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METHODS AND SYSTEMS FOR MODIFYING VERTICAL POSITIONS OF POWERTRAINS OR COMPONENTS THEREOF

Abstract

Methods, systems, and vehicles including such system are provided. The systems include a vertical position movement mechanism configured to raise and lower a powertrain or a component thereof of the vehicle relative to a chassis of the vehicle, and a controller configured to, by one or more processors, modify a vertical position of the powertrain or the component thereof between a top and a bottom of the chassis with the vertical position movement mechanism to controllably adjust a first angle of a first joint at a first end of a drive shaft of the vehicle. The drive shaft functionally couples the powertrain and wheels of the vehicle to transfer rotational power from the powertrain to the wheels.

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Background/Summary

INTRODUCTION

[0001] The technical field generally relates to vehicle drivetrains, and more particularly relates to a vehicle having a vertical position movement mechanism configured for raising and lowering a powertrain or component thereof to adjust an angle between the powertrain and wheels coupled thereto by a drive shaft.

[0002] A drivetrain of a vehicle typically includes a drive shaft (also referred to as a prop shaft, Cardan shaft, half-shaft, etc.) functionally coupling the transmission to the wheels, for example, directly to the wheels for front wheel drive vehicles or via an axle and a differential for rear wheel drive vehicles. As the engine produces power, the transmission transfers the power to the drive shaft which, in turn, transmits this rotational power to the wheels. As the vehicle travels over uneven terrain, the suspension system allows the wheels to move relative to the transmission. Therefore, the drive shaft includes joints at each of the ends thereof, such as universal joints (U-joints) or constant velocity joints (CV-joints), that are configured to accommodate for changes in angle and alignment between the transmission and the wheels (or the differential) to promote a continuous transfer of power from the engine to the wheels despite variations in the relative positions therebetween. However, when these joints are positioned at angles other than their optimum baseline angles, the joints may experience an increase in fatigue which may reduce their operational lifespan. In addition, the vehicle may experience increases in vibrations and noise.

[0003] Accordingly, it is desirable to provide systems and methods capable of promoting efficient operation of vehicle drivetrains. Furthermore, other desirable features and characteristics of the present disclosure will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing introduction.

SUMMARY

[0004] A method is provided for adjusting one or more angles associated with a drive shaft of a vehicle. In one example, the method includes modifying, with a vertical position movement mechanism of a vehicle, a vertical position of a powertrain or component thereof of the vehicle between a top and a bottom of the vehicle to adjust a first angle of a first joint at a first end of a drive shaft of the vehicle. The drive shaft functionally couples the powertrain and wheels of the vehicle to transfer rotational power from the powertrain to the wheels.

[0005] A system is provided for a vehicle. In one example, the system includes a vertical position movement mechanism configured to raise and lower a powertrain or a component thereof of the vehicle relative to a chassis of the vehicle, and a controller configured to, by one or more processors, modify a vertical position of the powertrain or the component thereof between a top and a bottom of the chassis with the vertical position movement mechanism to controllably adjust a first angle of a first joint at a first end of a drive shaft of the vehicle. The drive shaft functionally couples the powertrain and wheels of the vehicle to transfer rotational power from the powertrain to the wheels.

[0006] A vehicle is provided that, in one example, includes a chassis, wheels, a suspension system coupling the wheels to the chassis and configured to provide for relative movement between the wheels and the chassis, a powertrain secured to the chassis and configured to generate rotational power, and a drive shaft functionally coupling the powertrain and the wheels and configured to transmit the rotational power from the powertrain to the wheels to rotate the wheels and thereby propel the vehicle. The drive shaft is functionally coupled to the powertrain with a first joint and to the wheels with a second joint. The first joint and the second joint are configured to accommodate for changes in angle and alignment between the powertrain and the wheels or intermediate components therebetween to provide for continuous transfer of the rotational power from the

powertrain to the wheels despite variations in vertical positions of the wheels relative to the powertrain. The vehicle includes a vertical position movement mechanism configured to raise and lower the powertrain or a component thereof relative to the chassis, and a controller configured to, by one or more processors, modify a vertical position of the powertrain or the component thereof between a top and a bottom of the chassis with the vertical position movement mechanism to controllably adjust a first angle of the first joint of the drive shaft.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The exemplary embodiments will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

[0008] FIG. **1** is a functional block diagram of a vehicle having a powertrain vertical position management system in accordance with an example;

[0009] FIG. **2** is an isolated side view schematically representing a vertical position movement mechanism of the powertrain vertical position management system of FIG. **1** in accordance with an example;

[0010] FIGS. **3**, **4**, **5**, and **6** are side views schematically illustrating a method of changing a vertical position of a powertrain with a vertical position movement mechanism in accordance with an example;

[0011] FIG. **7** is a flowchart illustrating a method of adjusting drive shaft angles of a vehicle based on an active vehicle mode in accordance with an example; and

[0012] FIG. **8** is a flowchart illustrating a method of modifying a vertical position of a powertrain of a vehicle using torque generated by the powertrain in accordance with an example.

