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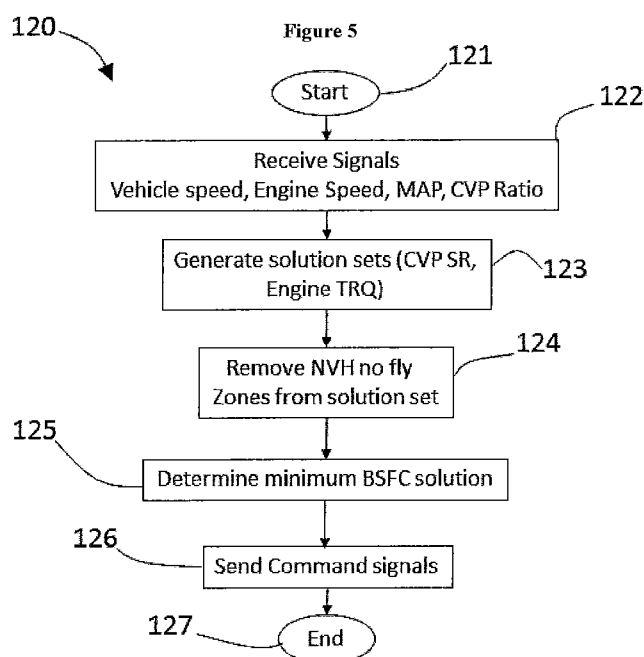
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(54) Title: METHOD FOR CONTROL OF A BALL PLANETARY TYPE CONTINUOUSLY VARIABLE TRANSMISSION TO EXTEND CYLINDER CUTOFF TIME



(57) Abstract: Provided herein is a control system for a multiple-mode continuously variable transmission having a ball 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 cylinder deactivation control process. The cylinder deactivation control process is configured to generate and select a commanded CVP speed ratio and a commanded engine torque based on a desired NVH standard and minimum BSFC.

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METHOD FOR CONTROL OF A BALL PLANETARY TYPE
CONTINUOUSLY VARIABLE TRANSMISSION
TO EXTEND CYLINDER CUTOFF TIME

5 RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application No. 62/416,379 filed on November 2, 2016 which is incorporated herein by reference in its entirety.

10 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.

Modern vehicles typically employ a variety of technologies to reduce fuel consumption and improve exhaust emissions. One type of technology is variable displacement systems for internal combustion engines (ICE) that typically achieve variable displacement through engine cylinder deactivation

during operation. Cylinder deactivation is used to reduce fuel consumption and emissions of an ICE during light-load operation. In typical light-load driving the driver uses around 30% or less of the engine's maximum power. By selectively shutting down cylinders of the ICE, fuel consumption can be reduced.

5 However, there are limitations on operating engine operating conditions where deactivation of cylinders is avoided due to noise-vehicle-harshness (NVH) and torque demand considerations. It is desirable to expand the engine operating conditions where cylinder deactivation can be used.

10 SUMMARY

Provided herein is a method for controlling a continuously variable transmission having a ball-planetary variator (CVP) provided with a ball in contact with a first traction ring assembly, a second traction ring assembly, a first sun member, and a second sun member, wherein the continuously variable
15 transmission is operably coupled to an engine. The method includes the steps of: generating a first plurality of solution sets comprising a commanded cylinder deactivation mode, a commanded CVP speed ratio, and a commanded engine torque, wherein the each solution set is based at least on a vehicle speed, an engine speed, an engine manifold air pressure, and a current CVP speed ratio;
20 generating a second plurality of solution sets by removing solution sets from the first plurality of solution sets corresponding to vehicle speeds, engine speeds, engine manifold air pressures, and CVP speed ratios outside of a noise-vehicle-harshness (NVH) standard; determining a solution set corresponding to the minimum brake specific fuel consumption of the engine
25 based on the second plurality of solution sets; and issuing the commanded cylinder deactivation mode, the commanded engine torque and the commanded CVP speed ratio from the solution set corresponding to the minimum brake specific fuel consumption of the engine to the CVP and the engine.

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 devices 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 ball-type 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 a block diagram schematic of one embodiment of a vehicle control system.

Figure 5 is a flow chart depicting a cylinder deactivation control process implementable in the vehicle control system of Figure 4.

Figure 6 is a flow chart depicting an enable process implementable in the vehicle control system of Figure 4.

25 Figure 7 is a block diagram depicting an optimization process implementable in the cylinder deactivation control process of Figure 5.

Figure 8 is chart depicting regions of cylinder deactivation with respect to engine torque verses engine speed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is to be understood that the preferred embodiments may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the concepts defined herein. Hence, specific dimensions, directions or other physical characteristics relating to the embodiments disclosed are not to be considered as limiting, unless expressly stated otherwise.

