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(54) **IMPROVED RISER TENSIONER BEARING SYSTEM**

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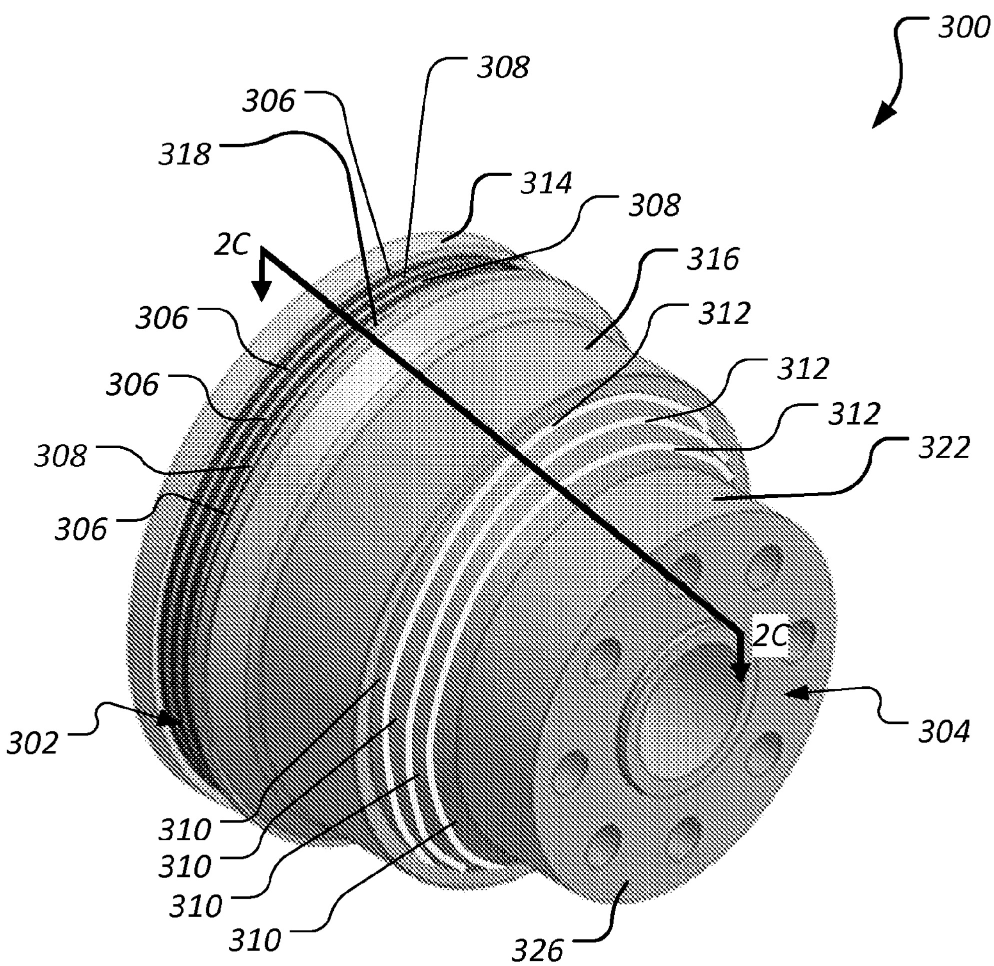
(57) **ABSTRACT**

A serial bearing (**300**) for a riser tensioner system is provided. The serial bearing improves lateral and axial load performance when severe side-loads are transferred to the riser tensioner system.



