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(54) Title: ANTI-ROTATING HYDRAULIC PISTON

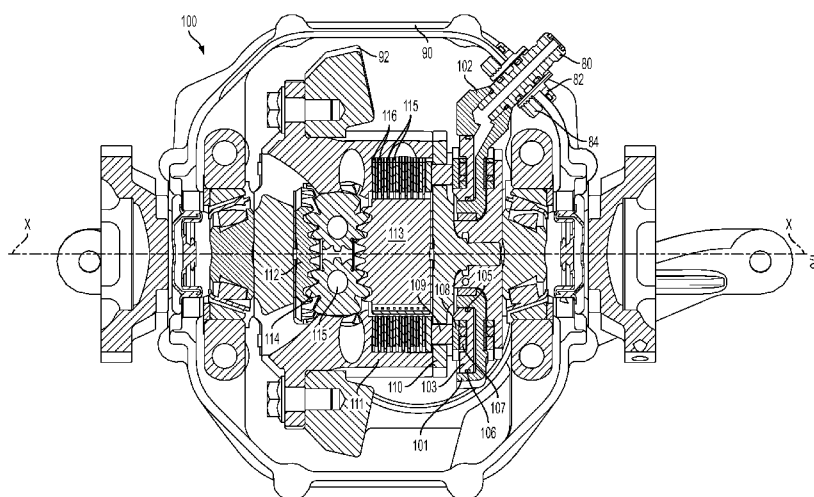


FIG. 1

(57) Abstract: A semi-annular piston may comprise a first face (303), a second face (301), a neck (307) extending from the first face (303), a radially extending inner surface (315) between the first face and the second face, and an outer surface (311) between the first face and the second face. The outer surface (311) extends radially along an arc AKB and the outer surface extends linearly along a chord AB. The first face (303) and the second face (301) are bounded by the outer surface (311).

ANTI-ROTATING HYDRAULIC PISTON

Field

[001] This application relates to hydraulically actuated differentials, more specifically, to a non-rotating actuation piston for a hydraulically actuated differential.

Background

[002] Hydraulically actuated differentials may have a piston in a plenum. The plenum may have a hydraulic port for supplying hydraulic fluid to move the piston. When pressurized by the hydraulic fluid, the piston may press against other objects in the differential to lock side gear rotation for the purpose of distributing even torque to axles of a motive device. The hydraulic port may also enable fluid to exit the plenum, thereby depressurizing the piston and returning the differential to an open mode. In the open mode the side gears and affiliated axles may receive differentiated torque.

SUMMARY

[003] It can be advantageous to restrict the rotation of the piston in a hydraulically actuated differential.

[004] The devices disclosed herein overcome the above disadvantages and improves the art by way of a semi-annular piston which may comprise a first face, a second face, a neck extending from the first face, a radially extending inner surface between the first face and the second face, and an outer surface between the first face and the second face. The outer surface may extend radially along an arc AKB and the outer surface may extend linearly along a chord AB. The first face and the second face may be bounded by the outer surface.

[005] A hydraulically actuated differential comprises a semi-annular piston comprising a first face and a second face, a plenum housing the piston, the plenum comprising a hydraulic port, a clutch pack, and transfer members. The first face and the second face comprise boundaries, the boundaries comprise at least a circular inner surface and an outer surface. The outer surface may comprise at least an arc AKB and a flat surface. The plenum comprises a surface that conforms to the shape of the piston.

[006] Additional objects and advantages will be set forth in part in the description which follows, and in part will be obvious from the description, or may be

learned by practice of the disclosure. The objects and advantages will also be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[007] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the claimed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[008] Figure 1 is a cross section view of a hydraulically actuated differential.

[009] Figure 2 is simplified view of an annulus.

[010] Figure 3A is a side view of a piston.

[011] Figure 3B is another side view of the piston.

[012] Figure 3C is a cross section view of the piston.

[013] Figure 4 is an exterior view of the plenum interfaced with portions of a drive train.

DETAILED DESCRIPTION

[014] Reference will now be made in detail to the examples illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. Directional references such as “left” and “right” are for ease of reference to the figures.

[015] Figure 1 is side view of a hydraulically actuated differential 100. An axle carrier or outer housing 90 comprises multiple connecting pieces to provide a fluid compartment for lubricant. A ring gear 92 interfaces with a pinion 402 of a drive shaft to rotate the left hand case 111 as the drive shaft receives torque. The left hand case 111 is coupled to the right hand case 110. The parts housed therein can rotate in synchrony with the cases, or the parts therein may provide differentiated torque to drive axles coupled to side gears 112, 113, as determined by the actuation status. Additional couplings provide a fluid seal between the drive axles, the left hand case 111, the right hand case 110, and the outer housing 90.

[016] Pinion shafts 115 are coupled to the left hand case 111 to rotate the differential pinion gears 114 as the ring gear 92 rotates. The pinion shafts 115 provide an additional axis of rotation for the differential pinion gears 114. In the open mode, the side gears 113 and 112 are free to rotate at different rates, and in the locked mode, the side gears 113 and 112 rotate at synchronous rates, via meshing engagement with the differential pinion gears 114.

