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(54) **WEDGE CLUTCH WITH AXIALLY DISPLACEABLE WEDGE PLATE**

(71) Applicant: **Schaeffler Technologies AG & Co. KG**, Herzogenaurach (DE)

(72) Inventors: **Brian Lee**, York, SC (US); **Carsten Ohr**, Charlotte, NC (US)

(73) Assignee: **Schaeffler Technologies AG & Co. KG**, Herzogenaurach (DE)

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(51) **Int. Cl.**

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F16D 15/00	(2006.01)
F16D 25/08	(2006.01)
F16H 48/10	(2012.01)

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

CPC ***F16D 13/06*** (2013.01); ***F16D 13/14*** (2013.01); ***F16D 15/00*** (2013.01); ***F16H 48/10*** (2013.01); *F16D 25/082* (2013.01)

(58) **Field of Classification Search**

CPC F16D 13/06; F16D 13/14; F16D 13/18; F16D 13/20; F16D 13/24; F16D 13/15; F16D 13/16; F16D 13/36; F16D 15/00; F16D 25/082

USPC 192/65

See application file for complete search history.

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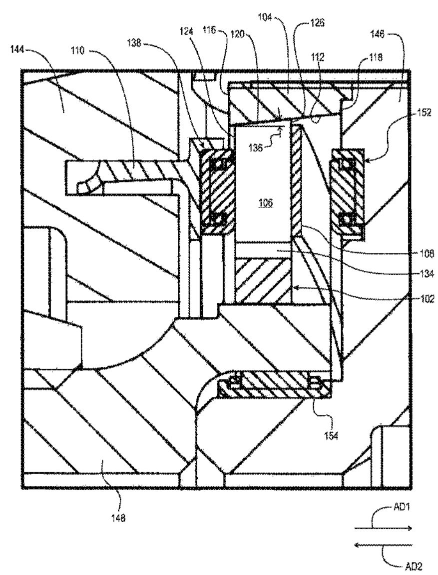
Primary Examiner — Richard Lorence
(74) *Attorney, Agent, or Firm* — Simpson & Simpson, PLLC

(57) **ABSTRACT**

A wedge clutch, including: an inner race; an outer race with a first inner circumferential surface sloping radially outward in a first axial direction; a wedge plate disposed between the inner and outer races in a radial direction and including a first outer circumferential surface sloping radially outward in the first axial direction; a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite the first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races.

18 Claims, 6 Drawing Sheets



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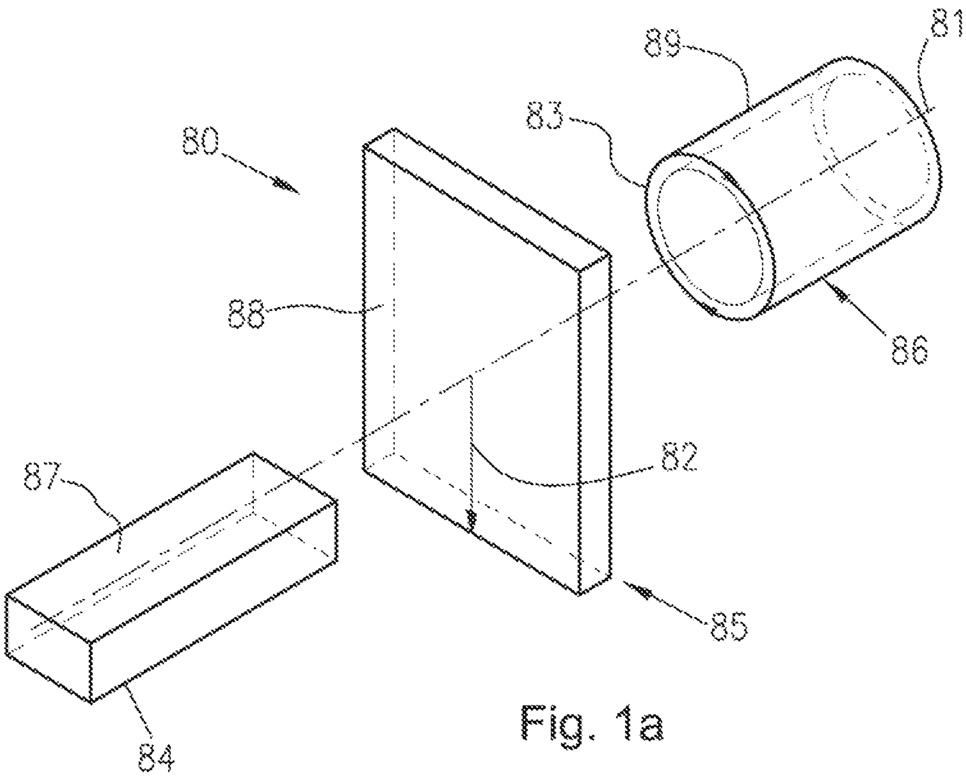

