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(54) METHODS AND APPARATUS FOR MOUNTING A GAS TURBINE ENGINE TO A PYLON

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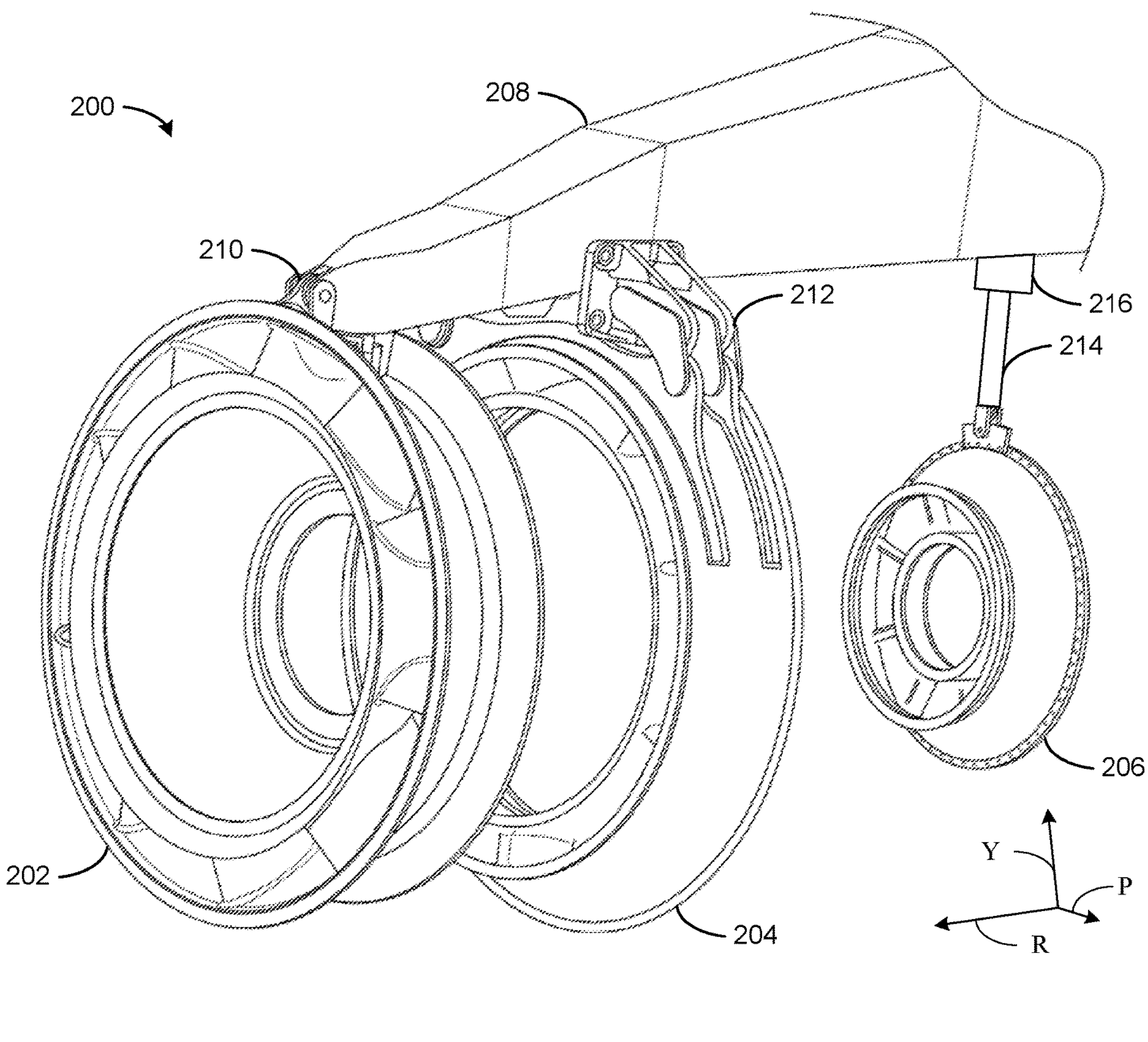
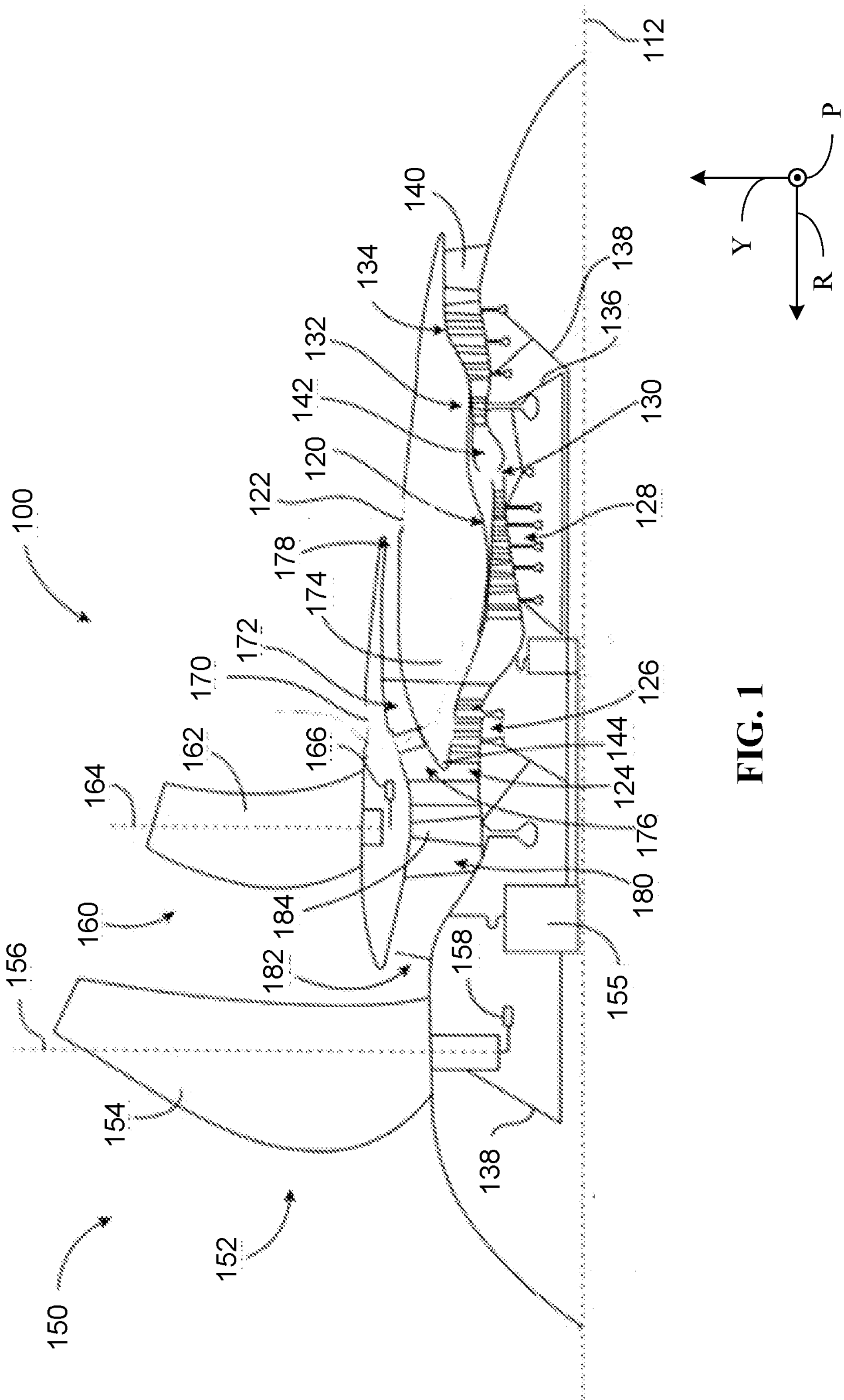
CPC ***B64D 27/402*** (2024.01); ***B64D 27/406*** (2024.01)

(57) **ABSTRACT**

Systems, apparatus, articles of manufacture, and methods for mounting a gas turbine engine to a pylon are disclosed. An example gas turbine engine disclosed herein a first mount, a first frame portion to be coupled to a pylon via the first mount, a second frame portion coupled to the first frame portion such that second frame portion is cantilevered from the first frame portion, and a second mount to couple the second frame portion to the pylon, the second mount defining a load path between the pylon and the second frame portion, the second mount including an elastic element disposed in the load path.

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P

FIG. 1

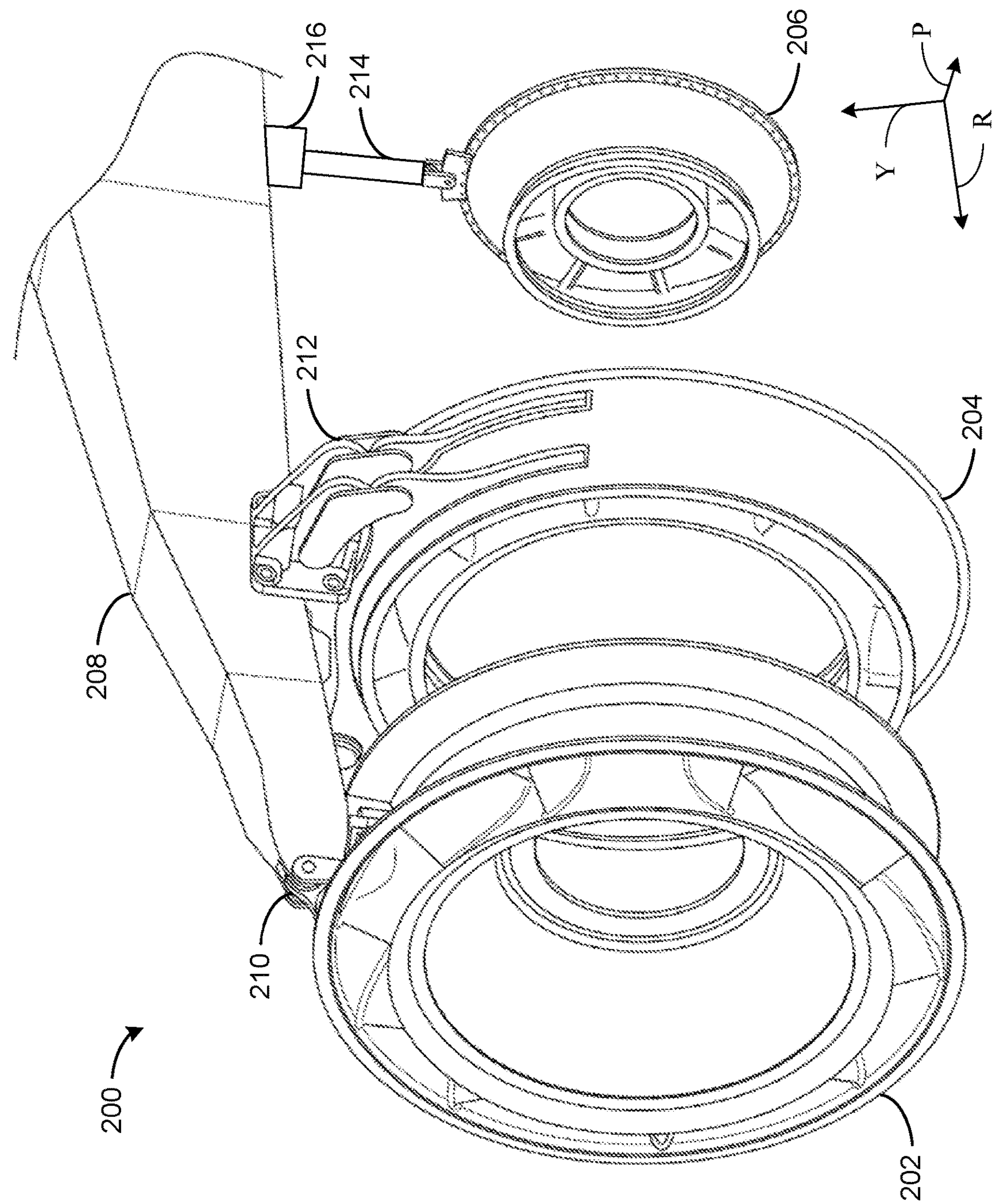
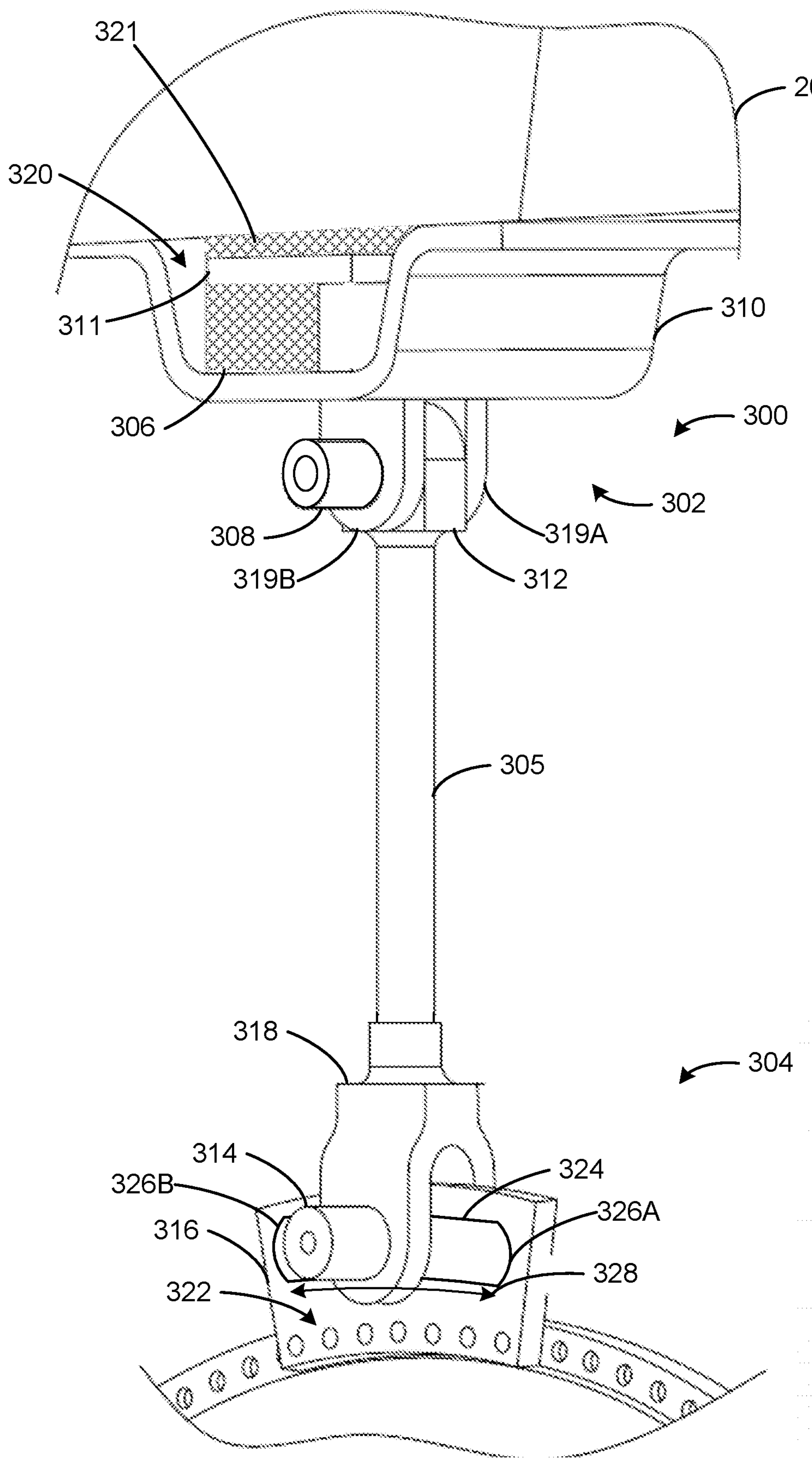


FIG. 2


321
208
320
310
311
306
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302
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319A
319B
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305
318
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324
326B
326A
316
328
322

