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- (71) Applicant: DANA LIMITED [US/US]; P.O. Box 1000,
Maumee, OH 43537 (US).
- (72) Inventor: VERSTEYHE, Mark, R.J.; Rivierstraat 7, B-
8020 Oostkamp (BE).
- (74) Agent: HAVRANEK, Kristin; Wilson Sonsini Goodrich
& Rosati, 650 Page Mill Road, Palo Alto, CA 94304 (US).
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- (54) Title: IVT BASED ON A BALL TYPE CVP INCLUDING POWERSPLIT PATHS

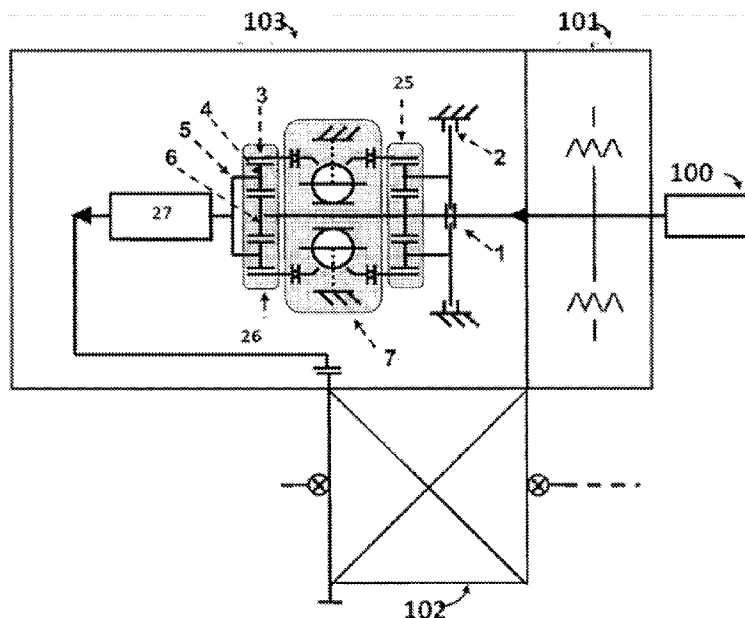


FIG. 4

(57) Abstract: A variable transmission includes an input shaft, two planetary gear sets, a first planetary set on the input side of a variator, and a second planetary set on the output side of the variator, to split the torque drivingly engaged with a variator comprising, a first ring assembly, a second ring assembly; various arrangements of brakes and clutches; a gearbox; and the output shaft to produce transmissions with continuously variable or infinitely variable torque output ratios.



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IVT BASED ON A BALL TYPE CVP INCLUDING POWERSPLIT PATHS**CROSS-REFERENCE**

[0001] This application claims the benefit of U.S. Provisional Application No. 61/697,960, filed September 7, 2012 and U.S. Provisional Application No. 61/784,255, filed March 14, 2013, which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] Automatic and manual transmissions are commonly used on automobile vehicles. Those transmissions are becoming more and more complicated since the engine speed has to be more precisely controlled to limit the fuel consumption and the emissions of cars. This finer control of the engine speed in usual transmissions can only be done by adding more discrete step ratio gears and increasing the overall complexity and cost. Consequently, 6-speed manual transmissions then become more frequently used as are 8 or 9 speed automatic transmissions.

SUMMARY OF THE INVENTION

[0003] Provided herein is a variable transmission comprising: an input shaft; two planetary gear sets, a first planetary set on the input side of a variator, and a second planetary set on the output side of the variator, to split the torque; a variator comprising, a first ring assembly, a second ring assembly; various arrangements of brakes and clutches; a gearbox; and the output shaft.

[0004] In some embodiments, the variable transmission comprises a continuously variable mode, an infinitely variable mode or a combination thereof.

[0005] In some embodiments the variable transmission can provide a reverse function, a standstill function and a low speed function.

[0006] In some embodiments, the transition between continuously variable transmission mode and infinitely variable transmission mode is accomplished by releasing the clutch and engaging the brake, or alternatively engaging the clutch and releasing the brake.

[0007] In some embodiments, the variator is able to continuously change its ratios in both the continuously variable mode and infinitely variable mode to provide the best ratio achievable for the engine to optimize power consumption.

[0008] Provided herein is a variable transmission comprising: an input shaft; a first planetary gear set comprising a sun gear drivingly engaged to the input shaft; a clutch member coupled to the input shaft for engaging the carrier of the first planetary gear set; a brake member

coupled to the carrier of the first planetary gear set; the ring of the input planetary gear set drivingly engaged to a first ring assembly of a variator; said variator comprising a first ring assembly, and a second ring assembly; said second variator ring assembly drivingly engaged to the ring of a second planetary gear set; wherein the second sun of the second planetary gear set is also drivingly engaged to the input shaft; and the carrier of said second planetary gear set is drivingly engaged to a gearbox; and said gearbox is mechanically connected to a differential.

[0009] In some embodiments, the power will pass through the variator while part of the power will pass directly from one planetary gear set to the other planetary gear set through a mechanical path with higher efficiency.

[0010] In some embodiments, when the clutch is engaged and the brake is disengaged the carrier of the input planetary is held fixed to the input shaft, the whole planetary gear set turning then with the input shaft, thereby engaging a continuously variable mode.

[0011] In some embodiments, the power passes directly through the entire first planetary gear set to the first ring assembly of the variator, combining with the output from the input shaft on the second sun of the second planetary gear set and the second ring assembly of the variator when the transmission is in continuously variable mode.

[0012] In some embodiments, the clutch is disengaged and the brake is engaged, the carrier of the first planetary gear is held while the first and second sun gears are still turning at the speed of the input shaft, thereby engaging an infinitely variable mode.

[0013] In some embodiments, the ring of the input planetary gear set carrier will turn in the reverse direction of the input shaft and in underdrive.

[0014] In some embodiments, the power output going to the gearbox can go from reverse speeds to positive speeds through standstill thereby providing an infinitely variable mode.

[0015] In some embodiments, when in the infinitely variable mode, the variator provides a reverse function, a standstill function and a low speed function.

[0016] In some embodiments, when in the infinitely variable mode, the first planetary provides a reverse function, a standstill function and a low speed function.

[0017] In some embodiments, when in the continuously variable mode, the ring of the planetary gear set has a positive rotation speed.

[0018] In some embodiments, when in the infinitely variable mode, the ring of the planetary gear set has a negative rotation speed.

[0019] In some embodiments, the transition between continuously variable mode and infinitely variable mode is accomplished by simultaneously closing the brake while releasing the clutch.

[0020] In some embodiments, the variator continuously changes its torque ratios in both the continuously variable mode and infinitely variable mode to optimize power consumption.

[0021] In some embodiments, the only interruptions of power are to change from continuous to infinitely mode and to change the gear ratio in the gearbox.

[0022] In some embodiments, a dry-clutch is not required between the input shaft and the variable transmission.

