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(54) Titre : MODULE D'ENTRAINEMENT ELECTRIQUE AVEC TRANSMISSION AYANT DES PAIRES DE ROUES DOUBLES COAXIALES PARALLELES PARTAGEANT UNE CHARGE A UNE ROUE DE COMMANDE FINALE
(54) Title: ELECTRIC DRIVE MODULE WITH TRANSMISSION HAVING PARALLEL TWIN GEAR PAIRS SHARING LOAD TO A FINAL DRIVE GEAR

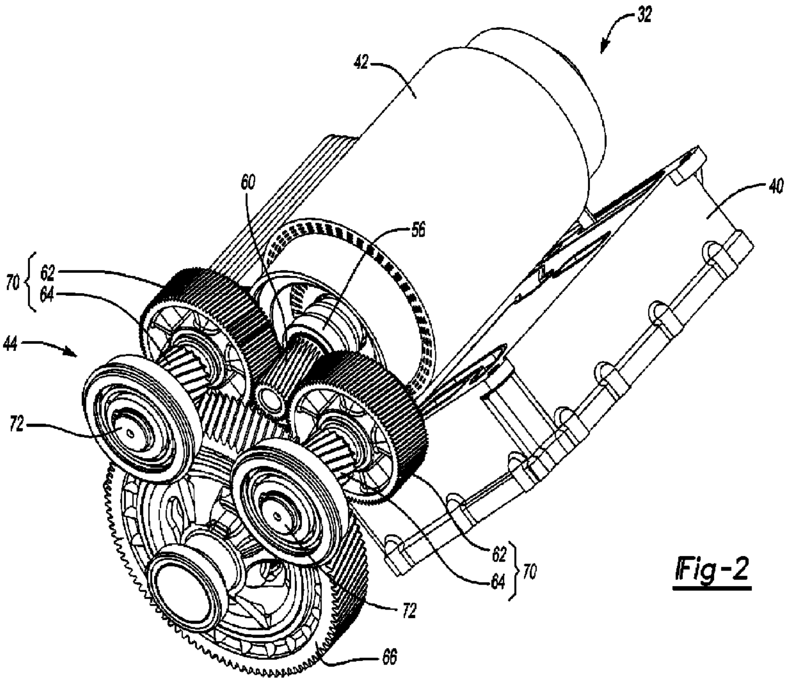

Fig-2

(57) Abrégé/Abstract:
An electric drive module that includes an electric motor, a differential assembly, and a transmission that transmits rotary power between the electric motor and the differential assembly. The transmission has first and second reductions. The first reduction has a drive gear, which is rotatable about a first axis, and a pair of first reduction gears that are each meshingly engaged to the drive gear rotatable about a respective second axis. The second axes are spaced apart from one another and are parallel to the first axis. The second reduction has a driven gear and a pair of second reduction gears. The driven gear is rotatable about a third axis that is parallel to the first axis. Each of the second reduction gears is being meshingly engaged to the driven gear and non-rotatably coupled to an associated one of the first reduction gears.

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An electric drive module that includes an electric motor, a differential assembly, and a transmission that transmits rotary power between the electric motor and the differential assembly. The transmission has first and second reductions. The first reduction has a drive gear, which is rotatable about a first axis, and a pair of first reduction gears that are each meshingly engaged to the drive gear rotatable about a respective second axis. The second axes are spaced apart from one another and are parallel to the first axis. The second reduction has a driven gear and a pair of second reduction gears. The driven gear is rotatable about a third axis that is parallel to the first axis. Each of the second reduction gears is being meshingly engaged to the driven gear and non-rotatably coupled to an associated one of the first reduction gears.

ELECTRIC DRIVE MODULE WITH TRANSMISSION HAVING PARALLEL TWIN GEAR PAIRS SHARING LOAD TO A FINAL DRIVE GEAR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/942496 filed December 2,2019, the disclosure of which is incorporated by reference as if fully set forth in detail herein.

FIELD

[0002] The present disclosure relates to an electric drive module with a transmission having parallel gear pairs that share load to a final drive gear.

BACKGROUND

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] It is known in the art to provide an electric drive module having an electric motor that drives a differential assembly through a transmission. Known electric drive module configurations can have a coaxial arrangement, in which the output shaft of the electric motor, differential assembly and input and output of the transmission are disposed about a common rotational axis, or an arrangement in which the output shaft of the electric motor, the differential assembly and the input and output of the transmission are disposed about two or more rotational axes that are parallel to one another. While such configurations are well suited for their intended purpose, they can be somewhat difficult to package or fit into certain vehicles as there may be insufficient space in a lateral or side-to-side direction or in a radial direction. Accordingly, there remains a need in the art for an electric drive module that is relatively compact in design.

SUMMARY

[0005] This section provides a general summary of the disclosure and is not a comprehensive disclosure of its full scope or all of its features.

[0006] In one form, the present disclosure provides an electric drive module that includes an electric motor, a differential assembly, and a

CA 03151002 2022-3-11

transmission that transmits rotary power between the electric motor and the differential assembly. The transmission has first and second reductions. The first reduction has a drive gear, which is rotatable about a first axis, and a pair of first reduction gears that are each meshingly engaged to the drive gear rotatable about a respective second axis. The second axes are spaced apart from one another and are parallel to the first axis. The second reduction has a driven gear and a pair of second reduction gears. The driven gear is rotatable about a third axis that is parallel to the first axis. Each of the second reduction gears is being meshingly engaged to the driven gear and non-rotatably coupled to an associated one of the first reduction gears.

[0007] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0008] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0009] Figure 1 is a schematic illustration of an exemplary vehicle having an electric drive module constructed in accordance with the teachings of the present disclosure;

[0010] Figure 2 is a perspective, partly fragmented portion of the electric drive module of Figure 1 illustrating an electric motor and a transmission in more detail;

[0011] Figure 3 is a cross-sectional view of a portion of the electric drive module of Figure 1 illustrating a final drive gear of the transmission and a differential assembly;

[0012] Figure 4 is a schematic illustration of a portion of the electric drive module of Figure 1 illustrating the relative positioning of the electric motor, the transmission and the differential assembly;

[0013] Figure 5 is a perspective view of portion of the electric drive module of Figure 1 illustrating an optional park lock mechanism;

[0014] Figure 6 is a plan view of a portion of the park lock mechanism illustrating a pawl disposed in engagement with a pair of park gears to immobilize the countershafts of the electric drive module;

[0015] Figure 7 is a sectional view taken through a portion of the park lock mechanism, the view illustrating a cam plate oriented in a first rotational position and a pair of plungers disposed in an extended position;

[0016] Figure 8 is perspective view of a portion of the park lock mechanism illustrating the pawl disengaged from a pair of park gears to permit rotation of the countershafts of the electric drive module;

[0017] Figure 9 is a sectional view taken through a portion of the park lock mechanism, the view illustrating the cam plate oriented in a second rotational position and a pair of plungers disposed in a retracted position;

[0018] Figure 10 is a partially sectioned perspective view of the park lock mechanism;

[0019] Figure 11 is a perspective view of a portion of the park lock mechanism illustrating a first face of the cam plate in more detail;

[0020] Figure 12 is a section view of a portion of the park lock mechanism illustrating a lock actuator in more detail;

[0021] Figure 13 is a perspective view of a portion of the cam plate illustrating a lock aperture formed in a second face of the cam plate; and

[0022] Figure 14 is perspective view of a portion of the park lock mechanism illustrating the plungers in the extended position and the pawl in the engaged position.

[0023] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0024] With reference to Figure 1 of the drawings, an exemplary vehicle having a drive module constructed in accordance with the teachings of the present disclosure is generally indicated by reference numeral 10. The vehicle 10 can include a front or primary driveline 14 and a rear or secondary driveline 16. The front driveline 14 can comprise an engine 18 and a transmission 20 and can be configured to drive a front or primary set of drive wheels 22. The rear driveline 16 can comprise an electric drive module 24 that can be

CA 03151002 2022-3-11

configured to drive a rear or secondary set of drive wheels 26 on an as needed or "on demand" basis. While the front wheels 22 are associated with the primary driveline 14 and the rear wheels 26 are associated with the secondary driveline 16 in the present example, it will be appreciated that in the alternative, the rear wheels could be driven by the primary driveline and the front wheels could be driven by the secondary driveline. Moreover, while the electric drive module 24 has been depicted in this example as being configured to drive a secondary set of drive wheels on a part time basis, it will be appreciated that a drive module constructed in accordance with the present teachings could be employed to drive a (front, rear or other) set of drive wheels (e.g., a front or set of wheels) on a full-time basis, either as the sole means of propulsion for the vehicle or in conjunction with another means of propulsion. The electric drive module 24 can comprise a drive unit 30, and a pair of axle shafts 32.

[0025] With reference to Figures 2 and 3, the drive unit 30 can comprise a housing 40, an electric motor 42, a transmission 44, and a differential assembly 46. The housing 40 can define a structure to which the other components of the drive unit 30 are mounted. The housing 40 can be formed of two or more housing elements that can be fixedly coupled together, such as via a plurality of threaded fasteners. The electric motor 42 can be any type of electric motor, such as a permanent magnet motor. The electric motor 42 can be mounted to a flange (not specifically shown) on the housing 40 and can have an output shaft 56 that can be disposed along a first rotary axis 58 (Fig. 4) and received into the housing 40.

[0026] With reference to Figures 2 and 4, the transmission 44 can comprise one or more transmission stages or reductions that provide a transmission input, which is driven by the output shaft of the electric motor 42, and a transmission output that drives the differential assembly 46. The transmission 44 can comprise one or more transmission stages or reductions to provide multiple levels of gear reduction, and optionally can include one or more multi-speed transmission stages. Also optionally, a clutch (not shown) can be employed between the transmission output and the differential assembly 46 to selectively de-couple the differential assembly 46 from the electric motor 42. In the example provided, the transmission 44 comprises a drive gear or input pinion 60, a plurality of first reduction gears 62, a plurality of second reduction gears 64, and a driven gear or final drive gear 66. The input pinion 60 can be coupled to the output shaft of the electric motor 42 for rotation therewith. The first reduction gears 62 are meshingly engaged with the input pinion 60, have more teeth than the input pinion 60 and have a pitch diameter that is relatively larger than the pitch diameter of the input pinion 60. Each of the first reduction gears 62 can be fixedly coupled to an associated one of the second reduction gears 64 to form a compound reduction gear 70. The second reduction gears 64 are larger in pitch diameter and have more teeth than the first reduction gears 62. Each of the compound reduction gears 70 can be disposed on a countershaft or axle 72 that is mounted to the housing 40 for rotation about a second rotational axis 74 that is parallel to and offset from first rotary axis 58. Each of the countershafts 72 can be supported by a pair of bearings that can be mounted to the housing 40. It will be appreciated that each of the countershafts 72 can be formed as a discrete component that can be assembled to a corresponding one of the compound reduction gears 70, or could be unitarily and integrally formed with a corresponding one of the compound reduction gears 70. The final drive gear 66 can be supported by the housing 40 for rotation about an output axis 76 that is parallel to and offset from the second rotational axes 74 and the first rotary axis 58. In the example provided, the input pinion 60, the first reduction gears 62, the second reduction gears 64 and the final drive gear 66 are helical gears, with the first reduction gears 62 and the second reduction gears 64 being opposite handed to cancel out axial forces on the compound reduction gears 70 that are associated with the transmission of rotary power between the input pinion 60 and the first reduction gears 62 and between the second reduction gears 64 and the final drive gear 66. While the transmission 44 has been described as employing helical gears, it will be appreciated that some or all of these gears could be constructed as spur gears.

