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(54) Title: METHOD FOR DETECTING CAM HOP IN A BALL-TYPE PLANETARY CONTINUOUSLY VARIABLE TRANSMISSION

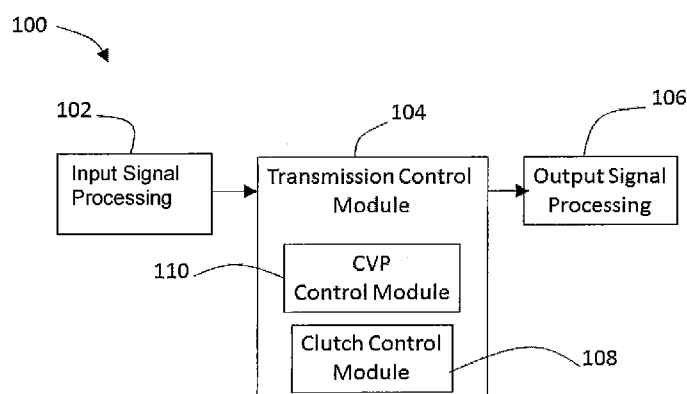


Figure 5

(57) Abstract: Provided herein is a control system for a multiple-mode continuously variable transmission having a ball-type planetary variator. The control system has a transmission control module configured to receive a plurality of electronic input signals, and to determine a mode of operation from a plurality of control ranges based at least in part on the plurality of electronic input signals. The transmission control module includes a CVP control module. The CVP control module is adapted to implement a cam hop detection process. The cam hop detection process is configured to evaluate electronic input signals and determine if a cam-ramp axial force generator mechanism is operating in a condition where the cam rollers are rolling over the cam ramp.



TITLE

METHOD FOR DETECTING CAM HOP IN A BALL-TYPE PLANETARY
CONTINUOUSLY VARIABLE TRANSMISSION

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RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application No. 62/362,465 filed on July 14, 2016, which is incorporated herein by reference in its entirety.

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BACKGROUND

Continuously variable transmissions (CVT) and transmissions that are substantially continuously variable are increasingly gaining acceptance in various applications. The process of controlling the ratio provided by the CVT is complicated by the continuously variable or minute gradations in ratio presented by the CVT. Furthermore, the range of ratios that are available to be implemented in a CVT are not sufficient for some applications. A transmission is capable of implementing a combination of a CVT with one or more additional CVT stages, one or more fixed ratio range splitters, or some combination thereof in order to extend the range of available ratios. The combination of a CVT with one or more additional stages further complicates the ratio control process, as the transmission will have multiple configurations that achieve the same final drive ratio.

The different transmission configurations could for example, multiply input torque across the different transmission stages in different manners to achieve the same final drive ratio. However, some configurations provide more flexibility or better efficiency than other configurations providing the same final drive ratio.

The criteria for optimizing transmission control could be different for different applications of the same transmission. For example, the criteria for optimizing control of a transmission for fuel efficiency will differ based on the type of prime mover applying input torque to the transmission. Furthermore, for

a given transmission and prime mover pair, the criteria for optimizing control of the transmission will differ depending on whether fuel efficiency or performance is being optimized.

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SUMMARY

Provided herein is a computer-implemented system for a vehicle having an engine coupled to a continuously variable transmission having a ball-type planetary variator (CVP), the computer-implemented system including: a digital processing device having an operating system configured to perform
10 executable instructions and a memory device; a computer program including instructions executable by the digital processing device, the computer program having a software module configured to control the CVP and the engine; and a plurality of data signals including: an input speed, an output speed, a CVP input torque, a CVP ratio, wherein the software module is configured to execute a
15 cam hop detection process, wherein the cam hop detection process is configured to detect a cam hop event based at least in part on the input speed, the output speed, the CVP input torque, and the CVP ratio, and wherein the software module sends a fault mitigation command based on the detection of the cam hop event, wherein the fault mitigation command imparts a change in
20 operating condition to the CVP or the engine.

