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Trumpet arm with internal buttresses

Abstract

Described herein is a trumpet arm for use in an electric drive axle. In one embodiment, the trumpet arm comprises a housing with an arm section extending an arm length, the arm section having an outlet at a first end, and a flange with a planar face at a second end opposite the first end. The trumpet arm further comprises internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) The present application claims priority to U.S. Provisional Application No. 63/582,182, entitled “TRUMPET ARM WITH INTERNAL BUTTRESSES”, and filed on Sep. 12, 2023. The entire contents of the above-listed application are hereby incorporated by reference for all purposes.

TECHNICAL FIELD

(1) The present description relates generally to a trumpet arm for an axle of an electric vehicle (EV).

BACKGROUND AND SUMMARY

(2) Axle assemblies are adapted to transmit rotational power from a rotational power source of a vehicle to the wheels thereof. Typically, an axle assembly includes a differential assembly that is rotatably supported within a non-rotating housing (e.g., carrier). The differential is connected between an input drive shaft extending from the rotational power source/transmission and a pair of output axle shafts extending to the vehicle wheels. The axle shafts are contained in respective non-rotating beam housing portions, which are secured to a central housing. Thus, rotation of the differential by the drive shaft causes corresponding rotation of the axle shafts. The central housing and the beam housing portions form an axle housing for these drive train components of the axle assembly, with the differential and the axle shafts supported for rotation therein.

(3) One type of axle housing includes a unitized central housing construction, commonly referred to as a Salisbury axle assembly. In this structure, the central housing (which houses the differential assembly) is directly connected to the two beam tube portions (which house the rotatable axle shafts). Another type of axle housing includes a central housing construction which is continuous with two arm portions, where each of the arm portions form a smooth, gradual, flared connection with the central housing. This central portion is generally hollow and cylindrical in shape, having a large generally circular opening formed therethrough. The overall shape of this type of axle housing generally resembles the shape of a banjo musical instrument. Hence, this type of axle housing is commonly referred to as a banjo type axle housing.

(4) As electric vehicles move towards the use of electric axles, traditional banjo and Salisbury axles with their streamlined housings may not provide enough room to package all of the components needed for an electric axle, such as one or more motors, gears, shafts, bearings, shift actuators, differentials, pumps, heat exchangers, filters, sensors, and so on. For example, the long, gradual transition from the arm section to the bowl of a banjo axle may distribute a road load in a y-z plane (e.g., perpendicular to a drive surface) and reduce stresses on the banjo axle. Some banjo axles may include a stiffening ring within the bowl to further stiffen the bowl in the y-z plane. However, the shape of the bowl, both with and without the stiffening ring, may provide a space which is smaller than is desired for packaging electric axle components therein. The geometry of a Salisbury axle may similarly restrict a space for packaging electric axle components to a curved space which is smaller than is desired for the electric axle components. Thus, there is demand for an axle which provides a desirable amount and shape of space in which to package electric axle components. A rectangular packaging envelope may be desired to package electric axle components, for example, however the rectangular shape may impinge on structural reinforcements (e.g., the stiffening ring, the long, gradual transition) of the banjo axle and/or the Salisbury axle.

(5) A potential solution is an axle with a gearbox housing having relatively flat sides and two trumpet arms extending along an output axle axis. This may help achieve a packaging space demanded to fit electric axle components. However, challenges arise where an arm of a trumpet arm meets a flange of the trumpet arm (e.g., a flange/arm transition), where the flange is used to bolt the trumpet arm to the gearbox housing. The flange/arm transition is a high-stress region. However, decreasing a length of the arm is undesirable, as the full arm length may be used to enable integration of multiple different suspension mounting packages. Maintaining a desired length of the arm while providing a desirable packaging space may prevent the trumpet arm from

having a gradual transition, a long chamfer, or external gussets to assist in stiffening and strengthening the flange/arm transition.

(6) Described herein is an axle housing configured as a trumpet arm having internal buttresses as a means to help stiffen and strengthen the flange/arm transition while still maintaining a desired length of the arm section. For example, a trumpet arm comprises a housing with an arm section extending an arm length, the arm section having an outlet at a first end, and a flange with a planar face at a second end opposite the first end. The trumpet arm further comprises internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length. In some embodiments, the trumpet arm further comprises external buttresses (gusset, trusses), where external buttresses extend at least a second portion of the flange length and where endpoints of the internal buttresses and external buttresses are offset from each other. The flange may include a curved extension or an angled extension from the planar face to the flange/arm transition. In this way, the flange/arm transition may be desirably resistant to degradation due to deflection of the arm during use of the trumpet arm in a vehicle axle. Further, the planar face of the flange provides a rectangular envelope in which components of an electric axle may be positioned, which may enable use of the trumpet arm in an e-axle for an electric vehicle (e.g., electric vehicle, hybrid electric vehicle, and/or plug-in electric vehicle).

(7) It should be understood that the summary above is provided to introduce in simplified form a selection of concepts that are further described in the detailed description. It is not meant to identify key or essential features of the claimed subject matter, the scope of which is defined uniquely by the claims that follow the detailed description. Furthermore, the claimed subject matter is not limited to implementations that solve any disadvantages noted above or in any part of this disclosure.

Description

BRIEF DESCRIPTION OF THE FIGURES

- (1) FIG. 1 shows a schematic representation of an electric drive system with trumpet arms.
- (2) FIG. 2 shows a perspective view of an electric drive system, according to one example, which includes two trumpet arms.
- (3) FIG. 3 shows a profile view of the electric drive system, according to one example.
- (4) FIG. 4 shows perspective views of a trumpet arm.
- (5) FIG. 5 shows profile views of the trumpet arm of FIG. 4.
- (6) FIG. 6 shows a cross section view of the trumpet arm.
- (7) FIG. 7 shows a first perspective view of a trumpet arm with a spindle.
- (8) FIG. 8 shows a second perspective view of the trumpet arm with the spindle of FIG. 7.
- (9) FIG. 9 shows a cross section view of the trumpet arm with the spindle.
- (10) FIG. 10 shows a perspective view of a trumpet arm with a spindle and a differential lock/axle disconnect assembly.
- (11) FIG. 11 shows a cross section view of the trumpet arm with the spindle and the differential lock/axle disconnect assembly of FIG. 10.
- (12) FIG. 12 shows schematic representations of load distribution by internal buttresses of a trumpet arm.
- (13) FIG. 13 shows example orientations of internal buttresses and cross sections of an arm section of a trumpet arm.
- (14) FIGS. 14A and 14B show perspective views of a trumpet arm with a curved flange.
- (15) FIG. 15 shows a first set of profile views of the trumpet arm with the curved flange of FIGS. 14A and 14B.

(16) FIG. 16 shows a second set of profile views of the trumpet arm with the curved flange.

(17) FIG. 17 shows a cross section view of the trumpet arm with the curved flange.

(18) FIG. 18 shows a perspective view of a trumpet arm with a curved flange and a spindle.

(19) FIG. 19 shows a profile view of the trumpet arm with the curved flange and the spindle of FIG. 18.

(20) FIG. 20 shows a cross section view of the trumpet arm with the curved flange and the spindle.

DETAILED DESCRIPTION

(21) The following description relates to systems for an electric axle and, specifically, a trumpet arm comprising a housing with an arm section extending an arm length, the arm section having an outlet at a first end, and a flange with a planar face at a second end opposite the first end. The trumpet arm further comprises internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length. The internal buttresses provide strength and rigidity to the trumpet arm. The flange with the planar face enables formation of a rectangular space between two trumpet arms configured as described herein, where electric axle components may be positioned in the rectangular space. Further, the arm section length is configured to enable mounting of different sized and shaped suspension packages thereon. The configuration of the trumpet arm enables electric axle components to be included in the electric drive axle (e.g., e-axle) while achieving a desired rigidity and strength of the trumpet arm.

(22) The trumpet arm may have different embodiments, as further described herein, which are configured to provide a desirable amount of space, rigidity, and resistance to degradation with respect to a system in which the trumpet arm is included. For example, a body of the flange may be angled and include external buttresses (gussets, trusses) in some embodiments, while in other embodiments, the body of the flange may be curved, where a convex or concave side of the body of the flange is coupled to the arm. The internal buttresses may have a variety of configurations comprised of two or more legs (e.g., “x” configuration, “y” configuration, and so on), where different configurations may be used in different vehicle applications. Additionally, a cross section (e.g., rectangular, circular, and so on) of the arm section may be different for different vehicle applications. Embodiments of the trumpet arm described herein may be used in an e-axle, where a first trumpet arm and a second trumpet arm are coupled to an electric machine via the flange of each trumpet arm. Further, a sizing of the arm section (e.g., the arm length, the cross section of the arm section) may enable mounting of different suspension packages on the trumpet arm. The e-axle may also include a differential lock/axle disconnect assembly in one or more of the trumpet arms which is coupled to a differential and used to control rotational power outlet from the electric machine to wheels of the e-axle. As further described herein, inclusion of reinforcing buttresses (e.g., internal buttresses and external buttresses) may provide rigidity at pivot points (e.g., stress points) of the trumpet arm. In this way, the trumpet arm described herein provides a geometry which enables mounting of electric machine components and suspension packages on an e-axle, while also providing a strength and rigidity which may protect against degradation of the trumpet arm due to deflective force stresses.

(23) FIG. 1 schematically depicts an electric drive system in a vehicle with at least one trumpet arm used for an e-axle of the electric drive system, where the trumpet arm is configured as described herein and acts as a non-rotating beam housing portion in which rotatable axle shafts are contained. FIGS. 2 and 3 show views of an electric drive system (e.g., of FIG. 1) wherein a first trumpet arm and a second trumpet arm are positioned to form a rectangular space in which a main gearbox housing may be positioned and coupled to each of the first trumpet arm and the second trumpet arm. FIGS. 4-11 show different profile, perspective, and cross section views of a trumpet arm which may be included in the systems of FIGS. 1-3, including embodiments of the trumpet arm which include additional components, such as a spindle and a differential lock/axle disconnect

assembly. FIG. 12 shows schematic representations of load reactions by internal buttresses of a trumpet arm (e.g., of FIGS. 4-11). FIG. 13 shows illustrations of different embodiments of cross sections of the arm section and different orientations of internal buttresses of the trumpet arm. FIGS. 14A-20 show different profile, perspective, and cross section views of a second embodiment of a trumpet arm where the flange of the trumpet arm has a curved geometry. The second embodiment of the trumpet arm of FIGS. 14A-20 may be included in the systems of FIGS. 1-3. FIGS. 14A-16 show perspective and profile views, and FIG. 17 shows a cross section view of the second embodiment of the trumpet arm. FIGS. 18-20 show perspective views and a cross sectional view of the second embodiment of the trumpet arm with a spindle. FIGS. 2-11 and 14A-20 are drawn approximately to scale. However, other relative component dimensions may be used, in other embodiments.