Provided herein is a computer-implemented method and system for controlling a variable ratio transmission of a vehicle having an engine coupled to the variable transmission having a ball-planetary variator (CVP), the vehicle having a plurality of sensors and an electronic controller.

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 Variable Transmission (IVT), or variator. In some embodiments, the electronic controller is configured to receive input signals indicative of parameters associated with an engine coupled to the transmission. The parameters can include, but are not limited to, throttle position sensor values, accelerator pedal position sensor values, vehicle speed, engine speed, engine coolant temperature, engine oil temperature, engine manifold air pressure, gear selector position, user-selectable mode configurations, and the like, or some combination thereof. In some embodiments, the electronic controller receives one or more control inputs. In some embodiments, the electronic controller determines an active range and an active variator mode based on the input signals and control inputs. In some embodiments, the electronic controller controls 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 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, U.S. Patent Application Number 62/158,847, entitled "Control Method of Synchronous Shifting of a Multi-Range 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, is optionally configured to control any of several types of variable ratio transmissions.

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 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 (first) traction ring assembly 2 and output (second) traction ring assembly 3, and an idler (sun) assembly 4 as shown on FIG. 1. In some embodiments, the output traction ring assembly 3 includes an axial force generator mechanism. 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 and second carrier members to impart a tilting of the axles 5 and thereby adjusts the speed ratio of the variator. Other types of ball CVTs also exist, 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 speed ratio of the variator. The angular misalignment in the first plane is referred to here as "skew", "skew angle", and/or "skew condition". In 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 speed ratio of the variator.

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
5 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
10 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
15 “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
20 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
25 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
30 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.”

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 herein 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 CVT comprises a processor (not shown).

In some embodiments, the control system 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 includes 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 computers, laptop computers, notebook computers, sub-notebook computers, netbook computers, netpad 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. 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 the device's hardware and provides services for execution of applications. Those of skill in the art will recognize that suitable server operating systems include, by way of non-limiting examples, FreeBSD, OpenBSD, NetBSD®, Linux, Apple® Mac OS X Server®, Oracle® Solaris®, Windows Server®, and Novell® NetWare®. Those of skill in the art will recognize that suitable personal computer operating systems include, by way of non-limiting examples, Microsoft® Windows®, Apple® Mac OS X®, UNIX®, and UNIX-like operating systems such as GNU/Linux®. In some embodiments, the operating system is provided by cloud computing. Those of skill in the art will also recognize that suitable mobile smart phone operating systems include, by way of non-limiting examples, Nokia® Symbian® OS, Apple® iOS®, Research In Motion® BlackBerry OS®, Google® Android®, Microsoft® Windows Phone® OS, Microsoft® Windows Mobile® OS, Linux®, and Palm® WebOS®.

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 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 further embodiments, the non-volatile memory includes flash memory. In some embodiments, the nonvolatile memory includes dynamic random-access memory (DRAM). In some embodiments, the non-volatile memory includes ferroelectric random access memory (FRAM). In some embodiments, the non-volatile memory includes phase-change random access memory (PRAM). In other embodiments, the device is a storage device including, by way of non-limiting examples, CD-ROMs, DVDs, flash memory devices, magnetic disk drives, magnetic tapes drives, optical disk drives, and cloud computing based storage. In further embodiments, the storage and/or memory device is a combination of devices such as those disclosed herein.

In some embodiments, the control system 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 may be 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 may be written in various versions of various languages.

The functionality of the computer readable instructions may be combined or distributed as desired in various environments. In some embodiments, a computer program includes one sequence of instructions. In some embodiments, a computer program includes 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 include, but are not limited to, 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 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. In some embodiments, the engine control module 112 is configured to manage cylinder deactivation of an engine equipped in the vehicle. Cylinder deactivation is used to reduce fuel consumption and emissions of an ICE during light-load operation. In typical light-load driving the driver uses around 30% or less of the engine's maximum power. By selectively shutting down cylinders of the ICE, fuel consumption can be reduced. However, there are limitations on operating engine operating conditions where deactivation of cylinders is avoided due to noise-vehicle-harshness (NVH) considerations. It is desirable to expand the engine operating conditions where cylinder deactivation can be used.

