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Electric vehicle powertrain assembly having nested shafts

Abstract

A drivetrain system includes a first drive gear driven by a first motor and a second drive gear driven by a second motor. The first drive gear and the second drive gear are arranged along the axis. The first drive gear includes a first extension and the second drive gear includes a second extension arranged radially within and axially overlapping the first extension. The drivetrain system includes a system of bearings arranged between the first drive gear and the second drive gear, either drive gear and a stationary component, or a combination thereof. In some embodiments, the drivetrain system includes a clutch assembly arranged between the first drive gear and the second drive gear that interfaces to the first drive gear and to the second drive gear. The clutch assembly allows the drive gears to be locked or otherwise engaged to improve torque transfer.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application is a continuation of U.S. patent application Ser. No. 16/892,501, filed Jun. 4, 2020, the disclosures of which is hereby incorporated by reference herein in its entirety.

(1) The present disclosure is directed to vehicle powertrains, and more particularly, to electric vehicle powertrains having nested components.

SUMMARY

(2) Electric vehicles include electric powertrains. The arrangements of electric vehicle powertrains are dependent on design considerations, crash considerations, and performance considerations. It would be advantageous to provide a relatively more compact powertrain arrangement for an electric vehicle.

(3) In some embodiments, the present disclosure is directed to drivetrains, and components thereof, that achieve a compact arrangement while allowing for torque vectoring.

(4) The present disclosure is directed to a drivetrain system. The drivetrain system includes (i) a first drive gear arranged on an axis and driven by a first motor and (ii) a second drive gear arranged on the axis and driven by a second motor. The first drive gear includes a first extension along the axis, and the second drive gear includes a second extension along the axis. The second extension is arranged radially within and axially overlaps the first extension. In some embodiments, the drivetrain system includes one or more bearings. In some embodiments, the drivetrain system includes a clutch assembly.

(5) In some embodiments, the drivetrain system includes a bearing arranged between the first drive gear and the second drive gear that interfaces to the first extension and to the second extension. In some embodiments, the bearing includes a taper roller bearing for transmitting axial force between the first drive gear and the second drive gear. In some embodiments, the bearing is a first bearing and the first drive gear includes a third extension radially outside of the second extension. In some such embodiments, the drivetrain system includes a second bearing arranged between the first drive gear and the second drive gear that interfaces to the second extension and to the third extension. For example, in some embodiments, the second bearing is a roller bearing. In some embodiments, a second bearing is arranged between the first drive gear and a component that is stationary, such as a housing.

(6) In some embodiments, the first drive gear includes a third extension extending axially opposite of the first extension, and the second drive gear comprises a fourth extension extending axially opposite of the second extension. For example, in some such embodiments, the drivetrain system includes a further bearing interfacing to the third extension and a still further bearing interfacing to the fourth extension. To illustrate, these further bearings may include tapered roller bearings arranged outboard of both the first and second drive gears.

(7) In some embodiments, the second extension includes a recess for holding lubricating grease. In some embodiments, the drivetrain system includes a seal interfacing with the first drive gear and with the second extension to at least partially seal the recess.

(8) In some embodiments, the bearing is configured to not rotate relative to the first drive gear when the first drive gear and the second drive gear rotate at the same rotational speed.

(9) In some embodiments, a drivetrain system includes a first drive train, a second drive, and one or more bearings. The first drivetrain includes a first electric motor having a motor shaft and a first motor gear, a first intermediate shaft engaged with the first motor gear, and a first drive gear engaged with the first intermediate shaft. The second drivetrain includes a second electric motor having a motor shaft and a second motor gear, a second intermediate shaft engaged with the second motor gear, and a second drive gear arranged coaxially with the first drive shaft and partially overlapping axially with the first drive gear forming a first region. In some embodiments, the bearing is arranged between the first drive gear and the second drive gear in the first region, and interfaces to the first drive gear and to the second drive gear. In some embodiments, the second drive gear is engaged with the second intermediate shaft.

(10) In some embodiments, the bearing includes a taper roller bearing for transmitting axial force between the first drive gear and the second drive gear.

(11) In some embodiments, the first drive gear includes a first extension, the second drive gear includes a second extension, and the first extension and the second extension form the first region. For example, the bearing interfaces to the first extension and to the second extension.

(12) In some embodiments, the bearing is a first bearing, and the first drive gear includes a third

extension radially outside of the second extension. In some such embodiments, the drivetrain system includes a second bearing arranged between the second extension and the third extension. (13) In some embodiments, the bearing is a first bearing, and the drivetrain system includes a second bearing arranged between the first drive gear and a component that is stationary, such as a housing.

(14) In some embodiments, the second extension of the second drive gear includes a recess for holding lubricating grease. In some embodiments, the drivetrain system includes a seal interfacing with the first drive gear and with the second extension to at least partially seal the recess.

(15) In some embodiments, the bearing is configured to not rotate relative to the first drive gear when the first drive gear and the second drive gear rotate at the same rotational speed.

(16) In some embodiments, the first intermediate shaft includes a first intermediate gear, the second intermediate shaft includes a second intermediate gear, and the first intermediate gear and the second intermediate gear partially overlap axially.

(17) In some embodiments, the drivetrain system includes a first drive gear, a second drive gear, and a clutch assembly. The first drive gear is arranged on an axis, is driven by a first motor, and includes a first extension along the axis. The second drive gear is arranged on the axis, is driven by a second motor, and includes a second extension along the axis. The second extension is arranged radially within and axially overlaps the first extension. The clutch assembly is arranged between the first drive gear and the second drive gear, and is affixed to a housing of the drivetrain system. The clutch assembly interfaces to the first extension and to the second extension.

(18) In some embodiments, the clutch assembly includes a first clutch element affixed to the first drive gear, a second clutch element affixed to the second drive gear, and an actuator for engaging the first clutch element and the second clutch element. For example, in some embodiments, the first clutch element is affixed to the first extension and the second clutch element is affixed to the second extension. In a further example, in some embodiments, the first extension includes one or more features for affixing the first clutch element. In a further example, in some embodiments, the second extension includes one or more features for affixing the second clutch element. Features may include splines, keyways, steps, any other suitable features, or any combination thereof.

(19) In some embodiments, the second drive gear includes a third extension arranged radially inside of the second extension. In some such embodiments, the drivetrain system includes a bearing engaged with the second extension and the third extension.

(20) In some embodiments, the first drive gear includes at least one passage extending axially through the first drive gear to allow lubricant to flow axially through the first drive gear.

(21) In some embodiments, the drivetrain system includes a bearing arranged between and engaged with the first drive gear and the second drive gear. In some embodiments, the drivetrain system includes a bearing arranged between and engaged with a component that is stationary, such as the housing, and one of the first drive gear or the second drive gear.

(22) In some embodiments, when the clutch assembly is engaged, the first drive gear and the second drive gear apply a respective torque on each other to reduce a difference in rotational speed between the first drive gear and second drive gear. For example, the clutch assembly may lock up the first drive gear and the second drive gear to rotate at the same rotational speed.

(23) In some embodiments, the drivetrain system includes a first drivetrain, a second drivetrain, and a clutch assembly. The first drivetrain includes a first electric motor having a motor shaft and a first motor gear, a first intermediate shaft engaged with the first motor gear, a first drive gear engaged with the first intermediate shaft, and a first housing configured to cover the first motor gear, the first intermediate gear, and the first drive gear. The second drivetrain includes a second electric motor having a motor shaft and a second motor gear, a second intermediate shaft engaged with the second motor gear, a second drive gear arranged coaxially with the first drive gear and partially overlapping axially with the first drive gear forming a first region. The second drive gear is engaged with the second intermediate shaft. The second drive unit also includes a second

housing configured to cover the second motor gear, the second intermediate gear, and the second drive gear. The drivetrain system also includes a third housing affixed between the first housing and the second housing. The drivetrain system further includes a clutch assembly arranged between the first drive gear and the second drive gear. The clutch assembly is affixed to the third housing of the drivetrain system and interfaces to the first drive gear and to the second drive gear.