(24) FIG. 1 schematically illustrates an electric vehicle **100** with an electric drive system **102** that provides power to and/or is incorporated into an axle assembly **104** of vehicle **100**. The vehicle **100** may take a variety of forms in different examples, such as a light, medium, or heavy duty vehicle. Additionally, the electric drive system **102** may be adapted for use in front and/or rear axles, as well as steerable and non-steerable axles. To generate power, the electric drive system **102** may include an electric machine **106**. In some examples, the electric machine **106** may be an electric motor-generator and may thus include conventional components such as a rotor, a stator, and the like housed within an electric machine housing **107** for generating mechanical power as well as electric power during a regenerative mode, in some cases. Further, in other examples, the vehicle **100** may include an additional motive power source, such as an internal combustion engine (ICE) (e.g., a spark and/or compression ignition engine), for providing power to another axle. As such, the electric drive system **102** may be utilized in an electric vehicle (EV), such as a hybrid electric vehicle (HEV) or a battery electric vehicle (BEV).

(25) In some examples, the electric machine housing **107** may be coupled (e.g., via bolts) to a gearbox housing **109** of a gearbox **108**. Further, the electric machine **106** may provide mechanical power to a differential **110** via the gearbox **108**. From the differential **110**, mechanical power may be transferred to drive wheels **112**, **114** (e.g., a first wheel **112**, a second wheel **114**) by way of axle shafts **117**, **115**, respectively, of the axle assembly **104**. As such, the differential **110** may distribute torque, received from the electric machine **106** via the gearbox **108**, to the drive wheels **112**, **114** of the axle shafts **117**, **115**, respectively, during certain operating conditions. In some examples, the differential **110** may be a locking differential, an active or passive limited slip differential, or a torque vectoring differential.

(26) One or both of the axle shafts **117**, **115** may be housed in a trumpet arm, as further described herein. For example, axle shaft **117** is housed in a first trumpet arm **118**, and axle shaft **115** is housed in a second trumpet arm **116**. Each of the first trumpet arm **118** and the second trumpet arm **116** have the same configuration for a trumpet arm, which comprises: a housing with an arm section **162** extending an arm length, the arm section having an outlet at a first end, and a flange **164** with a planar face at a second end opposite the first end; and internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length. Each of the first trumpet arm **118** and the second trumpet arm **116** may be coupled to the differential **110** at a respective planar face of the flange.

(27) In some embodiments, axle assembly **104** includes additional elements which are coupled to, mounted on, or otherwise joined with at least one of the first trumpet arm **118** and the second trumpet arm **116**. For example, a suspension package **152** may be mounted on both of the first trumpet arm **118** and the second trumpet arm **116** along the respective arm section **162**. In some embodiments, a spindle **154** may be coupled to the outlet of each of the first trumpet arm **118** and the second trumpet arm **116**. For example, a first spindle end of the spindle **154** may be coupled to the respective trumpet arm, and drive wheels (e.g., the first wheel **112** or the second wheel **114**)

may be coupled to each of the first spindle and the second spindle at a second spindle end of the respective spindle, opposite the first spindle end of the spindle.

(28) As further described herein, one or more of the first trumpet arm **118** and the second trumpet arm **116** may also include a differential lock/axle disconnect assembly positioned in a body of the flange **164**. The differential lock/axle disconnect assembly may be configured to selectively mate with a mating clutch of the differential **110** and/or the gearbox **108**, respectively.

(29) The gearbox **108** may be a single-speed gearbox, where the gearbox **108** operates in one gear ratio. However, other gearbox arrangements have been envisioned such as a multi-speed gearbox that is designed to operate in multiple distinct gear ratios. Further, in one example, the electric machine **106**, the gearbox **108**, and the differential **110** may be incorporated into the axle **104**, forming an electric axle (e-axle) in the vehicle **100**. The e-axle, among other functions, provides motive power to the wheels **112**, **114** during operation. Specifically, in the e-axle embodiment, the electric machine **106** and gearbox **108** may be coupled to and/or otherwise supported by the first trumpet arm **118** and the second trumpet arm **116**. The e-axle may provide a compact arrangement for delivering power directly to the axle **104**. For example, the first trumpet arm **118** may be coupled to a first side of the gearbox housing **109** and the second trumpet arm **116** may be coupled to a second side of the electric machine housing **107**, opposite the first side, as further described with respect to FIGS. 2-3.

(30) The electric drive system **102** may further include an oil circuit **120** for circulating oil (e.g., natural and/or synthetic oil) through the gearbox housing **109** to lubricate and/or cool various system components. The oil circuit **120** may include a filter **123** and an oil pump **124** that draws oil from an oil reservoir **111** (e.g., a sump) in the gearbox housing **109**, via an outlet **122**, and drives a pressurized oil flow through a delivery line **126** to an inlet **128** of the gearbox housing **109**. In some examples, the oil pump **124** may be provided at an exterior portion of the gearbox housing **109**. However, in other examples, the oil pump may be included within the gearbox housing **109**. Various distribution components and arrangements (e.g., nozzles, valves, jets, oil passages, and the like) of the oil circuit **120** may be included within the electric drive system **102** in order to facilitate routing of the oil within the gearbox housing **109** and, in one particular example, to a portion of the electric machine housing **107**. In some case, the oil circuit **120** may be used for routing oil to various gearbox bearings and gears as well as the motor stator, motor rotor, and rotor shaft bearings of the electric machine **106**, thereby providing an efficient system for effectively using the gearbox oil to cool said systems. In some embodiments, the oil circuit **120** may further include a heat exchanger (e.g., radiator) which removes heat from the oil that exits the gearbox housing **109** by way of the outlet **122**.

(31) The electric drive system **102** may further include a coolant circuit **130** that circulates coolant (e.g., water, glycol, and/or oil) through coolant passages **131** formed in the electric machine **106** or electric machine housing **107**. The coolant circuit **130** may include a coolant inlet **138** and a coolant outlet **132** positioned on (or in) the electric machine housing **107**. The coolant circuit **130** may further include a filter **133** and a pump **134** that circulates coolant from the coolant outlet **132** to the coolant inlet **138** via a coolant delivery line **136**. From the coolant inlet **138**, the coolant travels into the coolant passages **131** formed in the electric machine **106** or the electric machine housing **107** which removes heat from components of the electric machine **106**. In some examples, the coolant circuit **130** may further include a heat exchanger (e.g., radiator) which removes heat from the coolant that exits the electric machine housing **107** by way of the coolant outlet **132**.

(32) The vehicle **100** may also include a control system **140** with a controller **141**. The controller **141** may include a processor **142** and a memory **144**. The memory may hold instructions stored therein that when executed by the processor cause the controller **141** to perform various methods, control techniques, and the like described herein. The processor **142** may include a microprocessor unit and/or other types of circuits. The memory **144** may include known data storage mediums such as random access memory, read only memory, keep alive memory, combinations thereof, and the

like. The controller **141** may receive various signals from sensors **146** positioned in different locations in the vehicle **100** and electric drive system **102**. The controller **141** may also send control signals to various actuators **148** coupled at different locations in the vehicle **100** and electric drive system **102**. For instance, the controller **141** may send command signals to the oil pump **124** and/or the pump **134** and, in response, the actuator(s) in the pump(s) may be adjusted to alter the flowrate of the oil and/or coolant delivered therefrom. In other examples, the controller may send control signals to the electric machine **106**, and in response to receiving the command signals, the electric machine may be adjusted to alter a rotor speed or torque. The other controllable components in the system may be operated in a similar manner with regard to sensor signals and actuator adjustment.

(33) An axis system **150** is provided in FIG. **1**, as well as FIGS. **2-20**, for reference. The z-axis may be a vertical axis (e.g., parallel to a gravitational axis), the x-axis may be a longitudinal axis (e.g., horizontal axis), and/or the y-axis may be a lateral axis, in one example. However, the axes may have other orientations, in other examples.

(34) FIG. **2** depicts an example electric drive system **200** with electric axle components **202** for providing power to an axle assembly **204**. The electric axle components **202** of the electric drive system **200** may include an electric machine **206** operatively coupled to a gearbox **208**, and may be included in a vehicle, such as the vehicle **100** depicted in FIG. **1**. The electric drive system **200** may thus share similarities with the electric drive system **102**. For instance, at least a portion of the components discussed with regard to the drive system **102**, shown in FIG. **1**, may be included in the electric drive system **200**, shown in FIG. **2**, or vice versa.

(35) The axle assembly **204** includes a first trumpet arm **216** and a second trumpet arm **218**, both of which are examples of a trumpet arm comprising a housing **212** with an arm section **222** extending an arm length, the arm section **222** having an outlet at a first end, and a flange **214** with a planar face **228** at a second end opposite the first end, and further including internal buttresses (not shown in FIG. **2**) positioned in an interior of the housing **212** and extending through at least a first portion of a flange length of the flange **214**, a flange/arm transition at which the flange transitions into the arm section **222**, and at least a portion of the arm length. The planar face of the flange **214** enables positioning of electric axle components **202**, such as the electric machine **206**, the gearbox **208**, and/or a differential (not shown in FIG. **2**) in the axle assembly **204** while achieving a desired strength and rigidity of the axle assembly **204** which distributes a road load and reduce stresses on the trumpet arms, as further described herein.

(36) The electric machine **206** may include an electric machine housing **207**, which is coupled to a gearbox housing **209** of the gearbox **208**. In some cases, the electric machine housing **207** may be coupled to the gearbox housing **209** via any suitable attachment mechanism (e.g., bolts, brackets, welds, and/or combinations thereof), such as bolts **211**. As further described herein, the flange **214** of each of the first trumpet arm **216** and the second trumpet arm **218** includes multiple through holes around a perimeter of the flange **214** at the planar face. Bolts **211** may extend through each of the multiple through holes and couple the first trumpet arm **216** and the second trumpet arm **218** to the gearbox housing **208**. In other embodiments, the first trumpet arm **216** and the second trumpet arm **218** may be additionally or alternatively coupled to the electric machine housing **207**. Each of the first trumpet arm **216**, the second trumpet arm **218**, the electric machine housing **207**, and the gearbox housing **209** may be made of a metal (e.g., aluminum, steel, iron, combinations thereof, and the like) which may be the same or a different metal for each housing.