FIG. 3

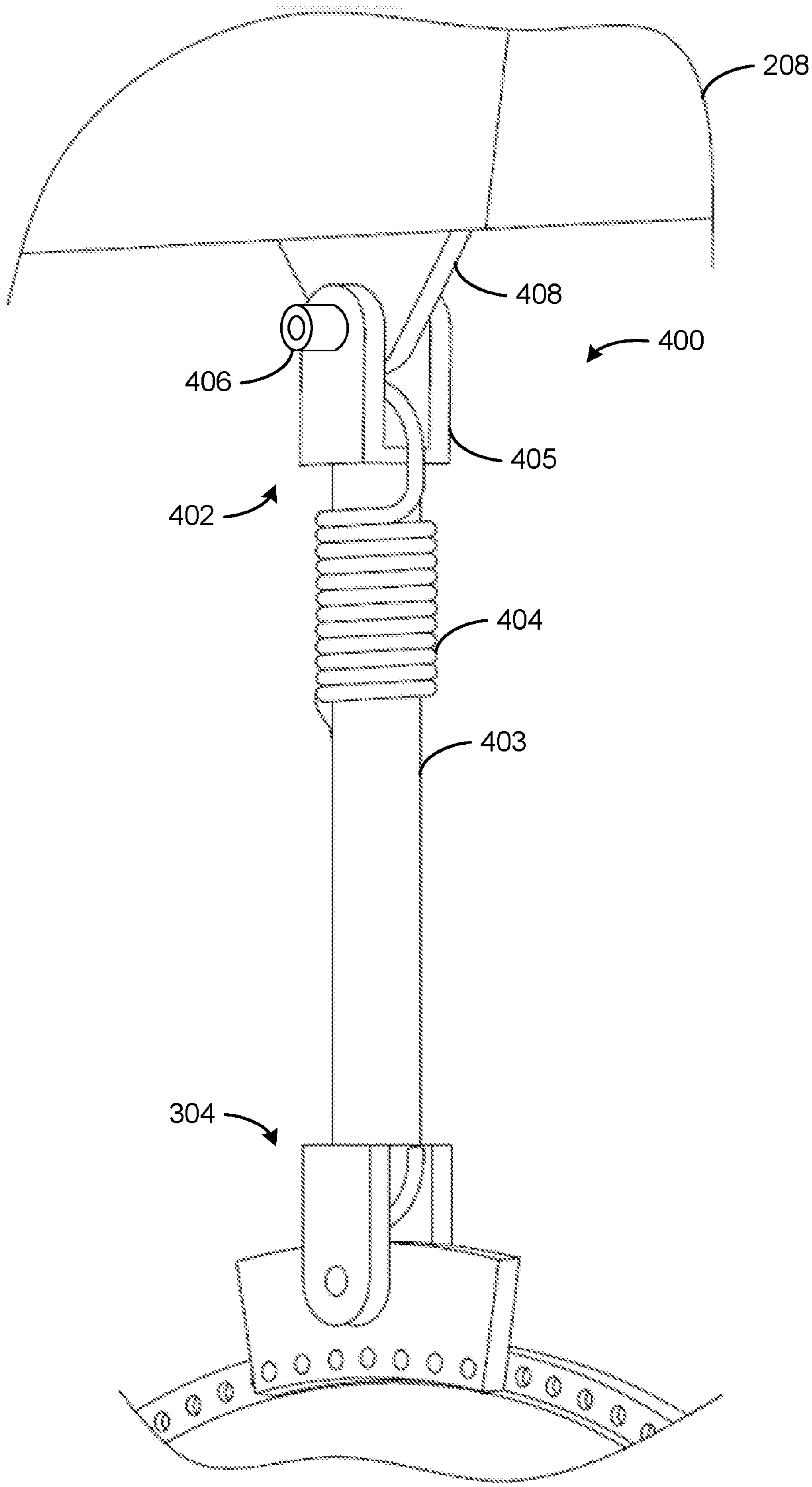


FIG. 4

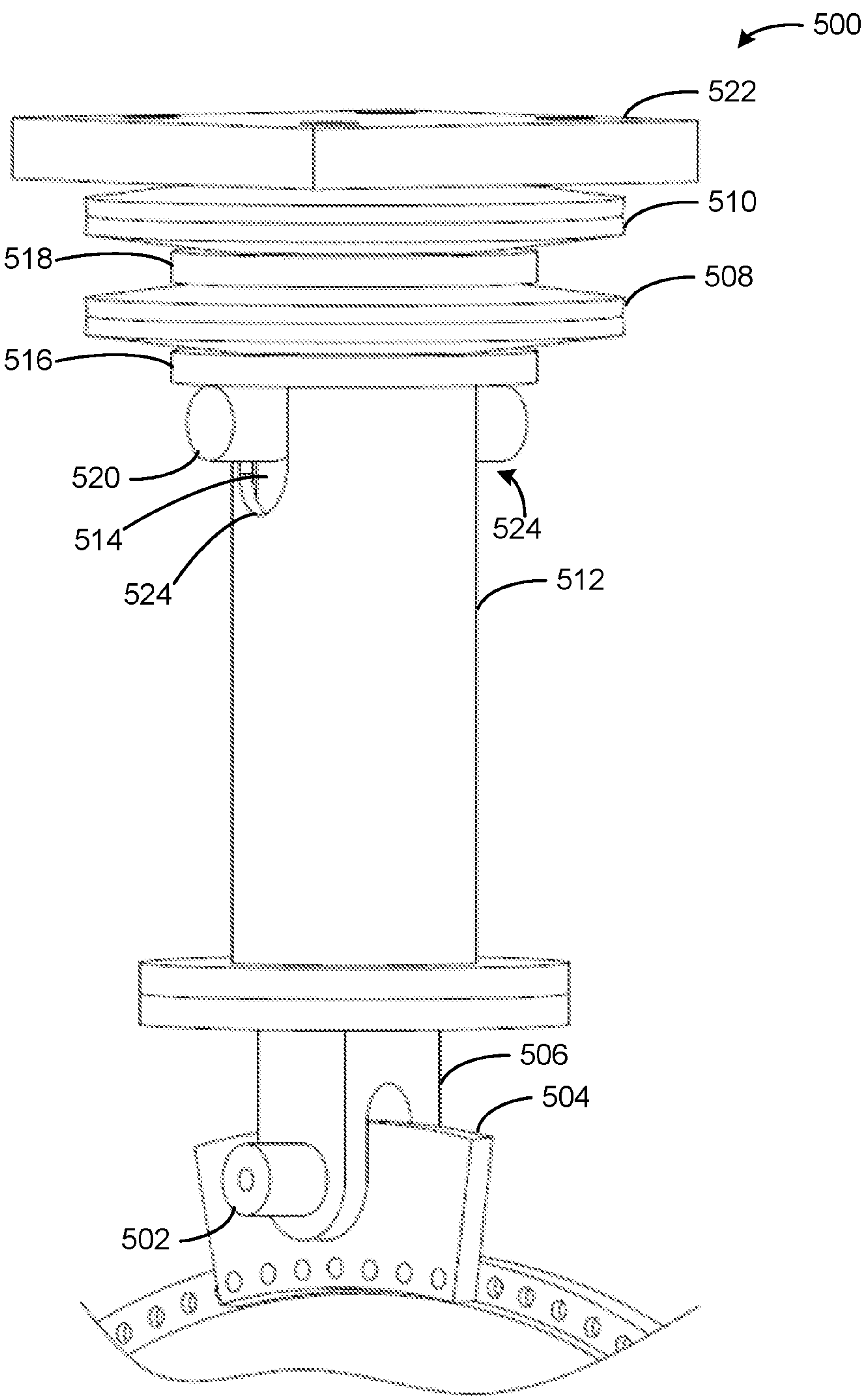
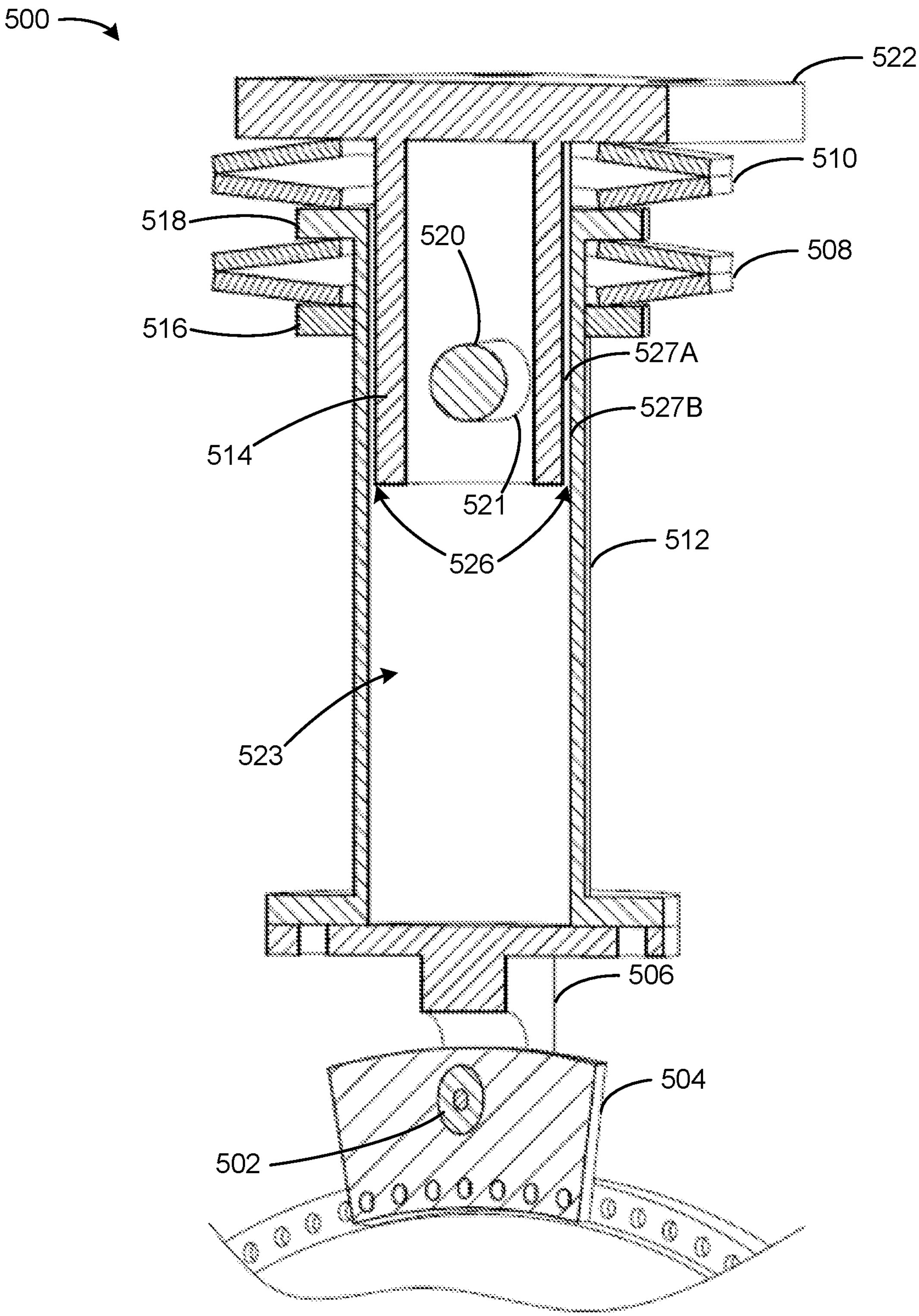


FIG. 5A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527A
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527B
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502

FIG. 5B

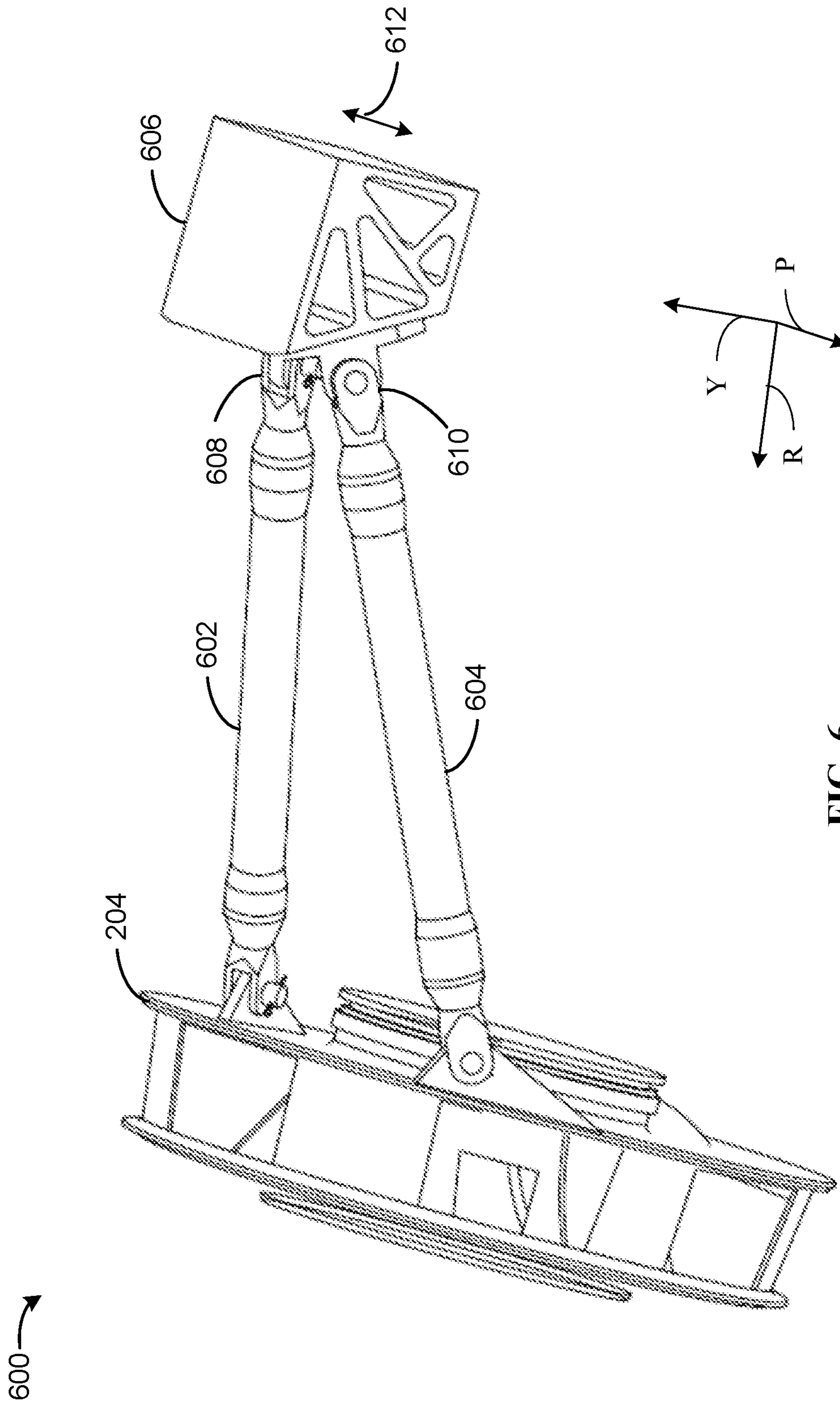


FIG. 6

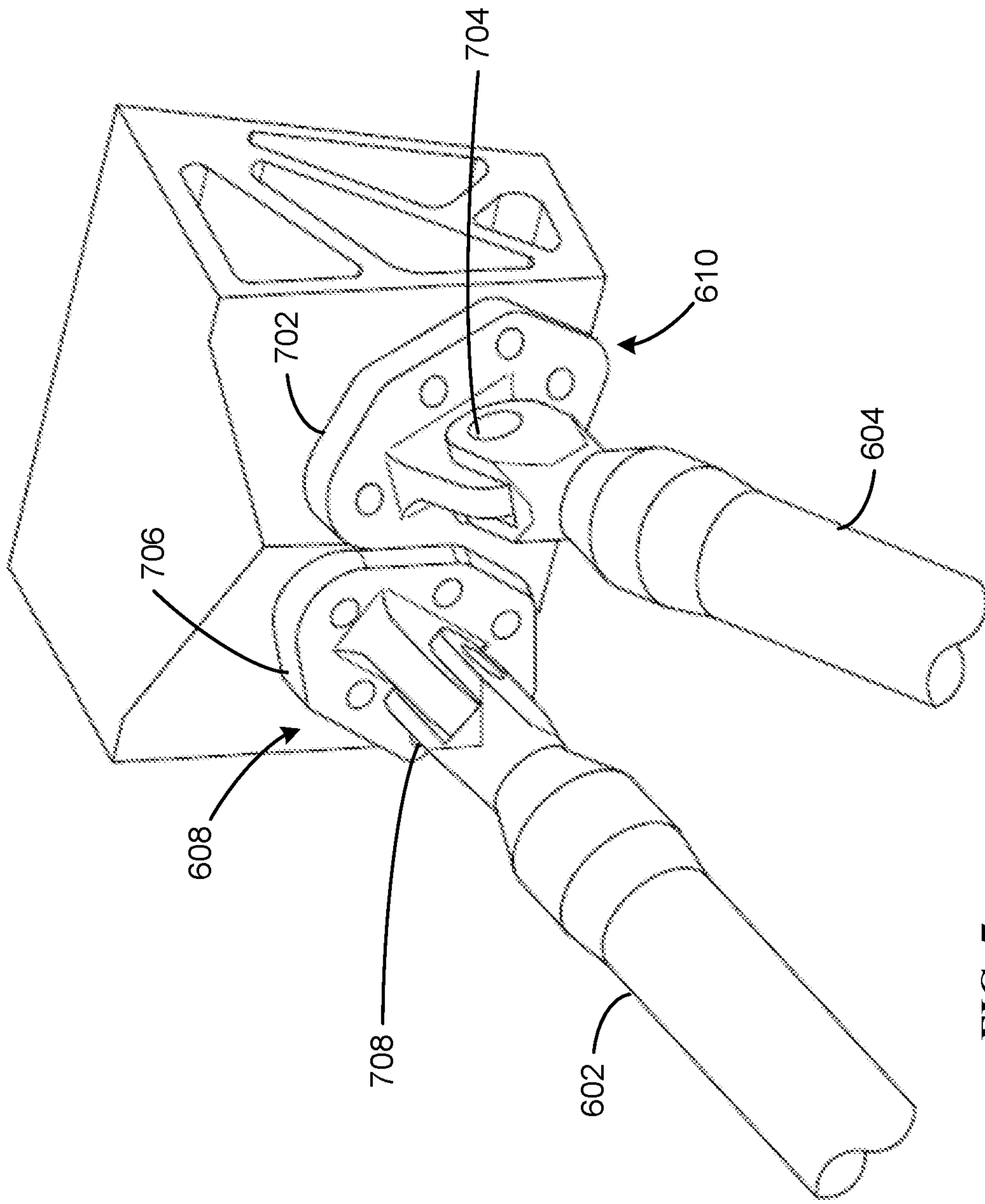
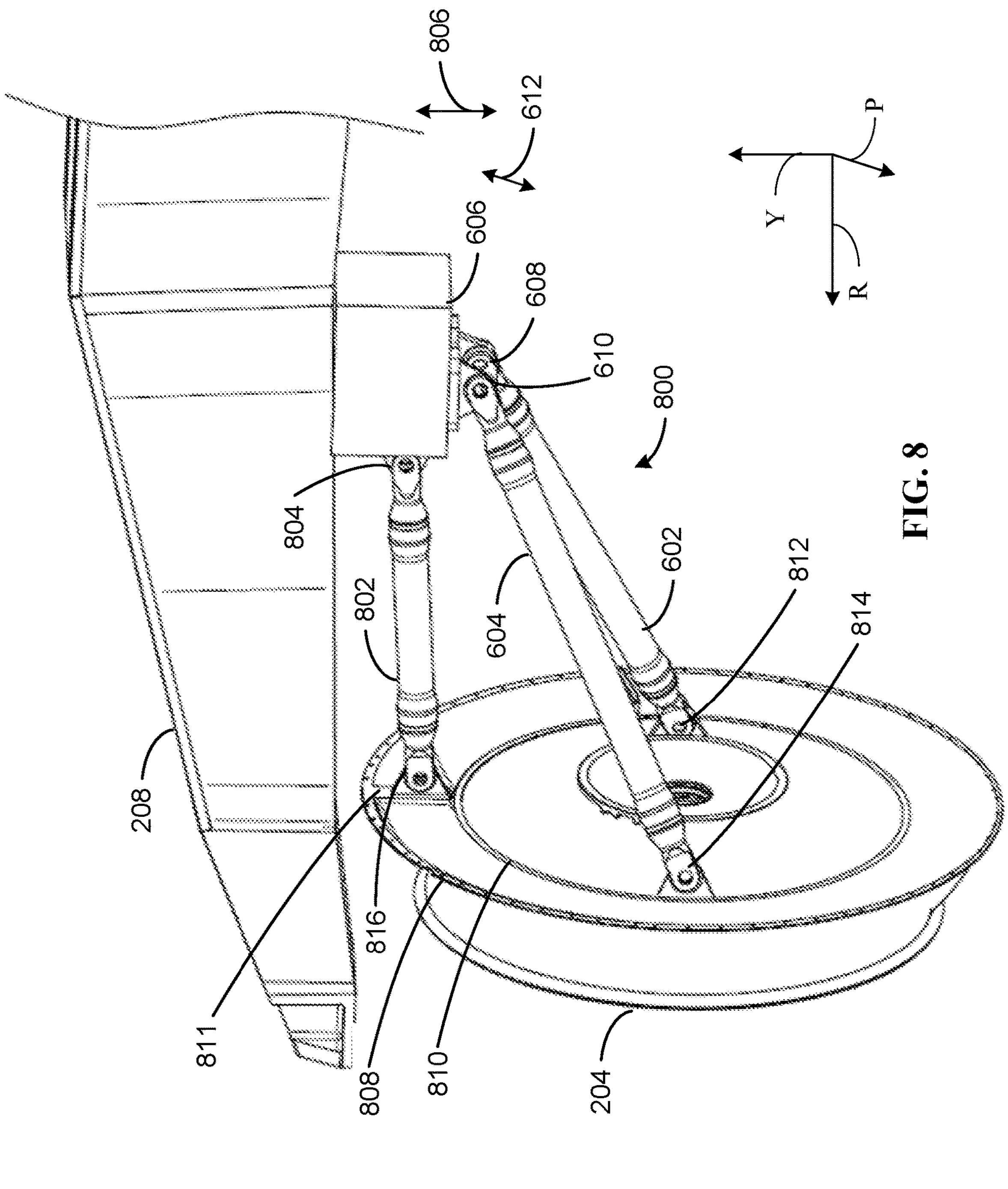


FIG. 7


806
612
606
608
610
800
804
802
604
602
812
814
208
816
811
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810
204
Y
P
R