[0027] With reference to Figure 3, the differential assembly 46 can include a differential input member and a pair of differential output members. The differential input member can be coupled to the final drive gear 66 for rotation therewith about the output axis 76, while each of the differential output members can be coupled for rotation with a corresponding one of the axle shafts 32. In the particular example provided, the differential assembly 46

CA 03151002 2022-3-11

includes a differential case 80 and a differential gearset 82. The differential case 80 can function as the differential input member and can be supported for rotation on the housing 40 about the output axis 76 by a pair of bearings 84. The bearings 84 are illustrated as being tapered roller bearings in the example provided, but it will be appreciated that bearings 84 could be configured as angular ball bearings or as ball bearings in the alternative. The differential gearset 82 can include a pair of differential pinions 90 and a pair of side gears 92. The differential pinions 90 can be received in the differential case 80 and are rotatably disposed on a cross-pin 94 that is mounted to the differential case 80. The cross-pin 94 can extend at least partly through the differential case 80 and is oriented perpendicular to the output axis 76. The side gears 92 are the differential output members in the example provided. The side gears 92 are received in the differential case 80 and are rotatable relative to the differential case 80 about the output axis 76. Each of the side gears 92 is meshingly engaged with the differential pinions 90.

[0028] Each of the axle shafts 32 can be non-rotatably but axially slidably engaged to a corresponding one of the side gears 92. In the example provided, each of the axle shafts 32 has a male-splined segment 100 that is matingly engaged to an internally splined aperture 102 in a corresponding one of the side gears 92. Each of the axle shafts 32 is configured to transmit rotary power between one of the side gears 92 and an associated one of the vehicle wheels.

[0029] The configuration of the transmission 44 is advantageous in several aspects. For example, the compound reduction gears 70 permit the use of a relatively high-speed electric motor and a relatively small input pinion, which lowers the pitch line velocity and thus affects bending stress, load capacity and the service life of the input pinion 60 and the first reduction gears 62 in a positive manner. As another example, the loading on the final drive gear 66 is shared across the second reduction gears 64, which permits a reduction in the size of the second reduction gears 64 (as opposed to an arrangement where the entire load is transmitted into the final drive gear 66 by a single gear). Consequently, the arrangement of the gearing between the electric motor 42 and the final drive gear 66 permits a reduction in the package size of the drive unit 30, and moreover, these gears can be formed relatively smaller and/or from less expensive materials than components of the known electric drive units to thereby reduce the cost and mass of the electric drive module 24.

[0030] If desired, a park-lock mechanism (not shown) can be incorporated into the electric drive module 24. With reference to Figures 2 and 4, the park-lock mechanism could be configured in a conventional manner with a pawl, which is pivotably coupled to the housing 40, a toothed locking wheel, which is rotatably coupled to the final drive gear 66 or to a component of the differential assembly 46 that is rotatable about the output axis 76. The pawl can be pivoted into and out of engagement with the teeth on the toothed locking wheel to inhibit rotation of the final drive gear 66 relative to the housing 40. Alternatively, the park-lock mechanism could be configured to selectively lock the countershafts 72 to the housing 40. A scissor mechanism or a teeter-totter lever mechanism could be employed to simultaneously lock the countershafts 72 to the housing 40.

[0031] With reference to Figures 5 through 7, an optional The park-lock mechanism 200 may be incorporated into the drive unit 30. The park-lock mechanism 200 can include a pair of park gears 202, a pawl 204, a pair of plungers 206, a pair of plunger biasing springs 208, and an actuator 210.

[0032] Each of the park gears 202 can be non-rotatably coupled to an associated one of the countershafts 72 and can define a plurality of teeth 216 and a plurality of valleys 218. Each of the valleys 218 is disposed between a respective pair of the teeth 216.

[0033] The pawl 204 includes a pawl body 220 and a pair of pawl teeth 222 that are disposed on the opposite ends of the pawl body 220. The pawl body 220 is pivotably coupled to the housing 40 of the drive unit 30 so that the pawl 204 can be moved between an engaged position (Fig. 6), in which each of the pawl teeth 222 engages an associated one of the park gears 202 (i.e., each pawl tooth 222 is received into a valley 218 in an associated one of the park gears 202) to thereby rotationally lock the park gears 202 and the countershafts 72 to the housing 40, and a disengaged position (Fig. 8) in which each pawl tooth 222 clears the teeth 216 on the associated one of the park gears 202 so that the pawl 204 does not inhibit rotation of the park gears 202 or the countershafts 72 relative to the housing 40. In the example provided, a pivot axle 226 is mounted to the housing 40 and extends through the pawl 204 and into the actuator 210. The pawl 204 can be received somewhat loosely on the pivot axle 226 to ensure that the load transmitted through the park-lock mechanism 200 is shared equally by the park gears 202, as well as equally by the pawl teeth 222. The pawl 204 can be biased about the pivot axle 226 toward a desired rotational position, such as the disengaged position. In the example provided, a helical torsion spring 258 is disposed about the pivot axle 226 and is engaged to the housing 40 and to the pawl body 220.

[0034] With reference to Figure 7, each of the plungers 206 can have a plunger body with a guide portion 230, a first body portion 232, a transition portion 234, and a second body portion 236. The guide portion 230 can be disposed on a first axial end of the plunger 206 and can be cylindrically shaped with a first diameter. The first body portion 232 can be disposed between the guide portion 230 and the transition portion 234 and can be sized in a desired manner. For example, the first body portion 232 could be generally cylindrically shaped having a desired diameter, such as the first diameter. In the example provided, the first body portion 232 is frusto-conically shaped, having a base (where the first body portion 232 intersects the guide portion 230) with a diameter that is equal to the first diameter and a relatively shallow cone angle that causes the exterior surface of the first body portion 232 to taper inwardly toward the central axis of the plunger 206 between the guide portion 230 and the transition portion 234 by a desired amount, such as 2 degrees to 30 degrees, preferably 5 degrees to 15 degrees.

[0035] The second body portion 236 can also be cylindrically shaped but has a second diameter that is smaller than the first diameter. The transition portion 234 can be frusto-conically shaped so as to taper between the first and second body portions 232 and 236. A spring aperture 240 can be formed in the first axial end of the plunger 206 and is sized to receive a corresponding one of the plunger biasing springs 208 therein. In the example provided, each of the plunger biasing springs 208 is a helical coil compression spring, but it will be appreciated that other types of springs could be used instead of or in addition to a helical coil compression spring.

[0036] Each plunger 206 and plunger biasing spring 208 is received into a plunger aperture 244 in the housing 40. In the example shown, the housing 40 includes an optional pair of plunger bushings 246 that can be formed of a suitable material, such as hardened steel. Each of the plunger bushings 246 defines a plunger aperture 244 that is sized to receive the first body portion 232 of a corresponding one of the plungers 206 and a corresponding one of the plunger biasing springs 208. The plunger aperture 244 can be a blind hole so that the plunger bushing 246 defines an interior wall 248 against which an end of the corresponding one of the plunger biasing springs 208 can abut.

[0037] Each of the plungers 206 is movable along its longitudinal axis relative to the housing 40 between an extended position (shown in Figs. 6 & 7) in which the first body portion 232 of each of the plungers 206 is disposed in a rotational path of the pawl body 220, and a retracted position (shown in Figs. 8 & 9). To position the plungers 206 in the extended position, the pawl teeth 222 must be engaged to the park gears 202. If the exterior surface of the first body portion 232 is tapered (frusto-conical), the plunger biasing springs 208 will urge the plungers 206 outwardly from the plunger apertures 244 such that the exterior surface of the first body portion 232 of each plunger 206 contacts the pawl body 220. When the plungers 206 are disposed in their retracted positions, the pawl 204 can be rotated via the torsion spring 258 to the disengaged position. The pawl 204 can contact the second body portion 236 of one or both of the plungers 206 when the pawl 204 is in the disengaged position.

[0038] With reference to Figures 7 and 10, the actuator 210 is configured to control movement of the plungers 206 between the extended and retracted positions. The actuator 210 can include a pair of cam followers 250, an actuator hub 252, a cam plate 254, a bearing 256, a torsion spring 258, a rotary actuator 260, and a lock actuator 262.

[0039] With reference to Figures 7 and 9, each of the cam followers 250 can be disposed in-line with an associated one of the plungers 206. In the example provided, each of the cam followers 250 is unitarily and integrally formed with an associated one of the plungers 206. More specifically the cam follower 250 can be a spherical radius on a second axial end of the plunger 206 that is opposite the first axial end.

[0040] The actuator hub 252 can be fixedly coupled to the housing 40 concentrically about the axis about which the pawl 204 pivots. In the example provided, the actuator hub 252 is press-fit to the pivot axle 226. The actuator hub 252 can include a central portion 270, a bearing mount 272 and a lock actuator mount 274. The central portion 270 can define a pivot axle aperture 280 and a threaded aperture 282 that are aligned along a common axis. The pivot axle aperture 280 is formed through a first axial side of the central portion 270 and sized to engage the pivot axle 226 in a press-fit manner. The threaded aperture 282 is formed through a second, opposite axial side of the central portion 270. The bearing mount 272 is disposed concentrically about the central portion 270 and can be coupled to the central portion 270 through a flange member 284 or alternately, through a plurality of spokes or webs. The bearing mount 272 has an exterior circumferential surface 286, a shoulder 288 that extends radially outwardly from the exterior circumferential surface, and a retaining ring groove 290 that is formed into the exterior circumferential surface 286. The lock actuator mount 274 can have a fabiform (i.e., kidney bean) shape, which is best seen in Figure 5, and can be fixedly coupled to (e.g., unitarily formed with) the bearing mount 272 so as to be radially offset from the central portion 270.

