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(54) Title: REVERSIBLE STARTER MOTOR

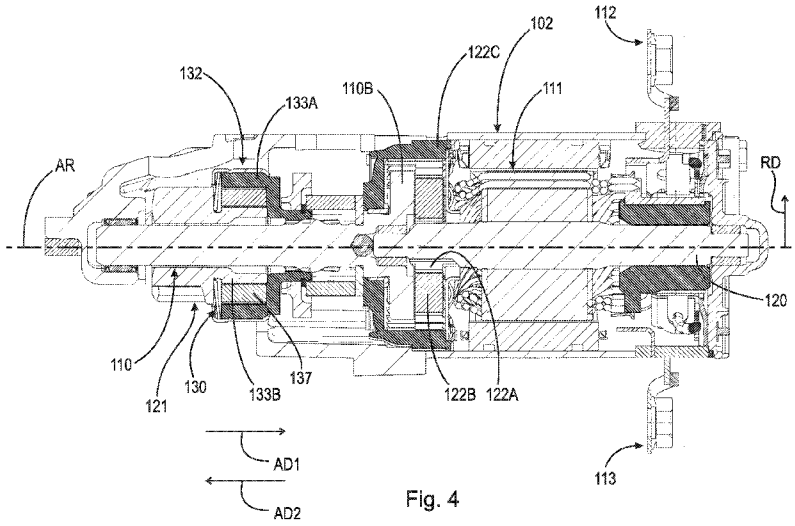


Fig. 4

(57) Abstract: A starter including: a housing; a motor shaft located within the housing; an electric motor located within the housing and arranged to rotate the motor shaft in first and second opposite circumferential directions about an axis of rotation; an output shaft non-rotatably connected to the motor shaft; and a one-way clutch including first and second races. The first race includes a pinion gear fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing and arranged to mesh with a ring gear. The second race is non-rotatably connected to the output shaft. For a start mode, the electric motor is arranged to rotate the motor shaft and the pinion gear in a first circumferential direction.

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REVERSIBLE STARTER MOTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Patent Application No. 14/717,682, filed May 20, 2015, which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to a starter for an internal combustion engine. In particular, to a starter with a reversible motor and a one-way clutch to enable the starter to remain engaged with a ring gear.

BACKGROUND

[0003] Known starter motors include a retractable pinion gear disengageable from a flywheel of a combustion engine after a starting sequence. The engagement and disengagement of the pinion gear can cause damage to respective gear teeth on the pinion gear and flywheel and also places a high current load on the starter motor, which can lead to premature failure of the rotor and brushes. Further, the pinion gear and the ring gear may clash if the ring gear is rotating when the pinion gear is engaged with the ring gear.

SUMMARY

[0004] According to aspects illustrated herein, there is provided a starter including: a housing; a motor shaft located within the housing; an electric motor located within the housing and arranged to rotate the shaft in first and second opposite circumferential directions about an axis of rotation; an output shaft non-rotatably connected to the motor shaft; and a one-way clutch including first and second races. The first race includes a pinion gear fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing and arranged to mesh with a ring gear. The second race is non-rotatably connected to the output shaft. For a start mode, the electric motor is arranged to rotate the motor shaft and the pinion gear in a first circumferential direction.

[0005] According to aspects illustrated herein, there is provided a starter including: a housing; a motor shaft located within the housing; an electric motor located within the housing arranged to rotate the motor shaft in first and second opposite circumferential directions about an axis of rotation; an output shaft non-rotatably connected to the motor shaft; and a one-way clutch including a first race including a pinion gear fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing and arranged to

mesh with a ring gear, and a second race non-rotatably connected to the output shaft. For a start mode the electric motor is arranged to rotate the motor shaft in the first circumferential direction and the one-way clutch is arranged to non-rotatably connect the motor shaft and the pinion gear. For a release mode: the electric motor is arranged to rotate the shaft in the second circumferential direction; and the pinion gear is arranged to rotate in the second circumferential direction; or the motor shaft is arranged to rotate with respect to the pinion gear in the second circumferential direction.

[0006] According to aspects illustrated herein, there is provided a starter, including a housing; a motor shaft located within the housing; an electric motor located within the housing arranged to rotate the motor shaft in first and second opposite circumferential directions about an axis of rotation; an output shaft; a sun gear non-rotatably connected to the motor shaft; a planetary carrier formed from a portion of the output shaft; a ring gear grounded to the housing; a plurality of planet gears meshed with the sun and ring gears and connected to the planetary carrier; and a one-way clutch including a first race including a pinion gear fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing and arranged to mesh with a ring gear, and a second race non-rotatably connected to the output shaft. For a start mode, the electric motor is arranged to rotate the motor shaft in the first circumferential direction and the one-way clutch is arranged to non-rotatably connect the motor shaft and the pinion gear. For a release mode: the electric motor is arranged to rotate the shaft in the second circumferential direction; and the pinion gear is arranged to rotate in the second circumferential direction or the motor shaft is arranged to rotate with respect to the pinion gear in the second circumferential direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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:

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

Figure 2 is a perspective view of a starter with an axially fixed pinion gear;

Figure 3 is a side view of the starter in Figure 2;

Figure 4 is a cross-sectional view of the starter taken generally along line 4-4 in Figure 2;

Figure 5 is a schematic view of a control circuit for the starter in Figure 2;

Figure 6 is a cross-sectional view of the starter taken generally along line 6-6 in Figure 3.

DETAILED DESCRIPTION

[0008] 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.

