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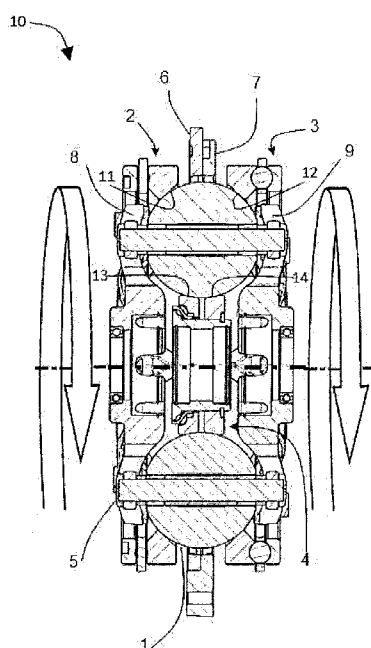


Figure 1

(57) Abstract: Provided herein is a method for controlling the supply of a traction fluid to a continuously variable planetary (CVP) having a carrier assembly for a continuously variable transmission having a plurality of balls, each having a tiltable axis of rotation, a first traction ring assembly in contact with each ball, a second traction ring assembly in contact with each ball, the carrier assembly having a plurality of guide slots, each guide slot adapted to operably couple to, and provide support to each ball. In one embodiment, a flow control process is implemented in an electronic control unit. The flow control process determines flow rate and pressure of traction fluid supplied to the CVP based on a minimum acceptable lubrication profile (MALP).

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LUBRICANT FLOW CONTROL FOR A BALL-TYPE CONTINUOUSLY VARIABLE PLANETARY TRANSMISSION

RELATED APPLICATION

5 The present application claims the benefit of U.S. Provisional Application No. 62/509,481 filed on May 22, 2017, which is incorporated herein by reference in its entirety.

BACKGROUND

10 Automatic and manual transmissions are commonly used on motor vehicles. Such transmissions have become more and more complicated since the engine speed has to be adjusted to limit fuel consumption and the emissions of the vehicle. A vehicle having a driveline including a tilting ball variator allows an operator of the vehicle or a control system of the vehicle
15 to vary a drive ratio in a stepless manner. A variator is an element of a Continuously Variable Transmission (CVT) or an Infinitely Variable Transmission (IVT). Transmissions that use a variator can decrease the transmission's gear ratio as engine speed increases. This keeps the engine within its optimal efficiency while gaining ground speed, or trading speed for
20 torque during hill climbing, for example. Efficiency in this case can be fuel efficiency, decreasing fuel consumption and emissions output, or power efficiency, allowing the engine to produce its maximum power over a wide range of speeds. That is, the variator keeps the engine turning at constant
25 RPMs over a wide range of vehicle speeds.

SUMMARY

25 Provided herein a method for controlling a traction fluid supply to the CVP ball-planetary variator (CVP) having a first traction ring assembly and a second traction ring assembly in contact with a plurality of balls, wherein
30 each ball of the plurality of balls has a tiltable axis of rotation and wherein the ball variator assembly, the method including the steps of: receiving a plurality of data signals provided by sensors located on the transmission, the plurality of data signals including: a CVP ratio, an input speed, and an input

torque; determining a power loss through the CVP based on the CVP ratio, the input speed, and the input torque; and delivering traction fluid to the CVP at a flow rate and a pressure based on power loss.

5 In some embodiments, determining the power loss includes using a look-up table correlating power loss as a function of the input speed, the CVP ratio, and the input torque.

In some embodiments, the flow rate and pressure are determined using a minimum acceptable lubrication profile.

10 In some embodiments, the minimum acceptable lubrication profile is a look-up table based at least on power loss.

In some embodiments, the minimum acceptable lubrication profile is a look-up table based on power loss and fluid exit temperature.

15 In some embodiments, the minimum acceptable lubrication profile is based on power loss at a current operation condition, wherein the current operation condition is function of input speed, CVP ratio, and input torque.

In some embodiments, determining the power loss includes determining a CVP efficiency based on the input speed, the CVP ratio, and the input torque.

20 In some embodiments, receiving a plurality of data signals further comprises receiving an output torque.

In some embodiments, the output torque is determined based on a CVP actuator force feedback.

In some embodiments, the minimum acceptable lubrication profile is based at least in part on the CVP efficiency.

25 In some embodiments, the CVP efficiency is based at least in part on the output torque.

In some embodiments, the data signals further comprise a traction fluid life parameter.

30 In some embodiments, the input torque is based on a brake specific fuel consumption (BSFC) map of the engine.

In some embodiments, the data signals further comprise a fluid exit temperature and a fluid supply temperature.

In some embodiments, determining the power loss is a function of fluid supply temperature and the fluid exit temperature.

In some embodiments, the minimum acceptable lubrication profile is based on power loss and fluid exit temperature.

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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.

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BRIEF DESCRIPTION OF THE DRAWINGS

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:

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

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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.

25

Figure 4 is a block diagram of a vehicle control system implementing the variator of Figure 1.

Figure 5 is a flow control process for the ball-type variator of Figure 1.

Figure 6 is a cross-section view of certain components of the ball-type variator of Figure 1.

30

Figure 7 is a schematic diagram of a ball-type variator provided with an idler assembly having another axial positioning mechanism.

Figure 8 is a partial cross-section view of a ball-type variator having a carrier assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A control process is described herein that enables electronic control over a variable ratio transmission having a continuously variable ratio portion, such as a Continuously Variable Transmission (CVT), Infinitely Variable Transmission (IVT), or variator. In some embodiments, an electronic controller is configured to receive input signals indicative of parameters associated with an engine coupled to the transmission. The parameters includes throttle position sensor values, accelerator pedal position sensor values, vehicle speed, gear selector position, user-selectable mode configurations, and the like, or some combination thereof. The electronic controller also receives one or more control inputs. The electronic controller determines an active range and an active variator mode based on the input signals and control inputs. The electronic controller can control a final drive ratio of the variable ratio transmission by controlling one or more electronic actuators and/or solenoids that control the ratios of one or more portions of the variable ratio transmission as well as other elements of the transmission.

The electronic controller described herein is described in the context of a continuous variable transmission, such as the continuous variable transmission of the type described in U.S. Patent Application Number 14/425,842, entitled "BALL-TYPE CVT/IVT INCLUDING PLANETARY GEAR SETS," and U.S. Patent Application Number 15/572,288, entitled "CONTROL METHOD FOR SYNCHRONOUS SHIFTING OF A TRANSMISSION COMPRISING A CONTINUOUSLY VARIABLE PLANETARY MECHANISM", each assigned to the assignee of the present application and hereby incorporated by reference herein in its entirety. However, the electronic controller is not limited to controlling a particular type of transmission, but optionally configured to control any of several types of variable ratio transmissions.