Referring now to FIG. 5, in some embodiments, the transmission control module 104 is configured to implement a cylinder deactivation control process 120. The cylinder deactivation control process 120 begins at a start state 121 and proceeds to a block 122 where a number of input signals are received. For example, the input signals are provided by the input signal processing module 102 and are indicative of a vehicle speed, an engine speed, a manifold air pressure of the engine (MAP), and a CVP speed ratio, among others. In some embodiments, a mass air flow (MAF) is used in place of the MAP to indicate an engine load. The cylinder deactivation control process 120 proceeds to a block 123 where a number of solution sets are generated. Each solution set includes a commanded deactivation mode, a commanded CVP speed ratio signal, and a commanded engine torque based at least in part on the vehicle speed, the engine speed, the MAP, and the current CVP speed ratio. In some embodiments, the commanded deactivation mode corresponds to a command to shut off certain cylinders of the engine. For example, an engine having eight cylinders may optionally shut off four of the cylinders. In other embodiments, the commanded deactivation mode corresponds to a random shut off of cylinders in an engine. It should be appreciated that methods to deactivate or shut off engine cylinders are known. In some embodiments, the block 123

implements algorithms containing calibrateable look up tables to generate the solution sets. The cylinder deactivation control process 120 proceeds to a block 124 where operating conditions that are prohibited by noise-vehicle-harshness (NVH) standards are removed from the solution set generated in the block 123.

5 In some embodiments, the block 124 is optionally configured to remove operating conditions from the solution set that do not satisfy a desired output torque. The cylinder deactivation control process 120 proceeds to a block 125 where a minimum brake specific fuel consumption (BSFC) solution is determined from the available solution sets. The cylinder deactivation control
10 process 120 proceeds to a block 126 where command signals corresponding to the solution set identified in the block 125 are sent to the CVP control module 110 and the engine control module 112, for example.

Turning now to FIG. 6, in some embodiments an enable process 115 is implemented in the transmission control module 104. The enable process 115
15 is used to enable the cylinder deactivation control process 120 during operation of a vehicle equipped with the transmission control module 104. The enable process 115 begins at a start state 115 and proceeds to a block 117 where a number of signals are received such as a vehicle speed from a vehicle speed sensor, an engine torque from an engine control module, and an engine
20 temperature from a temperature sensor sensing engine coolant or engine oil temperature. The enable process 115 proceeds to an evaluation block 118 where the signals are compared to calibrateable threshold values. When the evaluation block 118 returns a false result, indicating that the vehicle speed, the engine torque, and/or the engine temperature are not within the threshold limits
25 for acceptable operation of the cylinder deactivation control process 120, the enable process 115 returns to the block 117. When the evaluation block 118 returns a true result, indicating that the vehicle speed, the engine torque, and the engine temperature are within the threshold limits for acceptable operation of the cylinder deactivation control process 120, the enable process 115
30 proceeds to a block 119 where command signals are sent to implement the cylinder deactivation control process 120. The enable process 115 returns to

the block 117.

Turning now to FIG. 7, in some embodiments, the block 123 of the cylinder deactivation control process 120 is adapted to determine solution sets for CVP ratio for two modes: a cylinder deactivation on mode and a cylinder deactivation off mode. The cylinder deactivation on mode corresponds to the operating condition where the enable process 115 has commanded the cylinder deactivation process active and reduced engine operation is allowed. The cylinder deactivation off mode corresponds to the operating condition where the enable process 115 has commanded the cylinder deactivation process inactive and reduced engine operation is not allowed. In some embodiments, the block 123 receives an engine power request 130 representative of a driver's input from an accelerator pedal, for example. The engine power request 130 is passed to a first look-up table 131 having stored calibrated values of engine speed based on optimized brake specific fuel consumption (BSFC) as a function of the engine power request 130 for operation in the cylinder deactivation on mode. For example, the first look-up table 131 returns an engine speed 133 representing an optimized engine BSFC when the cylinder deactivation process 120 is running and the engine is powered by only a few of the available cylinders. The engine power request 130 is passed in parallel to a second look-up table 132 having stored calibrated values of engine speed based on optimized engine BSFC as a function of the engine power request 130 for operation in the cylinder deactivation off mode. For example, the second look-up table 132 returns an engine speed 134 representing an optimized engine BSFC when the cylinder deactivation process 120 is not enabled. The engine speed 133 is divided by a normalized speed formed by multiplying a vehicle speed 135 by a calibrateable gain 136 to form a commanded CVP ratio 137 for cylinder deactivation on mode. Likewise, the engine speed 134 is divided by the normalized speed and forms a commanded CVP ratio 138 for operation in the cylinder deactivation off mode. It should be appreciated that the CVP control module 110 uses the commanded CVP ratio 137 when the cylinder deactivation process 120 is running, and the CVP control

module 110 uses the commanded CVP ratio 138 when the cylinder deactivation process 120 is not running.