[0009] 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.

[0010] 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.

[0011] By "non-rotatably connected" first and second components we mean that the first component is connected to the second component so that any time the first component rotates, the second component rotates with the first component, and any time the second component rotates, the first component rotates with the second component. Axial displacement between the first and second components is possible. It is not necessary for the first and second components to rotate at the same rate.

[0012] Figure **1** is a perspective view of cylindrical coordinate system **10** demonstrating spatial terminology used in the present application. The present application is at least partially described within the context of a cylindrical coordinate system. System **10** includes longitudinal axis **11**, used as the reference for the directional and spatial terms that follow. Axial direction **AD** is parallel to axis **11**. Radial direction **RD** is orthogonal to axis **11**. Circumferential direction **CD** is defined by an endpoint of radius **R** (orthogonal to axis **11**) rotated about axis **11**.

[0013] To clarify the spatial terminology, objects **12**, **13**, and **14** are used. An axial surface, such as surface **15** of object **12**, is formed by a plane parallel to axis **11**. Axis **11** is coplanar with planar surface **15**; however it is not necessary for an axial surface to be coplanar with axis **11**. A radial surface, such as surface **16** of object **13**, is formed by a plane

orthogonal to axis **11** and coplanar with a radius, for example, radius **17**. Surface **18** of object **14** forms a circumferential, or cylindrical, surface. For example, circumference **19** forms a circle on surface **18**. As a further example, axial movement is parallel to axis **11**, radial movement is orthogonal to axis **11**, and circumferential movement is parallel to circumference **19**. Rotational movement is with respect to axis **11**. The adverbs "axially," "radially," and "circumferentially" refer to orientations parallel to axis **11**, radius **17**, and circumference **19**, respectively.

[0014] Figure 2 is a perspective view of starter **100** with an axially fixed pinion gear.

[0015] Figure 3 is a side view of starter **100** in Figure 2.

[0016] Figure 4 is a cross-sectional view of starter **100** taken generally along line 4-4 in Figure 2. The following should be viewed in light of Figures 2 through 4. Starter **100** includes housing **102**, motor shaft **120** located within housing **102**, electric motor **111** located within housing **102**, and output shaft **110**. Motor **111** is arranged to rotate motor shaft **120** in opposite circumferential directions **CD1** and **CD2** about axis of rotation **AR**. Starter **100** includes one-way clutch **132** with races **133A** and **133B**. Race **133A** is non-rotatably connected to output shaft **110**. Race **133B** includes pinion gear **121**. Gear **121** is arranged to mesh with a ring gear for a starting assembly (not shown) for an internal combustion engine (not shown). Pinion gear **121** is fixed, with respect to movement in opposite axial directions **AD1** and **AD2**, parallel to axis **AR**, with respect to housing **102**. For a start mode, motor **111** is arranged to rotate shaft **120** and gear **121** in direction **CD1**. In an example embodiment, output shaft **110** is fixed with respect to housing **102**, in directions **AD1** and **AD2**.

[0017] In an example embodiment, starter **100** includes: sun gear **122A** fixed to shaft **120**, planetary carrier **110B** formed by output shaft **110**, planet gears **122B** which rotate on shafts extending from planet carrier **110B**, and ring gear **122C** non-rotatably connected, or grounded, to housing **102**. Planet gears **122B** are meshed with the sun gear and ring gear **122C**. By two or more components "non-rotatably connected" we mean that whenever any one of the components rotates, the other components rotate as well. That is, the components are fixed to each other with respect to rotation.

[0018] For the start mode, race **133A** is arranged to non-rotatably connect to race **133B**. For a release mode, in which the starting cycle for the internal combustion engine is complete, electric motor **111** is arranged to rotate motor shaft **120** in circumferential direction **CD2** and as further described below, pinion gear **121** is arranged, in a first phase, to rotate in

circumferential direction **CD2**, and, in a second phase, race **133A** is arranged to rotate, with respect to race **133B** and pinion gear **121**, in circumferential direction **CD2**. In the second phase, rotation of the pinion gear in direction **CD2** is blocked.

[0019] One-way clutch **132** includes resilient element **130** directly engaged with races **133A** and **133B**. Element **130** can be in direct contact with races **133A** and **133B** or can be in direct contact with respective components non-rotatably connected to races **133A** and **133B**. Resilient element **130** reacts against race **133B** to apply a frictional force to race **133A**, or resilient element **130** reacts against race **133A** to apply a frictional force to race **133B**. For the first phase of the release mode, the frictional force is greater than a force resisting rotation of gear **121** in direction **CD2**. Thus, resilient element **130** is arranged to frictionally connect races **133A** and **133B** and gear **121** is arranged to rotate with motor shaft **120** in circumferential direction **CD2**. That is, resilient element **130** is connected to races **133A** and **133B** by respective frictional connections.

[0020] The frictional connections can be non-rotatable connections or there can be slip between resilient element **130** and one or both of races **133A** and **133B**. For example: motor **111** rotates race **133A**, in direction **CD2**, at a first speed and race **133B** rotates at the first speed as well (non-rotatable connection of element **130** with races **133A** and **133B**); or, motor **111** rotates race **133A**, in direction **CD2**, at a first speed and the slip/respective frictional connections result in element **130** rotating race **133B**, but at a lower speed than the first speed (slip between resilient element **130** and one or both of races **133A** and **133B**). The slip can be between element **130** and one or both of races **133A** and **133B**. For example: resilient element **130** can be non-rotatably connected to race **133A** and slip with respect to race **133B**; resilient element **130** can be non-rotatably connected to race **133B** and slip with respect to race **133A**; or resilient element **130** can slip with respect to both races **133A** and **133B**.