Provided herein are configurations of CVTs based on 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 United States Patent No.

8,870,711 incorporated herein by reference in their entirety. In some embodiments, a CVP 10, adapted herein as described throughout this specification, includes a number of balls (planets, spheres) 1, depending on the application, two ring (disc) assemblies with a conical surface contact with the balls 1, as a first traction ring 2 and a second traction ring 3, and an idler (sun) assembly 4 as shown on FIG. 1. The balls 1 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 one embodiment, 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. The radial guide slots 8 and the radially offset guide slots 9 are adapted to guide the tiltable axles 5. The axles 5 is adjusted to achieve a desired ratio of input speed to output speed during operation of the CVP 10. In some embodiments, adjustment of the axles 5 involves control of the position of the first carrier member and the second carrier member to impart a tilting of the axles 5 and thereby adjusts the ratio of the variator.

In some embodiments, the ratio is a speed ratio, for example the ratio of an input speed to an output speed. In other embodiments, the ratio is a torque ratio, for example the ratio of an input torque to an output torque. Other types of ball CVTs also exist, like the one produced by Milner, but are slightly different.

The working principle of such the CVP 10 of FIG. 1 is shown in FIG. 2 and FIG. 3. The CVP itself works with a traction fluid. The lubricant (traction fluid) between the ball and the conical rings acts as a solid at high pressure, transferring the power from the input (first) ring, through the balls, to the output (second) ring. As used herein, the term "traction contact" refers to the area between contacting components. For example, a first traction contact 11 is formed between the first traction ring 2 and the ball 1; the second traction contact 12 is formed between the second traction ring 3

and the ball 1; the third contact 13 is formed between the sun assembly 4 and the ball 1; and the fourth contact 14 is formed between the sun assembly 4 and the ball 1. By tilting the balls' axes, the ratio is changed between input and output. When the axis is horizontal the ratio is one, 5 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 10 rotation that is capable of being 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 15 adjusting the ratio of the variator. The angular misalignment in the first plane is referred to here as "skew", "skew angle", and/or "skew condition". In one embodiment, 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 20 adjusts the ratio of the variator.

As used here, the terms "operationally connected," "operationally coupled", "operationally linked", "operably connected", "operably coupled", "operably linked," and like terms, refer to a relationship (mechanical, linkage, coupling, etc.) between elements whereby operation of one element results 25 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 30 linkage or coupling may take a variety of forms, which in certain instances will be readily apparent to a person of ordinary skill in the relevant technology.

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, ramped surface 52A and ramped surface 52B) will be referred to collectively by a single label (for example, bearing 1011).

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 forces which would be available at the interfaces of the contacting components and is a measure of the maximum available drive torque.

In some embodiments, the traction coefficient is a design parameter in the range of 0.3 to 0.6. 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 may operate in both tractive and frictional applications. As a general matter, the traction coefficient μ is a function of the traction fluid properties, the normal force at the contact area, and the velocity of the traction fluid in the contact area, among other things. For a given traction fluid, the traction coefficient μ increases with increasing relative velocities of components, until the traction coefficient μ reaches a maximum capacity after which the traction coefficient μ decays. The condition of exceeding the maximum capacity of the traction fluid is often referred to as “gross slip condition”.

As used herein, “creep”, “ratio droop”, or “slip” is the discrete local motion of a body relative to another and is exemplified by the relative velocities of rolling contact components such as the mechanism described herein. In traction drives, the transfer of power from a driving element to a driven element via a traction interface requires creep. Usually, creep in the direction of power transfer is referred to as “creep in the rolling direction.” Sometimes the driving and driven elements experience creep in a direction orthogonal to the power transfer direction, in such a case this component of creep is referred to as “transverse creep.”

For description purposes, the terms “prime mover”, “engine,” and like terms, are used herein to indicate a power source. In some embodiments, the power source may be fueled by energy sources including hydrocarbon, electrical, biomass, nuclear, solar, geothermal, hydraulic, pneumatic, and/or wind to name but a few. Although typically described in a vehicle or automotive application, one skilled in the art will recognize the broader applications for this technology and the use of alternative power sources for driving a transmission including this technology.

Those of skill will recognize that the various illustrative logical blocks, modules, circuits, strategies, schemes, and algorithm steps described in connection with the embodiments disclosed herein, including with reference to the control system described herein, for example, is optionally implemented as electronic hardware, software stored on a computer readable medium and executable by a processor, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, strategies, schemes, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans could implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention. For example, various illustrative logical blocks, modules, strategies, schemes, and circuits described in connection with the embodiments disclosed herein is optionally

implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor is optionally a microprocessor, but in the alternative, the processor is optionally any conventional processor, controller, microcontroller, or state machine. A processor is also optionally implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Software associated with such modules optionally resides in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other suitable form of storage medium known in the art. An exemplary storage medium is coupled to the processor such that the processor is capable of reading information from, and writing information to, the storage medium. In the alternative, the storage medium is optionally integral to the processor. The processor and the storage medium optionally reside in an ASIC. For example, in one embodiment, a controller for use of control of the CVT includes a processor (not shown).

In some embodiments, the control system for a vehicle equipped with a variable transmission described herein includes a digital processing device, or use of the same. In further embodiments, the digital processing device includes one or more hardware central processing units (CPU) that carry out the device's functions. In still further embodiments, the digital processing device further comprises an operating system configured to perform executable instructions. In some embodiments, the digital processing device is optionally connected a computer network. In further embodiments, the digital processing device is optionally connected to the Internet such that it accesses the World Wide Web. In still further embodiments, the digital processing device is optionally connected to a cloud computing infrastructure. In other embodiments, the digital processing device is optionally connected to an

intranet. In other embodiments, the digital processing device is optionally connected to a data storage device.

In accordance with the description herein, suitable digital processing devices include, by way of non-limiting examples, server computers, desktop
5 computers, laptop computers, notebook computers, sub-notebook computers, netbook computers, set-top computers, media streaming devices, handheld computers, Internet appliances, mobile smartphones, tablet computers, personal digital assistants, and vehicles. Those of skill in the art will recognize that many smartphones are suitable for use in the system described herein.

10 Suitable tablet computers include those with booklet, slate, and convertible configurations, known to those of skill in the art.

In some embodiments, the digital processing device includes an operating system configured to perform executable instructions. The operating system is, for example, software, including programs and data, which manages
15 the device's hardware and provides services for execution of applications.