Referring now to FIG. 8, in some embodiments, the block 124 is adapted to remove operating conditions that are unacceptable for cylinder deactivation of a particular engine. As an illustrative example, a chart 140 has an x-axis 141 representing engine speed and a y-axis representing engine torque. A curve 143 represents engine torque for a given engine having a maximum torque 144. For low engine speeds and engine torques, for example engine speeds below a lower speed limit 145, a region 146 corresponds to the engine operating conditions under which the cylinder deactivation process 120 is not enabled to run due to noise-vehicle-harshness (NVH) considerations, among others.

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

WHAT IS CLAIMED IS:

1. A method for controlling a continuously variable transmission having a ball-planetary variator (CVP) provided with a ball in contact with a first traction ring assembly, a second traction ring assembly, a first sun member, and a second sun member, wherein the continuously variable transmission is operably coupled to an engine, the method comprising the steps of:

generating a first plurality of solution sets comprising a commanded cylinder deactivation mode, a commanded CVP speed ratio, and a commanded engine torque, wherein the each solution set is based at least on a vehicle speed, an engine speed, an engine manifold air pressure, and a current CVP speed ratio;

generating a second plurality of solution sets by removing solution sets from the first plurality of solution sets corresponding to vehicle speeds, engine speeds, engine manifold air pressures, and CVP speed ratios outside of a noise-vehicle-harshness (NVH) standard;

determining a solution set corresponding to the minimum brake specific fuel consumption of the engine based on the second plurality of solution sets; and

issuing the commanded cylinder deactivation mode, the commanded engine torque and the commanded CVP speed ratio from the solution set corresponding to the minimum brake specific fuel consumption of the engine to the CVP and the engine.

2. The method of Claim 1, wherein the vehicle speed is provided by a vehicle speed sensor configured to sense a vehicle speed.

3. The method of Claim 1, wherein the engine speed is provided by an engine speed sensor configured to sense an engine speed of the engine.

4. The method of Claim 1, wherein the engine manifold air pressure is provided by an engine manifold air pressure sensor configured to sense a manifold air pressure of the engine.

5 5. The method of Claim 1, wherein the current CVP speed ratio is provided by an input speed sensor and an output speed sensor, wherein the input speed sensor is configured to sense an input speed of the CVP, and wherein the output speed sensor is configured to sense an output speed of the CVP.

10 6. The method of Claim 1, further comprising determining a set of enable criteria including a vehicle speed threshold, an engine torque threshold, and an engine temperature.

15 7. The method of Claim 6, further comprising comparing a current vehicle speed, a current engine torque and a current engine temperature to the set of enable criteria.

20 8. The method of Claim 7, wherein generating a first plurality of solution sets further comprises generating a solution set for a cylinder deactivation on mode and a solution set for cylinder deactivation off mode.

25 9. The method of Claim 8, further comprising selecting the solution set for the cylinder deactivation on mode when the current vehicle speed, the current engine torque and the current engine temperature meet the set of enable criteria.

30 10. The method of Claim 8, further comprising selecting the solution set for a cylinder deactivation off mode when the current vehicle speed, the current engine torque and the current engine temperature do not meet the set of enable criteria.

11. The method of Claim 6, wherein the engine temperature is determined from an engine coolant temperature or an engine oil temperature.

12. The method of Claim 1, wherein the commanded cylinder
5 deactivation mode includes a command to shut-off a portion of the cylinders of the engine.

13. The method of Claim 1, wherein generating a second plurality of
10 solution sets further comprises removing solution sets not meeting an output torque requirement.

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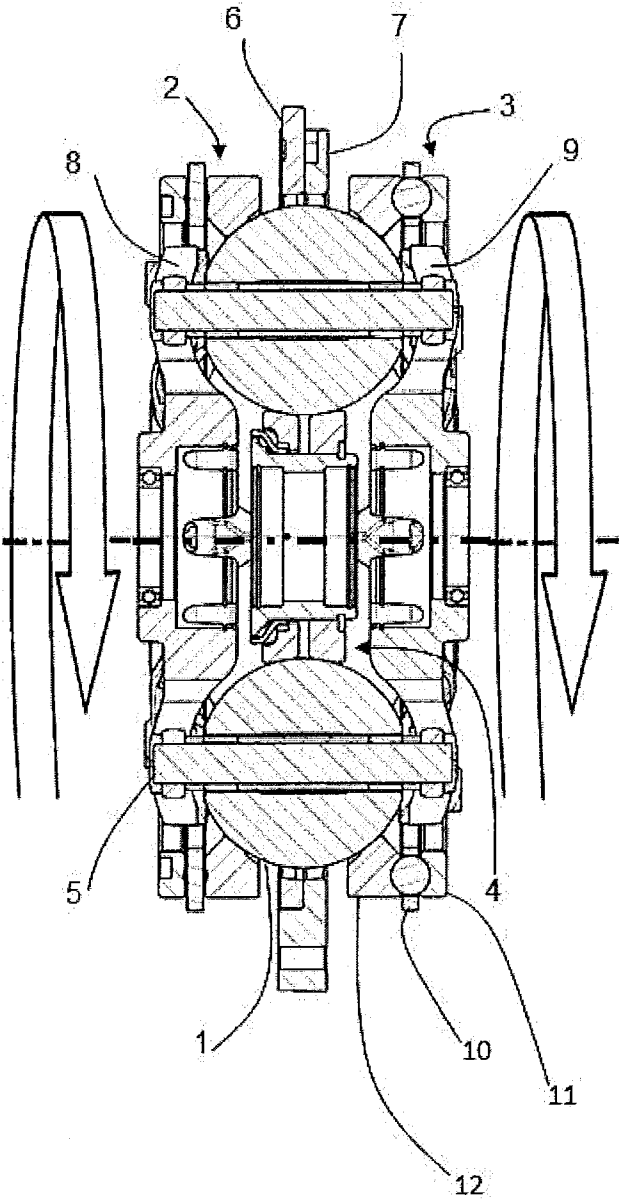


