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(54) **DISCONNECT FOR A SWITCHABLE WEDGE CLUTCH**

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F16D 13/26 (2006.01)
F16D 13/16 (2006.01)
F16D 23/12 (2006.01)

(52) **U.S. Cl.**
CPC **F16D 13/26** (2013.01); **F16D 13/16** (2013.01); **F16D 2023/123** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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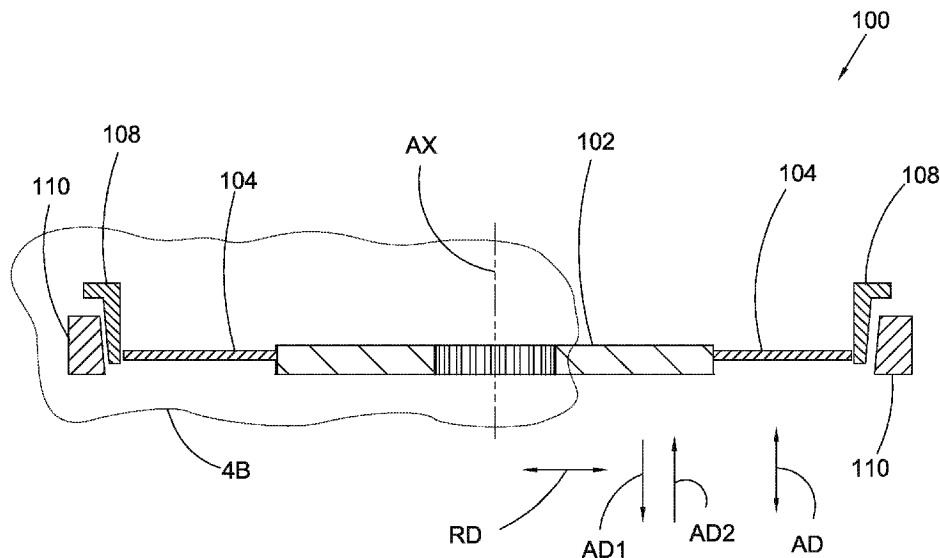
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(57) **ABSTRACT**

A wedge clutch, including: an inner hub; an outer race; and a conical outer race; including a first portion aligned with the outer race in a radial direction orthogonal to an axis of rotation for the wedge clutch and in an axial direction, and a second portion aligned with the outer race in an axial direction parallel to the axis. The conical outer race is axially displaceable with respect to the outer race to bring the first and second portions into contact with the outer race to non-rotatably connect the inner hub and the outer race and to separate the first and second portions from the outer race to enable relative rotation of the inner hub and the outer race. The wedge clutch includes a wedge plate radially located between the inner hub and the conical outer race and engaged with the inner hub and the conical outer race.