[0023] In some embodiments, a torque converter is not required between the input shaft and the variable transmission

[0024] Provided herein is a variable transmission comprising: an input shaft; a first planetary gear set comprising an input ring drivingly engaged to the input shaft; a carrier from a first planetary gear set mechanically connected through a clutch to the first ring assembly of a variator and the first sun of the first planetary gear set; said variator comprising a first ring assembly, and a second ring assembly; a brake member coupled to the carrier of the first planetary gear set; the second ring assembly of the variator drivingly connected to the second sun of a second planetary gear set; a countershaft drivingly connecting the rings of the first and second planetary gear sets, wherein said countershaft transfers power from one ring to the other; the carrier of the second planetary gear set drivingly connected to a gearbox; said gearbox mechanically linked to a differential

[0025] In some embodiments, the variable transmission comprises a continuously variable mode and an infinitely variable mode.

[0026] In some embodiments, the torque will be split between planetary gear sets on either side of the variator

[0027] In some embodiments, part of the power will pass through the variator while part of the power will pass from one planetary to the other through a mechanical path with higher efficiency.

[0028] In some embodiments, the clutch is engaged and the brake is disengaged, connecting the carrier and the first sun of the first planetary gear set, thereby engaging a continuously variable mode.

[0029] In some embodiments, the entire first planetary gear set is turning at the same speed as the input shaft and speed of the input shaft is directly applied to the first input ring assembly of the variator.

[0030] In some embodiments, the second planetary gear set combines the power from the input shaft on the ring with the output from the variator on the second sun of the second planetary set.

[0031] In some embodiments, the clutch is disengaged and the brake is engaged, holding the carrier of the first planetary gear set, thereby engaging an infinitely variable mode.

[0032] In some embodiments, the rings of the first and second planetary gear sets turn at engine speed, the first sun of the first planetary gear set will turn in reverse direction to the input shaft and in overdrive.

[0033] In some embodiments, the second planetary gear set in continuously variable mode whereby the power from the input shaft and output of the variator are combined, and the rotation of the second sun of the second planetary gear set is reversed.

[0034] In some embodiments, the output from the second planetary gear set going to the gear box provides reverse speeds to positive speeds through a standstill, thereby providing an infinitely variable mode.

[0035] In some embodiments, the first and second sun gears turn in a positive rotation when in a continuously variable mode.

[0036] In some embodiments, the first and second sun gears turn in a negative rotation when in an infinitely variable mode.

[0037] In some embodiments, a transition between continuously variable mode and infinitely variable mode is accomplished by simultaneously closing the brake while releasing the clutch.

[0038] In some embodiments, the vehicle output comprises a wheel differential and one or more wheels of a vehicle.

[0039] In some embodiments, the vehicle output comprises a wheel differential and a drive axle.

[0040] In some embodiments, the dampener is disposed between the engine and the variable transmission.

[0041] In some embodiments, the dampener comprises at least one torsional spring.

[0042] Provided herein is a method comprising providing a variable transmission of any of configuration described herein or obvious to one of skill in the art upon reading the disclosure

herein. In some embodiments, the variable transmission comprises a traction fluid in the variator.

[0043] Provided herein is a method comprising, providing a vehicle driveline of any of configuration described herein or obvious to one of skill in the art upon reading the disclosure herein.

INCORPORATION BY REFERENCE

[0044] 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

[0045] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0046] **Figure 1** is a side sectional view of a continuously variable planetary (CVP) transmission;

[0047] **Figure 2** is a magnified, side sectional view of a ball and ring of the CVP transmission of Figure 1;

[0048] **Figure 3** is a block diagram of a continuously variable transmission (CVT) used in an automobile;

[0049] **Figure 4** is a block diagram of a continuously variable transmission (CVT) according to an embodiment of the present disclosure used in an automobile having both a continuously variable mode and an infinitely variable mode;

[0050] **Figure 5** is a graph of a speed diagram of the output planetary gear set of the CVT of Figure 4;

[0051] **Figure 6** is a block diagram of a continuously variable transmission (CVT) according to another embodiment of the present disclosure used in an automobile having both a continuously variable mode and an infinitely variable mode;

[0052] **Figure 7** is a graph of a speed diagram of the output planetary gear set of the CVT of Figure 6.

DETAILED DESCRIPTION OF THE INVENTION

[0053] Continuously Variable Transmissions or CVTs are of many types: belts with variable pulleys, toroidal, and conical, for non-limiting example. The principle of a CVT is that it enables the engine to run at its most efficient rotation speed by changing steplessly the transmission ratio in function of the speed of the car and the torque demand (throttle position) of the driver. If needed for example when accelerating, the CVT can also shift to the most optimum ratio providing more power. A CVT can change the ratio from the minimum to the maximum ratio without any interruption of the power transmission, as opposed to the opposite of usual transmissions which require an interruption of the power transmission by disengaging to shift from one discrete ratio to engage the next ratio.

[0054] A specific use of CVTs is the Infinite Variable Transmission or IVT. Where the CVT is limited at positive speed ratios, the IVT configuration can perform a neutral gear and even reverse steplessly. A CVT can be used as an IVT in some driveline configurations.

[0055] Provided herein are configurations based on a ball type CVT, also known as CVP (for constant variable planetary) or a variator, herein. Aspects of an example CVT are described in US20040616399 or AU2011224083A1, incorporated herein by reference in their entirety. The type of CVT used herein is comprised a variator comprising a plurality of variator balls 997 (for example, 3-15 balls), depending on the application, two discs 995, 996 or annular rings (i.e. a first ring assembly and a second ring assembly) each having an engagement portion that engages the variator balls, as input and output respectively. The engagement portions may be in a conical or toroidal convex or concave surface contact with the variator balls, as input and output. The variator may include an idler 999 contacting the balls as well as shown on FIG. 1. The variator balls are mounted on axes 998, themselves held in a cage or carrier allowing changing the ratio by tilting the variator balls' axes. Other types of ball CVTs also exist, like the one produced by Milner but are slightly different. These alternative ball CVTs are additionally contemplated herein. The working principle generally speaking, of a ball-type variator of a CVT is shown in FIG. 2.

[0056] The variator 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 first ring assembly, through the variator balls, to the second ring assembly. By tilting the variator balls' axes, the ratio can be changed between input and output. When the axis of each of the variator balls is horizontal the ratio is one, when the axis is tilted the distance between the axis and the contact point change, modifying the overall ratio. For example, when the axis is

horizontal the ratio is one (1:1), when the axis is tilted the distance between the axis and the contact point change, modifying the overall ratio (input radius > output radius = underdrive; input radius < output radius = overdrive). All the variator balls' axles are tilted at the same time with a mechanism included in the cage.

[0057] In a car, the CVT 103 includes a CVP (continuously variable planetary) 7 and is used to replace traditional transmission and is located between the engine 100 and the differential 102 as shown on FIG. 3. A torsional damper 101 has to be introduced between the engine and the CVT 103 to avoid transferring torque peaks and vibrations that could seriously damage the CVT 103. In some configurations, this damper 101 can be coupled with a clutch for the starting function.