[0021] In an example embodiment, element **130** is a diaphragm spring with an inner circumference engaged with race **133B** and an outer circumference engaged with race **133A**. In an example embodiment, element **130** is in contact with a component non-rotatably connected to race **133A** and/or with a component non-rotatably connected to race **133B**. In an example embodiment (not shown), element **130** includes: an inner circumference engaged with race **133A**; and an outer circumference engaged with race **133B**.

[0022] For the second phase, pinion gear **121** is arranged to resist, with a second force, greater than the first force, rotation in circumferential direction **CD2** and race **133A** and motor shaft **120** are arranged to rotate in circumferential direction **CD2** with respect to race **133B** and gear **121**.

[0023] In an example embodiment, at least a portion of race **133A** is located outward of race **133B** in direction **RD** orthogonal to axis of rotation **AR**. In an example embodiment, one-way clutch **132** is a trapped roller clutch including cylindrical rolling elements **137** radially disposed between races **133A** and **133B**.

[0024] Figure 5 is a schematic view of a control circuit for the starter in Figure 2. Starter **100** includes a control circuit, for example, control circuit **150**, configured to supply power to electric motor **111** to rotate motor shaft **120** in circumferential direction **CD1** for the start mode, or in circumferential direction **CD2** for the release mode. In an example embodiment, control circuit **150** includes battery power feed **151**, starter relay switch **152**, on delay timer **153**, off delay timer switch **154**, off delay timer **155**, on delay timer switch **156**, forward solenoid **158**, and reverse solenoid **159**.

[0025] In an example embodiment, for the start mode, control circuit **150** is configured to close switch **152** to: initiate a first time interval by triggering timer **153**; and supply power to solenoid **158** to rotate motor shaft **120** in direction **CD1**. In an example embodiment, for the release mode, control circuit **150** is configured to close switches **154** and **156**, upon expiration of the first time interval to. Switch **154** supplies power to solenoid **159** to rotate motor shaft **120** in circumferential direction **CD2**. Switch **156** initiates a second time interval by triggering timer **155**. Upon expiration of the second time interval: circuit **150** is arranged to open switch **154** to turn off power to electric motor **111** and open switch **156**.

[0026] Figure 6 is a cross-sectional view of starter **100** taken generally along line 6-6 in Figure 3. In an example embodiment, electric motor **111** includes armature **103** and brushes **104** and **105**. To enable rotation of motor **111** in directions **CD1** and **CD2**, normally grounded brushes **104** are electrically isolated from housing **102**. Motor **111** includes separate leads **107** and **108** for brushes **104** and **105**, respectively, and mounts **112** and **113** for leads **107** and **108**, respectively. Springs **116** maintain contact between armature **103** and brushes **104** and **105**.

[0027] Starter **100** includes mounts, for example mounts **106**, which enable starter **100** to be mounted to the bell housing of a transmission (not shown) or on an engine block (not shown).

[0028] Advantageously, starter **100** eliminates the problem noted above with respect to an axially displaceable pinion for a starter engaging with and disengaging from a ring gear. Specifically, output shaft **110** remains engaged with a ring gear at all times, not just during a starting sequence.

[0029] In an example embodiment, rotation of gear **121** in direction **CD1** winds a wrap spring (not shown) engaged with a torque converter cover (not shown). For the first phase of the release mode, rotation of gear **121** in direction **CD2** unwinds the wrap spring. The wrap spring does not resist rotation of output shaft **110** in direction **CD2** with a force greater than the frictional force non-rotatably connecting resilient element **130** with races **133A** and **133B**. For the second phase of the release mode, the wrap spring is fully unwound and essentially acts as a stop for rotation of the pinion gear in direction **CD2**. The stop action of the wrap spring resists rotation of gear **121** in direction **CD2** with a force greater than the frictional force non-rotatably connecting resilient element **130** with races **133A** and **133B**. As a result, clutch **132** slips and shafts **110** and **120** and race **133A** are able to rotate with respect to the pinion gear to prevent damage to motor **111**.

[0030] It should be understood that directions **CD1** and **CD2** can be reversed from the orientation shown in the figures.

[0031] 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.

CLAIMS

What is claimed is:

1. A starter, comprising:

a housing;

a motor shaft located within the housing;

an electric motor located within the housing and arranged to rotate the motor shaft in first and second opposite circumferential directions about an axis of rotation;

an output shaft non-rotatably connected to the motor shaft; and,

a one-way clutch including:

a first race including a pinion gear, the pinion gear:

fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing; and,

arranged to mesh with a ring gear; and,

a second race non-rotatably connected to the output shaft, wherein for a start mode, the electric motor is arranged to rotate the motor shaft and the pinion gear in the first circumferential direction.

2. The starter of claim 1, wherein:

for the start mode, the first race is arranged to non-rotatably connect to the second race; and,

for a release mode:

the electric motor is arranged to rotate the motor shaft in the second circumferential direction; and,

the pinion gear is arranged to rotate in the second circumferential direction; or,

the second race is arranged to rotate, with respect to the first race, in the second circumferential direction.

3. The starter of claim 2, wherein:

for a first phase of the release mode, the pinion gear is arranged to rotate in the second circumferential direction; and,

for a second phase of the release mode, the second race is arranged to rotate with respect to the pinion gear in the second circumferential direction.

