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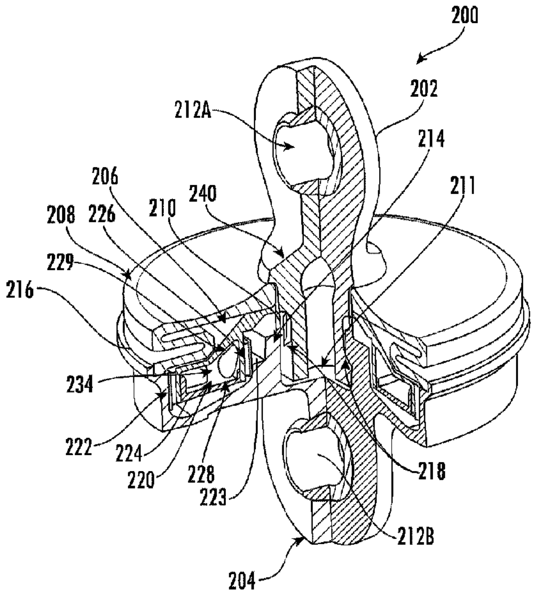
(54) Titre : SYSTEME DE BATI MOTEUR ET ELEMENTS POUR UNE TRANSMISSION DE FORCE REDUITE ET UN MOUVEMENT STATIQUE REDUIT, ET METHODES CONNEXES

(54) Title: ENGINE MOUNT SYSTEM AND ELEMENTS FOR REDUCED FORCE TRANSMISSION AND REDUCED STATIC MOTION AND ASSOCIATED METHODS



(57) Abrégé/Abstract:

Compliant mounting systems, devices, and methods for mounting a vehicle engine to a vehicle structure or base include a top mount, a lower mount, a center trunnion mount, and an aft mount which are configured to react forces transmitted by the engine to the vehicle structure. Metallic and elastomeric elements can provide vibrational and force isolation characteristics. Stops (e.g., snubbing elements) allow for a specific range of motion before internal mount structures contact each other to act as a conventional hard mount. Fluid elements and compressible gas-filled spaces/bladders may be incorporated to provide fluid damping behaviors to complement the metallic and elastomeric elements.

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(54) **Title:** ENGINE MOUNT SYSTEM AND ELEMENTS FOR REDUCED FORCE TRANSMISSION AND REDUCED STATIC MOTION AND ASSOCIATED METHODS

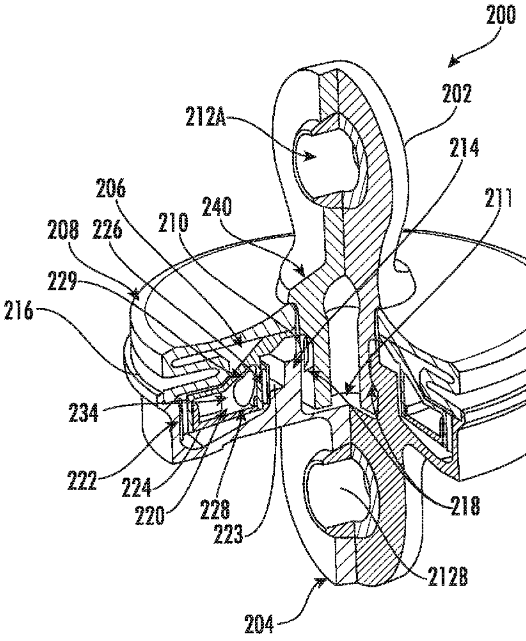

FIG. 7B

(57) **Abstract:** Compliant mounting systems, devices, and methods for mounting a vehicle engine to a vehicle structure or base include a top mount, a lower mount, a center trunnion mount, and an aft mount which are configured to react forces transmitted by the engine to the vehicle structure. Metallic and elastomeric elements can provide vibrational and force isolation characteristics. Stops (e.g., snubbing elements) allow for a specific range of motion before internal mount structures contact each other to act as a conventional hard mount. Fluid elements and compressible gas-filled spaces/bladders may be incorporated to provide fluid damping behaviors to complement the metallic and elastomeric elements.

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ENGINE MOUNT SYSTEM AND ELEMENTS FOR REDUCED FORCE TRANSMISSION AND REDUCED STATIC MOTION AND ASSOCIATED METHODS

FIELD OF INVENTION

[0001] The subject matter disclosed herein relates to an engine mount system. In particular, the subject matter relates to engine mount systems as well as associated methods of use and manufacture that reduce force transmission and static motion between an engine and a base or a vehicle.

BACKGROUND

[0002] Modern vehicles continue to offer improved refinement and isolation for passengers from noises and vibrations generated by components of the vehicle during travel. This is especially important in applications for aircraft, in particular for small jets.

[0003] Compliant mount systems are often used to reduce force from engines or similar machines to a base or a vehicle. These mount systems can provide good reduction to vibration and force transmission to the vehicle but result in increased motion compared to a stiffer "hard" engine mounting system. This increased motion induced in such conventional compliant mounting systems must be controlled, traditionally requiring a design to make certain compromises in seeking to minimize the vibration, force, and motion transmission.

[0004] Conventional compliant mounts often incorporate elastomers because of their ability to compensate and control larger ranges of motion with softer spring rates. However, one disadvantage of elastomers is the tendency of such materials to take a compression set (e.g., the amount by which an elastomeric material fails to return to its original size after release from a constant compressive load) and/or to exhibit characteristics of creep (e.g., the time-dependent part of a strain resulting from stress) over time when these materials are loaded, thereby requiring additional accommodation for motion of the engine.

[0005] To minimize excess undesired motions, stops (e.g., snubbing elements) can be used within such compliant mounting systems. However, when stops are incorporated in conjunction with elastomers, the stops must be set to accommodate the set and/or creep of the elastomeric materials during the life of such a mounting system. This required additional motion control capability is necessary to ensure the mount system continues to operate over the expected life.

[0006] Furthermore, the incorporation of resonant fluid devices can be used to generate a reduction in the forces transmitted through a mount over a designed frequency range. Such a fluid mount is known in the art using elastomeric flexing elements to seal the fluid and avoid sliding seals.

[0007] Accordingly, it would be advantageous for improved compliant engine mounting systems which are able to reduce vibration and force transmission from an engine or such similar structure to a base or a vehicle without all of the drawbacks of the conventional compliant engine mount systems presently known.

SUMMARY

[0008] In one aspect, a mounting device for reacting loads from an engine of an aircraft to an aircraft structure along a longitudinal axis of the mounting device is provided. The mounting device has an upper link and a housing. The upper link comprising an upper bearing surface disposed along the longitudinal axis of the mounting device, along which loading occurs. The housing comprising a lower bearing surface and a center structure. The lower bearing surface is disposed along the longitudinal axis of the link device. The center structure is centrally disposed relative to the longitudinal axis. The center structure further comprises at least one compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension. The upper link is configured to interlock within the center structure.

[0009] In another aspect, a top mount is provided for reacting tension loads from an engine of an aircraft to an aircraft structure along a longitudinal axis of the top mount. The top mount has an upper link, a flexing element, a fluid, and an inner member. The upper link having an upper bearing surface. The housing comprises a lower bearing surface and a center mount. The lower bearing is disposed along the longitudinal axis of the top mount. The center structure is centrally disposed relative to the longitudinal axis of the top mount. The center structure further comprising a compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension. The upper link is configured to interlock within the center structure. The flexing element is in sealing contact with the housing; a fluid which fills, at least partially, a space within the flexing element and the housing. The fluid, which fills, at least partially, a cavity within the flexing element and the housing. The inner member having the cavity formed therein, the cavity having a gas-filled space/bladder therein. The loading of the top mount occurs along the longitudinal axis thereof.

[0010] In still another aspect, a lower mount is provided for reacting compression loads from an engine of an aircraft to an aircraft structure along a longitudinal axis of the lower mount. The lower mount comprising an upper link, a housing, a flexing element, a fluid, and an inner member. The upper link having an upper bearing surface. The housing comprising a lower bearing surface and a center structure. The lower bearing surface being disposed along the longitudinal axis of the lower mount. The center structure is centrally disposed relative to the longitudinal axis of the lower mount. The center structure further comprises a compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension. The upper link is configured to interlock within the center structure. The flexing element in sealing contact with the housing. The fluid which fills, at least partially, a space within the flexing element and the housing. The inner member located within the cavity, the cavity having a gas-filled space/bladder therein. The loading of the lower mount occurs along the longitudinal axis thereof.

[0011] In yet another aspect, a center trunnion mount is provided for reacting loads from an engine of an aircraft to aircraft structure. The center trunnion mount has a pin, a pivot element, and an elastomeric compliance element. The pin is configured to be received within an engine bearing structure of the engine. The pivot element is disposed on a surface of the pin, the pivot element being configured to react the loads from the engine. The elastomeric compliance element is disposed inboard on the pin relative to the pivot element.

[0012] In still another aspect, an aft mound is provided for reacting loads from an engine of an aircraft to an aircraft structure. The aft mount comprises an inner lug, a housing, and an inboard elastomer package. The inboard elastomer package is configured to move laterally with the inner lug inside of the housing. The lateral movement of the inner lug and inboard elastomer package is bounded by a first position and a second position. The inboard elastomer package comprises an inner member configured to form a fluid cavity at an inboard end of the housing. The inner member is movable along a longitudinal axis of the housing to modify a volume of the fluid cavity. The lateral movement of the inner lug and inboard elastomer package pumps a fluid into or out of the fluid cavity to change a volume of a gas-filled space/bladder.

[0013] In one aspect, a compliant engine mount system for reacting loads from an engine of an aircraft to an aircraft structure. The compliant engine mount system comprising a top mount, a lower mount, and a center trunnion mount. The top mount has an upper link, a flexing element, a fluid, and an inner member. The upper link having an upper bearing surface. The housing comprises a lower bearing surface and a center mount. The lower bearing is disposed along the longitudinal axis of the top mount. The center structure is centrally disposed relative to the longitudinal axis of the top mount. The center structure further comprising a compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension. The upper link is configured to interlock within the center structure. The flexing element is in sealing contact with the housing; a fluid which fills, at least partially, a space within the flexing element and the housing. The fluid, which fills, at least partially, a cavity within the flexing element and the housing. The inner member having the cavity formed therein, the cavity having a gas-filled space/bladder therein. The loading of the top mount occurs along the longitudinal axis thereof. The lower mount comprising an upper link, a housing, a flexing element, a fluid, and an inner member. The upper link having an upper bearing surface. The housing comprising a lower bearing surface and a center structure. The lower bearing surface being disposed along the longitudinal axis of the lower mount. The center structure is centrally disposed relative to the longitudinal axis of the lower mount. The center structure further comprises a compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension. The upper link is configured to interlock within the center structure. The flexing element in sealing contact with the housing. The fluid which fills, at least partially, a space within the flexing element and the housing. The inner member located within the cavity, the cavity having a gas-filled space/bladder therein. The loading of the lower mount occurs along the longitudinal axis thereof. The center trunnion mount has a pin, a pivot element, and an elastomeric compliance element. The pin is configured to be received within an engine bearing structure of the engine. The pivot element is disposed on a surface of the pin, the pivot element being configured to react the loads from the engine. The elastomeric compliance element is disposed inboard on the pin relative to the pivot element.

[0014] A method of reacting loads from an engine of an aircraft to an aircraft structure is provided. The method comprises: applying a pre-load force to an upper link of an engine mount device; coupling the upper link to a flexing element; transmitting a load from the engine to a bearing surface of the engine mount device. When the load from the engine is greater than the pre-load force, the upper link is movable with respect to a housing of the engine mount device along a longitudinal axis of the engine mount device. A movement of the upper link relative to the housing is bounded by a distance between a first position and a second position and deforms the flexing element and pumps a fluid into or out of a cavity within the engine mount device to change a volume of a gas-filled space/bladder.

[0015] A method for reacting loads from an engine of an aircraft to an aircraft structure is provided. The method comprises: providing an engine bearing on the engine, the engine bearing having an engine bearing surface; inserting a pin at least partially within the engine bearing; and transmitting a load from the engine to the pin at the engine bearing surface. Lateral movement of the pin is bounded in an inboard direction along a longitudinal axis of the housing by a first position. When the load acts along a longitudinal axis of the pin, the pin moves substantially freely along the longitudinal axis of the housing. When the load acts transverse to the longitudinal axis of the pin, the load is reacted by a pivot element and an elastomeric compliance element.

[0016] A method for reacting loads from an engine of an aircraft to an aircraft structure is provided. The method comprises: coupling an inner lug to move with an inboard elastomer package of an engine mount device; coupling the inboard elastomer package to an inner surface of a housing of the engine mount device; and transmitting a load to the inner lug of the engine mount device. Lateral movement of the inner lug and the inboard elastomer package relative to the housing is bounded by a first position and a second position. When the load acts along a longitudinal axis of the housing, the inner lug and the inboard elastomer package move laterally and pump a fluid into or out of a fluid cavity within the engine mount device to change a volume of a gas-filled space/bladder. When the load acts transverse to the longitudinal axis of the housing, the load is reacted by the inboard elastomer package.

[0017] In a further aspect, a method for limiting the deflection of an engine mechanically to an aircraft structure of an aircraft is provided. The method comprising providing a mounting device having at least one compression stop (111, 211) configured to carry loads in compression and at least one tension stop (110, 210) configured to carry loads in tension, the mounting device further comprising: an upper link (102, 202) comprising an upper bearing surface (112A, 212A) disposed along the longitudinal axis of the mounting device, along which loading occurs; and a housing (104, 204) comprising a lower bearing surface (112B, 212B), which is disposed along the longitudinal axis of the mounting device, and a center structure (114, 214), which is centrally disposed relative to the longitudinal axis; wherein the center structure (114, 214) includes the at least one compression stop (111, 211) and the at least one tension stop (110, 210); wherein the upper link (102, 202) is configured to interlock within the center structure (114, 214); and reacting an operational load from the engine (4) with the mounting device.

[0018] Although some of the aspects of the subject matter disclosed herein have been stated hereinabove, and which are achieved in whole or in part by the presently disclosed subject matter, other aspects will become evident as the description proceeds when taken in connection with the accompanying drawings as best described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1A is a schematic front view of a conventional aircraft engine mount system.

[0020] FIG. 1B is a schematic perspective view of the conventional aircraft engine mount system shown in FIG. 1A.

[0021] FIG. 1C is a schematic rear view of a conventional aircraft engine mount system shown in FIG. 1A.

[0022] FIG. 2A is a front view of a compliant aircraft engine mount system according to an example embodiment.

[0023] FIG. 2B is an isometric view of a compliant aircraft engine mount system according to an example embodiment.

[0024] FIG. 2C is a side view of a compliant aircraft engine mount system according to an example embodiment.

[0025] FIG. 2D is a top view of a compliant aircraft engine mount system according to an example embodiment.

[0026] FIG. 3A is an isometric view of an upper link according to an embodiment of the presently disclosed subject matter.

[0027] FIG. 3B is a cutaway perspective view of an upper link according to an embodiment of the presently disclosed subject matter.

[0028] FIG. 3C is an exploded perspective view of view of an inner member and a housing.

[0029] FIG. 3D is a perspective view of a housing.

[0030] FIG. 3E is a perspective view of an inner member.

[0031] FIG. 3F is a cutaway perspective view of an inner member and housing in an installed position.

[0032] FIG. 3G is a cutaway view of an upper link according to an embodiment of the presently disclosed subject matter.

[0033] FIG. 4A is a perspective view of a flexing element and a housing.

[0034] FIG. 4B is a cutaway perspective view of a flexing element and a housing in an assembled configuration.

[0035] FIG. 5A is a perspective view of the inner member and central plate in an assembled configuration.

[0036] FIG. 5B is a cutaway perspective view of the inner member.

[0037] FIG. 5C is a perspective view of the central plate.

[0038] FIG. 5D is a sectional perspective view of the inner member and central plate in an assembled configuration.

[0039] FIG. 6A is a chart of force versus deflection for a top link according to an embodiment.