(37) The electric machine **206** may provide power to a differential (not shown) via the gearbox **208** to provide rotational power to a first axle shaft and a second axle shaft (to which drive wheels may be coupled) of the axle assembly **204**. The first axle shaft and the second axle shaft are not shown in FIG. **2**, and are to be understood as being at least partially enclosed within the housing **212** of the first trumpet arm **216** and the second trumpet arm **218**, respectively. In some embodiments, each of the first trumpet arm **216** and the second trumpet arm **218** have a spindle coupled to the housing **212** at the outlet of the arm section **222**. For example, a first spindle **224** is coupled to the first

trumpet arm **216** and a second spindle **226** is coupled to the second trumpet arm **218** at an outlet **220** of each trumpet arm, as further described with respect to FIG. 3. A drive wheel may be mounted on each of the first spindle **224** and the second spindle **226**, and the first axle shaft and the second axle shaft may extend through each of the first spindle **224** and the second spindle **226**, respectively, to drive rotation of the respective drive wheel.

(38) In the embodiment of a trumpet arm shown in FIG. 2, either or both of the first trumpet arm **216** and the second trumpet arm **218** may be configured with a differential lock/axle disconnect assembly **260**, which may be at least partially enclosed within the respective housing **212**. As further described herein with respect to FIGS. 7 and 10, the differential lock/axle disconnect assembly **260** may selectively mate with a mating clutch of the differential to selectively couple the axle shaft extending through the respective trumpet arm to the differential, or in other instances selectively mate with a mating clutch of the gearbox **208** to selectively decouple the axle shaft extending through the respective trumpet arm from the power path.

(39) FIG. 3 shows a profile view **300** of the electric drive system **200**, including the first trumpet arm **216**, the second trumpet arm **218**, and electric axle components **202**. As described with respect to FIG. 2, each of the first trumpet arm **216** and the second trumpet arm **218** have the same configuration and include the flange **214** with the planar face **228** at a first end **302** of the housing **212** and the outlet **220** at a second end **304**, opposite the first end **302**. The arm section **222** extends between the flange **214** and the outlet **220**, and intersects with the flange **214** at a flange/arm transition **306**. In the embodiment of the electric drive system **200** shown in FIGS. 2 and 3, and as further described with respect to FIGS. 4-12 the flange **214** includes an angled extension from the planar face **228** to the flange/arm transition **306**. In other embodiments, such as described with respect to FIGS. 14A-20, the flange **214** may include a curved extension from the planar face **228** to the flange/arm transition **306**.

(40) The flange/arm transition **306** is a high stress region due to the abrupt junction between the flange **214** and the arm section **222**, compared to a gradual transition between a flange and an arm section in axles such as the banjo axle and the Salisbury axle. For example, as a vehicle (e.g., the vehicle **100** of FIG. 1) including the electric drive system **200** with drive wheels coupled to each of the first spindle **224** and the second spindle **226** of the axle assembly **204** travels down a road, the drive wheels may drive over bumps and/or holes in the road which cause the vehicle and thus the trumpet arms to move up and down along the z-axis, with reference to the axis system **150**. This may create stress at the flange/arm transition **306**, which may lead to degradation of the respective trumpet arm at the flange/arm transition **306**.

(41) The trumpet arms described herein are configured with internal buttresses, and in some embodiments external buttresses (gussets, trusses), to assist in mitigating stress at the flange/arm transition **306**. As further described herein with respect to FIGS. 4-20, internal buttresses positioned inside the housing **212** may extend at least a first portion of a flange length **308** of the flange **214**, through the flange/arm transition **306**, and at least a portion of an arm length **312** of the arm section **222**. As shown in FIGS. 2-3, the arm section **222** has a rectangular shape with a rectangular cross section in the z-x plane, with respect to the axis system **150**. As described with respect to FIG. 13, the arm section may have a cross section which is a square, circle, oval, hour glass, or other shape in other embodiments of the trumpet arm. The different cross sections of the arm section **222** are configured to enable different configurations of internal buttresses formed two or more legs, as further described with respect to FIG. 13. The cross section of the arm section may maintain a constant profile through the arm length **312**. Additionally, the outlet **220** of the trumpet arm (e.g., the first trumpet arm **216** and the second trumpet arm **218**) may be annular, as shown herein, or may have the same shape as the cross section of the arm section **222** in other embodiments. For example, the outlet **220** of the arm section **222** may be configured to have a spindle (e.g., the first spindle **224**, the second spindle **226**) coupled thereto, and/or to couple directly to a non-rotating portion of a driving wheel. In this way, the configuration of the trumpet

arm (e.g., the first trumpet arm **216** and the second trumpet arm **218**) enables electric axle components to be included in a rectangular envelope **310** of the electric drive axle while achieving a desired rigidity and strength of the electric drive axle at the flange/arm transition and along the length of the arm section **222**.

(42) FIG. **4** shows a first perspective view **400** and a second perspective view **450** of a trumpet arm **402** in orientations which enable partial visualization of internal buttresses. The trumpet arm **402** is an example of the first trumpet arm **216** and the second trumpet arm **218** of FIGS. **2-3**, and elements of FIGS. **2-3** which are included in FIG. **4** may be similarly numbered (e.g., the flange **214** of FIG. **2-3** is equivalent to a flange **414** of FIG. **4**).

(43) The trumpet arm **402** comprises a housing **412** with an arm section **422** extending an arm length **432**, the arm section **422** having an outlet **420** at a second end **444**, and a flange **414** with a planar face **428** at a first end **442** opposite the second end **444**. The trumpet arm **402** further including internal buttresses **408** positioned in an interior **410** of the housing **412** and extending through at least a first portion of a flange length of the flange **414**, a flange/arm transition **406** at which the flange **414** transitions into the arm section **422**, and at least a portion of the arm length **432**, as further described with respect to FIGS. **6, 9, and 11**. The internal buttresses **408** may be cast as part of the housing **412** (e.g., continuous with housing **412**). In some embodiments, the internal buttresses **408** are formed as pieces separate from the housing **412** (e.g., castings, stampings, formed pieces, machined pieces) and welded or otherwise fixedly positioned in the interior **410** of the housing **412**. The housing **412** and the internal buttresses **408** may be formed of a same material, such as cast steel, nodular iron, or cast aluminum. In other embodiments, the housing **412** and the internal buttresses **408** may be formed of different metals or other rigid materials. In yet other embodiments, the housing **412** and internal buttresses **408** may be formed as various cast, stamped, or machined components fixtured and assembled as a weldment.

(44) As briefly described with respect to FIGS. **1-3**, the flange **414** has multiple through holes **416**, positioned around a perimeter of the flange **414**, which are configured to have fastening attachments, such as bolts, pass through to couple the trumpet arm **402** to the electric axle components, such as a gearbox housing and/or an electric machine housing. In some embodiments, each of the multiple through holes **416** have a raised bolt pad **418**, which may assist in positioning a fastening attachment, such as a bolt, and distributed bolt loading. The raised bolt pad **418** may further aid in manufacturing of the trumpet arm **402**. In some embodiments, the raised pads may or may not be used. For example, a spot face may be used instead. The flange **414** further has an angled extension **430** from the planar face **428** to the flange/arm transition **406**. The angled extension **430** includes an actuator through hole **424**, in which an actuator for a differential lock may be positioned, as further described with respect to FIGS. **10 and 11**. The angled extension **430** also includes external buttresses (gussets, trusses) **426** which may be formed as three-dimensional triangles, where a first face of a triangle is coupled to and/or continuous with the planar face **428**, and a second face of the triangle is coupled to and/or continuous with the angled extension **430**. In this way, the external buttresses (gussets, trusses) **426** provide additional support and rigidity to the flange **414** and to the flange/arm transition **406**, as further described with respect to FIG. **12**.

(45) Both the first perspective view **400** and the second perspective view **450** show geometry of the housing **412**, wherein the arm section **422** has a rectangular shape which extends along the arm length **432**, and the outlet **420** has an annular shape. The arm section **422** may gradually transition into the outlet **420**, such that the rectangular shape smoothly transitions to the annular shape without sharp (e.g., angled) intersections. The rectangular shape of the arm section **422** may provide space in the interior **410** of the trumpet arm **402** for internal buttresses **408** to be positioned and for positioning an axle shaft (e.g., the axle shaft **115, 117**) therein. The arm section **422** is further shaped to enable mounting of suspension packages having different shapes and sizes (e.g., from different manufacturers) thereon. The annular shape of the outlet **420** may enable the axle shaft to be positioned therein without being in contact with the housing **412**. The annular shape of

the outlet **420** may further enable a spindle (e.g., the first spindle **224**, the second spindle **226**) to be coupled thereto. In other embodiments, the outlet **420** may be directly coupled to a non-rotating portion of a drive wheel. In other embodiments of the trumpet arm **402** (e.g., as described with respect to FIG. **13**) may have a different shaped cross section, which may be configured to enable mounting different suspension packages thereon and/or integration of the trumpet arm **402** in different sizes and shapes of e-axle for different vehicle types, for example.

(46) As may be visualized in the second perspective view **450**, an interior area **434** of the flange **414** decreases from the first end **442** towards the flange/arm transition **406**. The internal buttresses **408** include one or more legs which are continuous with the housing **412**. In the trumpet arm **402**, the internal buttresses **408** include four legs, as further described with respect to FIG. **5**. Each of the four legs extends from the planar face **428** and the angled extension **430** towards a central axis **436** of the trumpet arm **402**. Each of the four legs further extends into the arm section **422** of the housing **412**, and are each coupled to and/or continuous with walls of the arm section **422**. As shown in FIGS. **6**, **9**, and **11**, each of the four legs of the internal buttresses **408** extend through at least a first portion of the flange length, the flange/arm transition **406** at which the flange **414** transitions into the arm section **422**, and at least a portion of the arm length **432**. The four legs of the internal buttresses **408** form an “x” configuration in the example of the trumpet arm **402** shown in FIG. **5**, however in other embodiments of the trumpet arm **402**, the internal buttresses **408** may be formed of more than four or less than four legs which are arranged in different configurations to provide resistance to deflection stresses along the arm length **432** of the arm section **422** and at the flange/arm transition **406**. Additional configurations of the internal buttress **408** are described with respect to FIG. **13**.