FIG. 8

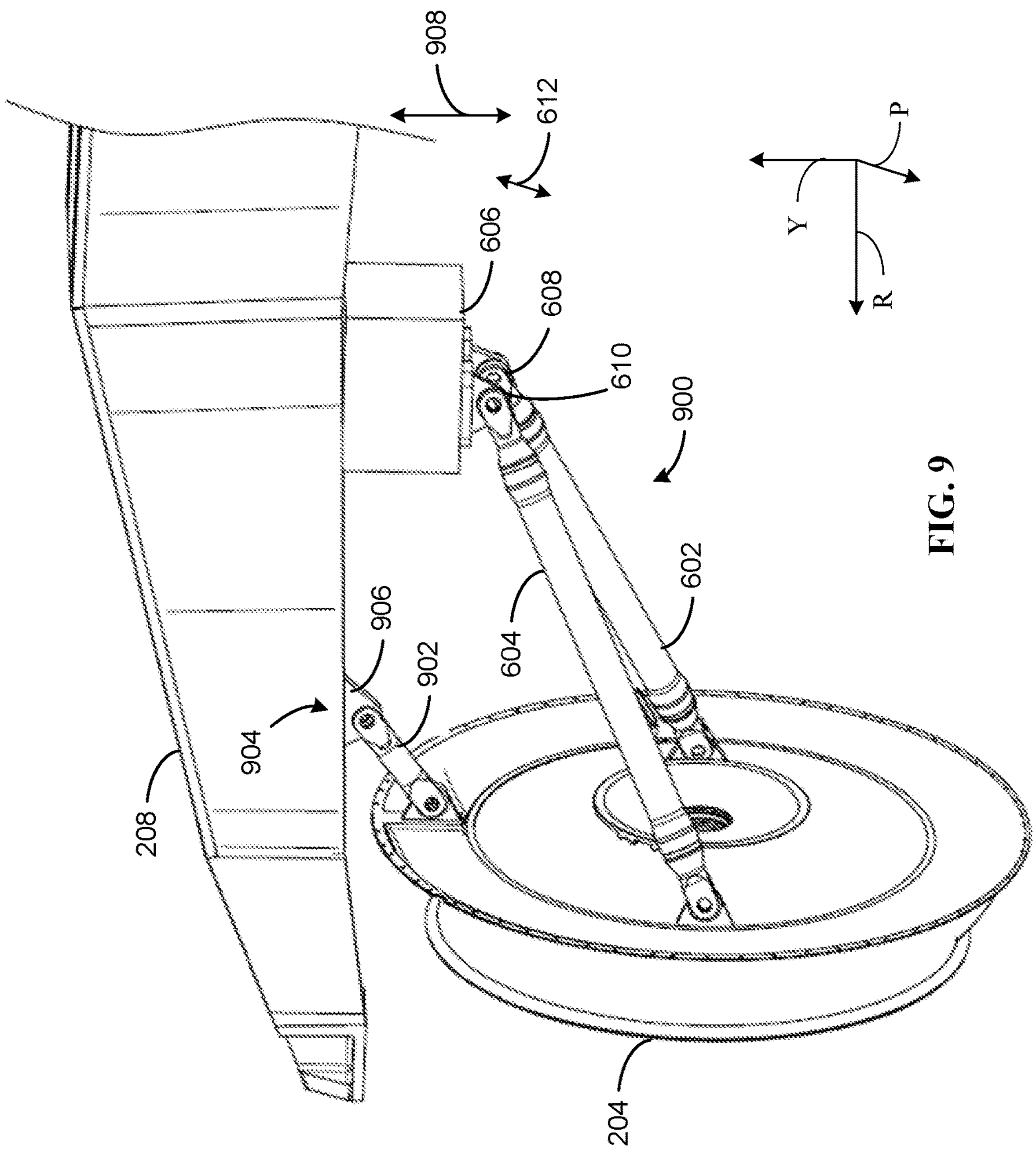
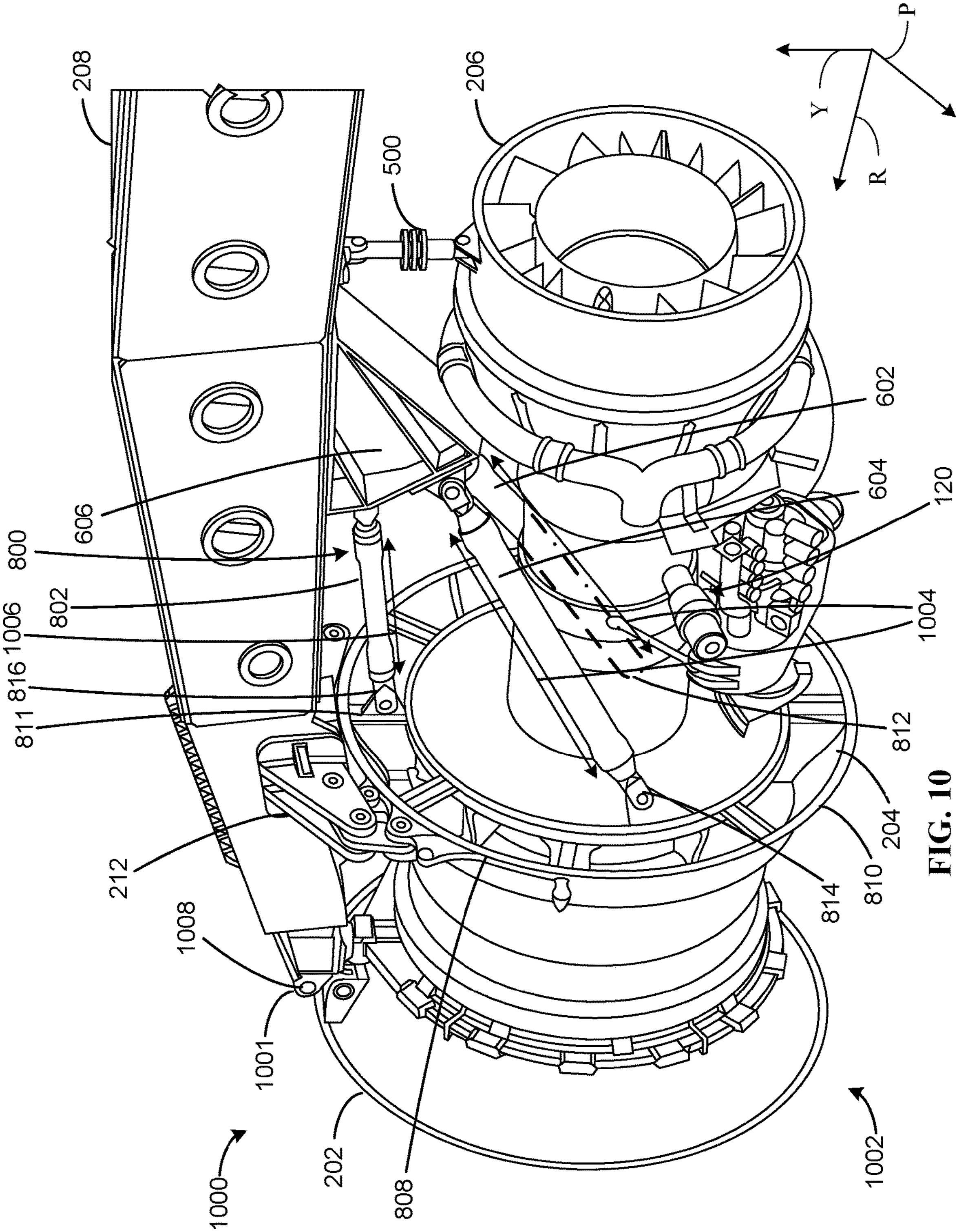


FIG. 9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606
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802
1006
816
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812
212
1008
1001
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814
810
204
1002
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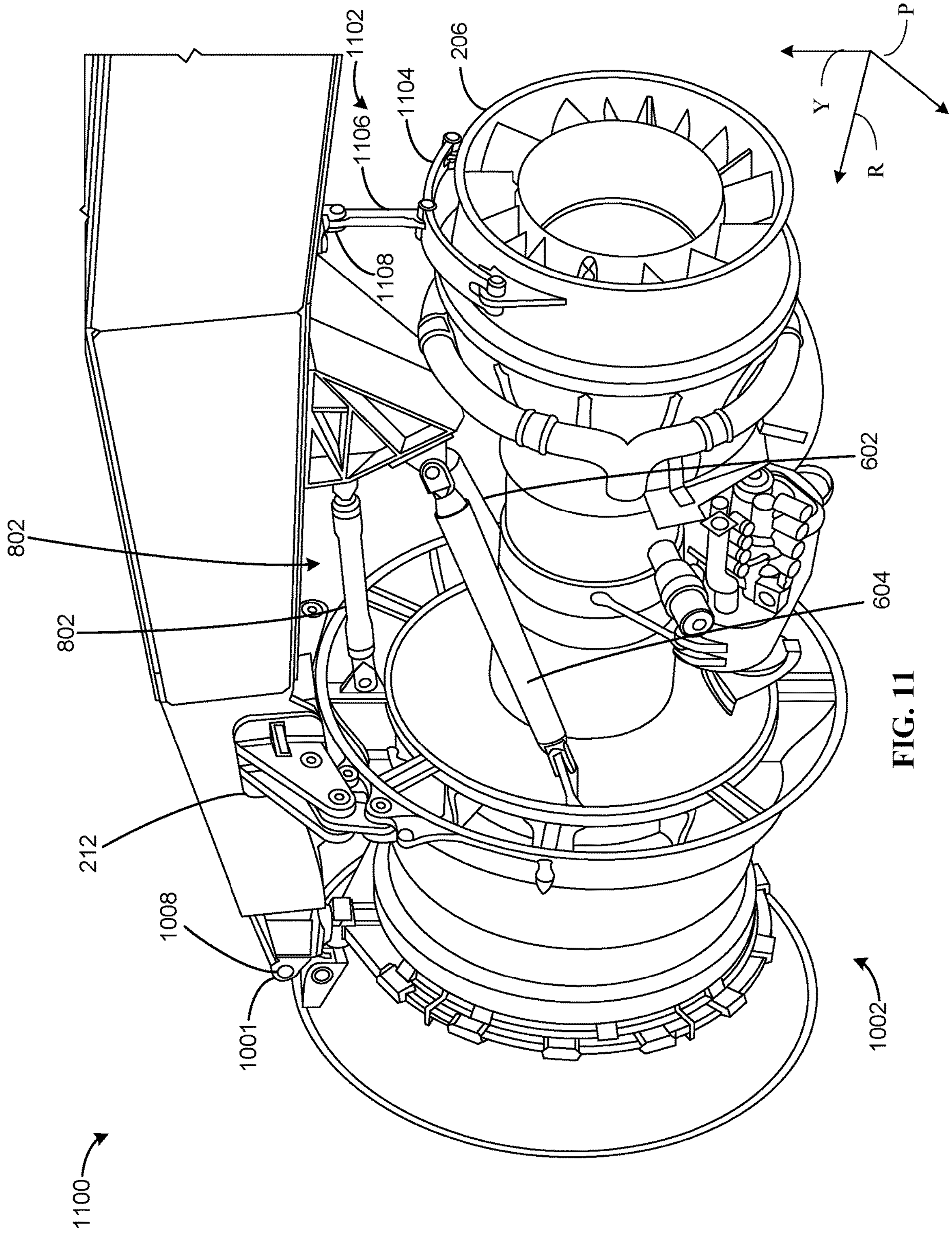
Y
R

FIG. 10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212
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802
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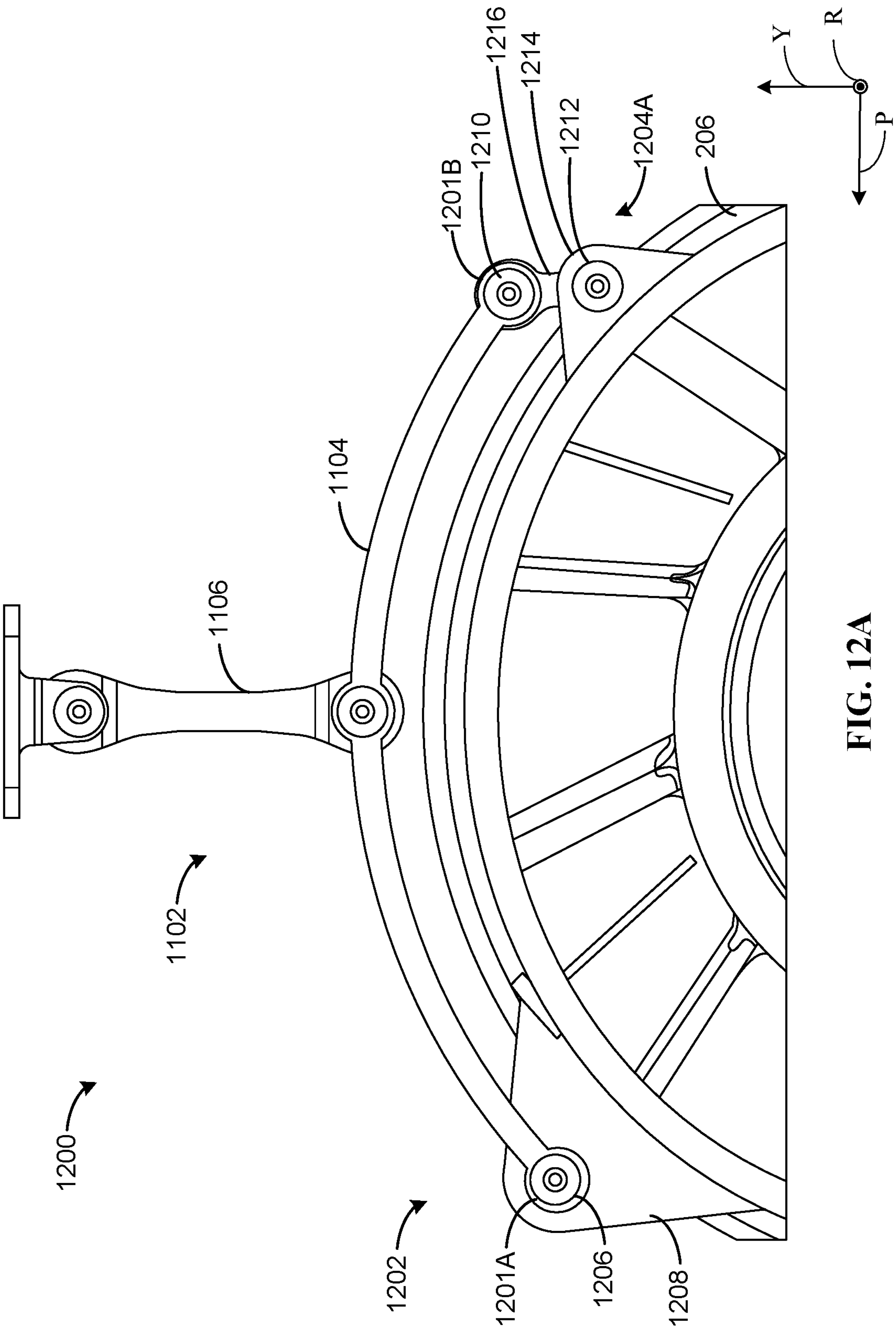
602
1002
1108
1106
1104
1102
206
Y
P
R

FIG. 11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1102
1106
1104
1201B
1210
1216
1214
1212
1204A
206
Y
R
P
1202
1201A
1206
1208

FIG. 12A

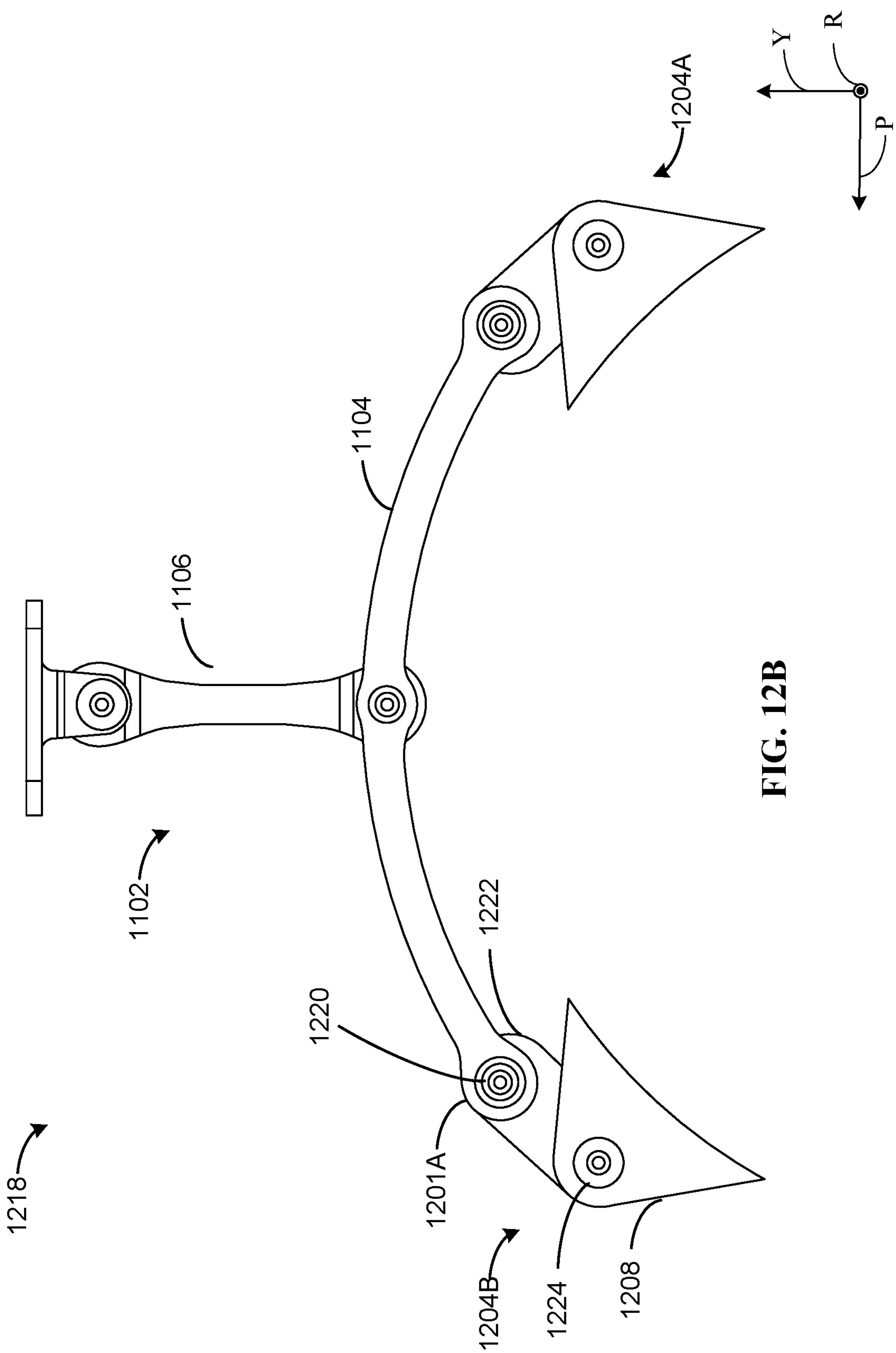
1204A
Y
R
P
1104
1106
1102
1222
1220
1218
1201A
1204B
1224
1208