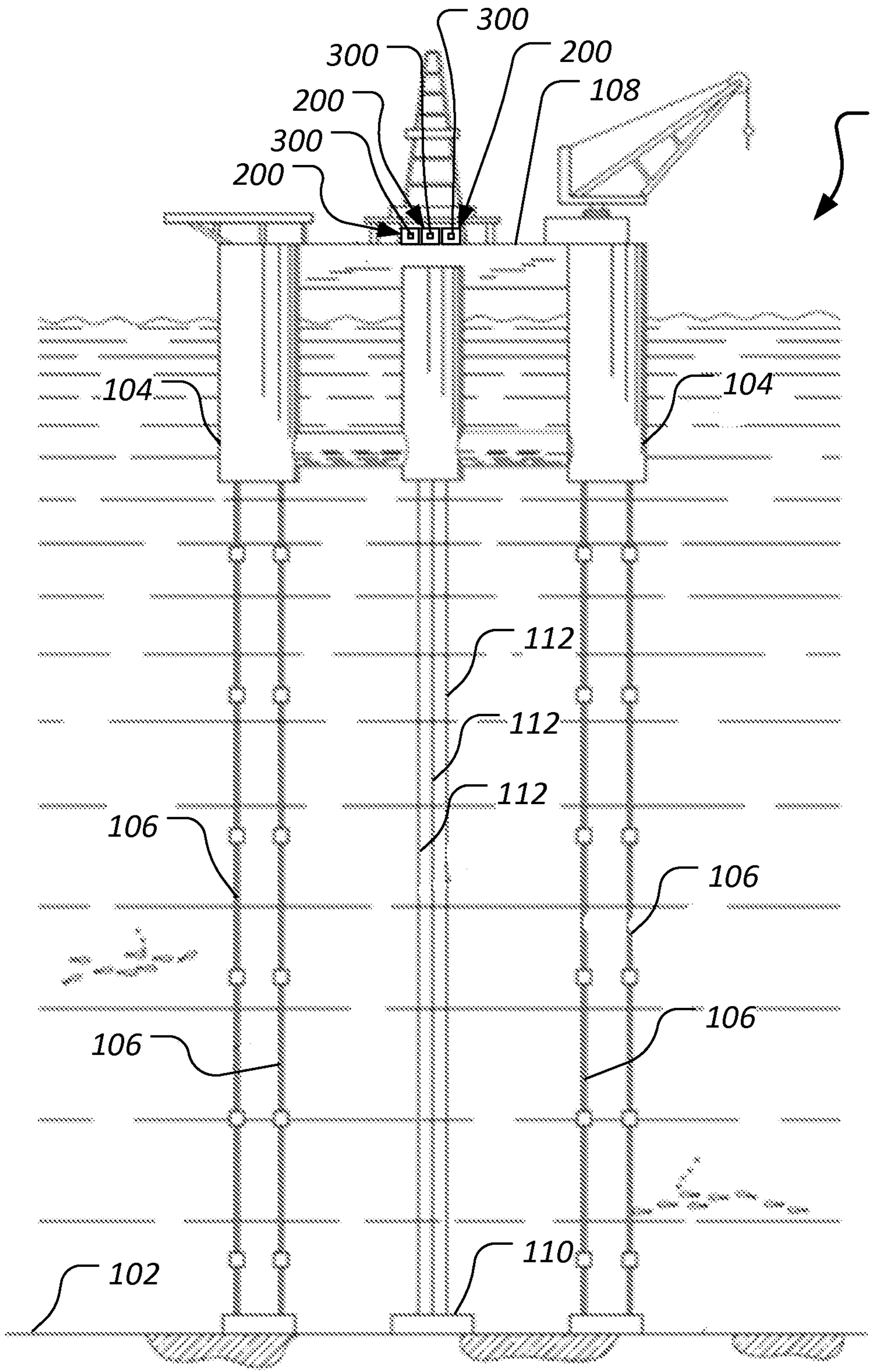

300
300
200
200
108
100
200
300
200
104
104
112
112
112
106
106
106
106
110
102

FIG. 1

