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### SYSTEMS AND METHODS FOR A SUSPENSION ASSEMBLY ON AN ELECTRIFIED VEHICLE

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#### Abstract

A suspension assembly for an electrified vehicle includes a first linkage rod coupled to a first bracket and a second linkage rod coupled to a second bracket. The first linkage rod is arranged at an angle relative to a central longitudinal axis so that as the first linkage rod extends from the axle housing toward the first bracket, the first linkage rod angles laterally outwardly and away from the central longitudinal axis. The second linkage rod is arranged at an angle relative to the central longitudinal axis so that as the second linkage rod extends from the axle housing toward the second bracket, the second linkage rod angles laterally outwardly and away from the central longitudinal axis.

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## **Background/Summary**

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 18/589,164, filed on Feb. 27, 2024, which is a continuation-in-part of U.S. patent application Ser. No. 18/371,311, filed on Sep. 21, 2023, which claims the benefit of and priority to U.S. Provisional Application No. 63/408,903, filed on Sep. 22, 2022, each of which is hereby incorporated by reference herein.

### **BACKGROUND**

[0002] Vehicles typically include a suspension coupled between a chassis and one or more tractive elements (e.g., wheels, tracks, etc.) to absorb and/or dampen road forces acting on the tractive elements.

### **SUMMARY**

[0003] At least one embodiment relates to a suspension assembly for an electrified vehicle. A suspension assembly for an electrified vehicle includes a first linkage rod coupled to a first bracket and a second linkage rod coupled to a second bracket. The electrified vehicle includes a chassis and an axle assembly. The chassis includes a first frame rail and a second frame rail laterally separated from the first frame rail. The axle assembly includes an axle housing arranged laterally between the first frame rail and the second frame rail. The first linkage rod is arranged at an angle relative to a central longitudinal axis so that as the first linkage rod extends from the axle housing toward the first bracket, the first linkage rod angles laterally outwardly and away from the central longitudinal axis. The second linkage rod is arranged at an angle relative to the central longitudinal axis so that as the second linkage rod extends from the axle housing toward the second bracket, the second linkage rod angles laterally outwardly and away from the central longitudinal axis.

[0004] At least one embodiment relates to an electrified vehicle. The electrified vehicle includes a chassis having a first frame rail and a second frame rail laterally separated from the first frame rail, an axle assembly having an axle housing arranged laterally between the first frame rail and the second frame rail, and an energy storage system supported on the chassis, and a suspension assembly. The suspension assembly includes a first linkage rod coupled between the axle housing and the first frame rail, a second linkage rod coupled between the axle housing and the second frame rail, a first bracket coupling at least the first linkage rod to the first frame rail, and a second bracket coupling at least the second linkage rod to the second frame rail. The first linkage rod is arranged at an angle relative to a central longitudinal axis so that as the first linkage rod extends from the axle housing toward the first frame rail, the first linkage rod angles laterally outwardly and away from the central longitudinal axis. The second linkage rod is arranged at an angle relative to the central longitudinal axis so that as the second linkage rod extends from the axle housing toward the second frame rail, the second linkage rod angles laterally outwardly and away from the central longitudinal axis.

[0005] At least one embodiment relates to an electrified vehicle. The electrified vehicle includes a chassis having a first frame rail and a second frame rail laterally separated from the first frame rail,

a first bracket fixedly coupled to the first frame rail, a second bracket fixedly coupled to the second frame rail, a first axle assembly including a first axle housing arranged laterally between the first frame rail and the second frame rail, a second axle assembly including a second axle housing arranged on an opposing side of a central lateral axis from the first axle housing, an energy storage system supported on the chassis between the first frame rail and the second frame rail, and a suspension assembly. The suspension assembly is transitionable between a riding position, one or more rebound positions, and one or more jounce positions.

[0006] This summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices or processes described herein will become apparent in the detailed description set forth herein, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements.

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## Description

### BRIEF DESCRIPTION OF THE FIGURES

[0007] The disclosure will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

[0008] FIG. 1 is a left side view of a vehicle, according to an exemplary embodiment;

[0009] FIG. 2 is a perspective view of the vehicle of FIG. 1 configured as a refuse vehicle, according to an exemplary embodiment;

[0010] FIG. 3 is a perspective view of the vehicle of FIG. 1 configured as a mixer vehicle, according to an exemplary embodiment;

[0011] FIG. 4 is a perspective view of the vehicle of FIG. 1 configured as a fire fighting vehicle, according to an exemplary embodiment;

[0012] FIG. 5 is a left side view of the vehicle of FIG. 1 configured as an airport fire fighting vehicle, according to an exemplary embodiment;

[0013] FIG. 6 is a perspective view of the vehicle of FIG. 1 configured as a boom lift, according to an exemplary embodiment;

[0014] FIG. 7 is a perspective view of the vehicle of FIG. 1 configured as a scissor lift, according to an exemplary embodiment;

[0015] FIG. 8 is a schematic illustration of a suspension assembly of a vehicle, according to an exemplary embodiment;

[0016] FIG. 9 is a top perspective view of a suspension assembly of a vehicle with a first frame rail and a second frame rail being transparent, according to an exemplary embodiment;

[0017] FIG. 10 is a top view of the suspension assembly of FIG. 9;

[0018] FIG. 11 is a side view of the suspension assembly of FIG. 9;

[0019] FIG. 12 is a front view of the suspension assembly of FIG. 9; and

[0020] FIG. 13 is a schematic diagram of an axle of the suspension of FIG. 9, according to an exemplary embodiment.

[0021] FIG. 14 is a top perspective view of a suspension assembly of a vehicle, according to an exemplary embodiment;

[0022] FIG. 15 is a side perspective view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0023] FIG. 16 is a rear perspective view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0024] FIG. 17 is a left side view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0025] FIG. 18 is a right side view of a bracket of a suspension assembly, according to an

exemplary embodiment.

[0026] FIG. **19** is a bottom view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0027] FIG. **20** is a top view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0028] FIG. **21** is a front view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0029] FIG. **22** is a bottom perspective view of a bracket of a suspension assembly, according to an exemplary embodiment.

[0030] FIG. **23** is a side view of the suspension assembly of FIG. **14**, according to an exemplary embodiment.

[0031] FIG. **24** is a side view of the suspension assembly of FIG. **14** in a rear rebound position, according to an exemplary embodiment.

[0032] FIG. **25** is a side view of a suspension assembly of FIG. **14** in a front rebound position, according to an exemplary embodiment.

[0033] FIG. **26** is a side view of a suspension assembly of FIG. **14** in a rear jounce position, according to an exemplary embodiment.

[0034] FIG. **27** is a side view of a suspension assembly of FIG. **14** in a front position, according to an exemplary embodiment.

[0035] FIG. **28** is a side view of a suspension assembly of FIG. **14** in a rebound position, according to an exemplary embodiment.

#### DETAILED DESCRIPTION

[0036] Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

[0037] Vehicles (e.g., a commercial vehicle, a refuse vehicle, a fire fighting vehicle, a fire suppression vehicle, a military vehicle, a mixing vehicle, a lift vehicle, etc.) are being electrified by incorporating one or more batteries (e.g., battery cells or battery packs) that are used to supply electrical power to one or more components of the vehicle. The batteries mounted on a vehicle require mounting space, and the amount of available mounting space on a vehicle may limit the amount of batteries, and the energy storage capacity, on the vehicle. In general, conventional suspension assemblies are not designed to incorporate batteries. For example, conventional suspension assemblies include linkages or rods that are arranged within and extend into a space between frame rails of a chassis. Linkages or rods extending into the space between the frame rails prevent batteries from being mounted between the frame rails and/or limit the size or number of batteries mounted between the frame rails.

[0038] The systems and methods described herein include a suspension assembly with linkage rods (e.g., upper control links) that are arranged to free up the space between the frame rails on a vehicle. In some embodiments, the linkage rods extend laterally outwardly so that the linkage rods angle away from a central longitudinal axis and provide more useable area between the frame rails within which batteries may be mounted. The increased area between the frame rails enables more and/or larger batteries to be mounted between the frame rails, when compared to conventional suspension designs, which increases an energy storage capacity available to the vehicle.

