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(54) Title: A HYDROSTATIC POWERTRAIN FOR A WHEEL LOADER AND METHOD OF OPERATION THEREOF

(57) Abstract: The present disclosure relates to a hydrostatic powertrain (100) including a hydraulic pump (12) configured to be driven by a prime mover (11) for generating hydraulic flow. A plurality of first valves (13) are fluidly coupled to the hydraulic pump and are configured to distribute the hydraulic flow. A plurality of second valves (14) are fluidly coupled to the plurality of first valves. A hydraulic motor (15) is coupled to wheels of the vehicle and is fluidly coupled to at least one second valve (14). A plurality of sensors (16) are configured to detect acceleration of the vehicle and angular position of steering wheel of the vehicle. A control unit (17) is configured to regulate operation of the at least one of the plurality of first valves (13) and the at least one of the plurality of second valves (14), based on signals received from the plurality of sensors (16).

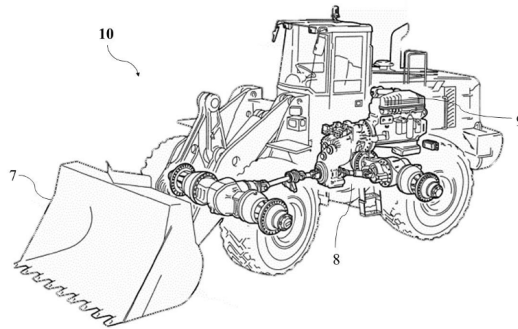


Figure 1

FORM 2

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003
Complete Specification
(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

A HYDROSTATIC POWERTRAIN FOR A WHEEL LOADER AND METHOD OF OPERATION THEREOF

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is to be performed.

DESCRIPTION

TECHNICAL FIELD

[001] The present disclosure is related, in general, to the field of wheel loaders. Particularly, but not exclusively, the present disclosure relates to a powertrain for the wheel loaders. More particularly, the present disclosure discloses a hydrostatic powertrain for wheel loaders.

BACKGROUND OF THE DISCLOSURE

[002] Wheel loaders are earth moving vehicles, also referred to as off-road or off-highway vehicles, employed to move or load loose materials such as soil, rock, sand, ores, and construction debris onto one or more of a dump truck, feed-hopper, conveyor belt, and railroad cars. Wheel loaders are equipped with attachments such as, but not limited to a bucket, container or other type of work implement for at least one of excavation, digging, carrying, and transportation of a load. The attachments are either front-mounted or rear-mounted on the wheel loader. Further, wheel loaders are self-propelled vehicles and generally include an internal combustion engine configured to propel the wheel loader. The internal combustion engine is coupled to a transmission configured to provide driving torque to the wheels of the wheel loader. The wheel loader also includes a hydraulic system powered by the internal combustion engine. The hydraulic system is configured to actuate one or more implements, such as, but not limited to drive motors, that are in turn configured to drive the attachments of the wheel loader.

[003] Figure 1 illustrates one such wheel loader (10) with the above-described features. The wheel loader (10) includes an attachment (7), which may be a bucket configured to perform at least one of excavation, digging, carrying, and transportation of a load. The wheel loader (10) further includes a mechanical powertrain (8) configured to deliver driving torque to the wheels of the wheel loader (10). The mechanical powertrain (8) includes, among other components, an internal combustion engine (9), a drivetrain (also referred to as ‘transmission’, either mechanical or hydrostatic), a front axle, a rear axle, and a differential, working in tandem, to deliver driving torque to the wheels of the wheel loader (10).

[004] Wheel loaders (10) are usually employed to perform repeated works such as excavation and loading of load. Such repeated works performed by the wheel loader (10) may be identified and measured in terms of job cycles. The term ‘job cycle’ as used herein collectively refers to route of the wheel loader (10) and movements of the attachment (7) of the wheel loader (10), that are included in a loading cycle and an unloading cycle of the wheel loader (10).

[005] Figure 2 illustrates an exemplary job cycle of the wheel loader (10) depicting route of the wheel loader (10) and movements of the attachment of the wheel loader (10), that are included in the loading cycle and the unloading cycle of the wheel loader (10). Steps involved in the job cycle of the wheel loader (10) is suggestively depicted by reference numerals 1 to 6 in Figure 2, corresponding to steps 1 to 6 involved in the job cycle of the wheel loader (10) and is explained as follows. The loading cycle begins with the wheel loader (10) driving towards the load, as depicted at step 1. The load may be at least one of a heap of sand, soil, ore, debris, and the like. Further, the loading cycle includes lowering of the attachment (7) for excavation of the load, excavating the load and lifting of the attachment with the load, as depicted at step 2. The loading cycle further includes reversal and movement of the wheel loader (10) towards a load receiver (20) for unloading of the load, as depicted at step 3. The load receiver (20) may be at least one of a dump truck, feed-hopper, conveyor belt, and railroad cars, configured for receiving and/or conveying the load. The unloading cycle is initiated with completion of loading cycle. The unloading cycle includes movement of the wheel loader (10) towards the load receiver (20), as depicted at step 4. Further, the attachment (7) is lowered, and the load is unloaded onto the load receiver (20), as depicted at step 5. The unloading cycle further includes operations such as raising of the attachment (7) after unloading, followed by reversal and movement of the wheel loader (10) away from the load receiver (20), as depicted at step 6. One job cycle is completed with execution of one such loading cycle and unloading cycle. The wheel loader (10) may begin with a second job cycle on completion of the first job cycle.

[006] During regular operation of the wheel loader (10), in job cycles as described above, movement of the wheel loader (10) in forward gear and reverse gear, is almost in a ratio of 1:1. Due to such operational conditions, the mechanical powertrain (8), particularly, the transmission, is subjected to high wear and tear. Further, due to higher utilization of the transmission, in comparison with the transmission utilization of other on-road vehicles, the transmission of the wheel loader (10) requires regular maintenance and may suffer from frequent breakdowns. Repair and servicing of transmission

is expensive, time-consuming and requires skilled servicemen. Further, in most cases, overhauling of the transmission can only be carried out by fully isolating and disassembling the transmission from the powertrain. Such complete isolation and disassembly of the transmission may be mandated by the assembly layout of the wheel loader (10) and/or to improve accessibility for the servicemen and to satisfy precision & contamination control requirements during overhauling. Such servicing requirements of the transmission (used in wheel loaders (10)) results in heavy maintenance costs and increases overall downtime of the wheel loaders (10).

[007] Figure 3 is a graph illustrating power requirements of the wheel loader (10), during regular operation of the wheel loader (10) in one job cycle. The graph illustrates power requirements of the wheel loader (10), for steps 1 to 6 of the job cycle. Overall power requirement of the wheel loader (10) may generally include two major components, such as, power requirement of the mechanical powertrain (8) required for movement of the wheel loader (10) and power requirement of the hydraulic system configured to drive one or more attachment (7) of the wheel loader (10). The graph includes a dotted line outlining the power requirement of the mechanical powertrain (8) required for movement of the wheel loader (10). Further, a solid continuous line outlines the power requirement of the hydraulic system configured to drive one or more attachment (7) of the wheel loader (10). It can be inferred from the graph that average power requirement of the wheel loader (10) during regular operation, is around 60 percent of peak power requirement of the wheel loader (10). However, it is essential that the internal combustion engine (9) of the wheel loader (10) be designed and configured to cater to peak power requirement of the wheel loader (10). Accordingly, configuring the internal combustion engine (9) based on the peak power requirement of the wheel loader (10), results in an increase in dimension and size of the internal combustion engine (9). Such increase in size of the internal combustion engine (9) requires higher accommodation space, is bulky and may decrease overall fuel efficiency of the wheel loader (10).

[008] The present disclosure is directed to overcome one or more limitations stated above or any other limitations associated with the prior art.