20 Claims, 8 Drawing Sheets



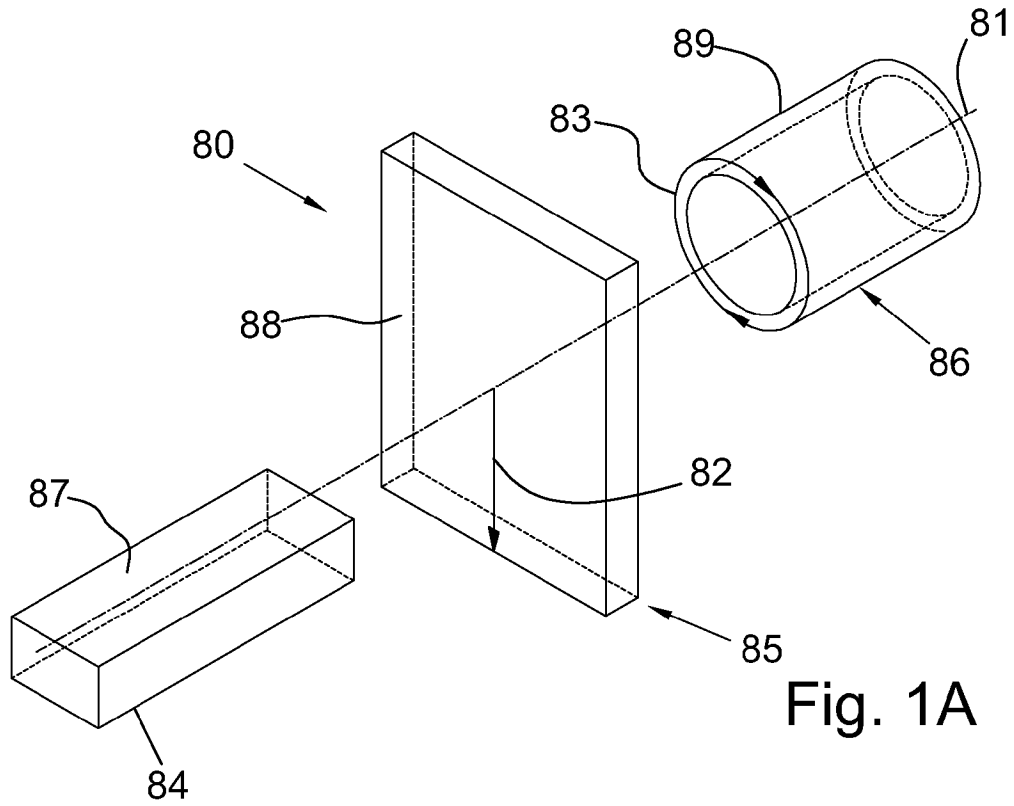


Fig. 1A

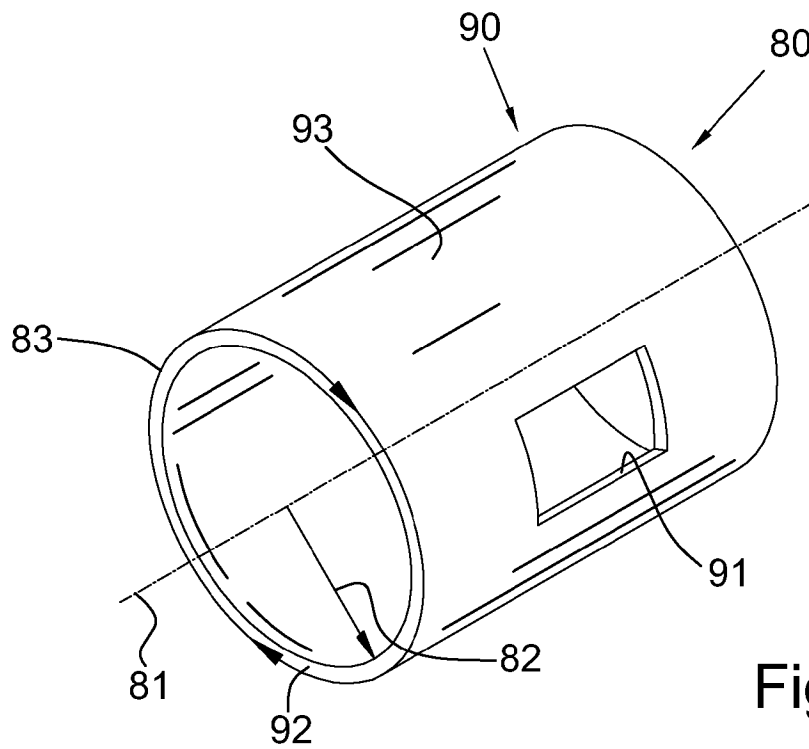


Fig. 1B