In some embodiments, the device includes a storage and/or memory device. The storage and/or memory device is one or more physical apparatuses used to store data or programs on a temporary or permanent
20 basis. In some embodiments, the device is volatile memory and requires power to maintain stored information. In some embodiments, the device is non-volatile memory and retains stored information when the digital processing device is not powered.

In some embodiments, the digital processing device includes a display to send visual information to a user.

25 In some embodiments, the digital processing device includes an input device to receive information from a user. In some embodiments, the input device is a keyboard. In some embodiments, the input device is a pointing device including, by way of non-limiting examples, a mouse, trackball, track pad, joystick, game controller, or stylus. In some embodiments, the input
30 device is a touch screen or a multi-touch screen. In other embodiments, the input device is a microphone to capture voice or other sound input. In other embodiments, the input device is a video camera or other sensor to capture

motion or visual input. In still further embodiments, the input device is a combination of devices such as those disclosed herein.

In some embodiments, the control system for a vehicle equipped with a variable transmission disclosed herein includes at least one computer program, or use of the same. A computer program includes a sequence of instructions, executable in the digital processing device's CPU, written to perform a specified task. Computer readable instructions are optionally implemented as program modules, such as functions, objects, Application Programming Interfaces (APIs), data structures, and the like, that perform particular tasks or implement particular abstract data types. In light of the disclosure provided herein, those of skill in the art will recognize that a computer program is optionally written in various versions of various languages.

The functionality of the computer readable instructions are optionally combined or distributed as desired in various environments. In some embodiments, a computer program comprises one sequence of instructions. In some embodiments, a computer program comprises a plurality of sequences of instructions. In some embodiments, a computer program is provided from one location. In other embodiments, a computer program is provided from a plurality of locations. In various embodiments, a computer program includes one or more software modules. In various embodiments, a computer program includes, in part or in whole, one or more web applications, one or more mobile applications, one or more standalone applications, one or more web browser plug-ins, extensions, add-ins, or add-ons, or combinations thereof.

Referring now to FIG. 4, in some embodiments, a vehicle control system 100 includes an input signal processing module 102, a transmission control module 104 and an output signal processing module 106. The input signal processing module 102 is configured to receive a number of electronic signals from sensors provided on the vehicle and/or transmission. The sensors optionally include temperature sensors, speed sensors, position sensors, among others.

Those of skill will recognize that position sensors are optionally electronic, and in some cases, well-known potentiometer type sensors. The sensors, and associated hardware for transmitting and calibrating the

signals, are capable of being selected in such a way as to provide a relationship between the pedal position and signal to suit a variety of implementations.

In some embodiments, the signal processing module 102 optionally includes various sub-modules to perform routines such as signal acquisition, signal arbitration, or other known methods for signal processing. The output signal processing module 106 is optionally configured to electronically communicate to a variety of actuators and sensors.

In some embodiments, the output signal processing module 106 is configured to transmit commanded signals to actuators based on target values determined in the transmission control module 104.

The transmission control module 104 optionally includes a variety of sub-modules or sub-routines for controlling continuously variable transmissions of the type discussed here. For example, the transmission control module 104 optionally includes a clutch control sub-module 108 that is programmed to execute control over clutches or similar devices within the transmission.

In some embodiments, the clutch control sub-module 108 implements state machine control for the coordination of engagement of clutches or similar devices.

The transmission control module 104 optionally includes a CVP control sub-module 110 programmed to execute a variety of measurements and determine target operating conditions of the CVP, for example, of the ball-type continuously variable transmissions discussed here. It should be noted that the CVP control sub-module 110 optionally incorporates a number of sub-modules for performing measurements and control of the CVP.

In some embodiments, the vehicle control system 100 includes an engine control module 112 configured to receive signals from the input signal processing module 102 and in communication with the output signal processing module 106. The engine control module 112 is configured to communicate with the transmission control module 104.

Referring now to FIG. 5, in some embodiments, a flow control process 200 is implemented to actively control the flow of fluid through the CVP 10

depicted in FIGS. 1-3. The flow control process 200 is implementable in the electronic controller configured to control the CVP 10. As discussed previously, the electronic controller is adapted to receive a number of input signals, calculate operating conditions of the CVP 10, and determine command signals to adjust a number of actuators coupled to the CVP 10.

In some embodiments, the actuators include a shift actuator configured to adjust ratio of the CVP 10, a flow control valve configured to adjust fluid pressure and fluid flow rate of the traction fluid supplied to the CVP 10, and/or a variable pump configured to supply traction fluid to the CVP 10. It should be appreciated that there are a number of known ways to route and supply traction fluid to the first traction contact 11, the second traction contact 12, the third traction contact 13, and the fourth traction contact 14.

Examples of lubricant passages and routing are found in pending Patent Cooperation Treaty Patent Application No. PCT/US17/059430, which is hereby incorporated by reference. It should be appreciated that the flow control process 200 is implementable on a variety of lubricant system designs. For example, a lubricant system having electronic valves configured to regulate the flow of fluid delivered to contacting traction surfaces of the variator as described in United States Patent No. 8,996,263, which is hereby incorporated by reference.

FIG. 6 depicts one embodiment of a shaft 21 and carrier assembly 29 configured to facilitate flow of fluid, such as traction fluid, through the CVP 10 to provide lubrication and cooling, among other purposes.

In some embodiments, lubricant flow is actively controlled through an idler assembly such as those disclosed in United States Patent Applications Nos. 62/661814, which is hereby incorporated by reference and depicted in FIG. 7.

In some embodiments, lubricant flow is actively controlled through a carrier assembly such as those disclosed in United States Patent Application No. 15/260472, which is hereby incorporated by reference and depicted in FIG. 8.

In some embodiments, the flow control process 200 begins at a start state 201 and proceeds to a block 202 where signals are received.

In some embodiments, the signals include input speed, ratio, and input torque sent from by sensors position on the vehicle. In some
5 embodiments, the signals also include a fluid supply temperature and a fluid exit temperature. For example, a fluid supply temperature is optionally provided by a temperature sensor adapted to measure the temperature of the traction fluid delivered to the first traction contact 11, the second traction contact 12, the third traction contact 13, and/or the fourth traction contact 14.
10 The fluid exit temperature is optionally provided by a temperature sensor adapted to measure fluid exiting the traction contact.

In some embodiments, the input torque is based on a brake specific fuel consumption (BSFC) map of an engine supplying power to the CVP.

In some embodiments, the signals optionally include a traction fluid
15 life parameter that provides an indication of thermal properties of the traction fluid over time, and is typically provided by the traction fluid manufacture based on empirical data. For example, for traction fluids that exhibit degradation in thermal capacity over a number of hours of operation, the traction fluid life parameter provides an adjustment factor for use in the flow
20 control process 200.