SUMMARY OF THE DISCLOSED INVENTION

[009] The present disclosure overcomes one or more drawbacks of conventional wheel loaders with mechanical powertrain as described above and provides additional advantages through a powertrain as claimed in the present disclosure. Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered a part of the claimed disclosure.

[0010] In one non-limiting embodiment of the present disclosure, a hydrostatic powertrain (also referred to as ‘powertrain’ hereinafter) for a vehicle is disclosed. The powertrain includes a hydraulic pump coupled to a prime mover of the vehicle. The hydraulic pump is configured to be driven by the prime mover for generating hydraulic flow. A plurality of first valves are fluidly coupled to the hydraulic pump. The plurality of first valves are configured to distribute hydraulic flow generated by the hydraulic pump. A plurality of second valves are fluidly coupled to the plurality of first valves. A hydraulic motor is coupled to each wheel of the vehicle and is fluidly coupled to at least one second valve of the plurality of second valves. A plurality of sensors are coupled to a steering wheel and to wheels of the vehicle. The plurality of sensors are configured to detect acceleration and angular position. Further, a control unit is communicatively coupled to the plurality of sensors, to at least one of the plurality of first valves, and to at least one of the plurality of second valves. The control unit is configured to regulate operation of the at least one of the plurality of first valves and the at least one of the plurality of second valves, based on signals received from the plurality of sensors.

[0011] In an embodiment of the present disclosure, the at least one of the plurality of first valves is a directional control valve configured to regulate at least one of flow rate, direction and magnitude of the hydraulic flow supplied to the plurality of second valves.

[0012] In an embodiment of the present disclosure, the at least one of the plurality of second valves is a motor control valve configured to regulate at least one of pressure and magnitude of the hydraulic flow supplied to the hydraulic motor.

[0013] In an embodiment of the present disclosure, the plurality of sensors includes an acceleration sensor configured to detect acceleration of the vehicle and a gyroscope configured to detect the angular acceleration of the vehicle.

[0014] In an embodiment of the present disclosure, the plurality of sensors includes a position sensor configured to detect angular position of the steering wheel of the vehicle.

[0015] In an embodiment of the present disclosure, the control unit is configured to regulate operation of each of the hydraulic motor coupled to each wheel, independent of each other, based on signals received from the plurality of sensors.

[0016] In an embodiment of the present disclosure, the control unit is configured to regulate operation of each of the hydraulic motor coupled to each wheel, to regulate speed and torque delivered to the wheels of the vehicle.

[0017] In an embodiment of the present disclosure, the prime mover is an internal combustion engine of the vehicle, and the hydraulic pump is a tandem hydraulic pump.

[0018] In an embodiment of the present disclosure, the vehicle is a wheel loader.

[0019] In another non-limiting embodiment of the present disclosure, a method for operating a hydrostatic powertrain of a vehicle is disclosed. The method includes generating hydraulic flow by a hydraulic pump coupled to a prime mover of the vehicle. The method further includes distributing the hydraulic flow to a hydraulic motor coupled to each wheel of the vehicle. The hydraulic flow is distributed through a plurality of first valves and a plurality of second valves in fluid communication with the hydraulic pump. The method further includes regulating, by a control unit, operation of at least one of the plurality of first valves and at least one of the plurality of second valves. Regulation is based on signals received from a plurality of sensors configured to detect acceleration and angular position, for operating hydrostatic powertrain of the vehicle.

[0020] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF DRAWINGS

[0021] The novel features and characteristics of the disclosure are set forth in the appended description. The disclosure itself, however, as well as a preferred mode of use, further objectives, and

advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying figures. One or more embodiments are now described, by way of example only, with reference to the accompanying figures wherein like reference numerals represent like elements and in which:

[0022] **Figure 1** illustrates a conventional wheel loader, in accordance with prior art.

[0023] **Figure 2** illustrates an exemplary job cycle of the wheel loader of Figure 1.

[0024] **Figure 3** is a graph illustrating power requirements of the wheel loader of Figure 1, in one exemplary job cycle.

[0025] **Figure 4** illustrates a hydrostatic powertrain, in accordance with an embodiment of the present disclosure.

[0026] **Figure 6** illustrates a hydraulic circuit of the hydrostatic powertrain, in accordance with an embodiment of the present disclosure.

[0027] **Figure 5** illustrates a flow chart of a method for operating the hydrostatic powertrain of Figure 4, in accordance with an embodiment of the present disclosure.

[0028] The figures depict embodiments of the disclosure for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the assemblies and methods illustrated herein may be employed without departing from the principles of the disclosure described herein.

DETAILED DESCRIPTION

[0029] While the embodiments in the disclosure are subject to various modifications and alternative forms, specific embodiment thereof has been shown by way of example in the figures and will be described below. It should be understood, however, that it is not intended to limit the disclosure to the particular forms disclosed, but on the contrary, the disclosure is to cover all modifications, equivalents, and alternatives falling within the scope of the disclosure.

[0030] It is to be noted that a person skilled in the art would be motivated from the present disclosure and modify a hydrostatic powertrain for a vehicle as disclosed herein. However, such modifications should be construed within the scope of the disclosure. Accordingly, the drawings show only those specific details that are pertinent to understand the embodiments of the present disclosure, so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

[0031] The terms “comprises”, “comprising”, or any other variations thereof used in the disclosure, are intended to cover a non-exclusive inclusion, such that a system and method that comprises a list of components does not include only those components but may include other components not expressly listed or inherent to such system, method, or assembly, or device. In other words, one or more elements in a system or device preceded by “comprises... a” does not, without more constraints, preclude the existence of other elements or additional elements in the system or device.

[0032] Embodiments of the present disclosure disclose a hydrostatic powertrain (also referred to as ‘powertrain’ hereinafter) for a vehicle is disclosed. The powertrain includes a hydraulic pump coupled to a prime mover of the vehicle. The hydraulic pump is configured to be driven by the prime mover for generating hydraulic flow. A plurality of first valves are fluidly coupled to the hydraulic pump. The plurality of first valves are configured to distribute hydraulic flow generated by the hydraulic pump. A plurality of second valves are fluidly coupled to the plurality of first valves. A hydraulic motor is coupled to each wheel of the vehicle and is fluidly coupled to at least one second valve of the plurality of second valves. A plurality of sensors are coupled to a steering wheel and to wheels of the vehicle. The plurality of sensors are configured to detect acceleration and angular position. Further, a control unit is communicatively coupled to the plurality of sensors, to at least one of the plurality of first valves, and to at least one of the plurality of second valves. The control unit is configured to regulate operation of the at least one of the plurality of first valves and the at least one of the plurality of second valves, based on signals received from the plurality of sensors.

[0033] The following paragraphs describe the present disclosure with reference to Figures 1 - 5. In the figures, the same element or elements which have similar functions are indicated by the same reference signs. It is to be noted that, the vehicle including the prime mover (such as, an internal combustion engine) and the mechanical powertrain including transmission is not illustrated in the figures for the purpose of simplicity. One skilled in the art would appreciate that the hydrostatic

powertrain as disclosed in the present disclosure may be used in any vehicle, where such vehicle may include, but not be limited to, wheel loaders, light duty vehicles, passenger vehicles, commercial vehicles, and the like. Also, such hydrostatic powertrain may be employed in any other systems such as conveyor systems, robotic systems, automated motion control systems and the like.

[0034] The term ‘vehicle’ as used herein refers to a wheel loader. However, the term ‘vehicle’ as used herein also refers to any other vehicle having a powertrain configured to provide driving torque to wheels of the vehicle. Further, although the present disclosure is described in the context of the vehicle being a wheel loader, such description may not be viewed as a limitation of the present disclosure and may be suitably adapted to be implemented in any other type of vehicle. The vehicle may be at least one of an earth moving vehicle, off-road vehicle, off-highway vehicle, passenger vehicle, commercial transport vehicle, car, van, minivan, public transport vehicles, traveler buses, trucks, SUVs, and goods transport vehicles, and the like.