DETAILED DESCRIPTION

[0013] The following detailed description is merely exemplary in nature and is not intended to limit the application and uses. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding introduction or the following detailed description. As used herein, the term module refers to any hardware, software, firmware, electronic control component, processing logic, and/or processor device, individually or in any combination, including without limitation: application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

[0014] Examples of the present disclosure may be described herein in terms of functional and/or logical block components and various processing steps. It should be appreciated that such block components may be realized by any number of hardware, software, and/or firmware components configured to perform the specified functions. For example, an embodiment of the present disclosure may employ various integrated circuit components, e.g., memory elements, digital signal processing elements, logic elements, look-up tables, or the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices. In addition, those skilled in the art will appreciate that examples of the present disclosure may be practiced in conjunction with any number of systems, and that the systems described herein is merely examples of the present disclosure.

[0015] For the sake of brevity, certain techniques related to signal processing, data transmission, signaling, control, and other functional aspects of the systems (and the individual operating components of the systems) may not be described in detail herein. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent example functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in an example of the present disclosure.

[0016] FIG. **1** illustrates a vehicle **10**, according to an example. The vehicle **10** includes a powertrain vertical position management system **100** configured for modifying a vertical position of one or more components of a powertrain of the vehicle **10** to accommodate for variations in vertical positions of wheels of the vehicle **10**.

[0017] In various examples, the vehicle **10** may be any one of a number of different types of automobiles, such as, for example, a sedan, a wagon, a truck, or a sport utility vehicle (SUV), and may be two-wheel drive (2WD) (i.e., rear-wheel drive or front-wheel drive), four-wheel drive (4WD) or all-wheel drive (AWD), and/or various other types of vehicles or mobile platforms in certain examples.

[0018] As depicted in FIG. **1**, the exemplary vehicle **10** generally includes a chassis **12**, a body **14**, front wheels **16**, and rear wheels **18**. The body **14** is arranged on the chassis **12** and substantially encloses components of the vehicle **10**. The body **14** and the chassis **12** may jointly form a frame. The wheels **16** and **18** are each rotationally coupled to the chassis **12** near a respective corner of the body **14**.

[0019] The vehicle **10** further includes a propulsion system **20**, a transmission system **22**, a suspension system **26**, a sensor system **28**, an actuator system **30**, at least one data storage device **32**, and at least one controller **34**. The propulsion system **20** includes an engine and/or motor **21** such as an internal combustion engine (e.g., a gasoline or diesel fueled combustion engine), an electric motor (e.g., a 3-phase alternating current (AC) motor), or a hybrid system that includes more than one type of engine and/or motor. The transmission system **22** is configured to transmit power from the propulsion system **20** to the wheels **16-18** according to selectable speed ratios. According to various examples, the transmission system **22** may include a step-ratio automatic transmission, a continuously-variable transmission, or other appropriate transmission. In this example, the vehicle **10** is a rear wheel drive vehicle having the transmission system **22** functionally coupled to the rear wheels **18** by a drive shaft **25**, a differential **27**, and a rear axle **29** in a longitudinal mount arrangement. However, the vehicle **10** is not limited to rear wheel drive vehicles or to rear wheel drive vehicles having this particular arrangement. The suspension system **26** couples the wheels **16** and **18** to the chassis **12** and provides for relative motion therebetween to accommodate for uneven terrain. The suspension system **26** may include, for example, various springs, shock absorbers, and linkages.

[0020] The sensor system **28** includes one or more sensing devices **40***a*-**40***n* that sense observable conditions of the exterior environment, the interior environment, and/or a status or condition of a corresponding component of the vehicle **10** and provide such condition and/or status to other systems of the vehicle **10**, such as the controller **34**. It should be understood that the vehicle **10** may include any number of the sensing devices **40***a*-**40***n*. The sensing devices **40***a*-**40***n* can include, but are not limited to, current sensors, voltage sensors, temperature sensors, motor speed sensors, position sensors, etc.

[0021] The actuator system **30** includes one or more actuator devices **42***a*-**42***n* that control one or more vehicle features such as, but not limited to, the propulsion system **20** and/or the transmission system **22**.