FIG. 12B

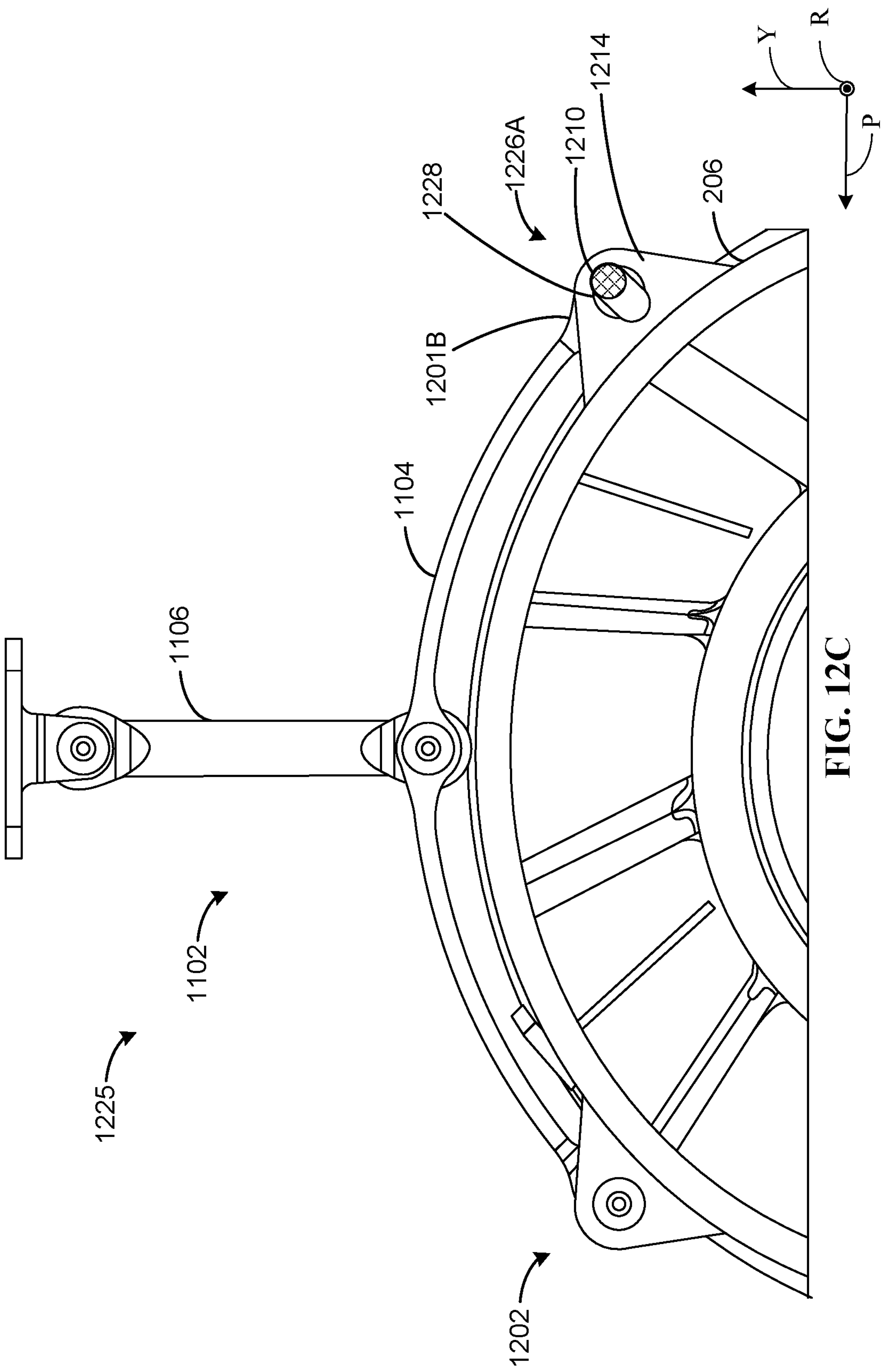

FIG. 12C

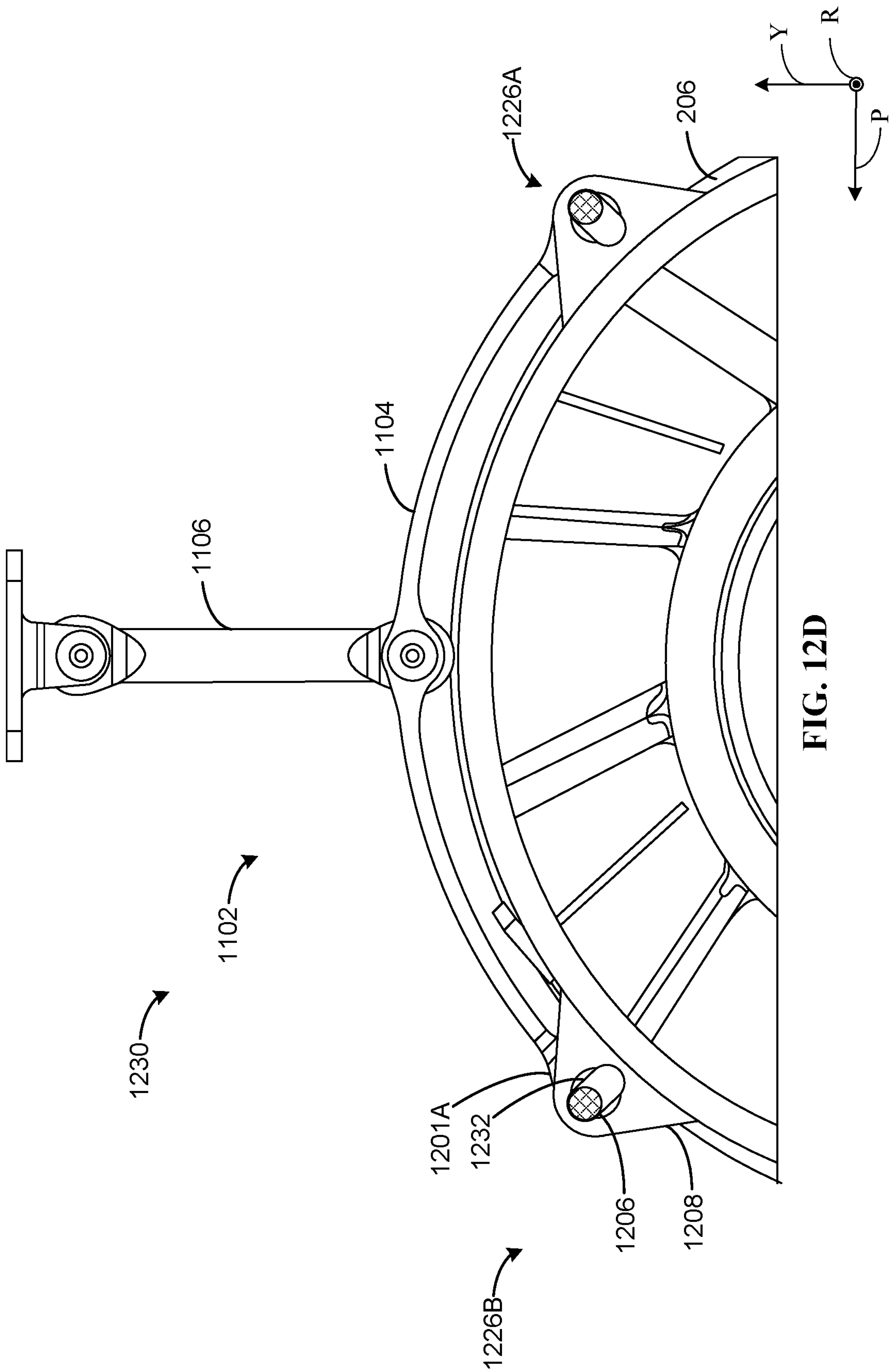

FIG. 12D

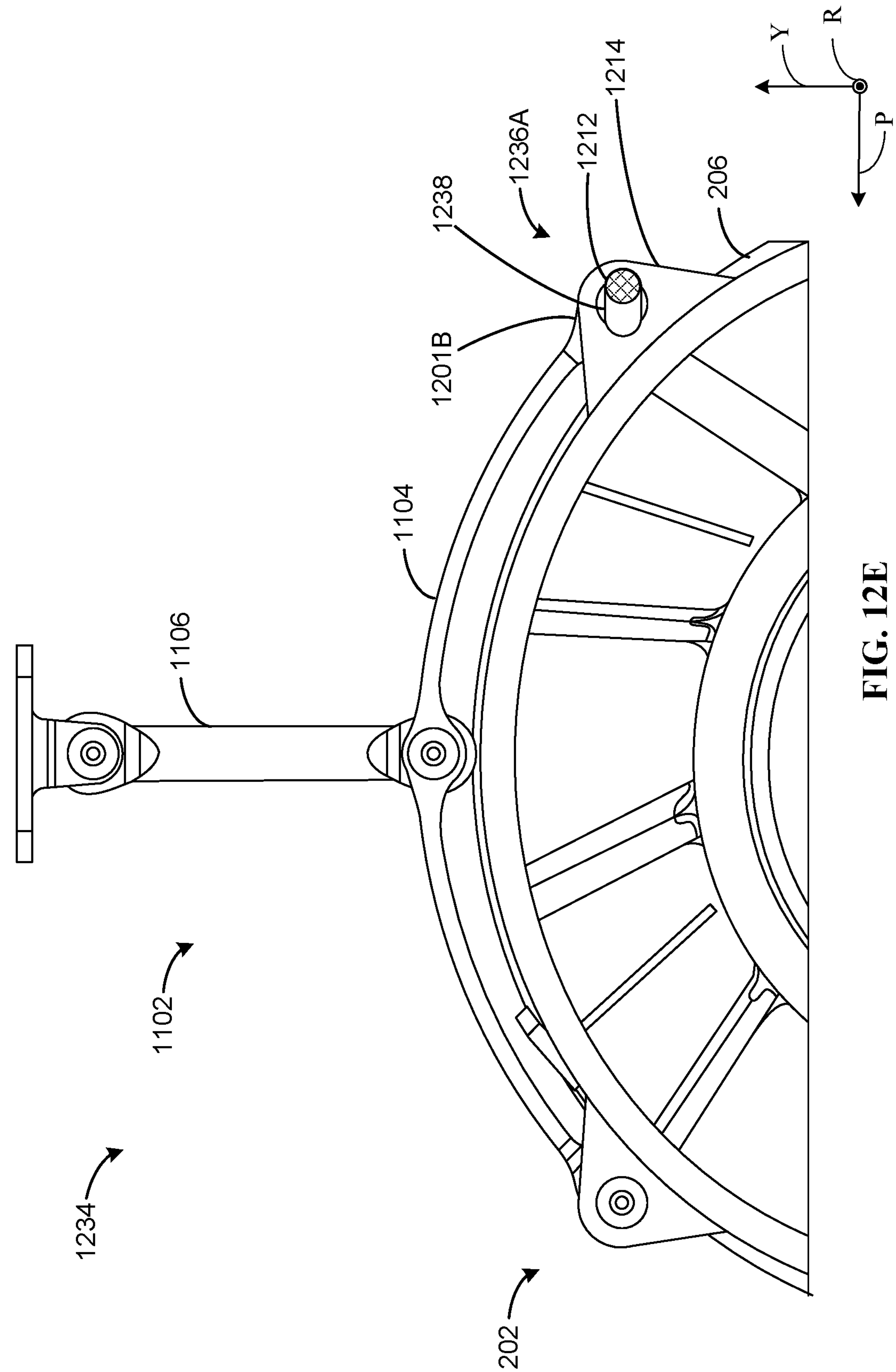

FIG. 12E

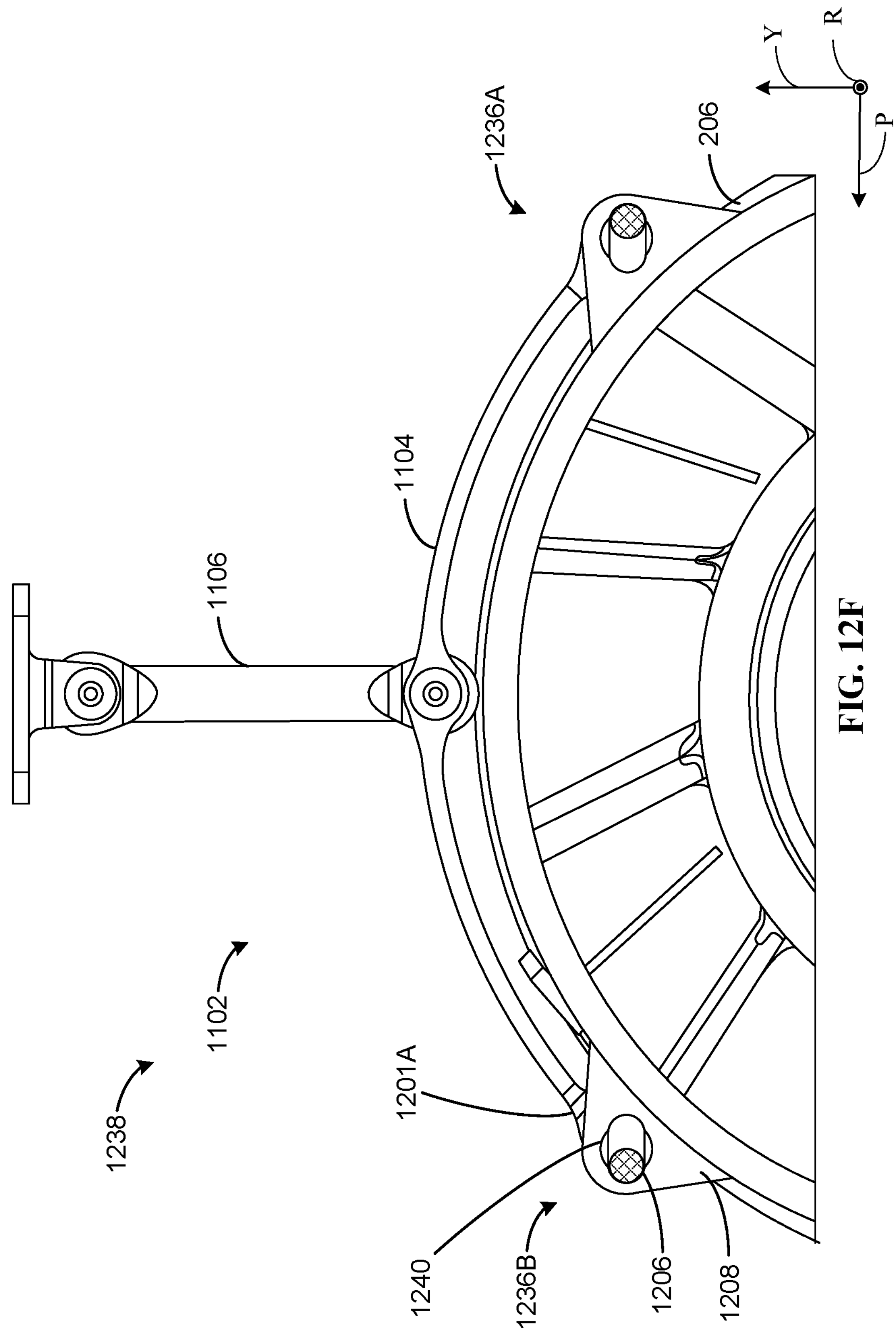

FIG. 12F

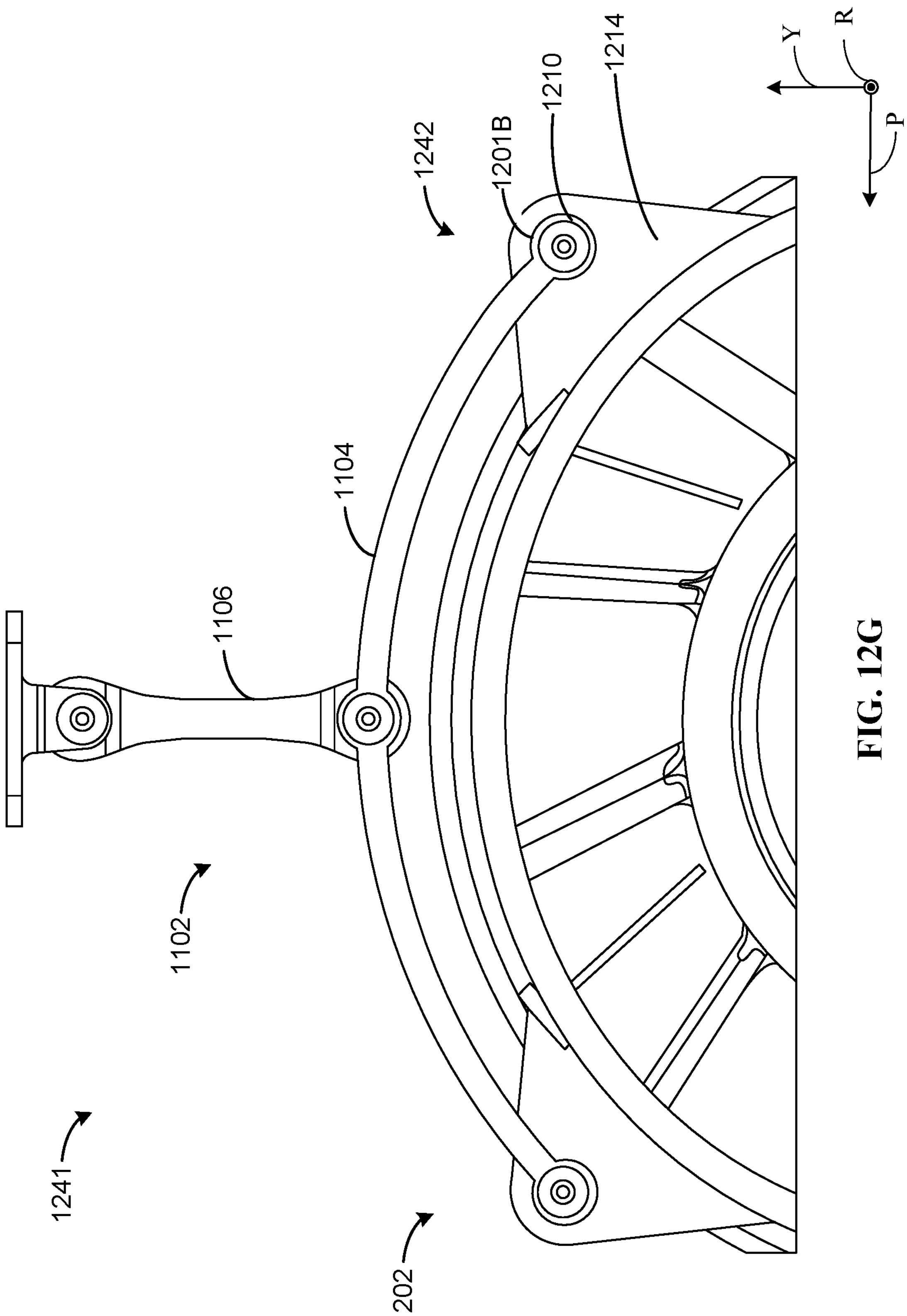

FIG. 12G

METHODS AND APPARATUS FOR MOUNTING A GAS TURBINE ENGINE TO A PYLON

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 63/589,170, filed on Oct. 10, 2023, and entitled "METHODS AND APPARATUS FOR MOUNTING A GAS TURBINE ENGINE TO A PYLON," and U.S. Provisional Patent Application No. 63/518,992, filed on Aug. 11, 2023, and entitled "METHODS AND APPARATUS FOR MOUNTING A GAS TURBINE ENGINE TO A PYLON," both of which are incorporated herein by reference in their entireties.

FIELD OF THE DISCLOSURE

[0002] This disclosure relates generally to gas turbines, and, more particularly, to methods and apparatus for mounting a gas turbine engine to a pylon.

BACKGROUND

[0003] A gas turbine engine generally includes, in serial flow order, an inlet section, a compressor section, a combustion section, a turbine section, and an exhaust section. In operation, air enters the inlet section and flows to the compressor section where one or more axial compressors progressively compress the air until it reaches the combustion section, thereby creating combustion gases. The combustion gases flow from the combustion section through a hot gas path defined within the turbine section and then exit the turbine section via the exhaust section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A full and enabling disclosure of the present disclosure, 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 FIGS., in which:

[0005] FIG. **1** is a cross-sectional view of an example gas turbine engine in which examples disclosed herein may be implemented.

[0006] FIG. **2** is a perspective view of an example frame components of a gas turbine engine coupled to a pylon including an aft mount implemented in accordance with the teachings of this disclosure.

[0007] FIG. **3** is a perspective view of the aft mount of FIG. **2**.

[0008] FIG. **4** is a perspective view of another aft mount implemented in accordance with the teachings of this disclosure.

[0009] FIG. **5**A is a perspective view of another aft mount implemented in accordance with the teachings of this disclosure.

[0010] FIG. **5**B is a cross-sectional view of another aft mount implemented in accordance with the teachings of this disclosure.

[0011] FIG. **6** is a perspective view of a thrust linkage configuration that can be used in conjunction with the frame components and the aft mount of FIG. **2**.

[0012] FIG. **7** is a perspective view of a rear coupling of a thrust linkage configuration of FIG. **6**.

[0013] FIG. **8** is a perspective view of another thrust linkage configuration that can be used in conjunction with the frame components and the aft mount of FIG. **2**.

[0014] FIG. **9** is a perspective view of another thrust linkage configuration that can be used in conjunction with the frame components and the aft mount of FIG. **2**.

[0015] FIG. **10** is a perspective view of a gas turbine engine including the aft mount of FIG. **5**A and the thrust linkage configuration of FIG. **6**.

[0016] FIG. **11** is a perspective view of a gas turbine engine including another aft mount and the thrust linkage configuration of FIG. **6**.

[0017] FIG. **12**A is a front view of the aft mount of FIG. **11** including an example first frame coupling.

[0018] FIG. **12**B is a front view of the aft mount of FIG. **11** including an example second frame coupling.

[0019] FIG. **12**C is a front view of the aft mount of FIG. **11** including an example third frame coupling.

[0020] FIG. **12**D is a front view of the aft mount of FIG. **11** including an example fourth frame coupling.

[0021] FIG. **12**E is a front view of the aft mount of FIG. **11** including an example fifth frame coupling.

[0022] FIG. **12**F is a front view of the aft mount of FIG. **11** including an example sixth frame coupling.

[0023] FIG. **12**G is a front view of the aft mount of FIG. **11** including an example seventh coupling.

[0024] The figures are not to scale. Instead, the thickness of the layers or regions may be enlarged in the drawings. In general, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts. As used in this patent, stating that any part (e.g., a layer, film, area, region, or plate) is in any way on (e.g., positioned on, located on, disposed on, or formed on, etc.) another part, indicates that the referenced part is either in contact with the other part, or that the referenced part is above the other part with one or more intermediate part(s) located therebetween. Connection references (e.g., attached, coupled, connected, joined, etc.) are to be construed broadly and may include intermediate members between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection/disconnection references do not necessarily infer that two elements are directly connected and in fixed relation to each other. Stating that any part is in "contact" with another part means that there is no intermediate part between the two parts.

[0025] Descriptors "first," "second," "third," etc. are used herein when identifying multiple elements or components which may be referred to separately. Unless otherwise specified or understood based on their context of use, such descriptors are not intended to impute any meaning of priority, physical order or arrangement in a list, or ordering in time but are merely used as labels for referring to multiple elements or components separately for ease of understanding the disclosed examples. In some examples, the descriptor "first" may be used to refer to an element in the detailed description, while the same element may be referred to in a claim with a different descriptor such as "second" or "third." In such instances, it should be understood that such descriptors are used merely for ease of referencing multiple elements or components.

DETAILED DESCRIPTION

[0026] Compressor blade tip clearances in gas turbine engines are affected by operational distortions caused by the internal forces of the gas turbine engines. Particularly, thrust, aerodynamic, and/or propeller loads can create internal bending moments in the gas turbine engine, which can cause the gas turbine engine to bend between the mounting linkages of the gas turbine engines. In recent years, some gas turbine engines have mitigated the distortions caused by such internal forces via cantilevered coupled core sections. However, the reaction of the gravitational loads of the cantilevered cores via the forward mounts of the gas turbine engine can cause distortions within the core section. Examples disclosed herein provide a mount system including an aft mount that includes an elastic element. Example mounts disclosed herein react a portion of the vertical load of a cantilevered core while reducing the operational distortions caused by bending moments associated with the thrust, aerodynamic, and/or propeller loads. Example mounts disclosed herein reduce distortions caused by the gravitational loading via an elastic member.