(24) In some embodiments, the clutch assembly includes a first clutch element affixed to the first drive gear, a second clutch element affixed to the second drive gear, and an actuator for engaging the first clutch element and the second clutch element.

(25) In some embodiments, the first drive gear includes a first extension that axially overlaps at least part of the second drive gear, and the first clutch element is affixed to the first extension. In some such embodiments, the first extension includes one or more features for affixing the first clutch element. In some embodiments, the second drive gear includes a second extension radially inside of the first extension and is at least partially affixed to the second extension. In some such embodiments, the second drive gear includes one or more features for affixing the second clutch element.

(26) In some embodiments, the first drive gear includes at least one passage extending axially through the first drive gear to allow lubricant to flow axially through the first drive gear.

(27) In some embodiments, the drivetrain system includes a bearing arranged between and engaged with the first drive gear and the second drive gear.

(28) In some embodiments, the drivetrain system includes a bearing arranged between and engaged with a third housing and one of the first drive gear or the second drive gear, and the third housing is arranged axially between the first housing and the second housing.

(29) In some embodiments, when the clutch assembly is engaged, the first drive gear and the second drive gear apply a respective torque on each other to reduce a difference in rotational speed between the first drive gear and second drive gear.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The present disclosure, in accordance with one or more various embodiments, is described in detail with reference to the following figures. The drawings are provided for purposes of illustration only and merely depict typical or example embodiments. These drawings are provided to facilitate an understanding of the concepts disclosed herein and shall not be considered limiting of the breadth, scope, or applicability of these concepts. It should be noted that for clarity and ease of illustration these drawings are not necessarily made to scale.

(2) FIG. 1 shows a top view of illustrative components of an electric vehicle, in accordance with some embodiments of the present disclosure;

(3) FIG. 2 shows three illustrative drive unit configurations, in accordance with some embodiments of the present disclosure;

(4) FIG. 3 shows a top cross-sectional view of an illustrative drivetrain system, in accordance with some embodiments of the present disclosure;

(5) FIG. 4 shows a cross-sectional view of an illustrative bearing arrangement for nested drive gears, in accordance with some embodiments of the present disclosure;

(6) FIG. 5 shows a cross-sectional view of an illustrative drive system having nested drive gears and bearings, in accordance with some embodiments of the present disclosure;

(7) FIG. 6 shows a cross-sectional view of an illustrative bearing arrangement for nested drive gears and a clutch assembly, in accordance with some embodiments of the present disclosure;

(8) FIG. 7 shows a cross-sectional view of an illustrative drive system having nested drive gears, bearings, and a clutch assembly, in accordance with some embodiments of the present disclosure;

(9) FIG. 8 shows a cross-sectional view of an illustrative bearing arrangement for nested drive gears and a stationary component, in accordance with some embodiments of the present disclosure; (10) FIG. 9 shows a cross-sectional view of an illustrative drive system having nested drive gears, bearings, and a clutch assembly, in accordance with some embodiments of the present disclosure; (11) FIG. 10 shows a cross-sectional view of an illustrative drive system having nested drive gears, bearings, and a clutch assembly, in accordance with some embodiments of the present disclosure; (12) FIG. 11 shows a cross-sectional view of an illustrative bearing system for intermediate gears of a drive system, in accordance with some embodiments of the present disclosure; (13) FIG. 12 shows a cross-sectional view of another illustrative bearing system for intermediate gears of a drive system, in accordance with some embodiments of the present disclosure; (14) FIG. 13 shows a cross-sectional view of another illustrative bearing system for intermediate gears of a drive system, in accordance with some embodiments of the present disclosure; and (15) FIG. 14 shows a cross-sectional perspective view of an illustrative bearing assembly, in accordance with some embodiments of the present disclosure.

DETAILED DESCRIPTION

(16) In some embodiments, an electric drivetrain may include one or more electric motors configured to achieve torque vectoring (e.g., a two-motor or four-motor architecture). For example, a vehicle may include a front drive unit and a rear drive unit that each include respective motors, independent gearsets integrated into a compact and cost-efficient package. In some embodiments, the present disclosure is directed to assemblies having nested gears driven by independent motors. In some embodiments, the present disclosure is directed to drive trains that include clutches for coupling the drive gears.

(17) A drive system may be configured to provide a mode of independent speed and torque control, a mode of providing additional torque for off-road events and to prevent thermal overload during extended high torque events, or both. In some embodiments, a compact and integrated locking system is included to lock the outputs such that torque of two electric motors can be transferred to one output shaft.

(18) The drive system may include a shaft and hub system, with output shafts that may be disengaged for independent control of each output by a single motor, or may be locked together so both output shafts are driven by both motors. In some embodiments, the two output shaft members (e.g., the drive gears) are nested in an arrangement that allows for a compact package, reduced number of bearings, and high mechanical efficiency while optionally providing sufficient power-flow to connect to a clutch device that engages the two outputs. In an illustrative example, the clutch assembly may be coupled using a splined interface, fastener interface, or by an integrated feature in the shaft. The clutch may include a torque-transferring device such as, for example, a friction surface, a sprag, a roller, a movable spline such as a dog clutch or face clutch, any other suitable components or clutch types, or any combination thereof. The clutch system couples the two output shaft members under actuation by a mechanical, hydraulic or electromechanical actuator, for example.

(19) In some embodiments, the nested shafts of the drive system are supported by bushings, bearings, or both that are configured and arranged to accommodate loads and reaction forces. The nested configuration and connections of the shafts allow the bushing or bearing members to be reduced or minimized in quantity. Further, in some embodiments, the location and kinematics of the configuration reduce or eliminate differential motion between the drive gears during normal operation to reduce power losses of the bearings and provide a higher efficiency design than a separate shaft configuration. In some embodiments, the nested shafts and any connection to the clutch assembly, along with the supporting bearings, provides independent shaft power-flow and allows for the connection of a locking mechanism.

(20) In some embodiments, the drive systems of the present disclosure allow for improved off-road capability and thermal capability of a vehicle, for longer duration, high-load events. Further, the

drive systems of the present disclosure allow for compact packaging (e.g., width, diameter), desired mechanical efficiency, and relatively low complexity.

(21) FIG. 1 shows a top view of illustrative components of electric vehicle **100**, in accordance with some embodiments of the present disclosure. In some embodiments, a vehicle may include two or more electric motors (e.g., four motors), arranged in one or more drive units. For example, some of the motor assemblies may be identical, while some may have different handedness or shaft rotation direction relative to the motor. As illustrated, electric vehicle **100** includes front drive unit **110** and rear drive unit **120**. Front drive unit **110** and rear drive unit **120** may each include two motor drivetrains, which each include a motor, a gearset, bearings, and output interface. For example, the drivetrains of the present disclosure may be included in either or both of front drive unit **110** and rear drive unit **120**.

(22) FIG. 2 shows three illustrative drive unit configurations, in accordance with some embodiments of the present disclosure. Configuration **200** includes two separate motor drives **210** and **220**, each capable of operating as a single drive. Each of motor drive **210** and **220** may be, for example, sealed, mechanically separate (e.g., complete bearings and lubrication systems), and include a motor, gearbox, and output (e.g., an output spline or output half-shaft).