[0022] The data storage device **32** stores data for use in controlling the vehicle **10** and/or systems and components thereof. As can be appreciated, the data storage device **32** may be part of the controller **34**, separate from the controller **34**, or part of the controller **34** and part of a separate system. The storage device **32** can be any suitable type of storage apparatus, including various different types of direct access storage and/or other memory devices. In one example, the storage device **32** comprises a program product from which a computer readable memory device can receive a program that executes one or more examples of one or more processes of the present disclosure, such as the steps of the process discussed further below in connection with FIGS. **7** and

8. In another example, the program product may be directly stored in and/or otherwise accessed by the memory device and/or one or more other disks and/or other memory devices.

[0023] The controller **34** includes at least one processor **44**, a communication bus **45**, and a computer readable storage device or media **46**. The processor **44** performs the computation and control functions of the controller **34**. The processor **44** can be any custom made or commercially available processor, a central processing unit (CPU), a graphics processing unit (GPU), an auxiliary processor among several processors associated with the controller **34**, a semiconductor-based microprocessor (in the form of a microchip or chip set), a macroprocessor, any combination thereof, or generally any device for executing instructions. The computer readable storage device or media **46** may include volatile and nonvolatile storage in read-only memory (ROM), random-access memory (RAM), and keep-alive memory (KAM), for example. KAM is a persistent or non-volatile memory that may be used to store various operating variables while the processor **44** is powered down. The computer-readable storage device or media **46** may be implemented using any of a number of known memory devices such as PROMs (programmable read-only memory), EPROMs (erasable PROM), EEPROMs (electrically erasable PROM), flash memory, or any other electric, magnetic, optical, or combination memory devices capable of storing data, some of which represent executable instructions, used by the controller **34** in controlling the vehicle **10**. The bus **45** serves to transmit programs, data, status and other information or signals between the various components of the vehicle **10**. The bus **45** can be any suitable physical or logical means of connecting computer systems and components. This includes, but is not limited to, direct hard-wired connections, fiber optics, infrared, and wireless bus technologies.

[0024] The instructions may include one or more separate programs, each of which comprises an ordered listing of executable instructions for implementing logical functions. The instructions, when executed by the processor **44**, receive and process signals from the sensor system **28**, perform logic, calculations, methods and/or algorithms, and generate data based on the logic, calculations, methods, and/or algorithms. Although only one controller **34** is shown in FIG. **1**, examples of the vehicle **10** can include any number of controllers **34** that communicate over any suitable communication medium or a combination of communication mediums and that cooperate to process the sensor signals, perform logic, calculations, methods, and/or algorithms, and generate data.

[0025] As can be appreciated, that the controller **34** may otherwise differ from the example depicted in FIG. **1**. For example, the controller **34** may be coupled to or may otherwise utilize one or more remote computer systems and/or other control systems, for example as part of one or more of the above-identified vehicle devices and systems. It will be appreciated that while this example is described in the context of a fully functioning computer system, those skilled in the art will recognize that the mechanisms of the present disclosure are capable of being distributed as a program product with one or more types of non-transitory computer-readable signal bearing media used to store the program and the instructions thereof and carry out the distribution thereof, such as a non-transitory computer readable medium bearing the program and containing computer instructions stored therein for causing a computer processor (such as the processor **44**) to perform and execute the program. Such a program product may take a variety of forms, and the present disclosure applies equally regardless of the particular type of computer-readable signal bearing media used to carry out the distribution. Examples of signal bearing media include recordable media such as floppy disks, hard drives, memory cards and optical disks, and transmission media such as digital and analog communication links. It will be appreciated that cloud-based storage and/or other techniques may also be utilized in certain examples. It will similarly be appreciated that the computer system of the controller **34** may also otherwise differ from the example depicted in FIG. **1**, for example in that the computer system of the controller **34** may be coupled to or may otherwise utilize one or more remote computer systems and/or other control systems.

[0026] As the propulsion system **20** produces power, the transmission system **22** transfers the power to the drive shaft **25** which, in turn, transmits this rotational power to the rear wheels **18**. As the vehicle **10** travels over uneven terrain, the suspension system **26** allows the wheels **16** and **18** to move relative to the chassis **12**, and therefore the transmission system **22**. Therefore, the drive shaft **25** includes joints at each of the ends thereof, such as universal joints (U-joints) or constant velocity joints (CV-joints), that are configured to accommodate for changes in angle and alignment between the transmission system **22** and the rear wheels **18** or the differential **27** to promote a continuous transfer of power from the propulsion system **20** to the rear wheels **18** despite variations in the relative positions therebetween.