[0027] Some engines including cantilevered cores can experience comparatively large vertical (e.g., yaw axis aligned, etc.) and lateral (e.g., pitch axis aligned, etc.) displacements during operation. Particularly, because the cantilevered cores are not directly coupled to the pylon, such cores can vertically and laterally displace during operation. In some examples, such displacements can reduce the efficacy of seals within the gas turbine engine and can make integration of the cantilevered core with the nacelle difficult. Examples disclosed herein include thrust link configurations that mitigate such vertical and lateral displacements associated with cantilevered cores. Examples disclosed herein include a mount system for a cantilevered core engine to react some or all of the bending moments between thrust linkages of the engine. In some example mount systems disclosed herein, thrust linkages are provided that have laterally displaced coupling points, which enables the thrust linkages to react yaw moments and reduce lateral displacements. In some example mount systems disclosed herein, thrust linkages are provided that have vertically displaced coupling points, which enables the thrust linkages to react pitch moments and reduce vertical displacements.

[0028] 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. As used herein, the term "linkage" refers to a connection between two parts that restrain the relative motion of the two parts (e.g., restrain at least one degree of freedom of the parts, etc.).

[0029] Various terms are used herein to describe the orientation of features. As used herein, the orientation of features, forces, and moments are described with reference to the yaw axis, pitch axis, and roll axis of the vehicle associated with the features, forces, and moments. In general, the attached figures are annotated with reference to the axial direction, radial direction, and circumferential direction of the gas turbine associated with the features, forces, and moments. In general, the attached figures are annotated with a set of axes including the roll axis R, the pitch axis P, and the yaw axis Y. As used herein, the terms "longitudinal," and "axial" are used interchangeably to refer to directions parallel to the roll axis. As used herein, the term "lateral" is used to refer to directions parallel to the pitch axis. As used herein, the term "vertical" is used to refer to directions parallel to the yaw axis.

[0030] "Including" and "comprising" (and all forms and tenses thereof) are used herein to be open-ended terms. Thus, whenever a claim employs any form of "include" or "comprise" (e.g., comprises, includes, comprising, including, having, etc.) as a preamble or within a claim recitation of any kind, it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim or recitation. As used herein, when the phrase "at least" is used as the transition term in, for example, a preamble of a claim, it is open-ended in the same manner as the term "comprising" and "including" are open ended. The term "and/or" when used, for example, in a form such as A, B, and/or C refers to any combination or subset of A, B, C such as (1) A alone, (2) B alone, (3) C alone, (4) A with B, (5) A with C, (6) B with C, and (7) A with B and with C. As used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing structures, components, items, objects and/or things, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. As used herein in the context of describing the performance or execution of processes, instructions, actions, activities, and/or steps, the phrase "at least one of A and B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B. Similarly, as used herein in the context of describing the performance or execution of processes, instructions, actions, activities and/or steps, the phrase "at least one of A or B" is intended to refer to implementations including any of (1) at least one A, (2) at least one B, and (3) at least one A and at least one B.

[0031] As used herein, singular references (e.g., "a", "an", "first", "second", etc.) do not exclude a plurality. The term "a" or "an" entity, as used herein, refers to one or more of that entity. The terms "a" (or "an"), "one or more", and "at least one" can be used interchangeably herein. Furthermore, although individually listed, a plurality of means, elements or method actions may be implemented by, e.g., a single unit or processor. Additionally, although individual features may be included in different examples or claims, these may possibly be combined, and the inclusion in different examples or claims does not imply that a combination of features is not feasible and/or advantageous.

[0032] As used herein, "approximately" and "about" modify their subjects/values to recognize the potential presence of variations that occur in real world applications. For example, "approximately" and "about" may modify dimensions that may not be exact due to manufacturing tolerances and/or other real world imperfections as will be understood by persons of ordinary skill in the art. For example, "approximately" and "about" may indicate such dimensions may be within a tolerance range of +/−10% unless otherwise specified herein.

[0033] Some prior gas turbine engines are configured to be mounted to the wings of an aircraft (e.g., under-wing mounting) via a pylon. These pylons transfer the loads associated with the operation of gas turbine engines (e.g., thrust loads, aero-inlet loads, propeller loads, gravitational loading/weight, etc.) to the wing of the aircraft. Some such prior gas turbine engine is mounted to the pylon via a forward mount and an aft mount for the engine. In some prior-art examples, the forward mount couples the fan casing of the gas turbine engine to the pylon and the aft mount couples the core section of the gas turbine engine to the gas turbine engine. Other prior gas turbine engines do not include mounts to couple the core section to the pylon and include two forward mounts to couple the forward frame portions of such gas turbine engines to the pylon. The core sections of such gas turbine engines are referred to as "cantilevered core sections" because such core sections are cantilevered relative to the forward sections of the gas turbine engine.

[0034] Open rotor gas turbine engines, also called open fan gas turbine engines, propfans, and/or unducted fan gas turbine engines, are gas turbine engines that include fans with unducted blades. Open rotor gas turbines offer high performance and fuel efficiency and lack the fan casing of traditional turbofan gas turbine engines. In some such engine configurations, gas turbine engine components that are typically disposed within the fan casing (e.g., the accessory gearbox, oil tanks, etc.) are disposed at another location for gas turbine engines, such as the core casing. However, the disposing of such components within the core casing can increase gravitational loading on the core engine.

[0035] In some gas turbine engines, particularly open rotor engines and turboprop engines, a high vibratory load is experienced during various phases of the flight due to asymmetric propeller loading (e.g., P-Factor or 1P loading). 1P loading, also referred to as +/−1P loading, is the asymmetric force on blades and asymmetric disk loading caused by aerodynamic forces at aircraft angles of attack. 1P loading is typically highest during operational conditions with high-power and high angles of attack, such as takeoff and climb.

[0036] Blade tip clearances at several locations throughout the engine are often defined based on the sum of axisymmetric closures and the local circumferential clearance distortions during a take-off (TO) rotation maneuver. That is, in some examples, a minimum blade tip clearances in the compressor (e.g., closest clearances, etc.) can occur during TO engine operation. In some examples, the minimum blade tip clearance at which the compressor can operate during take-off is based on clearance reduction caused in part by engine vibrations and distortion (e.g., strain, etc.) caused by the operation of the engine. Operational distortion in an engine can be caused by internal forces and/or moments in the engine caused by thrust, 1P loading, aero inlet loads, etc. The operational loads can cause the engine body to bend and/or otherwise distort between the forward and aft mount attachment point of the gas turbine engine to the aircraft, for example. Designing an engine to compensate for these distortions (e.g., by increasing cold or cruise clearances) correspondingly reduces engine operating efficiency (e.g., specific fuel consumption, etc.). In some prior-art engine configurations, the generated bending moments (e.g., moments about the yaw and pitch axis, etc.) are reacted through the engine carcass (e.g., the fan and core sections of the engine, etc.). The reaction of the bending moments through the engine carcass can cause deterioration (e.g., deformation, distortion) of the engine, which in turn affects blade tip clearances. Other prior-art engine configurations, such as cantilevered core gas turbine engines, do not generate carcass bending due to the lack of an aft mount.

[0037] Examples disclosed herein provide a mount system suitable for use with a cantilevered open rotor gas turbine engine. Example mount systems described herein include a gas turbine engine frame with a partially cantilevered core section coupled to a pylon. Examples disclosed herein include a tuned stiffness aft mount that couples a rear frame of a core section to a pylon. Some example aft mounts disclosed herein include an elastomer to partially react vertical loads and reduce distortions transmitted through the engine carcass. Some example aft mounts disclosed herein include a spring to partially react vertical loads and reduce distortions transmitted through the engine carcass. Some example aft mounts disclosed herein include a composite disc spring to partially react vertical loads. In some examples disclosed herein, the aft mounts include features that react yaw-moments during out-of-standard operation. In some such examples disclosed herein, the aft mount includes a slot. In some examples disclosed herein, the aft mount includes a first member having a hollow interior and a second member disposed within the hollow interior. Example mount systems disclosed herein reduce operational distortions associated with the reaction of bending mounts between engine forward mounts and aft mounts and reduce gravitational distortion associated with cantilevered engine configurations.

[0038] FIG. **1** is a schematic cross-sectional view of an example gas turbine engine **100** that can be used to implement the teachings of this disclosure. The gas turbine engine **100** can be mounted to an aerial vehicle, such as a fixed-wing aircraft, and can produce thrust for propulsion of the aerial vehicle. The gas turbine engine **100** includes a fan that is not ducted by a nacelle or cowl, such that it may be referred to herein as an "unducted fan," or the entirety of the gas turbine engine **100** may be referred to as an "unducted engine," "an open-rotor gas turbine engine," "an open-fan gas turbine engine," etc.

[0039] The gas turbine engine **100** includes a core engine **120** and a fan section **150** positioned upstream thereof. Generally, the core engine **120** includes, in serial flow order, a compressor section, a combustion section, a turbine section, and an exhaust section. Particularly, as shown in FIG. **1**, the core engine **120** includes a core cowl **122** that defines an annular core inlet **124**. The core cowl **122** further encloses a low-pressure system and a high pressure system. In certain examples, the core cowl **122** may enclose and support a booster or low pressure ("LP") compressor **126** for pressurizing the air that enters the core engine **120** through core inlet **124**. A high pressure ("HP"), multi-stage, axial-flow compressor **128** receives pressurized air from the LP compressor **126** and further increases the pressure of the air. The pressurized air stream flows downstream to a combustor **130** where fuel is injected into the pressurized air stream and ignited to raise the temperature and energy level of the pressurized air. It will be appreciated that as used herein, the terms "high/low speed" and "high/low pressure" are used with respect to the high pressure/high speed system and low pressure/low speed system interchangeably. Further, it will be appreciated that the terms "high" and "low" are used in this same context to distinguish the two systems and are not meant to imply any absolute speed and/or pressure values.

[0040] The high energy combustion products flow from the combustor **130** downstream to a high pressure turbine **132**. The high pressure turbine **132** drives the HP compressor **128** through a high pressure shaft **136**. In this regard, the high pressure turbine **132** is drivingly coupled with the HP compressor **128**. The high energy combustion products then flow to a low pressure turbine **134**. The low pressure turbine

134 drives the LP compressor 126 and components of the fan section 150 through a low pressure shaft 138. In this regard, the low pressure turbine 134 is drivingly coupled with the LP compressor 126 and components of the fan section 150. The LP shaft 138 is coaxial with the HP shaft 136 in this example. After driving each of the turbines 132, 134, the combustion products exit the core engine 120 through a core exhaust nozzle 140 to produce propulsive thrust. Accordingly, the core engine 120 defines a core flow path or core duct 142 that extends between the core inlet 124 and the core exhaust nozzle 140. The core duct 142 is an annular duct positioned generally inward of the core cowl 122 along the radial direction R.

[0041] The fan section 150 includes a fan 152, which is the primary fan in this example. For the depicted example of FIG. 1, the fan 152 is an open rotor or unducted fan. However, in other examples, the fan 152 may be ducted, e.g., by a fan casing or nacelle circumferentially surrounding the fan 152. As depicted, the fan 152 includes an array of fan blades 154 (only one shown in FIG. 1). The fan blades 154 are rotatable, e.g., about the longitudinal axis 112. As noted above, the fan 152 is drivingly coupled with the low pressure turbine 134 via the LP shaft 138. The fan 152 can be directly coupled with the LP shaft 138, e.g., in a direct-drive configuration. Optionally, as shown in FIG. 1, the fan 152 can be coupled with the LP shaft 138 via a speed reduction gearbox 155, e.g., in an indirect-drive or a geared-drive configuration.

[0042] Moreover, the fan blades 154 can be arranged in equal spacing around the longitudinal axis 112. Each blade 154 has a root and a tip and a span defined therebetween. Each of the fan blades 154 defines a central blade axis 156. For this example, each blade 154 of the fan 152 is rotatable about its respective central blade axes 156, e.g., in unison with one another. One or more actuators 158 can be controlled to pitch the blades 154 about their respective central blade axes 156. However, in other examples, each of the fan blades 154 may be fixed or unable to be pitched about its central blade axis 156.

[0043] The fan section 150 further includes a fan guide vane array 160 that includes fan guide vanes 162 (only one shown in FIG. 1) disposed around the longitudinal axis 112. For this example, the fan guide vanes 162 are not rotatable about the longitudinal axis 112. Each fan guide vane 162 has a root and a tip and a span defined therebetween. The fan guide vanes 162 may be unshrouded as shown in FIG. 1 or may be shrouded, e.g., by an annular shroud spaced outward from the tips of the fan guide vanes 162 along the radial direction R. Each fan guide vane 162 defines a central blade axis 164. For this example, each fan guide vane 162 of the fan guide vane array 160 is rotatable about its respective central blade axes 164, e.g., in unison with one another. One or more actuators 166 can be controlled to pitch the fan guide vane 162 about their respective central blade axes 164. However, in other examples, each fan guide vane 162 may be fixed or unable to be pitched about its central blade axis 164. The fan guide vanes 162 are mounted to a fan cowl 170.

[0044] As shown in FIG. 1, in addition to the fan 152, which is unducted, a ducted fan 184 is included aft of the fan 152, such that the gas turbine engine 100 includes both a ducted and an unducted fan that both serve to generate thrust through the movement of air without passage through core engine 120. The ducted fan 184 is shown at about the same axial location as the fan guide vane 162, and radially inward of the fan guide vane 162. Alternatively, the ducted fan 184 may be between the fan guide vane 162 and core duct 142, or be farther forward of the fan guide vane 162. The ducted fan 184 may be driven by the low pressure turbine 134 (e.g., coupled to the LP shaft 138), or by any other suitable source of rotation, and may serve as the first stage of booster or may be operated separately.

[0045] The fan cowl 170 annularly encases at least a portion of the core cowl 122 and is generally positioned outward of the core cowl 122 along the radial direction R. Particularly, a downstream section of the fan cowl 170 extends over a forward portion of the core cowl 122 to define a fan flow path or fan duct 172. Incoming air may enter through the fan duct 172 through a fan duct inlet 176 and may exit through a fan exhaust nozzle 178 to produce propulsive thrust. The fan duct 172 is an annular duct positioned generally outward of the core duct 142 along the radial direction R. The stationary struts 174 may each be aerodynamically contoured to direct air flowing thereby. Other struts in addition to the stationary struts 174 may be used to connect and support the fan cowl 170 and/or core cowl 122. In many examples, the fan duct 172 and the core cowl 122 may at least partially co-extend (generally axially) on opposite sides (e.g., opposite radial sides) of the core cowl 122. For example, the fan duct 172 and the core cowl 122 may each extend directly from the leading edge 144 of the core cowl 122 and may partially co-extend generally axially on opposite radial sides of the core cowl.

[0046] The gas turbine engine 100 also defines or includes an inlet duct 180. The inlet duct 180 extends between an engine inlet 182 and the core inlet 124/fan duct inlet 176. The engine inlet 182 is defined generally at the forward end of the fan cowl 170 and is positioned between the fan 152 and the fan guide vane array 160 along the axial direction A. The inlet duct 180 is an annular duct that is positioned inward of the fan cowl 170 along the radial direction R. Air flowing downstream along the inlet duct 180 is split, not necessarily evenly, into the core duct 142 and the fan duct 172 by a splitter or leading edge 144 of the core cowl 122. The inlet duct 180 is wider than the core duct 142 along the radial direction R. The inlet duct 180 is also wider than the fan duct 172 along the radial direction R.

[0047] FIG. 2 is a perspective view of an example engine mount system 200 including a first frame portion 202, a second frame portion 204, and a third frame portion 206. In the illustrated example of FIG. 2, the frame portions 202, 204, 206 are coupled to a pylon 208 via a first forward mount 210, a second forward mount 212, and an aft mount 214 implemented in accordance with the teachings of this disclosure.

[0048] The frame portions 202, 204, 206 are portions of a frame of a gas turbine engine (e.g., the gas turbine engine 100 of FIG. 1, etc.). The frame portions 202, 204, 206 contain and/or support the components of the gas turbine engine and facilitate the coupling thereof to the pylon 208. In the illustrated example of FIG. 2, the first frame portion 202 is a forward frame portion (e.g., the forward frame, etc.), the second frame portion 204 is a midframe portion (e.g., the midframe, etc.), and the third frame portion 206 is a turbine vane frame portion (e.g., a turbine vane frame, etc.). Because the frame portions 202, 204, 206 are associated with the open rotor engine (e.g., the gas turbine engine 100 of FIG. 1, etc.), the frame packaging space within the frame portions 202, 204 (e.g., frame portions associated with the fan section **150**, etc.) is limited by the fan blades. As such, in some examples, components that are typically supported by the forward frame portions **202**, **204**, such as the accessory gearbox and the oil tank, are supported by frame portions associated with the core engine **120** (e.g., the third frame portion **206**, etc.).

[0049] In the illustrated example of FIG. **2**, the first frame portion **202** is coupled to the pylon **208** via the first forward mount **210**, the second frame portion **204** is coupled to the pylon **208** via the second forward mount **212**, and the third frame portion **206** is coupled to the pylon **208** via the aft mount **214**. In some examples, the first frame portion **202** and the second frame portion **204** are components of the fan section **150** of the gas turbine engine **100** of FIG. **1** (e.g., the first frame portion **202** is a first fan frame portion, the second frame portion **204** is a second fan frame portion, etc.) and the third frame portion **206** is a component of the core engine **120** of the gas turbine engine **100** of FIG. **1**. It should be appreciated that a gas turbine engine including the frame portions **202**, **204**, **206** can include one or more additional frame portions disposed between ones of the frame portions **202**, **204**, **206**.

[0050] In the illustrated example of FIG. **2**, the third frame portion **206** is cantilevered (e.g., partially cantilevered, etc.) relative to the first frame portion **202** and the second frame portion **204**. That is, the third frame portion **206** is primarily supported via a coupling (not illustrated) to the first frame portion **202** and the second frame portion **204**. In some examples, as described above, the third frame portion **206** and/or other frame portions associated with the core section support components (e.g., the auxiliary gearbox (AGB), the oil tank, etc.) that are typically coupled within the fan frame portions (e.g., frame portions similar to the frame portions **204**, **206**, etc.). In some such examples, the additional weight of such components increases the gravitational load on the core section (e.g., the core engine **120**, etc.). In the illustrated example of FIG. **2**, to reduce (e.g., mitigate, etc.) potential distortions associated with the gravitational load on the core section, the engine mount system **200** includes the aft mount **214**, which couples the third frame portion **206** to the pylon **208**.

[0051] In the illustrated example of FIG. **2**, the aft mount **214** includes an elastic element **216**, which causes the aft mount **214** to have a lower stiffness than the forward mounts **210**, **212**. The comparatively low stiffness of the aft mount **214** enables some of the vertical load associated with the core engine **120** to be transferred to the pylon **208** via the aft mount **214**, while reducing the transmission of bending moments through the core engine **120**. In some examples, the aft mount **214** is a tuned mount. That is, in some examples, the material of the elastic element **216**, the cross-sectional shape of the elastic element **216**, and/or the thickness of the elastic element **216** can be selected (e.g., tuned, etc.) to balance the distortions associated with the gravitational loading (e.g., **1**G loading, etc.) and the distortions associated with propeller loading (e.g., 1P loading, etc.). In some examples, the elastic element **216** damps vibrations transmitted between the pylon **208** and the core engine **120**. In some examples, the elastic element **216** is a means for elastically coupling the core engine **120** and/or the third frame portion **206** to the pylon **208**.

[0052] In the illustrated example of FIG. **2**, the elastic element **216** includes an elastomer. The aft mount **214** and the elastic element **216** are described below in additional detail in conjunction with FIG. **3**. Additionally or alternatively, the aft mount **214** can include a spring. For example, the aft mount **214** can include one or more tension coil springs, one or more hollow-tubing springs, one or more leaf springs, one or more volute springs, one or more gas springs (e.g., one or more air springs, etc.), one or more disc springs (e.g., one or more Belleville washers, etc.), etc. An example aft mount including a coil spring is described below in conjunction with FIG. **4**. Another example aft mount including disc springs is described below in conjunction with FIGS. **5**A and **5**B. Other example aft mounts including leaf springs are described below in conjunction with FIG. **11**-**12**F.

[0053] In some examples, the elastic element **216** can have an adjustable stiffness. For example, if the elastic element **216** is an air spring and/or a hydropneumatic spring, the stiffness can be adjusted based on the expected and/or sensed loads transferred via the aft mount **214**. In some such examples, the stiffness of the elastic element **216** can be adjusted based on the ambient conditions of the engine mount system **200**, the flight phase of the gas turbine engine **100**, a property of the gas turbine engine **100**, and/or a property of an aircraft propelled by the gas turbine engine **100**.