[0041] With reference to Figures 5, 7 and 11, the cam plate 254 can comprise an annular plate 300, a gear portion 302, a torsion spring mount 304 and a pair of sensor targets 306a, 306b. The annular plate 300 can formed of a suitable material. The annular plate 300 can have an interior circumferential surface 310 and can define a pair of cams 312. Each of the cams 312 is formed into a first face of the annular plate 300 that faces toward the cam followers 250 and the plungers 206. Each of the cams 312 can be a circumferentially extending groove in the first face of the annular plate 300. Each of the cams 312 can taper between a first circumferential end 320 (Fig. 11) of the groove, where the groove is deepest, and a second, opposite circumferential end 322 (Fig. 11) of the groove where the groove is shallowest. Each of the cam followers 250 can be received into a corresponding one of the cams 312 (i.e., grooves) so that rotation of the cam plate 254 about an axis about which the pawl 204 pivots causes corresponding linear motion of the plungers 206. More specifically, placement of a cam follower 250 into the deepest part of an associated one of the cams 312 (i.e., the first circumferential end 320 of the groove that forms the associated one of the cams 312) as shown in Figure 7 permits a corresponding one of the plunger biasing springs 208 to urge the associated one of the plungers 206 into its extended position, while placement of a cam follower 250 in the shallowest part of an associated one of the cams 312 (i.e., the second circumferential end of the groove that forms the associated one of the cams 312) as shown in Figure 9 positions a corresponding one of the plungers 206 in its retracted position against the bias of the corresponding one of the plunger biasing springs 208. The gear portion 302 can include a plurality of gear teeth that can be fixedly coupled to the annular plate 300 such that gear teeth are concentric with the interior circumferential surface 310. In the example provided, the gear teeth are unitarily and integrally formed with the annular plate 300. The gear teeth can be disposed about the entire circumference of the annular plate 300, as is shown in the example provided, or could be formed about a sector of the annular plate 300. The torsion spring mount 304 can be a cylindrical post or projection that can extend from a second face of the annular plate 300 that is opposite the first face. Each of the sensor targets 306a, 306b can be mounted to the annular plate 300 and is configured to be sensed by a sensor 328 (Fig. 10) when the cam plate 254 is in a predetermined rotational position relative to the housing 40. In the example provided, each of the sensor targets 306a, 306b is a magnet and the sensor 328 is a Hall-effect sensor that is coupled to the housing 40.

[0042] With reference to Figure 7, the bearing 256 is configured to support the cam plate 254 for rotation relative to the actuator hub 252. The bearing 256 can include an inner bearing race 330, an outer bearing race 332, and a plurality of bearing elements 334 that are received between the inner and outer bearing races 330 and 332. The inner bearing race 330 can be received onto the exterior circumferential surface 286 of the bearing mount 272 and abutted against the shoulder 288. If desired, the inner bearing race 330 can be press-fit to the exterior circumferential surface 286 of the bearing mount 272. An external retaining ring 336 can be received into the retaining ring groove 290 and can inhibit axial movement of the inner bearing race 330 on the actuator hub 252 in a direction away from the shoulder 288. The outer bearing race 332 can be coupled to the cam plate 254 in any desired manner. For example, the outer bearing race 332 could be press-fit or adhesively bonded to the interior circumferential surface 310 of the annular plate 300. Alternatively, in instances where the annular plate is formed of a plastic material, the annular plate 300 could be overmolded onto the outer bearing race 332 such that the outer bearing race 332 is cohesively bonded to the annular plate 300.

[0043] With reference to Figures 5 and 7, the torsion spring 258 can be wound about the central portion 270 and can have a first tang 340, which can react against the actuator hub 252, and a second tang 342 that can react against the torsion spring mount 304 on the cam plate 254. In the example provided, the first tang 340 is received into a hole that is formed in the flange member 284. The torsion spring 258 can be secured to the central portion 270 via a washer 346 and a threaded fastener 348 that is threaded to the threaded aperture 282 in the central portion 270. The torsion spring 258 is configured to rotationally bias the cam plate 254 about its rotational axis toward a first rotational position, which can be a position that orients the deepest part of the cams 312 to the cam followers 250. Alternatively, the torsion spring 258 could be configured to rotationally bias the cam plate 254 about its rotational axis into a position where the shallowest part of the cams 312 is oriented to the cam followers 250.

[0044] With reference to Figure 10, the rotary actuator 260 is configured to control rotation of the cam plate 254 about its rotational axis between the first rotational position and a second rotational position. The rotary actuator 260 can include a rotary electric motor (not specifically shown) and an output pinion (not specifically shown) that is meshingly engaged to the gear teeth of the gear portion 302 of the cam plate 254. The electric motor can be coupled (e.g., mounted) to the housing 40. The output pinion can be driven by the electric motor, either directly (e.g., the output pinion is mounted on an output shaft of the electric motor), or through a transmission (not shown) having one or more gears (not shown) that are disposed in a power transmission path between the electric motor and the output pinion.

[0045] The electric motor can be operated to drive the cam plate 254 to the second rotational position, which can be a position that orients an opposite circumferential end of the cams 312, such as the shallowest part of the cams 312, to the cam followers 250. In some forms, the electric motor can be employed to drive the cam plate 254 into the desired rotational position and to thereafter hold the cam plate 254 in this rotational position. Optionally, the cam plate 254 can be configured with a stop member (not shown) that abuts a mating stop member (not shown) that is coupled to the housing 40 when the electric motor rotates or drives the cam plate 254 into the desired rotational position. In the example provided, however, the sensor target 306b, the sensor 328 and the lock actuator 262 are employed to maintain the cam plate 254 in the desired rotational position so that electric power to the electric motor need not be maintained.

[0046] Placement of the cam plate 254 into each of the first and second rotational positions can be sensed by the sensor 328, and the sensor 328 can responsively generate a corresponding sensor signal. For example, placement of the cam plate 254 in the first rotational position orients the sensor target 306a to the sensor 328 and the sensor 328 responsively generates a first sensor signal, while placement of the cam plate 254 in the second rotational position orients the sensor target 306b to the sensor 328 and the sensor 328 responsively generates a second sensor signal. In response to receipt of the second sensor signal, a controller (not shown) can control the lock actuator 262 to engage the lock actuator 262 to the cam plate 254 to inhibit rotation of the cam plate 254 out of the second rotational position (i.e., due to the moment applied to the cam plate 254 by the torsion spring 258).

[0047] With reference to Figures 10 and 12, the lock actuator 262 can comprise any means for inhibiting rotation of the cam plate 254 relative to the housing 40. In the example provided, the lock actuator 262 comprises a solenoid assembly 400 and a lock aperture 402. The solenoid assembly 400 can be coupled to the housing 40 and can include a solenoid 410, a solenoid plunger 412 and a solenoid spring 414. The solenoid plunger 412 is movable in the solenoid 410 between an extended or latched position, and a retracted or unlatched position. The solenoid spring 414 biases the solenoid plunger 412 into the extended or latched position. The lock aperture 402 is formed in the second face of the annular plate 300 and is configured to receive the solenoid plunger 412 therein when the cam plate 254 is in the second rotational position. In the example shown, the solenoid plunger 412 has a tip 420 that is defined by a spherical radius, and the lock aperture 402 has a frusto-conically-shaped sidewall 422. The contour of the tip 420 of the solenoid plunger 412 and the sidewall 422 of the lock aperture 402 permits the solenoid plunger 412 to be driven toward the retracted or unlatched position via the torsion spring 258 when electric power is not provided to the solenoid 410 or to the electric motor.

[0048] With reference to Figures 5, 7 and 12, when electrical power is not provided to the electric motor or the solenoid 410 during the operation of the drive unit 30, the torsion spring 258 biases the cam plate 254 into the first rotational position where the deepest part of the cams 312 are aligned to the cam followers 250 as shown in Figure 7 so that the plungers 206 are disposed in their extended positions such that the first body portions 232 contact the pawl body 220 and the pawl 204 is disposed about the pivot axle 226 such that the pawl teeth 222 engage the park gears 202 as shown in Figure 6. In this condition, the countershafts 72 are effectively non-rotatably locked to the housing 40 and due to the configuration of the park-lock mechanism 200, the load transmitted through each pawl tooth 222 and each park gear 202 is equal. In this condition, the sensor target 306a is aligned to the sensor 328, so that the sensor 328 generates responsively generates the first sensor signal. The first sensor signal can be received by a controller (not shown) and employed to determine that the cam plate 254 is in a rotational position that causes the park-lock mechanism 200 to lock the countershafts 72 to the housing 40. The solenoid spring 414 of the lock actuator 262 biases the tip 420 of the solenoid plunger 412 against the second face of the annular plate 300.

[0049] To unlock the countershafts 72 from the housing 40 to permit rotation of the countershafts 72 relative to the housing 40, electrical power can be applied to the electric motor to drive the output pinion to cause corresponding rotation of the cam plate 254 about its rotational axis in a first rotational direction. Rotation of the cam plate 254 in the first rotational direction aligns progressively shallower portions of the grooves or cams 312 to the cam followers 250 as shown in Figure 9, causing the plungers 206 to move from their extended positions toward their retracted positions. Due to the tapered configurations of the first body portion 232 and the transition portion 234 of the plungers 206, as well as the moment that is applied to the pawl 204 by the torsion spring 258, the pawl teeth 222 are progressively moved away from the teeth 216 of the park gears 202 as the plungers 206 move progressively toward their retracted positions. Placement of the pawl 204 in contact with the second body portions 236 of the plungers 206 as shown in Figures 8 and 9 positions the pawl teeth 222 away from the park gears 202 at a location where the park gears 202, and consequently the countershafts 72, are able to rotate freely relative to the housing 40. Further rotation of the cam plate 254 in the first rotational direction positions the cam plate 254 in the second rotational position, which orients the sensor target 306b to the sensor 328 so that the sensor 328 responsively generates the second sensor signal. In response to receipt of the second sensor signal, the controller can provide electrical power to the solenoid 410 to drive the solenoid plunger 412 into the lock aperture 402 and to hold the solenoid plunger 412 in this position. Optionally, the controller can also terminate the supply of electric power to the motor. The moment that is applied to the cam plate 254 by the torsion spring 258 to urge the cam plate 254 toward the first rotational position is insufficient to force the solenoid plunger 412 out of the lock aperture 402 when electrical power is supplied to the solenoid 410.