Fig. 1a

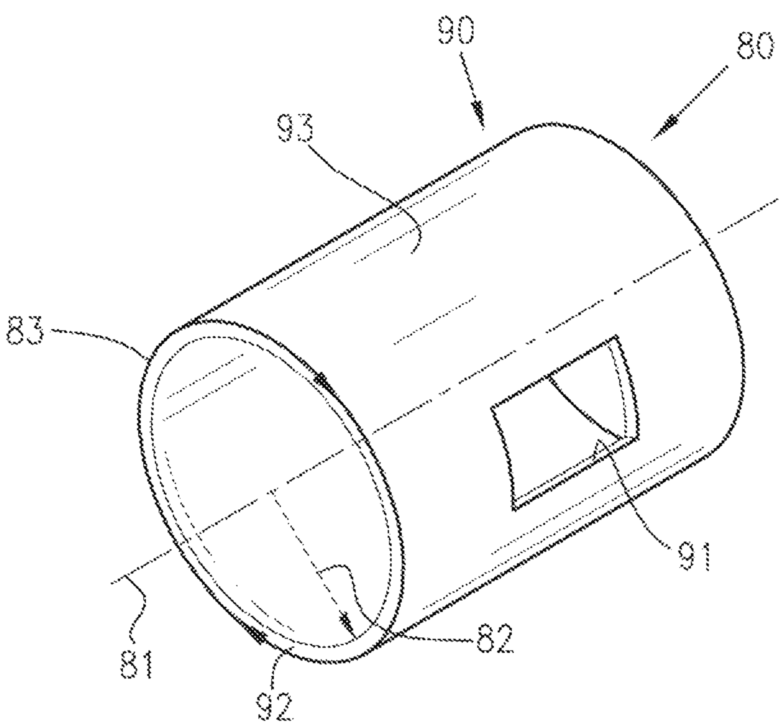

Fig. 1b

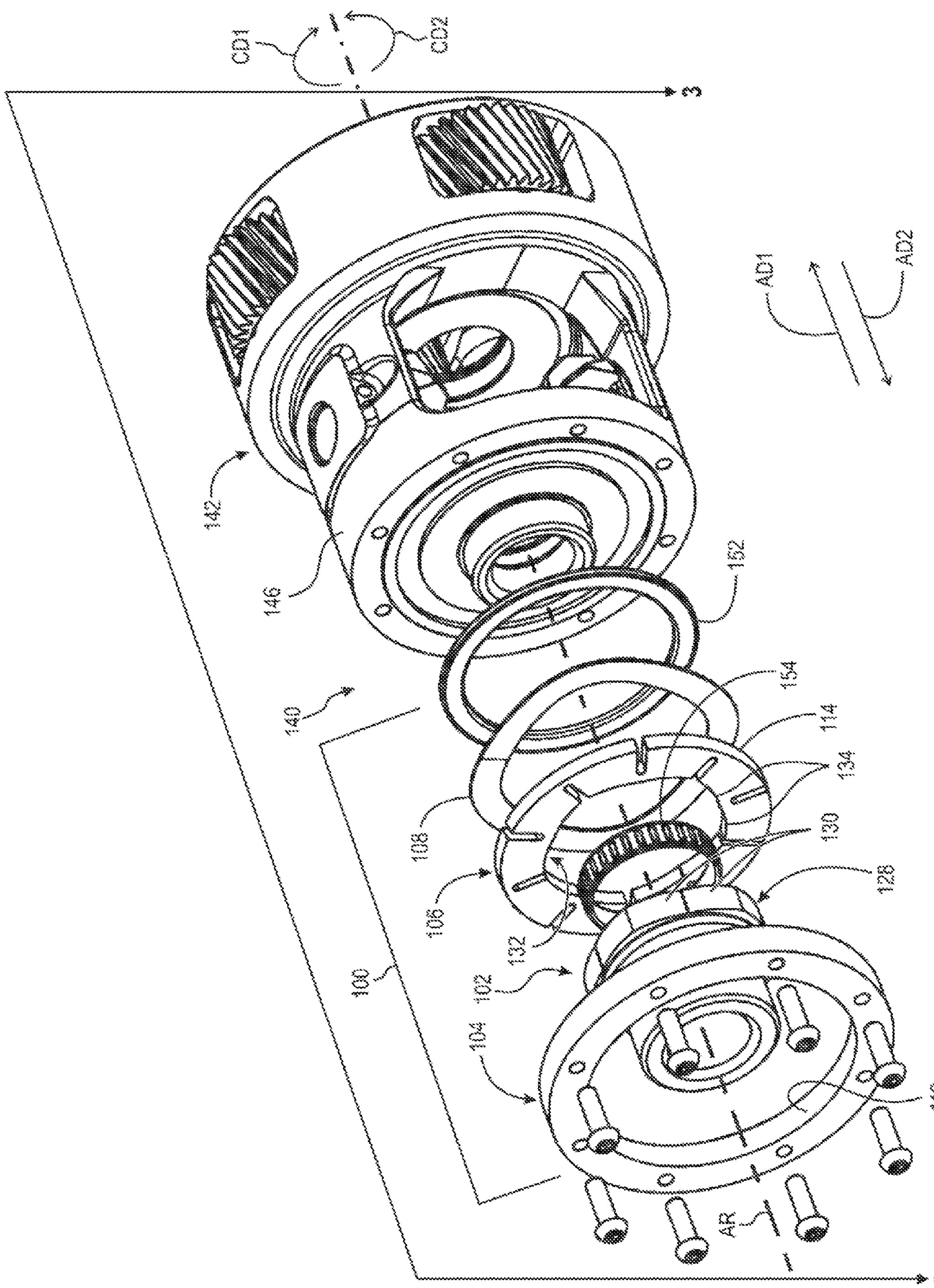
CD1
CD2
3
AD1
AD2
142
146
152
140
154
114
134
108
130
106
128
132
102
100
104
112
AR
3