Provided herein is a method of operating a continuously variable ball-type transmission (CVP) having a cam-ramp axial force generator mechanism, the method including the steps of: receiving an input speed signal, an output speed signal, an input torque signal, and a CVP ratio signal; determining a
25 speed error based at least in part on the input speed signal, the output speed signal and the desired ratio; determining a cam hop frequency based at least in part on the speed error; determining a cam hop detection criteria based at least in part on the speed error, the input torque, and the CVP ratio; determining a cam hop fault signal based at least in part on the cam hop detection criteria;
30 and commanding a change in the CVP ratio based on the cam hop fault signal.

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
5 individually indicated to be incorporated by reference.

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
10 and advantages of the present embodiments will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the preferred embodiments are utilized, and the accompanying drawings of which:

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

15 Figure 2 is a plan view of a carrier member that 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.

20 Figure 4 is an exploded view of an exemplary axial force generating device having cam ramps and rollers.

Figure 5 is a block diagram schematic of a transmission control system that could be implemented in a vehicle.

Figure 6 is a flow chart depicting a cam hop detection process that is implementable in the transmission control system of Figure 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An electronic controller 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
30 Variable Transmission (IVT), or variator. The electronic controller could be configured to receive input signals indicative of parameters associated with an engine coupled to the transmission. The parameters could include 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 could also receive one or more control inputs. The electronic controller could determine an active range and an active variator mode based on the input signals and control
5 inputs. The electronic controller could 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.

The electronic controller described herein is described in the context of a
10 continuous variable transmission, such as the continuous variable transmission of the type described in U.S. Patent Application Number 14/425,842, entitled "3-Mode Front Wheel Drive And Rear Wheel Drive Continuously Variable Planetary Transmission" and, PCT Patent Application Number PCT/US2016/
030930, entitled "Control Method of Synchronous Shifting of a Multi-Range
15 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 rather, could be configured to control any of several types of variable ratio transmissions.

20 Provided herein are configurations of CVTs based on a ball-type variator, also known as CVP, for continuously variable planetary. Basic concepts of a ball-type Continuously Variable Transmissions are described in United States Patent No. 8,469,856 and 8,870,711 incorporated herein by reference in their entirety. Such a CVT, adapted herein as described
25 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, as input traction ring assembly 2 and output traction ring assembly 3, and an idler (sun) assembly 4 as shown on FIG. 1. In some
30 embodiments, the output traction ring assembly 3 includes an axial force generator mechanism having a cam ball retainer disc 10 in contact with a cam driver 11. The cam ball retainer disc 10 retains a number of cam rollers 13. In some embodiments, the cam rollers 13 are spheres. A traction ring 12 contacts the balls 1. The balls are mounted on tiltable axles 5, themselves held in a

carrier (stator, cage) assembly having a first carrier member 6 operably coupled to a second carrier member 7. The first carrier member 6 rotates with respect to the second carrier member 7, and vice versa. In some embodiments, the first carrier member 6 is substantially fixed from rotation while the second carrier member 7 is configured to rotate with respect to the first carrier member, and vice versa. In 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, as illustrated in FIG. 2. The radial guide slots 8 and the radially offset guide slots 9 are adapted to guide the tiltable axles 5. The axles 5 are adjustable to achieve a desired ratio of input speed to output speed during operation of the CVT. In some embodiments, adjustment of the axles 5 involves control of the position of the first 6 and second carrier 7 members to impart a tilting of the axles 5 and thereby adjusts the ratio of the variator. Other types of ball CVTs also exist, like the one produced by Milner, but are slightly different.

The working principle of such a CVP of FIG. 1 is shown on FIG. 3. The CVP itself works with a traction fluid. The lubricant between the ball and the conical rings acts as a solid at high pressure, transferring the power from the input ring, through the balls, to the output ring. By tilting the balls' axes, the ratio is changed between input and output. When the axis is horizontal, the ratio is one, as 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 herein are related to the control of a variator and/or a CVT using generally spherical planets each having a tiltable axis of rotation that is adjustable to achieve a desired ratio of input speed to output speed during operation. In some embodiments, adjustment of said axis of rotation involves angular misalignment of the planet axis in a first plane in order to achieve an angular adjustment of the planet axis in a second plane that is substantially perpendicular to the first plane, thereby adjusting the 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 adjusts the ratio of the variator.