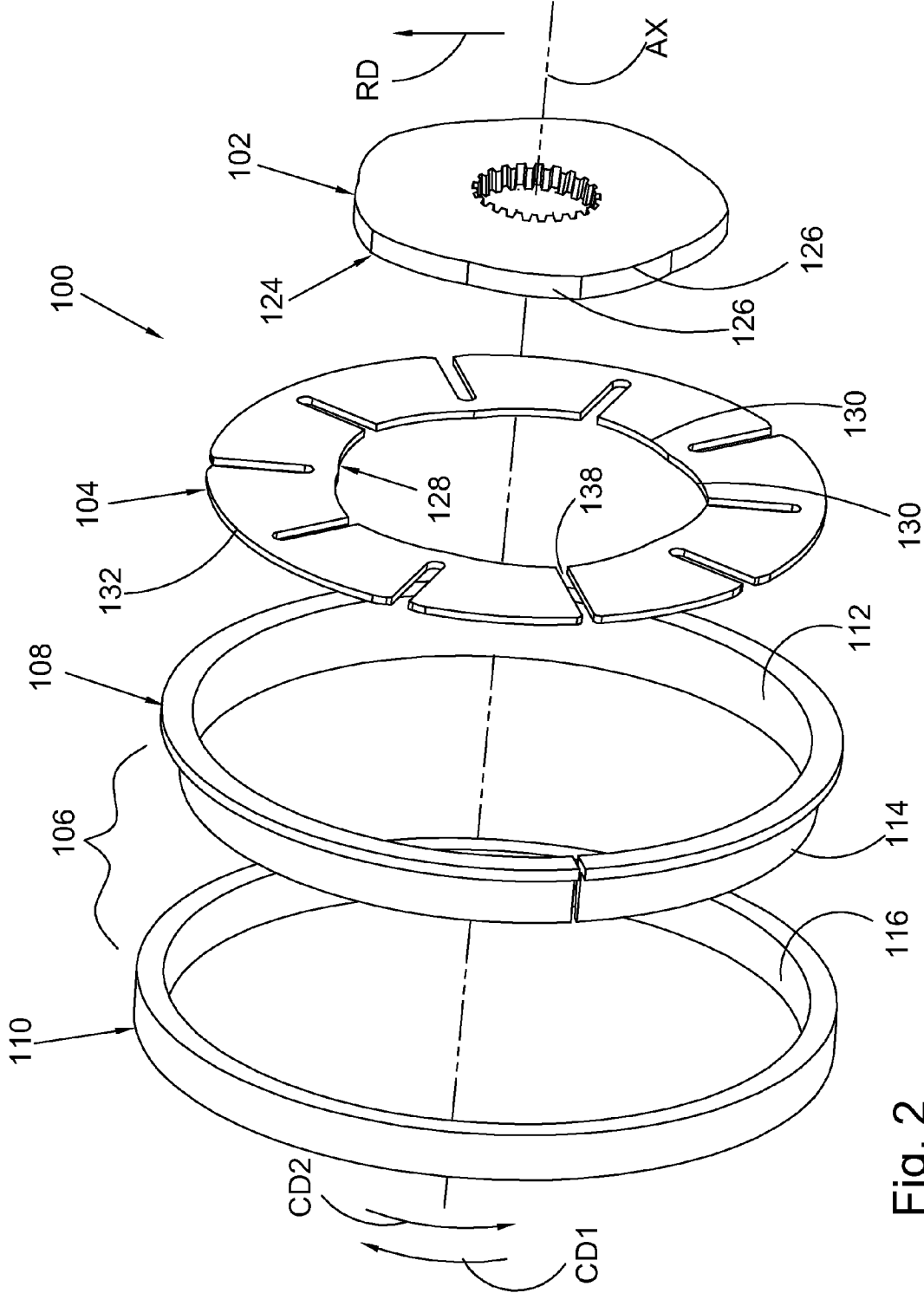


Fig. 2

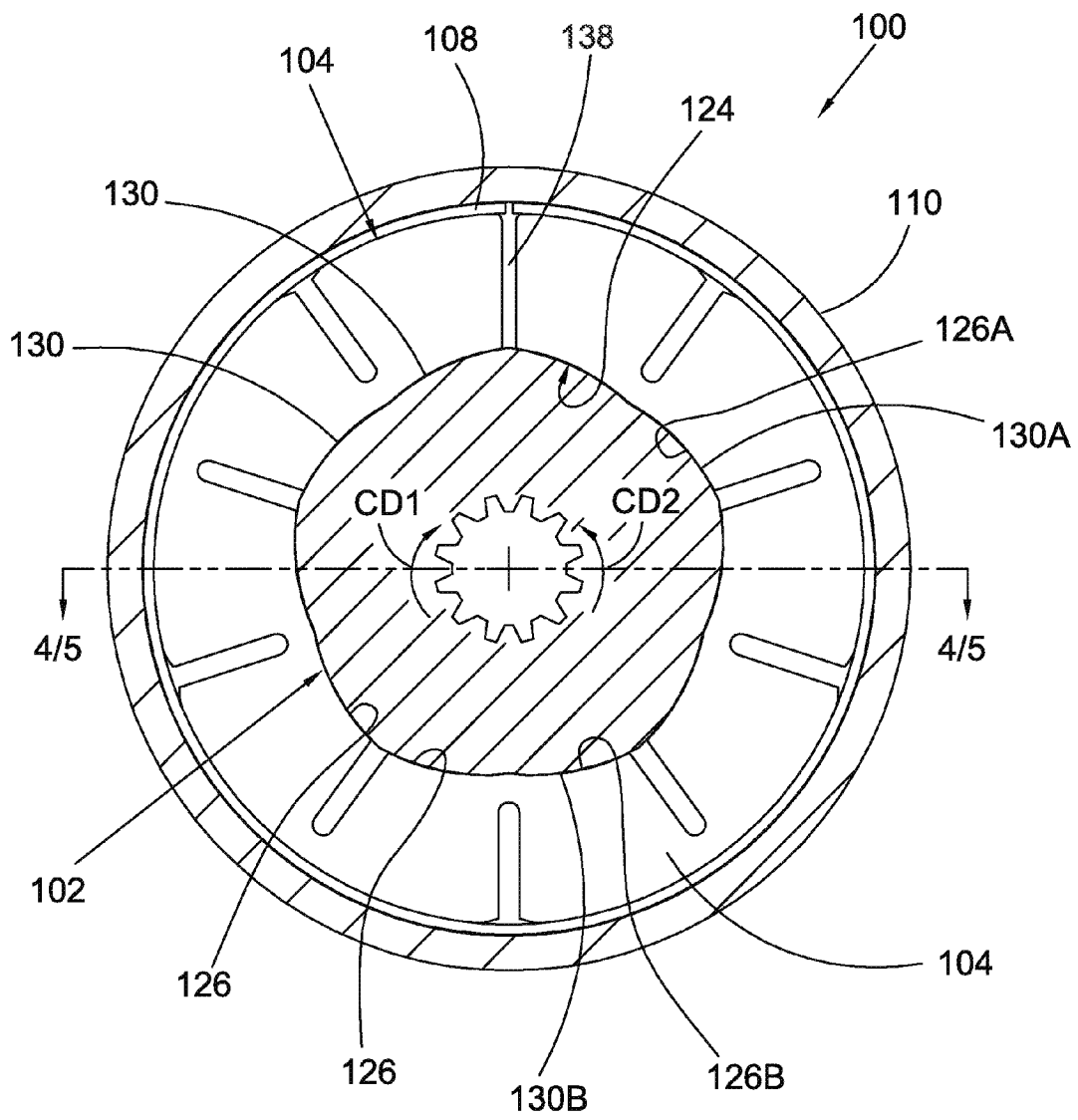


Fig. 3

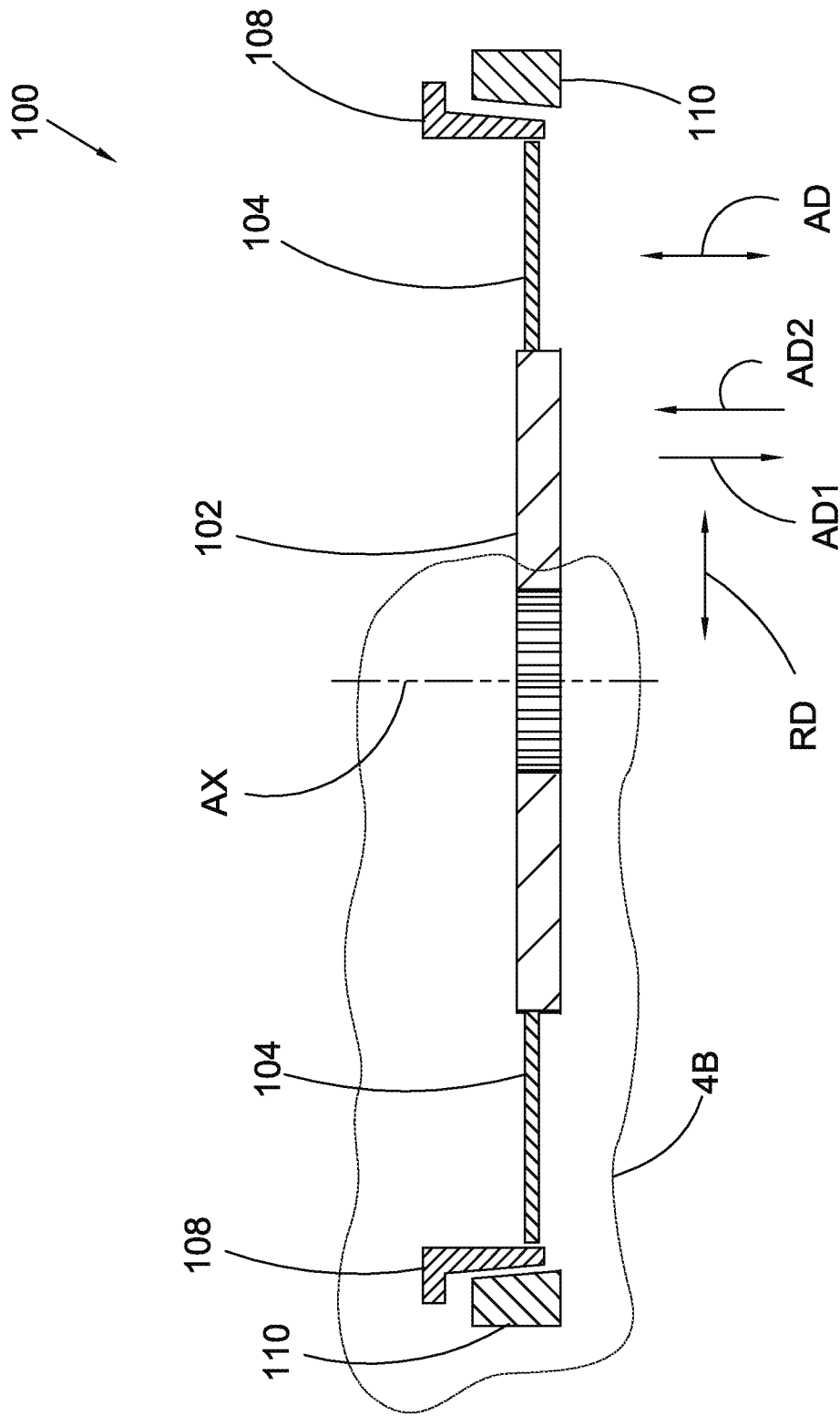


Fig. 4A