[0058] Embodiment variable transmissions (and resulting drivelines) 103 are shown in FIGS. 4 and 6. The central part of these configurations is a variator 7 (also called a CVP herein). Such variator 7 comprises a first ring assembly, a second ring assembly, and a carrier assembly disposed therebetween. The carrier assembly includes a plurality of variator balls having tiltable axle shafts as described herein. In some embodiments, the first ring assembly is rotatably disposed in a housing; the first ring assembly comprises a first variator ball engagement surface that is in driving engagement with a plurality of variator balls of the carrier assembly. The first ring assembly (shown on the right side of the variator embodiments of FIG. 4 and FIG.6) may be drivingly engaged with a ring of an input planetary gearset 25.

[0059] A first variator ball engagement surface is formed in a distal end of the first ring assembly. In some embodiments, the first variator ball engagement surface is a conical surface or a concave or convex toroidal surface in contact with or slightly spaced apart from each of the variator balls. In some embodiments, the first variator ball engagement surface is in driving engagement with each of the variator balls of the carrier assembly through one of a boundary layer type friction and an elastohydrodynamic film.

[0060] The carrier assembly of the variator of FIGS. 4 and 6 may be rotatably disposed in the housing. The carrier assembly comprises an annular arrangement of the plurality of tiltable variator balls each having tiltable ball axle shafts. In some embodiments, each of the ball axle shafts is adjusted using a cam style tilting mechanism. In some embodiments, each of the ball axle shafts is adjusted using a split carrier axle skewing mechanism.

[0061] As depicted in FIGS. 4 and 6, at least, a second ring assembly is rotatably disposed in the housing. The second ring assembly comprises a second variator ball engagement surface

that is in driving engagement with variator balls of the carrier assembly. In some embodiments, the second variator ball engagement surface is formed in a distal end of the second ring assembly. In some embodiments, the second variator ball engagement surface is a conical surface or a concave or convex toroidal surface in contact with or slightly spaced apart from each of the variator balls. In some embodiments, the second variator ball engagement surface is in driving engagement with each of the variator balls of the carrier assembly through one of a boundary layer type friction and an elastohydrodynamic film.

[0062] A ball ramp on each side of the variator provides the clamping force necessary to transfer the torque. Ball ramps, indicated in FIGS. 4 and 6 by a circle between a pair of vertical lines, making up a first thrust ring on the first ring assembly and a second thrust ring on the second ring assembly are disposed between components of the variable transmission as shown to generate an amount of axial force necessary for proper operation of the variable transmission (i.e. transfer of torque); however, it is understood that the amount of axial force necessary for proper operation may be generated by a clamping mechanism (not shown) or as a load applied during assembling of the variable transmission. Thus, as depicted in FIGS. 4 and 6, a ball ramp on each side of the variator provides the clamping force necessary to transfer the torque in this embodiment.

[0063] Provided herein is a variable transmission comprising: an input shaft; two planetary gear sets, a first planetary gear set 25 on the input side of a variator (i.e. the side comprising the first ring assembly), and a second planetary gear set 26 on the output side of the variator (i.e. the side comprising the second ring assembly) to split the torque; the variator of such variable transmission comprises a first ring assembly, a second ring assembly. The first planetary gear set 25 may alternatively be called the input planetary, or input planetary gear set herein. The second planetary gear set 26 may alternatively be called the output planetary, or output planetary gear set herein. The variable transmission may additionally comprise various arrangements of brakes and clutches; a gearbox 27; and an output shaft.

[0064] In some embodiments, the variable transmission comprises a continuously variable mode and an infinitely variable mode. In some embodiments the variable transmission can provide a reverse function, a standstill function and a low speed function.

[0065] In some embodiments, the transition between continuously variable transmission mode and infinitely variable transmission mode is accomplished by releasing a clutch and engaging a brake, or alternatively engaging the clutch and releasing the brake.

[0066] In some embodiments, the variator is able to continuously change its ratios in both the continuously variable mode and infinitely variable mode to provide the best ratio achievable for the engine to optimize power consumption.

[0067] Provided herein is a variable transmission comprising: an input shaft; a first planetary gear set comprising a sun gear drivingly engaged to the input shaft; a clutch member coupled to the input shaft for engaging the carrier of the first planetary gear set; a brake member coupled to the carrier of the first planetary gear set 25; the ring of the input planetary gear set drivingly engaged to a first ring assembly of a variator; said variator comprising a first ring assembly, and a second ring assembly; said second variator ring assembly drivingly engaged to the ring of a second planetary gear set 26; wherein the sun of said second planetary gear set 26 is also drivingly engaged to the input shaft; and the carrier of said second planetary gear set 26 is drivingly engaged to a gearbox 27; and said gearbox 27 is mechanically connected to a differential.

[0068] In some embodiments, the power will pass through the variator while part of the power will pass directly from the first planetary gear set 25 to the second planetary gear set 26 through a mechanical path with higher efficiency.

[0069] In some embodiments, when the clutch is engaged and the brake is disengaged the carrier of the first planetary gear set is held fixed together with the input shaft, the whole planetary turning then at the input shaft speed, thereby engaging a continuously variable mode.

[0070] In some embodiments, the power passes directly through the entire first planetary gear set to the first ring assembly of the variator, combining with the output from the input shaft on the second sun of the second planetary gear set and the second ring assembly of the variator when the transmission is in continuously variable mode.

[0071] In some embodiments, the clutch is disengaged and the brake is engaged, the carrier of the first planetary gear set is held while the first and second sun gears are still turning at the speed of the input shaft, thereby engaging an infinitely variable mode.

[0072] In some embodiments, the ring of the first planetary gear set will turn in the reverse direction of the input shaft and in underdrive.

[0073] In some embodiments, the power output going to the gearbox can go from reverse speeds to positive speeds through standstill thereby providing an infinitely variable mode.

[0074] In some embodiments, when in the infinitely variable mode, the variator provides a reverse function, a standstill function and a low speed function.

[0075] In some embodiments, when in the infinitely variable mode, the first planetary gear set provides a reverse function, a standstill function and a low speed function.

[0076] In some embodiments, when in the continuously variable mode, the ring of the first planetary gear set set has a positive rotation speed.

[0077] In some embodiments, when in the infinitely variable mode, the ring of the first planetary gear set has a negative rotation speed.

[0078] In some embodiments, the transition between continuously variable mode and infinitely variable mode is accomplished by simultaneously closing the brake while releasing the clutch.

[0079] In some embodiments, the variator continuously changes its torque ratios in both the continuously variable mode and infinitely variable mode to optimize power consumption.

[0080] In some embodiments, the only interruptions of power are to change from continuous to infinitely mode and to change the gear ratio in the gearbox.

[0081] In some embodiments, a dry-clutch is not required between the input shaft and the variable transmission.

[0082] In some embodiments, a torque converter is not required between the input shaft and the variable transmission

[0083] Provided herein is a variable transmission comprising: an input shaft; a first planetary gear set 25 comprising an input ring drivingly engaged to the input shaft; a carrier from a first planetary gear set mechanically connected through a clutch to the first ring assembly of a variator and a first sun of the first planetary gear set; said variator comprising a first ring assembly, and a second ring assembly; a brake member coupled to the carrier of the first planetary gear set; the second ring assembly of the variator drivingly connected to a second sun of a second planetary gear set 26; a countershaft 28 drivingly connecting the rings of the first and second planetary gear sets 25, 26, wherein said countershaft 28 transfers power from one ring to the other; the carrier of the second planetary gear set 26 drivingly connected to a gearbox 27; said gearbox 27 mechanically linked to a differential 102.