Fig. 2

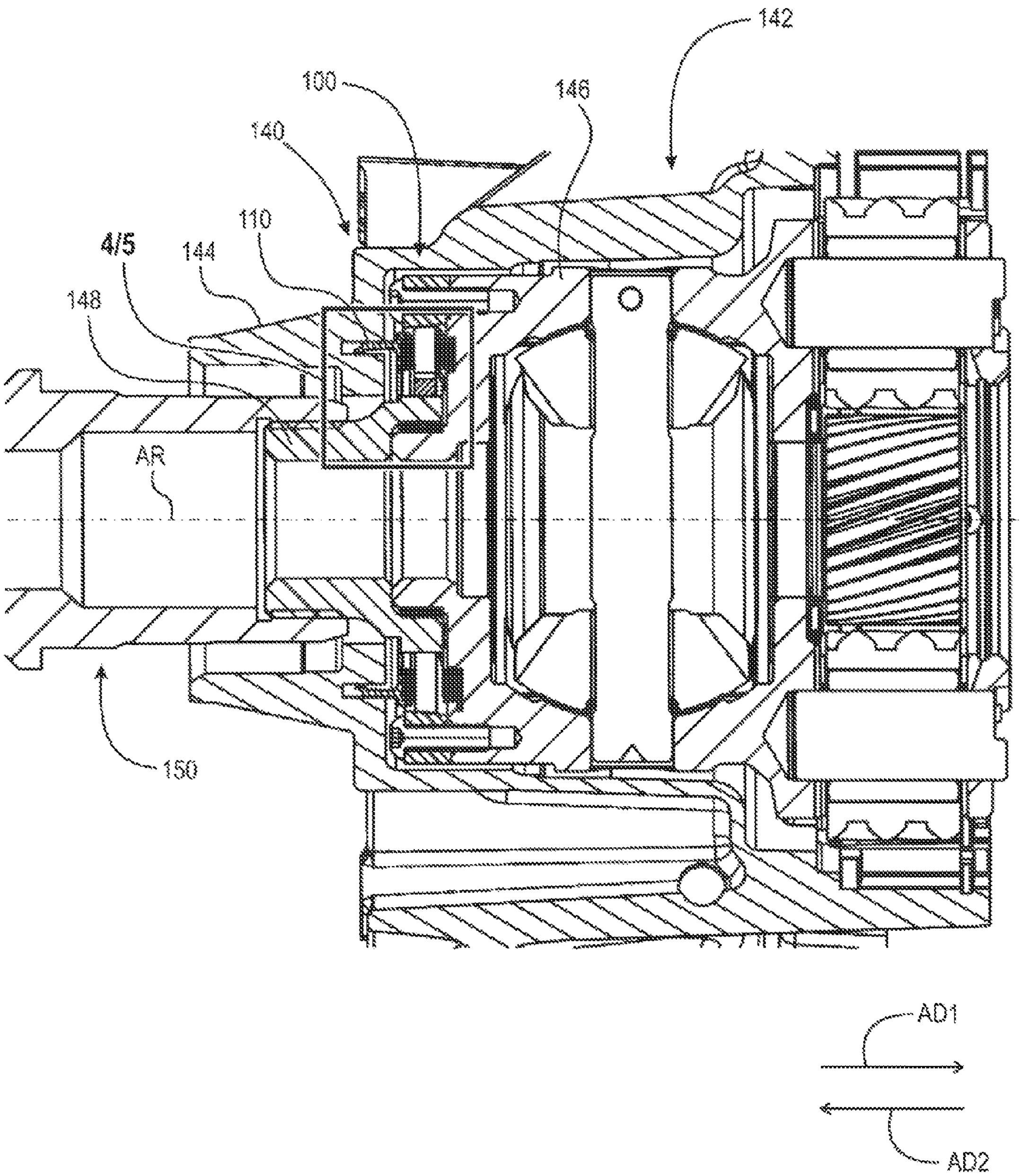

Fig. 3

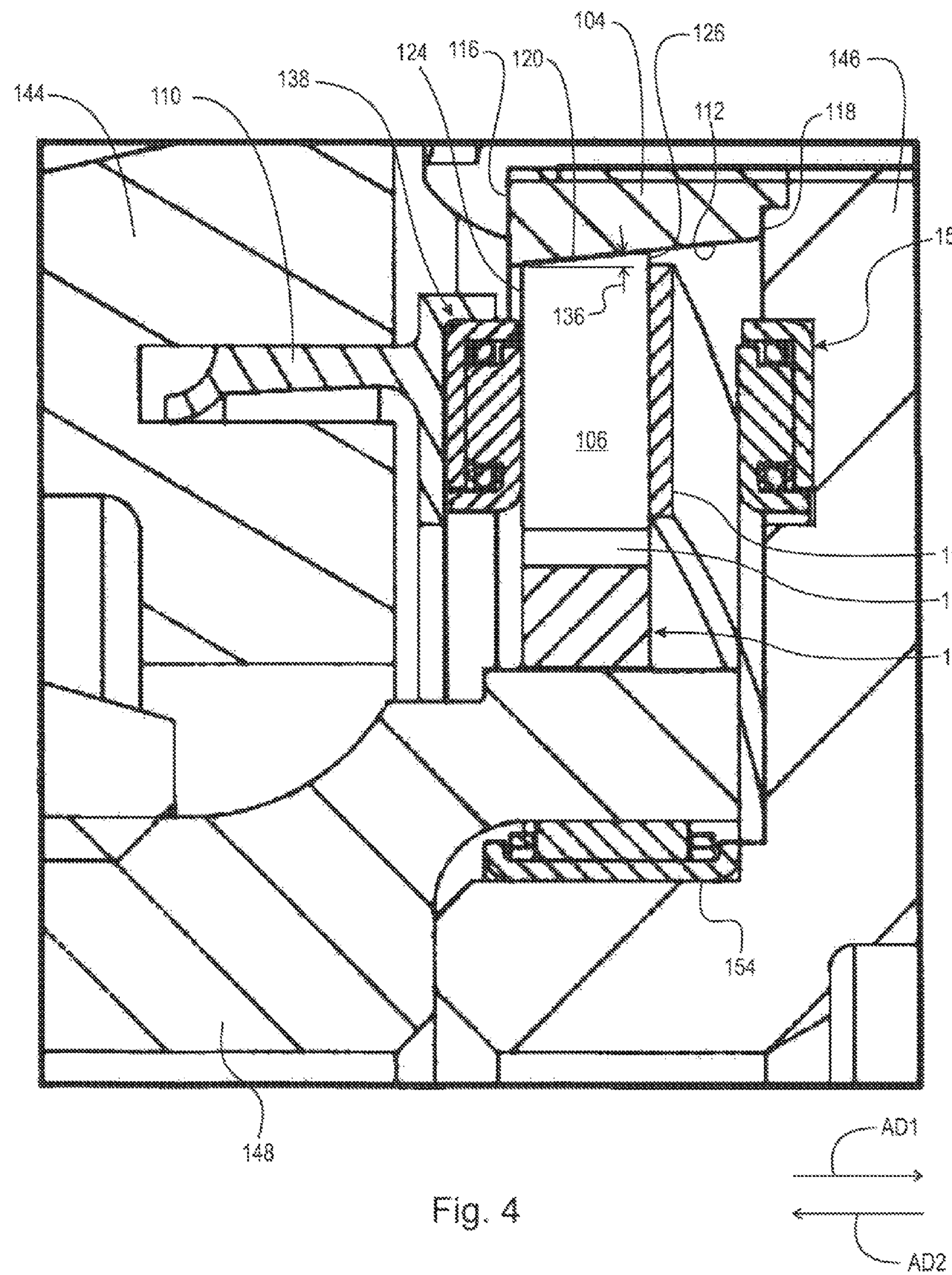
104
126
146
124
116
120
138
112
118
144
110
152
136
106
108
134
102
154
148
AD1
AD2