#### Vehicle

[0039] According to an exemplary embodiment, as shown in FIG. **1**, an electrified vehicle (e.g., a vehicle assembly, a truck, a vehicle base, etc.), shown as vehicle **10**, includes a frame assembly or chassis assembly, shown as chassis **20**. The chassis assembly may support other components of the vehicle **10**. In some embodiments, the chassis **20** extends longitudinally along a length of the

vehicle **10**. The chassis **20** may extend substantially parallel to a primary direction of travel of the vehicle **10**. In some embodiments, the chassis **20** includes a middle section **24** that acts as a storage portion that includes one or more vehicle components. The middle section **24** may include an enclosure that contains one or more vehicle components and/or a frame that supports one or more vehicle components. In some embodiments, the middle section **24** contains or includes one or more electrical energy storage devices (e.g., batteries, capacitors, etc.).

[0040] According to an exemplary embodiment, a cabin, operator compartment, or body component, shown as cab **40**, is coupled to a front end portion of the chassis **20** (e.g., the front section **22** of the chassis **20**). Together, the chassis **20** and the cab **40** define a front end of the vehicle **10**. The cab **40** extends above the chassis **20**. The cab **40** includes an enclosure or main body that defines an interior volume, shown as cab interior **42** that is sized to contain one or more operators. The cab **40** also includes one or more doors **44** that facilitate selective access to the cab interior **42** from outside of the vehicle **10**. The cab interior **42** contains one or more components that facilitate operation of the vehicle **10** by the operator. In one embodiment, the cab interior **42** contains components that facilitate operator comfort (e.g., seats, seatbelts, etc.), user interface components that receive inputs from the operators (e.g., steering wheels, pedals, touch screens, switches, buttons, levers, etc.), and/or user interface components that provide information to the operators (e.g., lights, gauges, speakers, etc.). The user interface components within the cab **40** may facilitate operator control over the drive components of the vehicle **10** and/or over any implements of the vehicle **10**.

[0041] According to an exemplary embodiment, the vehicle **10** further includes a series of axle assemblies, shown as front axle **50** and rear axles **52**. As shown, the vehicle **10** includes one front axle **50** coupled to the front section **22** of the chassis **20** and two rear axles **52** each coupled to the rear section **26** of the chassis **20**. In other embodiments, the vehicle **10** includes more or fewer axles. In one embodiment, the vehicle **10** includes a tag axle that may be raised or lowered to accommodate variations in weight being carried by the vehicle **10**. The front axle **50** and the rear axles **52** each include a plurality of tractive elements (e.g., wheels, treads, etc.), shown as wheel and tire assemblies **54**. The wheel and tire assemblies **54** are configured to engage a support surface (e.g., roads, the ground, etc.) to support and propel the vehicle **10**. The front axle **50** and the rear axles may include steering components (e.g., steering arms, steering actuators, etc.), suspension components (e.g., gas springs, dampeners, air springs, etc.), power transmission or drive components (e.g., differentials, drive shafts, etc.), braking components (e.g., brake actuators, brake pads, brake discs, brake drums, etc.), and/or other components that facilitate propulsion or support of the vehicle **10**.

[0042] In some embodiments, the vehicle **10** is configured as an electric vehicle that is propelled by an electric powertrain system. As shown in FIG. **1**, the vehicle **10** includes one or more electrical energy storage devices (e.g., batteries, battery packs, battery cells, capacitors, etc.), shown as batteries **60**. As shown, the batteries **60** are supported on the chassis **20** (e.g., between the frame rails of the chassis **20**). In other embodiments, the batteries **60** are otherwise positioned throughout the vehicle **10**. The vehicle **10** further includes one or more electromagnetic devices (e.g., motor/generators), shown as drive motors **62**. The drive motors **62** are electrically coupled to the batteries **60**. The drive motors **62** may be configured to receive electrical energy from the batteries **60** and provide rotational mechanical energy to the wheel and tire assemblies **54** to propel the vehicle **10**. The drive motors **62** may be configured to receive rotational mechanical energy from the wheel and tire assemblies **54** and provide electrical energy to the batteries **60**, providing a braking force to slow the vehicle **10**. As shown, the drive motors **62** are positioned within the rear axles **52** (e.g., as part of a combined axle and motor assembly). In other embodiments, the drive motors **62** are otherwise positioned within the vehicle **10** or within the axle assemblies.

[0043] In other embodiments, the vehicle **10** is configured as a hybrid vehicle that is propelled by a hybrid powertrain system (e.g., a diesel/electric hybrid, gasoline/electric hybrid, natural gas/electric

hybrid, etc.). According to an exemplary embodiment, the hybrid powertrain system includes a primary driver (e.g., an engine, a motor, etc.), an energy generation device (e.g., a generator, etc.), and/or an energy storage device (e.g., a battery, capacitors, ultra-capacitors, etc.) electrically coupled to the energy generation device. The primary driver may combust fuel (e.g., gasoline, diesel, etc.) to provide mechanical energy, which a transmission may receive and provide the front axle **50** and/or the rear axles **52** to propel the vehicle **10**. Additionally or alternatively, the primary driver may provide mechanical energy to the generator, which converts the mechanical energy into electrical energy. The electrical energy may be stored in the energy storage device (e.g., the batteries **60**) in order to later be provided to a motive driver.

[0044] In yet other embodiments, the chassis **20** is further configured to support non-hybrid powertrains. For example, the powertrain system may include a primary driver that is a compression-ignition internal combustion engine that utilizes diesel fuel.

[0045] As shown in FIG. **1**, the vehicle **10** includes a rear assembly, module, implement, body, or cargo area, shown as application kit **80**. The application kit **80** may include one or more implements, vehicle bodies, and/or other components. Although the application kit **80** is shown positioned behind the cab **40**, in other embodiments the application kit **80** extends forward of the cab **40**. The vehicle **10** may be outfitted with a variety of different application kits **80** to configure the vehicle **10** for use in different applications. Accordingly, a common vehicle **10** can be configured for a variety of different uses simply by selecting an appropriate application kit **80**. By way of example, the vehicle **10** may be configured as a refuse vehicle, a concrete mixer, a fire fighting vehicle, an airport fire fighting vehicle, a lift device (e.g., a boom lift, a scissor lift, a telehandler, a vertical lift, etc.), a crane, a tow truck, a military vehicle, a delivery vehicle, a mail vehicle, a boom truck, a plow truck, a farming machine or vehicle, a construction machine or vehicle, a coach bus, a school bus, a semi-truck, a passenger or work vehicle (e.g., a sedan, a SUV, a truck, a van, etc.), and/or still another vehicle. FIGS. **2-7** illustrate various examples of how the vehicle **10** may be configured for specific applications. Although only a certain set of vehicle configurations is shown, it should be understood that the vehicle **10** may be configured for use in other applications that are not shown.

[0046] According to an exemplary embodiment, the application kit **80** includes various actuators to facilitate certain functions of the vehicle **10**. In one embodiment, the application kit **80** includes hydraulic actuators (e.g., hydraulic cylinders, hydraulic motors, etc.), pneumatic actuators (e.g., pneumatic cylinders, pneumatic motors, etc.), and/or electrical actuators (e.g., electric motors, electric linear actuators, etc.). The application kit **80** may include components that facilitate operation of and/or control of these actuators. In another embodiment, the application kit **80** includes hydraulic or pneumatic components that form a hydraulic or pneumatic circuit (e.g., conduits, valves, pumps, compressors, gauges, reservoirs, accumulators, etc.). By way of another embodiment, the application kit **80** includes electrical components (e.g., batteries, capacitors, voltage regulators, motor controllers, etc.). The actuators may be powered by components of the vehicle **10**. In some embodiments, the actuators are powered by the batteries **60**, the drive motors **62**, or the primary driver (e.g., through a power take off).

[0047] As shown in FIG. **2**, the vehicle **10** is configured as a refuse vehicle **100** (e.g., a refuse truck, a garbage truck, a waste collection truck, a sanitation truck, a recycling truck, etc.). Specifically, the refuse vehicle **100** is a front-loading refuse vehicle. In other embodiments, the refuse vehicle **100** is configured as a rear-loading refuse vehicle or a side-loading refuse vehicle.