4. The starter of claim 3, wherein the one-way clutch includes a resilient element:
directly engaged with the first and second races; and,
reacting against the second race to apply a frictional force to the first race; or,
reacting against the first race to apply a frictional force to the second race.

5. The starter of claim 4, wherein for the first phase of the release mode, the resilient element is arranged to frictionally connect the first and second races.

6. The starter of claim 3, wherein for the second phase of the release mode, rotation of the pinion gear in the second circumferential direction is arranged to be blocked.

7. A starter, comprising:
a housing;
a motor shaft located within the housing;
an electric motor located within the housing and arranged to rotate the motor shaft in first and second opposite circumferential directions about an axis of rotation;
an output shaft non-rotatably connected to the motor shaft; and,
a one-way clutch including:
a first race including a pinion gear, the pinion gear:
fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing; and,
arranged to mesh with a ring gear; and,
a second race non-rotatably connected to the output shaft, wherein:
for a start mode:
the electric motor is arranged to rotate the motor shaft in the first circumferential direction; and,
the one-way clutch is arranged to non-rotatably connect the motor shaft and the pinion gear; and,
for a release mode:

the electric motor is arranged to rotate the motor shaft in the second circumferential direction; and,

the pinion gear is arranged to rotate in the second circumferential direction; or,

the motor shaft is arranged to rotate, with respect to the pinion gear, in the second circumferential direction.

8. The starter of claim 7, further comprising:

a control circuit configured to:

for the start mode:

supply power to the electric motor to rotate the motor shaft in the first circumferential direction; and,

initiate a first time interval; and,

for the release mode and upon expiration of the first time interval, supply power to the electric motor to rotate the motor shaft in the second circumferential direction.

9. The starter of claim 8, wherein the control circuit is configured to:

upon the expiration of the first time interval, initiate a second time interval; and,

upon expiration of the second time interval, turn off power to the electric motor.

10. A starter, comprising:

a housing;

a motor shaft located within the housing;

an electric motor located within the housing and arranged to rotate the motor shaft in first and second opposite circumferential directions about an axis of rotation;

an output shaft;

a sun gear non-rotatably connected to the motor shaft;

a planetary carrier formed from a portion of the output shaft;

a first ring gear non-rotatably connected to the housing;

a plurality of planet gears meshed with the sun and ring gears and connected to the planetary carrier; and,

a one-way clutch including:

a first race including a pinion gear, the pinion gear:

fixed with respect to axial movement, parallel to the axis of rotation, with respect to the housing; and,

arranged to mesh with a second ring gear; and,

a second race non-rotatably connected to the output shaft, wherein:

for a start mode:

the electric motor is arranged to rotate the motor shaft in the first circumferential direction; and,

the one-way clutch is arranged to non-rotatably connect the motor shaft and the pinion gear; and,

for a release mode:

the electric motor is arranged to rotate the shaft in the second circumferential direction; and,

the pinion gear is arranged to rotate in the second circumferential direction; or, the motor shaft is arranged to rotate, with respect to the pinion gear, in the second circumferential direction.

