(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 September 2017 (08.09.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/151568 A1

(51) International Patent Classification:
F16H 63/06 (2006.01) *F16H 63/08* (2006.01)
F16H 15/28 (2006.01)

(21) International Application Number:
PCT/US2017/019861

(22) International Filing Date:
28 February 2017 (28.02.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/301,992 1 March 2016 (01.03.2016) US

(71) Applicant: **DANA LIMITED** [US/US]; P.O. Box 1000, Maumee, OH 43537 (US).

(72) Inventors: **KUMAR, Krishna**; 7420 Nightingale Drive, Holland, OH 43528 (US). **WALTZ, William, F.**; 3514 Northwood Avenue, Toledo, OH 43613 (US).

(74) Agents: **EVANS, Stephen, P.** et al.; Marshall & Melhorn, LLC, Four SeaGate - 8th Floor, Toledo, OH 43604 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: SHIFT ACTUATOR SYSTEM AND METHOD FOR A CONTINUOUSLY VARIABLE BALL PLANETARY TRANSMISSION HAVING A ROTATING AND/OR GROUNDED CARRIER

(57) **Abstract**: Devices and methods are provided herein for the transmission of power in motor vehicles. Power is transmitted in a smoother and more efficient manner by splitting torque into two or more torque paths. A continuously variable transmission is provided with a ball variator assembly having a plurality of tiltable balls supported in a carrier assembly. In some embodiments, the carrier assembly is configured to be rotatable and selectively grounded. A carrier skew shift actuator mechanism is configured to provide a means for adjusting the relative position of a first carrier member to a second carrier member of the carrier assembly to thereby adjust the operation of the continuously variable transmission.

WO 2017/151568 A1

SHIFT ACTUATOR SYSTEM AND METHOD FOR A CONTINUOUSLY VARIABLE BALL PLANETARY TRANSMISSION HAVING A ROTATING AND/OR GROUNDED CARRIER

RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application No. 62/301,992 filed on March 1, 2016 which is incorporated herein by reference in its entirety.

BACKGROUND

A driveline including a continuously variable transmission allows an operator or a control system to vary a drive ratio in a stepless manner, permitting a power source to operate at its most advantageous rotational speed.

SUMMARY

Provided herein is a continuously variable transmission including: a plurality of tiltable balls arrayed radially about a longitudinal axis of the transmission; a first carrier member having a first plurality of guide slots, the tiltable balls operably coupled to the first plurality of guide slots; a second carrier member having a second plurality of guide slots, the tiltable balls operably coupled to the second plurality of guide slots, wherein the second plurality of guide slots are radially offset from the first plurality of guide slots; a first traction ring assembly in contact with each tiltable ball; a second traction ring assembly in contact with each tiltable ball; and a carrier skew shift actuator mechanism including: a first helical gear coupled to the first carrier member; a second helical gear coupled to the second carrier member; and a driver shaft coupled to the first helical gear and the second helical gear; a disconnect mechanism operably coupled to the driver shaft, the disconnect mechanism positioned between the first helical gear and the second helical gear.

INCORPORATION BY REFERENCE

All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of the preferred embodiments are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present embodiments will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the preferred embodiments are utilized, and the accompanying drawings of which:

Figure 1 is a side sectional view of a ball-type variator.

Figure 2 is a plan view of a carrier member that is used in the variator of Figure 1.

Figure 3 is an illustrative view of different tilt positions of the ball-type variator of Figure 1.

Figure 4 is a schematic diagram of a continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism utilizing a disconnect mechanism.

Figure 5 is a schematic diagram of another continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism utilizing a brake clutch.

Figure 6 is a schematic diagram of yet another continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism utilizing a clutch-brake unit.

Figure 7 is a schematic diagram of yet another continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism utilizing a force multiplying device.

Figure 8 is a schematic diagram of yet another continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism and a torsion spring.

Figure 9 is a schematic diagram of yet another continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism.

Figure 10 is a schematic diagram of yet another continuously variable transmission of the ball-type depicted in Figures 1-3 having a carrier skew shift actuator mechanism.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments will now be described with reference to the accompanying figures, wherein like numerals refer to like elements throughout. The terminology used in the descriptions below is not to be interpreted in any limited or restrictive manner simply because it is used in conjunction with detailed descriptions of certain specific embodiments. Furthermore, embodiments includes several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the preferred embodiments described.

Provided herein are configurations of CVTs based on a ball type variators, also known as CVP, for continuously variable planetary. Basic concepts of a ball type Continuously Variable Transmissions are described in United States Patent No. 8,469,856 and 8,870,711 incorporated herein by reference in their entirety. Such a CVT, adapted herein as described throughout this specification, comprises a number of balls (planets, spheres) 1, depending on the application, two ring (disc) assemblies with a conical surface in contact with the balls, an input traction ring 2, an output traction ring 3, and an idler (sun) assembly 4 as shown on **FIG. 1**. The balls are mounted on tiltable axles 5, themselves held in a carrier (stator, cage) assembly having a first carrier member 6 operably coupled to a second carrier member 7. The first carrier member 6 rotates with respect to the second carrier member 7, and vice versa. In some embodiments, the first carrier member 6 is substantially fixed from rotation while the second carrier member 7 is configured to rotate with respect to the first carrier member, and vice versa. In some embodiments, the first carrier member 6 is provided with a number of radial guide slots 8. The second carrier member 7 is provided with a number of radially offset guide slots 9, as illustrated in **FIG. 2**. The radial guide slots 8 and the radially offset guide slots 9 are adapted to guide the tiltable axles 5. The axles 5 are adjusted to achieve a desired ratio of input speed to output speed during operation of the CVT. In some embodiments, adjustment of the axles 5 involves control of the position of the first and second carrier members to impart a tilting of the axles 5 and thereby adjusts the speed ratio of the variator. Other types of ball CVTs also exist, but are slightly different.