[0027] In some examples, a first joint is disposed at a first end of the drive shaft **25** that defines a first angle between the central, longitudinal axis of the drive shaft **25** and a central axis of an output shaft (not shown) of the transmission system **22**, and a second joint disposed at a second end of the drive shaft **25** defines a second angle between the central, longitudinal axis of the drive shaft **25** and a central axis of an input shaft (not shown) of the differential **27**. As used herein, the first angle and the second angle are disposed in a vertical plane that passes through the central, longitudinal axis of the drive shaft **25**. The first and second angles are typically at respective baseline angles, and may deviate from these baseline angles during operation of the vehicle **10**, such as when traveling over uneven terrain. In exemplary embodiments, the first and second angles are maintained within certain operating angle ranges as determined by the manufacturer. The baseline angles may vary between applications. In some examples, the baseline angles of the first and second angles may be substantially opposite angles with equal absolute values, for example, within three degrees (absolute value), such as within two degrees, such as within one degree. For example, the operating angle ranges may be 0 to −17 degrees for the first angle and 0 to 17 degrees for the second angle (e.g., for a universal joint), such as an angle range of 0 to −3 degrees for the first angle and 0 to 3 degrees for the second angle, and the baseline angles may be −0.5 degrees for the first angle and 0.5 degrees for the second angle, or vice versa.

[0028] As used herein, the powertrain refers to a combination of components configured to generate rotational power. In the example of FIG. **1**, the powertrain includes at least the propulsion system **20** and the transmission system **22**. As used herein, the drivetrain refers to a combination of components configured to transfer the rotational power from the powertrain to the rear wheels **18**. In the example of FIG. **1**, the drivetrain includes the drive shaft **25**, the differential **27**, and the rear axle **29**.

[0029] The vehicle **10** includes a vertical position movement mechanism **23** that is configured to modify a vertical position of at least a portion of the powertrain of the vehicle **10** between a top and a bottom of the vehicle **10**, for example, by allowing for at least a portion of the transmission system **22** to be raised and/or lowered relative to the chassis **12** and maintained in various vertical positions. As used herein, the bottom of the vehicle **10** refers to a lowermost portion of the vehicle **10** closest to a surface on which the wheels **16** and **18** contact (e.g., a road) and the top of the vehicle **10** refers to an uppermost portion of the vehicle **10** that is furthest from such surface. In some examples, the vertical position of the powertrain may be adjusted in response to or in anticipation of a change in vertical position of one or more components of the drivetrain, such as the rear wheels **18**, the rear axle **29**, the differential **27**, and/or a rear end of the drive shaft **25**.

[0030] By modifying the vertical position of the powertrain, adjustments can be made to the first and/or second angles of the joints of the drive shaft **25**. This capability can be used to modify the performance of the vehicle **10**, extend the operating lifespan of various components of the vehicle **10**, and/or reduce noise and/or vibrations produced during operation of the vehicle **10**.

[0031] In some examples, the vertical position movement mechanism **23** may be operated manually by a user via interaction with one or more user interfaces, operated automatically by the controller **34** in response to various events, such as the vehicle **10** switching from a first vehicle mode to a second vehicle mode, and/or operated automatically by the controller **34** in real-time to continuously or periodically accommodate for variations in the suspension, vertical position of the rear wheels **18**, etc.

[0032] In various examples, the vehicle **10** may be capable of operating in more than one vehicle mode. For example, the user may select a specific vehicle mode by interaction with a user interface in accordance with a desired drive performance. In some examples, the vehicle **10** may automatically switch vehicle modes in response to certain conditions such as certain signals received from the sensor system **28** or from other systems of the vehicle **10**. Nonlimiting examples of vehicle modes may include a lifted vehicle mode, a rapid acceleration mode, a high maneuverability mode, an optimized comfort mode, etc. In such examples, one or more of the vehicle modes may have different exemplary baseline angles for the joints of the drive shaft **25**. Therefore, in response to the vehicle **10** switching from a first vehicle mode having, for example, a first baseline angle of the first joint to a second vehicle mode having a second baseline angle of the first joint, the controller **34** may be configured to modify the vertical position of the powertrain to adjust the first angle between the first baseline angle and the second baseline angle.

[0033] In various examples, the controller **34** may be configured to operate the vertical position movement mechanism **23** to automatically adjust the vertical position of the powertrain to accommodate for variations in positions of the rear wheels **18** or other components during propulsion of the vehicle **10**. In some examples, the controller **34** may be configured to detect, via signals from one or more of the sensing devices **40***a*-**40***n*, a change in vertical position of the rear wheels **18**, the rear axle **29**, the differential **27**, or another component of the drivetrain, determine a change in a vertical position of one or more components of the powertrain intended to offset the change in the detected change in vertical position, and operate the vertical position movement mechanism **23** to automatically adjust the vertical position of the powertrain to implement the change in the vertical position of the one or more components of the powertrain.