[0084] In some embodiments, the variable transmission comprises a continuously variable mode and an infinitely variable mode.

[0085] In some embodiments, the torque will be split between the first planetary gear set on one side of the variator, and the second planetary gear set on an opposing side of the variator.

[0086] In some embodiments, part of the power will pass through the variator while part of the power will pass from a first planetary gear set to the second planetary gear set through a mechanical path with higher efficiency.

[0087] In some embodiments, the clutch is engaged and the brake is disengaged, connecting the carrier and the first sun of the first planetary gear set, thereby engaging a continuously variable mode.

[0088] In some embodiments, the entire first planetary gear set is turning at the same speed as the input shaft and speed of the input shaft is directly applied to the first input ring assembly of the variator.

[0089] In some embodiments, the second planetary gear set combines the power from the input shaft and the ring with the output from the variator on the second sun of the second planetary gear set.

[0090] In some embodiments, the clutch is disengaged and the brake is engaged, holding the carrier of the first planetary gear set, thereby engaging an infinitely variable mode.

[0091] In some embodiments, the first ring of the first planetary gear set and the second ring of the second planetary gear set turn at engine speed, the first sun of the first planetary gear set will turn in reverse direction to the input shaft and in overdrive.

[0092] In some embodiments, the second planetary gear set in continuously variable mode whereby the power from the input shaft and output of the variator are combined, and the rotation of the second sun of the second planetary gear set is reversed.

[0093] In some embodiments, the output from the second planetary gear set going to the gear box provides reverse speeds to positive speeds through a standstill, thereby providing an infinitely variable mode.

[0094] In some embodiments, first and second sun gears turn in a positive rotation when in a continuously variable mode.

[0095] In some embodiments, the first and second sun gears turn in a negative rotation when in an infinitely variable mode.

[0096] In some embodiments, a transition between continuously variable mode and infinitely variable mode is accomplished by simultaneously closing the brake while releasing the clutch.

[0097] In some embodiments, the vehicle output comprises a wheel differential and one or more wheels of a vehicle.

[0098] In some embodiments, the vehicle output comprises a wheel differential and a drive axle.

[0099] In some embodiments, the dampener is disposed between the engine and the variable transmission.

[00100] In some embodiments, the dampener comprises at least one torsional spring.

[00101] Provided herein is method comprising, providing a variable transmission of any of configuration described herein or obvious to one of skill in the art upon reading the disclosure herein. In some embodiments, the variable transmission comprises a traction fluid in the variator.

[00102] Provided herein is a method comprising, providing a vehicle driveline of any of configuration described herein or obvious to one of skill in the art upon reading the disclosure herein.

Example 1

[00103] The embodiment of FIG. 4 comprises two planetary gear sets, one on each side of the variator to split the torque. This configuration includes a continuously variable mode as well as an infinitely variable mode providing a standstill, reverse, and starting function. No starting device such as a slipping clutch or torque converter is required, since the infinitely variable mode takes care of the starting function. But such a device might be added for other reasons.

[00104] In this configuration, a part of the power will pass through the variator while a part of it will pass directly from one planetary to the other through a mechanical path with higher efficiency.

[00105] This power splitting allows to have a relatively small variator, and thus relatively small variable transmission and to increase the native efficiency of the transmission. The central part of that configuration is the variator described previously in the document. A ball ramp on each side of the variator provides the clamping force necessary to transfer the torque.

[00106] This configuration results in a continuously variable mode and an infinitely variable mode of operation. The selection between those modes is made by engaging a clutch 1 or a brake 2. In addition, a gearbox 27 is added after the variator to increase the spread of the variator and avoid any gap between the modes.

[00107] The internal combustion engine (ICE) 100 is connected to the two suns of both planetary gear sets 25, 26. The carrier of the input planetary 25 can either be held fixed by a

brake 2, or can be connected to the sun by engaging a clutch 1. The first ring assembly of the variator is linked to the ring of the input planetary and the second ring assembly of the variator is then linked to the ring of the second planetary gear set. The carrier of the second planetary gear set is directly linked to a three speed gearbox of which the output is connected to the differential.

[00108] This device works in continuously variable mode when the clutch 1 is engaged and the brake 2 disengaged. By connecting the carrier and the sun of the input planetary 25 with each other, the whole planetary 25 turns at the same speed and the speed from the ICE 100 is directly applied to the input of the CVP 7. The output planetary 26 is combining the input from the ICE 100 on the sun 6 and the output from the CVP 7 on the ring 3.

[00109] The Infinitely variable mode is activated by disengaging the clutch 1 and engaging the brake 2. Thus, the carrier is held while the two suns are still turning at the ICE speed. By holding the carrier, the ring of the input planetary 25 will turn in the reverse direction compared to the ICE 100 and in underdrive. The second planetary 26 has the same function as in the continuously variable mode, combining the inputs from the ICE 100 and the output of the CVP 7. The only difference is that the input on the ring is now in a reverse direction. By doing this, the output going to the additional gearbox 27 can go from reverse speeds to positive speeds through standstill and therefore provides an IVP function.

[00110] As shown in FIG. 5, the three horizontal axes represent respectively, from the bottom to the top, the sun rotation speed, the carrier rotation speed and the ring rotation speed of the second planetary gear set. The carrier is the output and is linked to the three speed gearbox. The sun is always turning at ICE speed while the ring speed (IVP mode: A1-A2; CVP mode: A3-A4) changes from mode to mode. In the continuously variable mode, the ring has a positive rotation speed (A3-A3) while in infinitely variable mode, it has a negative rotation speed (A1-A2). The output speed on the carrier of the two modes is shown by the B1-B2 in IVP mode, and B3-B4 in CVP mode. The gap between B2 and B3, represented by a dotted line on the carrier axis, is covered with the additional gearbox.

[00111] The transition between the two modes is done by releasing one clutch and closing the brake. This device is able to change continuously its ratio to provide the best ratio achievable for the engine in function of the objectives of consumption or power. In a manual or automatic transmission, only some predetermined and discrete ratios are available and an

interruption of the power transmission is needed to shift of ratio. The only interruptions of power in this device are to change from the CVT mode (CVP mode) to the IVT mode (IVP mode) and to change the gear ratio in the gearbox. Other advantages of this configuration are that no dry-clutch or torque converter is needed between the internal combustion engine and the transmission; a very small variator can be chosen; spread is very large and the native efficiency of the transmission is increased by using the variator in a powersplit device, thereby letting part of the power pass through a more efficient mechanical path.

Example 2

[00112] An alternative configuration shown in FIG. 6 uses one planetary gearset on each side of the variator to split the torque. A part of the power will pass through the variator while the other part of it will pass directly from one planetary to the other through a mechanical path with higher efficiency. This power splitting allows to have a relatively small CVP 7 and to increase the native efficiency of the transmission. The central part of that configuration is the variator described previously in the document. A ball ramp on each side of the variator provides the clamping force necessary to transfer the torque.