The flow control process 200 proceeds to a block 203 where a power loss is determined. In some embodiments, the power loss is a calculated parameter based on the input speed, the ratio, and the input torque.

In some embodiments, the calculation of power loss is a function of a
25 temperature difference between the fluid supply temperature and the fluid exit temperature.

In other embodiments, a look-up table provides the power loss as a function of the input speed, the ratio, and the input torque.

In some embodiments, the power loss is determined in the block 203
30 through determination of a CVP efficiency. In some embodiments, the CVP efficiency is provided in a look-up table based on ratio and input speed, among others. In some embodiments, the CVP efficiency is provided by computational model.

In some embodiments, an output torque signal is used to determine the power loss. In some embodiments, the output torque signal is used to determine the CVP efficiency. The output torque of the CVP 10 is optionally provided by a torque sensor or inferred from the CVP shift actuator (not shown).

Still referring to FIG. 5, in some embodiments, the fluid control process 200 proceeds to a block 204 where a traction fluid flow rate is determined.

In some embodiments, an operating pressure is also determined in the block 204.

In some embodiments, the block 204 determines the flow rate and pressure of the traction fluid supplied to the CVP 10 based on the power loss.

In some embodiments, as shown in FIG. 6, the traction fluid is supplied to passage 37.

In some embodiments, the flow rate and pressure of the traction fluid is provided by a minimum acceptable lubrication profile ("MALP"). The MALP is an electronically stored map of flow rate and/or pressure based at least in part on the power loss at the current operating condition. For example, the power loss is provided for the input speed, ratio, and the input torque.

In some embodiments, the MALP is empirically derived based on the optimization of CVP efficiency, power capacity, and durability as a function of the power loss and fluid exit temperature of the CVP 10. The temperature of the fluid exiting a traction contact is directly correlated with the power loss at the said traction contact. Since temperature of the fluid exiting the traction contact is difficult to measure during operation of the CVP, power loss is used as an indicator of the fluid exit temperature.

It should be appreciated that the methods described herein are optionally configured to base MALP on the fluid exit temperature through direct measure or the power loss through calculation or calibration.

In other embodiments, the MALP is calculated during operation based on the power loss at a current operating condition, wherein the operating condition is a function of the input speed, ratio, and input torque.

During operation of the CVP 10, an electronically controlled valve and/or a variable flow pump is adapted to supply a metered flow of traction fluid to the CVP 10 based on the MALP. The flow control process 200 sends command signals for the electronically controlled valve and/or pump in the block 205.

In some embodiments, the flow control process 200 commands multiple electronically controlled valves adapted to control flow to each of the first traction contact 11, the second contact 12, the third traction contact 13, and the fourth traction contact 14.

Referring now to FIG. 6, for purposes of description and not limitation, certain components related to a fluid system in an exemplary CVP 22 are described. In some embodiments, the CVP 22, a shaft 21 and a carrier assembly 29 are configured to facilitate flow of fluid, such as traction fluid, through the CVP 22 to provide lubrication and cooling, among other purposes. In some embodiments, the shaft 21 is provided with a hollow central passage 37. In some embodiments, the hollow central passage 37 extends radially through and is blocked at one end. The hollow central passage 37 is in fluid communication with a source of pressurized fluid from a pump, for example. One or more fluid valves are configurable to electronically control the flow rate and pressure of the fluid in the hollow central passage 37.

In some embodiments, the shaft 21 is provided with a first carrier member lube port 39 arranged in proximity to the first carrier member 20. In some embodiments, the first carrier member lube port 39 is a drilled hole arranged between the hollow central passage 37 and the outer periphery of the shaft 21. The shaft 21 is provided with an idler assembly lube port 40 arranged in proximity to the idler assembly, for example. In some embodiments, the idler assembly lube port 40 is a radial hole arranged between the hollow central passage 37 and the outer periphery of the shaft 21. The shaft 21 is provided with a second carrier member lube port 41 arranged in proximity to the second carrier member. In some embodiments, the second carrier member lube port

41 is a radial hole drilled between the hollow central passage 37 and the outer periphery of the shaft 21.

A first carrier member is provided with a first array of radial lubricant passages 42. In some embodiments, the first array of radial lubricant passages 42 are arranged so that one of the radial lubricant passages 42 is between each ball. For example, a CVP having six balls is provided with six radial lubricant passages. The second carrier member is provided with a second array of radial lubricant passages 43. In some embodiments, the second array of radial lubricant passages 42 are arranged between each ball in a similar manner as the first array of radial lubricant passages 42. The first array of radial lubricant passages 42 and the second array of radial lubricant passages 43 are arranged to be in fluid communication with the first carrier member lube port 39 and the second carrier member lube port 41, respectively. In some embodiments, the first carrier member is provided with a first array of orifice lube passages 44. The first array of orifice lube passages 44 are in fluid communication with the first array of radial lubricant passages 42.

Each of the first array of orifice lube passages 44 is located between each ball. Each of the first array of orifice lube passages 44 are located radially outward of each of the first array of radial lubricant passages 42. In some embodiments, the second carrier member is provided with a second array of orifice lube passages 45. The second array of orifice lube passages 45 are in fluid communication with the second array of radial lubricant passages 43. Each of the second array of orifice lube passages 45 is located between each ball. Each of the second array of orifice lube passages 45 are located radially outward of each of the second array of radial lubricant passages 43. In some embodiments, the first array of orifice lube passages 43 and the second array of orifice lube passages 45 are configured to supply a metered flow of fluid to an array of input traction ring orifice plugs 46 and an array of output traction ring orifice plugs 47. The input traction ring orifice plugs 46 and the output traction ring orifice plugs 47 are arranged to spray fluid at the contacting location between the balls and the first traction ring and the second traction ring.

Referring to FIG. 7, in some embodiments, the CVP 50 includes an idler 55 located radially inward of, and in contact with, each ball 51. In some embodiments, the idler 55 is operably coupled to the first carrier member 53 with a first axial positioning mechanism 56. In some embodiments, the first axial positioning mechanism 56 provides damping to the idler 55.

In some embodiments, the first axial positioning mechanism 56 is supplied with a fluid through a fluid passage 57 formed in the first carrier member 53. In some embodiments, the fluid passage 57 is adapted to supply a fluid from a source to contacting surfaces of the CVP 50.