(47) Inclusion of external buttresses (gusset, trusses) **426** as well as internal buttresses **408** create a first pivot point at the planar face **428** of the flange **414** and a second pivot point at the flange/arm transition **406**, as further described with respect to FIG. **12**. Briefly, looking at a top portion of trumpet arm **402** in an illustration **1250**, a first pivot point **1202** and a second pivot point **1204** are both rigid when the arm section **422** experiences deflection in a first, downward direction indicated by a second arrow **1220** and a third arrow **1222** (e.g., towards a driving surface) due to the internal buttresses **408** being in compression and the external buttresses (gusset, trusses) **426** being in tension. As shown in an illustration **1200**, the first pivot point **1202** and the second pivot point **1204** are both rigid when the arm section **422** experiences deflection in a second, upward direction indicated by a first arrow **1206** (e.g., away from the driving surface) due to the internal buttresses **408** being in tension and the external buttresses (gusset, trusses) **426** being in compression.

(48) FIG. **5** shows a first profile view **500** and a second profile view **550** of the trumpet arm **402** of FIG. **4**. Elements of the trumpet arm **402** which are described with respect to FIG. **4** may not be reintroduced, for brevity. The first profile view **500** shows the trumpet arm **402** along the y-axis, looking into the interior **410** of the trumpet arm **402** from the flange **414** to the outlet **420** (e.g., from the first end **442** of the housing **412** to the second end **444**, as described with respect to FIG. **4**). The second profile view **550** shows the trumpet arm **402** along the y-axis, looking into the interior **410** of the trumpet arm **402** from the outlet **420** to the flange **414** (e.g., from the second end **444** of the housing **412** to the first end **442**).

(49) As described with respect to FIG. **4**, the internal buttresses **408** have an “x” configuration with vertical extensions **508** of each of the four legs (e.g., a first leg **408a**, a second leg **408b**, a third leg **408c**, and a fourth leg **408d**) coupling the internal buttresses **408** to arm section **422** and to the angled extension **430**. The vertical extensions **508** are to be understood as extensions of the “x” configuration which provide support for the internal buttress **408** in the flange **414**, for example, by anchoring the internal buttresses **408** to the flange **414**. The “x” configuration may be visualized in the first profile view **500** and the second profile view **550** of FIG. **5**. The external buttresses (gusset, trusses) **426** also have an “x” configuration, where legs of the external buttresses **426** (e.g., a fifth leg **426a**, a sixth leg **426b**, a seventh leg **426c**, and an eighth leg **426d**) may be axially

aligned with legs of the internal buttresses **408**. The external buttresses **426** may also include external vertical extensions **526**, which may assist in supporting (e.g., providing structural stability and rigidity to) the angled extension **430** of the flange **414**.

(50) Configuration of the internal buttresses **408** and the external buttresses (gusset, trusses) **426** in the “x” configuration may enable the internal buttresses **408** and the external buttresses **426** to react to both vertical and horizontal forces and torsional forces on the trumpet arm **402**, and thus on the internal buttresses **408** and external buttresses **426**. For example, the internal buttresses **408** and the external buttresses **426** may experience vertical forces when a vehicle having the e-axle which uses the trumpet arm **402** (e.g., the vehicle **100** of FIG. **1**) travels over protrusions and/or depressions in a driving surface (e.g., speed bumps, potholes). The internal buttresses **408** and the external buttresses **426** may experience horizontal forces and torsional forces when the vehicle brakes and/or accelerates. As further described with respect to FIG. **12**, the internal buttresses **408** and external buttresses (gusset, trusses) **426** may enable pivot points of the trumpet arm **402** to remain rigid when the trumpet arm experiences vertical and/or horizontal forces (e.g., deflection of the trumpet arm), which may reduce degradation of the trumpet arm **402**, especially at the flange/arm transition **406**.

(51) FIG. **6** shows a cross section side view **600** of the trumpet arm **402**. The cross section of FIG. **6** is a partial cross section taken along the central axis **436**, where elements above the central axis **436** are sectioned as indicated by line **650** of FIG. **4**, and elements below the central axis **436** are not cross-sectioned. Elements of the trumpet arm **402** which are described with respect to FIGS. **4** and **5** may not be reintroduced, for brevity.

(52) As described with respect to FIGS. **4** and **5**, the flange **414** of the trumpet arm **402** has a flange length **608**, the arm section **422** has the arm length **432**, and the internal buttresses **408** extend through at least a first portion of the flange length **608**, the flange/arm transition **406**, and at least a portion of the arm length **432**. FIG. **6** illustrates an embodiment of a configuration of the internal buttresses **408** in the housing **412** of the trumpet arm **402**. In the embodiment of the trumpet arm **402**, the internal buttresses **408** include four legs in an “x” configuration, as described above. Shown in FIG. **6** is a cross section of the first leg **408a**. The first leg **408a** extends along the entirety of the flange length **608** and the arm length **432**. As described with respect to FIG. **5**, each of the four legs of the internal buttresses **408** includes the vertical extension **508**, which extends linearly towards the central axis **436** for a first length **604**. The first leg **408a** extends along the angled extension **430** of the flange **414** at an angle parallel to that of the angled extension **430** for a second portion of the flange length **608**. Prior to the flange/arm transition **406**, the first leg **408a** transitions from the angle parallel to the angled extension **430** to a horizontal extension which is parallel to the arm section **422**. A width **602** of the first leg **408a** may gradually decrease along the arm length **432**, where the width **602** of the first leg **408a** is greatest at the flange/arm transition **406**. In this way, the configuration of the first leg **408a**, and thus, of the four legs of the internal buttresses **408**, may provide rigidity and resistance to degradation at the flange/arm transition **406** and along the arm length **432**, as further described herein and with respect to FIG. **12**. As further described with respect to FIG. **13**, different embodiments of the internal buttresses **408** may include more than or less than four legs which are oriented in a different configuration than the “x” configuration.

(53) The flange **414** is configured to provide a rectangular envelope for positioning electric axle components in an e-axle. The planar face **428** may be a face on the first end **442** of a plate or other planar structure, in some embodiments. The angled extension **430** is coupled to and/or continuous with, and extends from the plate or planar structure having the planar face **428** in a direction away from the planar face **428** (e.g., towards the second end **444**). The angled extension **430** has a funnel-like shape, where the interior area **434** of the flange **414** decreases from the first end **442** towards the flange/arm transition **406**. External buttresses (gusset, trusses) **426** which extend along an exterior **610** of the angled extension **430** may provide rigidity and resistance to degradation due

to stress by being coupled to and/or extending from the angled extension **430** and the plate or planar structure having the planar face **428**. In other embodiments, the flange **414** has a different shape and configuration. For example, as further described with respect to FIGS. **14A-20**, instead of an angled extension, the flange may have a curved extension from the planar face (e.g., a plate or planar structure having the planar face) to the flange/arm transition. The embodiment of the flange described with respect to FIGS. **14A-20** may provide structural stability and resistance to degradation due to stress in a similar way to the flange **414** described herein.

(54) The arm length **432** and the shape (e.g., cross section) of the arm section **422** may be configured to enable mounting or other forms of coupling of different suspension mounting packages to the arm section **422**. Different suspension mounting packages may be designed by the same or different manufacturers than those who manufacture the trumpet arm **402**, thus the arm section **422** is sized to sufficiently accommodate different shapes and sizes of suspensions mounting packages. In some embodiments, a suspension mounting package may be coupled to the trumpet arm **402** along parts of or all of the arm length **432**. For example, a suspension mounting package may be coupled to the trumpet arm **402** along a portion **612** of the arm section **422** and not coupled to the trumpet arm **402** at the portion of the arm length **432** where the rectangular shape of the arm section **422** transitions into the annular shape of the outlet **420**. As further described herein, different embodiments of the trumpet arm may have differently shaped arm sections (e.g., circular cross section, hour glass cross section, and so on), all of which may be configured to accommodate multiple different suspension mounting packages.

(55) FIG. **7** shows a first perspective view **700** of the trumpet arm **402**, as described with respect to FIGS. **4-6**, with a spindle **726** coupled to the trumpet arm **402** at the outlet **420**. The spindle **726** may be an example of the first spindle **224** or the second spindle **226**, as described with respect to FIGS. **1-3**. The spindle **726** may be coupled to the trumpet arm **402** via friction welding, for example. As described with respect to FIGS. **1-3**, an axle shaft which provides rotational motion to drive wheels from a rotational power source (e.g., the electric machine **106**) may pass through the interior **410** of the trumpet arm **402** and through an interior of the spindle **726** to couple to a drive wheel. In some embodiments, the spindle **726** may be coupled to a non-rotatable element of the drive wheel. In other embodiments, the spindle **726** may be adjacent to and axially aligned with a center of the drive wheel, but may not be in contact with the drive wheel.

(56) FIG. **8** shows a second perspective view **800** of the trumpet arm **402** with the spindle **726** coupled thereto, as described with respect to FIG. **7**. The spindle **726** is coupled to the trumpet arm **402** at the outlet **420**. The spindle **726** is coupled to the trumpet arm **402** at a first end **842** of the spindle **726**, and a drive wheel (not shown) may be coupled to the spindle **726** at a second end **844** of the spindle **726**, opposite the first end **842** of the spindle **726**. As described with respect to FIG. **7**, an axle shaft which provides rotational motion to drive wheels from a rotational power source may pass through the interior of the trumpet arm **402** and through an interior **810** of the spindle **726** to couple to a drive wheel. In some embodiments, the axle shaft may protrude out of the second end **844** of the spindle **726**, where the axle shaft may be coupled to the drive wheel and the spindle **726** is not in contact with the drive wheel.

(57) FIG. **9** shows a first cross section side view **900** of the trumpet arm **402** with the spindle **726** coupled thereto, as described with respect to FIG. **7**. The first cross section side view **900** sections the trumpet arm **402** with the spindle **726** along the line **950**, shown in FIG. **7**. As described with respect to FIGS. **4-8**, legs of the internal buttresses **408** extend from the flange **414**, through the flange/arm transition **406**, and along the arm length **432** of the arm section **422**. In the embodiment of the trumpet arm **402** shown in FIG. **9**, legs of the internal buttresses **408** (e.g., the first legs **408a** and the second legs **408b**) extend in an “x” configuration towards the central axis **436** of the trumpet arm **402**. Described another way, each of the first legs **408a** and the second legs **408b** (and the third legs **408c** and the fourth legs **408d**, not shown in FIG. **9**) extend from a respective vertical extension **508** at an angle, towards the central axis **436** of the trumpet arm **402** in such a way that

there is space between each of the legs of the internal buttresses, as well as space between the internal buttresses **408** and the housing **412** (e.g., walls of the arm section **422**). As further shown in FIG. **9**, the width **602** of legs of the internal buttresses **408** may decrease along the arm length **432**, in some embodiments. Described another way, the legs of the internal buttresses **408** may, for a portion **612** of the arm length **432** and while still being in the “x” configuration, flare away from the central axis **436** of the trumpet arm **402**. This configuration may provide strength and rigidity to the arm section **422** while providing space for positioning of the axle shaft. As described herein, the internal buttresses **408** may not extend into the spindle **726**. The internal buttresses **408** thus provide rigidity and resistance to degradation of the trumpet arm **402** at the flange **414**, at the flange/arm transition **406**, and along the arm length **432** of the arm section **422**.