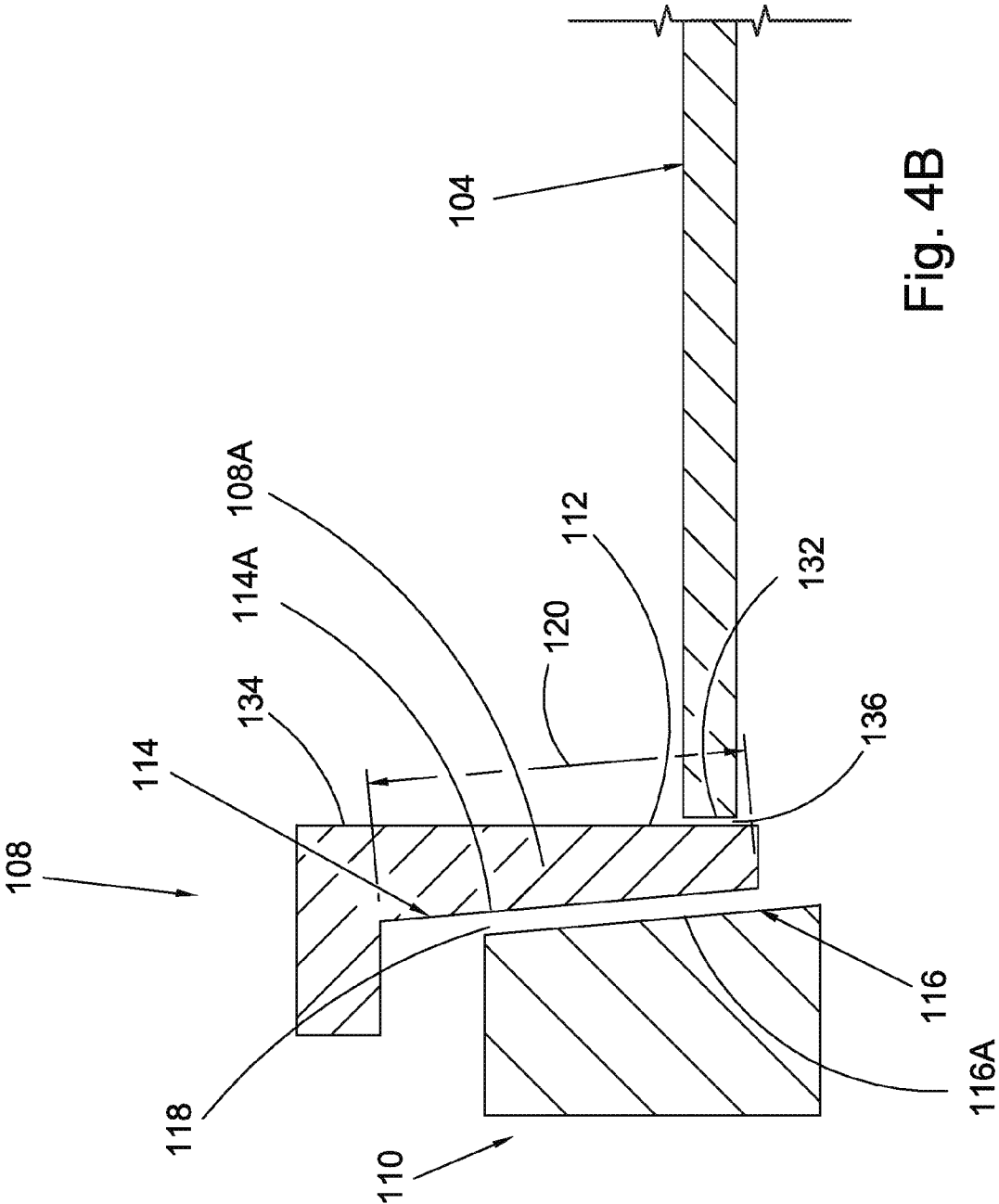


Fig. 4B

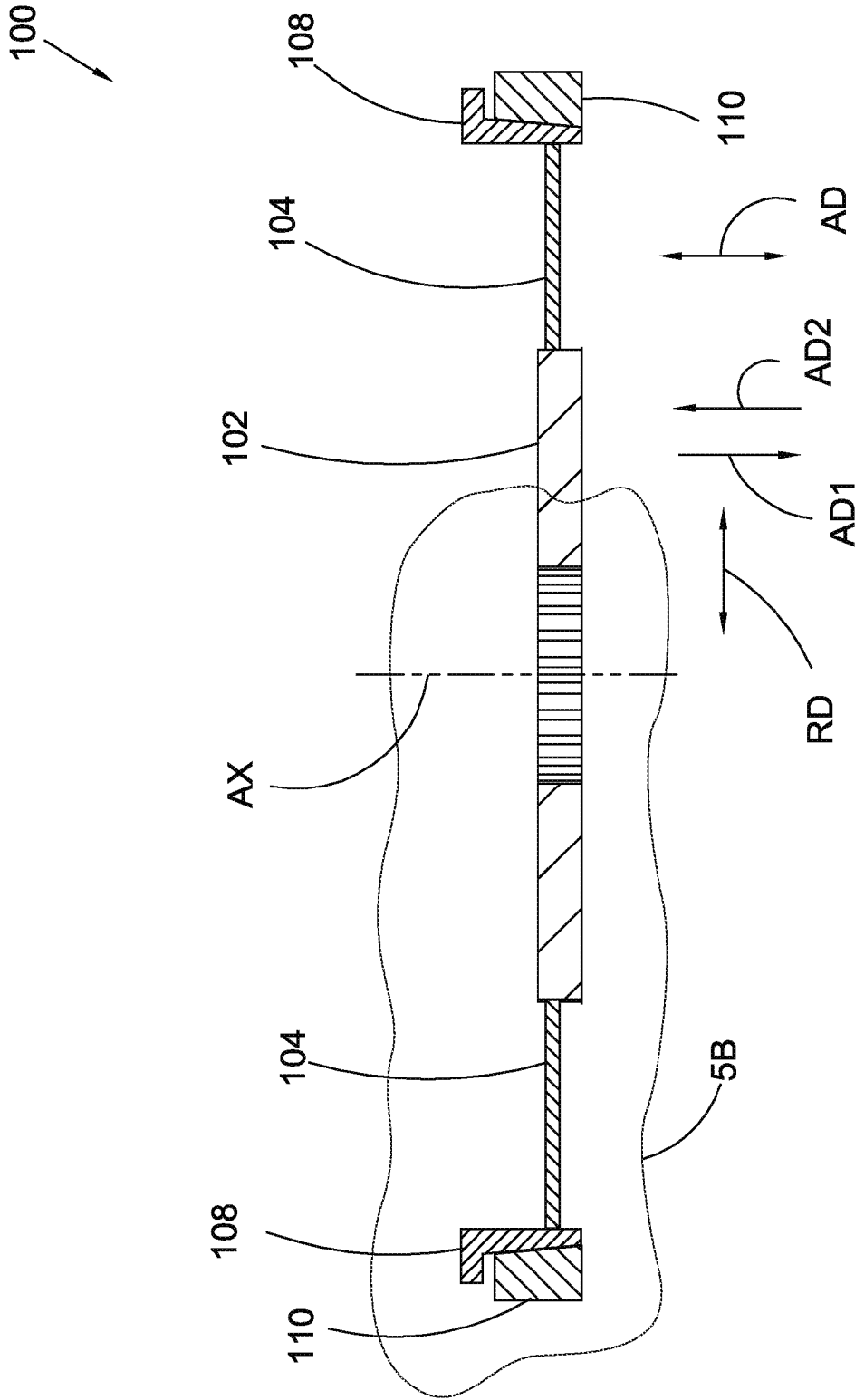


Fig. 5A

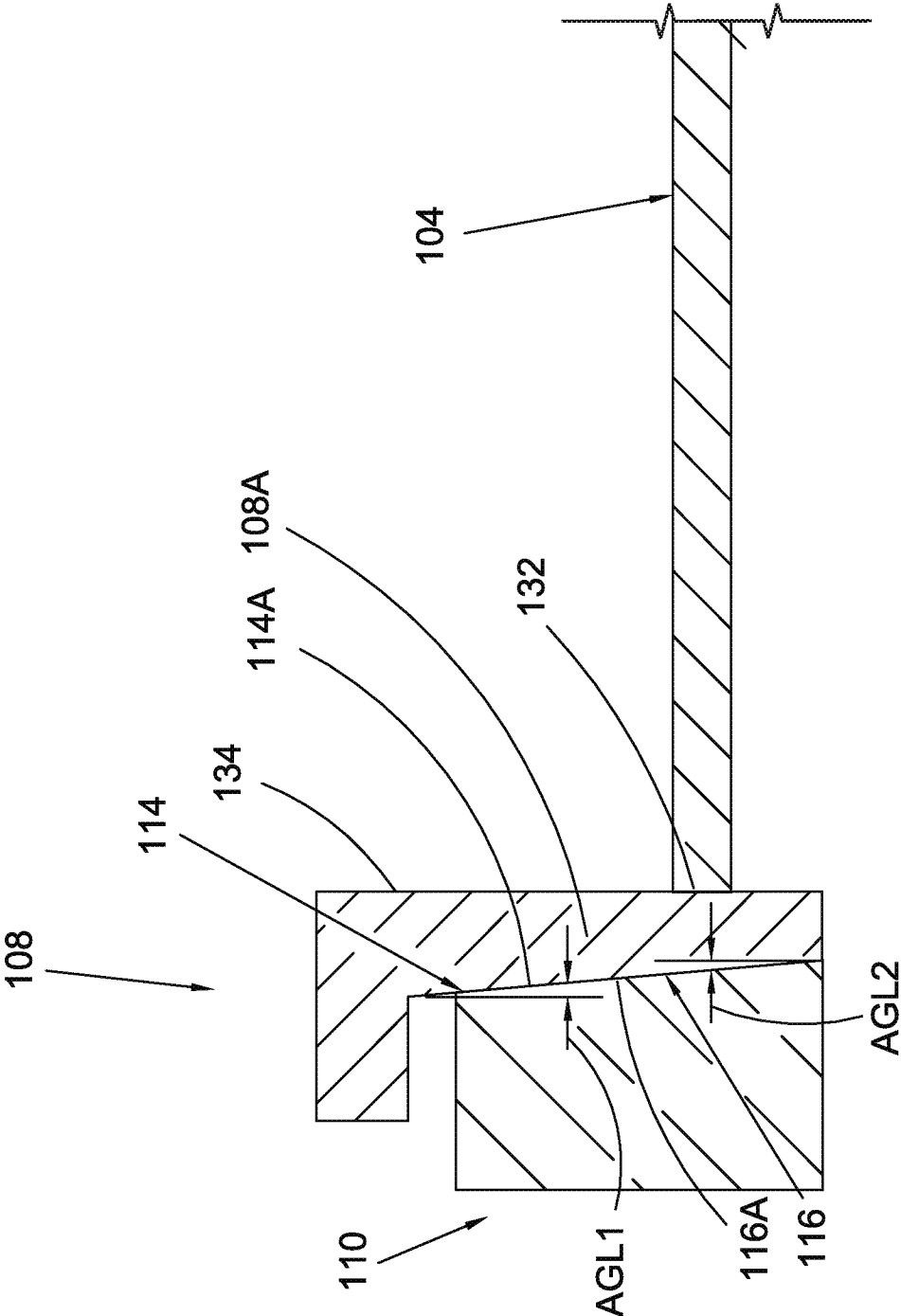


Fig. 5B