[017] To transition between open and locked mode, a hydraulic system actuates a clutch pack affiliated with side gear 110. A piston housing, or plenum 101, houses a piston 103. The piston 103 is fluid-sealed against the plenum 101 by way of o-ring seals 105 and 106, which may be square edged to form wiper seals or may be another shape. Hydraulic fluid may enter the plenum 101 via a port 102, which has connections through the housing 90 to fluid supply lines and control electronics. It is advantageous to keep the plenum 101 stationary with respect to the rotating parts of the differential to keep the hydraulic connections stationary.

[018] It is additionally advantageous to keep the piston 103 non-rotating to prevent galling, tearing, or other premature wear on the o-rings, which may occur if the piston 103 rotates in the plenum 101. To prevent piston 103 from rotating, it is given a flat surface 318, which is accomplished, for example, by milling an annular piston.

[019] When the piston 103 is pressurized by hydraulic fluid, the piston 103 moves towards the clutch pack. A bearing 107, such as a roller or thrust bearing, is seated in the piston 103 as an interface between rotating and non-rotating parts. The bearing 107 abuts transfer plate 108, which spans between the bearing 107 and the transfer pin 109. Transfer pin 109 passes through the right hand case 110 to press clutch plates 116 against clutch plates 115. The clutch plates 115 are coupled to side gear 112, and the clutch plates 116 are coupled to left hand case 111. When the clutch pack is compressed, the side gear 112 rotation is locked to coincide with the rotation of the left hand case 111, which ultimately forces both side gears 113 and 112 to rotate at the same rate and to pass equal torque to affiliated axles. When the clutch pack is not compressed, the differential operates in the open mode. The differential and affiliated control logic can alternatively include features for enabling limited slip in the locked mode.

[020] Transfer plate 108 may perform one or more of the following functions: preventing piston overtravel as the clutch material wears out, receiving and distributing forces from the transfer pin as the clutch pack attempts to expand, or the transfer plate 108 may retain the bearing 107 against the piston 103. Transfer plate 108 is sized and shaped to abut the right hand case 110 to assist with its function of preventing piston over-travel.

[021] The piston 103 is a semi-annular object. Figure 2 offers a simplified explanation of a semi-annular object. Piston 103 has a center point C of two

concentric circles having radii R_1 and R_2 , respectively. The outer circle has points A, K, and B. While an annulus is generally understood to be an area between two concentric circles, the piston 103 is semi-annular because it has an inner circle that maintains its circular nature, but the outer circle has a "D" shape. That is, the outer circle is a major arc AKB of a circle, and a portion of the annulus is removed by a chord AB. The removed portion forms the dash-line minor arc AB. A sagitta S indicates the height of material missing from an ideal annulus to form the D shape. Thus, the piston 103 is not a perfect annular object and is referred to herein as semi-annular.

[022] The piston 103 comprises several features described in Figures 3A-3C. Figure 3A illustrates a pressing side or first face 303 of the piston 103. A groove 305 in the pressing side 303 is sized and shaped to receive an annular bearing, such as a roller bearing 107. A neck 307 abuts the radially innermost side of the groove 305 and neck 307 extends from the pressing side 303. Neck 307 can be sized to radially restrict motion of the bearing 107 and transfer plate 108. A distal portion 308 of the neck 307 can be angled, or chamfered, to provide clearance for a projecting portion of right hand case 110. Neck 307 can be concentric with the inner surface 315 of the piston.

[023] A hydraulic side or second face 301 faces an interior surface of the plenum 101. Second face 301 receives hydraulic fluid pressure to slide the piston towards the clutch pack, which is along the central axis X-X of rotation of the differential. The sliding axis of the piston 103 may also be in another plane, but parallel to the central axis X-X of rotation of the differential. Second face 301 is shown as planar in Figure 3 but it may also be concave. A chamfer 316 may span between the hydraulic side 301 and an inner surface 315.

[024] A rim 309 surrounds the radially outermost portion of the groove 305. The rim 309 is wide along the arc AKB and is narrow along the chord AB. Because the rim 309 is milled or otherwise shaped to include the flat surface 318 of the "D" shape, the bearing 107 need not be structurally modified to accommodate the semi-annular nature of the piston 103.

[025] Consistent with the geometry of Figure 2, the first and second faces of the piston 103 are bounded by a circular inner surface 315 and a concentric semi-circular outer surface 311. The outer surface 311 of the piston 103 has a gland 313 to receive an o-ring 106. The gland 313 may be rounded or squared. If squared, the

o-ring 106 may also be square in cross-section or sharp-edged, for example, the o-ring may be a traditional "wiper" style seal or a QUAD® style seal. Similarly, the inner surface 315 may have a rounded or squared gland 317 for receiving o-ring 105, which may be the same type or a different type than o-ring 106. That is, o-rings 105 and 106 may have the same or different cross sections, and those cross sections may be round, square, or multi-ridged, wiper-style, or QUAD® style seals.