[0048] As shown in FIG. **2**, the application kit **80** of the refuse vehicle **100** includes a rear body or container, shown as refuse compartment **130**, and a pivotable rear portion, shown as tailgate **132**. The refuse compartment **130** may facilitate transporting refuse from various waste receptacles within a municipality to a storage and/or a processing facility (e.g., a landfill, an incineration facility, a recycling facility, etc.). According to an exemplary embodiment, loose refuse is placed into the refuse compartment **130** to be compacted. The refuse compartment **130** may also provide

temporary storage for refuse during transport to a waste disposal site and/or a recycling facility. In some embodiments, the refuse compartment **130** includes a hopper volume and storage volume. In this regard, refuse may be initially loaded into the hopper volume and later compacted into the storage volume. According to an exemplary embodiment, the hopper volume is positioned between the storage volume and the cab **40** (e.g., refuse is loaded into a position of the refuse compartment **130** behind the cab **40** and stored in a position further toward the rear of the refuse compartment **130**). In other embodiments, the storage volume is positioned between the hopper volume and the cab **40** (e.g., in a rear-loading refuse truck, etc.). The tailgate **132** may be pivotally coupled to the refuse compartment **130**, and may be movable between a closed position and an open position by an actuator (e.g., a hydraulic cylinder, an electric linear actuator, etc.), shown as tailgate actuator **134** (e.g., to facilitate emptying the storage volume).

[0049] As shown in FIG. 2, the refuse vehicle **100** also includes an implement, shown as lift assembly **108** (e.g., a front-loading lift assembly, etc.). According to an exemplary embodiment, the lift assembly **108** includes a pair of lift arms **140**, lift arm actuators **142**, and articulation actuators **144**. The lift arms **140** may be rotatably coupled to the chassis **20**. In another embodiment, the lift arms **140** are rotatably coupled to the refuse compartment **30** on each side of the refuse vehicle **100** (e.g., through a pivot, a lug, a shaft, etc.). Such an embodiment provides that the lift assembly **108** extends forward relative to the cab **40** (e.g., a front-loading refuse truck, etc.). In other embodiments, the lift assembly **108** extends rearward relative to the application kit **80** (e.g., a rear-loading refuse truck). In yet other embodiments, the lift assembly **108** extends from a side of the application kit **80** (e.g., a side-loading refuse truck). The lift arm actuators **142** are positioned such that extension and retraction of the lift arm actuators **142** rotates the lift arms **140** about an axis extending through the pivot. In this regard, the lift arms **140** may be rotated by the lift arm actuators **142** to lift a refuse container over the cab **40**. In an exemplary embodiment, the articulation actuators **144** are positioned to articulate the distal end of the lift arms **140** (e.g., a portion of the lift arms **140** that may be coupled to the refuse container) in order to assist in tipping refuse out of the refuse container and into the refuse compartment **130**. The lift arm actuators **142** may then rotate the lift arms **140** to return the empty refuse container to the ground.

[0050] According to another exemplary embodiment, as shown in FIG. 3, the vehicle **10** is configured as a mixer truck (e.g., a concrete mixer truck, a mixer vehicle, etc.), shown as mixer truck **200**. Specifically, the mixer truck **200** is a rear-discharge concrete mixer truck. In other embodiments, the mixer truck **200** is a front-discharge concrete mixer truck.

[0051] As shown in FIG. 3, the application kit **80** includes a mixing drum assembly (e.g., a concrete mixing drum), shown as drum assembly **230**. The drum assembly **230** includes a mixing drum **232**, a drum drive system **234** (e.g., a rotational actuator or motor), an inlet, shown as hopper **236**, and an outlet, shown as chute **238**. The mixing drum **232** may be coupled to the chassis **20** and may be disposed behind the cab **40** (e.g., at the rear and/or middle of the chassis **20**). In an exemplary embodiment, the drum drive system **234** is coupled to the chassis **20** and configured to selectively rotate the mixing drum **232** about a central, longitudinal axis. According to an exemplary embodiment, the central, longitudinal axis of the mixing drum **232** is elevated from the chassis **20** (e.g., from a horizontal plane extending along the chassis **20**) at an angle in the range of five degrees to twenty degrees. In other embodiments, the central, longitudinal axis is elevated by less than five degrees (e.g., four degrees, etc.). In yet another embodiment, the mixer truck **200** includes an actuator positioned to facilitate adjusting the central, longitudinal axis to a desired or target angle (e.g., manually in response to an operator input/command, automatically according to a control system, etc.).

[0052] The mixing drum **232** may be configured to receive a mixture, such as a concrete mixture (e.g., cementitious material, aggregate, sand, etc.), through the hopper **236**. In some embodiments, the mixer truck **200** includes an injection system (e.g., a series of nozzles, hoses, and/or valves). The injection system may include an injection valve that selectively fluidly couples a supply of

fluid to the inner volume of the mixing drum **232**. In one embodiment, the injection system is used to inject water and/or chemicals (e.g., air entrainers, water reducers, set retarders, set accelerators, superplasticizers, corrosion inhibitors, coloring, calcium chloride, minerals, and/or other concrete additives, etc.) into the mixing drum **232**. The injection valve may facilitate injecting water and/or chemicals from a fluid reservoir (e.g., a water tank, etc.) into the mixing drum **232**, while preventing the mixture in the mixing drum **232** from exiting the mixing drum **232** through the injection system. In some embodiments, one or more mixing elements (e.g., fins, etc.) are positioned in the interior of the mixing drum **232**, and may be configured to agitate the contents of the mixture when the mixing drum **232** is rotated in a first direction (e.g., counterclockwise, clockwise, etc.), and drive the mixture out through the chute **238** when the mixing drum **232** is rotated in a second direction (e.g., clockwise, counterclockwise, etc.). In some embodiments, the chute **238** includes an actuator positioned such that the chute **238** may be selectively pivotable to position the chute **238** (e.g., vertically, laterally, etc.), for example, at an angle at which the mixture is expelled from the mixing drum **232**.

[0053] As shown in FIG. **4**, the vehicle **10** is configured as a fire fighting vehicle or fire apparatus (e.g., a turntable ladder truck, a pumper truck, a quint, etc.), shown as fire fighting vehicle **300**. As shown in FIG. **4**, the fire fighting vehicle **300** is configured as a rear-mount aerial ladder truck. In other embodiments, the fire fighting vehicle **300** is configured as a mid-mount aerial ladder truck, a quint fire truck (e.g., including an on-board water storage, a hose storage, a water pump, etc.), a tiller fire truck, a pumper truck (e.g., without an aerial ladder), or another type of response vehicle. According to an exemplary embodiment, the vehicle **10** is be configured as a police vehicle, an ambulance, a tow truck, or still other vehicles used for responding to a scene (e.g., an accident, a fire, an incident, etc.).

[0054] As shown in FIG. **4**, in the fire fighting vehicle **300**, the application kit **80** is positioned mainly rearward from the cab **40**. The application kit **80** includes deployable stabilizers (e.g., outriggers, downriggers, etc.), shown as outriggers **330**, that are coupled to the chassis **20**. The outriggers **330** may be configured to selectively extend from each lateral side and/or the rear of the fire fighting vehicle **300** and engage a support surface (e.g., the ground) in order to provide increased stability while the fire fighting vehicle **300** is stationary. This increased stability is desirable when the ladder assembly **308** is in use (e.g., extended from the fire fighting vehicle **300**) to prevent tipping. In some embodiments, the application kit **80** further includes various storage compartments (e.g., cabinets, lockers, etc.) that are selectively opened and/or accessed for storage and/or component inspection, maintenance, and/or replacement.

[0055] As shown in FIG. **4**, the application kit **80** includes a ladder assembly **308** coupled to the chassis **20**. The ladder assembly **308** includes a series of ladder sections **340** that are slidably coupled with one another such that the ladder sections **340** may extend and/or retract (e.g., telescope) relative to one another to selectively vary a length of the ladder assembly **308**. A base platform, shown as turntable **342**, is rotatably coupled to the chassis **20** and to a proximal end of a base ladder section **340** (i.e., the most proximal of the ladder sections **340**). The turntable **342** may be configured to rotate about a vertical axis relative to the chassis **20** to rotate the ladder sections **340** about the vertical axis (e.g., up to 360 degrees, etc.). The ladder sections **340** may rotate relative to the turntable **342** about a substantially horizontal axis to selectively raise and lower the ladder sections **340** relative to the chassis **20**. As shown, a water turret or implement, shown as monitor **344**, is coupled to a distal end of a fly ladder section **340** (i.e., the most distal of the ladder sections **340**). The monitor **344** may be configured to expel water and/or a fire suppressing agent (e.g., foam, etc.) from a water storage tank and/or an agent tank onboard the fire fighting vehicle **300**, and/or from an external source (e.g., a fire hydrant, a separate water/pumper truck, etc.). In some embodiments, the ladder assembly **308** further includes an aerial platform coupled to the distal end of the fly ladder section **340** and configured to support one or more operators.