[0035] The term ‘hydraulic power’ (also called as fluid power) as used herein refers to power transmitted by controlled circulation of pressurized fluid (hydraulic fluid or hydraulic oil in context of present disclosure), to actuate one or more implements, such as, but not limited to a hydraulic motor, configured to convert the hydraulic power into a mechanical output. The term ‘hydraulic flow’ as used herein refers to volume of fluid (hydraulic fluid or hydraulic oil in context of present disclosure) that flows through a surface area in a specific timespan. The term ‘hydraulic oil’ or ‘hydraulic fluid’ as used herein refers to any oil or fluid that may be used in the wheel loader, such as, but not limited to, ISO viscosity grade (VG) 32, 46, 68, 100, 150, 220, 320, 460 and 680 oils or equivalent SAE oil grade, that is suitable for catering towards operational requirements of the wheel loader. The term ‘hydraulic flow’ as used herein refers to ‘hydraulic oil flow’ and/or ‘hydraulic fluid flow’, for distributing hydraulic power generated by the hydraulic pump.

[0036] Figure 4 illustrates a hydrostatic powertrain (100) (also simply referred to as ‘powertrain’ hereinafter) for a vehicle, in accordance with an embodiment of the present disclosure. The powertrain (100) may include a hydraulic pump (12) coupled to a prime mover (11) of the vehicle. The prime mover (11) may be an internal combustion engine of the vehicle. The hydraulic pump (12) may be configured to be driven by the prime mover (11) for generating hydraulic flow. A plurality of first valves (13) may be fluidly coupled to the hydraulic pump (12). The plurality of first valves (13) may be configured to distribute hydraulic flow generated by the hydraulic pump (12). A plurality of

second valves (14) may be fluidly coupled to the plurality of first valves (13). A hydraulic motor (15) may be coupled to each wheel of the vehicle. The hydraulic motor (15) may be fluidly coupled to at least one second valve (14) of the plurality of second valves (14). In an embodiment, the hydraulic motor (15) may be a bi-directional variable displacement hydraulic motor, suitably configured to cater towards operational requirements of the powertrain (100). Further, the hydraulic motor (15) may be coupled to wheels (18) of the powertrain (100), as depicted in Figure 4.

[0037] Further, a plurality of sensors (16) may be coupled to a steering wheel (19) (not shown in the Figures) and to wheels (18) (not shown in the Figures) of the vehicle. The plurality of sensors (16) may be configured to detect at least one of an acceleration of the vehicle and angular position of the steering wheel of the vehicle. Furthermore, a control unit (17) may be communicatively coupled to the plurality of sensors (16), to at least one of the plurality of first valves (13), and to at least one of the plurality of second valves (14). The control unit (17) may be configured to regulate operation of the at least one of the plurality of first valves (13) and the at least one of the plurality of second valves (14), based on signals received from the plurality of sensors (16).

[0038] In an embodiment, the hydraulic pump (12) may be a tandem hydraulic pump with a common inlet and two or more outlets configured to supply flow to two or more separate hydraulic systems. The phrase ‘two or more hydraulic systems’ as used herein may refer to the plurality of first valves (13) that may be fluidly coupled to the hydraulic pump (12). The hydraulic pump (12) may also be a variable displacement load sensing and pressure compensating pump, suitably configured to cater towards operational requirements of the powertrain (100).

[0039] In an embodiment, the at least one of the plurality of first valves (13) may be a directional control valve configured to regulate at least one of flow rate, direction and magnitude of the hydraulic flow supplied to the plurality of second valves (14). In an embodiment, the plurality of first valves (13) may be at least one of a two-way valve, three-way valve, and four-way valve, check valve, pilot operated check valve, manually actuated valve, pilot actuated valve, solenoid actuated valve, shuttle valve and the like. The plurality of first valves (13) may be operable between an open condition and a closed condition, for regulating hydraulic flow supplied to the plurality of second valves (14). The plurality of first valves (13) may be operable by the control unit (17) of the powertrain (100).

[0040] In an embodiment, the at least one of the plurality of second valves (14) may be a motor control valve (also known as motor operated valves) configured to regulate at least one of pressure and magnitude of the hydraulic flow supplied to the hydraulic motor (15). The plurality of second valves (14) may be at least one of a gate valve, ball valve, butterfly valve and the like and may be configured to be actuated by an actuator controlled by the control unit (17) of the powertrain (100). Further, the plurality of second valves (14) may be at least one of a pilot actuated valve, solenoid actuated valve, shuttle valve and the like. The plurality of second valves (14) may be operable between an open position and a closed position, for regulating hydraulic flow supplied to the hydraulic motor (15). The plurality of the second valves (14) may be operable by the control unit (17) of the powertrain (100).

[0041] In an embodiment, the plurality of sensors (16) may include an acceleration sensor configured to detect acceleration of the vehicle. Further, the plurality of sensors (16) may also be a gyroscope configured to detect angular acceleration of the vehicle. The plurality of sensors (16) may also be a gyro sensor configured to detect angular velocity of at least one wheel of the vehicle.

[0042] In an embodiment, the plurality of sensors (16) may include a position sensor configured to detect angular position of the steering wheel of the vehicle. The position sensor may be at least one of a capacitive displacement sensor, Eddy-current sensor, Hall effect sensor, inductive sensor, piezo-electric transducer (piezo-electric), position encoders, ultrasonic sensor and the like.

[0043] In an embodiment, the control unit (17) may be configured to regulate operation of each of the hydraulic motor (15) coupled to each wheel of the vehicle. The control unit (17) may be configured to regulate operation of each of the hydraulic motor (15) based on signals received from the plurality of sensors (16). The control unit (17) may be configured to selectively regulate operation of each of the hydraulic motor (15), to regulate speed and torque delivered to the wheels of the vehicle. The control unit (17) may be configured to selectively regulate operation of each of the hydraulic motor (15) independent of each other. Such configuration of the powertrain (100) allows an outer drive wheel of the vehicle to be rotated faster than an inner drive wheel during turning/in curves. Further, with such independent control of operation of each hydraulic motor (15), a differential mechanism (that is required in vehicles with conventional powertrains) of the vehicle may be eliminated.

[0044] Figure 5 is an exemplary embodiment of the present disclosure illustrating a flow chart of a method (200) for operating the hydrostatic powertrain (100) of the vehicle.

[0045] The order in which the method (200) is described is not intended to be construed as a limitation, and any number of the described method blocks may be combined in any order to implement the method (200). Additionally, individual blocks may be deleted from the method (200) without departing from the scope of the subject matter described herein.

[0046] As depicted at block 201, the method (200) includes generating hydraulic flow by a hydraulic pump (12) coupled to a prime mover (11) of the vehicle.

[0047] As depicted at block 202, the method (200) further includes distributing the hydraulic flow to a hydraulic motor (15) coupled to each wheel of the vehicle. The hydraulic flow is distributed through a plurality of first valves (13) and a plurality of second valves (14) in fluid communication with the hydraulic pump (12).

[0048] As depicted at block 203, the method (200) further includes regulating, by a control unit (17), operation of at least one of the plurality of first valves (13) and at least one of the plurality of second valves (14). Regulation is based on signals received from a plurality of sensors (16) configured to detect acceleration and angular position, for operating hydrostatic powertrain (100) of the vehicle.