[0040] FIG. 6B is a graph of force versus deflection for a lower mount according to an embodiment.

[0041] FIG. 7A is a perspective view of a lower mount according to an embodiment of the presently disclosed subject matter.

[0042] FIG. 7B is a cutaway perspective view of a lower mount according to an embodiment of the presently disclosed subject matter.

[0043] FIG. 8 is a cutaway side view of a conventional center trunnion mount.

[0044] FIG. 9 is a cutaway perspective view of a center trunnion mount according to an embodiment of the presently disclosed subject matter.

[0045] FIG. 10A is an isometric perspective view of a center trunnion pin according to an embodiment of the presently disclosed subject matter.

[0046] FIG. 10B is a front view of the center trunnion pin according to an embodiment of the presently disclosed subject matter.

[0047] FIG. 10C is an elevated front perspective view of the center trunnion pin according to an embodiment of the presently disclosed subject matter.

[0048] FIG. 11 is a schematic illustration showing the reaction of a center trunnion mount to a vertical force.

[0049] FIG. 12 is a graph of deflection versus force of an example center trunnion mount according to an embodiment of the presently disclosed subject matter.

[0050] FIG. 13 is a front perspective view of an aft mount assembly according to an embodiment of the presently disclosed subject matter.

[0051] FIG. 14 is a rear sectional view of an aft mount assembly according to an embodiment of the presently disclosed subject matter.

[0052] FIG. 15 is a partial cross-sectional view of an aft mount assembly according to an embodiment of the presently disclosed subject matter.

[0053] FIG. 16 is a cutaway view of an aft mount assembly according to an embodiment of the presently disclosed subject matter.

DETAILED DESCRIPTION

The presently disclosed subject matter addresses, for example, problems encountered in conventional aircraft engine mount systems by introducing systems, devices, methods of attachment, and methods of manufacture. These systems, devices, and methods provide a set of linkages, each of which are designed to react vibratory forces which would otherwise be transmitted from an engine into an aircraft. These systems, devices, and methods isolate the aircraft from these forces and vibrations generated by the engine during normal operation yet still provide for the transmission of abnormally large forces to the vehicle structure for abnormal operating conditions. In some embodiments, this system is provided with a set of linkages having mechanical, elastomeric, and/or fluidic damping components to dissipate forces typically transmitted from an engine to a vehicle. The present systems, devices, and methods allow an isolation of an aircraft from vibration and other forces typically generated while in motion but allow transmission of abnormally large magnitude forces to the vehicle structure when an abnormal operating condition occurs.

FIGS. 1A-16 illustrate various views, aspects, and/or features associated with compliant engine mounting devices, systems, and related methods of use and manufacture. In some embodiments, the compliant engine mounting devices, systems, and methods set forth herein are configured to isolate and prevent transmission of vibrations and movement of an engine to an aircraft structure. Devices, systems, and methods provided herein include one or more of a top mount **100**, a lower mount **200**, a center trunnion mount **300**, and an aft mount **400**.

Referring to FIGS. 1A-1C, a conventional aircraft engine mount system is shown. According to the typical aircraft mount system, an aircraft engine **4** is attached to an aircraft structure **3** of an aircraft **2** at two planes, referred to as the “fore” and “aft” planes. At the aft mounting plane, illustrated in FIGS. 1B and 1C, a conventional aft mount **60** is connected to engine **4** at a single attachment point in a scissor or A-frame style linkage arrangement reacts to vertical and lateral loads. Typically, conventional aft mount **60** is a hard link which is not compliant and does not isolate engine **4** from aircraft structure **3**. At the fore mounting plane, illustrated in FIGS. 1A and 1B, engine **4** is mounted to the aircraft structure **3** by a conventional center trunnion mount **50**, as well as by respective conventional top mount **30** and conventional lower mount **40**. According to such a conventional engine mounting system, conventional center trunnion mount **50** reacts vertical and thrust loads but is free to slide in a lateral direction. The conventional top and lower mounts **30**, **40** react only to loads along their respective longitudinal axes; these loads will therefore typically have both vertical and lateral components. According to conventional engine mount systems, the conventional top and lower mounts **30**, **40** are typically “hard” links which are fixed and do not isolate the engine **4** from the aircraft structure **3**. In normal gravity conditions, conventional top mount **30** primarily carries loads acting in tension and conventional lower mount **40** primarily carries loads acting in compression. In some conditions, such as during aircraft maneuver conditions, the conventional top and lower mounts **30**, **40** need to be able to carry, or bear, both tension and compression loads.

[0054] FIGS. 2A-2D show an example embodiment of a compliant engine mount system, including a mounting bracket **10** to which a top mount **100**, a lower mount **200**, and a center trunnion mount **300** are attached on their respective proximal ends, wherein top mount **100**, lower mount **200**, and center trunnion mount **300** are configured to interface with and react loads from an engine at respective distal ends thereof. An aft mount **400** is located at a distance from mounting bracket **10** in the thrust direction of the engine. It is contemplated that mounting bracket **10**, top mount **100**, lower mount **200**, and center trunnion mount **300** may be implemented in a system with a conventional (e.g., “hard”) aft mount. It is further contemplated that aft mount **400** may be implemented with a set of one or more of conventional (e.g., “hard”) top mounts, lower mounts, and center trunnion mounts. Other alternative embodiments will be understood by persons of ordinary skill in the art by referring to the following example embodiments and figures.

[0055] FIGS. 3A-5B are various views illustrating an embodiment of a top mount, generally designated as **100**, according to one embodiment for a compliant engine mounting system.

[0056] Referring to FIGS. 3A and 3B, one embodiment of a top mount **100** is illustrated. Top mount **100** has an upper link **102** and a housing **104**. As illustrated, upper link **102** has an upper bearing surface **112A** which is used to attach top mount **102** to an aircraft engine, see generally engine **4** in FIGS. 1A-1C, and housing **104** has a lower bearing surface **112B** to attach housing **104** to an aircraft structure, see generally aircraft structure **3** in FIGS. 1A-1C. Top mount **100** has an inner member **106** and a flexing element **108**, which is preferably metallic, with fluid elements **120** being provided inside of inner member **106**.

[0057] In the embodiment illustrated in FIGS. 3C-3F, top mount **100** includes one or more features which allow upper link **102** to be installed and retained within housing **104**. Housing **104** has a center structure **114** which is centrally disposed about a longitudinal axis of top mount **100**. Center structure **114** has a compression stop **111** which reacts compressive loads and tension stops **110** which react loads in tension. FIG 3C illustrates insertion of upper link **102** into center structure **114** of housing **104**. As illustrated, upper link **102** has lugs **118** are inserted beyond the tension stops and turned or rotated by a predetermined amount, for example, 90 degrees, so that the lugs cannot be removed from within the center structure **114** without the lugs being turned or rotated by the same predetermined amount, either in the same or opposite direction. FIG. 3D illustrates slots **116** formed between tension stops **110** within center structure **114** of housing **104**. Upper link **102** is configured to be inserted such that the lugs **118** thereof pass into and/or through slots **116** of center structure **114** of housing **104**. Lugs **118** of upper link **102** are illustrated in FIGS. 3C and 3E. After lugs **118** are inserted beyond slots **116**, upper link **102** is configured to be twisted, or rotated, by a predetermined rotation angle, e.g., approximately 90 degrees, into an installed position such that a bottom face of tension stops **110**, which are shown here as being integral with housing **104**, interface with upper flanges of lugs **118** to exert a retaining force to prevent removal of upper link **102** when in the installed position. FIG. 3F illustrates upper link **102** in the installed position with respect to the tension stops **110** of housing **104**. While upper link **102** is in the installed position, upper link **102** is captive in housing **104**. Once lugs **118** of upper link are installed within the center structure **114** of housing **104**, the tension stops **110** and the compression stop **111** are positioned to engage within the center structure **114** and a strong central load core is thereby defined. Stop clearances between the lugs **118** and the respective tension stops **110** and compression stop **111** are set as required by the system motion limits and performance requirements. As noted elsewhere herein, the flexing element **108** pre-loads the upper link **102** so that the lugs **118** are biased against the compression stop **111** and the upper link will not move in the longitudinal direction away from the compression stop **111** until a tension force of sufficient magnitude to overcome the compression pre-load force is transmitted into the top mount **100**. At a prescribed tension force, or load, having sufficient magnitude to overcome the compression pre-load force, the upper link **102** will move longitudinally away from housing **104** until the upper surfaces of the lugs **118** contact the tension stops **110** within the center structure **114** In some embodiments, the attachment points of top mount **100** on engine **4** and aircraft structure **3** are sufficiently rotationally fixed that upper link **102** and housing **104** are aligned and cannot rotate relative to each other thereby preventing unintended separation of upper link **102** from housing **104**.

[0058] Referring to FIG. 3G, a partial view of an assembled top mount **100** is shown. Inner member **106**, which will be described in greater detail regarding FIGS. 5A-5D, is located in a recessed cavity of housing **104**. Upper link **102** is located in housing **104**, as described above. Flexing element **108** is on top of housing **104** and in contact, at least in portions, with an upper surface of the collar **140** of upper link **102**. FIG. 4A illustrates installation slots **136A** and loading lugs **138A**, which are formed at an outer portion of flexing element **108**, and corresponding installation slots **136B** and loading lugs **138B** formed in a cylindrical upper portion of housing **104**. Installation slots **136A** and loading lugs **138A** of flexing element **108** are dimensioned circumferentially so as to be compatible with and accommodate passage therethrough of loading lugs **138B** and installation slots **136B**, respectively, of housing **104.** Before installation, the loading lugs **138A** of flexing element **108** are rotationally oriented to be substantially co-located with corresponding installation slots **136B** of housing **104**. In the installed position, installation slots **136A** and loading lugs **138A** of flexing element **108** are beyond a plane defined by loading lugs **138B** and are substantially aligned with loading lugs **138B** and installation slots **136B** of housing **104**, thus preventing separation of flexing element **108** and housing **104**. During installation, flexing element **108** and/or housing **104** are rotated with respect to each other in order to lock flexing element **108** to housing **104**, at least in a direction of extension. Loading lugs **138A** and **138B** may be one of many shapes, including compatible tapering profiles, such that rotation of flexing element **108** relative to housing **104** causes the tapered respective loading lugs **138A** and **138B** to exert a greater retention force as the degree of rotation is increased and also to aid in preventing over-rotation of flexing element **108** with respect to housing **104**, which may result in the loading lugs **138A** and **138B** being inadvertently only partially engaged. FIG. 4B illustrates flexing element **108** and housing **104** in a fully engaged position, with the respective loading lugs **138A** and **138B** fully engaged against each other.

[0059] FIG. 4B also illustrates an inner circumferential edge of the upper surface of the flexing element **108** overlaps collar **140** of upper link **102** in the respective installed positions. FIG. 4B illustrates the upper link **102** in the installed and clocked, or rotated, position. The number of lugs **118** can vary depending on operational parameters, including, for example, the forces being transmitted, the desired amount of rotary motion to move the upper link **102** into the clocked position, and the like. In some embodiments, this overlap creates an interaction between flexing element **108** and collar **140** of upper link **102**, whereby flexing element **108** applies a longitudinally oriented compressive force which provides an initial pre-load compressive force on the upper link **102**, such that lugs **118** of upper link **102** are fully recessed and seated against compression stop **111** of center structure **114** when no tensile force is applied to top mount **100**. In some embodiments, this initial pre-load compressive force ensures that no longitudinal displacement of upper link **102** occurs with respect to housing **104** until the initial pre-load compressive force is overcome by a tensile force (e.g., a tensile force exerted by engine **4**) being applied to top mount **100**.

[0060] According to this embodiment, once the initial pre-load compressive force is overcome in tension, upper link **102** and housing **104** are capable of longitudinal displacement over a defined range so as to isolate vibrational inputs to upper link from being translated directly into housing **104**. The initial pre-load compressive force is minimum compressive load of the operational subset described hereinbelow. In some embodiments, until this initial pre-load compressive force is overcome, top mount **102** acts as a hard mount, at least with respect to the ability to isolate longitudinal deflections and vibrational inputs received by upper link **102** from being transmitted to housing **104** by direct contact therebetween. The aforementioned defined range is dependent upon the engine mount stiffness and allowable motions for the engine. For example, an engine mount system may be sized to operate under of 1G ± 0.5G with engine thrust at idle up to and including climb levels, wherein the G in the 1G indicates the multiplier of the gravitational force. The pre-load of the engine mount system is set to enable the aforementioned operating condition. Importantly, the operational load of 1G ± 0.5G can be any design value selected by the engine mount designer, aircraft designer, and/or the engine designer. For example, it could be set at 10G ± 5G or more. Stops are set so that under a subset of the total operational load envelope, which constitutes loading for a majority (i.e., more than 50% of occasions) of the operational flight time of the aircraft, the engine mounts provide isolation. However, the load and distance in the example vary for each engine and type of aircraft due to engine size, thrust, and aircraft structure and mount stiffness. The advantage of this system is isolation for a majority of the aircraft operation without the need to accommodate motions associated with infrequent loading conditions. Returning to the embodiment, tension stops **110** interact with lugs **118** when tensile forces above a predetermined threshold are received by upper link **102** to prevent excessive longitudinal displacement of upper link **102** from housing **104**, thereby preventing top mount **100** from being damaged by such inputs, such as by flexing element **108** undergoing plastic deformation rather than elastic deformation. The predetermined threshold is the predetermined tensile forces that generate motions outside of the aforementioned defined range. It is load outside of the subset of operational load(s) or load(s) greater than the load experienced for the majority (i.e., more than 50% of occasions) of the aircraft's operational life. When a tensile force above the predetermined threshold is experienced and the lugs **118** come into contact with tension stops **110**, top mount **100** ceases behaving as a compliant isolating engine mount and instead behaves similarly to a conventional hard mount with minimal compliant characteristics, because upper link **102** and housing **104** are in direct contact when such abnormally large tensile forces are applied. Abnormally large tensile forces are those forces greater than the predetermined threshold.

[0061] Regarding the fluid elements illustrated in FIGS. 3A-5D, outer cylinder members **122** form a seal **130** between outer cylinder members **122** and housing **104**. The seal **130** is formed by bonding, using gaskets, using O-rings, press fitting, and other known techniques to ensure a fluid seal between two elements. In some embodiments, inner member **106** is attached to upper link **102** such that, when upper link **102** moves, inner member **106** moves relative to housing **104**. In some embodiments, two cylindrical elastomer sections **126** are sealed to inner member **106** on its inner and outer sides, as illustrated in FIG. 3G. In some embodiments, outer cylinder member **122** and inner cylinder member **123** are sealed to the respective elastomeric sections **126**, for example, at seals **130** illustrated in FIG. 3G. Similar seals may be present in the embodiment illustrated in FIGS 7A and 7B. Central plate **124** is housed at least partially within inner member **106**, thereby forming a cavity **134** therein with a fluid passage **132**, the combination of which forms a fluid pathway. An inner gas-filled space **128** is located inside cavity **134**. This inner gas-filled space **128** has a comparatively soft volumetric stiffness and allows for tuning the inertial fluid effects of top mount **100** as well as allowing for thermal compensation (e.g., from expansion and contraction). Inner gas-filled space **128** may be a pocket of a compressible gas filling a portion of cavity **134** as illustrated in FIGS. 3B, 3G, 4B and 5D, or in the alternative, an inner gas-filled bladder **129** may be positioned within cavity **134** as illustrated in FIG. 3G. For simplicity, the reference to inner gas-filled space **128** inner gas-filled bladder **129** are referred to as inner filled gas-filled space/bladder **128, 129**.