[0056] According to another exemplary embodiment, as shown in FIG. **5**, the vehicle **10** is



configured as a fire fighting vehicle, shown as airport rescue and fire fighting (ARFF) truck **400**. As shown in FIG. 5, the application kit **80** is positioned primarily rearward of the cab **40**. As shown, the application kit **80** includes a series of storage compartments or cabinets, shown as compartments **430**, that are coupled to the chassis **20**. The compartments **430** may store various equipment or components of the ARFF truck **400**.

[0057] The application kit **80**, as shown in FIG. 5, includes a pump system **432** (e.g., an ultra-high-pressure pump system, etc.) positioned within one of the compartments **430** near the center of the ARFF truck **400**. The application kit **80** further includes a water tank **434**, an agent tank **436**, and an implement or water turret, shown as monitor **438**. The pump system **432** may include a high pressure pump and/or a low pressure pump, which may be fluidly coupled to the water tank **434** and/or the agent tank **436**. The pump system **432** may pump water and/or fire suppressing agent from the water tank **434** and the agent tank **436**, respectively, to the monitor **438**. The monitor **438** may be selectively reoriented by an operator to adjust a direction of a stream of water and/or agent. As shown in FIG. 5, the monitor **438** is coupled to a front end of the cab **40**.

[0058] As shown in FIG. 6, the vehicle **10** is configured as a lift device, shown as boom lift **500**. The boom lift **500** may be configured to support and elevate one or more operators. In other embodiments, the vehicle **10** is configured as another type of lift device that is configured to lift operators and/or material, such as a skid-loader, a telehandler, a scissor lift, a fork lift, a vertical lift, and/or any other type of lift device or machine.

[0059] As shown in FIG. 6, the application kit **80** includes a base assembly, shown as turntable **504** that is rotatably coupled to the chassis **20**. The turntable **504** may be configured to selectively rotate relative to the chassis **20** about a substantially vertical axis. In some embodiments, the turntable **504** includes a counterweight positioned near the rear of the turntable **504**. The turntable **504** is rotatably coupled to a lift assembly, shown as boom assembly **508**. The boom assembly **508** includes a first section or telescoping boom section, shown as lower boom **540**. The lower boom **540** includes a series of nested boom sections that extend and retract (e.g., telescope) relative to one another to vary a length of the boom assembly **508**. The boom assembly **508** further includes a second boom section or four bar linkage, shown as upper boom **542**. The upper boom **542** may include structural members that rotate relative to one another to raise and lower a distal end of the boom assembly **508**. In other embodiments, the boom assembly **508** includes more or fewer boom sections (e.g., one, three, five, etc.) and/or a different arrangement of boom sections.

[0060] As shown in FIG. 6, the boom assembly **508** includes a first actuator, shown as lower lift cylinder **544**. The lower boom **540** is pivotally coupled (e.g., pinned, etc.) to the turntable **504** at a joint or lower boom pivot point. The lower lift cylinder **544** (e.g., a pneumatic cylinder, an electric actuator, a hydraulic cylinder, etc.) is coupled to the turntable **504** at a first end and coupled to the lower boom **540** at a second end. The lower lift cylinder **544** may be configured to raise and lower the lower boom **540** relative to the turntable **504** about the lower boom pivot point.

[0061] The boom assembly **508** further includes a second actuator, shown as upper lift cylinder **546**. The upper boom **542** is pivotally coupled (e.g., pinned) to the upper end of the lower boom **540** at a joint or upper boom pivot point. The upper lift cylinder **546** (e.g., a pneumatic cylinder, an electric actuator, a hydraulic cylinder, etc.) is coupled to the upper boom **542**. The upper lift cylinder **546** may be configured to extend and retract to actuate (e.g., lift, rotate, elevate, etc.) the upper boom **542**, thereby raising and lowering a distal end of the upper boom **542**.

[0062] As shown in FIG. 6, the application kit **80** further includes an operator platform, shown as platform assembly **550**, coupled to the distal end of the upper boom **542** by an extension arm, shown as jib arm **552**. The jib arm **552** may be configured to pivot the platform assembly **550** about a lateral axis (e.g., to move the platform assembly **550** up and down, etc.) and/or about a vertical axis (e.g., to move the platform assembly **550** left and right, etc.).

[0063] According to an exemplary embodiment, the platform assembly **550** provides a platform configured to support one or more operators or users. In some embodiments, the platform assembly

**550** includes accessories or tools configured for use by the operators. In one embodiment, the platform assembly **550** includes pneumatic tools (e.g., an impact wrench, airbrush, nail gun, ratchet, etc.), plasma cutters, welders, spotlights, etc. In other embodiments, the platform assembly **550** includes a control panel (e.g., a user interface, a removable or detachable control panel, etc.) configured to control operation of the boom lift **500** (e.g., the turntable **504**, the boom assembly **508**, etc.) from the platform assembly **550** or remotely. In other embodiments, the platform assembly **550** is omitted, and the boom lift **500** includes an accessory and/or tool (e.g., forklift forks, etc.) coupled to the distal end of the boom assembly **508**.

[0064] According to an exemplary embodiment, as shown in FIG. 7, the vehicle **10** is configured as a lift device, shown as scissor lift **600**. As shown in FIG. 7, the application kit **80** includes a body, shown as lift base **604**, coupled to the chassis **20**. The lift base **604** is coupled to a scissor assembly, shown as lift assembly **608**, such that the lift base **604** supports the lift assembly **608**. The lift assembly **608** is configured to extend and retract, raising and lowering between a raised position and a lowered position relative to the lift base **604**.

[0065] As shown in FIG. 7, the lift base **604** includes a series of actuators, stabilizers, downriggers, or outriggers, shown as leveling actuators **630**. The leveling actuators **630** may extend and retract vertically between a stored position and a deployed position. In the stored position, the leveling actuators **630** may be raised, such that the leveling actuators **630** do not contact the ground. Conversely, in the deployed position, the leveling actuators **630** may engage the ground to lift the base assembly **604**. The length of each of the leveling actuators **630** in their respective deployed positions may be varied in order to adjust the pitch (e.g., rotational position about a lateral axis) and the roll (e.g., rotational position about a longitudinal axis) of the base assembly **604** and/or the chassis **20**. Accordingly, the lengths of the leveling actuators **630** in their respective deployed positions may be adjusted to level the base assembly **604** with respect to the direction of gravity (e.g., on uneven, sloped, pitted, etc. terrain). The leveling actuators **630** may lift the wheel and tire assemblies **54** off of the ground to prevent movement of the scissor lift **600** during operation. In other embodiments, the leveling actuators **630** are omitted.

[0066] According to an exemplary embodiment, the lift assembly **608** includes a series of subassemblies, shown as scissor layers **640**, each including a pair of inner members **642** and a pair of outer members **644**. The scissor layers **640** may be stacked atop one another in order to form the lift assembly **608**. The inner members **642** may be pivotally coupled to the outer members **644** near the center of both the inner members **642** and the outer members **644**. In this regard, the inner members **642** may pivot relative to the outer members **644** about a lateral axis. Each of the inner members **642** and the outer members **644** may include a top end and a bottom end. The bottom end of each inner member **642** may be pivotally coupled to the top end of the outer member **644** immediately below it, and the bottom end of each outer member **644** may be pivotally coupled to the top end of the inner member immediately below it. Accordingly, each of the scissor layers **640** may be coupled to one another such that movement of one scissor layer **640** causes a similar movement in all of the other scissor layers **640**. The bottom ends of the inner member **642** and the outer member **644** that make up the lowermost scissor layer **640** may be coupled to the base assembly **604**. The top ends of the inner member **642** and the outer member **644** that make up the uppermost scissor layer **640** may be coupled to the platform assembly **650**. In some embodiments, scissor layers **640** may be added to, or removed from, the lift assembly **608** in order to increase, or decrease, the fully extended height of the lift assembly **608**.