Fig. 4

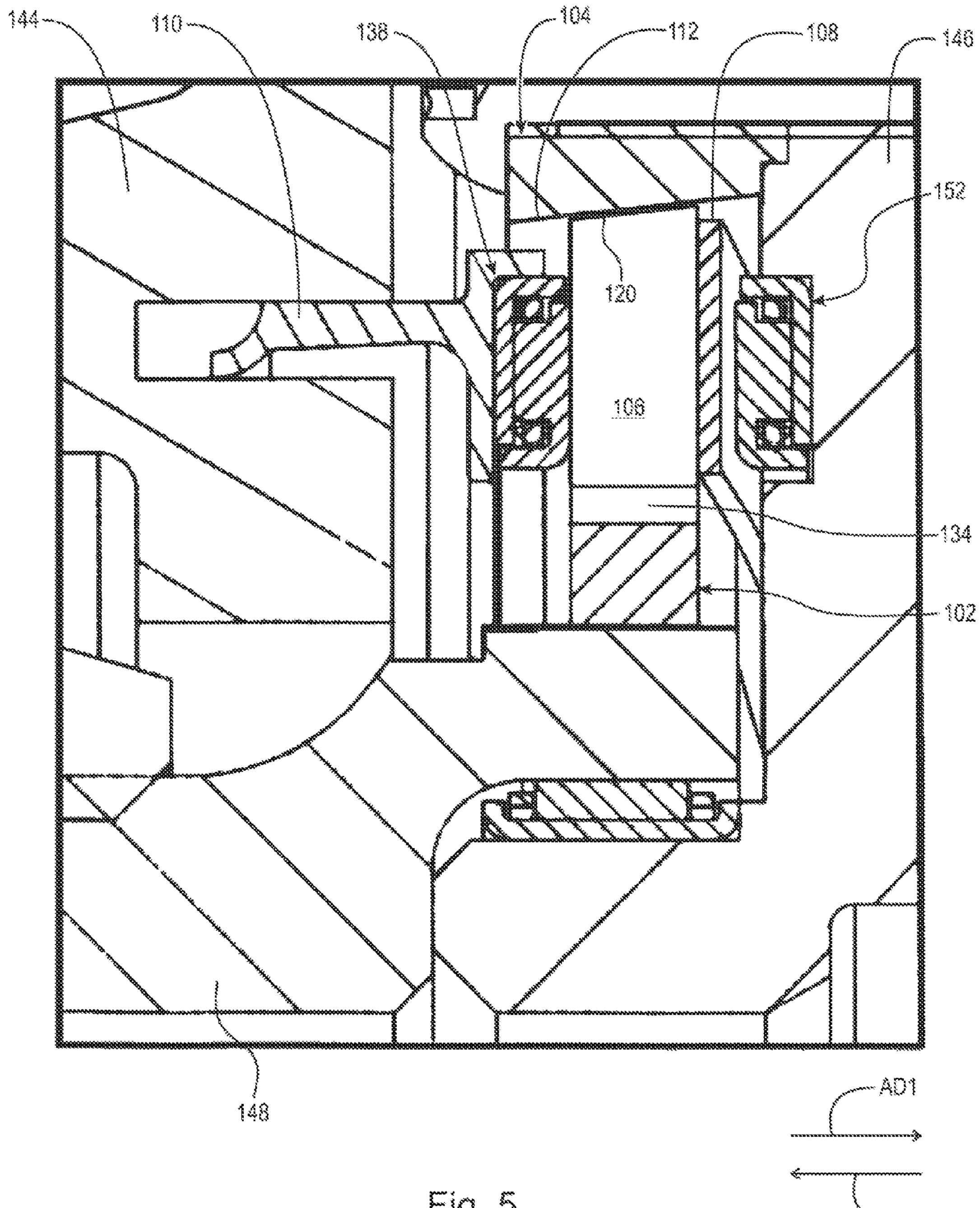

Fig. 5

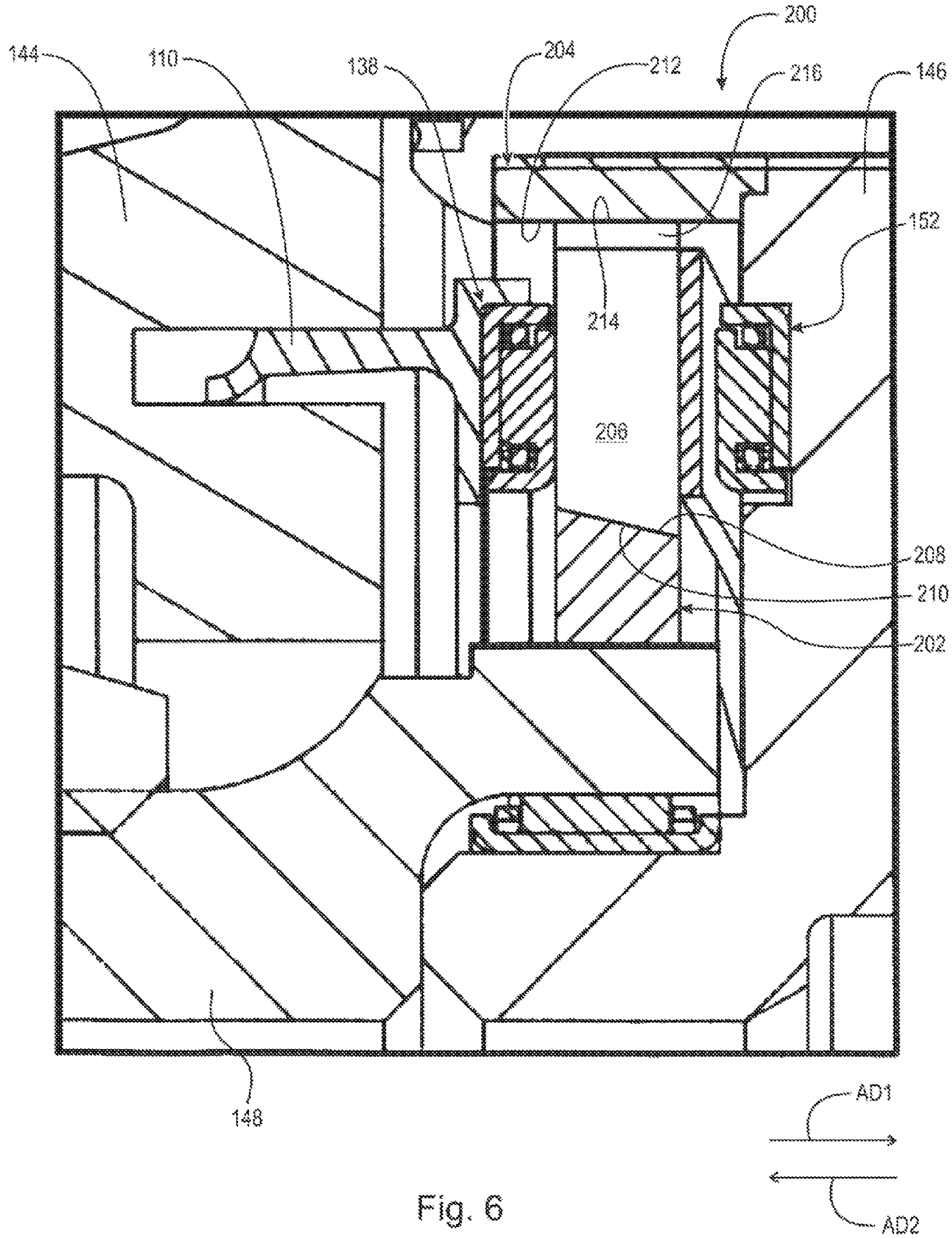
200
144
110
138
204
212
216
146
152
214
206
208
210
202
148
AD1
AD2

Fig. 6

WEDGE CLUTCH WITH AXIALLY DISPLACEABLE WEDGE PLATE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119 (e) of U.S. Provisional Patent Application No. 61/882,708, filed Sep. 26, 2013, which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to a wedge clutch using an axially displaceable wedge plate to lock inner and outer races. In particular, the clutch eliminates torque drag between the inner and outer races in a free-wheel mode while enabling rapid and consistent switching to a locking mode from the free-wheel mode.

BACKGROUND

It is known to use a dog clutch to connect a torque transmitting device, such as a differential carrier to a power shaft. However, a dog clutch requires a relatively long axial space for actuation and is prone to teeth clash or blocking.

SUMMARY

According to aspects illustrated herein, there is provided a wedge clutch, including: an inner race including a first outer circumferential surface; an outer race with a first inner circumferential surface; a wedge plate disposed between the inner and outer races in a radial direction and including second inner and outer circumferential surfaces; a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite the first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races. The first inner circumferential surface and the second outer circumferential surface each slope radially outward in the first axial direction; or the second inner circumferential surface and the first outer circumferential surface each slope radially outward in the second radial direction.

According to aspects illustrated herein, there is provided a wedge clutch, including: an inner race; an outer race with an inner circumferential surface sloped radially outward in the first axial direction; a wedge plate disposed between the inner and outer races in a radial direction and including an outer circumferential surface substantially parallel to the inner circumferential surface; a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite the first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races.