(58) FIG. **10** shows a third perspective view **1000** of the trumpet arm **402** with the spindle **726**, as described with respect to FIGS. **7-9**. The embodiment of the trumpet arm **402** shown in FIG. **10** further includes elements which may assist in positioning the trumpet arm **402** with respect to electric axle components, such as a gearbox, a differential, and/or an electric machine, as described with respect to FIGS. **1-3**. A differential lock/axle disconnect assembly **1002** may be positioned in the flange **414**, and may comprise a shift fork and a sliding collar **1004** which are coupled to a differential lock/axle disconnect actuator **1008** which is positioned in the actuator through hole **424**. The differential lock/axle disconnect assembly **1002** may be positioned in the flange **414** such that a through hole of the sliding collar **1004** is aligned with the central axis **436** of the trumpet arm **402**. This alignment may enable the axle shaft to pass through the through hole of the sliding collar **1004**. In other embodiments, the axle shaft may be coupled to the sliding collar **1004** on a second face of the sliding collar **1004** opposite a first face of the sliding collar **1004** having teeth **1006**. The sliding collar **1004** may be actuated to selectively engage with a differential (e.g., the differential **110** of FIG. **1**), and thus control rotation of the axle shaft coupled to the sliding collar **1004** (e.g., enable rotation by engaging the sliding collar **1004** with the differential). In other embodiments, the shift fork and the sliding collar **1004** are configured to selectively mate with a mating clutch of the gearbox (e.g., the gearbox **108** of FIG. **1**) to control rotation of the axle shaft positioned in the trumpet arm **402** and coupled to a drive wheel (not shown). Operation of the differential lock/axle disconnect actuator is further described with respect to FIG. **11**.

(59) The trumpet arm **402** may further include one or more locating dowels to assist in positioning the trumpet arm **402** with respect to electric axle components (e.g., the gearbox **108**, the differential **110**, the electric machine **106**, and/or housings thereof). For example, the trumpet arm **402** may include a first locating dowel **1012** which extends from an upper right corner of the planar face **428** towards the first end **442** and a second locating dowel **1010** which extends from a lower left corner of the planar face **428** towards the first end **442**. The first locating dowel **1012** and/or the second locating dowel **1010** may extend into and couple the trumpet arm **402** to the gearbox of the e-axle, for example. The trumpet arm **402** may additionally or alternatively include one or more pilot diameters, not shown, which extend into or out of the flange **414** and are configured to receive one or more mating diameters of the electric machine to locate the trumpet arm **402** to the electric machine.

(60) FIG. **11** shows a second cross section side view **1100** of the trumpet arm **402** with the spindle **726**, the differential lock/axle disconnect assembly **1002**, and the differential lock/axle disconnect actuator **1008** coupled thereto, as described with respect to FIG. **10**. As described with respect to FIG. **10**, the shift fork and the sliding collar **1004** of the differential lock/axle disconnect assembly **1002** are configured to mate with a mating clutch **1104** of the electric machine (e.g., the electric machine **106** of FIG. **1**). In the embodiment of FIG. **11**, the mating clutch **1104** is shown as a Curvic clutch. However, in other embodiments, the mating clutch **1104** with which the sliding collar **1004** selectively mates may be any one of a dog clutch, a synchronizer clutch, a cone clutch, a dry clutch, a wet clutch, friction plates, and so on without departing from the scope of the present disclosure. The differential lock/axle disconnect actuator **1008** may extend through the flange

length **608** of the flange **414** at the actuator through hole **424**, thus enabling the differential lock/axle disconnect actuator **1008** to selectively engage with components (e.g., the differential, elements of a suspension package mounted on the arm section **422**, and/or other element of the axle) on either of the first end **442** or the second end **444** of the trumpet arm **402**. The differential lock/axle disconnect actuator **1008** and the differential lock/axle disconnect assembly **1002** may be pneumatically, electromechanically, hydraulically, and/or magnetically actuated, in one instance. (61) FIG. **12** shows illustrations **1200** and **1250** of force distribution on the trumpet arm described herein having internal buttresses and external buttresses (gusset, trusses) (e.g., the trumpet arm **402** of FIGS. **4-11**). As described herein, inclusion of the internal buttresses and external buttresses in the trumpet arm (e.g., the trumpet arm **402**) provide strength and rigidity at the flange/arm transition and along the arm section, which may provide resistance to degradation of the trumpet arm due to stresses from deflection of the trumpet arm. For example, the internal buttresses and the external buttresses (gusset, trusses) may enable pivot points of the trumpet arm to be rigid during deflection of the trumpet arm.

(62) As briefly described with respect to FIG. **3**, when traveling along a road, a vehicle may experience deflection along a vertical axis when encountering bumps and/or holes in the roadway, and deflection along a longitudinal axis from braking/accelerating. The trumpet arm described herein is configured to distribute deflection in such a way that provides rigidity to the electric drive axle in which it is used, thus reducing degradation of the trumpet arm, the electric drive axle, and other components thereof. In simplified examples, deflection of the trumpet arm along a vertical axis (e.g., the z-axis with respect to the axis system **150**, perpendicular to road surface) results in two pivot points that the trumpet arm deflects up/down about the pivot points. A first pivot point **1202** is positioned at an intersection of the planar face **428** and the angled extension **430** of the flange **414**. A second pivot point **1204** is positioned at the flange/arm transition **406**. Incorporating internal buttresses **408** which extend from the flange **414** along the inside of the arm section **422** stiffens the second pivot point **1204** and adds strength along the arm section **422**. Incorporating the external buttresses (gusset, trusses) **426** outside the flange **414** (e.g., on the angled extension **430**) stiffens the first pivot point **1202**.

(63) Illustration **1200** shows a cross section side view of a top portion of the trumpet arm **402** (e.g., above the central axis **436** of FIG. **11**). As shown in illustration **1200**, when a load (indicated by the first arrow **1206**) is directing the trumpet arm **402** up (e.g., away from a driving surface), the external buttresses (gusset, trusses) **426** is in compression along a first side **1208**. The internal buttress **408** is in tension along a second side **1210** and a third side **1212**. The trumpet arm **402** deflects up with respect to the y-axis, as indicated by a first dashed line **1214**, at a reduced amount and with lower stresses at the first pivot point **1202** and the second pivot point **1204**, relative to deflection of trumpet arms without internal buttresses (gusset, trusses) and/or external buttresses.

(64) Illustration **1250** shows a cross section side view of the trumpet arm **402**. A bottom half **1254** of the trumpet arm **402** experiences deflection as described below. A top half **1252** of the trumpet arm **402** may be understood as experiencing deflection as described with respect to illustration **1200**. The configuration of the internal buttresses **408** and external buttresses (gusset, trusses) **426**, as well as the direction of load on the bottom half of the trumpet arm **402** may be equivalent to the top half **1252** of the trumpet arm, reflected over the central axis **436**. Described another way, both the top half **1252** and the bottom half **1254** of the trumpet arm **402** experience load in a downward direction, as indicated by the second arrow **1220** and the third arrow **1222**. The trumpet arm **402** thus includes a pair of first pivot points **1202** at the intersection of the planar face **428** and the angled extension **430** of the flange **414**, and a pair of second pivot points **1204** at the flange/arm transition **406**. For the top half **1252** of the trumpet arm **402**, when the load is going down, the external buttress (gusset, trusses) **426** is in tension along the first side **1208**. The internal buttress **408** is in compression along the second side **1210** and the third side **1212**. The trumpet arm **402** deflects down with respect to the y-axis, as indicated by a second dashed line **1216**, at a reduced

amount and with lower stress at the pair of first pivot points **1202** and the pair of second pivot points **1204** relative to deflection of trumpet arms without external buttresses and/or internal buttresses. For the bottom half **1254** of the trumpet arm **402**, when the load is going down, the external buttress (gusset, trusses) **426** is in compression, along a first side **1208**. The internal buttress **408** is in tension along the second side **1210** and the third side **1212**. The trumpet arm **402** deflects down with respect to the y-axis, as indicated by a third dashed line **1218**, at a reduced amount and with lower stresses at the pair of first pivot points **1202** and the pair of second pivot points **1204**, relative to deflection of trumpet arms without external buttresses and/or internal buttresses. Reduced deflection of the trumpet arm may increase a useable lifespan of the trumpet arm and of the e-axle, as degradation of the trumpet arm at the first pivot point and at the second pivot point may be decreased due to strength and rigidity of the trumpet arm provided by the internal buttresses and external buttresses.

(65) An embodiment of a trumpet arm is described with respect to FIGS. **4-12**, the trumpet arm comprising a housing with an arm section extending an arm length, the arm section having an outlet at a first end, and a flange with a planar face at a second end opposite the first end; and internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length. Different embodiments of the trumpet arm which include the elements described above may include different geometries which may be used to configure the trumpet arm to be used in different systems, such as e-axles for different sized and shaped vehicles. For example, a cross-section of the arm section may be adjusted during manufacturing of the trumpet arm to form embodiments of the trumpet arm which may be implemented in an electric drive system for a passenger vehicle, a heavy duty vehicle, and so on. Additionally or alternatively, the cross-section of the arm section **422** may be shaped and sized to provide space for mounting and/or coupling different suspension mounting packages thereon. Similarly, an orientation of legs of the internal buttresses of the trumpet arm may be different in different embodiments of the trumpet arm. For example, different configurations of the internal buttresses may include two or more legs. FIG. **13** shows illustrations of possible arm section cross sections **1300** and leg orientations **1350** of internal buttresses **408** for the trumpet arm described herein. The cross section of the arm section may be described as a: box **1302**, rectangle **1304**, circle **1308**, oval **1310**, hour glass **1312**, or a combination **1314** of two or more of these shapes. The orientation of legs of the internal buttresses may be angled (“x” configuration **1352**, as described with respect to FIGS. **4-11**), “y” shaped **1354**, horizontal configuration **1358**, vertical configuration **1360**, “+” shaped **1362**, curved configuration **1364**, or a combination **1366** of two or more of these orientations.