Figure 1

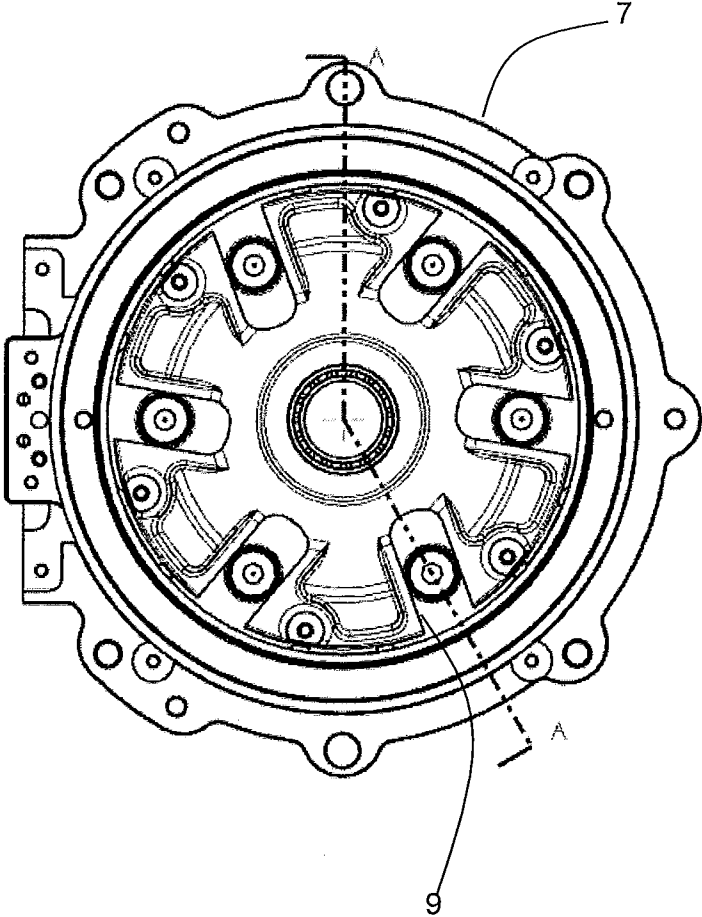


Figure 2