[0049] In an embodiment of the disclosure, the control unit (17) may be an Electronic Control Unit (ECU), or a centralized control unit, or a dedicated control unit associated with the powertrain (100). The control unit (17) may be implemented by any computing systems that is utilized to implement the features of the present disclosure. The control unit (17) may be comprised of a processing unit. The processing unit may comprise at least one data processor for executing program components for executing user- or system-generated requests. The processing unit may be a specialized processing unit such as integrated system (bus) controllers, memory management control units, floating point units, graphics processing units, digital signal processing units, etc. The processing unit may include a microprocessor, such as AMD Athlon, Duron or Opteron, ARM's application, embedded or secure processors, IBM PowerPC, Intel's Core, Itanium, Xeon, Celeron, or other line of processors, etc. The processing unit may be implemented using a mainframe, distributed processor, multi-core, parallel, grid, or other architectures. Some embodiments may utilize embedded technologies like application-

specific integrated circuits (ASICs), digital signal processors (DSPs), Field Programmable Gate Arrays (FPGAs), and the like.

[0050] Further, in some embodiments, the processing unit may be disposed in communication with one or more memory devices (e.g., RAM, ROM etc.) via a storage interface. The storage interface may connect to memory devices including, without limitation, memory drives, removable disc drives, etc., employing connection protocols such as serial advanced technology attachment (SATA), integrated drive electronics (IDE), IEEE-1394, universal serial bus (USB), fiber channel, small computing system interface (SCSI), etc. The memory drives may further include a drum, magnetic disc drive, magneto-optical drive, optical drive, redundant array of independent discs (RAID), solid-state memory devices, solid-state drives, and the like.

[0051] Figure 6 is an exemplary embodiment of a hydraulic circuit (300) (also referred to as the ‘circuit’ hereinafter) that is employed in the powertrain (100) of the present disclosure. The hydraulic circuit (300) includes two principal modes of operation, such as, forward travel and reverse travel, and a flushing operation common to both the forward travel and reverse travel modes of operation. The circuit (300) includes a variable displacement load sensing and pressure compensating pump (23) (simply referred to as the ‘pump (23)’ hereafter) driven by an engine (22) of the wheel loader (10). The pump (23) may be fluidly connected to a hydraulic tank (24). The hydraulic tank may also be fluidly connected to a hydraulic oil cooler (25) and a hydraulic oil filter (26) as depicted in the Figure 6. Further, the circuit (300) includes a forward travel solenoid valve (27) and a reverse travel solenoid valve (28) that are actuated by electronic control module (ECM) (21) (not shown in Figure 6), to provide pilot hydraulic signal to a direction control valve (DCV) (32). The pilot hydraulic oil signal (29) may be taken from an existing wheel loader pilot hydraulic system. The DCV (32) may be actuated by a pilot line signal received from forward travel solenoid valve (27) or reverse travel solenoid valve (28) depending upon ECM signal which actuates either of the forward travel solenoid valve (27) or reverse travel solenoid valve (28), for forward travel or reverse travel of wheel loader. The DCV (32) may be actuated for forward travel mode and reverse travel mode by transmitting at least one signal in direction depicted by pointers 31 and 30 respectively. Further, circuit (300) includes first crossover relief valve (33), second crossover relief valve (34), flushing shuttle valve (35) and a flushing relief valve (36) fluidly connected to the DCV (32) and four hydraulic motors (37, 38, 39 and 40) corresponding to four wheels of the wheel loader (10). The four hydraulic motors

correspond to a front left hydraulic motor (bi-directional variable displacement hydraulic motor type) (37), a front right hydraulic motor (bi-directional variable displacement hydraulic motor type) (38), a rear left hydraulic motor (bi-directional variable displacement hydraulic motor type) (39), and a rear right hydraulic motor (bi-directional variable displacement hydraulic motor type) (40). Forward travel mode of operation and reverse travel mode of operation is described in the following paragraphs, by referring to Figure 6.

[0052] Referring to Figure 6, in forward travel mode of operation, the ECM (21) actuates the forward travel solenoid valve (27), by transmitting electrical current to the forward travel solenoid valve (27), whereby energizing the forward travel solenoid valve (27). Such energization of the forward travel solenoid valve (27) will enable flow of pilot hydraulic oil (oil contained in hydraulic lines (conduits) connecting forward travel solenoid valve (27) to the DCV (32)) to the DCV (32), whereby activating a forward position of the DCV (32). The DCV (32) in the forward position facilitates flow of hydraulic oil to four hydraulic motors (37, 38, 39 and 40), to enable forward travel of the wheel loader (10). The hydraulic oil is then routed back to the hydraulic tank (24) via the hydraulic oil filter (26) and hydraulic oil cooler (25), which filter and cool the hydraulic oil, respectively. Hydraulic oil from DCV (32) is also routed to the first cross over relief valve (33) & the second cross over relief valve (34), however, does no flow further, unless second cross over relief valve (34) is actuated for operational safety of the circuit (300). In case, upstream hydraulic oil pressure (corresponding to forward travel mode of operation) increases beyond a set pressure of second cross over relief valve (34), then the hydraulic oil flows through the second cross over relief valve (34) to the hydraulic tank (24), until the first upstream hydraulic oil pressure decreases below the set pressure of second cross over relief valve (34). Such configuration of the circuit (300) ensures safety of components/elements of the circuit (300), in case the first upstream hydraulic oil pressure increases beyond the set pressure and/or a design pressure of the circuit (300) (i.e., a maximum pressure which the circuit can withstand without compromising on safety requirements of the hydrostatic powertrain (100)).

[0053] Referring again to Figure 6, in reverse travel mode of operation, the ECM (21) actuates the reverse travel solenoid valve (28), by transmitting electrical current to the reverse travel solenoid valve (28), whereby energizing the reverse travel solenoid valve (28). Such energization of the reverse travel solenoid valve (28) will enable flow of pilot hydraulic oil (29) (oil contained in hydraulic lines (conduits) connecting reverse travel solenoid valve (28) to the DCV (32)) to the DCV (32), whereby

activating a reverse position of the DCV (32). The DCV (32) in the reverse position facilitates flow of hydraulic oil to four hydraulic motors (37, 38, 39 and 40), to enable reverse travel of the wheel loader (10). The hydraulic oil is then routed back to the hydraulic tank (24) via the hydraulic oil filter (26) and hydraulic oil cooler (25), which filter and cool the hydraulic oil, respectively. Hydraulic oil from DCV (32) is also routed to the first cross over relief valve (33) and the second cross over relief valve (34), however, does not flow further, unless first cross over relief valve (33) is actuated for operational safety of the circuit (300). In case, upstream hydraulic oil pressure (corresponding to reverse travel mode of operation) increases beyond the set pressure of the first cross over relief valve (33), then the hydraulic oil flows through the first cross over relief valve (33) to the hydraulic tank (24), until the upstream hydraulic oil pressure decreases below the set pressure of first cross over relief valve (33). Such configuration of the circuit (300) ensures safety of components/elements of the circuit (300), in case the second upstream hydraulic oil pressure increases beyond the set pressure and/or the design pressure of the circuit (300) (i.e., a maximum pressure which the circuit can withstand without compromising on safety requirements of the hydrostatic powertrain system).

[0054] The flushing of hydrostatic powertrain may be performed by conjunctive operation of the flushing shuttle valve (35) and the flushing relief valve (36). The hydraulic oil flow may be routed to flushing shuttle valve in forward and reverse travel operation. With reference to Figure 6, when the pump (23) is working in an upstroke mode, high pressure on the pump (23) output side (pressured depending upon forward or reverse travel DCV (32) valve position), actuates the flushing shuttle valve (35). The hydraulic oil on a low-pressure side (i.e., downstream pressure, contrary to the upstream hydraulic oil pressure side in the circuit) flows through the flushing shuttle valve (35) to the flushing relief valve (36). The flushing relief valve (36) may be configured to maintain a preset back pressure in the low-pressure side of the circuit (300). The hydraulic oil is routed out of the flushing relief valve (36) flows into casing of the hydraulic motors (37, 38, 39 and 40). Such hydraulic oil flow through the casing of the hydraulic motors (37, 38, 39 and 40), cools down components included therein and further, purges wear particles contained therein. The hydraulic oil may be further routed to a casing of the pump (23) to cool down components included therein and further, purges wear particles contained therein. Further, the hydraulic oil may be routed to at least one of the hydraulic oil cooler (25) and the hydraulic oil filter (26), which filter and cool the hydraulic oil, respectively. The hydraulic may be further routed to the hydraulic tank (24).