[0067] As shown in FIG. 7, the lift assembly **608** also includes one or more lift actuators **646** (e.g., hydraulic cylinders, pneumatic cylinders, motor-driven leadscrews, etc.) configured to extend and retract the lift assembly **608**. The lift actuators **646** may be pivotally coupled to an inner member **642** at a first end and pivotally coupled to an inner member **642** of another scissor layer **640** at a second end. In an exemplary embodiment, these inner members **642** belong to a first scissor layer **640** and a second scissor layer **640** (which may be separated by a third scissor layer **640**). In other

embodiments, the lift actuators **646** are arranged in other configurations (e.g., the first scissor layer **640** and the second scissor layer **640** are not separated by a third scissor layer **640**, etc.).

[0068] According to an exemplary embodiment, a distal or upper end of the lift assembly **608** is coupled to an operator platform, shown as platform assembly **650**. The lift actuators **646** may be configured to actuate the lift assembly **608** to selectively reposition the platform assembly **650** between a lowered position (e.g., where the platform assembly **650** is proximate to the lift base **604**) and a raised position (e.g., where the platform assembly **650** is at an elevated height relative to the lift base **604**). Specifically, in some embodiments, extension of the lift actuators **646** moves the platform assembly **650** upward (e.g., extending the lift assembly **608**), and retraction of the lift actuators **646** moves the platform assembly **650** downward (e.g., retracting the lift assembly **608**). In other embodiments, extension of the lift actuators **646** retracts the lift assembly **608**, and retraction of the lift actuators **646** extends the lift assembly **608**. In some embodiments, the outer members **644** are parallel to and/or in contact with one another when the lift assembly **608** is in the stored position.

[0069] In some embodiments, the platform assembly **650** includes a platform that is configured to support one or more operators or users. Similar to the platform assembly **550**, the platform assembly **650** may include accessories or tools (e.g., pneumatic tools, plasma cutters, welders, spotlights, etc.) configured for use by an operator. The platform assembly **650** may include a control panel to control operation of the scissor lift **600**.

#### Suspension Assembly

[0070] FIGS. **8-12** illustrate a suspension assembly **700** of an electrified vehicle (e.g., a commercial vehicle, a refuse vehicle, a fire fighting vehicle, a fire suppression vehicle, a military vehicle, a mixing vehicle, a lift vehicle, etc.). In some embodiments, the suspension assembly **700** is included on any configuration of the vehicle **10** described herein. In general, the suspension assembly **700** is coupled between a chassis **702** (e.g., the chassis **20**) and one or more axles **704** (e.g., the front axle **50** and/or the rear axle **52**). In some embodiments, the chassis **702** includes a pair of frame portions, frame members, or frame rails, shown as a first frame rail **706** and a second frame rail **708**. The first frame rail **706** is laterally separated from the second frame rail **708**, which provides frame stiffness and space for vehicle components (e.g., batteries, motors, axles, gears, etc.) between the first frame rail **706** and the second frame rail **708**. The first frame rail **706** and the second frame rail **708** both extend longitudinally and parallel to one another (e.g., parallel to a central longitudinal axis **710**) and along a length of the electrified vehicle. In some embodiments, the first frame rail **706** and the second frame rail **708** both define a C-shaped cross-section (see FIG. **11**), for example, taken along an axis parallel to a central lateral axis **712**. In some embodiments, the first frame rail **706** and the second frame rail **708** define other shapes (e.g., I-beams, rectangular beams, etc.).

[0071] In some embodiments, the axles **704** include a first or front axle **714** (e.g., the front axle **50**) and a second or rear axle **716** (e.g., one of the rear axles **52**). In some embodiments, the axles **704** include more than one front axle **714** (e.g., two or more). In some embodiments, the axles **704** include more than one rear axle **716** (e.g., two or more). The front axle **714** is longitudinally separated from the rear axle **716**. In some embodiments, the front axle **714** includes an axle housing **718**, a first half-shaft assembly **720** extending laterally outwardly from one side of the axle housing **718**, and a second half-shaft assembly **722** extending laterally outwardly from an opposing side of the axle housing **718**. The axle housing **718** is arranged laterally between the first frame rail **706** and the second frame rail **708**. The first half-shaft assembly **720** and the second half-shaft assembly **722** are aligned along a first axle axis **724** (see FIG. **10**). A wheel hub **726** is arranged at a distal end of each of the first half-shaft assembly **720** and the second half-shaft assembly **722**. The wheel hubs **726** are each configured to couple to a tractive element or wheel (e.g., a wheel **54**).

[0072] Similar to the front axle **714**, the rear axle **716** includes an axle housing **728**, a first half-shaft assembly **730** extending laterally outwardly from one side of the axle housing **728**, and a

second half-shaft assembly **732** extending laterally outwardly from an opposing side of the axle housing **728**. The axle housing **728** is arranged laterally between the first frame rail **706** and the second frame rail **708**. The first half-shaft assembly **730** and the second half-shaft assembly **732** are aligned along a second axle axis **734** (see FIG. **10**). A wheel hub **736** is arranged at a distal end of each of the first half-shaft assembly **730** and the second half-shaft assembly **732**. The wheel hubs **736** are each configured to couple to a tractive element or wheel (e.g., a wheel **54**).

[0073] The suspension assembly **700** includes a pair of front linkage rods **740**, a pair of rear linkage rods **742**, a first or right bracket **744**, and a second or left bracket **746**. In general, the front linkage rods **740** are coupled between the front axle **714** and the chassis **702**, and the rear linkage rods **742** are coupled between the rear axle **716** and the chassis **702**. In some embodiments, the front linkage rods **740** include a first front linkage rod **748** coupled between the axle housing **718** and the first frame rail **706** and a second front linkage rod **750** coupled between the axle housing **718** and the second frame rail **708**. In some embodiments, the first front linkage rod **748** and the second front linkage rod **750** may be coupled to the axle housing **718** at one or more mounting points (e.g., bolt holes, protrusions, flanges, brackets, etc.). In some embodiments, the rear linkage rods **742** include a first rear linkage rod **752** coupled between the axle housing **728** and the first frame rail **706**, and a second rear linkage rod **754** coupled between the axle housing **728** and the second frame rail **708**. In some embodiments, the first rear linkage rod **752** and the second rear linkage rod **754** may be coupled to the axle housing **728** at one or more mounting points (e.g., bolt holes, protrusions, flanges, brackets, etc.).

[0074] The front linkage rods **740** and the rear linkage rods **742** are in a symmetric arrangement, which differs from conventional upper control linkages that are arranged asymmetrically and typically only couple to one frame rail, rather than symmetric ally to both frame rails. For example, the first front linkage rod **748** and the second front linkage rod **750** are arranged symmetrically about the central longitudinal axis **710**, and the first rear linkage rod **752** and the second rear linkage rod **754** are arranged symmetrically about the central longitudinal axis **710**. In addition, the first front linkage rod **748** and the first rear linkage rod **752** are arranged symmetrically about the central lateral axis **712**, and the second front linkage rod **750** and the second rear linkage rod **754** are arranged symmetrically about the central lateral axis **712**. The symmetric arrangement of the front linkage rods **740** and the rear linkage rods **742** provides stability to the axles **704** and does not require the use of separated, asymmetric upper control linkages that extend in perpendicular directions (e.g., one lateral linkage and one longitudinal linkage) like those used in conventional suspension assemblies.

[0075] In general, the front linkage rods **740** and the rear linkage rods **742** are oriented so that they provide an open area between the first frame rail **706** and the second frame rail **708** within which batteries (e.g., batteries **60**) may be mounted (see FIG. **8**). For example, each of the first front linkage rod **748**, the second front linkage rod **750**, the first rear linkage rod **752**, and the second rear linkage rod **754** is angled laterally outwardly away from the central longitudinal axis **710** to free up and not interrupt the area between the first frame rail **706** and the second frame rail **708**.