Referring now to FIG. 4, during operation of the CVP depicted in FIGS. 1-3, a torque dependent axial force is generated to provide sufficient traction between the traction ring 12 and the balls 1, for example. In some embodiments, a cam-ramp mechanism is used to generate the axial force. In some embodiments, the cam-ramp mechanism includes the cam rollers 13 in contact with a number of ramp surfaces 14 formed on the traction ring 12, for example. The ramp surface 14 has a peak surface 15 and a valley surface 16. During normal operation, the cam roller 13 is positioned along the ramp surface 14. Under certain operating conditions, the torque transmitted through the CVP exceeds the designed limit, and the cam roller 13 travels up the ramp 14 to the peak surface 15 and falls to the valley surface 16. This phenomenon is referred to herein as "cam hop" or "cam hop event".

During cam hop events, because the combined inertia of the engine and CVP is significantly less than the equivalent inertia of the vehicle mass connected to the output shaft, it is expected that the resulting speed disturbance will be primarily reflected in the input speed signal of the CVP rather than the output speed signal. Additionally, during cam hop events as the cam rollers 13 pass over the peak surface 15, the transmission unloads and the input speed signal will rise then subsequently fall as the transmission reloads when the cam roller 13 travels up the next ramp 14. This produces a half sinusoid disturbance in the input speed signal that occurs at a predictable frequency based in part upon the speed error and the number of cam rollers 13. It is this target frequency that is used as the basis for the cam hop detection method. Note that additional conditions exist that can result in a similar speed error in the drive, such as creep, gross slip, or actuator-based ratio errors. The differentiating condition between cam hop and the other speed error mechanisms is that only cam hop is expected to have significant frequency content. It is desirable to implement a control system that is capable of detecting operating conditions where cam hop is occurring.

For description purposes, the term “torque threshold”, as used herein, indicates a calibratable value of torque at which a designer desires a control sub-module to enable operation or dis-able operation.

As used here, the terms “operationally connected,” “operationally coupled”, “operationally linked”, “operably connected”, “operably coupled”, “operably coupleable”, “operably linked,” and like terms, refer to a relationship (mechanical, linkage, coupling, etc.) between elements whereby operation of one element results in a corresponding, following, or simultaneous operation or actuation of a second element. It is noted that in using said terms to describe inventive embodiments, specific structures or mechanisms that link or couple the elements are typically described. However, unless otherwise specifically stated, when one of said terms is used, the term indicates that the actual linkage or coupling will 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”, as used herein indicates a direction or position that is perpendicular relative to a longitudinal axis of a transmission or variator. The term “axial” as used herein refers to a direction or position along an axis that is parallel to a main or longitudinal axis of a transmission or variator.

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 herein, generally, these are 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 that would be available at the interfaces of the contacting components and is a measure of the maximum available drive torque. 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 could 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". Traction fluid is also influenced by entrainment speed of the fluid and temperature at the contact patch, for example, the traction coefficient is generally highest near zero speed and decays as a weak function of speed. The traction coefficient often improves with increasing temperature until a point at which the traction coefficient rapidly degrades.

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. Said power source could be fueled by energy sources having hydrocarbon, electrical, biomass, 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 having this technology.

Those of skill will recognize that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein, including with reference to the transmission control system described herein, for example, could be 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, 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 embodiments.

For example, various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein could be 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 could be a microprocessor, but in the alternative, the processor could be any conventional processor, controller, microcontroller, or state machine. A processor could also be 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 could reside 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 the processor reads information from, and write information to, the storage medium. In the alternative, the storage medium could be integral to the processor. The processor and the storage medium could reside in an ASIC. For example, in one embodiment, a controller for use of control of the IVT comprises a processor (not shown).

Referring now to FIG. 5, in one embodiment, a transmission controller 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. 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. One sub-module included in the CVP control sub-module 110 is described herein.