[0050] To re-lock the countershafts 72 to the housing 40 to inhibit rotation of the countershafts 72 relative to the housing 40, the supply of electric power to the solenoid 410 is terminated. The moment that is applied to the cam plate 254 by the torsion spring 258 to urge the cam plate 254 toward the first rotational position is sufficient to overcome the force that is applied to the solenoid plunger 412 by the solenoid spring 414 and force the solenoid plunger 412 out of the lock aperture 402. The moment applied to the cam plate 254 by the torsion spring 258 causes the cam plate 254 to rotate in a second rotational direction that is opposite the first rotational direction. Rotation of the cam plate 254 in the second rotational direction can cause the gear teeth of the gear portion 302 to back-drive the output pinion as the cam plate 254 rotates toward and into the first rotational position. Rotation of the cam plate 254 in the second rotational direction also aligns progressively deeper portions of the grooves or cams 312 to the cam followers 250, causing the plungers 206 to move from their retracted positions to their extended positions. Due to the tapered configurations of the transition portion 234 and the first body portion 232 of each of the plungers 206, contact between the pawl body 220 and the plungers 206 when the cam plate 254 is rotated in the second rotational direction drives the pawl 204 about the pivot axle 226 so that the pawl teeth 222 are rotated toward their respective park gear 202. The pawl teeth 222 are able to move directly into valleys 218 in the park gears 202 in situations where the park gears 202 are oriented in receptive positions. In other situations, movement of the pawl teeth 222 into valleys 218 may be blocked because the park gears 202 are oriented into positions where each pawl tooth 222 contacts a tooth - of an associated one of the park gears 202. However, the plunger biasing springs 208 provide compliance that drives the plungers 206 into their extended positions (where the exterior surfaces of the first body portions 232 engage the pawl 204 and thereby drive the pawl teeth 222 into engagement with the park gears 202) when the countershafts 72 are rotated slightly.

[0051] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

What is claimed is:

1. An electric drive module (24) having:

an electric motor (42);

a differential assembly (46); and

a transmission (44) transmitting rotary power between the electric motor (42) and the differential assembly (46), the transmission (44) including a first reduction and a second reduction, the first reduction having a drive gear (60) and a pair of first reduction gears (62), the drive gear (60) being rotatable about a first axis (58), each of the first reduction gears (62) being meshingly engaged to the drive gear (60) and being rotatable about a respective second axis (74), wherein the second axes (74) are spaced apart from one another and are parallel to the first axis (58), the second reduction having a driven gear (66) and a pair of second reduction gears (64), the driven gear (66) being rotatable about a third axis (76) that is parallel to the first axis (58), each of the second reduction gears (64) being meshingly engaged to the driven gear (66) and non-rotatably coupled to an associated one of the first reduction gears (62).

2. The electric drive module (24) of Claim 1, wherein the electric motor (42) includes an output shaft (56) and wherein the drive gear (60) is coupled to the output shaft (56) for rotation therewith about the first axis (58).

3. The electric drive module (24) of Claim 2, wherein the differential assembly (46) includes a differential input member (80) and wherein the driven gear (66) is coupled to the differential input member (80) for common rotation about the third axis (76).

4. The electric drive module (24) of Claim 3, wherein the differential assembly (46) includes a differential gearset (82).

5. The electric drive module (24) of Claim 4, wherein the differential gearset (82) comprises a plurality of differential pinions (90) that are in meshing engagement with a pair of side gears (92).

6. The electric drive module (24) of Claim 5, wherein a pair of the differential pinions (90) are mounted on a cross-pin (94) that is mounted to the differential input member (80).

7. The electric drive module (24) of Claim 1, wherein the differential assembly (46) includes a differential input member (80) and wherein the driven gear (66) is coupled to the differential input member (80) for common rotation about the third axis (76).

8. The electric drive module (24) of Claim 7, wherein the differential assembly (46) includes a differential gearset (82).

9. The electric drive module (24) of Claim 8, wherein the differential gearset (82) comprises a plurality of differential pinions (90) that are in meshing engagement with a pair of side gears (92).

10. The electric drive module (24) of Claim 9, wherein a pair of the differential pinions (90) are mounted on a cross-pin (94) that is mounted to the differential input member (80).

11. The electric drive module (24) of Claim 1, further comprising:

a housing (40) into which the transmission (22) and the differential assembly (46) are received;

a pair of park gears (202), each of the park gears (202) being non-rotatably couped to an associated one of the second reduction gears (64);

a pawl (204) having a pair of pawl teeth (222), the pawl (204) being coupled to the housing (40) and pivotable between an engaged position, in which each of the pawl teeth (222) engages a corresponding one of the park gears (202), and a disengaged position in which the pawl teeth (222) are disengaged from the park gears (202); and

a pair of plungers (206) that are movable between a first position and a second position, each of the plungers (206) having a first body portion (232) and a second body portion (236) that is smaller in diameter than the first body portion (232), wherein contact between the first body portion (232) of the plungers (206) and the pawl (204) positions the pawl (204) in the engaged position, and wherein the pawl (204) is disposed in the disengaged position when the second body portion (236) of the plungers (206) contact the pawl (204).

12. The electric drive module (24) of Claim 11, wherein when the pawl (204) is in the engaged position, a first load transmitted between a first one of the pawl teeth (222) and a first one of the park gears (202) is equal to a second load transmitted between a second one of the pawl teeth (222) and a second one of the park gears (202).

13. The electric drive module (24) of Claim 11, wherein the pawl (204) is pivotably disposed on a pivot axle (226), and wherein a fit between the pawl (204) and the pivot axle (226) permits non-rotational movement of the pawl (204) relative to the pivot axle (226) to permit load transmitted between the pawl teeth (222) and the park gears (202) to equalize.

14. The electric drive module (24) of Claim 11, wherein the first body portion (232) of the plungers (206) is frusto-conically shaped.

15. The electric drive module (24) of Claim 14, wherein each plunger (206) further comprises a transition portion (234) that is disposed between the first body portion (232) and the second body portion (236), wherein the transition portion (234) is frusto-conically shaped, and wherein a cone angle of the first body portion (232) is smaller than a cone angle of the transition portion (234).

16. The electric drive module (24) of Claim 11, further comprising an actuator (210) for controlling movement of the plungers (206) between the first and second positions, the actuator (210) comprising an actuator hub (252), a cam plate (254), and a plurality of cam followers (250), the actuator hub (252) being coupled to the housing (40), the cam plate (254) being rotatable about the actuator hub (252) and defining a pair of cams (312), each of the cams (312) being a circumferentially extending groove having a depth that tapers

between a first circumferential end (320) and a second circumferential end (322), each of the cam followers (250) being received in a corresponding one of the cams (312) and being disposed in-line with an associated one of the plungers (206).

17. The electric drive module (24) of Claim 16, wherein each of the cam followers (250) is fixedly coupled to the associated one of the plungers (206).

18. The electric drive module (24) of Claim 16, wherein the actuator (210) further includes a torsion spring (258) disposed between the actuator hub (252) and the cam plate (254), the torsion spring (258) biasing the cam plate (254) toward a first rotational position relative to the actuator hub (252).

19. The electric drive module (24) of Claim 16, wherein the actuator (210) further includes a lock actuator (262), the lock actuator (262) having a solenoid assembly (400) and a lock aperture (402), the solenoid assembly (400) having a solenoid plunger (412), the lock aperture (402) being formed in the cam plate (254), wherein the solenoid assembly (400) is energized to cause the solenoid plunger (412) to be received into the lock aperture (402) and engage the cam plate (254) when the cam plate (254) is rotated into a rotational position that aligns the second circumferential ends (322) of the cams (312) to the cam followers (250).

20. The electric drive module (24) of Claim 16, wherein a bearing (256) is disposed radially between the actuator hub (252) and the cam plate (254).