According to aspects illustrated herein, there is provided a wedge clutch assembly, including: an inner race with an outer circumferential surface sloped radially outward in a first axial direction; an outer race; a wedge plate disposed between the inner and outer races in a radial direction and including an inner circumferential surface substantially parallel to the outer circumferential surface; a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite the first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments are disclosed, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, in which:

FIG. **1**A is a perspective view of a cylindrical coordinate system demonstrating spatial terminology used in the present application;

FIG. **1**B is a perspective view of an object in the cylindrical coordinate system of FIG. **1**A demonstrating spatial terminology used in the present application;

FIG. **2** is an exploded perspective view of differential carrier including a wedge clutch with an axially displaceable wedge plate with a tapered outer circumference;

FIG. **3** is a cross-sectional view of the differential carrier and wedge clutch generally along line **3**-**3** in FIG. **2**;

FIG. **4** is a detail of area 4/5 in FIG. **3** showing the wedge clutch in a closed mode;

FIG. **5** is a detail of area 4/5 in FIG. **3** showing the wedge clutch in an open mode; and,

FIG. **6** is a detail similar to FIG. **5** showing a wedge clutch with an axially displaceable wedge plate with a tapered inner circumference in an open mode.

DETAILED DESCRIPTION

At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements of the disclosure. It is to be understood that the disclosure as claimed is not limited to the disclosed aspects.

Furthermore, it is understood that this disclosure is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present disclosure.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. It should be understood that any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the disclosure.