Specifically, the first front linkage rod **748** is arranged at an angle relative to the central longitudinal axis **710** so that as the first front linkage rod **748** extends from the axle housing **718** toward the first frame rail **706**, the first front linkage rod **748** angles laterally outwardly and away from the central longitudinal axis **710**. The second front linkage rod **750** is arranged at an angle relative to the central longitudinal axis **710** so that as the second front linkage rod **750** extends from the axle housing **718** toward the second frame rail **708**, the second front linkage rod **750** angles laterally outwardly and away from the central longitudinal axis **710**. The first rear linkage rod **752** is arranged at an angle relative to the central longitudinal axis **710** so that as the first rear linkage rod **752** extends from the axle housing **728** toward the first frame rail **706**, the first rear linkage rod **752** angles laterally outwardly and away from the central longitudinal axis **710**. The second rear linkage rod **754** is arranged at an angle relative to the central longitudinal axis **710** so that as the

second rear linkage rod **754** extends from the axle housing **728** toward the second frame rail **708**, the second rear linkage rod **754** angles laterally outwardly and away from the central longitudinal axis **710**. In other words, the first front linkage rod **748** and the first rear linkage rod **752** angle laterally outwardly toward the first frame rail **706** as they extend toward the first frame rail **706**, and the second front linkage rod **750** and the second rear linkage rod **754** angle laterally outwardly toward the second frame rail **708** as they extend toward the second frame rail **708**.

[0076] In addition to the angled arrangement of the front linkage rods **740** and the rear linkage rods **742** providing increased free area between the first frame rail **706** and the second frame rail **708**, the angled arrangement also forms virtual centers that restrain and locate the axles **704** laterally similar to a physical pivot or a laterally-installed linkage. The front linkage rods **740** form a front virtual center at a point where central axes extending longitudinally along the first front linkage rod **748** and the second front linkage rod **750** intersect. The front virtual center laterally locates and restrains the front axle **714**. The rear linkage rods **742** form a rear virtual center at a point where central axes extending longitudinally along the first rear linkage rod **752** and the second rear linkage rod **754** intersect. The rear virtual center laterally locates and restrains the rear axle **716**.

[0077] The first front linkage rod **748** and the first rear linkage rod **752** are both coupled to the first frame rail **706** by the first bracket **744**. The first bracket **744** includes a lower housing **756** and a mounting plate **758** extending upwardly (e.g., from the perspective of FIG. **8**) from the lower housing **756**. An end of both the first front linkage rod **748** and the first rear linkage rod **752** extends into and couples to the lower housing **756**. The lower housing **756** at least partially extends over and receives at least portion of a first spring beam **760**. The first spring beam **760** extends longitudinally and is coupled between the first half-shaft assembly **720** and the first half-shaft assembly **730**. In some embodiments, the mounting plate **758** includes a plurality of mounting apertures that extend through the mounting plate **758** that are configured to receive a fastener (e.g., a screw, a bolt/nut, etc.) that couples the mounting plate **758**, and thereby the first bracket **744**, to the first frame rail **706**.

[0078] The second front linkage rod **750** and the second rear linkage rod **754** are both coupled to the second frame rail **708** by the second bracket **746**. The second bracket **746** includes a lower housing **762** and a mounting plate **764** extending upwardly (e.g., from the perspective of FIG. **8**) from the lower housing **762**. An end of both of the second front linkage rod **750** and the second rear linkage rod **754** extends into and couples to the lower housing **762**. The lower housing **762** at least partially extends over and receives at least a portion of a second spring beam **766**. The second spring beam **766** extends longitudinally and is coupled between the second half-shaft assembly **722** and the second half-shaft assembly **732**. In some embodiments, the mounting plate **764** includes a plurality of mounting apertures that extend through the mounting plate **764** that are configured to receive a fastener (e.g., a screw, a bolt/nut, etc.) that couples the mounting plate **764**, and thereby the second bracket **746**, to the second frame rail **708**.

[0079] In some embodiments, the front linkage rods **740** and the rear linkage rods **742** extend downwardly (e.g., in a direction away from the respective one of the first frame rail **706** and the second frame rail **708**) as they extend toward the respective bracket (e.g., the first bracket **744** or the second bracket **746** (see FIGS. **10** and **11**)). For example, the first front linkage rod **748** and the first rear linkage rod **752** angle downwardly in a direction away from the first frame rail **706** as they extend toward the first bracket **744**. Similarly, the second front linkage rod **750** and the second rear linkage rod **754** angle downwardly in a direction away from the second frame rail **708** as they extend toward the second bracket **746**.

[0080] In some embodiments, the suspension assembly **700** includes a plurality of spring damping cylinders **768**. For example, the suspension assembly **700** may include two spring damping cylinders **768** coupled between the first spring beam **760** and the first frame rail **706** and arranged on longitudinally opposing sides of the first bracket **744**, and two spring damping cylinders **768** coupled between the second spring beam **766** and the second frame rail **708** and arranged on

longitudinally opposing sides of the second bracket **746**.

[0081] In general, the design and properties of the suspension assembly **700**, and specifically the arrangement of the front linkage rods **740** and the rear linkage rods **742**, provides increased mounting area between the first frame rail **706** and the second frame rail **708**, when compared to conventional suspension assemblies, without compromising suspension performance. The increased mounting area between the first frame rail **706** and the second frame rail **708** can accommodate more and/or larger batteries to increase a storage capacity of a vehicle (e.g., the vehicle **10**). In some embodiments, the batteries mounted between the first frame rail **706** and the second frame rail **708** may be used to power one or more electric motors. For example, at least one of the axles **704** can include an electric motor and be configured as an electronic axle. In some embodiments, the front axle **714** is configured as an electronic axle. In some embodiments, the rear axle **716** is configured as an electronic axle. In some embodiments, both the front axle **714** and the rear axle **716** are configured as electronic axles.

[0082] As shown in FIG. **13**, the axles **704** (e.g., the front axle **714** and/or the rear axle **716**) may include an electric motor **770** (e.g., a motor/generator, an electromagnetic device, etc.) that is configured to consume electrical energy from an electrical energy storage device **772** (e.g., the batteries **60**, or other battery cells or packs) and generate (e.g., provide) mechanical power (e.g., rotational mechanical energy) using the electrical energy. In some embodiments, the axles **704** may include multiple electric motors **770** (e.g., two or more). Accordingly, any embodiment described herein as including a single electric motor may include multiple electric motors operating cooperatively (e.g., multiple electric motors with output shafts coupled to one another).

[0083] In some embodiments, the front axle **714** may be an electric axle, and may include the electric motor **770** that drives the wheels **54** of the front axle **714** to propel the vehicle **10**. In some embodiments, the rear axle **716** may include the electric motor **770** (e.g., in addition to or in replacement of the electric motor **770** of the front axle **714**) to drive the wheels **54** of the rear axle **716** and to propel the vehicle **10**. In some embodiments, the electric motor(s) **770** are configured to perform regenerative braking by receiving rotational mechanical energy from the wheels **54** and providing electrical energy (e.g., to the electrical energy storage device **772**).

[0084] In some embodiments, the axles **704** includes the electric motor **770** and a gearbox/differential **774**. The electric motor **770** may drive an output driveshaft (e.g., an output shaft) that is received at an opposite end by the gearbox/differential **774**. The gearbox/differential **774** can be or include a reduction gearbox (e.g., a gear set that receives input mechanical energy at a first speed and outputs mechanical energy at a second, lower, speed and an increased torque) or may be or include a gearbox that receives input mechanical energy at a first speed and outputs mechanical energy at a second, higher, speed and a decreased torque. In some embodiments, the gearbox/differential **774** is or includes a differential that is configured to receive rotational kinetic energy or mechanical energy (e.g., through the output driveshaft) about an axis in a first direction, and output rotational kinetic energy or mechanical energy (e.g., through axles **704**) about an axis (e.g., the first axle axis **724** and/or the second axle axis **734**) that extends in a different direction.

[0085] In some embodiments, the axles **704** include a power take off (PTO) **776** that may be configured to selectively engage the output driveshaft by transitioning between an engaged state and a disengaged state. In some embodiments, the PTO **776** is electrically activated and transitions into the engaged state in response to receiving a control signal from a controller. In some embodiments, the PTO **776** can include a clutch (e.g., an electrically activated clutch) that is configured to engage the output driveshaft to selectively couple the PTO **776** with the output driveshaft. When the PTO **776** engages the output driveshaft, the PTO **776** transfers mechanical energy to an accessory of the vehicle **10**. The mechanical energy is transferred to the accessory through the PTO **776** to drive the accessory so that the accessory can perform its respective functions. For example, the accessory may be or include a hydraulic system including a hydraulic pump. The mechanical energy generated by the electric motor **770** can be transferred through the

PTO **776** to the hydraulic pump to pressurize the hydraulic system.