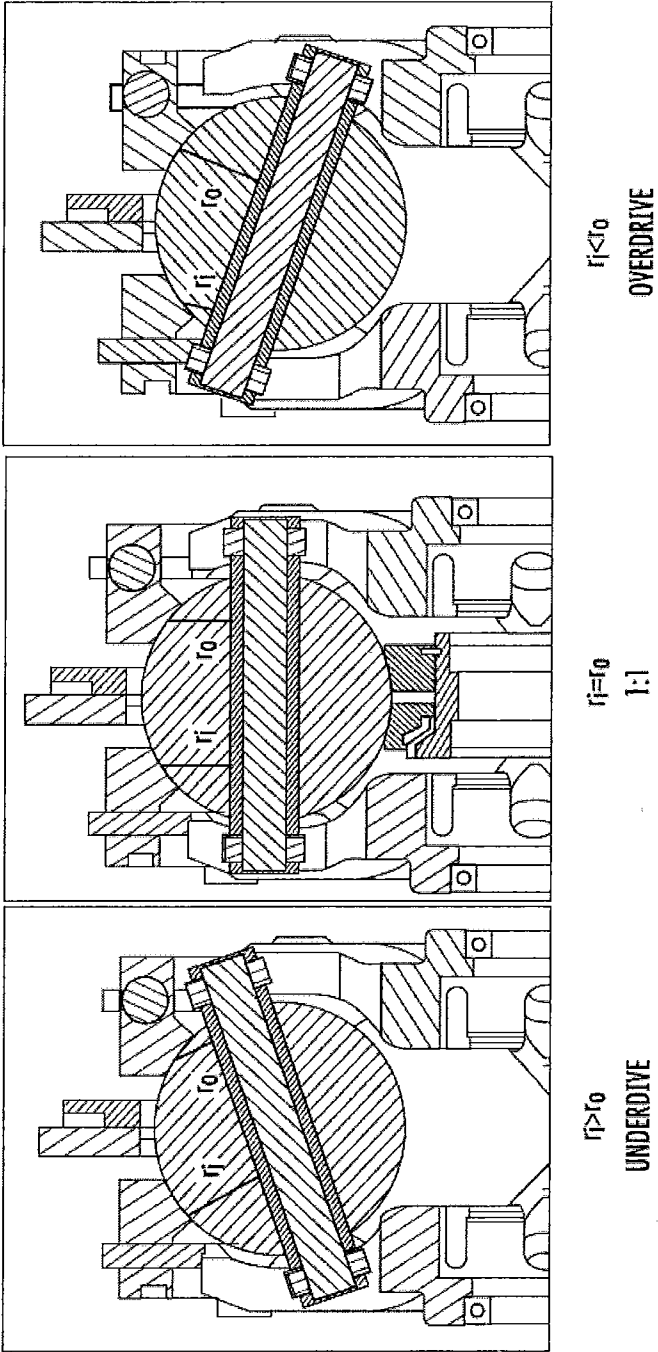
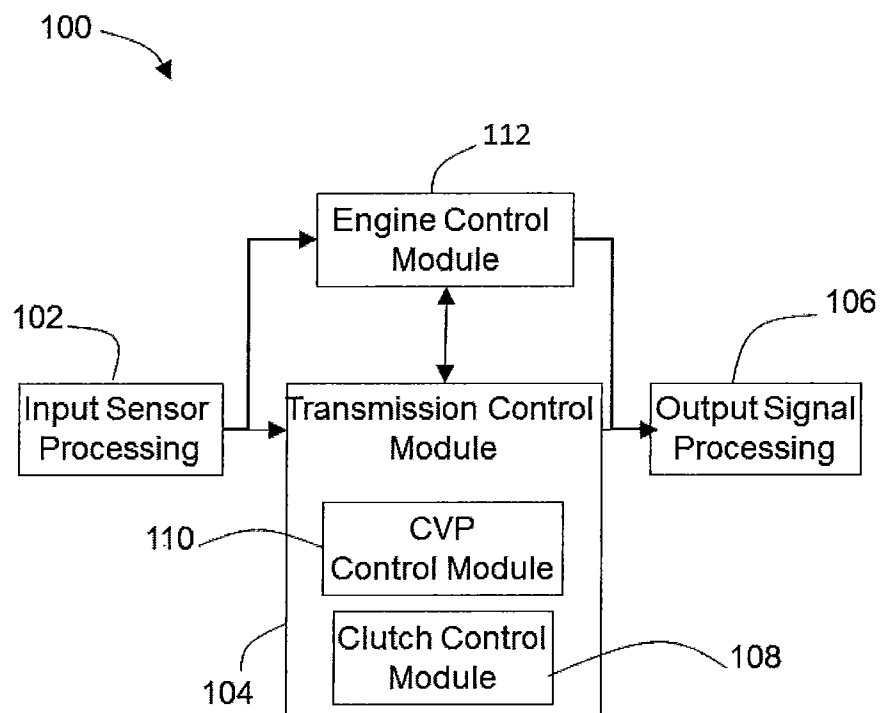