[0055] In an embodiment, the present disclosure provides a hydrostatic powertrain (100) and a method (200) for operating the hydrostatic powertrain of a vehicle. In comparison with a mechanical powertrain (8), the hydrostatic powertrain (100) includes far lesser number of moving parts, whereby resulting in lesser mechanical wear and tear, lesser power loss caused by friction, and an overall higher operational efficiency of the vehicle. The aspect of independent operational regulation of each of the hydraulic motor (15), facilitates actuating each of the hydraulic motors (15) to a desired speed (may be in revolutions per minute (rpm)) with different turning angles. Such independent operational control of each hydraulic motor (15) eliminates requirement of a differential mechanism that is required in vehicles with conventional powertrains. The powertrain (100) and the method (200) of the present disclosure overcomes drawbacks associated with conventional powertrain vehicles, such as, but not limited to, frequent breakdowns due to higher transmission utilization, expensive repair and servicing, heavy maintenance costs and associated downtime of the vehicle. Overall power requirement of the vehicle including power required for movement of the vehicle and power required for actuation of one or more attachment (7) of the vehicle is fully provided by the powertrain (100) alone, whereby eliminating requirement of a separate hydraulic system for operation of one or more attachment (7) of the vehicle. Dimensions and size of the powertrain (100) is considerably less in comparison with the size and dimensions mechanical powertrain (8), whereby saving space and/or providing extra space for configuring a powertrain (100) with higher capacity.

[0056] It is to be understood that a person of ordinary skill in the art may develop a powertrain of similar configuration without deviating from the scope of the present disclosure. Such modifications and variations may be made without departing from the scope of the present invention. Therefore, it is intended that the present disclosure covers such modifications and variations provided they come within the ambit of the appended claims and their equivalents.

EQUIVALENTS

[0057] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0058] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should typically be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean *at least* the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, typically means *at least two* recitations, or *two or more* recitations). Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system (100) having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system (100) having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.”

[0059] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0060] While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

We Claim:

1. A hydrostatic powertrain (100) for a vehicle, comprising:
 - a hydraulic pump (12) coupled to a prime mover (11) of the vehicle, the hydraulic pump (12) configured to be driven by the prime mover (11) for generating hydraulic flow;
 - a plurality of first valves (13) fluidly coupled to the hydraulic pump (12), wherein the plurality of first valves (13) are configured to distribute hydraulic flow generated by the hydraulic pump (12);
 - a plurality of second valves (14) fluidly coupled to the plurality of first valves (13);
 - a hydraulic motor (15) coupled to each wheel of the vehicle and fluidly coupled to at least one second valve (14) of the plurality of second valves (14);
 - a plurality of sensors (16) coupled to a steering wheel and to wheels of the vehicle, wherein the plurality of sensors (16) are configured to detect acceleration and angular position; and
 - a control unit (17) communicatively coupled to the plurality of sensors (16), to at least one of the plurality of first valves (13), and to at least one of the plurality of second valves (14), wherein the control unit (17) is configured to regulate operation of the at least one of the plurality of first valves (13) and the at least one of the plurality of second valves (14), based on signals received from the plurality of sensors (16).
2. The hydrostatic powertrain (100) as claimed in claim 1, wherein the at least one of the plurality of first valves (13) is a directional control valve configured to regulate at least one of flow rate, direction and magnitude of the hydraulic flow supplied to the plurality of second valves (14).
3. The hydrostatic powertrain (100) as claimed in claim 1, wherein the at least one of the plurality of second valves (14) is a motor control valve configured to regulate at least one of pressure and magnitude of the hydraulic flow supplied to the hydraulic motor (15).
4. The hydrostatic powertrain (100) as claimed in claim 1, wherein the plurality of sensors (16) includes an acceleration sensor configured to detect acceleration of the vehicle and a gyroscope configured to detect the angular acceleration of the vehicle.

5. The hydrostatic powertrain (100) as claimed in claim 1, wherein the plurality of sensors (16) includes a position sensor configured to detect angular position of the steering wheel of the vehicle.
6. The hydrostatic powertrain (100) as claimed in claim 1, wherein the control unit (17) is configured to regulate operation of each of the hydraulic motor (15) coupled to each wheel, independent of each other, based on signals received from the plurality of sensors (16).
7. The hydrostatic powertrain (100) as claimed in claim 1, wherein the control unit (17) is configured to regulate operation of each of the hydraulic motor (15) coupled to each wheel, to regulate speed and torque delivered to the wheels of the vehicle.
8. The hydrostatic powertrain (100) as claimed in claim 1, wherein the prime mover (11) is an internal combustion engine of the vehicle, and wherein the hydraulic pump (12) is a tandem hydraulic pump (12).
9. The hydrostatic powertrain (100) as claimed in claim 1, wherein the vehicle is a wheel loader.
10. A method for operating a hydrostatic powertrain (100) of a vehicle, the method comprising:
 - generating, hydraulic flow by a hydraulic pump (12) coupled to a prime mover (11) of the vehicle;
 - distributing, the hydraulic flow to a hydraulic motor (15) coupled to each wheel of the vehicle, wherein the hydraulic flow is distributed through a plurality of first valves (13) and a plurality of second valves (14) in fluid communication with the hydraulic pump (12); and
 - regulating, by a control unit (17), operation of at least one of the plurality of first valves (13) and at least one of the plurality of second valves (14) based on signals received from a plurality of sensors (16) configured to detect acceleration and angular position, for operating hydrostatic powertrain (100) of the vehicle.

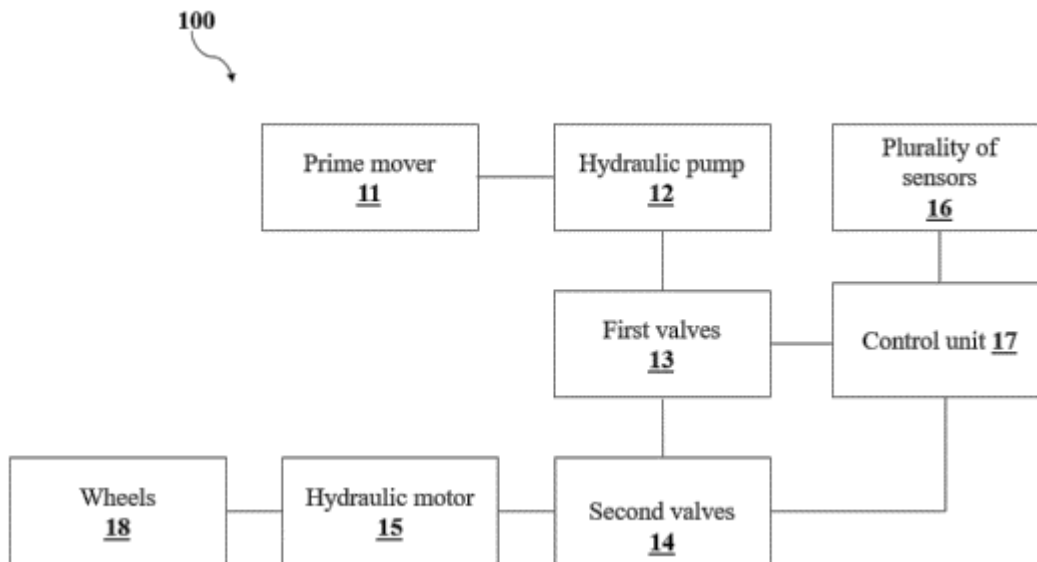
Dated this 10th Day of December 2021

**Robin Koshy Varghese (INPA No: 3705)
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ABSTRACT

A HYDROSTATIC POWERTRAIN FOR A WHEEL LOADER AND METHOD OF OPERATION THEREOF

The present disclosure relates to a hydrostatic powertrain (100) including a hydraulic pump (12) configured to be driven by a prime mover (11) for generating hydraulic flow. A plurality of first valves (13) are fluidly coupled to the hydraulic pump and are configured to distribute the hydraulic flow. A plurality of second valves (14) are fluidly coupled to the plurality of first valves. A hydraulic motor (15) is coupled to wheels of the vehicle and is fluidly coupled to at least one second valve (14). A plurality of sensors (16) are configured to detect acceleration of the vehicle and angular position of steering wheel of the vehicle. A control unit (17) is configured to regulate operation of the at least one of the plurality of first valves (13) and the at least one of the plurality of second valves (14), based on signals received from the plurality of sensors (16).