(23) Configuration **250** includes motor drives **260** and **270**, illustrated in an exploded view (e.g., unassembled). Motor drives **260** and **270** are configured to be coupled together by intermediate housing **252**. In some embodiments, each of motor drives **260** and **270** may include one or more housings (e.g., housings **262**, **272**, **269**, and **279**), a motor (e.g., motors **261** and **271**), a gearset (e.g., gearsets **263** and **273**), and an output (e.g., half-shafts **264** and **274**). As illustrated, motor drives **260** and **270** include, respectively, housings **262** and **272**, which may be configured to house a bearing, manage electrical terminations, provide cooling, provide mounting, any other suitable functions, or any suitable combination thereof. In some embodiments, housings **269** and **279** are not separately sealed and, for example, intermediate housing **252** (e.g., I-shield) may be configured to seal against both of housings **269** and **279**. Intermediate housing **252** may be configured to seal lubricant (e.g., bearing oil), seal coolant (e.g., water, mixtures, oil), provide noise reduction (e.g., attenuate gear-induced audible noise and vibration), align motor drives **260** and **270** to each other, mount motor drives **260** and **270** to a frame or other structural element, house one or more shaft bearings (e.g., one or more bearings for a motor shaft, intermediate shaft, output shaft, or a combination thereof), act as a mount for a clutch assembly, any other suitable functionality, or any suitable combination thereof.

(24) Configuration **290** includes motor drives **260** and **270** in an assembled state. For example, housings **269** and **279** may be affixed to intermediate housing **252** using fasteners (e.g., bolts, threaded studs and nuts), clamps, latches, mechanical interlocks, any other suitable affixments, or any combination thereof. In some embodiments, intermediate housing **252**, motor drive **260**, motor drive **270**, or a combination thereof may include alignment features that spatially align two or more components, constrain relative motion, or both. For example, intermediate housing **252** may allow each of motor drives **260** and **270** to be shorter (e.g., along the left-right axis in FIG. 2). In a further example, configuration **290** may be shorter than configuration **200** along the left-right axis, as illustrated, because motor drives **260** and **270** need not require fully sealed gearsets **263** and **273**.

(25) FIG. 3 shows a top cross-sectional view of illustrative drivetrain system **300**, in accordance with some embodiments of the present disclosure. Motors **340** and **380** include respective motor shafts **320** and **360**, to which respective motor gears **325** and **365** are affixed. Each of motor shafts **320** and **360** is positioned by three bearings: an outer bearing (not shown), a mid-bearing (e.g., bearing **321** and bearing **361**, respectively), and an inner bearing (e.g., bearing **323** and bearing **363**, respectively). Motor gears **325** and **365** engage with respective wheel gears **331** and **371** affixed to respective intermediate shafts (not shown). Also affixed to the respective intermediate shafts are respective pinion gears **332** and **372**. Each intermediate shaft is arranged in a respective position by a respective bearing system (e.g., an inner bearing and an outer bearing). For example,

an inner bearing of each intermediate shaft may be captured by an intermediate housing (e.g., mounted to, aligned to or both). Each of pinion gears **332** and **372** engages respective drive gears **335** and **375** affixed to a respective drive shaft. Each of drive gears **335** and **375** is positioned by one or more respective tapered bearings, which may be configured to react axial loads. For example, the axial loads may arise from a drive shaft (not shown) coupled to the respective drive gear. Region **399** includes the inner bearings of the intermediate and drive gears, for which illustrative examples are provided in FIGS. **4-13**. In some embodiments, wheel gears **331** and **371** may be positioned axially adjacent to, or overlapping with, the respective motor (e.g., motor **340** or **380**), depending upon the size of the motor gear (e.g., motor gear **325** and **365**) and mid bearing (e.g., bearings **321** and **361**).

(26) FIG. **4** shows a cross-sectional view of an illustrative bearing arrangement for nested drive gears, in accordance with some embodiments of the present disclosure. Arrangement **400**, as illustrated, represents a portion of a drivetrain and includes drive gear **410** (e.g., having extensions **411**, **412**, and **413**), drive gear **420** (e.g., having extensions **421** and **422**), and bearings **401-404**. Drive gear **410** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**) and drive gear **420** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**). Bearings **401-404** maintain alignment of drive gears **410** and **420** along axis **499** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, extension **421** of drive gear **420** nests radially within extension **411** of drive gear **410**.

(27) Bearing **401-404** may include, for example, roller bearings, needle bearings, ball bearings, taper bearings, thrust bearings, any other suitable type of bearing, or any combination thereof. For example, in some embodiments, bearing **403**, bearing **404**, and bearing **401** may include taper bearings and bearing **402** may include a needle bearing (e.g., as illustrated in FIG. **5**). In some embodiments, bearings **403** and **404** are configured to react against a stationary component (e.g., a housing or other component) to maintain alignment of drive gears **410** and **420** relative to the stationary component.

(28) As illustrated, extension **411** overlaps axially with extension **421**, which is arranged radially within extension **411**. Note that the radial direction in FIG. **4** is normal to axis **499** (e.g., in a direction extending from axis **499** outward). Because of the axial overlap of drive gears **410** and **420**, bearing **401** may be configured to transmit forces in the radial direction, axial direction, or both, between drive gears **410** and **420**. Similarly, as illustrated, extension **421** overlaps axially with extension **413**, which is arranged radially within extension **421**. Because of the axial overlap of drive gears **410** and **420**, bearing **402** may be configured to transmit forces in the radial direction, axial direction, or both, between drive gears **410** and **420**.

(29) Extension **412** of drive gear **410** and extension **422** of drive gear **420** are configured to engage with respective bearings **403** and **404**. Bearings **403** and **404** may also engage with (e.g., react forces against) a stationary component (e.g., a housing) to maintain alignment of drive gears **410** and **420**. In some embodiments, extensions **412** and **422** are configured to be outputs, and may include output interfaces. For example, as illustrated, extensions **412** and **422** each include a recess configured to accommodate a half shaft (e.g., a splined interface to insert a half shaft to drive a respective wheel). Drive gears **410** and **420** may include any suitable output interface such as, for example, a splined interface, a keyed interface, a flanged interface (e.g., with fasteners), a universal joint, a clutched interface, any other suitable interface, or any combination thereof.

(30) In an illustrative example, drive gears **410** and **420** may rotate about axis **499** at substantially the same speed when the vehicle is traveling straight on relatively consistent ground. During turning or under condition where one side may experience more traction or more slip, drive gears **410** and **420** may rotate at different speeds about axis **499** (e.g., drive gears **410** and **420** rotate relative to each other about axis **499**). Accordingly, during straight-line driving, bearings **401** and **402** do not experience relative rotation between drive gears **410** and **420**. As drive gears **410** and **420** differ in speed (e.g., one wheel slips, or a turn is made), bearings **401** and **402** experience the

relative rotation between drive gears **410** and **420**.

(31) In a further illustrative example, during assembly, drive gears **410** and **420**, and bearings **401-404** may be assembled, and a preload may be applied along axis **499** to bearings **403** and **404**. In some embodiments, the preload also loads bearing **401**, bearing **402** or both to the extent they include tapered bearings. To illustrate, because bearings **401** and **402** engage with drive gears **410** and **420** and not stationary components, in some embodiments, a single axial preload may be applied rather than a respective axial preload applied to bearings associated with each distinct drive gear.

