed along the axial direction A. As is discussed in greater detail below, in order to allow for the outer structural case **72** to define a flowpath surface **110** (i.e., a radially inner surface of the outer structural case **72** as a whole, defining a flowpath through the fan section **14**) that more closely resembles a circle for aerodynamic purposes, the forward strut assembly **30** further includes a plurality of wedge members **112** positioned along the inner surfaces **106** of the case ligaments **100**, adjacent to the mounting pads **98**. For the embodiment depicted, each of the plurality of wedge members **112** extends less than fifty percent (50%) of a length of the case ligament **100** (i.e., a distance between adjacent mounting pads **98**) adjacent to which it is positioned.

Referring now to FIGS. **4** and **5**, close-up views of the forward strut assembly **30** of FIG. **3** are provided. More particularly, FIG. **4** depicts a close-up view of a first mounting pad **98**A and a second mounting pad **98**B, with a first case ligament **100**A extending therebetween; and FIG. **5** provides a close-up view of the first mounting pad **98**A and the first case ligament **100**A. The first mounting pad **98**A is configured for mounting a first strut **66**A and the second mounting pad **98**B is configured for mounting a second strut **66**B. Specifically, the first and second struts **66**A, **66**B each include an outer mounting flange **102** (i.e., T-shaped flanges). The outer mounting flanges **102** are attached to the first and second mounting pads **98**A, **98**B through a plurality of fasteners, such as bolts and nuts **114**, and mounting brackets **116**. Specifically, the forward strut assembly **30** may include mounting brackets **116** positioned opposite the outer mounting flanges **102** for mounting the struts **66** to the respective mounting pads **98**. The mounting brackets **116** may be separate from the mounting pads **98**, or alternatively may be formed integrally with the mounting pads **98**.

As was discussed above, the first case ligament **100**A, first mounting pad **98**A, and second mounting pad **98**B each extend in substantially straight directions. Additionally, referring particularly to FIG. **5**, the mounting pads **98**A, **98**B define a neutral axis **115** extending therethrough and, similarly, the first case ligament **100**A defines a neutral axis **118** extending therethrough. The first mounting pad **98**A defines an angle **120** with the first case ligament **100**A, with the angle **120** being less than 180°. Notably, the second mounting pad **98**B similarly defines an angle **120** with the first case ligament **100**A (not labeled). The angles **120** defined by the first and second mounting pads **98**A, **98**B with the first case ligament **100**A are substantially the same (i.e., within a 10% margin of variation, based on a circumferential spacing of the struts **66**).

Further, the first and second mounting pads **98**A, **98**B are, for the embodiment depicted, formed integrally with the first case ligament **100**A. Notably, as was also described above, the first mounting pad **98**A, the second mounting pad **98**B, and the first case ligament **100**A are each formed of a continuous, structural composite material. As may be seen most clearly in FIG. **5**, the composite material forming the first case ligament **100**A includes a plurality of substantially aligned fibers **122**. The plurality of substantially aligned fibers **122** extend parallel to the neutral axis **118**, in a first direction from the first mounting pad **98**A to the second mounting pad **98**B. Notably, the composite material forming the first mounting pad **98**A also includes a plurality of substantially aligned fibers **124**, with the plurality of substantially aligned fibers **124** extending parallel to the neutral axis **115**. It should be appreciated, that as used herein, the term "substantially aligned fibers" refers to a component including at least one ply having mostly all (i.e., at least about 75%) of the fibers extending in substantially the same direction. Moreover, as used herein, the term "substantially aligned fibers" does not exclude a component from including one or more "cross-plies", or rather one or more plies with fibers extending generally in a direction perpendicular to the fibers of an adjacent ply to enhance various mechanical properties of the component.

Furthermore, the outer structural case **72** further includes the plurality of wedge members **112** positioned along the inner surfaces **106** of the case ligaments **100**, including the first case ligament **100**A. The plurality of wedge members **112** include wedge members **112** located adjacent to the first mounting pad **98**A and adjacent to the second mounting pad **98**B. Inclusion of the plurality of wedge members **112** may allow for the outer mounting flanges **102** of the plurality of struts **66** to be substantially recessed from a flowpath surface **110** of the fan section **14**. Also, inclusion of the plurality of wedge members **112** may allow for the outer structural case **72** to more closely define a circular flowpath surface **110**, despite utilization of substantially straight case ligaments **100**.

Referring again particularly to FIG. **5**, for the exemplary embodiment depicted the plurality of wedge members **112** are also formed of a composite material. However, the plurality of wedge members **112** are non-structural components, configured such that they do not influence a neutral axis **118** of the case ligaments **100** or a neutral axis **115** the mounting pads **98**. For example, the plurality of wedge members **112** may be formed separately from the plurality of mounting pads **98** and case ligaments **100** and attached to the case ligaments **100** in any suitable manner. Further, the composite material forming the wedge members **112** may be the same as the composite material forming the mounting pads **98** and case ligaments **100**, or alternatively, any other suitable composite material may be utilized. However, for the embodiment depicted, the composite material forming plurality of wedge members **112** also includes a plurality of substantially aligned fibers **126**, with the substantially aligned fibers **126** extending in a second direction either parallel to reference line **128** or perpendicular to reference line **128** (i.e., extending along the axial direction of FIG. **2**). As is depicted, the second direction (and the reference line **128**) is not parallel to the first direction (or the neutral axis **118**).