Referring now to FIG. 6, in some embodiment, the CVP control sub-module 110 is configured to implement a cam hop detection process 120. The cam hop detection process 120 begins at a start state 121 and proceeds to a block 122 where a number of signals are received. In some embodiments, the signals include an input speed signal, an output speed signal, an input torque

signal, and a CVP ratio signal. It should be appreciated that the signals are optionally configured to be provided by measurements from electronic sensors, or calculated or inferred from other measured signals. The cam hop detection process 120 proceeds to a block 123 where a speed error is computed. In some embodiments, the speed error is calculated by multiplying the first (i.e. input) traction ring speed by the commanded ratio and subtracting the result from the second (i.e. output) traction ring speed. The cam hop detection process 120 proceeds to a first evaluation block 124 where the speed error determined in the block 123 is compared to a threshold value. In some embodiments, the threshold value is a calibratable variable stored in memory. The threshold value is representative of an upper limit of speed error between the first traction ring and the second traction ring. If the first evaluation block 124 returns a false result, the cam hop detection process 120 proceeds to the block 122. If the first evaluation block 124 returns a true result, the cam hop detection process 120 proceeds to a block 125 where cutoff frequencies for a bandpass filter are determined. In some embodiments, the frequency of a cam hop event is a function of the number of cam balls and ramps in the device. For example, the cam hop frequency is the inverse of the equation $60/(\text{speed error} * \text{number_of_balls})$, where the speed error is the result of the block 123 and "number_of_balls" equals the number of cam balls. Stated differently, the cam hop frequency is the inverse of the elapsed time between cam hop events. The cam hop frequency is the basis for forming the upper and lower bandpass filter cutoff frequencies. It should be appreciated that the upper and lower bandpass cutoff frequencies are tunable to achieve desired operation.

Still referring to FIG. 6, the cam hop detection process 120 proceeds to a block 126 where a bandpass filter, or other well-known means of determining a signal magnitude at a specific frequency is applied to the speed error signal determined in the block 123. The cam hop detection process 120 proceeds to a block 127 where a magnitude at a target frequency is determined in order to set criteria for cam hop detection. The cam hop detection process 120 proceeds to a second evaluation block 128 where the results of the bandpass filter in the block 126 are compared to the cam hop detection criteria determined in the block 127. If the second evaluation block 128 returns a false

result, the cam hop detection process 120 proceeds to the block 122. If the second evaluation block 128 returns a true result, the cam hop detection process 120 proceeds to a block 129 where a cam hop fault signal is set as true. In some embodiments, the cam hop fault signal is sent to other modules and/or processes in the control system 100. The cam hop detection process 120 proceeds to a block 130 where mitigation commands are determined. In some embodiments, mitigation commands to reduce input torque to the CVP are formed in order to stop the cam hop event. In some embodiments, mitigation commands to change the ratio of the CVP are formed in order to stop the cam hop event. Because cam hop will occur on the ring with the highest torque, a CVP ratio shift from underdrive toward unity will balance the ring torques and reduce the peak torque on the system, thus serving to stop the cam hop event. The cam hop detection process 120 proceeds to the block 122.

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

The foregoing description details certain embodiments. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the preferred embodiments are 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
5 embodiments. It should be understood that various alternatives to the
embodiments described herein could 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.

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WHAT IS CLAIMED IS:

1. A computer-implemented system for a vehicle having an engine coupled to a continuously variable transmission having a ball-planetary variator (CVP), the computer-implemented system comprising:

a digital processing device comprising an operating system configured to perform executable instructions and a memory device;

a computer program including instructions executable by the digital processing device, the computer program comprising a software module configured to control the CVP and the engine; and

a plurality of data signals comprising:

- an input speed,
- an output speed,
- a CVP input torque,
- a CVP ratio,

wherein the software module is configured to execute a cam hop detection process;

wherein the cam hop detection process is configured to detect a cam hop event based at least in part on the input speed, the output speed, the CVP input torque, and the CVP ratio; and

wherein the software module sends a fault mitigation command based on the detection of the cam hop event, wherein the fault mitigation command imparts a change in operating condition to the CVP or the engine.