(32) FIG. 5 shows a cross-sectional view of an illustrative drive system **500** having nested drive gears and bearings, in accordance with some embodiments of the present disclosure. Drive system **500** is an illustrative example of arrangement **400** of FIG. 4. Drive system **500** includes drive gear **510** (e.g., having extensions **511**, **512**, and **513**), drive gear **520** (e.g., having extensions **521** and **522**), and bearings **501-504**. Drive gear **510** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3) and drive gear **520** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). In an illustrative example, the “open design” between drive gears **510** and **520** allows torque transfer and/or actuation devices to be installed and accessed radially (e.g., such as clutches or other locking devices). In a further illustrative example, bearings **501** and **502** improve stiffness to tilting for drive gears **510** and **520**.

(33) Drive gears **510** and **520** include toothed portions **551** and **552** (e.g., which may be spur, helical, or any other suitable gear type), respectively, configured to engage with corresponding toothed portions of motor gears or intermediate gears. Drive gears **510** and **520** also include output interfaces **515** and **525** (e.g., splined recesses, as illustrated), respectively, configured to engage with splined half shafts.

(34) Bearings **501-504** maintain alignment of drive gears **510** and **520** along axis **599** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **501**, **503**, and **504** are tapered roller bearings, and bearing **502** is a needle bearing. Bearing **501** is configured to react both axial and radial forces between drive gear **510** and drive gear **520**. Bearing **502** is configured to react radial forces between drive gear **510** and drive gear **520**. Extensions **511**, **513**, and **521** may include one or more features to engage with bearings **501** and **502** such as, for example, a step, splines, a keyway, any other suitable feature, or any combination thereof. For example, in some embodiments, an axial preload is applied to preload bearings **501**, **503**, and **504** in the axial direction, and such features may aid in transmitting axial preload to bearing **501**. Bearings **501**, **502**, **503**, and **504** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims, any other suitable components, or any suitable combination thereof.

(35) In some embodiments, drive system **500** is arranged in an enclosure (e.g., formed by one or more housings), in which oil or other lubricant is supplied to reduce friction, provide cooling, or both, between relatively moving components. Because bearing **501** is relatively open to the enclosure, sufficient lubrication may be provided to bearing **501** by the lubrication system. Bearing **502** is shielded from the inside of the enclosure and thus might not receive adequate lubrication from the enclosure lubrication system. As illustrated, drive gear **510** includes recess **514** arranged in extension **513**. Recess **514** is configured to be loaded with grease, which under rotation of drive gear **510** experiences centrifugal forces that push the grease into bearing **502**. In some embodiments, as illustrated, O-ring **560** or other restriction is arranged between extension **513** and extension **521** to limit or prevent grease migration away from bearing **502**. In some embodiment, output interface **525** is not open to interior of extension **521**. In some embodiment, output interface **525** is open to interior of extension **521**, although an optional plug or seal may be included to partition those regions.

(36) In an illustrative example, during assembly, drive gears **510** and **520**, and bearings **501-504** may be assembled, and a preload may be applied along axis **599** to preload bearings **501**, **503**, and

504 along direction **599**. To illustrate, because bearing **501** engages with drive gears **510** and **520** and not stationary components, in some embodiments, a single axial preload may be applied to preload bearing **501**.

(37) FIG. **6** shows a cross-sectional view of illustrative bearing arrangement **600** for nested drive gears and a clutch assembly, in accordance with some embodiments of the present disclosure. To illustrate, arrangement **600** is similar to arrangement **400** of FIG. **4** with addition of a clutch assembly to provide engagement between drive gears **610** and **620**. Arrangement **600**, as illustrated, represents a portion of a drivetrain and includes drive gear **610** (e.g., having extensions **611**, **612**, and **613**), drive gear **620** (e.g., having extensions **621** and **622**), and bearings **601-604**. Drive gear **610** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**) and drive gear **620** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**). Bearings **601-604** maintain alignment of drive gears **610** and **620** along axis **699** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, extension **621** of drive gear **620** nests radially within extension **611** of drive gear **610**, and extension **613** of drive gear **610** nests radially within extension **621** of drive gear **620**. The clutch assembly, as illustrated includes clutch element **671** affixed to drive gear **610**, and clutch element **672** affixed to drive gear **620**. Stationary component **698**, which may be part of a housing, interfaces with clutch element **671**, clutch element **672**, or both.

(38) Bearings **601-604** may include, for example, roller bearings, needle bearings, ball bearings, taper bearings, thrust bearings, any other suitable type of bearing, or any combination thereof. In some embodiments, bearings **603** and **604** are configured to react against a stationary component (e.g., a housing or other component) to maintain alignment of drive gears **610** and **620** relative to the stationary component.

(39) As illustrated, extension **611** overlaps axially with extension **621**, which is arranged radially within extension **611**. Because of the axial overlap of drive gears **610** and **620**, bearing **601** may be configured to transmit forces in the radial direction, axial direction, or both, between drive gears **610** and **620**. Similarly, as illustrated, extension **621** overlaps axially with extension **613**, which is arranged radially within extension **621**. Because of the axial overlap of drive gears **610** and **620**, bearing **602** may be configured to transmit forces in the radial direction, axial direction, or both, between drive gears **610** and **620**.

(40) Extension **612** of drive gear **610** and extension **622** of drive gear **620** are configured to engage with respective bearings **603** and **604**, which engage with a stationary component (e.g., a housing) to maintain alignment of drive gears **610** and **620**. In some embodiments, extensions **612** and **622** are configured to be outputs, and may include output interfaces. For example, as illustrated, extensions **612** and **622** each include a recess configured to accommodate a half shaft. Drive gears **610** and **620** may include any suitable output interface such as, for example, a splined interface, a keyed interface, a flanged interface (e.g., with fasteners), a universal joint, a clutched interface, any other suitable interface, or any combination thereof.

(41) The clutch assembly of bearing arrangement **600** is configured to mechanically couple drive gears **610** and **620**. For example, when the clutch assembly is not engaged, drive gears **610** and **620** are driven independently, and may rotate relatively freely with respect to each other. Further, when the clutch assembly is engaged, drive gears **610** and **620** are constrained by friction forces to rotate at the same rotational speed, or otherwise impart azimuthal forces on each other (e.g., depending on whether the clutch allows slippage). Accordingly, when the clutch assembly is engaged, power from both drivers (e.g., electric motors) may be transmitted among the outputs (e.g., the wheels). For example, if one wheel has traction and the other wheel is slipping, engagement of the clutch assembly allows power to be directed to the wheel having traction. Clutch elements **671** and **672** may include friction plates, pressure plates, actuators (e.g., hydraulic, electromechanical, mechanical), centrifugal elements, conical elements, a torque limiter, dampers, springs (e.g., to reduce chatter, to release engagement), dog clutch elements (e.g., for non-slip engagement), any

other suitable elements, or any combination thereof. Clutch elements **671** and **672** may partially interface to stationary component **698**, which provides a structure to transmit force. For example, a linear actuator may be used to engage the clutch assembly, and a stator of the linear actuator may be affixed to stationary component **698**. In a further example, an engagement mechanism of the clutch assembly may be affixed to stationary component **698** to provide a structure against which the engagement mechanism reacts a force.

(42) In an illustrative example, drive gears **610** and **620** may rotate about axis **699** as substantially the same speed when the vehicle is traveling straight on relatively consistent ground. During turning or under condition where one side may experience more traction or more slip, drive gears **610** and **620** may rotate at different speeds about axis **699** (e.g., drive gears **610** and **620** rotate relative to each other about axis **699**). In some such circumstances, wherein one wheel experiences slip, the clutch assembly may be engaged to transmit more power to the wheel with more traction. Accordingly, during straight-line driving, bearings **601** and **602** do not experience significant relative rotation between drive gears **610** and **620**. As drive gears **610** and **620** differ in speed (e.g., one wheel slips, or a turn is made), bearings **601** and **602** experience the relative rotation between drive gears **610** and **620**. Accordingly, in some circumstances, the clutch assembly may be engaged when the torques or rotation speeds differ between the drive gears.