[0062] Referring to FIGS. 3B-5D, the top mount **100** is filled with fluid in cavity **134** around inner gas-filled space/bladder **128, 129** and also in the lower section of housing **104**. The fluid is contained in the housing space below the inner member **106** and is bounded by the inner elastomer section **126** against the housing **104** and the outer elastomer layer **126** against the housing **104**. It is preferred that substantially all air be evacuated from within top mount **100** so that, other than inner gas-filled space/bladder **128, 129**, the entire internal volume of top mount **100** is occupied by fluid. When lugs **118** are no longer contacting either the tension stop **110** or the compression stop **111**, the motion of upper link **102** relative to housing **104** causes fluid to be pumped along a path defined by the housing **104** in the area below inner member **106**, fluid passage **132**, and into cavity **134** within inner member **106**. When upper link **102** moves towards housing **104**, fluid is pumped from an area of housing **104** outside of inner member **106** into cavity **134** via fluid passage **132**, thereby compressing inner gas-filled space/bladder **128, 129**. When the upper link moves away from housing **104**, fluid pressure decreases and the gas-filled space/bladder **128, 129** expands, thereby pumping fluid out of cavity **134** by fluid passage **132** and into housing **104** outside of inner member **106**. The dimensions of the fluid passage **132**, the elastomer sections **126**, and the volume and pressure of the gas within inner gas-filled space/bladder **128, 129** coupled with the spring rate of flexing element **108** allows for the fluid inertial effects to be tuned, thereby allowing for design of a “notch” in the force-transfer function over a desired frequency range. The dimensions are parameters know to one skilled in the art of fluid filled mount design and are known in literature. These primarily include the cross-sectional area of the inertia track, track length, and inlet and outlet dimensions. The very low damping in flexing element **108** enables even deeper “notch” effects than what is possible with conventional elastomer-only fluid mounts. Very low damping of metals compared to elastomers are known. The use of very low damping is similar a common metal spring, as is known to those having skill in the art of metal springs. Very low damping using metals is an advantage when compared to know fluid-filled mounts where elastomers are used as the primary spring element which have higher damping than a metal spring. For example, normal spring elements from metal would have damping of 1% or less where elastomers typically would have more than 5% damping.

[0063] As illustrated in FIGS. 3D two tension stops **110** are engaged through rotation. However, any number of stops can be used as one skilled in the art can readily understand upon reading this disclosure.

[0064] FIG. 6A illustrates a force versus deflection curve for a top mount **100** according to one embodiment. In this illustration, upper link **102** does not undergo any deflection until the initial pre-load compressive force is overcome by a tensile force of magnitude greater than the pre-load compressive force. As such, when a tensile force of less than the pre-load compressive force is received by the example upper link **102**, lugs **118** remain in contact with compression stop **111** of housing **104** and will be spaced apart from tension stops **110** by a maximum amount. According to this example, when a tensile force greater than the pre-load compressive force is received by top mount **100**, upper link **102** contacts tension stop **110** and cannot undergo any more deflection. As such, for forces less than the pre-load compressive force and greater than an upper threshold tensile load, e.g., the maximum subset of the aforementioned operation loads, the top mount in this example will behave as a hard mount, with minimal compliance characteristics. However, when upper link **102** receives a tensile force, or load, between the pre-load compressive force and the upper threshold tensile force, upper link **102** is “free” or “floats” to allow longitudinal deflection of the lugs **118** of upper link **102** relative to and within the center structure **114** of housing **104**, this longitudinal deflection being commensurate with the tensile force being received by, or transmitted to, upper link **102**. It is in this “free” or “floating” deflection range wherein top mount **100** acts as a compliant engine mount to isolate a supporting structure, such as the aircraft structure **3** in FIGS. 1A-1C, from forces, loads, vibrations, and the like coming from a supported structure, such as engine **4** in FIGS. 1A-1C.

[0065] Referring to FIGS. 7A and 7B, an example embodiment of lower mount **200** is illustrated. Similar to top mount **100**, lower mount **200** has upper link **202**, housing **204**, flexing element **208**, inner member **206**, tension stops **210**, upper and lower bearing surfaces **212A** and **212B**, and fluid elements **220**. In some embodiments, upper link **202** is located within, at least partially, housing **204** substantially similarly in lower mount **200** as was described for top mount **100**. Lugs **218** of upper link **202** are located within a center structure **214** of housing **204** and beyond a plane defined by tension stops **210**, which are shown as being integrally formed therein. Similar to top mount **100**, flexing element **208** is preferably metallic. Unlike in top mount **100**, however, upper link **202** has a collar **240** which is located on top of and is configured to interface with a top surface of flexing element **208** when upper link **202** is in an installed position. In some embodiments, flexing element **208** and housing **204** do not have any loading lugs or installation slots as is shown for top mount **100**. The reason for this is because collar **240** of upper link **202** applies a compressive load to flexing element **208** when upper link and flexing element **208** are in an installed position with respect to housing **204**. In this arrangement, inner member **206** is captive with respect to and attached to upper link **202**, such that longitudinal deflection of upper link **202** relative to housing **204** generates a corresponding longitudinal deflection of the same magnitude by inner member **206**. In some embodiments, flexing element **208** and housing **204** only need to have compatible flange structures where they meet so as to transmit compressive loads from upper link **202** to housing **204**. As in the upper link **202** the fluid space is only in the housing **204** and is bounded by the seal of the inner elastomer **226** to the housing **204** and the outer elastomer **222** to the housing **204**. Flexing element **208** does not need sealed to housing **204**.

[0066] In some embodiments, upper link **202** is captive and thereby is configured to hold flexing element **208** and inner member **206** in a captive manner by their interaction with collar **240**. In this embodiment, flexing element **208** exerts a tensile force oriented along the longitudinal axis of lower mount **200** against upper link **202** in the direction from housing **204** towards upper link **202**. This tensile force acting on upper link **202** by flexing element **208** causes upper link **202** to be initially pre-loaded in tension with respect to housing **204**. This pre-loading tensile force causes lugs **218** of upper link **202** to be in contact with tension stops **210** when a compressive force less than the pre-load tensile force is transmitted to lower mount **200**. The pre-load tensile force is a subset of the total operational load envelope, which constitutes loading for a majority (i.e., more than 50% of occasions) of the operational flight time of the aircraft, the engine mounts provide isolation. As discussed above in regard to the pre-load compressive force, for the pre-load tensile force the load and distance in the example vary for each engine and type of aircraft due to engine size, thrust, and aircraft structure and mount stiffness.

[0067] Referring to a non-limiting example for a specific test case in FIGS. 6A and 6B, FIG. 6B provides an example force versus deflection curve for lower mount **200** according to one embodiment. Unlike in FIG. 6A, which showed tensile forces being applied and a corresponding deflection of upper link **102** away from housing **104** as both being positive values, FIG. 6B shows compressive forces and the corresponding deflection of upper link **202** towards housing **204** as both being negative values. Just as in FIG. 6A, lower mount **200** is provided with a pre-load force, but in tension instead of compression. As such, when a compressive force of less than the pre-load tensile force is received by lower mount **200**, upper link **202** does not move because the compressive force received is not sufficient to counteract the pre-load tensile force. Also, according to the example illustrated in FIG. 6B, lower mount **200** is designed to have a maximum possible deflection, at which point upper link **202** contacts housing **204** and cannot move any further in the direction away from housing **204**. This maximum deflection occurs when a compressive force greater in magnitude than an upper threshold compressive force, e.g., the maximum subset of the aforementioned operation loads, is received by lower mount **200**. Therefore, upper link **202** and housing **204** are only “free” to move or “float” with respect to each other, allowing longitudinal deflection of the lugs **218** of upper link **202** relative to and within the center structure **214** of housing **204**, when a compressive force of a magnitude between the pre-load tensile force and the upper threshold compressive force is received by lower mount **200**. The amount or magnitude of this longitudinal deflection is commensurate with the compressive force being received by, or transmitted to, the upper link **202**. It is in this “free” or “floating” deflection range wherein lower mount **200** acts as a compliant engine mount to isolate a supporting structure, such as the aircraft structure **3** in FIGS. 1A-1C, from forces, loads, vibrations, and the like coming from a supported structure, such as engine **4** in FIGS. 1A-1C. The foregoing is a non-limiting example.

[0068] Fluid elements **220**, central plate **224**, inner member **206**, elastomer sections **226**, and inner and outer bonded cylindrical members **223**, **222** all operate in a substantially similar manner in lower mount **200** as has been described previously for top mount **100**. However, the assembly and method of manufacturing lower mount **200** differs from that of top mount **100**. For example, the method of manufacturing includes providing housing **204**, sealing inner member **206** and fluid elements **220** to housing **204**, providing tension stops **210** on an inner wall of inner cylindrical portion **214**, providing flexing element **208** over top of housing **204**, forming a seal **216** between a flange of flexing element **208** and housing **204**, and inserting upper link **202** such that lugs **218** thereof are below tension stops **210**, rotating upper link **202** and/or housing **204** to engage lugs **218** with tension stops **210**. Upper and lower spherical bearing **212A**, **212B** are illustrated as being positioned in outer portions of upper link **202** and housing **204**, respectively. However, any connective device capable of transmitting load to the upper link **204** and housing **204** may be used instead of spherical bearings **212A, 212B**. Seal **216** may be formed in a plurality of ways known to those having skill in the relevant art.

[0069] In some embodiments, a method of use for an engine mount device in the form of either a top mount **100** or lower mount **200** includes applying a pre-load force to an upper link (e.g., **102** or **202**) of engine mount device; coupling upper link to a flexing element (e.g., 108 or **208**); and transmitting a load to an upper bearing surface (e.g., **112A** or **212A**) of the engine mount device. According to this example method, when a load from engine 4 is greater than the pre-load force, the upper link **102, 202** is movable with respect to a housing (e.g., **104** or **204**) of the engine mount device along a longitudinal axis of the engine mount device. A movement of the upper link **102, 202** relative to the housing **104, 204** is bounded by a distance between a first position and a second position, and/or the movement of the upper link **102, 202** relative to the housing **104, 204** deforms the flexing element **108, 208** and pumps a fluid into or out of a cavity **134, 234** within the engine mount device to change a volume of a gas-filled space/bladder **128, 129, 228, 229**. In some embodiments, the first position can be defined such that the upper link **102, 202** contacts the tension stop **110, 210** when no force is applied, while the second position can be defined such that the upper link **102, 202** contacts the compression stop **111, 211** when the upper link **102, 202** is fully deflected. In other embodiments, the converse can be true, such that the upper link **102, 202** contacts the compression stop **111, 211** when in the first position and contacts the tension stop **110, 210** when fully deflected.

[0070] Referring to FIGS. 8-12, an example center trunnion mount is illustrated. FIG. 8 is a center trunnion mount **50** of a conventional design, with limited or no capabilities of force or vibrational isolation between aircraft **2** and engine **4**. A conventional center trunnion mount **50**

design has a rigid pin **52** located inside of a protective sleeve **54**, rigid pin **52** being fixedly connected to an engine bearing surface **56**. Rigid pin **52** and protective sleeve **54** are by their nature rigid and react forces in the vertical and thrust directions. However, rigid pin **52** is otherwise free to move laterally (e.g., along the bearing surface of engine **4** in the direction of the longitudinal axis) with comparatively minimal force required to induce lateral movement compared to the force required to cause a deflection of rigid pin **52** in either the thrust or vertical directions. As illustrated in FIG. 8, a conventional center trunnion mount **50** having a rigid pin **52** and protective sleeve **54** arrangement will result in a direct contact path thereby resulting in the transfer of forces and vibrations between engine **4** and vehicle structure **2** without any compliant or isolating characteristics.

[0071] Referring to FIGS. 9-10C, a fully contained center trunnion mount according to an example embodiment of the invention, generally designated **300**, is provided. As illustrated, the axial direction **A** is oriented along the length of pin **302** and the radial direction **R** is perpendicular to the axial direction **A**. Center trunnion mount **300** has very high stiffness in one or more radial directions **R**, compared to very soft stiffness in the longitudinal or "axial" direction **A**. As used herein, very high stiffness is comparable to the stiffness of a hard metallic bearing stiffness (i.e. metallic structure stiffness) and very soft stiffness is comparable to the stiffness of an elastomeric element, which may be 30% of the stiffness of the metallic structure stiffness, which may be 20% of the stiffness of the metallic structure stiffness, or which may be 10% or less of the stiffness of the metallic structure stiffness. Preferably, the very soft stiffness is 20% of the stiffness of the metallic structure stiffness. More preferably, the very soft stiffness is 10% or less of the stiffness of the metallic structure stiffness. Center trunnion mount **300** operates on the principle of a pivoting mechanism to provide vertical compliance by receiving a load through a center pin/bearing configuration on the engine (See, e.g., FIG. 9).

[0072] In the embodiment illustrated in FIGS. 9-10C, center trunnion mount **300** comprises a pin **302**, an inboard pivot element **304**, and an elastomeric compliance element **306**. Inboard pivot element **304** is a pivoting metallic-elastomeric flexing element. Inboard pivot element **304** is a very stiff radial elastomeric package, and one of the elements at which the load is being reacted. Inboard pivot element **304** allows for very high fore/aft spring rates, for example, of about 2,500,000 pounds-force per inch (lb_f/in) (about 3,389,545 Newton meters). Elastomeric compliance element **306** is a lateral/vertical metallic-elastomeric flexing element. Elastomeric compliance element **306** reacts the load and provides compliance characteristics and is located further inboard from pivot member **304** and the center of gravity of the supported structure, for example, engine **4** in FIGS. 1A-1C. Pin **302** has a bore **308**, which reduces the mass thereof, and a protruding portion **303** which is received within an engine bearing surface. Compliance in the radial, e.g., vertical and thrust, directions **R** is provided by the elastomer packages at both pivot element **304** and elastomeric compliance element **306**. Both the inboard pivot element **304** and the elastomeric compliance element **306** comprise elastomeric structures that are covered or clad with a metal surface, the metal surface being a contact point of the pin **302** with the inner surface of the housing **305**. The inboard pivot element **304** and the elastomeric compliance element **306** provide compliant force and vibration isolation in the lateral direction. In an installed position, the protruding portion of pin **302** is located coaxially within and in contact with an engine bearing surface (not shown) but is free to move laterally within the engine bearing. Lateral movement of pin **302** is restricted by first and second lateral stop members **310A**, **310B**, respectively. First lateral stop **310A** is shown as being two outer radial portions of pin **302** configured to restrict excessive lateral movement of pin **302** in the axial direction **A** with respect to the aircraft structure **3**. Second lateral stop **310B** is shown as being an inboard circular protruding portion of pin **302** centered coaxially around bore **308** and disposed radially about an outer surface of pin **302**; second lateral stop **310B** is configured to restrict excessive inboard movements of pin **302**. It is contemplated that first and second lateral stops **310A**, **310B** may be any suitable size and shape and can include one or a plurality of such members in order to restrict lateral outboard and inboard movement of pin **302**, respectively.

[0073] In some embodiments, compliance for center trunnion mount **300** is designed to target a narrow range of load conditions to minimize static deflections. As discussed above, first and second lateral stops **310A**, **310B** are integrated within pin **302** of center trunnion mount **300** to control system motions and carry large gravitational "G" loads. When either of first or second lateral stops **310A**, **310B** are engaged, center trunnion mount **300** behaves in the same manner as conventional center trunnion mount **50**, with minimal or no vibrational or force isolation characteristics. Direct contact of either of first or second lateral stops **310A**, **310B** effectively "short circuit" the isolating features of center trunnion mount **300** (e.g., the direct contact of either of first or second lateral stops **310A**, **310B** minimizes the behavior of the compliant elements).

Direct contract carries the excessive load through the secondary load path presented by the direct contact first or second lateral stop **310A**, **310B** to aircraft **2**. Carrying the excessive load through the secondary load path rather than through the compliant elements (e.g., pivot element **304** and elastomeric compliance element **306**) protects pivot element **304** and elastomeric compliance element **306** from an excessive increase in load or deflection. In some embodiments, first and second lateral stops **310A**, **310B** are oriented in the axial, or "soft," directions **A** to account for frictional conditions. Frictional conditions are such as a dynamic condition when engine **4** cannot freely slide on pin **302** due to a static normal load transmitted through the engine bearing. In such a condition, center trunnion mount **300** will reach its deflection snubbing point, at which time it can react enough load to allow the engine **4** to statically slide on the pin until a steady-state load and position is reached. At this point, engine vibration serves to space the pin apart from the first and second lateral stops **310A**, **310B**, and allows center trunnion mount **300** to once again be dynamically compliant.