The working principle of such a CVP of FIG. 1 is shown on **FIG. 3**. The CVP itself works with a traction fluid. The lubricant between the ball and the conical rings acts as a solid at high pressure, transferring the power from the input ring, through the balls, to the output ring. By tilting the balls' axes, the ratio is changed between input and output. When the axis is horizontal the ratio is one, illustrated in **FIG. 3,** when the axis is tilted the distance between the axis and the contact point change, modifying the overall ratio. All the balls' axes are tilted at the same time with a mechanism included in the carrier and/or idler. Embodiments disclosed here are related to the control of a variator and/or a CVT using generally spherical planets each having a tiltable axis of rotation that are adjusted to achieve a desired ratio of input speed to output speed during operation. In some embodiments, adjustment of said axis of rotation involves angular misalignment of the planet axis in a first plane in order to achieve an angular adjustment of the planet axis in a second plane that is substantially perpendicular to the first plane, thereby adjusting the speed ratio of the variator. The angular misalignment in the first plane is referred to here as “skew”, “skew angle”, and/or “skew condition”. In some embodiments, a control system coordinates the use of a skew angle to generate forces between certain contacting components in the variator that will tilt the planet axis of rotation. The tilting of the planet axis of rotation adjusts the speed ratio of the variator.

For description purposes, the term “radial” is used here to indicate a direction or position that is perpendicular relative to a longitudinal axis of a transmission or variator. The term “axial” as used here refers to a direction or position along an axis that is parallel to a main or longitudinal axis of a transmission or variator. For clarity and conciseness, at times similar components labeled similarly (for example, bearing 1011A and bearing 1011B) will be referred to collectively by a single label (for example, bearing 1011).

As used here, the terms “operationally connected,” “operationally coupled”, “operationally linked”, “operably connected”, “operably coupled”, “operably linked,” “operably coupleable” and like terms, refer to a relationship (mechanical, linkage, coupling, etc.) between elements whereby operation of one element results in a corresponding, following, or simultaneous operation or actuation of a second element. It is noted that in using said terms to describe inventive embodiments, specific structures or mechanisms that link or couple the elements are typically described. However, unless otherwise specifically stated, when one of said terms is used, the term indicates that the actual linkage or coupling take a variety of forms, which in certain instances will be readily apparent to a person of ordinary skill in the relevant technology.

It should be noted that reference herein to “traction” does not exclude applications where the dominant or exclusive mode of power transfer is through “friction.” Without attempting to establish a categorical difference between traction and friction drives here, generally these may be understood as different regimes of power transfer. Traction drives usually involve the transfer of power between two elements by shear forces in a thin fluid layer trapped between the elements. The fluids used in these applications usually exhibit traction coefficients greater than conventional mineral oils. The traction coefficient (μ) represents the maximum available traction force which would be available at the interfaces of the contacting components and is the ratio of the maximum available drive torque per contact force. Typically, friction drives generally relate to transferring power between two elements by frictional forces between the elements. For the purposes of this disclosure, it should be understood that the CVTs described here operate in both tactive and frictional applications. For example, in the embodiment where a CVT is used for a bicycle application, the CVT operates at times as a friction drive and at other times as a traction drive, depending on the torque and speed conditions present during operation.

As used here, the term infinitely variable transmission (IVT) is a type of continuously variable transmission (CVT) that is capable of shifting to a ratio of zero speed at one of the driving elements. An IVT comprises a CVT and all of the claims herein pertain to both CVTs and IVTs that use a continuously variable planetary (CVP). It should be appreciated that the mechanisms described herein operate in multiple modes, for example, an IVT mode, a CVT mode, or some combination thereof such as a planetary differential mode or an operating mode with all nodes or components of the CVP are free to rotate.

Referring now to **FIG. 4**, in some embodiments, a continuously variable transmission (CVT) 10 includes a CVP of the type described in FIGS. 1-3. The CVT 10 has a first carrier member 11 and a second carrier member 12 each configured to support a number of balls. The CVT 10 has a first traction ring assembly 13 and a second traction ring assembly 14 coupled to each ball. The CVT 10 has a sun assembly 15 coupled to each ball. The sun assembly 15 is positioned radially inward of each ball. The CVT 10 has a first rotatable shaft 16 coupled to the second carrier member 12. In some embodiments, the sun assembly 15 is rotatably supported on the first rotatable shaft 16 with a bearing, for example. The first second carrier member 11 is rotatably supported on the first rotatable shaft 16 with a bearing, for example. The CVT 10 has a second rotatable shaft 17 coupled to the first traction ring assembly 13. The CVT 10 has a third rotatable shaft 18 coupled to the second traction ring assembly 14. The second rotatable shaft 17 and the third rotatable shaft 18 are optionally configured to be rotatably supported with bearings (not shown) on the first rotatable shaft 16. The CVT 10 has a first axial thrust bearing 19 coupled to the first traction ring assembly 13 and a grounded member of the transmission, such as a housing (not shown). The CVT 10 has a second axial thrust bearing 20 coupled to the second traction ring assembly 14 and a grounded member of the transmission, such as a housing (not shown). In some embodiments, the CVT 10 is optionally configured with a selectable torque transmitting device 21 operably coupled to the first carrier member 11 and the first traction ring assembly 13. In some embodiments, the selectable torque transmitting device 21 is a one-way clutch such as a common roller clutch or a sprag clutch, among others. In some embodiments, the selectable torque transmitting device 21 is a bi-directional clutch configured to constrain the speed of the first carrier member 11 with respect to the first traction ring assembly 13. The first rotatable shaft 16, the second rotatable shaft 17, and the third rotatable shaft