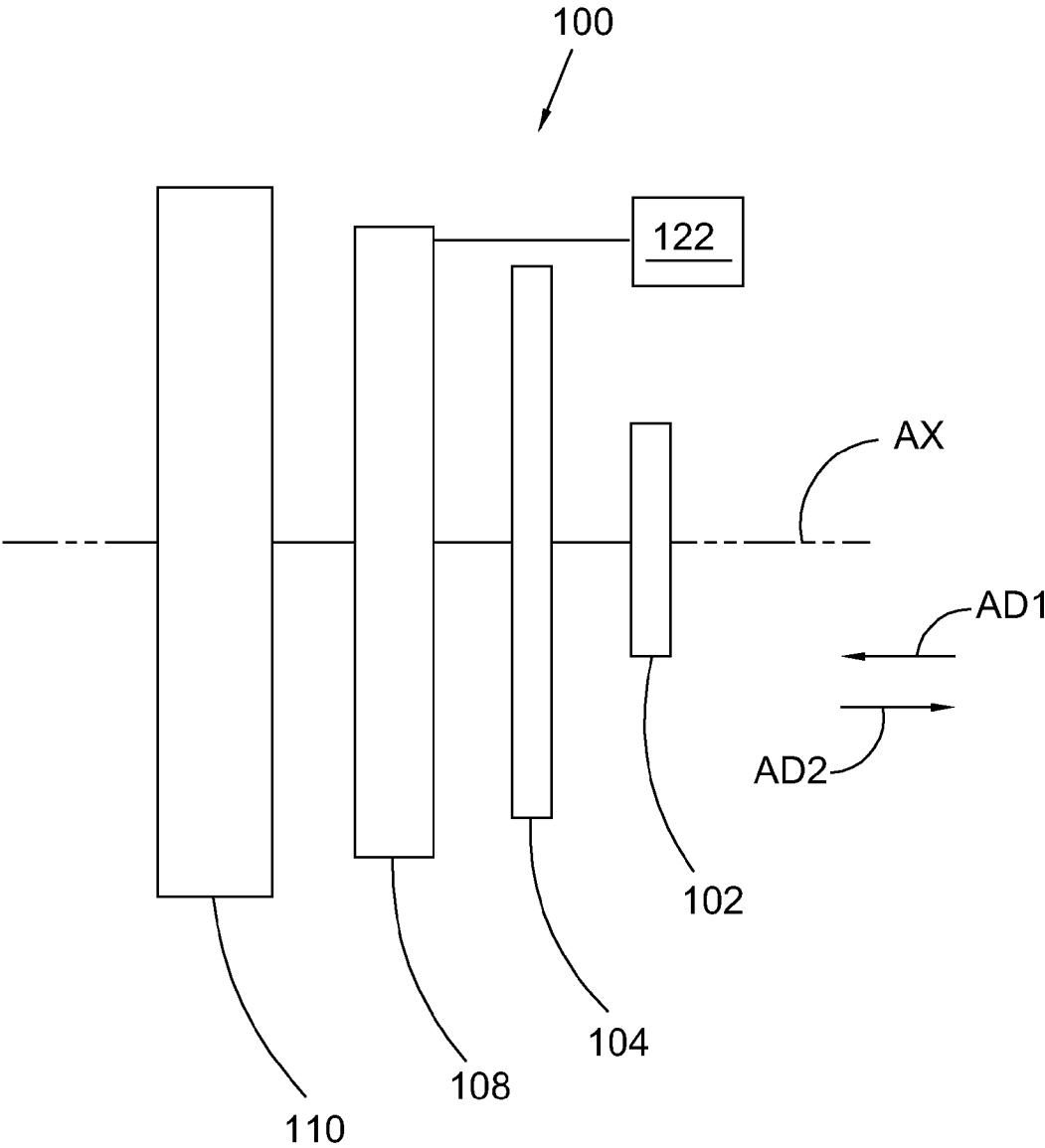


Fig. 6

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DISCONNECT FOR A SWITCHABLE WEDGE CLUTCH