FIG. **1**A is a perspective view of cylindrical coordinate system **80** demonstrating spatial terminology used in the present application. The present invention is at least partially described within the context of a cylindrical coordinate system. System **80** has a longitudinal axis **81**, used as the reference for the directional and spatial terms that follow. The adjectives "axial," "radial," and "circumferential" are with respect to an orientation parallel to axis **81**, radius **82** (which is orthogonal to axis **81**), and circumferential surface **83**, respectively. The adjectives "axial," "radial" and "circumferential" also are regarding orientation parallel to respective planes. To clarify the disposition of the various planes, objects **84**, **85**, and **86** are used. Surface **87** of object

84 forms an axial plane. That is, axis **81** forms a line along the surface. Surface **88** of object **85** forms a radial plane. That is, radius **82** forms a line along the surface. Surface **89** of object **86** forms a circumferential plane. That is, circumferential surface **83** forms a line along the surface. As a further example, axial movement or disposition is parallel to axis **81**, radial movement or disposition is parallel to radius **82**, and circumferential movement or disposition is parallel to circumferential surface **83**. Rotation is with respect to axis **81**.

The adverbs "axially," "radially," and "circumferentially" are with respect to an orientation parallel to axis **81**, radius **82**, or circumferential surface **83**, respectively. The adverbs "axially," "radially," and "circumferentially" also are regarding orientation parallel to respective planes.

FIG. **1B** is a perspective view of object **90** in cylindrical coordinate system **80** of FIG. **1A** demonstrating spatial terminology used in the present application. Cylindrical object **90** is representative of a cylindrical object in a cylindrical coordinate system and is not intended to limit the present invention in any manner. Object **90** includes axial surface **91**, radial surface **92**, and circumferential surface **93**. Surface **91** is part of an axial plane, surface **92** is part of a radial plane, and surface **93** is a circumferential surface.

FIG. **2** is an exploded perspective view of differential carrier including wedge clutch **100** with an axially displaceable wedge plate.

FIG. **3** is a cross-sectional view of the differential carrier and wedge clutch **100** generally along line **3-3** in FIG. **2**.

FIG. **4** is a detail of area **4/5** in FIG. **3** showing wedge clutch **100** in a closed mode. The following should be viewed in light of FIGS. **2** through **4**. Wedge clutch **100** includes inner race **102**, outer race **104**, wedge plate **106**, displacement element **108**, and displacement element **110**. In an example embodiment, element **108** is any resilient element known in the art and element **110** is any piston known in the art. It should be understood that the preceding configuration can be reversed such that a piston displaces wedge plate **106** in direction AD**2** and a resilient element displaces the wedge plate in direction AD**1**. Outer race **104** includes inner circumferential surface **112** sloping radially outward in axial direction AD**1**. That is, a radial distance of surface **112** from axis of rotation AR increases between radially disposed side **116** and radially disposed side **118**. The wedge plate includes outer circumferential surface **120** sloping radially outward in axial direction AD**1**. That is, a radial distance of surface **120** from axis AR increases between radially disposed side **124** and radially disposed side **126**. Resilient element **108** is engaged with the wedge plate, for example in contact with the wedge plate surface **114**, and urges the wedge plate in axial direction AD**2**, opposite axial direction AD**1**. The piston is arranged to displace the wedge plate in axial direction AD**1**. In an example embodiment, clutch **100** includes a single wedge plate **106**.

For a closed mode for the clutch in which inner race **102** is non-rotatably connected to outer race **104**: resilient element **108** displaces wedge plate **106** in axial direction AD**2**; outer circumferential surface **120** contacts inner circumferential surface **112**; and, wedge plate **106** non-rotatably connects inner race **102** and outer race **104**.

FIG. **5** is a detail of area **4/5** in FIG. **3** showing wedge clutch **100** in an open mode. The following should be viewed in light of FIGS. **2** through **5**. To switch to an open mode for the clutch: piston **110** displaces the wedge plate in axial direction AD**1**; outer circumferential surface **120** breaks contact with inner circumferential surface **112**; and inner race **102** and outer race **104** are rotatable with respect to each other. To switch from the open mode to the closed mode: piston **110** displaces in axial direction AD**2**; resilient element **108** displaces the wedge plate in axial direction AD**2**; and outer circumferential surface **120** non-rotatably connects to inner circumferential surface **112**. Any means known in the art can be used to displace piston **110** including hydraulic, pneumatic, or electrical actuation.

In an example embodiment, inner race **102** includes outer circumferential surface **128** with circumferentially sloping ramps **130**, and wedge plate **106** includes inner circumferential surface **132** with circumferential sloping ramps **134** engaged with ramps **130**. In the open mode, ramps **130** and **134** are engaged and the wedge plate is non-rotatably connected to the inner race. As noted above, to switch from the open mode to the closed mode, resilient element **108** displaces the wedge plate in axial direction AD**2**. As surface **112** contacts **120**, friction force between the surfaces, in combination with the relative rotation of race **102** and wedge plate **106** with respect to outer race **104**, causes wedge plate **106** to rotate with outer race **104** and relative to inner race **102**. The relative rotation of wedge plate **106** with respect to race **102** causes ramps **130** to rotate with respect to ramps **134**, in particular to slide up ramps **134** expanding wedge plate **106** radially outward. The outward expansion causes wedge plate **106** to non-rotatably connect to the inner and outer races.

The relative rotation between inner race **102** and wedge plate **106** and outer race **104** can be in circumferential direction CD**1** or CD**2** due to the configuration of ramps **130** and **134**. That is, in either of directions CD**1** or CD**2**, rotation of the wedge plate with respect to the inner race causes respective pairs of ramps **130** and **134** to slide across each other and expand the wedge plate radially outward. It should be understood that the relative rotation between inner race **102** and wedge plate **106** and outer race **104** can include inner race **102** and wedge plate **106** and outer race **104** rotating in the same circumferential direction but at different speeds, or in opposite circumferential directions. The relative rotation between inner race **102** and wedge plate **106** and outer race **104** also can include one of inner race **102** or wedge plate **106** and outer race **104** not rotating.