[0034] In some examples, the controller **34** may be configured to determine a difference in a first absolute value of the first angle of the first joint and a second absolute value of the second angle of the second joint at the second end of the drive shaft **25**, and operate the vertical position movement mechanism **23** to automatically adjust the vertical position of one or more components of the powertrain to reduce the difference between the first absolute value and the second absolute value. For example, if the controller **34** detects a change in the second angle from −0.5 to −1.0, the controller **34** may operate the vertical position movement mechanism **23** to change the vertical position of one or more components of the powertrain sufficient to change the first angle from 0.5 to 1.0 thereby reducing the absolute delta between the first and second angles from 0.5 to 0.

[0035] The vertical position movement mechanism **23** may include various components and structures configured to raise and/or lower one or more components of the powertrain of the vehicle **10**. Referring now to FIG. **2**, and with continued reference to FIG. **1**, a first example of a vertical position movement mechanism **23**A is provided. In this example, the vertical position movement mechanism **23**A may include one or more actuators **110** (e.g., linear actuators) configured to raise or lower the one or more components of the powertrain relative to the chassis **12** of the vehicle **10**. The actuator(s) **110** may be disposed, for example, between the transmission system **22** and a fixed surface **64**, and configured to controllably extend and retract to increase and decrease, respectively, a dimension between the transmission system **22** and the fixed surface **64**. In this example, only a first end of the powertrain is configured to be raised and lowered. An opposite, second end of the powertrain is coupled to a pivotable joint **112** and configured to pivot relative to the engine mount **64** as the first end is raised or lowered. In this example, the vertical position movement mechanism **23**A provided for adjustment of a first angle **60** between an axis **54** of the drive shaft **25** and an axis **56** of the powertrain, and/or adjustment of a second angle **62** between the axis **54** of the drive shaft **25** and an axis **58** of the differential **27**.

[0036] Referring now to FIGS. **3**, **4**, **5**, and **6**, and with continued reference to FIG. **1**, a second example of a vertical position movement mechanism **23**B is provided. In this example, the vertical position movement mechanism **23**B may include a hydraulic system **280** configured to selectively maintain a vertical position of one or more components of the powertrain. With this arrangement, the system **100** is configured to raise and/or lower the one or more components of the powertrain using torque generated by a propulsion system **220**.

[0037] In FIG. **3**, a transversely mounted powertrain including the propulsion system **220**, a transmission system **222**, and a drive shaft **225** is disposed on a support structure **270**. The support structure **270** may be disposed on a mounting structure **272**, such as a propulsion mount, which in turn is disposed on a fixed structure **274**, such as a frame, cradle, body, etc. of a vehicle. A first arrow **290** indicates a forward direction toward a front of the vehicle, a second arrow **292** indicates a rearward direction toward a rear of the vehicle, and a third arrow **294** indicates an up/down direction extending between a top and a bottom of the vehicle. The vertical position of the powertrain may be determined along the up/down direction of the third arrow **294**. A fourth arrow **296** indicates a first dimension between the support structure **270** and the fixed structure **274** representing a first vertical position of the powertrain. The powertrain is maintained in this first vertical position with the hydraulic system **280**. FIGS. **4-6** illustrate a method of raising the powertrain of FIG. **3**.

[0038] In FIG. **4**, a first valve **282** of the hydraulic system **280** is opened to allow for hydraulic fluid to flow therein and thereby allow for movement of a first, forward end of the powertrain. The propulsion system **220** may be operated to generate a reverse torque sufficient to raise the first, forward end of the powertrain and the first valve **282** may be closed to maintain the first, forward end of the powertrain in a raised position. In FIG. **5**, a second valve **284** of the hydraulic system **280** is opened to allow for hydraulic fluid to flow therein and thereby allow for movement of a second, rearward end of the powertrain. The propulsion system **220** may be operated to generate a forward torque sufficient to raise the second, rearward end of the powertrain and the second valve **284** may be closed to maintain the second, rearward end of the powertrain in the raised position. FIG. **6** presents the powertrain as maintained in a second vertical position represented by a fifth arrow **298** that indicates a second dimension between the support structure **270** and the fixed structure **274**. The powertrain may be maintained in this second vertical position while the first and second valves **282** and **284** remain closed. To lower the vertical position of the powertrain, one or both of the first and second valves **282** and **284** may be opened such that gravity pulls the powertrain to a lower position. Notably, the hydraulic system **280** may not be limited to maintaining the powertrain in the raised and lower positions, but instead may be configured to maintain the powertrain or components thereof in a plurality of vertical positions.