In some embodiments, the idler 55 is operably coupled to the second carrier member 54 with a second axial positioning mechanism 58. In some embodiments, the second axial positioning mechanism 58 is supplied with a fluid through a fluid passage 59 formed in the second carrier member 54. In some embodiments, the fluid passage 59 is adapted to supply a fluid from a source to contacting surfaces of the CVP 50.

In some embodiments, the first axial positioning mechanism 56 is provided with a first valve 61. The first valve 61 is adapted to control the flow of fluid through the fluid passage 57 in response to the idler 55.

In some embodiments, the second axial positioning mechanism 58 is provided with a second valve 62. The second valve 62 is adapted to control the flow of fluid through the fluid passage 59 in response to the idler 55.

Referring to FIG. 8, in one embodiment a continuously variable planetary (CVP) 60, the carrier assembly 65 can include a first carrier subassembly 65A and a second carrier subassembly 65B. The first carrier subassembly 65A can be adapted to rotate relative to the second carrier subassembly 65B to facilitate a change in operating condition of the CVP 60. In one embodiment, the carrier subassembly 65 can be operably coupled to a shift actuator (not shown). The CVP 60 is provided with a main shaft 66 positioned along the longitudinal axis. The main shaft 66 is operably coupled to the carrier assembly 65. The main shaft 66 is provided with a lubrication channel 67 located in the interior and positioned along the longitudinal axis. The lubrication channel 67 can be configured to deliver a pressurized fluid, such as transmission oil, to internal components of the

CVP 60. For illustrative purposes, dashed lines 68 represent fluid flow within the interior of the CVP 60. The main shaft 65 is configured to be in fluid communication with the carrier assembly 65. For example, the main shaft 66 can be provided with passages 69 that are configured to deliver a pressurized fluid to the carrier assembly 65.

The foregoing description details certain embodiments. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the embodiments can be practiced in many ways. As is also stated above, it should be noted that the use of particular terminology when describing certain features or aspects of the preferred embodiments should not be taken to imply that the terminology is being re-defined herein to be restricted to including any specific characteristics of the features or aspects of the preferred embodiments with which that terminology is associated.

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 practice. 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.

Aspects of the invention include:

Aspect 1. A vehicle including:

a continuously variable planetary (CVP), wherein the CVP is a ball variator assembly having a first traction ring assembly and a second traction ring assembly in contact with a plurality of balls, wherein each ball of the plurality of balls has a tiltable axis of rotation;

a controller configured to control a traction fluid supply to the CVP; and wherein the controller commands a change in the traction fluid supply based on a minimum acceptable lubrication profile.

Aspect 2. The vehicle of Aspect 1, wherein the minimum acceptable lubrication profile is an electronically stored map of a traction fluid flow rate and pressure as a function of an input speed, a CVP ratio, and an input torque.

5 Aspect 3. The vehicle of Aspect 2, wherein the controller is configured to control a valve based on the minimum acceptable lubrication profile.

Aspect 4. The vehicle of Aspect 2, wherein the controller is configured to control a pump based on the minimum acceptable lubrication profile.

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Aspect 5. The vehicle of Aspect 2, wherein the controller is configured to determine a power loss of the CVP based on the input speed, the CVP ratio, and the input torque.

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WHAT IS CLAIMED IS:

1. A method for controlling a traction fluid supply to the CVP ball-
planetary variator (CVP) having a first traction ring assembly and a
5 second traction ring assembly in contact with a plurality of balls, wherein
each ball of the plurality of balls has a tiltable axis of rotation and
wherein the ball variator assembly, the method comprising the steps of:
receiving a plurality of data signals provided by sensors located
on the transmission, the plurality of data signals comprising:
10 a CVP ratio,
an input speed, and
an input torque;
determining a power loss through the CVP based on the CVP
ratio, the input speed, and the input torque; and
15 delivering traction fluid to the CVP at a flow rate and a pressure
based on power loss.
2. The method of Claim 1, wherein determining the power loss includes
using a look-up table correlating power loss as a function of the input
20 speed, the CVP ratio, and the input torque.
3. The method of Claim 1, wherein the flow rate and pressure are
determined using a minimum acceptable lubrication profile.
- 25 4. The method of Claim 3, wherein the minimum acceptable lubrication
profile is a look-up table based at least on power loss.
5. The method of Claim 3, wherein the minimum acceptable lubrication
profile is a look-up table based on power loss and fluid exit temperature.

- 5
6. The method of Claim 3, wherein the minimum acceptable lubrication profile is based on power loss at a current operation condition, wherein the current operation condition is function of input speed, CVP ratio, and input torque.
7. The method of Claim 3, wherein determining the power loss includes determining a CVP efficiency based on the input speed, the CVP ratio, and the input torque.
- 10
8. The method of Claim 1, wherein receiving a plurality of data signals further comprises receiving an output torque.
9. The method of Claim 8, wherein the minimum acceptable lubrication profile is based at least in part on the CVP efficiency.
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10. The method of Claim 10, wherein the CVP efficiency is based at least in part on the output torque.
11. The method of Claim 1, wherein the data signals further comprise a traction fluid life parameter.
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12. The method of Claim 1, wherein the input torque is based on a brake specific fuel consumption (BSFC) map of the engine.
13. The method of Claim 1, wherein the data signals further comprise a fluid exit temperature and a fluid supply temperature.
- 25
14. The method of Claim 13, wherein determining the power loss is a function of fluid supply temperature and the fluid exit temperature.
- 30
15. The method of Claim 13, wherein the minimum acceptable lubrication profile is based on power loss and fluid exit temperature.