(66) FIGS. **14A-20** show a second embodiment of the trumpet arm described herein. Similarly to the trumpet arm **402** described with respect to FIGS. **4-11**, the trumpet arm **1402** includes a flange with a planar face, where the flange is coupled to an arm section at a flange/arm transition on a side of the flange opposite the planar face. As further described with respect to FIGS. **14A-20**, the flange of the trumpet arm **1402** includes a curved extension from the planar face to the flange/arm transition. The curved extension may have the same or similar benefits as the angled extension of the trumpet arm **402**, where the flange of both the trumpet arm **402** and the trumpet arm **1402** provide a relatively abrupt transition at the flange/arm transition, compared to the gradual transition present in a banjo axle or a Salisbury axle. The relatively abrupt transition described herein may assist in providing a substantially sized envelope in which to package electric axle components. Internal buttresses can also provide the flange/arm transition with strength and rigidity comparable to or greater than that of the banjo axle and/or the Salisbury axle, where the internal buttresses and the curved extension provide resistance to degradation of the trumpet arm, which may be caused by deflection of the trumpet arm over time.

(67) Turning to FIGS. **14A** and **14B**, a first perspective view **1400** and a second perspective view

1450 are shown of a trumpet arm **1402**. The trumpet arm **1402** is an example of the first trumpet arm **216** and the second trumpet arm **218** of FIGS. 2-3. Elements of FIGS. 2-3 which are included in FIGS. **14A** and **14B** may be similarly numbered (e.g., the flange **214** of FIG. 2-3 is equivalent to a flange **1414** of FIGS. **14A** and **14B**). The trumpet arm **1402** comprises a housing **1412** with an arm section **1422** extending an arm length **1432**, the arm section **1422** having an outlet **1420** at a second end **1444**, and a flange **1414** with a planar face **1428** at a first end **1442** opposite the second end **1444**. The trumpet arm **1402** further includes internal buttresses **1408** (e.g., shown in FIGS. **16**, **17**, and **20**) positioned in an interior **1410** of the housing **1412** and extending through at least a first portion of a flange length of the flange **1414**, a flange/arm transition **1406** at which the flange **1414** transitions into the arm section **1422**, and at least a portion of the arm length **1432**, as further described with respect to FIGS. **17** and **20**. The internal buttresses **1408** may be cast as part of the housing **1412** (e.g., continuous with housing **1412**). In some embodiments, the internal buttresses **1408** are formed as pieces separate from the housing **1412** (e.g., castings, stampings, formed pieces, machined pieces) and welded or otherwise fixedly positioned in the interior **1410** of the housing **1412**. The housing **1412** and the internal buttresses **1408** may be formed of a same material, such as cast steel, nodular iron, or cast aluminum. In other embodiments, the housing **1412** and the internal buttresses **1408** may be formed of different metals or other rigid materials. (68) As briefly described with respect to FIGS. 1-3, the flange **1414** has multiple through holes **1416**, positioned around a perimeter of the flange **1414**, which are configured to have fastening attachments, such as bolts, pass through to couple the trumpet arm **1402** to electric axle components, such as a gearbox housing and/or an electric machine housing. In some embodiments, each of the multiple through holes **1416** may have a raised bolt pad **1418**, which may assist in positioning a fastening attachment, such as a bolt, and distributed bolt loading. The raised bolt pad **1418** may further aid in manufacturing of the trumpet arm **1402**. In some embodiments, the raised pads may or may not be used. For example, a spot face may be used instead. Each of the multiple through holes **1416** may be strategically positioned around the perimeter of the flange **1414** to enable alignment of each through hole **1416** with a coupling hole of a gearbox housing and/or an electric machine housing.

(69) The flange **1414** in the second embodiment of the trumpet arm **1402** has a circular profile with a cutout **1454** along a first section **1452** of the perimeter of the flange **1414**, as may be visualized in FIG. **14B**. The cutout **1454** may be sized and shaped to enable components of an electric drive system (e.g., a gearbox, a differential, and/or an electric machine) to be compactly positioned within an envelope of an e-axle, the envelope formed as a space between two trumpet arms **1402**, as described with respect to FIGS. 1-3. The flange **1414** further includes a curved extension **1430** which extends from the planar face **1428** to the flange/arm transition **1406**. The curved extension **1430** in combination with the planar face **1428** give the flange **1414** a dome shape (convex as viewed from the second end **1444** of the housing **1412** to the first end **1442**), excluding the cutout **1454**. Furthermore, in another example, the curved extension **1430** in combination with the planar face **1428** may give the flange **1414** a concave shape (as viewed from the second end **1444** of the housing **1412** to the first end **1442**), excluding the cutout **1454**. As is further described with respect to FIGS. **15**, **16**, **17**, **19**, and **20**, an interior area of the flange **1414** decreases from the planar face **1428** to the flange/arm transition **1406**. The curved extension **1430** with the cutout **1454** may provide space in which internal buttresses **1408** may be included and an axle shaft may extend through the interior **1410** of the trumpet arm **1402** without contacting the housing **1412** or the internal buttresses **1408**. Additionally, and as further described herein, the curved extension **1430** may function similarly to the external buttresses (gusset, trusses) **426** of FIGS. 4-12 and provide additional support for the trumpet arm **402** and rigidity for two pivot points thereof, such that the trumpet arm **402** may be resistant to deflection and degradation due to forces in an upward/downward, forward/backward, and/or torsional direction. As described with respect to FIGS. 4-12, inclusion of external buttresses (gusset, trusses) **426** as well as internal buttresses **408**

in the first embodiment of the trumpet arm **402** create a first pivot point at the planar face **428** of the flange **414** and a second pivot point at the flange/arm transition **406**. The curved extension **1430** of the second embodiment of the trumpet arm **1402** may create a first pivot point around a curved perimeter **1458**, where the curved extension **1430** intersects with an angled extension region **1456** of the flange **1414** which couples the curved extension **1430** to the planar face **1428**. A second pivot point may be formed at the flange/arm transition **1406**, as described with respect to the first embodiment of the trumpet arm **402** of FIG. 12. Similar to illustration **1250**, the first pivot point and the second pivot point are both rigid when the arm section **1422** experiences deflection in a first, downward direction (e.g., towards a driving surface) due to the internal buttresses **1408** being in compression and the curved extension **1430** being in tension, and similar to illustration **1200** the first pivot point and the second pivot point are both rigid when the arm section experiences deflection in a second, upward direction (e.g., away from the driving surface) due to the internal buttresses **1408** being in tension and the curved extension **1430** being in compression.

(70) Both the first perspective view **1400** and the second perspective view **1450** show geometry of the housing **1412**, wherein the arm section **1422** has a rectangular shape which extends along the arm length **1432**, and the outlet **1420** has an annular shape. The arm section **1422** may gradually transition into the outlet **1420**, such that the rectangular shape smoothly transitions to the annular shape without sharp (e.g., angled) intersections. The rectangular shape of the arm section **1422** may provide space in the interior **1410** of the trumpet arm **1402** for internal buttresses **1408** to be positioned and for positioning an axle shaft (e.g., the axle shaft **115**, **117**) therein. The arm section **1422** is further shaped to enable mounting of suspension packages having different shapes and sizes (e.g., from different manufacturers) thereon. The internal buttresses **1408** may partially extend into the outlet **1420**, as further described with respect to FIGS. 17 and 20. The annular shape of the outlet **1420** may enable the axle shaft to be positioned therein without being in contact with the housing **1412**. The annular shape of the outlet **1420** may further enable a spindle (e.g., the first spindle **224**, the second spindle **226**) to be coupled thereto. In other embodiments, the outlet **1420** may be directly coupled to a non-rotating portion of a drive wheel. In other embodiments of the trumpet arm **1402** (e.g., as described with respect to FIG. 13) may have a different shaped cross section, which may be configured to enable mounting different suspension packages thereon and/or integration of the trumpet arm **1402** in different sizes and shapes of e-axle for different vehicle types, for example.

(71) Turning to FIG. 15, a first side view **1500** and a second side view **1550** of the second embodiment of the trumpet arm **1402** are shown. Elements of the trumpet arm **1402** which are described with respect to FIGS. 14A and 14B may not be reintroduced, for brevity. The flange **1414** of the trumpet arm **1402** has a flange length **1508**, the arm section **1422** has the arm length **1432**, and the internal buttresses **1408** extend through at least a first portion of the flange length **1508**, the flange/arm transition **1406**, and at least a portion of the arm length **1432**, as further described with respect to FIGS. 16, 17, and 20.

(72) FIG. 16 shows a first profile view **1600** and a second profile view **1650** of the trumpet arm **1402** of FIGS. 14A-15. Elements of the trumpet arm **1402** which are described with respect to FIGS. 14A-15 may not be reintroduced, for brevity. The first profile view **1600** shows the trumpet arm **1402** along the y-axis, looking into an interior area **1434** of the trumpet arm **1402** from the flange **1414** to the outlet **1420** (e.g., from the first end **1442** of the housing **1412** to the second end **1444**, as described with respect to FIGS. 14A and 14B). The second profile view **1650** shows the trumpet arm **1402** along the y-axis, looking into the interior **1410** of the trumpet arm **1402** from the outlet **1420** to the flange **1414** (e.g., from the second end **1444** of the housing **1412** to the first end **1442**). In some embodiments, the trumpet arm **1402** includes one or more dowel holes **1610** disposed about a perimeter of and extending through a thickness of the planar face **1428**. The one or more dowel holes **1610** may be configured to receive a dowel extension, for example, from a gearbox housing and/or an electric machine housing, to assist in positioning the trumpet arm **1402**

with respect thereto. The one or more dowel holes **1610** may be circular in some embodiments, and may be the same size, a larger size, or a smaller size than the multiple through holes **1416**.

(73) As described with respect to FIGS. **14A** and **14B**, the internal buttresses **1408** have an “x” configuration formed of four legs (e.g., a first leg **1408a**, a second leg **1408b**, a third leg **1408c**, and a fourth leg **1408d**) coupling the internal buttresses **1408** to arm section **1422** and to the curved extension **1430**. The “x” configuration may be visualized in the first profile view **1600** and the second profile view **1650** of FIG. **16**. Configuration of the internal buttresses **1408** in the “x” configuration may enable the internal buttresses **1408** to react to both vertical and horizontal forces and torsional forces on the trumpet arm **1402**, and thus on the internal buttresses **1408**. For example, the internal buttresses **1408** may experience vertical forces when a vehicle having the e-axle which uses the trumpet arm **1402** (e.g., the vehicle **100** of FIG. **1**) travels over protrusions and/or depressions in a driving surface (e.g., speed bumps, potholes). The internal buttresses **1408** may experience horizontal forces and torsional forces when the vehicle brakes and/or accelerates. As further described with respect to FIGS. **14A** and **14B**, the internal buttresses **1408** and the curved extension **1430**, which may function similarly to the external buttresses (gusset, trusses) **426** of the first embodiment of the trumpet arm **402**, may enable pivot points of the trumpet arm **1402** to remain rigid when the trumpet arm experiences vertical and/or horizontal forces (e.g., deflection of the trumpet arm), which may reduce degradation of the trumpet arm **1402**, especially at the flange/arm transition **1406**. The second embodiment of the trumpet arm **1402** may also have different configurations of the internal buttresses **1408**. For example, the internal buttresses **1408** may include more than or less than four legs, and the legs may be in a “y” configuration, a “+” configuration, and so on as described with respect to FIG. **13**.