Inclusion of a strut assembly having an outer structural case formed of mounting pads and case ligaments extending in substantially straight directions may allow for the outer structural case to better withstand forces thereon during operation of the gas turbine engine. More specifically, inclusion of substantially straight case ligaments and substantially straight mounting pads may reduce a bending stress on the outer structural case, and may also improve a structural load carrying capability of the outer structural case, while improving weight efficiency. More specifically, still, a strut assembly including a case formed in accordance with one or more aspects of the present disclosure may allow for the case to better handle push and/or pull loads exerted on the case by the plurality of struts, through the mounting pads. For example, a strut assembly including a case formed in accordance with one or more aspects of the present disclosure may allow for the case to handle "punch" loads, such as various dynamic loads, exerted on the case by the plurality of struts.

Further, when forming the outer structural case of the strut assembly of a composite material, inclusion of substantially straight case ligaments and mounting pads may reduce an interlaminar stress on such components.

Referring now to FIGS. **6** and **7**, close-up views of a forward strut assembly **30** in accordance with another exemplary embodiment of the present disclosure are provided. Specifically, FIG. **6** provides a close-up view of a first mounting pad **98**A and a second mounting pad **98**B, with a first case ligament **100**A extending therebetween; and FIG. **7** provides a close-up, cross-sectional view of the first mounting pad **98**A and the first case ligament **100**A.

The exemplary forward strut assembly **30** may be configured in substantially the same manner as the exemplary strut assembly described above with reference to FIGS. **4** and **5**. Accordingly the same numbers refer to the same or similar part. For example, the forward strut assembly **30** includes a first mounting pad **98**A and a second mounting pad **98**B, with a first case ligament **100**A extending therebetween. Each of these components extends in a substantially straight direction and defines a substantially straight neutral axis.

However, for the embodiment depicted, the forward strut assembly **30** additionally includes a cover ply **130** of, e.g., a composite material, extending between adjacent struts **66** or continuously along the circumferential direction C, such that a smoother inner flowpath surface is defined. However, as with the embodiment described above, the plurality of wedge members **112** and cover ply/plies **130** are non-structural components so as to not influence or alter a neutral axis of the case ligaments **100** and/or mounting pads **98**. Notably, by inclusion of a cover ply **130**, the wedge members **112** may be formed of any suitable material capable of filling a void between the cover ply and case ligaments **100**. For example, in certain exemplary embodiments, the wedge members **112** may be formed of a foam material, a honeycomb material, an injection molded plastic material, etc. For example, in certain exemplary embodiments, the wedge members **112** may be formed of a material having a Young's modulus (also known as tensile modulus) less than about one (1) million and/or having a density less than about five (5) pounds per cubic foot.

Moreover, for the exemplary embodiment depicted, the forward strut assembly **30** includes an attachment assembly **132** attached directly to at least one of the case ligament **100** or mounting pad **98**. Specifically, for the embodiment depicted, the forward strut assembly **30** includes an attachment assembly **132** attached directly to the first case ligament **100**A. The attachment assembly **132** generally includes a bolt **134** having a body **136** and a head **138**, with the head **138** positioned on an inside surface of the case ligament **100** and configured, for the embodiment depicted, as a stud grommet. The attachment assembly **130** additionally includes a plate **140** and a nut **142**. The body **136** of the bolt **134** extends through the case ligament **100** and plate **140** and includes a threaded portion that engages with the nut **142**. The plate **140** may be a portion of an engine component, or alternatively, may be a mounting plate for mounting the forward strut assembly **30**.

Further, it should be noted that the head **138** of the bolt **134** is positioned adjacent to (and contacts) the wedge member **112**, which may be, e.g., a foam material, covered by the cover ply **130**. Such a configuration may provide for an additional level of security, as the wedge member **112** and cover ply **130** may prevent the bolt **134** from entering the core air flowpath in the event that the nut **142** detaches. Accordingly, inclusion of a wedge member **112** and cover ply **130** may allow for mounting one or more components through an attachment assembly **132** to one or more case ligaments **100** of the forward case assembly **30** more safely.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A strut assembly for a gas turbine engine, the strut assembly comprising:
- an outer structural case comprising
  - a first mounting pad for mounting a first strut;
  - a second mounting pad for mounting a second strut;
  - a case ligament extending between the first mounting pad and the second mounting pad, the case ligament extending in a substantially straight direction from the first mounting pad to the second mounting pad, the case ligament defining an inside surface; and
  - a plurality of wedge members, the plurality of wedge members including a first wedge member positioned against the inside surface of the case ligament adjacent to the first mounting pad and extending along the inside surface of the case ligament adjacent to the first mounting pad.