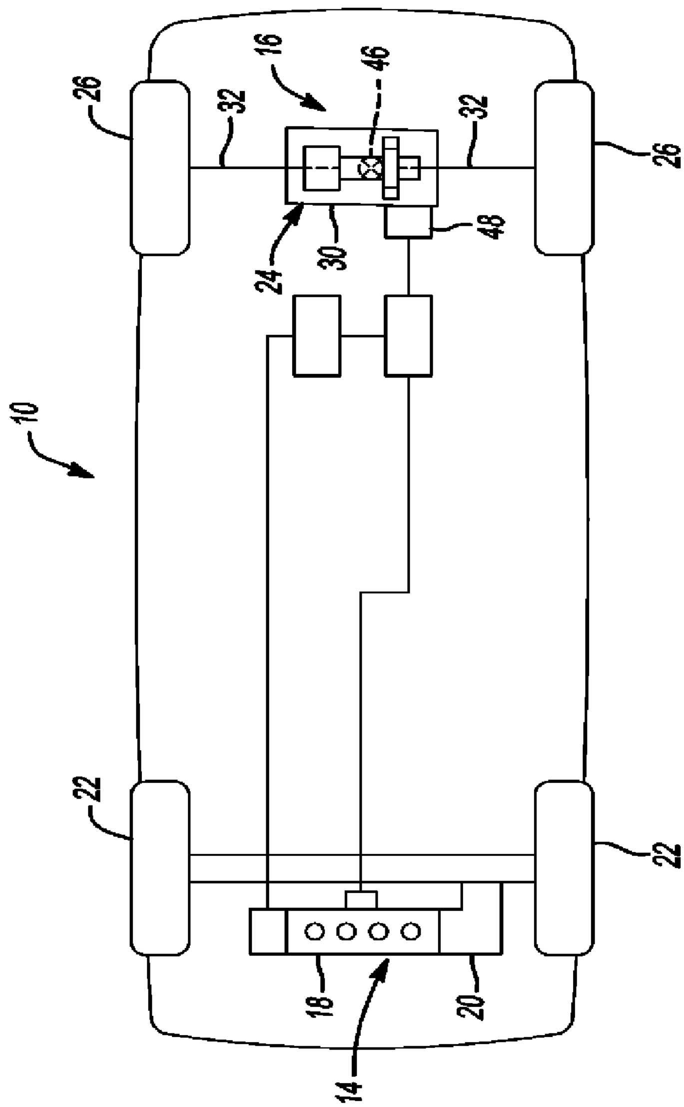


Fig-1

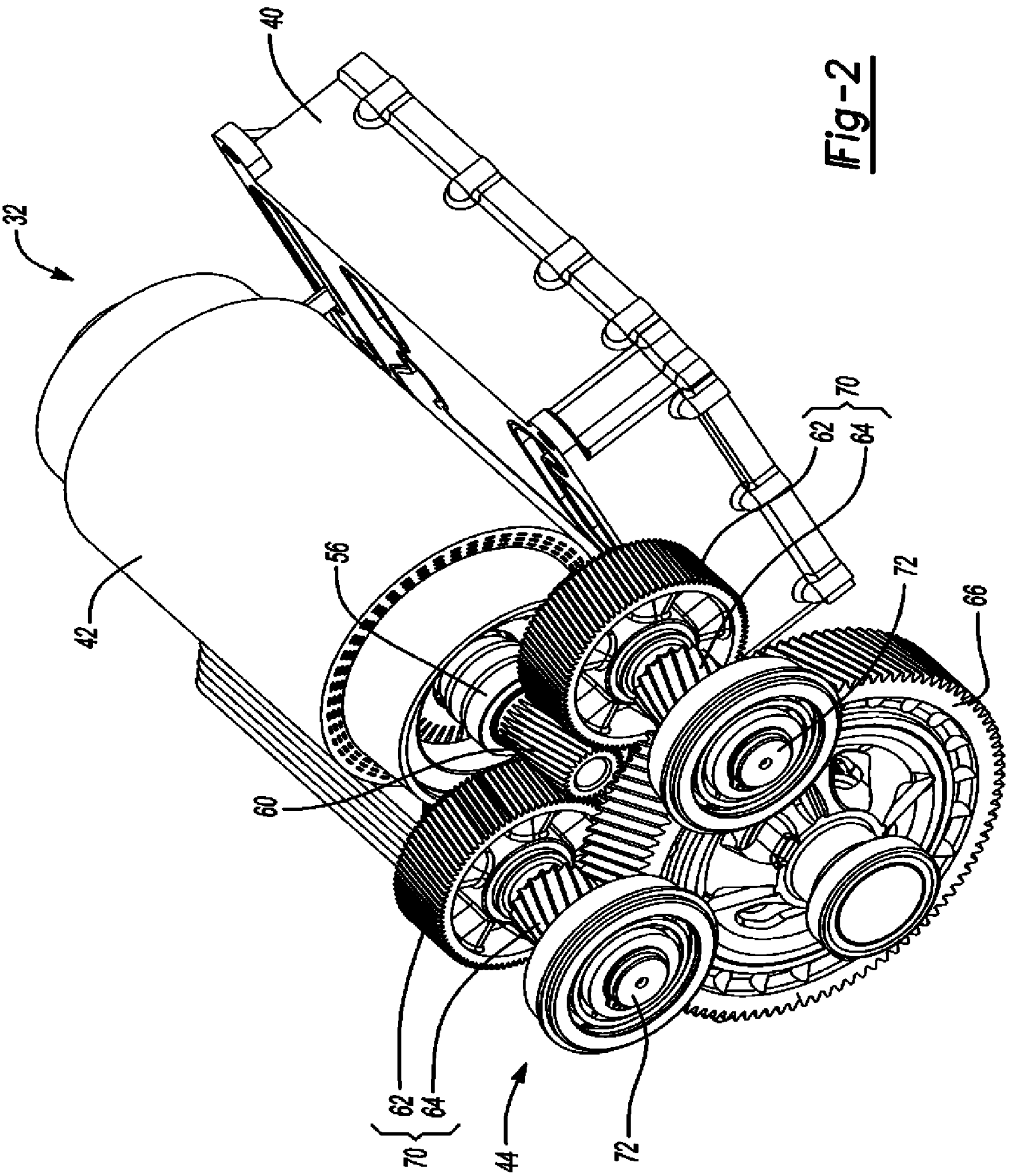
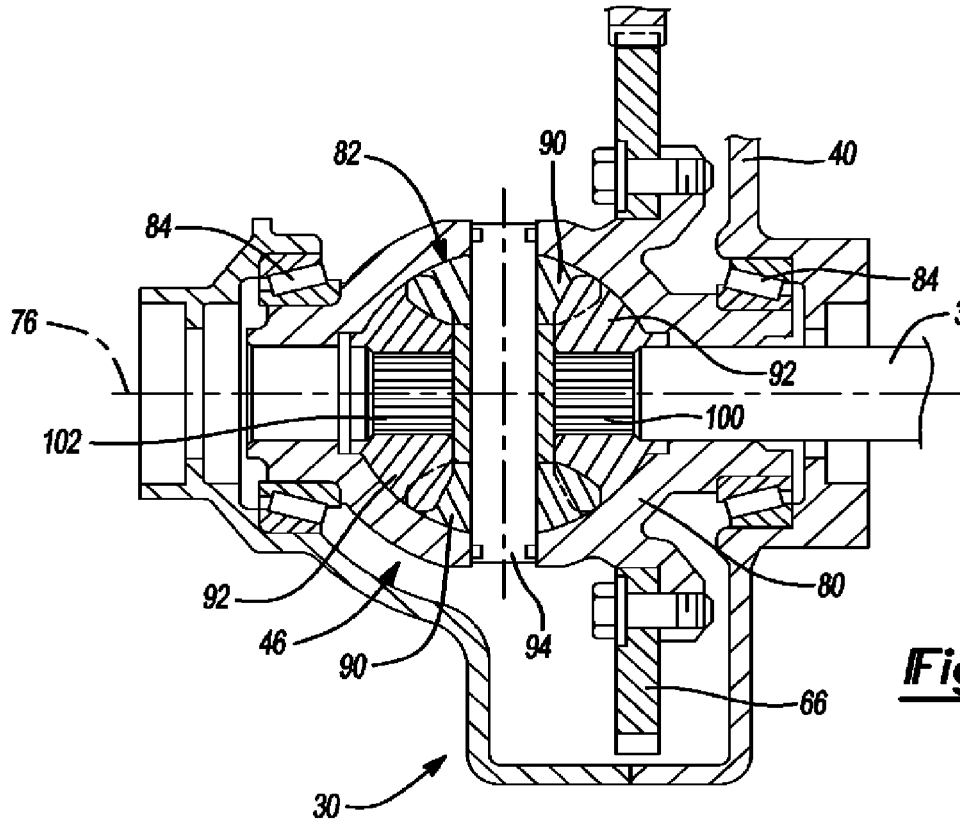


Fig-2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32
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92
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46
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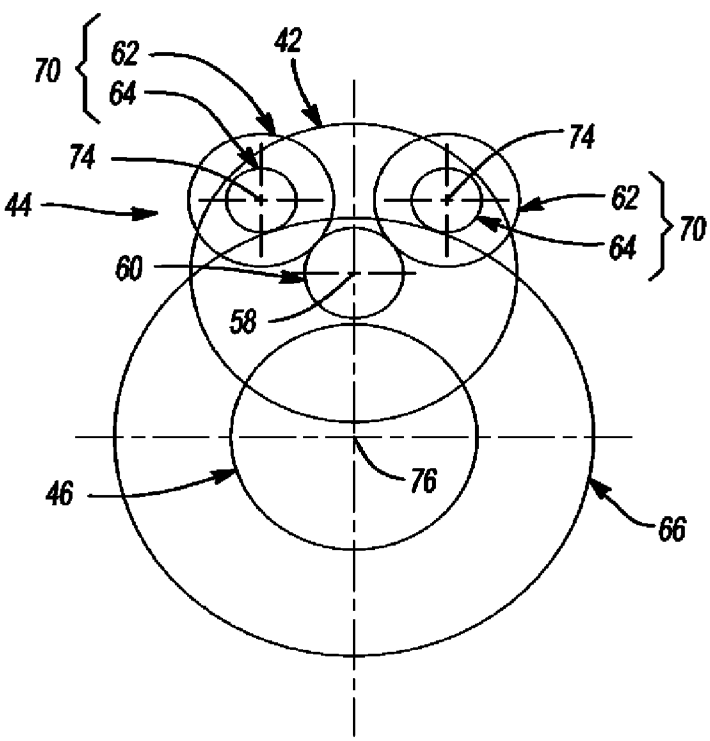
94
66
30

Fig-3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74
74
44
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64
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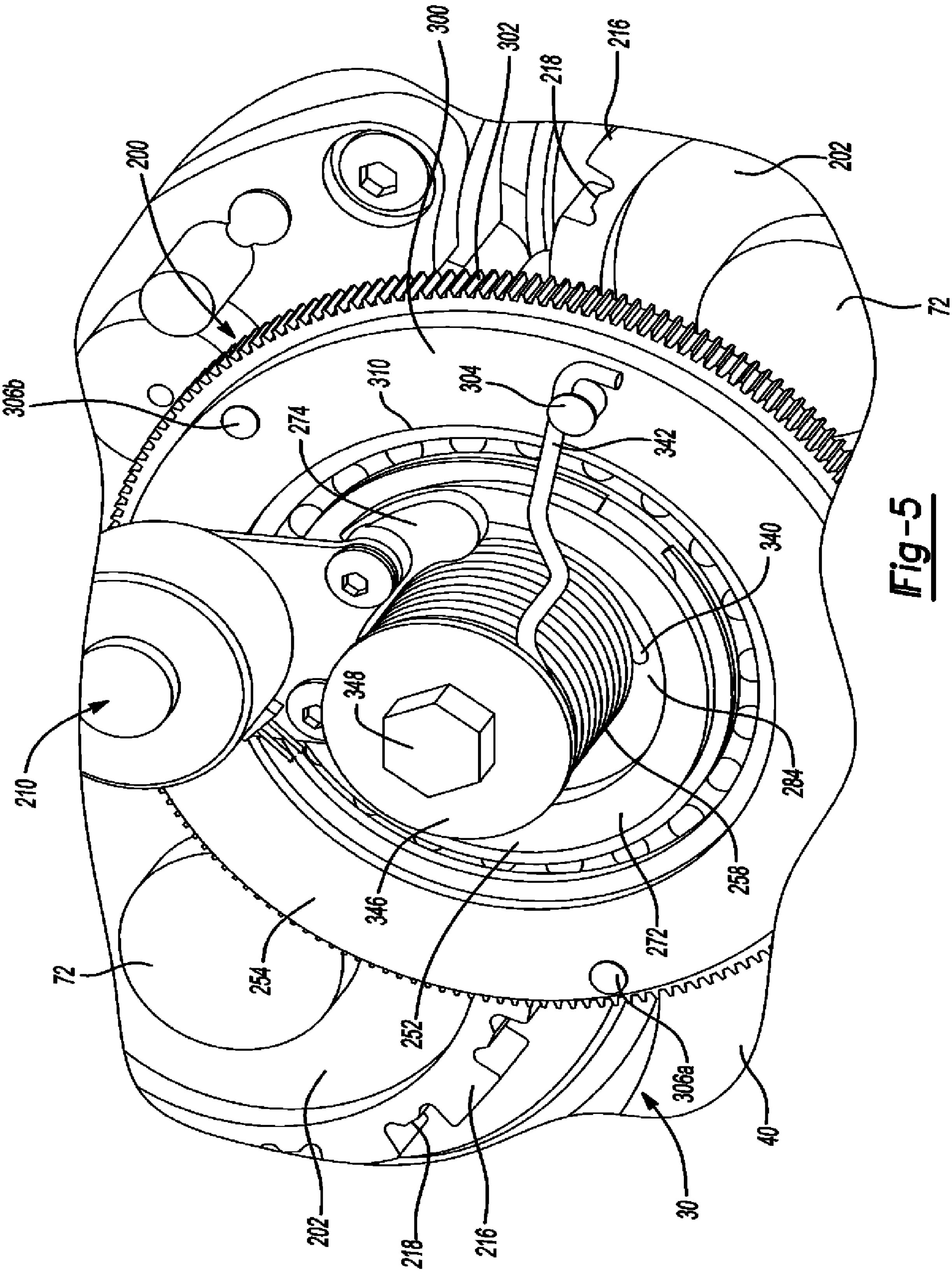
60
58
76
46
66