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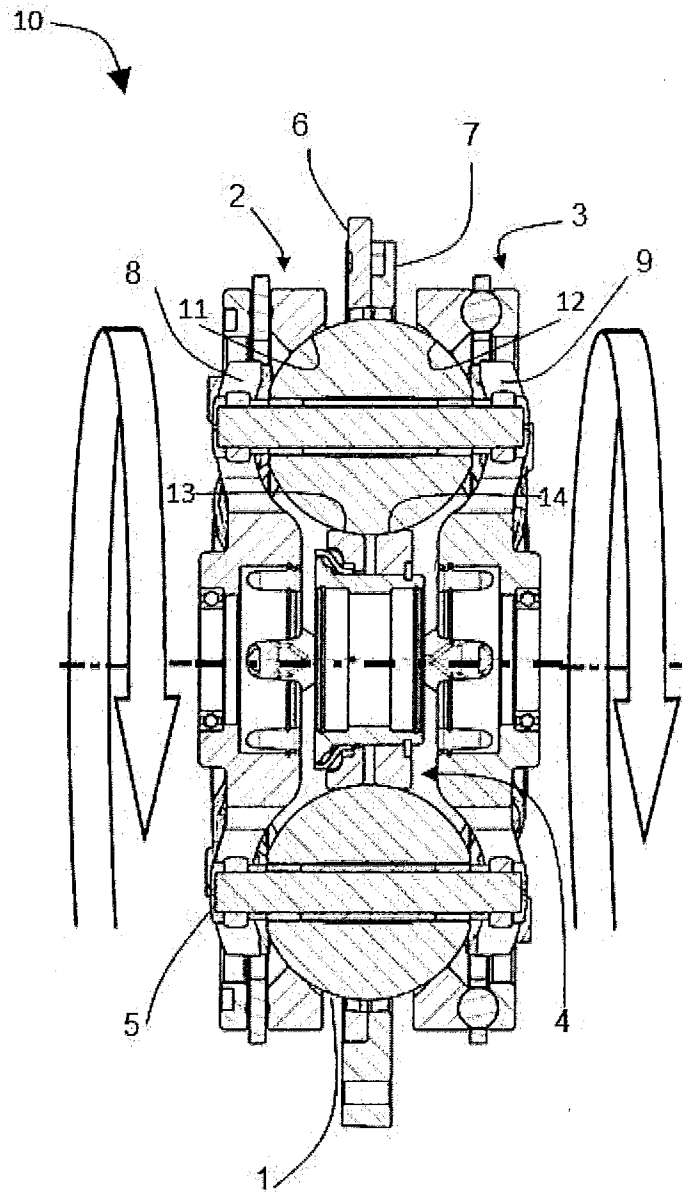