FIG. 3

**Figure 4**

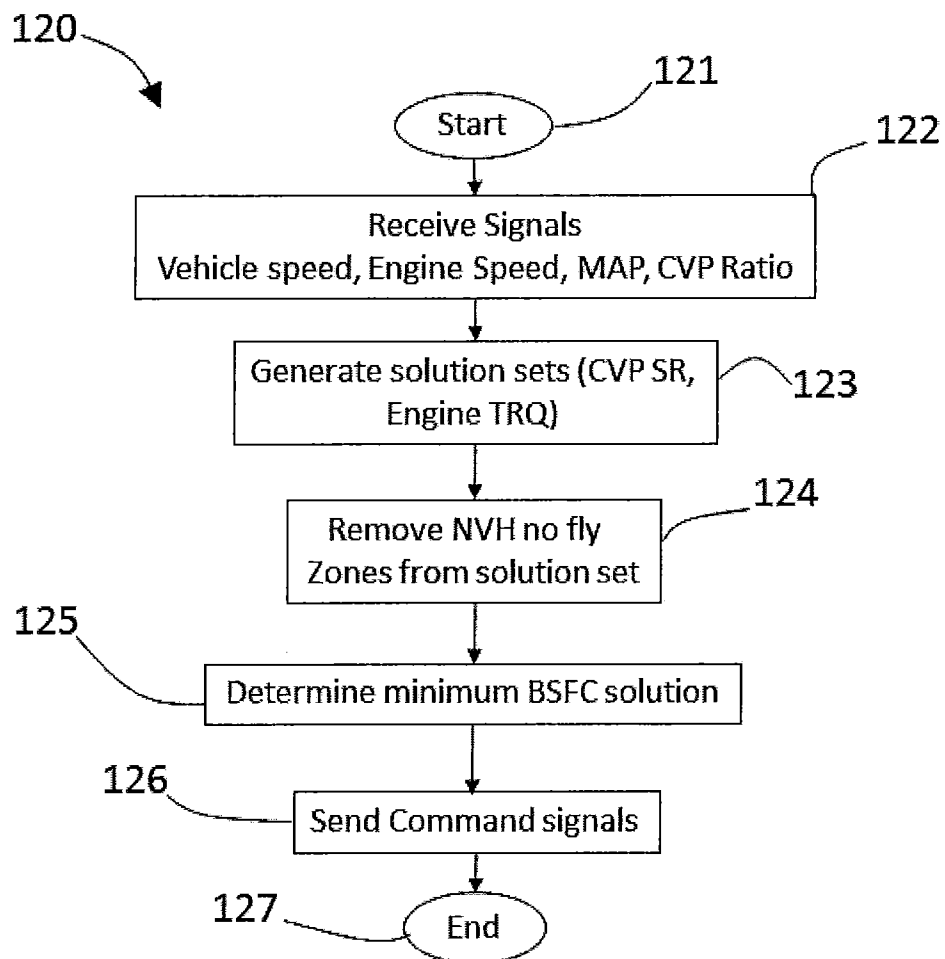
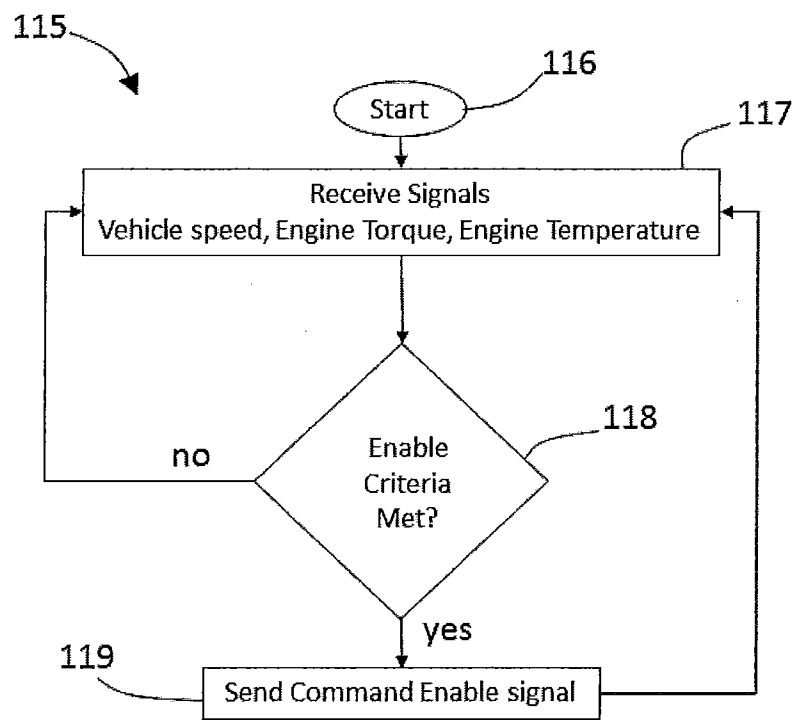