[00113] This configuration uses two modes performing continuously variable or infinitely variable mode. The selection between those two modes is made by engaging a clutch 1 or a brake 2. In addition, a gearbox 27 is added after the variator 7 to increase the spread of the variator 7 and avoid any gap between the modes.

[00114] The ICE 100 is linked to the ring of the input planetary 25. The carrier of the input planetary can either be held fixed by a brake 2 or can be connected to the sun by engaging a clutch 1. The first ring assembly of the variator 7 is linked to the sun of the input planetary 25 and the second ring assembly of the variator is then linked to the second sun of the second planetary gear set 26. The carrier of the second planetary gear set is directly linked to a gearbox 27 of which the output is connected to the differential 102. For practical reasons, a countershaft 28 connects the rings from the two planetary gear sets 25, 26 transferring power from one to another.

[00115] This device works in continuously variable mode when the clutch 1 is engaged and the brake 2 disengaged. By connecting the carrier 5 and the sun 6 of the input planetary 25 with each other, the whole input planetary 25 turns at the same speed and the speed from the ICE 100 is directly applied to the first ring assembly of the variator 7. The output planetary 26 is combining the input from the ICE 100 on the ring 3 and the second ring assembly from the variator 7 on the sun 6.

[00116] The Infinitely variable mode is activated by disengaging the clutch 1 and engaging the brake 2. Thus, the carrier 5 of the first planetary gear set 25 is held while the two rings turn at the engine speed. By holding the carrier, the sun of the input planetary 25 will turn in the reverse direction compared to the ICE and in overdrive. The second planetary 26 has the same function as in the continuously variable mode, combining the inputs from the ICE 100 and the output of the variator 7. The only difference is that the input on the second sun is now in a reverse direction. By doing this, the output going to the additional gearbox 27 can go from reverse speeds to positive speeds through standstill and therefore provides infinitely variable mode functionality.

[00117] FIG 7 shows the rotation speeds of the second planetary gear set. In FIG. 7, the three horizontal axes represent respectively, from the bottom to the top, the sun rotation speed, the carrier rotation speed and the ring rotation speed of the second planetary gear set. The carrier is the output and is linked to gearbox. The ring is always turning at ICE speed while the sun speed changes from mode to mode (IVP mode: C1-C2; CVP mode: C3-C4). In the continuously variable mode, the sun has a positive rotation speed (C3-C4) while in infinitely variable mode, it has a negative rotation speed (C1-C2). The output speed on the carrier of the two modes is represented on the carrier axis between the first diagonal dotted line and the third diagonal dotted line on the carrier axis which shows the carrier speed in IVP mode from D1-D2, and again between the fourth diagonal dotted line and the fifth diagonal dotted line on the carrier axis which shows the carrier speed in CVP mode from D3-D4. The gap between the two portions is covered with the additional gearbox shown as a dotted line on the carrier speed axis.

[00118] The transition between the two modes is done by releasing one clutch and closing the brake. This device is able to change continuously its ratio to provide the best ratio achievable for the engine in function of the objectives of consumption or power. In a manual or automatic transmission, only some predetermined and discrete ratios are available and an interruption of the power transmission is needed to shift of ratio. The only interruptions of power in this device are to change from the CVT mode (CVP mode) to the IVT mode (IVP mode) and to change the gear ratio in the gearbox. Other advantages of this configuration are that no dry-clutch or torque converter is needed between the internal combustion engine and the transmission; a very small variator can be chosen; spread is similar to a traditional gearbox and the native efficiency of the transmission is increased by using the variator in a powersplit device, therefore letting a part of the power passing

through a more efficient mechanical path. Native efficiency will be higher than the first variant shown on FIG .4, because the variator is connected to the sun, where the torque is lower, so more power is transmitted through the mechanical path (the ring and countershaft).

[00119] While preferred embodiments of the present invention 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 invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

WHAT IS CLAIMED IS:

1. A variable transmission comprising:
an input shaft;
a first planetary gear set comprising a sun gear drivingly engaged to the input shaft;
a clutch member coupled to the input shaft for engaging the carrier of the first planetary gear set;
a brake member coupled to the carrier of the first planetary gear set;
the ring of the input planetary gear set drivingly engaged to a first ring assembly of a variator;
said variator comprising a first ring assembly, and a second ring assembly;
said second variator ring assembly drivingly engaged to the ring of a second planetary gear set;
wherein the sun of said second planetary gear set is also drivingly engaged to the input shaft;
and
the carrier of said second planetary gear set is drivingly engaged to a gearbox; and said gearbox is mechanically connected to a differential.
2. The variable transmission of claim 1, comprising a continuously variable mode and an infinitely variable mode.
3. The variable transmission of claim 1 wherein part of the power will pass through the variator while part of the power will pass directly from one planetary gear set to the other planetary gear set through a mechanical path with higher efficiency.
4. The variable transmission of claim 1, wherein when the clutch is engaged and the brake is disengaged the carrier of the input planetary is held fixed together with the input shaft, the whole planetary turning then at the input shaft speed, thereby engaging a continuously variable mode.
5. The variable transmission of claim 4, wherein power passes directly through the entire first planetary gear set to the first ring assembly of the variator, combining with the output from the input shaft on the second sun of the second planetary gear set and the second ring assembly of the variator when the transmission is in continuously variable mode.
6. The variable transmission of claim 1, wherein the clutch is disengaged and the brake is engaged, the carrier of the first planetary gear is held while the first and second sun gears are still turning at the speed of the input shaft, thereby engaging an infinitely variable mode.

7. The variable transmission of claim 6, wherein the ring of the input planetary gear set carrier will turn in the reverse direction of the input shaft and in underdrive.
8. The variable transmission of claims 6 and 7, wherein the power output going to the gearbox can go from reverse speeds to positive speeds through standstill thereby providing an infinitely variable mode.
9. The variable transmission of claim 1, wherein in the infinitely variable mode, the driveline provides a reverse function, a standstill function and a low speed function.
10. The variable transmission of claim 1, wherein in the infinitely variable mode, the first planetary provides a reverse function, a standstill function and a low speed function.
11. The variable transmission of claim 1, wherein in the continuously variable mode, the ring of the planetary gear set has a positive rotation speed.
12. The variable transmission of claim 1, wherein in the infinitely variable mode, the ring of the planetary gear set has a negative rotation speed.
13. The variable transmission of claim 2, wherein a transition between continuously variable mode and infinitely variable mode is accomplished by simultaneously closing the brake while releasing the clutch.
14. The variable transmission of claim 2, wherein the variator continuously changes its torque ratios in both the continuously variable mode and infinitely variable mode to optimize power consumption.
15. The variable transmission of claim 2, wherein the only interruptions of power are to change from continuous to infinitely mode and to change the gear ratio in the gearbox.
16. The variable transmission of claim 1, wherein a dry-clutch is not required between the input shaft and the variable transmission.
17. The variable transmission of claim 1, wherein a torque converter is not required between the input shaft and the variable transmission
18. A variable transmission comprising:
 - an input shaft;
 - a first planetary gear set comprising an input ring drivingly engaged to the input shaft;
 - a carrier from a first planetary gear set mechanically connected through a clutch to the first ring assembly of a variator and the first sun of the first planetary gear set;
 - said variator comprising a first ring assembly, and a second ring assembly;
 - a brake member coupled to the carrier of the first planetary gear set;

the second ring assembly of the variator drivingly connected to the second sun of a second planetary gear set;

a countershaft drivingly connecting the rings of the first, input and second planetary gear sets, wherein said countershaft transfers power from one ring to the other;

the carrier of the second planetary gear set drivingly connected to a gearbox; said gearbox mechanically linked to a differential

19. The variable transmission of claim 18, comprising a continuously variable mode and an infinitely variable mode.

20. The variable transmission of claim 18, wherein the torque will be split between planetary gear sets on either side of the variator

21. The variable transmission of claim 18, wherein part of the power will pass through the variator while part of the power will pass from one planetary to the other through a mechanical path with higher efficiency.