[0074] Pivot element **304** may be non-compliant in some embodiments. FIG. 12 shows a static force versus deflection graph for an example center trunnion mount **300** in the directions along its longitudinal, vertical, and thrust axes. Where the X and Z axes are radial directions and the Y axis is the axial direction. The embodiment illustrated herein is a representative, non-limiting, example embodiment and other embodiments are within the scope of this disclosure.

[0075] A method for reacting loads from engine of vehicle to a vehicle structure via central trunnion mount **300** includes providing an engine bearing on the engine **4**, the engine bearing having an engine bearing surface. The method includes inserting the pin **302** inside an engine bearing structure of the engine **4** and transmitting a load from engine **4** to pin **302** through a compatible surface of the engine **4**. In some embodiments, lateral movement of the pin **302** is bounded in the inboard direction along a longitudinal axis **A** of pin **302** by a first position, where the first position corresponds to a position where pin **302** makes contact via second lateral stop **310B**. In other embodiments, at least first or second lateral stop **310A, 310B** is configured to bound a movement of the pin **302** within the housing **305** in an inboard direction, a fore direction, vertical direction, and/or an aft direction. A gap **307** is provided between the housing **305** and the respective first and second lateral stops **310A**, **310B**. This gap **307** allows for controlled longitudinal movement along the longitudinal axis **A** of pin **302** and provides for subsequent snubbing movements of the pin **302** within the housing **305**. In some embodiments, lateral movement of the pin **302** is bounded in the outboard direction along the longitudinal axis of pin **302** by a second position, where the second position corresponds to a position where pin **302** makes contact via first lateral stop **310B**. In some embodiments, when the load acts along a longitudinal axis of pin **302**, the pin **302** moves substantially freely along the longitudinal axis of pin **302**. In some embodiments, when the load acts transverse to the longitudinal axis of pin **302**, the load is reacted by pivot element **304** and elastomeric compliance element **306**.

[0076] FIGS. 13-16 illustrate an example of an aft mount, generally designated **400**, for reacting loads from an engine **4** of an aircraft **2** to an aircraft structure **3**. In some embodiments, aft mount **400** is designed to provide a low degree of stiffness in a lateral direction while providing a high degree of stiffness in a vertical direction. Similar to the discussion on the center trunnion mount **300** above, the high degree of stiffness is in the lateral direction, as compared to the very soft stiffness in the vertical direction. As used herein, a high degree of stiffness is comparable to the stiffness of a hard metallic bearing stiffness (i.e. metallic structure stiffness) and low degree of stiffness is comparable to the stiffness of an elastomeric element, which may be 30% of the stiffness of the metallic structure stiffness, which may be 20% of the stiffness of the metallic structure stiffness, or which may be 10% or less of the stiffness of the metallic structure stiffness. Preferably, the very soft stiffness is 20% of the stiffness of the metallic structure stiffness. More preferably, the very soft stiffness is 10% or less of the stiffness of the metallic structure stiffness. In the embodiments illustrated in FIGS. 13-16, aft mount **400** is a pivot-style mount which incorporates stops to prevent excess lateral movement. In some embodiments, fluid elements are included to allow for a tuned inertial fluid effect to further enhance the reduction in force transmission from engine **4** to aircraft **2**.

[0077] In the embodiment shown in FIG. 13, aft mount **400** has inner lug **402**, housing **404**, upper link **406**, lower link **408**, and lateral inboard and outboard stops **410A**, **410B**. Aft mount **400** is connected to engine **4** (not shown in FIG. 13) at inner lug **402** and to aircraft **2** (not shown in FIG. 13) by inboard ends of upper link **406** and lower link **408**. Lateral inboard and outboard stops **410A**, **410B** serve to limit lateral motion (e.g., motion in the inboard and/or outboard directions) induced by lateral forces greater than a predetermined threshold. This allows for aft mount **400** to operate in a compliant manner under normal force transmission conditions. This also allows for aft mount **400** to act as a hard mount when a sufficiently large magnitude lateral force is transmitted to aft mount **400** such as would cause either lateral inboard stop **410A** or lateral outboard stop **410B** to contact housing **404**. The small, restricted travel working zone is an advantage.

[0078] As is shown in FIG. 14, inner lug **402** is at least partially located within housing **404** and interfaces with inner member **414** of inboard elastomer package **412** and outboard elastomer package **422**. Vertical loads are reacted vertically at outboard elastomer package **422** and at inboard elastomer package **412**, which are designed to have higher controlled stiffness values to restrain vertical motion transfer from a supported structure, for example, engine **4** in FIGS. 1A-1C, into a supporting structure, for example, aircraft structure **3** in FIGS. 1A-1C. The generally tubeform configuration of aft mount **400** provides stiff vertical and comparatively softer lateral elastomeric members. Inboard elastomer package **412** has a high vertical stiffness and a controlled, typically softer, lateral stiffness.

[0079] As illustrated in FIGS. 13-16, inboard elastomer package **412** has two substantially tube-form elastomer sections **416A** and **416B**, each of which are located between an inner wall of housing **404** and inner member **414** of inboard elastomer package **412**. Interconnect sleeve **418** connects respective inner members **414** of inboard elastomer package **412** into a single inner member **414**. Inner lug **402** is partially disposed within housing **404** and interfaces with inner member **414** of inboard elastomer package **412** along the length thereof. Inner member **414** has an inboard portion which forms a collar **420** thereby creating a hole therethrough. Inboard end of inner lug **402** presses collar **420** and its hole when an inboard lateral force is received by inner lug **402**. Inner lug **402** has an extended portion **402E** which protrudes beyond collar **420** through its hole, through inboard compression elastomer package **424**, and is secured against inboard stop plate **428**. FIGS. 14 and 15 illustrate a bolt **430**, securing inboard stop plate **428** to inner lug **402** thereby securing inboard compression elastomer package **424** between inboard housing cover **432** and inboard stop plate 4**28**. As those having skill in the art know, any connective device capable of securing inboard stop plate **428** to inner lug **402** will work. During normal operation, lateral loads on inner lug **402** are transmitted to inner member **414** of the inboard elastomer package **412** and reacted, at least in part, through elastomer sections **416A** and **416B** thereof and into housing **404** in shear, thus providing a lower controlled stiffness.

[0080] Extended portion **402E** of inner lug **402** has an inner cavity which is threaded for insertion of stop plate retention bolt **430**. Stop plate **428** has a hole concentric with the internally threaded extended portion **402E** of inner lug **402** through which stop plate retaining bolt **430** engages with the internal threads of inner lug extended portion **402E**. Stop plate **428** is configured to contact inboard housing cover **432** when a force in the outboard direction is received by inner lug **402** and inboard compression elastomer package **424** between inboard housing cover **432** and inboard stop plate 428. This action prevents excess outboard motion of inner lug **402** and compression of optional outboard elastomer package **422** which would otherwise result in damage thereto. Inner lug **402** has an outboard stop portion **434** which prevents excess motion in the inboard direction relative to housing **404**. Thus, when excess inboard lateral motion of inner lug **402** is induced, outboard stop portion **434** of inner lug **402** contacts housing **404** and prevents further inboard motion of inner lug **402** relative to housing **404**. As such, when either stop plate **428** or outboard stop portion **434** contact housing **404**, aft mount **400** acts as a hard mount and the compliant characteristics thereof are essentially deactivated until the respective stop no longer contacts housing **404**. Outboard stop portion **434** includes, in some embodiments, separate wear plates.

[0081] FIGS. 15 and 16 show enlarged views of the interaction between inner lug **402**, inner member **414** and inboard elastomer package **412**, inboard compression elastomer package **424**, and inboard housing cover **432**. As was described above, inboard compression elastomer package **424** defines a non-compressed lateral position of inner member **414** and inner lug **402**. Inboard housing inner cover **432** sealingly interfaces with housing **404**. As before, sealing interface is formed by bonding, using gaskets, using O-rings, press fitting, and other known techniques to ensure a fluid seal between two elements. A sufficient amount of a suitable fluid is located within the interior of housing **404** such that substantially all air is evacuated therefrom when aft mount **400** is fully assembled. As seen in FIGS. 15 and 16, in some embodiments, a fluid cavity **436** is defined by a radial space outside of inboard compression elastomer package **424** and the inner surface **413** of housing **404**. When an inboard lateral force is received by inner lug **402** from engine **4**, inboard compression elastomer package **424** is compressed and the volume of fluid cavity **436** is decreased. As can be seen in FIG. 16, inner member has a cavity **438** with a gas-filled space/bladder **440, 441** which is in fluid communication with fluid cavity **436** by fluid passage **442**, which is located within inner member **414**. As such, when inner lug **402** and inner member **414** move laterally, the volume of fluid cavity **436** is reduced and fluid is pumped through fluid passage **442** into cavity **438** which contains gas-filled space/bladder **440, 441**, thereby compressing gas-filled space/bladder **440, 441** by the influx of fluid through fluid passage **442**. Thus, the gas-filled space/bladder **440, 441** is configured to provide a soft volumetric stiffness to accommodate movement of aft mount **400** and volumetric expansion or contraction of the gas due to temperature. The gas-filled bladder **441** may have, for example, an annular shape. In another embodiment, the gas-filled bladder **441** can be comprised of a plurality of separate or interconnected smaller bladders or balloons that, individually, occupy less than all of the cavity **438**. In some embodiments, the properties of the fluid, elastomer sections **416A** and **416B**, inboard compression elastomer package **424**, fluid passages **442**, and gas-filled space/bladder **440, 441** are selected to generate a notch in the force transfer function of aft mount **400** over a desired frequency range. This reduction in the transfer function or spring rate reduces the force transmission from a supported structure, such as an engine, into a supporting structure, such as an aircraft structure.

[0082] A method for reacting loads from an engine **4** of an aircraft **2**, to an aircraft structure **3** includes coupling inner lug **402** to move with inboard elastomer package **412** of an engine mount device, such as aft mount **400**; coupling inboard elastomer package **412** to an inner surface **413** of housing **404** of aft mount **400**; and transmitting a load to inner lug **402** of aft mount **400**. In some embodiments, lateral movement of inner lug **402** and inboard elastomer package **412** relative to housing **404** is bounded by a first position and a second position, the first position corresponding to a position at which outboard stop portion **434** contacts an outboard surface of housing **404** and the second position corresponding to a position at which stop plate **428** contacts inboard housing cover **432**. In some embodiments, when the load acts along a longitudinal axis of housing **404**, inner lug **402** and inboard elastomer package **412** move laterally and pump a fluid into or out of cavity **438** within the aft mount to change a volume of gas-filled space/bladder **440, 441**. In some embodiments, when the load acts transverse to the longitudinal axis of housing **404**, the load is reacted by inboard elastomer package **412**.

[0083] Other embodiments of the current invention will be apparent to those skilled in the art from a consideration of this specification or practice of the invention disclosed herein. Thus, the foregoing specification is considered merely exemplary of the current invention with the true scope thereof being defined by the following claims.

What is claimed:

1. A mounting device for reacting loads from an engine of an aircraft to an aircraft structure along a longitudinal axis of the mounting device, the mounting device comprising:

an upper link comprising an upper bearing surface disposed along the longitudinal axis of the mounting device, along which loading occurs;

a housing comprising:

a lower bearing surface disposed along the longitudinal axis of the mounting device; and

a center structure centrally disposed relative to the longitudinal axis;

wherein the center structure comprises at least one compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension, and

wherein the upper link is configured to interlock within the center structure; and

a flexing element that is attached to the housing;

wherein the upper link is in compression or tension resulting from the flexing element being biased against either the at least one compression stop or the at least one tension stop in a pre-loaded state.

2. The mounting device of claim 1, wherein the flexing element is connected to the upper link.

3. The mounting device of claim 2, wherein, when the flexing element is attached to the housing, a cavity is formed within a space formed between the flexing element and the housing.

4. The mounting device of claim 2, further comprising fluid elements and a gas-filled space/bladder within the cavity.

5. The mounting device of claim 4, wherein, upon a movement of the upper link relative to the housing, the flexing element is configured to deform and to cause a pumping of fluid into or out of the cavity.

6. The mounting device of claim 1, wherein the upper link comprises at least one lug and the center structure comprises at least one slot located between and in a same plane as at least one tension stop, wherein the at least one lug is configured to align with the at least one slot, and wherein the at least one lug is configured for insertion beyond a plane of the at least one tension stop and rotation such that each lug is substantially aligned with a corresponding tension stop.

7. The mounting device of claim 1, wherein, when a load greater than a mounting device designed pre-load of an operational load envelope is reacted along the longitudinal axis of the mounting device, the upper link is configured to move away from a respective one of the at least one compression stop or tension stop to which the upper link is in compression or tension resulting from flexing element thereby being biased until the upper link contacts the at least one compression stop or tension stop opposite the respective one of the at least one compression stop or one tension stop.

8. The mounting device of claim 1, wherein a distance between the compression stop and the at least one tension stop comprises an operational load in which the mounting device operates to reduce noise and vibration of the aircraft.

9. The mounting device of claim 8, wherein the operational load corresponds to 1G ± 0.5G and is an operation load resulting from engine thrust at idle up to and including climb levels.

10. A top mount for reacting tension loads from an engine of an aircraft to an aircraft structure along a longitudinal axis of the top mount, the top mount comprising:

an upper link having an upper bearing surface;

a housing comprising:

a lower bearing surface disposed along the longitudinal axis of the top mount; and

a center structure centrally disposed relative to the longitudinal axis of the top mount and comprising a compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension;

wherein the upper link is configured to interlock within the center structure;

a flexing element attached to and in sealing contact with the housing;

a fluid which fills, at least partially, the cavity; and

an inner member having a gas-filled space/bladder therein;

wherein loading of the top mount occurs along the longitudinal axis thereof; and

wherein the upper link is in compression or tension resulting from the flexing element being biased against either the at least one compression stop or the at least one tension stop in a pre-loaded state.

11. The top mount of claim 10, wherein, when the flexing element is attached to the housing, a cavity is formed within a space formed between the flexing element and the housing.

12. The top mount of claim 10, wherein the upper link is configured to move away from the compression stop against which the upper link is in compression or tension resulting from flexing element thereby being biased until the upper link contacts the at least one tension stop when a load greater than a mounting device designed pre-load of a total operational tension load is reacted along the longitudinal axis of the top mount.

13. A lower mount for reacting compression loads from an engine of an aircraft to an aircraft structure along a longitudinal axis of the lower mount, the lower mount comprising:

an upper link having an upper bearing surface;

a housing comprising:

a lower bearing surface disposed along the longitudinal axis of the lower mount; and a center structure centrally disposed relative to the longitudinal axis of the lower mount and comprising a compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension,

wherein the upper link is configured to interlock within the center structure;

a flexing element attached to an in sealing contact with the housing;

a fluid which fills, at least partially, the cavity; and

an inner member having a gas-filled space/bladder therein;

wherein loading of the lower mount occurs along the longitudinal axis thereof; and

wherein the upper link is in compression or tension resulting from the flexing element being biased against either the at least one compression stop or the at least one tension stop in a pre-loaded state.

14. The lower mount of claim 13, wherein, when the flexing element is attached to the housing, a cavity is formed within a space formed between the flexing element and the housing.

15. The lower mount of claim 13, wherein the upper link is configured to move away from the at least one tension stop against which the upper link is in compression or tension resulting from flexing element thereby being biased until the upper link contacts the compression stop when a load greater than a mounting device designed pre-load of a total operational compression load is reacted along the longitudinal axis of the lower mount.