[0054] In some examples, the aft mount **214** can include one or more features that enable the aft mount **214** to react yaw-moments (e.g., constrain the yaw-degree of freedom, etc.) during out-of-standard operations (e.g., during a blade-out event, etc.). For example, the aft mount **214** can include a slot that permits the relative rotation of the third frame portion **206** and the pylon **208** about the yaw-axis within an arc defined by the slot and constrains such rotation outside of the arc. In other examples, the aft mount **214** can include other features that enable the aft mount **214** to react yaw-moments (e.g., constrain the yaw-degree of freedom, etc.) during out-of-standard operations (e.g., during a blade-out event, etc.), while permitting such rotation during standard operation (e.g., expected flight phases, etc.). An example aft mount including such a feature is described below in conjunction with FIGS. **5**A and **5**B.

[0055] FIG. **3** is a perspective view of an example aft mount **300**, which can implement the aft mount **214** of FIG. **2**. In the illustrated example of FIG. **3**, the aft mount **300** includes a pylon coupling **302**, a frame coupling **304**, and a structural member **305**. In the illustrated example of FIG. **3**, the pylon coupling **302** includes a first elastomer **306**, a first pin **308**, a bracket **310**, a load plate **311**, and a clevis **312**. In the illustrated example of FIG. **3**, the frame coupling **304** includes a second pin **314**, a second plate **316**, and a second yoke **318**.

[0056] The pylon coupling **302** couples the aft mount **300** to the pylon **208**. In the illustrated example of FIG. **3**, the bracket **310** of the pylon coupling **302** is coupled to the pylon **208** (e.g., via one or more welds, via one or more fasteners, via one or more interference couplings, via one or more mechanical retainers, etc.). The clevis **312** of the pylon coupling **302** is an interface formed between the first elastomer **306** and the bracket **310**. In the illustrated example of FIG. **3**, the first pin **308** extends through the clevis **312**. In the illustrated example of FIG. **3**, the clevis **312** includes a first mounting plate **319**A and a second mounting plate **319**B. In the illustrated example of FIG. **3**, the first pin **308** extends through openings in the mounting plates **319**A, **319**B, and the structural member **305**, which forms an interface between the structural member **305** and the pylon coupling **302**. The clevis **312** reacts vertical loads applied via the aft mount **300** and permits rotation of the structural member **305** about the first pin **308** extending through the clevis **312**.

[0057] In the illustrated example of FIG. **3**, the structural member **305** is a rigid structural member that extends between the pylon coupling **302** and the frame coupling **304** and reacts vertical loads transferred therebetween. The structural member **305** can be composed of any suitable rigid material, including steel, titanium, aluminum, a nickel alloy, etc. In the illustrated example of FIG. **3**, the structural member **305** is coupled to the pylon coupling **302** via the clevis **312** and the first pin **308**. The clevis **312** and the first pin **308** facilitate the rotation of the structural member **305** about the first pin **308** (e.g., about the roll axis, etc.).

[0058] The load plate **311** and first elastomer **306** are disposed with an interior **320** defined by coupling of the bracket **310** to the pylon **208**. In the illustrated example of FIG. **3**, the mounting plates **319**A, **319**B of the clevis **312** extend through openings in the bracket **310** and the first elastomer **306** and are coupled to the load plate **311**. In some examples, the load plate **311** and the clevis **312** can be coupled via one or more welds, one or more fasteners, one or more interference couplings, etc. Additionally or alternatively, the load plate **311** and the clevis **312** are integral components. In the illustrated example of FIG. **3**, the load plate **311** is not directly coupled to the bracket **310** and is able to translate therewithin. In some examples, the coupling of the clevis **312** and the load plate **311** retains the load plate **311** within the interior **320**.

[0059] The first elastomer **306** is an elastic element disposed within the bracket **310**, such that the first elastomer **306** reacts vertical loads (e.g., gravitational loads, aerodynamic loads, maneuver loads, etc.) applied downwardly on the aft mount **300**. In the illustrated example of FIG. **2**, the aft mount **300** includes a second elastomer **321** disposed between the top of the load plate **311** and the pylon **208**. The second elastomer **321** reacts vertical loads (e.g., aerodynamic loads, maneuver loads, etc.) applied upwardly on the aft mount **300**. The first elastomer **306** and/or the second elastomer **321** can be any suitable elastic material (e.g., natural rubber, isoprene rubber, silicone rubber, acrylic rubber, ethylene propylene rubber, a thermoplastic, etc.) with comparatively low stiffness (e.g., compared to the other component of aft mount **300**, etc.).

[0060] The load plate **311** is movably disposed within the bracket **310**. That is, the load plate **311** can translate vertically within the bracket **310** (e.g., toward the pylon **208**, away from the pylon **208**, etc.). During operation, downwardly applied vertical loads (e.g., a load applied in the negative direction along the yaw-axis, etc.), cause the load plate **311** to compress the first elastomer **306** and transfer the applied load thereto. In some such examples, the first elastomer **306** transfers the applied load to the bracket **310**, which is then transferred to the pylon **208**. Generally, the stiffness of the first elastomer **306** affects the portion of the negative vertical load associated with the gas turbine engine **100** transferred via the aft mount **300**. That is, a greater stiffness of the first elastomer **306** causes a corresponding increase in the portion of the negative vertical loads (e.g., gravitational loads, maneuver loads, etc.) transferred via the aft mount **300** and a corresponding decrease in the portion of negative vertical loads applied via the other mounts associated with the gas turbine engine **100** (e.g., the forward mounts **210**, **212** of FIG. **2**, etc.).

[0061] During operation, upwardly applied vertical loads (e.g., a load applied in the positive direction along the yaw axis, etc.), cause the load plate **311** to move upward within the bracket **310**, compress the second elastomer **321** and transfer the applied load thereto. In some such examples, the second elastomer **321** transfers the applied load to the pylon **208**. Generally, the stiffness of the second elastomer **321** affects the portion of the positive vertical load associated with the gas turbine engine **100** transferred via the aft mount **300**. That is, a greater stiffness of the second elastomer **321** causes a corresponding increase in the portion of the positive vertical loads (e.g., aerodynamic loads, maneuver loads, etc.) transferred via the aft mount **300** and a corresponding decrease in the portion of positive vertical loads applied via the other mounts associated with the gas turbine engine **100** (e.g., the forward mounts **210**, **212** of FIG. **2**, etc.). In some examples, the second elastomer **321** is absent. In some such examples, because the load plate **311** can freely translate in response to applied vertical loads, the aft mount **300** does not react positive vertical loads. In some examples, the geometries (e.g., the shape(s), the thickness(es), the presence of opening(s), etc.) and/or material of the first elastomer **306** and/or the second elastomer **321** can be selected to tune the portions of the negative vertical load and the positive vertical load, respectively, carried by the aft mount **300**.

[0062] The frame coupling **304** couples the structural member **305** to the third frame portion **206**. In the illustrated example of FIG. **3**, the structural member **305** is coupled to the second yoke **318** (e.g., via one or more welds, one or more threaded connections, one or more fasteners, one or interference connections, etc.). Additionally or alternatively, the structural member **305** and the second yoke **318** can be integral.

[0063] The second plate **316** of the frame coupling **304** can be coupled to the third frame portion **206** via holes **322**. For example, the second plate **316** can be coupled to the third frame portion **206** via one or more fasteners (e.g., one or more bolts, one or more screws, one or more rivets, etc.) extending through the holes **322**. Additionally or alternatively, the second plate **316** can be coupled to the third frame portion via one or more welds, via one or more interference connections, etc. In other examples, the second plate **316** and the third frame portion **206** can be integral.

[0064] In the illustrated example of FIG. **3**, the second pin **314** extends through a slot **324** of the second yoke **318** and the second plate **316**. In the illustrated example of FIG. **3**, the second plate **316**, the second yoke **318**, and the second pin **314** form a clevis, which facilitates the transferring of vertical loads between the third frame portion **206** and the structural member **305**. The coupling of the structural member **305** and the third frame portion **206** via the second pin **314** facilitates the rotation of the structural member **305** about the second pin **314** (e.g., about the roll axis, etc.). In some such examples, the pins **308**, **314** prevent the aft mount **300** from transferring moments about the roll axis.

[0065] In the illustrated example of FIG. **3**, the slot **324** of the second plate **316** includes a first end **326**A and a second end **326**B. In the illustrated example of FIG. **3**, the slot **324** defines an example arc **328** between the ends **326**A, **326**B. During standard operation (e.g., takeoff, cruise, descent, landing, etc.), the second pin **314** slides within the slot **324**, which prevents the aft mount **300** from reacting yaw moments. In some examples, yaw moments can be generated by 1P loading. In some such examples, because the aft mount **300** does not react yaw moments during standard operation, operational distortions associated with 1P loading transferred via the aft mount **300** can be reduced. In some examples, during non-standard operation (e.g., a blade-out event, etc.), the yaw moment applied through the gas turbine engine **100** can increase and cause the gas turbine engine **100** to rotate such that the second pin **314** abuts one of the ends **326**A, **326**B. In some such examples, the contact between the second pin **314** and one of the ends **326**A, **326**B causes the aft mount **300** to react yaw moments, which can mitigate the impact of such non-standard operation. In other examples, the slot **324** can be absent. In some such examples, the second plate **316** can include a hole to receive the second pin **314**.

[0066] FIG. **4** is a perspective view of another example aft mount **400** implemented in accordance with the teachings of this disclosure. The aft mount **400** can be used to implement the aft mount **214** of FIG. **2**. In the illustrated example of FIG. **4**, the aft mount **400** includes a pylon coupling **402**, the frame coupling **304** of FIG. **3**, a structural member **403**, and a spring **404**. The example aft mount **400** is similar to the aft mount **300** of FIG. **3**, except that aft mount **400** includes the spring **404** instead of the first elastomer **306**. While the aft mount **400** does not include a slot in the illustrated example of FIG. **4**, in other examples, the aft mount **400** can include a slot similar to the slot **324** of FIG. **3**.

[0067] In the illustrated example of FIG. **4**, the pylon coupling **402** includes a yoke **405**, a pin **406**, and a mounting plate **408**. In the illustrated example of FIG. **4**, the structural member **403** is coupled to the yoke **405** (e.g., via one or more welds, one or more threaded connections, one or more fasteners, one or more interference connections, etc.). Additionally or alternatively, the structural member **403** and the yoke **405** can be integral. In the illustrated example, the mounting plate **408** extends from the pylon **208** and facilitates the coupling of the aft mount **400** thereto. In the illustrated example of FIG. **4**, the pin **406** extends through the yoke **405** and the mounting plate **408**. In the illustrated example of FIG. **3**, the mounting plate **408**, the yoke **405**, and the pin **406** form a clevis, which facilitates the transferring of vertical loads between the third frame portion **206** and the structural member **403**. The coupling of the structural member **403** and the third frame portion **206** via the pin **406** facilitates the rotation of the structural member **403** about the pin **406** (e.g., about the roll axis, etc.). In some such examples, the pin **406** and the frame coupling **304** (e.g., the second pin **314** of FIG. **3**, etc.) prevent the aft mount **400** from transferring moments about the roll axis.

[0068] The spring **404** is a coil spring (e.g., a helical spring, etc.) that resists tension applied between the pylon coupling **302** and the frame coupling **304**. In the illustrated example of FIG. **4**, the spring **404** is disposed in the load path between the pylon coupling **402** and the frame coupling **304**, such that the spring **404** reacts negative vertical loads (e.g., gravitational loads, aerodynamic loads, maneuver loads, etc.) transferred between the pylon coupling **402** and the frame coupling **304**. In some examples, the spring **404** does not react positive vertical loads between the pylon coupling **402** and the frame coupling **304**.

[0069] In some examples, the aft mount **400** can include additional structural members (not illustrated) disposed between the pylon coupling **302** and the frame coupling **304**. In some examples, the geometry and/or material of the spring **404** can be selected to reduce the distortion associated with gravitational and maneuver loading and to reduce the distortion associated with bending moments transferred between the aft mount **400** and the forward mounts of the gas turbine engine (e.g., the forward mounts **210**, **212**, etc.). In some examples, the material can be any suitable material, including spring steel, titanium, nickel-alloy, composite, and/or any other suitable material.

[0070] FIG. **5**A is a perspective view of another example aft mount **500** implemented in accordance with the teachings of this disclosure. FIG. **5**B is a cross-sectional view of the aft mount **500**. The aft mount **500** can implement the aft mount **214** of FIG. **2**. In the illustrated example of FIGS. **5**A and **5**B, the aft mount **500** includes a first pin **502**, a plate **504**, and a yoke **506** similar to the second pin **314** of FIG. **3**, the second plate **316** of FIG. **3**, and the second yoke **318** of FIG. **3**. For example, the plate **504** can be coupled to a frame portion of the core engine **120** (e.g., the third frame portion **206**, etc.) in a manner similar to the frame coupling **304** of FIGS. **3** and **4**. In other examples, the aft mount **500** can be coupled to the core engine **120** via any other suitable coupling.

[0071] In the illustrated example of FIGS. **5**A and **5**B, the aft mount **500** includes a first disc spring **508**, a second disc spring **510**, a first structural member **512**, a second structural member **514**, a first flange **516**, a second flange **518**, a second pin **520**, and a mounting plate **522**. In the illustrated example of FIGS. **5**A and **5**B, each of the disc springs **508**, **510** include two frustoconical portions. In other examples, one or both of the disc springs **508**, **510** can have any other suitable shape (e.g., a conical shape, a frustoconical shape, etc.). In the illustrated example of FIGS. **5**A and **5**B, each of the disc springs **508**, **510** is a single spring. In other examples, one or both of the disc springs **508**, **510** can include one or more portions stacked in parallel and/or one or more portions stacked in sequence. In some examples, the thickness of the portions of the disc springs **508**, **510**, and/or the quantity thereof can be used to adjust the stiffness of the aft mount **500** in the negative vertical direction and the positive vertical direction, respectively. In the illustrated example of FIGS. **5**A and **5**B, the disc springs **508**, **510** are composite springs. In other examples, the disc springs **508**, **510** can be composed of any other suitable material (e.g., steel, aluminum, a nickel alloy, bronze, etc.).

[0072] The first structural member **512** is a rigid structural member (e.g., a tubular member, a tube, etc.) that transfers load between the yoke **506** and one or both of the disc springs **508**, **510**. In the illustrated example of FIGS. **5**A and **5**B, the first structural member **512** has a generally circular cross-section. In other examples, the first structural member **512** can have any other suitable cross-section (e.g., an ovoid cross-section, a polygonal cross-section, etc.). The first structural member **512** can be composed of any suitable rigid material including steel, titanium, aluminum, a nickel alloy, a composite, etc. In the illustrated example of **5**B, the first structural member **512** has an interior **523**, which receives the second structural member **514**.

[0073] The second structural member **514** is a rigid structural member (e.g., a tubular member, a tube, etc.) that transfers load between the mounting plate **522** and one or both of the disc springs **508**, **510**. In the illustrated example of FIG. **5**B, the second structural member **514** has a same cross-sectional shape as the first structural member **512** and has a smaller cross-sectional size than the first structural member **512** such that a gap **526** is formed between an outer diameter **527**A of the second structural member **514** and an inner diameter **527**B of the first structural member **512**. The second structural member **514** can be composed of any suitable rigid material including steel, titanium, aluminum, a nickel alloy, a composite, etc.

[0074] The first flange **516** is an annular member disposed between the second pin **520** and the first disc spring **508**. In the illustrated example of FIGS. **5**A and **5**B, the first flange **516** is not fixedly coupled to the first structural member **512** or the second structural member **514** and is retained in compression between the second pin **520** and the first disc spring **508**. The first flange **516** can be composed of any suitable rigid material including steel, titanium, aluminum, a nickel alloy, a composite, etc. In some examples, the first flange **516** is a washer and/or a circular disc. In other examples, the first flange **516** can be any other suitable shape. The second flange **518** is an annular member disposed between the first disc spring **508** and the second disc spring **510**. In the illustrated example of FIGS. **5**A and **5**B, the second flange **518** is integral with the first structural member **512**. In other examples, the second flange **518** can be an annular member coupled to the first structural member **512** via one or more welds, via one or more fasteners (e.g., bolts, screws, rivets, etc.), via one or more interface connections, and/or via one or more mechanical interfaces. In some examples, the second flange **518** is composed of a same material as the first structural member **512**. In other examples, the second flange **518** can be composed of a different rigid material.

[0075] The second pin **520** couples the first structural member **512** and the second structural member **514**. In the illustrated example of FIGS. **5**A and **5**B, the second pin **520** abuts the first flange **516**, which retains the coupling of the first structural member **512** to the second structural member **514**. In the illustrated example of FIGS. **5**A and **5**B, the first structural member includes slots **524**. In the illustrated example of FIGS. **5**A and **5**B, the second pin **520** extends through the slots **524** and openings **521** in the second structural member **514**.

[0076] The mounting plate **522** enables the aft mount **500** to be coupled to a pylon (e.g., the pylon **208** of FIG. **2**, etc.). For example, the mounting plate **522** can be coupled to a pylon **208** via one or more welds, via one or more fasteners (e.g., bolts, screws, rivets, etc.), via one or more interface connections, and/or via one or more mechanical interfaces. In other examples, the mounting plate **522** can be integral with a pylon and/or a portion of a pylon. In the illustrated example of FIG. **5**B, the mounting plate **522** and the second structural member **514** are integral. In other examples, the mounting plate **522** can be coupled to the second structural member **514** via one or more welds, via one or more fasteners (e.g., bolts, screws, rivets, etc.), via one or more interface connections, and/or via one or more mechanical interfaces.

[0077] During operation, the slots **524** permit the vertical translation of the first structural member **512** relative to the second structural member **514** and the second pin **520**. For example, during positive vertical loads (e.g., the gas turbine engine **100** is pushing upwards on the pylon **208**, a compression load, etc.), the second pin **520** slides downward within the slots **524** until the second pin **520** abuts a bottom of the slots **524**, which enables the compression of the second disc spring **510**. The compression of the second disc spring **510** reduces the stiffness of the aft mount **500** in tension, which reduces the portion of positive vertical load associated with the gas turbine engine **100** transferred via the aft mount **500** and increases the portion of positive vertical loads transferred via the other mounts of the gas turbine engine **100**. In some examples, the second disc spring **510** is absent. In some such examples, the aft mount **500** can include a rigid connection to react positive vertical loads.

[0078] During operation, if a negative vertical load is applied to the aft mount **500** (e.g., the gas turbine engine **100** is pulling downwards on the pylon **208**, a tension load, etc.), the second flange **518** applies a compressive load to the first disc spring **508**. In some such examples, the first disc spring **508** is compressed between the second flange **518** and the first flange **516**. The compression of the first disc spring **508** reduces the stiffness of the aft mount **500** in compression, which reduces the portion of negative vertical load associated with the gas turbine engine **100** transferred via the aft mount **500** and increases the portion of negative vertical loads transferred via the other mounts of the gas turbine engine **100**. In some examples, the first disc spring **508** is absent. In some such examples, the aft mount **500** can include a rigid connection to react negative vertical loads.

[0079] The gap **526** enables the relative rotation of the first structural member **512** and the second structural member **514** about the second pin **520**. During standard operation (e.g., takeoff, cruise, descent, landing, etc.), the second structural member **514** rotates within the interior **523** about the second pin **520**, which prevents the aft mount **500** from reacting yaw moments. In some examples, yaw moments can be generated by 1P loading. In some such examples, because the aft mount **500** does not react yaw moments during standard operation, operational distortions associated with 1P loading transferred via the aft mount **214** can be reduced. In some examples, during non-standard operation (e.g., a blade-out event, etc.), the yaw moment applied through the gas turbine engine **100** can increase and cause the gas turbine engine **100** to rotate such that the second structural member **514** rotates within the gap **526** until the outer diameter **527**A of the second structural member **514** abuts the inner diameter **527**B of the first structural member **512**. In some such examples, the contact between the second structural member **514** and the first structural member **512** causes the aft mount **500** to react yaw moments, which can mitigate the impact of such non-standard operation. In other examples, the gap **526** can be absent and the aft mount **500** can react yaw moments during standard operation.

[0080] FIG. **6** is a perspective view of an example first thrust linkage configuration **600** that can be used in conjunction with the second frame portion **204** of FIG. **2**. In the illustrated example of FIG. **6**, the first thrust linkage configuration **600** includes a first thrust linkage **602** and a second thrust linkage **604**, which extend between the second frame portion **204** of FIG. **2** and a pylon block **606**. In the illustrated example of FIG. **6**, the first thrust linkage **602** is coupled to the pylon block **606** at a first block attachment point **608** and the second thrust linkage **604** is coupled to the pylon block **606** at a second block attachment point **610**.