[0039] The example of FIGS. **3-6** may be achieved with various other structures. For example, the hydraulic system **280** may be replaced with a mechanical locking system, such as a pin system, configured to selectively lock one or both ends of the powertrain in two or more vertical positions. In addition, the hydraulic system **280** and/or another locking system may be disposed in another location relative to the other components of the vehicle. For example, the hydraulic system **280** may be disposed between the mounting structure **272** and the fixed structure **274**, between the fixed structure **274** and another structure of the vehicle, or in another location as long as the hydraulic system **280** is capable of securing the vertical position of the powertrain.

[0040] With reference now to FIG. **7** and with continued reference to FIGS. **1-6**, a flowchart provides a method **300** for adjusting drive shaft angles based on an active vehicle mode, for example, as performed by the system **100**, in accordance with various examples. As can be appreciated in light of the disclosure, the order of operation within the method **300** is not limited to the sequential execution as illustrated in FIG. **7**, but may be performed in one or more varying orders as applicable and in accordance with the present disclosure. In various examples, the method **300** can be scheduled to run based on one or more predetermined events, and/or can run continuously during operation of the vehicle.

[0041] In one example, the method **300** may start at **310**. At **312**, the method **300** may include determining whether a vehicle mode is active or if the vehicle is entering a vehicle mode that requires a change to the drive shaft angle (or first and second angles of the joints thereof). For example, a controller (e.g., the controller **34**) may determine that a lifted vehicle mode is active and that the powertrain should be raised to adjust the drive shaft angle. If the vehicle is not in or entering a vehicle mode that requires a change to the drive shaft angle, the method **300** continues to monitor the vehicle mode status. If the vehicle is in or entering a vehicle mode that requires a change to the drive shaft angle, the method continues to **314**.

[0042] At **314**, the method **300** may include raising or lowering one or more components of the powertrain with the vertical position movement mechanism to achieve the desired drive shaft angle. At **316**, the method **300** may optionally include determining whether the powertrain is disposed in the proper vertical position, for example, based on signals received from a position sensor of the powertrain. This step **316** may optionally be used to identify software faults and/or component failures in the system. If the powertrain is not in the proper vertical position at **316**, the method **300** may include, at **318**, locking the powertrain in the current vertical position, exiting the current vehicle mode that necessitated the change in vertical position of the powertrain, and/or remain in the vehicle mode and impose speed restrictions on operation of the vehicle based on the vehicle mode. As used herein, the term “locking” refers to maintaining the nominal vertical position of the powertrain. If the powertrain is in the proper position at **316**, the method **300** may continue to **320**.

[0043] At **320**, the method **300** may include locking the vertical position of the powertrain. At **322**, the method **300** may include monitoring the active vehicle mode to detect when the vehicle exits the current vehicle mode, thereby requiring another change to the drive shaft angle, for example, to the original angle. If the vehicle mode is not changed at **322**, the method **300** continues to monitor the active vehicle mode. If the vehicle exits the current vehicle mode at **322**, the method may continue to **324**. At **324**, the method **300** may include raising or lowering one or more components of the powertrain with the vertical position movement mechanism to achieve a new, desired drive shaft angle, such as the original drive shaft angle. The method **300** may end at **326**.

[0044] With reference now to FIG. **8** and with continued reference to FIGS. **1-7**, a flowchart provides a method **400** for modifying the vertical position of a powertrain of a vehicle using torque generated by the powertrain, for example, as performed by the system **100** and/or the vertical position movement mechanism **23**B, in accordance with various examples.

[0045] The method **400** may start at **410**. At **412**, the method **400** may include determining whether the transmission system of the vehicle is in “park.” If the vehicle is in “park,” the method **400** may include, at **414**, unlocking at least a first portion of one or more components of the powertrain, locking all brakes of the vehicle, and generating a torque with the propulsion system of the vehicle to raise at least the first portion of the powertrain. If the first portion of the powertrain is in the raised vertical position at **416**, the method **400** continues at **418** by locking the first portion of the powertrain in the raised vertical position, unlocking a second portion of the one or more components of the power train (if not previously unlocked), and generating a torque with the propulsion system in an opposite direction to raise the second portion of the powertrain. If the second portion of the powertrain is in the raised vertical position at **420**, the method **400** may continue to **422** by locking the vertical position of the second portion, and releasing the brakes.