[026] The outer gland 313 is generously radiused at points A and B of the chord. The generous radii may extend to like locations on the rim 309 and second face 301. The generous radiusing can result in transitions between the arc AKB and the chord AB. The transitions may be, for example, at least three times the cross sectional thickness of the O-ring or other seal that must traverse the transition. The resulting outer boundary would have the radius of the arc AKB, a first transition between a first end of the arc and a first end of the chord AB, a linearly extending flat surface 318 along the chord, and a second transition between the second end of the arc and a second end of the chord AB. The transitioning avoids undue strain on the o-ring or other seal.

[027] The plenum 101 receives the piston 103, and thus it is advantageous to include corresponding receiving shapes on the inner surface of the plenum 101 that will sealingly mate with the o-ring 106. In the illustrated example, the plenum 101 is also semi-annular. The inner surface of the plenum 101 is "D" shaped and may have cooperatively generous radii between a major arc of the inner surface and a corresponding chord.

[028] In the illustrated example, the outer surface of the plenum 101 is also "D" shaped. Since the plenum is ordinarily circular along its outer radius, the shape-tracking of the illustrated embodiment results in an area of space for accommodating other driveline parts. As shown in Figure 4, the drive shaft pinion gear 402 can extend into the space that would be otherwise occupied by a perfectly annular plenum and piston. Thus, extending the "D" shape of the piston 103 to the exterior surface shape of the plenum 101 saves space, allows for tighter packing, and enables more design flexibility.

[029] Also shown in Figure 4, the hydraulic fluid connection extends at an angle that is not parallel to the axis X-X of Figure 1. The hydraulic fluid connection is designed to inhibit the rotation of the plenum and hydraulic connections. The

hydraulic fluid connection is comprised primarily of a valve 80, a floating screw-down 82, and a hex nut 84 which cooperate to connect hydraulic fluid to the port 102.

[030] Screw-down 82 and hex nut 84 seal low pressure lubricating fluid, such as gear oil, inside the axle housing 90 and prevent the gear oil from being splashed out of the housing 90. The housing may have an over-sized hole spot-faced on the outside for the seal located on screw-down 82. The screw-down 82 can float inside the over-sized hole in housing 90 due to the axial movement that may occur when the differential is shimmed for ring and pinion pattern. Hex nut 84 threads to screw-down 82 to provide a clamp load on the seal and to hold the assembly together.

[031] The port 102 in this example is not perpendicular to the axis X-X. The angle chosen enables design flexibility. The cooperating valve 80 passes through the housing 90 in to fluid communication with the port 102. Valve 80 provides a low pressure seal on its outer diameter against the inner diameter of screw-down 82. Valve 80 also seals the high pressure hydraulic fluid into the differential with a seal such as an Eaton Corporation ORS® seal on the exterior face and an ORB® seal going into the port 102 of the plenum 101.

[032] Gaskets, such as O-rings, are placed in glands in the valve 80 and cooperating screw-downs 82 and hex nut 84 to provide additional fluid sealing. The valve 80 may then connect to tubing or other hydraulic fluid supply system component.

[033] Chamfering, including angling, rounding or otherwise modifying edges of the piston 103, may be done to account for variations in the fit between the piston 103 and the other differential parts, such as the plenum, bearing, and transfer plate. Thus, in addition to chamfering present at 308, chamfering may be used as necessary at one or more other locations on the piston, such as between the neck 307 and groove 305, between the inner surface 315 and the hydraulic surface 301, between the rim 309 and the groove 305, between the rim 309 and the outer surface 311, and as necessary along other edges of the piston 103.

[034] Other implementations will be apparent to those skilled in the art from consideration of the specification and practice of the examples disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

AMENDED CLAIMSWHAT IS CLAIMED IS:

1. A semi-annular piston (103) comprising:
 - a first face (303);
 - a second face (301);
 - a neck (307) extending from the first face (303);
 - a radially extending inner surface (315) between the first face (303) and the second face (301); and
 - an outer surface (311) between the first face (303) and the second face (301),wherein the outer surface (311) extends radially along an arc AKB and the outer surface extends linearly along a chord AB, and
- wherein the first face (303) and the second face (301) are bounded by the outer surface (311).
2. The semi-annular piston of claim 1, comprising a groove (305) in the first face (303).
3. The semi-annular piston of claim 1, wherein the inner surface (315) comprises a gland (317) and the outer surface (311) comprises a second gland (313).
4. The semi-annular piston of claim 1, wherein the neck (307) is concentric with the inner surface (315).
5. The semi-annular piston of claim 4, wherein at least a distal portion (308) of the neck (307) is chamfered.
6. The semi-annular piston of claim 2, wherein the first face (303) further comprises a rim (309) between the groove (305) and the outer surface (311).
7. The semi-annular piston of claim 1, wherein the arc AKB is concentric with the radially extending inner surface (315).
8. The semi-annular piston of claim 1, wherein the second face (301) is planar.
9. The semi-annular piston of claim 1, wherein the second face (301) is concave.
10. A semi-annular piston (103) bounded by a circular inner surface (315) and a concentric semi-circular outer surface (311), wherein the piston further comprises:

a first face (303) between an upper edge of the circular inner surface (315) and an upper edge of the concentric semi-circular outer surface (311); and

a second face (301) parallel to the first face (303), the second face between a lower edge of the circular inner surface (315) and a lower edge of the concentric semi-circular outer surface (311),

wherein the semi-circular outer surface (311) comprises at least an arc AKB and a flat surface (318).