18 are each configured to transmit or receive rotational power. In some embodiment, the first rotatable shaft 16 and the second rotatable shaft 17 are optionally configured to couple to a source of rotational power such as an engine, an electric motor, generator, flywheel, auxiliary power devices (fans, air conditioners, pumps), energy storage devices, upstream or downstream gearing, among others. In some embodiments, the third rotatable shaft 18 is configured to couple to a driven component. In some embodiments, the third rotatable shaft 18 is optionally configured to receive a power input from a source of rotational power. In some embodiments, the first rotatable shaft 16 or the second rotatable shaft 17 are configured to be selectively grounded from rotation. It should be appreciated, that additional gearing, chain drives, or countershafts are optionally configured to be used in the embodiments disclosed herein.

Still referring to **FIG. 4**, in some embodiments, the CVT 10 is provided with a carrier skew shift actuator mechanism 30. The carrier skew shift actuator mechanism 30 includes a driver shaft 31 adapted to rotate and to translate axially. The carrier skew shift actuator mechanism 30 includes a first helical gear 32 and a second helical gear 33 coupled to the driver shaft 31. The first helical gear 32 is coupled to the first carrier member 11. In some embodiments, the first helical gear 32 has helical teeth engaged with the first carrier member 11. The second helical gear 33 is coupled to the second carrier member 12. In some embodiments, the second helical gear 33 has helical teeth engaged with the second carrier member 12. The first helical gear 32 and the second helical gear 33 have helical teeth with different helix angles. In some embodiments, the first helical gear 32 has straight teeth and the second helical gear 33 has angle teeth. In some embodiments, the first helical gear 32 and the second helical gear 33 have common pitch diameters. In some embodiments, the carrier skew shift actuator mechanism 30 includes an actuator 34 coupled to the driver shaft 31. In some embodiments, the actuator 34 is an electrical motor adapted to provide axial translation of the driver shaft 31. In some embodiments, the actuator 34 incorporates an electromagnetic, hydraulic, pneumatic, or electromechanical actuation system equipped with or without a mechanical locking mechanism such as a lead screw. In some embodiments, the CVT 10 includes a disconnect mechanism 35 coupled to the driver shaft 31. The disconnect mechanism 35 is positioned between the first helical gear 32 and the second helical gear 33. The disconnect mechanism 35 is configured to selectively engage and disengage the first helical gear 32 and the second helical gear 33 to selectively control the feedback torque between the first carrier member 11 and the second carrier member 12. In some embodiments, the skew shift actuator mechanism 30 is operably coupled to a motor/generator or other electrical, mechanical, or hydraulic machine (not shown) configured to control speed to a zero speed condition.

During operation of the CVT 10, an adjustment in the ratio of the input speed to output speed corresponds to a relative rotation of the first carrier member 11 with respect to the second carrier member 12. The carrier skew shift actuator mechanism 30 facilitates the relative rotation of the first carrier member 11 with respect to the second carrier member 12. For example, an axial translation of the driver shaft 31 corresponds to an axial translation of the second helical gear 33 to thereby rotate the first carrier member 11 with respect to the second carrier member 12. It should be appreciated that the selection of the helical angle of the gear teeth on the first helical gear 32 and the second helical gear 33 is within a designer's choice to produce a desired phasing of the first carrier member 11 and the second carrier member 12. During operation of the CVT 10, an electronic control system (not shown) is configured to control the selective engagement of the disconnect mechanism 35 to engage and disengage the first helical gear 32 with the second helical gear 33. In some embodiments, the electronic control system is configured to control the actuator 34. In some embodiments, the actuator 34 is a lead screw type actuator having an integral position sensor. The electronic control system is optionally configured to monitor the signal from the position sensor corresponding to a position of the driver shaft 31. In some embodiments, the electronic control system is optionally configured to monitor the relative position of the first helical gear 32 with respect to the second helical gear 33 using any position sensing mechanism, a calculation within the control software, or any combination thereof.

Turning now to **FIGS. 5 and 6**, in some embodiments, a continuously variable transmission (CVT) 40 is configured in a substantially similar way to the CVT 10. For description purposes, only the differences between the CVT 40 and the CVT 10 will be described. In some embodiments, the CVT 40 includes a braking mechanism 41 coupled to the driver shaft 31. In some embodiments, the braking mechanism 41 is configured to be a mechanical brake. In some embodiments, the braking mechanism 41 is configured to be an electro-mechanical, electro-magnetic, or hydraulic braking mechanism. In some embodiments, a continuously variable transmission (CVT) 50 is configured in a substantially similar way to the CVT 10. For description purposes, only the differences between the CVT 50 and the CVT 10 will be described. In some embodiments, the CVT 50 includes a clutch-brake unit 51 coupled to the driver shaft 31 and positioned between the first helical gear 32 and the second gear helical 33. In some embodiments, the clutch-brake unit 51 operates as a clutch when engaged in a first position, and operates as a brake when engaged in a second position. In some embodiments, the clutch-brake unit 51 is a typical clutch with a band brake surrounding the clutch. In some embodiments, the clutch-brake unit 51 is an electric/electromagnetic device configured to be controlled by an electronic control system (not shown).

Referring now to **FIG. 7**, in some embodiments, a continuously variable transmission (CVT) 60 is configured in a substantially similar way to the CVT 50. For description purposes, only the differences between the CVT 60 and the CVT 50 will be described. In some embodiments, the CVT 60 includes force multiplying mechanism 61 coupled to the driver shaft 31 and the actuator 34. The force multiplying mechanism 61 is configured to provide a mechanical advantage between the actuator 34 and the driver shaft 31. In some embodiments, the force multiplying mechanism 61 is a cam-and-follower mechanism. In some embodiments, the force multiplying mechanism 61 is a ball-ramp cam mechanism. In some embodiments, the force multiplying mechanism 61 is configured with a lead screw mechanism.