(43) In a further illustrative example, during assembly, drive gears **610** and **620**, and bearings **601-604** may be assembled, and a preload may be applied along axis **699** to bearings **603** and **604**. In some embodiments, the preload also loads bearing **601**, bearing **602** or both to the extent they include tapered bearings. To illustrate, because bearings **601** and **602** engage with drive gears **610** and **620** and not stationary components, in some embodiments, a single axial preload may be applied rather than a respective axial preload applied to bearings associated with each distinct drive gear.

(44) FIG. 7 shows a cross-sectional view of illustrative drive system **700** having nested drive gears, bearings, and a clutch assembly, in accordance with some embodiments of the present disclosure. Drive system **700** is an illustrative example of arrangement **600** of FIG. 6. Drive system **700** includes drive gear **710** (e.g., having extensions **711**, **712**, and **713**), drive gear **720** (e.g., having extensions **721** and **722**), and bearings **701-704**. Drive gear **710** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3) and drive gear **720** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). In an illustrative example, bearings **701** and **702** improve stiffness to tilting for drive gears **710** and **720**.

(45) Drive gears **710** and **720** include toothed portions **751** and **752** (e.g., which may be spur, helical, or any other suitable gear type), respectively, configured to engage with corresponding toothed portions of motor gears or intermediate gears. Drive gears **710** and **720** also include output interfaces **715** and **725** (e.g., splined recesses, as illustrated), respectively, configured to engage with splined half shafts.

(46) Bearings **701-704** maintain alignment of drive gears **710** and **720** along axis **799** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **701**, **703**, and **704** are tapered roller bearings, and bearing **702** is a needle bearing. Bearing **701** is configured to react both axial and radial forces between drive gear **710** and drive gear **720**. Bearing **702** is configured to react radial forces between drive gear **710** and drive gear **720**. Extensions **711**, **713**, and **721** may include one or more features to engage with bearings **701** and **702** such as, for example, a step, splines, a keyway, any other suitable feature, or any combination thereof. For example, in some embodiments, an axial preload is applied to preload bearings **701**, **703**, and **704** in the axial direction, and such features may aid in transmitting axial preload to bearing **701**. Bearings **701**, **702**, **703**, and **704** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims, any other suitable components, or any suitable combination thereof.

(47) In some embodiments, drive system **700** is arranged in an enclosure (e.g., formed by one or

more housings that may include stationary component **798**), in which oil or other lubricant is supplied to reduce friction, provide cooling, or both, between relatively moving components. Because bearing **701** is relatively open to the enclosure, sufficient lubrication may be provided to bearing **701** by the lubrication system. Bearing **702** is shielded from the inside of the enclosure and thus might not receive adequate lubrication from the enclosure lubrication system. As illustrated, drive gear **710** includes recess **714** arranged in extension **713**. Recess **714** is configured to be loaded with grease, which under rotation of drive gear **710** experiences centrifugal forces that push the grease into bearing **702**. In some embodiments, as illustrated, seal **760** (e.g., an O-ring) or other suitable restriction is arranged between extension **713** and extension **721** to limit or prevent grease migration away from bearing **702**. In some embodiments, output interface **725** is not open to interior of extension **721**. In some embodiment, output interface **725** is open to interior of extension **721**, although an optional plug or seal may be included to partition those regions.

(48) In an illustrative example, during assembly, drive gears **710** and **720**, and bearings **701-704** may be assembled, and a preload may be applied along axis **799** to preload bearings **701**, **703**, and **704** along direction **799**. To illustrate, because bearing **701** engages with drive gears **710** and **720** and not stationary components, in some embodiments, a single axial preload may be applied to preload bearing **701**.

(49) The clutch assembly includes clutch element **771**, clutch element **772**, and actuator **773** for engaging/disengaging the clutch. As illustrated, actuator **773** is affixed to stationary component **798** (e.g., an inward extension of an intermediate housing, as illustrated). Actuator **773** is configured to linearly actuate clutch element **772**, which is affixed to drive gear **720**, thus causing clutch element **772** to engage with clutch element **771**, which is affixed to drive gear **710**. When clutch elements **771** and **772** are engaged, drive gears **710** and **720** transmit torque to each other. For example, when the clutch assembly is not engaged, drive gears **710** and **720** are driven independently by respective motors, and may rotate relatively freely with respect to each other. Further, when the clutch assembly is engaged, drive gears **710** and **720** are constrained by friction forces to rotate at the same speed, or otherwise impart azimuthal forces (torque) on each other. Accordingly, when the clutch assembly is engaged, power from both drivers (e.g., electric motors) may be transmitted among the outputs (e.g., the wheels). For example, if one wheel has traction and the other wheel is slipping, engagement of the clutch assembly allows power to be directed to the wheel having traction. Clutch elements **771** and **772** may include friction plates, pressure plates, actuators (e.g., hydraulic, electromechanical, mechanical), centrifugal elements, conical elements, a torque limiter, dampers, springs (e.g., to reduce chatter, to release engagement), dog clutch elements (e.g., for non-slip engagement), any other suitable elements, or any combination thereof. As illustrated, for example, actuator **773** engages the clutch assembly, with a stator of actuator **773** affixed to stationary component **798**. In a further example, an engagement mechanism of the clutch assembly may be affixed to stationary component **798** to provide a structure against which the engagement mechanism reacts a force.

(50) FIG. **8** shows a cross-sectional view of illustrative bearing arrangement **800** for nested drive gears **810** and **820**, and stationary component **898**, in accordance with some embodiments of the present disclosure. Arrangement **800**, as illustrated, represents a portion of a drivetrain and includes drive gear **810** (e.g., having extensions **811** and **812**), drive gear **820** (e.g., having extensions **821** and **822**), and bearings **801-804**. Drive gear **810** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**) and drive gear **820** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**). Bearings **801-804** maintain alignment of drive gears **810** and **820** along axis **899** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, extension **821** of drive gear **820** nests radially within extension **811** of drive gear **810**, and extension **811** is positioned radially inside of stationary component **898**.

(51) Bearing **801-804** may include, for example, roller bearings, needle bearings, ball bearings,

taper bearings, thrust bearings, any other suitable type of bearing, or any combination thereof. In some embodiments, bearings **803** and **804** are configured to react against a stationary component (e.g., a housing or other component) to maintain alignment of drive gears **810** and **820** relative to the stationary component. As illustrated, extension **811** overlaps axially with extension **821**, which is arranged radially within extension **811**. Because of the axial overlap of drive gears **810** and **820**, bearing **802** may be configured to transmit forces in the radial direction, axial direction, or both, between drive gears **810** and **820**. In an illustrative example, during assembly, drive gears **810** and **820**, and bearings **801-804** may be assembled, and a preload may be applied along axis **699** to bearings **603** and **604**. In some embodiments, the preload also loads bearing **801**, bearing **802**, or both to the extent they include tapered bearings.