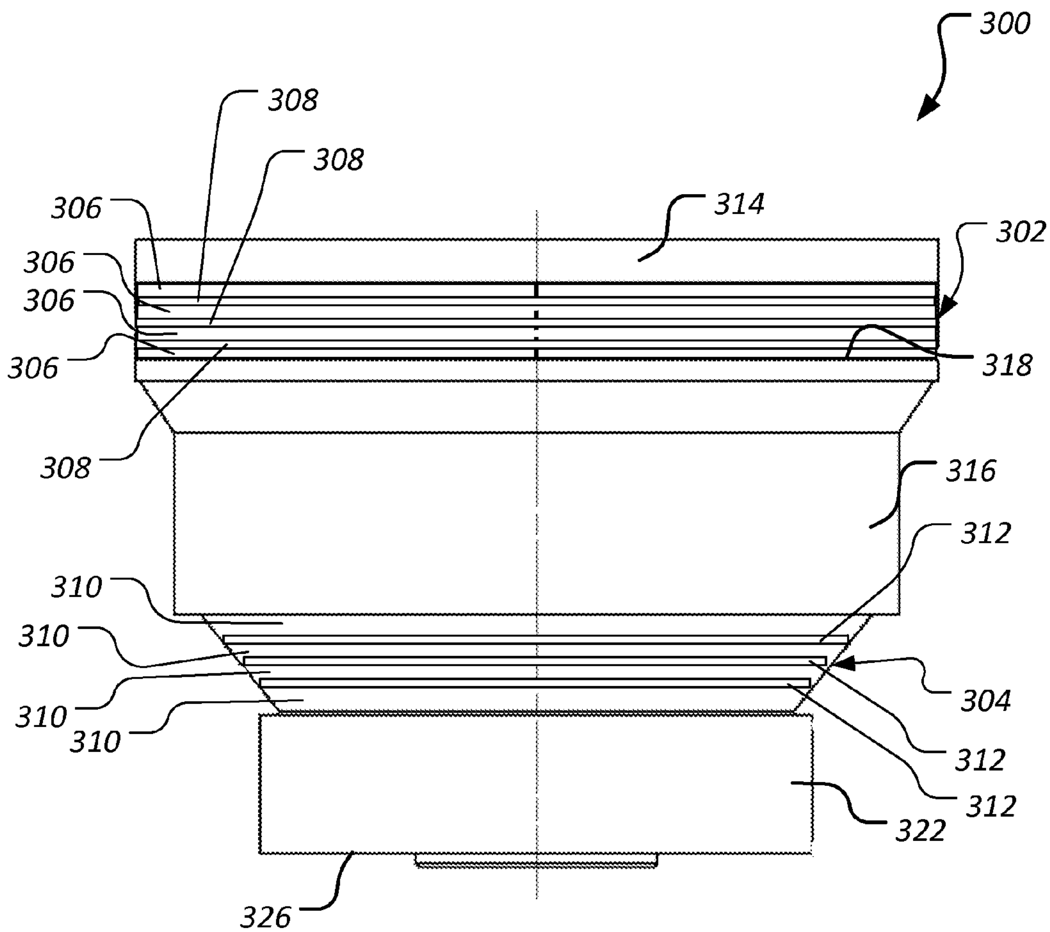

300
308
308
306
314
302
306
306
306
318
308
316
312
310
310
304
310
310
312
312
322
326