2. The computer-implemented system of Claim 1, wherein the cam hop detection process is configured to determine a speed error based on the input speed and the output speed.

3. The computer-implemented system of Claim 2, wherein the cam hop detection process is configured to determine a cam hop frequency.

4. The computer-implemented system of Claim 3, wherein the cam hop detection process is configured to apply a bandpass filter to the speed error.

5. The computer-implemented system of Claim 4, wherein the cam hop detection process is configured to determine a cam hop detection criteria comprising a speed error magnitude at a target frequency.

6. The computer-implemented system of Claim 5, wherein the cam hop detection process is configured to determine a cam hop fault signal.

7. A method of operating a continuously variable ball-type transmission (CVP) having a cam-ramp axial force generator mechanism, the method comprising the steps of:

receiving an input speed signal, an output speed signal, an input torque signal, and a CVP ratio signal;

determining a speed error based at least in part on the input speed signal and the output speed signal;

determining a cam hop frequency based at least in part on the speed error;

determining a cam hop detection criteria based at least in part on the speed error, the input torque, and the CVP ratio;

determining a cam hop fault signal based at least in part on the cam hop detection criteria; and

commanding a change in the CVP ratio based on the cam hop fault signal.

8. The method of Claim 7, wherein determining a cam hop frequency further comprises applying a bandpass filter.

9. The method of Claim 8, further comprising determining cam hop fault mitigation commands.

10. The method of Claim 9, wherein determining cam hop fault mitigation commands comprises determining an input torque command signal.

11. The method of Claim 9, wherein determining cam hop fault mitigation commands comprises determining a CVP ratio command.

12. The method of Claim 11, wherein the CVP ratio command is 1.

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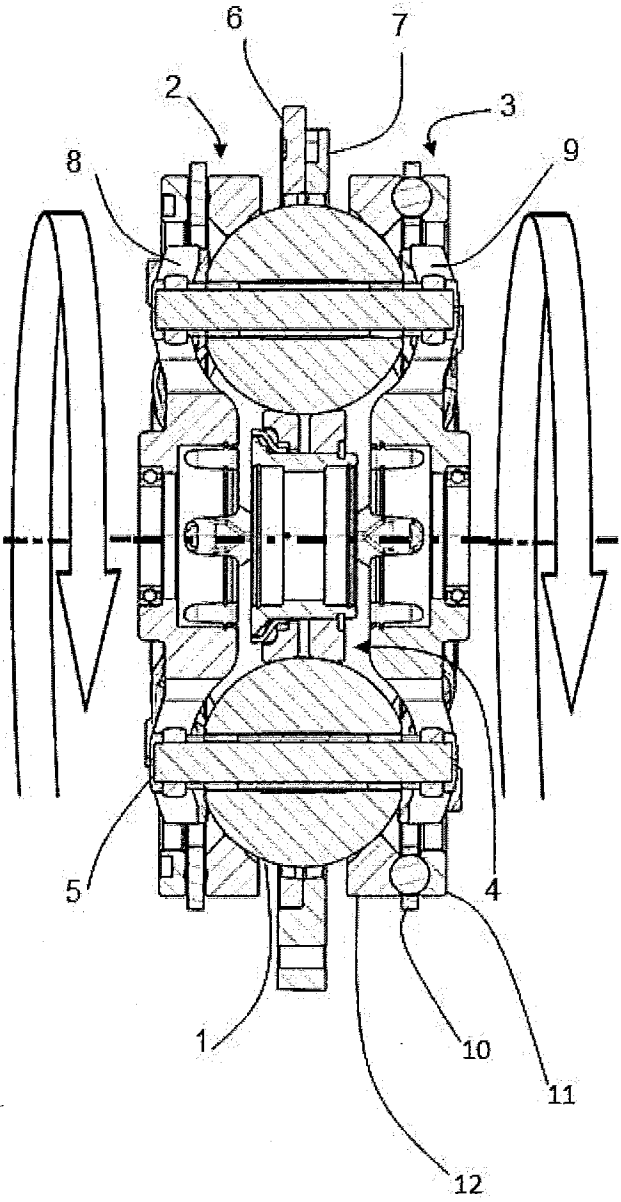