[0081] The pylon block **606** is a mounting component that is coupled to a pylon supporting the second frame portion **204** (e.g., the pylon **208** of FIG. **2**, etc.). In some examples, the pylon block **606** can be absent. In some such examples, the thrust linkages **602**, **604** can extend directly to the pylon **208**. In some examples, an aft mount (e.g., one of the aft mounts **214**, **400**, **500** of FIGS. **2**-**5**B, etc.) can be coupled to the pylon block **606**.

[0082] The first thrust linkage configuration **600** enables the yaw moment generated by the operation of a gas turbine engine including the second frame portion **204** (e.g., the gas turbine engine **100** of FIG. **1**, etc.) to be constrained by the thrust linkages **602**, **604** in combination. The thrust linkages **602**, **604** prevent yaw moments from being transferred through the cantilevered core. In the illustrated example of FIG. **6**, the thrust linkages **602**, **604** transfer axial forces between the second frame portion **204** to the pylon block **606**. In some examples, either or both of the thrust linkages **602**, **604** can be implemented by multiple thrust linkages (e.g., two thrust linkages, three thrust linkages, etc.). In some such examples, the plurality of linkages implementing the first thrust linkage **602** can be joined together via a yoke and/or a whiffletree connection, which evenly distributes the load between each of the plurality of linkages. In some such examples, the plurality of linkages implementing the second thrust linkage **604** can be joined together via a yoke and/or whiffletree connection, which evenly distributes the load between each of the plurality of thrust linkages.

[0083] The block attachment points **608**, **610** of the thrust linkages **602**, **604** on the pylon block **606** are separated by a lateral displacement **612**. The lateral displacement **612** enables the thrust linkages **602**, **604** to bear different amounts of axial loads generated by the gas turbine engine **100**. As such, this imbalance of axial forces between the thrust linkages **602**, **604** enables the thrust linkages to transfer yaw moments generated by the gas turbine engine **100** between the second frame portion **204** and the pylon block **606**.

[0084] FIG. **7** is a perspective view of the coupling between the thrust linkages **602**, **604** of FIG. **6** to the pylon block **606** of FIG. **6**. In the illustrated example of FIG. **7**, the first thrust linkage **602** is coupled to a first lug **702** via a first pin **704**, and the second thrust linkage **604** is coupled to a second lug **706** via a second pin **708**. In the illustrated example of FIG. **7**, the lugs **702**, **706** are discrete components that can be coupled to the pylon block **606** via one or more fasteners (e.g., bolts, rivets, etc.). In other examples, one or both of the lugs **702**, **706** can be integral with the pylon block **606**. In some examples, one or both of the pins **704**, **708** can include and/or be coupled to one or more bearings and/or bushings. In some such examples, the bearings and/or bushings can prevent non-axial forces from being reacted via the thrust linkages **602**, **604**.

[0085] In the illustrated example of FIG. **7**, the block attachment points **608**, **610** independently couple the thrust linkages **602**, **604** to the pylon block **606**. That is, unlike some prior connections, the thrust linkages **602**, **604** are not coupled via a yoke, such as a whiffletree connection, and are directly coupled to the pylon block **606**. As such, the thrust linkages **602**, **604** are capable of reacting with different amounts of axial force, which enables the thrust linkages **602**, **604** to react yaw moments between the second frame portion **204** and the pylon block **606**.

[0086] FIG. **8** is a perspective view of an example second thrust linkage configuration **800** that can be used in conjunction with the second frame portion **204** of FIG. **2**. In the illustrated example of FIG. **8**, the second thrust linkage configuration **800** includes the first thrust linkage **602** of FIG. **6**, the second thrust linkage **604** of FIG. **6**, and a third thrust linkage **802**. In the illustrated example of FIG. **8**, the third thrust linkage **802** is coupled to the pylon block **606** of FIG. **6** at a third block attachment point **804**. The second thrust linkage configuration **800** enables both yaw and pitch moments generated by the operation of a gas turbine engine (e.g., the gas turbine engine **100**, etc.) to be constrained by the thrust linkages **602**, **604**, **802**, which mitigates lateral and vertical displacements of the cantilevered core of the gas turbine engine. In the illustrated example of FIG. **8**, the pylon block **606** is coupled to the pylon **208**. In the illustrated example of FIG. **8**, the second frame portion **204** includes an outer ring **808**, an inner ring **810**, and a bifurcation **811**. In the illustrated example, the first thrust linkage **602** is coupled to the inner ring **810** at a first frame attachment point **812**, the second thrust linkage **604** is coupled to the inner ring **810** at a second frame attachment point **814**, and the third thrust linkage **802** is coupled to the bifurcation **811** at the third frame attachment point **816**.

[0087] In the illustrated example of FIG. **8**, the thrust linkages **602**, **604**, **802** transfer axial forces generated by the second frame portion **204** to the pylon block **606** and the pylon **208**. The block attachment points **608**, **610** of the thrust linkage **602**, **604**, and the third block attachment point **804** of the third thrust linkage **802** are separated by a vertical displacement **806**. Similarly, the thrust linkages **602**, **604** are separated by the lateral displacement **612** of FIG. **6**. The vertical displacement **806** and the lateral displacement **612** allow imbalances of axial forces to occur between the thrust linkages **602**, **604**, **802**. As such, the thrust linkages **602**, **604**, **802** can transfer yaw and pitch moments associated with the second frame portion **204** to the pylon **208** (e.g., via the pylon block **606**, etc.). In other examples, the thrust linkages **602**, **604**, **802** can have any other suitable (e.g., having both vertical and lateral displacements, etc.).

[0088] FIG. **9** is a perspective view of an example third thrust linkage configuration **900** that can be used in conjunction with the second frame portion **204** of FIG. **2**. In the illustrated example of FIG. **9**, the third thrust linkage configuration **900** includes the first thrust linkage **602** of FIG. **6**, the second thrust linkage **604** of FIG. **6**, and a third thrust linkage **902**. In the illustrated example of FIG. **9**, the third thrust linkage **902** is coupled to the pylon **208** at a third block attachment point **904**. The example third thrust linkage configuration **900** is similar to the second thrust linkage configuration **800**, except that the third thrust linkage **902** is coupled directly to the pylon **208** via a lug **906** unlike the third thrust linkage **802** of FIG. **8**, which is coupled to the pylon block **606**.

[0089] In the illustrated example of FIG. **9**, the thrust linkages **602**, **604**, **902** transfer axial forces generated by the second frame portion **204** to the pylon block **606** and the pylon **208**. The block attachment points **608**, **610** of the thrust linkage **602**, **604**, and the third attachment point **904** of the third thrust linkage **802** are separated by a vertical displacement **908**. Similarly, the thrust linkages **602**, **604** are displacement by the lateral displacement **612** of FIG. **6**. The vertical displacement **908** and the lateral displacement **612** allow imbalances of axial forces to occur between the thrust linkages **602**, **604**, **902**. As such, the thrust linkages **602**, **604**, **902** can transfer yaw and pitch moments associated with the second frame portion **204** to the pylon **208** (e.g., via the pylon block **606**, etc.). In other examples, the thrust linkages **602**, **604**, **902** can have any other suitable configuration (e.g., having both vertical and lateral displacements, etc.).

[0090] The first thrust linkage configuration **600** of FIGS. **6** and **7**, the second thrust linkage configuration **800** of FIG. **8**, and the third thrust linkage configuration **900** are configurations that react yaw and/or pitch moments and mitigate lateral and/or vertical displacements of the cantilevered core sections associated therewith. In some examples, the first thrust linkage configuration **600** of FIGS. **6** and **7**, the second thrust linkage configuration **800** of FIG. **8**, and/or the third thrust linkage configuration **900** can be used in conjunction with the aft mount **214** of FIGS. **2** and **3**, the aft mount **400** of FIG. **4** and/or aft mount **500** of FIGS. 5A and 5B. In some such examples, because the thrust linkage configurations **600**, **800**, **900** of FIGS. **6-9** react yaw and/or pitch moments transmitted through the gas turbine engine and prevent the aft mounts **214**, **400**, **500** from reacting yaw and pitch moments. In some such examples, by preventing the aft mounts **214**, **400**, **500** from reacting yaw and pitch moments, operational distortions in the engine carcass are reduced (e.g., eliminated, etc.).

[0091] In some examples, frame mount systems including the thrust linkage configurations **600**, **800**, **900** of FIGS. **6-9** can be over constrained and/or statically indeterminate. In some such examples, the thermal expansion of the thrust linkage configurations **600**, **800**, **900** can cause engine carcass distortions due to stress and strain associated with the expansion of the thrust linkages of the thrust linkage configurations **600**, **800**, **900**. Example mount systems to mitigate such thermal expansion-associated distortions are described below in conjunction with FIGS. **10** and **11**.

[0092] FIG. **10** is a perspective view of another example engine mount system **1000** including the aft mount **500** of FIGS. 5A and 5B, the second thrust linkage configuration **800** of FIG. **8**, a first forward mount **1001**, and the second forward mount **212** of FIG. **2**. In the illustrated example of FIG. **10**, the engine mount system **1000** couples a gas turbine engine **1002** to the pylon **208**. The gas turbine engine **1002** includes the core engine **120** of FIG. **1** and the frame portions **202**, **204**, **206** of FIG. **2**. The gas turbine engine **1002** is similar to the gas turbine engine **100** of FIG. **1**, except as otherwise noted.

[0093] In the illustrated example of FIG. **10**, the aft mount **500** extends between the pylon **208** and the third frame portion **206**. In the illustrated example of FIG. **10**, the first forward mount **1001** extends between the pylon **208** and the first frame portion **202**. In the illustrated example of FIG. **10**, the first thrust linkage **602** of the second thrust linkage configuration **800** of FIG. **8** is coupled to the second frame portion **204** at the first frame attachment point **812**, the second thrust linkage **604** of the second thrust linkage configuration **800** is coupled to the second frame portion **204** at the second frame attachment point **814**, and the third thrust linkage **802** of the second thrust linkage configuration **800** is coupled to the second frame portion **204** at the third frame attachment point **816**. In the illustrated example of FIG. **10**, the first thrust linkage **602** and the second thrust linkage **604** have a first length **1004** and the third thrust linkage **802** has a second length **1006**.

[0094] In the illustrated example of FIG. **10**, the engine mount system **1000** over constrains the gas turbine engine **100**. That is, the mounting components of the engine mount system **1000** (e.g., the forward mounts **212**, **1001**, the aft mount **500**, the first thrust linkage **602**, the second thrust linkage **604**, the third thrust linkage **802**, etc.) include 9 static constraints. For example, forward mounts **212**, **1001** constrain lateral translation, vertical translation, longitudinal translation, yaw translation, and roll rotation, the thrust linkages **602**, **604**, **802** constrain longitudinal translation, yaw rotation, and pitch translation, and the aft mount **500** constrains vertical translation. In other examples, depending on the configuration of the forward mounts **212**, **1001**, the aft mount **500**, the first thrust linkage **602**, the second thrust linkage **604**, the third thrust linkage **802**, the engine mount system **1000** can include fewer static constraints (e.g., 6 static constraints, 7 static constraints, 8 static constraints, etc.) and/or additional static constraints (e.g., 10 static constraints, etc.). As such, because the engine mount system **1000** includes more than 6 static constraints, the engine mount system **1000** is statically indeterminate (e.g., over constrained, statically overdetermined, unresolvable via force and moment balancing, etc.). Because the engine mount system **1000** is statically indeterminate, the loads carried by the forward mounts **212**, **1001**, the aft mount **500**, the first thrust linkage **602**, the second thrust linkage **604**, and the third thrust linkage **802** are dependent on the ambient conditions (e.g., temperature, etc.) material properties (e.g., stiffness, thermal properties, etc.), and the geometry (e.g., the length, the thickness, etc.) of the forward mounts **212**, **1001**, the aft mount **500**, the first thrust linkage **602**, the second thrust linkage **604**, the third thrust linkage **802**.

[0095] During the operation of the gas turbine engine **1002**, a portion of the air that enters the gas turbine engine **1002** flows through the core engine **120**. Within the core engine **120**, the air is pressurized (e.g., via the LP compressor **126** and the HP compressor **128** of FIG. **1**, etc.) and combusted (e.g., via the combustor **130**, etc.). The comparably hot and dense air increases the relative temperature of the core engine **120** and components of the gas turbine engine **1002** adjacent to the core engine **120** when compared to other components of the gas turbine engine **1002**. Additionally, during the operation of the gas turbine engine **1002**, ambient air (e.g., about −50 degrees Fahrenheit at operational altitudes, etc.) passes between the inner ring **810** and the outer ring **808**, which is cooler than the air flowing through the core engine **120** (e.g., about **3000** degrees Fahrenheit, etc.). In the illustrated example of FIG. **10**, the frame attachment points **812**, **814** and the block attachment points **608**, **610** of the first thrust linkage **602** and the second thrust linkage **604** are closer to the core engine **120** than the third frame attachment point **816** and the third block attachment point **804** of the third thrust linkage **802**. As such, the first thrust linkage **602** and the second thrust linkage **604** are closer to the core engine **120** than the third thrust linkage **802**. The closer proximity of the thrust linkages **602**, **604** to the core engine **120** and the position of the third thrust linkage **802** on the bifurcation **811** causes the operational temperatures of the thrust linkage **602**, **604** to be greater than the operational temperature of the third thrust linkage **802**.

[0096] The linear expansion of a component due to a temperature change is set forth in Equation (1):

$$\Delta L = \alpha L \Delta T \tag{1}$$

where ΔL is the change in length, α is the linear coefficient of thermal expansion for the material of the component, L is the original length of the component, and ΔT is the change in temperature of the component. In the illustrated example of FIG. **10**, the first length **1004** of the thrust linkages **602**, **604** is greater than the second length **1006** of the third thrust linkage **802**. Because the thrust linkages **602**, **604** are greater in length (e.g., a greater L, etc.) and are subjected to a larger temperature change than the third thrust linkage **802** (e.g., a greater ΔT, etc.), the thrust linkages **602**, **604** are more susceptible to thermal expansion (e.g., a greater ΔL, etc.) than the third thrust linkage **802** during operation of the gas turbine engine **100**. In some examples, a greater thermal expansion of the thrust linkages **602**, **604** than the third thrust linkage **802** can create a bending stress in the second frame portion **204** and/or distortions in the core engine **120**. For example, the thermal expansion of the thrust linkages **602**, **604**, **802** can cause thrust linkages **602**, **604**, **802** to exert a pitch moment between the frame attachment points **812**, **814** and the third frame attachment point **816** (e.g., the thermal expansion of the thrust linkage **602**, **604** pushes the bottom of the second frame portion **204** along the roll axis and pivots the second frame portion **204** about the third frame attachment point **816**, etc.).

[0097] In some examples, to mitigate the bending distortions caused by the thermal expansion of the thrust linkages **602**, **604**, **802**, the thrust linkages **602**, **604**, **802** can be composed of materials with different coefficients of thermal expansion. For example, the first thrust linkage **602** and the second thrust linkage **604** can be composed of a first material with a lower coefficient of thermal expansion than a second material of the third thrust linkage **802**. For example, the thrust linkages **602**, **604** can be composed of nickel alloy **909** (e.g., INCONEL® **909**, etc.) and the third thrust linkage **802** can be composed of nickel alloy **718** (e.g., INCONEL® **718**, etc.) because the coefficient of thermal expansion of the nickel alloy **718** is ~40% greater than the coefficient of thermal expansion of nickel alloy **909**. In other examples, the thrust linkages **602**, **604**, **802** can be composed of any other materials that have different coefficients. Additionally or alternatively, the lengths **1004**, **1006**, and/or material of the thrust linkages **602**, **604**, **802** can be chosen such Equation (2) is true:

$$\alpha_1 L_1 \Delta T_1 \approx \alpha_2 L_2 \Delta T_2 \tag{2}$$

where α_1 is the linear coefficient of thermal expansion for the material of the thrust linkages **602**, **604**, α_2 is the linear coefficient of thermal expansion for the material of the thrust linkages **802**, L_1 is the original length of the thrust linkages **602**, **604** (e.g., the room temperature lengths of the thrust linkages **602**, **604**, etc.), L_2 is the original length of the thrust linkage **802** (e.g., the room temperature lengths of the third thrust linkage **802**, etc.), ΔT_1 is the change in temperature experienced by the thrust linkages **602**, **604**, and ΔT_2 is the change in temperature experienced by the third thrust linkage **802**. Equation (2) includes the symbol "~." As used herein, the symbol indicates that the two quantities related by the symbol are approximately equal. In some examples, the materials and lengths of the thrust linkages of the third thrust linkage configuration **900** of FIG. **9** (e.g., the thrust linkages **602**, **604**, **902** of FIG. **9**, etc.) can be similarly configured based on Equation (2).

[0098] The first forward mount **1001** is similar to the first forward mount **210** of FIG. **2**, except that the first forward mount **1001** includes an elastomer bearing **1008**. The elastomer bearing **1008** is disposed in the load path through the first forward mount **1001** between the gas turbine engine **1002** and the pylon **208**. In the illustrated example of FIG. **10**, the elastomer bearing **1008** is an elastomer bushing disposed around a pin of the first forward mount **1001**. In other examples, the elastomer bearing **1008** is disposed at another suitable location in the load path through the first forward mount **1001**. The comparatively lower stiffness of the elastomer bearing **1008** releases stress associated with the thermal expansion of the gas turbine engine **1002** during operation and the static indeterminateness of the engine mount system **1000**. That is, the bending moments transmitted through the gas turbine engine **1002** are released (e.g., partially released, fully released, etc.) via the deformation of the elastomer bearing **1008** associated with a small displacement of the gas turbine engine **1002** relative to the pylon **208**. In some examples, the elastomer bearing **1008** includes one or more of a natural rubber, a silicon rubber, a thermoplastic elastomer, a synthetic rubber, etc. In other examples, the first forward mount **1001** is implemented by the first forward mount **210** of FIG. **2**, and the elastomer bearing **1008** is absent.

[0099] FIG. **11** is a perspective view of another example engine mount system **1100** including the second thrust linkage configuration **800** of FIG. **8**, the first forward mount **1001** of FIG. **10**, and the second forward mount **212** of FIG. **2**. The engine mount system **1100** is similar to the engine mount system **1000** of FIG. **10**, except that the engine mount system **1100** includes another example aft mount **1102** instead of the aft mount **500** of FIGS. **5**A, **5**B, and **10**. In the illustrated example of FIG. **11**, the engine mount system **1100** couples the gas turbine engine **1002** of FIG. **10** to the pylon **208** of FIGS. **2** and **10**. In the illustrated example of FIG. **11**, the engine mount system **1100** includes the second thrust linkage configuration **800** of FIG. **8**.

[0100] Like the engine mount system **1000** of FIG. **10**, the engine mount system **1100** is overconstrained (e.g., statically indeterminate, etc.). Accordingly, the components of the engine mount system **1100** and the gas turbine engine **1002** are sensitive to the thermal stress on the engine mount system **1100** (e.g., the thermal expansion of the components of the engine mount system **1100** can introduce internal stresses into the gas turbine engine **1002** and the engine mount system **1100**, etc.). In some examples, the thrust linkages **602**, **604**, **802** can be designed based on Equation (2). That is, the lengths and materials of the thrust linkages **602**, **604**, **802** can be selected to mitigate (e.g., prevent, reduce, etc.) internal distortions caused by the thermal expansion of the engine mount system **1100** and the gas turbine engine **1002**.

[0101] The aft mount **1102** is another aft mount implemented in accordance with the teachings of this disclosure and can be used to implement the aft mount **214** of FIG. **2**. In the illustrated example of FIG. **11**, the aft mount **1102** includes a leaf spring **1104**, a mount member **1106**, and a pylon coupling **1108**. The leaf spring **1104** is an elastic element that resists tension applied between the pylon coupling **1108** and the third frame portion **206**. In the illustrated example of FIG. **11**, the leaf spring **1104** is disposed in the load path between the pylon **208** and the third frame portion **206**, such that the leaf spring **1104** reacts negative vertical loads (e.g., gravitational loads, aerodynamic loads, maneuver loads, etc.) transferred between the pylon **208** and the third frame portion **206**. In some examples, the leaf spring **1104** also reacts positive vertical loads (e.g., aerodynamic loads, maneuver loads, etc.). In some examples, the geometry and/or material of the leaf spring **1104** can be selected to reduce the distortion associated with gravitational and maneuver loading and to reduce the distortion associated with bending moments transferred between the aft mount **1102** and the forward mounts **212**, **1001**. For example, the thickness of the leaf spring **1104**, the thickness profile of the leaf spring **1104**, and/or the length of the leaf spring **1104** can be used to modify the stiffness of the aft mount **1102** and the distortion associated with the reaction of bending moments associated with the gas turbine engine **1002** via the engine mount system **1100**.