Referring now to **FIG. 8**, in some embodiments, a continuously variable transmission (CVT) 70 is configured in a substantially similar way to the CVT 60. For description purposes, only the differences between the CVT 70 and the CVT 60 will be described. In some embodiments, the CVT 70 includes a torsion spring 71 operably coupled to the first carrier member 11 and the second carrier member 12. During operation of the CVT 70, the torsion spring 71 applies a spring torque to the first carrier member 11 and the second carrier member 12 to bias the first carrier member 11 to a position relative to the second carrier member 12.

Passing now to **FIG. 9**, in some embodiments, a continuously variable transmission (CVT) 80 is configured in a substantially similar way to the CVT 60. For description purposes, only the differences between the CVT 80 and the CVT 60 will be described. In some embodiments, the CVT 80 includes a torsion spring 81 operably coupled to the first carrier member 11 and the second carrier member 12. During operation of the CVT 80, the torsion spring 81 applies a spring torque to the first carrier member 11 and the second carrier member 12 to bias the first carrier member 11 to a position relative to the second carrier member 12. In some embodiments, the CVT 80 includes an actuator gear 82 coupled to an actuator shaft 83. The actuator shaft 83 is coupled to the actuator 34. During operation of the CVT 80, the actuator gear 82 provides a mechanical advantage for driving the second helical gear 33.

Referring now to **FIG. 10,** in some embodiments, a continuously variable transmission (CVT) 90 is configured in substantially similar way as the CVT 50. For description purposes, only the differences between the CVT 90 and the CVT 50 will be described. In some embodiments, the

CVT 90 includes a second disconnect mechanism 91 coupled to the driver shaft 31. The CVT 90 includes a first transfer gear 92 coupled to the driver shaft 31. The second disconnect mechanism 91 is position between the first helical gear 32 and the first transfer gear 92. The first transfer gear 92 engages a second transfer gear 93. The second transfer gear 93 is coupled to the second rotatable shaft 17 and thereby the first traction ring assembly. During operation of the CVT 90, the second disconnect mechanism 91 is selectively engaged to control the transmission of rotatable power from the driver shaft 31 to and from the second rotatable shaft 17. The disconnect mechanism 91 is disengaged when the clutch-brake unit 51 is engaged as a brake. In some embodiments, the disconnect mechanism 91 is a clutch. In some embodiments, the first transfer gear 92 and the second transfer gear 93 are optionally configured to be a planetary gear set having a ring gear, planet carrier, and sun gear such that a defined speed differential is introduced between the first traction ring and the first carrier member of the CVT. It should be appreciated that any type of clutching, gearing, hydrodynamic, hydro-mechanical or electrodynamic mechanism that introduces a speed differential between the first traction ring and the first carrier member of the CVT is an optional configuration.

It should be noted that the description above has provided dimensions for certain components or subassemblies. The mentioned dimensions, or ranges of dimensions, are provided in order to comply as best as possible with certain legal requirements, such as best mode. However, the scope of the preferred embodiments described herein are to be determined solely by the language of the claims, and consequently, none of the mentioned dimensions is to be considered limiting on the inventive embodiments, except in so far as any one claim makes a specified dimension, or range of thereof, a feature of the claim.

While preferred embodiments have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the preferred embodiments. It should be understood that various alternatives to the embodiments described herein may be employed in practicing the preferred embodiments. It is intended that the following claims define the scope of the preferred embodiments and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

WHAT IS CLAIMED IS:

1. A continuously variable transmission comprising:
   a plurality of tiltable balls arrayed radially about a longitudinal axis of the transmission;
   a first carrier member having a first plurality of guide slots, the tiltable balls operably coupled to the first plurality of guide slots;
   a second carrier member having a second plurality of guide slots, the tiltable balls operably coupled to the second plurality of guide slots, wherein the second plurality of guide slots are radially offset from the first plurality of guide slots;
   a first traction ring assembly in contact with each tiltable ball;
   a second traction ring assembly in contact with each tiltable ball; and
   a carrier skew shift actuator mechanism comprising:
      a first helical gear coupled to the first carrier member;
      a second helical gear coupled to the second carrier member; and
      a driver shaft coupled to the first helical gear and the second helical gear;
   a disconnect mechanism operably coupled to the driver shaft, the disconnect mechanism positioned between the first helical gear and the second helical gear.
2. The continuously variable transmission of Claim 1, wherein an axial translation of the driver shaft corresponds to a relative rotation of the first carrier member with respect to the second carrier member.
3. The continuously variable transmission of Claim 1, further comprising a braking mechanism coupled to the driver shaft.
4. The continuously variable transmission of Claim 3, wherein the braking mechanism and the disconnect mechanism are integrated as a clutch-brake unit.
5. The continuously variable transmission of Claim 4, further comprising an actuator operably coupled to the driver shaft, the actuator configured to translate the driver shaft axially.
6. The continuously variable transmission of Claim 5, further comprising a force multiplying mechanism operably coupled to the actuator and the driver shaft.
7. The continuously variable transmission of Claims 5 or 6, further comprising a torsion spring coupled to the first carrier member and the second carrier member.

8. The continuously variable transmission of Claim 7, further comprising an actuator gear coupled to an actuator shaft, the actuator shaft coupled to the actuator, the actuator gear coupled to the first helical gear.
9. The continuously variable transmission of Claim 4, further comprising a second disconnect mechanism coupled to the driver shaft.
10. The continuously variable transmission of Claim 9, further comprising a first transfer gear coupled to the driver shaft, wherein the second disconnect mechanism is positioned between the first transfer gear and the first helical gear.
11. The continuously variable transmission of Claim 10, further comprising a second transfer gear operably coupled to the first traction ring assembly.