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119 (e) of U.S. Provisional Patent Application No. 61/857,785, filed Jul. 24, 2013, which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to a wedge disconnect clutch for an all-wheel drive, in particular, a wedge disconnect clutch with cone-shaped outer races, one of which is axially displaceable to connect and disconnect the clutch.

BACKGROUND

It is known to use wedge plate clutches for switchable clutch applications. Commonly owned U.S. Provisional Patent Application No. 61/715,518 discloses a switchable one way clutch using a two piece outer race. The two pieces are displaceable axially away from each other to open the clutch and the two pieces are displaceable axially toward each other to close the clutch. Active force must be applied to the two pieces to prevent the two pieces from separating due to radially outwardly acting forces from a wedge plate in contact with the two pieces.

SUMMARY

According to aspects illustrated herein, there is provided a wedge clutch, including: an inner hub; an outer race assembly including a first outer race and a conical outer race including a portion aligned with the first outer race in a radial direction orthogonal to an axis of rotation for the wedge clutch and axially displaceable with respect to the first outer race to open and close the wedge clutch; and a wedge plate radially located between the inner hub and the outer race assembly. In a closed position for the wedge clutch, the wedge plate is non-rotatably connected to the inner hub and the first outer race. In an open position for the wedge clutch, the inner hub and the first outer race are rotatable relative to each other.

According to aspects illustrated herein, there is provided a wedge clutch, including: an inner hub; an outer race assembly including a first outer race and a conical outer race including a first portion aligned with the first outer race in a radial direction orthogonal to an axis of rotation for the wedge clutch and including a second portion aligned with the first outer race in an axial direction parallel to the axis of rotation; and a wedge plate radially located between the inner hub and the conical outer race and engaged with the inner hub. The conical outer race is axially displaceable with respect to the first outer race: to bring the first and second portions into contact with the first outer race to non-rotatably connect the inner hub, the wedge plate, and the outer race assembly; and to separate the first and second portions from the first outer race to enable relative rotation between the inner hub and the first outer race.

According to aspects illustrated herein, there is provided a wedge clutch, including: an inner hub; an outer race assembly including a first outer race and conical outer race including a portion radially inward of the first outer race and aligned with the first outer race in a radial direction orthogonal to the axis of rotation; and a wedge plate engaged with the inner hub and

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located between the inner hub and the conical outer race in the radial direction. For a closed position of the wedge clutch, the conical outer race is displaceable in a first axial direction, parallel to the axis of rotation, to bring the portion of the conical outer race and the first outer race into contact to non-rotatably connect the inner hub and the first outer race. For an open position of the clutch, the conical outer race is displaceable in a second axial direction, opposite the first axial direction, to separate the portion of the conical outer race from the first outer race so that the inner hub and the first outer race are rotatable relative to each other.

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

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

FIG. 2 is an exploded view of a switchable wedge clutch; FIG. 3 is a back view of the switchable wedge clutch of claim 2 in a closed position;

FIG. 4A is a cross-sectional view generally along line 4/5-4/5 in FIG. 3, showing the switchable wedge clutch of FIG. 2 in an open position;

FIG. 4B is a detail of area 4B in FIG. 4A;

FIG. 5A is a cross-sectional view generally along line 4/5-4/5 in FIG. 3, showing the switchable wedge clutch of FIG. 2 in a closed position;

FIG. 5B is a detail of area 5B in FIG. 5A; and,

FIG. 6 is a schematic block diagram of the wedge clutch of FIG. 2 showing an actuator.

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. 1A 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 circumference **83**, respectively. The adjectives "axial," "radial" and "circumferential" also

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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, circumference **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 circumference **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 circumference **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.

It should be understood that FIGS. 2A through 6B are schematic in nature and are not to scale. Further, features in FIGS. 2A through 6B such as proportions, sizes, lengths, spacing, widths, gaps, and contact surfaces, are not to scale and may be exaggerated or otherwise altered for the sake of clarity.

FIG. 2 is an exploded view of switchable wedge clutch **100**.

FIG. 3 is a back view of switchable wedge clutch **100** of FIG. 2. The following should be viewed in light of FIGS. 2 and 3. Clutch **100** includes inner hub **102**, wedge plate **104**, and outer race assembly **106** including conical outer race **108** and outer race **110**. Wedge plate **104** is located between hub **102** and assembly **106** in radial direction RD orthogonal to axis of rotation AX for clutch **100**. As further described below, in a closed position for wedge clutch **100**, plate **104** is non-rotatably connected to inner hub **102** and outer race assembly **106**. More specifically, in the closed position for clutch **100**, plate **104** is non-rotatably connected to hub **102** and race **108** and race **108** is non-rotatably connected to race **110**. In an open position for the wedge clutch, the inner hub and outer race **110** are rotatable relative to each other.

FIG. 4A is a cross-sectional view generally along line 4/5-4/5 in FIG. 3, showing switchable wedge clutch **100** of FIG. 2 in an open position.

FIG. 4B is a detail of area 4B in FIG. 4A.

FIG. 5 is a cross-sectional view generally along line 4/5-4/5 in FIG. 3, showing switchable wedge clutch **100** of FIG. 2 in a closed position.

FIG. 5B is a detail of area 5B in FIG. 5A. The following should be viewed in light of FIGS. 2 through 5B. Conical outer race **108** includes radially inner surface **112** and radially outer surface **114**. Outer race **110** includes radially inner surface **116**. Portion **114A** of surface **114** and portion **116A** of surface **116** are aligned in radial direction RD. In an example embodiment, at least some of portion **114A** is aligned with surface **116** in axial direction AD parallel to axis AX. Portion **108A** of conical outer race **108** is located radially inward of outer race **110** and in alignment with outer race **110** in radial direction RD.

In the open position of FIGS. 4A and 4B, surfaces **114** and **116** are free of contact, for example, surfaces **114** and **116** are

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separated by gap **118** along length **120** of surface **114**. Thus, races **108** and **110** are independently rotatable with respect to each other in rotational, or circumferential, directions CD1 and CD2 about axis AX. In the closed position of FIGS. 5A and 5B, surfaces **114** and **116** are in contact and non-rotatably connected.