11. The semi-annular piston of claim 10, wherein the semi-circular outer surface (311) comprises radiused transitions between the flat surface (318) and the arc AKB.

12. The semi-annular piston of claim 11, wherein the inner surface (315) comprises a gland (317), and wherein the outer surface (311) comprises a second gland (313).

13. The semi-annular piston of claim 10, further comprising a neck (307) extending from the first face (303), wherein the neck (307) is concentric with the inner surface (315).

14. The semi-annular piston of claim 13, wherein the first face (303) further comprises a groove (305) and a rim (309), and the groove (305) is between the neck (307) and the rim (309).

15. A hydraulically actuated differential comprising:

a semi-annular piston (103) comprising a first face (303) and a second face (301);

a plenum (101) housing the piston (103), the plenum (101) comprising a hydraulic port (102);

a clutch pack (115, 116); and

transfer members (107, 108, 109),

wherein the first face (303) and the second face (301) are bounded by at least a circular inner surface (315) and an outer surface (311),

wherein the outer surface (311) comprises at least an arc AKB and a flat surface (318), and

wherein the plenum (101) comprises a surface that conforms to the shape of the piston (103).

16. The differential of claim 15, further comprising:

an inner gland (317) in the inner surface (315);

an outer gland (313) in the outer surface (311),
an inner seal (105) in the inner gland (317); and
an outer seal (106) in the outer gland (313);

wherein the outer seal (106) sealingly cooperates with the surface of the plenum (101), and

wherein the inner seal (105) sealingly cooperates with the surface of the plenum (101).

17. The differential of claim 16, wherein the outer surface (311) comprises radiused transitions between the flat surface (318) and the arc AKB.

18. The differential of claim 15, wherein:

the transfer members comprise a bearing (107), a transfer plate (108), and a transfer pin (109),

the first face (303) comprises a neck (307) extending from the first face (303), a rim (309), and a groove (305) between the neck (307) and the rim (309),

the bearing (107) is seated in the groove (305),

the transfer plate (108) abuts the neck (307), and

the transfer pin (109) abuts the clutch pack (115, 116) and the transfer plate (108).