[0086] In some embodiments, the axles **704** are self-contained axle assemblies. For example, the axle housings (e.g., the axle housing **718** and/or the axle housing **728**) house and support the components of the axles. In some embodiments, the axle housings (e.g., the axle housing **718** and/or the axle housing **728**) may at least partially (e.g., partially, completely) enclose the electric motor **770**, the gearbox/differential **774**, and the PTO **776**. In some embodiments, the electric motor **770** and/or the PTO **776** may be arranged externally from the axle housings (e.g., the axle housing **718** and/or the axle housing **728**).

[0087] In configurations where the axles **704** are electrified, the design and properties of the suspension assembly **700** efficiently accommodates the electrical energy storage device(s) **772** by providing a large mounting area between the first frame rail **706** and the second frame rail **708**.

[0088] As described herein, the suspension assembly **700** includes brackets that are coupled to the frame rails and the linkage rods. FIGS. **14-28** illustrate an exemplary embodiment of the suspension assembly **700** including the first bracket **744** and the second bracket **746** being coupled to the suspension assembly **700**. Each bracket includes a lower housing with two cavities in which a mounting wall is located. The linkage rod extends into the cavity and is coupled to the mounting wall by a fastener. The mounting wall includes a bore in which the fastener is inserted. The bore is acutely angled towards the center of the suspension assembly. The lower housing of the bracket partially extends over a portion of a spring beam, which extends along either side of the bracket in the direction of the frame rail. A leaf spring assembly is centered within the lower housing and located between the spring beams.

[0089] Referring to FIG. **14**, an alternative embodiment illustrates the first bracket **744** and the second bracket **746** coupled within the suspension assembly **700** by the pair of front linkage rods **740**, the pair of rear linkage rods **742**, the first frame rail **706**, and the second frame rail **708**. The pair of front linkage rods **740** is coupled to either the first bracket **744** or the second bracket **746** and the axle housing **718**. The axle housing **718** has a pair of linkage brackets **778** that receives one or more fasteners **780** to couple the first front linkage rod **748** and the second front linkage rod **750** to the axle housing **718**. The pair of rear linkage rods **742** is coupled to either the first bracket **744** or the second bracket **746** and the axle housing **728**. The axle housing **728** has a pair of linkage brackets **782** that receive one or more fasteners **784** to couple the first rear linkage rod **752** and the second rear linkage rod **754** to the axle housing **728**. The first bracket **744** and second bracket **746** are symmetrically installed about the central longitudinal axis **710** of the suspension assembly **700** as shown in FIGS. **9-12**. All embodiments of the first bracket **744** described herein may be applied to the second bracket **746**.

[0090] The first bracket **744** includes the lower housing **756** and the mounting plate **758** that extends upwardly from the lower housing **756** and is coupled to the first frame rail **706**. The lower housing **756** includes a front or first side **786**, a back or second side **788**, and a third or bottom side **790**. The first front linkage rod **748** and the first rear linkage rod **752** extend into and are coupled within a first cavity **792** and a second cavity **794**, respectively, located on the front side **786** of the lower housing **756** and the back side **788** of the lower housing **756**. In the illustrated embodiment, the first front linkage rod **748** and the first rear linkage rod **752** are coupled to the first bracket **744** by one or more fasteners **796** (e.g., screws, bolts, rivets, or another equivalent fastener).

[0091] Referring to FIGS. **15-22**, the first cavity **792** and the second cavity **794** include a first or top surface **798**, a second or bottom surface **800**, a third or inner surface **802**, a fourth or outer surface **804** that is opposite the inner surface **802**, and a fifth or rear surface **806** that is parallel to the opening provided by the first cavity **792** and the second cavity **794**. A mounting wall **808** extends outward from the rear surface **806** and includes a tubular portion **810** that forms a rectangular portion **812** that extends to the top surface **798** and the bottom surface **800**. The mounting wall **808** includes a bore **814** that extends through the rectangular portion **812** and the tubular portion **810** to the back side **788** of the lower housing **756**. The bore **814** is acutely angled

between the central longitudinal axis **710** and the central lateral axis **712**.

[0092] The back side **788** of the lower housing **756** includes a surface **816** with a first circular protrusion **818** and a second circular protrusion **820**. Both the first circular protrusion **818** and the second circular protrusion **820** have a first cutout **822** and a second cutout **824**, respectively, that coincide with the surface **816** of the back side **788**. Both the first cutout **822** and the second cutout **824** include the bore **814** from each the first cavity **792** and the second cavity **794**. The first circular protrusion **818** and the second circular protrusion **820** follow the same acute angle as the bore **814**. The back side **788** of the lower housing **756** is symmetrical about the central lateral axis **712**.

[0093] Referring to FIGS. **23-28**, the first bracket **744** and the second bracket **746** are assembled within an alternative embodiment of the suspension assembly **700**. The first bracket **744** and the second bracket **746** remain fixed to the first frame rail **706** and the second frame rail **708** as the suspension assembly transitions between a riding position **826**, a first or rear rebound position **828**, a second or front rebound position **830**, a third or extended rebound position **836**, a first or rear jounce position **832**, and second or front jounce position **834**. In the first rebound position **828**, the second rebound position **830**, and the third rebound position **836**, the suspension assembly **700** is moving downward such that at least one or more of the spring damping cylinders **768** may be at least partially extended. In the first jounce position **832** and the second jounce position **834**, the suspension assembly is moving upward such that at least one or more of the spring damping cylinders **768** may be at least partially compressed.

[0094] Referring to FIG. **23**, the suspension assembly **700** is in the riding position **826** such that the front axle **714** and the rear axle **716** are coincident along a horizontal or x-axis **838**. The first spring beam **760** is approximately parallel to the first frame rail **706**, and the front axle **714** and the rear axle **716** require minimal adjustment along a vertical or y-axis **840** while in the riding position **826**.

[0095] Referring to FIG. **24**, the suspension assembly **700** is in the first or rear rebound position **828** such that rear axle **716** moves downward along the y-axis **840**, and the front axle **714** remains in approximately the same location on the y-axis **840** as the location of the front axle **714** in the riding position **826**. In the first rebound position **828**, the front axle **714** and the rear axle **716** are no longer coincident along the x-axis **838**. The first spring beam **760** and the first frame rail **706** are no longer parallel, and the second spring beam **766** and the second frame rail **708** are no longer parallel.

[0096] Referring to FIG. **25**, the suspension assembly **700** is in the second or front rebound position **830** such that the front axle **714** moves downward along the y-axis **840** and the rear axle **716** remains in approximately the same location on the y-axis **840** as the location of the rear axle **716** in the riding position **826**. In the second rebound position, the front axle **714** and the rear axle **716** are no longer coincident along the x-axis **838**. The first spring beam **760** and the first frame rail **706** are no longer parallel, and the second spring beam **766** and the second frame rail **708** are no longer parallel.

[0097] Referring to FIG. **26**, the suspension assembly **700** is in the first or rear jounce position **832** such that the rear axle **716** moves upward along the y-axis **840** and the front axle **714** remains in approximately the same location on the y-axis **840** as the location of the front axle **714** in the riding position **826**. In the first jounce position **832**, the front axle **714** and the rear axle **716** are no longer coincident along the x-axis **838**. The first spring beam **760** and the first frame rail **706** are no longer parallel, and the second spring beam **766** and the second frame rail **708** are no longer parallel.

[0098] Referring to FIG. **27**, the suspension assembly **700** is in the second or front jounce position **834** such that the front axle **714** moves upward along the y-axis **840** and the rear axle **716** remains in approximately the same location on the y-axis **840** as the location of the rear axle **716** in the riding position **826**. In the second jounce position, the front axle **714** and the rear axle **716** are no longer coincident along the x-axis **838**. The first spring beam **760** and the first frame rail **706** are no longer parallel, and the second spring beam **766** and the second frame rail **708** are no longer parallel.



[0099] Referring to FIG. 28, the suspension assembly 700 is in the third or extended rebound position 836 such that the front axle 714 and the rear axle 716 are coincident below the x-axis 838 and the spring damping cylinders 768 are both evenly extended. In the extended rebound position, both the front axle 714 and the rear axle 716 move downward along the y-axis 840. The first spring beam 760 and the first frame rail 706 are approximately parallel, and the second spring beam 766 and the second frame rail 708 are approximately parallel.