Figure 1

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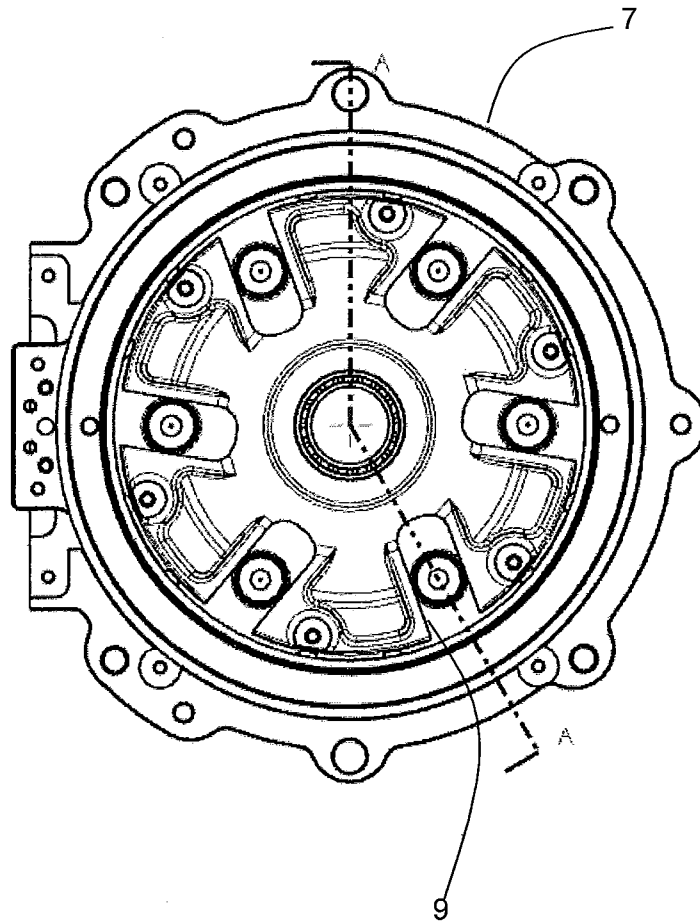