Surface **114** slopes toward axis AX in direction AD1, as shown by angle AGL1. Surface **116** slopes toward axis AX in direction AD1, as shown by angle AGL2. To switch wedge clutch **100** from the open position of FIGS. 4A and 4B to the closed position of FIGS. 5A and 5B, the conical outer race is arranged to displace axial direction AD1, such that surface **114**, in particular portion **114A**, contacts and slides across surface **116**. Outer race **110** is radially fixed; therefore, the movement of sloped surface **114** across sloped surface **116** generates radially inward compressive force on outer race **108**, displacing portion **108A** radially inward. The inward displacement of race **108** engages race **108** with the wedge plate. The displacement of race **108** in direction AD1 also frictionally engages surfaces **114** and **116**. As a result, races **108** and **110** are non-rotatably connected and as further explained below, relative rotation between the inner hub and race **110** causes wedge plate **104** to non-rotatably connect with race **108** and the inner hub.

To switch wedge clutch **100** from the closed position of FIGS. 5A and 5B to the open position of FIGS. 4A and 4B, the conical outer race is arranged to displace in axial direction AD2, opposite AD1, relieving the radially inward compressive force noted above, separating surface **114** from surface **116**, enabling race **108** to expand radially outward, and creating gap **118**. As further explained below, the radially outward expansion of race **108** enables relative rotation between the inner hub and race **110**.

In an example embodiment, outer race **110** is fixed with respect to movement in directions AD1 or AD2. In an example embodiment, wedge plate **104** is fixed with respect to movement in directions AD1 or AD2 and race **108** displaces in directions AD1 and AD2 with respect to the wedge plate.

FIG. 6 is a schematic block diagram of the wedge clutch of FIG. 2 showing actuator **122**. Actuator **122** is used to displace race **108** in axial directions AD1 and AD2. Any actuator known in the art, including, but not limited to mechanical, hydraulic, or pneumatic actuators can be used for actuator **122**.

Returning to FIGS. 2 through 5B, in an example embodiment, radially outer surface **124** of inner hub **102** includes radially outwardly extending ramps **126**. Wedge plate **104** includes radially inner surface **128** with radially inwardly extending ramps **130**. In the open position for clutch **100**, ramps **126** and **130** are engaged and radially outer surface **132** of wedge plate **104** is free of contact with radially inner surface **134** of race **108**, for example, surfaces **132** and **134** are separated by gap **136**. The inner hub and the wedge plate rotate together and are rotatable with respect to race **108**. Due to gap **118**, race **108** is rotatable with respect to outer race **110**.

To transit from the open position of clutch **100** to the closed position for clutch **100**, race **108** is axially displaced in direction AD1 so that surfaces **114** and **116** frictionally engage, non-rotatably connecting races **108** and **110** and displacing race **108** radially inward to engage surface **132** of the wedge plate as described above. The non-rotatable connection of races **108** and **110** and the engagement of wedge plate **104** with race **108** enables relative rotation between wedge plate **104** and inner hub **102**. For example, for relative rotation of wedge plate **104** with respect to the inner hub in circumferential direction CD1, ramps **130A** begin to slide along ramps

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126A in direction CD1. Thus, the radially inwardly increasing portions of ramps 130 slide across the radially outwardly increasing portions of ramps 126 causing wedge plate 104 to expand radially outward to relieve the force between ramps 126 and 130. As a result, plate 104 is wedged between the inner hub and race 108, non-rotatably connecting the inner hub and race 108.

For example, for relative rotation of wedge plate 104 with respect to the inner hub in circumferential direction CD2, ramps 130B begin to slide along ramps 126B in direction CD2. Thus, the radially inwardly increasing portions of ramps 130 slide across the radially outwardly increasing portions of ramps 126 causing wedge plate 104 to expand radially outward to relieve the force between ramps 126 and 130. As a result, plate 104 is wedged between the inner hub and race 108, non-rotatably connecting the inner hub and race 108. In an example embodiment, plate 104 includes gap 138 to facilitate radial displacement of plate 104.

In an example embodiment, angles AGL1 and AGL2 are calculated such that the frictional engagement and non-rotatable connection of surfaces 114 and 116 is self-locking. Thus, outer races 108 and 110 are not pushed apart (race 108 is not displaced in direction AD2 with respect to race 110) due to forces from wedge plate 104, for example, radially directed forces due to a torque load on clutch 100. As a result, it is not necessary to keep actuator 122 actively engaged to apply pressure to outer race 108, reducing the energy requirement and increasing the service life for actuator 122. In another example embodiment, the angles are calculated so that only a minimal force from actuator 122 keeps the clutch engaged and removal of the actuator force disengages the clutch.

Advantageously, outer race assembly provides a means of opening and closing clutch 100 without the necessity of changing or removing torque loads on the inner hub or outer race 110 and without the necessity of modifying rotation of the inner hub or outer race 110. Regardless of the torque loads on clutch 100 or relative rotation of components of clutch 100, outer race 108 can be axially displaced in directions AD1 and AD2 to close and open the clutch, respectively.

Further, since outer races 108 and 110 are not in contact in the open position for clutch 100, frictional losses associated with operation of clutch 100 in the open mode are eliminated or greatly reduced.

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.

We claim:

1. A wedge clutch, comprising:

an inner hub including a first radially outer surface with a plurality of radially outwardly extending ramps;

an outer race assembly including:

a first outer race; and,

a conical outer race:

including a portion aligned with the first outer race in a radial direction orthogonal to an axis of rotation for the wedge clutch; and,

axially displaceable with respect to the first outer race to open and close the wedge clutch; and,

a wedge plate:

radially located between the inner hub and the outer race assembly; and,

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including a first radially inner surface with a plurality of radially inwardly extending ramps engaged with the plurality of radially outwardly extending ramps, wherein:

in a closed position for the wedge clutch, the wedge plate is non-rotatably connected to the inner hub and the first outer race; and,

in an open position for the wedge clutch, the inner hub and the first outer race are rotatable relative to each other.

2. The wedge clutch of claim 1, wherein the conical outer race is displaceable:

in a first axial direction, parallel to an axis of rotation for the wedge clutch, with respect to the first outer race to non-rotatably connect the inner hub and the first outer race; and,

in a second axial direction, opposite the first axial direction, with respect to the first outer race to separate the conical outer race from the first outer race.

3. The wedge clutch of claim 1, wherein:

the portion of the conical outer race is located radially inward of the first outer race in the radial direction.

4. The wedge clutch of claim 1, wherein:

the wedge plate includes a second radially outer surface; the conical outer race includes a second radially inner surface;

in the open position for the clutch, the second radially inner surface and the second radially outer surface are free of contact; and,

in the closed position for the clutch, the second radially inner surface and the second radially outer surface are in contact.