Fig-4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202
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306b
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346
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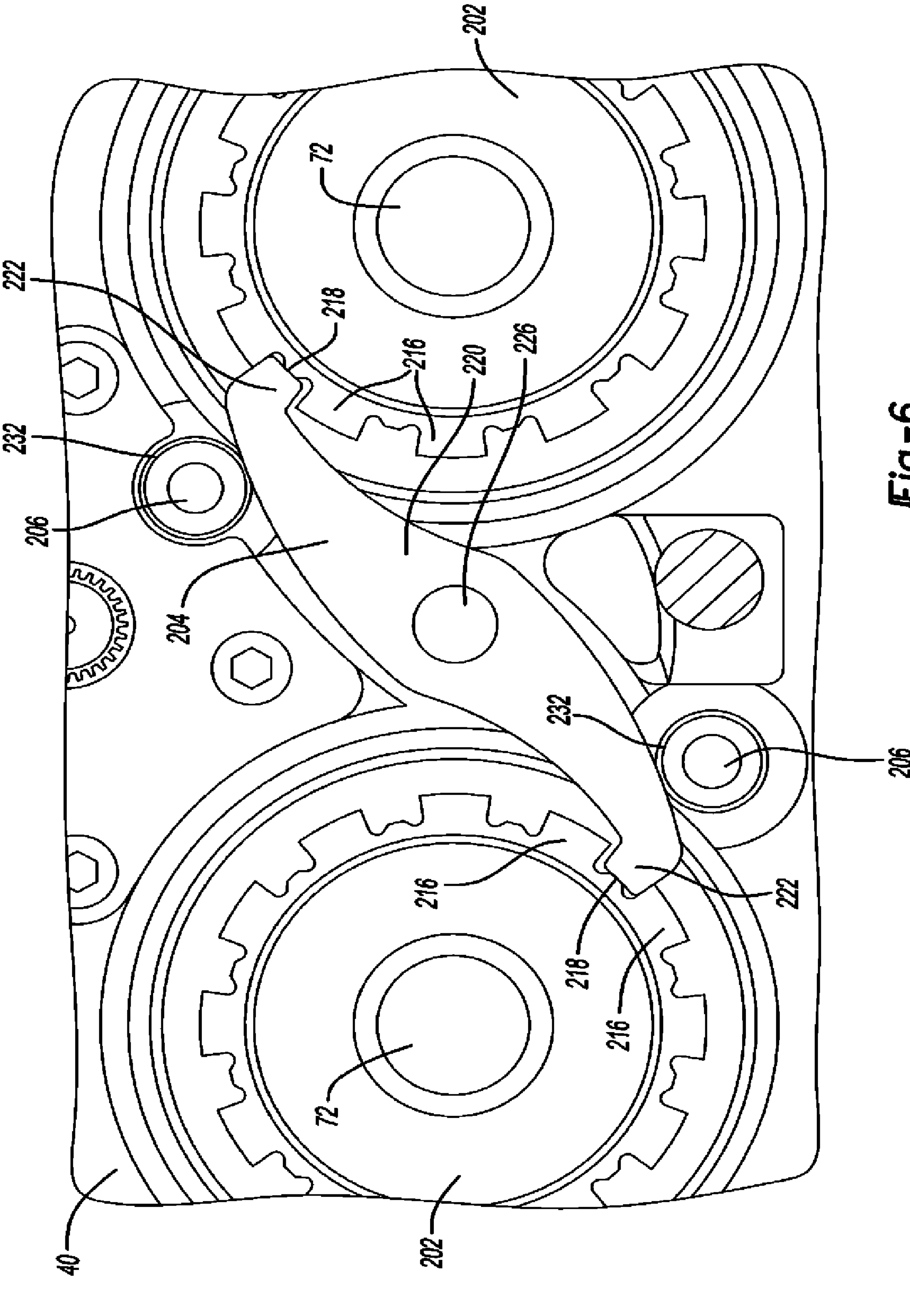
252
306a
40
30
218
216
202

Fig-5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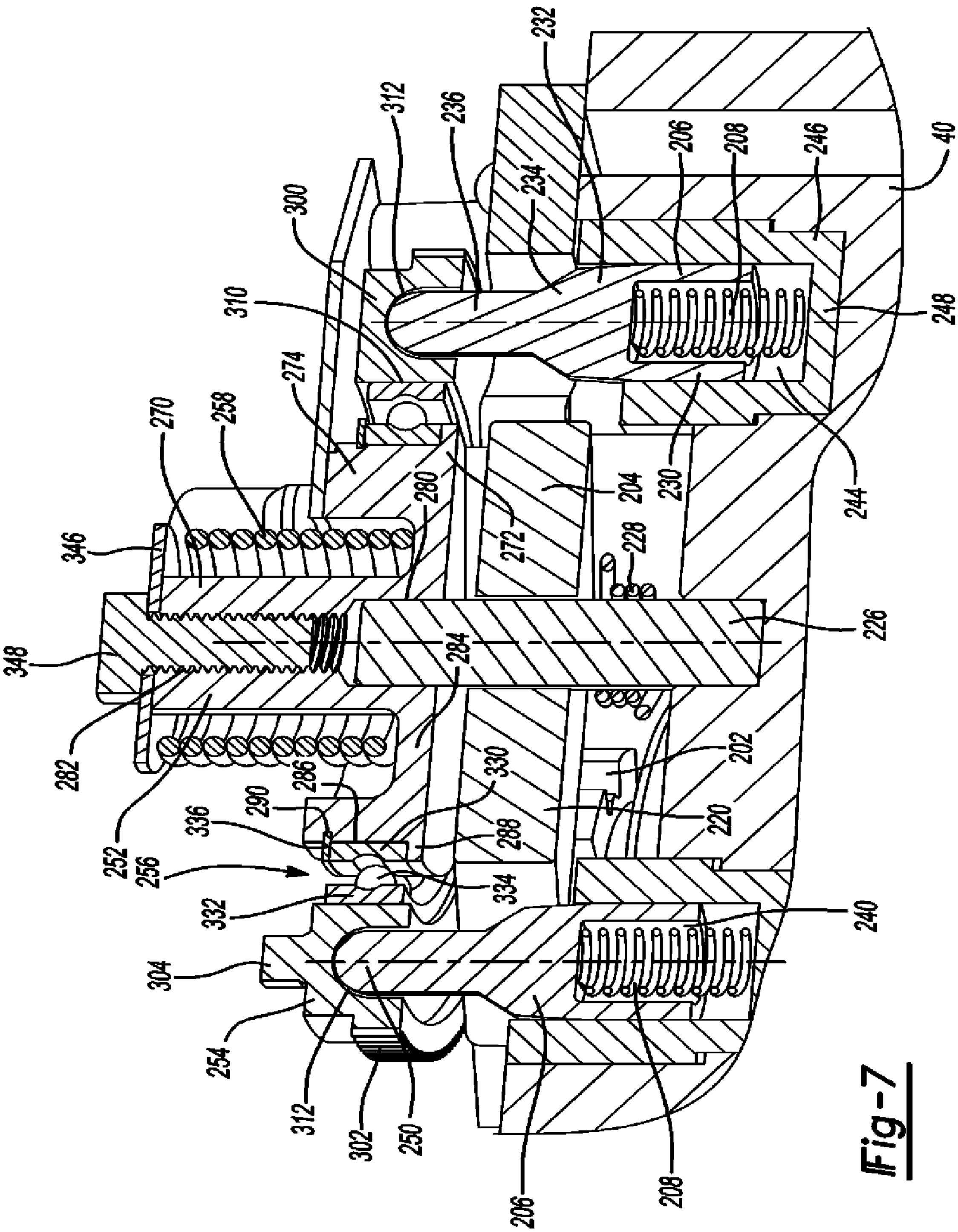
202

Fig-6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226
348
284
202
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312
302
250
206
208