22. The variable transmission of claim 18, wherein clutch is engaged and the brake is disengaged, connecting the carrier and the first sun of the first planetary gear set, thereby engaging a continuously variable mode.

23. The variable transmission of claim 22, wherein the entire first planetary gear set is turning at the same speed as the input shaft and speed of the input shaft is directly applied to the first input assembly of the variator.

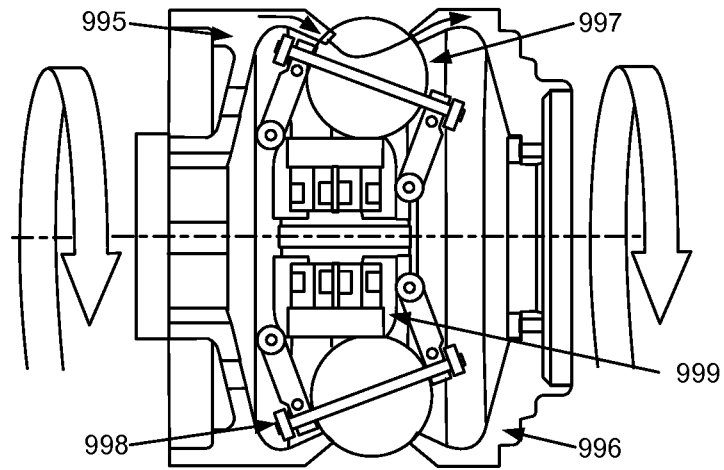
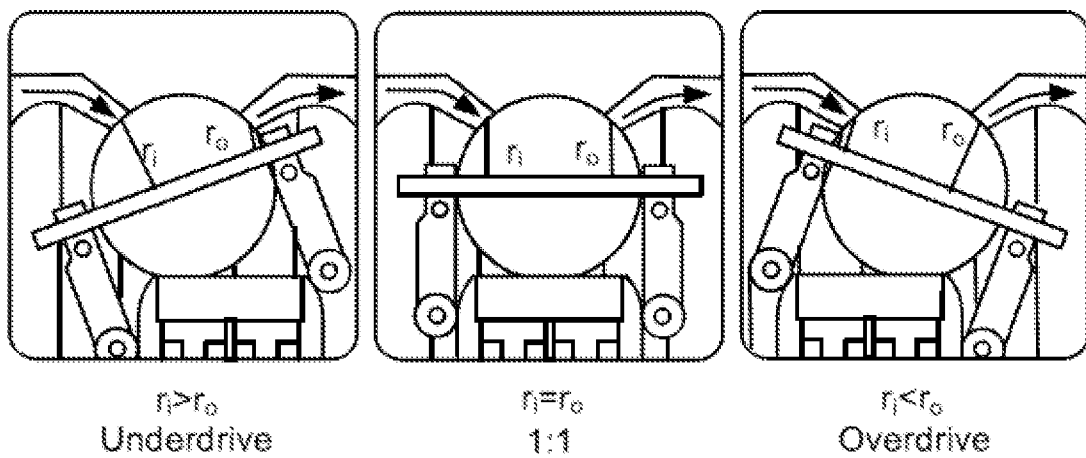
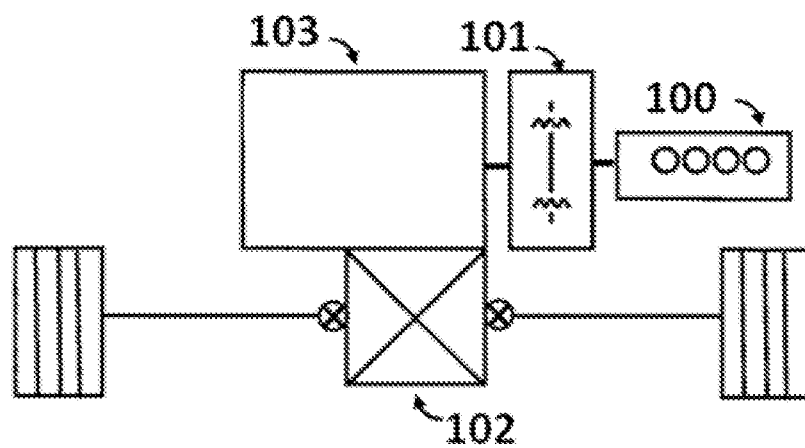
24. The variable transmission of claim 22, wherein the second planetary gear set combines the power from the input shaft and the ring with the output from the variator on the second sun of the second planetary set.

25. The variable transmission of claim 19, wherein clutch is disengaged and the brake is engaged, holding the carrier of the first planetary gear set, thereby engaging an infinitely variable mode.

26. The variable transmission of claim 25 wherein, the rings of the first, input and second planetary gear sets turn at engine speed, the first sun of the first input planetary gear set will turn in reverse direction to the input shaft and in overdrive.

27. The variable transmission of claims 25 and 26, wherein the second planetary gear set in continuously variable mode whereby the power from the input shaft and output of the variator are combined, and the rotation of the second sun of the second planetary gear set is reversed.

28. The variable transmission of claim 27, wherein the output from the second planetary gear set going to the gear box provides reverse speeds to positive speeds through a standstill, thereby providing an infinitely variable mode.
29. The variable transmission of claim 19, wherein the first and second sun gears turn in a positive rotation when in a continuously variable mode.
30. The variable transmission of claim 19, wherein the first and second sun gears turn in a negative rotation when in an infinitely variable mode.
31. The variable transmission of claim 19, wherein a transition between continuously variable mode and infinitely variable mode is accomplished by simultaneously closing the brake while releasing the clutch.
32. The variable transmission of claim 19, wherein the variator continuously changes its torque ratios in both the continuously variable mode and infinitely variable mode to optimize power consumption.
33. The variable transmission of claim 19, wherein the only interruptions of power are to change from continuous to infinitely mode and to change the gear ratio in the gearbox.
34. The variable transmission of claim 19, wherein a dry-clutch is not required between the input shaft and the variable transmission.
35. The variable transmission of any of claims 1-34, further comprising a traction fluid in the variator.
36. A vehicle driveline comprising an engine, a variable transmission of any of claims 1-35, and a vehicle output.
37. The vehicle driveline of claim 36, wherein the vehicle output comprises a wheel differential and one or more wheels of a vehicle.
38. The vehicle driveline of claim 36, wherein the vehicle output comprises a wheel differential and a drive axle.
39. The vehicle driveline of claim 36, wherein the dampener is disposed between the engine and the variable transmission.
40. The vehicle driveline of claim 36, wherein the dampener comprises at least one torsional spring.
41. A method comprising providing a variable transmission of any of claims 1-35.
42. A method comprising providing a vehicle driveline of any of claims 36-40.
43. A vehicle comprising the variable transmission of any of claims 1-35 or the vehicle driveline of any of claims 36-40.