[0046] If the vehicle is not in “park” at **412**, the method **400** may continue at **424** by maintaining any previously imposed speed restrictions, and unlocking all or a portion of one or more components of the powertrain. In some examples, the method **400** may generate a user notification instructing the user to place the vehicle in “park” to complete the powertrain height adjustment sequence. If the user transitions the vehicle into ‘park,” the method **400** may return to **412**. If the vehicle is continued to be operated in, for example, “drive” or “reverse,” the method **400** may continue to **426** by monitoring the vertical position of the powertrain. Since the powertrain or a portion thereof is unlocked, the normal operation of the vehicle may apply torque to the powertrain sufficient to raise all or the portion of the powertrain to the raised vertical position. At **426**, the method **400** may include monitoring the vertical position of the first portion of the powertrain. If the first portion of the powertrain is raised, the method **400** may continue at **428** by locking the first portion. At **430**, the method **400** may include monitoring the vertical position of the second portion of the powertrain. If the second portion of the powertrain is raised, the method **400** may continue at **432** by locking the second portion.

[0047] If the powertrain or portions thereof do not raise at steps **416**, **420**, **426**, and/or **430** within a predetermined time period, the method **400** may include, at **434**, generating an error notification, ending the height adjustment sequence, and/or locking the vertical position of the powertrain.

[0048] At **436**, the method **400** may include monitoring the vertical position of the powertrain of components thereof. If at **436**, the powertrain is not in the raised vertical position as intended, the method **400** may continue to monitor the vertical position of the powertrain of components thereof. If at **436**, the powertrain is in the raised vertical position as intended, the method **400** may continue at **438** by lifting any previously imposed speed limitations and allowing the vehicle to be operated within normal drive speed limits in accordance with, for example, the active vehicle mode. The method **400** may end at **440**.

[0049] The systems and methods disclosed herein provide various benefits over certain existing systems and methods. For example, the systems and methods disclosed herein provide for modifying the vertical position of the powertrain and thereby adjusting one or more angles associated with the drive shaft. This capability can be used to modify the performance of the vehicle, extend the operating lifespan of various components of the vehicle, and/or reduce noise and/or vibrations produced during operation of the vehicle. In some examples, the systems and methods disclosed herein may be used to extend an operating angle range of a drive shaft and the joints at ends thereof. In some examples, this capability may allow for use of other types of joints, for example, use of universal joints rather than constant velocity joints.

[0050] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the disclosure in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiment or exemplary embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope of the disclosure as set forth in the appended claims and the legal equivalents thereof.

Claims

1. A method comprising modifying, with a vertical position movement mechanism of a vehicle, a vertical position of a powertrain or component thereof of the vehicle between a top and a bottom of the vehicle to adjust a first angle of a first joint at a first end of a drive shaft of the vehicle, wherein the drive shaft functionally couples the powertrain and wheels of the vehicle to transfer rotational power from the powertrain to the wheels.

2. The method of claim 1, wherein modifying the vertical position of the powertrain or the component thereof is performed to reduce a difference between a first absolute value of the first angle of the first joint and a second absolute value of a second angle of a second joint at a second end of the drive shaft.

3. The method of claim 1, wherein the vehicle is configured to selectively operate in a first vehicle mode having a first baseline angle of the first joint or a second vehicle mode having a second baseline angle of the first joint, wherein modifying the vertical position of the powertrain or the component thereof is performed to adjust the first angle between the first baseline angle and the second baseline angle.