16. A method for reacting loads from an engine of an aircraft to an aircraft structure, the method comprising:

applying a pre-load force to an upper link of an engine mount device;

coupling the upper link to a flexing element; and

transmitting a load from the engine to a bearing surface of the engine mount device;

wherein the flexing element is attached to the housing;

wherein, when the load from the engine is greater than the pre-load force, the upper link is movable with respect to a housing of the engine mount device along a longitudinal axis of the engine mount device;

wherein a movement of the upper link relative to the housing is bounded by a distance between a first position and a second position;

wherein the movement of the upper link relative to the housing deforms the flexing element and pumps a fluid into or out of a cavity within the engine mount device to change a volume of a gas-filled space/bladder; and

wherein the upper link is in compression or tension resulting from the flexing element being biased against either the at least one compression stop or the at least one tension stop in a pre-loaded state.

17. A method for reacting loads from an engine of an aircraft to an aircraft structure, the method comprising:

coupling an inner lug to move with an inboard elastomer package of an engine mount device;

coupling the inboard elastomer package to an inner surface of a housing of the engine mount device; and

transmitting a load to the inner lug of the engine mount device;

wherein lateral movement of the inner lug and the inboard elastomer package relative to the housing is bounded by a first position and a second position,

wherein, when the load acts along a longitudinal axis of the housing, the inner lug and the inboard elastomer package move laterally and pump a fluid into or out of a fluid cavity within the engine mount device to change a volume of a gas-filled space/bladder;

wherein, when the load acts transverse to the longitudinal axis of the housing, the load is reacted by the inboard elastomer package.

18. A method for limiting the deflection of an engine mechanically to an aircraft structure of an aircraft, the method comprising:

providing a mounting device having at least one compression stop configured to carry loads in compression and at least one tension stop configured to carry loads in tension, the mounting device further comprising:

an upper link comprising an upper bearing surface disposed along the longitudinal axis of the mounting device, along which loading occurs;

a housing comprising:

a lower bearing surface, which is disposed along the longitudinal axis of the mounting device; and

a center structure, which is centrally disposed relative to the longitudinal axis;

wherein the center structure includes the at least one compression stop and the at least one tension stop;

wherein the upper link is configured to interlock within the center structure; and

a flexing element that is attached to the housing;

biasing the flexing element against either the at least one compression stop or the at least one tension stop in a pre-loaded state, wherein the upper link is in compression or tension; and

reacting an operational load from the engine with the mounting device.

19. The method of claim 18, wherein the flexing element is connected to the upper link.

20. The method of claim 18, wherein, when the flexing element is attached to the housing, a cavity is formed within a space formed between the flexing element and the housing.

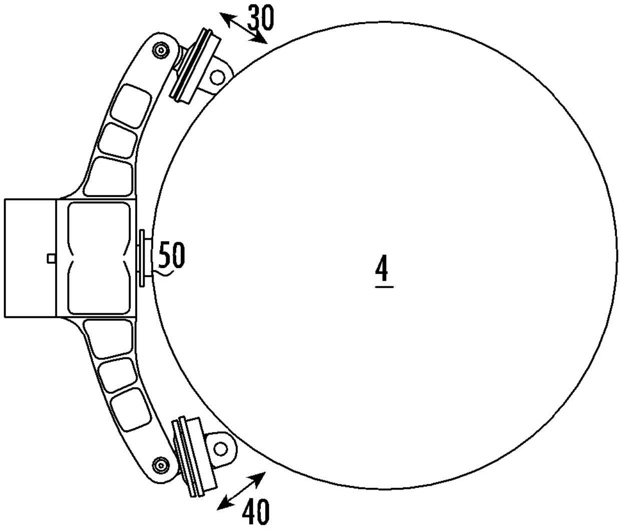

FIG. 1A

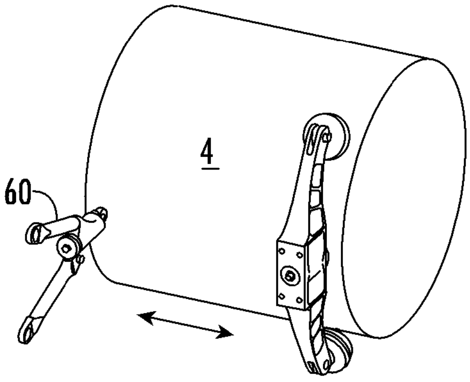

FIG. 1B

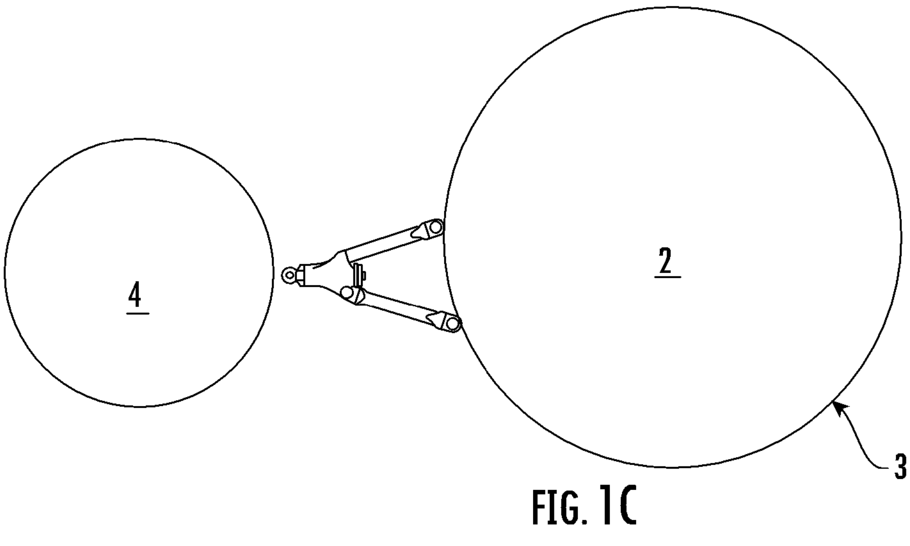

FIG. 1C

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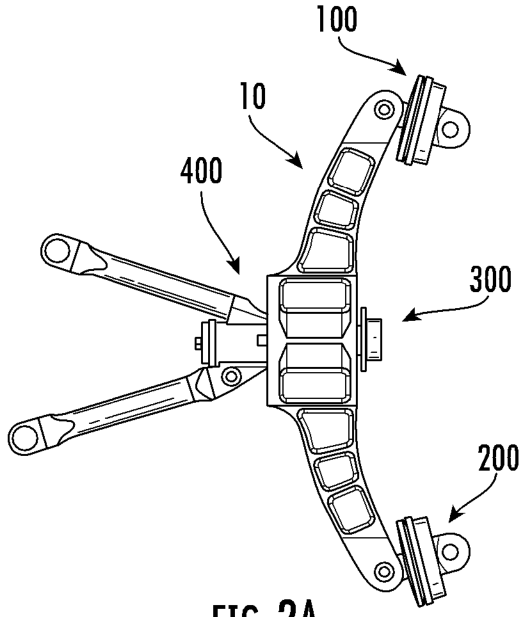

FIG. 2A

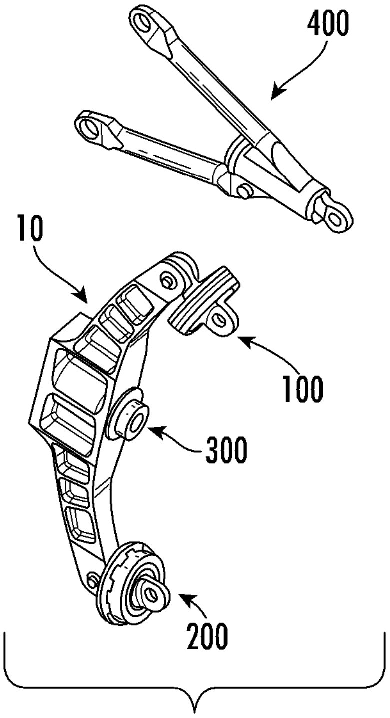

FIG. 2B

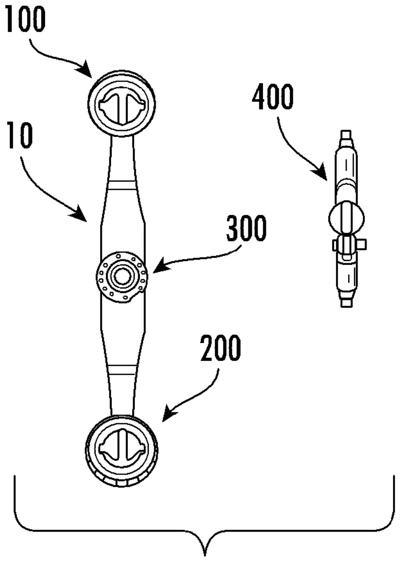

FIG. 2C

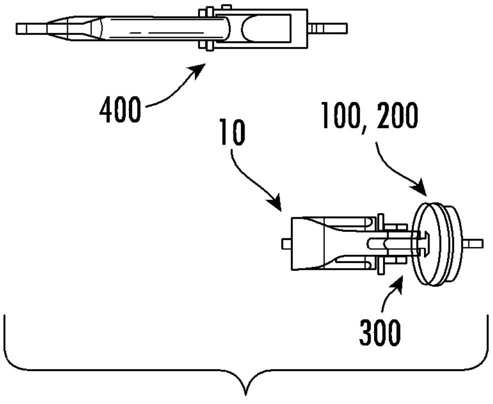

FIG. 2D

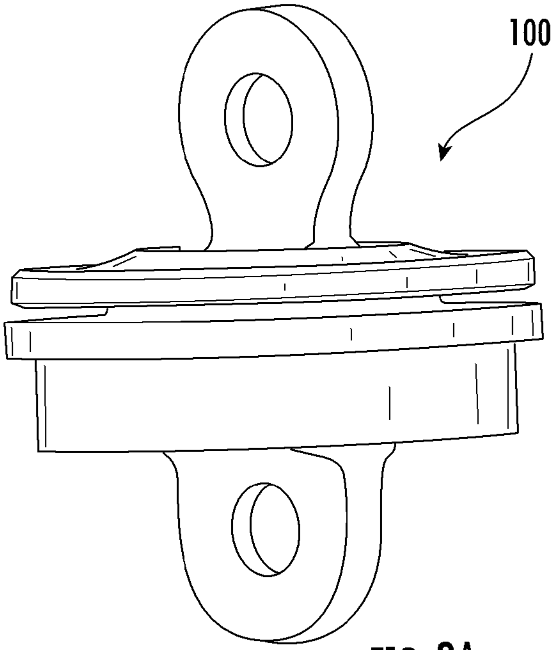

FIG. 3A

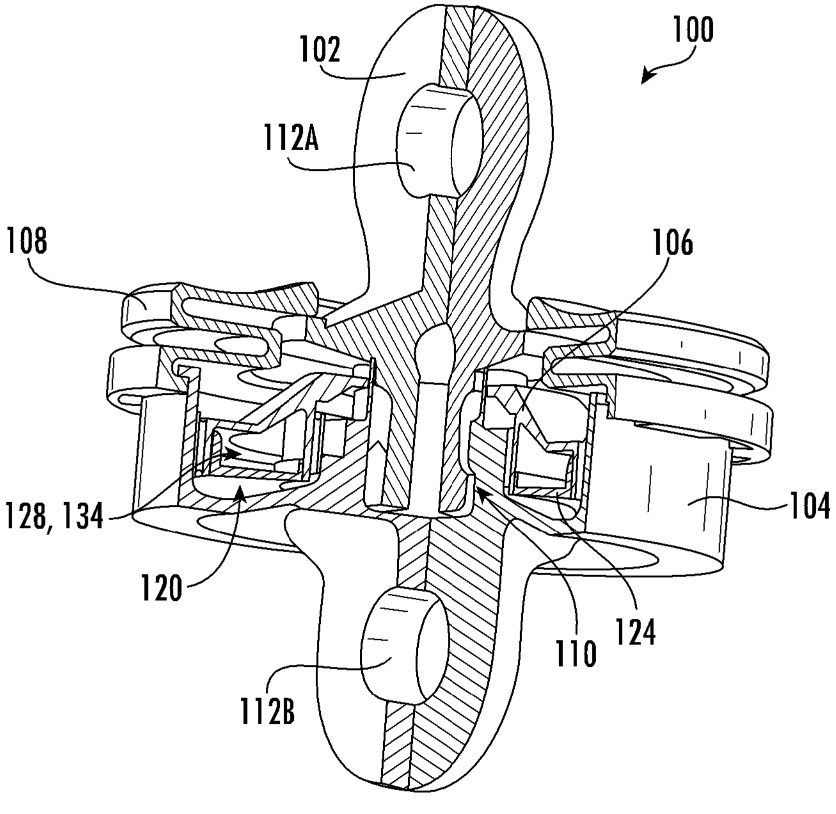

FIG. 3B

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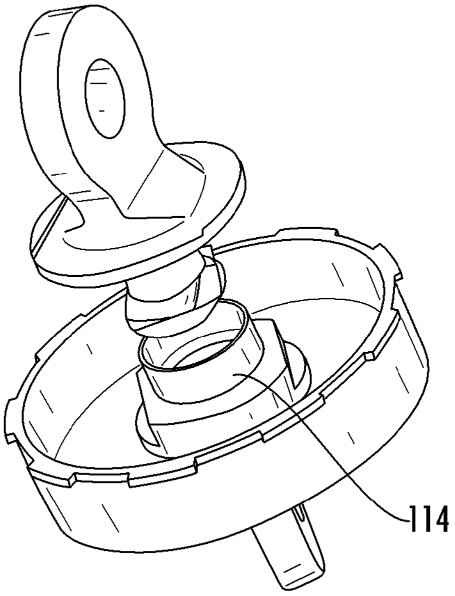