5. The wedge clutch of claim 1, wherein:

the first outer race includes a second radially inner surface; the portion of the conical outer race includes a second radially outer surface aligned with the second radially inner surface in the radial direction; and,

the second radially inner surface and the second radially outer surface each slope toward the axis of rotation in a first axial direction parallel to the axis of rotation.

6. The wedge clutch of claim 5, wherein to switch the wedge clutch from the open position to the closed position the conical outer race is arranged to displace in the first axial direction to slide the second radially outer surface across the second radially inner surface to:

displace the portion of the conical outer race radially inward; and,

bring the conical outer race and the wedge plate into contact.

7. The wedge clutch of claim 6, wherein:

in the open position for the wedge clutch, the respective pluralities of radially outwardly and inwardly extending ramps are in contact and the inner hub and the wedge plate rotate together; and,

the contact of the wedge plate with the conical outer race is arranged to cause relative rotation between the wedge plate and the inner hub such that:

the plurality of radially inwardly extending ramps slide along the plurality of radially outwardly extending ramps in a circumferential direction; and,

the wedge plate expands radially outward to non-rotatably connect the inner hub with the first outer race.

8. The wedge clutch of claim 1, wherein the first outer race is fixed with respect to movement parallel to the axis of rotation.

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9. The wedge clutch of claim 1, further comprising:
 an actuator arranged to displace the conical outer race, in
 first and second opposite axial directions parallel to an
 axis of rotation for the wedge clutch, to switch the wedge
 clutch between the closed and open positions.
10. The wedge clutch of claim 1, wherein in the closed
 position the inner hub and first outer race are rotatable
 together in one of first or second opposite rotational direc-
 tions about the axis of rotation for the wedge clutch.
11. A wedge clutch, comprising:
 an inner hub including a first radially outer surface with a
 plurality of radially outwardly extending ramps;
 an outer race assembly including:
 a first outer race; and,
 a conical outer race:
 including a first portion aligned with the first outer
 race in a radial direction orthogonal to an axis of
 rotation for the wedge clutch; and,
 including a second portion aligned with the first outer
 race in an axial direction parallel to the axis of
 rotation; and,
 a wedge plate:
 radially located between the inner hub and the conical
 outer race; and,
 including a first radially inner surface with a plurality of
 radially inwardly extending ramps engaged with the
 plurality of radially outwardly extending ramps for
 the inner hub, wherein:
 the conical outer race is axially displaceable with respect
 to the first outer race:
 to bring the first and second portions into contact with
 the first outer race to non-rotatably connect the
 inner hub, the wedge plate, and the outer race
 assembly; and,
 to separate the first and second portions from the first
 outer race to enable relative rotation between the
 inner hub and the first outer race.
12. The wedge clutch of claim 11, wherein:
 the wedge plate includes a second radially outer surface;
 the conical outer race includes a second radially inner
 surface;
 in the open position for the clutch, the second radially inner
 surface and the second radially outer surface are free of
 contact; and,
 in the closed position for the clutch, the second radially
 inner surface and the second radially outer surface are in
 contact.
13. The wedge clutch of claim 11, wherein:
 the first outer race includes a second radially inner surface;
 the first and second portions of the conical outer race
 include a second radially outer surface aligned with the
 second radially inner surface in the radial direction; and,
 the second radially inner surface and the second radially
 outer surface each slope toward the axis of rotation in a
 first axial direction parallel to the axis of rotation.
14. The wedge clutch of claim 13, wherein to switch the
 wedge clutch from the open position to the closed position the
 conical outer race is arranged to displace in a first axial
 direction, parallel to the axis of rotation, to slide the second
 radially outer surface across the second radially inner surface
 to:
 displace the first and second portions of the conical outer
 race radially inward; and,
 bringing the conical outer race and the wedge plate into con-
 tact.

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15. The wedge clutch of claim 14, wherein:
 in the open position for the wedge clutch, the respective
 pluralities of radially outwardly and inwardly extending
 ramps are in contact and the inner hub and the wedge
 plate rotate together; and,
 the contact of the wedge plate with the conical outer race is
 arranged to cause relative rotation between the wedge
 plate and the inner hub such that:
 the plurality of radially inwardly extending ramps slide
 along the plurality of radially outwardly extending
 ramps in a circumferential direction; and,
 the wedge plate expands radially outward to non-rotat-
 ably connect the inner hub with the first outer race.
16. The wedge clutch of claim 11, wherein the first outer
 race is fixed with respect to movement parallel to the axis of
 rotation.
17. The wedge clutch of claim 11, further comprising:
 an actuator arranged to axially displace the conical outer
 race.
18. A wedge clutch, comprising:
 an inner hub;
 an outer race assembly including
 a first outer race; and,
 conical outer race including a portion radially inward of
 the first outer race and aligned with the first outer race
 in a radial direction orthogonal to the axis of rotation;
 and,
 a wedge plate engaged with the inner hub and the conical
 outer race and located between the inner hub and the
 conical outer race in the radial direction, wherein:
 for a closed position of the wedge clutch, the conical
 outer race is displaceable in a first axial direction,
 parallel to the axis of rotation, to bring the portion of
 the conical outer race and the first outer race into
 contact to rotate the wedge plate with respect to the
 inner hub to non-rotatably connect the inner hub and
 the first outer race; and,
 for an open position of the clutch, the conical outer race
 is displaceable in a second axial direction, opposite
 the first axial direction, to separate the portion of the
 conical outer race from the first outer race so that the
 inner hub and the first outer race are rotatable relative
 to each other.
19. The wedge clutch of claim 18, wherein:
 the portion of the conical outer race includes a radially
 outer surface sloping toward the axis of rotation in the
 first axial direction;
 the first outer race includes a radially inner surface sloping
 toward the axis of rotation in the first axial direction;
 for the closed position of the wedge clutch, the conical
 outer race is displaceable in the first axial direction to
 bring the radially inner surface and the radially outer
 surface into contact to non-rotatably connect the inner
 hub and the first outer race; and,
 for the open position of the wedge clutch, the conical outer
 race is displaceable in the second axial direction to sepa-
 rate the radially inner surface and the radially outer
 surface to enable relative rotation of the inner hub and
 the first outer race.
20. The wedge clutch of claim 19, wherein:
 in the open position for the wedge clutch, the conical outer
 race and wedge plate are free of contact; and,
 to switch the wedge clutch from the open position to the
 closed position the conical outer race is arranged to
 displace in the first axial direction to slide the radially
 outer surface across the radially inner surface to:

displace the portion of the conical outer race radially inward;
bring the conical outer race and the wedge plate into contact; and,
cause relative rotation between the wedge plate and the inner hub.

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