Figure 5

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**Figure 6**

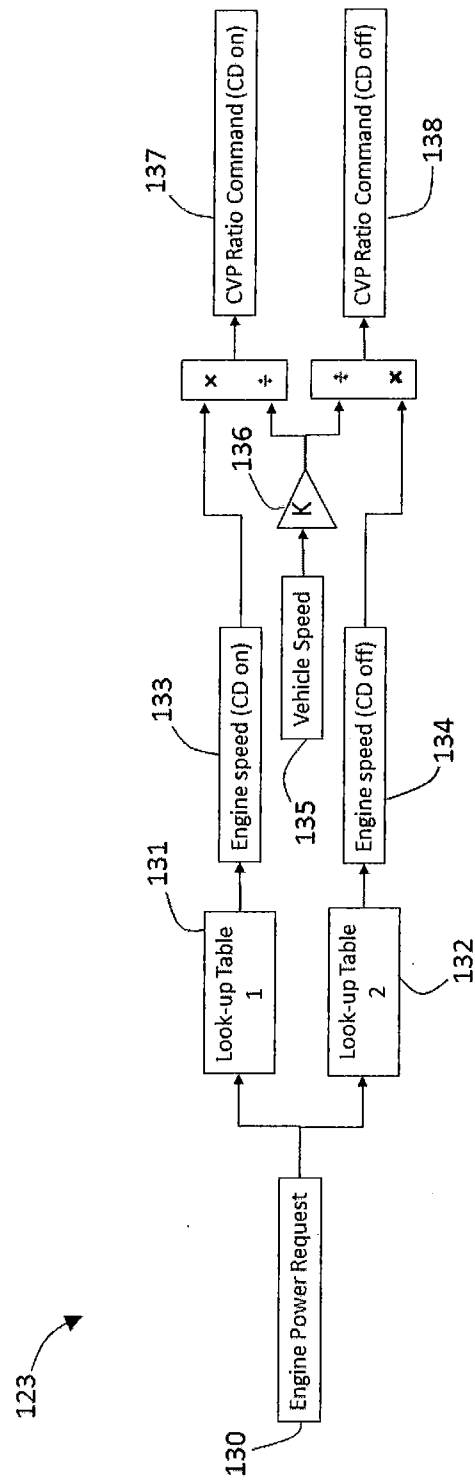


Figure 7

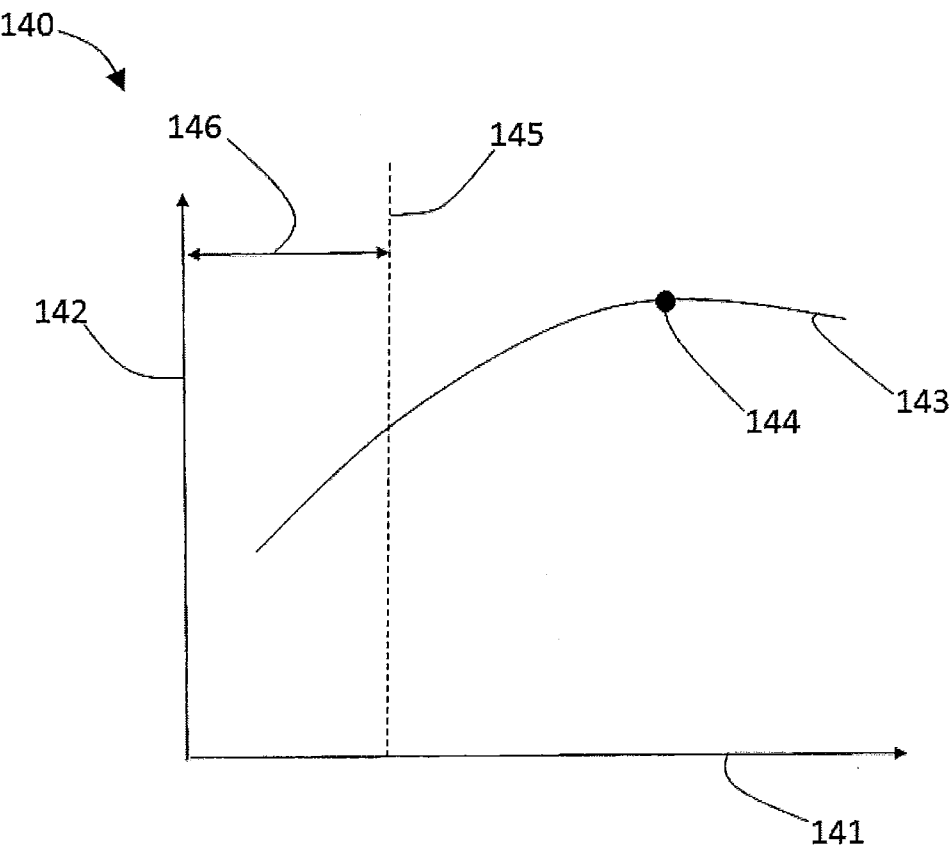


Figure 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/059716

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H61/664 F02D17/02 F16H59/76
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 F02D

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

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Y	US 2013/184949 A1 (SAITO HIROSHI [JP] ET AL) 18 July 2013 (2013-07-18) abstract; figures 1-9 paragraphs [0021] - [0027], [0030], [0031], [0035], [0036], [0041], [0043] - [0044] -----	1-13
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Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

9 April 2018

Date of mailing of the international search report

17/04/2018

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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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