(52) Extension **812** of drive gear **810** and extension **822** of drive gear **820** are configured to engage with respective bearings **803** and **804**, which engage with a stationary component (e.g., a housing) to maintain alignment of drive gears **810** and **820**. In some embodiments, extensions **812** and **822** are configured to be outputs, and may include output interfaces. For example, as illustrated, extensions **812** and **822** each include a recess configured to accommodate a half shaft. Drive gears **810** and **820** may include any suitable output interface such as, for example, a splined interface, a keyed interface, a flanged interface (e.g., with fasteners), a universal joint, a clutched interface, any other suitable interface, or any combination thereof.

(53) FIG. **9** shows a cross-sectional view of an illustrative drive system having nested drive gears, bearings, and a clutch assembly, in accordance with some embodiments of the present disclosure. Drive system **900** is an illustrative example of arrangement **800** of FIG. **8**, with a clutch assembly included. Drive system **900** includes drive gear **910** (e.g., having extensions **911** and **912**), drive gear **920** (e.g., having extensions **921** and **922**), bearings **901-904**, and a clutch assembly. Drive gear **910** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**) and drive gear **920** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**). In an illustrative example, bearings **901** and **902** improve stiffness to tilting for drive gears **910** and **920**.

(54) Drive gears **910** and **920** include toothed portions **951** and **952** (e.g., which may be spur, helical, or any other suitable gear type), respectively, configured to engage with corresponding toothed portions of motor gears or intermediate gears. Drive gears **910** and **920** also include output interfaces **915** and **925** (e.g., splined recesses, as illustrated), respectively, configured to engage with splined half shafts.

(55) Bearings **901-904** maintain alignment of drive gears **910** and **920** along axis **999** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **902**, **903**, and **904** are tapered roller bearings, and bearing **901** is a roller bearing. Bearing **902** is configured to react both axial and radial forces between drive gear **910** and drive gear **920**. Bearing **901** is configured to react radial forces between drive gear **910** and stationary component **99**. Extensions **911** and **921** may include one or more features to engage with bearing **902** such as, for example, a step, splines, a keyway, any other suitable feature, or any combination thereof. For example, in some embodiments, an axial preload is applied to preload bearings **902**, **903**, and **904** in the axial direction, and such features may aid in transmitting axial preload to bearing **902**. Bearings **901**, **902**, **903**, and **904** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims, any other suitable components, or any suitable combination thereof. For example, as illustrated, shim **991** is included to ensure axial loading of bearing **902** (e.g., to accommodate any tolerance stack up to ensure bearing **902** is constrained axially). In some embodiments, only a single shim is needed to provide the axial stack-up (e.g., shim **991**, as illustrated). In an illustrative example, during assembly, drive gears **910** and **920**, and bearings **901-904** may be assembled, and a preload may be applied along axis **999** to preload bearings **902**, **903**, and **904** along axis **999**. To illustrate, because bearing **902** engages with drive gears **910** and **920** and not stationary components, in some embodiments, a single axial

preload may be applied to preload bearing **902**. As illustrated, bearing **901** is configured to react radial forces between drive gear **910** and stationary component **989**. In some embodiments, bearing **902** may be reduced in size by including bearing **901** to support some radial loading.

(56) In some embodiments, drive system **900** is arranged in an enclosure (e.g., formed by one or more housings that may include stationary component **989**), in which oil or other lubricant is supplied to reduce friction, provide cooling, or both, between relatively moving components. Because bearing **901** is relatively open to the enclosure, sufficient lubrication may be provided to bearing **901** by the lubrication system. Bearing **902** is mostly shielded from the inside of the enclosure and thus might not receive adequate lubrication from the enclosure lubrication system. As illustrated, drive gear **910** includes passage **996**, which is configured to allow lubricant to reach bearing **902** from the outboard side of drive gear **910**. For example, lubricant may flow towards extension **995** of drive gear **910** (e.g., under centrifugal forces), and then flow into passage **996** to reach bearing **902**. It will be understood that drive gear **910** may include multiple passages **996** spaced around gear **910**. In some embodiment, output interface **925** is open to interior of extension **921**, although as illustrated, seal **997** is included to partition those regions.

(57) The clutch assembly includes clutch element **971**, clutch element **972**, and actuator **973** for engaging/disengaging the clutch. As illustrated, actuator **973** is affixed to stationary component **989** (e.g., an inward extension of an intermediate housing, as illustrated). Actuator **973** is configured to linearly actuate clutch element **972**, which is affixed to drive gear **920**, thus causing clutch element **972** to engage with clutch element **971**, which is affixed to drive gear **910**. When clutch elements **971** and **972** are engaged, drive gears **910** and **920** transmit torque to each other. For example, when the clutch assembly is not engaged, drive gears **910** and **920** are driven independently by respective motors, and may rotate relatively freely with respect to each other. Further, when the clutch assembly is engaged, drive gears **910** and **920** are constrained by friction forces to rotate at the same speed, or otherwise impart azimuthal forces (torque) on each other. Accordingly, when the clutch assembly is engaged, power from both drivers (e.g., electric motors) may be transmitted among the outputs (e.g., the wheels). For example, if one wheel has traction and the other wheel is slipping, engagement of the clutch assembly allows power to be directed to the wheel having traction. Clutch elements **971** and **972** may include friction plates, pressure plates, actuators (e.g., hydraulic, electromechanical, mechanical), centrifugal elements, conical elements, a torque limiter, dampers, springs (e.g., to reduce chatter, to release engagement), dog clutch elements (e.g., for non-slip engagement), any other suitable elements, or any combination thereof. As illustrated, for example, actuator **973** engages the clutch assembly, with a stator of actuator **973** affixed to stationary component **989**. In a further example, an engagement mechanism of the clutch assembly may be affixed to stationary component **989** to provide a structure against which the engagement mechanism reacts a force. Drive gear **910** may include features (e.g., splines, flats, keyways, or other suitable features) for affixing clutch element **971**. For example, extension **911** may include splines on the radially inner surface to engage clutch element **971**. Drive gear **920** may include features (e.g., splines, flats, keyways, or other suitable features) for affixing clutch element **972**. For example, extension **921** may include splines on the radially outer surface to engage clutch element **972**.

(58) FIG. **10** shows a cross-sectional view of an illustrative drive system having nested drive gears, bearings, and a clutch assembly, in accordance with some embodiments of the present disclosure. Drive system **1000** is another illustrative example of arrangement **800** of FIG. **8**, with a clutch assembly included. Drive system **1000** includes drive gear **1010** (e.g., having extensions **1011** and **1012**), drive gear **1020** (e.g., having extensions **1021** and **1022**), bearings **1001-1004**, and a clutch assembly. Drive gear **1010** is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**) and drive gear **1020** is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. **2-3**).

(59) Drive gears **1010** and **1020** include toothed portions (e.g., which may be spur, helical, or any

other suitable gear type), respectively, configured to engage with corresponding toothed portions of motor gears or intermediate gears. Drive gears **1010** and **1020** also include output interfaces **1015** and **1025** (e.g., splined recesses, as illustrated), respectively, configured to engage with splined half shafts.