Figure 1

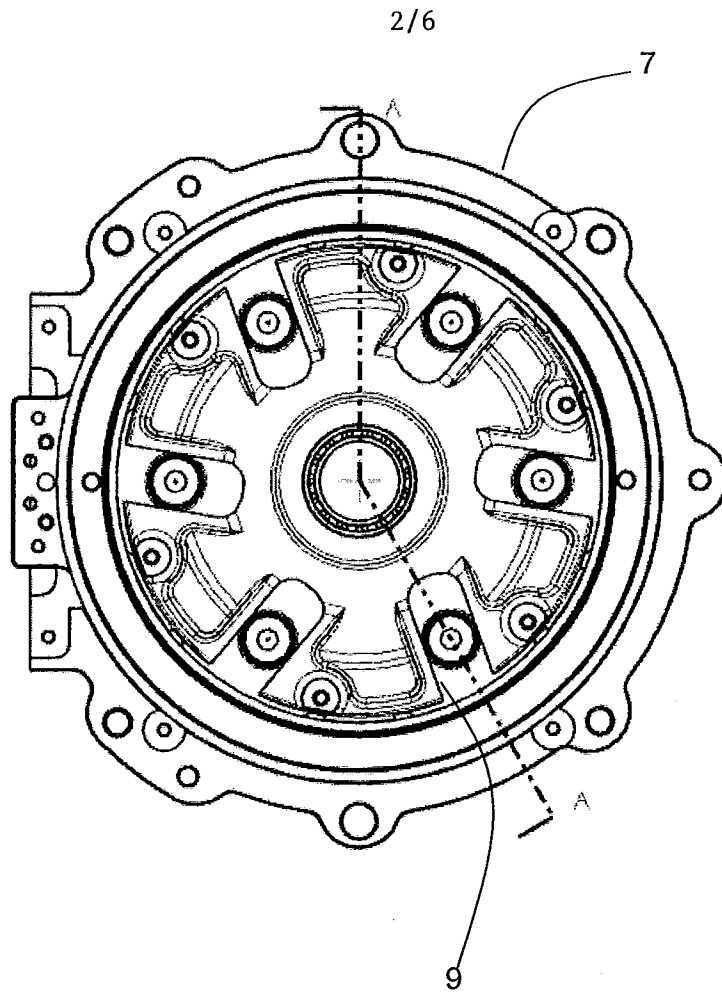


Figure 2

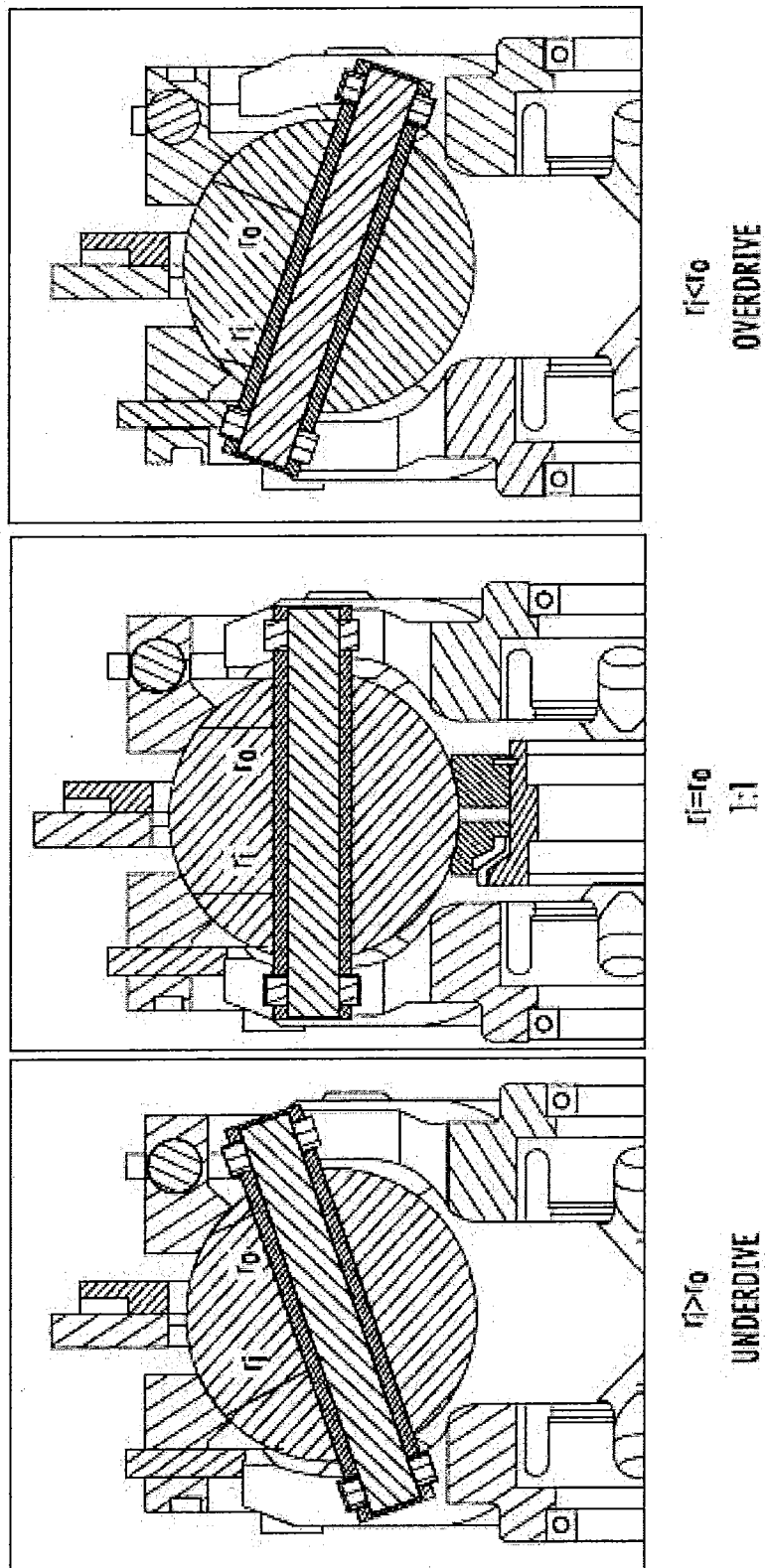


FIG. 3

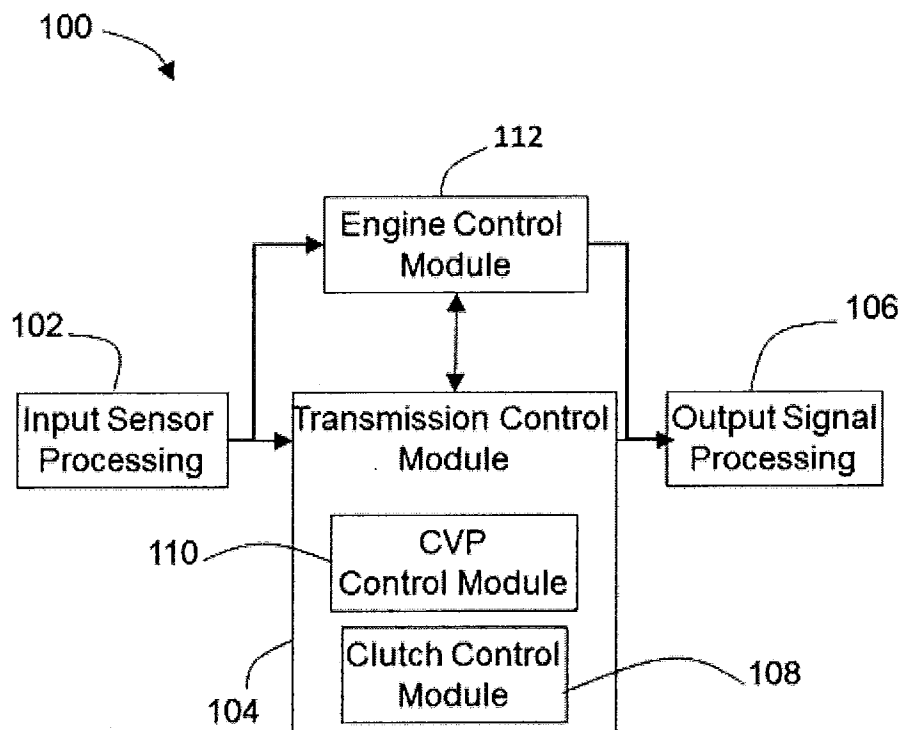


Figure 4

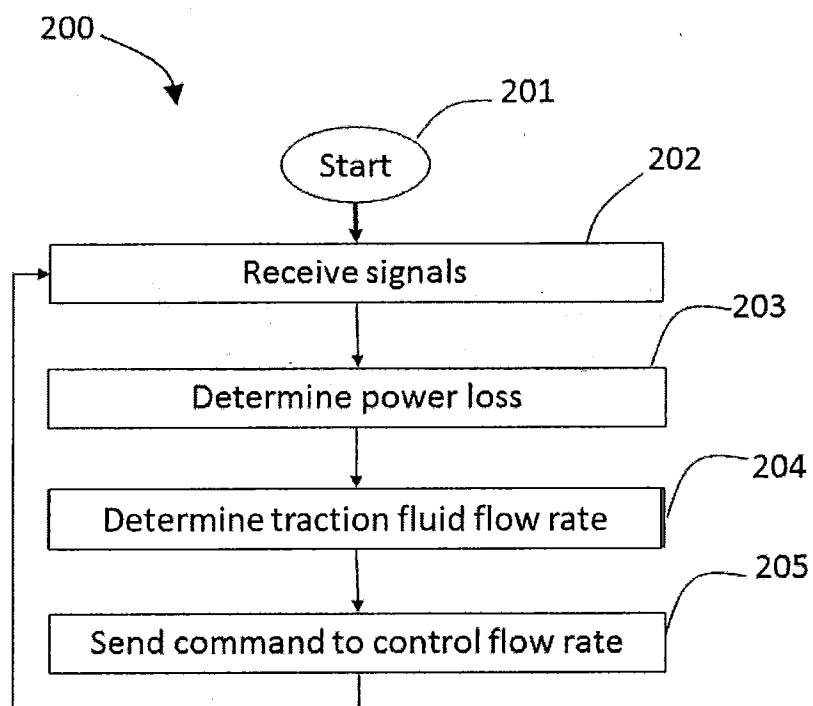


Figure 5

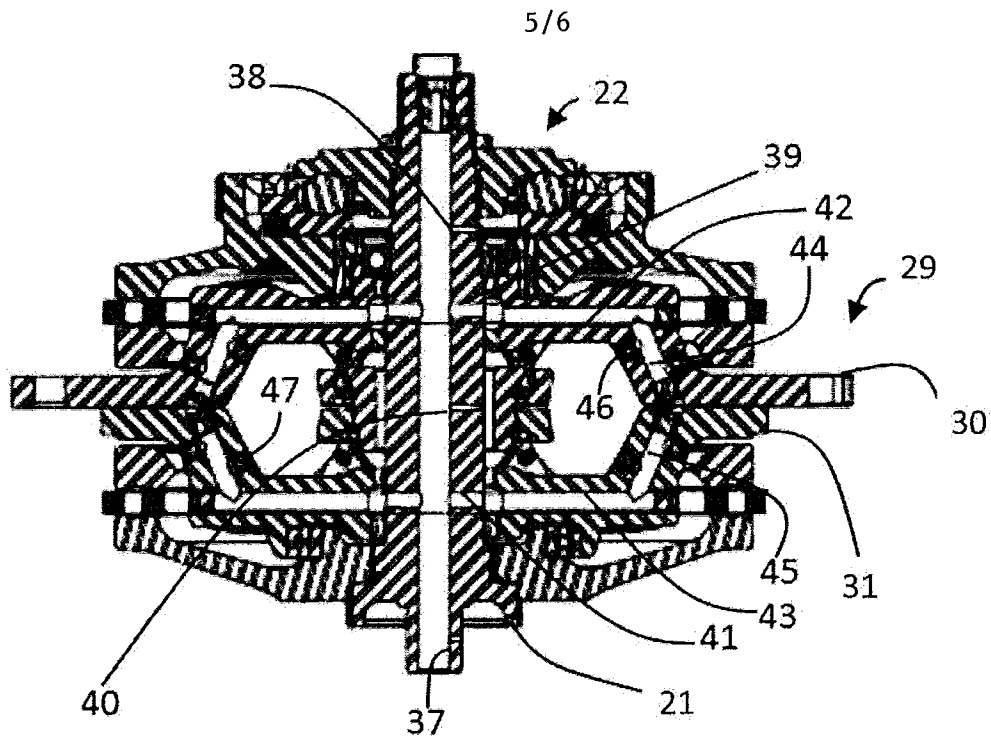


Figure 6

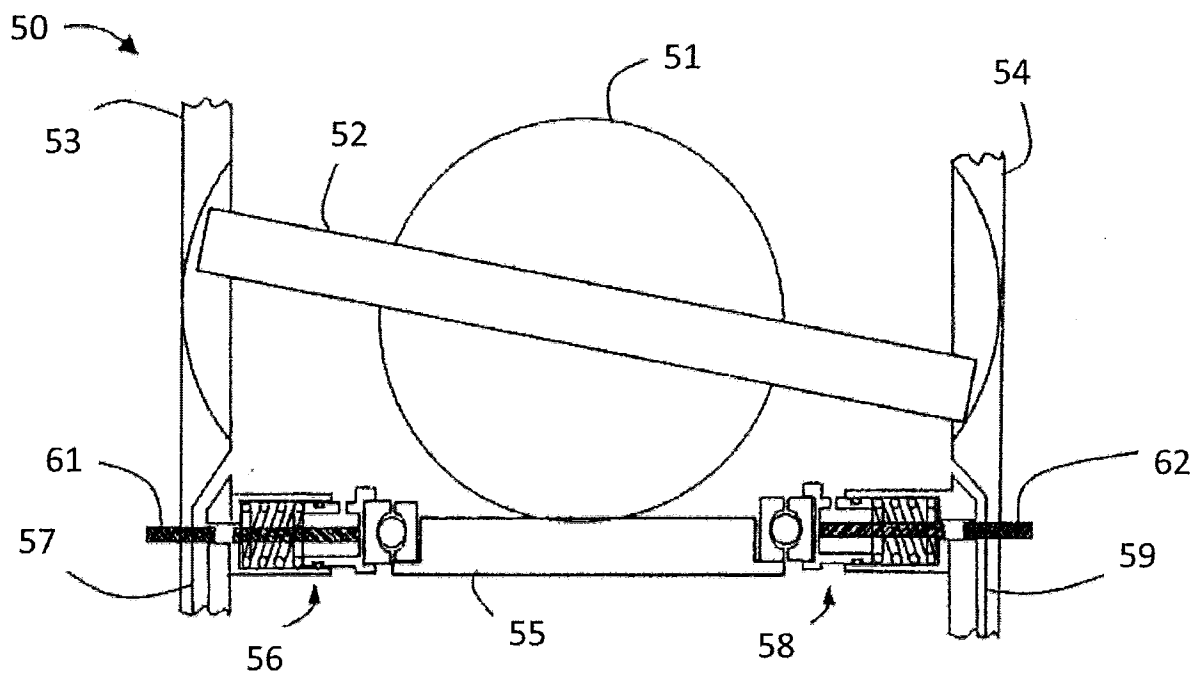


Figure 7

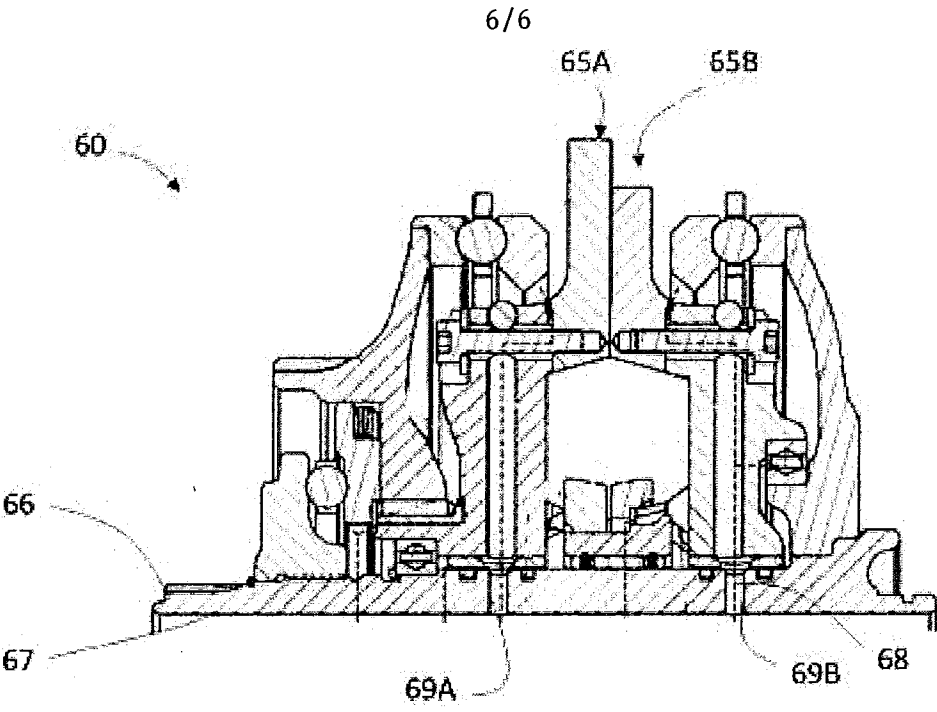


Figure 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/033825

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H61/664 F16H57/04
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	US 2017/120915 A1 (DAVID JEFFREY M [US] ET AL) 4 May 2017 (2017-05-04) paragraphs [0063] - [0065]; figures 5-12 -----	1-15
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

31 July 2018

Date of mailing of the international search report

08/08/2018

Name and mailing address of the ISA/

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Meritano, Luciano

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/033825

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

PCT/US2018/033825

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