FIG. 3C

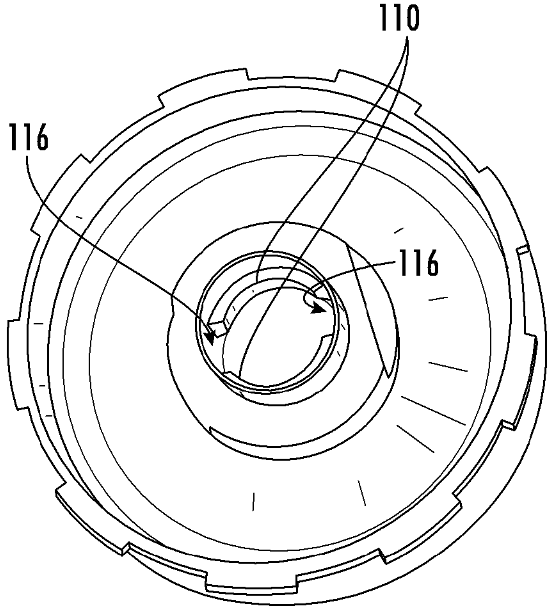


FIG. 3D

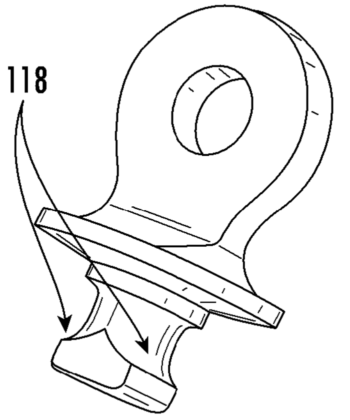


FIG. 3E

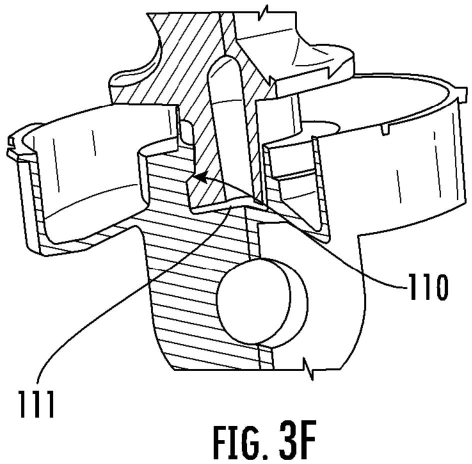


FIG. 3F

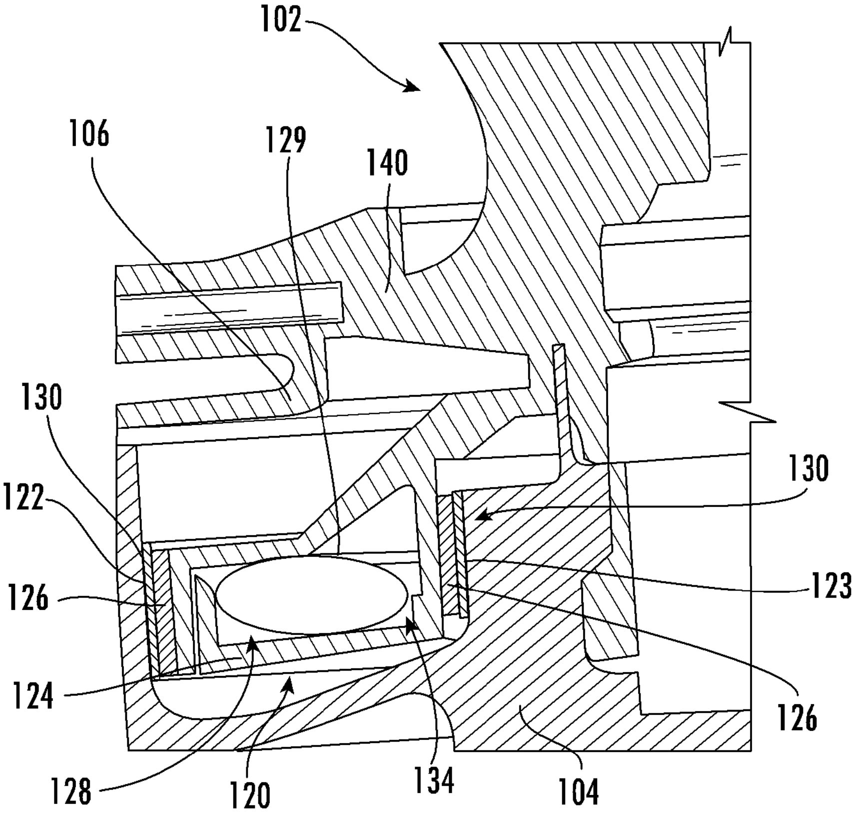


FIG. 3G

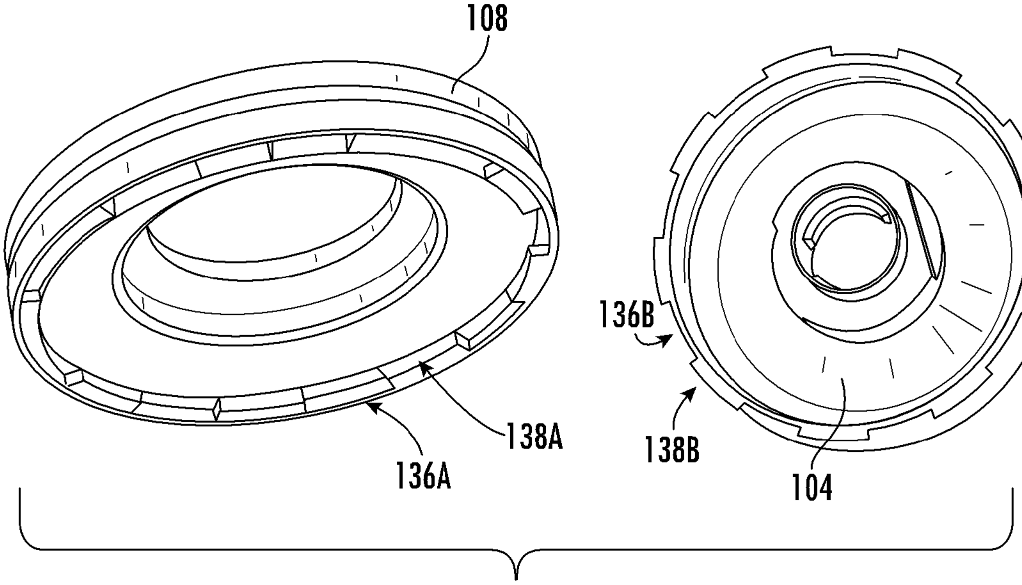

108
136B
138A
136A
138B
104

FIG. 4A

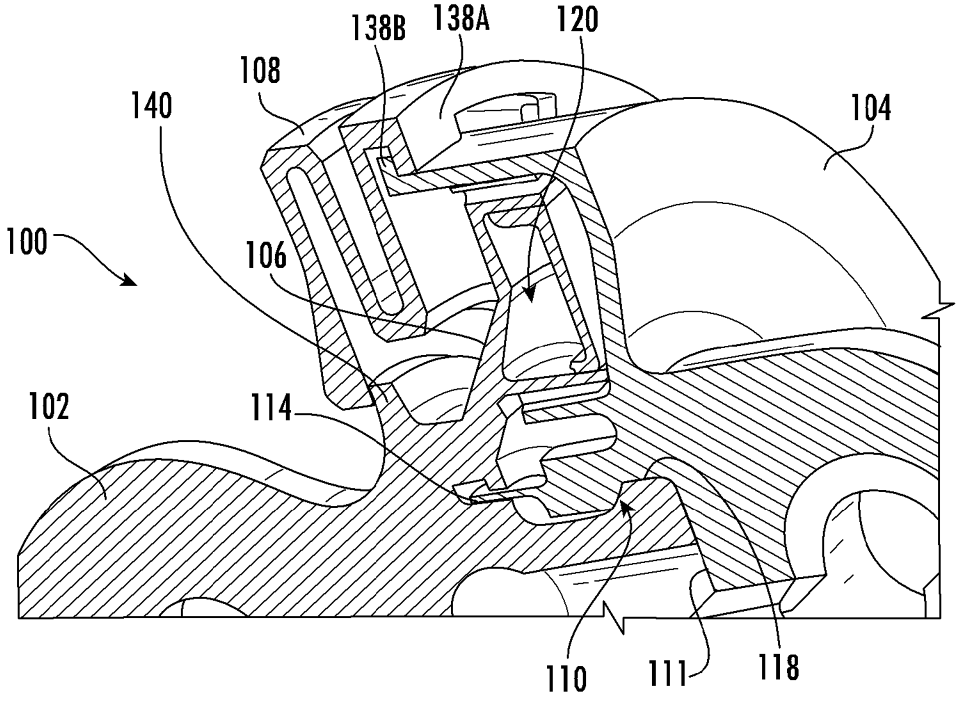

138B
138A
120
108
140
104
100
106
102
114
110
111
118

FIG. 4B

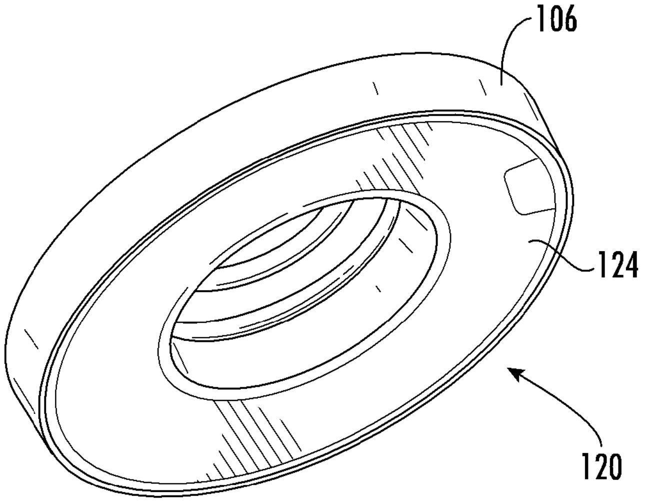


FIG. 5A

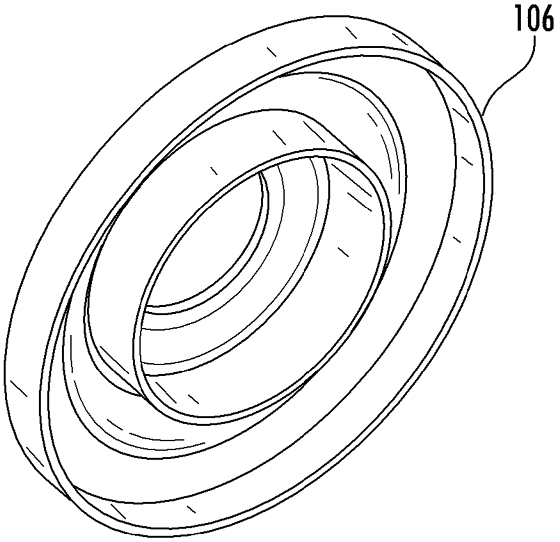


FIG. 5B

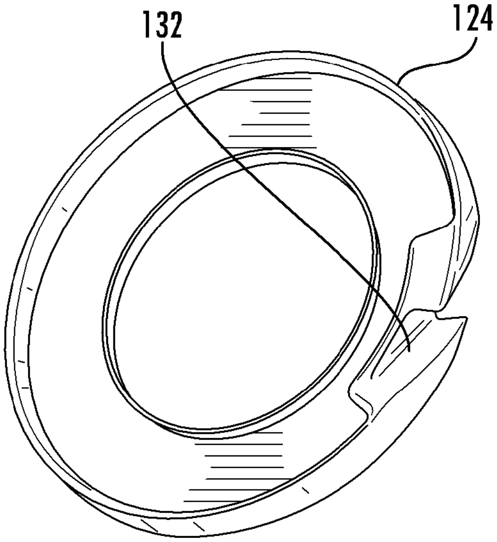


FIG. 5C

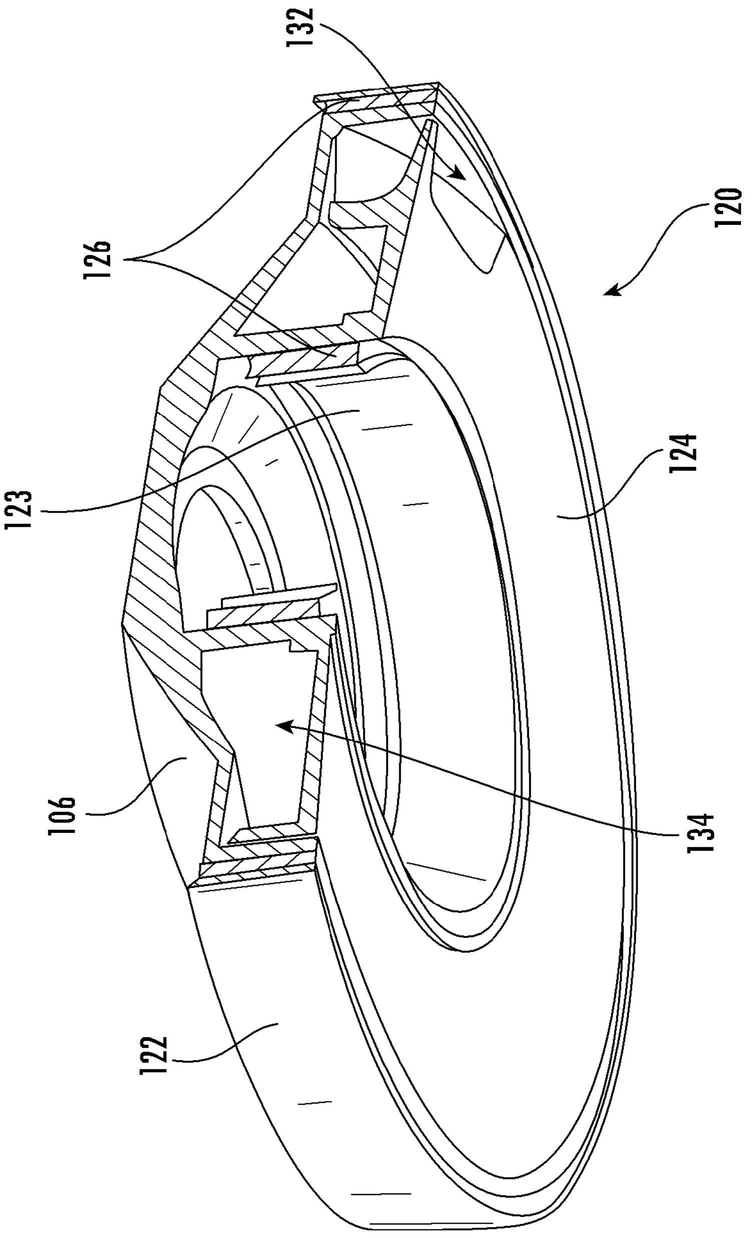
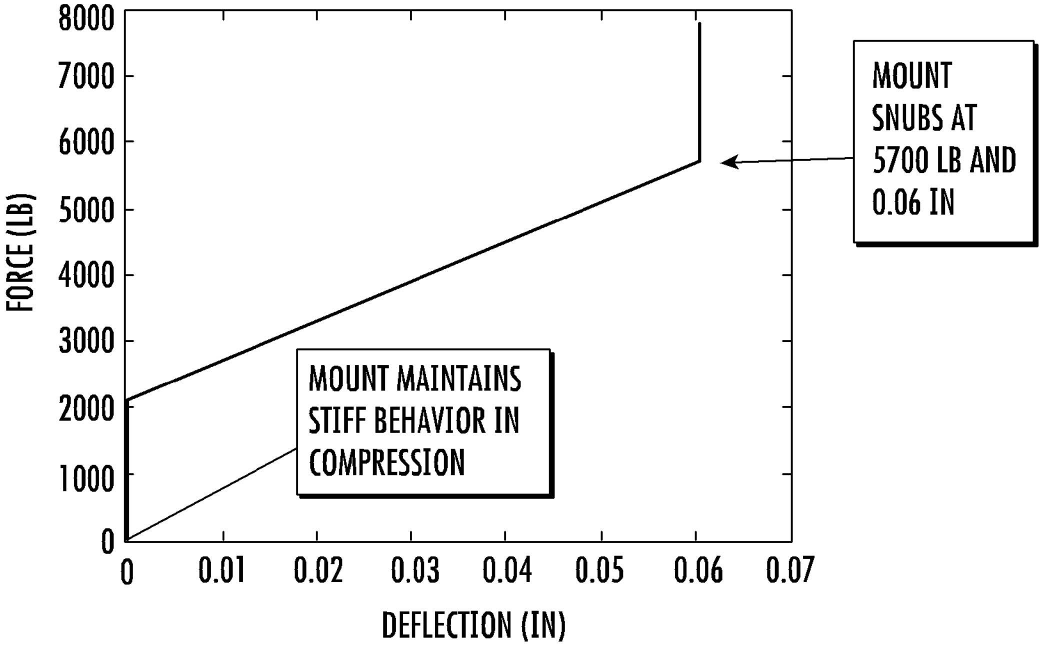
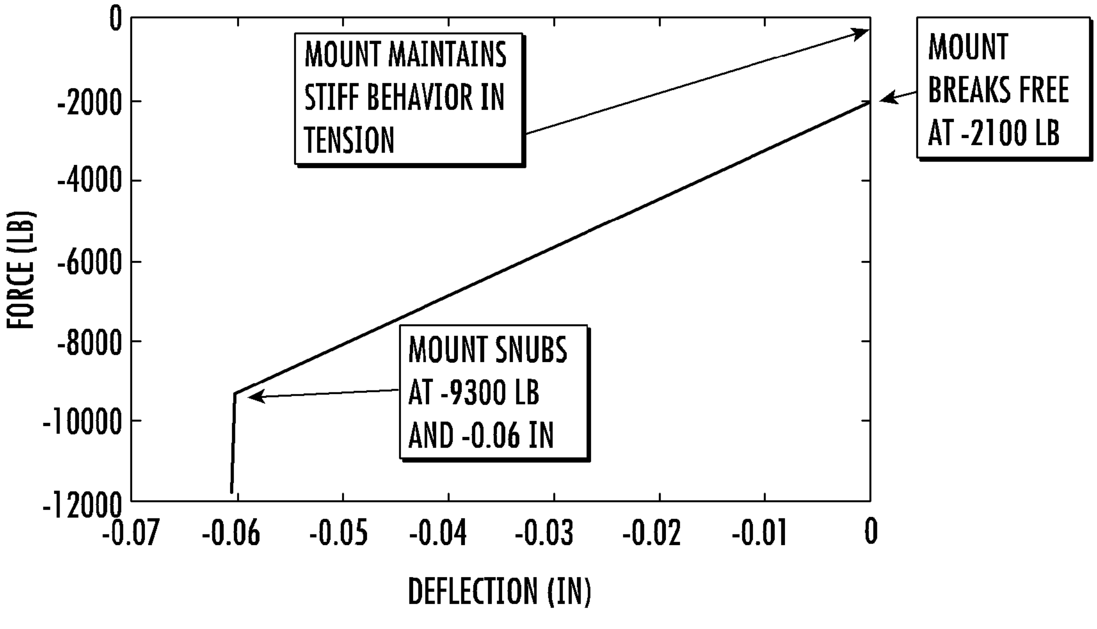