(60) Bearings **1001-1004** maintain alignment of drive gears **1010** and **1020** along axis **1099** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **1002**, **1003**, and **1004** are tapered roller bearings, and bearing **1001** is a roller bearing. Bearing **1002** is configured to react both axial and radial forces between drive gear **1010** and drive gear **1020**. Bearing **1001** is configured to react radial forces between drive gear **1010** and stationary component **1098**. Extensions **1011** and **1021** may include one or more features to engage with bearing **1002** such as, for example, a step, splines, a keyway, any other suitable feature, or any combination thereof. For example, in some embodiments, an axial preload is applied to preload bearings **1002**, **1003**, and **1004** in the axial direction, and such features may aid in transmitting axial preload to bearing **1002**. Bearings **1001**, **1002**, **1003**, and **1004** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims, any other suitable components, or any suitable combination thereof. For example, as illustrated, a shim may be included to ensure axial loading of bearing **1002** (e.g., to accommodate any tolerance stack up to ensure bearing **1002** is constrained axially). In an illustrative example, during assembly, drive gears **1010** and **1020**, and bearings **1001-1004** may be assembled, and a preload may be applied along axis **1099** to preload bearings **1002**, **1003**, and **1004** along axis **1099**. To illustrate, because bearing **1002** engages with drive gears **1010** and **1020** and not stationary components, in some embodiments, a single axial preload may be applied to preload bearing **1002**. As illustrated, bearing **1001** is configured to react radial forces between drive gear **1010** and stationary component **1098**. In some embodiments, drive system **1000** is arranged in an enclosure (e.g., formed by one or more housings that may include stationary component **1098**), in which oil or other lubricant is supplied to reduce friction, provide cooling, or both, between relatively moving components.

(61) The clutch assembly includes clutch element **1071**, clutch element **1072**, and actuator **1073** for engaging/disengaging the clutch. As illustrated, actuator **1073** is affixed to stationary component **1098** (e.g., an inward extension of an intermediate housing, as illustrated). Actuator **1073** is configured to linearly actuate clutch element **1072**, which is affixed to drive gear **1020**, thus causing clutch element **1072** to engage with clutch element **1071**, which is affixed to drive gear **1010**. When clutch elements **1071** and **1072** are engaged, drive gears **1010** and **1020** transmit torque to each other. For example, when the clutch assembly is not engaged, drive gears **1010** and **1020** are driven independently by respective motors, and may rotate relatively freely with respect to each other. Further, when the clutch assembly is engaged, drive gears **1010** and **1020** are constrained by friction forces to rotate at the same speed, or otherwise impart azimuthal forces (torque) on each other. Accordingly, when the clutch assembly is engaged, power from both drivers (e.g., electric motors) may be transmitted among the outputs (e.g., the wheels). For example, if one wheel has traction and the other wheel is slipping, engagement of the clutch assembly allows power to be directed to the wheel having traction. Clutch elements **1071** and **1072** may include friction plates, pressure plates, actuators (e.g., hydraulic, electromechanical, mechanical), centrifugal elements, conical elements, a torque limiter, dampers, springs (e.g., to reduce chatter, to release engagement), dog clutch elements (e.g., for non-slip engagement), any other suitable elements, or any combination thereof. As illustrated, for example, actuator **1073** engages the clutch assembly, with a stator of actuator **1073** affixed to stationary component **1098**. In a further example, an engagement mechanism of the clutch assembly may be affixed to stationary component **1098** to provide a structure against which the engagement mechanism reacts a force.

(62) FIG. **11** shows a cross-sectional view of illustrative bearing system **1100** for intermediate gears **1110** and **1120** of a drive system, in accordance with some embodiments of the present disclosure.

Bearing system **1100** includes bearings **1101-1104** configured to maintain alignment of intermediate gear **1110** and intermediate gear **1120** (e.g., and also wheel gear **1130** and wheel gear **1140**). Wheel gear **1130**, which is rigidly affixed to intermediate gear **1110**, is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). Wheel gear **1140**, which is rigidly affixed to intermediate gear **1120**, is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). To illustrate, intermediate gears **1110** and **1120** may engage with respective drive gears of the drive system.

(63) Bearings **1101-1104** maintain alignment of intermediate gears **1110** and **1120** along axis **1199** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **1102**, **1103**, and **1104** are tapered roller bearings, and bearing **1101** is a roller bearing. Bearing **1102** is configured to react both axial and radial forces between intermediate gear **1110** and intermediate gear **1120**. Bearing **1101** is configured to react radial forces between intermediate gears **1110** and **1120**, and stationary component **1198**. Intermediate gears **1110** and **1120** may include one or more features to engage with bearing **1102** such as, for example, a step (as illustrated), splines, a keyway, any other suitable feature, or any combination thereof. For example, in some embodiments, an axial preload is applied to preload bearings **1102**, **1103**, and **1104** in the axial direction, and such features may aid in transmitting axial preload to bearing **1102**. Bearings **1101**, **1102**, **1103**, and **1104** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims (e.g., such as shim **1191** configured to retain bearing **1101**), any other suitable components, or any suitable combination thereof. As illustrated, bearings **1101** and **1102** share an intermediate structure that includes respective races for the bearings. Bearings **1101** and **1102** also include non-shared races. In an illustrative example, during assembly, intermediate gears **1110** and **1120**, and bearings **1101-1104** may be assembled, and a preload may be applied along axis **1199** to preload bearings **1102**, **1103**, and **1104** along direction **1199**. To illustrate, because bearing **1102** engages with intermediate gears **1110** and **1120** and not stationary components, in some embodiments, a single axial preload may be applied to preload bearing **1102**. As illustrated, bearing **1101** is configured to react radial forces between intermediate gears **1110** and **1120**, and stationary component **1198**.

(64) In some embodiments, bearing system **1100** is arranged in an enclosure (e.g., formed by one or more housings that may include stationary component **1198**), in which oil or other lubricant is supplied to reduce friction, provide cooling, or both, between relatively moving components. For example, as illustrated, housing **1151**, housing **1152**, and stationary component **1198** (e.g., an intermediate housing) form the enclosure.

(65) FIG. 12 shows a cross-sectional view of illustrative bearing system **1200** for intermediate gears **1210** and **1220** of a drive system, in accordance with some embodiments of the present disclosure. Bearing system **1200** includes bearings **1201-1204** configured to maintain alignment of intermediate gear **1210** and intermediate gear **1220** (e.g., and also wheel gear **1230** and wheel gear **1240**). Wheel gear **1230**, which is rigidly affixed to intermediate gear **1210**, is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). Wheel gear **1240**, which is rigidly affixed to intermediate gear **1220**, is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). To illustrate, intermediate gears **1210** and **1220** may engage with respective drive gears of the drive system.

(66) Bearings **1201-1204** maintain alignment of intermediate gears **1210** and **1220** along axis **1299** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **1202**, **1203**, and **1204** are tapered roller bearings, and bearing **1201** is a ball bearing. Bearing **1202** is configured to react both axial and radial forces between intermediate gear **1210** and intermediate gear **1220**. Bearing **1201** is configured to react radial forces between intermediate gears **1210** and **1220**, and stationary component **1298**. Intermediate gears **1210** and **1220** may include one or more features to engage with bearing **1202** such as, for example, a step (as illustrated), splines, a keyway, any other suitable feature, or any combination thereof. For

example, in some embodiments, an axial preload is applied to preload bearings **1202**, **1203**, and **1204** in the axial direction, and such features may aid in transmitting axial preload to bearing **1202**. Bearings **1201**, **1202**, **1203**, and **1204** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims (e.g., such as shim **1291** configured to retain bearing **1201**), any other suitable components, or any suitable combination thereof. As illustrated, bearings **1201** and **1202** share an intermediate structure that includes respective races for the bearings. Bearings **1201** and **1202** also include non-shared races. In an illustrative example, during assembly, intermediate gears **1210** and **1220**, and bearings **1201-1204** may be assembled, and a preload may be applied along axis **1299** to preload bearings **1202**, **1203**, and **1204** along direction **1299**. To illustrate, because bearing **1202** engages with intermediate gears **1210** and **1220** and not stationary components, in some embodiments, a single axial preload may be applied to preload bearing **1202**. As illustrated, bearing **1201** is configured to react radial forces between intermediate gears **1210** and **1220**, and stationary component **1298**.