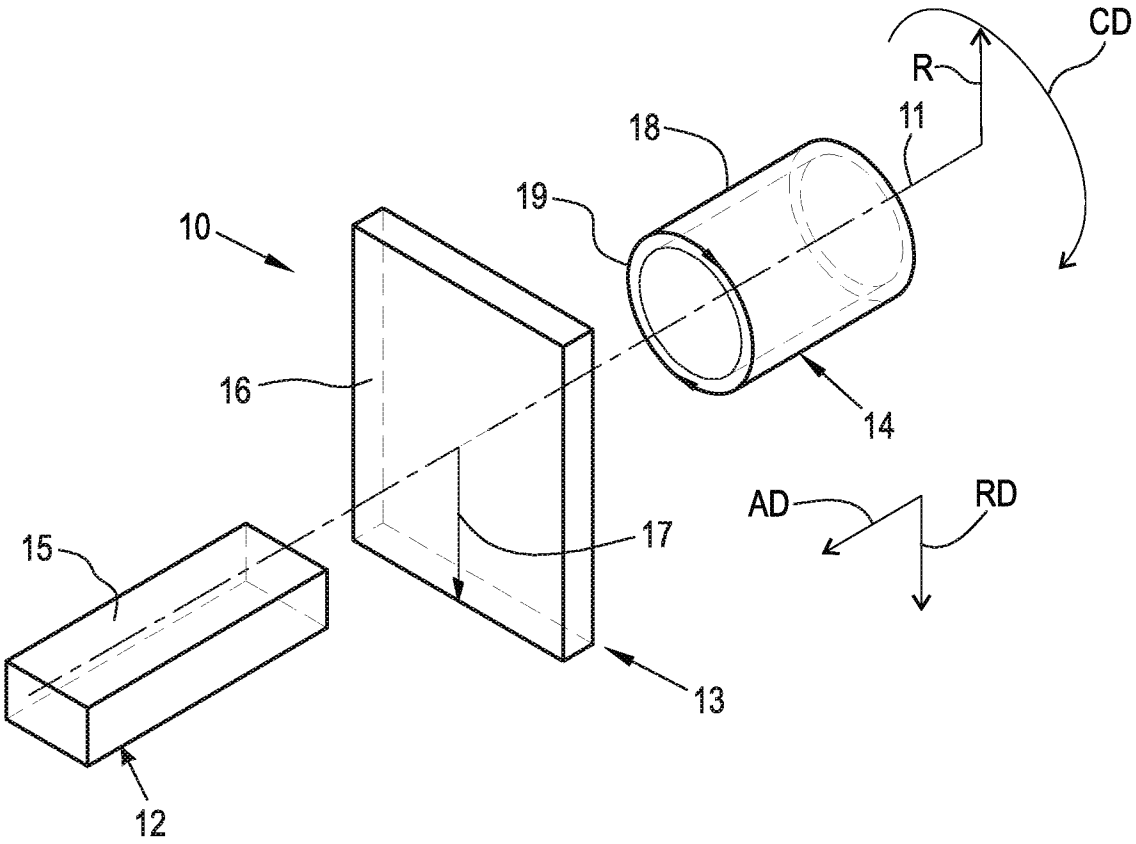


Fig. 1

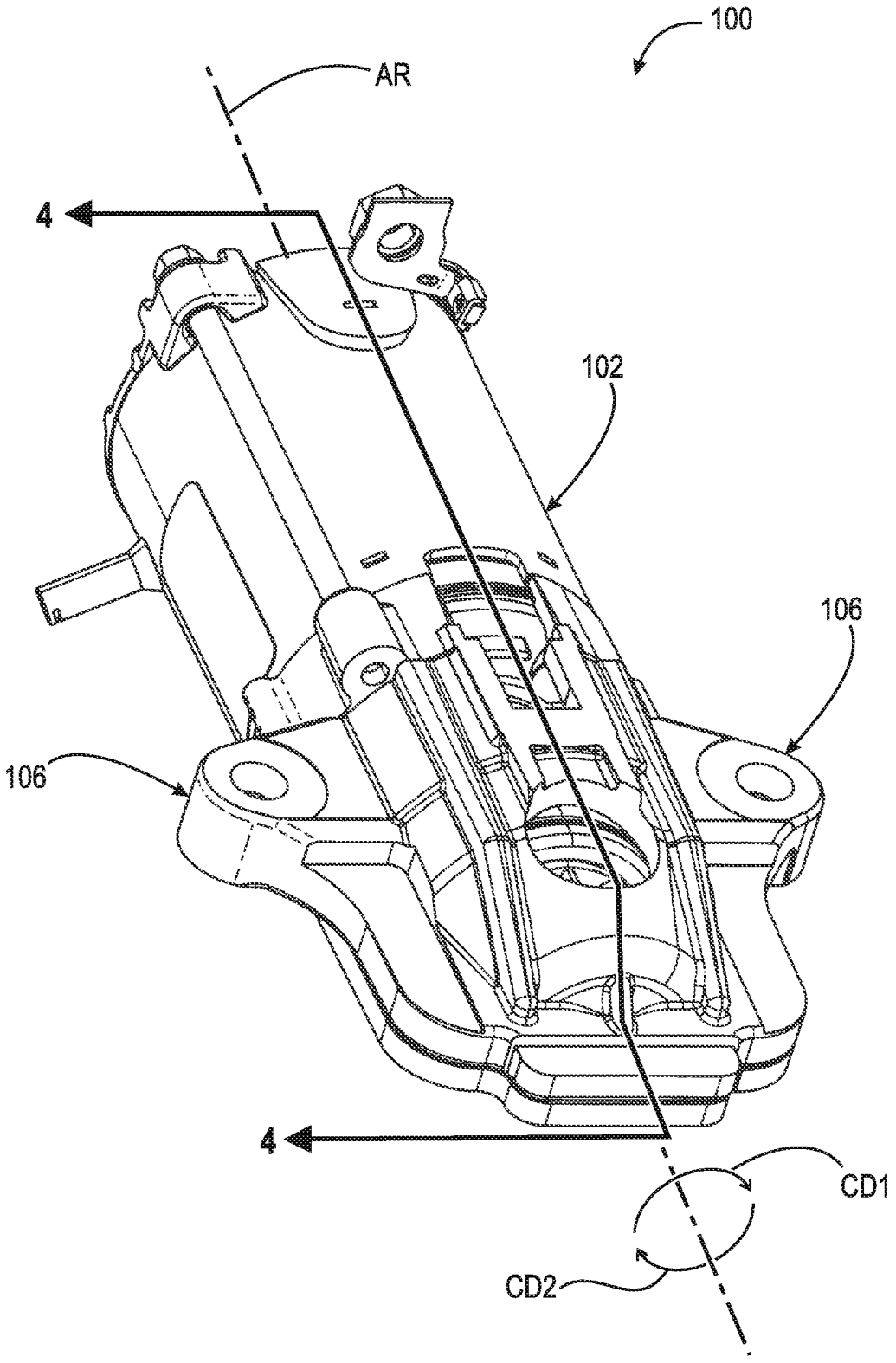


Fig. 2

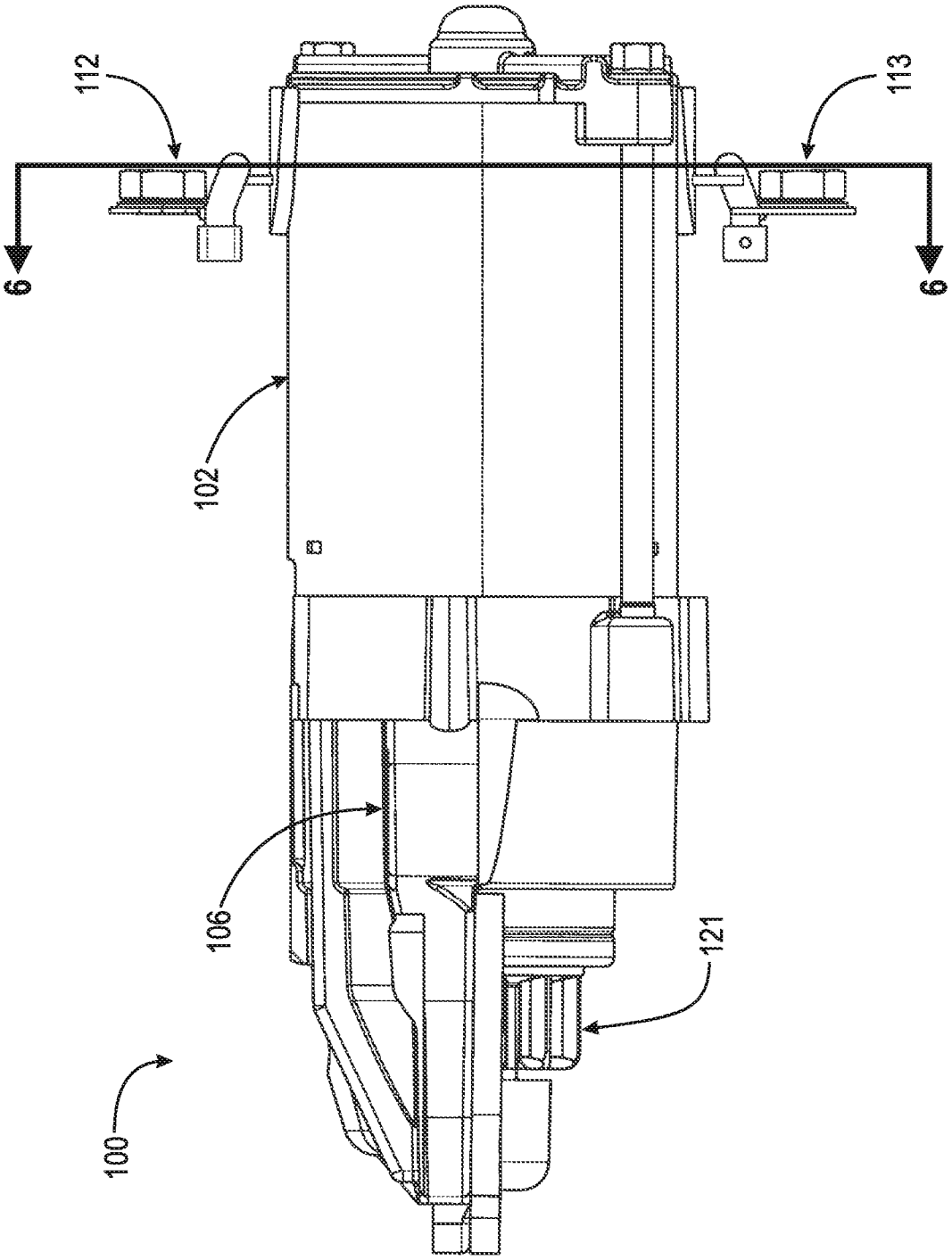


Fig. 3

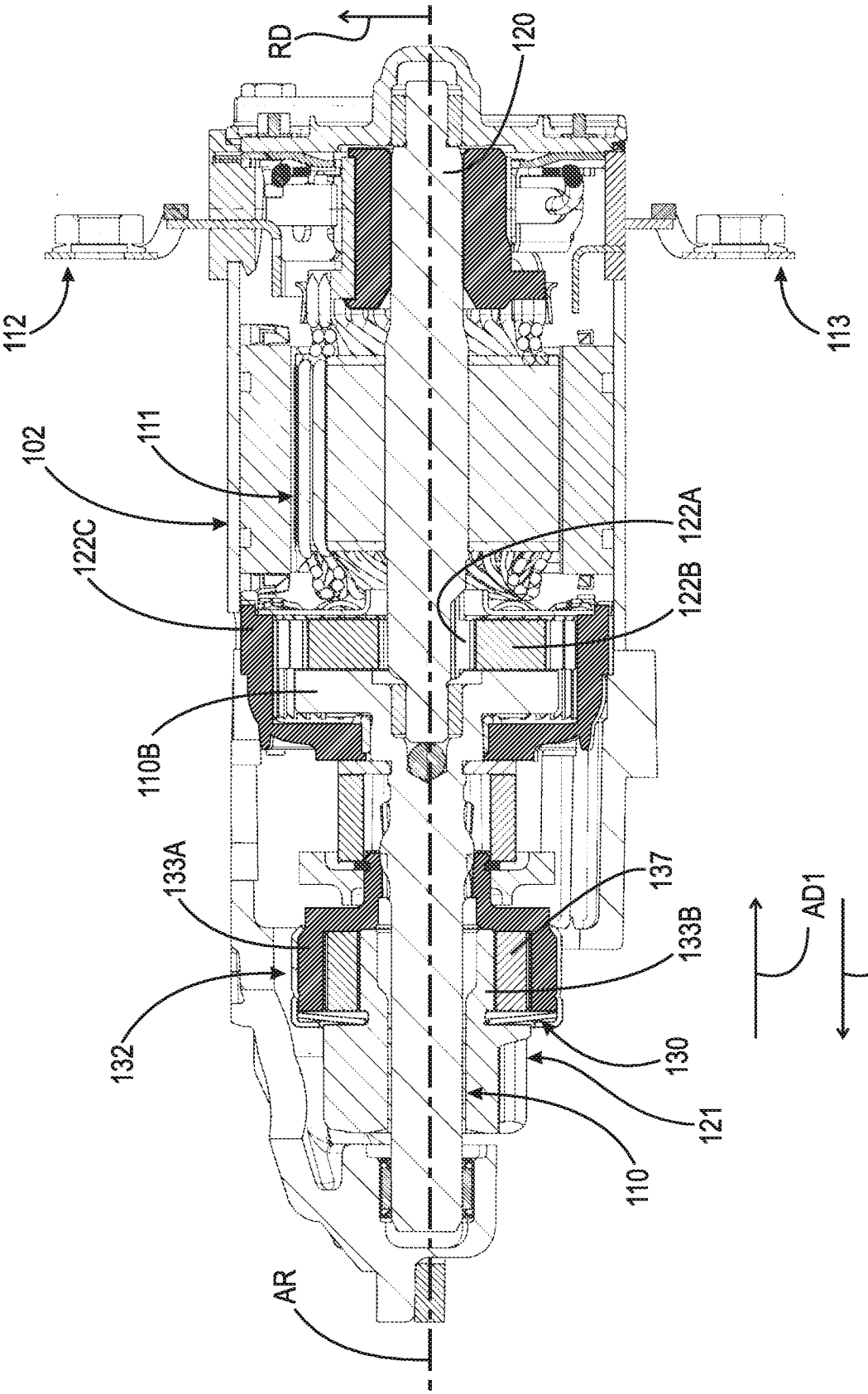

RD
120
112
113
102
111
122C
122A
122B
110B
133A
137
133B
132
130
121
110
AR
AD1
AD2

Fig. 4

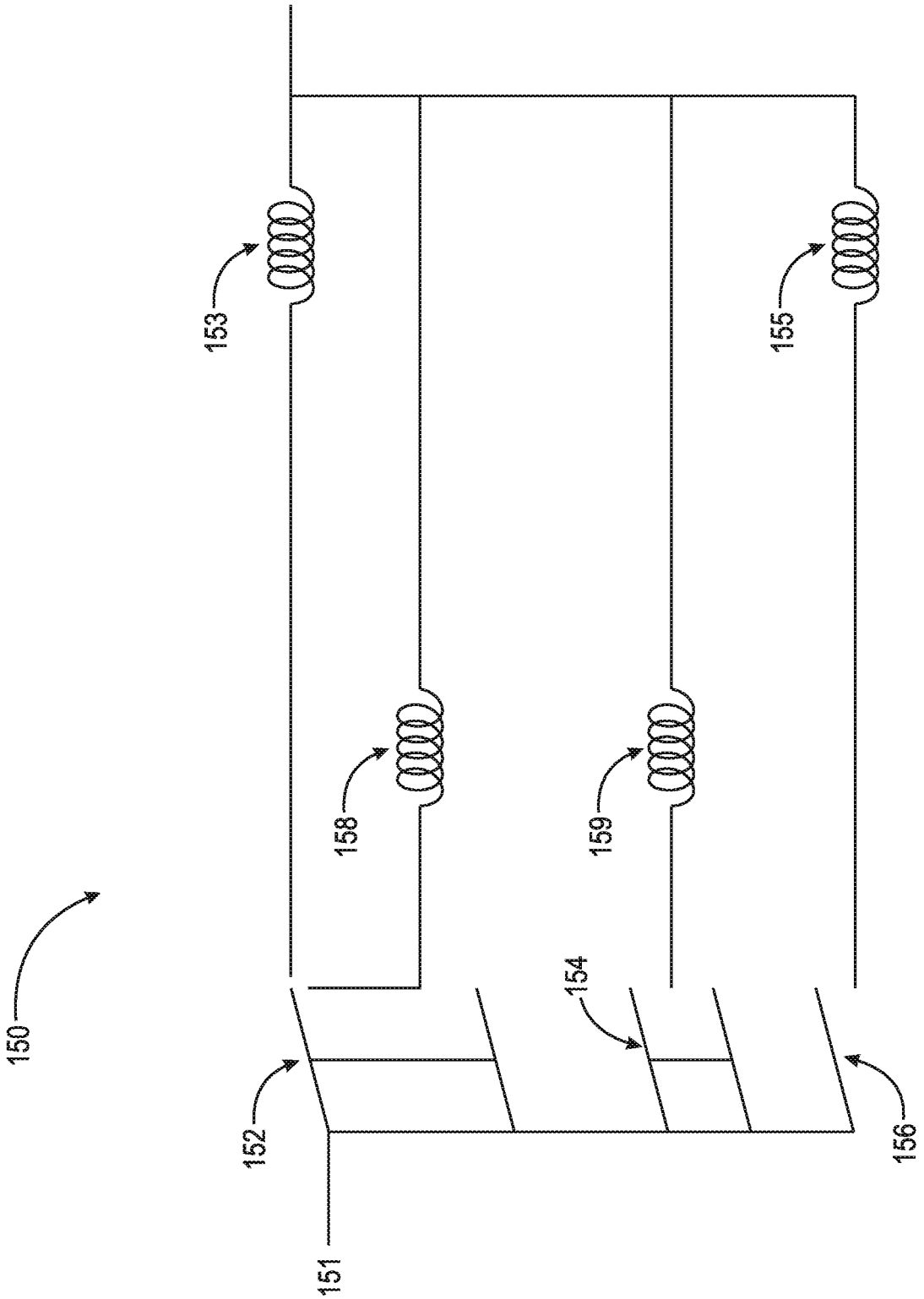


Fig. 5

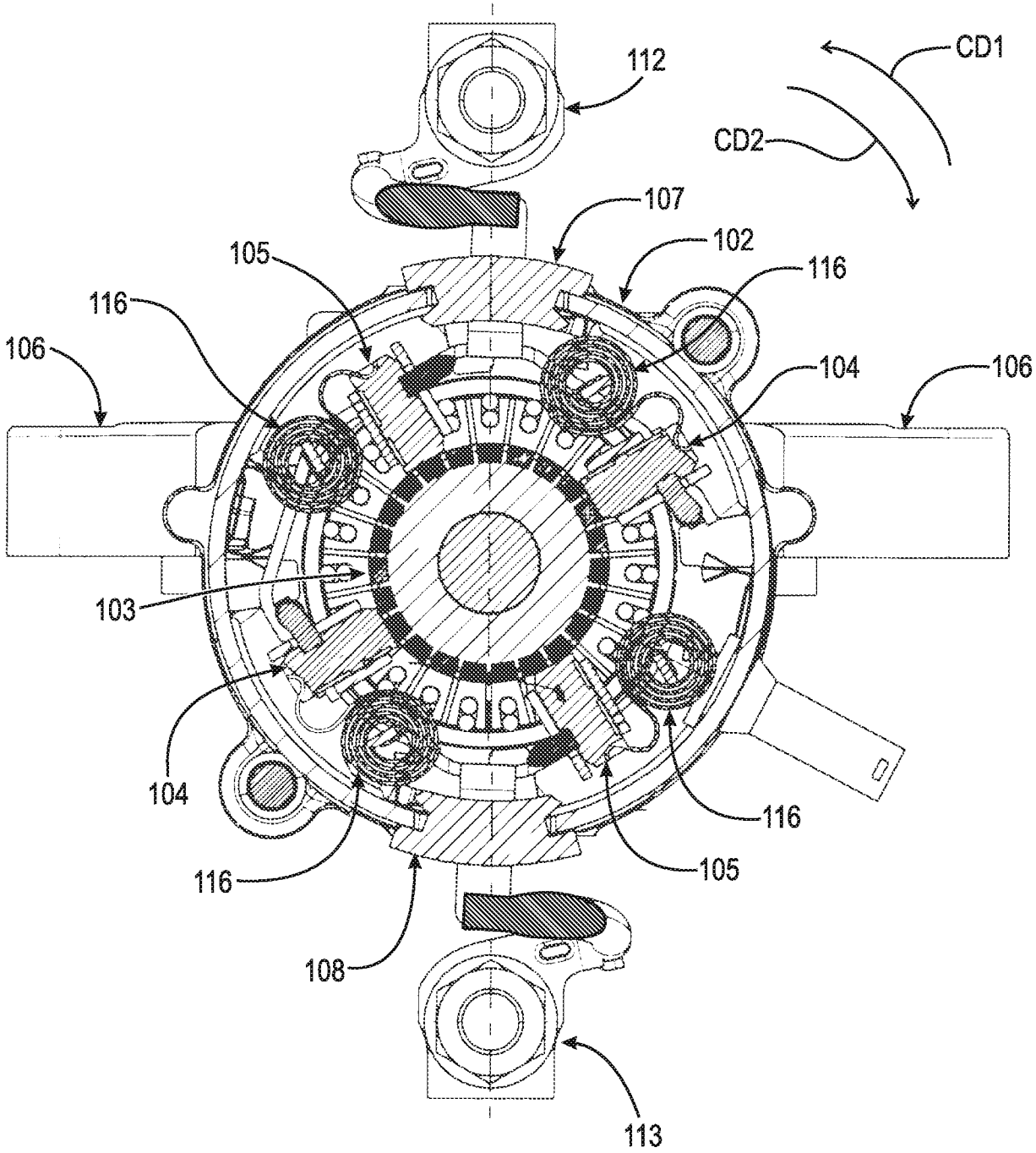

112
CD1
CD2
107
102
105
116
116
106
104
106
103