19. The differential of claim 15, wherein the second face (301) comprises a planar surface or a concave surface.

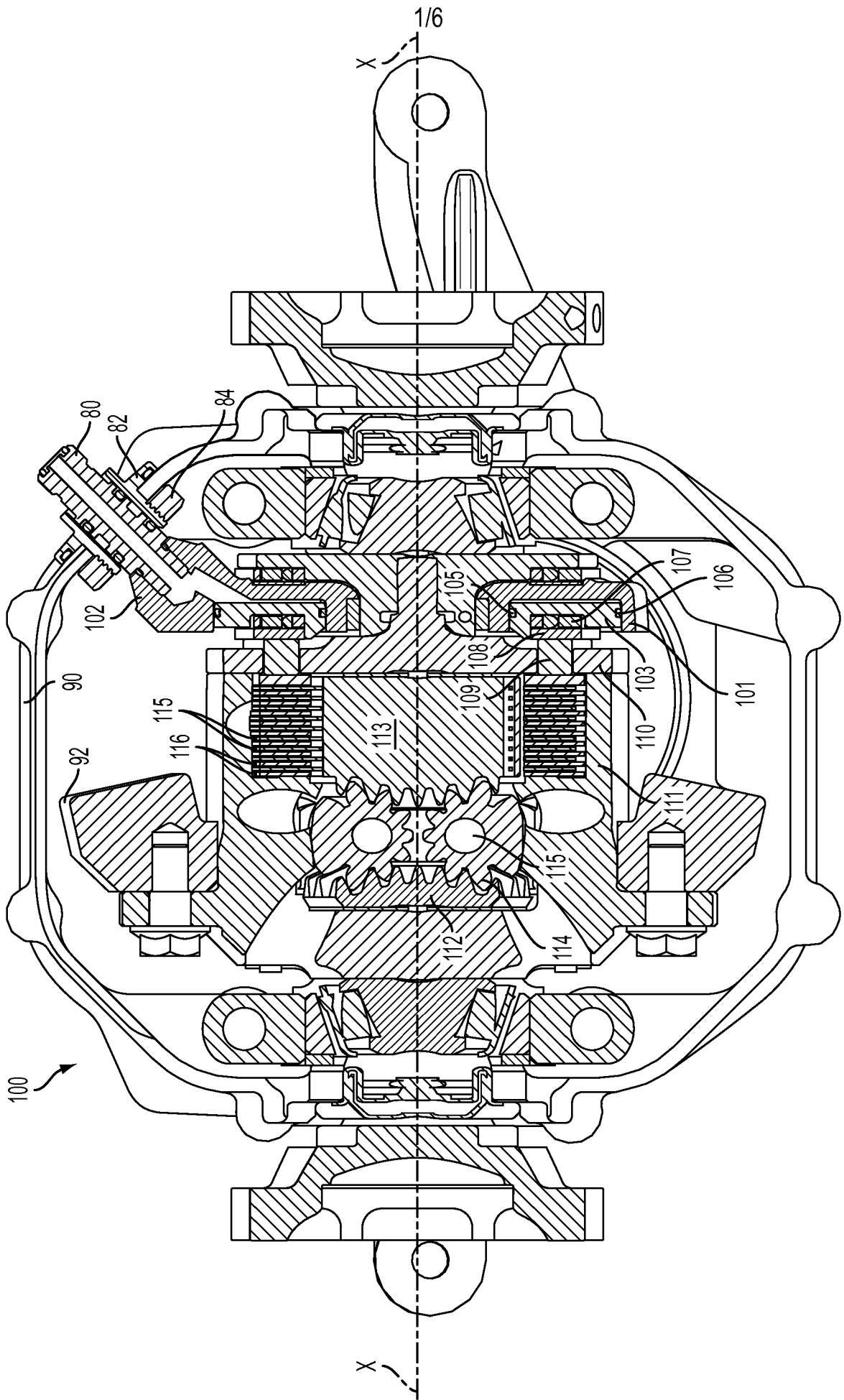


FIG. 1

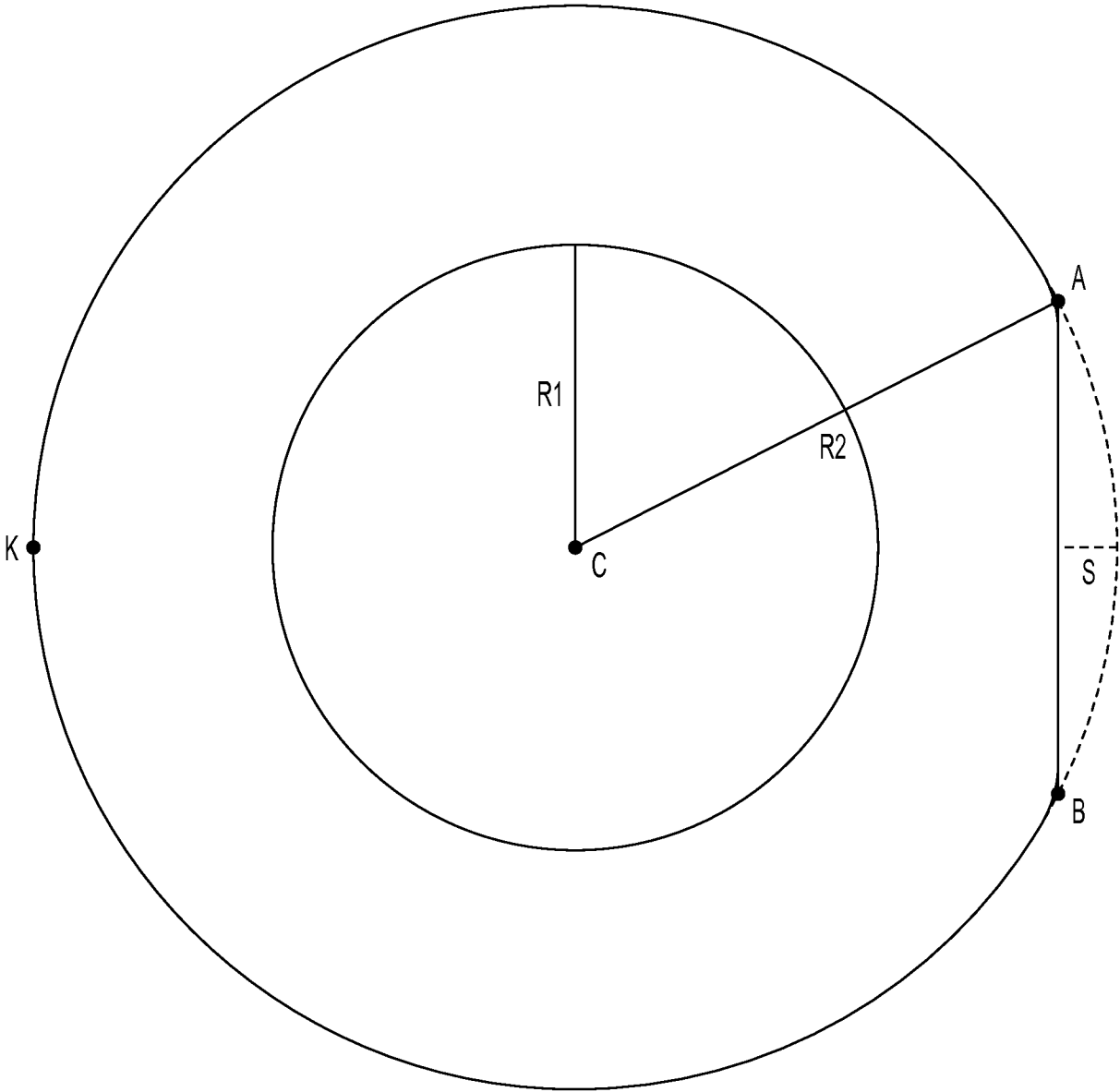


FIG. 2

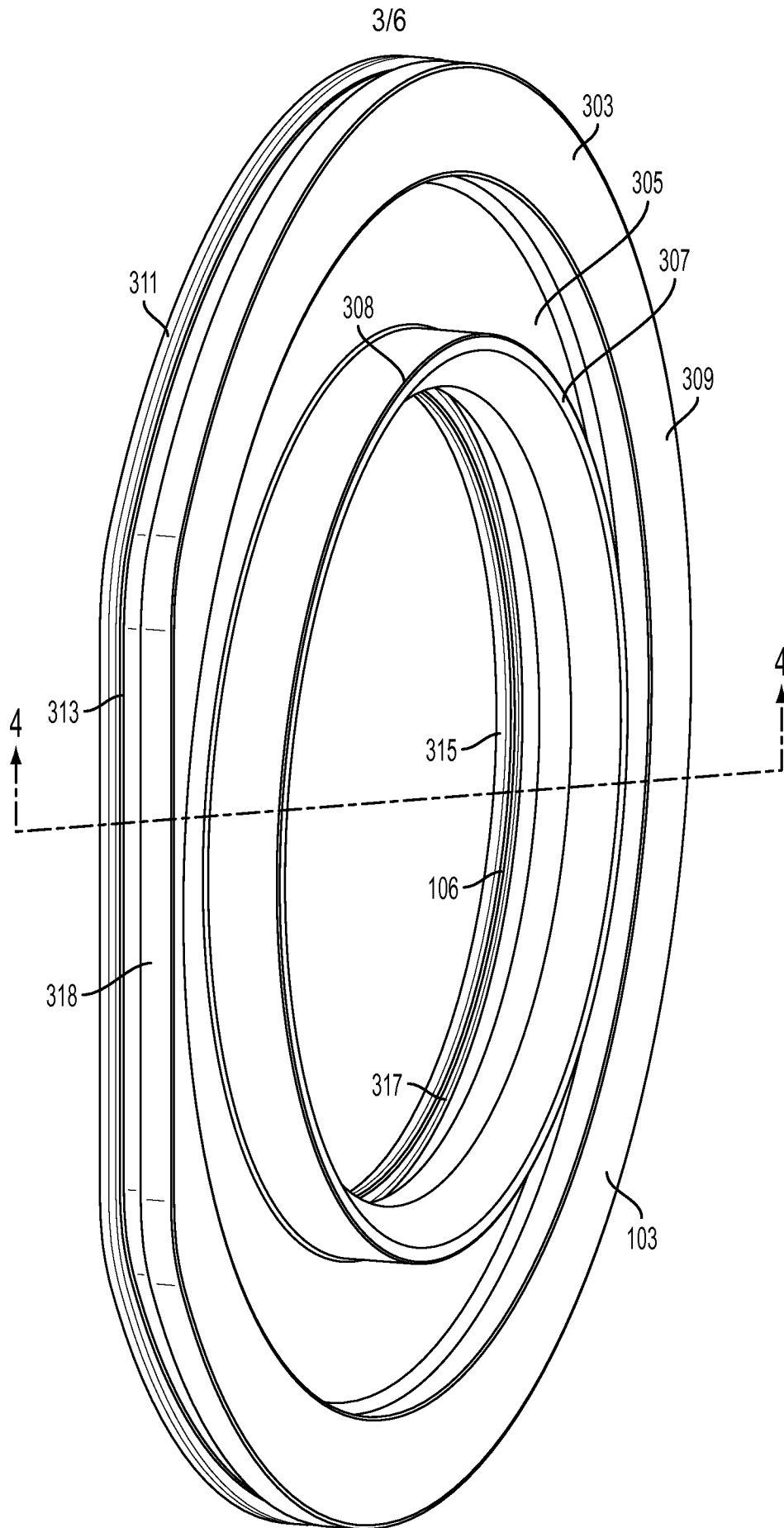


FIG. 3A

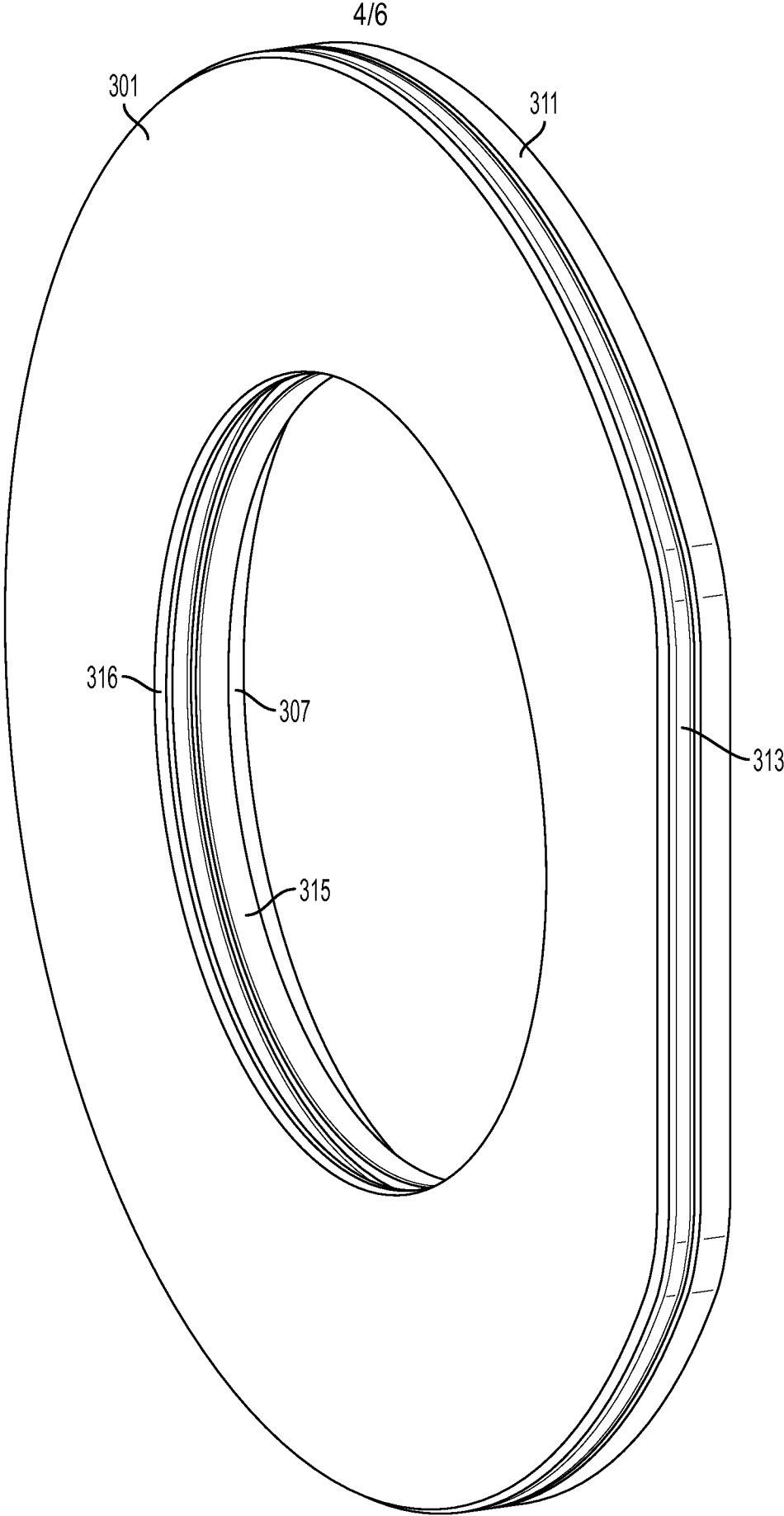


FIG. 3B

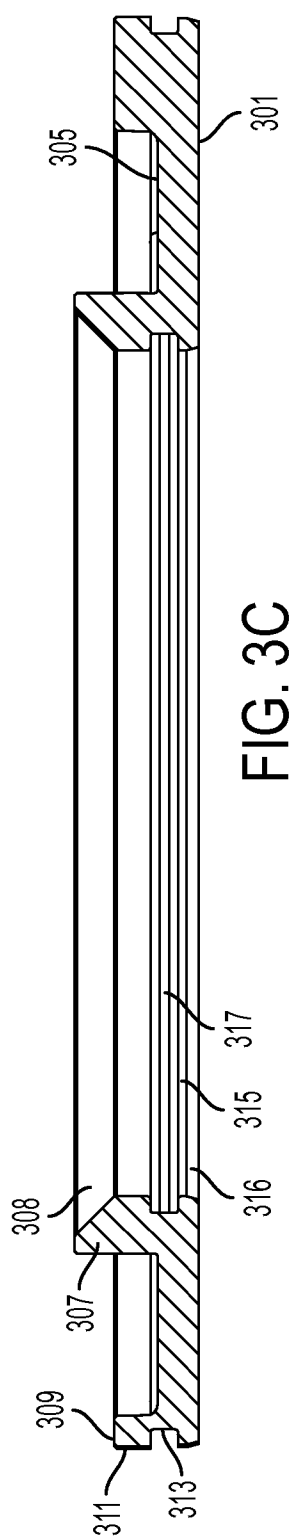


FIG. 3C

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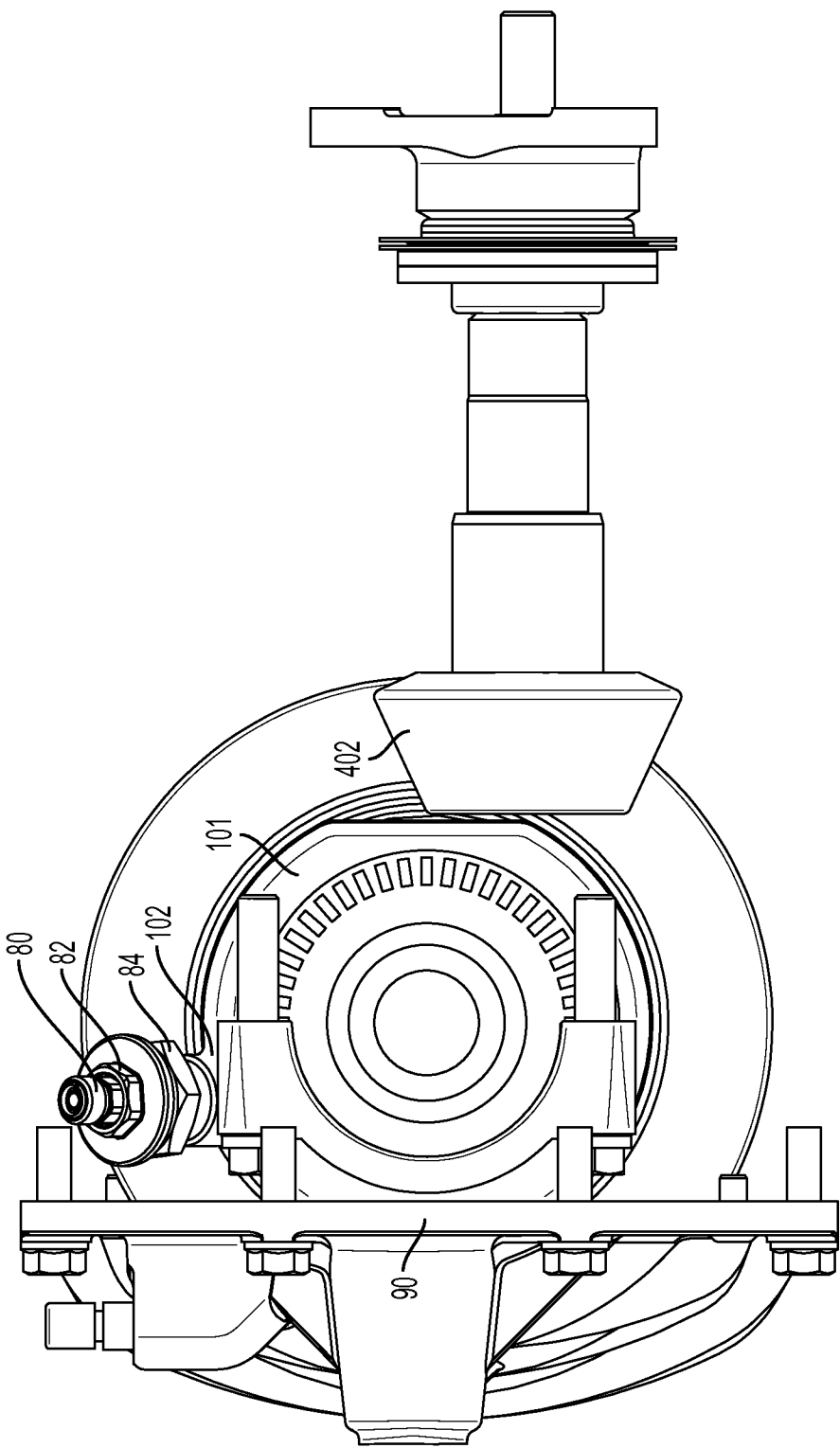