In an example embodiment, clutch **100** is self-locking. That is, once surfaces **112** and **120** are non-rotatably engaged to close the clutch, angle **136** of the slope of surface **112** and **120** and the coefficient of friction between surface **112** and **120** is such that axial force is not required to prevent wedge plate **106** for displacing in direction AD**1** to disconnect surfaces **112** and **120** and opening clutch **100**.

In an example embodiment, piston **110** is non-rotatable, that is, rotationally fixed, and clutch **100** includes thrust bearing **138** axially disposed between the piston and the wedge plate to enable relative rotation between the piston and the wedge plate.

In an example embodiment, clutch **100** is part of a clutch assembly **140**, which in turn is part of a larger apparatus, for example, differential carrier **142**. For example, assembly **140** includes non-rotatable component **144**, in this example, a housing for carrier **142**, and rotatable component **146**, in this example, a portion of a power shaft for carrier **142**. Wedge clutch **100** is axially disposed between components **144** and **146**. Outer race **104** is non-rotatably connected to component **146** and inner race **102** is non-rotatably connected to portion **148** of input shaft **150** for carrier **142**. Piston **110** is at least partially located in component **144**. Bearing **138** is engaged with the piston and wedge plate **106** and enables rotation of wedge plate **106** with respect to rotationally fixed piston **110**. Thrust bearing **152** is engaged with component **146** and the wedge plate and enables relative rotation between wedge plate **106** and component **146**. Operation of clutch **100** is as described above. Bearing **154** enable rotation between components **146** and **148**.

Thus, in the example of the differential carrier, in the open mode for clutch **100**, input shaft **150** is rotatable with respect to component **146** and power is not transmitted to component **146**. In the closed mode for clutch **100**, shaft **150** is non-rotatably connected to component **146** and torque is transmitted from shaft **150** to carrier **142**.

FIG. **6** is a detail similar to FIG. **5** showing wedge clutch **200** with an axially displaceable wedge plate with a tapered inner circumference in an open mode. The discussion for FIGS. **2** through **5** is applicable to wedge clutch **200** except as noted. Clutch **200** includes inner race **202**, outer race **204**, and wedge plate **206**; the remainder of the components of clutch **200** are substantially the same as those for clutch **100**.

Inner race **202** includes outer circumferential surface **208** sloping radially inward in axial direction AD**1**. The wedge plate includes inner circumferential surface **210** sloping radially inward in axial direction AD**1**.

For a closed mode for the clutch in which inner race **202** is non-rotatably connected to outer race **204**: resilient element **108** displaces wedge plate **206** in axial direction AD**2**; inner circumferential surface **210** contacts outer circumferential surface **208**; and, wedge plate **206** non-rotatably connects inner race **202** and outer race **204**.

To switch to an open mode for the clutch: piston **110** displaces the wedge plate in axial direction AD**1**; inner circumferential surface **210** breaks contact with outer circumferential surface **208**; and inner race **202** and outer race **204** are rotatable with respect to each other. To switch from the open mode to the closed mode: piston **110** displaces in axial direction AD**2**; resilient element **108** displaces the wedge plate in axial direction AD**2**; and inner circumferential surface **210** non-rotatably connects to outer circumferential surface **208**.

In an example embodiment, outer race **204** includes inner circumferential surface **212** with circumferentially sloping ramps, and wedge plate **206** includes outer circumferential surface **214** with circumferential sloping ramps **216** engaged with the ramps for surface **212**. In the open mode, ramps **216** and the ramps for surface **212** are engaged and the wedge plate is non-rotatably connected to the outer race. As noted above, to switch from the open mode to the closed mode, resilient element **108** displaces the wedge plate in axial direction AD**2**. As surface **208** contacts surface **210**, friction force between the surfaces, in combination with the relative rotation of race **204** and wedge plate **206** with respect to race **202**, causes wedge plate **206** to rotate with race **202** and relative to race **204**. The relative rotation of wedge plate **206** with respect to race **204** causes ramps **216** to rotate with respect to the ramps for surface **212**, in particular to slide up the ramps for surface **212**, compressing wedge plate **206** radially inward. The inward expansion causes wedge plate **206** to non-rotatably connect to the inner and outer races.

The following discussion is directed to clutch **100**; however, it should be understood that the discussion is applicable to clutch **200** as well. Advantageously, in the open mode for clutch **100**, piston **110** displaces wedge plate **106** in direction AD**1** so that surfaces **112** and **120** are free of contact or have only nominal contact. Thus, in the open mode, there is little or no drag loss caused by contact between surfaces **112** and **120**. Further, clutch **100** enables rapid and consistent connection of races **102** and **104**. Resilient element **108** needs only to apply a relatively small amount of axial force to displace wedge plate **106** a relatively small axial distance to contact race **104**. Once contact is made, the self-locking aspect of wedge plate **106** and race **104** ensures a rapid and stable non-rotatable connection of the inner and outer races.

As well, due to the self-locking aspect of clutch **100**, there is no need to apply axial force in direction AD**2** to hold the wedge plate in the closed position. Thus, there is no need for an active element to provide such force, reducing complexity and energy requirements, and in the alternative, there is no need for element **108** to provide such force beyond what is needed to displace the wedge plate to initiate contact with the outer race. As a further result, piston **110** does not need to overcome a holding force from an active element or element **108** to displace the wedge to initiate the open mode, reducing the energy requirement for the piston.

Surfaces **112** and **120** are shown sloping radially outward in direction AD**1**; however, it should be understood that the slopes of the surfaces could be reversed such that surfaces **112** and **120** slope radially outward in direction AD**2**.

It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What we claim is:

1. A wedge clutch, comprising:
- an inner race including a first outer circumferential surface, the first outer circumferential surface including a first plurality of circumferentially sloping ramps;
- an outer race with a first inner circumferential surface;
- a wedge plate:
  - disposed between the inner and outer races in a radial direction;
  - at least partially rotatable with respect to the inner and outer races; and,
  - including second inner and outer circumferential surfaces, the second inner circumferential surface including a second plurality of circumferential sloping ramps engaged with the first plurality of circumferentially sloping ramps;
- a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite a first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and,
- a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races, wherein the first inner circumferential surface and the second outer circumferential surface each slope radially outward in the first axial direction.