FIG. 2A

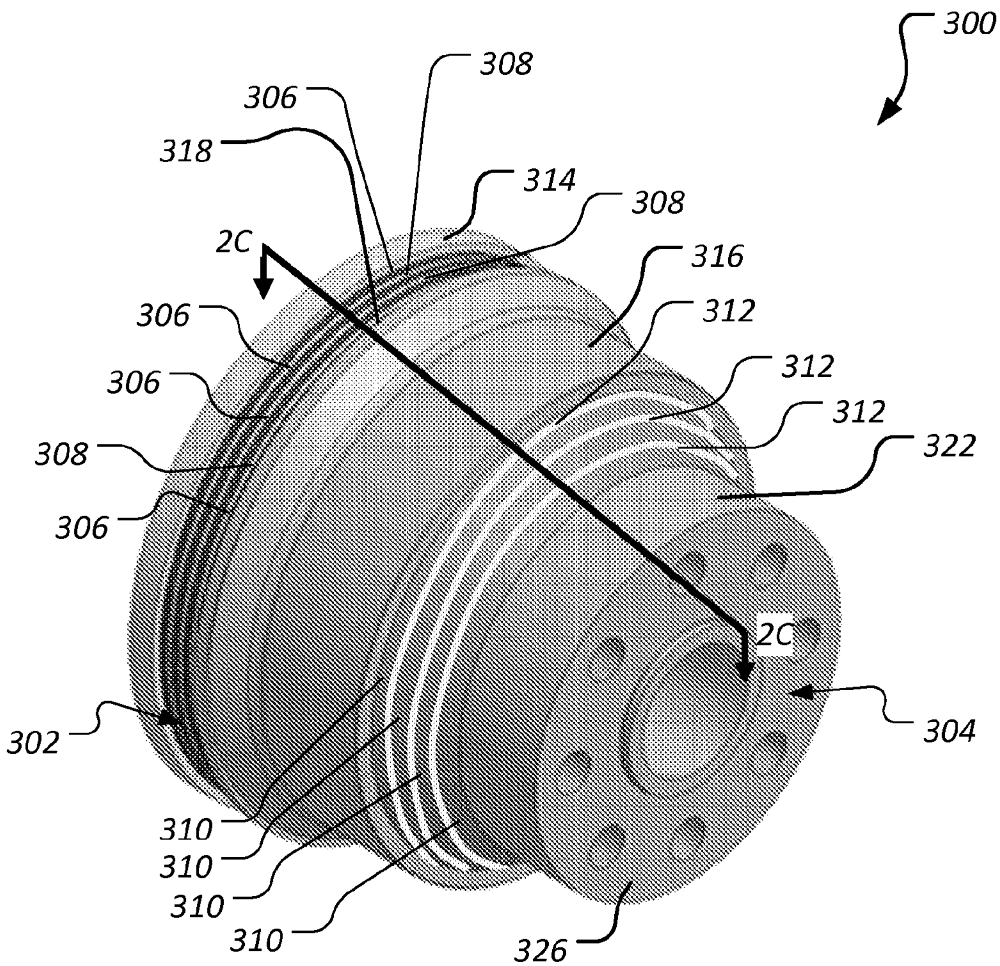

300
308
306
318
314
308
2C
316
312
306
312
306
312
308
322
306
2C
302
304
310
310
310
310
326

FIG. 2B

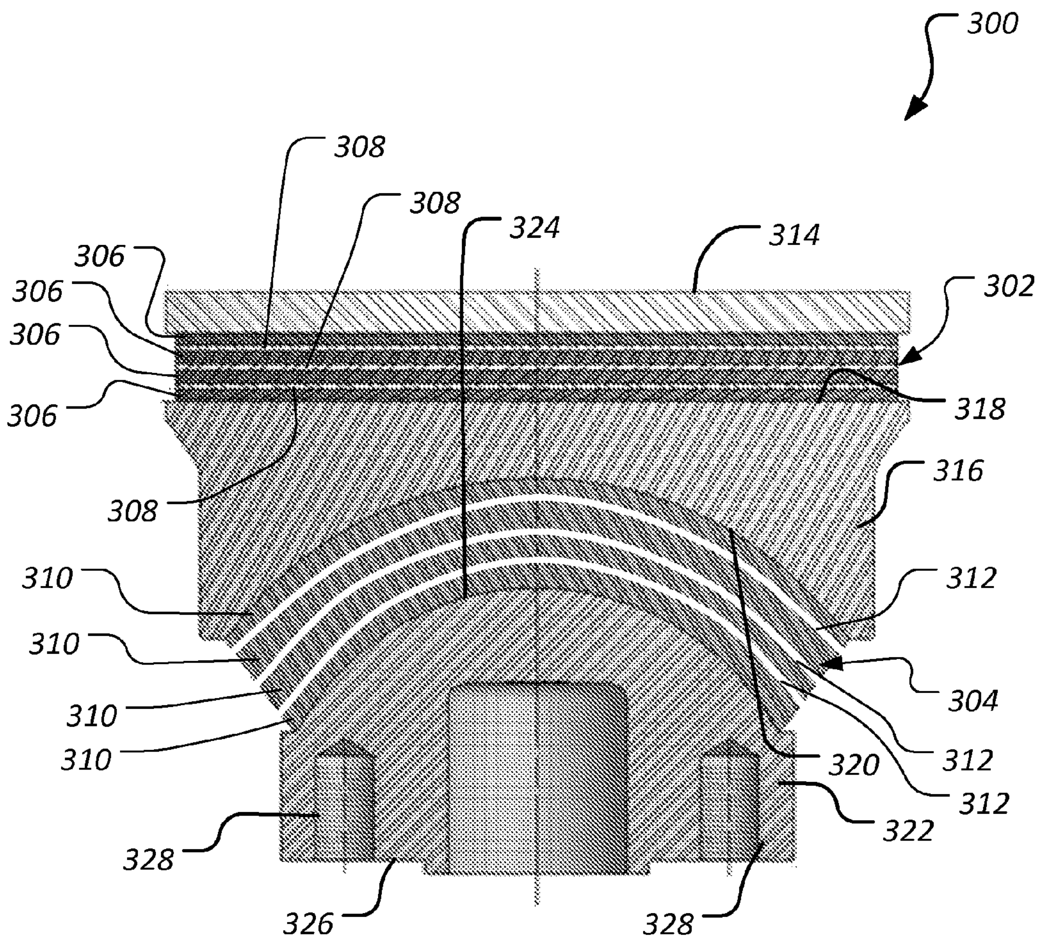

300
308
308
324
314
306
306
306
302
306
318
316
308
310
312
310
304
310
320
312
310
312
322
328
326
328

FIG. 2C

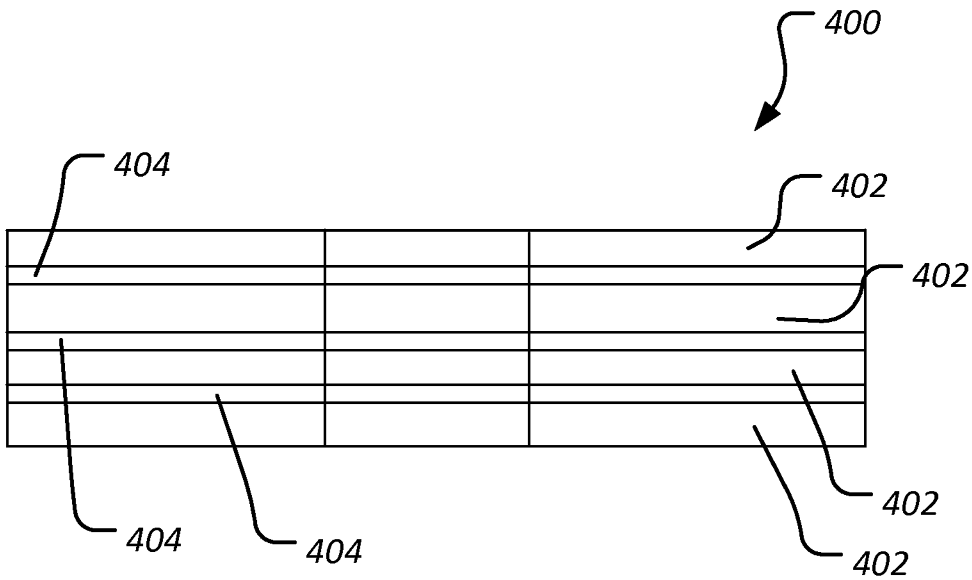


FIG. 3

IMPROVED RISER TENSIONER BEARING SYSTEM

PRIORITY CLAIM

[0001] The present application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/898,860, filed Nov. 1, 2013, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The subject matter disclosed herein relates to offshore oil platforms and support structures. More particularly, the subject matter disclosed herein relates to devices, systems, and methods for reducing riser tensioner system failures attributable to side-loads applied to hydraulic or pneumatic cylinders of riser tensioner systems.

BACKGROUND

[0003] Riser tensioner systems are subjected to side-loading during normal operations. These side-loads, also known as lateral loads or bending loads, are forces impacting the riser tensioner system. In many designs, the riser tensioner systems include hydraulic or pneumatic cylinders. Most vertically positioned riser tensioner systems are vulnerable to being damaged by these side-loads as the result of oceanic wave energy being transferred to the riser tensioner systems due to the ebb and flow of the waves around these riser tensioner systems and the components supported by the riser tensioner systems. When the oceanic waves have more energy the forces transferred to the riser tensioner systems increase. There is a point where the oceanic waves create failure modes of the riser tensioner systems due to the high energy forces acting upon the riser tensioner systems as severe side-loads. This is a case of excessive side-loads impacting the hydraulic or pneumatic cylinders.