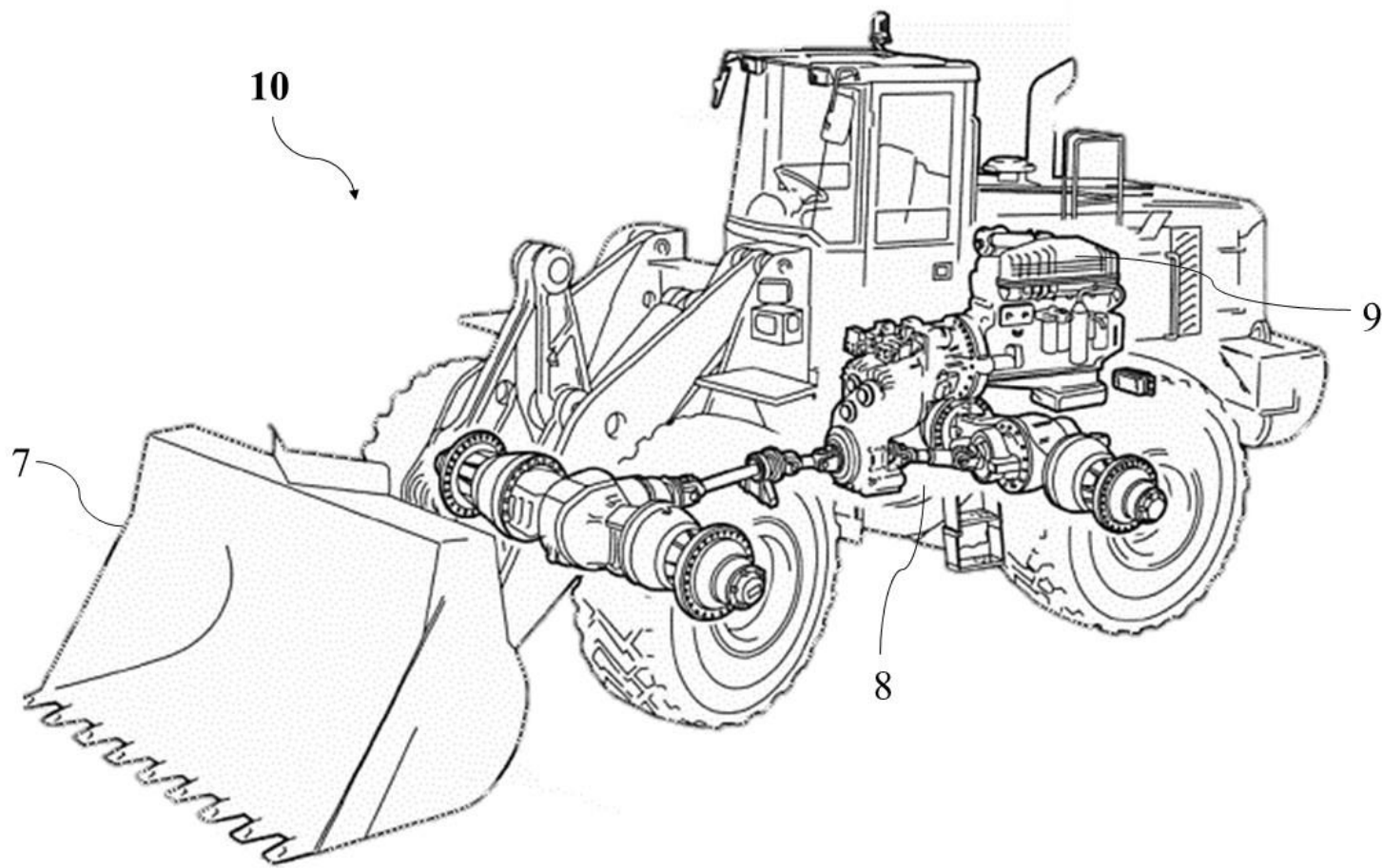


Figure 1

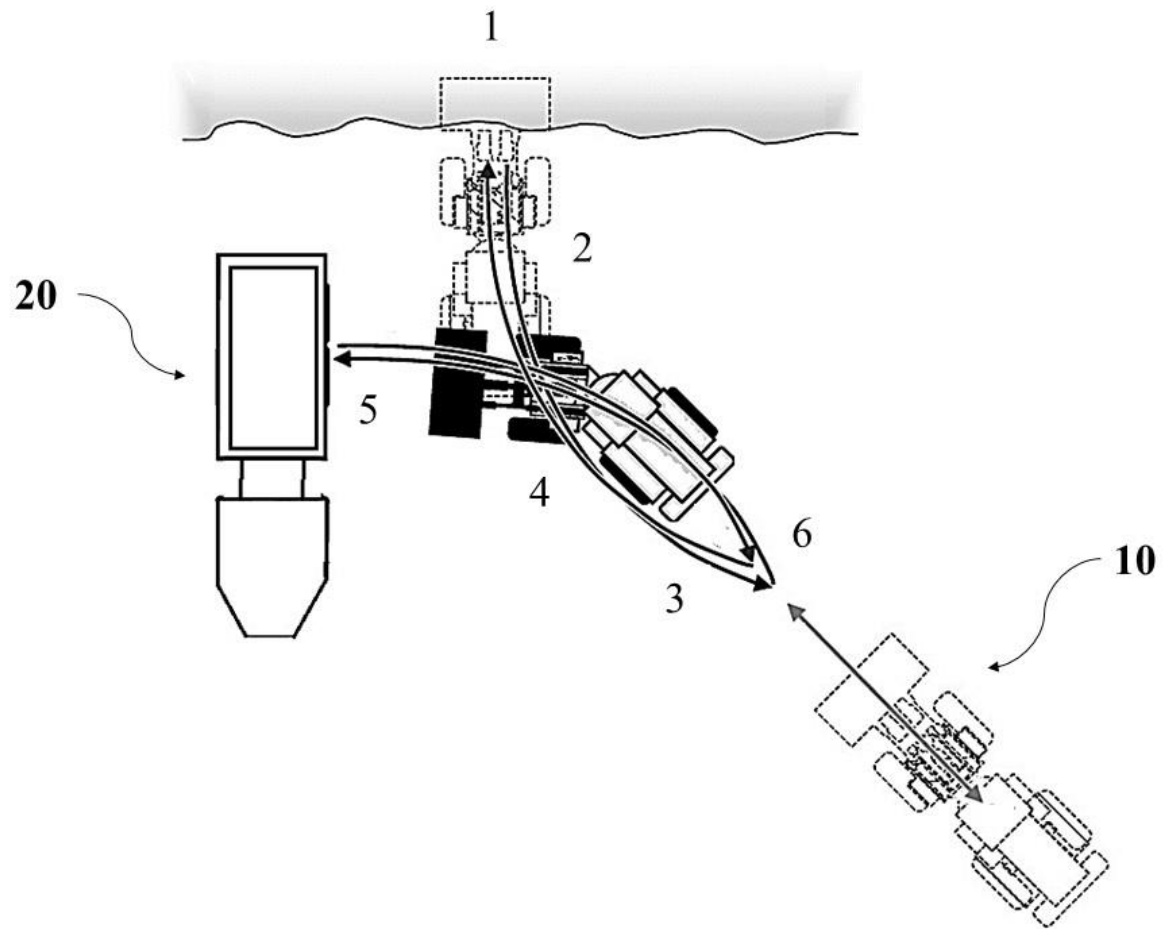


Figure 2