FIG. 5D



FORCE (LB)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
DEFLECTION (IN)
MOUNT SNUBS AT 5700 LB AND 0.06 IN
MOUNT MAINTAINS STIFF BEHAVIOR IN COMPRESSION

FIG. 6A



FORCE (LB)
0
-2000
-4000
-6000
-8000
-10000
-12000
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
DEFLECTION (IN)
MOUNT MAINTAINS STIFF BEHAVIOR IN TENSION
MOUNT BREAKS FREE AT -2100 LB
MOUNT SNUBS AT -9300 LB AND -0.06 IN

FIG. 6B

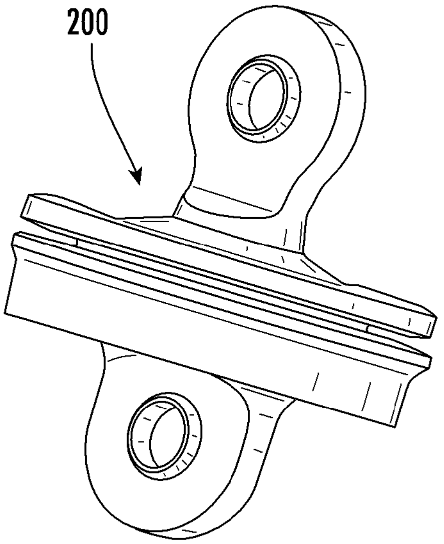
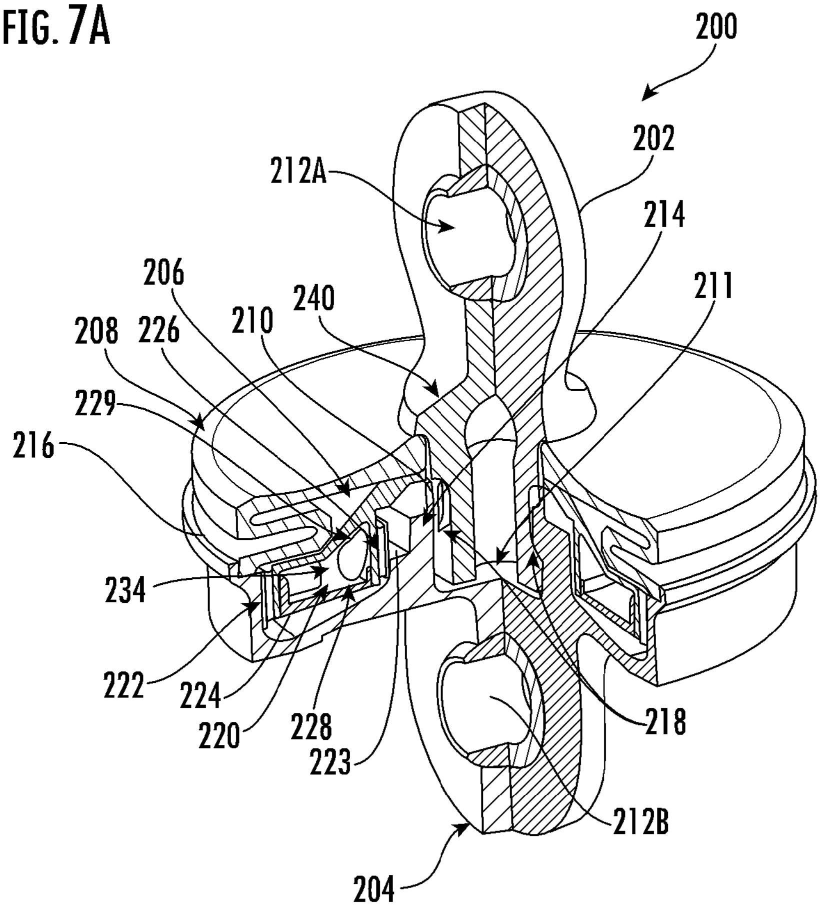

200

FIG. 7A


200
202
212A
214
211
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226
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229
216
234
222
224
220
228
223
218
212B
204