**FIG. 1****FIG. 2****FIG. 3**

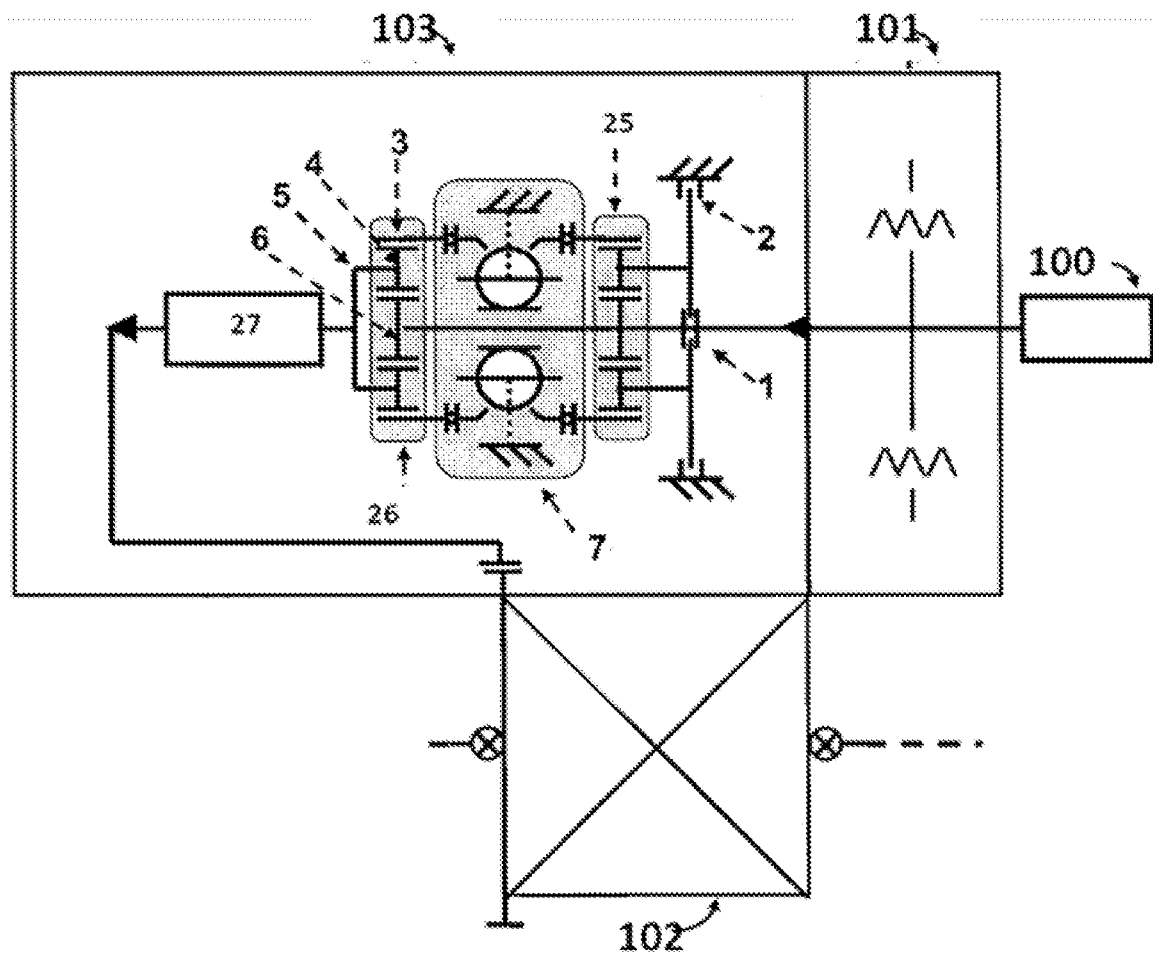


FIG. 4

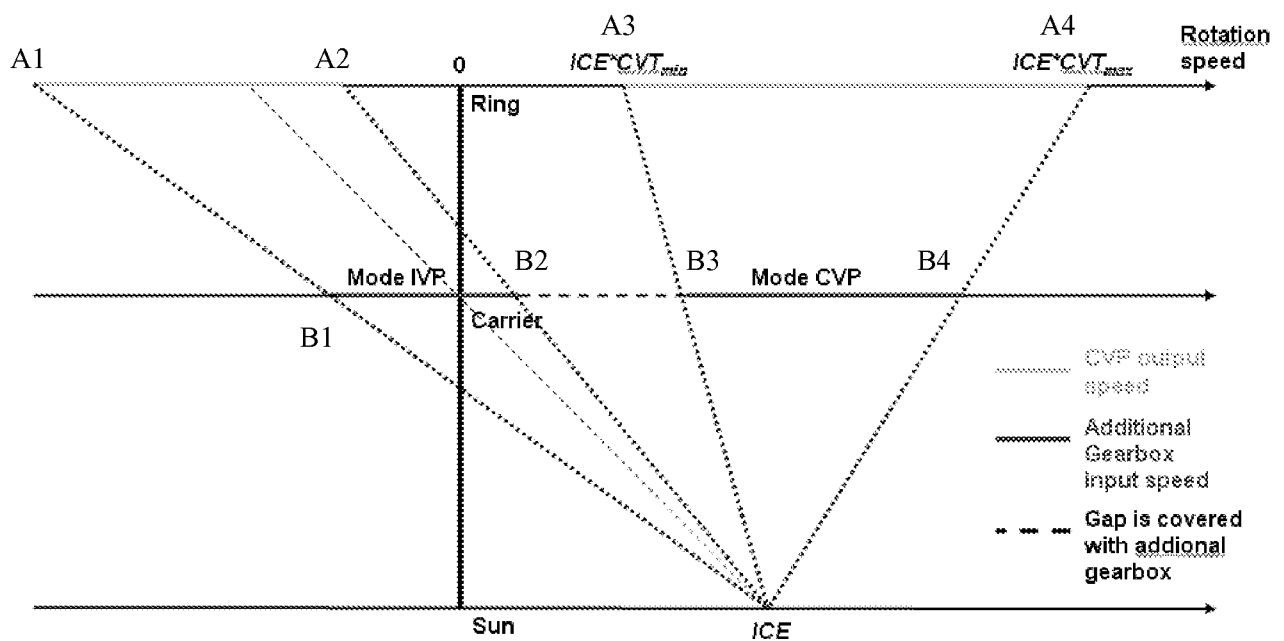


FIG. 5

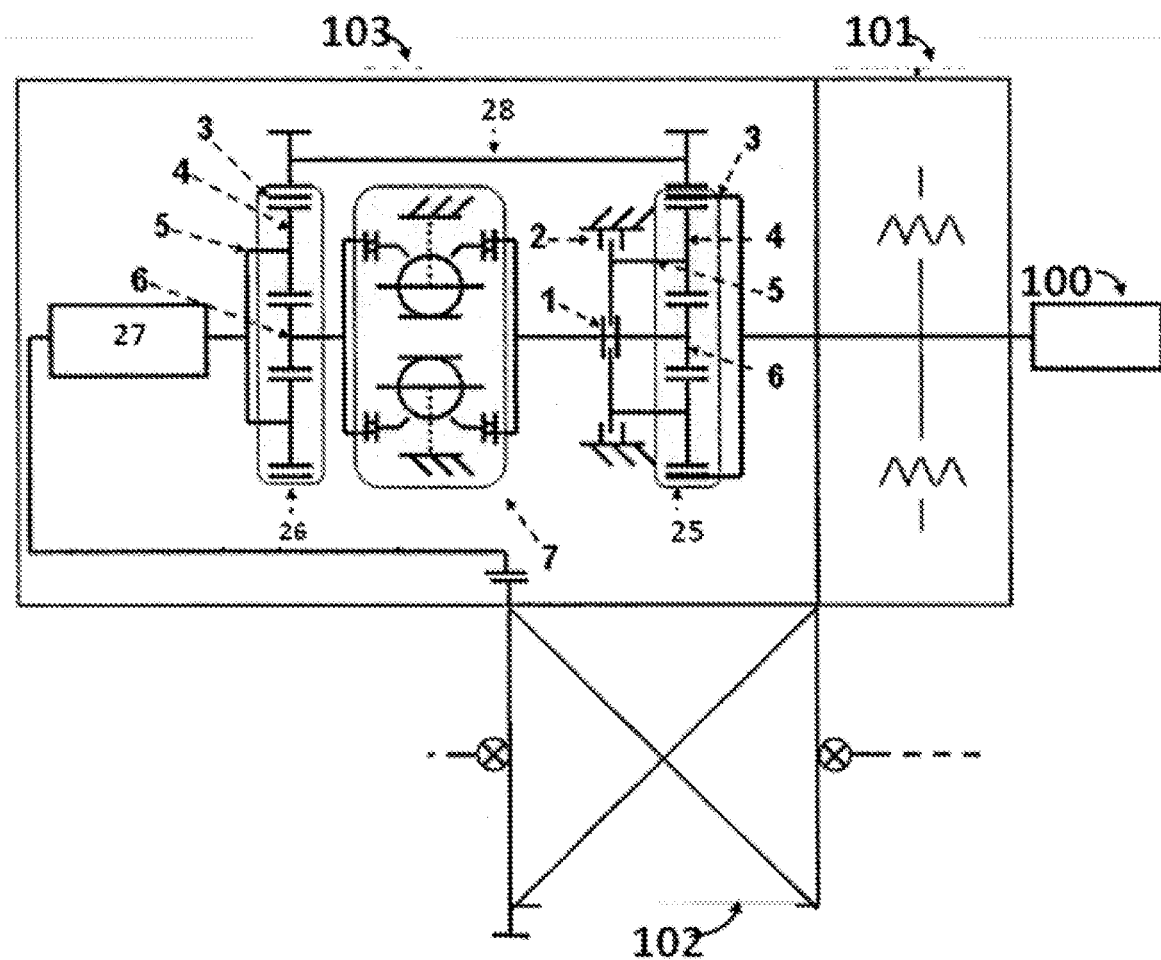


FIG. 6

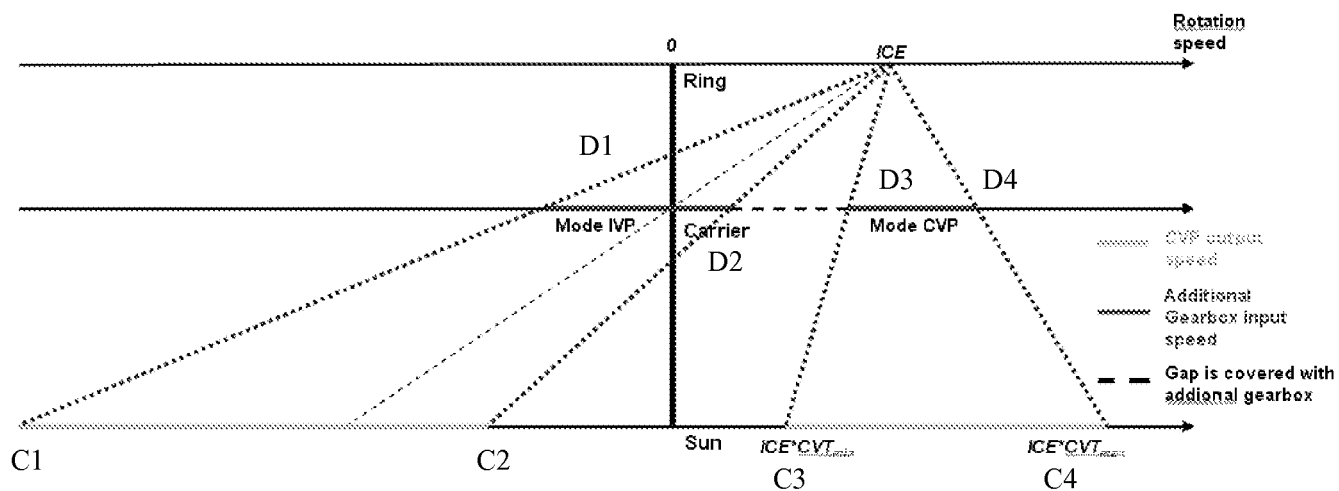


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2013/058318

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F16H 37/08 (2014.01)

USPC - 475/215

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)

IPC(8) - F16H 15/26, 15/40, 15/52, 37/08 (2014.01)

USPC - 180/65.265; 192/48.611, 48.614; 475/189, 214, 215, 216; 476/37, 38, 40, 41, 42; 701/51, 66; 903/930

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

CPC - F16H 15/503, 37/086 (2013.01)

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

PatBase, Google Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,045,477 A (SCHMIDT) 04 April 2000 (04.04.2000) entire document	1-7, 9-26, 29-34
A	US 4,056,988 A (KUBO et al) 08 November 1977 (08.11.1977) entire document	1-7, 9-26, 29-34
A	US 2011/0165986 A1 (HOFFMAN et al) 07 July 2011 (07.07.2011) entire document	1-7, 9-26, 29-34
A	US 2012/0165154 A1 (WITTKOPP et al) 28 June 2012 (28.06.2012) entire document	1-7, 9-26, 29-34
A, P	WO 2013/123117 A1 (COOPER et al) 22 August 2013 (22.08.2013) entire document	1-7, 9-26, 29-34

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

* 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

27 January 2014

Date of mailing of the international search report

11 FEB 2014

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2013/058318

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 8, 27, 28, 35-43
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.