104
116
116
105
108
113

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/027704

A. CLASSIFICATION OF SUBJECT MATTER

F02N 11/08(2006.01)i, F02N 15/02(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)
F02N 11/08; F02N 15/02; F02N 11/00; F02D 29/02; F16D 41/066; H02P 9/14; F02N 5/04

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: engine starter, reversible motor, motor shaft, pinion gear, first direction, second direction, one-way clutch, spring, inner race and outer race

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4487173 A (MAUCHER et al.) 11 December 1984 See column 5, lines 57-63; column 7, lines 39-57; column 9, lines 17-22,; column 10, lines 6-68 and figures 1-3.	1-10
Y	JP 2008-240616 A (TOYOTA MOTOR CORP.) 09 October 2008 See paragraphs [0026], [0029]-[0031], [0038]-[0039] and figures 2-3.	1-10
Y	US 2014-0260796 A1 (ROBERT BOSCH GMBH) 18 September 2014 See paragraphs [0031]-[0032] and figures 1-3.	10
A	JP 4746624 B2 (VALEO EQUIPEMENTS ELECTRIQUES MOTEUR) 10 August 2011 See paragraphs [0032]-[0034] and figure 1.	1-10
A	US 2010-0294078 A1 (ONO et al.) 25 November 2010 See paragraphs [0003]-[0007], [0030]-[0032] and figures 1-4B.	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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