4. The method of claim 1, further comprising operating, by a controller of the vehicle having one or

more processors, the vertical position movement mechanism to automatically adjust the vertical position of the powertrain or the component thereof to accommodate for variations in positions of the wheels during propulsion of the vehicle.
5. The method of claim 1, further comprising: determining, by a controller of the vehicle having one or more processors, a difference in a first absolute value of the first angle of the first joint and a second absolute value of a second angle of a second joint at a second end of the drive shaft; and operating, by the controller with the one or more processors, the vertical position movement mechanism to automatically adjust the vertical position of the powertrain or the component thereof to reduce the difference between the first absolute value and the second absolute value.
6. The method of claim 1, wherein modifying the vertical position of the powertrain or the component thereof is performed by raising or lowering the powertrain or the component thereof relative to a chassis of the vehicle with one or more actuators.
7. The method of claim 1, wherein modifying the vertical position of the powertrain or the component thereof includes: producing torque with the powertrain to raise or lower at least a portion of the powertrain or the component thereof; and maintaining the vertical position of at least the portion of the powertrain or the component thereof with a hydraulic system of the vehicle.
8. The method of claim 1, wherein modifying the vertical position of the powertrain or the component thereof includes raising or lowering the first end of the powertrain of the component thereof, wherein a second end of the powertrain or the component thereof is pivotally coupled to the vehicle and configured to pivot in response the first end raising or lowering.
9. A system for a vehicle, comprising: a vertical position movement mechanism configured to raise and lower a powertrain or a component thereof of the vehicle relative to a chassis of the vehicle; and a controller configured to, by one or more processors, modify a vertical position of the powertrain or the component thereof between a top and a bottom of the chassis with the vertical position movement mechanism to controllably adjust a first angle of a first joint at a first end of a drive shaft of the vehicle, wherein the drive shaft functionally couples the powertrain and wheels of the vehicle to transfer rotational power from the powertrain to the wheels.
10. The system of claim 9, wherein the controller is configured to, by the one or more processors, modify the vertical position of the powertrain or the component thereof to reduce a difference between a first absolute value of the first angle of the first joint and a second absolute value of a second angle of a second joint at a second end of the drive shaft.
11. The system of claim 9, wherein the vehicle is configured to selectively operate in a first vehicle mode having a first baseline angle of the first joint or a second vehicle mode having a second baseline angle of the first joint, wherein the controller is configured to, by the one or more processors, modify the vertical position of the powertrain or the component thereof to adjust the first angle between the first baseline angle and the second baseline angle.
12. The system of claim 9, wherein the controller is configured to, by the one or more processors, operate the vertical position movement mechanism to automatically adjust the vertical position of the powertrain or the component thereof to accommodate for variations in positions of the wheels during propulsion of the vehicle.
13. The system of claim 9, wherein the controller is configured to, by the one or more processors: determine a difference in a first absolute value of the first angle of the first joint and a second absolute value of a second angle of a second joint at a second end of the drive shaft; and operate the vertical position movement mechanism to automatically adjust the vertical position of the powertrain or the component thereof to reduce the difference between the first absolute value and the second absolute value.
14. The system of claim 9, wherein the vertical position movement mechanism includes one or more actuators configured to raise or lower the powertrain or the component thereof relative to the chassis of the vehicle.
15. The system of claim 9, wherein the vertical position movement mechanism includes a hydraulic

system, and the controller is configured to, by the one or more processors, produce torque with the powertrain to raise or lower the powertrain or the component thereof and maintaining the vertical position of the powertrain or the component thereof with the hydraulic system.

16. The system of claim 9, wherein the vertical position movement mechanism is configured to raise or lower the first end of the powertrain or the component thereof, wherein a second end of the powertrain or the component thereof is pivotable relative to the chassis and configured to pivot in response the first end raising or lowering.

17. A vehicle, comprising: a chassis; wheels; a suspension system coupling the wheels to the chassis and configured to provide for relative movement between the wheels and the chassis; a powertrain secured to the chassis and configured to generate rotational power; a drive shaft functionally coupling the powertrain and the wheels and configured to transmit the rotational power from the powertrain to the wheels to rotate the wheels and thereby propel the vehicle, wherein the drive shaft is functionally coupled to the powertrain with a first joint and to the wheels with a second joint, wherein the first joint and the second joint are configured to accommodate for changes in angle and alignment between the powertrain and the wheels or intermediate components therebetween to provide for continuous transfer of the rotational power from the powertrain to the wheels despite variations in vertical positions of the wheels relative to the powertrain; a vertical position movement mechanism configured to raise and lower the powertrain or a component thereof relative to the chassis; and a controller configured to, by one or more processors, modify a vertical position of the powertrain or the component thereof between a top and a bottom of the chassis with the vertical position movement mechanism to controllably adjust a first angle of the first joint of the drive shaft.

18. The vehicle of claim 17, wherein the vehicle is configured to selectively operate in a first vehicle mode having a first baseline angle of the first joint or a second vehicle mode having a second baseline angle of the first joint, wherein the controller is configured to, by the one or more processors, modify the vertical position of the powertrain or the component thereof to adjust the first angle between the first baseline angle and the second baseline angle.

19. The vehicle of claim 17, wherein the vertical position movement mechanism includes one or more actuators configured to raise or lower the powertrain or the component thereof relative to the chassis of the vehicle.

20. The vehicle of claim 17, wherein the vertical position movement mechanism includes a hydraulic system, and the controller is configured to, by the one or more processors, produce torque with the powertrain to raise or lower the powertrain or the component thereof and maintaining the vertical position of the powertrain or the component thereof with the hydraulic system.