Fig-7

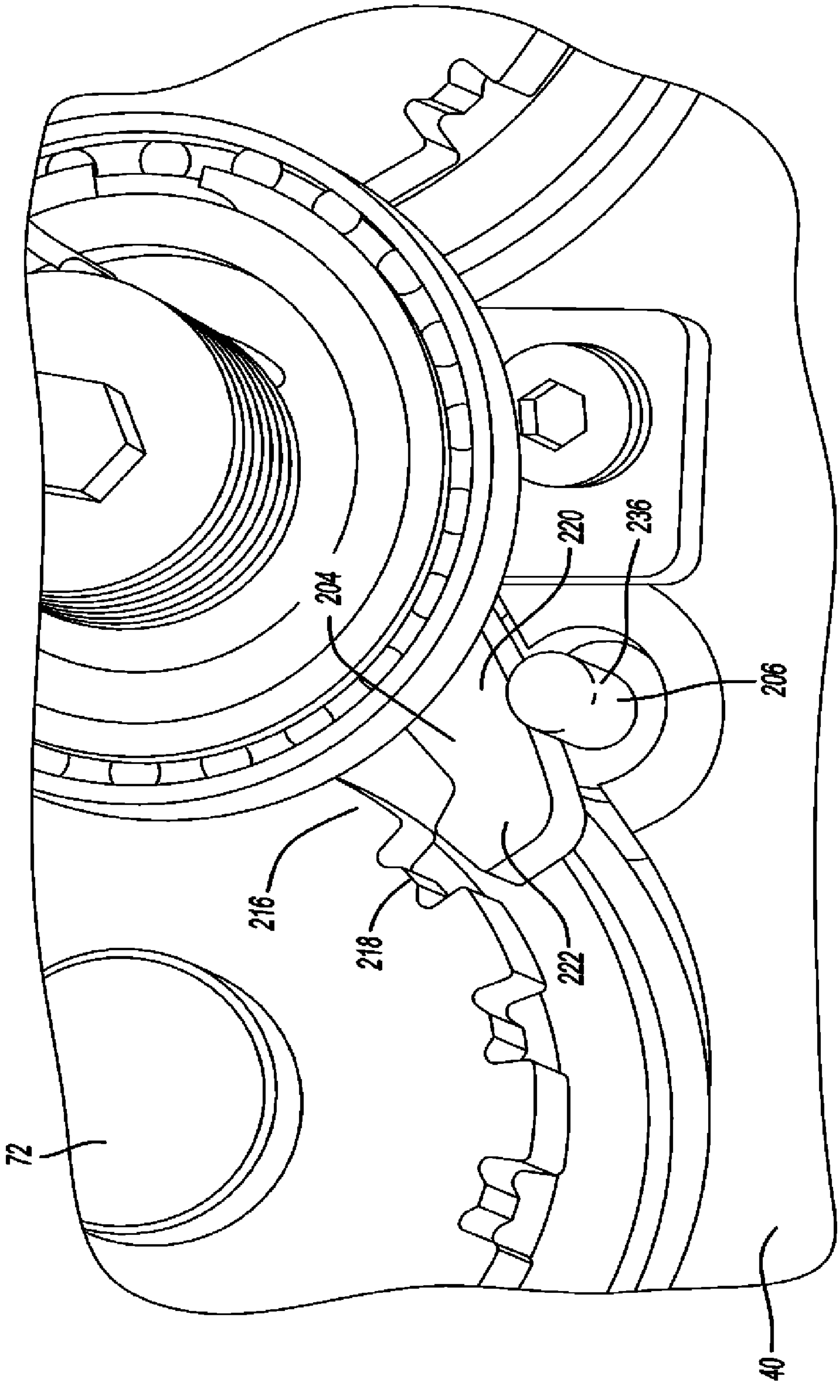


Fig-8

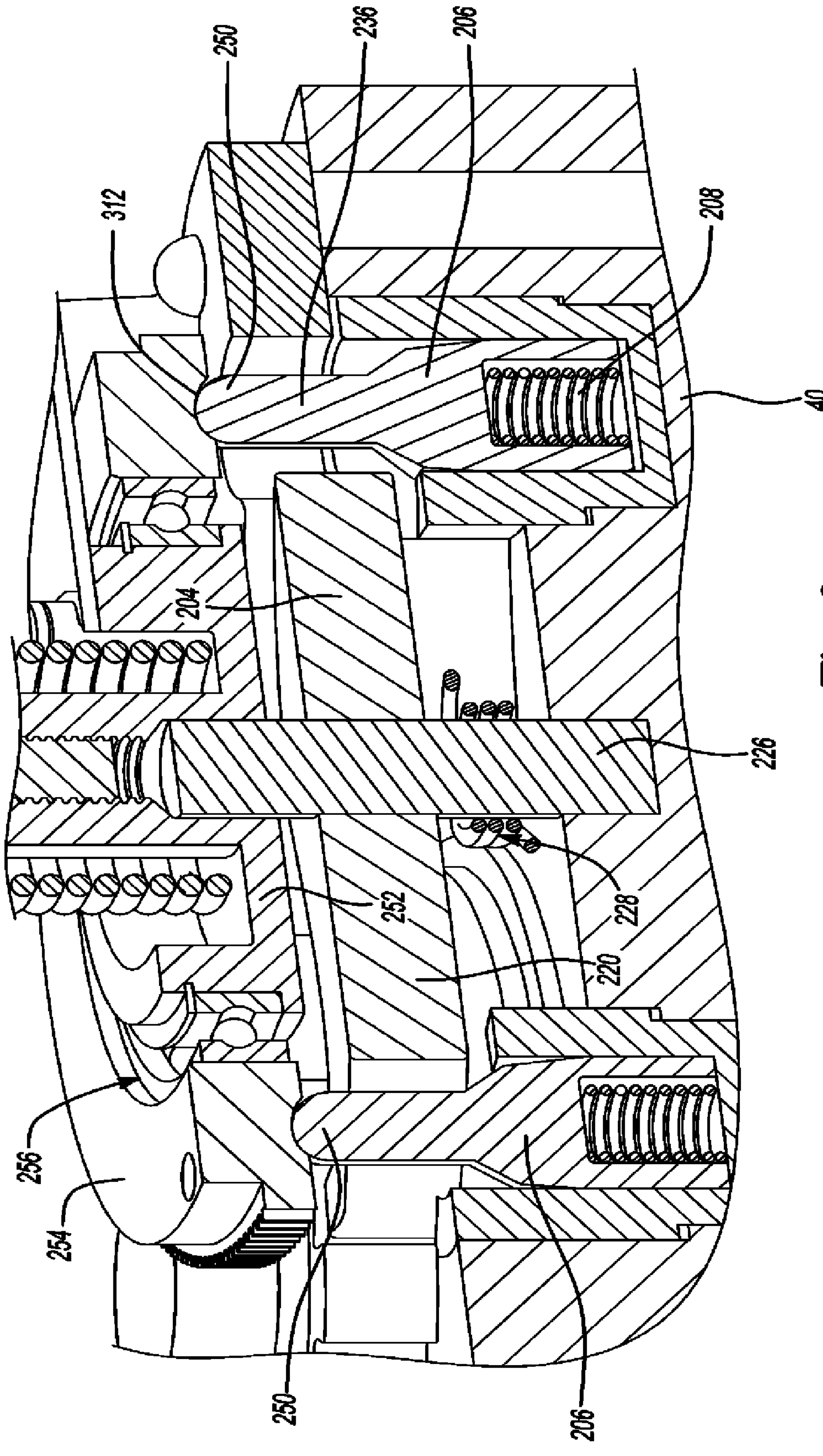


Fig-9

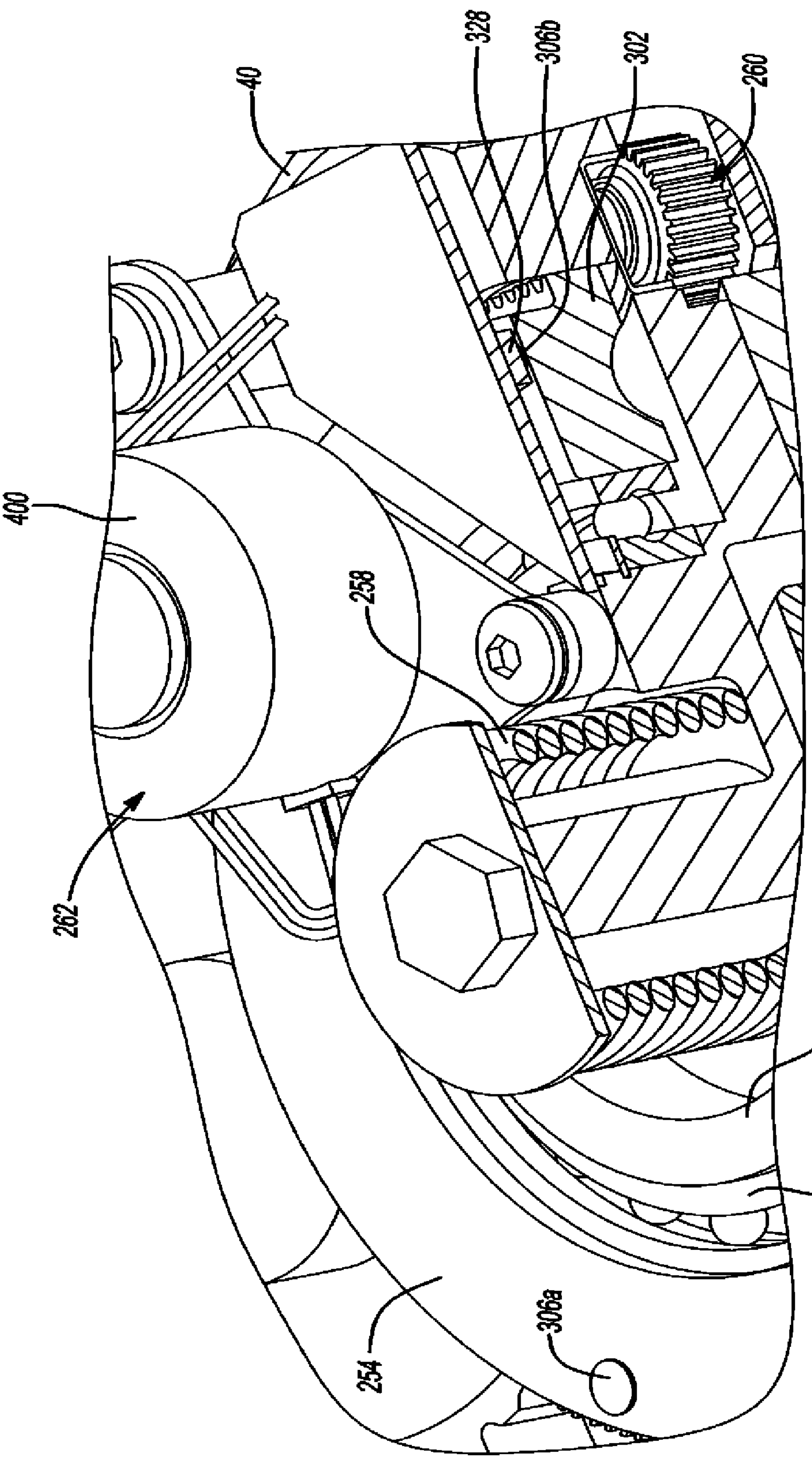
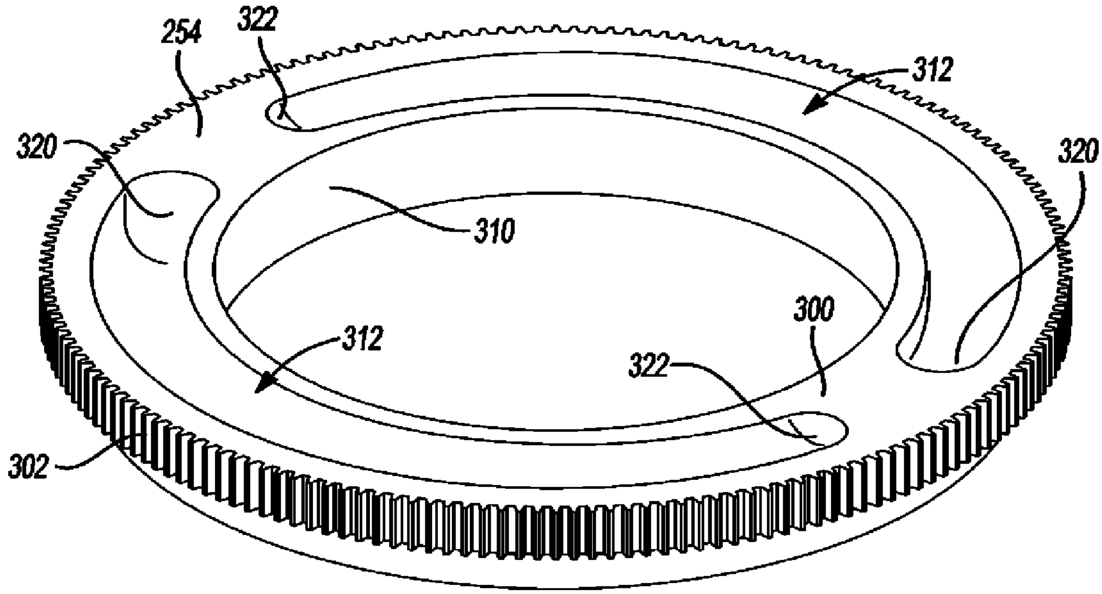