[0100] As utilized herein with respect to numerical ranges, the terms “approximately,” “about,” “substantially,” and similar terms generally mean  $\pm 10\%$  of the disclosed values. When the terms “approximately,” “about,” “substantially,” and similar terms are applied to a structural feature (e.g., to describe its shape, size, orientation, direction, etc.), these terms are meant to cover minor variations in structure that may result from, for example, the manufacturing or assembly process and are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

[0101] It should be noted that the term “exemplary” and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0102] The term “coupled” and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If “coupled” or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of “coupled” provided above is modified by the plain language meaning of the additional term (e.g., “directly coupled” means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of “coupled” provided above. Such coupling may be mechanical, electrical, or fluidic.

[0103] References herein to the positions of elements (e.g., “top,” “bottom,” “above,” “below”) are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0104] The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single-or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various

processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes described herein.

[0105] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0106] Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above. Such variation may depend, for example, on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations of the described methods could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

[0107] It is important to note that the construction and arrangement of the suspension assembly **700** as shown in the various exemplary embodiments is illustrative only. Additionally, any element disclosed in one embodiment may be incorporated or utilized with any other embodiment disclosed herein. For example, the suspension assembly **700** and the chassis **702** of the exemplary embodiments shown in at least FIGS. **8-12** and **14-28** may be incorporated in the chassis **20** of the exemplary embodiment shown in at least FIGS. **1-7**, and/or the axles **704** of the exemplary embodiments shown in FIGS. **8-28** may be incorporated in the axles assemblies **50**, **52** of the exemplary embodiment shown in FIGS. **1-7**. Although only one example of an element from one embodiment that can be incorporated or utilized in another embodiment has been described above, it should be appreciated that other elements of the various embodiments may be incorporated or utilized with any of the other embodiments disclosed herein.

## Claims

1. A suspension assembly comprising: a first bracket coupled to a first frame rail; a second bracket coupled to a second frame rail; a first linkage rod coupled between the first bracket and an axle housing, wherein the first linkage rod is arranged at an angle relative to a central longitudinal axis so that as the first linkage rod extends from the axle housing toward the first bracket, the first

linkage rod angles laterally outwardly and away from the central longitudinal axis, wherein the first linkage rod is coupled to the axle housing at a location that is arranged laterally outwardly from the central longitudinal axis and closer to the first frame rail than the central longitudinal axis; and a second linkage rod coupled between the second bracket and the axle housing, wherein the second linkage rod is arranged at an angle relative to the central longitudinal axis so that as the second linkage rod extends from the axle housing toward the second bracket, the second linkage rod angles laterally outwardly and away from the central longitudinal axis, wherein the second linkage rod is coupled to the axle housing at a location that is arranged laterally outwardly from the central longitudinal axis and closer to the second frame rail than the central longitudinal axis.

**2.** The suspension assembly of claim 1, wherein the first bracket and the second bracket are arranged symmetrically about the central longitudinal axis.

**3.** The suspension assembly of claim 1, wherein the first linkage rod is received within a first cavity of the first bracket and coupled to the first bracket by a first fastener, and wherein the second linkage rod is received within a second cavity of the second bracket and coupled to the second bracket by a second fastener.

**4.** The suspension assembly of claim 3, wherein the first fastener is received within a first bore and the second fastener is received within a second bore.

**5.** The suspension assembly of claim 3, wherein a first bore extends through the first bracket at an acute angle between the central longitudinal axis and a central lateral axis, and a second bore extends through the second bracket at an acute angle between the central longitudinal axis and the central lateral axis.

**6.** The suspension assembly of claim 1, further comprising a spring beam coupled to a half-shaft assembly.

**7.** The suspension assembly of claim 6, further comprising a damping cylinder coupled between the spring beam and the first frame rail.

**8.** The suspension assembly of claim 1, wherein the first linkage rod and the second linkage rod form a first pair of linkage rods, and a second pair of linkage rods are arranged symmetric to the first pair of linkage rods about a central lateral axis.

**9.** An electrified vehicle comprising: a chassis including a first frame rail and a second frame rail laterally separated from the first frame rail; an axle assembly including an axle housing arranged laterally between the first frame rail and the second frame rail; an energy storage system supported on the chassis; and a suspension assembly comprising: a first linkage rod coupled between the axle housing and the first frame rail, wherein the first linkage rod is arranged at an angle relative to a central longitudinal axis so that as the first linkage rod extends from the axle housing toward the first frame rail, the first linkage rod angles laterally outwardly and away from the central longitudinal axis, wherein the first linkage rod is coupled to the axle housing at a location that is arranged laterally outward from the central longitudinal axis and closer to the first frame rail than the central longitudinal axis; a second linkage rod coupled between the axle housing and the second frame rail, wherein the second linkage rod is arranged at an angle relative to the central longitudinal axis so that as the second linkage rod extends from the axle housing toward the second frame rail, the second linkage rod angles laterally outwardly and away from the central longitudinal axis, wherein the second linkage rod is coupled to the axle housing at a location that is arranged laterally outward from the central longitudinal axis and closer to the second frame rail than the central longitudinal axis; a first bracket coupling at least the first linkage rod to the first frame rail; and a second bracket coupling at least the second linkage rod to the second frame rail.

**10.** The electrified vehicle of claim 9, wherein the first linkage rod and the second linkage rod are arranged symmetrically about the central longitudinal axis.

**11.** The electrified vehicle of claim 9, wherein the first linkage rod is received within a first cavity of the first bracket, and wherein the second linkage rod is received within a second cavity of the second bracket.

- 12.** The electrified vehicle of claim 11, wherein the first bracket and the second bracket each include a mounting wall positioned within the first cavity and the second cavity, respectively, wherein the mounting wall defines a bore extending through the mounting wall of the first bracket and the mounting wall of the second bracket.
- 13.** The electrified vehicle of claim 12, wherein the bore extends at an acute angle between the central longitudinal axis and a central lateral axis.
- 14.** The electrified vehicle of claim 9, wherein the first bracket and the second bracket each include one or more protrusions, wherein the one or more protrusions define a bore that extends at an acute angle between the central longitudinal axis and a central lateral axis.
- 15.** The electrified vehicle of claim 12, wherein the mounting wall of the first bracket and the mounting wall of the second bracket each extend between a first surface and a second surface of the first cavity and the second cavity, respectively.
- 16.** The electrified vehicle of claim 9, wherein the first linkage rod and the second linkage rod form a first pair of linkage rods, and a second pair of linkage rods that are arranged symmetric to the first pair of linkage rods about a central lateral axis.
- 17.** An electrified vehicle comprising; a chassis including a first frame rail and a second frame rail laterally separated from the first frame rail; a first bracket fixedly coupled to the first frame rail; a second bracket fixedly coupled to the second frame rail; a first axle assembly including a first axle housing arranged laterally between the first frame rail and the second frame rail; a second axle assembly including a second axle housing arranged on an opposing side of a central lateral axis from the first axle housing; an energy storage system supported on the chassis between the first frame rail and the second frame rail; and a suspension assembly including: a first linkage rod coupled between the first axle housing and the first bracket, wherein the first linkage rod is arranged at an angle relative to a central longitudinal axis so that as the first linkage rod extends from the first axle housing toward the first frame rail, the first linkage rod angles laterally outwardly and away from the central longitudinal axis, wherein the first linkage rod is coupled to the first axle housing at a location that is arranged laterally outward from the central longitudinal axis and closer to the first frame rail than the central longitudinal axis; and a second linkage rod coupled between the second bracket and the second axle housing, wherein the second linkage rod is arranged at an angle relative to the central longitudinal axis so that as the second linkage rod extends from the second axle housing toward the second bracket, the second linkage rod angles laterally outwardly and away from the central longitudinal axis, wherein the second linkage rod is coupled to the second axle housing at a location that is arranged laterally outwardly from the central longitudinal axis and closer to the first frame rail than the central longitudinal axis.
- 18.** The electrified vehicle of claim 17, wherein, when the suspension assembly is in a rebound position, at least one or more spring damping cylinders are at least partially extended.
- 19.** The electrified vehicle of claim 17, wherein, when the suspension assembly is in a jounce position, at least one or more spring damping cylinders are at least partially compressed.
- 20.** The electrified vehicle of claim 17, wherein, when the suspension assembly is in a riding position, the first axle assembly and the second axle assembly coincide on a horizontal axis.
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