[0102] The leaf spring **1104** can be composed of any suitable rigid material that is resistant to plastic deformation (e.g., a nickel alloy, steel, titanium, etc.). In some examples, to reduce internal stresses on the gas turbine engine **1002** caused by the thermal expansion of the leaf spring **1104**, the leaf spring **1104** and/or the mount member **1106** can be composed of a material with a comparatively low coefficient of thermal expansion (e.g., nickel alloy **909**, etc.). In the illustrated example of FIG. **11**, the leaf spring **1104** includes a single leaf (e.g., a single bar of material, etc.). In other examples, the leaf spring **1104** can include multiple leaves (e.g., two leaves, three leaves, five leaves, etc.), which can modify the stiffness of the aft mount **1102** (e.g., cause the spring response of the leaf spring **1104** to be non-linear, etc.).

[0103] The pylon coupling **1108** couples the aft mount **1102** to the pylon **208**. In some examples, the pylon coupling **1108** can be implemented by a pin linkage and/or a clevis (e.g., similar to the pylon coupling **302** of FIG. **3**, similar to the pylon coupling **402** of FIG. **4**, etc.). In other examples, the pylon coupling **1108** can be implemented by a boomerang linkage, a whiffletree linkage, a ball joint, a cotter joint, etc. Example couplings that can be used to couple the aft mount **1102** to the third frame portion **206** are described below in conjunction with FIGS. **12**A-**12**G.

[0104] In the illustrated example of FIG. **11**, the mount member **1106** is a rigid structural member that extends between the pylon coupling **1108** and the third frame portion **206** and reacts vertical loads transferred therebetween. In the illustrated example of FIG. **11**, the mount member **1106** is a bar-shaped member. In other examples, the mount member **1106** can be implemented by a cylindrical member, a prismatic member, a tube, etc. The mount member **1106** can be composed of any suitable rigid material, including a same material as the leaf spring **1104**, steel, titanium, aluminum, a nickel alloy, etc.

[0105] FIGS. **12**A is a front view of the aft mount **1102** of FIG. **11** including an example first frame coupling **1200**. In the illustrated example of FIG. **12**A, the leaf spring **1104** includes a first eye **1201**A and a second eye **1201**B. In the illustrated example of FIG. **12**A, the first frame coupling **1200** includes a first pin linkage **1202** and a first swing linkage **1204**A. In the illustrated example of FIG. **12**A, the first pin linkage **1202** includes a first pin **1206** and a first mounting boss **1208**. In the illustrated example of FIG. **12**B, the first swing linkage **1204**A includes a second pin **1210**, a third pin **1212**, a second mounting boss **1214**, and a linkage member **1216**.

[0106] In the illustrated example of FIG. **12**A, the mounting bosses **1208**, **1214** are plates (e.g., a sheet member, etc.) that are fixedly coupled to and extend from the third frame portion **206**. In other examples, one or both of the mounting bosses **1208**, **1214** can be integral with the third frame portion **206**. The first pin linkage **1202** is formed via the coupling of the first pin **1206** through the first eye **1201**A of the leaf spring **1104** and the first mounting boss **1208**. The first pin linkage **1202** reacts forces in the yaw and pitch directions. In the illustrated example of FIG. **12**A, the first swing linkage **1204**A is formed via (**1**) the coupling of the second pin **1210** through the second eye **1201**B of the leaf spring **1104** and the linkage member **1216** and (**2**) the coupling of the third pin **1212** through the linkage member **1216** and the second mounting boss **1214**. The first swing linkage **1204**A reacts forces in the negative yaw direction. Accordingly, the combined use of the first swing linkage **1204**A and the first pin linkage **1202** causes the first frame coupling **1200** to only react forces in the negative yaw direction. The first frame coupling **1200** facilitates the thermal expansion of the leaf spring **1104**, the mount member **1106**, and/or the third frame portion **206** by releasing pitch and positive yaw reactions via the first swing linkage **1204**A and enabling small relative displacements between the aft mount **1102** and the third frame portion **206** in the pitch and positive yaw directions.

[0107] FIG. **12**B is a front view of the aft mount **1102** of FIG. **11** including an example second frame coupling **1218**. The second frame coupling **1218** includes the first swing linkage **1204**A and is similar to the first frame coupling **1200**, except that the second frame coupling **1218** includes a second swing linkage **1204**B instead of the first pin linkage **1202**. In the illustrated example of FIG. **12**A, the second swing linkage **1204**B is formed via (**1**) the coupling of a fourth pin **1220** through the first eye **1201**A of the leaf spring **1104** and a second linkage member **1222** and (**2**) the coupling of a fifth pin **1224** through the second linkage member **1222** and the second mounting boss **1214**. Like the first swing linkage **1204**A, the second swing linkage **1204**B reacts loads in the negative yaw. Accordingly, the second frame coupling **1218** facilitates the thermal expansion of the leaf spring **1104**, the mount member **1106**, and/or the third frame portion **206** by releasing pitch and positive yaw reactions via the first and second swing linkages **1204**A, **1204**B and enabling small relative displacements between the aft mount **1102** and the third frame portion **206** in the pitch and positive yaw directions.

[0108] FIG. **12**C is a front view of the aft mount **1102** of FIG. **11** including a third frame coupling **1225**. The third frame coupling **1225** includes the first pin linkage **1202** of FIG. **12**A and is similar to the first frame coupling **1200** of FIG. **12**A, except that the third frame coupling **1225** includes a first radial slot linkage **1226**A instead of the first swing linkage **1204**A of FIG. **12**A. In the illustrated example of FIG. **12**C, the first radial slot linkage **1226**A is formed by the coupling of the second pin **1210** of FIG. **12**A through the second eye **1201**B and a first slot **1228** through the second mounting boss **1214** of FIG. **12**A. In the illustrated example of FIG. **12**C, the first slot **1228** has a radial orientation in the second mounting boss **1214**. That is, the first slot **1228** has a major axis that is oriented along an axis that is perpendicular to the axial centerline of the third frame portion **206**. The first slot **1228** enables the second pin **1210** to move within the first slot **1228** during the operation of the gas turbine engine **1002**. The radial orientation of the first slot **1228** facilitates the movement of the second pin **1210** in the yaw direction and the radial direction. As such, the first radial slot linkage **1226**A only reacts forces in the negative yaw. Accordingly, the combined use of the first radial slot linkage **1226**A and the first pin linkage **1202** causes the third frame coupling **1225** to only react forces in the negative yaw direction. The third frame coupling **1225** facilitates the thermal expansion of the leaf spring **1104**, the mount member **1106**, and/or the third frame portion **206** by releasing pitch and positive yaw reactions via the first radial slot linkage **1226**A and enabling small relative displacements between the aft mount **1102** and the third frame portion **206** in the pitch and positive yaw directions.

[0109] FIG. **12**D is a front view of the aft mount of FIG. **11** including an example fourth frame coupling **1230**. The fourth frame coupling **1230** includes the first radial slot linkage **1226**A of FIG. **12**D and is similar to the third frame coupling **1225** of FIG. **12**C, except that the fourth frame coupling **1230** includes a second radial slot linkage **1226**B instead of the first pin linkage **1202**. In the illustrated example of FIG. **12**D, the second radial slot linkage **1226**B is formed via (1) the coupling of a first pin **1206** through the first eye **1201**A of the leaf spring **1104** and a second slot **1232** in the first mounting boss **1208**. Like the first radial slot linkage **1226**A, the second radial slot linkage **1226**B reacts forces in the negative yaw direction. Accordingly, the fourth frame coupling **1230** facilitates the thermal expansion of the leaf spring **1104**, the mount member **1106**, and/or the third frame portion **206** by releasing pitch and positive yaw reactions via the radial slot linkages **1226**A, **1226**B and enabling small relative displacements between the aft mount **1102** and the third frame portion **206** in the pitch and positive yaw directions.

[0110] FIG. **12**E is a front view of the aft mount of FIG. **11** including an example fifth frame coupling **1234**. The fifth frame coupling **1234** includes the first pin linkage **1202** of

[0111] FIG. **12**A and is similar to the first frame coupling **1200** of FIG. **12**A, except that the fifth frame coupling **1234** includes a first lateral slot linkage **1236**A instead of the first swing linkage **1204**A of FIG. **12**A. In the illustrated example of FIG. **12**E, the first lateral slot linkage **1236**A is formed by the coupling of the second pin **1210** of FIG. **12**A through the second eye **1201**B and a second lateral slot **1240** through the second mounting boss **1214** of FIG. **12**A. That is, the second lateral slot **1240** has a major axis that is oriented along the pitch axis. The second lateral slot **1240** enables the second pin **1210** to move within the second lateral slot **1240** during the operation of the gas turbine engine **1002**. The lateral orientation of the second lateral slot **1240** facilitates the movement of the second pin **1210** in the pitch direction. As such, the first lateral slot linkage **1236**A only reacts forces in the negative yaw direction. Accordingly, the combined use of the first lateral slot linkage **1236**A and the first pin linkage **1202** causes the fifth frame coupling **1234** to only react forces in the negative yaw direction. The fifth frame coupling **1234** facilitates the thermal expansion of the leaf spring **1104**, the mount member **1106**, and/or the third frame portion **206** by releasing pitch and positive yaw reactions via the first lateral slot linkage **1236**A by enabling small relative displacements between the aft mount **1102** and the third frame portion **206** in the pitch and positive yaw directions.

[0112] FIG. **12**F is a front view of the aft mount of FIG. **11** including an example sixth frame coupling **1238**. The sixth frame coupling **1238** includes the first lateral slot linkage **1236**A and is similar to the fifth frame coupling **1234** of FIG. **12**E, except that the sixth frame coupling **1238** includes a second lateral slot linkage **1236**B instead of the first pin linkage **1202**. In the illustrated example of FIG. **12**F, the second lateral slot linkage **1236**B is formed via the coupling of a first pin **1206** through the first eye **1201**A of the leaf spring **1104** and a second lateral slot **1240** in the first mounting boss **1208**. Like the first lateral slot linkage **1236**A, the second lateral slot linkage **1236**B reacts loads in the negative yaw. Accordingly, the sixth frame coupling **1238** facilitates the thermal expansion of the leaf spring **1104**, the mount member **1106**, and/or the third frame portion **206** by releasing pitch and positive yaw reactions via the lateral slot linkages **1236**A, **1236**B by enabling small relative displacements between the aft mount **1102** and the third frame portion **206** in the pitch and positive yaw directions.

[0113] FIG. **12**G is a front view of the aft mount of FIG. **11** including an example seventh frame coupling **1241**. The seventh frame coupling **1241** includes the first pin linkage **1202** of FIG. **12**A and an example second pin linkage **1242**. The example second pin linkage **1242** is similar to the first pin linkage **1202** of FIG. **12**A. In the illustrated example of FIG. **12**A, the second pin linkage **1242** is formed via the coupling of the second pin **1210** through the second eye **1201**B of the leaf spring **1104** and the second mounting boss **1214**. The seventh frame coupling **1241** reacts loads in the positive and negative yaw directions and the pitch direction.

[0114] From the foregoing, it will be appreciated that example systems, apparatus, articles of manufacture, and methods have been disclosed to reduce engine carcass distortions associated with operational distortions caused by bending moments associated with the thrust, aerodynamic, and/or propeller loads and reduce distortions caused by the gravitational loading associated with cantilevered core engines. Example mount systems disclosed herein aft mounts with an elastic member, which offers comparatively reduced stiffness of the coupling between the rear frame and the pylon. Examples disclosed herein facilitate tighter blade tip clearances, particularly in cantilevered open-rotor gas turbine engines, which can provide increased engine performance and reduced fuel consumption. Examples disclosed herein include mounting configurations with multiple thrust linkages that are laterally and vertically displaced, which enables the reaction of yaw and/or pitch moment via the thrust linkages.

[0115] Methods and apparatus for mounting a gas turbine engine to a pylon are disclosed herein. Further examples and combinations thereof include the following:

[0116] A gas turbine engine, comprising a first mount, a first frame portion to be coupled to a pylon via the first mount, a second frame portion coupled to the first frame portion such that the second frame portion is cantilevered from the first frame portion, and a second mount to couple the second frame portion to the pylon, the second mount defining a load path between the pylon and the second frame portion, the second mount including an elastic element disposed in the load path.

[0117] The gas turbine engine of any preceding clause, wherein the elastic element is an elastomer.

[0118] The gas turbine engine of any preceding clause, wherein the second mount includes a frame coupling, a pylon coupling including a bracket coupled to the pylon, and a load plate movably disposed within the bracket, wherein the elastomer is disposed between the load plate and the bracket, and a structural member extending between the frame coupling and the pylon coupling, the structural member coupled to the load plate.

[0119] The gas turbine engine of any preceding clause, wherein the elastomer is a first elastomer and further including a second elastomer disposed between the load plate and the pylon.

[0120] The gas turbine engine of any preceding clause, wherein the elastic element is a leaf spring.

[0121] The gas turbine engine of any preceding clause, wherein the elastic element is a disc spring.

[0122] The gas turbine engine of any preceding clause, wherein the second mount includes a first member coupled to the pylon, a second member coupled to the second frame portion, a flange coupled to the first member, and a pin extending through the first member and the second member, the disc spring being disposed between the flange and the pin.

[0123] The gas turbine engine of any preceding clause, wherein the disc spring is a first disc spring and the second mount further includes a mounting plate coupled to the pylon and the second member, and a second disc spring disposed between the flange and the mounting plate.

[0124] The gas turbine engine of any preceding clause, wherein the first member has a hollow interior, the second member is disposed within the hollow interior such that a gap is formed between an outer diameter of the second member and an inner diameter of the first member, and the pin and the gap facilitate a rotation of the first member relative to the second member.

[0125] The gas turbine engine of any preceding clause, wherein the second mount includes a slot, the second frame portion coupled to the second mount via the slot, the slot facilitating a rotation about a yaw-axis relative to the pylon.

[0126] The gas turbine engine of any preceding clause, further including a first thrust linkage extending between a third frame portion and the pylon at a first block attachment point, a second thrust linkage extending between the third frame portion and the pylon at a second block attachment point laterally displaced from the first block attachment point, and a third thrust linkage extending between the third frame portion and a third block attachment point vertically displaced from the first block attachment point.

[0127] The gas turbine engine of any preceding clause, wherein the first thrust linkage has a first length and includes a first material, and the third thrust linkage has a second length and includes a second material, the first length greater than the second length, the first material having a lower coefficient of thermal expansion than the second material.

[0128] An apparatus comprising a first mount coupling a first frame portion of a gas turbine engine to a pylon, and a second mount coupling a second frame portion of the gas turbine engine to the pylon, the second mount including an elastic element, the second frame portion cantilevered relative to the first frame portion, the second mount defining a load path between the pylon and the second frame portion, wherein the elastic element is disposed in the load path.

[0129] The apparatus of any preceding clause, wherein the elastic element is an elastomer.

[0130] The apparatus of any preceding clause, wherein the second mount includes a frame coupling, a pylon coupling including a bracket coupled to the pylon, and a load plate movably disposed within the bracket, wherein the elastomer is disposed between the load plate and the bracket, and a structural member extending between the frame coupling and the pylon coupling, the structural member coupled to the load plate.

[0131] The apparatus of any preceding clause, wherein the elastic element is a spring.

[0132] The apparatus of any preceding clause, wherein the second mount further includes at least one of a slot linkage or a swing linkage coupling an eye of the spring to the second frame portion.

[0133] The apparatus of any preceding clause, wherein the second mount further includes a first member coupled to the pylon, a second member coupled to the second frame portion, a flange coupled to the first member, and a pin extending through the first member and the second member, the spring disposed between the flange and the pin.

[0134] The apparatus of any preceding clause, wherein the spring is a first spring and the second mount further includes a mounting plate coupled to the pylon and the second member, and a second spring disposed between the flange and the mounting plate.

[0135] The apparatus of any preceding clause, wherein the first member has a hollow interior, the second member is disposed within the hollow interior such that a gap is formed between an outer diameter of the second member and an inner diameter of the first member, and the pin and the gap facilitate a rotation of the first member relative to the second member.

[0136] The following claims are hereby incorporated into this Detailed Description by this reference. Although certain example systems, apparatus, articles of manufacture, and methods have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all systems, apparatus, articles of manufacture, and methods fairly falling within the scope of the claims of this patent.

What is claimed is:

1. A gas turbine engine, comprising:

a first mount;

a first frame portion to be coupled to a pylon via the first mount;

a second frame portion coupled to the first frame portion such that the second frame portion is cantilevered from the first frame portion; and

a second mount to couple the second frame portion to the pylon, the second mount defining a load path between the pylon and the second frame portion, the second mount including an elastic element disposed in the load path.

2. The gas turbine engine of claim **1**, wherein the elastic element is an elastomer.

3. The gas turbine engine of claim **2**, wherein the second mount includes:

a frame coupling;

a pylon coupling including:

a bracket coupled to the pylon; and

a load plate movably disposed within the bracket;

wherein the elastomer is disposed between the load plate and the bracket; and

a structural member extending between the frame coupling and the pylon coupling, the structural member coupled to the load plate.

4. The gas turbine engine of claim **3**, wherein the elastomer is a first elastomer and further including a second elastomer disposed between the load plate and the pylon.

5. The gas turbine engine of claim **1**, wherein the elastic element is a leaf spring.

6. The gas turbine engine of claim **1**, wherein the elastic element is a disc spring.

7. The gas turbine engine of claim **6**, wherein the second mount includes:

a first member coupled to the pylon;

a second member coupled to the second frame portion;

a flange coupled to the first member; and

a pin extending through the first member and the second member, the disc spring being disposed between the flange and the pin.

8. The gas turbine engine of claim **7**, wherein the disc spring is a first disc spring and the second mount further includes:

a mounting plate coupled to the pylon and the second member; and

a second disc spring disposed between the flange and the mounting plate.

9. The gas turbine engine of claim **7**, wherein the first member has a hollow interior, the second member is disposed within the hollow interior such that a gap is formed between an outer diameter of the second member and an inner diameter of the first member, and the pin and the gap facilitate a rotation of the first member relative to the second member.

10. The gas turbine engine of claim **1**, wherein the second mount includes a slot, the second frame portion coupled to the second mount via the slot, the slot facilitating a rotation about a yaw-axis relative to the pylon.

11. The gas turbine engine of claim **1**, further including:

a first thrust linkage extending between a third frame portion and the pylon at a first block attachment point;

a second thrust linkage extending between the third frame portion and the pylon at a second block attachment point laterally displaced from the first block attachment point; and

a third thrust linkage extending between the third frame portion and a third block attachment point vertically displaced from the first block attachment point.

12. The gas turbine engine of claim **11**, wherein:

the first thrust linkage has a first length and includes a first material; and

the third thrust linkage has a second length and includes a second material, the first length greater than the second length, the first material having a lower coefficient of thermal expansion than the second material.

13. An apparatus, comprising:

a first mount coupling a first frame portion of a gas turbine engine to a pylon; and

a second mount coupling a second frame portion of the gas turbine engine to the pylon, the second mount including an elastic element, the second frame portion cantilevered relative to the first frame portion, the second mount defining a load path between the pylon and the second frame portion, wherein the elastic element is disposed in the load path.

14. The apparatus of claim **13**, wherein the elastic element is an elastomer.

15. The apparatus of claim **14**, wherein the second mount includes:

a frame coupling;

a pylon coupling including:

a bracket coupled to the pylon; and

a load plate movably disposed within the bracket; wherein the elastomer is disposed between the load plate and the bracket; and

a structural member extending between the frame coupling and the pylon coupling, the structural member coupled to the load plate.

16. The apparatus of claim **13**, wherein the elastic element is a spring.

17. The apparatus of claim **16**, wherein the second mount further includes at least one of a slot linkage or a swing linkage coupling an eye of the spring to the second frame portion.

18. The apparatus of claim **16**, wherein the second mount further includes:

a first member coupled to the pylon;

a second member coupled to the second frame portion;

a flange coupled to the first member; and

a pin extending through the first member and the second member, the spring disposed between the flange and the pin.

19. The apparatus of claim **18**, wherein the spring is a first spring and the second mount further includes:

a mounting plate coupled to the pylon and the second member; and

a second spring disposed between the flange and the mounting plate.

20. The apparatus of claim **19**, wherein the first member has a hollow interior, the second member is disposed within the hollow interior such that a gap is formed between an outer diameter of the second member and an inner diameter of the first member, and the pin and the gap facilitate a rotation of the first member relative to the second member.

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