[0004] One failure mode for hydraulic or pneumatic cylinders, hereinafter referred to as cylinders, occurs when the cylinder is subjected to high lateral or bending loads which exceed the load bearing capabilities of the cylinder's sealing mechanism. These excessive loads can compromise the sealing mechanism, thereby reducing the life of the cylinder. Another failure mode for cylinders occurs when high lateral or bending loads exceed the load bearing capabilities of a piston rod of the cylinder, thereby potentially preventing desired actuation of the piston rod of the cylinder. In such cases maintenance or replacement efforts are required, which significantly impact associated lost time and financial expenses.

[0005] Because the available riser tensioner systems do not have a sufficient ability to resist the high-side loads the lifetime of the riser tensioner systems are reduced. A crude approach to solving this problem is to design a more robust cylinder and seal capable of withstanding the high side-loads. Unfortunately, this approach increases the physical size and the cost of the riser tensioner system. Thus, this approach is less economically feasible to manufacture and creates immense handling and installation issues.

[0006] What is needed is a riser tensioner system which provides the ability to withstand high side-loading conditions, provide beneficial performance while maintaining economical manufacturability and provide robust life of service.

SUMMARY

[0007] In one aspect a riser tensioner system utilizing a serial elastomeric bearing arrangement is provided. The serial elastomeric bearing includes a spherical bearing which provides for cocking compliance in series with a radial bearing of a riser tensioner system thereby providing for lateral compliance in high side-load conditions. The combined bearing, a series bearing, has a high axial stiffness providing for the efficient transmission of axial loads. The cocking compliance is provided by a spherical bearing which in turn provides protection from high side-loads. The lateral compliance from a spherical bearing provides for additional motion accommodation. The additional motion accommodation protects the cylinder from particularly severe side-loads. As such, the possibility for cylinder failure is reduced, as is the need to design a higher cost, more robust cylinder.

[0008] In one aspect, the series bearing is directly bonded using typical elastomer manufacturing methods. In another aspect, a sequential bonding process using structural adhesives is used to fabricate the series bearing in a modular manner. Sequential bonding provides for rapid application design iterations and facilitates using the rubber bearing in multiple arrangements. Sequential bonding can reduce design manufacturing tooling efforts and costs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic side view an offshore a hydrocarbon system including a plurality of riser tensioner systems that each include a series bearing.

[0010] FIG. **2**A is an orthogonal side view of a series bearing of the riser tensioner system of FIG. **1**.

[0011] FIG. **2**B is an oblique lower-side view of the series bearing of FIG. **2**A.

[0012] FIG. **2**C is an orthogonal cross-sectional view of the series bearing of FIG. **2**A taken along cutting line **2**C-**2**C of FIG. **2**B.

[0013] FIG. **3** is an orthogonal cutaway view of an alternative radial bearing stack.

DETAILED DESCRIPTION

[0014] Referring now to FIG. **1**, a hydrocarbon system **100** for use in discovering and producing hydrocarbons or petroleum materials is illustrated. The hydrocarbon system **100** is located offshore and is tethered to the ocean floor **102**. The hydrocarbon system **100** includes buoyant platform foundations **104** that are tethered to the ocean floor **102** by tendons **106**. The platform foundations **104** support a deck foundation **108**. The hydrocarbon system **100** further includes a well template **110** from which multiple risers **112** rise up to the deck foundation **108**. Each riser **112** is associated with separate wells or wellbores formed in the earth below the well template **110**. The hydrocarbon system **100** also includes a plurality of riser tensioner systems **200**, one riser tensioner system **200** for each of the risers **112**. The riser tensioner systems **200** are configured to accommodate relative movement between the risers **112** and the platform foundations **104** or deck foundation **108** to prevent buckling of the risers **112**.

[0015] The riser tensioner systems **200** of hydrocarbon system **100** include a vertical support frame having legs configured for connection to the deck foundation **108**. The riser tensioner systems **200** include a plurality of vertically oriented cylinders which each comprise a piston rod that extends and retracts vertically relative to the support frame. Each riser tensioner system **200** includes a collar configured to engage with a riser **112**. The collar has a plurality of laterally extending arms. Each arm extends laterally to a location vertically above an associated one of the cylinders. The piston rods are attached to their associated arms with a serial bearing **300**. The serial bearings **300** accommodate both relative lateral movement between the piston rods and the collar as well as relative cocking movement between the piston rods and the collar. Accordingly, the serial bearings **300** collectively accommodate relative movement between the riser **112** and the cylinders of the riser tensioner systems **200**.