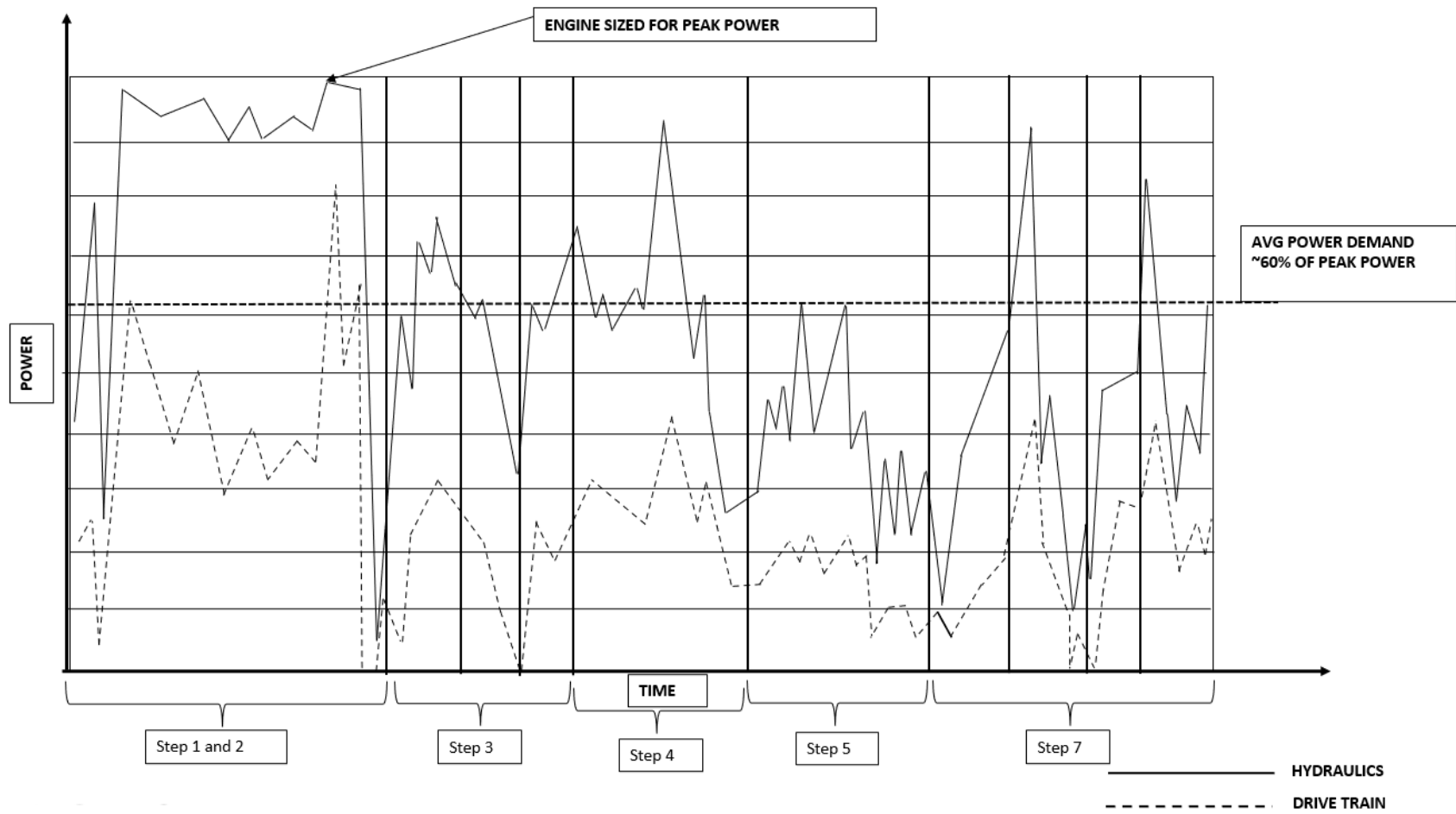


Figure 3

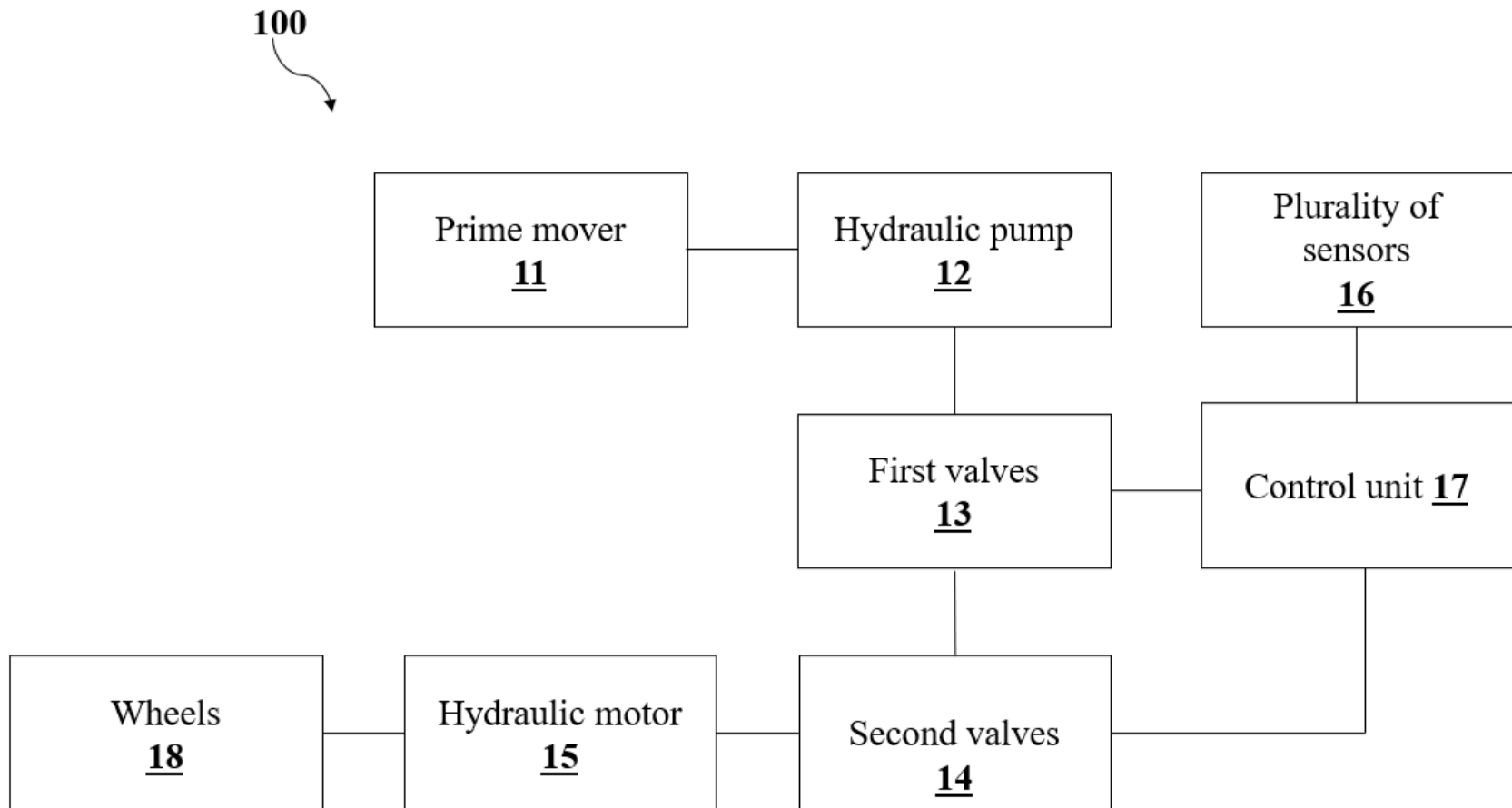


Figure 4