FIG. 7B

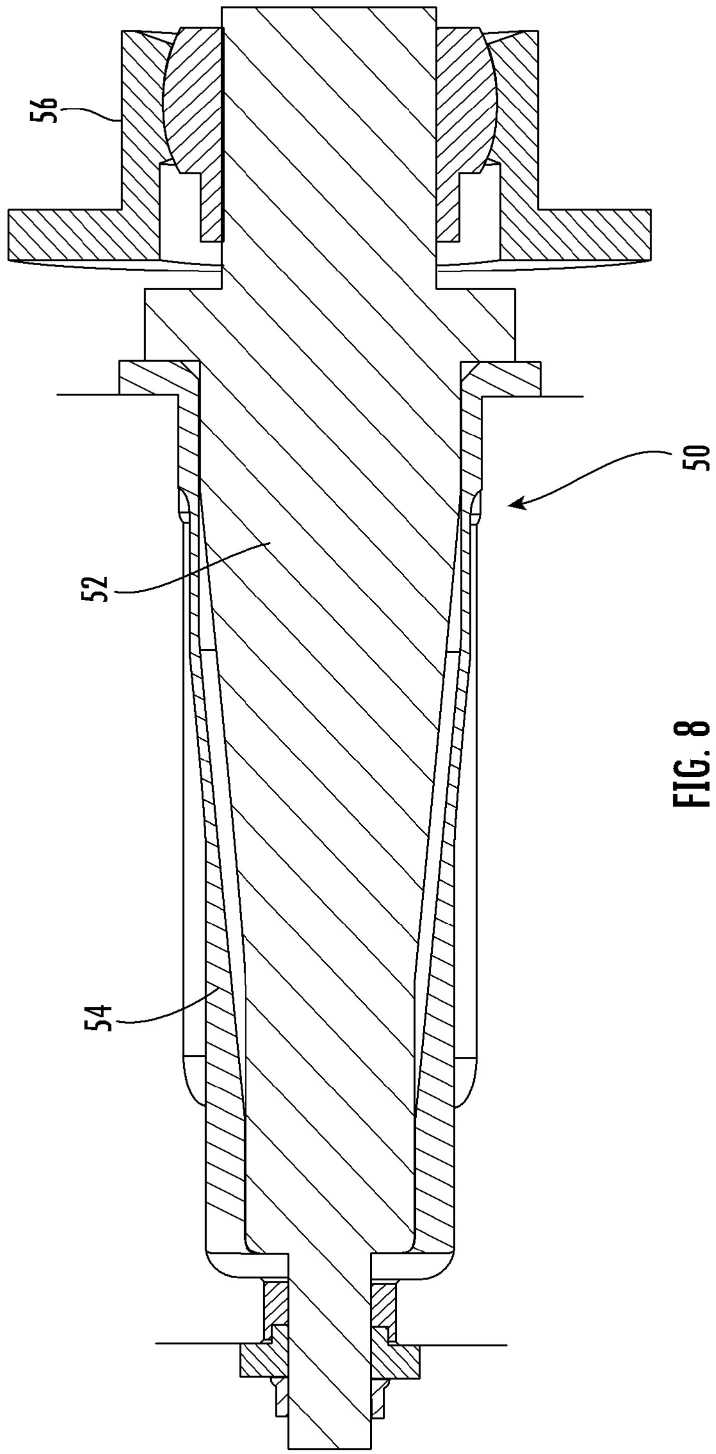


FIG. 8
PRIOR ART

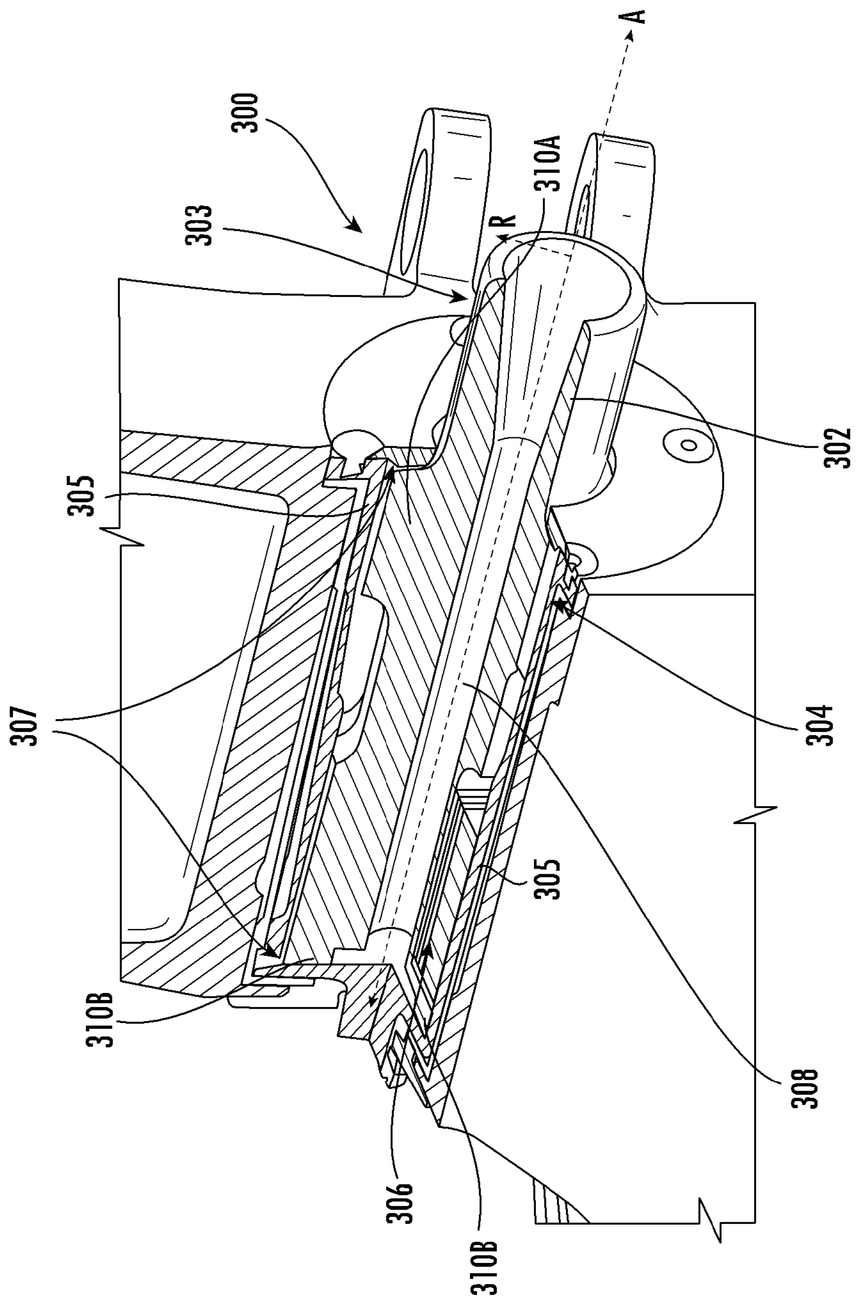


FIG. 9

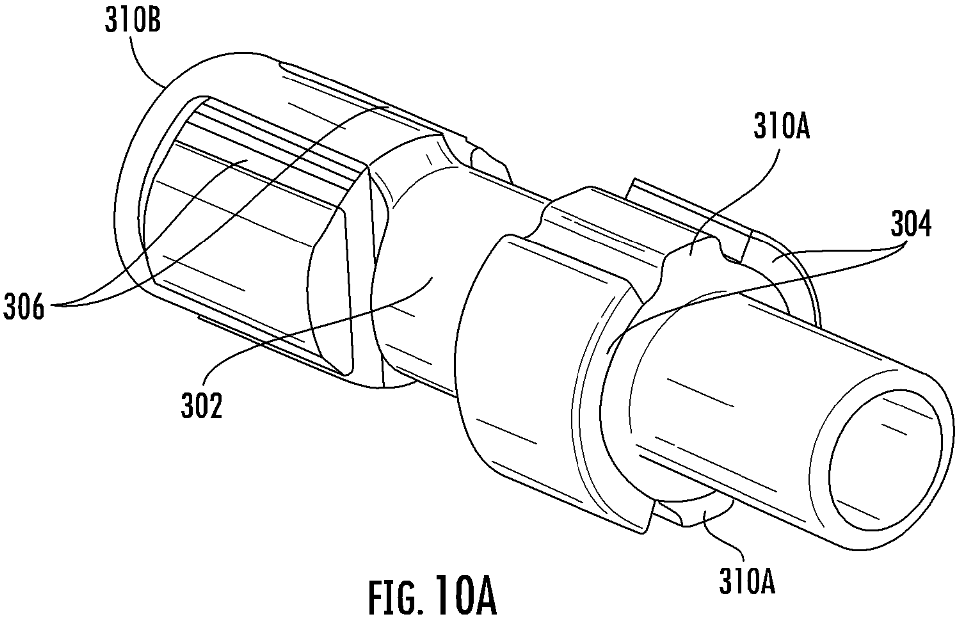


FIG. 10A

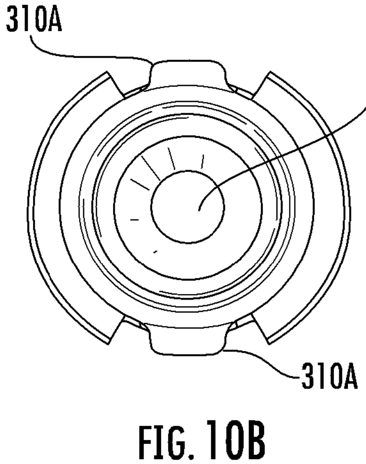


FIG. 10B

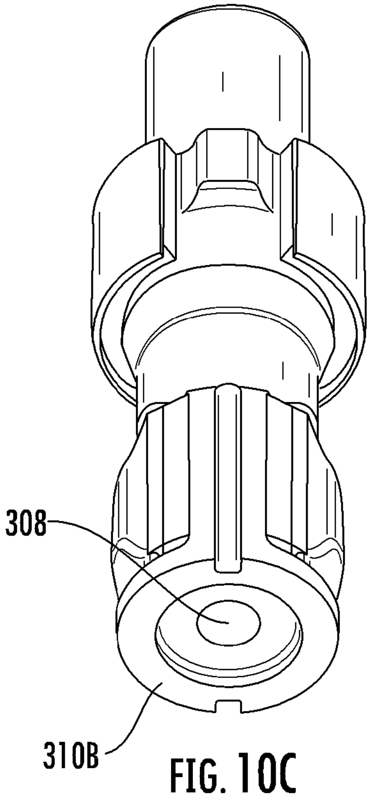


FIG. 10C

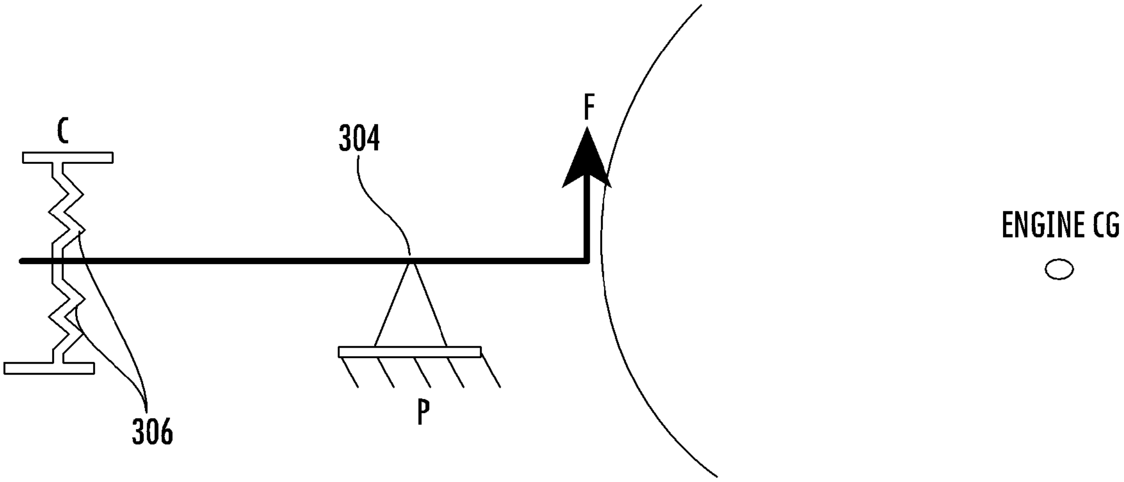


FIG. 11

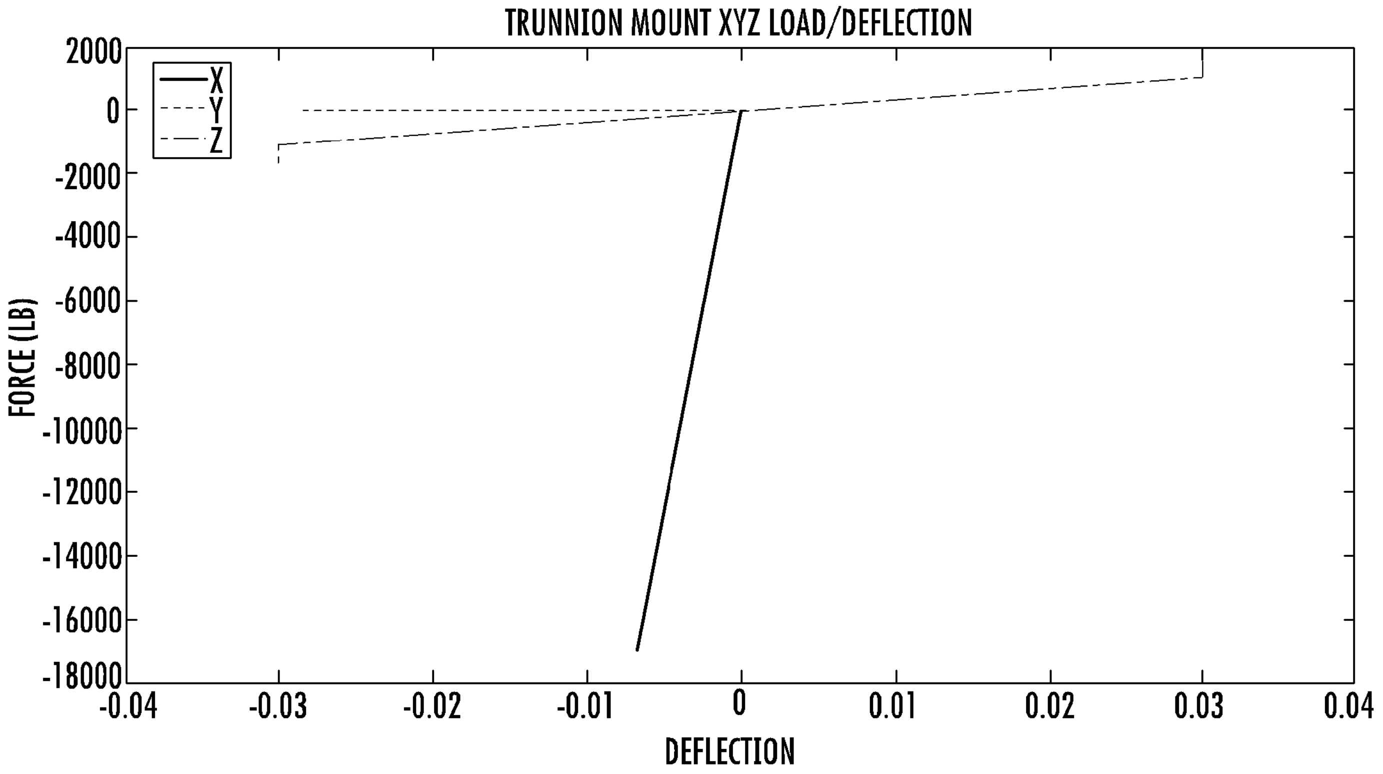

TRUNNION MOUNT XYZ LOAD/DEFLECTION
X
Y
Z
FORCE (LB)
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
DEFLECTION

FIG. 12

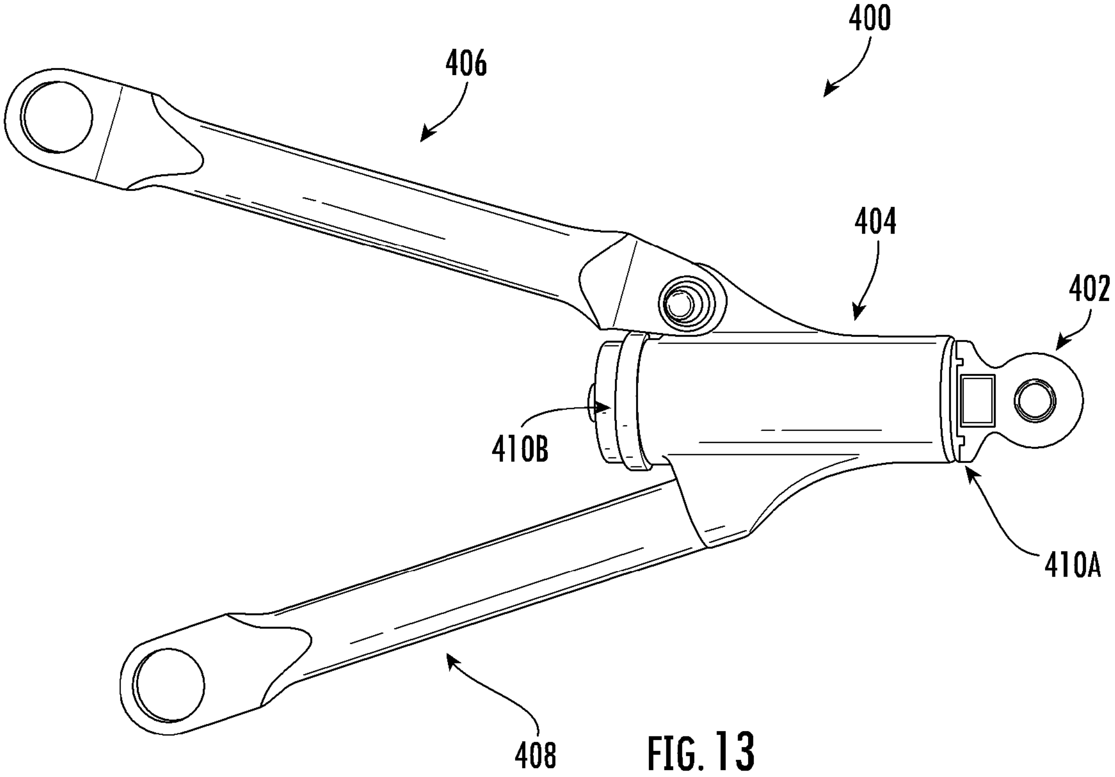

400
406
404
402
410B
410A
408

FIG. 13

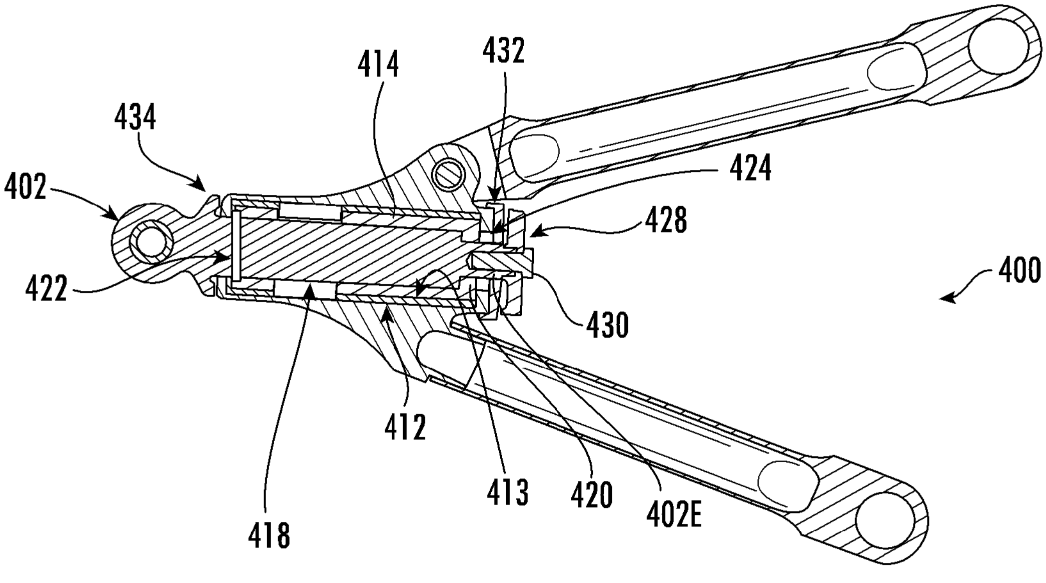

414
432
434
402
424
428
422
400
430
412
413
420
402E
418

FIG. 14

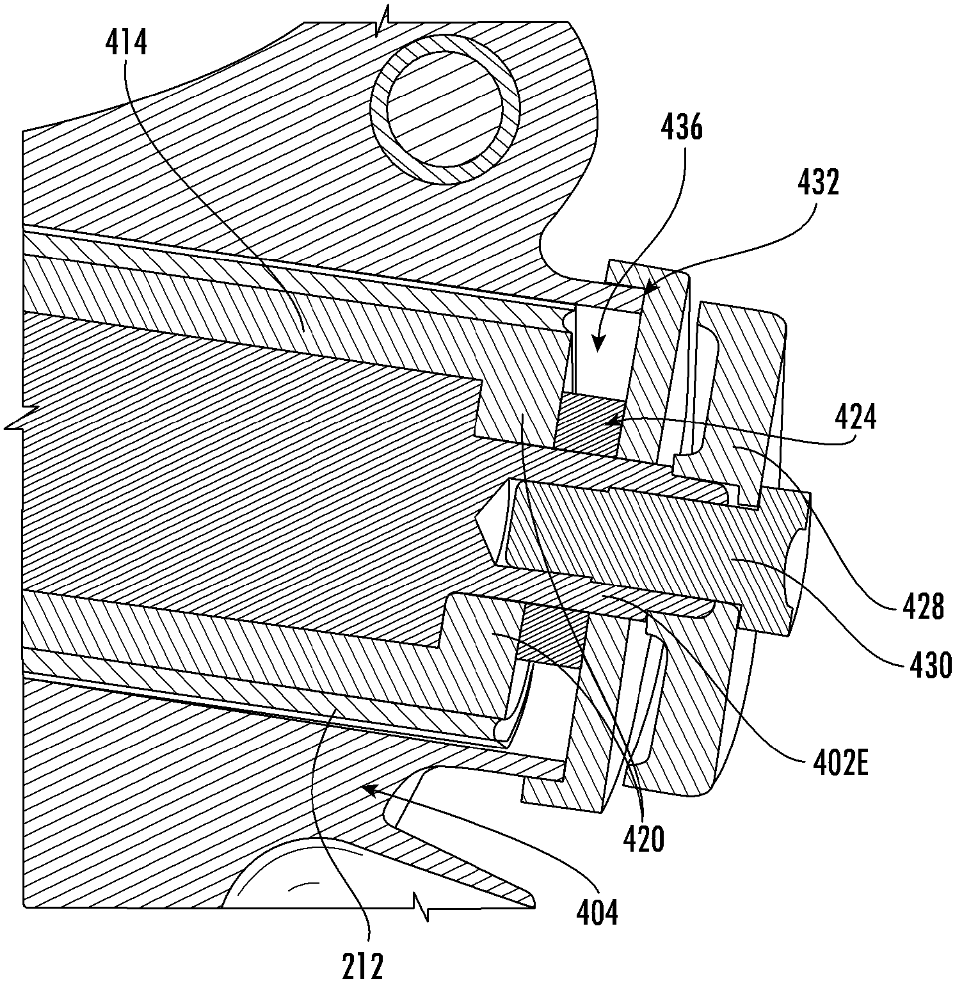


FIG. 15

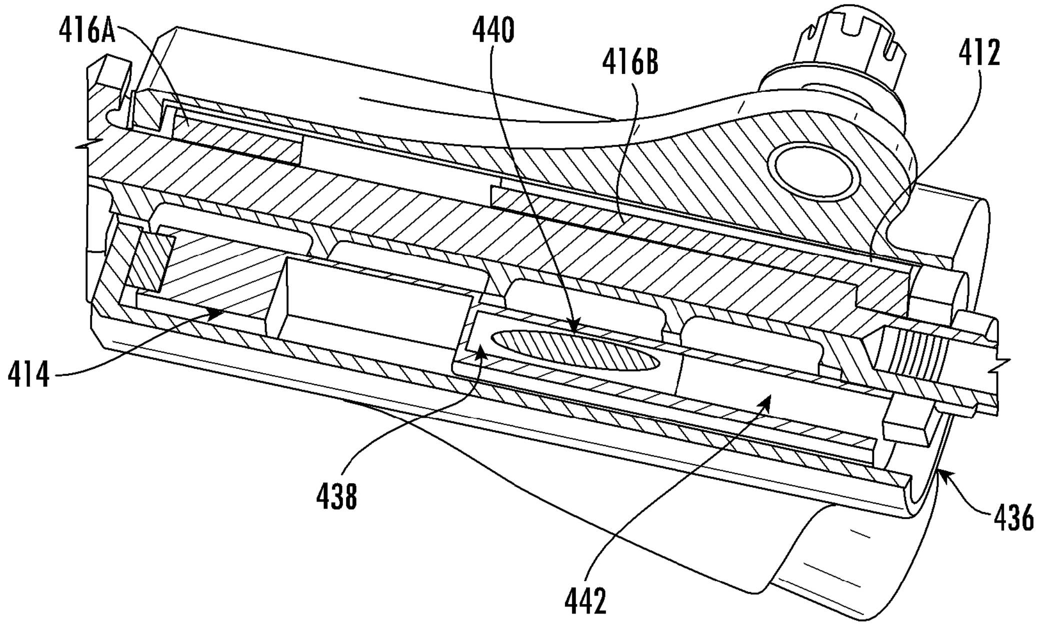
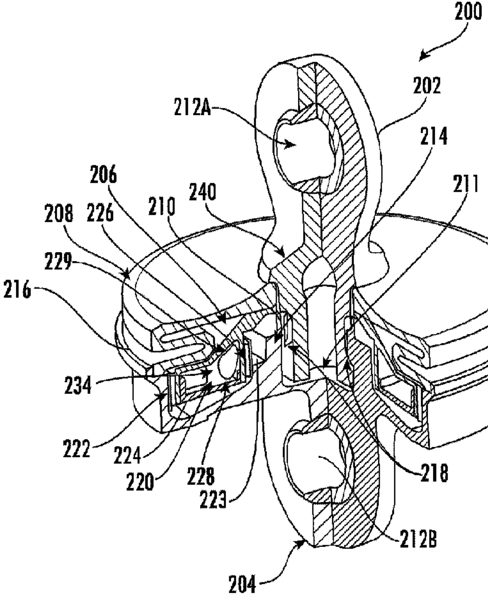


FIG. 16


200
202
212A
214
211
206
240
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222
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223
218
212B
204