[0016] Referring now to FIGS. **2**A-2C, an orthogonal side view, an oblique lower view, and an orthogonal cross-sectional view of a serial bearing **300** of the riser tensioner systems **200** are shown, respectively. The serial bearing **300** includes a radial bearing stack **302** and a spherical bearing stack **304** located in series to provide lateral and cocking compliance or movement, respectively. The radial bearing stack **302** is a high capacity laminate (HCL) bearing manufactured with known HCL technologies. The radial bearing stack **302** has elastomeric elements **306** and shim elements **308**. The elastomeric elements **306** and the shim elements **308** are disc shaped. The spherical bearing stack **304** is an HCL bearing manufactured with known HCL technologies. The spherical bearing stack **304** has elastomeric elements **310** and shim elements **312**. The elastomeric elements **310** and the shim elements **312** are shaped as spherical sections. Series bearing **300** is customizable for the particular end user's requirements. Spherical bearing stack **304** accommodates cocking motions and radial bearing stack **302** accommodates radial motions relative to riser **112**. In alternative embodiments, a spherical bearing stack is designed to allow radial motion in addition to the radial motion allowed by the radial bearing stack **302**. The performance characteristics of spring rates and motions allowed by the serial bearing **300** can be controlled by adding or removing elastomeric elements **306**, **310** and shim elements **308**, **312**. In this case the spring rates are selected for a given set of environmental conditions defined by the user. The spring rates are modifiable to provide softer or stiffer spring rates, depending upon the end user's needs.

[0017] The radial bearing stack **302** is mounted between a radial bearing mount **314** and an intermediate mount **316**. The radial bearing mount **314** includes a flat and rigid disc having a diameter at least as large as a diameter of the radial bearing stack **304**. The intermediate mount **316** includes a rigid component having a flat radial bearing interface surface **318** connected to the radial bearing stack **302** and a spherical section shaped concave surface **320** connected to the spherical bearing stack **304**. The spherical bearing stack **304** is mounted between the intermediate mount **316** and a spherical bearing mount **322**. The spherical bearing mount **322** includes a spherical section shaped convex surface **324** connected to the spherical bearing stack **304**. The spherical bearing mount **322** also includes a riser interface **326** connected to a piston rod or other portion of a cylinder. The radial bearing mount **314** also includes an arm interface **328** connected to an arm of a collar. The serial bearing **300** provides lateral and cocking compliance while maintaining high axial stiffness for transmission of axial loads. Serial bearing **300** reduces severe side-loads caused by extreme weather events (green impact waves), etc., that would otherwise result in high lateral loading of cylinder seals which adversely affects the seal life. Cocking compliance provides elastomeric bearing protection from severe side-loads while the radial bearing stack **304** provides significantly increased compliance to protect the riser tensioner systems **200** from particularly severe side-loads. The radial bearing mount **314** is welded or otherwise rigidly fixed to an arm of a collar. In alternative embodiments, the radial bearing mount is sized to overhang or extend beyond the radial bearing stack (not shown) so that through holes are provided to receive bolts or other fasteners that are configured to aid in attaching the radial bearing mount to the arm of a collar. Similarly, the spherical bearing mount **322** comprises recesses **328** or apertures configured to aid in attaching the spherical bearing **322** to a riser **112** or to another component rigidly attached to a riser **112**. In alternative embodiments, the vertical orientation of the serial bearing **300** may be reversed to similarly provide the above-described lateral and cocking compliance.

[0018] In a preferred embodiment, spherical bearing stack **304** with elastomeric elements **310** and shim elements **312** is designed to have a specific stiffness. Preferably, spherical bearing stack **304** has a radial spring rate of about 781,000 lbf/in (about 136,774.1 KN/m), a torsional spring rate of about 1900 in-lbf/deg (about 215 Nm/deg), a cocking spring rate of about 4000 in-lbf/deg (about 452 Nm/deg), and an axial spring rate of about 4.7×10^{6} lbf/in (about 823,096.1 KN/m). The axial and radial spring rates of the spherical bearing stack **304** are nonlinear, where an increase in load yields an increase in the stiffness. Typically, the stiffness for the cocking spring rate will be less than 4000 in-lbf/deg (about 452 Nm/deg). The maximum cocking motion of spherical bearing stack 304 is about +/−15 degrees from the vertical. These stiffness values are added in series with the radial bearing values.