(74) FIG. **17** shows a cross section side view **1700** of the trumpet arm **1402**, the sectioning axis indicated by line **1750** of FIG. **14B**. Elements of the trumpet arm **1402** which are described with respect to FIGS. **14A-16** may not be reintroduced, for brevity. FIG. **17** illustrates an embodiment of a configuration of the internal buttresses **1408** in the housing **1412** of the trumpet arm **1402**. In the embodiment of the trumpet arm **1402**, the internal buttresses **1408** include four legs in an “x” configuration, as described above. The third leg **1408c** and the fourth leg **1408d** are shown in FIG. **17**, and it is to be understood that the first leg **1408a** and the second leg **1408b** have the same positioning as described with respect to the third leg **1408c** and the fourth leg **1408d**, respectively, reflected over the line **1750**. Each of the third leg **1408c** and the fourth leg **1408d** extend along a first portion **1708** of the flange length **1508** and an entirety of the arm length **1432**. The third leg **1408c** and the fourth leg **1408d** may further extend a first length **1710** into the outlet **1420**. The third leg **1408c** and the fourth leg **1408d** extend along the curved extension **1430** of the flange **1414** at an angle which is parallel to a curvature of an exterior surface **1438** of the curved extension **1430** for the first portion **1708** of the flange length **1508**. At the flange/arm transition **1406**, a shape of each of the third leg **1408c** and the fourth leg **1408d** transitions from the angle parallel to the curved extension **1430** to a horizontal extension which is parallel to the arm section **1422**. The horizontal extension extends for a third portion **1714** of the arm length **1432**. The third leg **1408c** and the fourth leg **1408d** both divert away from the central axis **1436** of the trumpet arm **1402**, towards walls of the arm section **1422**, for a fourth portion **1716** of the arm length **1432** and the outlet **1420**. In this way, the configuration of the third leg **1408c** and the fourth leg **1408d**, and thus, of the four legs of the internal buttresses **1408**, may provide rigidity and resistance to degradation at the flange/arm transition **1406**, along the arm length **1432**, and at the transition between the arm section **1422** and the outlet **1420**. As described with respect to FIG. **13**, different embodiments of the internal buttresses **1408** may include more than or less than four legs which are oriented in a different configuration than the “x” configuration.

(75) The flange **1414** is configured to provide a rectangular envelope for positioning electric axle components in an e-axle. The planar face **1428** may be a face on the first end **1442** of a plate or other planar structure, in some embodiments. The curved extension **1430** is coupled to and/or

continuous with, and extends from the plate or planar structure having the planar face **1428** in a direction away from the planar face **1428** (e.g., towards the second end **1444**). As described with respect to FIGS. **14A-15**, the curved extension **1430** has a dome-like shape with a cutout **1454**, where the interior area **1434** of the flange **1414** decreases from the first end **1442** towards the flange/arm transition **1406**. Described another way, the flange **1414** has a concave shape where a first diameter **1720** is positioned at the first end **1442** of the trumpet arm **1402** and may be coupled to electric axle components, and a second diameter **1722** of the concave shape is positioned at the flange/arm transition **1406**, the first diameter **1720** being greater than the second diameter **1722**. The curved extension **1430** may function as external buttresses which provide rigidity and resistance to degradation due to stress.

(76) The arm length **1432** and the shape (e.g., cross section) of the arm section **1422** may be configured to enable mounting or other forms of coupling of different suspension mounting packages to the arm section **1422**. Different suspension mounting packages may be designed by the same or different manufacturers than those who manufacture the trumpet arm **1402**, thus the arm section **1422** is sized to sufficiently accommodate different shapes and sizes of suspensions mounting packages. In some embodiments, a suspension mounting package may be coupled to the trumpet arm **1402** along parts of or all of the arm length **1432**. For example, a suspension mounting package may be coupled to the trumpet arm **1402** along the third portion **1714** of the arm section **422** and not coupled to the trumpet arm **1402** at the fourth portion **1716** of the arm length **432**. The cutout **1454** of the flange **1414** may also provide space for gear covers to be positioned. For example, at least a portion of a gear cover may extend into the flange length **1508** from the arm length **1432** through the cutout **1454**. As described herein with respect to FIG. **13**, different embodiments of the trumpet arm may have differently shaped arm sections (e.g., circular cross section, hour glass cross section, and so on), all of which may be configured to accommodate multiple different suspension mounting packages.

(77) FIG. **18** shows a perspective view **1800** of the trumpet arm **1402**, as described with respect to FIGS. **14A-17**, with a spindle **1826** coupled to the trumpet arm **1402** at the outlet **1420**. The spindle **1826** may be an example of the first spindle **224** or the second spindle **226**, as described with respect to FIGS. **1-3**. The spindle **1826** is coupled to the trumpet arm **1402** at a first end **1842** of the spindle **1826**, and a drive wheel (not shown) may be coupled to the spindle **1826** at a second end **1844** of the spindle **1826**, opposite the first end **1842** of the spindle **1826**. The spindle **1826** may be coupled to the trumpet arm **1402** via friction welding, for example. As described with respect to FIGS. **1-3**, an axle shaft which provides rotational motion to drive wheels from a rotational power source (e.g., the electric machine **106**) may pass through the interior **1410** of the trumpet arm **1402** and through an interior **1810** of the spindle **1826** to couple to a drive wheel. In some embodiments, the spindle **1826** may be coupled to a non-rotatable element of the drive wheel. In other embodiments, the spindle **1826** may be adjacent to and axially aligned with a center of the drive wheel, but may not be in contact with the drive wheel. In some embodiments, the axle shaft may protrude out of the second end **1844** of the spindle **1826**, where the axle shaft may be coupled to the drive wheel and the spindle **1826** is not in contact with the drive wheel. FIG. **19** shows a side view **1900** of the trumpet arm **1402**, as described with respect to FIG. **18**, with the spindle **1826** coupled to the trumpet arm **1402** at the outlet **1420**.

(78) FIG. **20** shows a cross section side view **2000** of the trumpet arm **1402** with the spindle **1826** coupled thereto, as described with respect to FIG. **18-19**. The first cross section side view **2000** sections the trumpet arm **1402** with the spindle **1826** along the line **2050**, shown in FIG. **18**. As described with respect to FIGS. **14A-19**, legs of the internal buttresses **1408** extend from the flange **1414**, through the flange/arm transition **1406**, and along the arm length **1432** of the arm section **1422**. In the embodiment of the trumpet arm **1402** shown in FIG. **20**, arms of the internal buttresses **1408** (e.g., the first leg **1408a** and the second leg **1408b**) extend in an “x” configuration towards the central axis **1436** of the trumpet arm **1402**. Described another way, each of the first leg **1408a** and

the second leg **1408b** (and the third leg **1408c** and the fourth leg **1408d**, not shown in FIG. 20) extend from the curved extension **1430** at an angle, towards the central axis **1436** of the trumpet arm **1402** in such a way that there is space between each of the legs of the internal buttresses, as well as space between the internal buttresses **1408** and the housing **1412** (e.g., walls of the arm section **1422**). Described another way, the legs of the internal buttresses **1408** may, for the fourth portion **1716** of the arm length **1432** and while still being in the “x” configuration, flare away from the central axis **1436** of the trumpet arm **1402**. This configuration may provide strength and rigidity to the arm section **1422** while providing space for positioning of the axle shaft. As described herein, the internal buttresses **1408** may extend into the outlet **1420**, and may not extend into the spindle **1826**. The internal buttresses **1408** thus provide rigidity and resistance to degradation of the trumpet arm **1402** at the flange **1414**, at the flange/arm transition **1406**, and along the arm length **1432** of the arm section **1422**.

(79) The technical effect of the trumpet arm having internal buttresses and a flange with a planar face is that a strength, rigidity, and resistance to stress-based degradation of the trumpet arm at the flange/arm transition is increased compared to conventional axle arms. A useable lifespan of the trumpet arm may be increased. Further, a usability of the trumpet arm is increased in e-axles, as the planar face of the flange provides a rectangular envelope in which electric axle components may be mounted. Additionally, the trumpet arm described herein may have different configurations of legs of the internal buttresses and cross-section of the arm section, which provides space for mounting of different suspension packages thereon, as well as provide a sufficient and desirable strength of the trumpet arm for use in different systems, such as passenger and/or heavy duty electric vehicles.

(80) The disclosure also provides support for a trumpet arm for an axle, comprising: a housing with an arm section extending an arm length, the arm section having an outlet at a first end, and a flange with a planar face at a second end opposite the first end, and internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length. In a first example of the system, the internal buttresses include one or more legs which extend from walls of the housing towards the interior of the housing in an “x” configuration, a “y” configuration, a horizontal configuration, a vertical configuration, a “+” configuration, a curved configuration, or a combination of two or more of the aforementioned configurations. In a second example of the system, optionally including the first example, a cross section of the arm section is a box, a rectangle, a circle, an oval, an hourglass, or a combination of two or more of the aforementioned shapes. In a third example of the system, optionally including one or both of the first and second examples, the system further comprises: external buttresses extending a second portion of the flange length to the flange/arm transition, and wherein endpoints of the external buttresses are offset from endpoints of the internal buttresses. In a fourth example of the system, optionally including one or more or each of the first through third examples, the flange includes an angled extension from the planar face to the flange/arm transition. In a fifth example of the system, optionally including one or more or each of the first through fourth examples, the flange includes a curved extension from the planar face to the flange/arm transition. In a sixth example of the system, optionally including one or more or each of the first through fifth examples, the system further comprises: a spindle coupled to the housing at the outlet of the arm section. In a seventh example of the system, optionally including one or more or each of the first through sixth examples, a cross section of the arm section maintains a constant profile throughout the arm length. In an eighth example of the system, optionally including one or more or each of the first through seventh examples, the system further comprises: multiple through holes around a perimeter of the flange, wherein one or more of the multiple through holes includes a raised bolt pad. In a ninth example of the system, optionally including one or more or each of the first through eighth examples, an interior area of the flange decreases from the first end towards the flange/arm transition. In a tenth example of the system, optionally including one or more or each of the first through ninth

examples, the housing and the internal buttresses are formed of cast steel, cast aluminum, and/or nodular iron. In an eleventh example of the system, optionally including one or more of each of the first through tenth examples, the housing and the internal buttresses are formed as various cast, stamped, or machined components fixtured and assembled as a weldment.