Fig-10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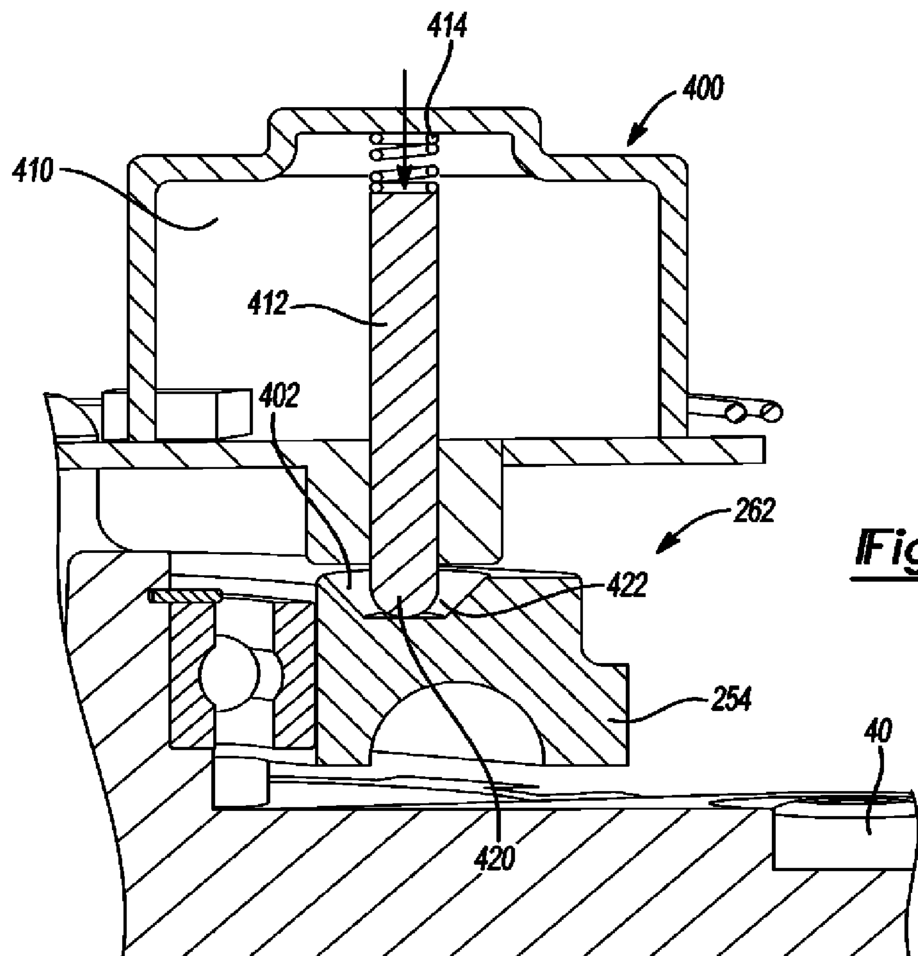
322
312
320
320
310
300
312
322
302

Fig-11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412
402
262
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254
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420

Fig-12

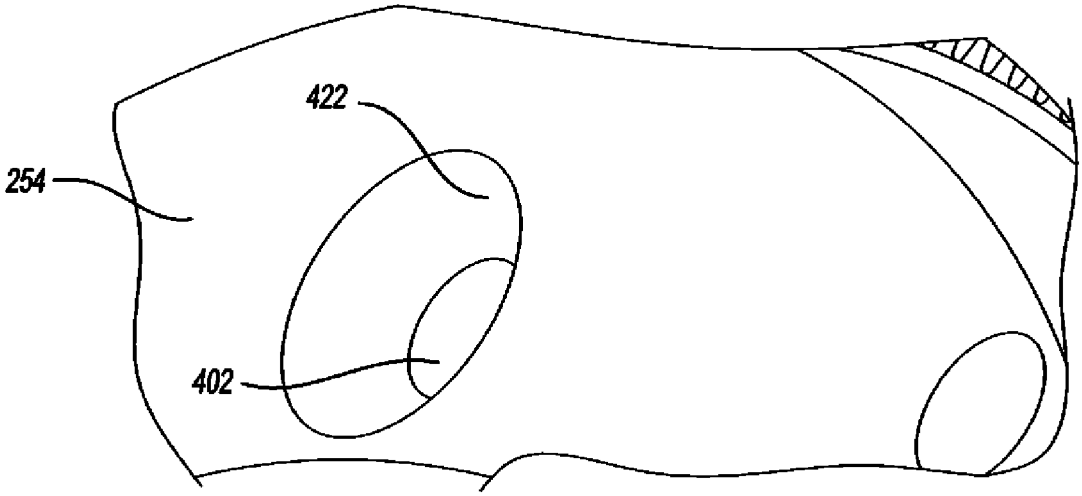

Fig-13

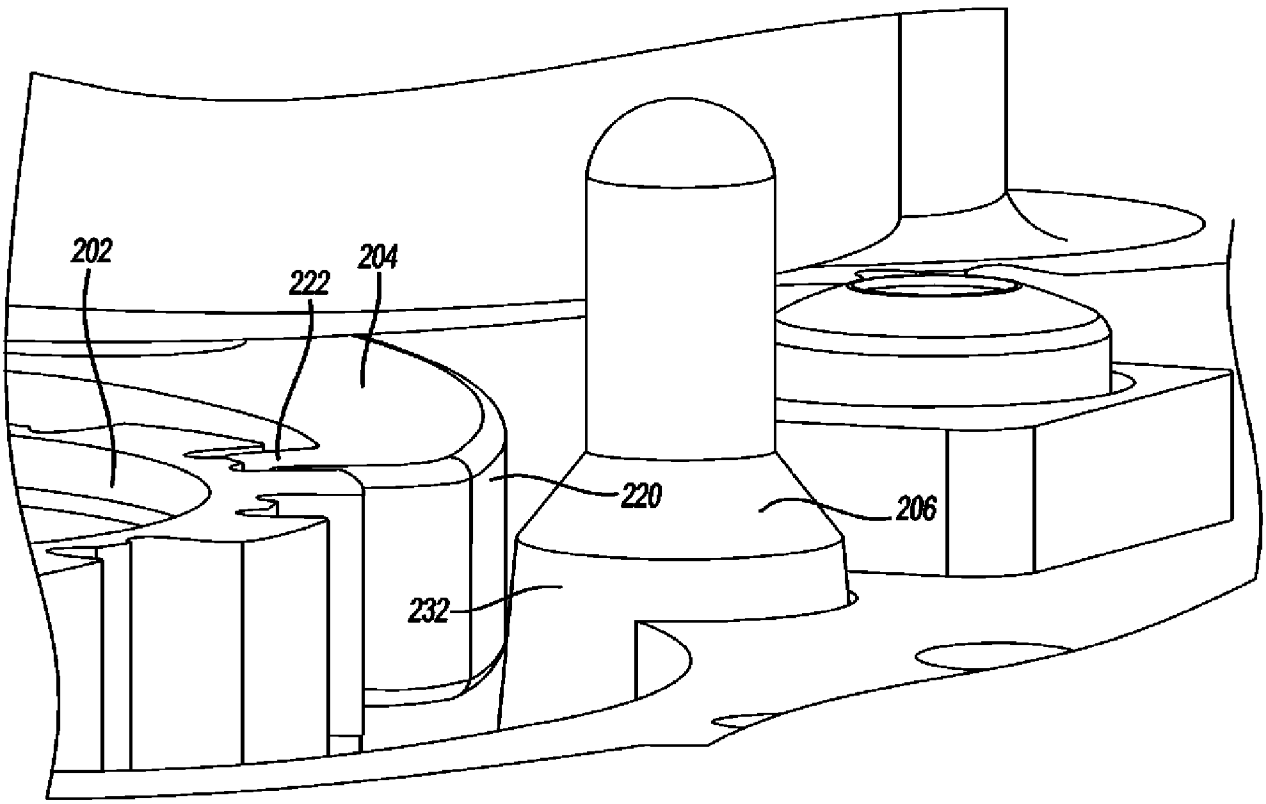

Fig-14

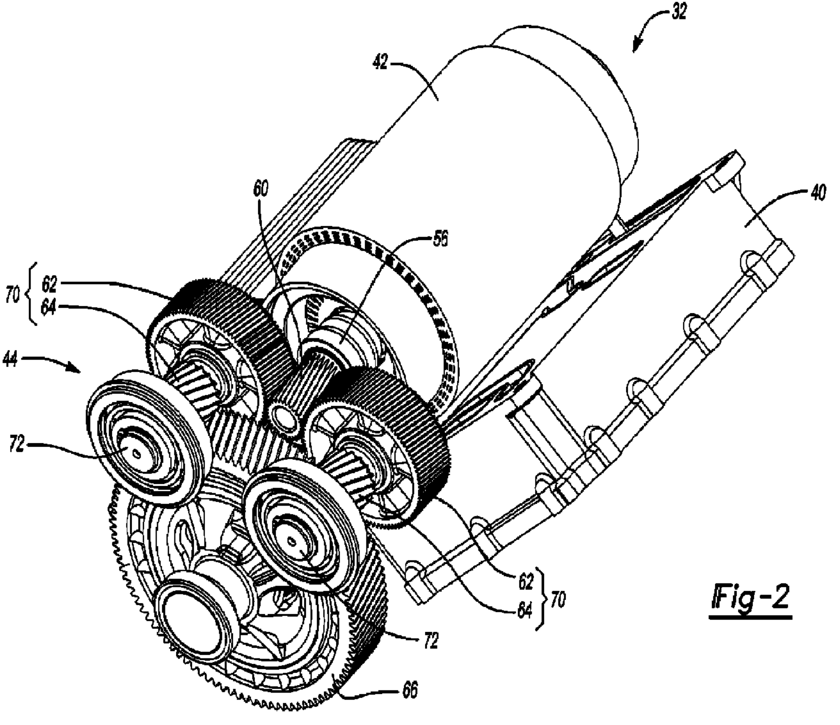

Fig-2