2. The clutch as recited in claim **1**, wherein the wedge plate comprises only one single wedge plate.

3. The clutch as recited in claim **1**, wherein the first displacement element is a resilient element and the second displacement element is a piston.

4. The clutch as recited in claim **3**, wherein the first inner circumferential surface is arranged to contact the second outer circumferential surface in response to the resilient element displacing the wedge plate in the second axial direction and the wedge plate is arranged to non-rotatably connect to the inner and outer races in the closed mode.

5. The clutch as recited in claim **3**, wherein the first inner circumferential surface is arranged to break contact with the second outer circumferential surface in response to the piston displacing the wedge plate in the first axial direction.

6. The clutch as recited in claim **3**, further comprising:

a bearing axially disposed between the piston and the wedge plate to enable relative rotation between the piston and the wedge plate.

7. The clutch as recited in claim **1**, wherein to switch from the open mode to the closed mode, the second displacement element is arranged to displace in the second axial direction.

8. The clutch as recited in claim **1**, wherein in the closed mode for the clutch, axial force on the wedge plate in the second direction is not needed to maintain the non-rotatable connection of the inner and outer races.

9. The clutch as recited in claim **1**, wherein:

the first inner circumferential surface includes first and second ends furthest in the first and second axial directions, respectively and the second end is closer, in a radial direction, than the first end to an axis of rotation for the clutch; and,

the second outer circumferential surface includes first and second ends furthest in the first and second axial directions, respectively and the second end is closer, in a radial direction, than the first end to an axis of rotation for the clutch.

10. The clutch as recited in claim **1**, wherein:

to switch from the open mode to the closed mode:

the second displacement element is arranged to displace in the second axial direction;

the first displacement element is arranged to displace the wedge plate in the second axial direction;

the second outer circumferential surface is arranged to contact the first inner circumferential surface;

the wedge plate is arranged to rotate with respect to the inner race; and,

the second plurality of circumferential sloping ramps is arranged to slide across the first plurality of circumferential sloping ramps to expand the wedge plate radially outward.

11. A wedge clutch, comprising:

an inner race including a first outer circumferential surface;

an outer race with a first inner circumferential surface, the first inner circumferential surface including a first plurality of circumferentially sloping ramps;

a wedge plate:

disposed between the inner and outer races in a radial direction;

at least partially rotatable with respect to the inner and outer races; and,

including second inner and outer circumferential surfaces, the second outer circumferential surface including a second plurality of circumferential sloping ramps engaged with the first plurality of circumferentially sloping ramps;

a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite a first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and,

a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races, wherein the second inner circumferential surface and the first outer circumferential surface each slope radially outward in the second axial direction.

12. The clutch as recited in claim **11**, wherein the first displacement element is a resilient element and the second displacement element is a piston, wherein the second inner circumferential surface is arranged to contact the first outer circumferential surface in response to the resilient element displacing the wedge plate in the second axial direction and the wedge plate is arranged to non-rotatably connect to the inner and outer races in the closed mode.

13. The clutch as recited in claim **12**, wherein the second inner circumferential surface is arranged to break contact with the first outer circumferential surface in response to the piston displacing the wedge plate in the first axial direction.

14. The clutch as recited in claim **11**, wherein:

the first outer circumferential surface includes first and second ends furthest in the first and second axial directions, respectively and the first end is closer, in a radial direction, than the second end to an axis of rotation for the clutch; and,

the second inner circumferential surface includes first and second ends furthest in the first and second axial directions, respectively and the first end is closer, in a radial direction, than the second end to an axis of rotation for the clutch.

15. The clutch as recited in claim **11**, wherein:

to switch from the open mode to the closed mode:

the second displacement element is arranged to displace in the second axial direction;

the first displacement element is arranged to displace the wedge plate in the second axial direction;

the second inner circumferential surface is arranged to contact the first outer circumferential surface;

the wedge plate is arranged to rotate with respect to the outer race; and,

the second plurality of circumferential sloping ramps is arranged to slide across the first plurality of circumferential sloping ramps to compress the wedge plate radially inward.

16. A wedge clutch, comprising:

an inner race including a first outer circumferential surface, the first outer circumferential surface including a first plurality of circumferentially sloping ramps;

an outer race with a first inner circumferential surface sloped radially outward in a first axial direction;

a wedge plate:

disposed between the inner and outer races in a radial direction;

at least partially rotatable with respect to the inner and outer races; and,

including second inner and outer circumferential surfaces, the second inner circumferential surface including a second plurality of circumferential sloping ramps engaged with the first plurality of circumferentially sloping ramps, the second outer circumferential surface substantially parallel to the first inner circumferential surface;

a first displacement element engaged with the wedge plate and arranged to urge the wedge plate in a second axial direction, opposite the first axial direction, to close the clutch to non-rotatably connect the inner and outer races; and,

a second displacement element arranged to displace the wedge plate in the first axial direction to open the clutch to enable relative rotation between the inner and outer races.

17. The clutch as recited in claim **16**, wherein the first displacement element is a resilient element and the second displacement element is a piston.

18. The clutch as recited in claim **16**, wherein:

to close the clutch:

the first displacement element is arranged to displace the wedge plate in the second axial direction;
the second outer circumferential surface is arranged to contact the first inner circumferential surface; and,
the wedge plate is arranged to non-rotatably connect to the inner and outer races;
to open the clutch:
the second displacement element is arranged to displace the wedge plate in the first axial direction; and,
the second outer circumferential surface is arranged to break contact with the first inner circumferential surface; and,
to close the clutch from an open mode for the clutch:
the second displacement element is arranged to displace in the second axial direction;
the first displacement element is arranged to displace the wedge plate in the second axial direction; and,
the second outer circumferential surface is arranged to non-rotatably connect to the first inner circumferential surface.

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