(67) In some embodiments, bearing system **1200** is arranged in an enclosure (e.g., formed by one or more housings that may include stationary component **1298**), in which oil or other lubricant is supplied to reduce friction, provide cooling, or both, between relatively moving components. For example, as illustrated, housing **1251**, housing **1252**, and stationary component (e.g., an intermediate housing) form the enclosure.

(68) FIG. **13** shows a cross-sectional view of illustrative bearing system **1300** for intermediate gears **1310** and **1320** of a drive system, in accordance with some embodiments of the present disclosure. Bearing system **1300** includes bearings **1301-1305** configured to maintain alignment of intermediate gear **1310** and intermediate gear **1320** (e.g., and also wheel gear **1330** and wheel gear **1340**). Wheel gear **1330**, which is rigidly affixed to intermediate gear **1310**, is driven by a first motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). Wheel gear **1340**, which is rigidly affixed to intermediate gear **1320**, is driven by a second motor (e.g., in a similar arrangement as illustrated in FIGS. 2-3). To illustrate, intermediate gears **1310** and **1320** may engage with respective drive gears of the drive system.

(69) Bearings **1301-1305** maintain alignment of intermediate gears **1310** and **1320** along axis **1399** during rotation and loading (e.g., axial loading, radial loading, and azimuthal loading). As illustrated, bearings **1302**, **1303**, **1304**, and **1305** are tapered roller bearings, and bearing **1301** is a ball bearing. Bearings **1302** and **1305** are configured to react both axial and radial forces between intermediate gear **1310** and intermediate gear **1320**. Bearing **1301** is configured to react radial forces between intermediate gears **1310** and **1320**, and stationary component **1398**. Intermediate gears **1310** and **1320** may include one or more features to engage with bearing **1302** such as, for example, a step (as illustrated), splines, a keyway, any other suitable feature, or any combination thereof. For example, in some embodiments, an axial preload is applied to preload bearings **1302**, **1305**, **1303**, and **1304** in the axial direction, and such features may aid in transmitting axial preload to bearings **1302** and **1305**. Bearings **1301**, **1302**, **1303**, **1304**, and **1305** each include races (e.g., inner and outer, which may include any suitable profile), a plurality of rollers, one or more spacers, shims, any other suitable components, or any suitable combination thereof. As illustrated, bearings **1301**, **1302**, and **1305** share an intermediate structure that includes respective races for the bearings. Bearings **1301**, **1302**, and **1305** also include non-shared races. In an illustrative example, during assembly, intermediate gears **1310** and **1320**, and bearings **1301-1305** may be assembled, and a preload may be applied along axis **1399** to preload bearings **1302**, **1303**, **1304**, and **1305** along direction **1399**. To illustrate, because bearings **1302** and **1305** engages with intermediate gears **1310** and **1320** and not stationary components, in some embodiments, a single axial preload may be applied to preload bearings **1302** and **1305**. As illustrated, bearing **1301** is configured to react radial forces between intermediate gears **1310** and **1320**, and stationary component **1398**.

(70) In some embodiments, bearing system **1300** is arranged in an enclosure (e.g., formed by one or more housings that may include stationary component **1398**), in which oil or other lubricant is

supplied to reduce friction, provide cooling, or both, between relatively moving components. For example, as illustrated, housing **1351**, housing **1352**, and stationary component (e.g., an intermediate housing) form the enclosure.

(71) FIG. **14** shows a cross-sectional perspective view of illustrative bearing assembly **1400**, in accordance with some embodiments of the present disclosure. As illustrated, bearing assembly **1400** includes element **1401**, element **1402**, element **1404**, ball rollers **1403**, rollers **1405**, spacer **1406**, surface **1410**, and surface **1420**. Ball rollers **1403** are configured to roll between element **1401** (e.g., which includes an outer race having a curved groove extending azimuthally around the bearing to accommodate ball rollers **1403**, as illustrated) and element **1402** (e.g., which includes an inner race having a curved groove extending azimuthally around the bearing to accommodate ball rollers **1403**, as illustrated). For example, ball rollers **1403** are part of a ball bearing. Rollers **1405** are configured to roll between element **1402** (e.g., which includes an outer race for rollers **1405**) and element **1404** (e.g., which includes an inner race for rollers **1405**), with spacer **1406** constraining the spacing and trajectory of rollers **1405**. For example, rollers **1405** are part of a tapered roller bearing. In an illustrative example, a bearing assembly such as bearing assembly **1400** is included in bearing system **1200** of FIG. **12** as bearings **1201** and **1202**. The tapered roller bearing is configured to react axial and radial loads. The ball bearing is configured to react radial loads and to a lesser extent axial loads. Element **1404** includes surface **1410** for interfacing to a shaft (e.g., of an intermediate gear or any other suitable gear). Element **1402** includes surface **1420** for interfacing to, for example, an opposing shaft (e.g., of an intermediate gear or any other suitable gear).

(72) In an illustrative example, the drivetrains of the present disclosure may be combined or otherwise modified in accordance with the present disclosure. For example, one or more components may be added to a drivetrain (e.g., a clutch, a bearing, an extension), removed from a drivetrain, or combined with components of other embodiments.

(73) The foregoing is merely illustrative of the principles of this disclosure, and various modifications may be made by those skilled in the art without departing from the scope of this disclosure. The above-described embodiments are presented for purposes of illustration and not of limitation. The present disclosure also can take many forms other than those explicitly described herein. Accordingly, it is emphasized that this disclosure is not limited to the explicitly disclosed methods, systems, and apparatuses, but is intended to include variations to and modifications thereof, which are within the spirit of the following claims.

Claims

1. A drive system comprising: a first bearing arranged between a first drive gear and a second drive gear that axially overlap each other; and a second bearing arranged radially between the first drive gear and a stationary component and axially between first gear teeth of the first drive gear and second gear teeth of the second drive gear.
2. The drive system of claim 1, wherein the stationary component is a housing configured to house the first drive gear and the second drive gear, the drive system further comprising: a third bearing arranged between the first drive gear and the housing; and a fourth bearing arranged between the second drive gear and the housing.
3. The drive system of claim 2, wherein: the third bearing comprises a tapered roller bearing configured to react axial loads of the first drive gear; and the fourth bearing comprises a tapered roller bearing configured to react axial loads of the second drive gear.
4. The drive system of claim 1, wherein: the first bearing is arranged radially within a first extension of the first drive gear; and the second bearing is arranged radially outside of the first extension.
5. The drive system of claim 1, wherein the first drive gear further comprises a passage configured

to allow a lubricant to flow to the first bearing.

6. The drive system of claim 1, wherein the first bearing comprises a tapered roller bearing between the first drive gear and the second drive gear.

7. A drive system comprising: a first bearing arranged between a first drive gear and a second drive gear that axially overlap each other; a second bearing arranged radially between the first drive gear and a stationary component and axially between first gear teeth of the first drive gear and second gear teeth of the second drive gear; and a clutch assembly arranged between the first drive gear and the second drive gear.

8. The drive system of claim 7, wherein the clutch assembly comprises: a first element affixed to the first drive gear; a second element affixed to the second drive gear; and an actuator configured to engage the first element with the second element.

9. The drive system of claim 7, wherein: the first drive gear is geared to a first motor; the second drive gear is geared to a second motor; and when the clutch assembly is engaged, the first motor and the second motor drive both the first drive gear and the second drive gear.

10. The drive system of claim 7, further comprising: a third bearing arranged between the first drive gear and the stationary component; and a fourth bearing arranged between the second drive gear and the stationary component.