Figure 2

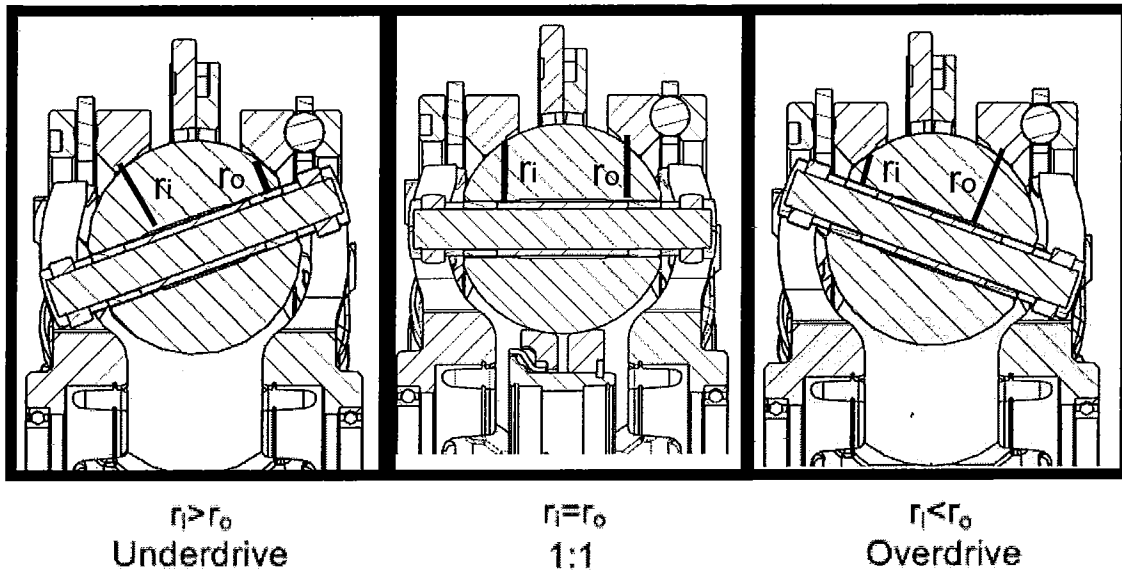


Figure 3

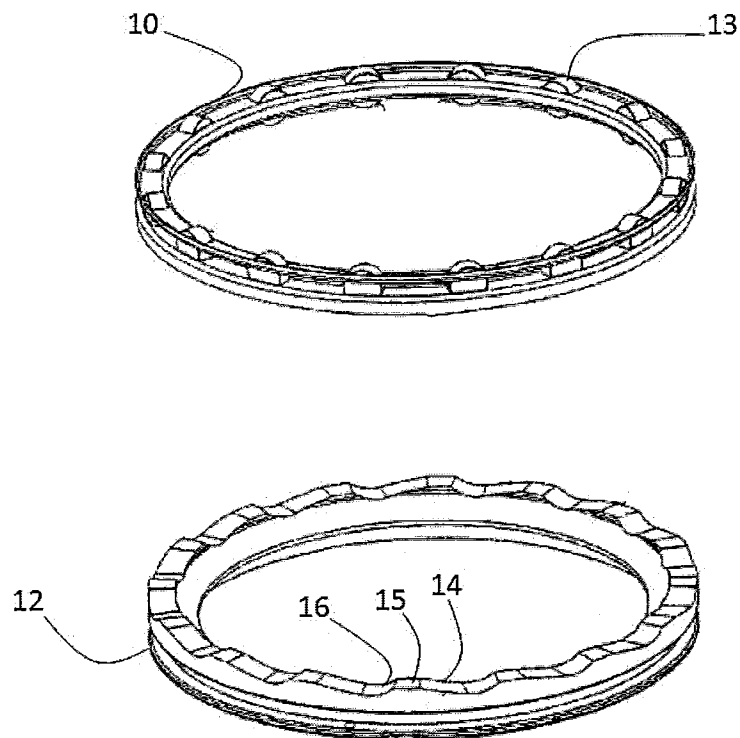


Figure 4

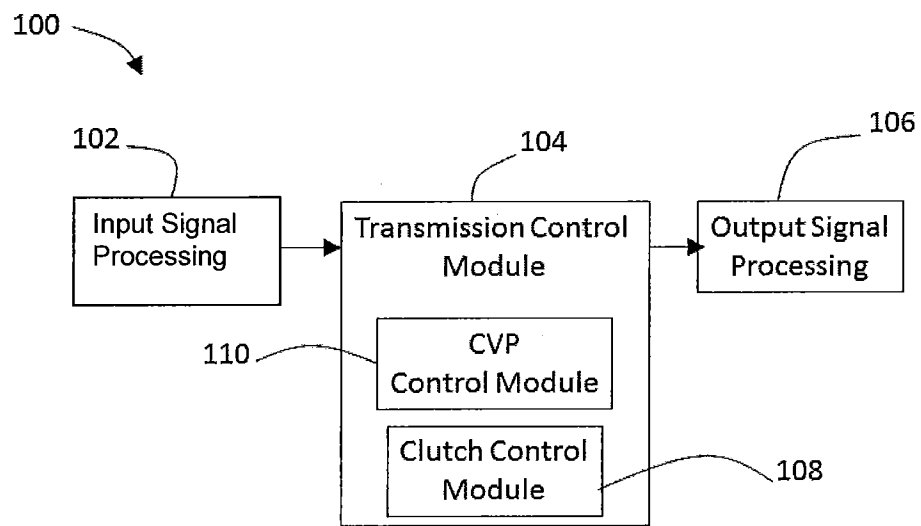


Figure 5

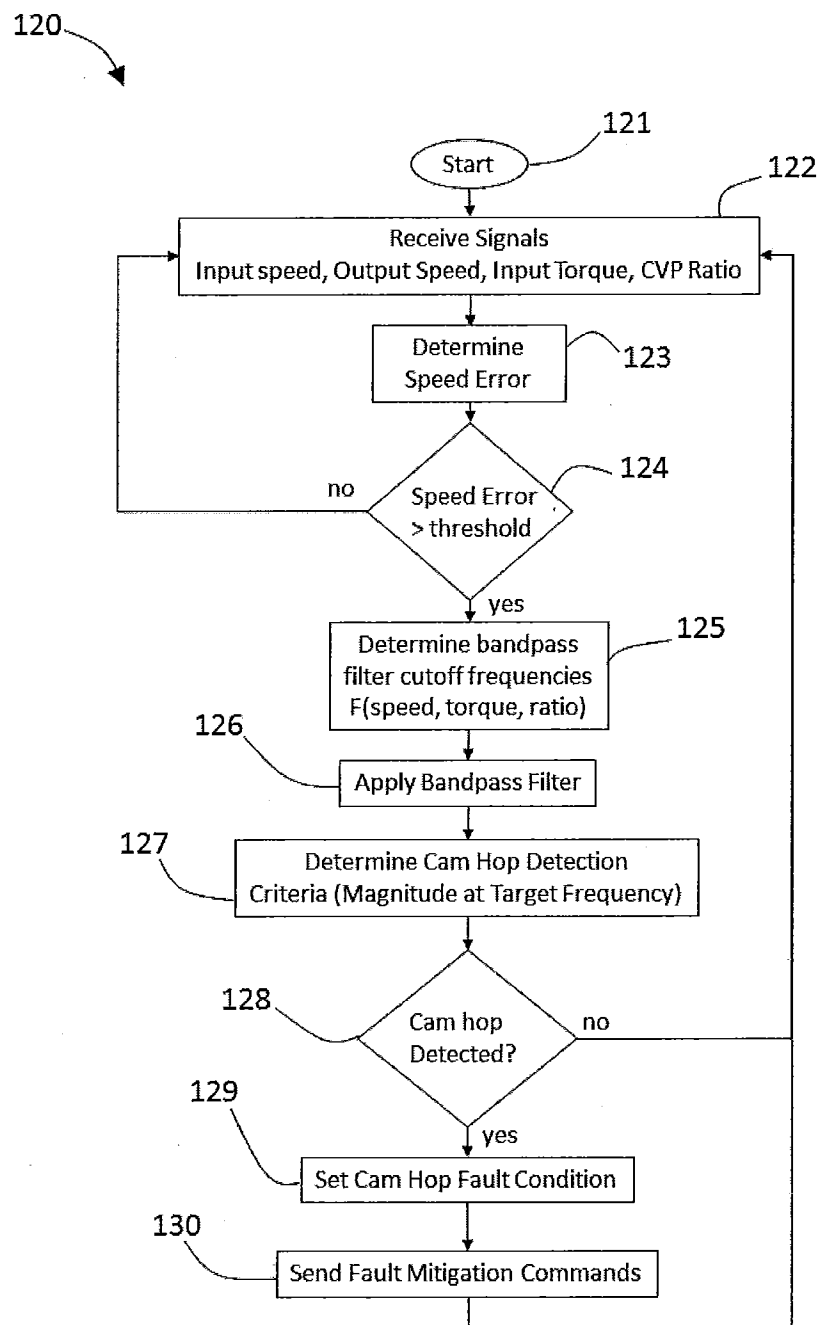


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/041833

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H61/12 F16H61/664 F16H15/28 F16H37/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16H

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/073948 A2 (DANA LTD) 21 May 2015 (2015-05-21)	1
A	figures 1, 12, 20 paragraphs [0031], [0032], [0033] -----	3-12
A	GB 2 330 186 A (LUK GETRIEBE SYSTEME GMBH [DE]) 14 April 1999 (1999-04-14) figures 8, 9a, 9b, 10 pages 27-28 -----	1-12
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