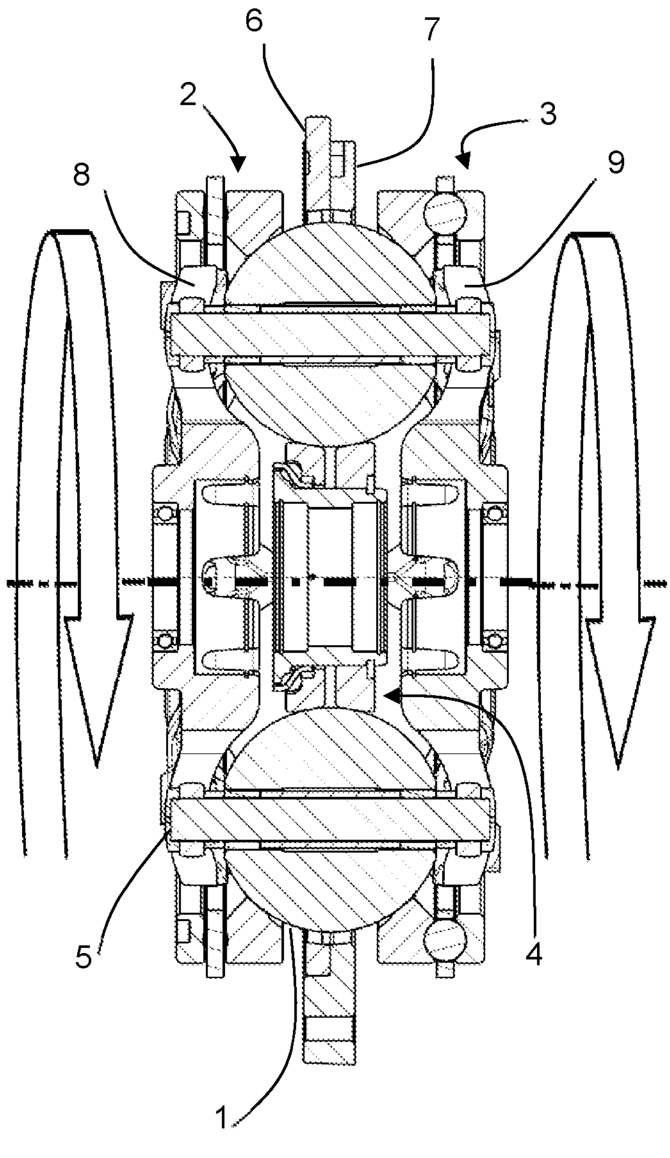


Figure 1

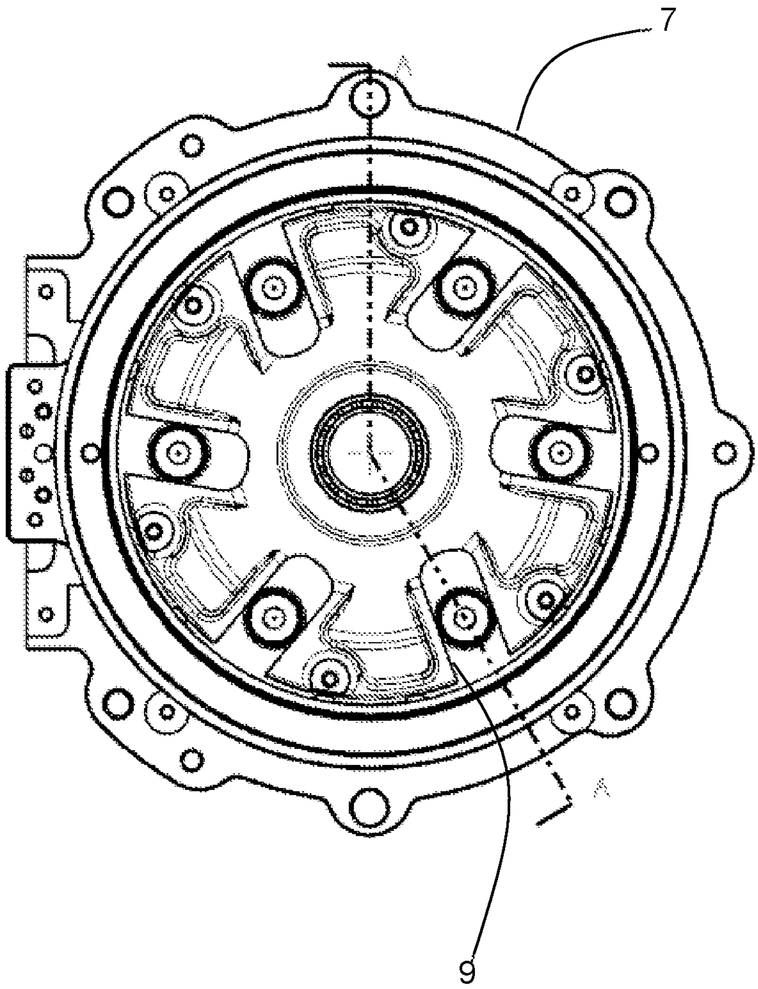
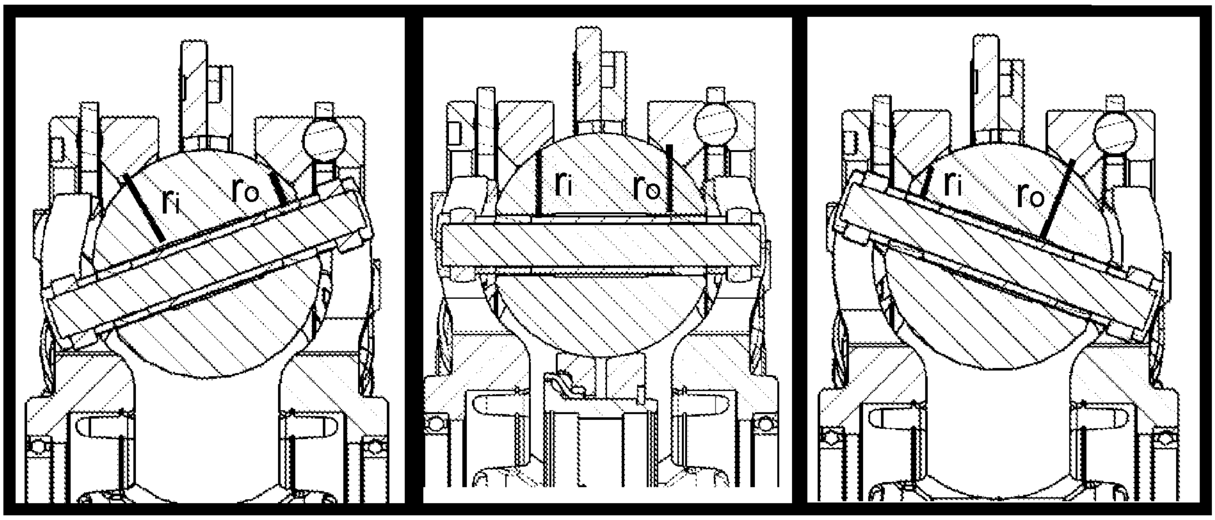