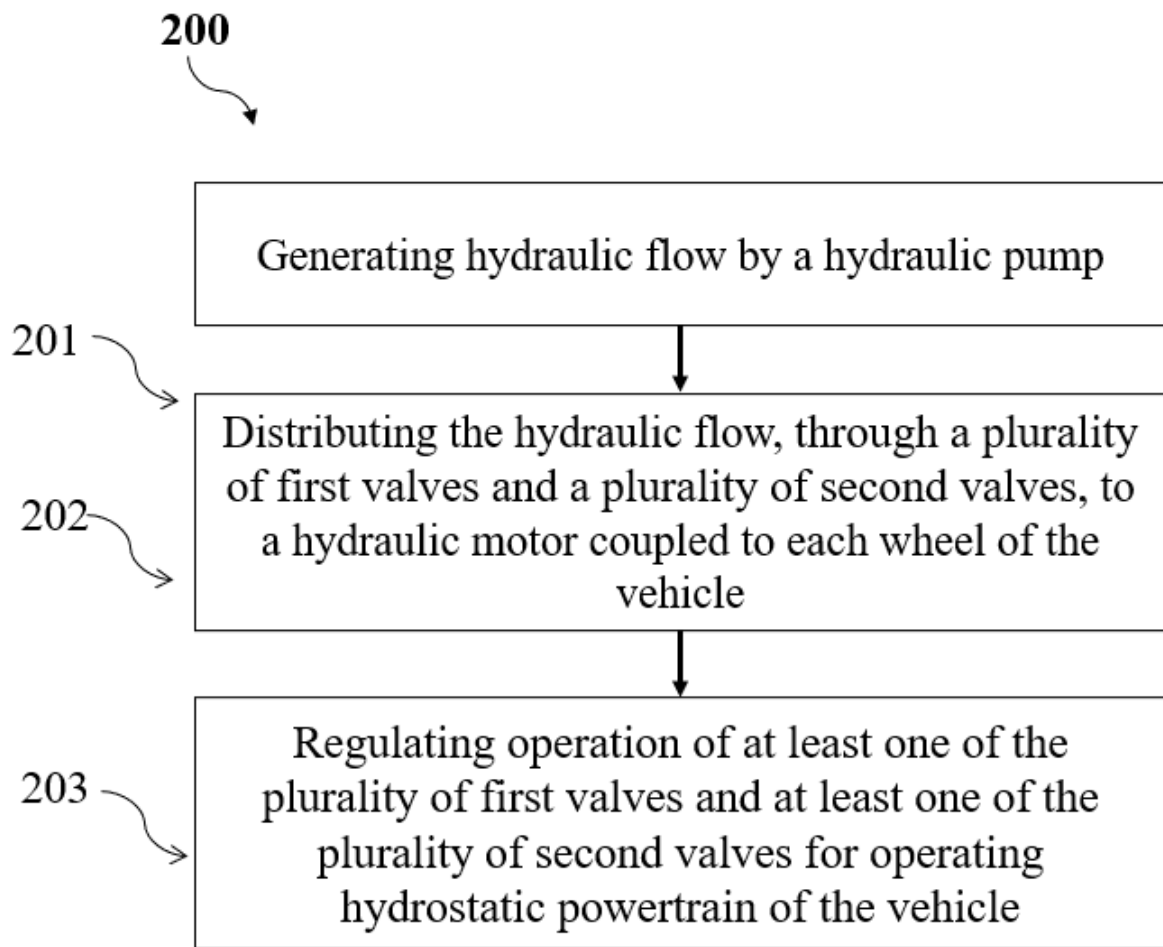


Figure 5

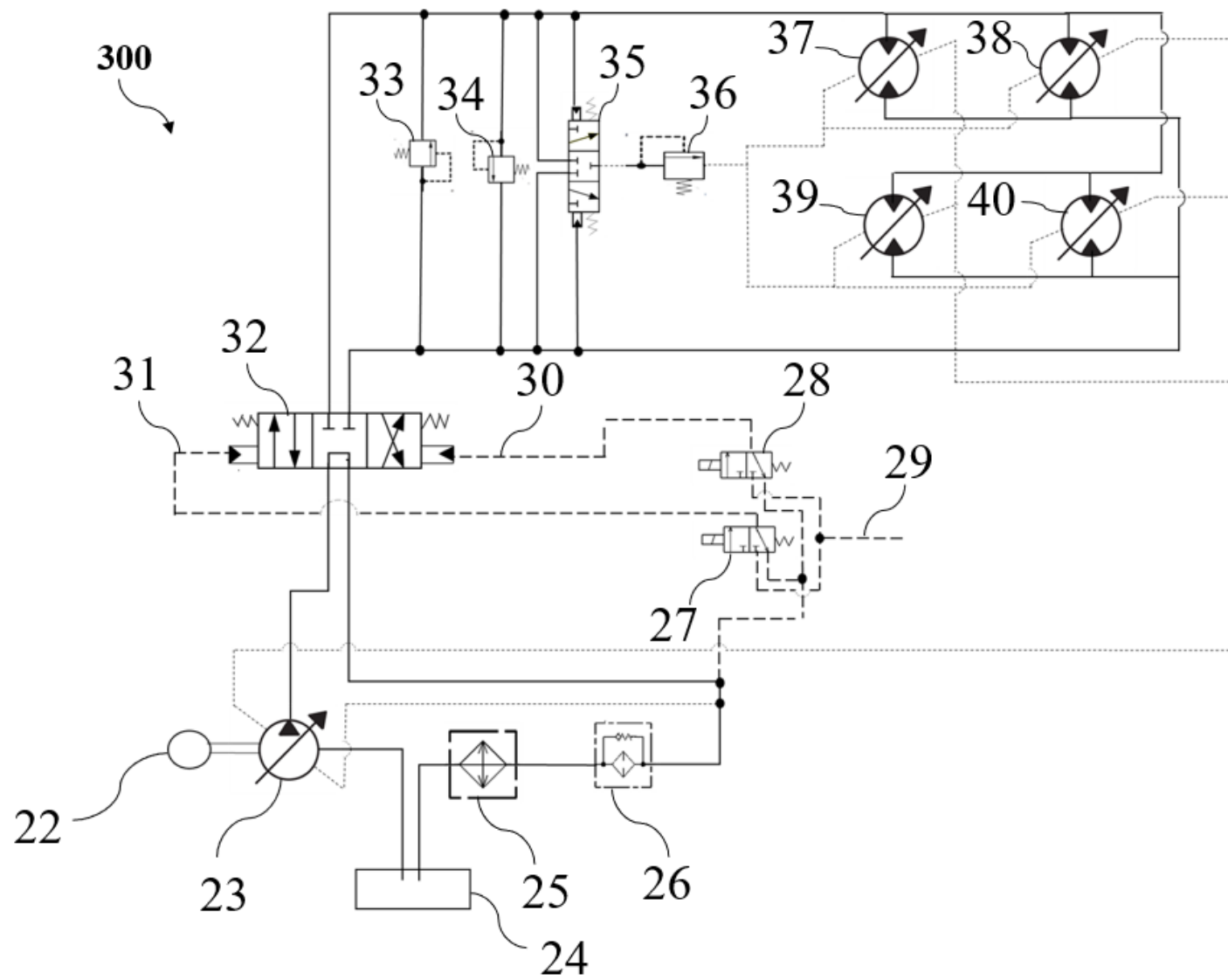


Figure 6