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/041895**A. CLASSIFICATION OF SUBJECT MATTER****F16J 1/00(2006.01)i, F04B 1/04(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16J 1/00; F16H 3/44; B21J 13/04; F16H 48/22; B21D 37/06; F16J 1/20; F04B 1/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: piston, surface, groove, hydraulic, arc, chord

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 101915311 A (XUANHUA CONSTRUCTION MACHINERY CO., LTD. et al.) 15 December 2010 See abstract, paragraphs [0011]-[0015], claim 1 and figures 9-11.	1-19
Y	US 3919877 A (NETTA, LOUIS A.) 18 November 1975 See abstract, column 3, line 24 - column 5, line 50, claims 1, 2 and figures 1-11.	1-19
Y	US 6095939 A (BURNS et al.) 01 August 2000 See abstract, column 3, line 7 - column 4, line 65 and figures 1-4.	15-19
A	US 2007-0032335 A1 (GOTO et al.) 08 February 2007 See abstract, paragraphs [0037]-[0043] and figures 3-5.	1-19
A	US 6276261 B1 (MANFREDA, JURIJ) 21 August 2001 See abstract, column 2, lines 1-60 and figures 1-3.	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

15 October 2014 (15.10.2014)

Date of mailing of the international search report

15 October 2014 (15.10.2014)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/041895

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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