Figure 2



$r_i > r_o$
Underdrive

$r_i = r_o$
1:1

$r_i < r_o$
Overdrive

Figure 3

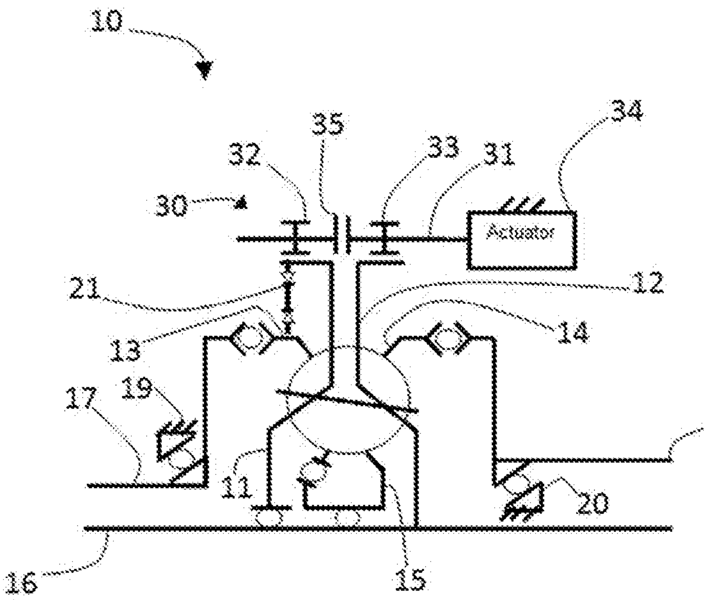


Figure 4

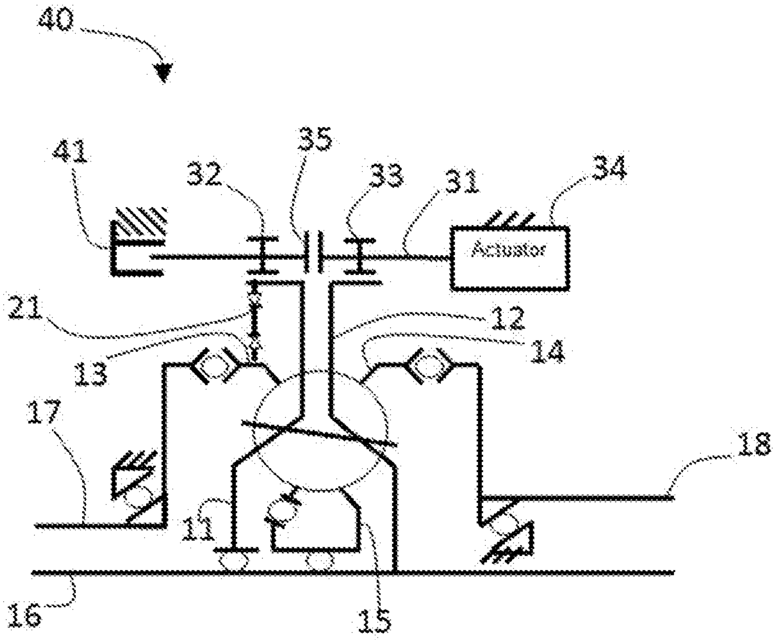


Figure 5

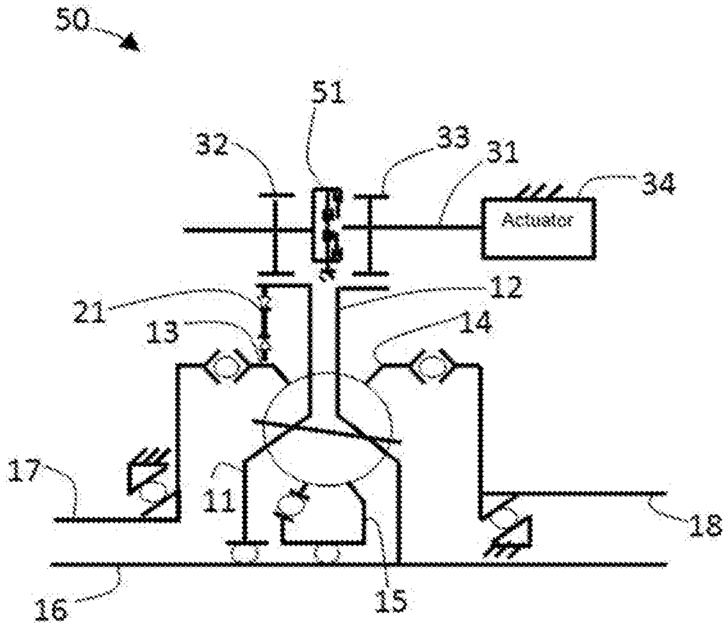


Figure 6

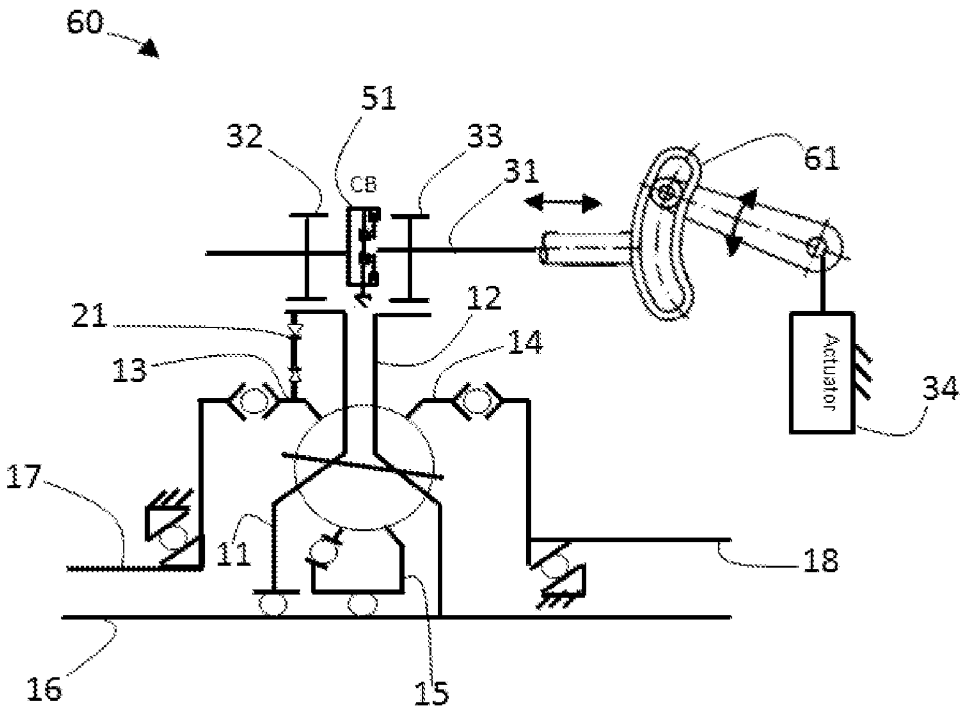


Figure 7

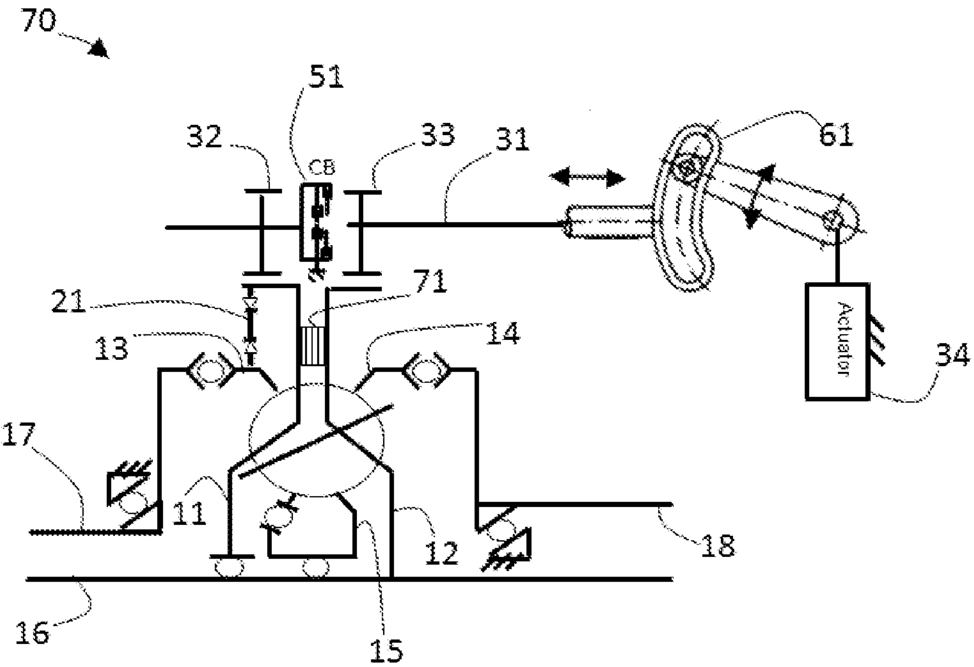


Figure 8

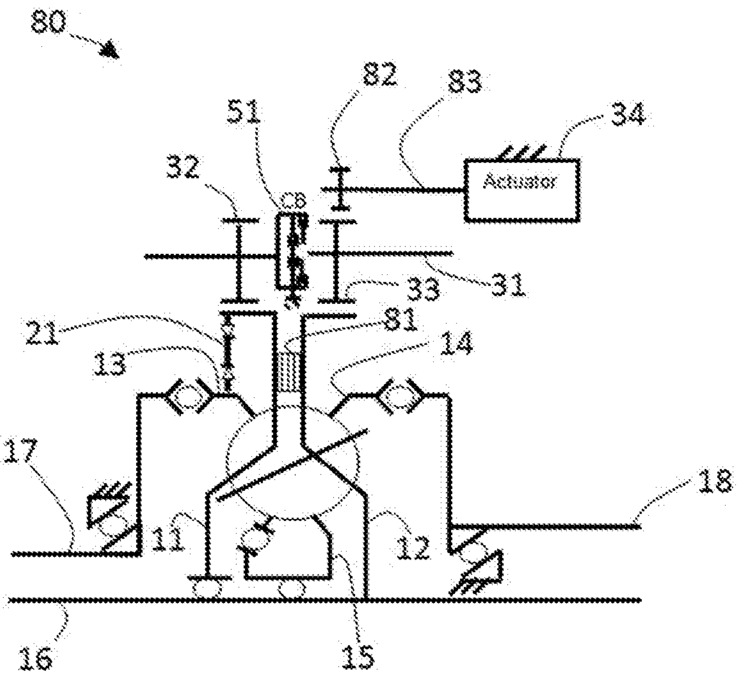


Figure 9

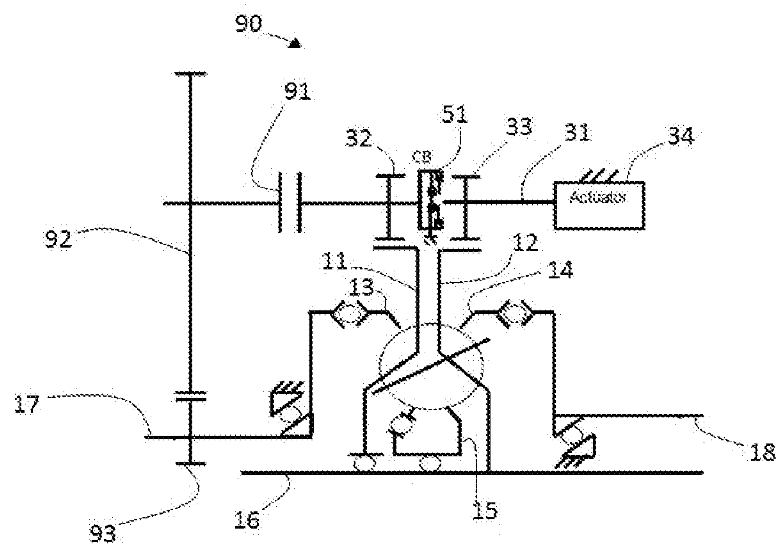


Figure 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/019861

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H63/06 F16H15/28 F16H63/08
ADD.

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)
F16H

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2015/345599 A1 (OGAWA HIROYUKI [JP]) 3 December 2015 (2015-12-03) paragraphs [0049], [0054], [0068] - [0070], [0076]; figures 2-4	1-4,6-11 5
Y	US 2010/267510 A1 (NICHOLS JON M [US] ET AL) 21 October 2010 (2010-10-21) paragraph [0150]; figure 54	5