2. The strut assembly of claim **1**, wherein the first mounting pad, the second mounting pad, and the case ligament are each formed of a composite material.

3. The strut assembly of claim **1**, wherein the case ligament is formed of a composite material, wherein the composite material forming the case ligament includes a plurality of substantially aligned fibers.

4. The strut assembly of claim **3**, wherein the plurality of substantially aligned fibers extend in a direction from the first mounting pad to the second mounting pad.

5. The strut assembly of claim **1**, wherein the plurality of wedge members further comprises a second wedge member positioned against the inside surface of the case ligament adjacent to the second mounting pad and extending along the inside surface of the case ligament adjacent to the second mounting pad, the first wedge member being separate from the second wedge member.

6. The strut assembly of claim **5**, wherein the plurality of wedge members are non-structural components.

7. The strut assembly of claim **6**, wherein the plurality of wedge members are formed of a composite material, wherein the case ligament is formed of a composite material, wherein the composite material forming the case ligament includes a plurality of substantially aligned fibers extending in a first direction, wherein the composite material forming the wedge members includes a plurality of substantially aligned fibers extending in a second direction, and wherein the first direction is not parallel to the second direction.

8. The strut assembly of claim **6**, wherein the plurality of wedge members are formed of a foam material.

9. The strut assembly of claim **6**, further comprising:
- an attachment assembly including a bolt having a head and a body, wherein the body extends through the case ligament at a location between the first and second mounting pads and wherein the head is positioned adjacent to and contacting the first wedge member.

10. The strut assembly of claim **1**, wherein the first mounting pad extends in a substantially straight direction, wherein the second mounting pad extends in a substantially straight direction, wherein the first mounting pad defines a first angle with the case ligament, wherein the second mounting pad defines a second angle with the case ligament, wherein the first and second angles are less than 180 degrees.

11. The strut assembly of claim **10**, wherein the first angle is substantially equal to the second angle.

12. The strut assembly of claim **1**, wherein the first and second mounting pads are formed integrally with the case ligament.

13. A strut assembly for a gas turbine engine defining a circumferential direction, the strut assembly comprising:
- a plurality of struts; and
- an outer structural case comprising
  - a plurality of mounting pads spaced generally along the circumferential direction, each mounting pad having a strut of the plurality of struts mounted thereto, the plurality of mounting pads including a first mounting pad; and
  - a plurality of case ligaments extending between adjacent mounting pads, each case ligament extending in a substantially straight direction between adjacent mounting pads and defining an inside surface, the plurality of case ligaments including a case ligament; and
  - a plurality of wedge members, the plurality of wedge members including a first wedge member positioned against the inside surface of the case ligament adjacent to the first mounting pad and extending along the inside surface of the case ligament adjacent to the first mounting pad.

14. The strut assembly of claim **13**, wherein the outer structural case is formed of a composite material.

15. The strut assembly of claim **13**, wherein the plurality of case ligaments are formed of a composite material, wherein the composite material forming the case ligaments includes a plurality of substantially aligned fibers.

16. The strut assembly of claim **13**, wherein the plurality of struts each include a T-shaped flange, wherein the plurality of struts are attached to the plurality of mounting pads using the T-shaped flanges.

17. The strut assembly of claim 13, wherein each of the mounting pads extend in a substantially straight direction, wherein each of the mounting pads define an angle with the case ligaments adjacent to the mounting pad, wherein each of the angles defined between the mounting pads and the case ligaments are substantially the same.

18. The strut assembly of claim 13, wherein the plurality of struts includes between thirteen and twenty-one struts.

19. A gas turbine engine comprising:

a core turbine engine; and

a fan section in flow communication with the core turbine engine, the fan section comprising a strut assembly having an outer structural case, the outer structural case comprising

a first mounting pad for mounting a first strut;

a second mounting pad for mounting a second strut; and

a case ligament extending between the first mounting pad and the second mounting pad, the case ligament extending in a substantially straight direction from the first mounting pad to the second mounting pad, the case ligament defining an inside surface; and

a plurality of wedge members, the plurality of wedge members including a first wedge member positioned against the inside surface of the case ligament adjacent to the first mounting pad and extending along the inside surface of the case ligament adjacent to the first mounting pad.

20. The gas turbine engine of claim 19, wherein the case ligament is formed of a composite material, wherein the composite material forming the case ligament includes a plurality of substantially aligned fibers extending in a direction from the first mounting pad to the second mounting pad.

21. The gas turbine engine of claim 19, wherein the strut assembly is a forward strut assembly of the fan section.

22. The strut assembly of claim 13, wherein the plurality of struts includes a first strut, wherein the first mounting pad includes a first strut of the plurality of struts mounted thereto, wherein the first wedge member extends between a first end and a second end, and wherein the first end contacts the inner surface of the case ligament and the first strut.

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