(81) The disclosure also provides support for an e-axle, comprising: an electric machine, a first trumpet arm, and a second trumpet arm, wherein at least one of the first trumpet arm and the second trumpet arm comprise a housing with an arm section extending an arm length, a flange with a planar face at a first end of the arm length, and internal buttresses positioned in an interior of the housing, where the first trumpet arm and the second trumpet arm are each configured to couple to the electric machine via a respective flange. In a first example of the system, internal buttresses of the first trumpet arm and the second trumpet arm extend through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length. In a second example of the system, optionally including the first example, the system further comprises: a differential lock/axle disconnect assembly having a shift fork and a sliding collar positioned in the flange of the first trumpet arm or the second trumpet arm, the shift fork and the sliding collar configured to mate with a mating clutch of the electric machine, and where the differential lock/axle disconnect assembly is pneumatically, hydraulically, electro-mechanically, or magnetically operated. In a third example of the system, optionally including one or both of the first and second examples, the differential lock/axle disconnect assembly includes a differential lock/axle disconnect actuator which extends through a flange length of the flange of the first trumpet arm or the second trumpet arm. In a fourth example of the system, optionally including one or more of each of the first through third examples, the system further comprises: one or more locating dowels which extend from the flange of each of the first trumpet arm and the second trumpet arm to the electric machine, and/or one or more pilot diameters which extend into the flange of each of the first trumpet arm and the second trumpet arm and are configured to receive one or more connectors of the electric machine. In a fifth example of the system, optionally including one or more of each of the first through fourth examples, the system further comprises: a suspension package coupled to at least one of the first trumpet arm and the second trumpet arm at the respective arm section(s). In a sixth example of the system, optionally including one or more of each of the first through fifth examples, the system further comprises: a first spindle and a second spindle coupled to each of the first trumpet arm and the second trumpet arm, respectively, at a second end of the arm length opposite the first end of the arm length and at a first spindle end of the respective spindle, and a first wheel and a second wheel coupled to each of the first spindle and the second spindle, respectively, at a second spindle end of the respective spindle, opposite the first spindle end of the spindle.

(82) The disclosure also provides support for an axle housing, comprising: an arm section extending an arm length, a flange extending a flange length and having a planar face at a first end of the flange length, the flange coupled to the arm section at a flange/arm transition, internal buttresses positioned in an interior of the flange and the arm section, the internal buttresses extending at least a portion of the arm length of the arm section and at least a first portion of the flange length, external buttresses positioned on an exterior of the flange, the external buttresses extending at least a second portion of the flange length, a pair of first pivot points at the planar face of the flange, and a pair of second pivot points at the flange/arm transition, wherein: the pair of first pivot points and the pair of second pivot points are both rigid when the arm section experiences deflection in a first, downward direction due to, in a top half of the axle housing, the internal buttresses being in compression and the external buttresses being in tension, and in a bottom half of the axle housing the internal buttresses being in tension and the external buttresses being in compression, and the pair of first pivot points and the pair of second pivot points are both rigid when the arm section experiences deflection in a second, upward direction due to, in the top half of the axle housing, the internal buttresses being in tension and the external buttresses being in

compression and in the bottom half of the axle housing, the internal buttresses being in compression and the external buttresses being in tension.

(83) FIGS. 1-20 show example configurations with relative positioning of the various components. If shown directly contacting each other, or directly coupled, then such elements may be referred to as directly contacting or directly coupled, respectively, at least in one example. Similarly, elements shown contiguous or adjacent to one another may be contiguous or adjacent to each other, respectively, at least in one example. As an example, components laying in face-sharing contact with each other may be referred to as in face-sharing contact. As another example, elements positioned apart from each other with only a space there-between and no other components may be referred to as such, in at least one example. As yet another example, elements shown above/below one another, at opposite sides to one another, or to the left/right of one another may be referred to as such, relative to one another. Further, as shown in the figures, a topmost element or point of element may be referred to as a “top” of the component and a bottommost element or point of the element may be referred to as a “bottom” of the component, in at least one example. As used herein, top/bottom, upper/lower, above/below, may be relative to a vertical axis of the figures and used to describe positioning of elements of the figures relative to one another. As such, elements shown above other elements are positioned vertically above the other elements, in one example. As yet another example, shapes of the elements depicted within the figures may be referred to as having those shapes (e.g., such as being circular, straight, planar, curved, rounded, chamfered, angled, or the like). Further, elements shown intersecting one another may be referred to as intersecting elements or intersecting one another, in at least one example. Further still, an element shown within another element or shown outside of another element may be referred to as such, in one example.

(84) It will be appreciated that the configurations and routines disclosed herein are exemplary in nature, and that these specific embodiments are not to be considered in a limiting sense, because numerous variations are possible. Moreover, unless explicitly stated to the contrary, the terms “first,” “second,” “third,” and the like are not intended to denote any order, position, quantity, or importance, but rather are used merely as labels to distinguish one element from another. The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various systems and configurations, and other features, functions, and/or properties disclosed herein.

(85) As used herein, the term “approximately” is construed to mean plus or minus five percent of the range unless otherwise specified.

(86) The following claims particularly point out certain combinations and sub-combinations regarded as novel and non-obvious. These claims may refer to “an” element or “a first” element or the equivalent thereof. Such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements. Other combinations and sub-combinations of the disclosed features, functions, elements, and/or properties may be claimed through amendment of the present claims or through presentation of new claims in this or a related application. Such claims, whether broader, narrower, equal, or different in scope to the original claims, also are regarded as included within the subject matter of the present disclosure.

Claims

1. A trumpet arm for an axle, comprising: a housing with an arm section extending an arm length, the arm section having an outlet at a first end, and a flange with a planar face at a second end opposite the first end; and internal buttresses positioned in an interior of the housing and extending through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length, wherein the housing and the internal buttresses are formed as various cast, stamped, or machined components fixtured

and assembled as a weldment.

2. The trumpet arm of claim 1, wherein the internal buttresses include one or more legs which extend from walls of the housing towards the interior of the housing in an “x” configuration, a “y” configuration, a horizontal configuration, a vertical configuration, a “+” configuration, a curved configuration, or a combination of two or more of the aforementioned configurations.
3. The trumpet arm of claim 1, wherein a cross section of the arm section is a box, a rectangle, a circle, an oval, an hourglass, or a combination of two or more of the aforementioned shapes.
4. The trumpet arm of claim 1, further comprising external buttresses extending a second portion of the flange length to the flange/arm transition, and wherein endpoints of the external buttresses are offset from endpoints of the internal buttresses.
5. The trumpet arm of claim 1, wherein the flange includes an angled extension from the planar face to the flange/arm transition.
6. The trumpet arm of claim 1, wherein the flange includes a curved extension from the planar face to the flange/arm transition.
7. The trumpet arm of claim 1, further comprising a spindle coupled to the housing at the outlet of the arm section.
8. The trumpet arm of claim 1, wherein a cross section of the arm section maintains a constant profile throughout the arm length.
9. The trumpet arm of claim 1, further comprising multiple through holes around a perimeter of the flange, wherein one or more of the multiple through holes includes a raised bolt pad.
10. The trumpet arm of claim 1, wherein an interior area of the flange decreases from the first end towards the flange/arm transition.
11. The trumpet arm of claim 1, wherein the housing and the internal buttresses are formed of cast steel, cast aluminum, and/or nodular iron.
12. An e-axle, comprising: an electric machine; a first trumpet arm; a second trumpet arm, wherein the first trumpet arm and the second trumpet arm each comprise a housing with an arm section extending an arm length, a flange with a planar face at a first end of the arm length, and internal buttresses positioned in an interior of the housing, where the first trumpet arm and the second trumpet arm are each configured to couple to the electric machine via their respective flange; and one or more locating dowels which extend from the flange of each of the first trumpet arm and the second trumpet arm to the electric machine, and/or one or more pilot diameters which extend into the flange of each of the first trumpet arm and the second trumpet arm and are configured to receive one or more connectors of the electric machine.
13. The e-axle of claim 12, wherein internal buttresses of the first trumpet arm and the second trumpet arm extend through at least a first portion of a flange length of the flange, a flange/arm transition at which the flange transitions into the arm section, and at least a portion of the arm length.
14. The e-axle of claim 12, further comprising a differential lock/axle disconnect assembly having a shift fork and a sliding collar positioned in the flange of the first trumpet arm or the second trumpet arm, the shift fork and the sliding collar configured to mate with a mating clutch of the electric machine, and where the differential lock/axle disconnect assembly is pneumatically, hydraulically, electro-mechanically, or magnetically operated.
15. The e-axle of claim 14, wherein the differential lock/axle disconnect assembly includes a differential lock/axle disconnect actuator which extends through a flange length of the flange of the first trumpet arm or the second trumpet arm.
16. The e-axle of claim 12, further comprising a suspension package coupled to at least one of the first trumpet arm and the second trumpet arm at the respective arm section(s).
17. The e-axle of claim 12, further comprising a first spindle and a second spindle coupled to each of the first trumpet arm and the second trumpet arm, respectively, at a second end of the arm length opposite the first end of the arm length and at a first spindle end of the respective spindle, and a

first wheel and a second wheel coupled to each of the first spindle and the second spindle, respectively, at a second spindle end of the respective spindle, opposite the first spindle end of the spindle.

18. An axle housing, comprising: an arm section extending an arm length; a flange extending a flange length and having a planar face at a first end of the flange length, the flange coupled to the arm section at a flange/arm transition; internal buttresses positioned in an interior of the flange and the arm section, the internal buttresses extending at least a portion of the arm length of the arm section and at least a first portion of the flange length; external buttresses positioned on an exterior of the flange, the external buttresses extending at least a second portion of the flange length; a pair of first pivot points at the planar face of the flange; and a pair of second pivot points at the flange/arm transition, wherein: the pair of first pivot points and the pair of second pivot points are both rigid when the arm section experiences deflection in a first, downward direction due to, in a top half of the axle housing, the internal buttresses being in compression and the external buttresses being in tension, and in a bottom half of the axle housing the internal buttresses being in tension and the external buttresses being in compression; and the pair of first pivot points and the pair of second pivot points are both rigid when the arm section experiences deflection in a second, upward direction due to, in the top half of the axle housing, the internal buttresses being in tension and the external buttresses being in compression and in the bottom half of the axle housing, the internal buttresses being in compression and the external buttresses being in tension.