A	WO 2010/044778 A1 (FALLBROOK TECHNOLOGIES INC [US]; THOMASSY FERNAND A [US]; LOHR CHARLES) 22 April 2010 (2010-04-22) paragraph [0154]; figure 51	1-11
A	US 2014/274551 A1 (YOUNGGREN BRUCE H [US] ET AL) 18 September 2014 (2014-09-18) paragraph [0068]; figure 4c	1-11

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 June 2017	11/07/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Martínez Hurtado, L

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/019861

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015345599 A1	03-12-2015	JP 5880624 B2	09-03-2016
		JP 2015227689 A	17-12-2015
		US 2015345599 A1	03-12-2015
US 2010267510 A1	21-10-2010	CA 2756273 A1	21-10-2010
		CA 2964358 A1	21-10-2010
		CN 102395814 A	28-03-2012
		DK 2419658 T3	13-01-2014
		EP 2419658 A1	22-02-2012
		EP 2669550 A1	04-12-2013
		ES 2439647 T3	24-01-2014
		JP 5668205 B2	12-02-2015
		JP 5994147 B2	21-09-2016
		JP 2012524225 A	11-10-2012
		JP 2015052395 A	19-03-2015
		JP 2016196963 A	24-11-2016
		KR 20120014133 A	16-02-2012
		KR 20170030660 A	17-03-2017
		RU 2011140072 A	27-05-2013
		TW 201043810 A	16-12-2010
		US 2010267510 A1	21-10-2010
		US 2013102434 A1	25-04-2013
		US 2014179479 A1	26-06-2014
		US 2016186847 A1	30-06-2016
		WO 2010120933 A1	21-10-2010
WO 2010044778 A1	22-04-2010	CA 2740194 A1	22-04-2010
		CA 2924145 A1	22-04-2010
		CN 102227577 A	26-10-2011
		DK 2342479 T3	26-08-2013
		DK 2620672 T3	24-08-2015
		EP 2342479 A1	13-07-2011
		EP 2620672 A1	31-07-2013
		ES 2423934 T3	25-09-2013
		ES 2545662 T3	14-09-2015
		JP 5335092 B2	06-11-2013
		JP 2012506001 A	08-03-2012
		KR 20110079884 A	11-07-2011
		RU 2011113409 A	27-11-2012
		WO 2010044778 A1	22-04-2010
US 2014274551 A1	18-09-2014	CA 2906343 A1	25-09-2014
		CN 105121904 A	02-12-2015
		EP 2971857 A1	20-01-2016
		US 2014274551 A1	18-09-2014
		WO 2014150012 A1	25-09-2014