[0019] In a preferred embodiment, radial bearing stack **302** has stiffness values for compression, cocking and radial (shear) forces. For compression, radial bearing stack **302** has a value of about 1.2×10^{7} lbf/in (about 2,101,522 KN/m). For cocking, radial bearing stack **302** has a value of about 9×10^{5} lbf ft/deg (about 1,220.2 KNm/deg). For radial (shear) radial bearing stack **302** has a value of about 22,000 lbf/in (about 3,852.8 KN/m). The axial (compression) and cocking spring rates of radial bearing stack **302** are nonlinear, where an increase in load yields an increase in the stiffness. In a preferred embodiment, radial bearing stack **302** has radial motion capabilities of about 1.125 inches to about 1.875 inches (about 2.86 centimeters to about 4.76 centimeters) under survival conditions and about 0.160 inches (about 0.41 centimeters) under fatigue conditions.

[0020] Spherical bearing stack **304** and radial bearing stack **302** are capable of being manufactured with direct bonding or sequential bonding. The sequential bonding process uses structural adhesives to fabricate the serial bearing **300** in a modular manner. Sequential bonding provides for rapid application design iterations and facilitates using the elastomeric element **306** in multiple arrangements. Sequential bonding may reduce design manufacturing tooling efforts and costs.

[0021] Referring now to FIG. **3**, an orthogonal cutaway view of an alternative radial bearing stack **400** is shown. The radial bearing stack has an outside diameter of 16 inches (about 40.6 centimeters), a 4.813 inch (about 12.23 centimeters) inner diameter and an 8 inch (about 20.3 centimeters) thickness to yield a radial stiffness of 2200 lb/in (about 385, 279 N/m). The radial bearing stack **400** includes elastomeric element rings **402** and shim rings **404**.

[0022] 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 is:

1. A serial bearing for a riser tensioner system, said serial bearing including:

a radial bearing mount;

a spherical bearing mount;

an intermediate mount disposed between the radial bearing mount and the spherical bearing mount;

a radial bearing stack disposed between the radial bearing mount and the intermediate mount; and

a spherical bearing stack disposed between the spherical bearing mount and the intermediate mount.

2. The serial bearing of claim **1**, wherein the radial bearing stack includes a high capacity laminate (HCL).

3. The serial bearing of claim **2**, wherein said HCL is formed using direct bonding.

4. The serial bearing of claim **2**, wherein said HCL is formed using sequential bonding.

5. The serial bearing of claim **1**, wherein the spherical bearing stack includes a high capacity laminate (HCL).

6. The serial bearing of claim **5**, wherein said HCL is formed using direct bonding.

7. The serial bearing of claim **5**, wherein said HCL is formed using sequential bonding.

8. The serial bearing of claim **1**, wherein said spherical bearing stack has a spring rate of about 1.2×10^{7} lbf/inch in compression, about 22,000 lbf/inch in shear, and about 9×10^{5} lb·ft/deg for cocking.

9. The serial bearing of claim **1**, wherein said spherical bearing stack has a radial spring rate of about 781,000 lbf/inch, a torsional spring rate of about 1900 in-lbf/deg, a cocking spring rate of about 4000 in-lbf/deg, and an axial spring rate of about 4.7×10^{6} lbf/inch.

10. The serial bearing of claim **9**, where said axial spring rate and said radial spring stack are nonlinear and are configured to increase in a stiffness as a load acting upon said spherical bearing stack increases.

11. The serial bearing of claim **9**, wherein said spherical bearing stack has cocking spring rate less than or equal to about 4000 in-lbf/deg.

12. The serial bearing of claim **1**, wherein at least one of the radial bearing mount and the spherical bearing mount are configured for connection to a riser.

13. The serial bearing of claim **12**, wherein a cocking motion of said spherical bearing stack is about +/−15 degrees from a vertical direction relative to said riser.

14. The serial bearing of claim **1**, wherein the radial bearing stack includes at least one of ring shaped elastomeric elements and ring shaped shim elements.

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